Plant Plumbing

Principle of Plant Biology #10

Water is the major molecule present in plant cells and organs. In addition to an essential role in plant structure, development, and growth, water can be important for the internal circulation of organic molecules and salts.

Imagine carrying 100 buckets of water to the top of a 10-story building. This is hard work for humans, but trees do it every day! Trees and other plants take water in through their roots, pull it up through their stems, and finally transpire it into the air through their leaves. Just as you suck water up through a straw, transpiration sucks water up through plants and out into the air through tiny holes in leaves called stomata. This flow of water is essential for plants, since water is involved in practically everything plants do.

Plants do not have blood vessels like humans. Instead, they have vascular tissue that allows water and other molecules to flow. One kind of vascular tissue called xylem (pronounced “zī-lem”) allows the flow of water and nutrients from the roots up through the rest of the plant. Another kind of vascular tissue called phloem (pronounced “flōm”) carries sugars and other molecules down from the leaves through the rest of the plant. Just as blood vessels carry blood to nourish every cell in your body, vascular tissues carry water, nutrients, and sugars to nourish plant cells.

Within plant cells, most water is held in a sac called the vacuole. Vacuoles occupy most of the volume of plant cells. When a plant has plenty of water, the water-filled vacuoles press against the outside of cells, making them firm (or turgid). The overall effect of many turgid cells is an upright, sturdy plant. However, when plant cells do not have enough water, the plant wilts!

Real-world Connection:

Some plants require irrigation, while others can survive in extremely dry conditions. Plant biologists are developing drought-resistant varieties of many crops to help deal with hunger and agricultural problems around the world.

Activity: Water Flow in Broccoli and Celery

Procedure:

1. Work in a team of 4 to complete the following procedure (or your teacher may do one demonstration for the class).
2. Obtain 4 small cups and label them as the following: Broccoli Treatment, Celery Treatment, Broccoli Control, and Celery Control. Add 20 ml of water to each cup.
3. Add 4 drops of red food coloring to the Broccoli Treatment and Celery Treatment cups. Swirl both cups so that the water is brightly colored and well mixed.
4. Put 3 pieces of celery into the Celery Treatment cup and 3 more pieces into the Celery Control cup. Then add 3 broccoli stems to each broccoli cup. Try to get each piece of celery and broccoli to stand up straight. Let the cups sit for a day.

Observations:

After a day, cut open the celery and broccoli stems to observe where the colored water has traveled. If microscopes and slides are available, cut paper-thin sections of the stems and look at them under a microscope.

1. What differences do you observe between the treatments and the controls? Sketch what you see.
2. Where is the vascular tissue in celery? In broccoli? How are the vascular tissues of celery and broccoli different?
3. Is the colored tissue xylem or phloem? Why do you think so?
4. Now that you can identify vascular tissue, try to come up with a question for further exploration. What could you discover by doing more experiments?

Student-Designed Experiments

Using the methods you learned in the activity above and the "Guide for Student Experimentation" below, design and carry out your own experiment. Question topics you might consider include the location of vascular tissues in different plants or plant parts, the rate of water flow in different plants or plant parts, the rate of water flow in different environmental conditions, differences between fresh and aged vegetables, etc.

Guide for Student Experimentation

Guidelines for Achieving Great Experiments

1. Ask a very specific, testable question.
2. Test a control for comparison (a group that does not receive the experimental treatment).
3. Use a sample size large enough to allow firm conclusions.
4. To understand a whole population, obtain a random sample of that population to avoid bias.
5. Replicate each part of the experiment (at least 3 times).
6. Hold all variables constant between trials except the variable being tested.
7. Collect quantitative data whenever possible.
8. Measure using metric units.
9. Gather data carefully and accurately.
10. Be objective and honest.

Introduction

Question:

Hypothesis:

Materials and Methods

Independent variable:

Dependent variable:

Experimental constants:

Control:

Protocol:

Results

Data collected:

Other observations:

Graph(s):

Discussion

Interpretation of data:

Conclusions:

Teacher's Guide to "Plant Plumbing"

Links to National Science Education Standards

Grades 5-8:
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry
- Structure and function in living systems
- Diversity and adaptations of organisms
- Science and technology in society

Grades 9-12:
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry
- The cell
- Matter, energy, and organization in living systems
- Science and technology in local, national, and global challenges

Materials (for a class of 32)

- 8 celery stems
- 8 large heads of broccoli (with large stems attached)
- 32 small cups (9 oz)
- Red food coloring with 8 droppers
- 8 graduated cylinders
- 8 razor blades
- Microscopes, slides, and cover slips

Note: The student-designed experiments will require more celery and broccoli.

Preparation (for a class of 32)

Once you have the materials, this can be a zero-prep lab if you don't mind your students cutting their own celery and broccoli stems. Each group of 4 will need the following:

- 6 pieces of celery stem (or 1 stem if the students will cut it)
- 6 pieces of broccoli stem (or 1 large stem if the students will cut it)
- 4 cups
- 1 bottle of food coloring
- 1 dropper
- 1 graduated cylinder
- 1 razor blade

A typical celery stem can be cut into 6 usable pieces by cutting it into thirds and then cutting each third longitudinally. A large broccoli stem can be cut into 8 usable pieces by cutting it in half and then cutting each half longitudinally into quarters. You can either cut the "head" off of the broccoli stem or leave it attached. Either way, each smaller piece needs to be about the same. Smaller celery and broccoli stems may produce fewer pieces. It is best to cut the broccoli and celery at the time of the experiment.

Answer Key

1. Some cells in the treatments will be stained red. These cells are part of the vascular tissue where the water traveled up the stem. (Notes: Over time, the redness will fade into other cells throughout the stem as the water travels to all parts of the plant. Some non-vascular cells will also be stained red near the bottom of the stems where they sat in the cups.)
2. In celery, vascular tissue is found in many small, circular bundles. In broccoli, vascular tissue is found in one large ring near the outer edge of the stem.
3. Xylem, since it carries water from the roots to the rest of the plant (see Introduction).

4. Students questions will vary widely. Push students to ask specific questions that can be tested by more experiments.

Teaching hints

1. **Faster results**: Water often moves faster in uncut tissues. If you want to see results faster, let the whole stems sit in the colored water first and then cut them into pieces (as opposed to cutting them first and then letting them sit in colored water).
2. **Lack of materials**: Allowing each student group to set up their own demonstration will be more meaningful for students. However, if this is not possible, then you can set up one version of the demonstration at the front of the class with student assistance. Then you can cut the broccoli and celery into pieces for students to look at. You can also have students perform the treatments (with food coloring), but perform just one set of controls for the whole class.
3. **Safety**: If giving students razor blades is a concern in your classroom, then have a designated station for all cutting to take place.
4. **Successful student-designed experiments**:
    - Emphasize the "Guidelines for Achieving Great Experiments."
    - Have enough plant material available for students to use in their own experiments. Having more allows for better experiments that include replicates, controls, and multiple treatments. Alternatively, you could ask students to bring in what they need.
    - Students need time each day for several days to work. Before students design their experiments, tell them how many days they have to run their experiments and how much time each day they will have.
    - Allow students to present their experiments and lead a short discussion about each one. Encourage other students to ask questions. Talk about characteristics of good experiments, such as controls, replicates, etc.

Acknowledgements

Credits for figures are as follows: Water leaf, ©iStockphoto.com/stdemi; Irrigation, ©iStockphoto.com/westphalia; Cacti, ©iStockphoto.com/mikenorton. This work was funded by the Education Foundation of the American Society of Plant Biologists.

ASPB education foundation