Exercise 12
Photosynthesis

Introduction:

All of the oxygen we breathe, food we eat, and the fossil fuels we use are products of photosynthesis. Photosynthesis is the process that converts energy in sunlight to chemical forms of energy that can be used by living organisms.

Photosynthesis is carried out by many different organisms, ranging from plants to bacteria, with about 90% of the photosynthesis on the planet occurring in the oceans. All of these organisms convert CO_2 (carbon dioxide) from the atmosphere to organic material (carbohydrates) in a complex set of reactions. The carbohydrates produced are then used by the plants (or the animals that eat the plants) to make all the "stuff" they need to live. Water is converted to oxygen and hydrogen using energy provided by sunlight The extra oxygen is released as a waste product and the hydrogen is used to make the carbohydrate. (Remember, plants need some oxygen for respiration).

In simple terms we can describe photosynthesis as follows:

> Using chlorophyll and sunlight, 6 molecules of carbon dioxide + 12 molecules of water are changed to one molecule of sugar + 6 molecules of water + six molecules of oxygen.

The general equation for photosynthesis can be expressed as follows:

$$\mathbf{6\ CO_2 + 12\ H_2O + light\ energy\text{------->}C_6H_{12}O_6 + 6\ H_2O + 6\ O_2}$$

The energy for this reaction is absorbed by photosynthetic pigments (primarily chlorophyll) which absorb blue and red light. The pigments in plants do not effectively absorb green light; therefore, green light is either reflected by leaves or passes through the leaves, so plants appear green.

Exercise 1: Photosynthesis and Carbon Dioxide
(This exercise should be done in teams of four students).
We can show that carbon dioxide is used in photosynthesis in a simple experiment.

Materials needed:
Floodlight
Test tubes (5)
Test tube rack
250 ml. Beaker
600 ml. Beaker
Drinking straw
Phenol red indicator (pH indicator- red=basic or neutral, yellow=acid)
Aluminum foil
Elodea

Procedure:
1. Add about 100 ml. of tap water to a 250 ml. beaker. Add 8 drops of phenol red indicator. Phenol red is red in neutral or basic solutions.
Fill a test tube about half full with this solution, and set aside in a rack. This will serve as a standard to compare with your experimental tubes.

2. Using a soda straw, gently blow into the remaining solution of phenol red. As you blow, you will be adding carbon dioxide from your breath to the solution. This will cause the solution to become acidic as the carbon dioxide dissolves in the water, forming carbonic acid.
Continue to blow until the phenol red solution turns yellow.

$$\mathbf{CO_2 + H_2O \text{ <-----> } H_2CO_3}$$

3.Fill four more test tubes about 2/3 full of the yellow solution.
Select three healthy pieces of the water plant Elodea. These should be a healthy green color with lots of leaves, and be of nearly equal size (about 2-3 inches long).

4. Place one piece of Elodea in each of three tubes so that the bottom cut end points up (see diagram).

5. Wrap one tube with Elodea in aluminum foil. Place it and one other tube with Elodea in one end of a test tube rack. Place the tube without Elodea, containing only the yellow, CO_2 enriched solution with these tubes..

6. Place the last tube with Elodea in the opposite end of the rack.

7. Set the rack so that the end with three tubes is about 12 inches away from the front of a floodlight bulb. Place a 600 ml. beaker filled with water halfway between the lamp and the tubes in the rack. This acts as a heat filter so the tubes don't get to hot

8. Record the time, and allow the experiment to run for 45 minutes to an hour. At some point notice the bubbles being released by the plants.
What is this gas?___________________

9.At the end of the time, unwrap the foil covered tube and compare the color of all the tubes. Hold the tubes over a piece of white paper to compare the colors. Record your observations in the table below.

Tube 1- Yellow solution, Elodea, close to lamp

Color?___________________________

What does this mean?___________________________________

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Tube 2- Yellow solution, Elodea, close to lamp, covered with foil

Color?_____________________________

What does this mean?___________________________________

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Tube 3- Yellow solution, no Elodea, close to lamp

Color?_____________________________

What does this mean?___________________________________

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Tube 4- Yellow solution, Elodea, farthest from lamp

Color?_____________________________

What does this mean?___________________________________

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Tube 5- Red solution, no Elodea (for color comparison)

Color?_____________________________

What does this mean?___________________________________

Exercise 2: Leaf structure
(This exercise works well with a partner. One member should look, while the other reads the description, then switch roles).

Leaves are the primary photosynthetic organs of land plants. The flat, thin shape of leaves makes them ideal solar collectors to gather the energy. The veins in leaves are part of a vascular system to provide a constant supply of water to act as a raw material in photosynthesis and as a cooling system for the leaf.

Obtain a microscope slide of "Typical Dicot Leaf" or "*Tilia americana* leaf". This slide is a cross section of a leaf, so you can see the internal structure. If you have trouble finding anything, you may have to refer to a diagram of a leaf. There is also a 3D model of a leaf available for you to look at to help you to understand what you're seeing.
The outer layer of cells on both the upper and lower surfaces is the **epidermis**. If you look carefully, you can see a thin layer on the outside of the leaf. This is the **cuticle**; a waxy coating that helps make the leaf waterproof. Just below the upper epidermis is the **palisade parenchyma.** (A "palisade" was originally a fortress wall made of logs stuck in the ground). This is a layer of tightly packed elongated cells with numerous **chloroplasts** whose primary function is to capture light and carry out photosynthesis. There may be more than one layer of these cells if the plant was grown in very bright light. Below the palisade parenchyma, is the **spongy parenchyma**, an area of loosely packed cells that contains a lot of air space. This area facilitates gas exchange inside the leaf so the palisade cells can absorb carbon dioxide, and get rid of oxygen. Notice that the lower epidermis has numerous holes or pores called **stomata** (sing. **stoma**). These allow gas exchange between the spongy parenchyma and the outside atmosphere. In addition to carbon dioxide and oxygen, water vapor passes through the stomata. Each stoma has a pair of **guard cells** that shrink or swell to open or close the stoma. Note that these guard cells have chloroplasts, unlike the rest of the epidermal cells. Look for the vascular bundles that provide the "plumbing" for the leaf. Near the center of the leaf these are cut straight across, so the cells appear round. Towards the edges of the leaf these cells are cut on a diagonal so appear oval. The **xylem** cells, which conduct water upwards, are stained red. The **phloem** cells, which conduct the photosynthetic products (sugar) down to the rest of the plant, are stained green.

Exercise 3: The absorption spectrum of chloroplasts.
(Work with a partner to hold tubes, etc.)

White light is composed of many colors. We can see these colors in a rainbow created in the lab by using an instrument called a **spectroscope**. It uses a diffraction grating to separate the colors in white light according to their wavelength. All of these colors of light are not equally used by plants to trap energy.

Look in the eyepiece of the spectroscope to see the normal spectrum. The numbers you can see represent the wavelength of the light. After you observe the spectrum, have your lab partner hold a tube of chloroplast pigments in front of the slit that lets light into the spectroscope, and observe how the spectrum changes.
(Pigments were extracted from the leaf using organic solvents).

What colors of light disappear, or become less bright?

What does this show us?