WARD'S™
DataHub
The Power of Twelve
The Convenience of One

What is Photosynthesis?
Measuring Air Pressure Inside an Active Photosynthetic System
(Teacher's Guide)

OVERVIEW

After placing a photosynthetic organism inside a syringe, students will measure the air pressure inside the syringe. They will relate their observations to the results obtained during the experiment, and display them in a graph for analysis.

MATERIALS NEEDED

Ward's DataHub
USB connector cable*
3 grams of *Elodea canadensis* aquatic plant
1 Luer-Lock syringe, 60 mL
Plastic tube
Paper towel
Water
Laboratory clamp for small tubes
Nut
Laboratory stand
Lamp with 100 watt capability

** – The USB connector cable is not needed if you are using a Bluetooth enabled device.*

NUMBER OF USES

This demonstration can be performed once, using 3 grams of *Elodea canadensis*. See the Ward's catalog and/or visit www.wardsci.com to order materials.

FRAMEWORK FOR K-12 SCIENCE EDUCATION © 2012

* The Dimension I practices listed below are called out as **bold** words throughout the activity.

Dimension 1 Science and Engineering Practices				
	✓	Asking questions (for science) and defining problems (for engineering)		Use mathematics and computational thinking
	✓	Developing and using models	✓	Constructing explanations (for science) and designing solutions (for engineering)
	✓	Planning and carrying out investigations		Engaging in argument from evidence
	✓	Analyzing and interpreting data	✓	Obtaining, evaluating, and communicating information

Dimension 2 Cross Cutting Concepts				
		Patterns	✓	Energy and matter: Flows, cycles, and conservation
	✓	Cause and effect: Mechanism and explanation		Structure and function
		Scale, proportion, and quantity		Stability and change
	✓	Systems and system models		

Dimension 3 Core Concepts	Discipline	Core Idea Focus
	Life Science	LS1: From Molecules to Organisms: Structures and Processes
		LS1.A: Structure and Function
		LS1.C: Organization of Matter and Energy Flow in Organisms
		LS2: Ecosystems: Interactions, Energy, and Dynamics
		LS2.A: Interdependent Relationships in Ecosystems
		LS2.B: Cycles of Matter and Energy Transfer in Ecosystems

NGSS Standards	Middle School Standards Covered	High School Standards Covered
	MS.LS-SFIP: Structure, Function, and Information Processing	HS.LS-SFIP: Structure, Function, and Information Processing
	MS.LS-MEOE: Matter and Energy in Organisms and Ecosystems	HS.LS-MEOE: Matter ad Energy in Organisms and Ecosystems
	MS.LS-IRE: Interdependent Relationships in Ecosystems	HS.LS-IRE: Interdependent Relationships in Ecosystems

NATIONAL SCIENCE EDUCATION STANDARDS © 2002

Content Standards (K-12)			
✓	Systems, order, and organization		Evolution and equilibrium
✓	Evidence, models, and explanation		Form and Function
✓	Constancy, change, and measurement		

Life Science Standards Middle School		Life Science Standards High School	
✓	Structure and Function in Living Systems	✓	The Cell
	Reproduction and Heredity		Molecular Basis of Heredity
✓	Regulation and Behavior		Biological Evolution
✓	Populations and Ecosystems	✓	Interdependence of Organisms
✓	Diversity and Adaptations of Organisms	✓	Matter, Energy, and Organization in Living Systems
			Behavior of Organisms

✓ Indicates Standards Covered in Activity

LEARNING OBJECTIVES

Core Objectives (National Standards):

- Develop the ability to refine ill-defined questions and direct to phenomena that can be described, explained, or predicted through scientific means.
- Develop the ability to observe, measure accurately, identify and control variables.
- Decide what evidence can be used to support or refute a hypothesis.
- Gather, store, retrieve, and analyze data.
- Become confident at communicating methods, instructions, observations, and results with others.

Activity Objectives:

The purpose of this activity is to study air pressure variation inside a closed system where photosynthesis is taking place. Students will formulate a hypothesis and proceed to test it, using the Ward's DataHub air pressure sensor.

Time Requirement:

60-90 minutes

VOCABULARY

Air Pressure: The force exerted by air when it is compressed or confined in an area.

Autotroph: An organism that can capture energy from sunlight or chemicals and use it to produce its own food from inorganic compounds; also called a producer.

Barometer: An instrument that measures atmospheric pressure.

Calvin Cycle: The second of two major stages in photosynthesis (following the light reactions), involving atmospheric CO_2 fixation and the reduction of the fixed carbon into carbohydrates.

Carbon fixation: The incorporation of carbon from carbon dioxide into an organic compound by an autotrophic organism.

Chlorophyll: A green pigment found in some chloroplasts of plants, algae, and some bacteria.

Heterotroph: An organism that obtains organic food molecules by eating other organisms or their by-products and that cannot synthesize organic compounds from inorganic materials.

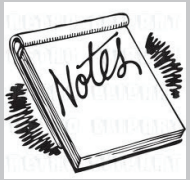
Light reactions: The steps in photosynthesis that occur on the thylakoid membranes of the chloroplast and that convert solar energy to the chemical energy of ATP and NADPH, evolving oxygen in the process.

NADP+: Nicotinamide adenine dinucleotide phosphate, an acceptor that temporarily stores energized electrons produced during the light reactions of photosynthesis.

Phosphorylation: The process of adding a phosphate group to ADP to make ATP; cells use the energy released by ATP to power essential activities.

Photosynthesis: Process by which plants and some other organisms use light energy to convert water and carbon dioxide into oxygen and high-energy carbohydrates such as sugars and starches.

Pressure: The number of pounds per square inch exerted by gaseous molecules.



Teacher Notes

INTRODUCTION

All living organisms need energy to survive. That's the reason why humans eat, to get the necessary energy from what we consume. However, not all living organisms obtain energy through the same process. Just as there are organisms that eat other organisms to obtain energy, there are also some organisms that can synthesize chemical compounds in order to survive. This is the case with organisms like plants, alga, and some types of bacteria. They are able to synthesize glucose, a molecule that is vital to their metabolic functions, through a process called photosynthesis.

- **What elements or factors are necessary to fulfill our energy needs?**
- **What is the name of the metabolic process that plants perform to survive?**

Carry out the experiment with your class so that at the end students will be able to answer the following question:

- **How could we detect that photosynthesis is really happening inside an organism?**

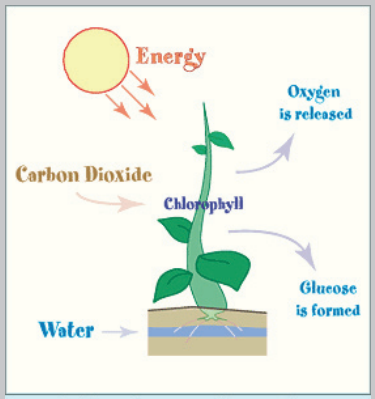
BACKGROUND

Photosynthesis is a process used by organisms like plants, alga and some photosynthetic bacteria to obtain nutrients. Broadly speaking, it is the process of converting light energy from the Sun to chemical energy.

Presented below is the overall general reaction that is involved in the photosynthetic process:

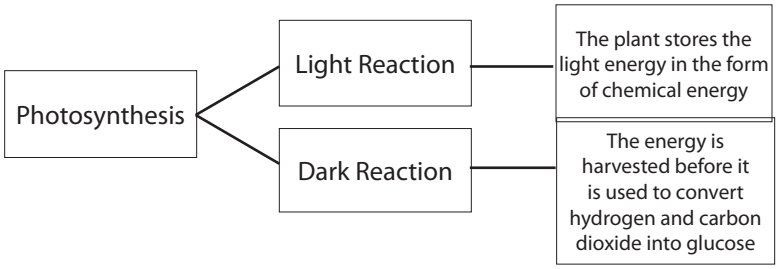
$$6CO_2 + 6H_2O \text{ (+ light energy)} \rightarrow C_6H_{12}O_6 + 6O_2$$

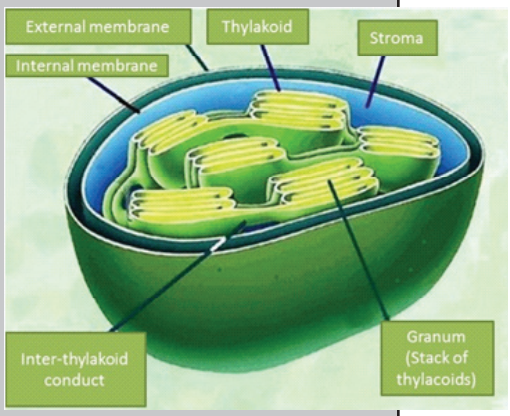
This equation represents a set of chemical reactions, where light energy is used to break apart six water molecules (H_2O) into hydrogen (H) and oxygen (O_2), which are released into the environment. The hydrogen obtained from the water molecule then bonds to six CO_2 (carbon dioxide) molecules, to produce glucose ($C_6H_{12}O_6$).



Photosynthesis

There are two parts to photosynthesis:





Photosynthesis takes place inside a cell organelle specialized for this process, the chloroplast. The chloroplast has a system of membranes, the inner and the outer membrane. Within the inter-membrane space are the thylakoids, which are a kind of elongated flattened sac. These sacks are stacked in a granum. Finally, there is the stroma, which is the fluid occupying all the spaces left between the thylakoids.

There are different colors of pigment, but only one of them is essential to the process of photosynthesis, and common to all photosynthetic organisms. This special pigment is called chlorophyll, and is responsible for the green color we observe in most plants. The light reaction (light-dependent phase) occurs in the thylakoid membrane, where the chloroplast can store light energy due to the presence of chlorophyll. This is the reason why light is vital to the reaction. On the other hand, the dark reaction (light-independent phase) takes place in the stroma of the chloroplast, and its final product is glucose. This phase takes place during night and day, but it is called the "dark" reaction because it does not require light to occur.

It is important to highlight the cycle produced as a result of photosynthesis. As animals breathe, they use oxygen (O_2) from the air and release carbon dioxide (CO_2) into the environment. Meanwhile, plants take the CO_2 and release O_2 in exchange. The oxygen is then used by the animals, thus repeating the cycle.

At this point, encourage students to formulate a hypothesis to test as part of this activity. Students may find it helpful to formulate their hypothesis as an answer to the following question:

- **Suppose you place an active photosynthetic plant inside a closed system. What would you expect the pressure variation to be inside the system?**

DID YOU KNOW?

Photosynthesis takes place mainly in the chloroplasts of plant leaf mesophyll cells.

CONNECTING THE WARD'S DATAHUB TO A COMPUTER

If you are using a Bluetooth communication device:

Right-click on the Bluetooth icon in the lower right corner of the screen and select the Ward's DataHub you are using. The icon will change from gray to blue, as shown at right, indicating that the Ward's DataHub and the computer are now connected via Bluetooth.

If you are using a USB communication device:

In order to use USB communication, connect the Ward's DataHub and the computer with the USB cable supplied. Click on the USB icon at the lower right corner of the screen. This icon will change from gray to blue, as shown at right, indicating that the Ward's DataHub is connected to the computer via USB.

USING THE WARD'S DATAHUB

= Select key = On/Off and Escape key = Scroll key

To collect measurements with the Ward's DataHub, it must first be configured as follows:

1. Turn on the Ward's DataHub by pressing the On/Off/Esc key.	
2. Go to setup by using the Scroll key then select Setup by pressing the Select key.	then
3. Select the Set Sensors option by pressing the Select key.	
4. If any sensor(s) appear on the screen, press the key representing that sensor to deactivate it. Once you have a blank window, turn on the **Air Pressure Sensor** by pressing the Air Pressure key.	
5. Press the On/Off/Esc key once to return to the Setup menu.	
6. Press the Scroll key then the Select key to set the Sampling Rate.	then
7. Use the Scroll key to highlight a Sampling Rate of "**1/min**", then press the Select key.	then
8. Press the On/Off/Esc key to return to the setup menu.	
9. Press the Scroll key then the Select key to set the Number of Samples to be collected.	then
10. Use the Scroll key to highlight "**100**" as the Number of Samples to be collected then press the Select key.	then
11. Press the On/Off/Esc key three times to return to the main operating screen.	x 3
12. **Press the Select key to start measuring.** (You are collecting data when there is an icon of a runner in the upper left hand corner of the screen.)	
13. Once you have finished measuring, stop the Ward's DataHub by pressing the Select key, followed by the Scroll key.	then

ACTIVITY

DID YOU KNOW?

Elodea canadensis is a perennial aquatic plant that is native to most of North America. It grows rapidly under favorable conditions and even has the ability to choke off shallow ponds, canals, and slow flowing rivers. The young plants grow indefinitely at the stem tips, and a single specimen may reach a length of 3 meters or more.

1. Take the plunger out of the syringe barrel.
2. Block the opening of the syringe, and place a fresh *Elodea canadensis* with 50 mL of water inside the barrel.
3. Insert the plunger back inside the syringe barrel and leave about 10 mL of air in the syringe.
4. Connect the air pressure tube between the syringe and the Ward's DataHub air pressure sensor port.
5. Arrange the apparatus as shown in the figure at right, using the Ward's DataHub, nut, and laboratory clamp and stand. Make sure there is an airtight connection between the datahub, tube and syringe.

   MAKE SURE NO WATER FLOWS FROM THE SYRINGE THROUGH THE TUBE INTO THE WARD'S DATAHUB!

6. Place the lamp 5 cm away from the set up, and turn it on.
7. Start recording data for 24 minutes by pressing the RUN icon in the software.
8. Observe the plant and record your observations.
9. Press the STOP icon in the software when you have completed the measurements.

DID YOU KNOW?

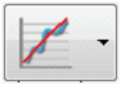
The average rate of energy capture by photosynthesis globally is approximately 130 terawatts, which is more than six times larger than the power consumption of the human civilization on Earth today.

RESULTS AND ANALYSIS

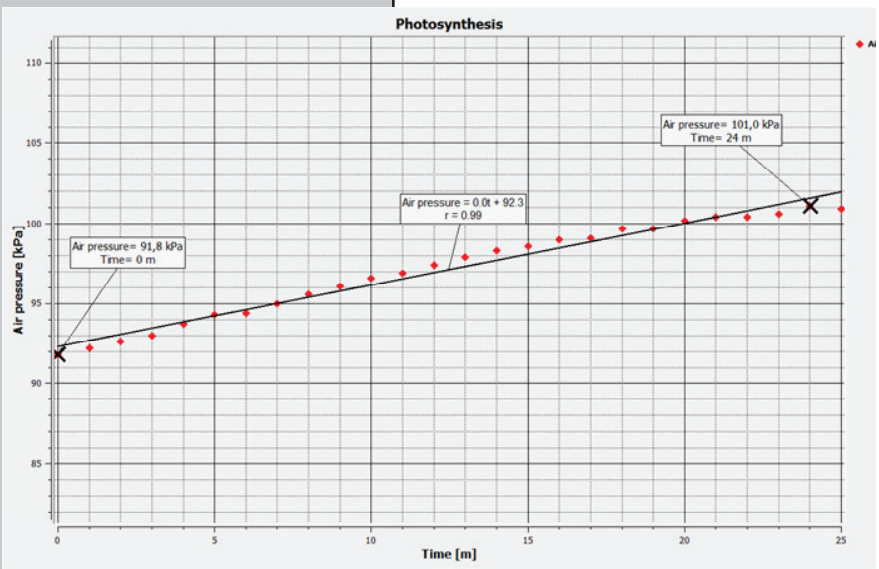
The following steps explain how to analyze the experiment results.

1. Observe the graph displayed on the screen.
2. If necessary, fit the scale to observe the variations displayed. You can do this by registering the maximum and minimum values using the button shown at right, then right-click on the y-axis and enter the rounded minimum and maximum values in the "SET RANGE" dialog box.

3. Press the button shown at right to select data points on the graph and pick the extreme points. Then draw a linear regression line by pressing the same button again.



- **How do the results relate to your initial hypothesis?**
- **What was the change in pressure during the experiment?**
- **Calculate the increase in air pressure per minute using the markers. What was the rate of air pressure increase in this experiment?**
- **Repeat the experiment in the same conditions and with a double amount of *E. canadensis*. How does the air pressure rate increase in this experiment when compared with the previous one?**



- **What effect should we observe if we increase the light intensity used?**
- **How would you explain the air pressure variation inside the system?**

The graph at left should be similar to the one the students come up with.

CONCLUSIONS AND ASSESSMENTS

1. How can we infer that photosynthesis is really happening in the system (sealed syringe)?

   After the teacher has presented the background information, students should conclude from the theoretical background that the plant is consuming CO_2 and releasing O_2 into the environment. Therefore, the oxygen released contributes to the increased air pressure inside the closed syringe system.

2. How could it be known that a gas is being released as a product of photosynthesis? **Explain** why you think this.

   Students should point out that, according to their observations, the plant was producing bubbles that went up across the water column. This indicates that a gas was being released into the air of the system, raising the pressure inside the system.

3. What kind of gas is released by the plant during photosynthesis?

   Students should answer that the gas released during this process is molecular oxygen. This can be concluded by reviewing the general photosynthesis equation, shown in the background section.

4. Which properties of the system change if you increase the number of oxygen molecules inside? Why? **Explain.**

   Students should conclude that if you increase the amount of oxygen inside the system, raising the number of molecules in a given volume, the air pressure will increase just as we observed in the experiment using the sensor.

5. How would you prove with this experiment that the gas released was oxygen and not another kind of gas?

   Students should understand that while they can make deductions based on the information given from the teacher background and previous experiences, they are not able to prove (with this experiment) that the gas produced by the plant is indeed oxygen.

   However, the same experiment, using the Ward's DataHub BioChem model, measuring DO_2 (dissolved oxygen) can directly measure the oxygen released by the E. canadensis and dissolved in the water.

Students should reach the following conclusions:

Photosynthesis is a process that takes place in photosynthetic organisms (algae, plants, and some bacteria), which have specialized organelles for this function. This organelle is the chloroplast, which needs chlorophyll in order for photosynthesis to occur. Active photosynthetic organisms use carbon dioxide to produce glucose, through a series of chemical reactions involving light. As a result, they release oxygen into the environment.

In this lesson, we studied an aquatic plant inside a closed system, during the process of photosynthesis. We observed an internal pressure rise as the process was taking place because the plant was releasing oxygen as a product of photosynthesis. Even if we can conclude that the gas is oxygen based on the theoretical background, using this particular experiment, we have no way to prove that it is not another gas.

ACTIVITIES FOR FURTHER APPLICATION

The aim of this section is for students to extrapolate the knowledge acquired during this class and apply it to different contexts and situations. Furthermore, it is intended that students question and present possible explanations for the experimentally observed phenomena.

1. Why do you think we used *Elodea canadensis* for this experiment?

   Students should recognize or investigate some of the characteristics of this aquatic plant, as a good model to study. Some answers might note this plant's high photosynthetic rate, and the ease of raising and storing this plant.

2. What method other than oxygen detection would you use to indicate photosynthesis?

   Students should think about alternatives to study photosynthesis. One example could be the detection of other chemical compounds involved in the reaction with glucose. Another example could be the measurement of reactants consumption, like carbon dioxide.

3. During this lesson, the photosynthesis process was studied measuring the air pressure inside a closed system, using the air pressure sensor. However, the sensor is not able to discriminate different gas types, and therefore, using the background information presented, we can only conclude that the gas in the system was oxygen. How would you prove the gas was oxygen? **Explain.**

   Students should suggest and explain strategies to prove that the gas responsible for the air pressure increase inside the system was indeed oxygen. For example, they could suggest bringing a flame into contact with the air of the system and measuring the flame size. An increase in flame size would indicate air rich in oxygen, because oxygen is needed for the process of burning.

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DID YOU KNOW?

The first photosynthetic organisms evolved most likely 3,500 million years ago, when all forms of life on Earth were microorganisms and the atmosphere was comprised mainly of carbon dioxide. Because water was not present, early photosynthetic organisms most likely used hydrogen or hydrogen sulfide as the source of electrons.

4. Based on background information presented by your teacher, do you think that trees and plants with leaves that are not green also have green pigments, or only pigments the color of their foliage?

   Students should remember that chlorophyll (which is the green pigment) is present in all photosynthetic organisms and is vital to the process of photosynthesis. In other words, all plants have chlorophyll and if we see another color, it is due to the presence of other pigments masking the green of the chlorophyll.

5. What do you think would happen if all plants were to become extinct?

   Students should understand that if all plants died out, there would remain only a few organisms capable of performing photosynthesis (only some bacteria and algae). This would cause a serious drop in the amount of oxygen in the air, in turn causing problems for all aerobic organisms (organisms that breathe oxygen). Additionally, students may notice that autotroph organisms are fundamental to all food chains, because they synthesize their own food by taking molecules from the air. If plants (autotrophic organisms) were to become extinct, many terrestrial organisms would also die out.

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- **What elements or factors are necessary to fulfill our energy needs?**

- **What is the name of the metabolic process that plants perform to survive?**

After carrying out this experiment, you should be able to answer the following question:

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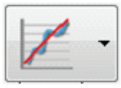

- **How do the results relate to your initial hypothesis?**

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- **What effect should we observe if we increase the light intensity used?**

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- **How would you explain the air pressure variation inside the system?**

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2. How could it be known that a gas is being released as a product of photosynthesis? **Explain** why you think this.

3. What kind of gas is released by the plant during photosynthesis?

4. Which properties of the system change if you increase the number of oxygen molecules inside? Why? **Explain.**

5. How would you prove with this experiment that the gas released was oxygen and not another kind of gas?

6. Write a **concluding** paragraph describing what you observed during the experiments.