Reference 4

More about Photosynthesis

Photosynthesis Requires Light

Most life on Earth depends on the continual release of light energy from the Sun. Of the sunlight that reaches our planet, only about one percent is involved in photosynthesis. The rest is absorbed or reflected by clouds or dust in Earth's atmosphere or by Earth's surface. Visible light, which is only a small fraction of the energy coming from the Sun, consists of a spectrum of colors, each with a different wavelength and energy content (figure R4.1). When light strikes an object, it may be transmitted, absorbed, or reflected. In plant cells, several different pigments can absorb light energy. Each pigment is a chemical compound that absorbs only certain wavelengths of light and reflects or transmits all others. Green plants, for example, appear green because chlorophyll absorbs most wavelengths of visible light except green, which it reflects.

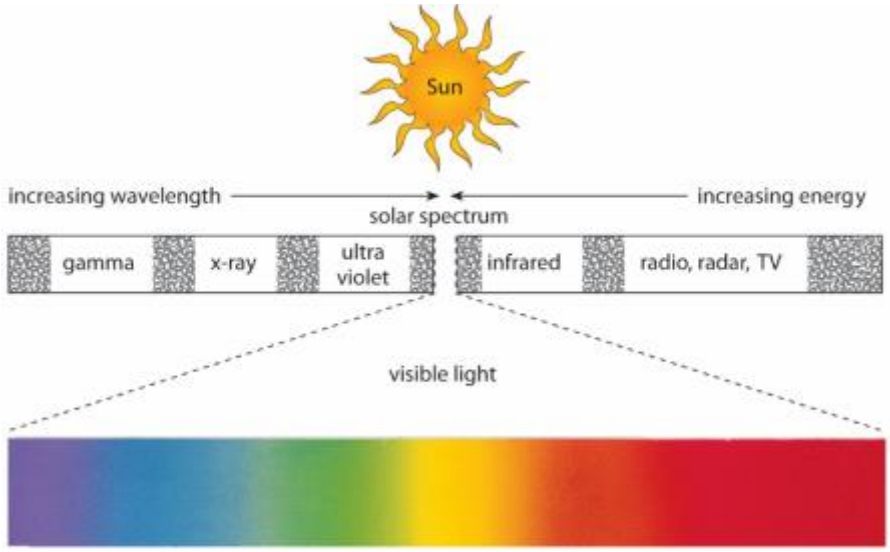

Figure R4.1: Radiations from the Sun form a continuous series. The range of radiations that organisms can detect with the eyes—visible light—is roughly the same range that plants use. Shorter wavelengths (blue light) are more energetic than longer wavelengths (red light). Leaves are green because chlorophyll absorbs red and blue wavelengths and only a little green. Chlorophyll mainly reflects green light.

Photosynthesis depends on the green pigment chlorophyll, which occurs in several forms. Chlorophyll *a* apparently is present in all photosynthetic plants; other forms may be present in different combinations. Figure R4.2 shows an absorption spectrum (a simple graph that displays the percentage of light absorbed by a pigment at each wavelength) for chlorophylls *a* and *b*. Note that the chlorophylls absorb much of the light in the violet/blue and orange/red wavelengths and very little or none in the green/yellow wavelengths. Plants can use only the energy from absorbed wavelengths. The action spectrum at the top of figure R4.2 shows this clearly. An action spectrum measures the rate of photosynthesis at certain wavelengths of light.

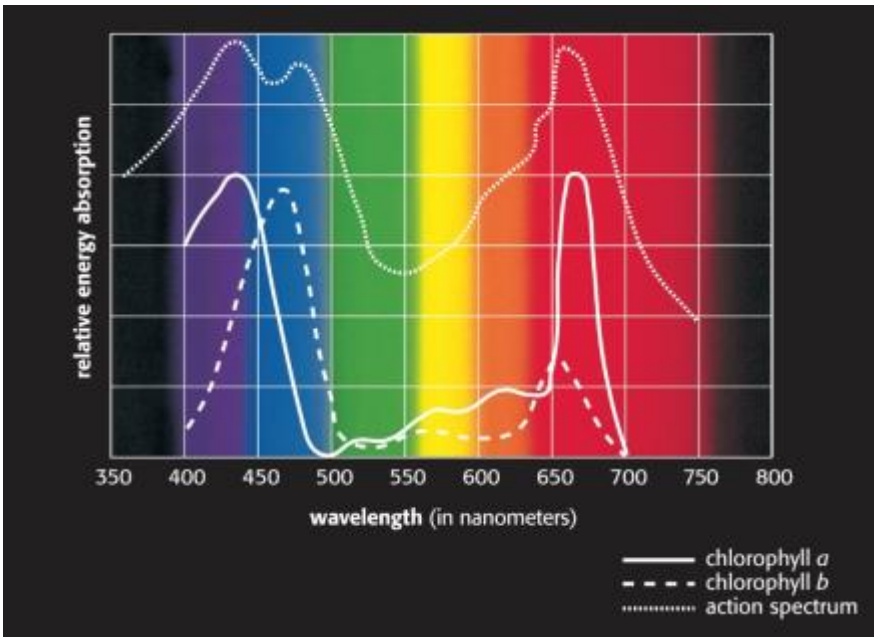

Figure R4.2: The upper curve shows the action spectrum for photosynthesis. The lower curves show absorption spectra for chlorophylls *a* and *b*. It is clear from comparing the action spectra that both chlorophylls are required to absorb the full range of wavelengths of light used in photosynthesis. Which wavelengths do these chlorophylls absorb most? least?

Photosynthesis Involves Many Interdependent Reactions

Three major events occur in photosynthesis: (1) absorption of light energy, (2) conversion of light energy into chemical energy, and (3) storage of chemical energy in carbohydrates (sugars). The reactions by which these events occur may be considered in two distinct but interdependent groups, shown in figure R4.3.

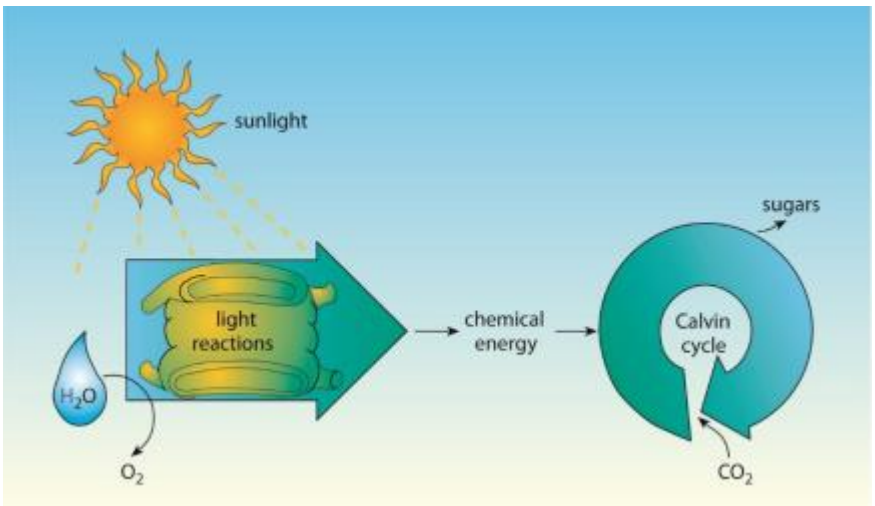

Figure R4.3: The reactions of photosynthesis occur in two groups: the light reactions and the Calvin cycle.

In the first group of reactions, the light reactions, light is absorbed and converted into chemical energy as short-lived, energy-rich molecules are formed. These molecules are then used to make 3-carbon sugars from carbon dioxide in the second group of reactions known as the Calvin cycle. In this cycle, chemical energy is stored in the carbohydrates, and new carbon is incorporated into the plant for future growth.

The light reactions of photosynthesis convert the energy in visible light into the chemical energy that powers sugar production. In these reactions, chlorophyll and other pigments in the thylakoid absorb light energy; water molecules are split into hydrogen and oxygen, releasing oxygen gas to the atmosphere; and light energy is stored as chemical energy.

The enzyme-catalyzed reactions of the Calvin cycle do not involve the absorption of light energy. They do, however, require the ATP and energy-rich molecules produced in the light reactions. The Calvin cycle is a series of reactions in which carbon dioxide is combined with the hydrogen split from water in the light reactions.

The Calvin cycle and the Krebs cycle are similar in involving many rearrangements of carbon chains. Both produce carbon skeletons for use in biosynthesis reactions. Carbon dioxide is used in the Calvin cycle and released in the Krebs cycle. Much ATP is used in the Calvin cycle, and a little is formed in the Krebs cycle.

Photosynthesis takes place in cellular organelles called chloroplasts. Inside chloroplasts, green-colored chlorophylls and other plant pigments capture light energy during a phase of photosynthesis called the light reactions. The captured light energy is used to transform water molecules into oxygen, which also releases electrons and hydrogen ions. These are bound to NADP+ to form NADPH, a temporary storage form of energy. In the second phase of photosynthesis, the Calvin cycle, captured light energy and hydrogen in NADPH is used to fix carbon dioxide, forming the sugar glucose and regenerating NADP+. The light energy that was captured from sunlight is thus partially stored in the chemical bonds of the sugar. By photosynthesis in green tissues, plants produce usable forms of energy and carbon that they need to live and grow.

What Makes Plants Green?

The colors we see are wavelengths of light reflected. Plants are green because their chlorophylls reflect green light. However, chlorophylls capture other wavelengths of light and use the energy for photosynthesis. Land plants have two major forms of chlorophyll, and distinct families of algae produce three other types. Chlorophylls *a* and *b*, found in land plants, absorb energy in the wavelengths shown below.

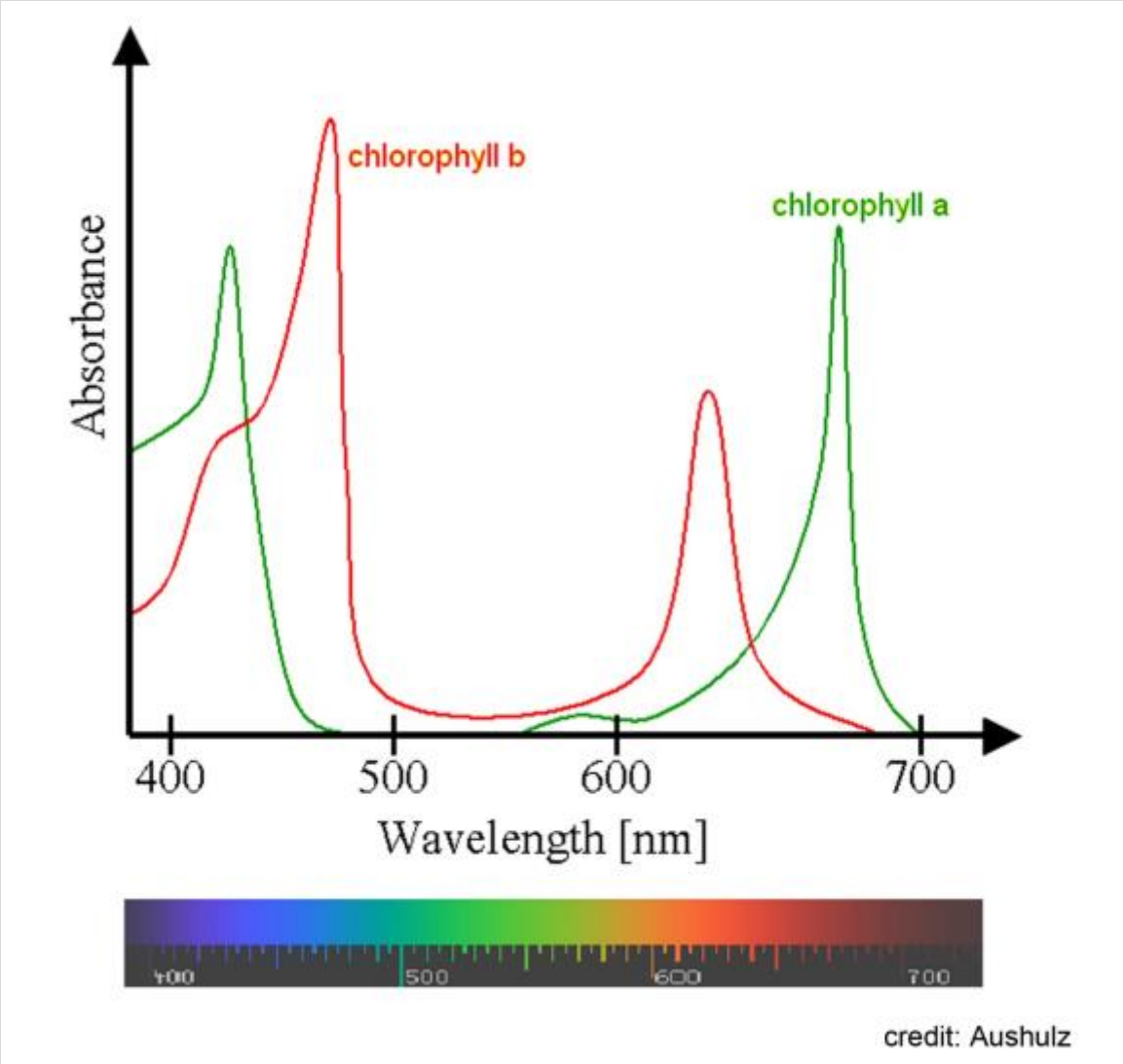

Figure R4.4: Chlorophylls *a* and *b* differ slightly in their absorption of visible light. For example, light with a wavelength of 460 nm is not significantly absorbed by chlorophyll *a* but will instead by absorbed by chlorophyll *b*. The two forms of chlorophyll in plants complement enable plants to meet their energy requirements by absorbing light from the blue and red parts of the spectrum.