Leaves: All-Natural Solar Collectors

SPN LESSON #17

TEACHER INFORMATION

LEARNING OUTCOME

After handling leaves and determining leaf surface areas, students are able to make good inferences having to do with leaf form and function. Many of these inferences can then be applied to the functioning of photovoltaic panels.

LESSON OVERVIEW

During this lesson, students closely examine tree leaves and identify adaptations present for collecting light energy. First, students outline five different leaves on graph paper. Then they count the number of squares each leaf covers. This procedure provides students with a numerical representation of relative surface area. These figures are compared and students are asked to describe other adaptations that enhance the amount of energy capture/photosynthesis a leaf/plant can carry out. Students relate how various environmental factors have influenced the evolution of plant leaf adaptations. Students begin to consider leaf form and function.

Students are asked to transfer what they have learned about how leaves collect light energy and convert it to chemical energy to how the school's solar panel collects light energy and converts it to electrical energy.

GRADE-LEVEL APPROPRIATENESS

This Level II Living Environment lesson is intended for use with students in grades 5–8.

MATERIALS

Each student or team of two students requires:

- 5 leaves from different tree species
- graph paper
- pencil
- calculator
- tree identification guides

SAFETY

- Some leaves are poisonous. Do not use these for this activity.
- Caution students not to eat the leaves or any other materials used in a laboratory investigation.

TEACHING THE LESSON

Before class:

- Run off enough copies of the student handout so that everyone has a copy of the activity and two or three sheets of graph paper.
- Collect a large supply of leaves directly from a variety of tree species. You can do this yourself or ask students to bring leaves in a day or two before you plan to start the activity. The leaves can be placed in large plastic bags and kept in a refrigerator for several days or left at room temperature overnight.
- On the day of the lesson, tape leaves to the wall, tack some to the bulletin board, and tape some to the chalkboard. Also pile up leaves on a desk or the front demonstration table.

During class, before starting the activity:

1. Ask students the following questions about the leaves:
   - How are the leaves scattered around the room alike? (Record student responses on an overhead transparency or chart paper.)
   - How are the leaves different? (Again record student responses.)
   - What is the function of leaves? (Ask this question even if students have already responded that one way all leaves are alike is that they carry out photosynthesis or make food. The emphasis here is on *function*. Students may say that leaves are involved in gas exchange and are also important in regulating water loss. This is true, but it is not the focus of the activity.)
   - What raw materials are necessary for the leaf to carry out photosynthesis? (Depending on earlier science experiences, students may respond that plants need carbon dioxide, water, and sunlight.)
   - What do plants use the sunlight for? (Guide students to the conclusion that light provides the plants with energy needed for life processes and that it is through photosynthesis that light energy is captured and converted into chemical energy the plant can utilize.)
   - What is present in a leaf that allows the plant to trap light energy and convert it to chemical energy? (If students do not know the answer, explain that the green pigment chlorophyll is necessary.)
2. Hold up two different leaves—one large and one small—and ask students, “Do you think these two leaves carry out the same amount of photosynthesis? Why?” (Students will say, “No, because one is bigger. The bigger one has a larger surface and can trap more light energy.”)
3. Hold up two different leaves that are similar in size and ask the same question. (Students will speculate but suggest to them that there is a more precise way to compare the sizes.) Now they are ready to begin the activity. Note: If students are using compound leaves for one or more of their outlines, point out that they should determine the surface area of the entire leaf and not just one of the leaflets. Show them that leaflets do not have buds, but leaves do.

During class, after completing the activity:

1. Ask students:
   - Did any of the long, narrow leaves you measured have a surface area similar to one of the short, wide leaves? (Answers will vary.) If all students respond "no," ask how it would be possible for two such leaves to have the same surface area.
   - How is it possible for a tree with leaves that have a small surface area to carry out enough photosynthesis for the tree to stay alive? (The tree may be smaller and not require as much energy or it may have many more leaves. The arrangement of the leaves might also figure in.)
   - How can your observations about leaves be used in the design and operation of solar panels? (Students should mention that it is important to consider characteristics common to both leaves and the solar panel such as surface area, shape, availability of light, and so on.)

ACCEPTABLE RESPONSES FOR DEVELOP YOUR UNDERSTANDING SECTION

Table 1: Leaf Surface Area Data

Type of leaf (maple, spruce, etc.)	Number of *x*-ed squares
1. *Answers will vary depending on the types of leaves available.*	*Answers will vary depending on the types of leaves available.*
2.	
3.	
4.	
5.	

Activity Analysis

1. Make a list of the leaves that possess a) the greatest surface area; b) the least surface area.

   Answers will vary. Generally, oak and maple leaves will be large while willow or poplar and pine will be small.

2. All of the leaves you outlined came from very large trees. It doesn't seem that a tree with small leaves could possess enough leaf surface area to capture an adequate amount of light energy to keep the tree alive. Describe at least two leaf adaptations these trees have evolved that permit them to meet their energy requirements.

   Answers may include but are not limited to the following:
   - *A tree with small leaves may have many more leaves on it than a tree with large leaves.*
   - *Small leaves may be arranged in a way that permits each leaf to receive more sunlight than those on trees with large leaves.*

3. Many plants growing in the lower levels of a dense tropical rain forest produce leaves that are extremely large, while the leaves on desert plants are usually very small. Describe how water and the availability of sunlight have influenced the evolution of leaf size in these two regions.

   Leaves growing in the lower levels of a tropical rain forest do not receive much sunlight. To compensate for this, the leaves grow very large. The large size allows for more surface area to capture available light. Also, since water is not in short supply, the leaves can be large. Large leaves lose more water through evaporation (transpiration) than small leaves. In the desert, there is an abundance of sunlight. The leaves are small, but a small surface area is all that is needed to capture enough sunlight to keep the plant alive. The small leaf size in the desert also helps prevent the loss of water from the plant.

4. Explain how the photovoltaic panel on the roof of your school is like a plant leaf. In your answer be sure to:
   - explain the importance of sunlight to the functioning of both

     Sunlight is important because it is the source of energy for both the panel and plants.
   - list the basic energy conversions that take place in each

     Light energy is converted into chemical energy through the process of photosynthesis in plants and into electrical energy by the panel.
   - describe how your school could use what you have learned about plant adaptations for energy capture to design a photovoltaic system that would produce more electricity and make it available for around-the-clock use.

     By adding more panels, the school could increase the surface area available for capturing light energy. The school could also position the panels in different arrangements. Plants do this by having more leaves present or by arranging the leaves in ways that make it possible for them to capture more light. There could also be a storage system that would provide a way to store electrical energy when there is an excess and make it available when there is not enough to meet the needs of the school. Plants do something similar to this by converting excess sugar into starch and storing it in the roots until needed.

5. The leaves of some plants actually move as the day progresses in a way that allows their wide surfaces to face the Sun all the time. Solar panels are sometimes set up to have motors move them to keep the surface facing the Sun all day. Before building a large-scale system that would be capable of "moving with the Sun," you would need to see if a prototype system would be cost-effective. State what information you would need from the prototype system to determine if this energy-efficient idea would be worth applying on a large scale.

   You would have to know how the amount of energy needed to operate the motors would compare to the additional amount of energy gained as a result of moving the panels during the day. In addition, you would need to know if the additional cost of building movable panels and motors would be offset by the additional energy produced.

ADDITIONAL SUPPORT FOR TEACHERS

BACKGROUND INFORMATION

Leaves come in a multitude of shapes and sizes. Some are very small. A duckweed leaf is only as big as the letter *o*. The leaf of the royal water lily is about the size of a door. The leaves on some tropical plants are as long as a three-story building is tall.

Leaves grow out of meristematic tissue in the stem of a plant. The region of the stem where a leaf is attached is the node and the regions in between the nodes are the internodes. Dicot leaves are usually composed of two parts, the blade and the petiole. The blade is the flattened portion of the leaf and allows for maximum exposure of the leaf surface to light. Some blades are as thick as a pencil while others are paper-thin. The petiole is the stem-like structure that attaches the blade to the plant stem or branch. There is always a bud at the base of each petiole. Monocot leaves typically consist of a blade surrounded by a sheath.

A leaf with a petiole attached to a single blade is referred to as a simple leaf. Common examples are maple, oak, and willow. Some leaves have many small blades, or leaflets, attached to one petiole. The entire structure, because it came from a single bud, is called a compound leaf. Common examples are ash, horse chestnut, and sumac. You can tell the difference between a group of simple leaves and a single compound leaf by looking for the buds. Compound leaves have a bud located at the base of its single petiole.

How the leaves are arranged on a stem differs widely. Some commonly observed arrangement patterns include leaves being positioned on the stem or branch a) directly opposite each other; b) alternately on opposite sides; c) in a spiral pattern; and d) in clusters. No matter how they are arranged, the leaves overlap very little. By not overlapping, each leaf is able to receive the most possible sunlight. Notice the shape of a tree. The leafy top of a tree is much narrower than the bottom.

REFERENCES FOR BACKGROUND INFORMATION

Field Guide to North American Trees (National Audubon Society). Alfred A. Knopf, Inc., New York, 1995.

Miller, Kenneth and Joseph Levine. *Biology.* Pearson Education, Inc., Upper Saddle River, NJ, 2003.

National Science Education Standards. National Academy Press, Washington, DC, 1996.

Petrides, George A. *A Field Guide to Trees and Shrubs* (The Peterson Field Guide Series). Houghton Mifflin Company, Boston, 1972.

Strauss, Eric and Marylin Lisowski. *Biology: The Web of Life.* Addison Wesley Longman, Inc., Menlo Park, CA, 1998.

Wright, Richard T. and Bernard J. Nebel. *Environmental Science: Toward a Sustainable Future.* Pearson Education, Inc., Upper Saddle River, NJ, 2002.

EXTENDED ACTIVITIES

Modeling

Provide teams of students with three or four solar cells, a ring stand, clamps, wire, a milliammeter, and a light source. Explain to the students that the ring stand represents a tree branch and the solar cells represent leaves on that branch. Next, have students examine several tree branches with the leaves still attached. They should record various leaf arrangement patterns either in writing or by making a series of sketches. To test the efficiency of the different arrangements, students should use the clamps to attach the solar cells to the ring stand in a pattern similar to the first one they recorded. Common patterns include leaves being positioned a) directly opposite each other; b) alternately on opposite sides of the branch; (c) in a spiral pattern; and d) in clusters at the ends of branches. Once in place, the cells should be wired together and connected to the milliammeter. Students should then turn on the light and shine it on the cells from a predetermined distance and position. Once the amount of electricity being produced is recorded, students should simulate the movement of the Sun during the course of a day. Have them record morning, noon, and evening readings. This process should be repeated for at least three different leaf arrangement patterns.

Using Computer Technology

If digital imaging software is available, have students make scans of the different leaves used in this activity. Use the imaging software to record actual surface areas and compare these figures to the relative surface areas made through drawing an outline of the leaf and *x*-ing in the outline of graph paper.

Observing

- Ask students to bring in 10 different kinds of tree leaves. These should then be pressed and mounted on individual sheets of paper. Using field guides, students should identify the species (maple, oak, etc.) of the tree the leaf came from. Each sheet should then be labeled with a) the name of the tree; b) the date the leaf was collected; and c) a description of the habitat where the tree is growing.
- Have each student develop a dichotomous key for his/her leaf collection. To see if the key is accurate, one other student should try the key and see if they are able to successfully identify two or three of the leaves in the collection.

Research

Assign students different biomes or habitats. Ask them to research special adaptations the leaves of plants growing in these regions possess. You might tell the students to look for information about size, the presence of drip spouts, stomata, guard cells, cuticle thickness, and so on. The depth of detail depends on how much time you want them to spend on the task. Students should describe how these adaptations enable the plant to live successfully in the region where they flourish.

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(STUDENT HANDOUT SECTION FOLLOWS)

Name____

Date ____

Leaves: All-Natural Solar Collectors

Introduction

Leaves are the organs of a plant that trap the Sun's energy to make sugar. It is during the process of photosynthesis that leaf pigments, primarily two kinds of chlorophyll, trap light energy and convert it to the chemical energy in sugar molecules. Generally speaking, the process of photosynthesis uses light to combine carbon dioxide with water to produce sugar and release oxygen. Some of the trapped energy is stored in glucose (sugar) molecules and released later during respiration.

The diagram below (Figure 1) shows how a plant uses glucose. Some of the glucose releases energy that is used for various life processes. The plant also uses glucose in the synthesis of other types of compounds such as fats, proteins, and nucleic acids. Extra glucose may be combined to form large molecules of starch and stored in the roots. The starch molecules are broken down into sugar and used when the plant requires more energy than what is available through photosynthesis at the time.

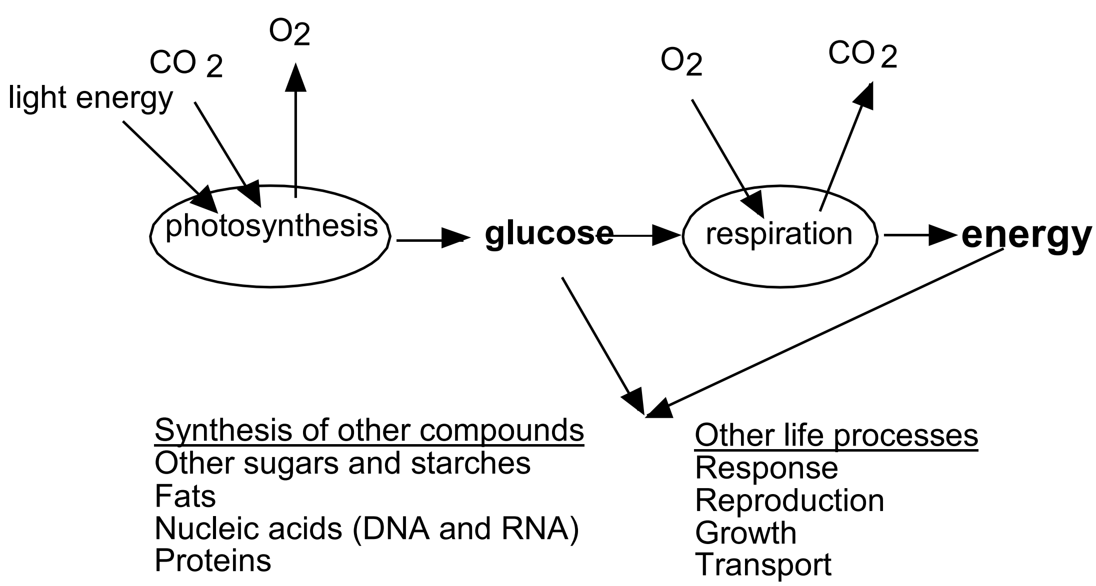

Figure 1: Use of glucose in a plant

Although all leaves have the same function, they vary widely in shape and size. Some trees have needlelike leaves (pines, spruces, and cacti), while others have broad leaves (maples, oaks, and catalpa). How can short, wide leaves (long, narrow leaves; all shapes and sizes in between) satisfy the energy requirements of a very large tree?

DEVELOP YOUR UNDERSTANDING

Materials

- 5 leaves from different tree species
- graph paper
- pencil
- calculator
- tree identification guides

Procedures

1. Collect four or five leaves from different tree species such as willow, maple, oak, poplar, pine, or spruce.

2. Lay each leaf on a piece of graph paper and trace around it.

3. Identify each leaf and label the outline with the correct name. Also place the name in the appropriate place on Table 1: Leaf Surface Area Data.

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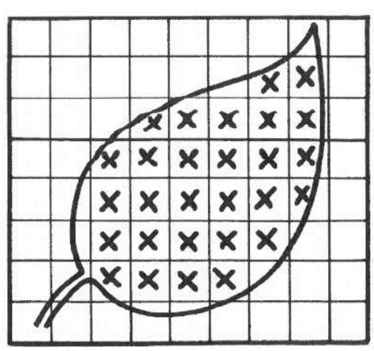
Type of leaf (maple, spruce, etc.)	Number of *x*-ed squares
1.	
2.	
3.	
4.	
5.	

4. Using a pencil, place a small *x* in each square of the graph grid that is inside the outline for leaf #1. See Figure 2: Leaf Grid.



5. Count the number of squares and record that number beside your leaf outline and in the appropriate place on Table 1. When only partial squares are enclosed by the outline, count those that fill half of a square or more. However you make your estimate of which squares to count and which to exclude, be consistent from one leaf to the next.

6. Repeat steps 4 and 5 for each of the leaves you outlined.

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