AP® INVESTIGATION #11

INTERACTIONS: TRANSPIRATION – TEACHER'S GUIDE

Kit # 36W7411

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ABSTRACT

This lab addresses the process of transpiration and has students explore factors that affect its rate. Students analyze stomata density in leaf types and determine the rate of transpiration in a living plant by constructing a simple potometer. Students consider how plants adapt to changing environments to regulate water loss and photosynthesis in the short term of an experiment as well as in evolutionary context.

GENERAL OVERVIEW

The College Board has revised the AP Biology curriculum to begin implementation in the fall of 2012. Advanced Placement (AP) is a registered trademark of the College Entrance Examination Board. The revisions were designed to reduce the range of topics covered, to allow more depth of study and increased conceptual understanding for students. There is a shift in laboratory emphasis from instructor-designed demonstrations to student-designed investigations. While students may be introduced to concepts and methods as before, it is expected that they will develop more independent inquiry skills. Lab investigations now incorporate more student-questioning and experiment design. To accomplish this, the College Board has decreased the minimum number of required labs from 12 to 8 while keeping the same time requirement (25% of instruction time devoted to laboratory study). The College Board has defined seven science practices that students must learn to apply over the course of laboratory study. In brief, students must:

1. Use models
2. Use mathematics (quantitative skills)
3. Formulate questions
4. Plan and execute data collection strategies
5. Analyze and evaluate data
6. Explain results
7. Generalize data across domains

The College Board published 13 recommended laboratories in the spring of 2011. They can be found at: http://advancesinap.collegeboard.org/science/biology/lab

Many of these laboratories are extensions of those described in the 12 classic labs that the College Board has used in the past. The materials provided in this lab have been prepared by Ward's to adapt to the specifications outlined in AP Biology Investigative Labs: An Inquiry-Based Approach (2012, The College Board). Ward's has provided instructions and materials in the AP Biology Investigation series that complement the descriptions in this College Board publication. We recommend that all teachers review the College Board material as well as the instructions here to get the best understanding of what the learning goals are. Ward's has structured each new AP investigation to have at least three parts: Structured, Guided, and Open Inquiry. Depending on a teacher's syllabus, s/he may choose to do all or only parts of the investigations in scheduled lab periods.

The College Board requires that a syllabus describe how students communicate their experiment designs and results. It is up to the teacher to define how this requirement will be met. Having students keep a laboratory notebook is one straightforward way to do this.

RECORDING DATA IN A LABORATORY NOTEBOOK

All of the Ward's Investigations assume that students will keep a laboratory notebook for student-directed investigations. A brief outline of recommended practices to set up a notebook, and one possible format, are provided below.

1. A composition book with bound pages is highly recommended. These can be found in most stationary stores. Ward's offers several options with pre-numbered pages (for instance, item numbers 32-8040 and 15-8332). This prevents pages from being lost or mixed up over the course of an experiment.
2. The title page should contain, at the minimum, the student's name. Pages should be numbered in succession.
3. After the title page, two to six pages should be reserved for a table of contents to be updated as experiments are done so they are easily found.
4. All entries should be made in permanent ink. Mistakes should be crossed out with a single line and should be initialed and dated. This clearly documents the actual sequence of events and methods of calculation. When in doubt, over-explain. In research labs, clear documentation may be required to audit and repeat results or obtain a patent.
5. It is good practice to permanently adhere a laboratory safety contract to the front cover of the notebook as a constant reminder to be safe.
6. It is professional lab practice to sign and date the bottom of every page. The instructor or lab partner can also sign and date as a witness to the veracity of the recording.
7. Any photos, data print-outs, or other type of documentation should be firmly adhered in the notebook. It is professional practice to draw a line from the notebook page over the inserted material to indicate that there has been no tampering with the records.

For student-directed investigations, it is expected that the student will provide an experimental plan for the teacher to approve before beginning any experiment. The general plan format follows that of writing a grant to fund a research project.

1. Define the question or testable hypothesis.
2. Describe the background information. Include previous experiments.
3. Describe the experiment design with controls, variables, and observations.
4. Describe the possible results and how they would be interpreted.
5. List the materials and methods to be used.
6. Note potential safety issues.

(continued on next page)

RECORDING DATA IN A LABORATORY NOTEBOOK (CONTINUED)

After the plan is approved:

7. The step-by-step procedure should be documented in the lab notebook. This includes recording the calculations of concentrations, etc., as well as the weights and volumes used.
8. The results should be recorded (including drawings, photos, data print-outs, etc.).
9. The analysis of results should be recorded.
10. Draw conclusions based on how the results compared to the predictions.
11. Limitations of the conclusions should be discussed, including thoughts about improving the experiment design, statistical significance, and uncontrolled variables.
12. Further study direction should be considered.

The College Board encourages peer review of student investigations through both formal and informal presentation with feedback and discussion. Assessment questions similar to those on the AP exam might resemble the following questions, which also might arise in peer review:

- Explain the purpose of a procedural step.
- Identify the independent variables and the dependent variables in an experiment.
- What results would you expect to see in the control group? The experimental group?
- How does a specific concept (XXXX) account for described findings (YYYY)?
- Describe a method that could be used to determine a given concept/observation (XXXX).

MATERIALS CHECKLIST

MATERIALS INCLUDED IN KIT

Units per kit	Description
1 box	Microscope slides
1	Spray mist dispenser bottle
1 pkg.	Kidney bean seeds
8	T-Connectors, 1/8"-1/4"-1/8"
8 lengths	Clear flexible tubing, 1/8" I.D.
1 length	Clear flexible tubing, 1/4" I.D.
8	Plastic hose clamps
8	Non-sterile pipets, borosilicate glass, 1 mL x .01
8	Non-sterile 10-mL syringes
1 bag	Potting soil
8	Sutton inserts, 6-cell unit
1 sheet	Cobalt chloride paper, 8" x 10"
2 bottles	White glue
8	Poly bags
1	Instructions (this booklet)

For a list of replacement items, visit: www.wardsci.com, and click on the AP Biology tab for this kit/item #.

MATERIALS NEEDED BUT NOT PROVIDED

Lab notebook
Petroleum jelly
Compound microscope
Metric rulers, clear
Fresh leaves
Scissors
Light (100 W)
Electric fan
Scale
Ring stand with two adjustable clamps
Razor blade
Extension clamps
Fine point forceps
Graph paper
Distilled water

OPTIONAL MATERIALS (NOT PROVIDED)

Paper clips
Other materials as determined by students' experiment design
Thermometers

This lab is aligned with the 2012 AP Biology Curriculum (registered trademark of the College Board). Listed below are the aligned Content Areas (Big Ideas and Enduring Understandings), the Science Practices, and the Learning Objectives of the lab as described in AP Biology Investigative Labs: An Inquiry-Based Approach (2012). This is a publication of the College Board that can be found at http://advancesinap.collegeboard.org/science/biology/lab.

CURRICULUM ALIGNMENT

Big Ideas

- **Big Idea 2:** Biological systems utilize energy and molecular building blocks to grow, to reproduce, and to maintain homeostasis.
- **Big Idea 4:** Biological systems interact, and these interactions possess complex properties

With connections to:

- **Big Idea 1:** The process of evolution drives the diversity and unity of life.

Enduring Understandings

- 1A2: Natural selection acts on phenotypic variations in populations.
- 2A3: Organisms must exchange matter with the environment to grow, reproduce, and maintain organization.
- 4A4: Organisms exhibit complex properties due to interactions between their constituent parts.
- 4A6: Interactions among living systems and with their environment result in the movement of matter and energy.

Science Practices

- 1.4 The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively.
- 2.2 The student can apply mathematical routines to quantities that describe natural phenomena.
- 4.1 The student can justify the selection of the kind of data needed to answer a particular scientific question.
- 6.4 The student can make claims and predictions about natural phenomena based on scientific theories and models.
- 7.1 The student can connect phenomena and models across spatial and temporal scales.

LEARNING OBJECTIVES

- The student is able to connect evolutionary changes in a population over time to a change in the environment (1A2 & SP 7.1).
- The student is able to use calculated surface area-to-volume ratios to predict which cell(s) might eliminate wastes or procure nutrients faster by diffusion (2A3 & SP 2.2).
- The student is able to justify the selection of data regarding the type of molecules that an animal, plant, or bacterium will take up as necessary building blocks and excrete as waste products (2A3 & SP 4.1).
- The student is able to represent graphically or model quantitatively the exchange of molecules between an organism and its environment, and the subsequent use of these molecules to build new molecules that facilitate dynamic homeostasis, growth, and reproduction (2A3 & SP 1.1, SP 1.4).
- The student is able to predict the effects of change in a component(s) of a biological system on the functionality of an organism(s) (4A4 & SP 6.4).
- The student is able to apply mathematical routines to quantities that describe interactions among living systems and their environment that result in the movement of matter and energy (4A6 & SP 2.2).
- The student is able to use visual representation to analyze situations or solve problems qualitatively to illustrate how interactions among living systems and with their environment result in the movement of matter and energy (4A6 & SP 1.4).

TIME REQUIREMENTS

Pre-Lab Prep: Begin growing seedlings (can be done by either teacher or students – see page 10)	2 weeks prior to lab
Part 1: Structured Inquiry – Stomata Prints and Transpiration	**Total of 75 minutes**
Part 1A: Making Stomata Prints (Optional: Take measurements/make calculations outside of lab period)	30 minutes
Part 1B: Transpiration in Living Plants (Optional: Do concurrently with Part 2, below)	45 minutes
Part 2: Guided Inquiry – Environmental Factor of Student's Choice	**Total of 50 minutes:** 10 minutes set up 30 minutes observation and recording 10 minutes analysis
Part 3: Open Inquiry	**Total time:** Depends on student/teacher scheduling and parameters of experiment

GENERAL SAFETY PRECAUTIONS

- The teacher should 1) be familiar with safety practices and regulations in his/her school (district and state) and 2) know what needs to be treated as hazardous waste and how to properly dispose of non-hazardous chemicals or biological material.
- Consider establishing a safety contract that students and their parents must read and sign. This is a good way to identify students with allergies (e.g., latex) so that you (and they) will be reminded of specific lab materials that may pose risks to individuals. A good practice is to include a copy of this contract in the student lab book (glued to the inside cover).
- Students should know where all emergency equipment (safety shower, eyewash station, fire extinguisher, fire blanket, first aid kit etc.) is located.
- Require students to remove all dangling jewelry and tie back long hair before they begin.
- Remind students to read all instructions, Material Data Safety Sheets (MSDSs) and live care sheets before starting the lab activities, and to ask questions about safety and safe laboratory procedures. Appropriate MSDSs and live care sheets can be found on the last pages of this booklet. Additionally, the most updated versions of these resources can be found at www.wardsci.com. The most updated version of most MSDSs can usually be found on the chemical manufacturer's website. *(Note that in this particular lab there are no live material care sheets.)*
- In student directed investigations, make sure that collecting safety information (like MSDSs) is part of the experimental proposal.
- As general laboratory practice, it is recommended that students wear proper protective equipment, such as gloves, safety goggles, and a lab apron.

At the end of the lab:

- All laboratory bench tops should be wiped down with a 10% bleach solution or disinfectant to ensure cleanliness.
- Remind students to wash their hands thoroughly with soap and water before leaving the laboratory.

OPTIONAL PRE-LABORATORY DEMONSTRATION

Cobalt chloride paper changes color in the presence of water. Demonstrate the loss of water through number and location of plant stomata on leaves.

Materials:
Cobalt chloride paper (provided)
A leaf
Scissors
Paper clips
Coverslips (provided)

Procedure:

- Cut a 1"x 4" strip from the sheet of cobalt chloride paper and fold the strip in half, to make a 1" x 2" envelope.
- Place the leaf within the cobalt chloride envelope, then place a coverslip on both the top and the bottom of the envelope. Secure with a paper clip.
- Have students observe any changes to the paper at the end of class period and have them explain what happened to the cobalt chloride paper.

PRE-LABORATORY PREPARATION

GROWING SEEDLINGS

1. **Two weeks before conducting the lab**: Plant the provided bean seeds. Fill a pot (or each cell of a six-cell Sutton insert, included in this kit) with soil, and plant the bean seeds at a depth of 1 cm. Cover the seeds with soil. Keep the seeds watered and place in a well-lit area for approximately two weeks. If you are setting up a light system for your plants, make sure that water does not get on electrical connectors.
   - OPTIONAL: You may wish to have the students grow their own seedlings.
2. **Before the lab**: Collect a variety of leaf types (or have students collect a variety of leaf types) that represent adaptations to different levels of environmental water. A bean plant leaf is a good start. You may want to also get leaves from common houseplants and common aquarium plants for comparisons. They should be fresh, not dried leaves and you should have a minimum of 5 leaf specimens per plant type.

BEFORE CLASS

1. Make copies of the Student Guide copymasters for distribution.
2. Cut the 1/4" ID tubing into eight pieces, each approximately 1" long.
3. Prepare a materials for the class demonstration to support your lecture or laboratory introduction. (See sidebar, left.)