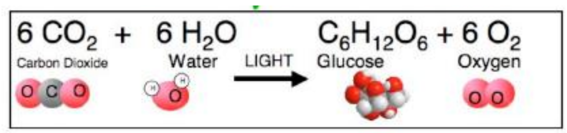
Sugar Makers

<u>Principle of Plant Biology #1</u>

Plants contain the same biological processes and biochemistry as microbes and animals. However, plants are unique in that they have the ability to use energy from sunlight along with other chemical elements for growth. This process of photosynthesis provides the world's supply of food and energy.

Plants have the amazing ability to convert solar energy into the chemical energy of sugar. They do this through a set of chemical reactions called photosynthesis. The energy of photosynthesis drives our planet. Plants are the primary producers of food within ecosystems and the foundation of the food chain. Therefore, when you eat, you're using the energy from photosynthesis to run your body. Most of our machines also run on "plant power." For example, when you ride in a gas-powered car, you're using energy from photosynthesis which took place millions of years ago (plants were buried and cooked in the Earth to form oil).

Photosynthesis occurs in chloroplasts, small organelles in plant cells that contain the light-absorbing chemical chlorophyll. Photosynthesis requires light, water, and also carbon dioxide (CO_2), which provides the carbon atoms that make up the product – glucose.



Plants link glucose molecules together as starch for long-term storage. Starch stores a lot of energy and is a very important source of energy for humans and other animals. Seeds, grains and potatoes contain a lot of starch, which is a carbohydrate. Athletes often "carbo-load" before a race by eating lots of starchy foods, whereas people who want to lose weight sometimes go on "low-carb" diets.

In this activity you will investigate the photosynthetic activity of leaves by examining them for starch accumulation. Starch is colorless, but it is stained dark blue by the stain potassium iodine.

Real-world Connection:
Energy harnessed by photosynthesis powers ecosystems, machines, and even our own bodies.

Activity: Investigating Photosynthesis

Setting up the experiment:

1. Your instructor will provide you with a plant that has been stored in the dark for 24 to 48 hours. During this time, the plant used up its starch reserves (why?).

2. Cover one half of a leaf with dark paper or foil – cover both the front and back of the leaf, using paper clips to attach the cover to the leaf. Illuminate the leaf with a bright light or the sun for several hours to up to four days.

Decolorizing and staining the leaves:

To examine the starch accumulation in your experimentally treated leaves, you first need to remove the green chlorophyll from them.

3. Carefully remove the treated leaf from the plant and place it into a beaker of boiling water for one minute. This step disrupts the cell membranes and makes the staining steps easier.

4. Use tweezers or tongs to transfer the leaf to a beaker containing hot ethanol. Leave it in hot ethanol for three or more minutes. CAUTION – do not use ethanol near a flame!

5. Carefully transfer the leaf to a bowl of cold water – the leaf will be very fragile at this point, so be gentle with it.

6. Drop iodine solution onto the leaf – make sure to cover the whole leaf. Record your observations – do you see any difference in starch accumulation in the light and dark-treated portions of the leaf? What do your results tell you? Is light needed for photosynthesis to occur?

Optional activity – starch in foods:

This can be done before or during the starch staining of leaves. Cover a table with newspaper and then a piece of plastic wrap, followed by white paper as a background. Select a few food items that you think will contain a lot of starch, and some that you do not expect to have starch. Place small pieces of these foods onto the paper, and then place a few drops of the iodine solution onto them. Record your observations – which foods reacted most strongly with the iodine by turning black or bluish-purple? Are these the foods you expected to be rich in carbohydrates?

Student-Designed Experiments

Using the methods you learned in the activity above and the "Guide for Student Experimentation" below, design and carry out your own inquiry. Question topics you might consider include the role of light, chlorophyll, or carbon dioxide in the formation of starch.

- *Light requirements for photosynthesis* - You can use colored plastic films rather than dark paper or foil to block only some light colors from reaching the leaf. Do you think all colors of light support photosynthesis equally? Why or why not?
- *Chlorophyll requirement for photosynthesis* - You can examine starch production in variegated leaves – leaves that have both green and white patches (i.e. spider plant, coleus and geranium). The white patches in the leaves do not have chlorophyll. How do you expect starch accumulation to compare in white versus green parts of the leaf?
- *CO_2 requirement for photosynthesis* – Room air is about 0.03% CO_2 (by contrast, air is about 21% O_2!). You can artificially raise or lower this amount to determine how the CO_2 concentration affects photosynthesis. You will need to place your plant or leaf in a sealed chamber while you expose it to light – you can put a small plant under a large beaker, or use a detached leaf instead. Increase the concentration of CO_2 by placing a leaf or a plant in a closed environment containing dry ice (solid CO_2), carbonated liquid (soda) or a solution of 5% sodium bicarbonate (baking soda). Or, you can fill balloons with your own exhaled breath (about 4% CO_2), and release this enriched air into the plant's environment. To decrease the amount of CO_2 in the plant's environment, you can place a beaker containing sodium hydroxide pellets into your sealed environment (caution – do not touch sodium hydroxide pellets with bare skin!). Be sure to do proper controls for these experiments!

Guide for Student Experimentation

Guidelines for Achieving Great Experiments

1. Ask a very specific, testable question.
2. Test a control for comparison (a group that does not receive the experimental treatment).
3. Use a sample size large enough to allow firm conclusions.
4. To understand a whole population, obtain a random sample of that population to avoid bias.
5. Replicate each part of the experiment (at least 3 times).
6. Hold all variables constant between trials except the variable being tested.
7. Collect quantitative data whenever possible.
8. Measure using metric units.
9. Gather data carefully and accurately.
10. Be objective and honest.

Introduction

Question:

Hypothesis:

Materials and Methods

Independent variable:

Dependent variable:

Experimental constants:

Control:

Protocol:

Results

Data collected:

Other observations:

Graph(s):

Discussion

Interpretation of data:

Conclusions:

Teacher's Guide to "Sugar Makers"

Links to National Science Education Standards

Grades 5-8:
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry
- Structure and function of living systems
- Diversity and adaptations of organisms
- Science and technology in society

Grades 9-12:
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry
- The cell
- Matter, energy, and organization in living systems
- Science and technology in local, national, and global challenges

Materials

Per Group:
- Small pieces of foil or black paper. Students can cut them into interesting shapes if they like.
- Paper clips to attach covers to leaves
- Potted plants. Geraniums work well and are inexpensive at garden centers, or students can bring in leaves of their choice.

For Class Use:
- I_2KI (Iodine potassium iodide) stain, also known as Lugol's stain. Available from laboratory suppliers such as Carolina Biological for less than $10 per 500 ml.
- Hot plates
- Ethanol
- Beakers
- Tweezers or tongs

Teaching hints

1. **Leaves can be hole-punched:** Students can use a hole-punch to remove small pieces from the dark and light-exposed leaves rather than staining the entire leaf. If you don't have access to potted plants, students can also examine starch accumulation in freshly detached leaves, provided the leaves are kept moist and alive through the experiment. If possible, place the cut end of the petiole (leaf stem) into water during the experiment.

2. **Leaves can stay in petri dishes:** If you put the leaf into a Petri dish or small watch glass, you can add the hot boiling water, pour it off, pour on the hot ethanol, pour that off, and then pour on the iodine solution so that you don't have to move the leaf.

3. **Leaves can remain green**: The leaf doesn't have to de-green in the ethanol for the iodine reaction to take place. The ethanol treatment helps the iodine solution penetrate into the cells.

4. **Examine results immediately:** After the leaves dry they will shrink and become brittle, so have the students examine their results while the leaves are still wet.

5. **Printing pictures:** Students can set up an interesting demonstration of starch accumulation by printing a picture on the

leaf. See the Web Resources below for suggestions of how to do this.

6. **Safety considerations:** Ethanol is flammable. Do NOT use ethanol around a flame.

7. **Successful student-designed experiments**:
    - Emphasize the "Guidelines for Achieving Great Experiments."
    - Before students design experiments, tell them how much time they will have.
    - Allow students to present their experiments and lead a short discussion about each one. Encourage other students to ask questions.

Web Resources

Photosynthetic Pictures Are Worth More Than a Thousand Words. C.F. Morisita.
www.accessexcellence.org/AE/AEC/AEF/1996/morishita_pictures.php

Geranium Leaves as Film? Bending Nature to Your Will.
www.cheapshooter.com/2008/08/20/geranium-leaves-as-film-bending-nature-to-your-will/

Experiment to Show the Factors Required in Photosynthesis.
www.biotopics.co.uk/plants/psfac2.html

References

Hangarter, R.P. and Gest, H. 2004. Pictorial demonstrations of photosynthesis. Photosyn. Research 80: 421–425.

Acknowledgements

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