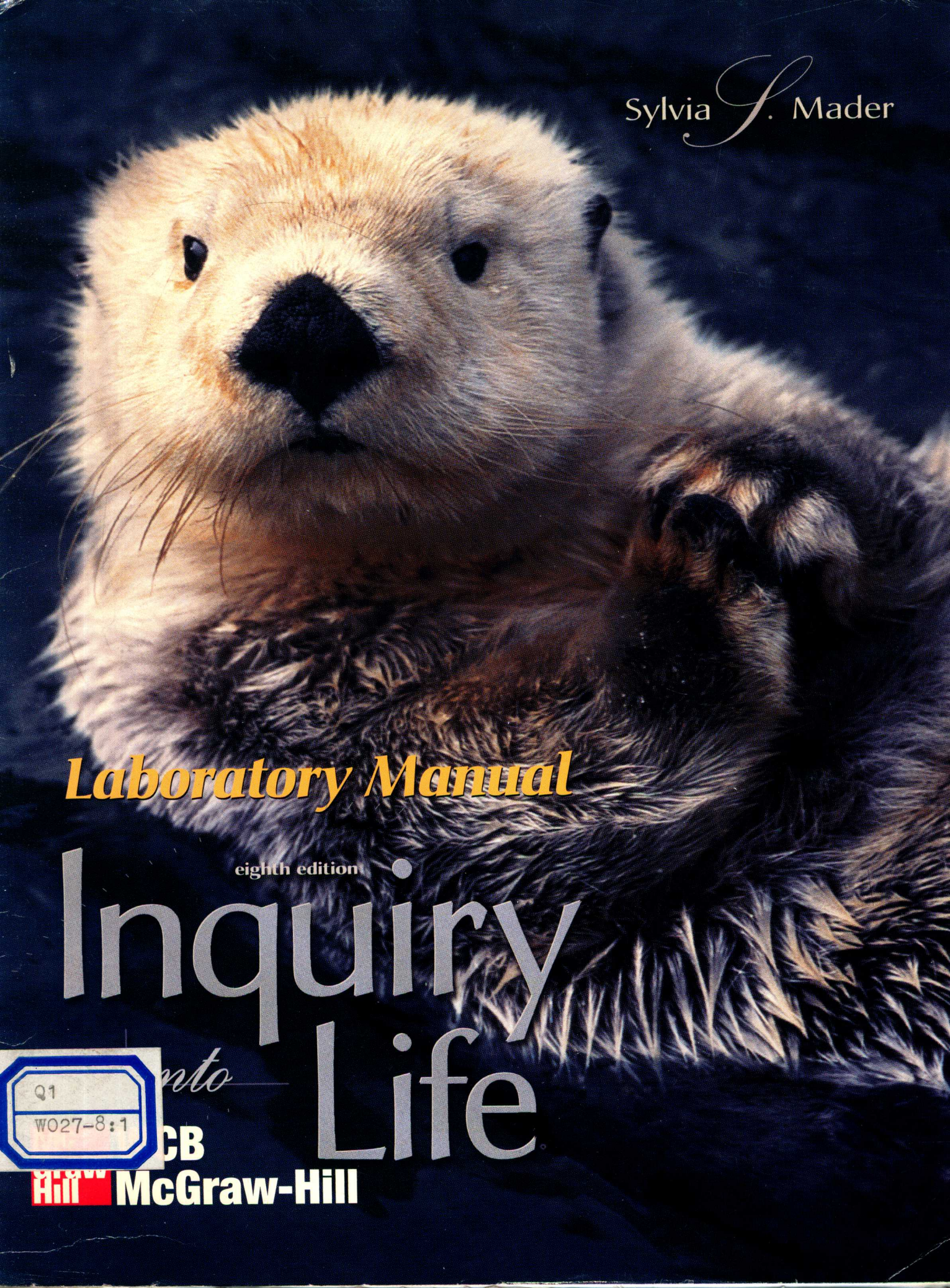
Sylvia S. Mader
Laboratory Manual
eighth edition
Inquiry into Life
McGraw-Hill

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Laboratory Manual

eighth edition •

Inquiry *into* Life

Sylvia S. Mader

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Some of the laboratory experiments included in this text may be hazardous if materials are handled improperly or if procedures are conducted incorrectly. Safety precautions are necessary when you are working with chemicals, glass test tubes, hot water baths, sharp instruments, and the like, or for any procedures that generally require caution. Your school may have set regulations regarding safety procedures that your instructor will explain to you. Should you have any problems with materials or procedures, please ask your instructor for help.

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preface

To the Instructor

The laboratory exercises in this manual are coordinated with *Inquiry into Life,* a general biology text that covers the entire field of biology. The text emphasizes how we can apply biological knowledge to our own lives and to our relationships with other organisms.

Although each laboratory is referenced to the appropriate chapter in *Inquiry into Life,* this manual may be used in coordination with other general biology texts. Several features in this laboratory manual allow adaptation to a variety of course orientations and designs. There are a sufficient number of laboratories to permit a choice of activities over the length of the course. Many activities may be performed as demonstrations rather than as student activities, thereby shortening the time required to cover a particular concept.

The Exercises

All exercises have been tested for student interest, preparation time, estimated time of completion, and feasibility. Students work with living material during some part of almost all laboratories. The exercises can be performed easily in most laboratory settings, and instructors can be confident that the exercises provide opportunities for their students to actively learn both laboratory skills and the scientific process.

To aid in advanced planning, the estimated time for completion of the laboratories and special requirements are given in the table of contents and in the *Laboratory Resource Guide.* The majority of exercises are designed to be easily performed by a number of laboratory sections in succession.

The Appendixes and Index

For instructors who wish to have their students write lab reports, Appendix A provides students with a format to follow. The lab report is divided into sections: Introduction, Procedure, Results, and Discussion. There are instructions and examples for each section, and a report form is included. You may wish to begin this course by asking students to complete the report form for one particular exercise within a given laboratory and end the course by requiring a completely prepared laboratory report for the entire exercise, using the instructions and form simply as a guide. If students are particularly advanced, you may wish to add more sections to the outline, particularly later on. For example, a more lengthy discussion could also include alternative interpretations, identification of assumptions, and countering of possible criticism.

The other appendixes are also helpful. Appendix B gives a review of the metric system. Appendix C is the classification system used in the manual and the text. Appendix D contains answers to laboratory review questions. Practical Examination Sheets are also provided.

This manual also includes an index. By consulting the index it is possible to determine on what page or pages various topics are discussed and/or activities are found.

New to this Edition

This laboratory manual has been widely accepted but, none the less, changes have been made that will even further enhance its appeal.

Integrated Opening. Each laboratory begins with a list of learning objectives that are organized according to the major sections of the laboratory. The major sections of the laboratory are numbered on the opening page, in the laboratory text material, and in the review. This organization will help students better understand the goals of each laboratory session.

Materials List. In the previous edition, each laboratory began with a materials list. Now instructors should consult the *Resource Guide* for materials required and for all information needed to successfully complete each exercise.

Student Activities. Separate color bars are used to designate which student activities are observations and which are experimental procedures. An icon appears whenever a procedure requires a period of time before results can be viewed. Sequentially numbered steps now guide students as they perform an activity.

Self-contained Content. New to this edition, each laboratory contains all the background information necessary to understand the concepts being studied and to answer the questions asked. This feature will reduce student frustration and increase learning.

Scientific Method. All laboratories stress the scientific method, and many opportunities are given for students to gain an appreciation of the scientific process. The first laboratory of this edition explicitly explains the steps of the scientific method and gives students an opportunity to use them. I particularly recommend this laboratory because it utilizes the garden snail, a living subject.

Laboratory Safety. Laboratory safety is of prime importance and the listing on page viii will assist instructors in their efforts to make the laboratory experience a safe one.

New Laboratories

All laboratories have been revised. New introductory material, student activities, and illustrations appear throughout the manual. The laboratories listed below are new or have been significantly revised.

Laboratory 1 Scientific Method utilizes the scientific method and uses the snail as the experimental material.

Laboratory 5 Mitosis and Meiosis has been revised to include simulation activities.

Laboratory 17 Nervous System and Senses contains material that was in two separate laboratories in the previous edition. Observation of the brain and spinal cord and the eye and ear are retained. Experimental procedures regarding reflexes and the senses are also found in this laboratory.

Laboratory 20 Mendelian Genetics now contains exercises other than those requiring the use of fruit flies, and the fruit fly experiments have been considerably shortened.

Laboratory 22 Molecular Genetics now begins with simulation activities that will allow all instructors to include this laboratory in the course syllabus.

Laboratory 29 Echinoderms and Chordates features the starfish and frog as before but now includes a section on comparative vertebrate anatomy.

Laboratory 31 Sampling Ecosystems now includes more explicit directions to guide instructors and students as they venture out of the laboratory setting.

Customized Editions

The thirty-two laboratories in this manual are now available as individual "lab separates," so instructors can custom-tailor the manual to their particular course needs.

Laboratory Resource Guide

The *Laboratory Resource Guide* is essential for instructors and laboratory assistants and is available free to adopters of the *Laboratory Manual.*

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To the Student

Special care has been taken in preparing the *Laboratory Manual for Inquiry into Life* so that you will *enjoy* the laboratory experience as you *learn* from it. The instructions and discussion are written clearly so you can understand the material while working through it. Student aids are designed to help you focus on important aspects of each exercise.

Student Learning Aids

Student learning aids are carefully integrated throughout this manual. The *learning objectives* set the goals of each laboratory session and help you review the material for a laboratory practical or any other kind of exam. In this edition, the major topics are numbered, and the learning objectives are grouped according to these topics. The section numbering is used in the text material and in the laboratory review questions. This system allows students to study the chapter in terms of the objectives presented.

The *introduction* establishes the rationale for coming work and reviews much of the necessary background information required for comprehension of upcoming experiments. *Color bars* bring attention to exercises that require your active participation by highlighting Observations and Experimental Procedures, and an icon indicates a timed experiment. Throughout, *space* is provided for recording answers to questions and the results of investigations and experiments. Each laboratory ends with a set of review questions covering the day's work.

Appendixes at the end of the book provide useful information on preparing a laboratory report, the metric system, classification of organisms, and answers to review questions. Practical examination answer sheets are also provided.

Laboratory Preparation

Read each exercise before coming to the laboratory. *Study* the introductory material and the experimental procedures. If necessary, to obtain a better understanding *read* the corresponding chapter in your text. If your text is *Inquiry into Life,* by Sylvia S. Mader, see the text *chapter reference* in the table of contents at the beginning of the *Laboratory Manual.*

Explanations and Conclusions

Throughout the laboratory you are often asked to formulate explanations or conclusions. To do so, you will need to synthesize information from a variety of sources, including the following:

1. Your experimental results and/or the results of other groups in the class. If your data are different from other groups in your class, do not erase your answer; add the other answer in parentheses.
2. Your knowledge of underlying principles. Obtain this information from the laboratory introduction or the appropriate section of the laboratory and the corresponding chapter of your text.
3. Your understanding of how the experiment was conducted and/or the materials that were used. *Note:* ingredients can be contaminated or procedures incorrectly followed, resulting in reactions that seem inappropriate. If this occurs, consult with other students and your instructor to see if you should repeat the experiment.

In the end, be sure you are truly writing an explanation or conclusion and not just giving a restatement of the observations made.

Color Bars and Icon

Throughout the chapter, the following color bars and icon are used to assist you:

Observation—An activity in which you observe models or slides and make identifications or draw conclusions.

Experimental Procedure—An activity in which a series of laboratory steps is followed to achieve a learning objective.

Time—Allow the designated amount of time for this activity. Start these activities at the beginning of the laboratory, proceed to other activities, and return to these when the designated time is up.

Student Feedback

If you have any suggestions for how this laboratory manual could be improved, you can send your comments to

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laboratory safety

Many of the reagents (chemicals) and some equipment in a biology laboratory are potentially dangerous. Following rules of laboratory safety and using common sense throughout the course will enhance the learning experience by increasing the student's confidence in his or her ability to safely use chemicals and equipment.

The following rules of laboratory safety should be studied and should become a habit.

1. Wear safety glasses or goggles during exercises in which glassware and solutions are heated, or during which dangerous fumes may be present, creating possible hazard to eyes or contact lenses.
2. Assume that all reagents are poisonous and act accordingly. Read labels on chemical bottles for safety precautions and know the nature of the chemical you are using. If chemicals come into contact with skin, wash immediately with water.
3. **DO NOT**
   a. ingest any reagents;
   b. eat, drink, or smoke in the laboratory. Toxic material may be present, and some chemicals are flammable;
   c. carry reagent bottles around the room;
   d. pipette anything by mouth;
   e. put chemicals in sink or trash unless instructed to do so;
   f. pour chemicals back into containers unless instructed to do so;
   g. operate any equipment until you are instructed in its use.
4. **DO**
   a. keep work area neat, clean, and organized. Ask your instructor for assistance in cleaning up broken glassware and spills. Wash hands, desk area, and glassware at the end of each exercise and/or before leaving the laboratory.
   b. stopper all reagent bottles when not in use. Immediately wash reagents off yourself and your clothing if they spill on you, and immediately inform the instructor. If you accidentally get any reagent in your mouth, rinse mouth thoroughly and immediately inform your instructor.
   c. handle hot glassware with test-tube clamp or tongs. Use caution when using heat, especially when heating chemicals. Do not leave a flame unattended; do not light a Bunsen burner near a gas tank or cylinder; do not move a lit Bunsen burner; keep long hair and loose clothing well away from the flame; make certain gas jets are off when Bunsen burner is not in use. Use proper ventilation and hoods when instructed.
   d. use extra care when working with scalpels, knives, and glass tubing.
   e. wear clothing that, if damaged, would not be a serious loss, or use aprons or laboratory coats, since some chemicals may damage fabrics.
   f. wear shoes as protection against broken glass or spillage which may not have been adequately cleaned up.
   g. be familiar with the experiments you will be doing before coming to the laboratory. This will increase your understanding, enjoyment,and safety during exercises. *Confusion is dangerous.* Completely follow the procedure set forth by the instructor.
   h. note the location of emergency equipment such as a first aid kit, eyewash bottle, fire extinguisher, switch for ceiling showers, fire blanket(s), sand bucket, and telephone (911). Report all accidents immediately.
   i. report any condition that appears unsafe or hazardous to the instructor.

I understand the safety rules as presented above, and agree to follow them and all other instructions given by the instructor.

_____ _____

Name Date

_____

Laboratory Class and Time

contents

***Special Requirements Key**

- **I** Incubation
- **L** Living material—advanced order with timely delivery
- **F** Fresh material—local purchase as needed
- **C** Culture or growth
- **T** Trip to field site—prior planning required

Scientific Method

LABORATORY

Learning Objectives

STUDENTS SHOULD BE ABLE TO

1.1 INTRODUCTION

1. outline the steps of the scientific method.
2. distinguish between observations, hypotheses, conclusions, and theories.

1.2 OBSERVING THE GARDEN SNAIL

3. describe the external anatomy of a garden snail, *Helix,* and relate the anatomy to various behaviors.
4. describe how a garden snail moves.

1.3 FORMULATING HYPOTHESES

5. formulate a hypothesis when supplied with previously collected data.

1.4 PERFORMING AN EXPERIMENT

6. design an experiment that can be repeated by others.
7. reach a conclusion based on observation and experimentation.

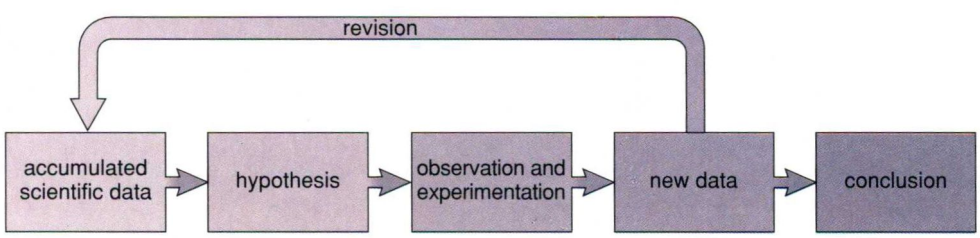
1.1 Introduction

Science is often defined as the study of the natural world. Even though scientists use instruments such as microscopes and pH meters, they are still working with phenomena that are observable by one or more of the senses.

Scientists use the scientific method (fig. 1.1) to collect data. **Data** are any factual information that can be observed either independent of or as a result of experimentation. Scientific data allow scientists to formulate a hypothesis. A **hypothesis** is a tentative explanation of observed phenomena.

After a hypothesis is formatted, it must be tested by making new observations and/or doing new experiments. Observations are made and experiments are done in such a way that others can repeat them. Only repeatable observations and experiments are accepted as valid contributions to the field of science. When doing experiments scientists often include a **control sample,** which is a sample that undergoes all the steps in the experiment except the one being tested.

Figure 1.1
Steps of the scientific method.



The new data are used to reach a conclusion. Observations or experiments either support the hypothesis or prove it false. Data can prove a hypothesis false but cannot prove a hypothesis true. Scientists are always aware that the present body of information represents the truth available at the moment and that further observations and experiments could lead to a change in prior conclusions.

As the arrow in figure 1.1 indicates, research often enters a cycle of hypothesis-experimentation-data-hypothesis. Occasionally a hypothesis is not disproved and instead is supported. If many related hypotheses are supported, a theory may be formulated. A **theory** is a generalization accepted by the scientific community after many years of testing and study. For example, after testing the cause of many individual diseases, the germ theory of disease was formulated. It states that infectious diseases are caused by microorganisms that can be passed from one person to another. Even though theories are based on years of experimentation, scientists are ever ready to modify or even discard any theories that new data call into question.

1.2 Observing the Garden Snail

Scientists often begin by making observations about the subject of interest. Today our subject will be the garden snail, *Helix aspersa,* which is a type of mollusk adapted to life on land. Snails have three obvious divisions of the body: a head with two pairs of tentacles, one pair of which bears eyes at the tips; a flat, long muscular foot; and a visceral mass surrounded by a shell. The shell not only offers protection but also prevents desiccation, or drying out.

The mantle cavity, whose front edge is fused to the neck of the animal, does not contain gills—the mantle tissue is adapted for gas exchange with air. As the foot contracts and waves of contraction run from anterior to posterior, a lubricating mucus is secreted to facilitate movement. Snails are hermaphroditic; when two snails mate, each inserts a penis into the mantle cavity of the other, providing sperm for future fertilization of eggs that are deposited in the dirt. While eggs are usually laid within a few weeks, sperm can be stored as long as a year.

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1. Obtain a garden snail that has been numbered with white correction fluid. First examine the shell and body with the unaided eye and then with a magnifying lens or dissecting microscope.
2. In the space provided draw a large outline of your snail's shell (at least 10–12 cm across).
3. Examine the shell shape, color, texture. **Note:** As snails grow, they keep adding to their shell. If the front edge of the shell forms a continuous line with the rest of the shell, your snail is still growing. An upward curl at the front edge of the shell indicates that the snail is fully grown. Is your snail still growing? _____

4. In the space provided, draw the underside of your snail, making the foot at least 7 cm long. NOTE: When you pick up a snail, slide it along the surface, rather than lifting it straight up. This procedure is safer for the snail, since you are less likely to crush the shell or to pull the shell off the body.
5. Label the shell, foot, and **pneumostome** (a breathing hole) on your second drawing. The pneumostome is a hole between the shell and body. The hole may not be open when you first look, but with a little patience you should see it open.

Observation of Garden Snail's Motion

1. Watch a garden snail's underside as the snail moves up a transparent surface, such as the side of a beaker. Describe the wave action of the foot and any motion you see in the pneumostome.

   _____

2. As you watch the snail, identify behaviors that might
   a. protect it from predators _____
   b. help it to acquire food _____
   c. protect it from the elements _____
   d. allow interaction with the environment _____
3. Allow a garden snail to crawl on your hand. Describe how it feels.

   _____

4. Place a garden snail on a moveable flat surface, such as a 20-by-30-cm piece of plywood. Experiment with the angle of the plywood and the position of the snail to determine the snail's preferred direction of motion. For example, place the plywood on end, and position the snail so that it can move up or down. Try other arrangements also. Repeat this procedure with three other snails. Record the preferred direction of motion and other observations for each snail in table 1.1.

Table 1.1 Preferred Direction of Motion

Snail	Direction Moved	Comments
1		
2		
3		
4		

5. Measure the speed of a "snail's pace." Use what you learned about each snail's preferred direction of motion (see table 1.1) to get maximum cooperation from each of the four snails you worked with in number 4. Place each snail on a metric rule, and use a stopwatch to measure the time it takes for the snail to move a certain number of centimeters. Record your results for each snail in table 1.2. Calculate each snail's average speed in centimeters per minute.

Table 1.2 Snail Speed

Snail	Centimeters Traveled	Time (min.)	Average Speed (cm/min.)
1			
2			
3			
4			

1.3 Formulating Hypotheses

You will be testing whether garden snails are attracted to, repelled by, or show no response to particular substances. Snails move away from and/or foam when they are repelled by a substance and they move toward and eat a substance they are attracted to. If a snail simply withdraws into its shell, nothing is proven and you may wish to choose another snail.

1. Choose
   a. three to five powders, such as flour, cornstarch, laundry detergent, and baking soda.
   b. three to five liquids, such as milk, orange juice, vinegar, honey, and water.
2. Hypothesize in table 1.3 how you expect the snail to respond, and offer an explanation for your reasoning.

Table 1.3 Hypotheses about Snail's Response to Different Substances

Substance	Hypothesis about How Snail Will Respond to Substance	Reasoning for Hypothesis
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

1.4 Performing an Experiment

1. Design an experiment to test the snail's reaction to the chosen substances. The snail must be treated humanely; no substance must be put directly on the snail, nor can the snail be put directly onto the substance. Also, it is advisable to design an experiment that requires minimal clean-up on your part.
2. Does your experiment contain a control? Explain. _____
3. Did other students get results which support your hypothesis? _____
4. What is needed by other experimenters in order for them to repeat your experiment? _____
5. When testing the snails reaction, consider carefully what it is about each substance that is causing the snail's response. Complete table 1.4. _____

Table 1.4 Snail's Reaction to Common Powders and Liquids

Substance Tested	Snail's Reaction	Comments
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

6. Study your results, and decide what factors may have caused the snail to be attracted to or repelled by a substance. _____

_____

7. Test this new hypothesis, and describe what your results show or do not show. Can you come to a conclusion? _____

_____

Laboratory Review 1

1.1 Introduction

_____ 1. What kind of phenomena do scientists study?

_____ 2. What do scientists collect when making observations and doing experiments?

_____ 3. What occurs following observations and experiments?

_____ 4. What do you call a sample that goes through all the steps of an experiment except the one being tested?

Indicate whether 5 and 6 are hypotheses, conclusions, or theories.

_____ 5. The data show that vaccines protect people from disease.

_____ 6. All living things are made up of cells.

1.2 Observing the Garden Snail

_____ 7. Wavelike contractions along what organ allow a snail to move?

1.3 Formulating Hypotheses

_____ 8. Name one criterion you used to formulate your hypotheses regarding snail behavior toward various substances.

1.4 Performing an Experiment

_____ 9. Snails that foam are (attracted to/repelled by) a substance.

_____ 10. What do you call an experiment that can be done by someone else in exactly the same way?

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