AP® INVESTIGATION #6

CELL PROCESSES: CELLULAR RESPIRATION – TEACHER'S GUIDE

Kit #36W7406

Table of Contents

ABSTRACT

Living organisms must metabolize compounds derived from food to produce energy for maintenance, growth and reproduction. Cellular respiration is a process that produces energy by metabolizing glucose in the presence of oxygen (O_2). In this lab, students measure the rate of oxygen consumption related to cellular respiration. This is achieved through the construction and utilization of a microrespirometer. Students compare the results obtained using germinating seeds versus a non-germinating control, acrylic beads. Students then design their own experiments to investigate the effects of various factors on the rate of cellular respiration.

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 activity 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

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

Units per kit	Description
1 bag/300	Cotton balls
1 bag	Rayon balls
1	CD-ROM, AP Biology Lab #6
1 lb.	Pea seeds (viable)
360	Acrylic beads
8 sets of 6	Vials with glued washers
8 sets of 6	Stoppers and washers
48	Pipets, non-sterile Pyrex, 1 mL × .01
15	6" Graduated plastic pipets
16	Trays, 21¼ × 11 × 2 inches
1 bottle	Red food coloring
1 bottle/30 mL	Potassium hydroxide, 15% solution
1	Instructions (this booklet)

MATERIALS NEEDED BUT NOT PROVIDED

Thermometer °C
Glass marking pens
Timers or stopwatches
Paper towels
100 mL graduated cylinders
Ice
Other materials as determined by students' experiment design
Distilled water
Petroleum jelly
Lab notebook
Safety goggles or glasses
Lab aprons
Gloves

OPTIONAL MATERIALS (NOT PROVIDED)

	Hot plates or temp-controlled water baths
1 pkg.	Kidney bean seed, viable, 1 lb
1 pkg.	Seeds, black-eyed peas, 1 lb

This lab activity 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.

With links to:

- **Big Idea 1:** The process of evolution drives the diversity and unity of life; and
- **Big Idea 4:** Biological systems interact, and these interactions possess complex properties.

Enduring Understandings

- 1B1: Organisms share many conserved core processes and features that evolved and are widely distributed among organisms today.
- 2A1: All living systems require constant input of free energy.
- 2A2: Organisms capture and store free energy for use in biological processes.
- 2B3: Eukaryotic cells maintain internal membranes that partition the cell into specialized regions (e.g., mitochondria).
- 4A2: The structure and function of subcellular components, and their interactions, provide essential cellular processes.
- 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.
- 3.1 The student can pose scientific questions.
- 6.1 The student can justify claims with evidence.
- 6.2 The student can construct explanations of phenomena based on evidence produced through scientific practices.
- 7.2 The student can connect concepts in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.

LEARNING OBJECTIVES

- The student is able to describe specific examples of conserved core biological processes and features shared by all domains or within one domain of life, and how these shared, conserved core processes and features support the concept of common ancestry for all organisms (1B1 & SP 7.2).
- The student is able to justify the scientific claim that organisms share many conserved core processes and features that evolved and are widely distributed among organisms today (1B1 & SP 6.1).
- The student is able to justify a scientific claim that free energy is required for living systems to maintain organization, to grow, or to reproduce, but that multiple strategies exist in different living systems (2A1 & SP 6.1).
- The student is able to use representations to pose scientific questions about what mechanisms and structural features allow organisms to capture, store, and use free energy (2A2 & SP 1.4, SP 3.1).
- The student is able to use representations and models to describe differences in prokaryotic and eukaryotic cells (2B3 & SP 1.4).
- The student is able to construct explanations based on scientific evidence as to how interactions of subcellular structures provide essential functions (4A2 & SP 6.2).
- The student is able to apply mathematical routines to quantities that describe interactions among living systems and their environment, which result in the movement of matter and energy (4A6 & SP 2.2).

TIME REQUIREMENTS

If you order any of the live materials suggested in Part 3, please order 2 weeks prior to the date of the lab to allow for on-time delivery.

Part 1: Structured Inquiry – Respirometer Assembly and Structured Lab	60 minutes
Part 2: Guided Inquiry – Respirometer Assembly and Guided Lab Optional—do concurrently with Part 1 with additional respirometers.	45 minutes
Part 3: Open Inquiry – Student Designed Experiment	Varies, depending on students' experiment designs

SAFETY PRECAUTIONS

Lab Specific Safety

- See the last pages of this booklet for the potassium hydroxide Materials Safety Data Sheet (MSDS). Review all precautions, handling procedures, storage, and disposal information. The most updated MSDS version can be found at www.wardsci.com.
- Potassium hydroxide is a poison if ingested and is very corrosive to all body tissues. Handle with extreme caution.

General Safety

- 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. *(Note: There are no live care sheets included in this particular lab.)* 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.
- 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.

NOTES

PRE-LABORATORY PREPARATION

1. **Two days before performing the investigation:**
   a) Prepare the germinating peas in the following manner: place half of the peas provided in a beaker or pan, cover them with warm water, and leave them overnight (the non-germinated seeds can be used for guided or self-directed study).
   b) Make copies of the Student Guide (copymaster pages).
2. **The day before the lab:**
   a) Place a dampened paper towel in a resealable bag, and place the peas on the paper towel. Cover the peas with another dampened paper towel.
   b) Partially inflate the bag by exhaling into it a few times (the CO_2 will speed up germination), then seal.
   c) Store the bag in a warm, dark area until ready for use.
   d) Prepare the water bath by filling one of the large trays with distilled water until it reaches a level about an inch from the top, and let it equilibrate overnight to about 20 °C.
   e) Cut the non-absorbent rayon balls so that they are slightly smaller than the absorbent cotton balls.