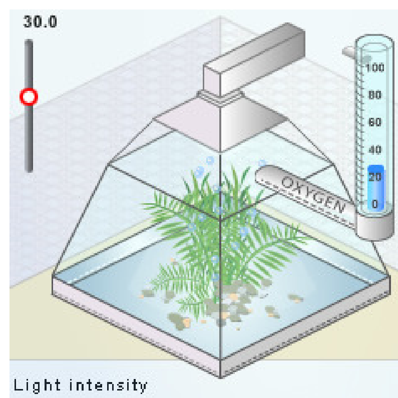
Teacher Guide: Photosynthesis Lab

Learning Objectives
Students will…

- Discover that plants require light, water, and carbon dioxide for photosynthesis.
- Understand that oxygen is produced by photosynthesis.
  - Increased oxygen production indicates more rapid rates of photosynthesis.
  - Decreased oxygen production indicates slower rates of photosynthesis.
- Determine how temperature, light intensity, and carbon dioxide levels affect rates of photosynthesis.
- Observe that the color of light can affect the rate of photosynthesis.
  - Explain why photosynthesis works most slowly under green light.
- Explore the concept of limiting factors. (Extension)
  - In a given situation, determine which required substance is in shortest supply and therefore limits the rate of photosynthesis.

Vocabulary
carbon dioxide, chlorophyll, glucose, limiting factor, nanometer, photosynthesis, wavelength

Lesson Overview
In the process of photosynthesis, plants use light energy to combine carbon dioxide and water to form glucose. A by-product of photosynthesis is oxygen, which is released.



With the *Photosynthesis Lab* Gizmo™, students can infer rates of photosynthesis by measuring oxygen production. Temperature, light intensity, and CO_2 levels can be varied. Students can also experiment with different colors of light.

The Student Exploration sheet contains two activities and an extension:

- Activity A – Students determine the ideal light intensity, temperature, and carbon dioxide levels for photosynthesis.
- Activity B – Students explore the effects of colored light on photosynthesis.
- Extension – Students discover how limiting factors affect rates of photosynthesis.

Suggested Lesson Sequence

1. **Pre-Gizmo activity: Oxygen production** (15 – 20 minutes)
   Obtain an aquatic plant such as *Elodea* (water weed) and place it in a glass water tank under bright lights. Add a pinch of baking soda as a source of carbon dioxide. After a while, you and your students will be able to see small bubbles of oxygen coming from the leaves of the plants. Place plants into different lighting conditions (full sunlight, shade, artificial light), and have students count the bubbles produced in a minute to determine the rates of photosynthesis.

Another way to demonstrate that photosynthesis is happening is to use the indicator bromthymol blue. Dissolved carbon dioxide causes water to become slightly acidic and turns the bromthymol blue solution yellow. Plants remove the CO_2 as they produce oxygen, removing the acid and causing the indicator to turn blue again. You can create a yellow solution by blowing into the bromthymol blue through a straw. (Caution: Do NOT drink the bromthymol blue solution.) Add this to plants in test tubes, seal the tubes, and place plants in sunlight and in the dark. After a day, the solution will be blue for the plants in the light and green or yellow for the plants in the dark.

2. **Prior to using the Gizmo** (10 – 15 minutes)
   Before students are at the computers, pass out the Student Exploration sheets and ask students to complete the Prior Knowledge Questions. Discuss student answers as a class, but do not provide correct answers at this point. Afterwards, if possible, use a projector to introduce the Gizmo and demonstrate its basic operations. Demonstrate how to take a screenshot and paste the image into a blank document.

3. **Gizmo activities** (15 – 20 minutes per activity)
   Assign students to computers. Students can work individually or in small groups. Ask students to work through the activities in the Student Exploration using the Gizmo. Alternatively, you can use a projector and do the Exploration as a teacher-led activity.

4. **Discussion questions** (15 – 30 minutes)
   As students are working or just after they are done, discuss the following questions:
   - Which gas is being produced by the plant?
   - Why is oxygen production a good measure of the rate of photosynthesis?
   - In the default settings of the Gizmo, why doesn't oxygen production continue to rise as CO_2 level increases? (The same applies to light intensity.)
   - With white light, what settings lead to the maximum oxygen production?
   - Why does photosynthesis occur most slowly under green light?

5. **Follow-up activity: Colored light** (3 – 4 weeks)
   In the second activity of the Student Exploration, students discover that the color of light can greatly affect rates of photosynthesis. To illustrate this, try growing plants under different colors of light. Use young seedlings that are about the same size. (Bean plants are easy to grow.) Colored light bulbs are available in many stores. You could also use Christmas lights or colored filters. Be sure to give each plant plenty of light. Surround each plant with a cardboard box so that it only receives light from one source.

   Grow plants under white, blue, red, green, and no lights. Be sure that, other than the color of light, all other experimental variables (light intensity, temperature, plant type, soil, water) are the same for each plant.

   After several weeks, measure the plants, compare their leaves, and measure their mass. In theory, the most robust plants will be the ones grown under white, red, and blue light. The plants grown under green light will be paler in color, less massive and less healthy than the others. (Note: Height is not a very reliable indicator of the health of the plant. Plants grown in low light often grow tall and spindly as they seek better light.)

Scientific Background

The process of photosynthesis is a complex process that occurs in two phases: a *light-dependent* phase and a *light-independent* phase. The light-dependent phase begins when light hits plant cells. The light is absorbed by a green pigment called *chlorophyll*, which is found within cell organelles called *chloroplasts*. When a photon of light hits a chlorophyll molecule, a single electron is released. The electron is passed along a chain of molecules and ends up in a molecule of NADPH (nicotinamide adenine dinucleotide phosphate).

As electrons are stripped from chlorophyll molecules, the electrons are replaced by electrons donated by hydrogen atoms in water molecules. Removing electrons from two water molecules ($2H_2O$) yields 4 electrons, 4 protons, and a single oxygen molecule (O_2) that is released by the plant. The 4 protons are used to convert molecules of adenosine diphosphate (ADP) to molecules of adenosine triphosphate (ATP). The summary equation for the light-dependent reaction is:

$$2H_2O + 2NADP^+ + 2ADP + 2P_i + \text{light} \rightarrow 2\ NADPH + 2H^+ + 2ATP + O_2$$

In the light-independent reactions, energy from the ATP, H^+, and NADPH is used to transform carbon dioxide (CO_2) to glucose ($C_6H_{12}O_6$). This process is called the Calvin cycle. The end result is a sugar-phosphate molecule called glyceraldehyde-3-phosphate (G3P). The G3P molecules are then combined to form familiar sugars such as glucose ($C_6H_{12}O_6$), fructose ($C_6H_{12}O_6$), and sucrose ($C_{12}H_{22}O_{11}$), as well as the complex carbohydrates cellulose and starch.

Environmental connection: Oxygen in the atmosphere

Much of Earth's iron ore comes from peculiar deposits called banded iron formations (BIFs). A BIF consists of alternating layers of iron ore and chert, a quartz-like mineral. Most of these deposits are very ancient, about 1.8 to 2.5 billion years old. What happened at this time to cause so much iron to be deposited? Most scientists agree that this period corresponds to the evolution of photosynthesis in ancient bacteria and algae.

Prior to photosynthesis, Earth's atmosphere had little or no free oxygen. Oceans were highly acidic, and contained high concentrations of dissolved iron and other metals. When bacteria began to produce their own food through photosynthesis, oxygen was released into the water. This oxygen reacted with the dissolved iron to form oxidized iron, or rust, that precipitated out of the water and settled as layers on the seafloor. It wasn't until all the dissolved iron was removed, around 1.8 billion years ago, that oxygen was released into Earth's atmosphere, setting the stage for the evolution of aerobic (oxygen-dependent) organisms.

Selected Web Resources

Elodea labs: http://www.qacps.k12.md.us/cms/sci/life/Lab_Photosynthesis.doc, http://kenpitts.net/bio/energy/elodea_lab.htm, http://www.iit.edu/~smile/bi9201.html
Photosynthesis lab: http://chem.lapeer.org/Bio1Docs/PhotoLab.html
Photosynthesis summary: http://biology.clc.uc.edu/Courses/bio104/photosyn.htm
Oxygen in Earth's atmosphere: http://www.palaeos.com/Earth/Atmosphere/oxygen.htm

Related Gizmos:
Cell Energy Cycle: http://www.explorelearning.com/gizmo/id?455
Plants and Snails: http://www.explorelearning.com/gizmo/id?641
Dehydration Synthesis: http://www.explorelearning.com/gizmo/id?464