NAME ______________________________

DATE ______________________________

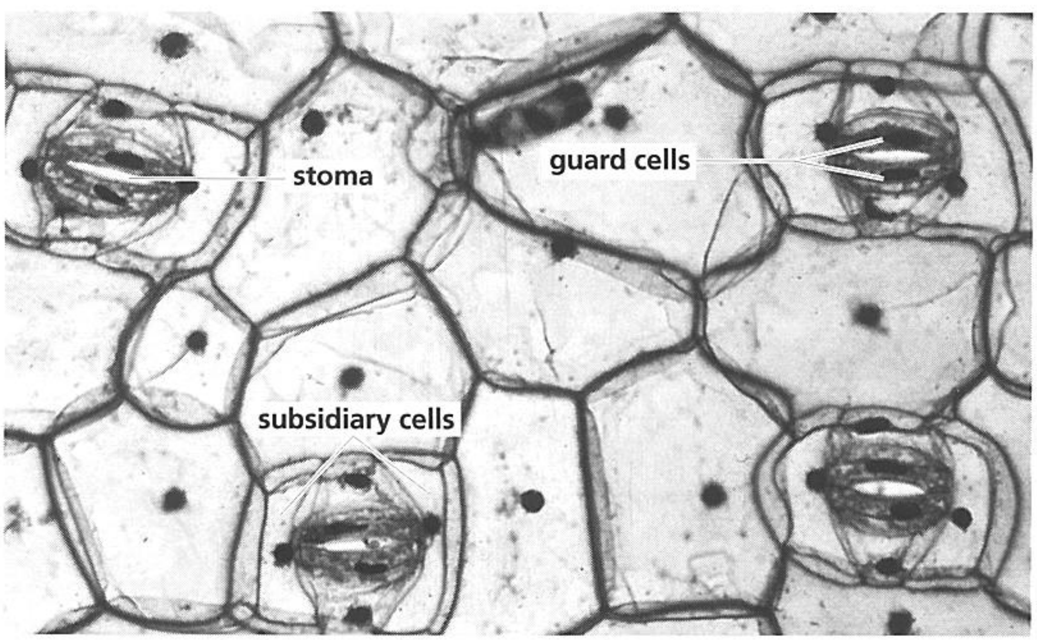
Carolina™ Transpiration Kit for AP Biology

Imagine that your family has received a bouquet of cut flowers as a gift. You place the flowers in a vase with a small volume of water, and return the following afternoon to notice that the water has disappeared and the flowers are wilting and drooping. What has happened to the water that was in the vase?

In this activity, you will investigate the action of transpiration, or water loss from a plant. You will assemble a potometer to measure transpiration. Your potometer will consist of a glass pipet attached to plastic tubing. The potometer is filled with water, and then the stem of a bush bean seedling is inserted into the open end of the plastic tubing. As the seedling transpires, it absorbs water from the potometer, and the water level in the pipet drops. Notice that you will be measuring the amount of water that is absorbed, not the water vapor that is lost. (The two should be practically equivalent.)

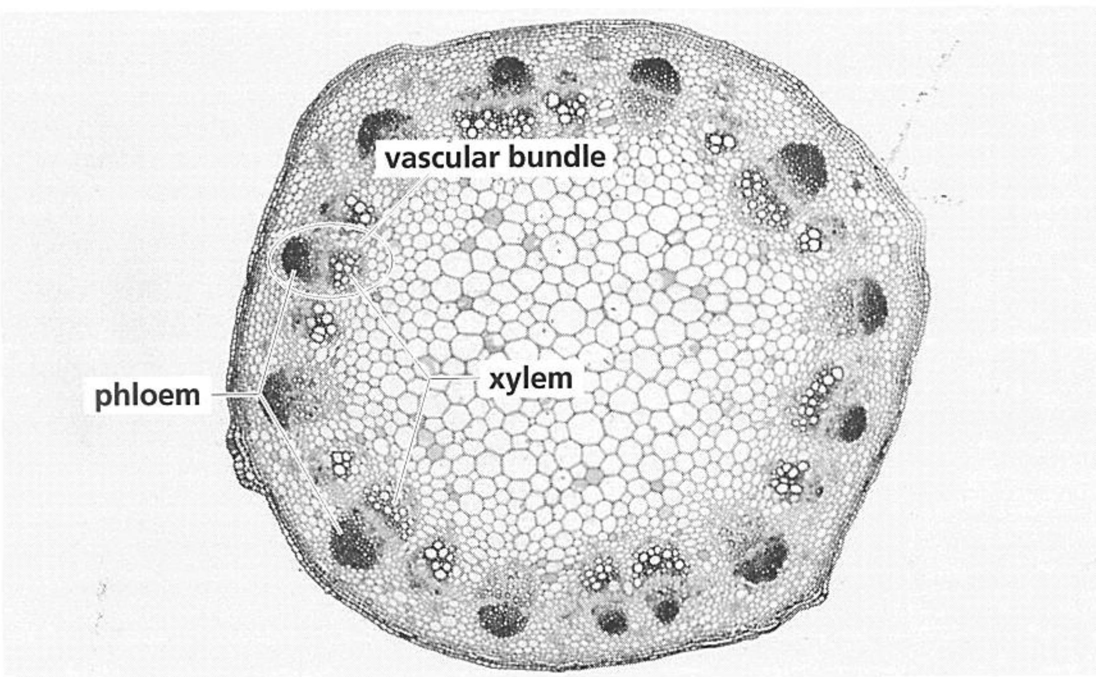
Background

Transpiration is the loss of water vapor from a plant. The surface of a plant, called the epidermis, has microscopic pores called stomata, which allow for gas exchange between the interior of the plant and external atmosphere. The gas exchange of oxygen and carbon dioxide is essential to the processes of photosynthesis and cellular respiration. Most water lost by transpiration escapes through the stomata. Although all aboveground parts of plants commonly have stomata (except for woody stems), leaves usually have the greatest total number and thus account for most of the water lost from a plant by transpiration. Each stoma is opened and closed by the actions of a pair of guard cells, which border the opening of the pore. In many plants, other specialized epidermal cells, called subsidiary cells or accessory cells, border the guard cells and also contribute to the operation of the stomata.



Stomata, guard cells, and subsidiary cells on a leaf epidermis, under a light microscope

Water moves by osmosis from the soil across cell membranes into cells on the root hairs. From the roots, water moves up the stem to cells within the leaves through specialized vascular tissue called xylem. Water evaporates from the surfaces of these cells into the intercellular spaces until those air spaces are saturated. Unless the air outside the leaves is also saturated, the water potential inside the leaf will be greater than outside the leaf and water vapor will diffuse from the leaf through the stomata to the surrounding air. This lowers the water potential of the leaf spaces to below that of the leaf cells, causing more water to diffuse from the cells into the spaces, and so on. This loss of water and lowering of water potential exerts a powerful tension or pull on the water contained within the specialized water-conducting tissues of the stem and helps move water from the roots to the aerial portions of the plant.



Vascular bundles in a sunflower stem cross section. The water-conducting xylem and sap-conducting phloem are arranged in these bundles.

The cohesive properties of water assist in its transport through the plant. Water molecules form hydrogen bonds with one another, and a chain of water molecules is "pulled" from the roots to the leaves as transpiration occurs. As a water molecule exits the plant through a stoma, another moves into its position. This process continues as long as water molecules are available in the soil to diffuse into the roots.

Pre-laboratory Questions

1. Does the majority of the dry body mass of a plant derive from the soil or from the air? Explain.

2. Describe a method for measuring the amount of water absorbed by a plant.

Guided Activity

Materials

2 bush bean seedlings
2 1.0-mL pipets in 0.01 divisions
2 pieces of plastic tubing
10-mL syringe
single-edge razor blade
2 ring stands
4 extension clamps
thermometer
Teflon® tape
basin of water

Procedure

1. Work cooperatively in pairs to assemble the potometer. Read the instructions carefully and familiarize yourself with the procedure before beginning.
2. Insert the tip of the pipet into the plastic tubing. This will be your potometer.
3. Use a basin filled with water to hold the pipet and plastic tubing underwater.
4. Fill the 10-mL syringe with water, connect the syringe to the end of the plastic tubing, and inject water into the potometer until the plastic tubing and pipet are full. There should not be any air bubbles in either the pipet or plastic tubing.
5. While keeping the potometer underwater, disconnect the syringe from the plastic tubing.
6. Obtain a bean seedling that has had the soil washed from its roots, and place the roots of the bean seedling in the water with the potometer.
7. Identify a point on the stem where you will make your cut. Select a location where the stem is the same diameter as, or slightly larger than, the inside diameter of the plastic tubing. There should be two or more healthy leaves on the shoot.
8. Keep the stem underwater at all times. Cut the stem at an angle, rather than straight across. Make a clean cut without crushing the stem. Keep the leaves dry.
9. Insert the cut end of the stem into the plastic tubing. If the cut end of the stem happens to be removed from the water, quickly re-submerge it and make a fresh cut at least 3–4 cm above the first cut. This will remove any air bubbles that may have blocked the water-conducting (xylem) vessels. If this is not possible, discard the shoot and obtain a new plant.
10. Mount your potometer on a ring stand using extension clamps. Keep the pipet slightly higher than the opposite end of the plastic tubing.
11. Check for leaks. If you detect a leak, use Teflon tape to make an airtight seal between the plastic tubing and the stem. *The seal must be airtight, or the experiment will not work.* If the Teflon tape does not stop the leak, ask your teacher for assistance.

Assembled potometer

12. After fully assembling the potometer, allow 10 minutes for the plant cutting to recover and resume normal transpiration.
13. After the resting period, record the beginning water level in the pipet, and use the thermometer to record the air temperature.
14. Take and record water level readings every 3 minutes for a total of 30 minutes.
15. Design a data table to organize the measurements you collect. Be sure to include units.
16. At the end of your transpiration measurements, cut the leaf blades from your bean plant (cutting only the blades—not the leaf stems).
17. Brainstorm a way to determine the total leaf surface area of your plant and then do so. Be sure that your final measure is in meters squared.

Analysis

1. Fill in the water loss data in your table for each time interval. (For example: if the reading at 0 minutes is 0.10 mL, and the reading at 6 minutes is 0.05 mL, then the water loss over that interval is 0.05 mL.)
2. Calculate the water loss per meter squared for each time interval by dividing the water loss by the total leaf surface area. Record your results in your data table.
3. Determine class averages and complete the following class table:

Class Averages for Cumulative Water Loss in mL/m^2

Time (minutes)	0	3	6	9	12	15	18	21	24	27	30
Class average											

4. Graph class averages from the table. Title the graph and supply the following information:
   a. The independent variable is ____
   b. The dependent variable is ____

   On your graph grid, plot the independent variable on the x-axis and the dependent variable on the y-axis.
5. Using your graph or the data from the Class Averages for Cumulative Water Loss in mL/m^2, calculate the average rate of water loss per minute per meter squared.

Title: ____

Laboratory Questions

1. A 1-hectare field contains 2500 bean plants having a total leaf surface area of 557 m^2. Ambient temperature is 21°C, winds are calm, and humidity is 45%. If each plant is transpiring at the average water loss (mL/m^2) calculated for the class data in step 2 of the Analysis, how much water is lost from the field each hour due to transpiration? Show your calculation in the space below.

2. How would you expect the following conditions to affect the rate at which water is transpired from the 1-hectare field described above?

   Ambient temperature of 35°C: ______________________________

   ____

   Winds of 15 to 25 km/h: ______________________________

   ____

   Relative humidity of 100%: ______________________________

   ____

   Ambient temperature of 35°C, winds of 15 to 25 km/h: ______________________________

   ____

Inquiry Activity

On the basis of what you learned in the Guided Activity, develop a question to test about transpiration. In developing an experimental question, consider the materials, equipment, and time available to you. Consult your instructor for the availability of additional supplies.

Additional Materials

lamp with 100-W bulb	plastic bag
fan	spray bottle
petroleum jelly	plants

Other materials may be available. Consult your teacher.

Procedure

1. In your group, collaborate to come up with a question about transpiration and transpiration rates that can be tested using a potometer, as in the Guided Activity. If you have trouble, ask your teacher for guidance.
2. Design an experiment to test your question. Consider the following as you frame your experiment:
   - **Question** - What are you testing in your experiment? What are you trying to find out?
   - **Hypothesis** - What do you think will happen? Why do you think so? What do you already know that helps support your hypothesis?
   - **Materials** - What materials, tools, or instruments are you going to use to find out the answer to the question?
   - **Procedure** - What are you going to do? How are you going to do it? What are you measuring? How can you make sure the data you collect are accurate? What are the independent and dependent variables in this experiment? What is your control? What safe practices do you need to use?
   - **Data Collection** - What data will you record, and how will you collect and present it? Show and explain any data tables and graphs that you plan to use.
3. Have your teacher approve your experimental plan before you begin the experiment.
4. After you perform the experiment, analyze your data:
   - **Data Analysis** - What happened? Did you observe anything that surprised you? Show and explain any tables and graphs that support your data.
   - **Conclusion** - What conclusions can you draw from the results of your experiment? How does this compare with your initial hypothesis? Identify some possible sources of error in your experiment. If given the opportunity, how might you conduct the experiment differently?
5. Be prepared to present the findings of your experiment to the class according to your instructor's specification.

Experimental Design Template

Part A: To be completed and approved before beginning the investigation

What question will you explore? ______________________________

____

On the basis of your previous laboratory exercise, background knowledge, and research, what is the hypothesis that you will test? ______________________________

____

____

What will be the independent and dependent variables? ______________________________

____

What will be the control group(s)? ______________________________

____

What equipment and materials will you need (list items and quantity)? ______________________________

____

____

What procedure (step-by-step) will you follow? ______________________________

____

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____

____

____

What safety steps will you follow (equipment and procedures)? ______________________________

____

____

How will you collect data? ______________________________

____

How will you analyze data? ______________________________

____

Teacher approval to begin your investigation: ______________________________

Part B: To be completed during or after your investigation

What changes or modifications have you made to the investigation? ______

Attach any data collection or analysis as instructed by your teacher.

What results did you see in the experiment? ______

Was the hypothesis accepted or rejected? What conclusions can you draw on the basis of the data and analysis?

What sources of error may have existed, and how might the experiment have been conducted differently? What additional questions arose from the experiment?

Big Idea Assessments

1. Organisms' response to changes in their external environment helps maintain homeostatic balance.
   a. Describe one mechanism used by a particular organism or type of organism to maintain homeostasis.

   b. Propose two scenarios in which the organism responds to a change in the environment to maintain homeostatic balance.

   c. Predict what would happen if the organism did not have the ability to maintain this homeostatic mechanism.

2. Growth and dynamic homeostasis are maintained by the constant movement of molecules across membranes.
   a. Explain a mechanism of molecular movement of water through a plant. Include a discussion of how molecular properties and plant anatomy contribute to this process.

   b. Describe how interactions with the environment influence the movement of molecules in this organism.