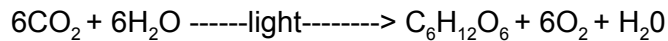


Investigation: What Factors Affect Photosynthesis

Background and PreLab

Photosynthesis fuels ecosystems and replenishes the Earth's atmosphere with oxygen. Like all enzyme-driven reactions, the rate of photosynthesis can be measured by either the disappearance of substrate, or the accumulation of products. The equation for photosynthesis is:

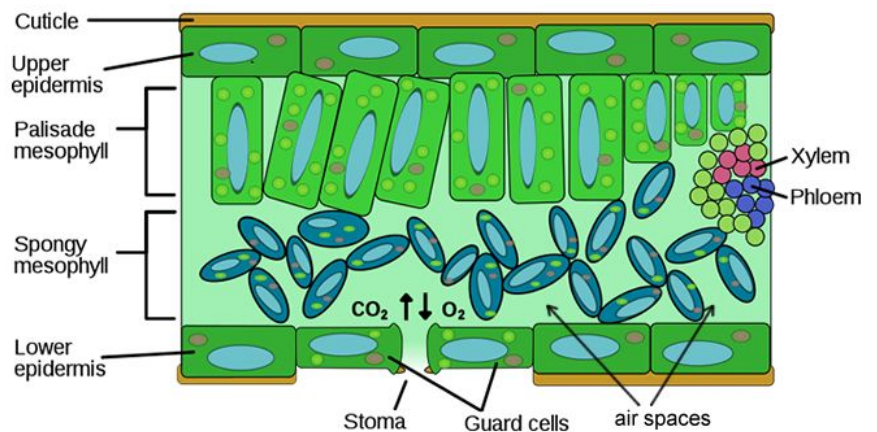


The rate of photosynthesis can be measured by: 1) measuring O_2 production 2) measuring CO_2 consumption

Leaf Structure and Function

In this investigation, you will use a system that measures the accumulation of oxygen in the leaf. Consider the anatomy of the leaf as shown below.

The leaf is composed of layers of cells. The spongy mesophyll layer is normally infused with gases, oxygen and carbon dioxide. Leaves (or disks cut from leaves) will normally float in water because of these gases. If you draw the gases out from the spaces, then the leaves will sink because they become more dense than water. If this leaf disk is placed in a solution with an alternate source of carbon dioxide in the form of bicarbonate ions, then photosynthesis can occur in a sunken leaf disk. As photosynthesis proceeds, oxygen accumulates in the air spaces of the spongy mesophyll and the leaf becomes buoyant and floats. Oxygen and carbon dioxide are exchanged through openings in the leaf called stroma.



While this is going on, the leaf is also carrying out cellular respiration. This respiration will consume the oxygen that has accumulated and possibly cause the plant disks to sink. The measurement tool that can be used to observe these counteracting processes is the floating (or sinking) of the plant disks. **In other words, the buoyancy of the leaf disks is actually an indirect measurement of the net rate of photosynthesis occurring in the leaf tissue.**

While this is going on, the leaf is also carrying out cellular respiration. This respiration will consume the oxygen that has accumulated and possibly cause the plant disks to sink. The measurement tool that can be used to observe these counteracting processes is the floating (or sinking) of the plant disks. **In other words, the buoyancy of the leaf disks is actually an indirect measurement of the net rate of photosynthesis occurring in the leaf tissue.**

Learning Objectives:

- 1) To design and conduct an experiment to explore factors that affect photosynthesis.
- 2) To connect and apply concepts, including the relationship between cell structure and function, strategies for capture and stores of energy, and the diffusion of gases across membranes.

Experimental Question: What factors affect the rate of photosynthesis?

PreLab Questions - these should be completed BEFORE the scheduled lab

1. How can the rate of photosynthesis be measured?

2. Where in the cells of the leaf do you find air spaces?

What is the function of the stoma?

3. What will happen if you remove the air from these spaces?

4. How will air return to these spaces?

5. Instead of carbon dioxide, what will be used as the reactant in this lab?

6. List any factors that you think may affect the rate of photosynthesis. Consider environmental factors that you could manipulate during the lab.

7. Watch the video that shows the set-up for the floating leaf disk lab at Bozeman Science. (Search for "bozeman leaf disk lab" or use QR code)

a) What is the ratio of water to baking soda you will need for your solution?

b) What is the purpose of the syringe?

c) Why did Mr. Anderson put a watch glass with water on top of the beaker?

d) How will you know when photosynthesis is occurring in your leaf disks?



Part 1: Basic Procedure for Measuring the Rate of Photosynthesis

Materials: baking soda, liquid soap, plastic syringes, spinach leaf, hole punch or straws, beakers, timer, light source

1. Collect leaf disks by punching holes in the leaf (try to get them between the veins), you will need 20 leaf circles.
2. Make a solution of sodium bicarbonate by mixing 300 ml of water to a pinch of baking soda (about 100 ml to 1g)
3. Make a diluted solution of liquid detergent in a small beaker by adding about 2 drops of dish soap to 100 ml of water. Do not make suds!
4. Add one drop of this dilute soap solution to your 300 ml bicarbonate solution. Swirl gently to avoid making suds.
5. Place 10 leaf disks into the syringe and pull in a small volume of the bicarbonate and soap solution. Replace the plunger and push out most of the air, but do not crush your leaves.
6. Create a vacuum by covering the tip of the syringe with your finger. Draw back on the plunger.
7. Release the vacuum so that the solution will enter the disks. It may take a few times to get the disks to sink. You may need to gently tap the syringe to dislodge discs from the sides.
8. Once they have sank, you can put them back into the sodium bicarbonate solution and expose the disks to light. Start a timer and record how many of the disks are floating at 1 minute intervals. (See data table.) While you are making observations, you can set up the control group.

Troubleshooting: Gently swirl solution to dislodge disks which may become stuck at the bottom. If no discs float within 5 minutes, add a couple more drops from your soap solution and start the timer over again. Place your beaker as close to the light as possible!

9. Control Group: Repeat your setup from above, but this time do not place baking soda in the beaker. Place another set of sunken disks into this solution and record data on the table.
10. Both the experimental group and the control should run until all the discs are floating.

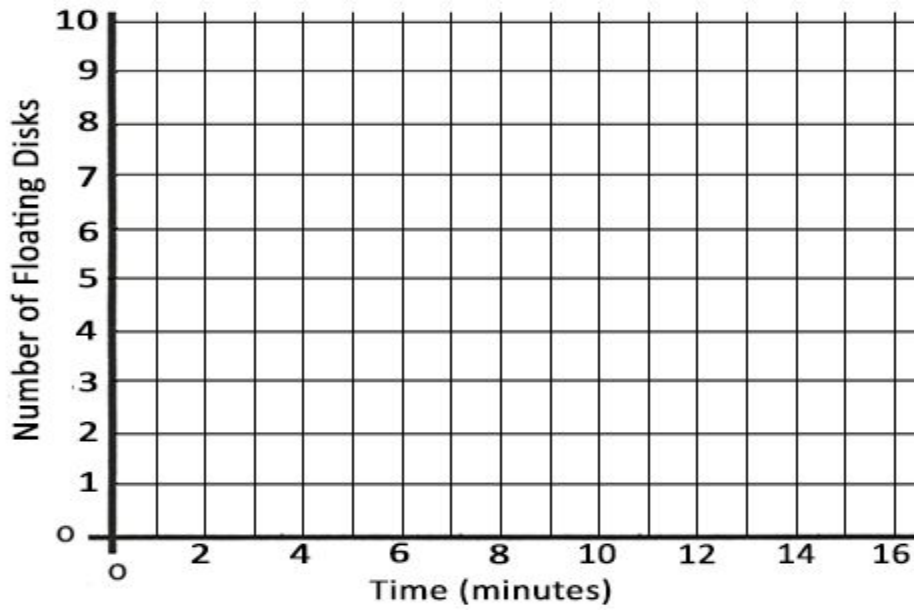
Data Table

Time (min)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
# of floating disks (bicarbonate, water, + soap)															
# of floating disks (control) (only water + soap)															

Analyzing Data

To make comparisons between experiments, a standard point of reference is needed. Repeated testing of this procedure has shown that the point at which 50% of the disks are floating (the median or ET_{50}) is a reliable and repeatable point of reference. In this case, the disks floating are counted at the end of each time interval. The median is chosen over the mean as the summary statistic. The median will generally provide a better estimate of the central tendency of the data because, on occasion, a disk fails to rise or takes a very long time to do so. A term coined by G. L. Steucek and R. J. Hill (1985) for this relationship is ET_{50} , the estimated time for 50% of the disks to rise. That is, rate is a change in a variable over time. The time required for 50% of the leaf disks to float is represented as Effective Time = ET_{50} .

Graph your data for the experimental group. Determine the ET_{50} for your leaf disks and determine the ET_{50} for your data.



What is the relationship between sodium bicarbonate and photosynthesis rate? This is your **CLAIM**.

Provide **evidence** that supports this claim; summarize data by referencing ET_{50} ?

Provide **reasoning** that links the evidence and the claim and explains why this relationship exists.

Lab Report Guidelines (optional)

- 1) Introduction - stating the problem or question you will be investigating, your predicted outcomes (hypothesis) and relevant information on photosynthesis
- 2) Procedure - describe how your experiment was set up, include materials (summarize, do not copy procedures from lab guide)
- 3) Data Tables and Graphs - present your data in an easy-to read format, include graphs and indicate the ET_{50} of your treatments.
- 4) Summary and Conclusions - did your experiment answer your question, what did you learn, how could your experiment be improved upon? If the experiment did not go as expected, offer an explanation.