Nashua River Watershed Investigations for Grades K- 8
Lesson # 6-3

Title: 6-3 Dissolved Oxygen Production in Submerged Aquatic Plants

Grade Level & Standard: Grade 6
6MS-LS1-2. Develop and use a model to describe the ways parts of cells contribute to key cellular functions of obtaining nutrients and water from its environment, disposing of waste, and producing energy:

a. the nucleus contains genetic information (DNA) which regulates a cell's activities
b. chloroplasts are the site of photosynthesis which produces necessary glucose & oxygen
c. mitochondria facilitate cellular respiration (energy production)
d. vacuoles store materials, including water, nutrients and waste
e. the cell membrane is a protective barrier that enables nutrients to enter the cell and wastes to be expelled
f. the cell wall provides structural support to some types of cells

Objective: Students will conduct an experiment to measure and analyze dissolved oxygen (average number of oxygen bubbles) produced during photosynthesis by submerged aquatic plants under low and high light or different distances from a light. Students will then create a bar graph comparing average oxygen production.

Background: In submerged aquatic plants, surface cells absorb water, nutrients and dissolved gases (needed to access sugars) from surrounding water.

<u>Characteristics of a Freshwater Environment</u>*

1. Water is plentiful, at least during the growing season.
2. PFD (wavelengths of sunlight used for photosynthesis) is low for submerged leaves, because light penetration through the water column is very much reduced.
3. Concentration of carbon dioxide dissolved in water is low (higher in water strongly acidic or strongly basic than in neutral pH solutions).

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4. Oxygen concentration of oxygen in the water and in thick tissues of the underwater plant is low.
5. Minerals and nutrients are scarce or dilute within the water medium, as compared with drier soil.
6. Moving water (currents and waves) can be damaging to the organs of the plant.

Photosynthesis: wavelengths of sunlight used for photosynthesis is low for submerged leaves, because light penetration through the water column is very much reduced.

Physical adaptations: Totally submerged plant adaptations: hydrophyte: no mechanical strength in stem, lack cuticles on external leaf surface. No stomata on a submerged leaf because leaves don't have to conserve water. This is a strategy to maximize surface-to-volume (S/V), permitting rapid diffusion of carbon dioxide into the chloroplasts of the cells by having proportionately greater surface area. The highly dissected underwater shoot can be tugged at and pulled by water currents without damaging the segments (i.e., little mechanical resistance to current).Certain aquatic species have very high ratios of surface to volume (S/V) by having one- or two-cell layer construction. These leaves have a very thin cuticle (wax), but the wax is porous enough to permit easy diffusion of gases through the surface. Many submerged plants have thin leaves. Plants that normally are submersed typically form their flowers raised above the water surface. An important adaptation for many freshwater aquatic plants is the formation of aerenchyma, which is tissue having large intercellular air spaces. Aerenchyma functions both to store oxygen and to transport gas to living tissues. This gas collection is important in leaves for buoyancy. In addition, the system of lacunae (open spaces) is a diffusion pathway for oxygen; the oxygen is, of course, made in the chloroplasts during the light reaction of photosynthesis. Oxygen, when released via photosynthesis, diffuses preferentially into the lacunae, because it cannot diffuse as rapidly into water and comes out of solution in the intercellular air spaces, where oxygen concentration of trapped air there may be one-third or greater. Here it can be used in constructive ways by aquatic plants. A leaf midvein, petiole, or stem develops an internal pressure, which enables oxygen to be transported via bulk flow in a lacunar network to rhizomes and roots located in the anaerobic mud and muck, permitting these organs to grow more rapidly. Gases can also move in bulk to young tissues, where the pressurized air helps expansion of developing lacunae near the growing tip. The cut end of an aquatic plant will give out bubbles (underwater, of course) from lacunar gas under pressure.

Nutrients and gases: Surface cells absorb water, nutrients and dissolved gases from surrounding water, therefore the xylem are reduced or absent. Co2 and O2 concentrations are low in water. Minerals are dilute too. In the water, dissolved O2 in water is absorbed. Roots are reduced, root hairs absent, specialized leaf shapes (highly

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dissected or divided) create large surface area. Air filled cavities help them float and create internal atmosphere. Leaves often have air spaces to allow them to float which maximizes photosynthesis and gas exchange Waste products are released through surface cells.

Examples of highly dissected submerged leaves

- European milfoil (*M. spicatum*)
- pondweed (*Potamogeton pectinatus, P. filiformis, P. crispus, P. foliosus*)
- hornwort (*Ceratophyllum demersum, C. submersum*)
- Cobomba (invasive)

**http://www.botgard.ucla.edu/html/botanytextbooks/lifeforms/index.html*

Vocabulary:

- **Photosynthesis -** All organisms, animals and plants, must obtain energy to maintain basic biological functions for survival and reproduction. Plants convert energy from sunlight into sugar in a process called photosynthesis. Photosynthesis uses energy from light to convert water and carbon dioxide molecules into glucose (sugar molecule) and oxygen (Figure 2). The oxygen is released, or "exhaled", from leaves while the energy contained within glucose molecules is used throughout the plant for growth, flower formation, and fruit development.

  Carbon Dioxide & Water & Light Energy = Glucose & Oxygen
- **Respiration** occurs when glucose (sugar produced during photosynthesis) combines with oxygen to produce usable cellular energy. This energy is used to fuel growth and all of the normal cellular functions. Carbon dioxide and water are formed as by-products of respiration.

  Glucose & Oxygen = Water & Energy & Carbon Dioxide
- **Elodea -** a submerged aquatic plant
- **Cabomba -** an invasive submerged aquatic plant

Discussion Points

How do aquatic plants get nutrients from environment into their cells? How do they dispose of waste and produce energy? How does a submerged plant get Co2 (photosynthesis) and O2 (respiration)? How do aquatic plant structures contribute to photosynthesis?

Materials:

- 5 liters of conditioned tap water (water should be left in an open container and allowed to sit for 36-48 hours)
- 15-20 total *Elodea canadensis*, bought through Carolina Biological Supply Company (www.carolina.com)

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- Cabomba works the best but can only be obtained from an infested river because it is illegal in Massachusetts.
- Twist ties to fasten plants into bunches
- Small rocks or similar objects to hold the *Elodea* plants underwater
- 500-ml beakers, 1 per group
- Baking soda, a few tablespoons (sodium bicarbonate)
- Timers or watches with second hands, 1 per team
- Small adjustable desk lamps for each group -these can be set up so that the light bulbs are a few inches above the beakers and shine vertically down onto them

Procedure:

1. Develop a hypothesis with the class, such as " the plants that receive more light produce more oxygen bubbles than the plants that receive less light".

2. Working in teams, students set up and conduct the experiment. Each team conducts two trials; one with the plants in a dark room and one with the plants receiving bright light from the desk lamps.

3. With the lights turned off, each team fills a beaker with about 500 ml of conditioned water for the *Elodea*. To this water, add one-quarter teaspoon of sodium bicarbonate (baking soda) to provide a source of carbon dioxide for the plants. Stir the water until the sodium bicarbonate is dissolved and the water looks clear.

4. Each team obtains enough sections of *Elodea* plants so that it has about 18-24 inches of total plant length. Arrange them so that all of the plants are at least 1½" under the water in the beaker. Use twist ties to hold plants together, and then add a small rock to keep the plants from floating to the surface.

5. As soon as the plants are arranged in the beakers, have the team start timing for five minutes. Count the bubbles as they emerge. The bubbles will be approximately 2 mm in diameter and easily observed as they rise to the surface.

6. If using Cabomba, turning the plant upside down may be another option.

7. When all teams have counted bubbles in dim light for five minutes, turn on the room lights and have students position the desk lamps directly above the beakers with the light bulbs only be a few inches above the beakers. Once the lights are in place, have the teams again begin timing and counting/recording bubbles for five minutes.

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8. You can experiment with different distances from the light. (see below)

9. Make a large chart on the classroom board in which teams can fill in the number of bubbles they counted during each of the two light conditions.

10. Provide students with grid paper and direct them to make a graph comparing the two class averages. Examine all the data and graphs and revisit the hypothesis.

11. Continue with a class discussion to analyze the data.

Data Sheets:

Sample data set

Lamp Distance from plant (cm)	Number of bubbles per minute		
	Test 1	Test 2	Average
0	**105**	**112**	**108.5**
2	**95**	**91**	**93.0**
4	**88**	**80**	**84.0**
6	**74**	**70**	**72.0**
8	**66**	**56**	**61.0**
10	**51**	**45**	**48.0**

Extension:

- Teachers can collect submerged aquatic plants from a river or a pond and have students look at them and explore structures. Plants can be identified using:
  - *A Guide to Aquatic Plants in Massachusetts (8.5 x 11 booklet)*
  - or on line at http://archives.lib.state.ma.us/handle/2452/128143

- Visit http://www.exploratorium.edu/imaging-station/gallery for Elodea prep and microscope viewing.

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