Plants Respire Too!

Principle of Plant Biology #5

Plants, like animals and many microbes, respire and utilize energy to grow and reproduce.

What happens when you burn wood or other plant material? The fire generates heat, consumes oxygen, and releases carbon dioxide. We sometimes harvest the energy in plant material by burning it, but fire is obviously not a good way for plants to use energy on a daily basis. A process called respiration allows plants (and other organisms) to release energy very slowly so that they can grow, develop, and perform other life processes.

During respiration, plant cells use oxygen (O_2) and the sugars from photosynthesis to produce high-energy molecules (such as ATP) that can be used to do work. During the process, carbon dioxide (CO_2) and water (H_2O) are produced. Just as we breathe in and out, the gases involved in respiration must be able to move in and out of plants. Leaves and young stems have pores called stomates where gas exchange occurs. Fruits, older stems and older roots can have spongy layers of cells called lenticels that allow for gas exchange. Gases can diffuse into and out of cells in young roots.

When the carbon dioxide from respiration is added to water, carbonic acid (H_2CO_3) is produced. Therefore, as more carbon dioxide is released, the more acidic a solution becomes. The equation below illustrates this reaction:

$$CO_2 + H_2O \longrightarrow H_2CO_3 \text{ (carbonic acid)}$$

An easy method to test for the release of carbon dioxide in a solution is to measure the change in the solution's pH. The pH scale (0 - 14) is used to measure how acid or basic a solution might be. When more hydrogen ions (H+) are present than hydroxide ions (OH-), then the solution is considered to be acidic (below 7) and when more hydroxide ions (OH-) are present than hydrogen ions (H+) the solution is considered to be basic (above 7). If the amount of hydrogen ions (H+) and hydroxide ions (OH-) is equal, then the solution is neutral (pH 7).

In the following activity, you will use changes in pH as an indicator that respiration has occurred in plants.

Real-world Connections:

Some plants such as lilies (left) use respiration to generate heat in cold conditions. Bread (right) rises when yeast performs anaerobic respiration (respiration without oxygen), breaking down plant sugars and releasing carbon dioxide.

Activity: Plant Respiration

Procedure:

1. Obtain 100 mL of water. Test the pH (using pH paper test strips) of this solution. Record in your lab notebook.

2. Place 3 test tubes in a test tube rack and label each with the date, plant material, and your name. Add 10 mL of water to each of the 3 test tubes. Then add 3 drops of phenol red pH indicator into each test tube and record the color.

3. Test tube 1 will be your control. Do not place any plant material in this tube. Place this test tube in a beaker or container to hold the test tube upright. Place a stopper in the tube.

4. Pat dry the germinating seeds that have NOT been boiled. In test tube 2, add enough germinating pea seeds to fill one half of the tube, making sure the seeds are in the liquid. Place this test tube in a beaker or container to hold the test tube upright. Place a stopper in the tube.

5. Pat dry germinating seeds that have been boiled. In test tube 3, add enough BOILED germinating pea seeds to fill one half of the tube, making sure the seeds are in the liquid. Place this test tube in a beaker or container to hold the test tube upright. Place a stopper in the tube.

6. Let these tubes sit quietly for 30 minutes. Observe and record the color of the liquid in the tubes. Pour a small amount of the liquid from each tube into small clear containers and place a piece of pH test strip in each solution. Leave for 2 minutes, and then record the pH of each solution. Pour the liquids back into the correct test tubes and put stoppers back into the tubes.

7. Let these test tubes sit overnight.

8. Pour some of the liquid from each test tube into smaller clear containers. Note any color changes in the liquids. Check and record the pH of the liquids by placing pH paper strips in each and leaving for several minutes.

Observations:

Are the colors of the liquids different after 24 hours? How so?

If the colors are different, what might have caused the change?

Are the temperatures different after 24 hours? How so?

If so, what might have caused the temperature change?

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 inquiry. Question topics you might consider include the differences between various plant parts, the differences between plant species, the conditions in which respiration takes place, 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 "Plants Respire Too!"

Links to National Science Education Standards

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

Grades 9-12:
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry
- The cell
- Matter, energy, and organization in living systems

Materials

Per Group:
- 10 or 25 mL graduated cylinder
- Test tube rack
- 6 test tubes with stoppers (3 are for student-designed experiments)
- 100 mL of water solution at pH 7
- Dropper bottle of phenol red pH indicator (0.04% aqueous solution)
- pH paper strips
- 5-6 small beakers or clear cups
- Metric ruler
- Plant material for testing (all groups will use some not boiled and boiled germinating pea seeds for their initial experiment)
- Marking pens
- Colored pencils
- Paper towels

For Class Use:

- Distilled water at pH 7 (enough for each group to have 100 mL)
- Germinating seeds of various types (radish, peas, corn, etc)
- Germinating seeds that have been boiled for 10 minutes (or microwaved for several minutes in water)
- Plastic spoons for gathering the seeds and placing in test tubes
- Plant material (brown and green stems)
    - Leaves and roots should not be used in this experiment (unless leaves are kept in the dark).
- Clippers for cutting plant stems into 7 cm lengths
- Instructor will need 5% Clorox for disinfesting certain seeds (See "Teaching Hints")
- *Teacher will need sodium bicarbonate (baking soda) for making a basic solution

Teaching hints

1. Preparing Seeds:
- Obtain a variety of seeds for students to use. You will need seeds that germinate quickly such as radish, peas, and corn.
- To germinate the radish seeds, spread all the radish seeds out on wet paper towels in a plastic sandwich container and let them sit covered overnight. Each group will probably need about one-fourth of a small packet of seeds.
- Corn and pea seeds need to be soaked in a 5% Clorox solution (5 mL of Clorox

and 95 mL of water for 100 mL of solution) for 15 minutes to disinfect the seeds then rinse the seeds five times in water to get rid of the Clorox. Let the seeds sit overnight (or a couple of days) in water until germination begins. Students will need to pat the seeds dry before using in the experiment to make sure the soaking water does not influence the pH indicator.

- Half of the germinating pea seeds will need to be boiled for 10 minutes. These will be used as a control in the experiment.
- Collect various types of small stems or let students collect these. Students will need to strip all the leaves off the stems, then rinse the stems in water and then pat the stems dry. Length of stems should be around 7 cm. Have students "stuff" as many stems as they can into the test tubes.

2. **Preparing the indicator solution**:

Obtain the amount of distilled water needed for the class (~100 mL per group) and check the pH of the solution using the pH test strips. This solution needs to be a slightly basic (a little above pH 8). If it is too acid, add enough sodium bicarbonate solution* to bring this to the correct pH.

* To make a sodium bicarbonate (baking soda) solution, dissolve 2 grams of baking soda in 200 mL of water. Baking soda makes a weak base with a pH around 8.

* Phenol red pH indicator can be purchased in a 0.04% aqueous solution or as a powder and mixed. This indicator is red at a pH above 8 (basic) and yellow below a pH of 6.8 (acidic).

3. **Choosing plant material**:

Teachers and/or students can collect plant material around the school and home. Germinating seeds are very good to use since they are respiring rapidly and usually not photosynthesizing much at this point. Any green parts of a plant will be photosynthesizing and will probably be taking in more carbon dioxide than releasing it. Therefore, green leaves and green stems are not going to work well in this experiment unless they are kept in the dark. This might be good to try and then discuss the competing processes of respiration and photosynthesis. Roots release hydrogen ions in soil solutions causing soil particles (clay) to release important cations they require. Therefore, roots should make the pH more acid but this is not necessarily caused by the release of carbon dioxide.

4. **Successful student-designed experiments**:
   - Emphasize the "Guidelines for Achieving Great Experiments."
   - Before students design experiments, tell them how much time they will have.
   - Allow students to present their experiments and lead a short discussion about each one. Encourage other students to ask questions.

References and Web Resources

Jentsch, J., H. Theurer, J. Bannwarth. 2008. Respiration and photosynthesis in context: Experiments demonstrating relationship between two physiological processes. International Journal on Hands-On Science. The Hands-On Science Network. http://www. uni-koeln.de/math-nat-fak/ didaktiken/bio/botanik/bannwarth/forschungsberichte/ijhsci_p12_08_horstp1online1.pdf

Sugar and carbohydrates, protein, fat and water – that's what little plants are made of! Modified by R. Hughes and K. Bittel, Portions modified from Teaching Science for

Understanding: Plant Nutrition Activity 5.2 and 5.3 by J. Hind, J. Lewis, P. Scott, Center for Studies in Science and Mathematics Educations, the University of Leeds. http://pulse.pharmacy.arizona.edu/10th_grade/dawn_new/science/sugar_carb.html

Skool.ie. 2008. Respiration Experiments. Intel Corporation. http://www.skoool.ie/skoool/homeworkzone.asp?id=255.

Acknowledgements

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