Plants

Lab 10

Energy and Photosynthesis

Concepts to be explored

- ✓ **Photosynthesis**
- ✓ **Light dependent and light independent reactions**
- ✓ **Chloroplasts**
- ✓ **Thylakoid**
- ✓ **Grana**
- ✓ **Lamella**
- ✓ **Stroma**
- ✓ **Calvin Cycle**

Introduction

Photosynthesis is how plants, even some algae and bacteria, produce energy and manufacture food. In this process, solar energy (light) is harvested and used to produce chemical energy (carbohydrates). Nearly all life on earth relies on this reaction in one way or another. Photosynthesis consumes carbon dioxide (a greenhouse gas) and releases oxygen. Photosynthesis takes carbon dioxide (CO_2), water (H_2O) and light energy and produces glucose ($C_6H_{12}O_6$) and oxygen (O_2). (Figure 19.1)

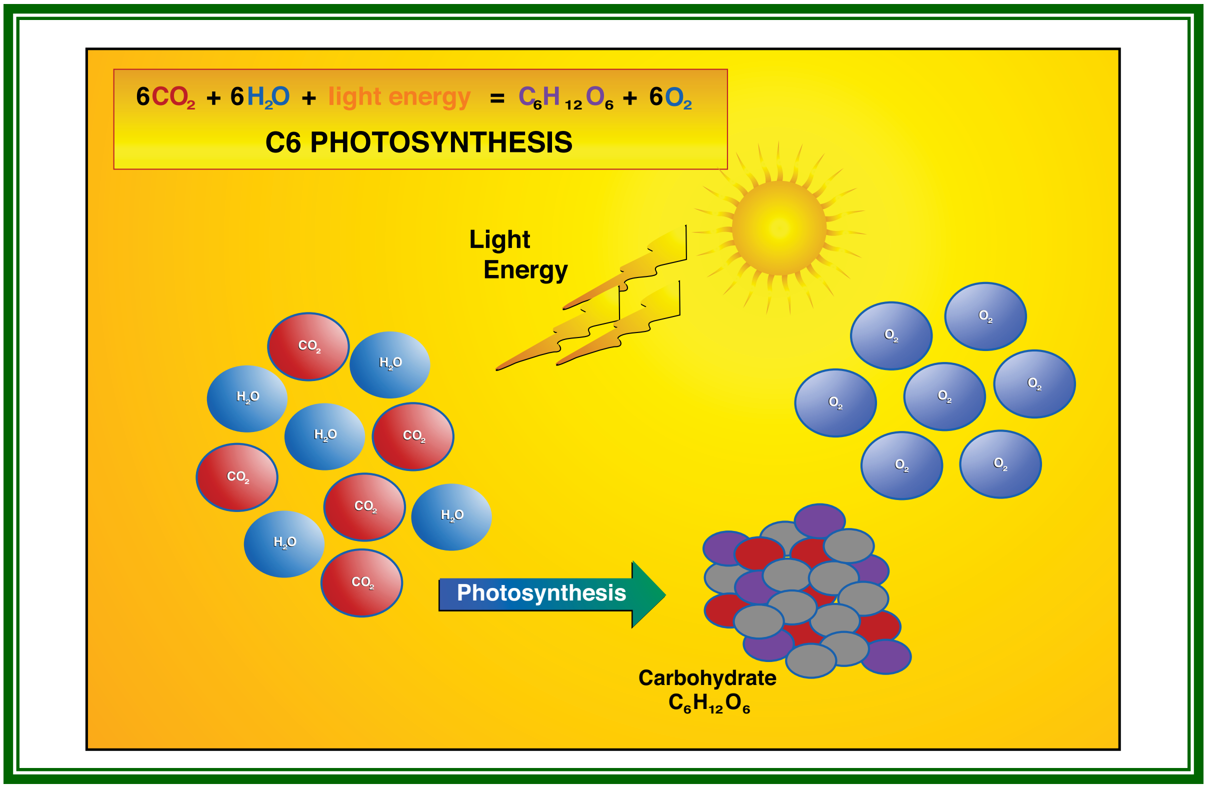

Figure 19.1: Photosynthesis

Many photosynthetic steps contribute to this equation, but all are either **light dependent** or **light independent reactions**. Both occur in the specialized organelles (**chloroplasts)** in plants and some algae.

A **chloroplast** has four principal structures that play a role in photosynthesis (Figure 19.2):

Thylakoids are small disk shaped structures that contain a pigment called chlorophyll. This pigment is responsible for capturing light energy.

Grana are stacks of connected thylakoids.

Lamella are structures that link the grana together.

Stroma is the fluid surrounding the grana and occupies the remainder of the chlororplast.

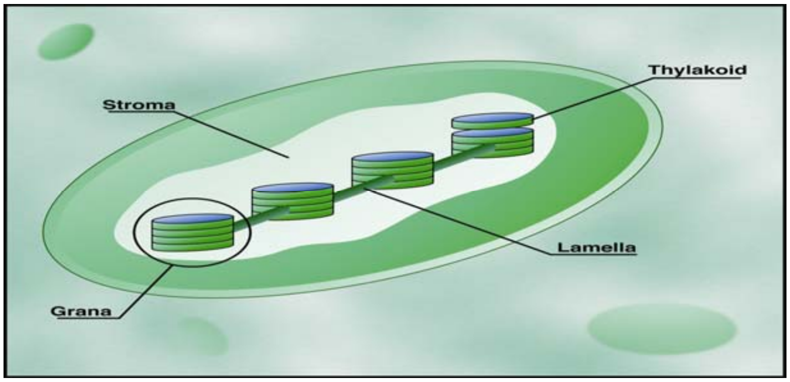

Figure 19.2: Chloroplast

Light dependent reactions depend on chlorophylls A & B and carotenoid pigments. Operating in tandem with other pigments, the energy collected by the chlorophyll break the chemical bonds of water (H_2O) and releases hydrogen (H) and oxygen (O_2).

These products, along with carbon dioxide (CO_2) undergo additional modifications in the stroma. Ultimately this results in the production of glucose, a carbohydrate used for energy. They are not dependent on the presence of light directly, hence the name light independent.

Chlorophyll gives plants their green color. Wheat grass juice, common in health food stores, has a high chlorophyll content, which gives it a pronounced dark green color.

Photosynthesis:

White light and green light

White light is a form of solar energy that contains all the wavelengths in the spectrum (i.e. “colors”: blue, green, yellow, etc.). This is the light you see when the with the rising of the sun.
Each pigment in a plant absorbs specific wavelengths of light, with most plants being unable to absorb green wavelengths. These are reflected back, which is why plants typically appear green. The color observed is the reflection and not the absorption color.

All of the other wavelengths (colors) are absorbed by the plant and its various pigments and initiate the formation of chemical energy.

Remember, color corresponds with the following wavelengths:

Violet 400 nm
Blue 475 nm
Green 515 nm
Yellow 570 nm
Orange 620 nm
Red 675 nm

Though there are many factors that can affect the rate of photosynthesis, without the presence of carbon dioxide, photosynthesis cannot take place. In this experiment we will test this claim and see if a source of carbon dioxide (sodium bicarbonate) is needed for plants to photosynthesize.

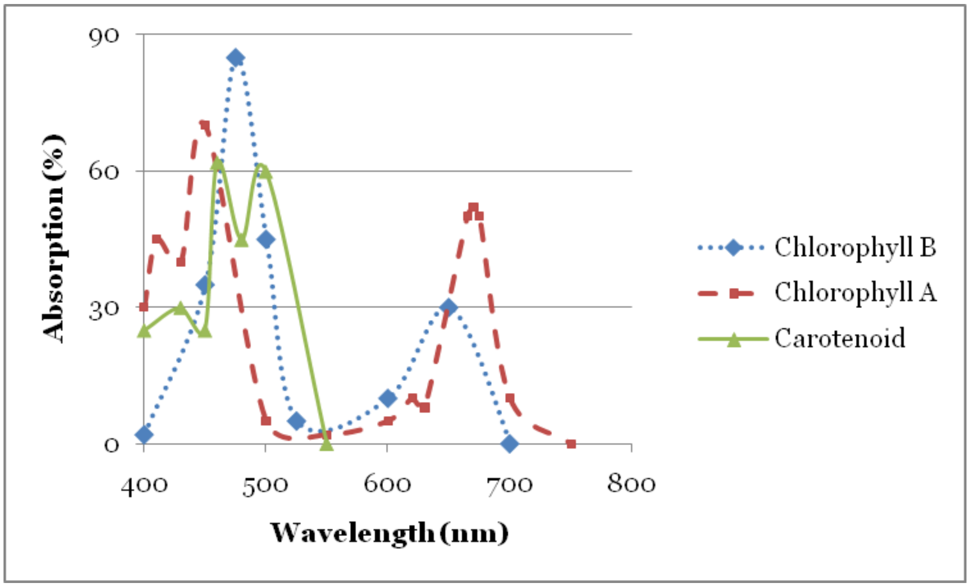

Figure 19.3: Wavelength absorption

Figure 19.3 illustrates how each pigment absorbs specific wavelengths, pigments have unique absorption wavelength patterns.

Experimental Protocol

Materials Needed:

*^Elodea
(2) Glass test tubes
(2) 250 mL beakers
10% Sodium bicarbonate solution
*Tap water
*Sunshine or bright light
*Watch
Permanent marker

*You Must Provide
^Elodea is a common water plant that can be found at pet stores that sell aquatic supplies

Procedure:

1. From your fresh elodea, cut two 5cm length pieces and place one into each test tube.

2. Using the permanent marker, label the test tubes 1 and 2.

3. Pour water into test tube 1 until it is completely full. Take a 250 mL beaker and turn it upside down so that the filled test tube is placed against the bottom of the beaker (Figure 19.4).

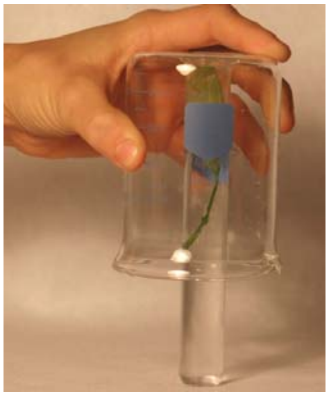

Figure 19.4

4. Carefully turn the test tube and beaker over without spilling any water or allowing any air to penetrate the test tube.

5. While you are still holding the test tube, quickly add 150 mL of water to the beaker containing the test tube.

6. As soon as the water is poured into the beaker you can let go of the test tube (Figure 19.5). Take note of the size of the bubble on the top of the test tube and carefully mark it on the test tube using a permanent marker.
   Note: your goal is to have the smallest bubble possible

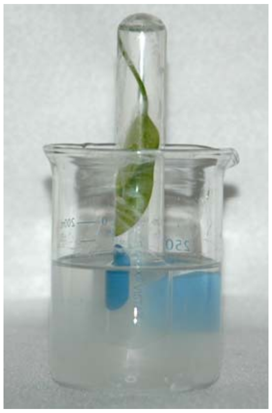

Figure 19.5

4. Fill test tube 2 to the top with the sodium bicarbonate solution.

5. Again take a 250 mL beaker, turn it over and place it on top of the test tube. As soon as that is stable, turn the test tube and beaker over.

6. Pour the remaining sodium bicarbonate solution into the beaker and then let go of the test tube. Take note of the size of the bubble on the top of the test tube and carefully mark it on the test tube with a permanent marker.
   Note: your goal is to have the smallest bubble possible

4. Using the utmost care, gently grasp a hold of one of the beaker and test tube combinations at a time and place them in the window sill or in front of a bright light.

5. Set your timer for 2 hours.

6. After 2 hours have passed, return to observe each test tube. Measure the distance from the previous mark made on the test tube to the current water level and record your results in Table 19.1.

Table 19.1 Elodea Lab (measured results)

	Distance Traveled (mm)
Test Tube 1	
Test Tube 2	

Questions

1. Which test tube had a bigger bubble on the top before the experiment?
   After the experiment?

2. What do you hypothesize is causing the bubble at the top?

3. What role do you hypothesize the sodium bicarbonate played?

4. From what you know about plants, if we were to place one of the test tube and beaker combinations in front of a green light, what would happen?

Light Independent Reaction

After the light dependent reaction, the **light independent reaction** takes the products of hydrogen and oxygen, along with carbon dioxide, and converts them to carbohydrates and oxygen in a process known as the **Calvin Cycle**.

The **Calvin Cycle** is composed of multiple reactions that link carbohydrates to ultimately form sucrose. Though we won't go into detail on this rather complex reaction, it is important to note that carbon fixation is the first step, which is then followed by the light independent reaction which yields sucrose.

Though we've seen in exercise 1 that a gas is produced while photosynthesis take place, it is not clear what type of gas it is. As you've learned, plants take in carbon dioxide and release oxygen. To detect carbon fixation, or the depletion of CO_2, we will be use a pH indicator, phenol red, to detect CO_2 levels. As CO_2 is reduced and oxygen is produced, pH will rise and the solution will become more basic. As CO_2 is produced and oxygen is depleted, pH drops and the solution becomes more acidic.

Phenol red turns yellow if the solution is acidic (below pH 7) and red if it is basic (above pH 7).

Photosynthesis:

Depletion of carbon dioxide

Experimental Protocol

Materials Needed:

*Elodea
Glass test tube
20 mL of Phenol red
Straw
Test tube rack
Pipette
*Water

* You must provide

Procedure: *Carbon dioxide depletion by photosynthesis*

1. Place a glass test tube in the test tube rack.

2. Using a pipette, add 20 mL of the phenol red solution to the test tube.

3. With your straw, blow bubbles over the top of the solution until it turns yellow (Figure 19.6). **DO NOT** insert the straw into the solution (keep it above the surface). Blowing on the surface adds CO_2 to the solution. You should observe this as a color change (when the water in the phenol red solution and CO_2 are combined, an acid is formed)

   DO NOT INHALE!

   This process is not quick. If you become light headed, take a break!

Figure 19.6

4. Cut 5 cm of fresh elodea and gently place it into the test tube. DO NOT touch the phenol red solution.

5. Place the test tube rack back into the sunshine or bright light and set your timer for one hour. Every 15 minutes record the color of the solution in Table 19.2 for one hour.

Table 19.2

Time	0 min	15 min	30 min	45 min	60 min
Color					

Questions

1. What happened to the color of the solution over one hour?

2. What is the process that is occurring to make the phenol red solution change colors?

3. If we placed a green light in front of the test tube, do you think the results would be different? Why or why not?

Additional Questions:

1. Some plants (grasses) tend to contain a greater concentration of chlorophyll than others (pines). Develop a hypothesis to explain this observation? Would it be testable?

2. Given what you now know about chloroplasts, pigments and wavelengths, consider trees whose leaves turn yellow in the fall. What is happening in the leaves at the cellular and molecular levels?

3. We have seen that chloroplasts are the organelles in plant cells that provide energy to the cell. The equivalent organelle in eukaryotic (animal) cells is the mitochondria. Both are unusual in that they have double membranes and contain their own set of DNA. Can you think of any explanations for this observation?