

# Transpiration: An inquiry-based adaptation of a traditional “cookbook” lab

Eleanor A. Pardini, Washington University in St. Louis, St. Louis, MO and University of Georgia, Athens, GA

## INTRODUCTION

Transpiration is the process by which water moves through plants from roots to small pores on leaf surfaces, where the water then evaporates as vapor into the atmosphere. Transpiration supplies leaf mesophyll cells with the water needed for photosynthesis, cools leaves, and delivers dissolved minerals from the roots for biosynthesis within the leaf. Only about 1% of the water transported from the roots to the leaves of a plant is actually used for photosynthesis – leaving an enormous amount of water that is lost through stomata as it evaporates as water vapor, making transpiration an important part of the global water system.

Transpiration is typically taught in a cookbook-style lab in which students follow instructions to carry out a pre-designed investigation. Many versions of this traditional lab for Intro and AP Biology are easily found with an Internet search.

In this inquiry-based adaptation of the traditional lab format, **students figure out how** to use the potometers on their lab benches and then **design their own experiments**. This lab emphasizes **the process of scientific inquiry** at the same time it demonstrates an important organismal process in action.

## COMPARISON BETWEEN LABS

### Traditional approach

- Instruction driven
- Students follow a list of instructions to set up potometers
- Students follow a list of instructions and are assigned an experimental treatment
- Students fill in data tables and graphs provided in lab handouts
- Students follow formulas to compare transpiration rates among plants

### Inquiry-based approach

- Student driven
- Guided by the instructor, students figure out how to use potometers
- Guided through the process of inquiry, students design their own experiment and choose their treatments
- Students design tables and graphs for data collection and presentation
- Students design a method to compare transpiration rates among plants

## MATERIALS

### Potometers

- One ring-stand with a clamp (for plant)
- One ring-stand with a ring (for funnel)
- Rubber tubing and 2 tubing clamps
- One T or Y-shaped tubing connector
- Plastic funnel and clothespin
- Plastic pipette with 1/100 mL gradations
- Plant cuttings

### Environmental treatments

- Utility or similar light bulbs
- Fans
- Mist sprayers
- Plastic bags
- Hair dryers

Left panel: Potometer with one ring-stand holding two clamps (for plant and funnel) and Y-shaped tubing connector. A substation is used to clamp the funnel to the funnel-ring and a substation with hole can be used to stabilize the stem.

Middle panel: Potometer with two ring-stands, one with a clamp for the plant, and one with a clamp for the funnel, holder, and a T-shaped tubing connector.

In both setups, the funnel is used to allow water through the pipette to “reset” the water to the “zero” mark. A bag can be used to catch water overflow from the pipette. Tubing clamps are used to control water flow.



## TRADITIONAL APPROACH

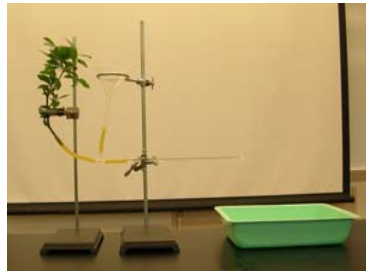
### Methods

Place the tip of a 0.1 mL pipette into a 16 -inch piece of clear plastic tubing.

1. Submerge the tubing and the pipette in a shallow tray of water. Draw water through the tubing until all the air bubbles are eliminated.
2. Carefully cut your plant stem under water. This step is very important because air bubbles must not be introduced into the xylem.
3. While your plant and tubing are submerged, insert the freshly cut stem into the open end of the tubing.
4. Bend the tubing upward into a “U” and use the clamp on a ring stand to hold both the pipette and the tubing.
5. If necessary use petroleum jelly to make an airtight seal surrounding the stem after it has been inserted into the tube. Do not put petroleum jelly on the end of the stem.
6. Let the potometer equilibrate for 10 minutes before the time zero reading.
7. Expose the plant in the tubing to one of the following treatments (you will be assigned a treatment by your teacher):
  1. Room conditions.
  2. Floodlight (over head projector light).
  3. Fan ( place at least 1 meter from the plant, on low speed).
  4. Mist ( mist leaves with water and cover with a transparent plastic bag; leave the bottom of the bag open).
8. Read the level of water in the pipette at the beginning of your experiment (time zero) and record your finding in Table 9.1.
9. Continue to record the water level in the pipette every 3 minutes for 30 minutes and record the data in Table 9.1.
10. At the end of your experiment, cut the leaves off the plant and mass them. Remember to blot off all excess water before massing.

### Analysis of Results

1. Calculate the average rate of water loss per minute for each of the treatments.
2. Explain why each of the conditions causes an increase or decrease in transpiration compared to the control.
3. How did each condition affect the gradient of water potential from stem to leaf in the experimental plant?
4. What is the advantage to a plant of closed stomata when water is in short supply? What are the disadvantages?
5. Describe several adaptations that enable plants to reduce water loss from their leaves. Include both structural and physiological adaptations.
6. Why did you need to calculate leaf surface area in tabulating your results?



## INQUIRY-BASED APPROACH

### Challenge 1: Determine how to use a potometer

Working in teams, study the potometers on the lab bench and determine how to use such an apparatus to measure the rate of transpiration of a leaf or plant.

- Which direction do you expect the water in the pipette to move during transpiration? Why?
- What would happen to the water in the pipette if the rate of transpiration were to increase? Why?
- What are some environmental variables that can influence the rate of transpiration? How do you think they would affect transpiration?
- How can you simulate some of these environmental variables in the lab?

### Challenge 2: Design an experiment to examine the effect of environmental variables on the rate of transpiration

Working as a lab team, design an experiment to test the effect of an environmental variable on the rate of transpiration in your “plant.” You can run your experiment once in ambient room conditions and, after waiting 5-10 minutes, you can repeat your experiment and alter the environmental variable. Address the following issues in your written experimental design:

- What kind of measurements will you take to record transpiration?
- What units will you use to report the rate of transpiration?
- What will your data table look like? What are the column headings?
- Design a method to compare the rates of transpiration between two different plants.

Question: *<space to fill in>*  
Hypothesis: *<space to fill in>*  
Prediction: *<space to fill in>*  
Methods: *<space to fill in>*

### Challenge 3: Measure the rate of transpiration

Carry out the experiment you have designed and record the data in your data table. Graph your results on graph paper and attach it to your lab activity. Make sure to include titles, axis labels, and units for tables and figures.

Table 1. *<space to fill in title>*

*<space to design and record data>*

Figure 1. *<space to fill in title>*



### Challenge 4: Reflection and discussion

1. Why is transpiration a mixed blessing?
2. Transpiration can be described as solar powered. Why?
3. Does water always move from the roots to the shoots? Why?

## ACKNOWLEDGEMENTS

This lab was adapted for Introduction to Plant Biology Lab in the Plant Biology Department of the University of Georgia by E. A. Pardini and R. Specker, based on a lab developed by R. Specker and M. Darley. L. B. Brouillette, K. Kulkarni, and W. L. Li provided useful feedback on its use in their lab sections.