THINKING ABOUT BIOLOGY AN INTRODUCTORY LABORATORY MANUAL S E C O N D E D I T I O N



MIMI BRES . ARNOLD WEISSHAAR

THINKING ABOUT BIOLOGY

AN INTRODUCTORY LABORATORY MANUAL SECOND EDITION

MIMI BRES . ARNOLD WEISSHAAR

PRINCE GEORGE'S COMMUNITY COLLEGE



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Preface

Thinking About Biology is designed for a one-semester, nonmajors, general biology course with a human focus. The topics and exercises are general enough to be compatible with most introductory level human and general biology texts currently in use. The activities demonstrate that basic biological concepts can be applied to a wide variety of plants, animals, and microorganisms.

This book is unique not because of the specific topics covered, but because of the approach to these topics. These laboratory exercises are planned to help your students

- gain practical experience that will help them understand lecture concepts,
- acquire the basic knowledge needed to make informed decisions about biological questions that arise in everyday life,
- develop the problem-solving skills that will lead to success in school and in a competitive job market,
- learn to work effectively and productively as a member of a team.

The basis of scientific work is asking questions and answering them by observations or experiments. Thus, we strongly feel that the most important goal of an introductory course in the life sciences should not be to simply outline facts about animals, molecules, or new techniques. Rather, students should come away with some understanding of the processes of investigation that are basic to science, and how scientists work to solve problems.

We hope that working through this laboratory manual will be an exciting experience for both students and instructors, and one that will leave students better prepared to meet the demands of our increasingly scientific society.

SPECIAL FEATURES FOR YOU, THE INSTRUCTOR

Three-Pronged Approach to Laboratory Learning

- Elicit Interest. Students perform better when they have a clear understanding of the reason and objectives behind each exercise. Students are often more willing to proceed if they know why they are asked to do each activity and what objectives they are expected to accomplish during the laboratory period.
- Clear Directions. Students need clearly and concisely written directions of how to proceed. This is the first and last science class for many students and we can make very few assumptions about lab skills they might bring into the class.
- Establish Relevance. A well-designed lab needs to help students understand the meaning and importance of the findings they just gathered, and to establish relevance between laboratory and lecture topics and with everyday life.

Clarity

• All content and problem solving goals are accomplished by using a simple, non-threatening approach to the lessons. Even students with little science background are able to get involved and master the material.

Instructional Objectives

■ A clear set of **Instructional Objectives** begins each exercise. This helps students identify the most important concepts that will be emphasized in each activity.

Focus on Thinking and Problem Solving

One of the most important features of this laboratory manual is the infusion of thinking and problem-solving skills with the content areas. Research has shown that it is easiest to master thinking and problem-solving skills when thinking and content are learned together. Thinking About Biology is based on this approach. Activities and questions within an exercise build on previously learned information and encourage students to transfer information from one section of the course to another.

Team Building Opportunities

Most laboratory activities emphasize a team approach. Group work is encouraged and often required. In the real world, we are expected to interact with others to solve problems and complete projects. This approach provides opportunities for students to work together, share ideas, and function effectively in groups to accomplish tasks.

Real-life Connections

• Questions throughout the activities and those incorporated into the Self Tests are designed to connect the laboratory activities to timely subjects and real-life experiences. The exercises are intended to stimulate interest in topics that can help them make decisions regarding their own health and nutrition, understand current topics in the news, and their role in the environment.

Many Opportunities to Practice Skills and Reinforce Concepts

- Activities are reinforced with relevant questions, many more than can be found in any competing editions. It is not only the number of questions, but also the type of questions that are important. Questions are designed to provide continuous feedback and elicit targeted thinking. This keeps the learner "on track" and fosters development of problem-solving skills.
- Through questions interwoven into each activity, Comprehension Checks, and Self Tests, recall of important concepts is reinforced. Students also have the opportunity to transfer content knowledge gained to new situations.

These Lessons Work!

These laboratory activities have been fully tested with more than 15,000 students on this and other campuses around the United States. Experience has shown that the simplified structure and easy-to-understand language of this manual works well with a diverse student population.

Requires Minimal Supplies and Equipment

These exercises are cost-effective and affordable even for schools with budget constraints. Most schools will already have all the equipment needed to perform the lab activities.

Designed for Simplicity

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- All activities are easy to set up and maintain. Our program is large and multisectional. Despite large numbers of instructors and students, this laboratory curriculum is incorporated smoothly in all sections. The simplicity of the laboratory approach has allowed new personnel to be "up and running" with minimal preparation time.
- Since the exercises require minimal equipment, many activities throughout the manual are suitable for use in on-line sections.

Adaptable to Any Curriculum

- Each exercise is designed for use in a three-hour laboratory period, but can easily be adapted to accommodate two-hour or 90-minute sessions. To provide maximum flexibility for instructors, each exercise is divided into several activities. Activities can be deleted or presented as demonstrations without diminishing the value of the remaining components.
- Laboratory exercises can be presented in sequence or rearranged to suit your needs. The manual includes 20 exercises, allowing you the latitude to tailor the laboratory curriculum to your course and the equipment available at your institution.

Support Materials - Instructor's Guide.

The Instructor's Guide provides you with

- complete preparation and setup instructions for each activity,
- a complete Answer Key for all activity questions,
- suggested schedule for split labs,
- helpful hints to facilitate smoothly running laboratories,
- master charts for recording results of classroom experiments.

SPECIAL FEATURES FOR YOU, THE STUDENT

Informal Style

■ The text is written in an active voice with easy-to-understand language. Key terms and important definitions are highlighted with bold print for easy recognition. Large spaces are provided throughout the manual for you to record and fully explain your answers.

Active Learning Experience

Every exercise gives you an opportunity to be an active participant in the scientific method. You will form hypotheses, set up experiments, collect data, record your data in graphs and charts, and draw conclusions from your experimental results.

Self-guided Approach

The laboratory procedures are clearly outlined to allow you to progress through each activity independently.

Tools for Success

The following components of each exercise will help you to succeed:

- **Instructional Objectives.** The objectives are listed first in each exercise so that you will be able to focus your attention on the main concepts of each activity.
- Content Focus. Each exercise includes a brief discussion of the background information that you will need to understand the subject of the exercise and prepare you to complete the activities that follow.
- Notes and Cautions. Note boxes provide helpful hints for solving problems and accomplishing laboratory tasks. Pay special attention to caution boxes that provide important safety information.
- Comprehension Checks. Stop and complete the Comprehension Check questions to get immediate feedback on your understanding of the basic principles covered in each activity. These questions also provide a chance for you to apply what you have learned to situations outside the classroom.
- Check-off Boxes. These boxes allow your instructor to check your progress before you move on to a new activity.
- Self Tests. Answer these questions after completing the laboratory exercise. Self Test questions allow you to assess your comprehension and apply your knowledge. Answers to the Self Test questions can be found in Appendix I at the back of the book.

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viii Preface

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Introduction to the Scientific Method

Objectives

After completing this exercise, you should be able to:

- use the scientific method to solve problems
- organize information to facilitate analysis of your data
- draw graphs that present data clearly and accurately
- interpret data in tables, charts, and graphs
- draw conclusions that are supported by experimental data
- analyze data using common statistical measures
- apply your knowledge of the scientific method to real-life situations.

CONTENT FOCUS

What is science? What do scientists *do* all day? These are not easy questions for most of you to answer. The widespread idea of a nerd in a white lab coat does not apply to most scientists. So, what are scientists really like? They all have the "**three Cs**" in common.

Just as you are, scientists are **curious** about the world around them. They ask questions about everything. Can my diet cause heart disease? Why does the river look brown instead of blue? How can squirrels remember where they bury their nuts? Why do some cars get better mileage than others? Science is a method for answering these and many other questions.

Scientists don't accept things without **collecting information**. All the facts relating to a problem or question have to be carefully explored and checked for accuracy.

Scientists are **comfortable with new concepts**. If a better explanation can be found, scientists are not afraid to give up old ideas for new ones.

To make the three Cs happen, scientists have developed a series of steps in investigation called **the scientific method**. Through trial and error, the scientific method has proven to be an efficient and effective way of attacking a problem. You have probably used some version of the scientific method many times in your life—without being aware of the steps you were following.

ACTIVITY 1. FORMING HYPOTHESES: DARING TO BE WRONG

Preparation

There are several different ways that a problem can come to your attention. Someone may **assign** you the problem (this happens often in a school or a work situation), the problem may **thrust itself** upon you (your car won't start), or you may discover the problem by simply being **curious** about something you have seen.

Let's begin with a simple situation that you might face any day.

The Problem

You drive to school and park in your usual spot. As you walk across the campus after your morning biology class, you discover that you can't find your car keys. You have a problem!

An easy way to attack the problem is to make an **educated guess** about the possible solution to the problem. It is an "educated" guess because you use all the background information that is available when making your guess.

In scientific terms, an educated guess is called a hypotheses.

- 1. On the next page, in Table 1-1, you will find some hypotheses that might shed some light on this problem.
- 2. Complete the table by adding some hypotheses of your own.



Check your hypotheses with your instructor before you continue.

TABLE 1-1
KEY LOSS: POSSIBLE HYPOTHESES
A: I didn't bring the keys with me today.
B: The keys are in my book bag.
C:
D:
E:

ACTIVITY 2 FORMING HYPOTHESES TO SOLVE PROBLEMS

The Problem

You were absent from chemistry class the day your professor gave out the instructions for making an important solution needed for your laboratory experiment. No problem. Your roommate was in class and had copied down the formula for you. You rush off to chemistry lab and prepare the solution, but when you use it in your experiment, it doesn't perform as expected.

In **Table 1-2**, **list three hypotheses** about why the formula didn't work. Don't forget—the hypotheses must be **testable**!

TABLE 1-2
CHEMISTRY EXPERIMENT: HYPOTHESES
A:
В:
D.
C:



Check your hypotheses with your instructor before you continue.

Some hypotheses can be tested by observation only, but more often, you will need a **combination of observation and experimentation** to be sure about the accuracy of your results. To understand how scientists work, you must follow the steps of the scientific method as they are used in actual **experiments**. **In Activities 3 and 4**, you will **see how scientific method skills** are used to **set up experiments** and analyze the **information (data)** that is collected.

ACTIVITY 3

TESTING HYPOTHESES

The Problem

Investigate the effects of fertilizer on plant growth.

STEP 1:

You form a hypotheses about what you think will happen.

Hypotheses: Adding fertilizer will make plants grow taller.

STEP 2:

You design an experiment that compares the growth (in height) of plants that receive fertilizer with those grown without fertilizer. Your design might be similar to the following:

Begin with **20 plants** (same size, same type), planted in the same-size pots, with the same amount and type of soil, placed on a windowsill with the same exposure to light. All these factors will be held constant.

- An experiment is designed to isolate the factor you are interested in testing. All other conditions must be held constant. In this way, you are sure that your observed results were caused by the only factor that was varied.
- Since you are investigating the effect of fertilizer, you will want to hold all other factors constant (plant type, plant size, pot size, amount of water, amount of light, etc.) to avoid confusion. This way you can be sure that any differences in height are due to the presence of fertilizer and not some other factor.

You decide to measure the growth of your plants (height in centimeters) **once a week for a month**. You will keep detailed **records** of your **observations**.

It is helpful to plan an experiment with a **group** of plants (or animals). There are **two good reasons** to use groups:

- If unexpected factors (such as disease) affect one or two experimental subjects, it will not ruin the experiment.
- Natural genetic variability will cause some plants to grow taller than others (just as some people grow taller than others). You can separate this effect from that of the fertilizer by measuring the height in a group of plants for each treatment (fertilizer and no fertilizer).

You decide that 10 plants will receive identical measured amounts of fertilizer each week. These are the experimental plants. They are receiving the treatment (fertilizer) that will help you test your original hypotheses (does fertilizer make plants grow taller?).

Ten plants will receive no fertilizer. These are the control plants. They do not receive the experimental treatment. You will use these for comparison with the experimental group to help you interpret your results, and to show that any observed differences in height between the two groups are due to the only difference between them—application of fertilizer.

In the above example, there are 10 replications of the experimental treatment and 10 replications of the control treatment.

✓ Comprehension Check

1. Why is it necessary to divide the plants into two groups (a control group and an experimental group)?

2. Why is it important to keep conditions exactly the same in the control and experimental group, **except** for the application of fertilizer?

3. Why is it better to do the plant/fertilizer experiment with 10 plants in each group instead of just one or two? Give two reasons. Use your own words.

a.

b.



Check your answers with your instructor before you continue.

Preparation

The month is up. You are ready to draw conclusions from your **data** (the information you have recorded). You will be thinking about what your results mean and whether your hypotheses is **supported**.

The information you collected during your experiment is presented in **Tables 1-3 and 1-4**.

-	Com	prehe	nsion	Check
	COIL	PICIL	1131011	CIICCI

1. Were there differences in growth between the control and experimental plants?

If so, which group grew taller? How do you know?

2. Do the results support the original hypotheses? Explain your answer.

3. Why is it more accurate to compare the **average** height gain of the control and experimental groups (instead of comparing individual plants)?



Check your answers with your instructor before you continue.

TABL HEIGH	E 1-3 HT GAIN (cr	m) OVI	ER FOU	RWE	EKS—C	CONTROL	PLANTS
PLANT NUMBER	INITIAL HEIGHT (cm)	WEEK 1	WEEK 2	WEEK 3	WEEK 4	TOTAL HEIGHT GAIN	AVG HEIGHT GAIN
1	10.0	1.6	2.0	3.0	2.5	9.1	2.3
2	11.5	2.2	1.5	1.5	2.0	7.2	1.8
3	9.6	1.5	2.3	2.6	2.0	8.4	2.1
4	9.2	2.0	3.0	2.8	1.5	9.3	2.3
5	10.2	2.3	1.2	1.6	2.0	7.1	1.8
6	11.0	3.2	1.7	2.0	3.2	10.1	2.5
7	10.0	2.6	3.0	3.0	1.4	10.0	2.5
8	9.7	4.0	2.6	4.0	2.3	12.9	3.2
9	10.4	DIED	_	_		_	_
10	10.4	2.3	2.3	2.7	2.0	10.0	2.5
TOTAL						84.1	21.0

Plant Number	INITIAL HEIGHT (cm)	WEEK 1	Week 2	WEEK 3	WEEK 4	Total Height Gain	AVG HEIGHT GAIN
1	9.6	4.2	5.0	3.0	4.7	16.9	4.2
2	9.8	6.0	4.0	5.5	5.0	20.5	5.1
3	10.3	5.3	5.5	3.6	4.2	18.6	4.7
4	11.0	2.1	3.2	6.2	3.8	15.3	3.8
5	10.1	3.4	4.0	4.4	4.0	15.8	4.0
6	9.2	4.7	3.1	3.1	4.0	14.9	3.7
7	9.5	4.2	5.2	3.9	3.6	16.9	4.2
8	10.0	3.3	6.0	5.6	4.2	19.1	4.8
9	9.7	5,8	6.1	6.5	5.0	23.4	5.9
10	10.4	5.1	3.4	5.8	5.3	19.6	4.9
TOTAL						181.0	45.3