# Plant Adaptation to the Desert

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

**Materials**:
1) Heavy white paper
2) Scissors
3) Magnifying lenses/loupe*
4) Writing/drawing materials
5) Measuring cup*
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.

**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 size, shape, color, texture, and other characteristics they may have noticed. Discuss what they think happens when a plant is in the sun all day. What happens if a plant doesn't receive any water? Do plant leaves have different shapes, colors, etc? Does leaf color affect water use? Which leaf size would survive the desert heat best?

**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, "Do desert plants conserve water by having narrow leaves?" The hypothesis could be, "Plants with narrow leaves will lose less water than plants with broad leaves because narrow leaves expose less area to the air." Or it could be written as, "If plants lose water through leaves and we expose narrow and broad leaves to the sun, then the narrow leaves will lose less water than the broad leaves."

**Sample Experiment Design**: The **independent variable** is shape. The **dependent variable** is amount of water absorbed and then lost by the leaf through evaporation. Using heavy paper, cut out leaves in two different shapes, narrow and broad. Keep the total leaf area the same, changing only the shape. Each leaf needs an equal length stem, which is a continuation of the paper leaf. Make five copies of each leaf shape for **replication**. By keeping the leaf area and stem lengths the same you are **controlling** for these factors.

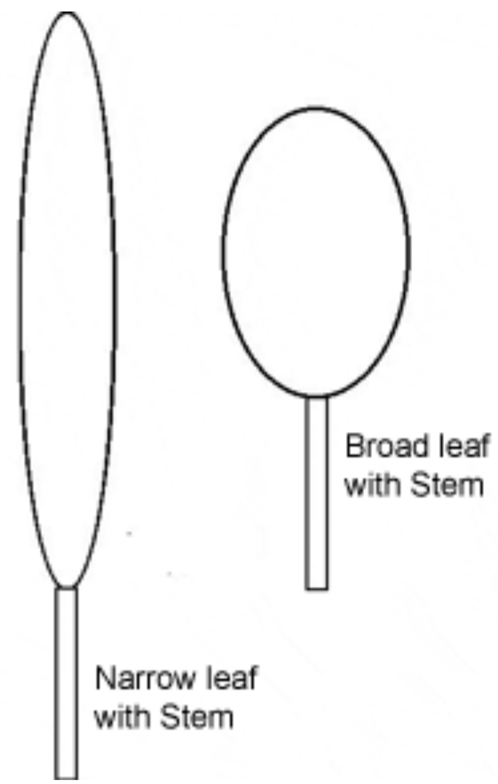


**Figure 1**. Leaf patterns. Each leaf is constructed from a single piece of paper. The area (length x width) of each leaf is the same. (For those conversant with areas of ovals, circles and the use of calculus, the areas may be a little less than exactly the same. Good math exercise!)

Place each leaf stem in a separate container with 500 ml of water. Cover each container with plastic wrap to reduce surface evaporation. Do not cover the leaves, just the top of the container itself. Place all containers in the same location in the habitat. After a set time (one hour, for example), come back and see which leaf shape has used the most water by measuring the water gone (evaporated) from the container. By keeping all variables the same except leaf size, you are conducting a **controlled** experiment.

NOTE: This experiment uses artificial materials to model an actual adaptation common in desert plants: narrow leaves that reduce water loss. Theoretically, it is possible to conduct an experiment to measure water loss from the leaves of living plants in a natural setting, but the protocol would be very difficult for students to implement and the equipment required would normally only be available in professional research labs.

**Sample Prediction**: Narrow leaves will lose less water than broad ones.

**Record Results**: Calculate how much water was lost for each individual leaf by subtracting the amount of water left in the container from the beginning amount. Measurements can be taken at different time points or just once.

**Sample Analysis of Data and Presentation**: Depending on mathematical level, you can calculate the **evapotransipration** rate per leaf area. The equation would be: $\frac{\text{Water lost (ml)}}{\text{Leaf area (mm}^2\text{)}}$.

Make a **bar graph** with leaf shape listed on the horizontal axis and amount of water lost on the vertical axis. For students who can divide, calculate the**average** water loss for each leaf shape. Graph the average number on the vertical axis. If the water loss is tracked over time, make a line graph with time on the x-axis and average water loss in ml on the y-axis.

**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) Elementary**:
**(a)** Simulate a waxy cuticle by making paper leaves as above, but all the same size and shape. Coat half the leaves in paraffin wax and then compare water loss out of the containers. Be careful not to coat the stems or the leaves will be unable to absorb the water.
**(b)** Soak washcloths of the same size in equal amounts of water. Crumple half the cloths tightly and lay the others flat. Place all the cloths in a plastic tray in the sunlight. Record how long it takes for each cloth to become dry. This simulates thick leaves with lots of mesophyll cells, and thin leaves without mesophyll cells and how these compare in water loss over time.
**(c)** See All Levels, below, for more.

**(2) Middle School**:
**(a)** Find the **mean**, **median**, **mode** and **range** of the data.
**(b)** See All Levels, below, for more.

**(3) High School**:
**(a)** Calculate the **variance** and **standard deviation** of the averaged data.
**(b)** Perform a **t-test** on water used from the containers. (T-test is a standard statistics test comparing **means** of two treatment groups.) Perform an **ANOVA**when comparing three or more treatment groups.
**(c)** Dissect leaf surfaces and look at stomates through a microscope. Estimate the number of stomates per leaf area. Compare different plant species.
**(d)** See All Levels, below, for more.

**(4) All Levels**:

**(a)** Look at leaf and stem color. Not all leaves are the same shade of green. Desert plants are quite often a very light green to almost white (e.g., brittlebush). Very light colored leaves are usually that way due to hairs (trichomes) on the leaf surface. Look at leaves through a hand lens, loupe, or dissecting microscope. Trichomes have several functions:

**(1)** to trap tiny herbivorous insects and prevent herbivory;
**(2)** to reduce loss of transpired water to the atmosphere by trapping the moisture close to the leaf surface; and
**(3)** to reduce heat load on the leaf by reflecting light.
**(b)** Compare leaf sizes of desert plants (creosote, brittlebush, ocotillo, hackberry, etc.) to each other and to non-desert plants (such as citrus, mulberry, etc.). Microphylly (small leaves) is an adaptation to heat.
**(c)** Design paper or cardboard boxes of various shades of green, similar to those of plants in your habitat. Make the boxes large enough to hold a small thermometer. Make five boxes of each color, plus five white and five black boxes for comparison. Place thermometers in the boxes and place all the boxes in the same area of the habitat so that all boxes receive the same amount of sunlight. Randomly place the boxes so that not all of one color are grouped together. Record the initial temperature for each box as they sit in the habitat. After a set time (fifteen minutes to one hour), check the temperatures.