CollegeBoard
inspiring minds™

AP® Biology Lab Manual for Teachers

Supplement

Carolyn Schofield Bronston and Allison Ingram

The College Board

The College Board is a not-for-profit membership association whose mission is to connect students to college success and opportunity. Founded in 1900, the College Board is composed of more than 5,600 schools, colleges, universities and other educational organizations. Each year, the College Board serves seven million students and their parents, 23,000 high schools, and 3,800 colleges through major programs and services in college readiness, college admissions, guidance, assessment, financial aid, enrollment, and teaching and learning. Among its best-known programs are the SAT®, the PSAT/NMSQT® and the Advanced Placement Program® (AP®). The College Board is committed to the principles of excellence and equity, and that commitment is embodied in all of its programs, services, activities and concerns.

For further information, visit www.collegeboard.com.

Contents

Introduction

Lab 1: Diffusion and Osmosis 1

Lab 2: Enzyme Catalysis 3

Lab 3: Mitosis and Meiosis 6

Lab 4: Plant Pigments and Photosynthesis 8

Lab 5: Cell Respiration 10

Lab 6: Molecular Biology 12

Lab 7: Genetics of Organisms 14

Lab 8: Population Genetics and Evolution 17

Lab 9: Transpiration 19

Lab 10: Physiology of the Circulatory System 22

Lab 11: Animal Behavior 25

Lab 12: Dissolved Oxygen and Aquatic Primary Productivity 27

Related Links to AP® Biology Free-Response Questions 30

About the Authors 31

Introduction

The 12 recommended labs that were developed for the College Board's AP® Biology program (sentimentally dubbed "The Dirty Dozen") have always served as a testament to the belief that science does not happen in a textbook or in a lecture, but occurs when students engage in a "hands-on and personal" investigation of living things and their processes.

For each of the AP labs, the supplement pages attempt to:

- point out the most common difficulties and misconceptions that students experience concerning the lab topic;
- mention useful modifications in lab preparation or procedure and share cost-cutting and time-saving tips from fellow teachers;
- suggest ways in which the lab can become more open-ended and inquiry based;
- discuss technology options for carrying out the lab;
- provide links to past AP Exam questions that model good assessment tools and help determine the level of student understanding of the lab work and the concepts upon which it is based;
- provide links to alternative labs that will satisfy the lab objectives and outstanding resources for the topic (Note: The Web sites listed in this supplement were all functioning at the time of publication.)

Lab 1: Diffusion and Osmosis

Overview

The information will assist teachers with aspects of Lab 1 that are not necessarily addressed in the *Lab Manual*. These suggestions are provided to enhance the students' overall lab experience as well as their conceptual understanding.

Addressing Student Misunderstandings

- Many students conclude that the terms iso-, hypo- and hypertonic refer to water content rather than to the solutes in the solution. Remind them that hypotonic translates as "low solutes" and, therefore, a higher percentage of water content.
- Water potential is an extremely difficult concept for students. It is defined as the measure of the relative tendency of water to move from a higher potential to a lower potential. Stress that the more negative the water potential, the higher the concentration of solutes present in the system: the water potential of distilled water is zero.

Suggestions for Procedural Modifications

- Be sure that the bags do not leak, that room is left for expansion and that the students use *the same balance* to weigh the bags before submersion and after submersion.
- Filling dialysis bags is often messy: large 50 mL syringes work very well and avoid overflow from beakers or funnels.
- Cheap sandwich bags can be used in place of the more expensive dialysis tubing in Exercise 1A.
- A French fry cutter produces potato strips that are easily cut into perfect cubes, eliminating the problems associated with cork borers in Exercise 1C.
- Red onions or *Tradescantia pendula* are excellent for plasmolysis in Exercise 1E.

Ideas for Introducing Inquiry

Interesting modifications to this lab can open it up to inquiry. Try using different types of potatoes (russet, Yukon, sweet) or fruits (apple, pear) in part 1C. Because of their varying natural sugar concentrations, the water potential will be very different. Students can make hypotheses on water potential values based on the evidence they gather for their predictions, and then carry out the experiments to test their beliefs. Given appropriate supplies, the students can also be asked to design and carry out their own experiments.

Technology Integration

The use of technology can be added into the protocol with use of calculators. See a modification to the lab from Access Excellence teacher Jeffrey Lukens at http://www.accessexcellence.org/AE/AEC/AEF/1995/lukens_analysis.php.

Alternative Labs/Resource Ideas

The classic experiment that uses eggs whose shells are removed using vinegar is a powerful one if it was not already part of courses taken prior to AP Biology. Consult Troy High School's Web site at http://www.troy.k12.ny.us/thsbiology/labs_online/home_labs/print_versions/osmosis_lab_home_print.html.

Preparation of agar cubes (and other shapes) made with phenolphthalein is a popular addition to the unit. Math calculations can add another facet to the study by asking how much of each cell is *not* affected by diffusion after a given amount of time. One possible protocol by Kirk Brown can be found at Access Excellence's Web site.

http://www.accessexcellence.org/AE/SH/NSTA_SF/brown.php

Good teacher information and demonstration suggestions for diffusion and osmosis topics as well as lab protocols can be found at the University of Arizona's "the biology project."

http://biology.arizona.edu/sciconn/lessons2/McCandless/page1.htm

A resource for understanding this lab, including basic explanations on all concepts, animations and quizzes to check comprehension, can be found at Pearson Education's Lab Bench site.

http://www.phschool.com/science/biology_place/labbench/lab1/intro.html

Visit "Twelve AP Biology Labs: Information and Tips" available through the AP Biology Course home page for specific teacher comments on this lab.

http://apcentral.collegeboard.com/apc/members/homepage/34458.html

Lab 2: Enzyme Catalysis

Overview

The information will assist teachers with aspects of Lab 2 that are not necessarily addressed in the *Lab Manual*. These suggestions are provided to enhance the students' overall lab experience as well as their conceptual understanding.

Addressing Student Misunderstandings

- Students equate high rate of reaction with the rapid time of completion. Rate reflects how quickly the enzyme is performing its job; time of completion is impacted both by enzyme rate and by amount of substrate.
- Titration is often done to find the amount of product generated (as in Lab 12); here students will find the amount of reactant (substrate) remaining uncatalyzed. Revisit the reaction equation to make sure they understand what they are measuring.

Suggestions for Procedural Modifications

- Students will often try to titrate the entire reaction mixture rather than a 5mL sample, and will often miss the titration endpoint, putting in too much permanganate and causing a big source of error in precise measurement. Reiterate the fractional titration amount and stress that the titration should be watched carefully when the pink color begins to linger rather than instantaneously disappearing.
- The importance of control run with titration after no enzyme (only water) is added is often lost on students. It will be impossible for them to calculate rates of reaction without knowledge of "zero time" titration numbers; help them determine the need for that baseline.
- If purified/crystallized catalase (available from many supply houses) is not available, calf liver or chicken gizzards can be blended with distilled water and filtered. Many teachers use one package of dry yeast in 250 mL warm water successfully.

- When burettes are not available, titration can be done with droppers (counting drops) or with syringes (which can easily measure mLs).
- Many teachers have found the value of using small white plastic bathroom cups for titration. (It is easy to see the color changes, and they are unbreakable.)

Ideas for Introducing Inquiry

Many teachers have expanded this lab and opened up inquiry possibilities concerning factors that might influence enzyme catalysis rate. From changes in enzyme and substrate concentrations to variations in pH, salinity and temperature (stay under 60°C for best results), plus investigations of inhibitors, students should be able to design reasonable protocols and run trials to determine optimal conditions for the enzyme. Another interesting addition is the "Enzyme Races" where students try to get the highest initial rate of reaction using 10 mL of fluid (any combination of components they wish and at any condition); those who truly understand the factors that affect speed have a great advantage!

Other variations might include the investigation of catalase from various sources (such as beef liver and potatoes) to investigate whether the optimal conditions for the same enzyme vary from kingdom to kingdom, or whether the amount of enzyme per unit of tissue differs in various types of related organisms (see *Journal of Chemical Education* table below).

Relative Catalase Activity in Selected Source Materials

Source	Relative activity
Potato	**1.0**
Potato shoot	**0.3**
Leek	**3.6**
Parsnips	**6.4**
Horseradish root	**0.5**
Raw milk	**7.5**

Reprinted from *Journal of Chemical Education*, Vol. 74, p. 211, February 1997.

Technology Integration

Use of gas pressure probeware provides a different means of running Lab 2 (a) more rapidly, (b) without the necessity of using caustic sulfuric acid or messy permanganate stain and (c) without timing problems involved in stopping the reaction at specific points. This protocol indirectly measures the output of one of the products (not the actual amount of O_2 gas but the pressure it produces), and is virtually flawless (if your probes are connected correctly and the stopper does not pop off). Every probeware company has a variation of Lab 2 with complete instructions in its experiment library.

Note: For students who have used both variations of the lab procedure, evaluation questions that ask for comparisons of the methodology and the meaning of the results quickly show if the concepts are understood on more than a cursory level.

Alternative Labs/Resource Ideas

Information on using enzymes for juice production, which also brings in some economics, can be found at the Scribd Web site.
http://www.scribd.com/doc/2656226/Lab-Enzymes

Ideas from Sharon Miller on several enzymes, including amylase, catecholase, invertase, papain, pectinase, pepsin and rennin, are at
http://www.ableweb.org/volumes/vol-6/10-miller.pdf.

Using turkey hearts as a source of succinate dehydrogenase, Brad Graba's Web site provides a protocol for investigating rates of reaction, effects of pH and inhibitors.
http://www.fhs.d211.org/departments/science/bgraba/AP%20Handouts/AP%20BIO%20CHEM%20UNIT/Bio449%20EnzymeExper.BWG.pdf

Visit "Twelve AP Biology Labs: Information and Tips" available through the AP Biology Course home page for specific teacher comments on this lab.

http://apcentral.collegeboard.com/apc/members/homepage/34458.html

Lab 3: Mitosis and Meiosis

Overview

The information will assist teachers with aspects of Lab 3 that are not necessarily addressed in the *Lab Manual*. These suggestions are provided to enhance the students' overall lab experience as well as their conceptual understanding.

Addressing Student Misunderstandings

- To obtain a gene to centromere distance in the meiosis section of the lab, crossover asci count is always divided by two. Although this is initially puzzling to students, remind them that since "the number of map units between two genes ... is equal to the percentage of recombinants" and since only half the spores in an ascus are able to recombine, it makes sense to divide by two.

Suggestions for Procedural Modifications

- *Sordaria* fungus can be a finicky grower, and some students are allergic to its spores, so always have prepared slides or photographs available with which to complete the lab.
  http://river.vansd.org/14544/Adv_Biology/Sordaria%20Tetrad%20Pictures.htm

Ideas for Introducing Inquiry

An excellent way to enhance inquiry for the mitosis section involves requiring the students to prepare the slides used for estimating time in each phase of the cell cycle. A simple protocol using green onions and an acid/acetocarmine stain produces some excellent squash preparations of root tips. These are perfect for counting and have the added benefit of convincing the students that the process is really occurring in living things! Other types of roots can be used and the results compared.
http://www.hcs.ohio-state.edu/hort/biology/Lab/mitosislab.html

A different protocol involves use of toluidine blue to stain chromosomes.
http://faculty.valenciacc.edu/tklenk/labs/mitosislab.htm

Alternative Labs/Resource Ideas

Mitosis World includes links to movies and slides including whitefish blastulas, onion root tips, etc.
http://www.bio.unc.edu/faculty/salmon/lab/mitosis/mitosis.html

Meiosis Square Dance (a cartoon song and dance explaining the process) can be downloaded from You Tube's archives.
http://www.youtube.com/watch?v=eaf4j19_3Zg

A resource for understanding this lab, which includes basic explanations on all concepts, animations and quizzes to check comprehension, can be found at Pearson Education's Lab Bench site.
http://www.phschool.com/science/biology_place/labbench/lab1/intro.html

Visit "Twelve AP Biology Labs: Information and Tips" available through the AP Biology Course home page for specific teacher comments on this lab.

http://apcentral.collegeboard.com/apc/members/homepage/34458.html

Lab 4: Plant Pigments and Photosynthesis

Overview

The information will assist teachers with aspects of Lab 4 that are not necessarily addressed in the *Lab Manual*. These suggestions are provided to enhance the students' overall lab experience as well as their conceptual understanding.

Addressing Student Misunderstandings

- Students often fail to understand why the transmittance numbers are going up in part 4B; they mistakenly attribute it to creation of oxygen gas or removal of CO_2 from the solution. The solution becomes lighter because DPIP (a substitute for NADP+) is complexing with electrons produced by the light reactions, reducing and changing the dye from blue to colorless.

Suggestions for Procedural Modifications

- For students to be successful with Spec 20 machines, specific instructions need to be given both verbally *and* in print, especially the initial zeroing with blank tube #1.
- "Boiling" chloroplasts often causes them to clump: instead, heat only to 60 degrees or microwave for 15 seconds — enough to denature! Re-blending can also alleviate the clumping.
- If chemicals for chromatography solvent are not available, isopropyl (rubbing) alcohol has been touted as doing an excellent stand-in job.
- If the coin delivery of pigment has not worked well, try macerating the leaves in acetone (under a fume hood) using a mortar and pestle, then "painting" a line of the extract with a capillary tube. Much more pigment is delivered and bands will be more vivid.
- Buffer solution can be made by using pH 5 and pH 7 Chemvelope solutions (or buffer capsules for smaller amounts) and simply mixing ¾ pH 7 with ¼ pH 5 to achieve pH 6.5 for the needed phosphate buffer solution.

Ideas for Introducing Inquiry

To add more inquiry to this lab, consider using various specific wavelengths of light (such as colored bulbs or cellophane) or intensities of light (such as the screens from Lab 12 Dissolved Oxygen) or varying the distance from the light source to see the effect on the normal, unboiled chloroplasts' rate of dye reduction.

Most freshmen classes do a chromatograph of photosynthetic pigments. Many teachers take advantage of this to skip this section. But use of (a) different leaves (successful alternatives include magnolia, geranium and mulberry; if performing in the fall, try some leaves that have lost their "green" to compare with those still chlorophylled) and (b) different solvents can turn this section into a real investigation about experimental setup and variation in plants.

Technology Integration

Colorimeters provide an excellent and less expensive alternative to the Spec 20 machines. Teachers without any technology availability can set up 11 DPIP dilutions to simulate 0–100 percent transmittance that will allow the students to estimate changes.

Alternative Labs/Resource Ideas

See Brad Williamson's alternative lab protocol using leaf discs at
http://www.elbiology.com/labtools/Leafdisk.html.

A resource for understanding this lab, which includes basic explanations on all concepts, animations and quizzes to check comprehension, can be found at Pearson Education's Lab Bench site.
http://www.phschool.com/science/biology_place/labbench/lab1/intro.html

Visit "Twelve AP Biology Labs: Information and Tips" available through the AP Biology Course home page for specific teacher comments on this lab.
http://apcentral.collegeboard.com/apc/members/homepage/34458.html

Lab 5: Cell Respiration

Overview

The information will assist teachers with aspects of Lab 5 that are not necessarily addressed in the *Lab Manual*. These suggestions are provided to enhance the students' overall lab experience as well as their conceptual understanding.

Addressing Student Misunderstandings

- Students have difficulty understanding what to do with the thermobarometer data. They do not understand that even over a short time period, barometric pressure can rise or fall, affecting the quantification of O_2 gas uptake. Added to the fact that the pressure may fluctuate back and forth during the experiment (notoriously caused by cycling of air conditioners and heaters), a careful explanation and initial monitoring of calculation of "corrected differences" are vital. Changes in barometric pressure must be added or subtracted from pea respiration data to achieve reliable data.

Suggestions for Procedural Modifications

- Respirometer tubes must be airtight. Many teachers have successfully used big 200 mL test tubes with 2 mL plastic pipettes inserted into 4X stoppers (added advantage of handling 40 peas/beans — 2X suggested number — with consequent increase in oxygen consumption). Silicon caulking of loose pipettes may also help.
- If the air-water interface is hard to visualize, the addition of a piece of aluminum foil to the bottom of the trough will reflect light and emphasize the bubble.
- Wallpaper troughs make excellent water baths, accommodating the longest apparatus.
- KOH is messy and often leaks into the seeds. The use of soda lime, a solid easy to keep above the seeds by a small cotton ball, solves that problem.

Ideas for Introducing Inquiry

Though English peas are the suggested organisms for this lab, pinto beans are another excellent choice, as are kidney, navy and other beans. Add some inquiry by allowing groups to use different seeds and compare the results, suggesting reasons for any differences noted.

Temperature is already a factor in the lab protocol, but the addition of other levels — for example 37 degrees (normal human body temperature) and 45 degrees (desert heat temperature) — allows a greater range as students inquire about the effect of large changes of temperatures on respiration.

Other inquiry inclusions for this lab might be the use of small animals such as grasshoppers, crickets or small frogs.

With a larger respirometer device (which can be purchased from supply houses or constructed from mason jars by adding very large stoppers with pipettes), it would be possible to contrast the respiration rate of an ectothermic organism (frog or small snake) versus a comparably sized endothermic organism (small mouse) as the temperatures change.

Technology Integration

Technologically, the use of gas pressure probes is an option, allowing runs of the thermobarometer and one experimental setup at a time. But the O_2 probe or CO_2 probes may be a superior alternative because they eliminate the BIG problem of correcting for changes in barometric pressure. Since each of these probes measures the gas used or produced directly, the results are clean. Additionally, these gas probes make it very easy to encourage inquiry as students can design new lab ideas and test them quickly with minimal staging time.

Alternative Labs/Resource Ideas

Fermentation is sometimes an overlooked aspect of cellular respiration. Using yeast with different sugars such as glucose, fructose and sucrose (interestingly, yeasts are lactose "intolerant" unless Lactaid is added), it is possible to investigate the anaerobic pathway that allows organisms to survive and make ATP even when oxygen is missing. http://apcentral.collegeboard.com/apc/members/courses/teachers_corner/4060.html

A resource for understanding this lab, which includes basic explanations on all concepts, animations and quizzes to check comprehension, can be found at Pearson Education's Lab Bench site. http://www.phschool.com/science/biology_place/labbench/lab1/intro.html

Visit "Twelve AP Biology Labs: Information and Tips" available through the AP Biology Course home page for specific teacher comments on this lab. http://apcentral.collegeboard.com/apc/members/homepage/34458.html

Lab 6: Molecular Biology

Overview

The information will assist teachers with aspects of Lab 6 that are not necessarily addressed in the *Lab Manual*. These suggestions are provided to enhance the students' overall lab experience as well as their conceptual understanding.

Addressing Student Misunderstandings

- Note a correction to the student version of the *Lab Manual* on page 68: HaeIII is named because it is the third (not the second) restriction enzyme discovered.
- Use of the word "restriction" can lead to misunderstandings. Most students associate it with "limiting access to" and not as something that cuts or separates. Also, many classes have studied the cell cycle before this biotechnology unit; there, restriction sites refer to the checkpoints within the cycle mediated by cyclins and CDKs. Point out the multiple meanings of this term.
- "Digest" evokes similar problems. Most students associate it with breaking down food, not with cutting pieces of DNA at specific sites.

Suggestions for Procedural Modifications

- This lab is best accomplished by the use of a commercial kit: many companies offer excellent Lab 6 options with faster protocols and improved methodology. Consult veterans or the AP electronic discussion group for suggestions. To help keep costs in check, consult with colleges in the area for possible help with agarose, etc. If there are other AP schools in the area, work out a system to share the electrophoresis equipment or borrow items from a nearby university.
- While the use of special water baths and incubators is a convenience, heated water can be monitored and adjusted through a timed cycle; an open box with a gooseneck lamp above it serves as an adequate incubator.
- It is possible to reuse the gels made for electrophoresis if DNA is "run off" the gel and the gel is then soaked in distilled water to remove any stain. Keep the gel in a plastic bag with some buffer in the refrigerator for later classes/demonstrations. It is also possible to remelt and recast them at this point.
- Experts at one supply company also say that buffer can be reused five to six times

if it is kept in sealed jugs (be sure to combine the buffer from both sides of the electrophoresis chamber).

- After adding 10 percent bleach solution and allowing the plates to stand for 15 minutes, bacterial plates can be safely thrown away. Taping the plates closed will help alleviate the mess.

Ideas for Introducing Inquiry

Other variations of this lab can be done with electrophoresis of protein molecules that highlight evolution among different groups of mammals or fish (kits are available from various supply houses). This allows the students to do an inquiry about the biochemical relationships of organisms. Forensic simulations using DNA fingerprinting are also readily available, as are studies of mitochondrial DNA and detection of GMOs in food products, opening up many avenues of inquiry.

Brad Williamson has shared his paper-and-pencil lab, which allows students to take their basic knowledge on restriction enzyme digestion and electrophoresis learned in Lab 6 and apply it to a new situation in which four different enzymes have digested a genome in an effort to find a single gene of interest. See his inquiry activity and sample results on AP Central®.

Alternative Labs/Resource Ideas

Many teachers do Rainbow Electrophoresis either in a class prior to AP Biology or as an exercise prior to or as a warm-up for Lab 6.
http://www.woodrow.org/teachers/bi/1993/rainbow.html

If DNA extraction was not done in a course prior to AP Biology, a simple and foolproof procedure can be found at the University of Utah's Genetic Science Learning Center.
http://learn.genetics.utah.edu/content/labs/extraction/howto/

A resource for understanding this lab, which includes basic explanations on all concepts, animations and quizzes to check comprehension, can be found at Pearson Education's Lab Bench site.
http://www.phschool.com/science/biology_place/labbench/lab6/intro.html

Visit "Twelve AP Biology Labs: Information and Tips" available through the AP Biology Course home page for specific teacher comments on this lab.
http://apcentral.collegeboard.com/apc/members/homepage/34458.html

Lab 7: Genetics of Organisms

Overview

The information will assist teachers with aspects of Lab 7 that are not necessarily addressed in the *Lab Manual*. These suggestions are provided to enhance the students' overall lab experience as well as their conceptual understanding.

Addressing Student Misunderstandings

- Students often do not understand the inheritance pattern associated with sex-linked traits. Be sure that students understand the genetic determination of gender. The instructor should also explain the difference between linkage and sex linked. Last, be sure that the students have a clear understanding of why sex-linked traits are most often observed in males.
- Verify that the students have a thorough understanding of the mode of inheritance for each trait.
- Explain Mendel's Law of Independent Assortment. Students will need a clear understanding of this law to understand the rationale behind dihybrid crosses. Be sure that they understand that alleles for different genes are inherited independently of one another.

Chi-square analysis is often very confusing for students. Explain that the information collected from their experiments only contributes to the existing data. In science, we can never say that a hypothesis has been proven to be 100 percent accurate. The instructor should perform sample problems to be sure that the students have a clear understanding of chi-square analysis. Verify the degrees of freedom (df) value for each cross and explain all aspects of the chi-square table (p, critical value, etc.).

- Be sure that the students understand what it means to reject or accept a null hypothesis.

Suggestions for Procedural Modifications

- Plan accordingly. Order your specimen at least two weeks in advance so that you have time to prepare the specimen and to ensure that students have time to perform all the needed crosses.

- If you are performing the P_1 crosses, it is advisable to cross these during the weekend or when you have ample time to remove the virgins.
- Verify that the flies are continually maintained at an appropriate temperature (approximately 21–25°C).
- To remove the flies for scoring, have the students align vials head to head and gently remove the plug from the original vial. Tap the vials together so that the flies fall into the new vial. Quickly place a plug on each vial.
- The instructor should demonstrate the proper technique for anesthetizing flies. If using Styrofoam plugs and FlyNap, do not remove the plugs. Place the FlyNap on the bristle and insert the bristle into the vial without removing the plug. Be sure all flies are out before removing the plug.
- Students should record mating dates/times to ensure they are clearing the P_1 and F_1 vials as needed to prevent parental and progeny mating.

Ideas for Introducing Inquiry

Students can make early observations using a stereomicroscope and “sample flies.” Provide each group with a fly that is wild type for all traits. The students should record all observable traits and record them as “prior observations.” They will also make observations about visible traits that may characterize gender. Next, provide each group with a fly that is mutant for one of the traits (i.e., eye color, wing type, etc.). As the students observe these flies, have them record any visible differences if comparing the second set of flies to those originally observed. Students should make predictions concerning which traits are normal and which are mutant. After they have completed this activity, have them research *Drosophila melanogaster*. It is important that students locate information pertaining to determination of gender, wild type alleles, mutant alleles and all sex-linked traits. After they have completed their research, allow the students to organize their information using a discussion-type format. They should discuss and reach conclusions about determination of gender, wild type, recessive and sex-linked alleles. The instructor should validate all information.

This portion of the inquiry-based activity can be performed if P_1 generations are performed by the supply company or by the instructor. The instructor should assign all F_1 crosses a number (e.g., vial 1A, vial 2A, etc.). Do not inform students of the P_1 generation for each cross. They should make observations of the F_1 generation and, using their previously collected data, deduce the parental cross. The instructor should verify that the predicted offspring for the parental generations are correct. Once the students have correctly deduced the genotype of the F_1 generation, they can score their flies and perform their F_1 crosses.

Technology Integration

Several commercial vendors sell CD- ROMs that allow students to collect and analyze data of readily observable genetic traits. The software provides students with an understanding of a monohybrid, dihybrid or sex-linked cross using chi-square analysis techniques. Information for suggested commercial vendors can be found on the AP Biology course home page on AP Central under Lab Activities and Resources.

There are also several online virtual labs that may be used to supplement this activity. Online virtual activities can be accessed using the following Web sites: http://bioweb.wku.edu/courses/Biol114/Vfly1.asp or http://www.sciencecourseware.org/vcise/drosophila/Drosophila.php?guestaccess=1

Alternative Labs/Resource Ideas

Visit "Twelve AP Biology Labs: Information and Tips" available through the AP Biology Course home page for specific teacher comments on this lab.

http://apcentral.collegeboard.com/apc/members/homepage/34458.html

Lab 8: Population Genetics and Evolution

Overview

The information will assist teachers with aspects of Lab 8 that are not necessarily addressed in the *Lab Manual*. These suggestions are provided to enhance the students' overall lab experience as well as their conceptual understanding.

Addressing Student Misunderstandings

- Explain the concept that natural selection acts on "phenotype." Students often have difficulty understanding natural selection and attribute changes in population makeup to a change in the organism's genotype. As in the case of the peppered moth study, many students have the misconception that individual moths are changing colors. Case II allows students to simulate selection. Continue to emphasize that populations, not individuals, evolve. Organisms that are reproductively fit will pass on their genes. This results in an increase in their population numbers.
- The Case III study allows the instructor to address the misconception that dominance is "better" or the misconception that dominant alleles have a greater chance of being inherited. Students often do not understand that individuals who are heterozygous for a trait might have a selection advantage over homozygous dominant and/or homozygous recessive individuals. The instructor should employ as many examples as possible to facilitate the students' understanding of this concept.
- Students should have a clear understanding of the conditions that result in deviation from the Hardy-Weinberg equilibrium. It is advisable to provide sample problems before the students perform their calculations. Many students often want to take the square root of q^2 and subtract it from 1 to find p. The instructor should explain that allele frequencies (p and q) should be calculated for the population first and then used to calculate genotypic frequencies. The actual and expected frequencies can then be compared to verify if the population is in Hardy-Weinberg equilibrium. The frequencies for the two may or may not coincide. Explain the concept that if there is a deviation between actual values and theoretical values then the population is evolving.

Suggestions for Procedural Modifications

- Instructors will need many “A” and “a” cards prior to the lab. Assign this task as homework prior to the lab.
- If students are hesitant about tasting PTC paper, other traits (such as tongue rolling/non-tongue rolling, widow’s peak/straight hairline, hitchhiker’s thumb/normal thumb, mid-digital hair /no mid-digital, etc.) may be used.

Ideas for Introducing Inquiry

Have the students observe their classmates and write down as many visible physical traits as possible that they believe are controlled by simple dominance. Each student will research one trait to determine whether or not that particular trait is caused by complete dominance. After the students complete their research, the instructor can initiate a class discussion on which traits are governed in this manner. Allow the class to decide on one trait to use to complete Exercise 8A.

After the students have completed Cases II and III, allow them to predict the trends they would observe if the simulations were carried out for another 5 or 10 generations. They should prepare a table with hypothetical numbers and then perform the simulation for another five generations to compare their predicted results to the actual outcome. Allow the students to draw conclusions as to why patterns do or do not continue as observed.

Technology Integration

Several commercial vendors sell CD-ROMs that allow students to collect and analyze data of readily observable genetic traits. The software provides students with an understanding of the mathematical concepts associated with population changes over time. Information about suggested commercial vendors can be found on the AP Biology course home page on AP Central under Lab Activities and Resources.

Alternative Labs/Resource Ideas

Visit “Twelve AP Biology Labs: Information and Tips” available through the AP Biology Course home page for specific teacher comments on this lab.

http://apcentral.collegeboard.com/apc/members/homepage/34458.html

Lab 9: Transpiration

Overview

The information will assist teachers with aspects of Lab 9 that are not necessarily addressed in the *Lab Manual*. These suggestions are provided to enhance the students' overall lab experience as well as their conceptual understanding.

Addressing Student Misunderstandings

- Plant transpiration can be a challenging concept for students to grasp because it is difficult for them to visualize the movement of water through plants. The instructor should review the concepts of root pressure, adhesion, and cohesion and their relationship to transpiration before beginning the activity. It may be beneficial to demonstrate the process of transpiration using celery and food coloring in water or using a plant that has been sealed in a plastic bag (which allows the students to see the condensation of water droplets on the inside of the plastic bag).
- Students may require more clarification on the properties of water. Review the properties associated with water.
- Students often do not understand the effect of temperature, humidity, wind and light on transpiration rates. It is a common misconception that high humidity increases transpiration. The instructor should review the concept that humidity is the amount of water vapor in the atmosphere. When humidity is high in the atmosphere, the air is more saturated with water. Water diffuses from areas of high concentration to areas of lower concentration, so when humidity is high, transpiration rates will slow. If humidity reaches 100 percent, transpiration ceases.
- Students often do not realize that a majority of the water taken in through the root system is lost through the process of transpiration. Because of this they usually do not include plants in their discussion of factors that affect the water cycle. The instructor should review the water cycle to help students see the connection between transpiration and the role of plants in biogeochemical cycles.
- The instructor should also clarify the misconception that stomata numbers are the same for all species of plants.

Suggestions for Procedural Modifications

- Vaseline or pinch clamps can be used to prevent leaks in the potometer. A few biological supply companies carry pinch clamps that can be placed around the tubing to prevent leakage.
- If you purchase leaves from a local nursery, use young, broad leaves as opposed to mature ones to demonstrate transpiration.

Ideas for Introducing Inquiry

Discuss the concepts of the uptake of water through the roots, solute, water potential and root pressure with students. The instructor can then ask them to hypothesize what happens to water once it enters a plant's roots. After they make a hypothesis, discuss the different factors that could influence the movement of water in a plant. Each group will choose one factor that impedes the rate of transpiration or one factor that increases the rate of transpiration. The instructor should not discuss how each factor influences the rate.

The instructor can provide students with a number of materials — plants (impatiens, geraniums or bean plants work well), small fans, light source, metric balance, potometers, Vaseline, pinch clamps, plastic bags, clear fingernail polish, string, tubing, ring stand, clamps, etc. The students will design a controlled experiment to test each factor. The instructor should approve all protocols before the students begin. All procedures should include the proper controls and variables. After data collecting, the students will analyze their data and discuss whether their hypotheses were supported or refuted based on the collected results. They will then draw conclusions about factors that affect transpiration rates.

The students can also design experiments to test whether leaf size affects transpiration rate and whether different plants transpire at different rates.

Technology Integration

The instructor can incorporate technology by using a low-pressure sensor, which can be purchased from a number of commercial vendors. If gas pressure sensors are used, the students will also need computers, interfaces and cables. Plants are connected to low-pressure sensors and instructions are followed as per the users manual. This modification will also alleviate the problem of leaks encountered when using potometers. Information about commercial vendors can be found on the AP Biology course home page on AP Central under Lab Activities and Resources.

Alternative Labs/Resource Ideas

Visit “Twelve AP Biology Labs: Information and Tips” available through the AP Biology Course home page for specific teacher comments on this lab.

http://apcentral.collegeboard.com/apc/members/homepage/34458.html

Lab 10: Physiology of the Circulatory System

Overview

The information will assist teachers with aspects of Lab 10 that are not necessarily addressed in the *Lab Manual*. These suggestions are provided to enhance the students' overall lab experience as well as their conceptual understanding.

Addressing Student Misunderstandings

- Many students do not understand that their heart rates change when their body positions change. Explain the relationship between the forces of gravity and the flow of blood.
- The students should remain in a reclining position while taking their reclining pulse rate. They should not talk during their timed trial.
- Students often equate "thinness" with "fitness." The instructor should explain that there are many factors that contribute to fitness. The students should understand that heredity, environment, gender and age all contribute to the individual's overall fitness.
- Students often confuse diastolic and systolic readings. The instructor should clarify the differences between the terms and explain how the students will determine their systolic and diastolic pressures.
- Students may have the perception that their heart rates will increase to twice the rate if they exercise twice as long. The instructor should explain how the heart compensates for the new stress and increases the blood flow to meet the body's needs.
- Students often want to use the words "cold-blooded" and "warm-blooded" to describe organisms. Verify that these terms are often misleading. The instructor should explain the difference between these terms and why the words "endothermy" and "ectothermy" are more appropriate.

Suggestions for Procedural Modifications

- Students may encounter problems keeping *Daphnia* alive as they adjust their temperatures. It might be advisable for them to take the heart rate immediately as they add the warm water.
- Students can also mark the heart rate on their illustration of *Daphnia* and count all the marks after they have completed their trial.
- Allow a student to serve as a spotter during the cardiovascular portion of the activity in the event that the step tester stumbles.
- If a stool is not available, the students may use bleachers or the bottom steps of the building stairs.
- If asked immediately before the activity, the students may not feel comfortable discussing a medical condition with their teacher. Therefore, the teacher might suggest a few days prior to beginning the lab that students send an e-mail or stop by after school if they have a medical condition that would prohibit their participation in this type of activity. These students may serve as spotters or data recorders for other participants.

Ideas for Introducing Inquiry

In Exercise 10B, determine the number of students who have taken their blood pressure in a grocery store or the local mall. Give the students a heart rate reading and ask them to discuss what the numbers from the reading represent. After they have developed a clear understanding of diastolic and systolic pressure, have each student make predictions about his or her “fitness.” The students should also list the factors that would lead them to make their predictions. It is not necessary for them to discuss their predictions with others. After the students have completed Exercise 10B (Test of Fitness), allow them to compare their predictions with their collected data.

In Exercise 10C, ask the students to explain the terms “cold-blooded” and “warm-blooded.” After they write their definitions, the instructor should clear up any misconceptions they may have about endothermic and ectothermic organisms. Explain why the terms “warm-blooded” and “cold-blooded” are often misleading. Show pictures of several animals and allow the students to guess which are ectotherms and which are endotherms. The pictures should include fish, amphibians, mammals, birds, reptiles and some arthropods. The arthropods should include *Daphnia*. After students have discussed the organisms and the rationale for their groupings, the instructor should clarify any misconceptions they may have before they begin the activity. The instructor should also ask students to hypothesize about the heart rate of *Daphnia* and the expected change of their heart rate as the temperature of the water increases.

Technology Integration

In portions of this activity, the students may use heart rate monitors to measure their heart rates. Many commercial vendors sell heart rate sensors. The use of exercise heart rate monitors often provide more consistent results than those obtained when students are calculating their own heart rates. Information about commercial vendors can be found on the AP Biology course home page on AP Central under Lab Activities and Resources.

Alternative Labs/Resource Ideas

Visit "Twelve AP Biology Labs: Information and Tips" available through the AP Biology Course home page for specific teacher comments on this lab.

http://apcentral.collegeboard.com/apc/members/homepage/34458.html

Lab 11: Animal Behavior

Overview

The information will assist teachers with aspects of Lab 11 that are not necessarily addressed in the *Lab Manual*. These suggestions are provided to enhance the students' overall lab experience as well as their conceptual understanding. Please remind students that any organisms used in this procedure are living and that care should be taken during the investigation.

Addressing Student Misunderstandings

- Students often believe that animal behavior is related solely to genetics or is primarily determined by the environment, mainly the animal's interactions with other organisms. They should have a clear understanding that most behaviors are both genetic and learned and that many genes may affect a trait.
- The instructor should explain the difference between taxis and kinesis. It might be beneficial to provide clear, relevant examples of each before beginning the activity. The instructor should observe students as they perform the lab and pose questions to be sure that they understand the difference between kinesis and taxis.

Suggestions for Procedural Modifications

- If the students are using pH in their investigation, the samples should be diluted to prevent pill bugs from dying. Students should measure the pH of the samples before placing them on the filter paper.
- Use glue sticks to glue filter paper to the choice chamber. Place a small amount around the edges only. This should affix the paper to the petri dish and prohibit pill bugs from crawling under the paper.
- The instructor can maximize instructional time by assigning students the task of collecting five pill bugs *before* they come to class.
- If using fruit flies to perform the experiment, only use virgin female flies. If virgin flies are not ordered, females used as virgins should be collected from the population within 10 hours of emerging from the pupae.
- If you have access to a local zoo or aquarium, the students can perform this lab while observing the behavior of a select group of organisms.

Ideas for Introducing Inquiry

Allow groups to choose one organism (e.g., pill bugs, ants, red worms, etc.) and then research the organism's habitat and any additional information that will facilitate its ability to survive in that environment. The students' research should focus on the organism's natural predators and preferential food source. They should also investigate optimal temperature and pH conditions for soil organisms, the organism's mating behaviors and any fixed-action patterns observed in the species. The groups should select two examples of animal behavior (e.g., circling, decamping, kinesis, taxis, etc.) discussed in the ecology unit. Each group will design controlled experiments to test their two chosen concepts. These could include behavioral response to members of the opposite sex, feeding behaviors, etc. The experimental setups should mimic, as much as possible, the organism's natural environment. Have the students analyze the results of their experiments and generate appropriate conclusions about the behaviors they observed. After they have completed their study, allow the groups to compare data among the organisms studied and hypothesize proximate and ultimate causes for the behaviors they observed.

Technology Integration

The instructor could videotape organisms (e.g., pill bugs, fruit flies, ants, etc.) for a specified period of time and allow the students to view the videotape. They can discuss behaviors and design experiments to test kinesis or other behaviors in one of the organisms viewed.

There are numerous virtual online activities that may be used to supplement this activity. Online virtual activities can be accessed using the following Web site:
http://bioweb.wku.edu/courses/Biol114/Behavior/PIll_bug1.asp

Alternative Labs/Resource Ideas

Visit "Twelve AP Biology Labs: Information and Tips" available through the AP Biology Course home page for specific teacher comments on this lab.

http://apcentral.collegeboard.com/apc/members/homepage/34458.html

Lab 12: Dissolved Oxygen and Aquatic Primary Productivity

Overview

The information will assist teachers with aspects of Lab 12 that are not necessarily addressed in the *Lab Manual*. These suggestions are provided to enhance the students' overall lab experience as well as their conceptual understanding.

Addressing Student Misunderstandings

- Verify the correct use of the nomagram and explain the difference between oxygen concentration and percent saturation. Students often think that these terms are interchangeable. The instructor should explain that oxygen saturation is calculated as the percentage of dissolved O_2 concentration relative to that when completely saturated at the temperature of the measurement depth.
- Students should understand that photoautotrophs photosynthesize *and* perform cellular respiration. They perform cellular respiration during the day and night. Most students only associate this process with photoautotrophs during the night. This lab may or may not be performed concurrently with the metabolism unit. It is advisable to introduce or review the processes before beginning the lab to clear up any misconceptions. The students should understand the role of oxygen in each process. The instructor should explain the process of photolysis in photosynthesis and the role of oxygen as the final electron acceptor in cellular respiration.
- Organisms do not split water molecules to obtain oxygen, nor does the oxygen atom dissolve out of the water molecule. The students should have a clear understanding of the concept of dissolved oxygen before performing the lab. Prior to the procedure, the instructor might want to explain the concept of how aquatic organisms, such as fish, obtain oxygen.

Suggestions for Procedural Modifications

- Many instructors often report that they obtain inconsistent results from the lab due to algal growth. The instructor can gather samples from a pond or lake if there is one in the vicinity. Demonstrate proper collection techniques and monitor the students as they collect samples. The preparation and use of *Chlorella* samples are generally reliable and will save time because students do not have to travel to a pond or lake to collect samples. If preparing algal (*Chlorella*) samples, use spring water or dechlorinated tap water. Do not use distilled water. *Elodea* should also produce reliable results and can be purchased from a local pet store. Duckweed may also be used. The students should use consistent amounts of each plant to be sure that they are not introducing an additional variable.

- If using the iodometric (Winkler) technique when completing the dissolved oxygen and temperature portion of experiment (12A), be sure that the students are not introducing additional oxygen by shaking the bottles during filling. All tests should be performed at the appropriate temperature. The students should fix bottles for the cold and warm temperatures first. The Winkler tests must be completed quickly, yet carefully, to be sure there are not huge temperature changes in the cold and warm bottles.
- When performing the second portion of the lab (12B), the students should cover the dark bottle completely. Students often leave the bottom of B.O.D. bottles uncovered, so verify that each is completely covered. All caps should be screwed on tightly to prevent oxygen leakage.

Ideas for Introducing Inquiry

To allow students to inquire about the effect of temperature on dissolved oxygen concentrations, the instructor can provide samples of tap water at varying temperatures and allow the students to design an experiment with appropriate controls and variables to test the effect of temperature on dissolved oxygen. The students will then analyze their data and generate appropriate conclusions to explain why temperature affects dissolved oxygen concentrations.

To allow students to inquire about the dissolved oxygen production at different depths allow them to design experiments to test samples at different depths in a natural body of water. The instructor can provide B.O.D. bottles and a meterstick. Instruct the students to record depths for each bottle. They will design an experiment to test their hypothesis about the effect of light on dissolved oxygen. The concept of production of dissolved oxygen in a biological community can be further extended. Many students may have some familiarity with algal blooms. This problem is exacerbated by nitrogen and phosphorus runoffs. The students could hypothesize about the increase in dissolved oxygen production if algae are supplied with nitrates and/or phosphates. Have them design a lab to test their hypothesis. Algal blooms are also the reason for the common misconception that nitrates and phosphates are used by algae or plants for energy in lieu of photosynthesis. Many students believe that plants and algae are using nitrates and phosphates for energy and do not need to perform photosynthesis. For further inquiry, the instructor could provide the setup for this lab, nitrates and phosphates. The students could discuss whether the latter two are sufficient for algae not performing photosynthesis. Have the students form hypotheses and design procedures to test dissolved oxygen production in algae that are supplied with nitrates or phosphorus and placed in the dark over a period of three or four days.

Technology Integration

Dissolved oxygen sensors are offered by a number of commercial vendors. If used properly, these sensors conserve valuable instructional time and the results are often less variable than those obtained using the Winkler technique. The major problem associated with the use of oxygen probes is inaccurate measurements due to calibration errors. Temperature probes can also be used to detect varying temperatures for part A of the lab. Information for suggested commercial vendors can be found on the AP Biology course home page on AP Central under Lab Activities and Resources.

Alternative Labs/Resource Ideas

Visit “Twelve AP Biology Labs: Information and Tips” available through the AP Biology Course home page for specific teacher comments on this lab.

http://apcentral.collegeboard.com/apc/members/homepage/34458.html

Related Links to AP Biology Free-Response Questions

AP Biology free-response questions from previous years are listed below. These are aligned and relevant to the labs within this Supplement. These questions and others can be found on the AP Central Web site listed under AP Courses and Exams — Exam Questions. Rubrics and actual essays are also located here.

- Lab 1: 2002 - 4; 2005B - 4
- Lab 2: 2000 - 1
- Lab 3: 2004A - 1; 2006B - 1
- Lab 4: 2004 - 3
- Lab 5: 2005 - 1
- Lab 6: 2007 - 4
- Lab 7: 2003 - 1
- Lab 8: 2008B - 3
- Lab 9: 2003B - 3; 2006B - 3
- Lab 10: 2002B - 2
- Lab 11: 2002 - 2; 2005B - 1
- Lab 12: 2001 - 3; 2008 - 2; 2004B - 2; 2008B - 1

About the Authors

Carolyn Schofield Bronston

Carolyn Schofield Bronston has taught at Spring Branch's Memorial High School, and Tyler's Robert E. Lee High School in Texas. She has been a consultant for the College Board since 1979, is a Reader for the AP Exam and is the author of the third edition of the *AP Biology Teacher's Guide*. Bronston created the AP Teacher's Corner for Biology, developed and edited the first three Special Focus publications for AP Biology, served as a member of the Biology Development Committee and was an AP Biology Adviser for the College Board. She has received the following awards: Presidential Award for Excellence, NABT's Outstanding Biology Teacher Award for Texas, Tandy Award, Texas Excellence Award and Siemen's Award for Excellence.

Allison Ingram

Allison Ingram has taught at Dunwoody High School in Dunwoody, Georgia, since 1998. She currently teaches AP Biology, advanced/gifted biology and general biology. Ingram holds gifted and International Baccalaureate certifications. She facilitates curriculum writing for the ninth-grade team at Dunwoody. She also provides guidance for scientific research for advanced/gifted students and mentors first-year science teachers.