Thirsty Plants

■ **Grade Level:**
Middle School

■ **Subject Areas:**
Life Science, Mathematics

■ **Duration:**
Preparation time:
Part I: 15 minutes
Part II: 30 minutes

Activity time:
Part I: 20 minutes
Part II: 50 minutes

■ **Setting:**
Classroom and schoolyard

■ **Skills:**
Gathering information (collecting, researching); Organizing (estimating, calculating); Analyzing (comparing); Applying (designing)

■ **Charting the Course**
An understanding of osmosis and diffusion ("Let's Even Things Out"), evaporation ("Water Models"), and adhesion and cohesion ("H2Olympics") supports this activity. This activity relates to concepts in "Irrigation Interpretation."

■ **Vocabulary**
capillary action, xylem, stomata, transpiration, evapotranspiration, xeriscaping

What do the plants in your backyard have to do with the water cycle?

▼ Summary

Through demonstration and field studies, students learn about transpiration and the significant role plants play in the water cycle.

Objectives

Students will:

- explain how plants transport water through transpiration.
- describe the importance of plants in the water cycle.
- recognize that certain plants are appropriate for xeriscaping.

Materials

- *Copies of the student activity sheet,* ***Water Cycle Diagram***
- *Celery stalks or white carnations*
- *Clear container with water colored with red or blue food coloring* (Place celery or carnation in water for several hours, until leaves or petals are colored with the dye.)
- *Paper towel tube*
- *Paper that is cut into a series of connecting circles* (See diagram; the circles are inserted through the paper towel tube. If possible, the width of the circles should equal the diameter of the tube so that the tube holds the paper in place. An alternative is to thread Pop-beads—the kind that lock into each other, used in children's necklaces—through a straw.)
- *Clear plastic bag and twist tie for each group*
- *Balance or scale* (optional)
- *Forceps or tweezers*

Making Connections

Most people are familiar with house plants and gardens and basically understand the need for watering plants to ensure successful growth. Students may have observed that plants wilt because of lack of water. How plants take in and transport water throughout their structure may be less understood. Learning how water moves through plants helps students appreciate the role of vegetation in the water cycle.

Background

Plants require water to live. Plants need water to transport nutrients and minerals necessary for plant metabolism and use water in photosynthesis. Since most photosynthesis takes place in the leaves, and the leaves of a plant can be many meters above ground level, how does water from the soil get to these leaves?

Transpiration (evaporation of water from pores, or stomata, on trunk, stem, and leaf surfaces) aids plants to transport water upward through their tissues. Root pressure, the cohesive and adhesive qualities of water (capillary action), and evaporation all contribute to water's circulation through a plant.

Many plants have a vascular system: narrow tubes or vessels that run the length of the plant's body. Like veins and arteries in humans, these tubes in plants carry nutrients and liquids. The vascular tissue through which water travels up a plant is called xylem. Xylem begins in the roots and ends as stomata in the leaves.

Through the process of osmosis (filtering of water into plant cells), water enters the roots and exerts an upward pressure (root pressure), that prevents it from flowing backward down the xylem. The cohesive and adhesive characteristics of water help support its placement in the tubing. Cohesion is water's attraction to itself—i.e., the formation of hydrogen bonds between water molecules. Adhesion is water's attraction to other materials, such as the inside of the tubing. This process, called capillary action, essentially creates a column of water in the xylem. Since the molecules are attached (or bonded) to each other, a tension is created among the molecules in the column.

However, root pressure and capillary action alone are unable to push water many meters above ground level. Evaporation is likely the main process whereby water is pulled up the tubing.

When water molecules reach the stomata, they are exposed to air and the sun's energy. The exposed molecules receive heat energy from the sun and begin to move faster. This motion makes it easier for the molecules to break away and become water vapor. However, because of capillary action, a tension still exists among water molecules in the xylem. Therefore, as one molecule is drawn away, it pulls on water molecules still bonded to it, bringing those molecules closer to the surface.

Plants can absorb large quantities of water; however, they lose most of this water through transpiration. Transpiration coupled with evaporation of surface water is called evapotranspiration. It plays a crucial role in the water cycle. Evapotranspiration returns water to its gaseous state, in which it can be carried by winds through the atmosphere until it condenses and returns to Earth as precipitation. This process helps purify water and move it around the planet.

The rate of transpiration from plants depends on humidity and the nature of the plants. Water evaporates readily in dry, warm air because room is available for more water. Some plants, such as Rocky Mountain juniper, Russian sage, and golden currant, require little water to survive. Frugal water users such as these have smaller leaves, deeper root systems, thick waxy surfaces, and other qualities that limit water loss. (A method of landscaping, called xeriscaping, entails garden layouts incorporating plants that require little water.) In addition to plant selection, xeriscaping also involves specialized placement of plants, watering techniques, mulching, and monitoring garden drainage patterns. Many communities promote xeriscaping, especially those that experience water shortages.

Plants need water to transport nutrients and minerals for metabolism and photosynthesis.

Procedure

▼ *Warm Up*

Distribute copies of the *Water Cycle Diagram* student activity sheet. Ask students to share what they know of the water cycle and then draw arrows indicating how water moves through the environment represented in the diagram. Note whether or not they included plants.

Show students the celery that has been soaking in blue- or red-dyed water. Ask them to make a list of possible explanations for how the water traveled through the cutting.

▼ *The Activity*

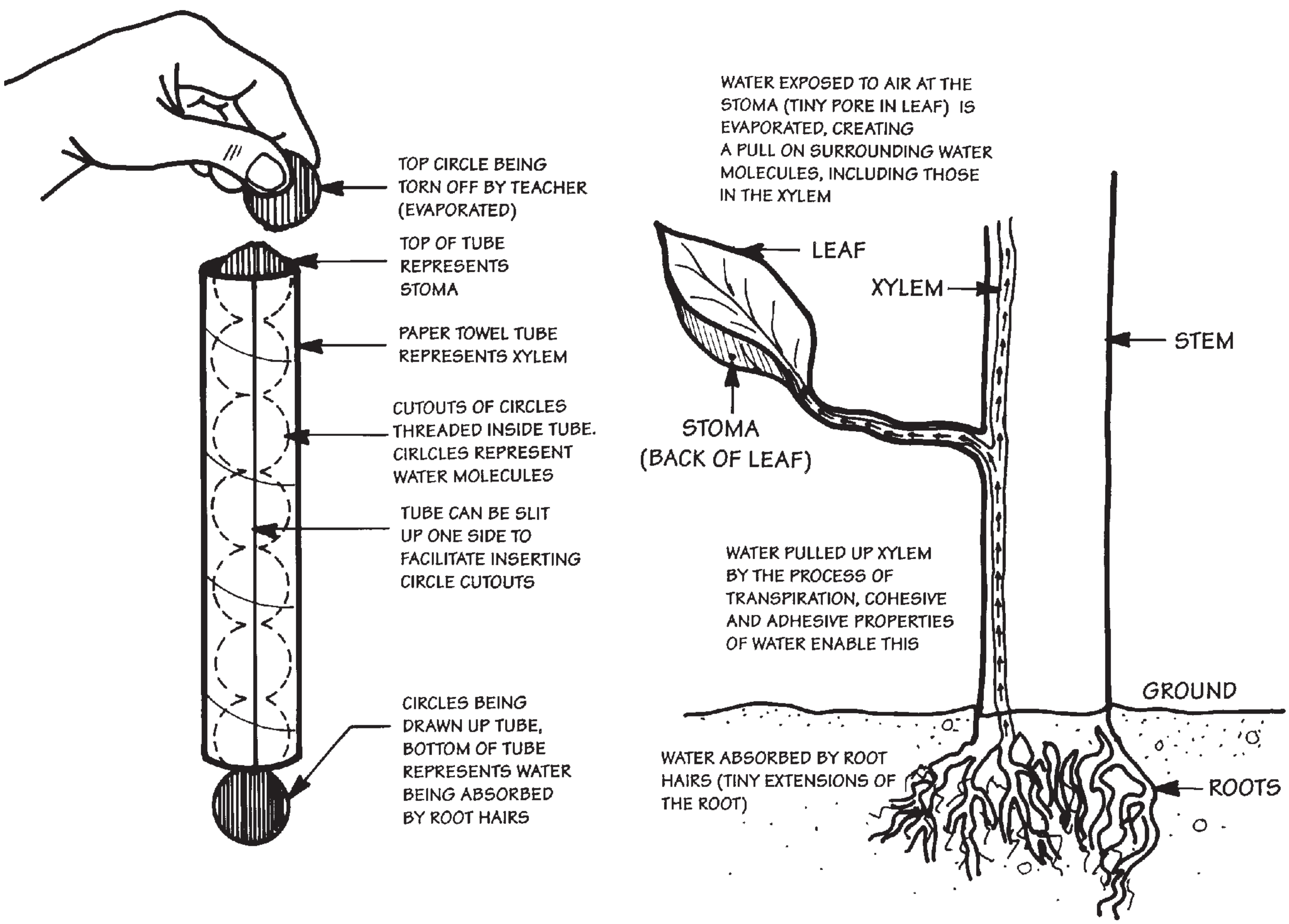
Part I

1. **Ask students to consider a 20-foot-tall tree; how do its leaves get water?** Students may think that plants suck water up to the leaves. Do they think they could draw water up a straw that length?

2. **Show students the paper towel tube with the cut-out circles inserted. See diagram below.** Explain that the tube represents part of the tissue inside a plant (xylem), similar to veins inside our bodies. The paper circles represent water molecules. Explain that in plants, water molecules remain inside the tube because they are attracted to each other and to the sides of the tube.

3. **Point out the water molecule near the top of the tube. Explain that this represents a molecule at a stoma or pore in a leaf. During the day, increased heat energy will cause water to evaporate**. Evaporation occurs when the energy of movement (caused by heat energy) is stronger than the forces holding the molecule to other water molecules.

4. **To show evaporation, pull on the top circle to draw the next circle near the top, then tear off the top**



circle. Explain that this represents a water molecule being evaporated from the leaf (transpiration). When the top molecule leaves the plant, it must break away from surrounding water molecules. This creates a pull on those water molecules, drawing them further up the xylem.

5. **Have students write descriptions of transpiration based on the demonstration, identifying areas where clarification is needed.**

Part II

NOTE: This activity will work best on a sunny day after a rain storm or after an area has been watered.

1. **Divide the class into small groups; give each group an empty plastic bag and have them record its weight**. If the scale is not sensitive enough to weigh one bag, the class can weigh all their bags together, or they can simply describe the appearance of the bag.

2. **Identify trees, shrubs, or small plants located on the school grounds. Assign each group to a plant. (More than one group to a plant also works.)**

3. **Have each group carefully place its bag over part of a limb of its tree or shrub. (Facing the sun works best.) Tie the bag with a twist tie or string. Each group should count and record the number of leaves in its bag.**

4. **Challenge the students to develop a method to estimate the number of leaves on the tree. After the groups have recorded their estimates, ask each group to carefully examine its bag for changes.**

5. **After 30 minutes (it can be longer, but all bags should be removed at the same time), carefully remove the bag from the limb; take it to the class and weigh it.** If leaves or debris are in the bag, remove them with forceps or tweezers before weighing it, trying not to remove any of the moisture. Again, if a scale is not available, students can observe the bags, looking for condensation.

6. **Have each group measure the amount of moisture accumulated in its bag by using the following formula: weight gain = total weight – starting weight.**

7. **Pool the class data and have each group answer the following questions based on the data collected by the class:**

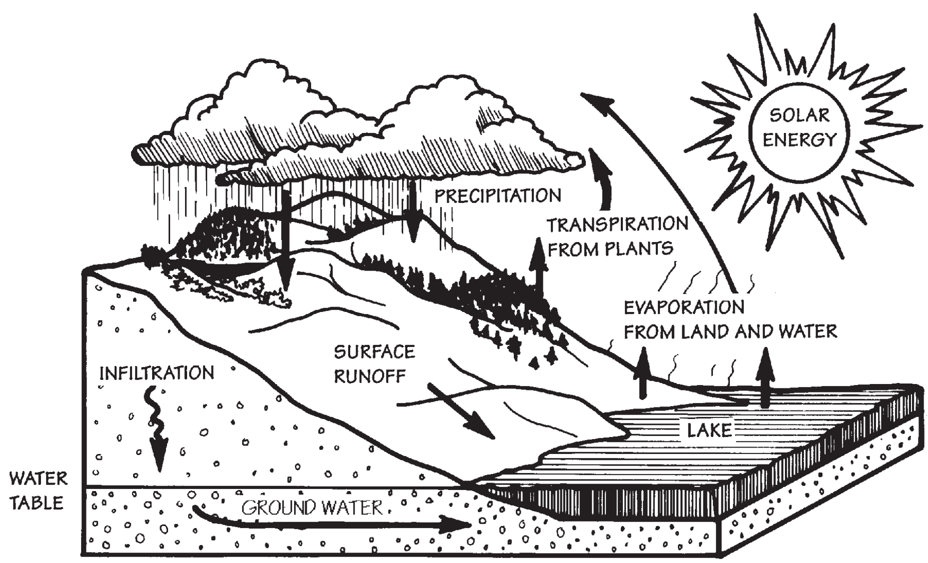
a. Which plant transpired the most water?

b. Which plant transpired the least water?

c. Estimate the mass of water each plant would transpire during seven hours of sunlight. Assume a constant rate of transpiration.

PLANT NAME OR DESCRIPTION	TRANSPIRATION RATE (OUNCES [OR GRAMS] PER 30 MIN.)	TRANSPIRATION PER SEVEN-HOUR DAY
Plant 1		
Plant 2		
Plant 3		

Water Cycle



▼ *Wrap Up and Action*

Have students summarize the process of transpiration. How did the water get into the plastic bags? Discuss the amount of water transpired by plants in the schoolyard and where water goes after it leaves the plant. Have students relate their answers to the role these plants play in the water cycle.

Return students' attention to the arrows they drew on the *Water Cycle Diagram* student activity sheet in the ***Warm Up***. Do they think the placement of their arrows is correct? Are revisions needed? Show students copies of the Water Cycle that includes arrows and labels and have students compare the two.

Students may have found that some plants transpired more water than others. Discuss the use of xeriscaping techniques to conserve water. Invite an extension agent or someone from the state natural resources department to provide additional information. Students can also conduct their own research. Have students survey their community for examples of residences or businesses that practice xeriscaping. What plants do they use? Why are these particular plants selected? Have students design a xeriscaped yard or garden.

Assessment

Have students:

- describe the process of transpiration (***Part I***, step 5 and ***Wrap Up***).
- estimate and/or calculate the mass of water transpired from plants in the schoolyard (***Part II***, step 7).
- indicate the role of plants in the water cycle (***Wrap Up***).
- design a garden using xeriscape techniques (***Wrap Up***).

Upon completing the activity, for further assessment have students:

- write a paragraph envisioning what the water cycle would look like without plants; they might want to consider Earth's poles and the pre-Cambrian period.

Extensions

Have the students use microscopes to look carefully at the leaves and stalk of the celery. They should be able to see that the dyed water has traveled though major tubes to individual cells. Explain that the dye in the water is similar to essential nutrients for plant growth, in that the nutrients, like the dye, are dissolved in water and are transported to each individual cell. The difference is that, whereas nutrients are essential for successful plant metabolism, the dye is not. Wet-mount slides of leaf epidermis can be made to enable students to study stomata.

Resources

Biological Science Curriculum Study. 1987. *Biological Science: An Ecological Approach*. Dubuque, Iowa: Kendall/Hunt Publishing Company.

Knox, Kim, ed. 1989. *Landscaping for Water Conservation—Xeriscape!* Denver, Colo.: City of Aurora and Denver Water Company.

Taylor's Guide to Water-Saving Gardening. 1990. Boston, Mass.: Houghton-Mifflin Company.

🍎 Walker, Sally M. 1992. *Water Up, Water Down: The Hydrologic Cycle*. Minneapolis, Minn.: Carolrhoda Books.

Notes ▼

Water Cycle Diagram

Name:____ Date: ________________

Use arrows to show all the places you think water moves throughout this land area.