Photosynthesis

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Introduction

Examine the overall reaction of photosynthesis:

\[ 6\text{CO}_2 + 12\text{H}_2\text{O} + \text{light} \rightarrow \text{glucose} + 6\text{O}_2 + 6\text{H}_2\text{O} \]

This equation does not tell you what type of light is used by photosynthesis. Looking around you, you will notice that there are many different types of light. Each color is a light of a different wavelength. White light is composed of light of many different wavelengths. There are some wavelengths of light that we can not see but may be used by other organisms. One aspect of this experiment is to make an initial determination of the wavelengths of light utilized in photosynthesis. This will be accomplished by quantitatively measuring the absorption of light by the pigments associated with photosynthesis. A second activity will be to measure the effect of temperature on the rate of photosynthesis in two different types of plants: bean and corn. These two plants have different metabolisms for removing carbon dioxide from the atmosphere. The bean plant has a photosynthetic metabolism referred to as C3 photosynthesis whereas the corn plant has a photosynthetic metabolism referred to as C4 photosynthesis.

To measure the speed or rate of photosynthesis, one could either examine the rate at which the components on the left side of the reaction are consumed or the rate at which the components on the right side of the reaction are produced. Since water is both consumed and produced, it would be a difficult substance to measure when studying the rate of this process. The absorption of light energy is also difficult to measure since light would not only be absorbed by the process of photosynthesis but would also be absorbed by plant tissues and radiated as heat. That leaves carbon dioxide, glucose, and oxygen. Methods to measure the consumption or production of all of these compounds have been developed to study the process of photosynthesis. In this simulation the rate of photosynthesis is measured by the amount of carbon dioxide assimilated by the plant and converted into glucose.
Activity 9.1
Action Spectrum

In this simulation, a plant is placed into an environmental chamber and the rate of photosynthesis is determined by the amount of carbon uptake by the plant. You can also monitor the chamber’s internal gas composition. The two meters on top of the chamber indicate the chamber’s carbon dioxide content and oxygen content. Carbon dioxide is measured in parts per million (ppm) while oxygen is measured as percent of atmosphere composition. See the diagram below for the layout of the simulation.

Initially the chamber is empty. You can place a bean plant or a corn plant into the chamber by clicking on the appropriate button in the lower right corner. There are several environmental conditions you can adjust.

Light spectrum: You can expose the plant in the chamber to the full spectrum of light or can limit its exposure to specific wavelengths. The “full spectrum” button acts like a toggle. Click once to turn it off (a red X appears in the button) and click again to turn it on. With the full spectrum off you can set the wavelength using the slider control. The wavelength value is given above the slider control. Do not be overly concerned if you can not set this on the exact value called for in the experiments. Set it as close to the called for values as possible then record the actual wavelengths used in the Results Section.

Light intensity: Above the wavelength controls in the lower left is a slider control which regulates how much light the plant is exposed to. One hundred percent is equivalent to full sunlight. You can reduce the light to zero percent or increase the light exposure to 300 percent of full sunlight.

Temperature: The thermometer acts like a slider control to regulate the temperature inside the chamber. While holding the mouse button down you can drag the temperature up or down. All temperature values in this simulation are in degrees centigrade.

Gas inputs: Two gases may be pumped into the chamber, oxygen and carbon dioxide. For each gas the ‘valve’
may be turned to increase or decrease the amount of gas entering the chamber. Click on the valve and while holding the mouse button down, move the cursor arrow to the left side of the valve and the input will increase. Move the cursor arrow to the right side of the valve and the input will decrease. For carbon dioxide the gas input is measured in parts per million (ppm). For oxygen the gas input is measured as percent of the total atmosphere.

You can turn off the gas input (no matter what the valve setting is) by clicking on the stopcock valves. Click once to turn the flow off. Clicking again will turn the flow on. With the valves off, the composition of the chamber’s atmosphere will be altered by the activity of photosynthesis. These changes may be monitored using the gas gauges located above the chamber.

**Experiment:**
The wavelengths of light used by photosynthesis are called the action spectrum. In this first simulation you will determine the plant’s action spectrum.

1. Place a bean plant into the photosynthesis chamber by clicking on the bean plant button.

2. Set the environmental condition to the following:
   - temperature: 20 degrees C
   - light level: 100%
   - oxygen input: 20%
   - carbon dioxide input: 280 ppm

Be sure the stopcocks for the gas inputs are in the open position.

3. Turn the full spectrum toggle off and set the wavelength to 400 nm (or as near to 400 nm as you can).

4. Click the ‘Start Experiment’ button to begin taking photosynthesis rate measurements. This simulation displays the rates of photosynthesis instantaneously. Record the rate of photosynthesis in the Results Section. For this experiment, you may let the experiment timer run, changes in photosynthetic rate will be displayed as conditions are altered.

5. Change the wavelength to 420 nm and record photosynthetic rate. Repeat this taking readings every 20 nm until you reach 740 nm. Graph your results in the Results Section. It may be difficult to set the wavelength exactly to these values. Set the wavelengths as close as you can to these values then record the actual values set in the Results Section.
Activity 9.2  
Effects of Temperature

One of the more important environmental factors that determines where organisms can live and thrive is temperature. This activity measures the effect of temperature on photosynthetic rates. You will also compare the effect of temperature on two different photosynthetic metabolisms, C3 photosynthesis and C4 photosynthesis.

1. Click on the Bean plant button to place it into the photosynthesis chamber. The bean plant is a C3 plant.

2. Set the light quality to full spectrum. Set the light quantity to 100%. Set the oxygen level to 20%. Set the carbon dioxide level to 280 ppm. Finally set the temperature to zero degrees C.

3. Measure the photosynthetic rate and record in the results section. Increase the temperature to 5 degrees and record the photosynthetic rate in the results section. Repeat this procedure increasing the temperature by 5 degrees each time up to 50 degrees C.

4. Select the corn plant (a C4 plant) to be placed in the photosynthetic chamber.

5. Repeat the above procedure to measure the photosynthetic rate from zero to 50 degrees in 5 degree increments.

6. Graph the photosynthetic rates of the C3 and C4 at the different temperatures.

Activity 9.3  
Photosynthesis Experiment

You have already conducted experiments examining the effects of wavelengths of light and temperature on photosynthetic rates. This simulation also allows you to investigate the effect of a number of other variables on photosynthetic rates. These include the intensity of light (light level), the quantity of oxygen the plant is exposed to and the quantity of carbon dioxide the plant is exposed to.

1. Design an experiment to measure the effect of one of the environmental variables you are able to control in this simulation other than the wavelength and temperature which were previously studied. Select a variable not previously tested in this lab exercise.

2. Outline your experimental procedures in the Results Section.

3. Conduct your experiment, record your observations.
## Results Section

### Activity 9.1
**Action Spectrum**

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[Graph of Photosynthesis Rate vs. Wavelength]

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### Activity 9.2

**Effects of Temperature**

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Activity 9.3
Photosynthesis Experiment

Experimental Hypothesis

Experimental Procedure

Experimental Results
Graph of Results

Conclusion
**From Activity 9.1**

At what wavelengths are there peaks of photosynthetic activity? What colors are absorbed most by the plant? What wavelengths of light produce the lowest levels of photosynthesis? What colors of light are least absorbed by the plant?

**From Activity 9.2**

Based on your observations of the bean and corn plants at the different temperatures, which plant would appear to be better adapted to warmer temperatures?

**From Activity 9.3**

Was your initial hypothesis supported by your results? Do your results have any environmental implications?