7.2: The Light-Dependent Reactions of Photosynthesis

Learning objectives

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

- *Explain how plants absorb energy from sunlight*
- *Describe how the wavelength of light affects its energy and color*
- *Describe how and where photosynthesis takes place within a plant*
- *Be able to define and explain all bolded terms*

How can light be used to make food? It is easy to think of light as just something that allows living organisms to see, but light is a form of energy. Like all energy, light can travel, change forms, and be harnessed to do work. In the case of photosynthesis, some autotrophs can take light energy and transform it into chemical energy to build carbohydrates (Figure 7.10).

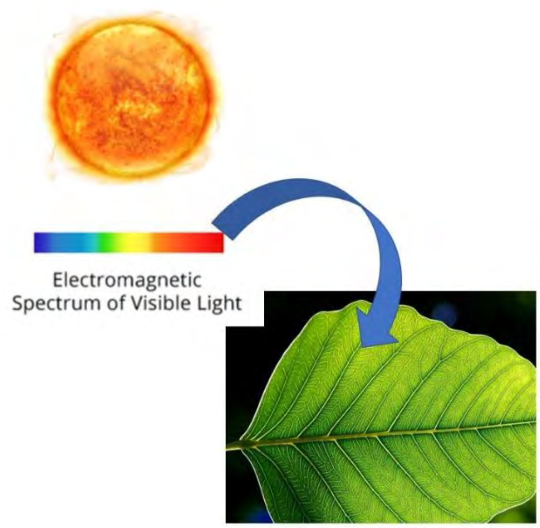

Figure 7.10 Plants can use light from the sun to photosynthesize. (credit: Elizabeth O'Grady original work of Geson Perry Wikimedia commons (sun and electromagnetic spectrum) /original work of Jon Sullivan Wikimedia commons (leaf))

What Is Light Energy?

The sun emits an enormous amount of electromagnetic radiation, more commonly referred to as solar or light energy. Light energy travels as waves. Scientists can determine the amount of energy a wave has by measuring its wavelength. **Wavelength** is the distance between two consecutive, similar points in a series of waves. For example, the wavelength can be measured by taking the distance from crest to crest or trough to trough in Figure 7.11.

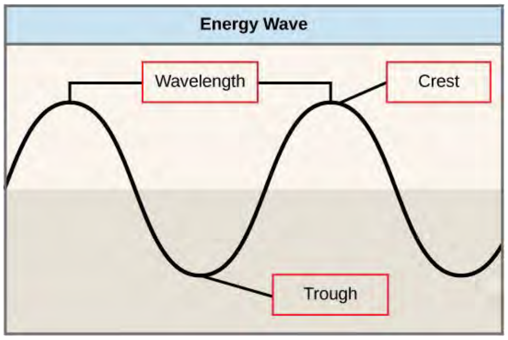

Figure 7.11 The wavelength of a single wave is the distance between two consecutive points along with the wave (credit: Clark et al. / Biology 2E OpenStax).

The sun emits a broad range of electromagnetic radiation (energy) including visible light, X-rays, and ultraviolet (UV) rays (Figure 7.12). The electromagnetic spectrum is the range of all possible wavelengths of energy.

Each wavelength corresponds to different amounts of energy. The longer the wavelength or the more stretched out it appears, the less energy it contains. Short, tight waves provide the most energy. For example, Figure 7.12 shows the wavelengths that correspond to the visible light spectrum. Visible light, which can be seen by humans and is used for photosynthesis, has wavelengths ranging from about 380 nanometers up to 750 nanometers. Note that Figure 7.12 shows that the red waves are considerably longer than the blue wavelengths and therefore have significantly less energy associated with them.

Keep in mind that living organisms cannot utilize all parts of the electromagnetic spectrum. For example, high-energy waves are dangerous to living organisms. Exposure to large quantities of X-rays and UV rays can be harmful to humans and have been identified as causes of cancer.

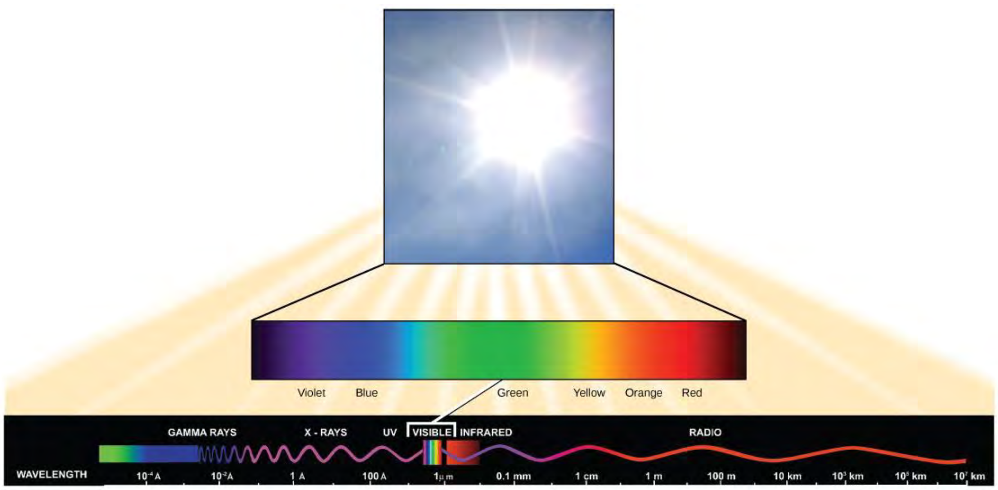

Figure 7.12 The sun emits energy in the form of electromagnetic radiation. (credit: Clark et al. / Biology 2E OpenStax)

Absorption of Light

During photosynthesis, plants use pigments to absorb parts of the visible light spectrum. The human eye perceives the visible light portion of the electromagnetic spectrum as a rainbow of colors (Figure 7.13). Certain objects, such as a prism or a drop of water, can disperse white light to reveal these colors.

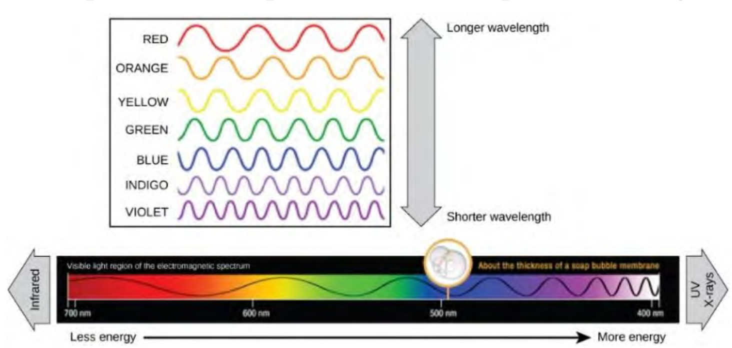

Figure 7.13 The illustration shows the colors of visible light. In order of decreasing wavelength, these are red, orange, yellow, green, blue, indigo, and violet. (credit: modification of work by NASA / [Biology 2E OpenStax](https://openstax.org/))

Understanding Pigments

Photosynthetic organisms use pigments to absorb light energy from the visible spectrum. **Pigments** are molecules which absorb certain wavelengths of light and reflect or transmit the other wavelengths. All photosynthetic organisms contain a pigment called **chlorophyll *a*.** Chlorophyll *a* absorbs wavelengths of light from either end of the visible spectrum: violet, indigo, blue, and red light. Chlorophyll *a* reflects the colors in the middle of the visible spectrum: green and yellow light. This explains why most plants appear to be green in color.

Plants use accessory pigments to absorb additional parts of the visible light spectrum. Other pigment types include chlorophyll *b,* xanthophyll, and beta-carotene. Chlorophyll *b* absorbs blue, red, and orange light whereas xanthophyll and beta-carotene absorb blue and violet light. The specific pattern of wavelengths can identify each type of pigment.

Not all photosynthetic organisms have full access to sunlight. Some organisms grow underwater, where the light intensity decreases with depth, and the water absorbs certain wavelengths. Other organisms grow in places where they must compete for light. For example, plants on the rainforest floor must be able to absorb any bit of light that comes through because taller trees block most of the sunlight (Figure 7.14). Keep in mind, if plants cannot absorb enough light to carry out photosynthesis, they will die.

Figure 7.14 Plants that commonly grow in the shade benefit from having a variety of light-absorbing pigments. (credit: Jason Hollinger / Concepts of Biology OpenStax)

How Light-Dependent Reactions Work

The overall purpose of the **light-dependent reactions** is to convert light energy into chemical energy in the form of ATP and NADPH. $NADP^+$ is an electron carrier, much like NAD^+ which is used during aerobic cellular respiration. When $NADP^+$ is reduced to NADPH, it shuttles high energy electrons from the light-dependent reactions to the Calvin cycle. Both ATP and NADPH will be used in the Calvin cycle to drive the synthesis of sugar molecules.

The light-dependent reactions begin in a complex called a **photosystem** (Figure 7.15). Photosystems are located in the thylakoid membrane and are made up of both pigments and proteins. Pigments in the photosystem absorb photons of light. A **photon** is a discrete quantity or "packet" of light energy.

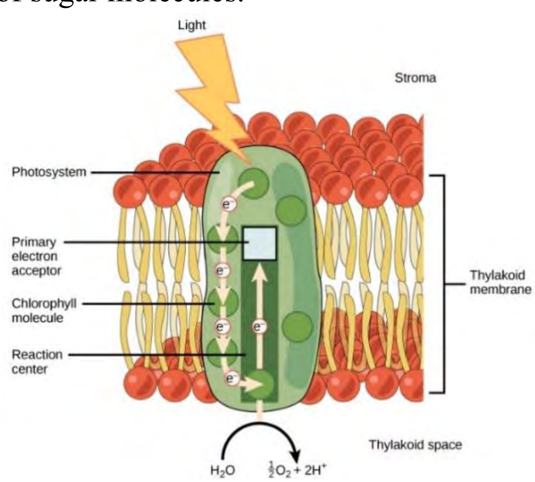

Figure 7.15 shows a photosystem with chlorophyll molecules that absorb light energy. (credit: Fowler et al. / Concepts of Biology OpenStax)