Chapter 4

How Cells Work

4.5 Photosynthesis

Along the highways of California's Central Valley, billboards celebrate the work of farmers. Some of them say, *"farmers: turning water and sunlight into food"*. This is what crops do and, in fact, what all plants do. They take sunlight and water and turn them into organic molecules, some of which are turned into living plant matter. (It turns out that plants need carbon dioxide from the air, too, as we will see.)

Plants and certain other organisms use **photosynthesis** to convert light energy from the Sun into chemical energy in organic molecules. Almost all life on Earth depends ultimately on photosynthesis for organic molecules and energy. This is because plants and other photosynthesizers (such as algae and certain bacteria) are food for herbivores, and herbivores are food for carnivores.

The chemical equation for photosynthesis is:
$6\,CO_2 + 6\,H_2O + \text{sunlight} \rightarrow C_6H_{12}O_6 + 6\,O_2$

Carbon dioxide, water, and sunlight go in; glucose and oxygen come out. Keep in mind that this is a summary of the overall process. In fact, a large number of chemical reactions are needed before the reactants in photosynthesis are converted into the products. Ultimately, the oxygen released is the source of the oxygen we breathe—yet another way photosynthesis is fundamental to life as we know it.

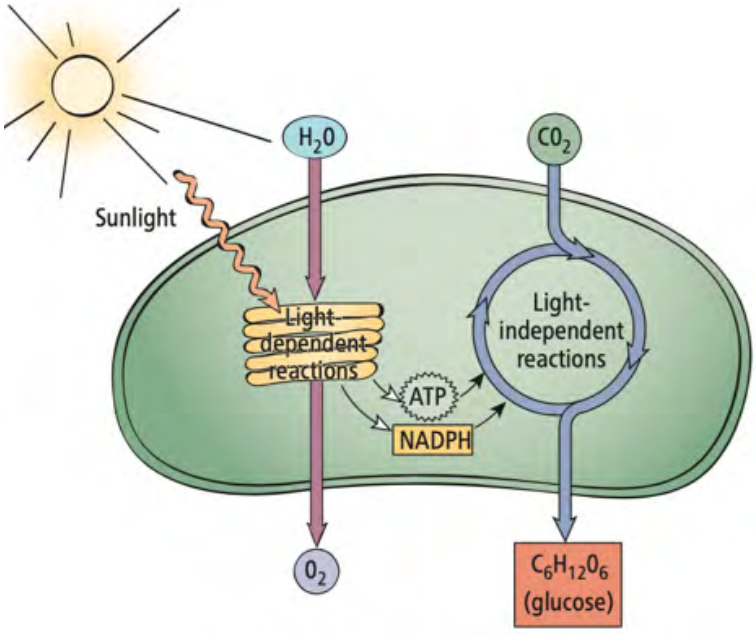
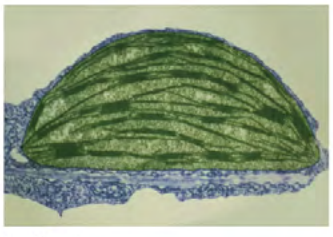


FIGURE 4.17

Photosynthesis takes place in plant organelles called chloroplasts, found primarily in stems and leaves. The subset photo shows a chloroplast in a lilac leaf. Photosynthesis occurs in two steps: the light-dependent and light-independent reactions.



Photosynthesis takes place in the plant organelles called **chloroplasts** (Figure 4.17). It occurs in two steps: *light-dependent reactions* and *light-independent reactions*. During the light-dependent reactions, energy is captured from sunlight. During the light-independent reactions, carbon is fixed—that is, carbon atoms are moved from atmospheric carbon dioxide to the organic molecule glucose.

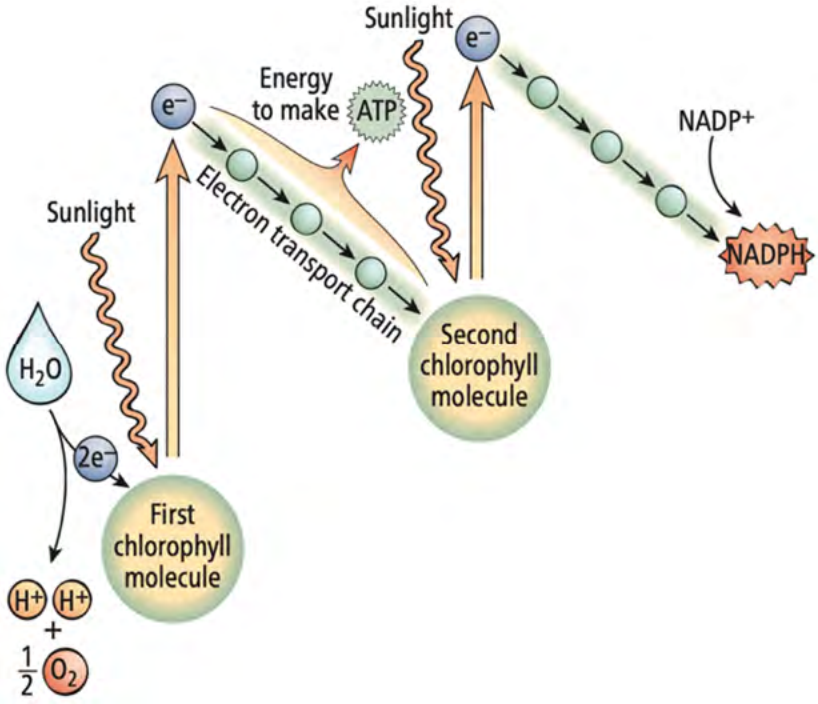


FIGURE 4.18

In the light-dependent reactions of photosynthesis, two electron transport chains capture energy from sunlight and store it in ATP and NADPH. Oxygen is released.

The light-dependent reactions begin when sunlight strikes a chlorophyll molecule inside a chloroplast. *Chlorophyll* is a pigment, meaning it is a molecule that absorbs light. Chlorophyll absorbs blue-violet light and red-orange light best. The light that chlorophyll does not absorb—green light—is reflected by plants. This is why plants are green.

When sunlight strikes a chlorophyll molecule, the energy in sunlight excites electrons in the chlorophyll molecule and knocks them out (Figure 4.18). The chlorophyll molecule, which is now missing electrons, extracts them from water (H_2O), which causes oxygen (O_2) to be produced. Meanwhile, a high-energy electron knocked out of the chlorophyll molecule passes down an electron transport chain. The *electron transport chain* consists of a series of carrier molecules, each of which receives the electron and then passes it on to the next carrier.

You can imagine the electron transport chain as a cartoon fire brigade, in which a bucket of water is passed from one person to the next until the last person tosses it over the flames (Figure 4.19). The electron is the bucket of water, passed from one carrier to the next.

FIGURE 4.19

In an electron transport chain, the electron is passed from one carrier to the next the way a bucket of water is passed from one person to the next in a cartoon fire brigade. The electron loses energy as it is passed down the chain.

As the electron passes down the transport chain, its energy is used to convert ADP into ATP. At the end of the transport chain, it is received by a different chlorophyll molecule sensitive to different frequencies of light. This chlorophyll molecule is struck by sunlight, which energizes the electron before it's passed down a second electron transport chain. This time, the energy lost by the electron as it passes down the transport chain is used to convert another molecule called $NADP^+$ into its higher energy state called NADPH. The NADPH is used to drive the subsequent light-independent reactions.

To summarize, two important things happen during the light-dependent reactions. First, energy from sunlight is converted into chemical energy in the form of ATP and NADPH. Second, oxygen is released.

In the light-independent reactions, also known as the *Calvin cycle*, the cell uses the energy stored in ATP and NADPH to fix carbon (see Figure 4.17b). During the Calvin cycle, six molecules of carbon dioxide (CO_2) are taken in and used to make a molecule of glucose ($C_6H_{12}O_6$). Cells use glucose as a starting point for making other carbohydrates, lipids, and, with the addition of nitrogen, amino acids and nucleic acids—in short, all the macromolecules of life.

READING CHECK

1. **What three things does a plant need to photosynthesize? What two products are made during photosynthesis?**
2. **Is oxygen released during the light-dependent or the light-independent reactions of photosynthesis?**

CHECK YOUR ANSWERS

1. Plants need sunlight, water, and carbon dioxide for photosynthesis. The two products are glucose and oxygen.
2. Oxygen is released during the light-dependent reactions.

Read more about photosynthesis here:

https://ssec.si.edu/stemvisions-blog/what-photosynthesis