Topic 7: Plants – 7c. Transpiration Lab

Resources: Miller, K., Levine, J. (2004). *Biology.* Boston, MA: Pearson Prentice Hall.

Ju, A. World's first synthetic tree is no giant redwood, but may lead to technologies for heat transfer, soil remediation [Internet]. *Chronicle Online,* Cornell University. 10 Sept. 2008. Available from: http://www.news.cornell.edu/stories/Sept08/stroock.trees.aj.html

Building on: *Transpiration* is the evaporation of water from a plant. It occurs when the *stomata* of the leaves are open so that gas exchange (release of oxygen and the uptake of carbon dioxide) can occur to maximize *photosynthesis.* The water lost to transpiration also plays a role in the *conduction of water* from the roots of the plant to the leaves and chloroplasts where some of that water will be used in photosynthesis. An understanding of the movement of this water is critical to the *transpiration flow theory,* explaining how water moves through *xylem.* The connection between the stomata, the gas exchange, and the water loss is important to the understanding of *photorespiration* and why it occurs.

Links to Chemistry:
Polar molecules
Properties of water
Phase change
Molecular movement

Links to Physics:
Pascal's principle
Atmospheric pressure
Temperature
Evaporation
Energy and changes of phase

Stories: Researchers at Cornell University have developed a synthetic tree. Actually, it isn't a tree, but a synthetic model for plant transpiration. It has the equivalent of a root, a trunk, and a leaf. The trunk is made of an ultrathin tube. The roots and the leaves were the big breakthrough; they are made of a hydrogel, similar to what is found in soft contact lenses. This hydrogel has nanometer scale pores and microfluid channels that act like a wick to take up water by osmosis in the root. The water is held in a *metastable* state, which is a liquid on the verge of becoming a vapor. The negative pressure created by the water in the leaves, pulls the water up from the roots.

This research is significant because it supports the transpiration pull theory, but it also proves that transpiration in plants is a physical process,

not a biological process. That means that the movement of water through xylem requires no energy on the part of the plant.

There are several placations for these findings. A larger model could be used to heat water by means of a solar collector on the roof of a building. The heated water could move through tubing down through the building, heating the building as it goes. When the water reaches the bottom of the building, the synthetic transpiration model would return water to the roof without the use of energy from electricity or burning of fossil fuels. Another benefit of this transpiration model would involve tapping water deep in the earth. In areas where the water table is very deep, extensive wells have to be constructed and pumps are used to bring the water to the surface. This new method would reduce the drilling and would eliminate the pumps.

To read more about this go to:
http://www.news.cornell.edu/stories/Sept08/stroock.trees.aj.html

Materials for the Lab:

- Celery stalks (one stalk for every two students; it is better to get celery with the leaves on the stalk.)
- Beakers or cups
- Razor blades
- Red food color (Put enough in each cup to get the water quite red.)
- Plastic wrap and Scotch tape
- A fluorescent light (emits very little heat)
- A box fan
- A cabinet or box for the dark room
- Clear plastic bags for the humidity
- Digital balance
- Stereo or dissecting microscopes that magnify about 100 times

Instructions for the Teacher:

This lab usually gets very good results. The wind (fan) usually has the greatest amount of transpiration and the humid condition has the least. Whether the light or dark will have more transpiration varies from year to year, and I think it has to do with how hydrated the celery is when the experiment begins.

This lab will work with celery stalks with no leaves, which might be simpler with lower level kids. If you use celery stalks with leaves, the issue of how many and what size leaves are on different stalks may come up. With upper level kids, you can have them remove all of the leaves at the end of the lab and mass them. They can then cut 1 cm^2 pieces of leaf and place them on the balance to find the mass of the leaves per cm^2. A proportion equation can then be used to determine the cm^2 of the leaves from each student's stalk, and transpiration per cm^2 can be calculated instead of % transpiration. Note, that depending on the sensitivity of your balance, you may need to put several sq. cm of leaves on it before you get a reading.

The comparison of the strength of the xylem and the strength of the collenchyma can be used as an introduction to plant ground tissue, a follow-up to discussions of plant ground tissue, or simply to illustrate the differences in the tissue types. I call the collenchymas the *dental floss* of the plant kingdom.

Biology
Transpiration Lab

Introduction: Transpiration is the term that describes the evaporation of water from a plant. The water that is lost by transpiration is conducted up through the plant by vascular tissue called xylem. Various factors can affect the rate of transpiration. Those factors include the amount of light, temperature, and humidity.

Hypothesis: Under which conditions do you think the most transpiration will take place: light, dark, room temp, warm, humid, or windy? Why?

Procedure:

1. Obtain a stalk of celery. Using a razor blade, make a clean cut at each end of the stalk.
2. Take a large plastic cup and fill it with water to the first line in the cup.
3. Add red food color to the water in the cup.
4. Place the celery in the water that is in the cup.
5. Place plastic wrap all around the celery, sealing it off inside the cup. With this setup, the only way that water can be lost from the cup is through the celery. Tape the plastic wrap to the cup where necessary.
6. Mass and record the mass of the setup (cup, celery, red water, and plastic wrap).
7. Place your celery in the assigned area. If you have been assigned "humidity," then you must cover the celery stalk with a plastic bag.
8. After 24 hours, mass the setup and record the new mass. If you were assigned humidity, you need to remove the plastic bag before you mass the setup.
9. Calculate the water loss per minute for your transpiration rate.
   Transpiration rate (grams/minute) = grams lost/minutes.

10. Now calculate the % change in mass.
    % change = ending mass – begin mass/begin mass X 100.

11. Record your data on the class record sheet on the board or overhead.
12. Construct a bar graph to show class data. This graph should include "conditions" as the independent variable and % change in mass as the dependent variable.
13. After recording your data, carefully remove your celery stalk from the water and use a razor blade to make a very thin slice through the celery close to the bottom of the stalk to get a "half moon" slice. Observe this for the presence of dye in the celery stalk. Using the stereoscopes, draw the cross-section of the celery stalk. In your drawing, identify the level of magnification, the vascular bundles, the xylem, phloem, parenchyma cells, and collenchyma.
14. Next, use the razor blade to gently cut the celery stalk lengthwise on the inner curve side. Carefully crack open the stalk and look for a red xylem bundle. Carefully pull/cut out a length of red xylem bundle and set it aside.
15. Now, starting at one end of the celery stalk, pull out one rib of the celery. You will need to get your fingernail under the rib and then pull.

16. Try taking the red xylem bundle and breaking it. Do the same thing with the rib.
17. Answer the analysis questions and write a conclusion.

Analysis Questions:

1. Does more transpiration occur in the light or the dark? Explain why.

2. What effect does warm temperature have on transpiration? Why?

3. Under what conditions would you expect the MOST transpiration: hot/dry, cool/wet, and cool/dry? Why?

4. Where is the xylem located in the celery stalk? Is the stalk a root or a stem?

5. How did the strength of the xylem compare with the strength of the rib?

6. What is the function of the ribs of the celery stalk?

7. What is the function of the following tissues?
   a. Parenchyma
   b. Collenchyma
   c. Sclerenchyma

8. What type of tissue makes up the rib of the celery?