7.13 – Photosynthesis

The Producers

Some organisms are called **producers** because they make or produce the source of chemical energy for themselves and for other organisms. Since we have the first law of thermodynamics and energy is neither created nor destroyed, animals that eat plants as well as animals that eat other animals get their chemical energy directly or indirectly from these producers.

Photosynthesis is a process that captures energy from sunlight to make sugars that store chemical potential energy. Plants absorb the visible range of the electromagnetic spectrum, all white light which makes up from red to violet, for photosynthesis.

Chlorophyll is a molecule in the **chloroplasts** that absorb some of the energy in visible light. Plants have two main types of chlorophyll, called chlorophyll a and chlorophyll b. Together, these two types of chlorophyll absorb mostly red and blue wavelengths of light and reflect the green portion of the spectrum. Therefore, the green color of the plants comes from this absorption and reflection in the electromagnetic spectrum of visible light. Just a note is that the prefix chloro- means "green" and the root –phyll means "leaf" and –plast means "molded."

Where the Action Happens

Chloroplasts are organelles that have a membrane in the plant cell where photosynthesis occurs. The two main parts in the chloroplast needed for photosynthesis are the grana and the stroma. **Grana** (or the plural **granum**) are stacks of coin-shaped compartments called **thylakoids**. The thylakoid's membrane contains chlorophyll and proteins. The **stroma** is the fluid that surrounds the grana inside a chloroplast.

(Stage 1) The **light-dependent reactions** absorb energy from the sunlight. These reactions take place in the thylakoid and water is also needed for this stage of photosynthesis.

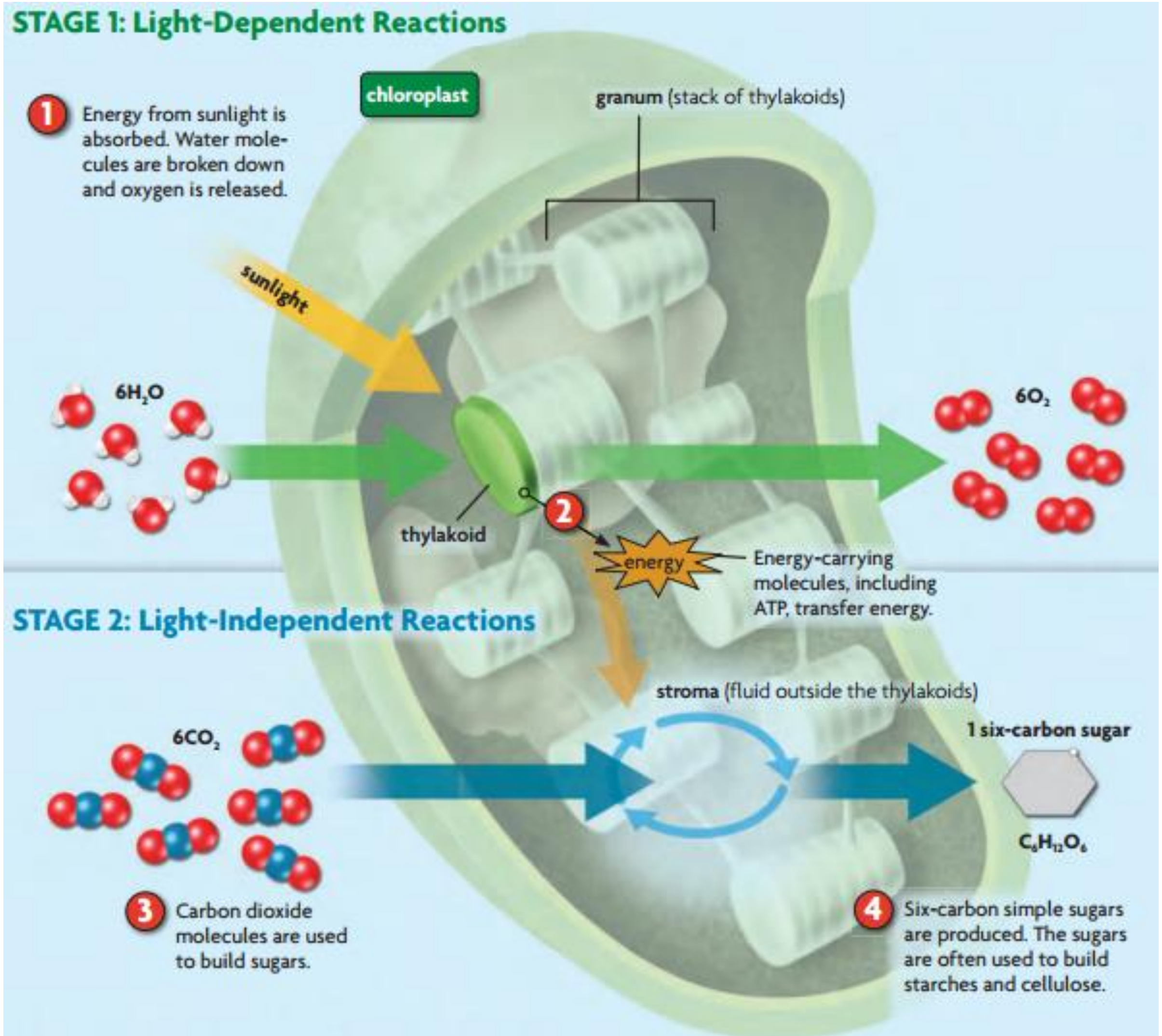
1. The chlorophyll absorbs energy from sunlight. Six moles of water molecules are broken down by this energy, producing six moles of oxygen gas molecules and a release of molecules.
2. These molecules, including ATP, contain a large amount of chemical potential energy are transferred.

(Stage 2) The **light-independent reactions** use energy from the light-dependent reactions to make sugars. These reactions occur in the stroma of the chloroplasts. Carbon dioxide (CO_2) is needed for this stage of photosynthesis. The name "light-independent" implies that sunlight is not needed. These reactions can take place anytime that energy is available. Primarily this is done with the light-dependent reactions energy.

3. Six moles of CO_2 is added and the energy from the light-dependent reactions help to break down these molecules.
4. A molecule of a simple sugar such as **glucose** ($C_6H_{12}O_6$) is produced which is used to build starches and cellulose.

This process of photosynthesis is not a single reaction but has many intermediate steps that include enzymes and other chemicals.

$$6\ CO_2 + 6\ H_2O \rightarrow \rightarrow \rightarrow \rightarrow \rightarrow \rightarrow C_6H_{12}O_6 + 6\ O_2$$



<u>The First Stage in Detail (Light-Dependent)</u>

The photosynthesis process above is actually much more involved than first described. For example, during the light-dependent reactions (Stage 1), energy is captured and transferred in the thylakoid membranes by two groups of molecules called **photosystems**. These two groups are often called **photosystem I** and **photosystem II**.

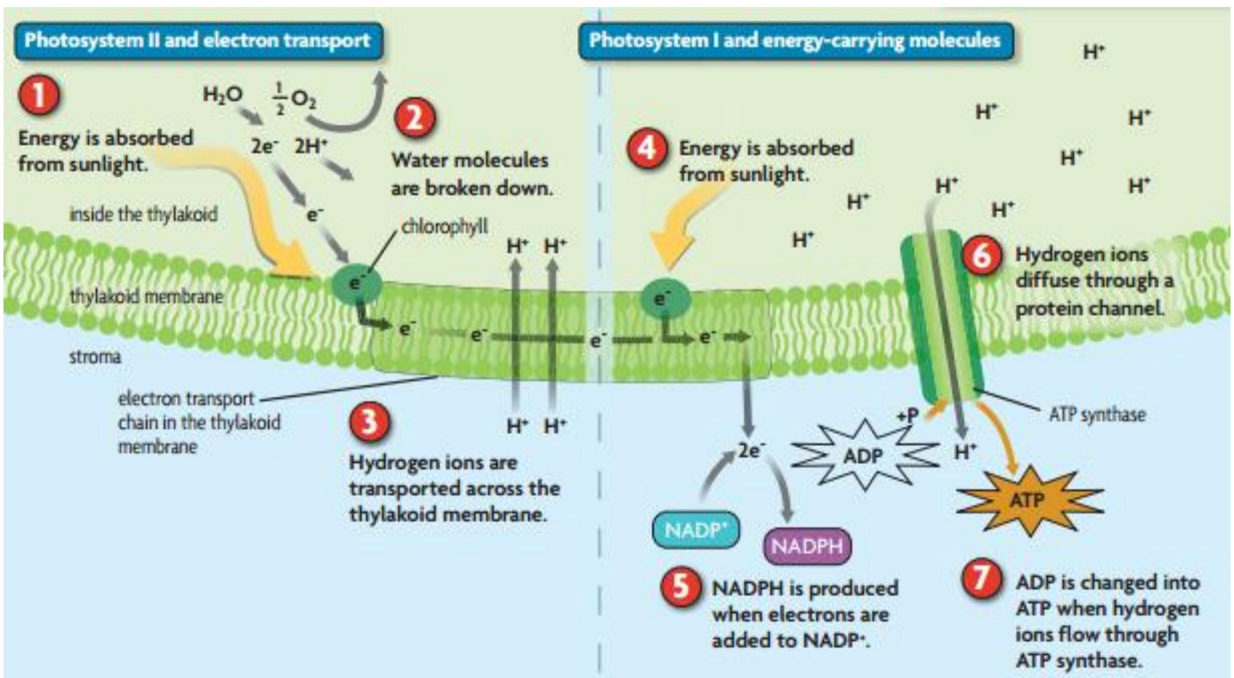
The initial part of Stage 1 is called **Photosystem II and electron transport**. The steps of this process are:

1. **Energy is absorbed form sunlight** from primarily chlorophyll in the thylakoid membrane. The energy is transferred to electrons (e-). These high energy electrons leave the chlorophyll and enter an **electron transport chain** which is a series of proteins in the membrane of the thylakoid.
2. **Water molecules are broken down** through enzymes. Oxygen gas molecules (O_2), hydrogen ions (H^+), and electrons are produced. The oxygen gas is released and electrons from water replace the electrons in step 1.

3. **Hydrogen ions (H^+) are transferred** while electrons move from protein to protein in the electron transport chain. Hydrogen ions are transferred across the thylakoid membrane and inside the thylakoid. The electrons move to photosystems I.

The next step of Stage 1 is called **Photosystems I and energy carrying molecules**. The steps of this process are:

4. **Energy is absorbed from sunlight** by the chlorophyll inside the thylakoid membrane and the electrons from photosystems II increase in energy and leaves the molecule.
5. **NADPH is produced** when the high-energy electrons are added to a molecule called $NADP^+$. The molecule NADPH goes to the light-independent reactions in Stage 2.
6. **Hydrogen ion (H^+) diffusion** occurs when the hydrogen ions flow through a protein channel in the thylakoid membrane. The difference in H^+ concentration is called a gradient and ions flow from high concentration to low concentration (osmosis).
7. **ATP is produced** as an enzyme called **ATP synthase** adds a phosphate to ADP with the H^+ ions.



The Second Stage in Detail (Light-Independent)

Again this second stage is much more involved than initially detailed above. The energy molecules produced in stage 1 such as NADPH and ATP are used in a series of chemical reactions called the **Calvin Cycle**. This is the "synthesis" part of photosynthesis. The stages of the Calvin Cycle are as follows:

1. **Carbon Dioxide (CO_2) is directly added** to a five-carbon molecule and a six-carbon molecule is now formed.
2. The energy from the 6 **ATP** and 6 **NADPH** from photosystems I is used to break the bond of the six-carbon molecule and it becomes 2 three-carbon molecules. ATP becomes ADP and NADPH become $NADP^+$ after releasing energy.
3. For every 3 three-carbon molecules that stay in the cycle, 1 high potential energy **three-carbon molecule leaves** the cycle. After two of these three-carbon molecules have left, they bond together to make a six-carbon sugar molecule such as glucose.
4. For every 5 three-carbon molecules that stay in the cycle form into a 3 five-carbon molecule and absorb energy from 3 **ATP** molecules. ATP again becomes ADP.