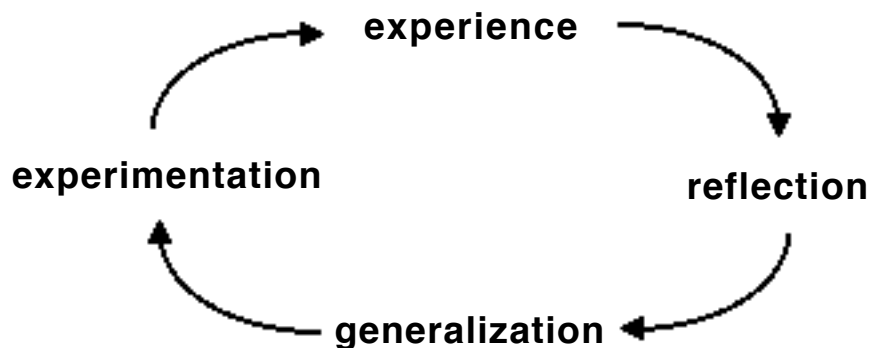


Concept and Investigative Activities

This document includes an overview of concept and investigative activities and some examples of each. The other two files in this folder include: 1) a set of lab instructors' notes and student handouts ("Lab Activities"), and some ideas on assessing student understanding of concepts and investigative skills ("Assessment"), including some sample exams from Workshop Biology. We have not yet written up all of our labs, so some may be described in this section but not included in "Lab Activities"; let us know if there's one you're particularly interested in.

Concept Activities

Concept activities allow students to discover important biological concepts through their own questioning and hypothesis-testing activities. Most importantly, we confront students' misconceptions about such central concepts as cell division (Smith, 1991), natural selection (Greene, 1990), and energy (Anderson, Sheldon, & DuBay, 1990), misconceptions which cannot effectively be addressed or even identified through traditional methods and which would preclude further learning in biology. These activities often appear superficially similar to more traditional lab activities, but in fact differ significantly in the way students are asked to formulate their own questions, make predictions, and analyze results, focusing on a deep understanding of a few significant concepts rather than trying to memorize details of many unrelated concepts. We often employ a "learning cycle" model (Kolb, 1980), shown below. In all cases, we want students to be able to construct their own understanding of concepts, rather than relying on the professor to provide "the answer."



Investigative activities

Investigative activities move one step beyond concept labs and involve students in the larger practice of scientific inquiry: problem-posing, problem-solving, and persuasion (Peterson & Jungck, 1988). Students design their own investigations in small groups and write up their results in a scientific paper. Setting up situations in which students can pose their own problems for investigation, develop methods of attacking the problem, and then persuade their peers that their conclusions are correct is more motivating and involving than being assigned instructor-generated problems, engages higher-order cognitive skills than repetition of "cookbook" exercises, and gives students a more realistic view of how science is actually conducted. Students begin to realize that

the design of investigations takes more effort than obtaining results, and that scientists do not automatically discover the "right" answer through experimentation, but must persuade their peers that their interpretation should be accepted. As one student put it, "The major thing I have learned in this class has been that questions are OK without answers, that questions are the most important thing."

Examples of Concept Labs

Protein synthesis (Modeling)

Understanding the way in which genes control the appearance and functioning of an organisms through the creation of proteins is one of the most important and most difficult tasks a biology students faces. We have found modeling to be an effective teaching tool for complex, abstract concepts like protein synthesis. Students use a variety of "building blocks" (pop-beads, styrofoam shapes, pipe cleaners, etc.) to construct their own models of protein synthesis. We do not tell them how to build their models, however; each group of students must decide for themselves which elements in the process to represent and how to represent them. They can use their textbooks, videodiscs, the instructors, and other students as resources during the design process. The goal is for students to build models which could be used to teach their classmates about protein synthesis, and which they can use to persuade us that they understand the process. We also ask each group to consider the strengths and limitations of their model and models in general.

We have used this modeling approach successfully with other biological systems, such as the cardiovascular system and the immune system. With a system as complex as the immune system, in particular, when students are asked to test each other's knowledge and the accuracy of their models, they have come up with some very interesting and realistic problems which require them to apply their knowledge in a novel situation—for example, what will happen to the system when a particular disease organism invades.

Heart Exploration (Guided Discovery)

A key concept lab we use in winter term is a "heart exploration." In no other lab has the difference between the methods of the traditional class and the workshop class been so evident. Students in both labs dissected hearts (sheep hearts in the workshop and pig hearts in the traditional class) in order to learn about their structure and function, but the design of the two labs made for very different experiences.

The traditional labs followed the pattern of most anatomy labs: the instructor began by showing diagrams of the heart, labeling the major structures with their anatomical names, and instructing the students in how they should proceed with the dissection and what they should expect to observe. The focus was on identifying and naming parts (a practice which, incidentally, involved a large amount of new terminology). The students then proceeded to follow the instructions and perform a detailed dissection.

In the workshop, we began with the idea that identifying parts is secondary to understanding how the form of the heart relates to its function. Our students began their dissections with no terms, no diagrams, and no directions, save to make careful observations of how the heart was structured. They were encouraged to formalize their observations with drawings and descriptions. Several leading questions on their handout asked them to infer the function of the different areas of the heart, and the path of blood flow. The idea of "double-loop" blood flow was unfamiliar to most students, and has been shown to be a source of misconceptions (Arnaudin & Mintzes, 1985), but they were able to infer this process from their observations. We introduced terminology only as it facilitated discussion about the different parts. Students thus not only gained a good understanding of form and function of the heart, but also began the term with some experience in making observations and inferences. Some students felt uncomfortable going in "cold," with no prior knowledge of heart structure, but most felt it was a valuable learning experience; in fact, last winter

term it was the highest-ranked course activity of any kind. Again, their conceptual understanding proved to be much higher than that of the traditional students.

This kind of “guided discovery” lab is extremely effective for learning about biological system that can be observed directly or with a microscope or dissecting scope. As another example, we have students explore reproductive systems and organismal development by dissecting plant reproductive structures (flowers and fruit) and observing pollen tube formation. Many of our students have never seen fruit outside of a grocery store, and have never considered how fruit forms from flowers or how plants fertilize each other. The idea of plant sex is completely new and intriguing! Then, we do an activity in which they can watch sea urchin sperm fertilize eggs and see the zygote develop. This enables them to compare plant and animal reproduction, and begin to consider evolutionary adaptations to ensure the formation and survival of offspring.

Kingdoms of life (learning cycle)

As an introduction to the kingdoms of life and to cell theory, we follow a classic learning cycle model (Kolb, 1984) . The “experience” phase of the learning cycle involves having students make their own slides of cells, including protists and bacteria (from pond water), plant cells (*Elodea*), and animal cells (from the inside of their cheek), and examine them to determine their differences. In the “reflection” and “generalization” phases, we conduct a short class discussion to compare students’ observations, and to construct a model of prokaryote-eukaryote distinctions and differences between kingdoms. Finally, for the “experimentation” phase, we give students “mystery” slides (accompanied by an entertaining murder story written by one of the TAs) to allow them to test their understanding of the cellular differences between kingdoms. A full write-up of this lab is included in this section.

The learning cycle approach works well for a variety of concept activities. As another example, we have students explore the classification and diversity of local tree species in which students first gather samples of trees on campus and bring them back to the classroom in order to make systematic observations of them (“experience”). They then construct a dichotomous key that can be used to identify the tree species they have collected (“reflection”). At this point, they generally don’t know anything about the trees they’ve collected, including their species names—in order to make constructing their key easier, the instructors often label certain trees in the area with names like “Doug,” or “Sarah,” and students use these as their samples. Then, students use a published key to identify their samples, and compare this key with their own, while thinking about the nature of dichotomous keys (“generalization”). Finally, they can use the computer program *MacClade* to experiment with different evolutionary trees and think about the differences between a key used for everyday identification, and one created to explain evolutionary patterns (“experimentation”).

Concept Activities in Lecture

As we have moved to a more traditional course format, with slightly more time spent in the large-class setting than in the lab, we have tried to develop concept-oriented activities that can be done effectively in a large class. For example, we have successfully used mitosis and meiosis modeling in this setting (the full writeups for the lab versions of these activities are included in the next section). Another example is an activity on natural selection, which can be done in about 15 minutes. The first part of the assembly is spent reviewing natural selection concepts and watching a David Attenborough video about bats. Then the instructor gives students a sheet with an exam question about how bats evolved, and a set of possible answers to the question—actually, these answers are taken from student responses on an actual exam in another class (see next page). The answers all display different types of misconceptions about natural selection. Students are asked to work in small groups to evaluate each answer and decide what, if anything, is wrong with it. While the students are talking and writing on their worksheets, the instructor circulates around the room, checking on groups that don't seem to be making much headway, and clearing up

Assembly 3: Group Activity

Listed below are several answers to the following question, taken from student answers on a past exam. For each response, indicate whether you think an evolutionary biologist would agree with it, and if not, why not.

QUESTION: Fossil evidence suggests that the ancestor of the modern-day bat resembled a shrew or mouse and could not fly. How can the evolution of bat wings from the paws of shrew-like ancestors be explained?

ANSWERS:

1. Bats would be better adapted if they had wings, so gradually they developed them. Bats in each generation had better wings than their parents did.

PROBLEM: Lamarckian, goal-directed. Sounds like bats developed wings because they "wanted" or "needed" them (Lamarck's internal will (note: this is the instructor's annotation, it would not appear on the students' sheets).

2. Because the environment of the shrew-like ancestors favored gliding or flying, mutant individuals arose that were able to glide. Selection favored these individuals, and eventually all of them could glide. Repeating this process led ultimately to modern day bats.

PROBLEM: Changes are not induced by the environment. Mutations are independent of selection pressures. Does this mean that selection is "random"? NO! Otherwise, this answer is close to satisfactory. It does describe the process of natural selection (differential survival and reproduction), and does describe how cumulative selection could lead to the evolution of a complex trait.

3. The existence of structures as complex as a bat wing can not be explained by traditional evolutionary theory because structures like these are too complex to arise by chance.

PROBLEM: Assumption is that because there is no intelligent designer, that the process is solely "chance". Apply the same logic to motion of the planets. What is the probability that the Earth's motion, by chance, would form such a perfect and consistent ellipse around the sun? Ignores the power of cumulative selection.

4. Because the shrew-like ancestors of bats needed to fly to catch food, nature allowed them to develop the ability to fly better and they turned into bats.

PROBLEM: Need does not direct change. If it did, then wouldn't nature always allow change that prevents extinction. What does it mean to say "Nature allowed"?

5. The bat evolved wings in order to make it easier to catch its prey.

PROBLEM: Evolution is not goal-oriented. Who is "the bat", and is it capable of making conscious decisions about the future of the species? This statement just ignores the whole issue by not defining what "evolve" means. Is it like going to the grocery store to pick up some wings?

6. The shrew-like ancestors of bats kept stretching the skin and arms while jumping from tree branch to tree branch because that would help them glide better and jump farther. Gradually, through continued use of their arms in this way, they developed into wings.

PROBLEM: Lamarckian inheritance of acquired traits, use and disuse of parts. Discussion in class indicates this statement may just be too vague. From one point of view, a Darwinian might agree with it, from a different point of view, a Lamarckian might also.

misunderstandings about the assignment. None of the answers given are totally "correct;" each has problems. By discussing these problems, students can come to a more complete conceptual understanding of how natural selection operates. They can then display this understanding on a later exam by answering a similar question—for example, how horses evolved hooves—but the possible variations are endless.

If you would like other examples of large-class activities, let us know. We'll be including more in future updates of this handbook.

Examples of Investigative Activities

We have tried to take advantage of our year-long sequence by developing activities which will build students' skills throughout the year. In the fall, we focus on the power and limits of scientific knowledge, and the idea that science is a persuasive activity. One investigation we use in the fall term is DNA fingerprinting using PCR (polymerase chain reaction). We set up a scenario in which one of the students is a suspect whom the class must identify, have students prepare their own DNA samples from saliva, run them through PCR to amplify the samples, and run gels in the classroom. One student is randomly selected to be the "suspect" (the scenario involves an arch-criminal known only as "The Drooler") and the class must figure out who it is based on the gel from the class and that from the "crime scene."

DNA fingerprinting is a useful technique in the classroom for several reasons: it allows students to perform a scientific technique about which they have heard much in the news; it gives those students interested in DNA fingerprinting as a social issue some important conceptual background; and it allows discussion of important methodological concerns. For example, the difference between identifying a guilty party using DNA fingerprinting and ruling out a suspect is essentially the same as the difference between proving and disproving a hypothesis. We emphasize throughout the concept labs and investigations the inability of scientific methodology to prove hypotheses, and this lab is a concrete example. Students also need to understand what kind of information is obtained through the procedure. Many have misconceptions that DNA fingerprinting might inadvertently identify crime suspects who are carriers of genetic diseases.

In the winter, we focus more on the actual practice of asking questions and testing hypotheses. We asked students to design an experiment investigating some aspect of homeostasis, using certain kinds of equipment (blood pressure cuffs and stethoscopes); their questions thus tended to focus on blood pressure and heart rate. These variables make excellent subjects for investigations, since they are easily manipulated and measured, and are relevant to questions of cardiovascular health, a topic of great interest among our students. Students focused on formulating an appropriate question and designing a controlled study, and we structured a number of the concept labs to include methodological considerations, in order to give students practice before they actually had to conduct their investigation. We adapted a technique (Lawson, Rissing, & Faeth, 1990) in one concept lab, on transpiration in plants, that allows students to discover for themselves the concepts of independent and dependent variables, observer bias, and experimental controls. We followed this with a critique of a sample investigation, written by the instructor, which then served as a model for their own papers (see the Index to Labs). We also had students write research proposals for their investigations, on which they received feedback both from their peers and from the instructors. The organization and structure of these experiences proved to be excellent preparation for the investigations, which improved significantly over previous terms.

In the spring, we introduce the idea of modeling as a investigative method, using a variety of computer simulations including *MacClade*, a tool for building phylogenetic trees, and the *BioQUEST* publication *Environmental Decision Making*, which allows students to design investigations of the growth of wild populations under certain environmental pressures. These and other population simulations we have developed are described below under "Computer-based Labs." We also continue with experimental labs, having the class as a whole design and conduct an investigation of soil organism diversity in local forests—the full writeup for this investigation is included in this section.

Creating Modules

As we have refined many of the activities we use in Workshop Biology, the line between concept and investigative activities has blurred. In addressing those concepts for which students have serious misconceptions and/or great difficulty building accurate conceptions (such as protein synthesis and natural selection), we have kept the concept labs focused on the concepts. In addressing many other concepts, however, we have been able to integrate conceptual goals and investigative goals, moving from concept-oriented discovery activities to investigative activities within a single, larger, thematically coherent module. For example, students can learn about cell division by viewing animations on laserdisc, observing onion root tip squashes under the microscope, using pop-beads or pipe cleaners to model mitosis and meiosis (using their textbooks for help), and then collaborating as a class on an investigation of how long each stage of mitosis takes. In a module on circulation, students complete the heart exploration concept lab and blood pressure investigation described above; often, we integrate the lab on water transport in plants to help reduce some of the traditional distinction between plants and animals. In a module on diversity, students begin by reading about the classification and diversity of organisms found in forest soil (in a published journal article), observe and attempt to classify these organisms with dissecting scopes, and finally design and conduct the class investigation of soil organism diversity.

The next logical step in creating modules, of course, is introducing issues. Current issues can help motivate students and drive their exploration of concepts. Using issues to introduce concept and investigative activities also gives students the opportunity to consider a wide range of issues before choosing one to analyze in greater depth for their issues project. Examples of issues that could be used in conjunction with the modules described above include cancer for cell division, cardiovascular health for circulation, and Northwest forestry issues, such as the effects of clearcutting, for the classification/diversity module. An appropriate and engaging issue can be found for just about any lab or lecture activity—if you can't think of one, perhaps that particular concept isn't so important after all!

When designing course activities we have found that, instead of choosing one approach to teaching a concept or principle, it is most effective to give students multiple opportunities to learn about it. This gives students a broader, richer set of experiences from which to generalize and learn inductively. We have asked students on course evaluations which of a set of activities was most effective for them in learning a particular concept, and the almost unanimous response was, "all of them together." Integrating activities into coherent modules can help create this rich environment while at the same time reducing confusion students might feel when participating in a widely varied set of activities.

Computer-based labs

Well-designed computer simulations can be effective and realistic tools for helping students learn to design and conduct their own scientific investigations. Another advantage of computer-based labs is that it is easy to combine the conceptual and investigative aspects of these activities into a module, addressing both goals in an integrated fashion. Much of the software we use is available from BioQUEST, a consortium of science educators/software developers working on developing a collection of inquiry-based software tools for biology teaching. The essence of the BioQUEST philosophy is the "3 P's": problem-posing, problem-solving, and persuasion. Students are the researchers, and instructors can serve only as peers, as co-investigators, not as authority figures, because they do not know the "answers" any more than the students do.

Selection in Action

One concept-oriented software module is "Selection in Action," a Hypercard stack which, along with a physical population model of colored beads on felt, allows students to investigate the effects of natural selection on different populations. Labs which involve students acting as "predators" on

some "prey" population (beans, paper chips, etc.) are common (e.g. Fifield & Fall, 1992), but have traditionally had one of two drawbacks: either the organisms must reproduce asexually, or students must be able to calculate gene frequencies for subsequent generations, something which we did not feel was necessary for our nonmajors. More importantly, most such labs are simple demonstrations, allowing little opportunity for students to experiment.

"Selection in Action" not only does the work of calculating gene frequencies based on data students enter, it presents situations which challenge students to create and test hypotheses about the patterns of change they observe. The program presents a series of "planets" whose populations have different underlying mechanisms of heredity and variability. Students, unaware of these differences, must make observations, generate hypotheses, and design tests in order to construct explanations for what they observe. In this way, the activity effectively confronts students' misconceptions about the role of heritable variation in evolutionary change, and allows them to explore the effects of environment and population size in different situations.

Genetics Construction Kit

GCK is one of the best-developed and most useful of the software tools available from BioQUEST. This simulation offers students the opportunity to do "real" research on inheritance in computer-generated fruit flies. Students are presented with a vial of fruit flies with a variety of traits, and must perform crosses to discover the inheritance patterns of these traits. The instructor can set the parameters of the problems presented, such as the number of alleles, whether co-dominance or sex-linkage is present, and so forth, so students can move from simple problems to much more complex ones (complex enough to stump professional geneticists). However, no one knows the "answer" to any particular problem—these are generated randomly by the computer. Though "real" fruit fly traits are used, their pattern of inheritance is artificial, so in one problem red eyes may be dominant to white eyes, but in the next problem they may be recessive. Students must build up a case for their conclusions and convince themselves and their peers (including the instructor) that they are correct. Students can do many more crosses than would ever be possible with real fruit flies, and can use this experience to construct a useful understanding of inheritance.

Ecological modeling

Another BioQUEST simulation is *Environmental Decision-Making*, which simulates the behavior of wild populations under different environmental pressures—for example, the effects of fishing on different species of pond life, or the effects of logging on forest species. We have developed two ecologically-oriented simulations that are available on the BioQUEST CD-ROM, also, called *Demography* and *Epidemiology*. *Demography* allows students to investigate the relationships between age structure, birth and death rates, and population growth in human populations (though it has also been modified to be used with other age-structured populations, notably spotted owls). This module has the added advantage of allowing students to address current social issues, such as those surrounding our aging U.S. population, the young growing populations of Third World countries, and the drastic attempts to control population growth in China. Students can enter and use vital statistics data which they have collected from newspapers, census data, and other sources. They can also perform experiments by altering variables in their population, to explore the effects of different birth control or health care programs which alter age-specific birth and death rates. *Epidemiology* allows students to investigate difference aspects of disease transmission, using models of diseases such as AIDS. Both of these software tools have fully graphical interfaces, allowing users to manipulate graphs directly and see the impact on other graphs and population parameters immediately, aiding understanding of mathematically difficult concepts.

Concepts and Investigations: Assessment

The “Assessment” folder on this disk includes resources for assessing teaching innovations and determining whether they’re more effective than traditional methods. This will necessarily include assessing students’ understanding of concepts and ability to reason scientifically. Although many of these assessment strategies will also work for testing students (for the purpose of assigning grades), we’d like to address developing tests and exams specifically. We’ve also included some sample final exams at the end of this document.

Most of the exams we use in Workshop Biology are a combination of multiple-choice (with explanation), short-answer, and essay questions. We do not use Scan-tron forms, even though the class is fairly large (200+ students)—we have found that these are just too inaccurate (see, “Explain your answer,” below) and impersonal-feeling to fit with the goals of the course. We normally give bi-weekly quizzes, and often give an ungraded “practice quiz” before the first real quiz, to give students an idea of the kinds of questions we ask. We have also used “practical” exams, in which students must perform an activity for the instructor (such as modeling mitosis). We have experimented extensively with take-home essay exams and portfolios, entirely eliminating in-class exams. This has proven to be quite effective in smaller classes (60 or less), but pretty much unworkable in larger classes, unless there are several TAs who can handle this kind of grading. We highly recommend portfolios, reflective journals, and take-home essays if you can handle the workload (and it’s not really as bad as you think), but if you plan to continue using exams, as we do, here are some suggestions.

Writing multiple-choice test items above the "recall" level

One of the main criticisms of multiple-choice tests is that they cannot test higher-level skills, only simple recall of facts and terms. We beg to differ! There is nothing inherent in a multiple-choice test that limits it to the recall level; the important thing is how the items are written. Here are some general strategies for writing multiple-choice questions we have found useful:

- Testing students' scientific reasoning abilities: provide a description of an experiment and ask students to choose from a series of possible conclusions, or ways of better controlling the experiment; provide a set of data or graph and ask students to choose from a set of hypotheses, asking them which hypothesis is best supported.
- Testing students' understanding of biological processes (such as feedback loops or immune system responses): Describe an unfamiliar process, and ask students to choose from a set of possible outcomes if some aspect of the process is altered.
- Writing problem-solving items: pose the problems as they would confront a real investigator. For example, many genetics problems are written "backward;" they give students genotype frequencies and ask them to predict phenotype frequencies. This kind of problem would probably not confront a geneticist, who starts out with phenotype frequencies and tries to determine genotype frequencies and patterns of inheritance. We use genetics problems that give students the results of a series of crosses, and at each step, asks them to decide whether a trait is recessive, dominant, or whether there is not enough information yet to tell.

Using students' misconceptions in developing test items

One of the most common recommendations for improving multiple-choice test items is to make the "distractors," the wrong choices, plausible. An excellent way to accomplish this is to use common misconceptions students are likely to hold. Unfortunately, this is easier said than done. An instructor with a great deal of experience teaching a particular subject area may have a good idea of the difficulties students typically have in that area. This is less likely, however, for a new instructor or for someone new to the subject area. Moreover, if an instructor has used only objective-format tests in the past, these will have provided little information about student misconceptions. It can be difficult to take sketchy observations of students' comments and questions in class discussions and turn them into effective test-item distractors. For some concepts, these problems can be surmounted

by referring to the misconceptions research literature (see the bibliography at the very end of this handbook), which can not only provide information about students' misconceptions but ideas for actual test items. Of course, not every misconception has been researched and documented, so this approach will not work for every concept.

We have successfully used a type of test item originally developed for use in science education research, "empirically-developed multiple-choice items" (Aikenhead, 1987), to construct tests that incorporate common misconceptions in item distractors. The essence of the procedure is to ask a question first as an essay-type question, then categorize students' responses, pick out the most common incorrect ones, and use these as choices in a multiple-choice item.

"Explain your answer"

Alternatively, we include an "explain your answer," section on each existing multiple-choice item, and use these written answers to revise the question or write new ones. The "explain your answer" section does not have to be graded in the same way that essay questions do, you can just scan them for misconceptions, or indications that the test item is being misunderstood.

This technique can also help you determine if the test is overestimating students' understanding, which seems to be an often-overlooked problem of multiple-choice tests. Studies of our students have indicated that some multiple-choice items overestimate students' understanding by 50%; that is, 50% of students choosing the correct choice give an inadequate or incorrect explanation. This finding is borne out by other studies, as well; Shea (1993) reports that, upon giving students two exams, one short-answer and one multiple-choice (using the same questions as on the short-answer exam), students scored 43% higher on the multiple-choice version. He found that his students might be able to choose the right answer on a multiple-choice item, but when confronted with the same question in short-answer format, they were unable to even come up with the right kind of answer. To the question, "What portion of a parent isotope remains after four half-lives have elapsed?" students gave responses like, "15," "nucleus," "uranium," and "10 million years." When students are given choices like, "one fourth," "one eighth," or "one sixteenth," they are clued in to the kind of answer needed, and then can often choose the right one. However, this may not represent real understanding.

If you have been relying solely on multiple-choice exams, you might want to consider adding a few "explain your answer" items; you might be surprised at the results!

Sources for Test Items

Analytical Problems in Biology, by Donovan and Allen (Burgess Publishing, 1983)

A whole book of multiple-choice questions that require higher-level reasoning and critical thinking skills. These can be used as test questions as well as in problems sets and homework assignments, which is what they were originally written for.

The Workshop Biology Testbank

A collection of questions on a wide range of biological concepts, scientific reasoning, and critical thinking. The questions have all been used successfully in research over the last four years as well as in exams in the Workshop Biology class at the University of Oregon. Many are multiple-choice. Call or email us to get a disk copy; a hard copy is included in Appendix B

Standardized Tests (yes, really!)

You might also check out standardized exams like the **CLEP** (College-Level Examination Program) exam in Biology, or the **MCAT**. Rather than trying to get an actual copy of the exam itself, try the many practice and preparation guides that are available. Many of these questions are written above the simple recall level. While you might not want to use the actual items (since they are copyrighted), they can give useful examples for writing your own versions of these kinds of test items.

Sample Exam on Cells and Genes

BI 101 Final Exam (100 points)

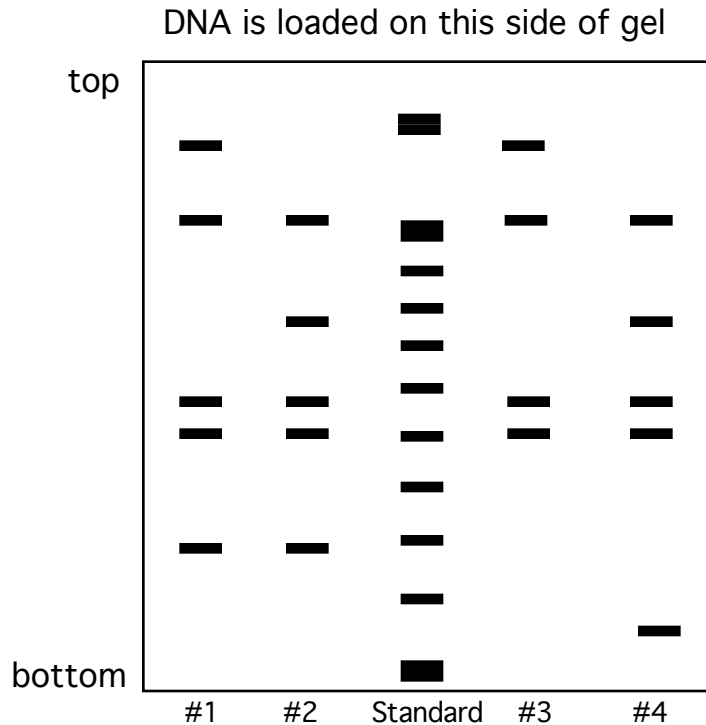
1. Put the following group of items in the correct order, according to size, from the smallest to the largest: (EXAMPLE: smallest: letter—>word—>page—>book :largest) (10 pts.)

cell, gene, nucleotide, chromosome, nucleus

smallest: _____ —> _____ —> _____ —> _____ —> _____ :largest

Put a star (*) under each item from the above groups that can be seen with a good light microscope (like the microscopes we used in lab).

2. The gel below is the result of a DNA fingerprinting procedure using PCR (similar to what we did in lab). The standard in the gel is similar to what we used in lab and is made up of pieces of DNA that are 600, 700, 800, 900, 1000, 1100, 1200, 1300, 1400, 1500 and 2000 base pairs. The thick bands represent pieces of DNA 600 base pairs, 1500 base pairs and 2000 base pairs.



Circle the polymorphic bands in individual #1. (2 pts.)

How many loci (on the entire gel) are polymorphic? _____ (2 pts.)

How big is the largest visible band in individual #4? _____ (2 pts.)

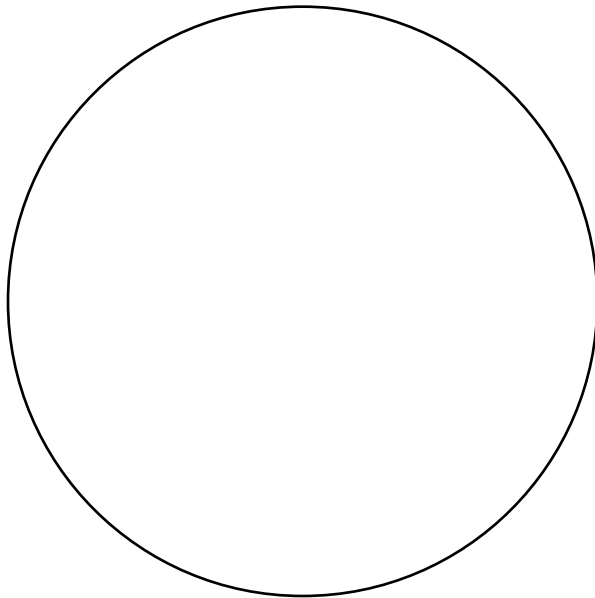
Would this locus (i.e. the largest visible band in individual #4) be useful in DNA fingerprinting? Explain. (2 pts.)

3. List two characteristics of plant cells, at the cellular level, that clearly distinguish them from animal cells and are easily visible in a light microscope. Each answer should be 5 words or less.

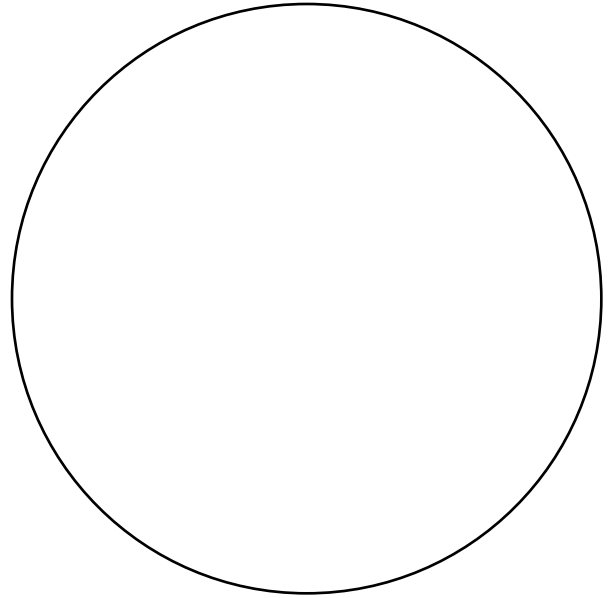
1st characteristic _____ (3 pts.)

2nd characteristic _____ (3 pts.)

4. Draw a cell in metaphase I of meiosis and another cell in metaphase of mitosis for which the diploid number is 6 (the human diploid number is 46). Indicate maternally derived chromosomes by filling them in and leave paternally derived chromosomes un-filled-in. Assume that crossing-over doesn't occur.



metaphase I of meiosis (4 pts.)



metaphase of mitosis (4 pts.)

Now draw what the cells look like at the end of mitosis and meiosis. Be sure to draw the proper number of cells for each process.

end of meiosis (4 pts.)

end of mitosis (4 pts.)

5. LDLs are large complexes of proteins and lipids that carry cholesterol in your blood. LDLs are broken down into smaller constituents in your liver. Cells in your liver first take up LDLs into a vesicle. The next step in LDL processing probably occurs when the vesicle

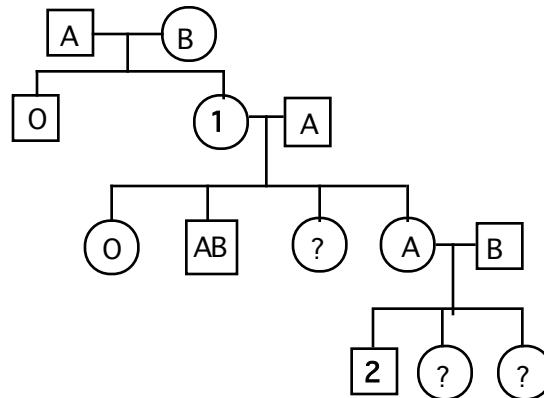
Circle one of the following (2 pts.)

- A) fuses with a lysosome.
- B) carries the LDL to the E.R.
- C) carries the LDL to the nucleus.
- D) fuses with a ribosome

Explain your answer: (2 pts.)

6. The ABO blood group system is controlled by a single gene. There are 4 blood types: type-O, type-A, type-B and type-AB. There are three alleles for this gene: A, B and O.
 Allele A is dominant to O
 Allele B is also dominant to O
 A and B are codominant

The following is a pedigree showing the ABO blood types of a family. As always, the symbols within the circles and squares indicate the persons phenotype not genotype. (The numbers are just used to identify individuals.) "?" means that the blood type is unknown.



List the possible **genotypes** of individual #1. _____ (4 pts.)

List the possible **genotypes** of individual #2. _____ (4 pts.)

7. In a cell, **DNA** is synthesized in the (cytoplasm / nucleus). **CIRCLE ONE** (2 pts.)
In a cell, **RNA** is synthesized in the (cytoplasm / nucleus). **CIRCLE ONE** (2 pts.)
In a cell, **protein** is synthesized in the (cytoplasm / nucleus). **CIRCLE ONE** (2 pts.)

What molecule carries the DNA sequence information from the DNA to the site of protein synthesis?
_____ (2 pts.)

8. Mutagens are chemicals that cause mutations in a cell's DNA. The DNA damage caused by mutagens results in a change in the sequence of nucleotides in a chromosome. After treating a cell with a mutagen, you discover that the cell is now producing "abnormal protein W" that no longer functions properly. What is likely to differ between normal protein W and abnormal protein W?

(Circle **ALL** that are correct) (4 pts.)

- A. Normal protein W and abnormal protein W probably have the same sequence of amino acids but different mRNAs.
- B. Normal protein W and abnormal protein W probably differ in their amino acid sequence.
- C. Normal protein W and abnormal protein W probably have different shapes.
- D. Normal protein W and abnormal protein W probably have the same shape.

Explain each of your answer(s): (4 pts.)

9. Red-green color-blindness is an X-linked recessive trait. A young woman named Gina tells you that her father and two of her brothers have red-green color-blindness, although she herself is not color-blind. (If you wish, you can use pedigrees or punnet-squares in your explanation.)

Is Gina's mother color-blind? _____ (2 pts.)

Explain your reasoning. (2 pts.)

Assume Gina marries a man with normal color vision.

What proportion of Gina's sons are likely to be color-blind? _____% (2 pts.)

Explain your reasoning. (2 pts.)

10. A hypothetical human trait is controlled by a single gene. Three alleles of this gene have been identified: **A**, **B**, and **C**.

A is dominant to **B** and **C**.

B is dominant to **C**.

List all of the possible genotypes. _____ (3 pts.)

How many phenotypes are possible? (just give a number) _____ (3 pts.)

11. Gray seed color in peas (*G*) is dominant to white (*g*). In the following experiments, parents with the indicated phenotypes produced the listed progeny. Fill in table below by indicating the most probable genotype for each parent? (18 pts.)

Parental Phenotypes		Progeny		Probable Parental Genotypes	
1st Parent	2nd Parent	gray	white	1st parent	2nd parent
gray	white	82	78		
gray	gray	118	39		
white	white	0	50		

Sample Exam on Organismal Physiology

BI 102, Final Exam

1. As the science officer of a starship, you're responsible for getting to know the physiology of alien organisms. A recent expedition to the remarkably earthlike planet called Cheapersets has yielded an alien creature; the crew has nicknamed it Spunky. Spunky is a warm, leathery skinned creature about the size of a basketball. Spunky darts quickly around the room on five pairs of spindly legs.
Before you've examined any of Spunky's insides, you decide to make some predictions about Spunky's circulatory system.

(9 pts) • Will Spunky's circulatory system have capillaries?

• What is main the function of capillaries in a circulatory system?

• What is it about Spunky that makes you think Spunky's circulatory system will (need / not need) capillaries?

2. Many *animals* will gladly eat sugar, which contains lots of chemical energy. Animals break down sugar and use the energy to make ATP, mostly in mitochondria.
Putting sugar cubes in your potting soil, however, does your *plants* no good — it can even be harmful. Do plants use sugar in their cells the same way that animals do? Explain.

(9 pts)

3. Antidiuretic hormone (ADH) acts at the collecting duct of the kidney's nephrons to make the collecting duct permeable to water. People with the disease NDI have collecting ducts that are unable to respond to ADH. As a consequence, NDI patients produce abnormally dilute urine. Explain why a person with unresponsive collecting ducts has dilute urine.

(9 pts)

4. When the immune system responds to a bacterial infection, macrophages engulf bacterial debris and then present antigens to helper T cells. HIV (the AIDS virus) prevents the immune system from responding properly to infections by killing helper T cells.

What critical role do the helper T cells play in an immune response to a bacterial infection?

(4 pts)

Even after a person's helper T cells are destroyed, some defenses are still intact. What defenses against disease continue to function normally in a patient with an advanced HIV infection?

(4 pts)

5. Late one night you're viciously attacked by a clawed toad (*Xenopus laevis*). One of your B cells is exposed to toad toenail antigen, which binds to antibody on the surface of the B cell. The B cell matures and divides many times, giving rise to plasma cells (mature B cells) and memory cells. The antibodies that are produced by the plasma cells can bind

(Choose one)

- A) to any antigen they encounter.
- B) to a limited number of toad antigens.
- C) only to toad toenail antigen.

Explain your answer:

(7 pts)

6. Insulin-dependent diabetics who inject the wrong amount of insulin can go into "insulin shock," a condition characterized by fainting. Insulin shock is treated by giving the diabetic patient sugar.

Insulin shock is probably produced by injecting too (_____) insulin, which causes most of the blood's glucose to (_____) the blood. The (_____) blood sugar levels cause fainting.

- A. (little); (be removed from); (low)
- B. (much); (be removed from); (low)
- C. (little); (remain in); (high)
- D. (little); (be removed from); (high)
- E. (much); (remain in); (high)

(4 pts) • Explain your reasoning

(4 pts) • Why do you think the change in blood sugar level that accompanies insulin shock causes fainting?

7. Thyroid hormone (TH) helps to regulate the body's general metabolic rate. Production of TH by the thyroid gland is normally regulated by thyroid stimulating hormone (TSH), which is secreted by the pituitary gland. The pituitary gland is controlled by the hypothalamus, which triggers the release of TSH when the hypothalamus senses low levels of TH.

Graves' disease occurs when certain white blood cells begin making "Ab" proteins that have the same effect on the thyroid as does thyroid stimulating hormone (TSH).

The TH levels of a person suffering from Graves' disease are likely to be

- A. high.
- B. low.
- C. normal.

(3 pts) • Defend the answer you chose.

The TSH levels of a person suffering from Graves' disease are likely to be

- A. high.
- B. low.
- C. normal.

(3 pts) • Defend the answer you chose.

The size of the thyroid gland in a person suffering from Graves' disease is likely to be

- A. enlarged (goiter).
- B. reduced.
- C. normal.

(3 pts) • Defend the answer you chose.

The treatment most likely to reduce the symptoms of Graves' disease, *while producing the fewest side effects*, is to

- A. remove or destroy part of the patient's pituitary gland.
- B. remove or destroy part of the patient's thyroid gland.
- C. remove or destroy all of the patient's white blood cells.
- D. remove or destroy part of the patient's hypothalamus.

(3 pts) • Elaborate on the answer you chose, and explain why the other answers are wrong.

8. GABA is an inhibitory neurotransmitter. The popular “tranquilizer” Valium alters behavior by binding to part of the GABA receptor and making it easier for GABA to bind to the receptor. Taking Valium probably
- A. causes fewer neurons to fire.
 - B. causes more neurons to fire.
 - C. causes some neurons to fire more often, while others fire less often.
 - D. causes some nerve impulses to last longer.
 - E. has no effect on the number or duration of nerve impulses.
- (6 pts) • Elaborate on the answer you chose.

9. Acetylcholine is a neurotransmitter. In vertebrates, it has opposite effects on skeletal muscle cells and on heart muscle cells. It excites skeletal muscle cells and inhibits heart muscle cells. These opposite effects probably occur because
- A. the two muscle types are controlled by different parts of the brain.
 - B. the two muscle types are triggered by different types of nerves.
 - C. the two muscle types have different types of acetylcholine receptors.
- (6 pts) • Explain why the other answers are wrong.

10. An animal’s brain can decipher a stimulus it receives as being light or sound or touch because each sense organ is specialized to detect a different physical stimulus and
- A. sends a different type of signal to the brain.
 - B. sends different frequencies of the same signal to the brain.
 - C. sends a signal to a different part of the brain.
- (6 pts) • Explain why the other answers are wrong.

11. Of the issue presentations you saw (OTHER THAN YOUR OWN), choose ONE PRESENTATION and identify two fundamental claims that were made, and the most persuasive piece of evidence that was used to convince you that each claim was reasonable.

(10 pts)

Issue presentation topic (USE THE TITLE FROM THE "OFFICIAL LIST"):

Claim #1:

Persuasive Evidence for Claim #1:

Claim #2:

Persuasive Evidence for Claim #2:

Sample Exam in Ecology and Evolution

BI 103 Final Exam

1. A naturalist, Dr. Sarah Warbler, thoroughly studies the bird populations on a newly discovered chain of islands. She discovers that there are no songbirds on the islands except for finches. Here are some excerpts from her journal:

_____ (a) "The finches on the islands are more variable in size, beak shape and behavior than finches on the mainland."

_____ (b) "Each island has at least one endemic species of finch." (Note: *Endemic* means that it occurs *only* on that island.)

_____ (c) "Each species of finch is extremely well-suited to the environment and resources on its particular island."

_____ (d) "On one island, Jabberwocky, there is a finch called the 'hummingbird finch' that gathers nectar from long, tubular flowers."

(Note: The flowers turn out to belong to the snapdragon family. They were found to be a new species, which Dr. Warbler named *Penstomen alicii*, after Alice in Wonderland.)

_____ (e) "Hummingbird finches could not survive on the mainland because they would be outcompeted by hummingbirds and nectar feeding insects."

_____ (f) "If hummingbirds were introduced onto this island, 'hummingbird finches' would be driven extinct."

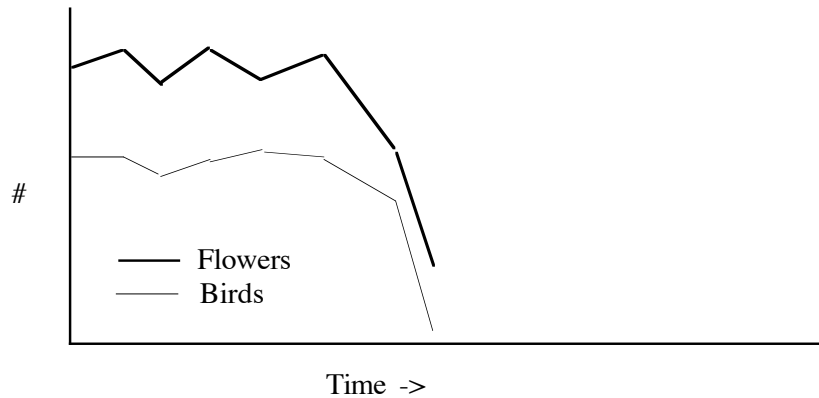
For each excerpt, place an O next to it if you consider it to be an observation, an I if you consider it an inference, an H if it is an hypothesis, and a P if it is a prediction. If you think something fits into more than one category, place all appropriate letters next to it. If you feel that any of your answers need elaboration, you may explain below.

2. Why do you think it is important to distinguish between an observation and an inference?

3. Explain how you think the situation on these islands arose. Be sure to include in your explanation (a) why there are so few songbirds on the islands, (b) why there is more variability in the finches, (c) why each island has its own endemic species, (d) how a "hummingbird finch" could evolve, and (e) why Dr. Warbler feels that "hummingbird finches" would be outcompeted by hummingbirds.

4. Dr. Warbler wants to investigate the population biology of the "hummingbird finches". Jabberwocky has a distinct wet side and dry side. The birds mainly occur in meadows, and she suspects that the birds are more common on the "wet" side of the island where she feels there are probably more flowers. Describe an experiment that she could perform to estimate bird populations and to test her hypothesis.

5. During a five-year period, Dr. Warbler monitored both flower numbers and bird numbers in a particularly large and lush meadow. She found that numbers fluctuated somewhat, but seemed fairly consistent (see the graph below). Then in years six and seven there was a severe drought, and the populations of flowers and birds crashed. Assuming that the drought is now over and that rainfall patterns remain steady for the next few years, predict what you think will happen to the populations of flowers and birds in this meadow (draw your predictions on the graph). Explain your answer.



6. Is the relationship between the "hummingbird finch" and *Penstomen alicii* an example of competition, predation, or mutualism? Is either species behaving altruistically? Explain.
7. Suppose that a beetle whose larvae specialize on eating the roots of penstomens is accidentally introduced onto Jabberwocky. The beetle is normally eaten by warblers on the mainland, and hence its numbers are kept low. In a diagram similar to the one on the second exam, draw the relationships between the flowers, the birds and the beetles on the island. Describe what you think will happen as a result of the introduction of these beetles. Explain your rationale.

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INTRODUCTION TO CELLS

Activity Type: **Learning cycle**

GOALS

This lab gives students an understanding of the cellular basis of life. It teaches basic concepts of cell size, structure, the difference between living and non-living material and diversity. Finally, it requires students to apply their knowledge to an unknown specimen.

TIME NEEDED: 2 hours (1 lab period)	
Classroom Time: Introduction: 30 minutes Student Work: 80 minutes Wrap up: 10 minutes	Instructor Time: Preparation: medium Assessment: medium

Lab Rationale

This is a classic introductory laboratory which can be linked with the presentation of the cell theory. It allows students to explore a variety of taxa, making their own observations and generalities. While it might not confront any obvious misconceptions, students might have some naive ideas about cells and living organisms. Students can do this lab before having any other material on cells, with the lab providing visual models for cells, relative size, etc.

The basis for the lab is the learning cycle described by Kolb (1984). Students make observations, then characterize the major groups by cell types. Students then test their characterizations by looking at an unknown specimen. This cycle allows students to make observations, reflect and organize new information, and test their knowledge in a new situation.

The lab is flexible in the materials used. Depending on the instructor's focus, a variety of living and non-living specimens can be used. It is important to offer a wide variety of specimens for students to observe in the discovery phase. No one student should be able to look at all of the specimens. This promotes cooperative learning as students share information from different specimens.

When needed prepared slides can be used to supplement the living material in order to include examples from many different taxa. Students react with more excitement towards slides that they prepare versus prepared slides. Whenever possible use live materials.

Overview of Lab

The first activity is a field of view measurement with their microscopes. Students become familiar with the microscope and create a visual model for the size of cells by using a ruler and simple algebra to calculate the field of view at different levels of magnification.

Next students look at samples of non-living and living material. They examine specimens from different groups of organisms, drawing a cell and making observations. After looking at several different cells students begin to apply their different observations, making generalities about plant cells, animal cells, bacteria, etc.

As a final exercise, students apply their observations to an unknown cell type. They need to support their statements about the type of cell with observations sufficient enough to convince peer groups and instructors.

Warnings/Safety

If using any stains, give warnings to students about skin and clothing.

Alternatives and Substitutions

As stated above, the instructor has a variety of organisms to choose from. This allows for individual class focus depending on the theme.

LEARNING CYCLE ACTIVITIES:

Experience	Examine various nonliving and living specimens
Reflection/ Abstraction	Individuals or groups make list of cell characteristics for each kingdom
Experimentation	Students apply their new understanding to unknown specimens

PRE-LAB DISCUSSION SUGGESTIONS:

Working with microscopes has been a novel experience for many of our non-major biology students. However, our experience is that everyone could use a refresher in how to use the microscope. Take time to let students feel familiar with this piece of equipment and get over any technology fear they may have.

We were surprised at how many students have trouble calculating their field of view. This is a two-tiered problem. Some simply cannot make the connection to millimeters between the different magnifications. The idea is for them to have a reasonable idea of the relative size of objects that they look at, not to be able to make precise size measurements. Having them use a ruler to measure field width brings something from their everyday macro-scale experience into this new world of microscopy and should help to bridge the gap. For most, the next problem is calculating a measurement that is a fraction of their field of view. The problem appears to be one with simple algebra which most students can work through logically. Do not simply tell the students how to do these calculations. They will be able to parrot an instructor answer but struggle when confronting a new situation. Be ready to ask some leading questions to help them to come up with the method if they get stuck.

If using stains, it is a good idea to give students a reason for its use. Let them look at the slide prior to adding the stain. This is a graphic demonstration of the use of stains.

Students tend to draw what is in their field of view. If this includes many cells, they will draw a generic sketch with a bunch of cells, rather than really examining a few cells. Before they begin making slides, tell students to draw only a few cell and include a magnification/size estimation. This will help them recall this information when they come to the unknown.

MID-LAB DISCUSSION SUGGESTIONS:

After students have sketched some of each cell kingdom, ask individual groups about their list of characteristics that distinguish eukaryotic and prokaryotic cells, plant and animal cells, etc. Have different members of the group justify their reasoning.

POST-LAB DISCUSSION SUGGESTIONS:

After students have identified the unknown, make them summarizing their reasons in relation to the taxa they examined earlier. This exercise causes students to construct and reflect on their knowledge of cells and taxa.

STUDENT WRITE UP:

Student handout of sketches, lists of characteristics, and answer to unknown

ASSESSMENT:

Grade student handout

MATERIALS NEEDED:

microscopes
dropper bottles (water)
forceps
Pasteur pipettes and bulbs
rulers (transparent are best)
petri dishes for free hand sections
necessary taxonomy guides
razor blades
microscopes slides
cover slips
non-living material (suggestions):
 cork slices
 crystals forming on a slide
 air bubbles, etc. that are captured under a coverslip
live material (suggestions):
 pond water or hay infusion
 leaf peels
 unicellular algae
 cyanobacteria
 termites (protazoa in gut)
 check cell scrapings
 yeast colony
 fungal hyphae
 bacteria (often found in pond water)

TIME EXPANSION/CONTRACTION ACTIVITIES:

Expansion

- Give students more than one unknown
- Have groups exchange and discuss their generalities about the taxa

Contraction

- Limit number of drawings/specimens

RESOURCES AND REFERENCES:

Kolb, D. (1984). *Experiential Learning*. Englewood Cliffs, NJ: Prentice-Hall.

Videodiscovery (1987). *The Cell Biology Videodisc*. Seattle, WA: Videodiscovery, Inc.

CELLS OF MYSTERY!

OBJECTIVES:

- Become familiar with microscopes
- Compare living and non-living specimens under a microscope
- Observe and list features of cells from different kingdoms
- Test your characteristics by solving a mystery

INTRODUCTION:

Today you are going to look at some different types of organisms under the microscope and compare them to things which are not alive. What makes something “alive”? Are all organisms made up of cells? Are all cells alike? What things can you observe with your microscope that might characterize a certain cell?

MATERIALS AVAILABLE:

microscopes	taxonomy guides
rulers	razor blades
microscopes slides	petri dishes for free hand sections
cover slips	forceps
dropper bottles (water)	microscope specimens
Pasteur pipettes and bulbs	

Warning: Microscopes are delicate, expensive equipment. Listen carefully to instructions on how to use your microscope. Handle them with care to avoid breaking lenses.

Calculation of Sizes:

As you look at things with your microscope, it can be difficult to gauge just how small or large the objects are. One of the easiest ways to determine the sizes of things under a microscope is to determine the width of the lowest magnification viewing field with a ruler. The width of the higher magnification viewing fields is then simple to calculate. The size of an object can then be estimated by knowing the width of the viewing field and the fraction of the field occupied by the object. Remember that total magnification is calculated by multiplying the power of the ocular lens by the power of the objective lens. The unit of measure usually used by light microscopists is the micrometer (1 mm = 1,000 μm).

<u>Objective Lens</u>	<u>Total Magnification</u>	<u>Field Width (μm)</u>
Low		
Medium		
High		

Observations:

Make a sketch of all of the different types of specimens available. **Include:** an indication of absolute size and label key distinguishing features, or include an annotation that indicates how each of these cell types could be distinguished from the others. Label whether each specimen is alive. Sketches need not be highly detailed--they are intended to get you to focus on and to remember the key distinguishing features of each type of cell. You may attach additional pages to your worksheet, if you need more room.

For each of the different taxa below, list the major distinguishing features:

Bacteria:

Protozoans:

Fungi:

Plants:

Animals:

Part II

It was a local tragedy. A number of college students were found dead around their campsite in the Green Lakes region of the Three Sisters Wilderness. The position of the bodies suggested to the sheriff that they were suffering from stomach aches just before death. The coroner decided to look at the contents of their stomachs to determine what they had eaten, thinking that they may have collected something poisonous from the wilderness. The first thing the coroner had to determine was what kingdom of living things the poisonous substance might be, and has asked for our help. You have one of the coroner's slides of the stomach contents.

What slide # do you have? _____

What kingdom do you think is represented on the slide?

What justification do you have for this opinion? (what traits are you using to base your answer on?)

What other information would you like to have? How might you get it?

CELL DIVISION IN THE ONION ROOT TIP

Activity Type: **Learning Cycle**

GOALS:

This laboratory makes students come up with their own descriptions and hypotheses for mitosis in plant cells. It provides students with a visual model for terminology introduced in later labs and lectures.

TIME NEEDED: 2 hours (1 lab period)	
Classroom Time: Introduction: 10-30 minutes (see below) Student Work: One and a half hours Wrap up: 20-30 minutes	Instructor Time: Preparation: Medium Assessment: Medium

Lab Rationale

Used as the groundwork for learning mitosis, this lab provides students with a visual model of chromosomes during division. It is a discovery-based lab in which students can categorize the types of cells they observe without the cumbersome new terminology. They make the categories, which can then be equated with the traditional labels of the phases of mitosis. Later labs can lead them through modeling exercises where the terms can be introduced and practiced.

One of the goals of this lab is to let students make observations and begin to categorize the different types of cells that they see on their slides. There does not have to be any formal introduction to mitosis prior to this lab; this would prompt students to be more concerned with the names of the phases than with making observations. Let the students make their own categories and distinctions before introducing the new terms.

Although prepared slides can be used in place of the dyed root tips, students are more excited by the experience of preparing their own slides. Students prepare their own slides by cutting off just the tips of the roots and squashing them under the coverslip. While the uniformity of cleanly prepared slides is lost, the squash gets the students actively involved in the lab.

Overview of Lab

Introduction time will vary depending on student experience and the individual instructor's goals for this lab. Students unfamiliar with the microscope will need an introduction to its use. A formal introduction to mitosis is not needed and may be counter productive. Students will worry about terms instead of making their own observations and hypotheses.

Give the first half of the lab in two sections: let the students look at their own slides and begin to get an image of cell division and categorize cells going through division. Then after they feel comfortable with their categories, hand them the second section of the lab and work with their neighbors on persuading each other about their own observations and inferences.

In the second half of the lab, students can use either their own slides or prepared slides to count the number of cells in each type of category of division. Students get an idea of the amount of time a cell spends in each phase of division based on their individual and the classes' pooled data.

Warnings/Safety

The Schiff's Reagent can permanently discolor clothing and will discolor skin for some time as well, so caution needs to be taken in handling the root tips. Bleach solution should be available to put the onion sets in when finished to neutralize the stain.

Be sure that the acetic acid does not get onto the microscope objectives as it can damage the lens.

Alternatives and Substitutions

If using the prepared slides students may have some trouble due to the nature of the preparation. Nuclei will be sliced, instead of squashed, and may not have a portion of the nucleolus and other landmarks students will recognize. Nuclei will also vary more in size, depending on the cross section of the slice. Tell the students about these problems with slices versus squashes and remind them to look near the end of the root for dividing cells.

LEARNING CYCLE ACTIVITIES:

Experience	Students make and observe onion root tips
Reflection	Discuss with neighbor and defend categories
Abstraction	Discuss areas of cell division in other organisms
Experimentation	Count and categorize a new sample of cells to look at temporal cycle

PRE-LAB DISCUSSION SUGGESTIONS:

An important relevance question to begin a discussion with is, “Where does cell division occur?” Pose this to students and make a list of responses. If students talk only about cell division in humans, encourage them to think about other organisms such as plants. The instructor can also direct the initial discussion to the continuous (open) growth seen in plants versus the growth seen in humans.

Then ask, “Why does division occur in these places?” This will lead to a discussion about the purpose of cell division. If time permits, ask students about the differences between the purpose of cell division in plants and humans. With this, introduce the onion root tip as the organism of study for this lab.

Most initial observations can be made using the 10x objective, but higher objectives should be used to describe and count the cells. Since the students' slide preparations will vary, remind students about focusing through the different layers of the root tip.

MID-LAB DISCUSSION SUGGESTIONS:

Before the second part of the lab where students count the number of cells in each of their categories, conduct a group discussion about the student-generated categories. Students have had the chance to confer with neighbors about each of the different phases and need the chance to ask the instructor questions. Often the question of distinction comes up. Remind students that this is a cyclical process that may not have very distinct starts and stops. At this point, depending on the background of your students, you may begin to hear the names of the different stages of mitosis.

One suggestion is to generate a class list on the chalkboard/overhead projector of the characteristics of cellular division. Students have generated a list with their neighbors and should be able to volunteer quickly. Different stages of mitosis will have been seen by different groups of students, leading to differing lists of characteristics.

At this point, students can begin thinking about the reasons why things happen the way they do in the cell. One question to ask is, “Why are the chromosomes visible in some cells and not in others?”

Two visual aids that work well for models of chromosomes are: a rubber band, stretched out, that winds back up upon itself to represent a double helical structure; and a ball of string, wound up then unwound, suggesting compactness of DNA during division.

To connect the two exercise sections of this lab, get students to think about the sequence of events in cell division. Ask them: “What would this cell look like in three hours? What about three hours ago?”

Students can then begin to construct models of their own or begin to understand the traditional cell cycle models. For some, a cyclical model is very confusing. Get these students to draw a linear model, paying close attention to the products. Models that show the parent cell and the daughter cells with a single arrow between them may need to be changed to include two different arrows to both daughter cells for some students to understand the concept of two daughter cells coming from the division of one original (parental) cell.

POST-LAB DISCUSSION SUGGESTIONS:

Students will have a problem with the idea that counting the number of cells can provide information about the amount of time spent in each stage of cell division. One analogy suggested by Alan is an estimation of the activities of college students and the amount of time they spend doing each (e.g. studying, going to lecture, partying, etc.). An estimation can be made by counting all of the students and their activities at one point in the day. With students, the time of day will make a difference, but with root tips this may not matter as much. Have the students come up with a list of controls for the onion root tip count.

Wrap up the discussion by reminding students of what they observed today. Let them know that they will have more practice with modeling mitosis in the near future. For some, the text will seem overwhelming with all of the new jargon. One suggestion is to de-emphasize the jargon, having students learn the process rather than simply memorizing the words.

STUDENT WRITE UP:

Students complete the questions on the handout.

ASSESSMENT:

Grade student handout.

MATERIALS NEEDED:

- Onion sets with active growth
- Schiff's Reagent
 - basic fuchsin
 - distilled water
 - hydrochloric acid
 - potassium or sodium metabisulfite
 - powdered charcoal
- 3:1 acid-alcohol fixative
 - ethyl alcohol
 - acetic acid
- 10% Bleach solution
- Rubber gloves
- Microscopes (at least 10x power)
- Razor blades
- Forceps (for handling the tips)
- Dissecting needles
- Slides
- Coverslips
- Paper Towels

TIME EXPANSION/CONTRACTION ACTIVITIES:

Expansion

- Compare cellular division in different parts of the root
- Look at prepared slides of human examples of stem cells

Contraction

- Discuss time spent in each phase in relative terms at end of Observations

RESOURCES AND REFERENCES:

- Brown, C. R. (1990). Some misconceptions in meiosis shown by students responding to an Advanced level practical examination question in biology. *Journal of Biological Education*, 24 (3), 182-185.
- Smith, M. U. (1991). Teaching cell division: student difficulties and teaching recommendations. *Journal of College Science Teaching* (Sep/Oct), 28-33.
- Stewart, J., Hafner, B., & Dale, M. (1990). Students' alternate views of meiosis. *The American Biology Teacher*, 52 (4), 228-232.

CELL DIVISION IN THE ONION ROOT TIP

Part I

OBJECTIVES:

- Use the microscope to examine the tips of onion roots for dividing cells.
- Learn to differentiate between dividing and non-dividing cells
- Work out the sequence of events during division from observing many different cells

INTRODUCTION:

In plants, a region of localized, highly active cell division is found at the tips of all roots and shoots. Since we are interested in seeing cell division, it is necessary to look at the tips of young, actively growing roots. Onion roots have been grown by placing onion sets with their bases in water. After a few days, the base of the onion and its several roots are placed in a fixative (3 parts ethanol:1 part acetic acid). This solution kills all the cells immediately, halting the process of cell division. Cells in various stages of cell division should therefore be present in the actively dividing region of the root tips. After being fixed, the roots, the roots were placed in Feulgen stain. This stain attaches to the DNA, making the chromosomes visible. You should be careful with this stain, it will stain your fingers and clothing if you get it on yourself. Properly prepared root tips will appear bright pink.

MATERIALS AVAILABLE:

Stained onion root tips
Rubber gloves
Razor blades
Forceps
Dissecting needles

Bleach solution (for root disposal)
Slides
Coverslips
Microscopes
Prepared slides

PREPARING CHROMOSOME SQUASHES:

Warning: This stain will turn things permanently pink, including skin and clothing. Be careful handling the liquids and wear rubber gloves.

- 1) Obtain an onion root tip from one of the instructors.
- 2) Place a small drop of 45% acetic acid on the slide close to the root tip.
- 3) Cut off the terminal 1-2 mm (the intensely stained part) with a razor blade or dissecting needle, and move this portion into the drop of acetic acid. Discard the remainder of the root tip into the bleach solution. Tease apart the tip with dissecting needles and/or a razor blade until the tip is in very fine pieces. Your preparation will be better if the pieces of root tip are cut exceedingly fine.
- 4) Cover the root tip with a clean cover slip, cover this with several thicknesses of paper towel and apply pressure with your thumb to squash the root tip. Push straight down but don't move the cover slip relative to the slide--the idea is to spread things out, but not to churn it around. This will be demonstrated. You may need to add a small amount of acetic acid again at this point.

- 6) Draw a cell that you think is actively dividing. Make sure you include labels of what you think are important structures.

Persuasion

- 7) Keep your microscope focused on the cell you just sketched and show it to a neighbor. Did they agree that the cell is dividing?

- 8) If not why not? If they did are their reasons the same as yours?

- 9) Now look at a neighbors cell and sketch. Do you think the cell is dividing?

- 10) Make a list of the differences you and your neighbor decided are important in order to categorize a cell as dividing:

- 11) Are there any subtle differences between your dividing cell and your neighbors?

- 12) Taking these differences into account whose step do you think occurs first in the process of division

13) Make a list of the steps your group think a dividing cell goes through.

14) Pick out four different cells and draw them in order from earliest to latest steps of cell division.

Questions:

15) Pick a characteristic in your dividing cell that you think is important and come up with an idea (hypothesis) about why the cell has this characteristic. What is your characteristic and hypothesis?

16) What support do you have?

17) How could you test this idea?

CELL DIVISION IN THE ONION ROOT TIP

Part II

OBJECTIVES:

- Identify and count the number of cells in different stages of division
- Estimate the amount of time a cell spends in dividing and growing stages

COLLECTING DATA:

Choose one area of your slide that shows many cells in active division. Categorize each cell into one of the five categories listed below and enter these data into the table on your worksheet. Count all the cells in the field, then go onto another field and continue this until you have counted 100 cells.. If there are more than 100 cells in the first field of view, choose a contiguous portion of the field and count all cells in that area until you have categorized 100 cells.

Record your data below:

<u>Stage</u>	Your Data	<u># of Cells</u>	<u>% of Total</u>
Cells <u>not</u> in mitosis:			
Mitosis: what are chromosomes doing	just became <u>visible</u>		
	lined along <u>middle</u> of cell		
	<u>separating</u> to opposite sides		
	<u>arrived</u> at opposite sides of cell		
<hr/>			
Totals:		_____	_____

Add your data to those collected by others in the lab by writing your results on the table on the black board.

<u>Stage</u>	Class Data	<u># of Cells</u>	<u>% of Total</u>
Cells <u>not</u> in mitosis:			
Mitosis: what are chromosomes doing	just became <u>visible</u>		
	lined along <u>middle</u> of cell		
	<u>separating</u> to opposite sides		
	<u>arrived</u> at opposite sides of cell		
<hr/>			
Totals:		_____	_____

Once all the data have been tabulated, estimate the absolute length of the various stages of the cell cycle. Assume that mitosis (all stages) lasts for three hours in onion root tips grown under these conditions. Only use the cells that are in mitosis (i.e. ignore the cells that are not in mitosis).

Stage:

visible

middle

separating

arrived

MITOSIS MODELING

Activity type: **Modeling**

GOALS:

This lab actively confronts and changes students' misconceptions about mitosis. Students realize their own mistakes through teaching mitosis to others in a small group setting.

TIME NEEDED: 2 hours (1 lab period)	
Classroom Time: Introduction: 20 minutes Student Work: 1 1/2 hours (1 lab period) Wrap up: 10 minutes	Instructor Time: Preparation: Low Assessment: Moderate (in-class)

• Lab Rationale

Misconceptions abound in students' minds about mitosis and meiosis. Below is a partial list of documented misconceptions about mitosis (Smith, 1991) :

- Confusion of terms (e.g. "chromosome vs. chromatid")
- The origin of duplicated chromosomes
- Ploidy number, number of chromosomes
- Fate of the parent cell during division
- Fate of monads (e.g. pairing up to form dyads)

Make sure that instructors review the literature on misconceptions in mitosis. This will help them anticipate the questions students ask and help identify students with misconceptions that need more help.

A good understanding of mitosis and meiosis lays the foundation for a good understanding of Mendelian genetics. By presenting several different models of mitosis and meiosis, students will be able to adopt the model best suited to their learning style. They can continue to use this model as they learn Mendelian genetics.

Students need to confront their own misconceptions before they can change them. The student teaching activity forces students to explain each step of mitosis as they understand it, and in the process they realize which pieces of information they do not really understand.

Overview of Lab

Use the introduction to present visual models to students. Several different biology video disks have sequences in both animal and plant cells that model mitosis and meiosis. Show these to students as a link to the static onion root tip lab, giving students a temporal model.

Next, students teach each other mitosis using pop bead or pipe cleaner models. After working in pairs in the teaching activity, students demonstrate their knowledge for an instructor. The instructor's role is to constantly ask the students questions both during the teaching activity and during the demonstration, probing students' understanding of mitosis and meiosis and pointing out their mistakes and misconceptions.

Alternatives and Substitutions

Two different physical models can be used. The more traditional model is the pipe cleaner model, using different colors to represent maternal and paternal chromosomes. Different sizes of chromosomes are helpful in representing homologous chromosomes. Another model, more often used for meiosis, is one with colored pop beads. Strings of beads are connected via surgical tubing that contains a magnet, which represents a centromere. The pop beads function in teaching concepts such as crossing over during meiosis, but will substitute well in modeling mitosis.

LEARNING CYCLE ACTIVITIES:

Experience	Students watch mitosis on video disk, teach each other mitosis
Reflection	Students demonstrate mitosis for instructor individually
Abstraction	Instructors quiz with novel chromosome numbers

PRE-LAB DISCUSSION SUGGESTIONS:

Use a video sequence to present mitosis to students. Show the sequence once without pointing anything out. The second time stop and point out special features such as when the chromosomes become visible, their general movement, etc. If available, show mitosis occurring in both an animal and plant cell. Discuss the differences in mitosis in the two types of cells and where in different organisms active division occurs.

Many of the students' misconceptions stem from the confusion of terms, both on the part of the student and on the part of the instructor. It is important to use consistent terms for structures and processes throughout the this lab and the meiosis lab. Agree with all instructors and assistants before hand in order to lessen student confusion. Use these terms consistently through out the introduction with the video clip and when asking the students questions.

Start out using a chromosome set of two homologous pairs ($2n=4$). Different lengths help distinguish the homologous chromosomes from each other and different colors distinguish paternal and maternal strands. Ask students about the number of chromosomes, DNA molecules, and ploidy under different circumstances, modeling with a set of chromosomes from a model kit.

Instruct the students to really *teach* mitosis to each other and ask questions. Confused students will automatically do this, but overly-confident students will not. It is the confident students that will often have the most misconceptions.

MID-LAB DISCUSSION SUGGESTIONS:

Informally quiz students individually or in small groups as they work through the exercise to make sure they understand the important concepts such as the difference between chromosomes and chromatids, replicated vs. unreplicated chromosomes, haploid vs. diploid nuclei etc. The object to get the students to tell you what they know, not just to answer you questions. Groups who are getting confused will ask for help, but it is necessary to get to all of the students informally in order to monitor the classes' level of understanding.

Some examples of the types of questions to ask groups while they work through mitosis are:

Show me a chromosome (duplicated, homologous, etc.).

Is this a haploid cell or a diploid cell? How can you tell?

How many chromatids are there?

How many molecules of DNA?

Try to avoid telling them the answer, get them to figure things out on their own. Many misconceptions will be missed if the instructor answers all of the students' questions.

The following is an example of a series of questions to ask students struggling with ploidy:

Students will say that a haploid cell has one of each kind of chromosome,

and then go on to say that a cell with 4 chromosomes (each with two chromatids) is diploid. Ask them: "How many chromosomes are there? (4).

How many kinds of chromosomes are there? (4). How many of each kind is there? (1). Is it haploid or diploid? (diploid, they say). Then ask them to define diploid: two of each kind of chromosome. Most see the problem and figure it out. A few will make you want to laugh or cry (resist the temptation).

Could this cell undergo mitosis right now? If not, why not? what would have to happen? (After they have modeled mitosis, construct a haploid cell that is in prophase (2 chromatids per chromosome). Make sure they understand that haploid cells can, and do, divide mitotically.

POST-LAB DISCUSSION SUGGESTIONS:

Students need a chance to reflect on their experience after working in groups with informal instructor assistance. By having them demonstrate the process of mitosis to an instructor individually, the student reviews their knowledge with the instructor asking and answering questions. The goal is not to grade the students' recall knowledge of mitosis. The instructor is instead checking each students' individual knowledge. Make the student go through the exercise until they feel comfortable with a correct model of mitosis.

Our experience is that students need a simple model to begin with, but then need a chance to use a different model in order to transfer their new knowledge to a novel situation. Students can transfer fairly easily, in words, to the human chromosome model, but have a difficult time when presented with a novel chromosome number. When the students demonstrate mitosis to an instructor, have them work with a model with an unfamiliar number of chromosomes (2, 6, etc.). This will allow the students to apply their knowledge to a new situation.

STUDENT WRITE UP:

None

ASSESSMENT:

Instructor check off upon demonstration.

MATERIALS NEEDED:

Either:

Colored pipe cleaners (optional)
Pop bead models of chromosomes
pop beads (at least two different colors)
surgical tubing
magnets

Video disk player
Biology video disk

TIME EXPANSION/CONTRACTION ACTIVITIES:

Expansion

• Use students to model chromosomes (with props) in a student-directed model of mitosis

Contraction

• Informally quiz all students within their groups instead of separately
• Do this lab in lecture!

RESOURCES AND REFERENCES:

Brown, C. R. (1990). Some misconceptions in meiosis shown by students responding to an Advanced level practical examination question in biology. *Journal of Biological Education*, 24 (3), 182-185.

Harper Collins Publishers (1991). *Biology Encyclopedia Videodisk*. New York, NY: Harper Collins Publishers, Inc.

Optical Data Corporation (1986). *Live Science - The Living Textbook*. Optical Data Corporation.

Smith, M. U. (1991). Teaching cell division: student difficulties and teaching recommendations. *Journal of College Science Teaching* (Sep/Oct), 28-33.

Stewart, J., Hafner, B., & Dale, M. (1990). Students' alternate views of meiosis. *The American Biology Teacher*, 52 (4), 228-232.

Videodiscovery (1990). *The Bio Sci II Videodisc Image Database for Biological Science*. Dubuque, IA: Wm. C. Brown Publishers.

Videodiscovery (1985). *The Life Cycles Videodisc - A Database on Reproductive Biology*. Seattle, WA: Videodiscovery, Inc.

Videodiscovery (1987). *The Cell Biology Videodisc*. Seattle, WA: Videodiscovery, Inc.

MEIOSIS MODELING

Activity type: **Modeling**

GOALS: This lab actively confronts students' misconceptions about meiosis. It contrasts meiosis with students' previous knowledge of mitosis.

TIME NEEDED: 2 hours (1 lab period)	
Classroom Time: Introduction: 20 minutes Student Work: 1 1/2 hours Wrap up: 10 minutes	Instructor Time: Preparation: Low Assessment: Moderate (in-class)

Rationale

Students have as many, if not more, misconceptions about meiosis as they have about mitosis. Due to confusion with mitotic division and its complexity, meiosis is a challenge to teach to students. Yet it is necessary to understand meiosis in order to understand other biological concepts such as Mendelian genetics. Below is a partial list from the biology teaching literature of misconceptions about meiosis:

- Fate of sister chromatids during meiosis I
- Failure to replicate and line up homologous chromosomes
- Replicate chromosomes again during meiosis II
- Failure to separate sister chromatids during meiosis II
- Difficulty with chromosome number and ploidy

Overview of Lab

Students should model mitosis as a review before moving on to meiosis. Students will need the reflection and stable base of knowledge from which to launch themselves into meiosis. After students review mitosis, begin the meiosis modeling activity with a discussion on the relevance and location of meiosis.

With the same pattern as the mitosis modeling lab, view some video disk models of mitosis and meiosis to present students with visual models of the two processes. Students then work at teaching each other meiosis. Instructors mingle, spending time with groups, both asking and answering questions. When students feel confident enough in their knowledge of meiosis, they individually demonstrate it for an instructor.

Alternative and Substitutions

The pop bead model works well for meiosis, but pipe cleaners can be substituted. The pop bead model is nice because the instructor can vary the length of the chromosomes, with each chromosome connected by a length of surgical tubing in the middle that contains a magnet. This acts as a centromere to gather chromatids for the students. The pop beads can be labeled with tape to indicate different alleles for students to follow through a meiotic division. Finally, crossing over is possible to model by exchanging ends of the pop bead strings between chromatids.

LEARNING CYCLE ACTIVITIES:

Experience	Students watch meiosis on video disk, then teach each other
Reflection	Students demonstrate meiosis for instructor individually
Abstraction	Instructors quiz with novel chromosome numbers

PRE-LAB DISCUSSION SUGGESTIONS:

Students need to relate meiosis to themselves. One way to do that is to ask students questions about reproduction and fertilization. The following are suggestions to get students to realize the importance of meiosis:

What would happen if an egg cell and a sperm cell had the same number of chromosomes as every other body cell?

In what part of the human body would you expect to find haploid cells?

In what part of the human body would you expect to find diploid cells?

Meiosis can also be issue-driven using something students are familiar with, such as Down's Syndrome. Describe the number of chromosomes present in a person with Down's Syndrome. Have students hypothesize as to what could create this odd number of chromosomes.

As with the mitosis modeling lab, tell the students that in order to really learn meiosis, they need to actively teach and question the whole process in their small groups.

MID-LAB DISCUSSION SUGGESTIONS:

The instructors' functions in this lab are again to go between groups and probe for student understanding. Ask the same kinds of questions as were asked in the mitosis lab. Meiosis is difficult for students the first time through and they hold many deep seated misconceptions about it. Probe for students' understanding of haploid and diploid cell conditions, position of the chromosomes at metaphase, etc.

Here are some other questions to ask students:

Put a haploid cell with replicated chromatids on the table (prophase II). Ask if the cell is haploid or diploid. Make sure they understand why. Ask if that cell could divide mitotically--why/why not? Can it divide meiotically? Why/why not?

If a student says that something could happen that cannot, don't simply tell them they are wrong, but ask them to show you how it would happen. This is the time for them to make their mistakes and confront the inconsistencies.

Ask about the genetic relatedness among daughter nuclei and between mother and daughter nuclei. Ask how many different gametes could be formed, without crossing over, if $2n=8$. Get them to derive the formula. Ask them to calculate how many gametes a human could make with no crossing over.

After students in the groups have gone through meiosis a few times with each other, have them model fertilization with a neighboring group. Some will want to connect homologous chromosomes from different sets at their centromeres. Let them try this, then ask if the cell is haploid or diploid. Ask them to go through the first cellular division (review their mitosis concepts). Get them to display that the cell would have to go through DNA synthesis before it could divide.

Borrow a set of chromosomes from a nearby bench or obtain a set of a different color. Put a triploid nucleus on the table. Ask if it could divide mitotically. Ask if it could divide meiotically. Get them to explain the problems that would arise in division and/or fertilization and development.

POST-LAB DISCUSSION SUGGESTIONS:

When students feel comfortable with their knowledge of meiosis, have them demonstrate it for an instructor. Use a novel chromosome number that the students have not worked with yet. Students do not generally have an easy time transferring to a new chromosome number. Assure them that they know the basics of meiosis.

While some students are demonstrating for the instructor, other groups can work on more complex problems such as crossing over and predicting the genotypes of the gametes or modeling non-disjunction (Down's Syndrome). These exercises are particularly helpful when confronted with a broad spectrum of student knowledge. The more advanced students can feel challenged while the students who are struggling have extra time to work through the modeling exercise.

STUDENT WRITE UP:

None

ASSESSMENT:

Instructor check off upon demonstration.

MATERIALS NEEDED:

Pop bead models of chromosomes
pop beads (at least two different colors)
surgical tubing
magnets
Optional substitution: Pipe cleaners

TIME EXPANSION/CONTRACTION ACTIVITIES:

Expansion

- Have advanced students model crossing over with two alleles
- Use students to model chromosomes (with props) in a student-directed model of meiosis

Contraction

- Skip physical review of mitosis
- Do this lab in lecture!

RESOURCES AND REFERENCES:

Brown, C. R. (1990). Some misconceptions in meiosis shown by students responding to an Advanced level practical examination question in biology. *Journal of Biological Education*, 24 (3), 182-185.

Harper Collins Publishers, Inc. (1991). *Biology Encyclopedia Videodisk*. In New York, NY: Harper Collins Publishers, Inc.

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Stewart, J., Hafner, B., & Dale, M. (1990). Students' alternate views of meiosis. *The American Biology Teacher*, 52(4), 228-232.

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Videodiscovery (1985). *The Life Cycles Videodisc - A Database on Reproductive Biology*. Seattle, WA: Videodiscovery, Inc.

Videodiscovery (1987). *The Cell Biology Videodisc*. Seattle, WA: Videodiscovery, Inc.

MODELING PROTEIN SYNTHESIS

Activity Type: Modeling

GOALS:

Students construct physical models of protein synthesis in order to create mental models of the process.

TIME NEEDED: 2 hours	
Classroom Time: Introduction: 45 minutes Student Work: 55 minutes Wrap up: 10 minutes	Instructor Time: Preparation: low Assessment: medium

Rationale

No matter how scintillating the lecture, or how colorful the pictures in the text, students will struggle with protein synthesis until they have worked through all of the steps in their own mind and modeled it in some way. We have taken some of the same raw materials used in other modeling labs and applied it to this problem. Students work at modeling a real gene (giving the lab relevance) and map out what happens when there is a base substitution, frame shift, or other mistake somewhere in the molecule.

Protein synthesis is a fundamental concept in biology, linking genes with phenotype. Many students, failing to make this connection, will simply ignore any future confusion and dissonance. Therefore it is important that students have a good conceptual basis of protein synthesis to return to in future lessons. This lab utilizes a learning cycle, with students constructing their own model, reflecting on it before an instructor, then abstracting it through a series of problems.

Overview of Lab

Independent of the sequence of presentation in lecture and lab, students will need to review the process of protein synthesis before working on their own models. One graphical way to do this by using video disks. The presentation/review can be halted on specific frames to allow the instructor to point out specific details, then started again to give students a temporal sequence of protein synthesis.

Students then work on modeling protein synthesis from a “real” strand of DNA, containing a known base sequence that is altered in a diseased condition. Given a set of objects, students make their own models based on their choices of objects to represent the different molecules. Within-lab variance in models is often less than between-lab variance due to students watching each other. Students work as a group on the various aspects of the model, then an instructor quizzes them as a check-off assignment.

After constructing the model, students work through a series of problems based on a real segment of DNA. The problems present such concepts as base changes and frame shifts due to base insertions and deletions. By working with the physical models, students build a mental model of these more complicated concepts.

LEARNING CYCLE ACTIVITIES:

Experience

Students review, model protein synthesis

Reflection/

Abstraction

Students present model to instructor

Experimentation

Students test their model’s ability to represent base changes, frame shifts

PRE-LAB DISCUSSION SUGGESTIONS:

Review major steps of protein synthesis. It is important to prompt students to think about protein synthesis on a macro scale. Draw a simplified model, if necessary, for the students to remember when they are modeling. Leave it up and remind students while instructors are probing for student knowledge. Make sure that the students are active participants in this discussion by asking them for information. Relate it to students by presenting it in terms of a real disease (e.g. Cystic Fibrosis, Sickle Cell Anemia) where the problems may result in a drastic change in shape of the protein, and thus a drastic change in function.

After a brief discussion, show students an animated version such as can be found on a video disk. This presents a visual model for students to base their mental models on. A video disk allows the instructor to freeze in specific frames for student questions or additional attention.

If necessary, give a brief lesson or review on reading codon tables.

Give students a set of various objects to model protein synthesis. Let them know that there is no right or wrong way to construct a model. Students may want more of a certain set of objects once they begin. Have some extras set aside to add to different kits.

MID-LAB DISCUSSION SUGGESTIONS:

Instructors should visit all groups during the model building activity to probe for student understanding. Ask questions about what each object represents and why. Student models will vary in complexity, with some building a complete double helical model of DNA, to others trying to simplify to the point of modeling only one codon.

When students are ready to demonstrate their model for an instructor, continue to ask students questions directed at their understanding of the process. Extrapolate from the model. Direct questions at specific members of the group who are passive. This will allow the instructor to correct any misconceptions students may have and make it a true group exercise.

What does this (object) represent in your model?

What does this (subunit) represent?

Where does this (event) occur in the cell?

What is the final product?

What does it do?

When satisfied, pose some relevant questions to students to lead them to model problems with protein synthesis.

What happens when a DNA base is changed?

How would you model that change?

What causes the symptoms of this (particular) disease?

POST-LAB DISCUSSION SUGGESTIONS:

Come back together as a large group and quickly review protein synthesis using specific diseases as models. This will point out to students the importance of protein synthesis and connect it to a disease they know. This review also acts as a reflection for students as a whole, bringing them back to offer up their knowledge.

STUDENT WRITE UP:

Answering specific questions on a handout.

ASSESSMENT:

Check off student demonstrations, correct student handouts.

MATERIALS NEEDED:

Pop beads
Pipe cleaners
Clothespins, paperclips
Styrofoam balls/shapes
Colored paper
Scissors
Markers
Sticky dots, other decorative/labeling items
Codon chart

TIME EXPANSION/CONTRACTION ACTIVITIES:

Expansion

Have students model deletion, substitution, and insertion of DNA bases

Contraction

Students model only change in DNA that is relevant to their disease

MODELING PROTEIN SYNTHESIS

OBJECTIVES:

- Review the process of turning DNA code into proteins
- Model this process for each other and for an instructor
- Observe what happens to a protein when the coding DNA sequence is changed

INTRODUCTION:

Protein synthesis is the process of converting the information stored in DNA into the proteins that carry out the functions of the cell. The process is vital; it is fundamental to the function of every cell in your body. Proteins play an integral role in almost every aspect of a cell's structure and function. The functions of proteins range from their enzymatic actions that facilitate virtually all life processes, to the color and texture of our hair and toenails.

Today you will use a variety of materials to represent the different molecules, modeling protein synthesis. Your group will decide on a model and demonstrate it to an instructor. Then you will model what happens when something is changed in the DNA sequence, and explore how the protein, and thus the phenotype, changes.

MATERIALS AVAILABLE:

Pop beads
Pipe cleaners
Clothespins, paperclips
Styrofoam balls/shapes
Colored paper
Scissors
Markers
Codon chart

ACTIVITIES:

Part I: Modeling Transcription and Translation

Many scientist use models to understand biological processes. Watson and Crick used models to figure out the structure of DNA and scientist today use models to study biological problems from the structure of proteins to the processes responsible for the evolution of species. In this exercise you will develop your own model to show the processes of transcription and translation. We hope that through this exercise you will get a better understanding for how information coded in DNA is responsible for the characteristics of an organism.

The DNA sequence below is part of the noncoding strand of the β -globin gene that codes for a part of your hemoglobin.

ACCCAGAGGTTCTTTGAGTCCTTT

What is the sequence of the coding strand?

What is the mRNA sequence that is coded for?

What is the amino acid sequence coded for by the mRNA?

Use the materials available -- pop beads, styrofoam shapes, pipe cleaners etc.--to make a model for transcription and translation of the above sequence from the β -globin gene. Be sure to include DNA, mRNA, nucleus, ribosomes, amino acids and any other features you feel are important. Work in groups of 3-4 and make sure each member of your group can demonstrate the process of transcription and translation using your model.

Part II: Modeling Mutations

Assume that there is a mutation that substituted an A for the third C of the noncoding strand. Use your model to demonstrate the affect of this mutation. Write the sequence of amino acids that would result:

What would the amino acid sequence be if you deleted the third C of the noncoding strand?

Is there a general rule you can make regarding the impact on a protein from these two types of mutations? (i.e. how does a substitution affect a protein compared to a deletion?)

When every member fully understands the model, demonstrate the model to one of the instructors and have them initial your handout.

instructor initials _____

EXPLORING THE HEART

Activity Type: **Guided discovery**

GOALS:

Students predict the function of the heart by observing its anatomy. They practice their observational skills to confirm and build upon their previous knowledge of the heart and confront any misconceptions.

TIME NEEDED: 2 hours	
Classroom Time: Introduction: 5 minutes Student Work: 75 minutes Wrap up: 10 minutes	Instructor Time: Preparation: low Assessment: medium

Rationale

This lab exemplifies the difference between the methods of the traditional class and the workshop class. In the traditional lab, the instructor began by showing diagrams of the heart, labeling the major structures with their anatomical names, and instructing the students in how they should conduct the dissection and what they should expect to observe. The focus was on identifying and naming parts (which, incidentally, involved a large amount of new terminology). The students then proceeded to follow the instructions and perform a detailed dissection.

In the workshop, we begin with the idea that identifying parts is secondary to understanding how the form of the heart relates to its function. Students begin their dissections with no terms, no diagrams, and no directions, save to make careful observations of how the heart is structured. They are encouraged to formalize their observations with drawings and descriptions. Several leading questions on their handout ask them to infer the function of the different areas of the heart, and the path of blood flow. The idea of “double-loop” blood flow is unfamiliar to most students, and has been shown to be a source of misconceptions (Arnaudin & Mintzes, 1985), but they are able to infer this process from their observations. We introduce terminology only as it facilitates discussion about the different parts. Students thus not only gain a good understanding of form and function of the heart, but also experience in making observations and inferences. Some students feel uncomfortable going in “cold,” with no prior knowledge of heart structure, but most feel it is a valuable learning experience, and it is ranked very highly on course evaluations. Again, workshop students' conceptual understanding in this area has improved much more than that of the traditional students, who often end the term more confused about the circulatory system than when they started.

Overview of Lab

Most of the lab time is allotted to student observations. A brief introduction is all that is needed to get students started. Give students a heart and circulate amongst the groups, answering and posing questions. Students work on their own, making observations and filling out a worksheet.

Warnings

The chemicals used to preserve biological specimens can cause skin irritations and their odor will often linger. Advise anyone handling a heart to wear rubber gloves.

Alternatives and Substitutions

This laboratory style can be applied to a variety of dissection labs.

LEARNING CYCLE ACTIVITIES:

This lab serves as the concrete experience and reflection that forms the basis for subsequent activities on the circulatory system.

PRE-LAB DISCUSSION SUGGESTIONS:

Do not give students a formal introduction to the heart. Instead, remind students that they already have some knowledge of the heart. Place it within a generalized organism and briefly ask students about its function. Leave the details for discovery by the students.

Remind students that the chemicals they are working with can be irritants.

MID-LAB DISCUSSION SUGGESTIONS:

Be available for student questions during the dissection. Probe groups for knowledge by asking them questions such as:

Why are there so many chambers?

Why is there a difference in chamber wall thickness?

What do the valves do?

Which direction does blood flow through (this) valve?

Where is (this) artery/vein going/coming from?

How do the heart muscle cells get oxygen and nutrients?

What is the pathway of blood through the heart?

What is the sequence of events in one heart beat?

POST-LAB DISCUSSION SUGGESTIONS:

Gather the group together and make a generalized drawing on the board. Discuss as a large group the students' observations about the function of the various structures of the heart. Place it within the larger circulatory system, discussing its overall function in the body.

STUDENT WRITE UP:

Students complete the questions on handout.

ASSESSMENT:

Grade student handout.

MATERIALS NEEDED:

dissection trays
sheep hearts (1 per pair)
razor blades/scalpels/blunt probes
rubber gloves

TIME EXPANSION/CONTRACTION ACTIVITIES:

Expansion

- Compare hearts from different organisms (i.e. mammal, bird, reptile, etc)

RESOURCES AND REFERENCES:

Arnaudin, M. W., & Mintzes, J. J. (1985). Students' alternative conceptions of the human circulatory system: a cross-age study. *Science Education*, 69 (5), 721-733.

Vogel, S. (1992). *Vital Circuits: On Pumps, Pipes, and the Workings of Circulatory Systems*. Oxford: Oxford University Press.

EXPLORING THE HEART

OBJECTIVES:

- Explore the anatomy of a heart
- Use anatomy to figure out the function of the heart

Warning: The chemicals used to preserve the heart can irritate your skin. Make sure to use rubber gloves when handling the heart.

MATERIALS AVAILABLE:

dissection trays
hearts (1 per group)
razor blades

blunt probes
gloves

INTRODUCTION:

As the science officer of well-known starship, you're responsible for getting to know the physiology of aliens from places where no one has been before. A recent expedition to the planet Montana has yielded a woolly alien race that call themselves The Sheep. An ambassador of The Sheep was going to take a tour of your starship, but there was a wee accident with the transporter. All that's left of the ambassador is before you in the tray. It appears to be a muscular circulatory pump — a heart. Try to make the best of a bad situation and examine the heart while the engineers fiddle with the transporter.

QUESTIONS:

Sketch the heart, with the major vessels up and toward you.

How many large vessels were severed (how many openings to the interior of the heart can you find)?

What purpose might the vessels that run along the surface of the heart serve?

Hearts pump blood. Complex hearts use valves to pump blood in specific directions. It's time to open it up and look for valves or other structures that will help you determine how The Sheep's circulatory system works.

Carefully cut the heart where you think you can get the best interior view (remember, this is an alien species to you!). Clear any residue from inside the heart and examine it for structures, especially things that might function as valves. Use your blunt probes to examine and follow any openings.

Sketch any structures you find. What purpose might these structures serve?

Continue exploring the heart, carefully cutting open other chambers and examining them for structures.

Sketch a cut-away view of the heart, including the chambers, passages, and valves that you've found. Also note any differences in sizes of chambers, or thickness of chamber walls.

The valves function by allowing passage of fluid in one direction only. Put an arrow near each valve in your sketch above to indicate which direction fluid would have flowed when the heart muscle contracted.

Draw a schematic that includes the heart chambers, a gas exchange organ (The Sheep's cells use oxygen), and a part of the Sheep's body where the oxygen is used. Indicate the direction of fluid flow at several points in your schematic.

BLOOD PRESSURE INVESTIGATIONS

GOALS:

Students learn about blood pressure in the context of studying the circulatory system. They practice the scientific method by conducting an experiment on what changes blood pressure.

TIME NEEDED: 3 hours	
Classroom Time:	Instructor Time:
Introduction: 30 minutes	Preparation: low
Student Work: 150 minutes	Assessment: high
Wrap up: 30 minutes	

Lab Rationale

This lab takes something familiar to the students and draws upon that knowledge to practice the scientific method. Learning how to take a person's blood pressure integrates real life application with concepts about the heart and circulation.

Students can then test their own hypotheses about what changes blood pressure. They get practice in the scientific method by designing and conducting an experiment. This particular exercise brings up a lot of questions about controls which students will have to answer before they conduct the experiment.

The lab follows a classic learning cycle in which students gain experience taking blood pressure, abstract their experience to design ways to alter blood pressure, conduct an experiment and synthesize their results.

Overview of Lab

During the first lab period, students learn about blood pressure. They are given time to practice listening to the sounds of the heart and associate these sounds to the circulatory system's activity. Then students begin their experiment by thinking of things that will alter blood pressure. They formulate a hypothesis and make predictions at the end of the first lab, and write a short proposal for their experiment.

For the next lab period students bring from home any materials they might need, such as caffeinated pop. They then conduct their experiments during class. If time permits, an example lab write up can be given to the students and analyzed by the class. If not, students do the write up at home and turn it in in future classes.

This also provides an opportunity for peer review of papers. Students can exchange write ups and critique the papers for content and clarity. Students are able to correct major errors before handing in the labs and learn from correcting each other.

Warnings

Students may need some guidelines for experiments. Have each group review their hypothesis and design with an instructor before they conduct the experiment to prevent any potentially harmful or illegal experiments.

PRE-LAB DISCUSSION SUGGESTIONS:

Begin the discussion by making connections with students' previous experiences. This includes their experiences with blood pressure and their knowledge of the heart. If the heart lab was done previously, remind students of what they discovered about the heart. A diagram presenting the heart in relation to the vessels would remind students of the heart lab and give them the "big picture" of human circulation.

Ask students about the action of the circulatory system:

What does it do?

How does the body change where blood goes (e.g. exercise vs digestion)?

What happens to blood pressure when the diameter of the vessels changes to shunt/accept blood?

One commonly used analogy is that of a hose. Students can relate to their experiences with hoses to understand the principles of pressure and how it is related to diameter and flow.

Describe to students how to take each other's blood pressure. A drawing and a graph of the actual vessel pressures might be helpful during the discussion. Students will have difficulty at first taking each other's blood pressure but need to experience the frustration themselves and practice the technique. They are not only unfamiliar with the equipment, but are accustomed to a quick procedure from practiced nurses. The instructor will want to explain the procedure by describing the sounds they should be listening for and define the diastolic and systolic numbers using a diagram. Students should equate the terms and definitions to their knowledge of the circulatory system.

MID-LAB DISCUSSION SUGGESTIONS:

At the end of a practice period pose the assignment to the students as a large group. What types of things might alter blood pressure? Make a list of the class' ideas. Students may only offer applied changes (e.g. exercise), the instructor should try to relate these suggestions to what is actually happening in the circulatory system. A partial list of physiological items that affect blood pressure is:

heart output (stroke volume and heart rate)

resistance in vessels (including vessel diameter)

blood volume and blood viscosity.

As a group discuss experimental design. What is a control? How many subjects should an experiment have? Have the students break up into groups and discuss which variable they would like to test. Tell them that they will be writing this experiment up as a formal lab report. They should generate a hypothesis, prediction, and list of controls before they conduct the experiment.

Instructors need to talk to each group to make sure that they have a safe experiment and an appropriate predictions. Remind students to bring any materials the class can't supply for the next lab period.

On the day of the experiment students can volunteer for each other's experiments as "subjects". Instructors can also become involved as volunteers, monitoring the students' learning and progress. Ask students about why they formulated their particular hypothesis and predictions. Are the data supporting their hypothesis? Why or why not?

POST-EXPERIMENTAL DISCUSSION SUGGESTIONS:

After the experiments are finished, discuss the parts of a formal scientific paper. The instructor may wish to hand out an example paper for students to discuss and model. If there is time to discuss the paper, it should contain both good points and bad points. Students will hopefully recognize the bad points during a class discussion, making them more relevant through example. Data presentation merits discussion, because many students have not had to present data before.

Finally, instruct students to tie their experiment back into their knowledge of the circulatory system. Their discussion is a place where they reflect and integrate the data they have gathered into what they already knew about blood pressure. With any luck some of them will confront some misconceptions and change their ideas based on their own experiment.

STUDENT WRITE UP: Initial proposal, formal lab report.

ASSESSMENT: Grading of student reports.

MATERIALS NEEDED:

Blood pressure cuffs
Stethoscopes
Isopropal alcohol

TIME EXPANSION/CONTRACTION ACTIVITIES:

Expansion

- Peer review of reports
- Discussion of each group's results

Contraction

- Instructor-directed experiments
- One day introduction to reading blood pressure with experiment

RESOURCES AND REFERENCES:

Vogel, S. (1992). *Vital Circuits: On Pumps, Pipes, and the Workings of Circulatory Systems*. Oxford: Oxford University Press.

EXPERIMENTS WITH BLOOD PRESSURE

OBJECTIVES:

- Gain familiarity with diagnostic procedures commonly used in your doctor's office
- Practice scientific investigation methods and further examine the art of experimental design
- Investigate some of the factors that can influence the results of blood pressure measurements

INTRODUCTION:

MATERIALS AVAILABLE:

stethoscopes

isopropyl alcohol

sphygmomanometer (blood pressure cuff)

QUESTIONS:

You know that the heart valves make a “lubb-dubb” sound as the heart beats, but if you've never actually heard those sounds yourself, **HERE'S YOUR CHANCE!**

1. Clean the earpieces of the stethoscope with alcohol (you don't know where it's been), then place them in your ears, with the top of each earpiece pointing inward and upward.
 2. Hold the bell of the stethoscope firmly against your partner's chest, about three inches left of their midline and three inches up from the bottom of their rib cage. (If your stethoscope has two sides, use the diaphragm; the cup is for listening to the lungs.)
 3. Listen for the heart sounds and describe them.
-
4. What is happening in the circulatory system that is making these sounds?
-
-
-
-
-
-
-
-
-
-
5. Now have your partner exercise for a couple of minutes.
 6. **Describe the heart sounds after exercises.**

Blood Pressure Measurement

1. Find a pulse over your brachial artery (the big one inside of the elbow). Use the stethoscope and listen to the artery. **Can you hear anything?**
2. Have your partner sit quietly with his or her right arm on the lab bench, so that the elbow is about level with the heart.
3. Wrap the cuff of the sphygmomanometer snugly around the arm about an inch above the elbow. Place the arrow on the cuff over the brachial artery and pull the end of the cuff to fasten it snugly in place.
4. Put the stethoscope on and place the diaphragm over the brachial artery.
5. Hold the rubber bulb of the sphygmomanometer in the palm of your hand with the screw between your thumb and index finger. Close the valve by tightening the screw.
6. Quickly inflate the cuff by pumping the rubber bulb. Continue until the manometer reads about 180 mm Hg. No sound should be heard.
7. Slowly release the cuff pressure (about 5 mm Hg/sec) by opening the screw valve. Listen for a tapping sound as the blood overcomes the pressure of the cuff. Note the pressure. This is the systolic pressure.
8. Continue to slowly release pressure. The sounds will become louder, then muffled, then disappear. The pressure at which they become muffled is the diastolic pressure.
9. Now have your partner measure your blood pressure. **Record your blood pressures:**

A Scientific Experiment

We all know that activity increases the heart rate, but what kinds of things affect blood pressure and its measurement? To answer that question in a scientific way, you and your partner will have to come up with a hypothesis, make a prediction, and design an experiment to test the prediction. When you're done, we will discuss the results.

Some observations and your question:

Your hypothesis:

A prediction that follows from your hypothesis:

Describe your test of your prediction (the experimental design):

Have an instructor initial here to make sure you're on the right track. _____

Format for Blood Pressure Investigation Report

- **Introduction**
 - Ask a question that you will address in your study. Grab the readers attention, it will make her or him want to read more.
 - Give some background information that explains why the question is significant.
 - State your hypothesis. (A good hypothesis will be a reasonable explanation that provides an answer to your question.)
 - Describe alternative hypotheses, if any.
 - Make your prediction.
- **Methods & Materials**
 - Briefly but clearly describe your procedures for all the experiments you performed.
 - Make sure you have the proper controls. State what you are controlling for.
- **Results**
 - Briefly but clearly describe your results. Use tables or charts.
- **Discussion**
 - Justify your experimental design either here or in your methods section.
 - Assess the quality of your procedures and the results you got.
 - Interpret your results.
 - Discuss how your results fit in to your understanding about blood pressure.
 - Discuss your hypothesis in terms of your results.
 - Discuss any alternative hypotheses in terms of your results.
 - Describe some future work suggested by your experiments.

PLANT REPRODUCTION LAB

Lab Type: **Learning Cycle**

GOALS:

Students look at familiar plants and fruits in terms of evolutionary adaptations plants have made to disperse gametes and zygotes. They hypothesize, from the general form of a flower and a fruit, as to the possible evolution behind the diversity of form displayed in common fruits and flowers. Students then test their hypotheses by classifying new plant specimens as to gamete and zygote dispersal.

TIME NEEDED: 2 hours	
Classroom Time: Introduction: 10 minutes Student Work: 90 minutes Wrap up: 10 minutes	Instructor Time: Preparation: medium Assessment: medium

Lab Rationale

This lab can be used in a variety of different settings, depending on the focus of the class. It takes items the students are familiar with and places those items within the students' newly acquired framework of biology. However, the biology framework may differ with the specific topic of the class. This lab can be used to discuss topics such as reproduction, development, botany, and evolution. The focus and questions can be altered to fit the class.

A learning cycle is utilized. Students are already familiar with many of the plants, flowers and fruits that can be used but observe them in the new context of gamete and zygote dispersal. Next they construct their own knowledge about flower and fruit types by comparing many different types of plants and hypothesizing as to the evolution of form. They then look at new flowers and fruits and test their hypotheses of the evolution of form and function.

Overview of Lab

Students are free to examine a wide variety of flowers and fruits. Working in pairs, students dissect and draw several specimens. For each, they hypothesize the method of dispersal of either the gametes or zygotes. If necessary, diagram a general model of a flower and a fruit. Label the parts pertinent for the lab, pointing out male and female reproductive structures and seeds. After many observations, individuals gather in groups to discuss the forms plants have evolved to take advantage of the various forms of dispersal.

In a large group discussion, list the various forms of dispersal of gametes and zygotes that the students can give the instructor on the board. For each have students come up with generalized forms from their observations.

Students, after agreeing on the generalities, then test their hypotheses about form with new specimens. Give students new samples, pictures, slides, etc. and have them write down how they think the gametes/zygotes are dispersed and why.

Warnings

Students should be careful when handling razor blades during dissections.

LEARNING CYCLE ACTIVITIES:

Experience

Examine various flowers and fruits

Reflection/

Groups make hypotheses about dispersal of gametes and zygotes

Abstraction

Experimentation

Students apply hypotheses to unknown specimens

PRE-LAB DISCUSSION SUGGESTIONS:

Students will be eager to start dissecting the wide variety of flowers and fruits. Guide them to think in terms of form, function, and evolution. A couple of questions at the beginning like the following will prompt them to think about evolution:

- What might be an evolutionary advantage to having flowers?
- What are the costs and benefits to flowers?
- Why do a lot of fruits become red when they ripen? (One hypothesis is that insects cannot see red and therefore do not selectively pick out the ripe fruit on a plant)
- What other changes occur with fruit ripening?
- Why don't animals eat unripe fruit?
- How is the fruit protected in various plants?

MID-LAB DISCUSSION SUGGESTIONS:

Part way through the lab, remind individual groups of students to continue making comparisons between the different flowers and gametes that they see. If necessary show students a generalized drawing or picture of a flower. Label the structures, pointing out where male and female gametes are produced. What process that students have studied creates gametes? Tie this back to meiosis by giving students a real structure and process to think about during the lab.

Point out that students have observed many different adaptations flowers have made. Make a list of the different ways plants get the two gametes together. Students should be able to come up with:

- animal fertilization (birds, insects, and bats)
- wind (pollen in the air, mostly from grasses and conifers)
- water (mosses and ferns)

Students should list or draw a generalized flower for each type of fertilization.

Do the same activity for the different ways that fruit are dispersed. Make a list of the different dispersal methods:

- animal (berries, other attractions to animals, etc.)
- wind (maple "wings", dandelions, milkweeds, cottonwood, etc.)
- water (coconut)

Again, have students make a list or draw a generalized fruit for each type of fruit dispersal that they list.

Evolution can be discussed at this point. The following questions are suggestions that might prompt students to think about form and function in terms of natural selection:

- What are the various hypotheses about why certain flowers are shaped the way they are?
- What about color? (Most bird pollinated flowers are red, while most moth pollinated flowers are white)
- Are there any generalizations that emerge about the fruits?
- Are foods that humans like to eat as appealing to animals?
- How do humans help or hinder seed dispersal? Do you think this has affected recent evolution?
- What might dispersal by birds mean for a population of plants over a long period of time?
- How many of each type of gamete are produced by one flower?
- What are the relative sizes of the gametes?
- What are the various adaptive schemes that they have observed in the different flowers?
- Why are most bird pollinated flowers red?
- What does the shape of the flower tell you about its mode of fertilization?
- What the difference between a fruit and a vegetable is to a produce manager and a biologist?
- What are the different ways plants have evolved to protect seeds?
- What are the advantages and disadvantages to having a hard outer coating on a seed?
- How have some fruits gotten around this problem? (passing through an animal's digestion track, fire, etc.).

POST-LAB DISCUSSION SUGGESTIONS:

After students have come up with generalized fruits and flowers, test them with new specimens. This is a time to mention some of the highly specialized plant systems.

Examples:

- orchids
- yucca and yucca moth
- sea grasses
- bat pollination

STUDENT WRITE UP: Complete handout

ASSESSMENT: Grade handout

MATERIALS NEEDED:

- Various fresh flowers and common plants
 - perfect flowers (lilies)
 - imperfect flowers (alder, oak, other flowering trees)
 - compound flowers (daisies)
 - Insect-pollinated flowers (legumes)
 - Wind-pollinated flowers (corn or other grasses)
 - Special cases (primrose-breeding types)
- Various fresh fruits, vegetables, and common plants
 - Simple fruit (melon, tomato)
 - Aggregate fruit (raspberries)
 - Drupe (peach, avocado)
 - Pome (apple, pear)
 - Legume (pea, bean)
 - Wind-dispersed seeds (dandelion, maple)
 - Animal-dispersed seeds (berries)
- Knife (gross dissection)
- Razor Blades
- Metal probes
- Tweezers

TIME EXPANSION/CONTRACTION ACTIVITIES:

Expansion

- View special cases of fertilization and fruit dispersal (video disk, slides)

Contraction

- Limit number of specimens

RESOURCES AND REFERENCES:

Adams, D. and Wivagg, D. (1994). Baylor University Bioliteracy Program. Paper presented at NSF Project Impact Conference, Washington, D. C.

Kolb, D. (1984). *Experiential Learning*. Englewood Cliffs, NJ: Prentice-Hall.

Raven, P. H., Evert, R. F., and Eichhorn, S.E. (1986). *Biology of Plants* (5th ed.). New York: Worth Publishers, Inc.

PLANT REPRODUCTION

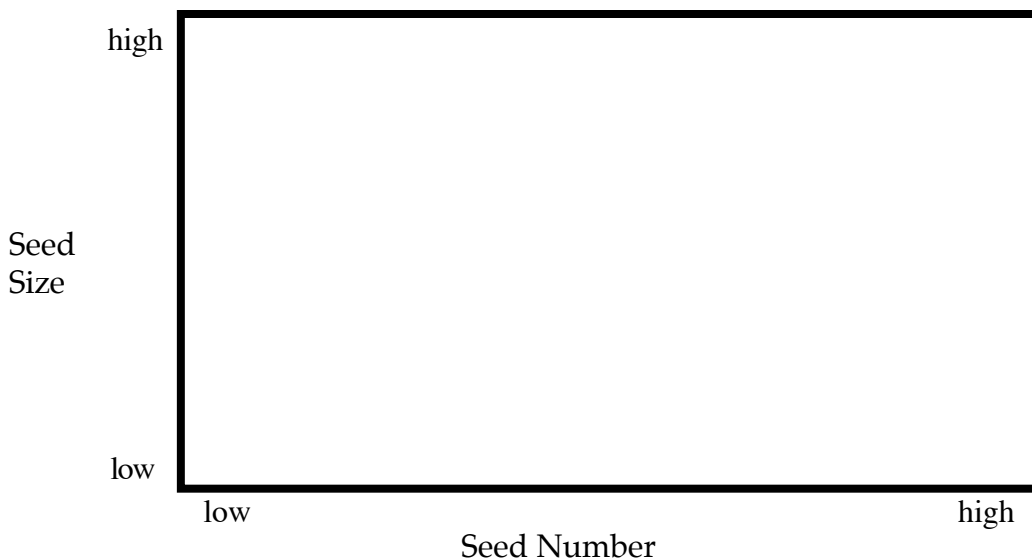
OBJECTIVES:

- Exam some old friends (or perhaps enemies!) in terms of biology and evolutionary theory.
- Hypothesize and generalize reproductive form from function in the different plant groups.
- Test your hypotheses with new samples of flowers and fruits.

INTRODUCTION:

Energy Allocation

Evolution works through natural selection on organisms. One “pressure” that can shape organisms through natural selection is energy allotment. If an organism can only take in so many calories, it has to divide them between growth and maintenance of its own body and reproduction (or passing on its genes). Often solutions to the reproductive question are divided between size and number. Based on this information, draw the line you would predict for the relationship between seed number and size on the graph below:



Gamete and Seed Dispersal

The energy balance can be very important in evolution. Keep it in mind as you look at the different flowers and fruits today.

By looking at flowers and fruits and vegetables, we can begin to hypothesize how evolution may have produced a certain shape or function in an organism. Each organism is faced with some of the same problems in reproduction:

1. How to get the gametes together.
2. How to disperse the zygotes to a new, hospitable environment.

Today, we will look at some different types of flowers and fruits. Start thinking about how they may have evolved this way.

MATERIALS AVAILABLE:

Various flowers
dissection knife
metal probes

Various fruits and vegetables
razor blades
tweezers

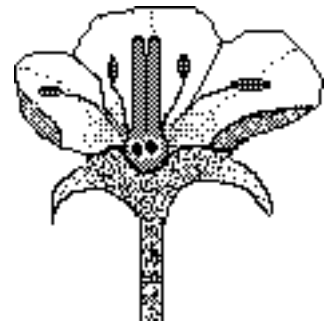
QUESTIONS:

In this lab, we will look at plant reproductive structures, or as they are more familiarly known, flowers, cones and fruits. Before you look at any of the prepared slides or fresh material today, take some time now to answer the following questions about plant reproduction and to make some predictions about what you will see...

Floral structure

How do plants reproduce? What do the words "male" and "female" mean with regard to plants?

How do the sexes (the gametes) get together in plants? (After all, aren't plants immobile?) Name several possible strategies that plants might use to achieve fertilization.



On the right is a generalized diagram of a basic flower. Variations on this pattern depend on what strategy the plant follows to get the pollen from the stamen to the pistil. **Predict and draw** the general floral design for several methods of pollination. For example, what type of pollination does the flower on the right have?

Using a dissecting microscope, and working with a partner, look at the samples of flowers brought in to the lab. Try to identify all the major structures. How do you think each of the different examples are pollinated? Explain why you think so. Use this space to draw what you see. Are all of the basic parts present? If not, why?

Dissect and draw at least three different types of flowers. For each flower, answer the following questions:

- A. Where are the male and female gametes produced?
- B. How are the gametes dispersed?
- C. What is a hypothesis as to how this flower evolved this way?

Zygotes

Look at the examples of fruits. But first, answer the following questions, recalling the generalized diagram of the basic flower.

What part of the flower are you looking at when you look at a fruit? How has the flower changed?

What is a fruit anyway? Botanists use the word a bit differently than the general public. So, since botanists generally know what they're talking about with regard to plants, how are you going to correct the next person who refers to a tomato as a "vegetable"?

Dissect and draw at least three different types of zygotes. For each of the zygotes, answer the following questions:

- A. Where are the seeds? Where is the flesh of the zygote?
- B. Does this fruit appear to produce many small zygotes or a few large zygotes?
- C. Based on the structure now, what type of environment did this fruit evolve in?
- D. How are the fruit dispersed?

Unknowns:

Write down the mode of dispersal you think each unknown flowers and fruits. Write down **why** you think that the gametes or zygotes are dispersed this way based on your previous observations.

Unknown 1:

Unknown 2:

Unknown 3:

Unknown 4:

Unknown 5

Unknown 6

OPTIONAL SECTIONS SUGGESTIONS

Gymnosperm reproduction

While you have the compound scope out, you should look at the prepared slides of gymnosperm reproductive structures. But first, answer the following questions, and make some predictions about what you'll see on the slides...

What's the difference between a flowering plant (an "angiosperm") and a cone-bearing plant (a "gymnosperm")? (A hint from a dead language, Latin - "angio-" is a prefix meaning "enclosed"; "gymno-" means "naked", and "sperm" refers to "seed")

How do you think gymnosperms are pollinated? When you think about a "pine cone", what reproductive structure are you thinking about?

Many gymnosperms have most of their female cones high up in the tree, above the male cones. Why do you think this is so?

INVESTIGATING SOIL FAUNA

GOALS:

This lab has two goals; expose students to soil microorganisms and teach/practice experimental design. Students learn about diversity in soil ecosystems by designing and carrying out an investigation into soil organisms.

TIME NEEDED: 3 hours	
Classroom Time: Introduction: 30 minutes Student Work: 120 minutes Wrap up: 30 minutes	Instructor Time: Preparation: medium Assessment: medium

Rationale

The first goal of this lab addresses a misconception that soil is inherently “dead”. Students often do not have an awareness for the life that abounds in soil and gives it many of its important properties. They gain a new appreciation for land management practices after viewing and reading a paper about soil organisms. This knowledge is useful in future discussions about land uses specific to the course topic and/or issues.

Secondly, after students have been introduced to soil organisms through observation and a background reading, they are asked to design an experiment around soil organisms. In the Pacific Northwest, we ask them to address the relative abundance of soil organisms in forests of different ages. This can be further restricted to specific forest type (i.e. conifer, deciduous). The class then comes up a sampling technique with their particular question in mind.

Instructors can adjust the lab to suit their local ecosystems and/or course topic. The students should be directed to address local land use practices and ecosystems in the experimental design.

Overview of Lab

Students are assigned the article "Life in the Soil is a Ferment of Little Rotters" (Anderson, 1983). They are asked to think about how soil fauna might differ in local land management areas. In the PNW, this can mean a discussion around soil fauna in very young (recently clearcut) "forests", in plantation style (20- 30 year old forests), and in oldgrowth (200+ year old) forests.

Students are then exposed to soil organisms by examining under the dissecting microscope some samples extracted from forest litter using a Tullgren or Berlese extraction set-up (*insert here a reference to a separate document or cite a reference for information on how to do this*). Most students enjoy looking at these organisms. This short exposure is meant to get them interested in the unit and to give them some experience in identifying these organisms.

The class then makes predictions, based on the reading and on the class discussion following the first exercise, about diversity and abundance of these organisms in different land management areas. The class as a whole comes up with a sampling scheme to try to test their individual predictions. A teaching assistant (along with student volunteers) then goes out into the woods to collect samples according to the scheme devised by the class. This helps the student "own" the activity, and it enforces a realistic waiting period before they can try to find out if their predictions are correct. Allow for a day/weekend in order to sample when planning the lab.

Samples are brought back to the lab and organisms are extracted over a period of several days. Students then analyze the samples, creating a tally of the number and kinds of organism present in each sample. The data are pooled, and given to students for analysis. Students write reports of this investigation. If time permits, select one or two groups of students to present their results to the class as a whole for discussion.

LEARNING CYCLE ACTIVITIES:

Experience	Students make observations of soil organisms previous collected by instructor
Reflection	Students read article about soil organisms
Experimentation	Class designs a sampling experiment to test predictions about soil organisms in different land management/ecosystem areas

PRE-LAB DISCUSSION SUGGESTIONS:

Introduce students to the apparatus and how it works to extract the soil organisms. Let students know that it is less important to know the name of what they are observing. Simply make observations as to the number of legs, segments, etc. Make keys available part way through the lab (after students have made some preliminary observations) so they can begin to assign names to their categories. Typically (for the PNW), there will be an abundance of mites and springtails, with smaller numbers of other groups (pseudoscorpions, symphylans, beetles) included.

Move from group to group, answering questions about taxonomy. Ask students what they think the different types of organisms do in the soil community. Students should start thinking about what makes up soil and how organisms survive and add to the soil components.

Where does soil come from? What happens to all of the matter that drops on soil in the fall?

After students have looked at the organisms for a while, hand out an article about soil organisms (see reference list). Tell students to think about the different types of forests. They need to reflect and abstract their experiences from lab. Can they make a hypothesis about soil organisms in the different types of forest? What are their predictions? How would they devise an experiment to test their hypotheses?

Ask students to design an experiment about soil organisms in different types of forests in the lab period after they have read an article. Decide on a hypothesis as a class. Students can make predictions within their working groups, but the class needs a common hypothesis in order to design an experiment together.

Begin asking students questions about the experimental design.:

What types of sampling should they use?

Does the size of the sample make a difference?

How deep should they sample?

Where in each forest type should the sample be taken?

Should more than one count be made in each area?

MID-LAB DISCUSSION SUGGESTIONS:

After collecting the samples and extracting the organisms, students observe the different soil organism samples and collect data. Draw a picture for the students of the sampling area. Carefully outline the sampling, perhaps providing pictures of each site. Remind students of their hypothesis. What was the class question being investigated?

After students collect their group data, pool the data for the class. Talk about pooled versus individual data.

POST-LAB DISCUSSION SUGGESTIONS:

Hand out the pooled data sheets. Discuss with students the write up. What was the original question? Does the data support their hypothesis and predictions? If it doesn't, what is the next step? What does the data mean?

The class can now participate in a discussion about land use policies. Ask students to make predictions about soil organism abundances in different types of crop rotations in agriculture or different ecosystems.

STUDENT WRITE UP:

A formal laboratory write up about the class experiment.

ASSESSMENT:

Grade lab write ups.

MATERIALS NEEDED:

Soil organism extraction apparatus
Soil samples from different plant communities
Dissecting microscopes
Small petri dishes
Probes/dissecting needles
Soil organism key
Data collection tables (file “soil data tables” included in this folder)

RESOURCES AND REFERENCES:

Anderson, J. (1983). Life in the soil is a ferment of little rotters. *New Scientist*, Oct 6, 29-37.
Eisenbeis, G. a. W., Wilfried (1987). *Atlas on the biology of soil arthropods*. New York: Springer-Verlag.
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SOIL FAUNA

Part I

OBJECTIVES:

- See and appreciate the diversity of microfauna present in forest soil
- Begin to identify some of the major groups of animals present in preparation for comparison of two forest soils
- Formulate a question for an experiment with soil organisms

INTRODUCTION:

Having read the article "Life in the Soil is a Ferment of Little Rotters", you should have begun to have some appreciation for the diversity of kinds of organisms present in forest soil. Today, we want you to look at a soil sample extraction in order to become familiar with some of the many different kinds of organisms that exist. At the end of this lab, we will design and experiment as a class to look at abundances of soil organisms in different types of plant communities. You will look at those extractions next lab.

Samples of forest soil (or of the litter layer) have been placed in the Tullgren apparatus which drives some of the animals present down into collection bottles below. To begin our investigation we want you to make some observations about the kinds of organisms present. The characters listed below will help you to identify them. You can also use the keys to these organisms that are in the lab for your use.

MATERIALS AVAILABLE:

dissecting microscopes
soil organism samples
small petri dishes

probes
taxonomy guides
data collection table handout

SOIL FAUNA

Part II

OBJECTIVES:

- Collect data and look at it for patterns
- Communicate your results in the form of a lab report

INTRODUCTION:

Samples for the class experiment have been taken and are ready for data collection. You should be familiar with the organisms. If not, review your data table from last time. What predictions did your group make about soil organism abundances?

-
-

Each group should collect data on at least two samples from each site. Class data will be pooled, and you will write your report based on these data. The report should communicate our experiment well enough so that another group of students (or scientists) could repeat what we have done. It should include the following sections:

Introduction. Explain what the question is that is being investigated, why it might be of interest to other ecologists, and what results you expect, if you have reason to expect a particular outcome. Relate it to other questions in ecology, if pertinent.

Methods. Give enough description of what was done so that someone else could repeat the experiment if they wanted to. Sometimes sketches of experimental design or apparatus used are helpful.

Results. Report only the results of the experiment; your own interpretation of these results belongs in the following section. It is almost never appropriate to include all of the raw data. Find a way (table, graph, etc.) for the reader to quickly grasp the essentials of what you want to present.

Discussion. Interpret the results. Did they support your hypothesis? Are there alternate explanations? Are there further studies that you think should be done? Were there flaws in the sampling or analysis that we should be aware of? Does this study have any significance with regard to other issues in forest ecology?

Citations. I don't expect you to do a lot of library work for this report, unlike the issues project. But you may want to cite the paper we gave you (Life in the Soil is a ferment...). Also, there is a book on reserve in the science library (by Eisenberg) that contains the photos and text from which the lab copies of pictures of soil organisms were made.

Other suggestions:

Type the paper on a word processor so that you can easily make changes that are suggested during peer review. Put in essential information, but keep it concise. The introduction, methods, and results all together should be less than two pages of text (plus figures, etc.), and the discussion should be a page. These are not meant as limitations, but as suggestions for the kind of work that would be appropriate.

Sample Number	# of body segments	# of legs	wings?	color	size	feeding structures	abundance	name?	Other Notes

Record numbers of observed organisms for each type. Make sure to record which sample you are looking at under the "Sample" column.

Sample Number	Mites predatory	Mites herbivorous	Springtails	Symphylans	Pseudo-scorpions	Beetles	Nematodes	Other (describe)

ANALYSIS OF A SCIENTIFIC ARTICLE

GOALS:

Practice critiquing an experiment and experimental report; understand the nature and purpose of scientific writing.

TIME NEEDED: 1 hour	
Classroom Time: Introduction: 10 minutes Student Work: 30 minutes Wrap up: 20 minutes	Instructor Time: Preparation: low Assessment: medium

Rationale

Most college students, let alone non-science majors, have never seen an actual scientific article before. When asked to write one, they have no models on which to draw, no idea of standards that would be appropriate for students at their level, and no idea even of the purpose of such an article. Students in Workshop Biology often get exposure to primary literature as they are preparing for the Issues Project (see the next section), and we do have discussions about the purpose of scientific papers, their structure, and the process of peer review. However, in writing up their investigation reports, they need some additional practice and guidance.

Overview

Have students read the article, “Heart rate and cinematic terror” (written by one of our more creative faculty members) and discuss it in small groups. You can use questions like those included in the “Evaluation Sheet,” included here, to guide their discussion. Bring them back together and, as a large group, list criticisms and suggestions for improvement on the board. Ask them to consider the organization of the article: does it make sense? Get them to see that the standard format (introduction, methods, results, discussion) is not arbitrary, but follows logically from the experimental process.

We highly recommend having students write formal proposals for their investigations, following this activity. Hand out the “Evaluation Sheet” when assigning the proposal, so students can see how their work will be evaluated.

TIME EXPANSION/CONTRACTION ACTIVITIES:

Expansion	Contraction
<ul style="list-style-type: none">• Have students peer-review their proposals using the “Experiment Critique Sheet”• Have students collaborate on coming up with the criteria for evaluating their papers	<ul style="list-style-type: none">• Have students critique article as homework assignment

REFERENCES

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Heart Rate and Cinematic Terror

Introduction

In the 1950's, movie promoters stationed nurses in theaters "in case anyone was overcome by the terror of the film" (1). We've all heard the expressions "I was scared to death," or "it made my heart skip a beat." I wondered: Can films (which present no real danger) actually produce a significant physiological response? This is a significant question, since special effects are becoming more realistic, and movies have become readily available in the home, where people too weak or sickly to make it to a theater are able to watch them. Are they in danger?

My hypothesis is that a well-done fright scene in a movie can invoke a fight-or-flight response (2) in a viewer. Since one of the characteristics of the fight-or-flight response is an increased heart rate, I predict that the heart rate of a person viewing a scary film will vary during the film, increasing significantly during or very soon after especially frightening scenes.

Materials & Methods

I monitored the heart of three people while they watched *Alien*. The viewings were done separately, and all subjects were allowed to eat microwave popcorn and drink Dr. Pepper.

Heart rate monitoring was done with a Sears Fit-O-Matic heart rate meter taken from a friend's exercise bike. The meter attaches to the ear lobe and can be monitored unobtrusively while the subject watches the movie.

Results

Before the experiment began, I viewed the film and selected three "soothing scenes" and three "scary scenes" during which I would monitor the heart rates of my subjects. The subjects were seated on a comfortable sofa and the monitor was attached to their ears. I sat in a chair behind the sofa and noted the readings on the monitor.

The results of the trials are shown in Table 1.

Discussion

The difference between the heart rates during the soothing scenes and the scary scenes are a measure of the ability of a film to exert an effect on a person's physiology. The increases in heart rate seen during the scary scenes were comparable in all three subjects. Dave's increase was somewhat less dramatic, but he had seen the movie several times before.

These results are consistent with the hypothesis that a well-done fright scene in a movie can invoke a fight-or-flight response in a viewer. I only measured heart rate, an indicator of flight-or-flight response. It is possible that the increase in heart rate was occurring without a full-blown fight-or-flight response. It would be necessary to measure other indicators of fight-or-flight response, such as epinephrine levels (2), to be certain.

Since films can evoke extreme physiological responses, something that might be dangerous in a weakened individual, film-makers might want to consider a physiological warning system similar to the current P/PG/PG-13/R system.

References

- 1) Kent Remember, *Horrors from Screen to Scream*, A Publisher, New York, 1972.
- 2) J. H. Postlethwait and J. Hopson, *Nature of Life*, McGraw Hill, New York, 1992.

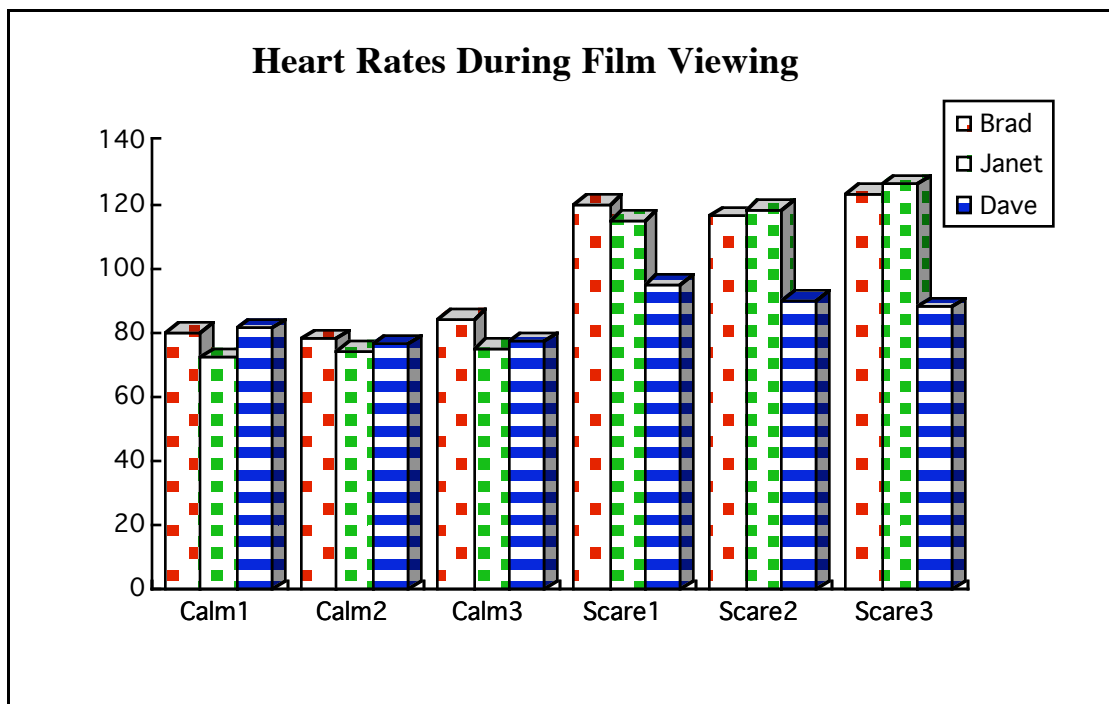
Heart Rate and Cinematic Terror

Experimental Data

The table and graph show the data in beats per minute. Calm = soothing scene; Scare = scary scene

	<u>Calm1</u>	<u>Calm2</u>	<u>Calm3</u>	<u>Scare1</u>	<u>Scare2</u>	<u>Scare3</u>
Brad	80	78	84	120	116	123
Janet	72	74	75	115	118	126
Dave	81	76	77	95	90	88
Average	77.7	76	79	110	108	112.3

Average Calm Heart Rate: 77.6 beats per minute
 Average Scare Heart Rate: 110.1 beats per minute (41.9% increase)



EXPERIMENT CRITIQUE SHEET

Scientists get the money for doing experiments by applying for grant money on the basis of proposed experiments. Since there are many more proposals than there is available money, granting agencies have developed peer review systems that involve the review of proposed research by panels of scientists. The research proposals deemed most worthy are awarded the grant money.

We're going to mimic that peer review system with your investigation proposals. You'll be handed a research proposal written by one of your peers and you'll evaluate it.

Remember while critiquing someone's proposed experiments that you are doing them a favor when you identify possible problems. Constructive advice is better than simply pointing out areas you "don't like."

Here are some questions to help guide you through someone else's proposal.

___ Does the hypothesis explain the observations? answer the questions?

Suggestions:

___ Are there alternate hypotheses? Were they treated fairly?

Suggestions:

___ Is the prediction reasonable?

Suggestions:

___ Are there adequate controls?

Suggestions:

___ Am I persuaded that the experimental design will answer the question?

Suggestions:

Overall Comments:

HOMEOSTASIS ARTICLE EVALUATION SHEET

Graded by _____

Name KEY KEY KEY KEY KEY KEY KEY KEY

Score _____ (100 pts poss)

Think of the listed point values as the maximum that can be taken off for deficiencies in that category.

••• (Introduction)

____ Has a reasonable case been made that this topic is important?
Comments: 2 pts; *be open-minded*

____ Does the hypothesis reasonably explain the observations or questions that are discussed?
Comments: 8 pts

____ Are there alternate hypotheses? Were they discussed? Were they treated fairly?
Comments: 4 pts; *go after obvious alternate hypotheses*

____ Is this a good hypothesis? Is the hypothesis trivial?
Comments: 6 pts; *“A good hypothesis will be a reasonable explanation that provides an answer to your question.” -- from their assignment instructions*

____ Is the prediction reasonable?
Comments: 4 pts

____ Does the prediction follow naturally from the hypothesis?
Comments: 6 pts

••• (Methods & Materials)

____ Can these procedures be reproduced from the information given?
Comments: 15 pts

••• (Results)

____ Are the results organized and presented so that they can be easily interpreted?
Comments: 10 pts; *clearly, if you can't understand the data, they're going to get killed on the rest of the evaluation -- I'll ask for a rewrite if it's that bad*

____ Am I persuaded that the design could answer the question?
Comments: 10 pts

____ Am I persuaded that the data are reliable?
Comments: 10 pts

••• (Discussion)

____ Am I persuaded that the data are interpreted reasonably?
Comments: 10 pts

____ Am I persuaded that the hypothesis is supported (or eliminated)?
Comments: 10 pts; *many of them will overstate their results (These results prove...). They should know better by now and shouldn't be surprised to lose points.*

____ Am I persuaded that the proposed future work is reasonable and important/interesting??
Comments: 5 pts; *be open-minded*

Overall Comments: *If there are problems that don't fall into the above categories, you can take off points here. Try to be consistent with the other point values.*