#5: PHOTOSYNTHESIS

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Introduction

Photosynthesis is the anabolic (synthesizing complex molecules from simpler ones) process cells use to convert carbon dioxide and water to glucose and oxygen according to the equation:

$$2H_2O + CO_2 + \text{light} \rightarrow \text{carbohydrate } (CH_2O) + O_2 + H_2O$$

An endergonic (energy-consuming) reaction, it derives its necessary energy from sunlight. Like all enzyme-driven reactions, the rate of photosynthesis can be measured by either the depletion of substrate or the accretion of product (or byproducts).

Ordinarily, leaves float on water because of the air pockets in the mesophyll, the inner tissue of the leaf that contains many chloroplasts (the plastids within the cell where photosynthesis takes place). In this experiment, these air bubbles are removed from chads (leaf disks) through a vacuum and infiltrated by the surrounding liquid solution, causing the chads to sink in the solution. Because oxygen is a product of photosynthesis, the time it takes for the chads to float again is a measure of the net rate of photosynthesis. This experiment compares the rate of photosynthesis in chads infiltrated with water (serving as control) to the rate of photosynthesis in chads infiltrated with bicarbonate solution.

Chlorophyll is the green porphyrin pigment in chloroplasts that is primarily responsible for photosynthesis in plants. In leaves, the red color results mainly from flavonoid pigments, and the yellow color comes mainly from carotenoid pigments. Chlorophyll a and chlorophyll b are most effective in blue-violet light and red-blue light, respectively. Covering the chads in one beaker with red Saran wrap will expose them mostly to red light, rather than the greater range of wavelengths the chads in the uncovered beakers are exposed to. This investigation explores how this manipulation of the wavelength of the light source affects the rate of photosynthesis.

Hypothesis 1: Rate of Photosynthesis

If three sets of 15 chads are submerged in a bicarbonate solution, a bicarbonate solution covered in red Saran wrap, and a water solution, respectively, the first set will exhibit the highest net rate of photosynthesis, the second set will exhibit a medium high net rate of photosynthesis, and the third set will exhibit the lowest net rate of photosynthesis relative to the other sets.

Hypothesis 2: Leaf Colors

If segments of two different-colored leaves of the same tree and one spinach leaf are crushed on three pieces of filter paper...

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Hypothesis 2: Leaf Colors

"Submerged in propanol solution, the dark green spinach leaf will leave a dark green pattern, the light green leaf will leave a light green pattern, and the reddish-yellow leaf will leave an orange pattern on the filter paper.

Materials

The materials used include:

- 1 stopwatch (iPhone)
- 5 living corn salad leaves
- 2 different-colored living leaves of the same tree
- 1 spinach leaf
- 300 mL 0.2% sodium bicarbonate solution
- dilute soap solution (~5mL dishwashing soap in 250mL water)
- 20 mL propanol solution
- 3 10cc plastic syringes w/out needle
- 1 camera (iPhone)
- 3 pieces of filter paper
- 1 hole puncher
- 1 pipette
- 1 lamp (light source)
- 4 beakers
- 1 large coin
- 1 pencil
- tap water
- red Saran wrap

Procedure 1: Rate of Photosynthesis

Using a hole puncher, three sets of 15 uniform chads were punched out of living corn salad leaves. Smooth, thin areas of the leaf were chosen and major veins avoided. Meanwhile, two beakers were filled with 100 mL of sodium bicarbonate solution and a third beaker was filled with 100mL of tap water. Using a pipette, a drop of dilute soap solution was added to each beaker. Next, the plunger was removed from each of the three syringes, and a set of 15 chads placed in each syringe barrel. In each syringe, the plunger was replaced and pushed in until only a small volume of air remained in the barrel. Then, the first syringe was filled with 5cc of bicarbonate solution from the first beaker, the second syringe was filled with 5cc of bicarbonate solution from the second beaker, and the third syringe was filled with 5cc of water from the third beaker.

The plunger of every syringe was moved until all remaining air was expelled. Next, a vacuum created in each syringe by holding a finger over the syringe opening while drawing back the plunger was held for 10 seconds, then released by letting the plunger spring back. This was repeated no more than three times for each syringe to ensure that as many chads as possible sank to the bottom of the solution in the syringe. After this, the chads from the first syringe were poured into the first beaker of bicarbonate solution, the chads from the second syringe were poured into the second beaker of bicarbonate solution, and the chads from the third syringe were poured into the third beaker of water. Any chads still floating were quickly removed.

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Procedure 1: Rate of Photosynthesis

Next, a red Saran wrap covering was fastened across the second beaker, and all three beakers were placed under a common light source for 15 minutes. The amount of chads that had floated to the top in each beaker was recorded at 1-minute intervals.

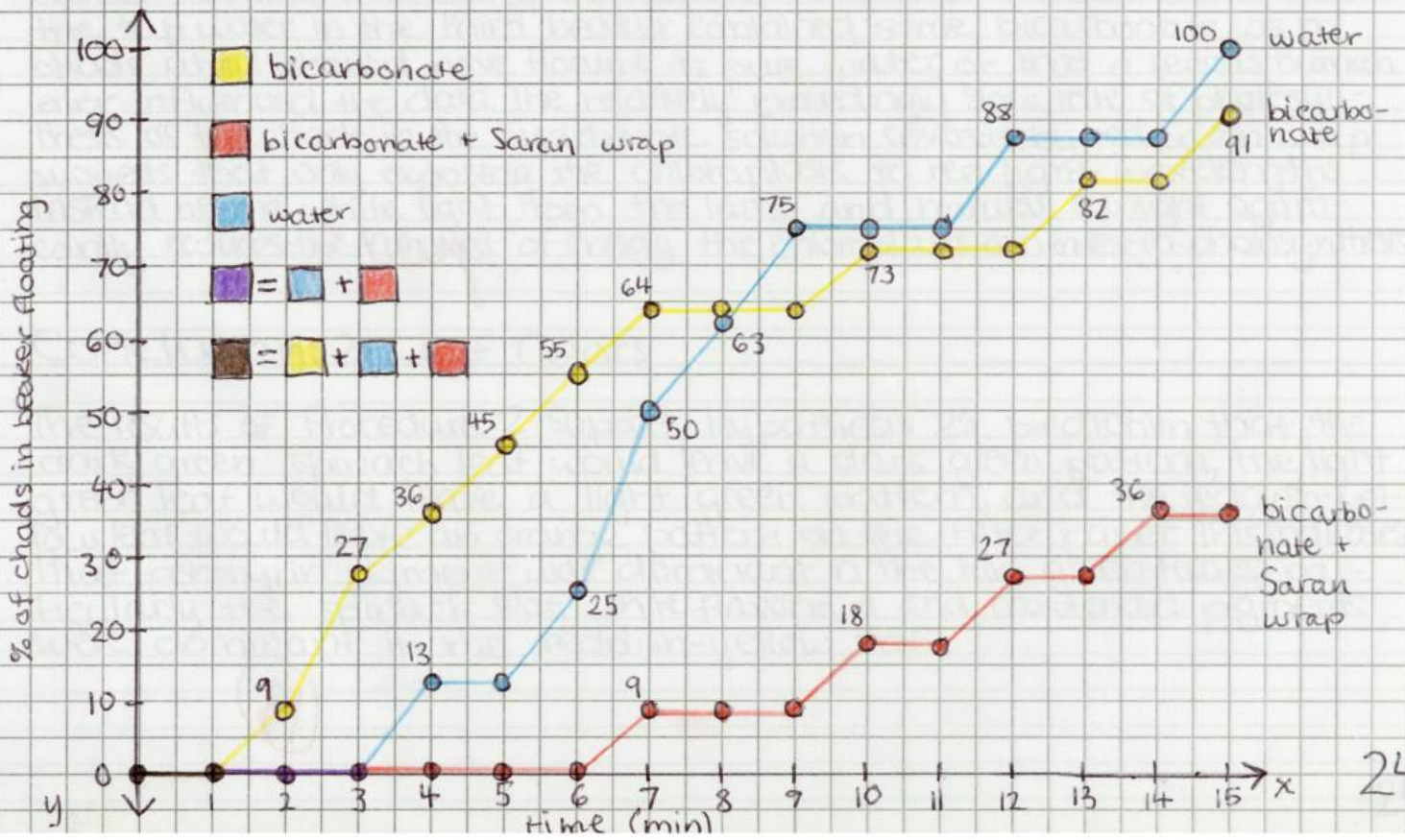
Procedure 2: Leaf Colors

One dark green spinach leaf and one reddish-yellow and one light green leaf from the same tree were each placed over a piece of filter paper. Using a pencil line as a guideline, a large ridged coin was rubbed over the leaves to push the crushed leaf cells onto the filter paper. Meanwhile, a beaker was filled with 20 mL propanol solution to a level about 2 cm below the pencil line. Once a clear horizontal line of color had been rubbed across each filter paper, the strip was placed upright in the propanol solution for 60 minutes. Afterwards, the filter papers were removed and the results recorded photographically

Results 1: Rate of Photosynthesis

ET_{50}, the estimated time at which 50% of the leaf disks had floated to the surface, is the standard point of reference used to compare the rates in this experiment. The net rate of photosynthesis was fastest in the first beaker of bicarbonate solution (ET_{50} = 5.5 mins), slowest in the second beaker of bicarbonate solution covered by red Saran wrap (ET_{50} = 19 mins), and medium fast in the third beaker of water (ET_{50} = 7 mins).

Graph 1: Chads rising over time (Procedure 1)



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Results 2: Leaf Colors

The dark green spinach leaf left a dark green pattern on the filter paper, the light green leaf left a light green pattern on the filter paper, and the reddish-yellow leaf left an orange pattern on the filter paper.

Error Analysis

In Procedure 1, chads floated to the surface in the beaker containing water, which should not have occurred if the water had been pure H_2O. It is possible that the impure tap water contained bicarbonate, which could offer the chloroplasts in the chads a source of carbon dioxide. Alternatively, the chads may have been damaged through improper use of the syringe, such as crushing the chads or creating too many vacuums.

Conclusion 1: Rate of Photosynthesis

The results of Procedure 1 show that Hypothesis 1 was mostly incorrect. While the chads submerged in the bicarbonate solution exhibited the highest net rate of photosynthesis as predicted, the chads exhibiting the slowest net rate of photosynthesis were those submerged in the bicarbonate solution covered in red Saran wrap, not in the water as had been predicted. The chads submerged in water exhibited a medium net rate of photosynthesis slightly (2.5 mins) slower than that of the chads in the bicarbonate solution and considerably (12 mins) faster than that of the chads in the beaker covered in red Saran wrap.

Since chloroplasts cannot photosynthesize in the absence of the substrates carbon dioxide and water, the results of Procedure 1 indicate either that the tap water in the third beaker contained some bicarbonate, as no chads at all should have floated in pure water, or that a serious human error influenced the data. The relatively exceedingly slow rate of photosynthesis of the chads in the bicarbonate solution covered by red Saran wrap suggests that only exposing the chloroplasts to red light wavelengths instead of the white light from the lamp and natural sunlight significantly reduces the amount of energy the chloroplasts can invest in photosynthesis.

Conclusion 2: Leaf Colors

The results of Procedure 2 support Hypothesis 2's prediction that the dark green spinach leaf would leave a dark green pattern, the light green leaf would leave a light green pattern, and the reddish-yellow leaf would leave an orange pattern on the filter paper. This indicates that porphyrin pigment was dominant in the two green leaves, particularly the spinach leaf, while flavonoid and carotenoid pigments were dominant in the reddish-yellow leaf.