Chapter 8 – Photosynthesis: Energy from the Sun

The general idea behind photosynthesis that you must remember is that it does exactly what it says ... in the order it says it. There are two general processes that occur: the “photo” process, or the light reaction, and the “synthesis” process, or the dark reaction. Each is a separate process, but both together are essential for the synthesis of glucose from just CO₂, water, and light.

The overall reaction is:

$$6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$$

Light Reaction:

The light reaction is made possible by small organic molecules called photopigments. These are organic molecules that, when stimulated by light, are able to trap the energy by bumping electrons into higher energy orbitals. There are two general classes of pigments: chlorophylls, which are the only pigments able to transfer light energy to chemical energy, and accessory pigments, which help absorb the wavelengths of light not absorbed by the chlorophylls. Chlorophyll is found in all photosynthetic organisms since it is necessary for this transfer of energy.

The light reaction consists mainly of the conversion of H₂O into O₂ with the help of light, ATP, and NADP⁺. This part of photosynthesis takes place in the membranes of small sacs found in the chloroplast called thylakoids. Located in these membranes are small groups of photopigments arranged in antennae complexes. They look like this:

Note the many different kinds of pigments found in the antenna complex. Located in the center is a single molecule of chlorophyll A (bright green) which is called the reaction center. When light enters the thylakoid membrane, it excites the electrons in a photopigment. This energy is then passed along to other nearby pigments via the same electron excitation method until it reaches the reaction center, which then sends the electron to the electron transport chain, also found in the thylakoid membrane. The lost
electron is replaced by nearby water molecules that split to yield protons (H+) and oxygen gas (the gas we breathe). It is important to note that the oxygen in photosynthesis comes from water, NOT CO2. Once in the electron transport chain, the energy is then passed along to each membrane molecule and used to pump protons from the stroma, the liquid between the thylakoid and chloroplast membranes, into the thylakoid, creating a proton gradient. This gradient is then used to fuel nearby ATP synthase in the thylakoid membrane. As protons flow through ATP synthase, the energy gained is coupled to the formation of ATP.

This arrangement of an antennae system and an electron transport chain is called a photosystem. There are two photosystems in the thylakoid membrane. The difference between the two has to do with where the extra electrons come from and where they go. In Photosystem II (which was discovered second but comes first in this process), the electrons come from water (as previously mentioned). This transport chain makes ATP. In Photosystem I, electrons are attained from Photosystem II and go to either of two pathways. Cyclic phosphorylation occurs when the electron returns to the antenna complex, creating a cycle of electrons in Photosystem I. This process produces ATP. Noncyclic electron flow occurs when the electron is passed to a nearby membrane protein called NADP+ reductase, which then uses this energy to reduce NADP+ to NADPH. NADPH and ATP then move along (with CO2) to the dark reactions. In a sense, the main input of electrons into the system is water and the output is NADPH.

The overall electron path is:
1. from water
2. to photosystem II (chlorophyll A) – P680
3. down the photosystem II electron transport chain
4. to photosystem I (chlobphyll A) – P700
5. either down the photosystem II electron transport chain and back to P700 – or – to NADPH

Q. Would photorespiration occur if the outer chloplast membrane was destroyed?
**Dark Reactions:**

The dark reactions include the making of glucose \((C_6H_{12}O_6)\) and water from \(CO_2\), ATP, and NADPH. In this reaction, 3 \(CO_2\) are mixed together with 3 molecules of ribulose bisphosphate (RuBP: a five carbon sugar) to make 6 molecules of glucose-3-phosphate (G3P). This is the actual product of the dark reaction. Of these 6 G3Ps, 5 will return to the start of the cycle and form the 3 RuBPs (15 total carbons). Eventually, two of the residual G3Ps that do not return to the cycle will join to form glucose (the reverse of the reaction which takes place in glycolysis). ATP and NADPH are used as energy sources in this reaction and are changed back into ADP and NADP⁺. They then are recycled to the light reactions. Water is also produced in this process.

**Q.** Can the dark reactions run without the light reactions? For how long?

**Q.** How is photosynthesis the same as glycolysis? How is it the reverse of glycolysis?