PHOTOSYNTHESIS

Background

Plants and other producers utilize the sun's energy to build the complex organic compounds that serve as a source of energy for the organism. Chloroplasts are the site of this energy capture and biosynthesis. Chlorophyll and other pigment molecules play a vital role in the light reactions of photosynthesis, capturing energy that drives an electron transport chain and ATP synthesis. Ultimately, through light-independent reactions, the chemical energy is transferred and stored within molecules such as glucose. This entire process is summarized by the chemical equation:

$$6CO_2 + 6H_2O \xrightarrow{\text{light}} C_6H_{12}O_6 + 6O_2$$

The uptake of carbon dioxide is an indication that photosynthesis is occurring within the chloroplasts of a leaf. The reactions that fix carbon into organic compounds depend on the products of the light reactions and are therefore dependent on the absorption of light by pigments.

While sunlight is composed of many different wavelengths of light, not all wavelengths are equally available to a plant. This investigation compares the amount of photosynthesis that occurs when different colors of light are provided to a plant.

Driving Question

Does the color of light affect the rate of photosynthesis in green leaves?

Materials and Equipment

Use the following materials to complete the initial investigation. For conducting an experiment of your own design, check with your teacher to see what materials and equipment are available.

- Data collection system
- Carbon dioxide gas sensor
- Sensor extension cable
- Sampling bottle, 250-mL
- Box, foil, or cloth for shading the setup
- Light source
- Compact fluorescent light bulb, 60 W equivalent (or higher), red
- Compact fluorescent light bulb, 60 W equivalent (or higher) green
- Fresh spinach leaves
- Forceps or pencil

Safety

Follow these important safety precautions in addition to your regular classroom procedures:

- Wear safety goggles at all times
- Allow the light bulb to cool before removing it from the light source

Initial Investigation

Complete the following investigation before designing and conducting your own experiment. Record all observations, data, explanations, and answers in your lab notebook.

1. Put on your safety goggles.

2. Connect the carbon dioxide gas sensor to your data collection system and calibrate the sensor.

3. Display a graph of Carbon dioxide (ppm) on the *y*-axis versus Time in minutes on the *x*-axis. Adjust the sample rate to one sample every 5 seconds.

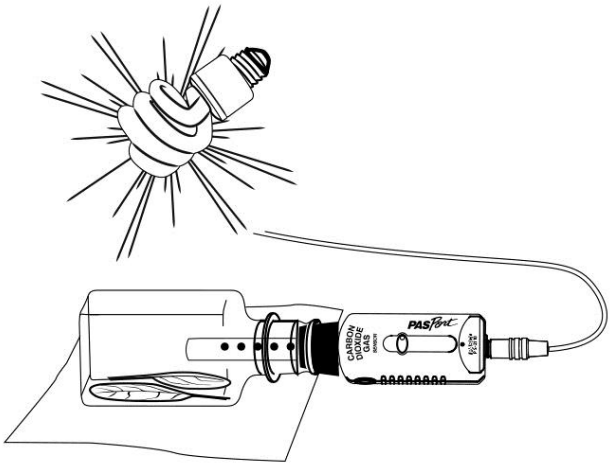
   NOTE: If your data collection system allows you to set an automatic stop condition, set the stop time for 7 minutes.

4. Holding the sampling bottle horizontally, place two fresh leaves into it. The leaves should lay flat and overlap as little as possible.

5. Seal the sampling bottle with the carbon dioxide sensor and stopper. Rest the bottle on its side on a flat surface.

6. Arrange the light source directly above the sampling bottle.

   NOTE: Make sure a colored light bulb (red or green) is in the light source.



7. Shade the bottle from ambient white light in the room.

8. Turn on the light source. Wait approximately 15 seconds and then start collecting data. Adjust the scale of the graph to show all data. Collect data for 7 minutes.

9. After 7 minutes, stop recording data and turn off the light source.

10. Refresh the air in the bottle by waving the bottle through the air a number of times. If necessary, readjust the leaves so they lay flat.

11. Remove the colored bulb from the light source and replace it with a different colored bulb.

12. Repeat the data collection using the other colored bulb.

13. Draw or print a record of the data.

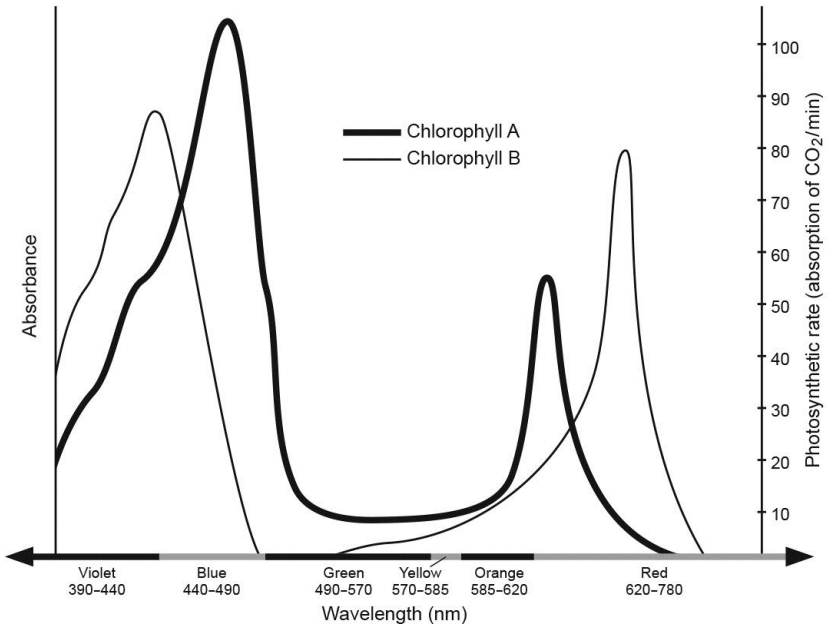
14. Describe the apparent trend of the data.

15. How can you quantify the results? What type(s) of mathematical analysis would be appropriate?

    a. Identify the method(s) chosen for quantification and analysis of results.

    b. Apply the method(s) chosen to the data collected in the initial investigation.

16. Create a graph that relates the absorbance spectrum to the action spectrum. The absorbance spectrum is provided in the graph below. For the action spectrum, draw a bar graph indicating the photosynthetic rate at the wavelengths tested in the investigation.

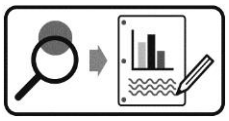


17. Based on a typical absorbance spectrum for leaves, explain the results of this investigation. Your response should provide a clear connection between light absorbance, the reactions of photosynthesis, and evidence from the investigation.

18. What could be done to confirm the relationship observed in the data collected by your group?

Design and Conduct an Experiment

Photosynthesis is critical for providing energy to organisms in an ecosystem. It is a process that can be affected by a number of factors. Think of possible factors and design an experiment to test one of them.



Design and carry out your experiment using either the Design and Conduct an Experiment Worksheet or the Experiment Design Plan. Then complete the Data Analysis and Synthesis Questions.

Design and Conduct an Experiment: Data Analysis

1. From your observations and your data,

   a. Describe how the independent variable you manipulated affected the rate of photosynthesis. Does the data support your hypothesis? Justify your claim with evidence from your experiment.

   b. Based on the evidence you collected, explain why the results occurred.

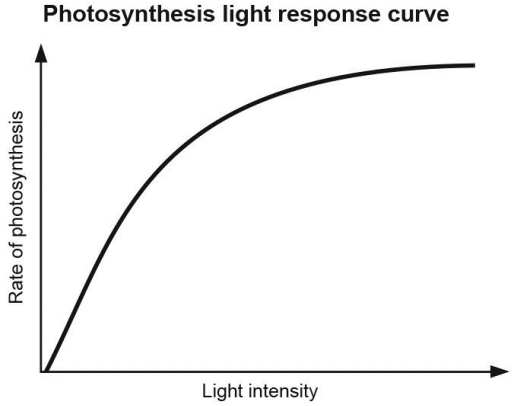
2. Is there any evidence in your data or from your observations that experimental error or other uncontrolled variables affected your results? If yes, is the data reliable enough to determine if your hypothesis was supported?

3. Identify any new questions that have arisen as a result of your research.

Synthesis Questions

1. Incandescent light bulbs are inefficient light sources due to a large amount of energy released as heat into the environment. If you carried out a photosynthesis experiment using an incandescent bulb, how would you expect this to affect the results? Explain your reasoning.

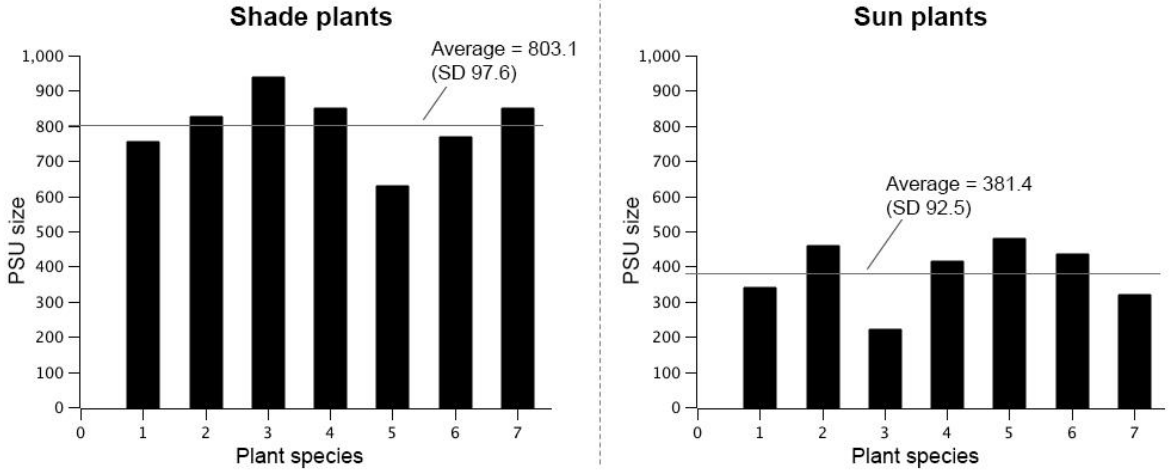
2. Refer to the generalized light response curve for photosynthesis to answer the following.



   a. For low to medium light intensity, explain the trend in the data.

   b. For higher levels of light intensity, explain the trend in the data.

3. A "photosynthetic unit" (PSU) is a complex of pigment molecules and one or more reaction centers. The reaction centers are responsible for passing excited electrons to an electron acceptor within a photosystem. Graphs of the data from a study that compared the PSU sizes for a variety of plants are shown below.[1] In the study, scientists measured the PSU size of seven different species of shade plants and seven different species of sun plants.



a. What conclusion can be made from the data acquired in this study?

b. Considering the environments of the plants, provide an explanation for the difference in the mean PSU sizes.

[1] Malkin, S.; Fork, D.C. Photosynthetic Units of Sun and Shade Plants. *Plant Physiology* 67 (1981): 580–583.

NAME PERIOD DATE

Design and Conduct an Experiment Worksheet

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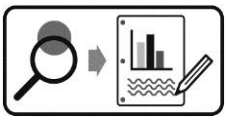

Develop and conduct your experiment using the following guide.

1. Based on your knowledge of photosynthesis, what environmental factors (abiotic or biotic) could affect this process?

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_____

2. Create a driving question: choose one of the factors you've identified that can be controlled in the lab and develop a testable question for your experiment.

_____

_____

3. What is the justification for your question? That is, why is it biologically significant, relevant, or interesting?

_____

_____

4. What will be the independent variable of the experiment? Describe how this variable will be manipulated in your experiment.

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_____

5. What is the dependent variable of the experiment? Describe how the data will be collected and processed in the experiment.

_____

_____

6. Write a testable hypothesis (If…then…).

_____

_____

7. What conditions will need to be held constant in the experiment? Quantify these values where possible.

_____

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_____

8. How many trials will be run for each experimental group? Justify your choice.

_____

_____

9. What will you compare or calculate? What analysis will you perform to evaluate your results and hypothesis?

_____

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_____

10. Describe at least 3 potential sources of error that could affect the accuracy or reliability of data.

_____

_____

11. Use the space below to create an outline of the experiment. In your lab notebook, write the steps for the procedure of the lab. (Another student or group should be able to repeat the procedure and obtain similar results.)

12. Have your teacher approve your answers to these questions and your plan before beginning the experiment.