2 Laboratory

Discovery and the Scientific Method in the Biological Sciences

Week I

LEARNING OBJECTIVES

Students will....

- identify the parts of the scientific method by participating in laboratory exercises and by answering specific questions.
- apply their knowledge of the scientific method by designing a controlled experiment, writing a laboratory report, and conducting an oral presentation.
- determine types of data, variables, and graphs by analyzing various figures of data representations and presenting their inferences to the class.
- distinguish between primary and secondary sources of scientific literature by searching for literature to provide background and references used in an experiment.

INTRODUCTION

We live in a world where scientific research is changing how we live our lives on an almost daily basis. At the same time, however, scientific literacy is on the decline here in the U.S. This type of literacy is defined as having scientific knowledge and the ability to use it through an understanding of how the scientific process works. An important element of scientific literacy is the ability to understand the interface between science and society. These days, this intersection often occurs in the popular press and on the Web. Even if you don't become a scientist yourself, being scientifically literate means being able to understand and critically evaluate issues of science that are important to you. For example, the use of stem cells for research purposes has generated significant controversy in recent years; however, some types of stem cells are not derived from human embryos and thus are much less controversial. Someone with a stronger science background will have no problem understanding this distinction and will consider this when reading a recent article about stem cell research in the popular press.

The following two lab units will provide you with a foundation for understanding the dynamic process of science—**discovery** and the **scientific method**. Discovery is just that—making observations about the natural world, putting them into context, and communicating that information to others. The scientific method, however, provides scientists with a formalized approach to answering questions and solving the problems encountered in the field of biological sciences. Although biology is a very broad discipline, this approach for solving problems and answering questions is consistent regardless of the field. A group of ophthalmic surgeons who seek to determine and report the optimal technique for surgical removal of cataracts employs the same general methods that an environmental toxicologist might use to determine the possible impact of malathion, an insecticide, on local amphibian populations. A behaviorist studying the effect of long-term stress on problem-solving abilities in rats would also follow the general methodology to answer her questions. All of these individuals, most likely lifetime researchers, will approach new angles or new questions once their current research efforts are completed, analyzed, and the results are contributed to the greater body of knowledge for that research area.

Discovery and the Scientific Method

Good scientists are keen and careful observers. Biologists often observe natural phenomena, record their findings, compare them with those of others, and when appropriate attempt to explain them. These explanations often begin as **hypotheses**, or testable explanations of the observed phenomena. Once a more general hypothesis is established, one or more predictions, based on the experiment planned to test the hypothesis, are determined. Careful testing will then allow the biologist to accept the hypothesis or reject it. Regardless, their work is not done—they often assess the factors that lead to the results they obtained, and either retest or modify their approach. The following is an example of the steps used in the scientific method:

1. *Observation:*

   "I have seen far fewer tiger swallowtail butterflies this summer compared to last summer."

2. *Hypothesis:*

   "The cold weather we had late this spring must have killed them."

3. *Experiment designed to test the hypothesis:* Two climate controlled greenhouses.

   Group I—Temperature changes based on average seasonal shift (our control).

   Group II—Temperature changes include a late freezing episode (our experimental group).

   Note: All other variables (for example: food, photoperiod, and habitat type) are the same.

4. *Prediction:*

   "If I subject swallowtails to freezing temperatures early in their development, they will die."

5. *Data collection and analysis:* The experimental group had only slightly fewer final numbers compared to the control group. The late freeze did not appear to affect them to the extent observed in the wild population.

6. *Accept or reject original hypothesis based on data:* Reject—the data do not support the hypothesis. Why not? The differences observed were not significant enough to accept the hypothesis.

7. *Reassess the question from a new point of view:* "Perhaps the frost also affected the wild butterflies' food source."

At this point, the researcher would set out to test his new hypothesis following a similar series of steps to those outlined previously.

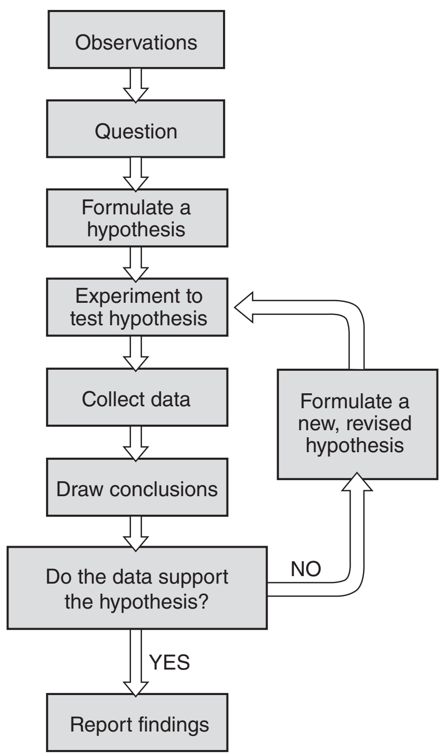

Figure 2-1. The Scientific Method

Activity One: Data Analysis—A Case Study of the Factors Contributing to the Decline of Steller Sea Lions in the NE Pacific

BACKGROUND

Data analysis is the heart of scientific investigation and it represents the findings of your experiment. Once you collect data during an experiment, you have to decide what type of data you have and how to represent it visually so that you can easily share your findings with others. During the following activity, you will receive at least one graph relating to the decline of the steller sea lions in the NE Pacific.

The steller sea lion (*Eumetopias jubatus*) is the largest of the eared seals. Its range includes northern California north to the Bering Sea in Alaska, and its diet consists mainly of fish. Since the 1970s, steller sea lion populations in the NE Pacific have been on a dramatic decline. When an organism with such a large range declines so precipitously, this implies a rather dramatic environmental change may be at work. It often takes exhaustive efforts on multiple fronts to determine the root cause or causes behind an observation of such large scale. Scientists from different disciplines have been studying this issue over the past 30 years. Their combined body of data, accumulated through the completion of multiple research projects, has elucidated to some extent the possible cause of their decline. You now have the opportunity to analyze some of the key data collected thus far and as a group come to a decision about the possible cause. These data are represented in either tabular, graph, or figure form.

1. Your TA will provide each table with recently collected data from research studies conducted in an effort to determine the cause of the steller sea lion's decline. As a group you will discuss the meaning of the information provided, and come up with some possible answers. To analyze the graphs, determine the following (refer to Appendix E to help you answer the questions below):
    a. Are the data **quantitative** or **qualitative?**
    b. If the data are **quantitative**, what **type of data** are they? (See pages 221–222 in Appendix E.)
    c. What are the **variables, dependent** and **independent,** represented in the graph?
    d. What is the **graph** trying to communicate? You will provide a statement to the class regarding findings communicated by the data you analyzed.

Statement:

2. The entire room will then work as a team to determine how the larger body of data relates to the current hypotheses regarding the steller sea lion's decline.

Decision:

Searching for Scientific Literature

Finding Resources on the Web

These days, people often use the internet as their main source of information when researching a topic. Although the internet is an excellent tool for locating information, it can be challenging to determine which resources are valid. Thus, it is important to be knowledgeable about the sites you use as well as how to choose the information you take from them. When looking for scientific information in particular, it is imperative that the sites you use are valid and reliable and that they provide the original literature source for any reported data.

Typically, you can verify a Web site's legitimacy by examining the top-level domain (TLD) or extension of the URL address. The TLD is indicated by the Web site's suffix, or the last three letters followed by a period; for example, .com, .gov, .org, .net, .mil, and .edu are all commonly encountered TLDs. You can be more confident that information is valid if the TLD is .gov, from a U.S. government agency, for example, www.nps.gov, the official Web site of the National Park Service, or .edu, from an educational institution (www.ncsu.edu). If it is .com, it is usually assigned to commercial Web sites.

Sites listed as .org are usually non-profit organizations and they can go either way. They can sometimes be legitimate, as in the case of www.iucn.org (the Web site for the World Conservation Union), but often are not, as in the case of www.wikipedia.org (the "Wikipedia" Web site). This latter site, although used extensively as a reliable source of information, can never be used in scientific reporting because the site is not peer-reviewed and is open to anyone for editing. We will talk more about the peer review process and why it is important below. Wikipedia can sometimes be a good starting point when learning about a topic or concept, but it should never be used as an official source of information. Any information you obtain from their site must be verified by visiting a legitimate site or finding literature from acceptable sources.

Finding Resources at the NCSU Library System

As part of your homework assignment last week, you completed an online tutorial hosted by the NCSU Libraries. This tutorial offers guidance in finding acceptable sources when researching a topic area.

Distinguishing Primary vs. Secondary Literature

As you accumulate information for this assignment and in other assignments for this and other courses, you will mainly encounter two forms of information: primary and secondary literature. Tertiary literature is another category, but it is often difficult to clearly distinguish between secondary and tertiary sources, so we will leave it out of this discussion. In science, primary literature typically refers to original research results that are being reported in written form for the first time. They can be articles in scientific journals, papers from conference proceedings, or technical reports, but all must be written by the individual or group who obtained the results. Primary literature is the direct result of research conducted by the author (or authors). Research was conducted and the results were analyzed. These results have been written up, subjected to a peer review by researchers familiar with the field of work, and have been accepted as legitimate for publication. This last part is the key; it ensures that information in primary literature is legitimate, not forged, faked, or based on inappropriate or inadequate research methodology. Typically when you report on the data available on a particular topic, you should be able to identify the primary source of the information. For the type of writing you will be asked to complete while in college, this type of literature is usually the most appropriate source of information.

Secondary literature sources are typically characterized as those that comment or report on the original work. Often, they report on primary sources to summarize the most current information known about a particular topic. This type of literature includes books, review articles from scholarly journals, textbooks, magazines, and other sources that provide background information that summarizes previously performed scientific work. When you see an article on the CNN Web site about a new research breakthrough in the treatment of diabetes, this is an example of secondary literature. The information about diabetes in your biology textbook is another example. Using a secondary source in your writing is acceptable if the source is legitimate. For instance, if you found some information on a federal or state government Web site or in one of their published documents, this information would be considered legitimate for use, as long as it is cited properly. It would also be acceptable to use your textbook as a source if appropriate.

Activity Two: Designing and Conducting an Experiment

BACKGROUND

The remainder of this lab will provide you with an opportunity to use the scientific method in the same manner as scientists. Scientists often begin by making **observations** about the subject of interest. Today our subject is the pillbug, *Armadillidium vulgare*, and the sowbug, *Porcellio scaber.* They are crustaceans that live on land and belong to the order Isopoda, which is characterized by being dorsoventrally flattened, lacking a carapace, having compound eyes, two pairs of antennae, and seven pairs of jointed legs. Like most arthropods, they molt (shed the exoskeleton) and have three body parts: head, thorax, and abdomen.

Pillbugs and sowbugs have overlapping "armored" plates that make them look like little armadillos. They are commonly found in damp and decaying leaf litter, under rocks, wood, and in basements or crawl spaces under houses. They tend to feed at night and breathe by gills located on the undersides of their bodies. The gills must be kept slightly moist, and that is why they are usually found in damp places.

In winter, they are inactive, but when spring arrives they become active and mate. Females have a pouch on the undersides of their bodies, where they can carry from 7–200 eggs. The eggs hatch several weeks after mating, and the young look like miniature adults. The young stay in the pouch another six weeks, and then they leave and begin to feed. They eat decaying plants and animals and some living plants. They can live up to three years.

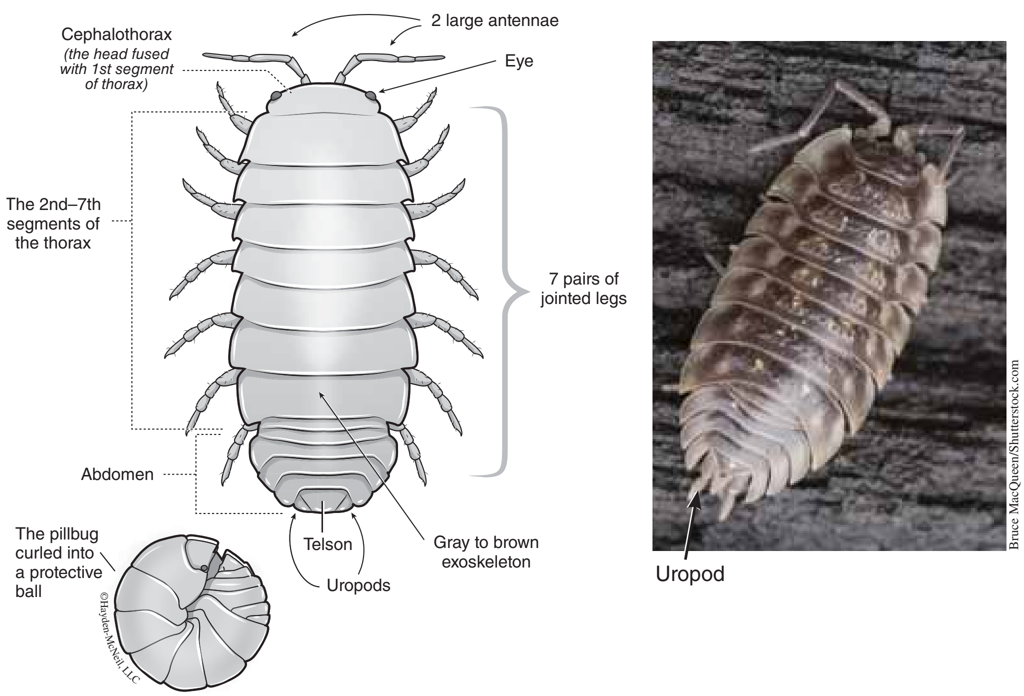

Figure 2-2. Pillbugs (roly-poly bugs), *A. vulgare*, seen on the left, are wingless, and coloration varies from brown to slate grey. The sowbug, *P. scaber,* seen on the right, looks very similar to pillbugs but has paired uropods that extend beyond the last segment of the body.

Pillbugs molt (shed the exoskeleton) four or five times. They have three body parts: head, thorax, and abdomen. They have seven pairs of jointed legs. Among crustaceans, pillbugs are classified as isopods because they are dorsoventrally flattened, lack a carapace, have compound eyes, and have one pair of antennae.

Isopods are the only crustaceans that include forms adapted to living their entire life on land, although moisture is required. Currently, it is believed that they do not transmit diseases, nor do they bite or sting. Because they eat dead organic material, such as leaves, they are easy to find and keep in a terrarium with leaf litter, rocks, and wood chips.

Since both pillbugs and sowbugs are isopods, there are very few differences between them. Pillbugs are known for their ability to roll into a tight ball in which their legs and head are no longer visible. This is what gives them the nickname, "roly-poly." Sowbugs are very similar to pillbugs, but they tend to be flatter and can have rough backs as compared to the smoothness of pillbugs. They also have paired uropods, posterior appendages that help with locomotion. Probably the biggest difference between pillbugs and sowbugs is that sowbugs do not roll into a small round ball, a process known as "conglobulating" (see Figure 2-2).

INITIAL OBSERVATIONS

First, become acquainted with your subject and how it normally moves. Then you will use your knowledge of the pillbug to hypothesize whether it will be attracted to, repelled by, or indifferent to various substances or living conditions of your choice. After you have tested your hypotheses, you will conclude whether they are supported. Your conclusions may lead to other hypotheses, and if time permits, you may go ahead and test those also. You will use the results of your own experiment to write a lab report.

Wash your hands before and after handling the pillbugs. Please handle them carefully so they are not crushed. When touched, they roll up into a ball or "pill" shape as a defense mechanism. They will soon recover if left alone.

SOWBUG'S/PILLBUG'S EXTERNAL ANATOMY

1. Obtain a few pillbugs from the stock culture. Put them in a Petri dish to keep them contained. First examine the exoskeleton and body with the unaided eye and then with a magnifying lens or dissecting microscope.
2. Examine the exoskeleton shape, color, and texture. Note the number of legs and antennae and whether there are any posterior appendages, such as uropods (paired appendages at the end of the abdomen) or brood pouches (females have leaflike growth at the base of some legs where developing eggs and embryos are held in pouches). Locate the eyes. Count the number of overlapping plates.

SOWBUG'S/PILLBUG'S MOTION

1. Watch a pillbug's underside as the pillbug moves around in the Petri dish.
2. As you watch the pillbug, identify behaviors that might:
    a. protect it from predators
    b. help it acquire food
    c. protect it from the elements
    d. allow interaction with the environment

YOUR EXPERIMENT

From these many observations, formulate a hypothesis to explain ecological or behavioral characteristics of pillbugs. Examine all of the materials available to you on the side counter before you write your hypothesis and design your experiment. The pillbugs must be treated humanely. No substance must be put directly on the pillbugs, nor can the pillbugs be placed directly on the substance. Since pillbugs tend to walk around the edge of a container, you could put the wet or dry substances around the edge of the dish. Or for wet substances, you could put liquid-soaked cotton in the pillbug's path.

1. Write a **hypothesis** to explain the behavior that you will study.

2. Design an experiment to test your hypothesis. You will need to review your experiment with your laboratory instructor before you begin your actual experiment. Be sure to consider and identify the following in the experiment you design:
   - based on the experiment you will be using to test your hypothesis, what are 1 or 2 plausible **prediction(s)**?–
   - independent variable(s)–
   - dependent variable(s) and how you'll measure it/them–
   - controlled variables–
   - control group (if applicable)–
   - experimental group (if applicable)–
   - whether the data are qualitative or quantitative–
   - how you might present this data–
   - replication and/or sample size–

Experimental design and setup (materials and methods):

Collected data:

Do your results support your hypotheses?

Your conclusion:

PRESENTATION OF YOUR FINDINGS

1. Writing a lab report—Your teaching instructor will discuss this further with you. You can also refer to the BIO 181 lab manual Appendices B, D, E, and the LabWrite Web site (http://labwrite.ncsu.edu/) for additional information. Lab reports will be written by each individual.

2. Oral presentation by your group.

ACKNOWLEDGMENTS

Engell, M., *Issues in Biology Lab Manual*, Spring 2008.

Mader, S. S., *Laboratory Manual: Essentials of Biology*, 2007. McGraw-Hill: New York. Reproduced with permission of The McGraw-Hill Companies.

[Questions]

Name Lab/Section

Partner's Name (if applicable) Date (of Lab Meeting)

1. Why do scientists use the scientific method when conducting experiments?

2. While the scientific method is outlined as a straight line of steps in your lab manual (Figure 2-1), describe how the method is actually more of a circular process for most scientists.

3. What is the difference between a hypothesis and a prediction?

4. Design a simple experiment that would test the effects of diet on mice. Be sure to indicate controls (or controlled variables), and dependent and independent variables.

5. What distinguishes primary from secondary literature? Give an example of each. When would each be useful?

Week II

LEARNING OBJECTIVES

Students will….

- practice presentation skills by effectively communicating the experimental design, results, and research/implications of their own experiment.
- practice the process of peer review by reading and evaluating each other's lab reports.

INTRODUCTION

This week in lab, we will continue our discussion of the scientific method and discovery, and we will focus mainly on how to communicate scientific information to others. We have discussed some of the ways in which scientific information is communicated in written form in primary and secondary literature. Often, however, scientists will present their work at a conference or workshop before it is formally published. These presentations typically take the form of talks or posters. In this lab, you and your group will be presenting your own experiment and research to the class. Your laboratory instructor will provide you with additional guidance.

[Questions]

Name | Lab/Section

Partner's Name (if applicable) | Date (of Lab Meeting)

1. As you listen to the presentations from each group, write a brief statement of that group's experimental focus and a question you would ask them about their project.

   Group 1:

   Group 2:

   Group 3:

   Group 4:

   Group 5:

   Group 6:

2. Based on what you heard from other groups, what would you do differently if you were to redesign your experiment?

3. Which other group's experiment could benefit from the work done by your own group? Explain how this would improve their experiment.