PEER-LED TEAM LEARNING
INTRODUCTORY BIOLOGY

MODULE 8: BIOLOGY IS A SCIENCE

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I. Introduction

Biology is the scientific study of life. Consistent with other science disciplines is the basic assumption among biologists that living things obey the same physical and chemical principles and laws that apply to non-living parts of our world. To understand Biology, one needs understand the process by which biologists gather and test their information about the living world—how they answer scientific questions. If the function of science is to find truth, how does science differ from other methods of searching for truth such as astrology or religion? Scientist use an approach, sometimes called the ***scientific method*** to answer questions about living things. It is a complex process that includes the hypothetico-deductive method, and requires a variety of skills and knowledge—often provided by a team of individuals working together. The basics of the scientific method can be mastered and used effectively by students, not only in biology classes, but in many life activities where questions need to be answered and decisions made. In this module you will have an opportunity to learn the basic elements and how to apply them. We hope you will see the applications to your daily life and adopt it in your own thinking.

Prepare for your workshop by reading your textbook (Campbell & Reese 6th edition, Chapter 1***) and completing the Pre-workshop Activities below. Show your work on most pages.

II. Pre-Workshop Activities

Activity 1. Define each of the following:

1. scientific observation
2. control
3. control group
4. experimental group
5. hypothesis
6. prediction
7. deductive reasoning
8. inductive reasoning
9. independent variable
10. dependent variable
11. nuisance variable
12. hypothetico-deductive method
13. theory
14. experiment

13. data

14. scientific (empirical) question

Activity 2. Questions, hypotheses, and predictions

Read the material below and answer the questions that follow.

Scientific investigations often have their origins in direct **observations** of living things or in reading reports of work by other scientists. These activities lead to **questions** that require additional investigation. Tentative answers to a scientific question are called **hypotheses**; hypotheses, in turn, naturally lead to **testable predictions**. Predictions follow from hypotheses and indicate what outcome will be expected in an investigation if a particular hypothesis is true. Predictions can be formulated as **if….then statements.**

To better understand these concepts, consider the following example. In many parts of the country, when daily temperatures drop in the fall and day length decreases, some trees undergo color changes in their leaves and eventually shed them. One might ask:

Q: Are seasonal changes in the environment responsible for causing leaves to drop?

To tentatively answer this question, one or more hypotheses can be developed:

H_1: the decline in average daily temperature causes leaves to turn different colors & be shed

H_2: the decline in day length triggers changes that cause leaves to turn colors & be shed

H_3: A combination of both external factors brings about the color changes & shedding.

Can you think of any additional hypotheses? _____ .

One prediction that emerges from these hypotheses is:

P: ***If*** H_1 (decline in daily temperatures) is the actual cause of color changes, ***then*** exposing plants to decreasing temperatures over several weeks while keeping day length constant should result in color changes.

What other predictions would you make from these hypotheses?

P: _____

P: _____

Activity 3: Variables

Read the material below and answer the questions that follow.

Hypotheses state a tentative relationship. In the H_1 it is the relationship between daily temperatures and change in leaf color. What is it for H_2 and H_3?

H_2 : _____

H_3: _____

For H_1 the two related factors, called **variables**, are average daily temperature and second, leaf color change. The temperature is called the **independent** variable. It is the one the scientist controls or that varies on its own during the experiment. The other, color change, is a **dependent** variable which according to the hypothesis is "dependent" for its expression on the independent variable. Another way of saying it is that the changes in the independent variable cause changes in the dependent variable. The idea of a "variable" comes from the fact that both temperature and color change can vary in their expression or value. Temperature can have a range of values; color change can occur or not occur, or occur more rapidly or to different degrees. Hypotheses, then are statements about possible relationships between independent and dependent variables.

For H_2 and H_3 determine what the independent and dependent variables are and indicate what range of values they might take.

Hypothesis	Indep. Variable	Range of values	Dep. Variable	Range of values
H_2				
H_3				

There is a third important type of variable which can have great influence on the outcome of a scientific investigation, the **nuisance variable**. Nuisance variables are factors that, in addition to the independent variable, can influence the dependent variable and thus, the outcome of the study. These also may be called **controlled variables**, because scientists try hard to control or standardize them so as not to confound their results. Consider the study of the relationship between temperature and leaf color. If in an investigation during the fall, day length shortened as temperatures dropped over several weeks, it would be difficult for the scientist to determine which factor caused the change in leaf color. For this experiment, day length is a nuisance variable and needs to be controlled in order that the results are not confounded. There are many other nuisance variables and ways of dealing with them that are dealt with in the next section.

Activity 4. Controls

Read the material below and answer the questions that follow.

A **control** is any means used eliminate or minimize factors that might confound or obscure the relationship between the independent and dependent variable in a scientific investigation. We provided just one example in the previous paragraph, but every good study has several or dozens of controls built into it. Consider the following:

*A microbiologist wants to investigate the relationship between antibiotic resistance and antibiotics in animal feed. She hypotheses that antibiotic resistance increases in animals given antibiotics in their food. Specifically, she predicts that " **If** animals have increasing levels of antibiotics in their feed, **then** there will be an increase in antibiotic resistant microbes." The dependent variable, number of antibiotic resistant microbes, can be measured in several ways. For example, the microbiologist can determine the different species of antibiotic resistant species, estimate the actual number of antibiotic resistant microbes in a population, etc. In carrying out the experiment, the amount of antibiotics put into the food (independent variable) is varied systematically. All other potential variables, such as species and breed of experimental animals, type of food, type of housing, water quality, temperature in the environment, etc. must be standardized. If they are not controlled, these nuisance variables may effect the outcome of the experiment and confound the relationship between the independent and dependent variable. The means of standardizing or eliminating nuisance variables are called controls.*

To check your understanding of controls, suggest how each of the following potential nuisance variables could be controlled.

1. species tested _____
2. breed of species tested _____
3. diet _____
4. water quality _____
5. temperature in the living quarters _____
6. amount of space for each animal _____

Control treatment groups are used in most scientific investigations to determine what happens to the dependent variable when the independent variable is eliminated or set to a standard value. A control group in the animal feed experiment could be fed no antibiotics. If the bacteria became more resistant in these control animals what would you conclude about the original hypothesis?

_____ .

III. Workshop Activities.

Activity 1. Identifying Empirical and Non-Empirical Statements

Science involves the construction of knowledge based on observation, testing, and measurement. Such knowledge is termed EMPIRICAL. Non-science disciplines may involve a different type of knowledge which is based in faith or opinion, and cannot be tested empirically. Identify each statement below as **A** if it is empirical or **B** if it is non-empirical. Give a short explanation for each answer next to the statement.

_____ Leonardo da Vinci is a better painter than Picasso.

_____ Alcohol consumption by pregnant women causes retardation and other birth defects in babies.

_____ I know there is a God.

_____ The sun rises in the East every morning.

_____ Four out of five dentists recommend Crest.

_____ People born between July 23 and August 22 should be concerned about things going wrong today, however people born November 23 - December 21 will have a good day.

_____ Fetal tissue transplanted into the brains of patients with Parkinson's disease causes improvement in brain function in these patients.

_____ Tissue from fetuses should be used to aid Parkinson's patients.

_____ Tylenol is a better pain reliever than aspirin.

Activity 2. Questions, Hypotheses, Variables and Predictions

Work in pairs on one of the combinations of variables #1-8 as assigned by your workshop leader. Put your work on the blackboard or a large sheet of newsprint for later sharing with others in the workshop.

The following are variables with potential relationships. For each pair of variables:
a. Write a question about the relationships
b. Write two or more hypotheses to tentatively answer the questions
c. Indicate the independent variable and a range of values it might take
d. Indicate the dependent variable and a range of values it might take
e. Make a prediction about the outcome of a scientific investigation to test one of your hypotheses

1. Studying and grades.
2. Ultra violet light exposure and the death of bacterial cells.
3. Bacterial growth and temperature.
4. Constant exposure to antibiotics and antibiotic resistance.
5. Number of children in a family and quality of parental care.
6. Muscle size and muscle strength
7. Type of conditioning for running and endurance
8. Select your own two variables

Share your work with other members of the workshop and discuss modifications or improvements.

Activity 3. Variables and Controls

Do this activity as a team competition. For the contest, divide the group into two teams. Each member of the team is called on in sequence to answer one item. If a team member misses one answer, the other team begins to answer the next questions in sequence. They answer until they miss, after which the first team begins to answer again. Each correct answer is worth one point.

For the following give:

a. the hypothesis
b. the prediction
a. the independent variable
b. the dependent variable
c. an experiment designed to test the prediction hypothesis.
d. one or more possible control treatments.
e. two or more potential nuisance variables
f. possible controls for the nuisance variables
g. your tentative conclusion about the hypothesis if the prediction proved correct.
h. alternative hypotheses you could suggest is the prediction proved false.

1. The concentration of salts in a solution surrounding red blood cells effects the size of the red blood cells. If the salt concentration of the solution is decreased, then the cells will swell.

2. The concentration of the enzyme A is related to the rate of the chemical reaction. If you increase the amount of enzyme, then you will increase the speed of the chemical reaction.

3. The type of sugar provided to growing yeast is related to the amount of alcohol produced by the yeast. If you grow the yeast in different sugars, the alcohol production will vary.

4. The time a bacteria culture is under UV light is related to the number of bacteria in that culture. As one increases the time a culture is under UV light the number of living bacteria decreases.

Activity 4. Design an Experiment

The public is becoming more aware of bacteria in the environment. People are aware that bacteria can be transferred from the hands to food, eyes, mouth, etc. The company wants to expand into the area of germicidal soaps for hand washing. These soaps may contain various antiseptics that kill bacteria. The effectiveness of different antiseptics working through soap is unknown. As microbiologists working for Soaps Dot Com you are asked to design an experiment to test the effectiveness of three different antiseptics that can be used in the company soaps.

Divide the workshop into teams of 2-4 students. Each team works to develop the best experiment to test the three antiseptics.

Complete the following:

1. Establish your hypothesis(es) with the dependent and independent variables.
2. Generate predictions for the hypotheses
3. Identify your nuisance variables and how you will control them.
4. Briefly outline the steps of your procedure.
5. Be sure to include your control treatment(s).
6. Indicate the measures you will use in the experiment.
7. Pick out one of your predictions and assume it is supported by the data. What might the results be like?

Activity 5. Flow-charting the Scientific method

Do this activity as a round robin. After each person provides an answer, other students may suggest alternate answer. A flow chart can be used to illustrate sequences of steps in a process. For example, in workshops one process of completing activities could be diagrammed as follows:

Leader assigns problems → teams develop solutions to the problems → teams explain their solutions to the other workshop members → listeners suggest corrections or additions

Briefly describe the scientific method in a flow chart for the terms listed above: prediction, observations, experiment, hypothesis, question, experiment, control group, experimental group, independent variable, dependent variable, nuisance (controlled) variable, data, theory and law.

Activity 6. Great Discovery Integration

Team competition. Divide the workshop into two teams. Members of the team should organize themselves to each do different parts of the story and then put them all together. The first group to finish notifies the peer leader and has the first chance to explain how the story illustrates the critical elements of the process. The second team takes notes and then presents their own improvements or variations. The peer leader announces a decision on the winner.

Put the following story about Edward Jenner into the steps of the scientific method. Refer to Pre-Workshop Activity 1 to make sure you include the essential elements.

Edward Jenner first developed the technique of vaccination in 1795. This was the result of a 26-year study of two diseases, cowpox and smallpox. Cowpox was known as vaccinae. From this word evolved the present term vaccination and vaccine. Jenner observed that milkmaids rarely became sick with smallpox, but they developed pocklike sores after milking cows infected with cowpox. This led him to perform an experiment in which he transferred pusslike material from the cowpox to human skin. Because the two disease organisms are so closely related, the person vaccinated with cowpox developed an immunity (resistance) to the smallpox virus. The reaction to cowpox was minor in comparison to smallpox. Public reaction was mixed. Some people thought that vaccination was a work of the devil. Thomas Jefferson had his family vaccinated. In 1979, almost 200 years after Jenner developed his vaccination the Centers of Disease Control and the World Health Organization declared that smallpox was extinct.

Activity 7. Getting to Truth the Scientific Way

Pairs or small groups of students complete these items and share their thinking with the other members of the workshop.

1. a. A philosopher once correctly stated that scientific knowledge is "what's left after you have demonstrated what cannot be true." Explain what is meant by this statement. considering what you know about the scientific method and how "hypotheses" become "theories."

b. Is there a difference when one tries to verify his/her hypothesis as opposed to trying to falsify his/her hypothesis: Explain

IV. Post-Workshop Activities

Activity 1. Design a controlled experiment

If possible work with other students so you may choose one or two of these to practice on. Then show them to a study partner and get his/her feedback. In turn evaluate what your partner has done.

Design a CONTROLLED experiment to test any one of the following:

Effect of . . .

Age of UM student on grade point average.

Low dose radiation on development of human fetuses.

Height of candidate on political success in the U.S.A.

Malathion spray on aphid populations in Homestead orchards.

Students in early morning classes perform better than those in late afternoon classes

Saturated fat in the diet on development of heart disease

Speed in driving on highway fatalities

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