AP® INVESTIGATION #10

ECOLOGY: ENERGY DYNAMICS – TEACHER'S GUIDE

Kit # 36W7410

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ABSTRACT

In this lab, students investigate the factors that affect energy capture, allocation, storage and transfer in a model ecosystem. Students track changes in the mass of both autotrophs (producers) and the heterotrophs that feed upon them (consumers), and analyze energy usage through accounting methods in the two types of interacting organisms – plants and insects.

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.

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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	Jiffy Greenhouse
1 pkg.	Hollyhock seeds
1 pkg.	Lupine seeds
30	Butterfly cups
30	Butterfly lids
1	Butterfly pavilion
1 box	Miracle Gro®
1	Wick
1	Live Perishable Items Fulfillment Coupon*: Includes coupon for 300 butterfly eggs, 30 larvae, 200 g food, 30 soufflé cups with lids, 1 scoop, and 1 paintbrush
1	Instructions (this booklet)

**** - It is recommended that you redeem your coupon for live/ perishable materials as soon as possible and specify your preferred delivery date. Generally, for timely delivery, at least two weeks advance notice is preferred.***

MATERIALS NEEDED BUT NOT PROVIDED

Lab notebook
Oven
Scale, 001 g sensitivity
Digital camera
10% bleach
Orange Gatorade
Plant station with grow light
Other materials as determined by students' experiment design

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

OPTIONAL MATERIALS (NOT PROVIDED)

Hollyhock plant
Additional food for butterfly larvae
Additional cups/lids for butterfly larvae
Soil mix

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 4**: Biological systems interact, and these interactions possess complex properties

Also connects to:

- **Big Idea 2:** Biological systems utilize energy and molecular building blocks to grow, to reproduce, and to maintain homeostasis.
- **Big Idea 1**: The process of evolution drives the diversity and unity of life.

Enduring Understandings

- 2A1: All living systems require constant input of free energy.
- 2D1: All biological systems from cells and organisms to populations, communities and ecosystems are affected by complex biotic and abiotic interactions involving exchange of matter and free energy.
- 4A6: Interactions among living systems and with their environment result in the movement of matter and energy.

Science Practices

- 1.3 The student can refine representations and models of natural or man-made phenomena and systems in the domain.
- 2.2 The student can apply mathematical routines to quantities that describe natural phenomena.
- 3.2 The student can refine scientific questions.
- 4.2 The student can design a plan for collecting data to answer a particular scientific question.
- 5.1 The student can analyze data to identify patterns or relationships.
- 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.
- 6.4 The student can make claims and predictions about natural phenomena based on scientific theories and models.
- 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 explain how biological systems use free energy based on empirical data that all organisms require constant energy input to maintain organization, to grow, and to reproduce (2A1 & SP 6.2).
- 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 predict how changes in free energy availability affect organisms, populations, and ecosystems (2A1 & SP 6.4).
- The student is able to refine scientific models and questions about the effect of complex biotic and abiotic interactions on all biological systems from cells and organisms to populations, communities, and ecosystems (2D1 & SP 1.3, SP 3.2).
- The student is able to design a plan for collecting data to show that all biological systems are affected by complex biotic and abiotic interactions (2D1 & SP 4.2, SP 7.2).
- The student is able to analyze data to identify possible patterns and relationships between a biotic or an abiotic factor and a biological system (2D1 & SP 5.1).
- 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).
- The student is able to predict the effects of a change of matter or energy availability on communities (4A6 & SP 6.4).

TIME REQUIREMENTS

	TIME FRAME	TEACHER TASK(S)	STUDENT TASK(S)
PRE-LAB PREP	At least 2 weeks before lab	Redeem coupon for live materials	
	1 day before lab	Expand peat pellets (See page 10)	
		Mix butterfly diet. (See page10)	
		Set up plant growth area	Read lab and safety precautions
PARTS 1 & 2: STRUCTURED INQUIRY AND GUIDED INQUIRY	Lab Day 1	Divide 30 pack of larvae into 8 lab groups (See page 10)	Plant hollyhock seeds Set up larvae
	Week 1		Care for plants and larvae, collect data (approx. 10 minutes/day)
	Week 2		Care for plants and larvae; Collect data (approx. 10 minutes/day) Analysis for Parts 1 & 2
PART 3: OPEN INQUIRY	Week 3 (Total time depends on student/teacher scheduling and paramaters of experiment)		Depends on student/teacher scheduling and parameters of experiment

NOTES

SAFETY PRECAUTIONS

Lab-Specific Safety

- If you are setting up a light system for your plants, make sure that water does not get on electrical connectors.

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. 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.

PREP TIP

- In this lab you will use live materials (including butterfly eggs and larva). **Prior to starting this lab, submit your live/perishable material redemption coupon via mail, fax, or simply calling into customer service at 1-800-962-2660.** ***It is recommended that you do this at least two weeks before the lab.***

PRE-LABORATORY PREPARATION

Redeem your coupon for all live materials at least one week before you are ready to start this lab.

One day before starting the lab:

1. Expand Jiffy peat pellets. Add 1 envelope or about 5 mL (about 1 scoopful) of fertilizer to 2.5 L of water and soak the peat pellets in their tray for about 2 hours or until peat pellets are more than 2.5 cm tall. Pour off excess water if necessary. Additional watering does not require additional fertilizer.
   - Plan to divide the 72 peat pellets amongst your students. If you have 8 student groups, a 3 x 3 block of 9 plants should be sufficient to generate data that can be pooled for the entire class.
2. In a 500 mL beaker, mix the 100 g of dry butterfly diet with 200 mL of deionized or distilled water. The consistency should resemble cookie dough. Cover and store in refrigerator overnight.
3. Set up the growing area as close to optimal as possible.
   - Optimal temperature is 23-25 degrees C.
   - Grow lights on a timer to deliver 16 hours of light/8 hours of dark at an intensity of 100-150 $\mu mol/m^2/s$.
4. Make copies of the Student Guide (copymaster pages).

On the day of the lab:

1. You or your students can divide the 30 pack of painted lady larvae into groups of 4 to 7 for your 8 lab groups (cups are over-packed to assure a minimum of 30 arrive alive). They may be transferred from the cup they came in into the empty cups (put lid on after transfer) using the paintbrush included until students are ready to use them.

OBJECTIVES

- Explain how biological systems use free energy based on empirical data that all organisms require constant energy input to maintain organization, to grow, and to reproduce.
- 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.
- Predict how changes in free energy availability affect organisms, populations, and ecosystems.
- Refine scientific models and questions about the effect of complex biotic and abiotic interactions on all biological systems from cells and organisms to populations, communities, and ecosystems.
- Design a plan for collecting data to show that all biological systems are affected by complex biotic and abiotic interactions.
- Analyze data to identify possible patterns and relationships between a biotic or an abiotic factor and a biological system.
- Apply mathematical routines to quantities that describe interactions among living systems and their environment, which result in the movement of matter and energy.
- Predict the effects of a change of matter or energy availability on communities.

BACKGROUND

On land, plants are the main producers of energy for biological systems. Plants use photosynthesis to capture and transform light energy into energy stored in the chemical bonds of complex organic molecules. Plants transform energy into biomass independent of other organisms, so they are referred to as autotrophs, or primary producers. The gross productivity of a producer is a measure of the energy captured. Net productivity subtracts out the energy lost as heat (waste) and spent by the plant to support processes like growth and reproduction. The energy that is successfully captured as plant biomass by chloroplasts may be used to power respiration or may be stored and consumed at a later time. Changes in biomass can be measured by calculating the change in weight over a given time frame. Water content will alter the measurement of the weight of the organic molecules, resulting in an inaccurate measure of biomass. To get an accurate measure of biomass, the sample should be dehydrated. The dehydrated biomass is made up of proteins, carbohydrates and fats that can be transformed back into energy by catabolism through the respiratory pathway at a variety of entry points. In general, organic molecules like proteins and carbohydrates can store about 4.35 kcal/g of dry weight, while fats can store more than twice as much at about 9 kcal/g of dry weight.

Primary consumers (or heterotrophs) are fully dependent upon other organisms to obtain energy and will consume autotrophs to get the energy necessary for growth and development as well as reproduction. Heterotrophs are not completely efficient in transforming biomass back into energy, and thus produce waste that includes heat, metabolic byproducts, and the body of the organism once it is no longer alive. The energy remaining in these waste products is subsequently harvested by organisms that complete decomposition of waste into simpler molecules that can be used as nutrients and building blocks for the next cycle of energy capture.

In this laboratory you will investigate ways to track energy flow through a simple model ecological system. You will use common hollyhock as the primary producer of energy and monitor the rate at which it generates biomass under known conditions. The larval painted lady butterfly will be investigated as a primary consumer of the hollyhock biomass, and its transformation of plant biomass to animal biomass and waste will also be investigated.

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