Exploring Biology Today

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To the student

Have you ever wondered how your body works or what different organisms are like and how they affect each other? Are you interested in how our living world changes? Welcome to the study of life! During this term, you will have opportunities to explore these and many other questions about life. As you start to understand how biologists learn about the living world, you can apply their methods to your life to help you understand your own body and the world around you.

During this term, you will be asked to think about your thinking. How do you think through problems and make sense out of a jumble of information? We can learn a lot about thinking and learning if we watch small children interacting with their environment. They investigate new objects and invent ways of doing things that may turn their surroundings into chaos. They handle, manipulate, and frequently explore objects in ways quite different from the ways that adults intended the objects to be used. From these investigations, children learn to understand their world. Exploring and manipulating new materials and examining processes when trying to understand them can be as useful to you now as it was when you were a child.

The laboratories associated with science classes give you the opportunity to explore materials, to get involved with them, and from these explorations to develop an understanding of materials and their processes—just as you might explore a puzzle such as Rubik's Cube.

You may find the laboratories that you work with in this book are considerably different from others you have encountered previously. One of the most striking differences may be that you will be working with materials in the laboratory *before* you attend a lecture or read about them in your textbook. There is an important reason for this arrangement: actual experience (handling, manipulating, and exploring materials) is one of the easiest ways to learn. Working with materials in a laboratory *after* you hear or read about them probably means that you will find what you were told you would find and observe processes that you were told would happen. This is not the way that scientists work. They become curious, get excited, and are challenged by the unknown as they seek answers to their questions about the natural world. If you only look for something that you have already accepted because you were told it is there, you lose the opportunity to challenge the unknown and to become fascinated and involved as you make new discoveries.

Sudents differ in the ways they handle information. Some students incorporate bits of information and draw relationships among a collection of facts and processes more quickly than others. Some students have been encouraged by their former teachers to wrestle with understanding material rather than just memorizing it. Those who have considerable experience building a framework of concepts from isolated experiences and information may find it easier to make sense of many pieces of information and use them as a foundation on which to incorporate new information. If you have not had such experiences in

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APPENDIXES

LABORATORY

1

Aspects of the scientific process

Is science a common or exotic activity?

Learning about things that make up the world is part of your daily life. At an early age, you learned that if you pushed a glass of milk off the highchair tray, the glass would fall and the milk would make an interesting pattern on the floor. Later, you learned that if you turned the room thermostat up to 90° F (32° C), you would become too hot. Determining cause-effect relationships such as these is a major part of your everyday life. In fact, you do it so often that you are seldom aware of the process that determines these relationships. They become part of a body of knowledge, an understanding of your world that is frequently called **common sense.** All of us develop common sense knowledge by drawing relationships among objects we encounter, activities in which we participate, and phenomena (happenings) we observe.

Is the way we acquire scientific knowledge an exotic activity? Or is it related to the way we acquire common sense knowledge? Most people would agree that scientists are human and the scientific process, the way scientists inquire about our world, is a human activity. Therefore the process of science cannot be too far removed from what people do in their normal lives. In fact, some scientists and scholars of science say that developing scientific knowledge is just a more formal version of obtaining common sense knowledge. For them, **science is a refinement of common sense.**

What do these scholars mean by the qualifying term *refinement?* If science and its methods are generally similar to common sense and its methods, what aspects of science are summarized by the term *refinement?* Developing an understanding of refinement is an important part of what you will be doing in the activities planned for this laboratory class.

Let's get on with it! Life and science are fascinating, and experience is a much more effective teacher than the "couch potato" process of reading about biology and science.

EXPLORING

The scientific process—termites

With your partner(s), get the following materials from the source indicated by your teacher:

1 hand lens
2 sheets of white paper
1 set of different colored ink pens
1 paintbrush
1 container with two termites
1 index card

As you begin exploring with the termites, be aware that worker termites cause millions of dollars in damage to homes each year. Using the hand lens for magnification, visually observe the structures of these organisms. Use your other senses as well. Can you detect a termite odor? Are their bodies soft or hard? As a **naturalist** (an observer of nature) you may also wonder about other questions such as the following:

How many legs does it have?
Are the legs better for walking or digging?
How many sections are in the body? Are they specialized or all alike?
Does it have structures that detect sounds, odors, and light?
What kind of structures are present for ingesting (taking in) food?
What other questions about termites might you explore?

1 ____

____

On the lines below, describe the form, or structure, of the termites.

2 ____

____

____

Now expand your exploration. Instead of just observing the termites' form, *quietly* watch their behavior as they are placed on the paper. You can move them around with the paintbrush. Observe their responses to ink lines drawn on the paper.

After a short period of casual checking, seek information a bit more scientifically—a bit more formally. Based on your observations and any other available information, propose a hypothesis about one type of termite behavior. In science, a **hypothesis** is a general statement—a tentative explanation—that links a possible cause to an effect. (For example, you might form a hypothesis that dogs scratch because they have biting fleas.) In your exploration, the effect is the termites' behavior. Because time is limited, pick an easy-to-change environmental factor that may be the cause of this behavior. Each of you should state your hypothesis about this proposed cause-effect relationship. What are these hypotheses?

3 ____

____

SCIENCE NOTE *Using all the information they can gather, scientists propose explanations for questions they have about events and things in our natural world. These tentative explanations are called* hypotheses.

Scientists do more than simply propose hypotheses, they also set up **experiments** to test them. They test a hypothesis by testing predictions that apply the hypothesis to specific situations. (For example, you might predict that if you remove the fleas from your dog, Waggles, he will stop scratching.) A **prediction** states an anticipated change in a specific response (stop scratching) as the proposed cause factor is changed (remove fleas). In an experiment, scientists manipulate the cause factor and measure the response. If the response corresponds to the prediction, the hypothesis is supported. If the measured response fails to correspond, the hypothesis is rejected.

With your partner(s), set up a test of one of the proposed hypotheses. State your prediction (the expected change in the termite's response as the possible cause factor is manipulated) below. Then describe the experiment you design.

4 Prediction

Experiment

CONCEPTS/TERMS

Useful terminology

Two components of your hypothesis and experiment are known by conventional scientific terms. One is the factor that you manipulate in your experiment to *cause* a change in the termites' behavior. This cause factor is the **independent variable.** What is the independent variable in your experiment?

5

The second component is the *proposed effect* on the termite that may change because you manipulate the independent variable. The effect is the **dependent variable.** What is the specific dependent variable in your experiment?

6

The relationship between the independent variable and the dependent variable is a **cause-effect relationship.**

EXPLORING

An experiment with termites

Carry out your experiment and record the results on the following lines or in an appropriate table.

7

Once the results are obtained, scientists examine the data (the results) and compare them to the prediction based on the hypothesis.

Examine your data and compare them to your prediction. What change did you predict in the termites' behavior as you changed the independent variable?

8

Describe how the data support or reject your prediction and its hypothesis.

9

SCIENCE NOTE

Scientists design experiments to test specific predictions that are based on hypotheses. These tests provide data that are analyzed to yield information about each prediction and its hypothesis. As information is gathered, our knowledge about the phenomena of the natural world increases.

Now that you and your collaborating investigator(s) have tested your prediction and drawn conclusions about your hypothesis from your experiment, share the information with other members of the class. On the chalkboard, put your information in Table 1-1. If directed by your teacher, record all class information in Table 1-1 of the manual.

Carefully look at the information from all the experiments and group together those with the same independent variable.

Table 1-1 Factors affecting termite behavior

Investigator initials	Independent variable	Dependent variable	Conclusion
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
13.			
14.			
15.			

Examine the group that has the largest numbers of experiments and answer the following questions: What is the independent variable for this group?

10 ______________________________

Within this group, did all investigators test for the same dependent variable?

11 ______________________________

If not, what are the dependent variables within this group?

12 ______________________________

____

Compare the experiments that have the same independent *and* dependent variables. Do all investigators of these experiments come to the same conclusion?

13 ______________________________

If all investigators working on the same question did not produce the same results and conclusion, there is a problem. How do you know if or how an independent variable is affecting the termites' behavior when investigators have different results and conclusions?

Try to determine the factors that might be contributing to these different conclusions. In a class discussion, suggest reasonable explanations for these different conclusions. What are these explanations?

14 ______________________________

____

____

____

____

Does one explanation refer to changing factors *other than* the planned independent and dependent variables?

15 ______________________________

If experimental conditions were not always constant, how can you determine a cause-effect relationship between the independent variable and the behavior?

16 ______________________________

CONCEPTS/TERMS

Increasing understanding of the scientific process

The factors other than independent and dependent variables must remain the same throughout the experiment. These are the **controlled** or **standard conditions.** They are controlled conditions because they *remain the same* throughout the experiment. They are standard conditions because they are used as a base for comparison. If any of these other factors changed in addition to the independent variable, you do not know which of the changing factors caused the change in the responding variable (termites' behavior). Only when all other factors are unchanged, or controlled, is the experiment a fair test of the effect of the independent variable on the dependent variable. Only then can comparing the measured value of the dependent variable before and after a change in the independent variable support the cause-effect relationship.

SCIENCE NOTE

Scientists design experiments to examine cause-effect relationships between the manipulated independent variable and the responding dependent variable. To develop a cause-effect relationship between the independent and dependent variables, all other factors that may affect the dependent variable must remain unchanged throughout the experiment. All unchanging factors are termed standard *or* controlled conditions *of the experiment.*

Keeping in mind your experiment with termites, consider all scientific experiments in general. Even if the investigator makes a great effort to plan and conduct a well-controlled experiment, is it possible to be absolutely sure that *only* the intended independent variable is changing? Scientists have to face a problem when answering this question because the answer is always "no." No one can be absolutely sure that at least one more changing factor is not affecting the data. How then can scientific information be determined?

In general, scientists handle this problem in the following ways:

1. Scientists frequently try to reject a null hypothesis. A **null hypothesis** proposes *no* change in the response as the independent variable is manipulated. If a null hypothesis is rejected, the scientists conclude that the independent variable does affect the dependent variable. Then other hypotheses (alternatives) are proposed.
2. Scientists make a great effort to uncover all factors that may affect the results of the experiment and establish controlled conditions for them.
3. Investigators are never satisfied with running the experiment only one time. The experiment is repeated until they are convinced that the independent variable is the cause of the dependent-variable response.

The process of science requires two levels of agreement or verification. The first level consists of the original experimenters agreeing that the data are accurate and support the conclusions. For science, this is not sufficient. It also requires that other scientists interested in the question agree. Information produced by investigators must always be examined and verified, or confirmed, by others. Interested scientists run experiments to satisfy themselves that the cause-effect relationship proposed and tested is reliable. Only after this **verification** process is the information accepted into the body of scientific knowledge as an explanation of one small phenomenon in the natural world. This requirement makes science *a community affair.*

How do the processes of acquiring common sense knowledge and scientific knowledge compare in the requirement for controlled experimental conditions and repetitions?

17 ______________________________

____

How do common sense and science compare in the requirement for verification of information by a community of people?

18 ______________________________

____

If science is defined as a refinement of common sense, to what does *refinement* refer?

19 ______________________________

____

SCIENCE NOTE *Because scientists can never be absolutely sure that only the intended independent variable is the cause for the observed change in the dependent variable, they frequently do the following: (1) Scientists work to reject null hypotheses, (2) they repeat the experiments under controlled conditions, and (3) other scientists verify the hypotheses before these cause-effect explanations are accepted as scientific information.*

APPLYING

The scientific process

Effects of heat on river fish (a hypothetical experiment)

Now put the scientific process into practice. Design an experiment to test a hypothesis. First, you need a problem situation about which there are some questions.

Suppose a northeastern resort town's new power plant is just beginning operations. The plant is designed to convert a source of energy into electricity that can be used by people in the town. This energy conversion involves a process that releases some of the energy as heat. River water is used to cool the equipment. The plant pumps 14° C (about 59° F) water from the town's river into the plant for cooling and returns 22° C (72° F) water to the river. The volume of water in the river remains the same as before the construction of the plant.

The resort owners and the fishermen of the area claim that the extra heat in the river water will harm the river's organisms and result in smaller native fish. They also claim the heat will even change the types of fish that live in the river. They believe that changes in the fish populations will damage the resort businesses and the fishermen's favorite pastime.

A class at the local college decides to run a fish growth experiment in their laboratory tanks to test the claim of the resort owners and fishermen. The class obtains native fish (brook trout) and two kinds of nonnative fish (rainbow and brown trout) that have been stocked in the river (Figure 1-1 and Plate 1). The class decides to test the hypothesis, *The warmer water decreases the growth of the*

A

B

C

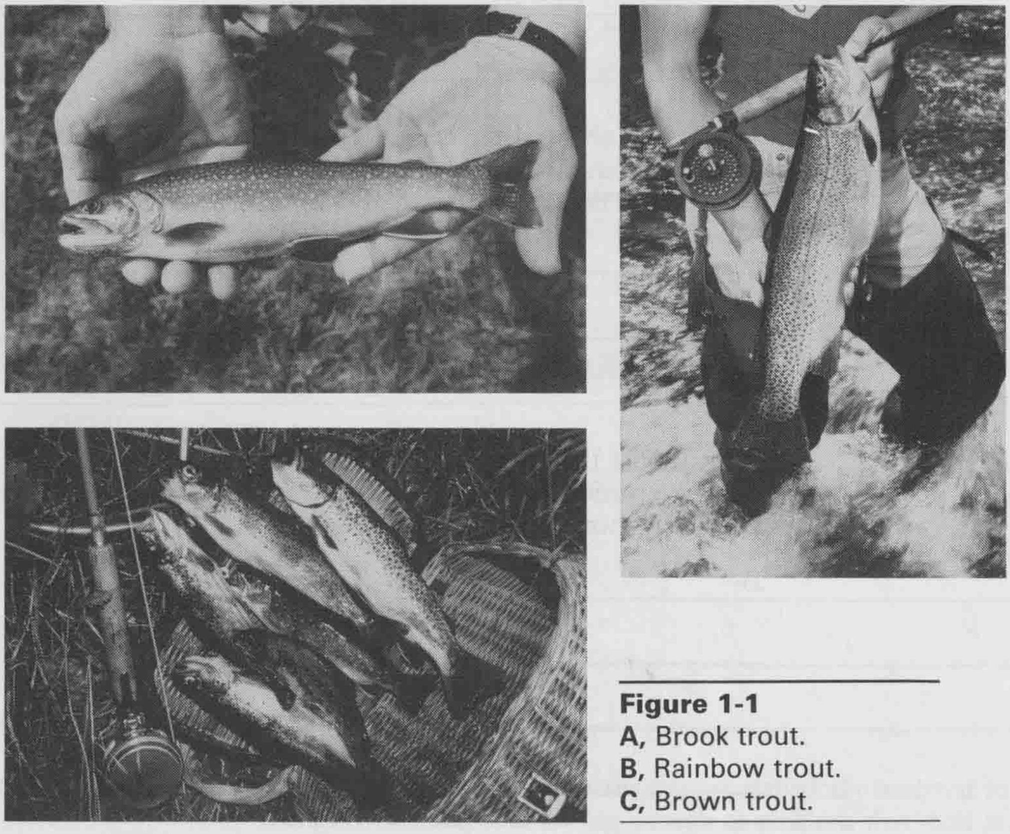

Figure 1-1
A, Brook trout.
B, Rainbow trout.
C, Brown trout.

native fish. What is the null hypothesis for the question about the effect of temperature on the fish?

20

Based on the null hypothesis, what is a specific prediction that can be experimentally tested?

21

Help the class determine the following:

Dependent variable

Independent variable

Standard conditions

Procedure for testing

The class obtained the data in Table 1-2 from their experiment. Examine the data. From the table, determine how the class designed their experiment. How is their design different from your suggested experiment?

22

What should the class conclude from their experiment? In your answer, include the particular observations that you think are most important and how you linked them together.

23

Table 1-2 Increase in length of fish grown at 14° and 22° C

Fish type/identification number		Initial length (cm)*	Length after 8 months (cm)*	Percent change	Average percent change ($\bar{X}$)
GROWTH IN WATER AT 14° C					
Brook trout	1	11	19	72	
	2	10	16	60	
	3	12	20	67	62
	4	11	16	45	
	5	9	15	67	
Rainbow trout	1	12	19	42	
	2	13	20	53	
	3	10	14	40	46
	4	12	18	50	
	5	11	16	45	
Brown trout	1	13	17	31	
	2	14	19	36	
	3	11	16	45	45
	4	9	15	67	
	5	13	19	46	
GROWTH IN WATER AT 22° C					
Brook trout	1	13	17	31	
	2	11	16	45	
	3	12	16	33	41
	4	13	19	46	
	5	10	15	50	
Rainbow trout	1	14	22	57	
	2	12	18	50	
	3	10	17	70	56
	4	12	19	58	
	5	14	20	43	
Brown trout	1	10	17	70	
	2	12	21	75	
	3	12	19	58	71
	4	11	19	73	
	5	10	18	80	

*Standard length measured from anterior tip to base of tail fin.

How convinced are you that the conclusion from the class experiment is correct?

24 ____________________

Explain your answer.

25 ____________________

____

____

In science, the results of experiments are statistically analyzed to determine if changes in the response are big enough to conclude that there is a difference.

Now think for a few minutes about the next step that should be taken by the townspeople. What do you recommend?

26 ____

____

____

In what ways do you agree *and* disagree with the following statements:

1. Life in the river will not be harmed by the small increase in heat at the power plant outlet because the heat soon dissipates in the flowing water of the river.
2. There should be no restrictions on the temperature of the outflow water from the plant.

27 ____

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____

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____

____

Effects of an environmental factor on growth of organisms (a semester-long project)

On the demonstration table is a display of organisms that have been grown under a variety of environmental conditions. Members of the same kind of organisms, such as begonias, were all of similar size and health at the beginning of the special treatments.

Some of the environmental conditions under which these organisms were grown are given on a card beside them. For plants, this information may include temperature, amount of light (measured in foot candles), type of soil (½ clay and ½ sand or ⅓ clay, ⅓ peat moss, and ⅓ sand), amount of water (number of milliliters [ml] given at specific times each week), and type of water (city, distilled, pond water, acid water, 10% alcohol). In some cases only part of this information is available.

For fungi, environmental information may include temperature, amount of water, type of water, amount of light, and growth substrate (bread, orange, newspaper, or leaves).

For animals, the environmental condition information may include temperature, type of food, type of soil, amount of water, and type of water.

Observe the organisms in the display. Prepare a list of characteristics you want to compare for each group of similar organisms. For example, a few characteristics you may observe for plants are size of leaves, color of leaves, number of flowers, and length of branches. List these and other characteristics on the appropriate line.

Plants ____

____

Fungi ____

____

Animals ____

____

In Table 1-3, indicate the environmental conditions given for each plant, fungal mass, or animal group. Describe their growth and apparent health by noting the state of observed characteristics.

Now that you have collected some information and a lot of unanswered questions from these display organisms, plan a long-term experiment. For this experimental project, work in groups designated by your teacher. Together, plan an experiment using one of the display organisms as the experimental organism. The following steps will assist your group in planning the experiment:

Step 1. Using observations of the display organisms and any other information your group members may have, choose an experimental organism and an

Table 1-3 Growth and health of organisms under varying environmental conditions

Type of organism	Light (ft cd)	Temperature (° C)	Water (ml)	Water Type	Soil Type	Substrate Type	Growth and health
1. ______							
2. ______							
3. ______							
4. ______							
5. ______							
6. ______							
7. ______							
8. ______							
9. ______							
10. ______							