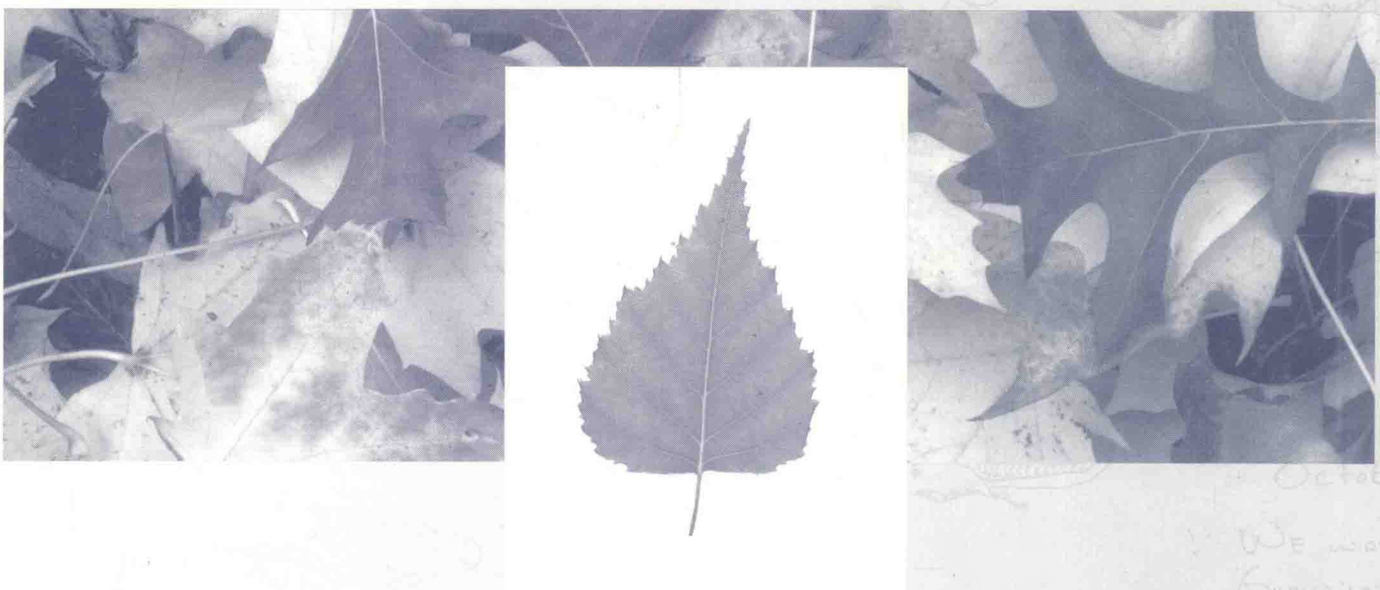
Biology II Lab



CUSTOMIZED FOR

Utah State University

MORGAN/CARTER

Biology II Lab

Customized for Utah State University

Judith Giles Morgan
Emory University

M. Eloise Brown Carter
Oxford College of Emory University

An imprint of Addison Wesley Longman, Inc.

Menlo Park, California • Reading, Massachusetts • New York • Harlow, England
Don Mills, Ontario • Sydney • Mexico City • Madrid • Amsterdam

The authors and publisher believe that the lab experiments described in this publication, when conducted in conformity with the safety precautions described herein and according to the school's laboratory safety procedures, are reasonably safe for the student to whom the manual is directed. Nevertheless, many of the described experiments are accompanied by some degree of risk, including human error, the failure or misuse of laboratory or electrical equipment, mismeasurement, spills of chemicals, and exposure to sharp objects, heat, bodily fluids, blood, or other biologics. The authors and publisher disclaim any liability arising from such risks in connection with any of the experiments contained in this manual. If students have questions or problems with materials, procedures or instruction on any experiment, they should always ask their instructor for help before proceeding.

Biology II Lab
Customized for Utah State University

Biology II Lab
is a custom version of *Investigating Biology*, Second Edition, by Judith Giles Morgan and M. Eloise Brown Carter (ISBN: 0-80531944-1).
The selection and order of material have been determined by the instructor at the institution for which this book is being published.

ISBN: 0-201-52061-3

1 2 3 4 5 6 7 8 9 1—00 99 98

Laboratory Safety: General Guidelines

1. Notify your instructor immediately if you are pregnant, color blind, allergic to any insects or chemicals, taking immunosuppressive drugs, or have any other medical condition (such as diabetes, immunologic defect) that may require special precautionary measures in the laboratory.
2. Upon entering the laboratory, place all books, coats, purses, backpacks, etc. in designated areas, not on the bench tops.
3. Locate and, when appropriate, learn to use exits, fire extinguisher, fire blanket, chemical shower, eyewash, first aid kit, broken glass container, and cleanup materials for spills.
4. In case of fire, evacuate the room and assemble outside the building.
5. Do not eat, drink, smoke, or apply cosmetics in the laboratory.
6. Confine long hair, loose clothing, and dangling jewelry.
7. Wear shoes at all times in the laboratory.
8. Cover any cuts or scrapes with a sterile, waterproof bandage before attending lab.
9. Wear eye protection when working with chemicals.
10. Never pipet by mouth. Use mechanical pipeting devices.
11. Wash skin immediately and thoroughly if contaminated by chemicals or microorganisms.
12. Do not perform unauthorized experiments.
13. Do not use equipment without instruction.
14. Report *all* spills and accidents to your instructor immediately.
15. Never leave heat sources unattended.
16. When using hot plates, note that there is no visible sign that they are hot (such as a red glow). Always assume that hot plates are hot.
17. Use an appropriate apparatus when handling hot glassware.
18. Keep chemicals away from direct heat or sunlight.
19. Keep containers of alcohol, acetone, and other flammable liquids away from flames.
20. Do not allow any liquid to come into contact with electrical cords. Handle electrical connectors with dry hands. Do not attempt to disconnect electrical equipment that crackles, snaps, or smokes.
21. Upon completion of laboratory exercises, place all materials in the disposal areas designated by your instructor.
22. Do not pick up broken glassware with your hands. Use a broom and dustpan and discard the glass in designated glass waste containers; never discard with paper waste.
23. Wear disposable gloves when working with blood, other body fluids, or mucous membranes. Change gloves after possible contamination and wash hands immediately after gloves are removed.
24. The disposal symbol indicates that items that may have come in contact with body fluids should be placed in your lab's designated container. It also refers to liquid wastes that should not be poured down the drain into the sewage system.

25. Leave the laboratory clean and organized for the next student.
26. Wash your hands with liquid or powdered soap prior to leaving the laboratory.
27. The biohazard symbol indicates procedures that may pose health concerns.

    The caution symbol points out instruments, substances, and procedures that require special attention to safety. These symbols appear throughout this manual.

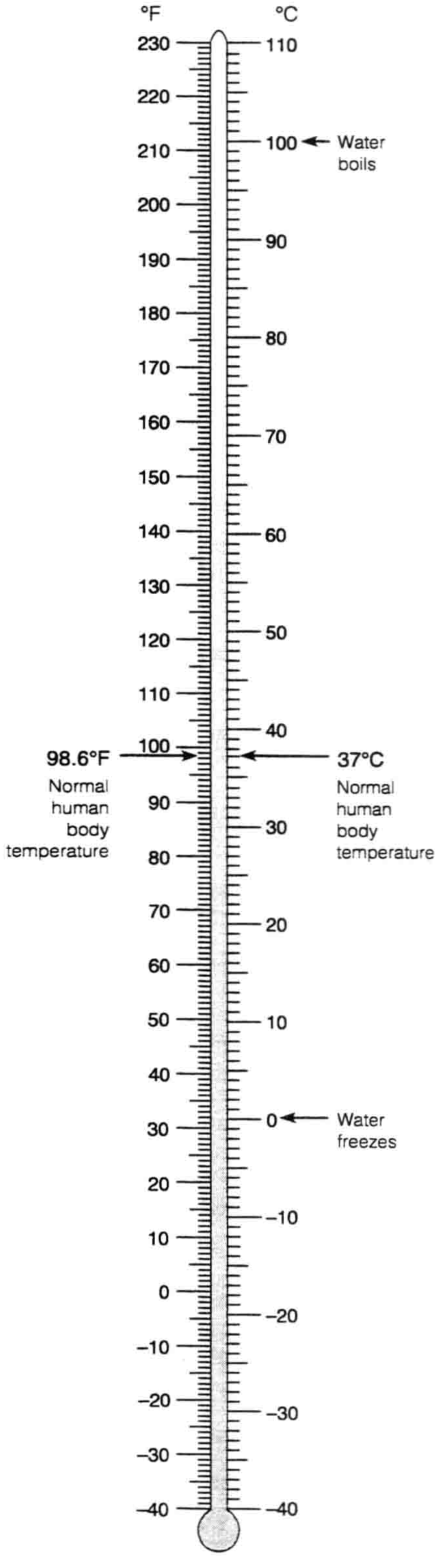
Measurement Conversions

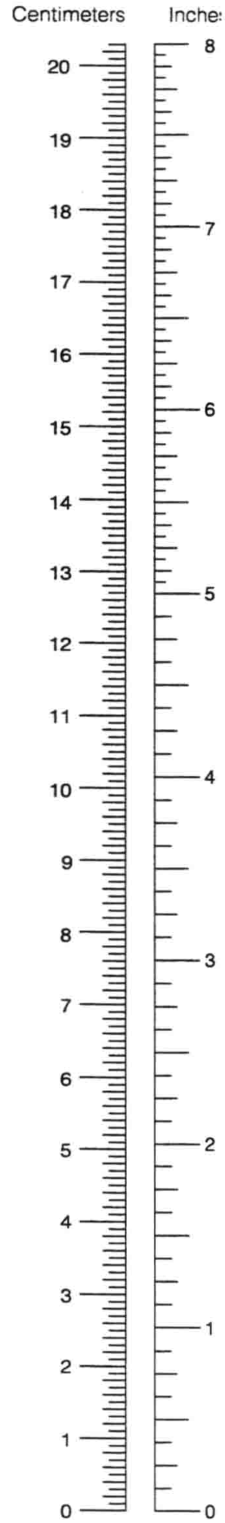
Metric to American Standard	American Standard to Metric
Length	
1 mm = 0.039 inches	1 inch = 2.54 cm
1 cm = 0.394 inches	1 foot = 0.305 m
1 m = 3.28 feet	1 yard = 0.914 m
1 m = 1.09 yards	1 mile = 1.61 km
Volume	
1 mL = 0.0338 fluid ounces	1 fluid ounce = 29.6 mL
1 L = 4.23 cups	1 cup = 237 mL
1 L = 2.11 pints	1 pint = 0.474 L
1 L = 1.06 quarts	1 quart = 0.947 L
1 L = 0.264 gallons	1 gallon = 3.79 L
Mass	
1 mg = 0.0000353 ounces	1 ounce = 28.3 g
1 g = 0.0353 ounces	1 pound = 0.454 kg
1 kg = 2.21 pounds	

Temperature

To convert temperature:

$°C = \frac{5}{9}(F - 32)$ $\quad$ $°F = \frac{9}{5}C + 32$





Preface

Nothing has such power to broaden the mind as the ability to investigate systematically and truly all that comes under thy observation in life.

MARCUS AURELIUS,
Roman Emperor and Philosopher (121–180)

Our knowledge of the biological world is based on the scientific enterprise of asking questions and testing hypotheses. An important aspect of learning biology is participating in the process of science and developing creative and critical reasoning skills. Our goal in writing this laboratory manual is to present a laboratory curriculum that encourages participation in the scientific process. We want students to experience the excitement of discovery and the satisfaction of solving problems and connecting concepts. For us, investigating biology is more than just doing experiments; it is an approach to teaching and learning.

The laboratory exercises are designed to encourage students to ask questions, to pose hypotheses, and to make predictions before they initiate laboratory work. Students are required to synthesize results from observations and experiments, then draw conclusions from evidence. Finally, whenever possible, students apply their results to new problems and are encouraged to pursue open-ended investigations of their own design. Scientific writing is emphasized throughout the laboratory manual.

We are convinced that involving students in the process of science through their investigating of biological phenomena is the best way to teach. The organization of this laboratory manual complements this approach to teaching and learning.

New in the Second Edition

We have added a new laboratory topic on protista and fungi (Lab Topic 13) to encompass all five kingdoms in our investigations of the diversity of life. This lab topic, besides including a survey of major groups, provides students with the opportunity to design their own investigation of these intriguing organisms.

Lab Topic 1, Scientific Investigation, has been extensively rewritten. Students use a sample investigation to develop their understanding of the elements of the scientific method. They critique questions and hypotheses and practice developing their own hypotheses and predictions. The Questions for Review are new, and an example of published research is used in the Applying Your Knowledge section.

Lab Topic 9, Molecular Biology, has been shortened so that it can be completed in one laboratory period. We have incorporated a practice mapping problem so that students are well prepared to analyze their data and produce a map of the DNA. The new restriction enzymes and plasmid DNA provide simple results that assure students' success in this exciting area of biology.

Other changes are more subtle but represent fine tuning based on our experiences and those of instructors and students who used the first edition. Lab Topic 26, Ecology II: Computer Simulations of a Pond Ecosystem has been updated to coordinate with the 1995 version of the BioQUEST software. We have included new slides and demonstration materials for the plant and animal diversity labs. To improve teaching and learning by improved communication, we have revised many of the original figures and included new photography and artwork throughout the lab manual.

The Prep Guide and Annotated Teacher's Edition have also been revised to coordinate with and support the laboratory manual.

Laboratory Exercises

The laboratory exercises are arranged by topic and in some cases build on information and techniques in previous exercises. The laboratory exercises incorporate a combination of directed procedures and investigative processes for both experimental and observational exercises. There are basically three types of lab topics included in the manual.

1. **Directed investigations** in which traditional exercises have been reconstructed to involve students in the process of science. We have reorganized traditional lab topics to include introductory information from which students develop hypotheses and then predict the results of their experiments. They collect their data and summarize it in tables and figures of their own construction. The students must then accept or reject their hypotheses, based on their results. Examples of these directed investigations include Lab Topic 2, Enzymes; Lab Topic 4, Diffusion and Osmosis; and Lab Topic 5, Photosynthesis.
2. **Thematic investigations** in which traditional laboratory exercises have been reconstructed to incorporate unifying themes in biology. These exercises have been the most challenging to write, to teach, and to do. We are convinced that observational exercises can be investigative if we provide the evolutionary themes of biology to assist students in summarizing and synthesizing their observations. Students can use their observations as evidence in support of these major concepts and apply their understanding to new problems. Examples of these laboratories (and their underlying concepts) include Lab Topic 3, Microscopes and Cells (Unity and Diversity of Life); Lab Topics 14 and 15, Plant Diversity (Adaptation to the Land Environment); and Lab Topics 20 to 22, Vertebrate Anatomy (Form and Function).
3. **Open-ended investigations** in which students generate their own hypotheses and design their own experiments. These exercises begin with an introduction and a simple experiment that demonstrates procedures. Then students are given suggestions for further investigation and a framework for performing these experiments. Examples of these open investigations include Lab Topic 19, Plant Growth; Lab Topic 25, Ecology II; and Lab Topic 26, Animal Behavior.

Scientific Communication—Writing and Speaking

Scientists must communicate their results in writing and in presentations to research groups and at meetings. Undergraduates need instruction in writing and an opportunity to practice these skills; however, instructors do not have the time to critique hundreds of student research reports for each exercise. Throughout this lab manual, teams of students work together on improving their skills. They are asked to organize and present their results to their peers during the discussion and summary sessions in the laboratory. Students are also required to write as part of each laboratory. They summarize and discuss their results and then apply information to new problems in the questions at the end of the laboratory.

We have also incorporated scientific writing into our lab manual in a stepwise fashion. Students must answer questions and summarize results within the context of the laboratory exercises. For directed investigations, students are required to submit one section of a scientific paper. For example, they submit the Results section for one experiment in Lab Topic 2, and the Discussion section for one experiment in Lab Topic 4. Once students have experience writing each section, they write at least one complete scientific paper for an open-ended investigation, for example, Lab Topics 19 and 26. Instructions for writing a scientific paper are included in Appendix A.

Integration of Other Sciences and Mathematics

Students often view biology as a separate and isolated body of knowledge. We have attempted to integrate biology, chemistry, some physics, and geology whenever possible. We provide opportunities for students to quantify observations, analyze and summarize results in tables and figures, and, ultimately, to use these data to construct arguments in support of their hypotheses.

Special Features

Applying Your Knowledge: As instructors, we want our students to be challenged to think and to develop critical thinking skills. Throughout this manual, students are asked to work logically through problems, critique results, and modify hypotheses. To further emphasize these skills, we have developed a section in each laboratory topic called Applying Your Knowledge, in which students are asked to apply their knowledge to other aspects of biology, to medicine, or to daily life.

Safety considerations: Safety concerns are noted in the text by the use of icons for general safety and for biohazards. Laboratory safety is also addressed in the teaching plans at the end of each lab topic in the Instructor's Edition.

Notes to students: To assure student success, cautionary reminders and notes of special interest are also highlighted in the text.

Appendixes: Information needed in several laboratory topics is included in the appendixes: scientific writing, using the chi-square statistic, and dissection terminology.

Color insert: Color photographs are particularly helpful in the study of cells and organisms. Photos and illustrations in the color insert are cross-referenced to the text.

Others: In a section entitled Investigative Extensions, we suggest topics for additional discussion, library research, and independent investigation.

Instructional Support

Annotated Instructor's Edition: Teaching biology using an investigative approach requires that instructors guide students in posing questions and hypotheses from which they can predict results for their experiments. We have included additional support for the instructor in the form of instructor's annotations in each lab topic. These annotations are intended to guide the instructor in responding to students, not to provide the right answers to every student question. We encourage instructors to become the guide to discovering rather than the repository of correct answers. Features of the Annotated Instructor's Edition include:

- **Margin notes** with simple suggestions, such as accepting hypotheses as long as they are testable, hints for success, and additional explanations appropriate for the instructor.
- **Suggested answers** to student questions.
- **Typical results.**
- **Explanatory figures.**
- **Teaching Plans.**

Teaching plans: The teaching plans are the instructor's guide to organizing and teaching each laboratory, and they reflect our objective to systematically develop more effective ways to engage students in the study of biology. The teaching plans have been particularly useful for instructors initiating investigative approaches to lab programs. Instructors should feel free to modify these plans to meet their specific needs. The teaching plan for each lab topic includes:

- **Detailed objectives,** both for content and for development of skills in problem solving and scientific methodology.
- **A list of activities** that correspond to specific objectives for the laboratory so that instructors can integrate concept objectives with features of the laboratory topic.
- **Suggested order of the lab.**
- **Estimated time requirements** for each portion of the lab.
- **Suggested options for organizing the activities for a 2-hour lab period.**
- **Hints on how to manage groups of students** and involve them in investigations that might otherwise become passive learning experiences.

Preparation Guide: A detailed Preparation Guide accompanies the laboratory manual. It contains materials lists, suggestions for vendors, instructions for preparing solutions and constructing materials, schedules for planning advance preparation, and organization of materials in the lab.

Acknowledgments

The development of our ideas, the realization of those ideas in laboratory exercises, and the preparation of this laboratory manual are the result of the effort of many colleagues over many years. We are especially indebted to all those laboratory educators who have shared their ideas, hints for success, and philosophies of teaching with us, especially our friends in the Association for Biology Laboratory Education (ABLE). We were fortunate to work with a creative, critical, and supportive editorial group at Benjamin Cummings. Our thanks to Don O'Neal, Kim Johnson, Rani Cochran, Vivian McDougal, Lisa Lougee, Judith Chaffin, and Karl Miyajima. Thanks to Rex Wolf for his affable and professional assistance as he guided us and the laboratory manual through the production process. Many colleagues made particularly helpful or critical contributions to our efforts, including Steve Baker, William Brillhart, Joy Budensiek, Katie Dew Floyd, William Murdy, John Pilger, Homer Sharp, Richard Swanson, Theodosia Wade, Margaret Waterman, and David Westmoreland. We are indebted to our teaching assistants, particularly Walter Escobar, Gary Falcon, Mary Rigger, Amanda Starnes, and Gail Westmoreland, whose critical evaluation and insightful suggestions helped shape the exercises. We thank our students who, over the years, have provided the ultimate tests for these exercises and our ideas. Special thanks to Jean Dickey, who served as a consultant on the first edition; to Arri Eisen, the author of the original version of Lab Topic 9, Molecular Biology; and to Walter Escobar, who helped with the revisions of this lab topic. Finally, we thank our reviewers for sharing their words of encouragement and criticism, which were essential to the success of our work. A special word of thanks to Carol Yeager, Charles Mims, Carol Alia, Elizabeth Odum, and Daniel L. Hoffman, who provided extensive comments and suggestions that were incorporated into this edition.

Reviewers for the First Edition

Phyllis Baudoin, *Xavier University of Louisiana*
Carol Bernson, *University of Illinois*
Charles Biggers, *Memphis State University*
Neil Campbell, *University of California, Riverside*
Charles Creutz, *University of Toledo*
Jean DeSaix, *University of North Carolina, Chapel Hill*
Rebecca Diladdo, *Suffolk University*
John Doherty, *Villanova University*
Regina Guiliani, *Saint Peter's College*
John Hare, *Linfield College*
Laurie Henderson, *Sam Houston State University*
Alan Jaworski, *University of Georgia*
Virginia A. Johnson, *Towson State University*
Raymond Lynn, *Utah State University*
Presley Martin, *Drexel University*
Dawn McGill, *Virginia Western Community College*
Greg Paulson, *Washington State University*
Nanci Smith, *University of Texas, San Antonio*
Gerald Summers, *University of Missouri*
Dan Wivagg, *Baylor University*
Roberta Williams, *University of Nevada, Las Vegas*

Reviewers for the Second Edition

Mitch Albers, *Minneapolis Community College*
Carol Alia, *Sarah Lawrence College*
Connie L. Allen, *Edison Community College*
Daniel L. Hoffman, *Bucknell University*
Brian T. Livingston, *University of Missouri, Kansas City*
Jacquiline Shea McLaughlin, *Penn State University, Allentown*
Charles W. Mims, *The University of Georgia*
Michael R. Schaefer *University of Missouri, Kansas City*
Daniel C. Scheirer, *Northeastern University*
Geraldine W. Twitty, *Howard University*
Carol Yeager, *The University of Alabama*

To our families for their unfailing love and support—
Bill, Rob, and Laura
Stefanie and Cindy

About the Authors

Judith Giles Morgan received her M. A. degree from the University of Virginia and her Ph.D. from the University of Texas, Austin. She teaches in the coastal biology program and the introductory biology program at Emory University. She has revised the general biology laboratory curriculum for majors to incorporate an investigative approach and has developed a TA training program for multi-section investigative laboratories. She has long emphasized the importance of writing and computer simulations in the lab.

M. Eloise Brown Carter earned her Ph.D. from Emory University and is currently Associate Professor of Biology at Oxford College of Emory University. With expertise in plant ecology, she has incorporated independent and team research into lecture and laboratory courses in introductory and advanced biology. Dr. Carter also teaches in the Oxford Institute for Environmental Education, a summer program of Oxford College for precollege teachers.

CONTENTS

3 Animal Diversity I 61

4 Animal Diversity II 81

5 Vertebrate Anatomy I: The Skin and Digestive System 105

Population Genetics: Hardy-Weinberg Theorem

Laboratory Objectives

After completing this lab topic, you should be able to:

1. Explain Hardy-Weinberg equilibrium in terms of allelic and genotypic frequencies and relate these to the expression $(p + q)^2 = p^2 + 2pq + q^2 = 1$.
2. Describe the conditions necessary to maintain the Hardy-Weinberg equilibrium.
3. Use the bead model to demonstrate conditions for evolution.
4. Test hypotheses concerning the effects of evolutionary change (migration, mutation, genetic drift, and selection) using a computer model.

Introduction

Charles Darwin's unique contribution to biology was not that he "discovered evolution" but, rather, that he proposed a mechanism for evolutionary change—**natural selection,** the differential survival and reproduction of individuals in a population. In *On the Origin of Species,* published in 1859, Darwin described natural selection and provided abundant and convincing evidence in support of **evolution,** the change in populations over time. Evolution was accepted as a theory with great explanatory power supported by a large and diverse body of evidence. However, at the turn of the century, geneticists and naturalists still disagreed about the role of selection and the importance of small variations in natural populations. How could these variations provide a selective advantage that would result in evolutionary change? It was not until evolution and genetics became reconciled with the advent of population genetics that natural selection became widely accepted.

Ayala (1982) defines evolution as "changes in the genetic constitution of populations." A **population** is defined as a group of organisms of the same species that occur in the same area and interbreed or share a common **gene pool,** all the alleles at all gene loci of all individuals in the population. The population is considered to be the basic unit of evolution. *Populations evolve, not individuals.* Can you explain this statement in terms of the process of natural selection?

In 1908, English mathematician G. H. Hardy and German physician W. Weinberg independently developed models of population genetics that showed that the process of heredity by itself did not affect the genetic structure of a population. The **Hardy-Weinberg theorem** states that the frequency of alleles in the population will remain the same regardless of the starting frequencies. Furthermore, the equilibrium genotypic frequencies will be established after one generation of random mating. This theorem is valid only if certain conditions are met:

1. The population is very large.
2. Matings are random.
3. There are no net changes in the gene pool due to mutation; that is, mutation from *A* to *a* must be equal to mutation from *a* to *A*.
4. There is no migration of individuals into and out of the population.
5. There is no selection; all genotypes are equal in reproductive success.

It is estimated, for example, that before the Industrial Revolution in Great Britain, more than 90% of the peppered moths were light colored, while less than 10% were dark. Under Hardy-Weinberg equilibrium, these proportions would be maintained in each generation for large, random-breeding populations with no change in the mutation rate and migration rate, as long as the environment was relatively stable. The process of heredity would not change the frequency of the two forms of the moth. Later in this laboratory, you will investigate what happened to these moths as the environment changed following the Industrial Revolution.

Basically, the Hardy-Weinberg theorem provides a baseline model in which gene frequencies do not change and evolution does not occur. By testing the fundamental hypothesis of the Hardy-Weinberg theorem, evolutionists have investigated the roles of mutation, migration, population size, nonrandom mating, and natural selection in effecting evolutionary change in natural populations. Although some populations maintain genetic equilibrium, the exceptions are intriguing to scientists.

Use of the Hardy-Weinberg Theorem

The Hardy-Weinberg theorem provides a mathematical formula for calculating the frequencies of alleles and genotypes in populations. If we begin with a population with two alleles at a single gene locus—a dominant allele, *A*, and a recessive allele, *a*—then the frequency of the dominant allele is p, and the frequency of the recessive allele is q. Therefore, $p + q = 1$. If the frequency of one allele, p, is known for a population, the frequency of the other allele, q, can be determined by using the formula $q = 1 - p$.

During sexual reproduction, the frequency of each type of gamete produced is equal to the frequency of the alleles in the population. If the gametes combine at random, then the probability of *AA* in the next generation is p^2, and the probability of *aa* is q^2. The heterozygote can be obtained two ways, with either parent providing a dominant allele, so the probability would be $2pq$. These genotypic frequencies can be obtained by multiplying $p + q$ by $p + q$. The general equation then becomes

$$(p + q)^2 = p^2 + 2pq + q^2 = 1$$

To summarize:

p^2 = frequency of *AA*
$2pq$ = frequency of *Aa*
q^2 = frequency of *aa*