Leaf Orientation

Grade Level: Middle School, High School
Ecological Concepts: **Adaptation**
Arizona Science Standards: Science as Inquiry; Life Science

Materials:
1) Heavy white paper
2) Scissors
3) Magnifying lenses/loupes*
4) Writing/drawing materials
5) Measuring cups*
6) Plastic wrap
7) Rulers
8) Water
*May be borrowed from SCENE.

BACKGROUND
This activity would fit well with a unit on plants, how they grow and produce food through photosynthesis. Provide as much of this information as is needed for the students to have a beginning grasp on the subject of photosynthesis.

Plants have green structures called leaves whose primary purpose is to collect the energy of sunlight and transform it through a chemical process called**photosynthesis** into food for the plant. Leaves come in many shapes, sizes, colors and textures. Sometimes they do not even look like what we think of as typical leaves; for example, cactus spines are a form of leaf.

Water is necessary for photosynthesis and food transport throughout the plant. Plants wilt and will eventually die if they do not have enough water. Where does the water go that a plant takes up through its roots? Is it all incorporated into the plant's physical structure? On a typical plant, leaves are the part with the most area exposed to the air. Leaves have microscopic **stomates** to release water as vapor during photosynthesis. Carbon dioxide, a gas, is needed for photosynthesis. Carbon dioxide is taken into the leaf through the stomates. Just as we use water in our cells to survive, plants do too. We inhale oxygen and exhale water vapor in our breath as a by-product, while plants take in carbon dioxide and release water through the stomates. (**See Energy Flow for more details**.) This creates a problem for plants in dry environments: how to conserve water.

Desert plants have adapted to environmental conditions of low water availability and high temperatures in a variety of ways, on the **macroscopic** as well as microscopic scale. Some characteristics are having a waxy **cuticle**, stomates on the under leaf surface, opening of stomates only at night, and a thick layer of**mesophyll** cells, among others.

Leaves are not all at the same angle to the sun. Some are horizontal, some vertical, some in between. Also, on some plant species, the leaf orientation changes throughout the day. Orientation to the sun is another adaptation to desert heat. Plants can tolerate only so much heat before the tissues burn. By not exposing most of the leaf to the direct rays of the sun, heat exposure is reduced.

GUIDED INQUIRY
Observation/Exploration Period: Observe the various types of plants in the habitat using eyes, magnifying lenses, flashlights, brushes, fingers, etc. Focus on leaves, but other plant structures can be observed as well. Have students categorize findings (for example, according to leaf characteristics—plants with spines, thin leaves, oval leaves, etc., or use another scheme) as they see fit.

Group Discussion and Question Period: Guide students to look for patterns among and between different types of plants, focusing on leaves in terms of orientation to the sun, size, shape, color, texture, and other characteristics they may have noticed. What happens when a plant is in the sun all day? What happens if a plant doesn't receive any water? Are all plant leaves on a plant at the same angle to the sun? Which leaf orientation would survive the desert heat best? At what angles are leaves found?

Important aspects of guided inquiry are encouraging students to generate multiple hypotheses, and letting students make decisions about what data are important and create their own data sheets. Keeping these ideas in mind, the sample in the box below illustrates how ONE OF MANY possible investigations around this topic might develop.

Sample Hypothesis: Let's use the question, "Which leaf orientation would survive the desert heat best?" The hypothesis could be, "Plants with leaves closest to vertical would survive the desert heat best because they are exposed to the least amount of direct sunlight." The hypothesis could be written as, "If leaves get hotter when exposed to direct sunlight, and we expose leaves to sunlight at horizontal, vertical, and 45-degree angles, then the leaves in the vertical position will experience the lowest temperature."

Sample Experiment Design: The **independent variable** is angle of the leaf to the sun. The **dependent variable** is the temperature of each leaf. Cut a leaf shape out of heavy paper like poster board. It needs to be large enough to hold a small thermometer taped to it. Cut fifteen "leaves" of the same size and shape. In a sunny site in the habitat, place five leaves horizontal to the ground, five vertical, and five at a 45-degree angle. Place the thermometer side out of direct sun. Use modeling clay or a similar substance to mount the leaf stems to a solid surface and place the leaf at the proper angle. You are**replicating** by using five leaves for each treatment. This is a **controlled** experiment because all leaves are the same size, shape, and color and placed in the same place in the habitat.

Sample Prediction: The leaves at 90 degrees (vertical) will have the lowest temperature, with the temperatures increasing as the angle goes to 45 degrees, and the 180-degree (horizontal) angle being the hottest.

Record Results: Record the temperatures of each leaf at the same time of day. Take measurements only once if doing this experiment for only one day. Take temperatures the same time each day if tracking changes over time.

Sample Analysis of Data and Presentation: Since you have five replicates of each leaf angle, you can **average** the temperatures of the five leaves to obtain a single **mean** number for temperature per angle. These mean numbers are the ones to put on the graph.

Discussion: Was your hypothesis supported? If yes, go on to test other hypotheses. If not, why not? What did happen? Why? This is a great opportunity to revise your hypothesis and do another test.

MORE:
(1) Middle School:
(a) Find the **mean**, **median**, **mode**, and **range** of the data.
(b) Make leaves out of paper as before. Place leaf stems in modeling clay so that five leaves are vertical and five are at a 45-degree angle. Place the leaf stems in containers with 250 ml of water. Cover the containers (not the leaves) with plastic wrap. Place all containers in the same place in the habitat. After several hours measure how much water is left in the containers. Less water in the container indicates a higher level of transpiration (water loss) from the leaf. At which angle do the leaves lose more water? (See **Plant Adaptation** activity for more information.) Note that you must leave a portion of the "stem" sticking out from under the modeling clay so that the "leaf" can absorb water.

(2) High School:

(a) Calculate the **variance** and **standard deviation** of the averaged data.
(b) Perform a **T-test** on temperatures. (T-test is a standard statistics test comparing **means** of two treatment groups). Perform an **ANOVA** when comparing three or more treatment groups.
(c) Plants reduce heat exposure through self-shading. Examine a plant with an open architecture. "Open architecture" means a plant with branches and leaves that are widely spaced with few touching. Determine the positions of a random sample of five leaves to the leaves around it. On a clear day when the sun is directly overhead, measure the amount of shade leaves give each other. Do this by measuring the leaf surface area of the leaves being shaded by your five randomly chosen leaves.

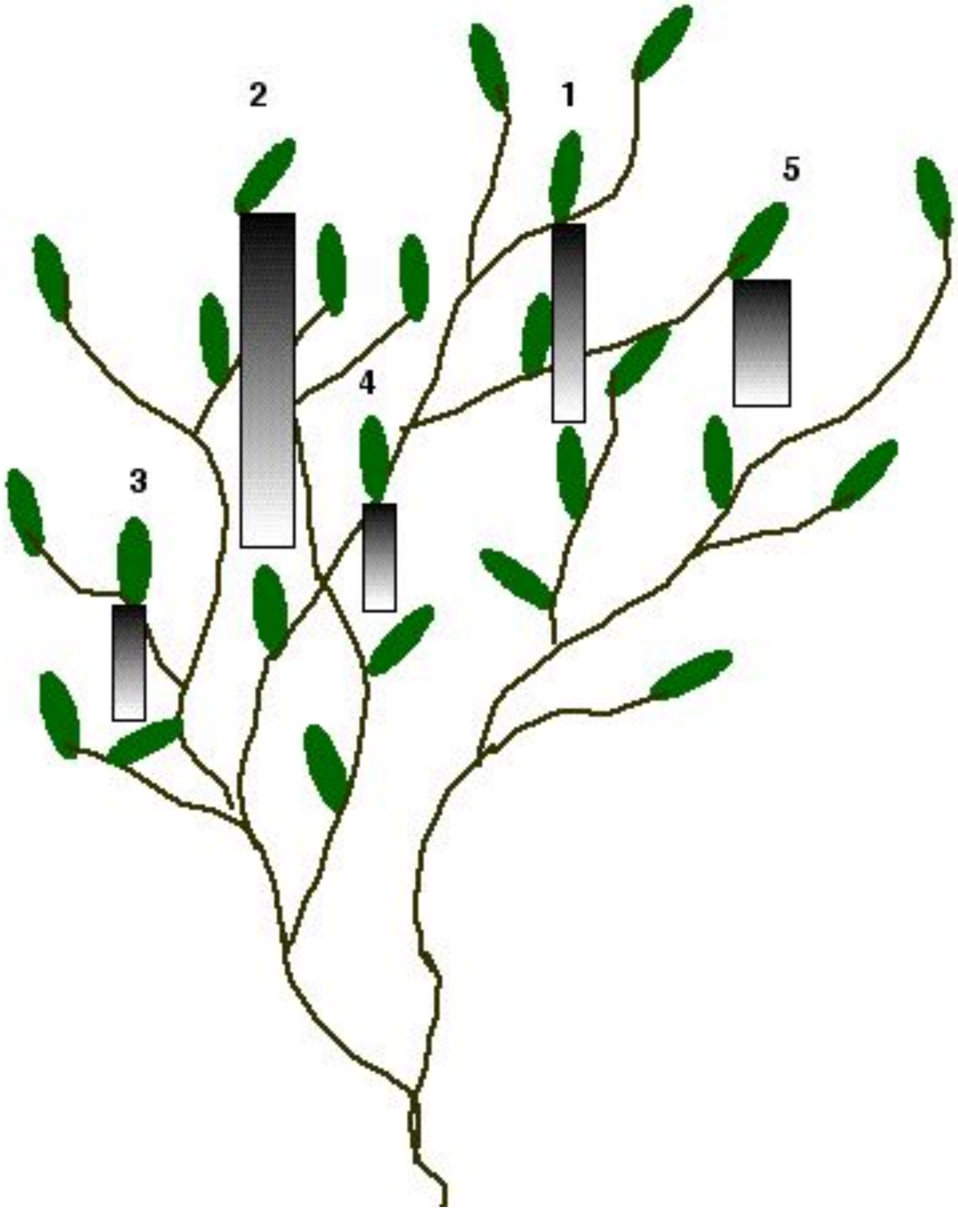

Figure 1. The numbers 1-5 label the 5 randomly chosen leaves. The grayish bars indicate the path of shading caused by the leaf when the sun is directly overhead. This path will change with the angle of the sun throughout the day.