Curriculum Units by Fellows of the Yale-New Haven Teachers Institute
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Purification v. Population: Green v. Gray The Plant Kingdom's Impact on Air Quality

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Is there new development in your area? If so, will this development contribute to pollution? Our booming economy assures expansion, but does new development always bring environmental deterioration? Is there a solution? Are plants the solution? This unit addresses a central question: Can plants erode or minimize the air pollution associated with urban expansion and development?

As the city of New Haven debates a major development proposalconstruction of a large mall next to a highwayscientists are reporting on "urban climates" and the health risks associated with urban sprawl. Can major planting efforts offset temperature increases and air pollution? Can plants produce enough oxygen to lessen increases in carbon dioxide and other gasses to minimize smog?

Upon completion of the unit, students will decide if planting is a solution. Students will participate in a mock trial, using results from research and experiments as evidence that supports their claim. Those that think plants can alleviate damage caused by a large-scale mall development, and wish to have the mall built in their neighborhood will defend plants' as air purifiers. Those who think mall development is too much for plants to bear will prosecute mall developers as polluters who damage air quality and harm residents.

Purification v. Population: Green v. Gray is an integrated science curriculum unit written for grades 6 through 9. The unit is inquiry-based and emphasizes data capture, analysis and validation. This unit is prepared for my eighth grade Integrated/Earth Science class. Most students in my classes are aware, and in favor of, a large-scale mall development proposal that would be located right in their community. They are fans of designer label shopping and expect to work at this mall. There are many, however, who are aware of consequences of air pollution as they or a family member have asthma or other respiratory illnesses. The air quality in our city is not great; smog and low-level pollution is already a problem for many in our city.

Students first examine their local environment, particularly air pollution. They identify contributing factors, and quantify car exhaust and carbon dioxide. They examine the effects of air pollution on plants and, by extension, on other living things.

After students assess current conditions, they assess the impacts plants have on the environment. Most of these laboratory investigations will provide the "evidence" students will present in court. Necessary to evidence is examination of all the processes imbedded in photosynthesis, validation and quantification of components. Through their investigations students verify the existence of carbon dioxide and oxygen, and its transfer. They conclude light, water and nutrients are necessary for the process. Students identify the parts of plants, which are necessary for photosynthesis and trace this process.

Underlying chemical and biological principles are critical to student understanding of the functionality and importance of plants and will be presented to my students in this unit. This study will be contrasted with development's consumption of clean air and deterioration of our atmosphere. Purification v. Population is an interdisciplinary unit in which debate, founded on research, data and modeling, provides student assessment.

This 12-week unit is divided into three major sections. The first section involves description, analysis and impact of air pollution. The second section involves investigation and understanding impact of the biology and chemistry of plants. Included in this section is detailed analysis of photosynthesis and plants' "air purification" capabilities. Students observe plant processes through experiments and demonstrations. The final piece requires research of a current development proposalin our investigationdevelopment of the Long Wharf Mall. This section includes substantial research and data analysis. The culminating unit activity will be presented as a court case.

Purification v. Population: Green v. Gray addresses National Science Standards and Benchmarks. Furthermore, it embraces the integrated approach to Science and includes many components of the City of New Haven's Science Standards in grades 7 through 9. Laboratory investigations are inquiry-based and reports are presented in CAPT format. Finally, the unit aligns itself with mathematics standards in grades 6 through 9; problem solving is a critical skill employed throughout the unit.

Goals & Objectives

Three categories of environmental science interact to influence all life: physical, chemical and biological. The study of plants and photosynthesis permits a solid understanding of environmental factors and investigations in these categories provide a foundation for good investigative science and successful experimenting. Upon completion of this unit, students will examine the world around themincluding what they hear and seewith a more critical eye.

Students will understand and appreciate our plants as "air purifiers". After identifying and describing air pollutants, students will assess air quality in their neighborhood. In our area, the air quality is poor. Given our reliance on oxygen, "clean air", students will investigate solutions. Upon the discovery of oxygen production in photosynthesis, students will conclude diverse plant life is critical to their comfort and health because photosynthesisthe process through which plants manufacture foodis necessary for our survival.

Students will validate the process of photosynthesis in which light energy is converted to chemical energy. In plants, energy is stored chemically in starch which is made of glucose, a form of sugar. From this process oxygen, upon which most living things rely, is released. Plants need sunlight in order to combine carbon dioxide and water to produce sugar. They will identify the chemical process:

6 H2O & 6 CO2 ((light(((CH2O)n & 6 O2.

Sunlight is pure energy. However, sunlight itself is not a very useful form of energy; it cannot be eaten and it cannot be stored. To be beneficial, the energy in sunlight must be converted to other forms. This is what photosynthesis is all about. It is the process by which plants change the energy in sunlight to kinds of energy that can be stored for later use. One of the major energy-harvesting processes in plants involves using the energy of sunlight to convert carbon dioxide from the air into sugars, starches, and other high-energy carbohydrates. Oxygen is released in the process, and it is this byproduct that may thwart the negative effects of development and lessen air pollution.

As the CO2 to O2 conversion is central to the unit, students will describe the physical and chemical properties of air. Physical properties identify an objectand students will conclude gasses and air are objectsby their shape, form, size and color. They will calculate the density of various gasses. Because air has weight and takes up space, students will deduce it is considered matter and has all the other physical and chemical properties that define matter. One of these chemical properties is the ability to form compounds with other substancesan important concept of photosynthesis.

Concepts and Strategies

Current Conditions: Assessing air quality

As Abram Katz reports in the June 21, 2000 New Haven Register, “This summer may not swelter, but New Haven will be hot”. He reports cities make their own microclimates, creating ozone and smog. This year, he notes, Connecticut has had more than 8 days of unhealthful airand the summer has yet to begin! The solution, according to a NASA scientist Dale Quattrochi: “Plant the right kind of trees in the right spaces”.

The United States releases 7000,000 metric tons of air pollutants each day. These include carbon dioxide, oxides of nitrogen and sulfur, and chlorofluorocarbons. Oxides of sulfur and nitrogen are among the worst air pollutants. Coal burning power plants, metal smelters and factories emit most sulfur dioxides. Motor vehicles, power plants that burn gas and oil, and nitrogen-rich fertilizers produce nitrogen oxides

During a thermal inversion weather conditions trap a layer of cool, dense air under a layer of warm air. If the trapped air contains pollutants, winds cannot disperse them, and they may accumulate to dangerous levels. Cities create their own thermal inversions because of a heat island effect. Heat reflected between buildings warms up the air which rises. As air flows upwards and outwards, it cools and begins to sink carrying air pollutants down near the ground. Thermal inversions have been a key factor in some of the worst air pollution disasters, because they intensify an atmospheric condition called smog, the pollutant most visible to students.

Urban areas also have large numbers of people living in a relatively small area. There is also usually more automobile driving, paved areas and industrial activity. These activities release tons of pollutants into relatively small volumes of air each day. The automobile is the chief source of primary air pollutants. Auto exhaustunburned fuelcontains Hydrocarbons, Carbon Monoxide and Nitrogen oxides. At present in the United States motor vehicles are responsible for up to half of the ozone-forming volatile organic compounds and nitrogen oxides. Motor vehicles release more than 50 percent of the hazardous air pollutants. Motor vehicles release up to 90 percent of the carbon monoxide found in urban air.

Furthermore, cities have more cars emitting pollutants, moreso at rush hour. Auto pollutants are emitted close to the ground, at just about breathing level. Traffic lights and slow moving traffic are the worst polluters as well. Stop-and-go driving produces more auto exhaust than open highway driving. Since morning rush hour traffic occurs usually when breezes are light and radiation inversions form, air pollution levels can be very high, especially at busy intersections or along highways. And the city of New Haven is particularly at risk as the city itself is congested and located right next to one of the most congested highways in the country--Interstate 95!

Experiment: The physical properties of air

A property describes objects and helps us identify an object, through its appearance or behavior. A physical property identifies an object by its shape, form, size, and color: appearance. A chemical property identifies an object by its behavior, particularly when it interacts with other objects. Chemical properties include the ability to form compounds with other substances and change.

Physically speaking, air is a mixture of gasses. Nitrogen (N2) and oxygen (O) make up 99% of the troposphere. The balance is composed of traces of argon, carbon dioxide and other gasses. Air is transparent, colorless, and tasteless and odorless. It has weight and takes up space. Because air posses these physical qualities, it is considered matter. Matter is anything that has weight and takes up space.

Materials Project 1: Air takes up space

- 2 soda bottles
- 2 small funnels
- glass beaker filled with water
- modeling clay

Project 1: Air takes up space procedures

- Set the funnels in open ends of the bottles
- Seal one of the funnels around the edges with clay Make sure the seal is tight and no air can get in or out of the bottle except through the funnel
- Pour water through the funnel and into the bottle that is not sealed
- Observe how much water goes in the unsealed bottle
- Pour water into the bottle that is sealed
- Observe how much water goes into the sealed bottle
- Explain: were there differences in the amount of water that went into each bottle? Why? What matter existed in the bottles?

Materials Project 2: Air has mass

- yardstick
- 3 15” long strings
- 2 balloons
- sharp pin

Project 2: Air has mass procedures

- Blow up 2 balloons to just about the same size
- Tie the ends so no air can escape
- Attach one 15” string to each balloon
- Tie the balloons to each end of a yardstick
- Tie the third string to the center of the yardstick with a loose knot
- While holding the yardstick up by the third string, use a sharp pin to puncture one of the balloons.
- What happens? What property explains the different mass of the balloons?

Experiment: Test for the presence of carbon dioxide

Baking soda consists of the chemical compound sodium bicarbonate ($NaHCO_3$). Compounds containing carbonate (CO_3) react with acids such as vinegar (acetic acid) to produce carbon dioxide gas (CO_2).

Limewater $Ca(OH)_2$ is used to test for the presence of carbon dioxide gas because it reacts with carbon dioxide to form the compound calcium carbonate ($CaCO_3$). The equation for this reaction follows: CO_2 + $Ca(OH)_2$ ($CaCO_3$ +H_2O

Materials:

- Glass soda bottle
- 63 ml water
- scissors

ruler
tissue
5 ml baking soda
baby-food jar with lid
limewater
63 ml vinegar
modeling clay
flexible drinking straw

1. Pour water and vinegar into the bottle
2. Cut a 7.6 cm strip of tissue
3. Spread the baking soda across the tissue
4. Roll the tissue around the baking soda. Secure the packet by twisting the ends of the tissue
5. Fill the baby food jar three-fourths full with limewater
6. Mold a walnut size piece of clay around the end of the straw. Do not cover the hole
7. Drop the packet of baking soda into the bottle.
8. Quickly plug the mouth of the bottle with the clay around the straw. The short end of the straw should be inside the bottle.
9. Hold the jar of limewater near the bottle so the other end of the straw is beneath the surface of the limewater.
10. When the bubbling ceases, observe the limewater
11. Secure the lid on the jar and allow the jar to stand overnight.
12. Observe the contents of the jar

Why? The chemical reaction:

$NaHCO_3 + HC_2 H_3O_2$ $NaC_2H_3O_2 + H_2O + CO_2$

Sodium bicarbonate + acetic acid yields sodium acetate + water + carbon dioxide

Experiment: Exhaust Effect on living things [PROSECUTION EVIDENCE 1]

Materials:

Bio bag (see Internet Resources: www.scotthubbard.com)
6 small planters
seeds: bean & dill germinate and grow quickly
water
graduated cylinder
metric ruler
light source
emmissions from a car (preferably older)

1. Plant three seeds in each of the six pots
2. Water all of the seeds 25 ml
3. Fill a biobag with car exhaust (use careadult supervision required)
4. Place three of the planters in the biobag and seal; put near light source
5. Place the other three planters near the same light source; this is your control set
6. Repeat procedures 2 through 4 every three days
7. Observe planters and record plant growth when you water and reset plants in
8. Biobag

Research [PROSECUTION EVIDENCE 2]

Investigate air quality in your area (in Connecticut, see State of Connecticut Department of Environmental Protection) for a town-by-town air quality index. Graph air quality and temperature daily for a month. Make a note of anything that could affect air quality: highway accidents, town events drawing many visitors, local construction. (See HYPERLINK http://dep.state.ct.us/updates/oz/aqi.asp http://dep.state.ct.us/updates/oz/aqi.asp and/or http://www.epa.gov/airnow/ http://www.epa.gov/airnow/)

Research [PROSECUTION EVIDENCE 3]

Ask students: If a car differs in size, make, and model, then the amount of pollution emitted from it will also vary. Research if different cars emit different amounts of pollution. Gather data on the amount of carbon monoxide, hydrocarbons, and nitrogen oxide since these emissions have restrictions on them set by the EPA. Go to the Emissions Testing Center to retrieve field information on this subject. Use sources from the internet, books and the Department of Emissions testing as well. Include as references any Annual Statewide Report as well as books such as, Lawrence White's The Regulation of Air Pollutant Emissions from Motor Vehicles (AEI Studies, 1992). Use Internet sources, including EPA's "Your Car and Clean Air" (1988)

(http://www.epa.gov/orcdizux/18-youdo.htm"http://www.epa.gov/orcdizux/18-youdo.htm) Survey a busy intersection. Record the model and number of vehicles that pass through the intersection. Estimate auto emissions for a day, week, month

Survey [PROSECUTION EVIDENCE 4]

Survey classmates to see if students or others in their family have asthma. Ask those with asthma to keep track of how well they feel each day for three weeks. Ask them to record if they feel any difficulty in breathing at all, as well as any attacks. Ask them to rate their breathing on a scale of 1 to 5: 1 being the most difficulty breathing, including any attack; 5 represents "best" days, where breathing is not labored at all. Record EPA air quality information and temperature. (See Prosecution Evidence 2). Set up a data table which includes the date, temperature, percentage of Asthmatic students who have difficulty breathing, (Respond 1, 2 or 3 when surveyed), and air quality information. Is there any correlation between labored breathing and /or Asthma attacks during poor air quality days? Is there any correlation with temperature? Determine if students with Asthma in your area have difficulty breathing when it is hot or during poor air quality days.

Another activity that you may want to perform is found in HANDS-ON SCIENCE by Dorothea Allen. This activity allows the student to see how burning puts pollutants into the atmosphere and how they travel, once in the atmosphere, by using a covered 10 gallon glass aquarium tank and burning wood chips.

Plants to the Rescue: Oxygen production & Air purification

"How long can an average person survive in an airtight room that's packed with plants, assuming there is plenty of food and water?" Environmental engineers have been working on this very question since the 1950s in hopes of one day sustaining life on Mars. Survival in an airtight podwhich requires 500 to 650 liters of oxygen per person dailydepends largely on the kinds of plants you choose as roommates. Cram a well-lit room with philodendrons or other slow-growing houseplants, and you'll be gasping for air within a month. But stock the same room with corn, beans, or other fast-sprouting vegetables, and you could spend a natural lifetime there. Plants take in carbon dioxide and emit oxygen during photosynthesis, and varieties that grow faster generate more oxygen; about 600 grams of new leaves, stem, or stalk produce the minimum 500 liters you need daily. Farm-variety vegetables grow six new grams every day under ideal conditions, so 100 seedlings would do the trick, notes former NASA engineer Bill Wolverton,

As photosynthesis consumes carbon dioxide and releases oxygen, it helps counteract the effect of combustion of fossil fuels. The burning of fossil fuels releases carbon dioxide as well as hydrocarbons, nitrogen oxides, and other trace materials that pollute the atmosphere and contribute to long-term health and environmental problems. Can the principles of photosynthetic solar energy harvesting be used in some way to produce non-polluting fuels or energy sources?

Photosynthesis Defined

Plants use chlorophyll to trap energy from the sun. They use this energy to combine carbon dioxide from the air and water from the soil to make food. This food making process is photosynthesis. Without photosynthesis, the replenishment of the Earth's fundamental food supply would halt, and the planet would become devoid of oxygen. During photosynthesis energy is used to convert carbon dioxide, water, and minerals from the environment into organic compounds and gaseous oxygen--the food we eat and the air we breathe. The process is an almost exclusive property of the plant kingdom.

Photosynthesis is the process of turning the energy of sunlight into chemical energy from the raw products of CO2 and H2O. Recall the chemical equation is:

6 H2O & 6 CO2 ((light(((CH2O)n & 6 O2.

Although numerous intermediary reactions are involved, the overall photosynthetic reaction is simple. Carbon dioxide combines with the hydrogen from water yielding a carbohydrate, the 6-carbon sugar (hexose) glucose, and oxygen. Ask students to balance the equation:

_____CO2 + _____H2O ----> C6H12O6 + _____O2

(Hint: How many carbons are needed to make the carbohydrate?).

This process is necessary to sustain nearly all forms of life. The whole process is begun by light reacting with pigments in the leaf causing the splitting of water molecules. Three products are produced in this reaction. Electrons from the hydrogen molecules and remaining H+ ions are used to form two separate energy storage molecules. The air we breathe is from the remaining oxygen portion of H2O.

Not all plants produce the same amount of oxygen, however. Some plants are more efficient “air purifiers” than others. Part of the photosynthetic process, the dark reaction, is also called the Calvin Cycle. With one cycle of this reaction 3 carbon atoms are fixed or placed in a sugar molecule. This pathway is called C-3 photosynthesis. This is the way that most dicots or broadleaf plants make sugars during the dark reaction. C-3 photosynthesis has a disadvantage though. Oxygen competes with CO2 for a binding site during the dark reaction. Sometimes sugars are not formed, but energy is still expended to complete the cycle. This is called photorespiration.

Another dark reaction pathway is called C-4 photosynthesis because 4 carbons are fixed or placed in a sugar molecule each time the cycle is completed. The dark reaction of C-4 photosynthesis occurs inside of specialized parts of leaf cells in the leaf called the bundle sheath, which exclude the presence of O_2. Because there is no oxygen present photorespiration does not occur. The C-4 photosynthetic pathway is what occurs in most monocots or grasses. This is a more efficient pathway and allows grasses to grow faster than broadleaf plants.

Use the Encarta Encyclopedia contents page for the Photosynthesis article and the animation on photosynthesis. Using the animation, guide students through the steps of the process. This video is an excellent resource for helping students understand photosynthesis. Show them the photograph of chloroplasts in the Onion Root Cells photo and mention the importance of chloroplasts in the process. For additional information and materials, see Plants, Milliken Publishing Company, St Louis, MO, 1986. The unit includes excellent overhead transparencies/graphics.

Experiment: How do we know plants produce oxygen? [DEFENSE EXHIBIT 1]

Materials:

Large bowl
Water
Glass jar
Plantselodea, an aquatic plant available at most pet stores, is ideal

1. Fill a bowl with water and add some elodea
2. Place the jar upside down in a bowl
3. Tilt the jar to let the air out of it
4. Push the weeds ½ way into the jar, then rest the jar on top of the stems
5. Leave the bowl in bright light for several hours (or overnight)
6. Observe the jardeduce: What are the bubbles?

Do all plants produce oxygen? [DEFENSE EXHIBIT 2]

Complete the above experiment, How do you know plants produce oxygen? Using as many aquatic plant types as can be collected; try to get at least one for each student.

Additional materials:

Triple-beam balance
Tracing paper and pencil
Guide to identify plants (http://plants.usda.gov/plants http://plants.usda.gov/plants, http://aquat1.ifas.ufl.edu/,)
Cm ruler

1. Observe all the plants. Lay them out one by one so all students can observe each.
2. Each students predicts which plant they think will produce the most oxygen. The least? Ask students to explain why they formulated these hypothesis.
3. Provide each student with one plant type
4. Working in teams, students trace their leaf and estimate volume
5. Students calculate mass using a triple beam balance
6. Each student completes “How do you know plants produce oxygen?” using his/her plant. Each student counts the number of bubbles after 40, 80, 120 and 160 minutes.

*note: I have 42-minute classes. On day one, we observe all the plants, calculate volume and mass (advanced students calculate density). On day two and three we set up the experiment with a recording chart in front of each plant station. Working in teams of two, period 1 sets up 10 plants for periods 2, 3 & 5 to record and observe. On day three, period 2 sets up for periods 3, 5 & 6 to observe and record.

7. Which plant created the most bubbles/produced the most oxygen? Was there any relationship between size of the plant and oxygen produced? What other factors might affect how much oxygen was produced?

According to David Hershey at the MAD Scientist Network:

> There are two phenomena that take place in the process of photosynthesis. One is the splitting of water (to obtain electrons and release oxygen) in the so-called 'light reactions' and the other is the fixation of carbon dioxide into an organic compound in 'dark reactions'. Both of these changes are used to measure photosynthetic rates. And

both require some specialized equipment.

Measurement of oxygen evolution is probably the easiest method. It can be performed using an oxygen electrode or, in the case of aquatic algae, Winkler titration. Winkler titration relies on chemical changes to measure oxygen content in water after photosynthesis takes place upon exposure to light. Oxygen electrodes measure oxygen concentration in air or water and are quick, efficient and accurate. Since most researchers are interested in the amount of carbon fixed more so than oxygen released, the oxygen-based rate is converted to carbon fixed by the ratio known as the photosynthetic quotient. (This is often assumed to be 1:1,but actually varies a bit). Both techniques require a "dark" control sample to account for respiration.

Both of these techniques measure net photosynthetic rates. That means that respiration is already factored into the results. In other words, when one measures oxygen evolution on a whole plant or cell, respiration, which consumes oxygen is also taking place and affects the measured oxygen evolution. Thus the need for a dark control sample.

There are some simple techniques for measuring productivity (rather than photosynthesis). In these cases the results of photosynthesis and growth are measured. Of course plants depend on photosynthesis for growth so there is a relationship. Some of these techniques are quite simple. They measure the mass of plant material. Weighing before and after treatment can do this. Aquatic botanists also relate the length of the blade of seagrass or seaweed to growth as well. Both methods give reliable results BUT the changes in mass (or blade length) must be large enough to measure. This means short-term experiments are not appropriate.

Factors affecting photosynthesis

To produce food for itself a plant requires energy from sunlight, carbon dioxide from the air and water from the soil. If any of these ingredients is lacking, photosynthesis, or food production, will stop. If any factor is removed for a long period of time, the plant will die. Photosynthesis literally means "to put together with light."

Photosynthesis is dependent on light. Generally speaking, as sunlight increases in intensity photosynthesis increases. This results in greater food production. Many garden crops, such as tomatoes, respond best to maximum sunlight.

Water plays an important role in photosynthesis in several ways. First, it maintains a plant's firmness of plant tissue. Firmness pressure in a cell can be compared to air in an inflated balloon. Water pressure or turgor is needed in plant cells to maintain shape and ensure cell growth. Second, water is split into hydrogen and oxygen by the energy of the sun that has been absorbed by the chlorophyll in the plant leaves. The oxygen is released into the atmosphere and the hydrogen is used in manufacturing carbohydrates. Third, water dissolves minerals from the soil and transports them up from the roots and throughout the plant, where they serve as raw materials in the growth of new plant tissues. The soil surrounding a plant should be moist, not too wet or too dry. Water is pulled through the plant by evaporation of water through the leaves (transpiration).

Photosynthesis also requires carbon dioxide (CO2) which enters the plant through the stomata. Carbon and oxygen are used in the manufacture of carbohydrates. Carbon dioxide in the air is 350 parts per million (ppm) or 0.035% at sea level and is plentiful enough so that it is not a limiting in plant growth.

Leaves have the important function of manufacturing food for the plant using water, carbon dioxide and light.

The single layer of cells that forms the upper outside surface of a cell is the upper epidermis. The lower epidermis has many minute openings that permit photosynthesis. The middle section contains layers of tissues that are rich in chlorophyll. Leaves are food producers. In photosynthesis, leaves use chlorophyll to convert water, carbon dioxide and light energy into sugar and oxygen. Photosynthesis occurs in green leaves and stems inside the chloroplasts in the cells. Carbon dioxide enters through the stomata. Oxygen is a byproduct of photosynthesis. It exits leaves through the stomata. Transpiration, the release of water vapor from a plant, occurs through the stomata.

Experiment: Investigate factors affecting photosynthesis: "The floating Leaf Disc"

This experiment is consistent with the Connecticut Academic Performance Task (CAPT) standards and includes a report outline consistent with the standards.

The Problem

The photosynthetic production of oxygen and our knowledge of leaf anatomy allow to construction of a system that can be used to experimentally investigate many of the photosynthetic variables. Many extracellular spaces exist within plant leaves which are normally filled with air for purposes of gas exchange; consequently, a leaf will float on water. If air is forced out and the intercellular spaces are filled with water, the leaf will sink. If we supply the necessary requirements for photosynthesis, the oxygen produced will form gas bubbles and the leaf would re-float. You will use small disks cut from leaves rather than a whole leaf to perform the floating leaf disk assay (FLDA).

This assay of photosynthesis may be used to answer many questions: What factors affect the rate of photosynthesis? How do changes in light intensity, CO2 concentration, plant adaptations, and chlorophyll content change the rate of photosynthesis?

One problem in measuring a rate of photosynthesis is that there is a competing process occurring at the same time, respiration, a process that uses oxygen. FLDA actually measures the rate of photosynthetic oxygen production minus the rate of respiratory oxygen use during the same time period. So FLDA measures the net rate of photosynthesis, that is, the energetic "profit" made by the plant. Actual photosynthetic activity is of course greater than this and is called the gross rate of photosynthesis. If respiration can be measured separately, a simple calculation can determine gross photosynthesis.

Your Task

You and your partners(s) will design and conduct experiments to determine which conditions (light, air and chlorophyll), or a combination of conditions best produces oxygen from plants. You will use a standard FLDA protocol (described below) to study the rate of oxygen production in plants. You will study the gross rate of photosynthesis to determine conditions which are most favorable to maximizing oxygen production. You may use any of the materials and equipment provided to complete your experiment.

Steps to follow

1. In your own words, state the problem you are going to investigate, and write your statement of

the problem on the page provided.

2. Design one or more experiments to solve the problem. Describe your experimental designs on the page provided. Show your designs to your teacher before you begin your experiment.

3. Cut the leaf disks and set up the environmental chamber first. Determine which variable(s) you will change to measure the time it takes to float the leaf disks.

4. After receiving approval from your teacher, work with your partner(s) to carry out your experiments. While conducting your experiments, take notes on the pages provided. Include tables, charts and graphs. You must keep your own notes because you will not work with your partner when you write your lab report. All lab reports will be completed and evaluated individually.

GENERAL FLDA PROTOCOL Materials:

Geranium and Ivy leaves
Plastic bag
graduated cylinder
60 ml of 0.2 % sodium bicarbonate solution.
test tube rack
Paper towels
single whole punch
100 ml graduated beaker
20 ml of phosphate buffer (pH 6.8)
20 cc syringe
Test tubes (4)
light source
metric ruler

A. Cutting Leaf Disks:

1. Use english ivy and geranium leaf disks in this experiment. Fresh leaves should be used because wilted leaves respond poorly. Collect leaves just prior to the assay and to prevent dehydration, keep them wrapped in moist paper towels in a plastic bag.

2. Use a common one hole paper punch to obtain leaf disks with a diameter of 6-7 mm. Major veins should be avoided as the presence of a vein may bias the photosynthetic rate of the disk. Place cut leaf disks between layers of wet paper toweling to keep them fresh.

B. Setting Up the Experimental Chambers

1. Take a 100 ml graduated beaker and add 20 ml of phosphate buffer (pH 6.8) and 60 ml of 0.2 % sodium bicarbonate solution. This mixture will reach equilibrium while you prepare the syringes used as assay chambers.

2. Prepare 2 (two) syringes as follows.

a. Remove the plunger from a 20 cc syringe and drop 10 leaf disks down the barrel of the syringe. Tap the syringe barrel so that the disks fall to the bottom (i.e. the tip end of the syringe).

b. An infiltration process can remove the air from the leaf disks and replace it with water. Carefully replace the syringe plunger. Do not crush the leaf disks. Pull 6 cc (1 cc = 1 ml) of buffered sodium bicarbonate solution into the syringe. Invert the syringe, tap a few times and push the plunger to the 4 cc mark to remove all air from the syringe. Air fills the intercellular space of leaf tissue (see Figure 1). In order to replace this air with water so the leaf disks will sink, a vacuum will be applied. Under vacuum, the extracellular air is drawn for the leaf disks and infiltration solution enters this space when the vacuum is released; the leaf disks will sink.

c. Hold the needle barrel of the syringe down firmly upon a rubber stopper. Pull the plunger up to the 10 cc mark and hold in this position. Shake the syringe and then release the plunger. Repeat this procedure several times until all the leaf disks sink.

d. After infiltration, invert the syringe and push out any bubbles that formed, then pull in additional solution to bring the volume to 16 ml. Plants can use the bicarbonate solution in place of the normal atmospheric CO_2.

e. Determine the optimal arrangement of a lamp and a test tube rack.

f. One syringe with submerged leaf disks should be placed in the rack adjacent to the center of the lamp. The other identical syringe should be placed in an unlighted rack nearby.

3. To start a FLDA, simply turn on the light and note the time. Every minute thereafter count the number of leaf disks that are floating, then swirl the syringe so that all disks are suspended in a vortex. Record your data on a data sheet as number of leaf disks floating by minutes. The assay is complete once all or nearly all of the leaf disks are floating.

a. What do you predict will happen to the leaf disks in each syringe?

b. Which syringe setup should be called a TREATMENT and which a CONTROL? Why? Record your answers to these questions before continuing.

4. The time required for a leaf disk to float is an index of the net rate of photosynthesis in that leaf disk. However, since some leaf disks will be "early floaters" and others will be "late floaters", this variable can be reduced in significance by plotting the percentage of leaf disks floating as a function of time.

5. You now should have at least one syringe with 10 floating leaf disks. Turn off the light and record the number of disks still floating each minute. The time the disks take to sink in the dark is an index of the rate of respiration (RS). Since some of the leaf disks will be "early sinkers" and others will be "late sinkers", once again this variable will be dealt with by plotting the percentage of leaf disks floating as a function of time, and finding the time required for 50 percent of the leaf disks to sink.

Post Lab Discussion

Clearly state the problem investigated. Identify the dependent and independent variables.

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2. Describe the experiment clearly. Indicate, step-by-step, how the procedure was completed 1.
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____(if necessary, continue on back)

3. Describe the results of your experiment on the next page. Use tables, charts, or graphs.

4. State your conclusion in the experiment. You conclusions should be fully supported by data.

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____ 5. How valid are your conclusions? Do you have a lot of confidence in your results? Are there any factors that could have been changed? Could you improve your experiment?

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6. How could you apply your results to your life/your community? What did you learn?

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Court

Students are divided into teams of four: prosecution team, defense team, jury and judges. Students may be assigned to teams based upon their response to the following question:

Should the mall at Long Wharf be developed?

Yes. It is good for the area and pollution from it is not that bad. The job and shopping benefits are more than pollution damages.

No. The city already has enough development that makes its air polluted. Summer smog, which is created by car exhaust, is already too much. We don't need more traffic.

I don't know.

Students who think the mall should be developed are members of the defense team. Students who do not think the mall should be developed are members of the prosecution team. Students who have no made up their minds are members of the jury or judges. Each class must have one, but have no more three, judges.

The case: People with Asthma are bringing a class action suit against the mall developer, the City of New Haven, and the State of Connecticut.

The defense team must prove they can plant enough to offset increased traffic to the area and minimize the incresed air pollutionparticularly CO_2. A key question is whether the area for plants is sufficient to offset the increased estimated CO_2 attributed to increased traffic that will visit the mall. To do this they must survey their neighborhood. Each student on the team will sketch a map of their neighborhooda 4 block radius and note open spaces as well as empty or dilapidated buildings. From this preliminary sketch, students will propose gardens and propose which plants should be planted which produce the most CO_2. They will use results from experiments and Internet resources to decide which plants produce the most oxygen.

Students may recall that 600 grams of new leaves, stem, or stalk produce the minimum 500 liters of oxygen you need daily, according to NASA engineer Bill Wolverton. Therefore students must research estimated traffic projections as a result of mall development. (See Mall's impact on air quality ignored; study not required, despite anticipated increase in traffic, PRIVATEBy Abram Katz, Register Science Editor (July 09, 2000)

They must then calculate the average mass of as many plants as possible. Bring cornhusks to school; ask students to gather leaves, houseplants, weeds, and any other growth to calculate plant mass. Use Internet resources to gather information about plant mass. Emphasis will be on woody trees and crops

Research how much acreage is needed to support these plants they measure and research. Students will then decide: Is there enough open space to negate increased pollutants attributed to traffic for the mall?

If students decide there is enough space for them to grow plants which offset increased CO_2 from mall traffic and they pursue their defense, they must also decide how to plant. For example, should a block watch be given an open lot to plant? Can they plant vegetables to be shared by members of the block? There are already examples of these community gardens in New Haven. A field trip to one of these gardens will be pursued.

Once students decide where and what to plant, their defense evidence which is the most crucial will be a new map of their area, which abuts the mall development. Included in this map will be all areas identified where gardens may be grown and types of growth recommended.

After all this work is done: prosecution has shown the negative effect of exhaust on living things, researched air quality, surveyed asthmatic students, researched projected increases in air pollution due to mall development; defense has shown plants produce oxygen, variables can enhance oxygen production, and space is available for a major planting effort, students will all participate as jury. They will address three major issues and answer the following questions:

1. Are the mall developers guilty? Are estimates of increased traffic and emissions valid? Will they contribute to air pollution and injure those with respiratory problems, particularly those with Asthma?
2. Can a major planting effort such as that planned by students be accomplished? Is it possible? Who will fund this effort? How confident are students that these plants will offset increased air pollution (CO_2) attributed to the mall?
3. Is it worth it? Is a new mall that important to warrant this effort?

Students should draw upon their notes, observations, lab results and research to answer these questions. Their final decision, with persuasive tone, and compelling evidence may provide a basis for unit assessment.

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Internet Resources

http://www.mhhe.com/sciencemath/biology/maderbiology/teach/critical20.html

http://www.mhhe.com/sciencemath/biology/maderbiology/teach/critical20.html

A teaching unit which uses the resources on the world wide web to investigate questions about how photosynthesis works and how plants in different environmental conditions have modified the process of photosynthesis to their advantage. The author/teacher poses questions which extend beyond the information presented in a text. He offers some URLs to investigate additional information on each topic.

http://www.microscopy-uk.org.uk/schools/images/root2.html

http://www.microscopy-uk.org.uk/schools/images/root2.html

A good overview of plants which includes: “Why study plants?”, “Why are plants important” as well as plant anatomy with graphics.

http://www.sciam.com/search/ http://www.sciam.com/search/

Scientific American Home. If you search “photosynthesis” you will be provided with more than 38 documents and the abilty to “ask the experts”.

http://www.epa.gov/oar/oaqps/airtrans/Index

http://www.epa.gov/oar/oaqps/airtrans/Index

Air quality data is listed as the pollutant standards index (PSI) developed by the Environmental Protection Agency.

http://www.scotthubbard.com/ProductPages/Default.asp

http://www.scotthubbard.com/ProductPages/Default.asp (Environmental)

Air Pollution Kit: Using a controlled environment and a common air pollutant, learners observe the direct effect sulfur dioxide has on plants. Squash and marigold plants are germinated and then placed in an SO2 saturated environment where growth is monitored and recorded. Kit includes a special glove bag to be used as an environmental chamber and all materials needed for a classroom demonstration. Teacher’s Guide and reproducible student worksheets are also included. $58.45 - Air Pollution Kit; $26.35 - Air Pollution Kit, replacement supplies

http://www.epa.gov/airsdata/sources.htm

http://www.epa.gov/airsdata/sources.htm

Source Reports provide information about stationary and mobile sources of air pollution. Source reports can be generated using data either from AIRS (stationary sources only) or the National Emission Trends (NET) Inventory (stationary and mobile sources).

http://library.envirolink.org/ http://library.envirolink.org/

EnviroLink Library to make information easier for you to access, interact with and use. Information is categorized by types of resources (organizations, publications, etc.) and environmental topics. Extensive searching tools exist to make finding the resources you want easier.

http://www.pirg.org/enviro/cleanair/

Includes reports which document the influence of the auto and oil industry on public policy and debates surrounding the control of pollution that causes smog, soot and global warming as well as plans for taking action. Site includes many “clean air links.”

Endnotes

The Plain English Guide to the Clean Air Act, U.S. EPA; What You Can Do to Reduce Air Pollution, U.S. EPA. ii.L. Reed Bradley at al, “Air Pollution”, FAST1, Foundational Approaches in Science Teaching Curriculum Research and Development Group, University of Hawaii, 1983 http://www.madsci.org/posts/archives/nov98/910304813.Bt.r.html http://www.madsci.org/posts/archives/nov98/910304813.Bt.r.html Excerpted from Compton's Interactive

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