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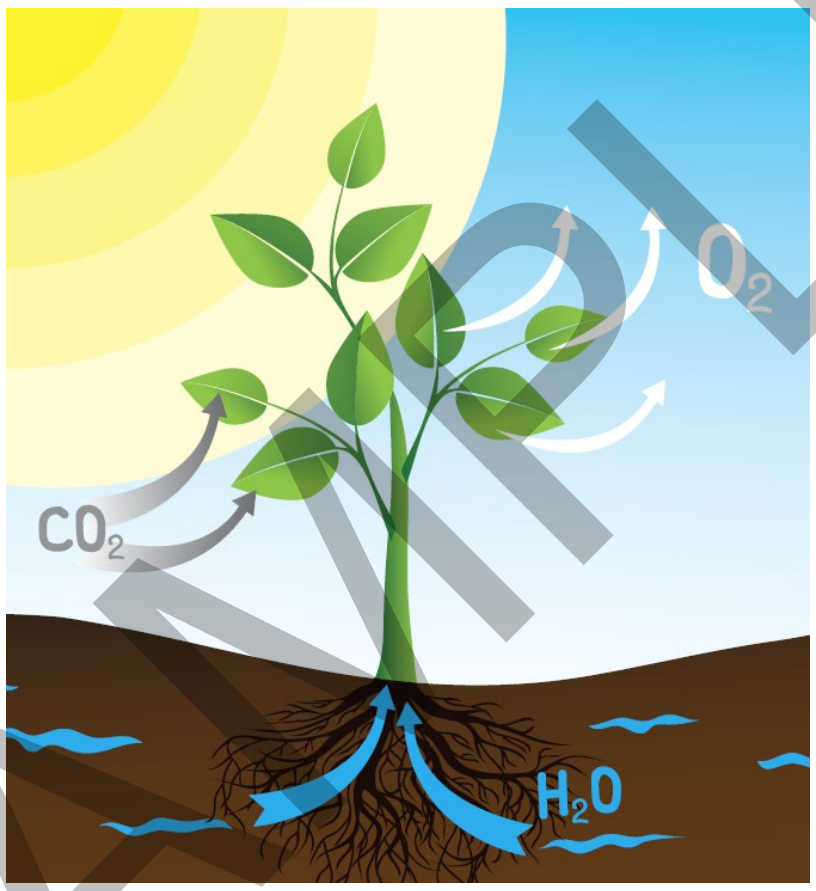

Exploring Photosynthesis:

Stored Carbon Using Energy from the Sun

TEACHER'S GUIDE

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Teacher Preparation	Time Required*	Target Grade Range
Review Teacher's Guide (15 min.) **Prepare Materials** (1 day in advance)	**Part 1**: 1.5 – 2.5 hrs **Part 2**: 20 – 30 min. **Part 3**: 1.5 – 2.5 hrs	**7th – 11th Grade**

*Note: The time required may vary based on the state of the algae used, the ambient lighting conditions and other variables.

IMPORTANT NOTE

These experiments will work best if the algae beads are first exposed to sunlight for a period of time (enough for the solution to start to turn pink/purple) then placed again in the dark. This can be done by opening the package upon arrival, placing the algae in an area with sunlight for 2 – 3 hours then placing them back in the bag overnight - to be used the next day.

In addition, between Part 1 & Part 3, the algae beads should be placed in the dark overnight to stop photosynthesis & start respiration. The solution must be yellow prior to starting the experiment in Part 3.

Lab Overview

Exploring Photosynthesis: Stored Carbon Using Energy from the Sun is an exciting, hands-on lab that uses pre-prepared, living algae to demonstrate key concepts of photosynthesis, respiration, and carbon cycles. In addition to conducting two experiments, students are challenged to consider the science behind natural phenomenon like the blue whale food chain. In this activity, they'll gain an even better understanding of the importance of energy and carbon transfer in ecosystems.

This lab consists of three parts:

Part 1: Demonstrating how light energy is required for photosynthesis.

Part 2: Using an understanding of carbon and energy flow to explain natural phenomenon.

Part 3: Exploring how the amount of a photosynthetic species changes carbon and energy flow.

Learning Outcomes

In this lab, students will learn:

- **To articulate that photosynthesis results in the cycling of matter and energy into and out of organisms in ecosystems as part of the global carbon cycle**
- **That photosynthetic organisms (like algae) require energy (sunlight) and CO_2 to survive and that they convert these to "food molecules" and oxygen**
- **That when photosynthetic species are consumed by other organisms, these "food molecules" can feed complex food webs**

Note: Alignment to NGSS Standards described in detail on Page 20.

SAFETY FIRST!

Chemicals used in these projects can be hazardous if misused. Follow standard laboratory working practices including always wearing the necessarily protective safety equipment and keeping chemicals away from food.

Part 1: Energy from the Sun

In most ocean environments, green algae are observed living only in the top 100 – 150 feet (30 – 45 meters) of the water's surface while brown algae are found in even shallower waters (less than 100 feet). Red algae, on the other hand, are found deeper – up to approximately 650 feet. With an average depth of the ocean of about 12,000 feet, this represents only a fraction of the height of the water.

TAKE ACTION

Based on the number of students/groups, **distribute supplies for Part 1 per the quantities below**. When working in groups, students will need to **share the Algae Beads and some other supplies provided in the kit**.

Materials Required

Item	Quantity Required (per group)
Algae Bead Tubes	6
Fluorescent Bulb	1
Bulb Socket with Cord	1
Ruler	1
Student Worksheet	1 (per student)
Lab Manual	1 (per student)

Note:

- The Single Kit provides materials for use by 1 student or as a demonstration for one small group, though copies of printed materials are recommended.
- The Classroom Kit provides materials for use by at most 3 groups - with 5 students per group. Copies of the Student Worksheet and Lab Manual are required.

In Part 1, students will explore how the intensity of light impacts the amount of photosynthesis that occurs in a given period of time. They will use this information to answer why algae do not grow beyond the top few percent of the ocean's surface.

Important Teacher Tips:

- Algae beads must start yellow (respiration). Be sure to store them in a dark location when not in use.
- In the ocean, light is "blocked" by the water. Thus, less energy is available for photosynthesis as you go deeper. In the experiment in Part 1, the light isn't "blocked" in the same manner, but this idea of available light energy is clearly demonstrated. Some students may need additional support and guidance to understand how this result relates to what occurs in the ocean.

Experimental Analysis

Experimental Background

In this lab, an algae species called *Chlorella vulgaris* will be used to demonstrate the following: energy from light is required in photosynthesis to convert dissolved CO_2 to stored chemical energy in the form of carbohydrates. Algae are provided immobilized in a sodium alginate matrix and suspended in a color-changing pH indicator. These "algae beads" are a great way to study photosynthetic processes. Photosynthesis or respiration can be easily visualized by monitoring the color of the solution. When the pH is elevated (about pH 8.5 – 9.5), the solution turns a dark purple color. When the pH is reduced (about pH 7.5 – 8) the solution is yellow to light orange. A complete color chart is provided with each tube of algae beads.

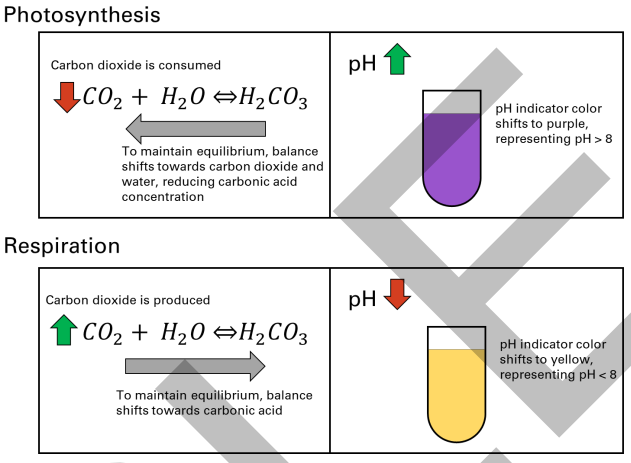
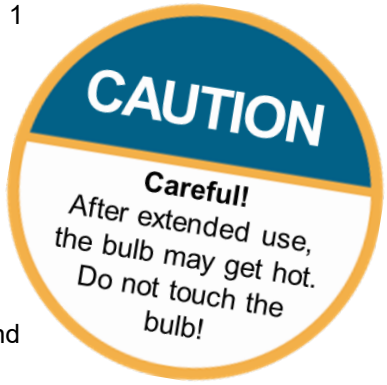


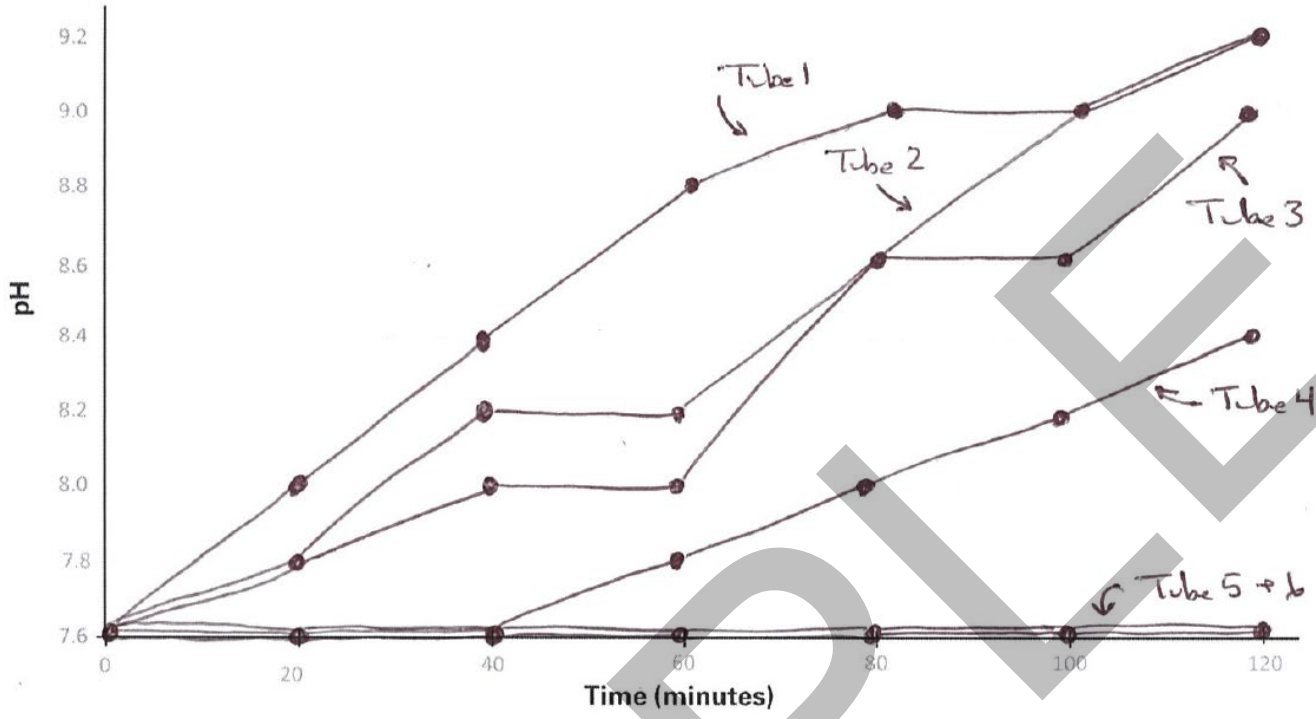
Figure 4. pH color change based on carbonic acid equilibrium.

How does this work? As noted in the Background, the algae actively consume CO_2 and convert it to stored carbohydrates during photosynthesis. In turn, the equilibrium in the solution shifts away from carbonic acid, which thus increases the pH (so the solution turns purple). During respiration, the algae produce CO_2, which drives equilibrium toward carbonic acid and reduces the pH. With this simple color change, it is possible to immediately determine if the algae are consuming CO_2 and making stored carbohydrates (photosynthesis), or if they're utilizing the stored carbohydrates for energy and making CO_2 (respiration).

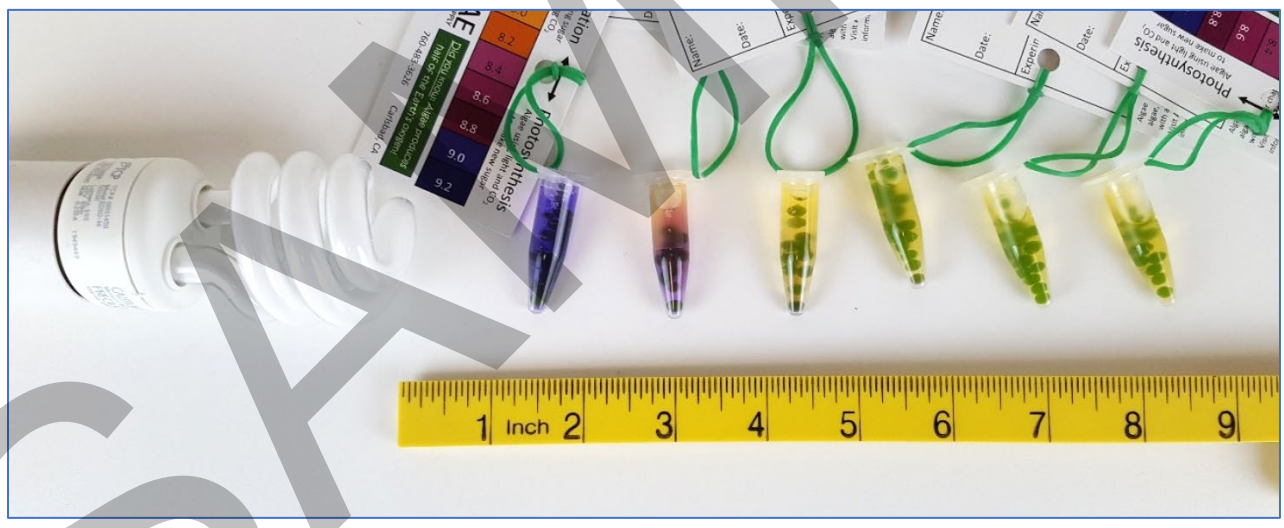
Procedure

1. Open the package of algae beads and ensure that the solution is yellow in color (store in the dark)
2. Find or make a location with little overhead or natural light
3. Screw the light bulb into the socket and lie it flat on a table (use a clamp or tape to hold in place, if needed)
4. Plug the cord into the wall (110V outlet) and ensure that the bulb lights up brightly, then shut off
5. Sort tubes of algae beads by the number of beads per tube
6. Select 6 tubes which have approximately the same number of beads
7. All tubes must start yellow; try to minimize their exposure to light as much as possible
8. Place the tubes flat on the table immediately in front of the bulb, starting approximately 2" from the bulb
9. Place the tubes in a row, leaving approximately 1 - 2" between each tube (Fig. 5)
10. Label the card on each tube with the position from the bulb, starting with 1 (being the closest) and ending with 6 (being the furthest)
11. Measure the distance from the end of the bulb to each tube and record under the "Distance from Bulb (in)" column on Student Worksheet Page 1
12. Assess the color and determine the approximate pH using the provided pH/color scale. Record under the "Initial pH" column on Student Worksheet Page 1
13. Start a timer and turn on the bulb, allowing the light to shine on the tubes
14. At each 20-minute interval, turn off the bulb, assess the color of the tubes and record the approximate pH





Here's what you can expect to see!



Describe the data, explaining how the number of algae beads affects the pH over time.
Answers will vary but should include a description that more algae beads increase the pH more quickly than fewer algae beads. For the lowest number of algae beads, very little pH change may be observed over the course of the experiment.
If there are more algae in an ecosystem, will more or less energy be available to consumers? Why?
Based on this experiment, more algae means that photosynthesis occurs more rapidly. In a given volume of an ecosystem, if more algae are present, the flux of energy into the system will be higher. There is room for ambiguity here because an increased rate of photosynthesis does not necessarily mean that consumers can obtain more energy. They may be limited by other things like space or nutrients – so, a higher rate of photosynthesis may make more energy potentially available, but not practically.
How does the number of photosynthetic organisms change the global carbon cycle?
Answers will vary widely as this question is purposefully open-ended. Students should recognize that more algae (or other photosynthetic organisms) will increase the flux of carbon dioxide and fixed carbon in the various spheres of the planet. Students may link this to phenomena like clearing of rainforests, which significantly reduce the CO_2 consumption potential of the land area. Further, some students may note that more photosynthetic organisms would technically increase flow through the global carbon cycle but other aspects of the system may be limiting, thus reducing the change in the carbon flux.

TAKE ACTION

Depending on available time, **further discussion and consideration of the abundance of photosynthetic species may be useful**. Encourage discussion by asking some of the questions below.

***Ask Questions**:*

How does the number of photosynthetic organisms on the planet (including algae, trees, etc.) relate to the idea of global warming and the greenhouse effect? (answer: CO_2 accumulation in the atmosphere from human activity is thought to be a primary cause for global warming; a sharp increase in photosynthetic activity on the planet could make a substantial impact in reducing or offsetting CO_2 production)

Why is the clearing of rainforests so detrimental to the environment, particularly considering the vast amount of photosynthesis that rainforests do? (answer: rainforests are responsible for a large fraction of CO_2 cycling and oxygen production; reducing rainforest area can directly impact the flux of CO_2 having a negative impact on global CO_2 concentrations)

Are more photosynthetic organisms like algae always a sign of a healthy ecosystem? (answer: no, often times, bodies of water have "algal blooms" that result from a run-off of nitrogen and phosphorous containing chemicals – these blooms can be very detrimental to local ecosystems and can even kill aquatic species)

Explore Even More!

Algae beads are an excellent tool to explore photosynthetic processes. In addition to the experiments above, consider conducting some of the following:

- **"Lights Out"** – Place two tubes of algae beads directly in front of the bulb but cover one with aluminum foil. After 20 – 40 minutes, compare the color of each tube and explain the differences. *What you'll discover:* The aluminum foil will block nearly all light from entering the tube and the algae will conduct respiration – the covered tube will remain yellow while the uncovered tube will turn purple.

- **"The Colors of Light"** – Wrap tubes of algae beads in different colors of cellophane (thin plastic film), including red, green, and blue. Make sure to leave one uncovered. Place all of the tubes near the light source for about 20 – 40 minutes, then record your observations. *What you'll discover:* The cellophane will filter the incoming light, only allowing certain wavelengths of light to reach the algae. You'll find that photosynthesis occurs most rapidly with the blue and red filters, while more slowly with green. This is because chlorophyll absorbs primarily blue and red light and reflects green light (thus making algae green!).

- **"It's Alive!"** – When you're ready to dispose of your algae beads, conduct a final experiment to demonstrate that the photosynthesis and respiration processes are active only in living organisms. Remove the algae beads from the indicator solution using a scoop. Then, find a convenient way to kill the algae – try soaking them in alcohol (e.g., ethyl alcohol, isopropanol), heating them (e.g., on a hotplate), or exposing them to disinfectants (e.g., bleach). After treating the algae beads, place them back in the indicator and repeat the "Lights Out" experiment, record your observations. *What you'll discover:* Killing the algae inside the beads will stop the photosynthesis and respiration processes. Because of this, you should see very little color change.

Alignment to NGSS Metrics

This lab was designed with the Next Generation Science Standards* as its basis. These standards outline an extensive program for science education that is relevant for a wide variety of educators. While not all schools will be required to meet these standards, they enable focused and productive teaching that trains students to think and act like professional scientists and engineers.

Key Performance Expectations

MS-LS1-6: Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.

HS-LS2-5: Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.

Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions	LS1.C: Organization for Matter and Energy Flow in Organisms	Energy and Matter
Engagement in Argument from Evidence	PS3.D: Energy in Chemical Processes and Everyday Life	Systems and System Models
Connections to Nature of Science: Scientific Knowledge is Based on Empirical Evidence	LS2.B: Cycles of Matter and Energy Transfer in Ecosystems	

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