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LABORATORY STUDIES IN anched DIVERSITY

THIRD EDITION

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LABORATORY STUDIES IN ANIMAL DIVERSITY, THIRD EDITION

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COVER PHOTO: Sally Lightfoot crabs (Grapsus grapsus), vivid splashes of color on a rugged shoreline of the Galápagos Islands, share a lava rock with three marine iguanas (Amblyrhynchus cristatus). Unlike any other lizard in the world, the unique Galápagos marine iguanas are totally dependent on the sea for their living, diving for their diet of marine algae. Marine iguanas, although described as ugly by some visitors, appear starkly beautiful to others in this exotic setting. Around the iguanas the nimble Sally Lightfoot crabs scamper over the rocks with surprising agility, while feeding principally on algae. It was here in Galápagos that the young English naturalist Charles Darwin observed the strange animals and plants that later contributed to his theory of evolution by natural selection.

The credits section for this book begins on page 266 and is considered an extension of the copyright page.

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

aboratory Studies in Animal Diversity offers students handson experience in learning about the diversity of life. It provides students the opportunity to become acquainted with the principal groups of animals and to recognize the unique anatomical features that characterize each group as well as the patterns that link animal groups to each other. Although this manual was written to accompany a particular textbook, Animal Diversity, it can easily be adapted to use with any other introductory zoology text and with a variety of course plans. Every effort has been made to provide clear instructions and enough background material to create interest and an understanding of the subject matter. Many illustrations complement the written word.

New to the Third Edition

· Project exercises are placed with certain chapters in units entitled "Experimenting in Zoology." A new project exercise uses molecular techniques to explore questions that are important to our understanding of zoology and evolution. Some of these exercises can be completed within a single laboratory period; others are followed for a longer period. In all project exercises the student follows experimental procedures, records and analyzes quantitative data, and draws conclusions from the results. Many instructors will want their

- students to gain additional experience by writing a laboratory report in which the student states the objectives, methods followed, results obtained, and conclusions that can be drawn from the results. The Experimenting in Zoology exercises are: Regeneration in Planaria (Exercise 7); Behavior of the medicinal leech, Hirudo medicinalis (Exercise 10): The Phototactic behavior of Daphnia (Exercise 12); Aggression in paradise fish, Macropodus opercularis (Exercise 16); Analysis of the multiple hemoglobin system in Carassius auratus, the common goldfish (Exercise 16).
- We have made the exercises more interactive with questions placed throughout the text, and with spaces provided for students to write down their responses and observations. This "active learning" approach involves students in the exercise and encourages them to think about the information as they read. Some questions may require students to consult their textbook for the answers. In some exercises we have placed questions in the figure legends, to be answered in the spaces provided when the student consults the figure. Examples of this interactive approach are found in Exercises 15 through 20.
- In several exercises we rewrote or expanded the "Where Found" sections to provide more interesting information

- on the biology of the organism or group. These enhanced introductions are found 6B (*Aurelia*), 7B (*Clonorchis*), 8A (*Ascaris* and pinworms), 9A (bivalves), 11A (horseshoe crab), 14 (sea stars, brittle stars, sea urchins, sea cucumbers), and 15A (tunicates).
- A complete new set of fullcolor illustrations drawn from frog specimens was prepared for Exercise 17 on the frog. Many existing illustrations throughout the manual were converted to full color.

Supplements

- · New to this edition is a supplement to Exercise 2, "Taxonomic Identification of Organisms to Species," which is found on this manual's website. This interactive exercise, prepared by Louise Wootton of Georgian Court College, leads the student through the construction of a dichotomous key, an exercise in phenetic analysis, and the construction of a cladogram. This interactive cladistics exercise may be found at www.mhhe.com/zoology (click on this book's cover).
- McGraw-Hill's *Digital Zoology* CD-ROM and Student
 Workbook by Jon Houseman is an interactive guide to the specimens and materials that you study in your laboratory and lecture sessions. This easy-to-use CD-ROM provides laboratory modules containing

illustrations, photographs, annotations of the major structures of organisms, interactive quizzes, and video clips. Students will also find interactive cladograms within lab modules, along with links to interactive synapomorphies of the various animal groups. Key terms are linked to an interactive glossary. The accompanying student workbook and website provide additional study tips, exercises, and phyla characteristics. Digital Zoology is the perfect complement to a zoology lab manual to ensure the best possible results in your zoology lab.

There are many aids for the student in this laboratory manual. Throughout the exercises, working instructions are clearly set off from the descriptive material. Classifications, where appropriate, are included with the text, together with a "pie" diagram showing the relative sizes of the classes in a phylum. Function is explained along with anatomy. Topic headings help the student mentally organize the material. Met-

ric tables and definitions are placed on the inside front and back covers for convenient use. Much of the artwork was designed to assist the student with difficult dissections.

Acknowledgments

We are indebted to the reviewers whose many suggestions were essential in guiding our revision for this edition.

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different approaches to taxonomic classification: *Taxonomic Identification of Organisms to Species*, found on our web site at www.mhhe.com/zoology.

The authors express their appreciation to the editors and support staff at McGraw-Hill Higher Education who guided this revision and were a pleasure to work with. Special thanks are due Marge Kemp, Publisher, and Donna Nemmers, Senior Developmental Editor, who guided this manual throughout its development. Susan Brusch, Senior Project Manager, guided the project expertly through production. Although we make every effort to bring to you an error-free manual, errors of many kinds inevitably find their way into a book of this scope and complexity. We will be grateful to readers who have comments or suggestions concerning content to send their remarks to Donna Nemmers, Senior Developmental Editor, McGraw-Hill Publishers, 2460 Kerper Boulevard, Dubuque, IA 52001. Donna may also be contacted by e-mail: donna nemmers@mcgraw-hill.com, or through this textbook's website at www.mhhe.com/zoology.

LABORATORY SAFETY PROCEDURES

- Keep your work area uncluttered. Unnecessary books, backpacks, purses, etc. should be placed somewhere other than on your desktop.
- Avoid contact with embalming fluids. Wear rubber or disposable plastic gloves when
- working with preserved specimens.
- Wear eyeglasses or safety glasses to protect your eyes from splattered embalming fluid.
- 4. Keep your hands away from mouth and face while in the
- laboratory. Moisten labels with tap water, not your tongue.
- Sponge down your work area and wash all laboratory instruments at the end of the period.
- Wash your hands with soap and water at the end of the laboratory period.

GENERAL INSTRUCTIONS

Equipment

Each student will need to supply this equipment:

Laboratory manual and textbook
Dissecting kit containing scissors, forceps, scalpel,
dissecting needles, pipette (medicine dropper),
probe, and ruler, graduated in millimeters
Drawing pencils, 3H or 4H
Eraser, preferably kneaded rubber
Colored pencils—red, yellow, blue, and green
Box of cleansing tissues
Loose-leaf notebook for notes and corrected drawings

The department will furnish each student with all other supplies and equipment needed during the course.

Aim and Purpose of Laboratory Work

The zoology laboratory will provide your "hands-on" experience in zoology. It is the place where you will see, touch, hear, smell—but perhaps not taste—living organisms. You will become acquainted with the major animal groups, make dissections of preserved or anesthetized specimens to study how animals are constructed, ask questions about how animals and their parts function, and gain an appreciation of some of the

architectural themes and adaptations that emphasize the unity of life.

General Instructions for Laboratory Work

Prepare for the Laboratory. Before coming to the laboratory, read the entire exercise to familiarize yourself with the subject matter and procedures. Read also the appropriate sections in your textbook. Good preparation can make the difference between a frustrating afternoon of confusion and mistakes and an experience that is pleasant, meaningful, and interesting.

Follow the Manual Instructions Carefully. It is your guide to exploring and understanding the organisms or functions you are investigating. Its instructions have been written with care and with you in mind, to help you do the work (1) in logical sequence, (2) with economy of time, and (3) to arouse a questioning attitude that will stimulate interest and curiosity.

Use Particular Care in Making Animal Dissections.

A glossary of directional terms used in dissections will be found inside the back cover. The object in dissections is to separate or expose parts or organs so as to see their relationships. Working blindly without the manual instructions may result in the destruction of parts before

you have had an opportunity to identify them. **Learn the functions** of all the organs you dissect.

Record Your Observations. Keep a personal record in a notebook of everything that is pertinent, including the laboratory instructor's preliminary instruction and all experimental observations. Do not record data on scraps of paper with the intention of recopying later; record directly into a notebook. The notes are for your own use in preparing the laboratory report later.

Take Care of Equipment. Glassware and other apparatus should be washed and dried after use. Metal instruments in particular should be thoroughly dried to prevent rust or corrosion. Put away all materials and equipment in their proper places at the end of the period.

Tips on Making Drawings

You need not be an artist to make laboratory drawings. You do, however, need to be **observant.** Study your specimen carefully. Your simple line drawing is a record of your observations.

Before you draw, locate on the specimen all the structures or parts indicated in the manual instructions. Study their relationships to each other. Measure the specimen. Decide where the drawing should be placed and how much it must be enlarged or reduced to fit the page (read further for estimation of magnification). Leave ample space for labels.

When ready to draw, you may want first to rule in faint lines to represent the main axes, and then sketch the general outlines lightly. When you have the outlines you want, draw them in with firm dark lines, erasing unnecessary sketch lines. Then fill in details. Do not make overlapping, fuzzy, indistinct, or unnecessary lines. Indicate differences in texture and color by stippling. Stipple deliberately, holding the pencil vertically and

making a neat round dot each time you touch the paper. Placing the dots close together or farther apart will give a variety of shading. Avoid line shading unless you are very skilled. Use color only when asked for it in the directions.

Label the Drawing Completely. Print labels neatly in lowercase letters and align them vertically and horizontally. Plan the labels so that there will be no crossed label lines. If there are to be many labels, center the drawing and label on both sides.

Indicate the magnification in size beneath the drawing, for instance, " \times 3" if the drawing is three times the length and width of the specimen. In the case of objects viewed through a microscope, indicate also the magnification at which you viewed the subject, for example, $430\times(43\times\text{ objective}$ used with a $10\times\text{ ocular}$).

Estimating the Magnification of a Drawing

A simple method for determining the magnification of a drawing is to find the ratio between the size of the drawing and the actual size of the object you have drawn. The magnification of the drawing can be expressed in this formula:

$$\times = \frac{\text{Size of drawing}}{\text{Size of object}}$$

If your drawing of the specimen is 12 cm (120 mm) long, and you have estimated the specimen to be 0.8 mm long, then \times = 120 \div 0.8, or 150. The drawing, then, is \times 150, or 150 times the length of the object drawn.

This same formula will hold good whether the drawing is an enlargement or a reduction. If, for example, the specimen is 480 mm long, and the drawing is 120 mm, then $\times = 120/480$, or 1/4.

STATEMENT ON THE USE OF LIVING AND PRESERVED ANIMALS IN THE ZOOLOGY LABORATORY

Congress has probably received more mail on the topic of animal research in universities and business firms than on any other subject. Do humans have the right to experiment on other living creatures to support their own medical, pharmaceutical, and commercial needs? A few years ago, Congress passed a series of amendments to the Federal Animal Welfare Act, a body of laws covering animal care in laboratories and other facilities. These amendments have become known as the three R's: reduction in the number of animals needed for research: refinement of techniques that might cause stress or suffering; and replacement of live animals with simulations or cell cultures whenever possible. As a result, the total number of animals used each year in research and in commercial product testing has declined steadily as scientists and businesses have become more concerned and more accountable. The animal rights movement, largely comprising vocal antivivisectionists, has helped to create an awareness of the needs of laboratory research animals and has stretched the resources and creativity of the researchers to discover cheaper and more humane alternatives to animal experimentation.

However, computers and cell cultures—the alternatives—can only simulate the effects on organismal systems of, for instance, drugs, when the principles are well acknowledged. When the principles are themselves being scrutinized and tested, computer modeling is insufficient. Nor can a movie or computer simulation match the visual and tactile comprehension of anatomical relationships provided by direct dissection of preserved or anesthetized animals. Medical and veterinarian progress depends on animal research. Every drug and every vaccine that you and your family have ever taken has first been tested on an animal. Animal research has wiped out smallpox and polio; has pro-

vided immunization against diseases previously common and often deadly, such as diphtheria, mumps, and rubella; has helped create treatments for cancer, diabetes, heart disease, and manic depression; and has been used in the development of surgical procedures such as heart surgery, blood transfusions, and cataract removal.

Animal research has also benefited other animals for veterinary cures. The vaccine for feline leukemia that could threaten the life of your cat, as well as the parvo vaccine given to your puppy, were first introduced to other cats and dogs. Many other vaccinations for serious animal diseases were developed through animal research; for example, rabies, distemper, anthrax, hepatitis, and tetanus.

The animal models used by the artist for the illustrations in the exercises of this laboratory manual, and the animals you will dissect in this laboratory course, were prepared for educational use following strict humane procedures. No endangered species have been used. No living vertebrate organisms will be harmed in this laboratory setting. Invertebrate animals that are to be dissected while alive are anesthetized before the procedure. The experiments selected are unoffensive, are respectful of the integrity of the animal's evolutionary contributions, and often require only close observation. The experiments closely follow the tenets of the scientific method, which cannot dictate ethical decisions but can provide the structure for common sense. Do not be wasteful. Share the animals with the other students as often as possible. At the same time, you are encouraged to observe the live animal in its natural setting and its relationships to other species, for only in this manner will you gain a full appreciation of the unique evolutionary position and special structure and systems of each animal.

BRIEF CONTENTS

PART ONE

ACTIVITY OF LIFE

EXERCISE 1

Ecological Relationships of Animals 2

EXERCISE 2

Introduction to Animal Classification 7

PART TWO

THE DIVERSITY
OF ANIMAL LIFE

EXERCISE 3

The Microscope 16

EXERCISE 4

Protozoan Groups 24

EXERCISE 5

The Sponges 49

EXERCISE 6

The Radiate Animals 57

EXERCISE 7

The Acoelomate Animals 72

EXERCISE 8

The Pseudocoelomate Animals 88

EXERCISE 9

The Molluscs 98

EXERCISE 10

The Annelids 112

EXERCISE 11

The Chelicerate Arthropods 127

EXERCISE 12

The Crustacean Arthropods 134

EXERCISE 13

The Uniramia Arthropods: Myriapods and Insects 146

EXERCISE 14

The Echinoderms 165

EXERCISE 15

Phylum Chordata: A Deuterostome Group 180

EXERCISE 16

The Fishes—Lampreys, Sharks, and Bony Fishes 188

EXERCISE 17

Class Amphibia 207

EXERCISE 18

Class Reptilia 224

EXERCISE 19

Class Aves 229

EXERCISE 20

Class Mammalia 232

CONTENTS

preface vi

PART ONE

ACTIVITY OF LIFE

EXERCISE 1

Ecological Relationships of Animals 2

Exercise 1: A study of population growth, with application of the scientific method 2

EXERCISE 2

Introduction to Animal Classification 7

Use of a taxonomic key for animal identification 7
Key to the major animal taxa 9

PART TWO

THE DIVERSITY OF ANIMAL LIFE

EXERCISE 3

The Microscope 16

Exercise 3A: Compound light microscope 16 Exercise 3B: Stereoscopic dissecting microscope 22

EXERCISE 4

Protozoan Groups 24

Classification 24
Exercise 4A: Amebas 25
Exercise 4B: Phylum Chlorophyta—
Volvox, Phylum Euglenozoa—
Euglena, and Trypanosoma 33

Exercise 4C: Phylum Apicomplexa, Class Gregarinea, Class Coccidea— Gregarina and Plasmodium 41 Exercise 4D: Phylum Ciliophora— Paramecium and other ciliates 43

EXERCISE 5

The Sponges 49

Classification: Phylum Porifera 49 Exercise 5: Class Calcarea—Sycon 49

EXERCISE 6

The Radiate Animals 57

Classification: Phylum Cnidaria 57
Exercise 6A: Class Hydrozoa—*Hydra*, *Obelia*, and *Gonionemus* 58
Exercise 6B: Class Scyphozoa— *Aurelia*, a "true" jellyfish 71
Exercise 6C: Class Anthozoa— *Metridium*, a sea anemone, and *Astrangia*, a stony coral 71

EXERCISE 7

The Acoelomate Animals 72

The acoelomate phyla 72
Classification: Phylum
Platyhelminthes 72
Exercise 7A: Class Turbellaria—
the planarians 73
Exercise 7B: Class Trematoda—
the digenetic flukes 78
Exercise 7C: Class Cestoda—
the tapeworms 81
Experimenting in Zoology: Planaria regeneration experiment 84

EXERCISE 8

The Pseudocoelomate Animals 88

Exercise 8A: Phylum Nematoda— Ascaris and others 88 Exercise 8B: A brief look at some other pseudocoelomates 94

EXERCISE 9

The Molluscs 98

Classification: Phylum Mollusca 98
Exercise 9A: Class Bivalvia

(= Pelecypoda)—the freshwater clam 99
Exercise 9B: Class Gastropoda—the pulmonate land snail 107
Exercise 9C: Class Cephalopoda—Loligo, the squid 109

EXERCISE 10

The Annelids 112

Classification: Phylum Annelida 112
Exercise 10A: Class Polychaeta—
the clamworm 113
Exercise 10B: Class Oligochaeta—
the earthworms 115
Exercise 10C: Class Hirudinea—
the leech 123
Experimenting in Zoology: Behavior of the medicinal leech, *Hirudo medicinalis* 125

EXERCISE 11

The Chelicerate Arthropods 127

Classification: Phylum Arthropods 127 Exercise 11: The chelicerate arthropods—the horseshoe crab and garden spider 128

EXERCISE 12

The Crustacean Arthropods 134

Exercise 12: Subphylum Crustacea the crayfish (or lobster) and other crustaceans 134 Experimenting in Zoology: The Phototactic Behavior of Daphnia 144

EXERCISE 13

The Uniramia Arthropods: Myriapods and Insects 146

Exercise 13A: The myriapods—
centipedes and millipedes 146
Exercise 13B: The insects—the
grasshopper and the honey bee 148
Exercise 13C: The insects—the house
cricket 155
Exercise 13D: Collection and
classification of insects 158
Key to the principal orders

EXERCISE 14

of insects 159

The Echinoderms 165

Classification: Phylum
Echinodermata 165
Exercise 14A: Class Asteroidea—the sea stars 166
Exercise 14B: Class Ophiuroidea—the brittle stars 171
Exercise 14C: Class Echinoidea—the sea urchin 173
Exercise 14D: Class Holothuroidea—the sea cucumber 176

EXERCISE 15

Phylum Chordata: A Deuterostome Group 180

What Defines a Chordate? 180 Classification: Phylum Chordata 180 Exercise 15A: Subphylum Urochordata— *Ciona*, an ascidian 181 Exercise 15B: Subphylum Cephalochordata—amphioxus 184

EXERCISE 16

The Fishes—Lampreys, Sharks, and Bony Fishes 188

Exercise 16A: Class Cephalaspidomorphi

(= Petromyzontes)—the lampreys

 (ammocoete larva and adult) 188

 Exercise 16B: Class Chondrichthyes—
 the cartilaginous fishes 192
 Exercise 16C: Class Osteichthyes—
 the bony fishes 198
 Experimenting in Zoology: Aggression in Paradise Fish, *Macropodus opercularis* 202
 Experimenting in Zoology: Analysis of the multiple hemoglobin system in *Carassius auratus*, the common goldfish 204

EXERCISE 17

Class Amphibia 207

Exercise 17A: Behavior and adaptations 207

Exercise 17B: The skeleton 210

Exercise 17C: The skeletal muscles 211

Exercise 17D: The digestive, respiratory, and urogenital systems 216

Exercise 17E: The circulatory system 219

EXERCISE 18

Class Reptilia 224

Exercise 18: The painted turtle 224

EXERCISE 19

Class Aves 229

Exercise 19: The pigeon 229

EXERCISE 20

Class Mammalia 232

Exercise 20A: The skeleton 233
Exercise 20B: The muscular system 237
Exercise 20C: The digestive system 245
Exercise 20D: The urogenital system 251
Exercise 20E: The circulatory system 255

Appendix: Sources of Living Material and Prepared Microslides 263

Credits 265 Index 266

PART ONE

Activity of Life



Ecological Relationships of Animals

Exercise 1*

A Study of Population Growth, with Application of the Scientific Method

ne goal of this course is to introduce students to the methods scientists use to gather knowledge. In this project you will apply the "scientific method" to the problem of determining what regulates animal populations.

The Scientific Method

People, scientists included, often acquire knowledge by applying a two-stage process, **conjecture** followed by **confirmation**—although few of us think of it this way. Conjecture consists of generating a general explanation of how the world is constructed, and is often based on general observations. Confirmation tests the validity of this conjecture. We all use such a method in our every-day lives; for example, we speculate on the quality of a future music concert based on our observations of recorded music, then subsequently confirm, reject, or modify that speculation based on our experiences while attending the concert.

Scientists employ a similar method, although with a lot more rigor, in attempting to discover new facts. An idealized form of the method used by scientists is known as the **scientific method**, and is broken down into four steps.

1. **Observation.** Observations may be based on direct examination of a system, or based on something we read, or even be the result of discussions with others about a process or concept. Such observations frequently stimulate questions about why species exhibit certain traits, why internal

EXERCISE 1

A Study of Population Growth, with Application of the Scientific method

The scientific method
Application of the scientific method to the study of populations
Experimental Procedures

organs interact the way they do, or what the advantages of a particular body shape might be, or the role of certain genes in a particular process.

- 2. **Hypothesis formulation.** Formulating an hypothesis is like saying "Let's suppose . . ." Its objective is to explain, by induction, the observation. Typically several alternative hypotheses are formulated, each a possible and reasonable explanation for the observation. Weeding out these hypotheses is the role of the third and fourth steps.
- 3. **Prediction.** Predictions are deduced from hypotheses, and often will be based on some knowledge of the organisms or concepts being studied. They follow the form of "If hypothesis A is true, then I predict the following pattern." Predictions must be generated such that one set of hypotheses predicts one result, but alternative hypotheses predict another result. A prediction is worthless if it can be made for all of the hypotheses under consideration. Testing whether a prediction holds true is the way in which one or more hypotheses can be rejected, thus reducing the number of hypotheses still under consideration.
- 4. **Testing of predictions.** The final step is to design a test so that a prediction, if incorrect, can confidently be rejected. Tests are accomplished using observations or experimental manipulations. The confidence with which we can make such a rejection is quantified by the use of inferential statistics, which we shall not discuss. However, note that our confidence in a result increases with the use of (1) treatments known as controls, in which all variables except for the one manipulated

^{*} Exercise written by James C. Munger, Department of Biology, Boise State University, Boise, Idaho; and Richard S. Inouye, Department of Biological Sciences, Idaho State University, Pocatello, Idaho.

are held the same, and (2) several replicates of each treatment, to give assurance that the observed result was due to conditions of the treatment and not simply due to variation among individuals. With skill (and perhaps some luck) all but one hypothesis will have been rejected. The unrejected hypothesis, however, is not proven to be true. Hypotheses can never be fully accepted; they can only be rejected (what lonely lives they must lead).

The next step is to repeat this process. With the results in hand from the tests of previous predictions, it is possible to fine-tune the hypothesis, then set about testing the new one. Here is an example of this repetitive process.

Initial observation: Generalization

Roommate breaks dish Roommate breaks everything

(hypothesis): Prediction: Test/observation

Will wreck borrowed car

New generalization/ hypothesis:

Didn't wreck car Only breaks dishes

Prediction:

Won't break borrowed camera

Does break camera Test:

New generalization/ Roommate breaks small objects

hypothesis:

And so on . . .

The unrejected hypothesis at each stage is our best guess as to how the world works. If a hypothesis withstands repeated tests and has great explanatory value, it may be elevated to the level of a scientific theory. Note that a scientific theory is not an untested hypothesis, but is instead as close as scientists will come to calling a hypothesis proven. The theory of evolution is an example.

Whether a hypothesis is accepted or rejected, the observations made while testing the hypothesis frequently lead to more hypotheses, more predictions, more tests, more observations, and so on. It is often said scientific investigation raises more questions than it answers; it is this aspect of science that, to many people, is most exciting.

Application of the Scientific Method to the Study of Populations

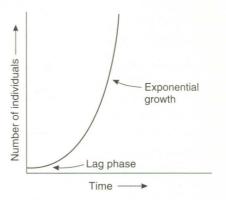
If you were a scientist, you would make your own observations, formulate your own hypotheses, derive your own predictions, and perform your own tests of those predictions. In a classroom situation, however, there are certain constraints, as you will see. We will apply the scientific method to the study of population growth.

Step 1—Observation

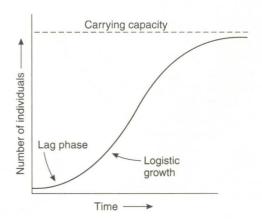
In 1798 a British economist, Thomas Malthus, published an essay in which he observed that populations do not grow indefinitely, but often tend to stay at relatively stable numbers. We can make similar observations: if we look around us, we do not see populations of organisms forever growing—instead they are relatively stable.

Step 2—Hypothesis Formulation

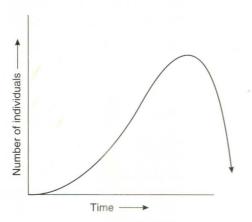
Why might this occur? Again we can look to Malthus, this time for one possible explanation (a hypothesis) as to why populations do not grow indefinitely. Malthus reasoned that if a population had unlimited resources, it would grow exponentially to infinite size. However, since no population grows to infinite size, resources must be limiting. He therefore hypothesized that a limitation of resources is the cause of limited population growth. We can depict these two possible conditions graphically. If resources are unlimited, the population should grow exponentially.



If resources are limited but in relatively constant supply, the population will experience logistic growth, rapidly growing at first and then eventually reaching an equilibrium, known as the carrying capacity. Logistic growth occurs in situations where resources are renewed (such as plankton reaching a barnacle), or because they are not consumed (such as nest sites, which can be used again and again).



A third type of population growth occurs when resources are consumed but not renewed. This sort of population growth would occur in a test tube bacterial culture in which the population increases until all the nutrients are consumed, then crashes.



Now we can erect our first hypothesis regarding what limits population growth:

H₁: Limited food limits population size.

However, there are a number of factors that could limit population size, such as predation, climate, disease, limited nest sites, and intraspecific strife, including cannibalism. Can you think of others? We can cast these factors as this list of hypotheses:

H₁: Limited food regulates population size.

H₂: Predation regulates population size.

H₃: Disease regulates population size.

H₄: Limited nest sites regulate population size.

H₅: Intraspecific strife regulates population size.

Note that this list is not exhaustive. Also note that in this case the hypotheses are not mutually exclusive, that is, more than one may be true in a particular population; this is especially true if we consider a wide range of species.

Step 3—Prediction Derivation

What predictions logically follow from these hypotheses? The best predictions are those that (1) allow the investigator to decide between two or more competing hypotheses, and (2) are straightforward to test.

For the purposes of discussion, we will focus on our hypotheses as they apply to the setup to be used in this exercise: a population of flour beetles eating flour, living in flour, laying eggs in flour, all contained in a small jar. In this system, we can discount the possibility of one hypothesis, predation, because we will not allow predators into the system.

A prediction that follows from H₁ is that if we limit food availability, we expect a smaller population to result (less flour, fewer beetles; more flour, more beetles). But do the other hypotheses make different predictions.

tions? If nest sites are limited, then adding more food will increase the availability of nest sites, giving the same prediction: more flour, more beetles. If intraspecific strife (e.g., cannibalism) is limiting, what will adding more flour do? It will give the beetles more room to hide, meaning fewer encounters, and more to eat, meaning less hunger; both mean less cannibalism. Again, more flour, more beetles. And if disease is limiting, more flour means fewer encounters among beetles and less disease transmission. Again, more flour, more beetles.

However, what if we were to vary the amount of food available while holding constant the total volume available for the beetles to roam? If H_1 were true, more food would lead to more beetles. But if H_3 or H_4 or H_5 (but not H_1) were true, then more food would have no effect on beetle numbers, so long as the total volume was constant. So this prediction allows us to distinguish among competing hypotheses.

Step 4—Test of Predictions

Next, we need to create an experiment that will allow us to vary food without varying volume. One way to accomplish this is to put various amounts of food into jars, then add an inert filler (such as vermiculite) to maintain constant volume.

Step 5—Repeat the Process

When you look at the results from your experiment, you can consider what modifications to make to your hypotheses and what new predictions you could use to test your new hypothesis.

Experimental Procedures

We will start cultures of *Tribolium confusum* (a flour beetle) with the same initial population size, but varying amounts of food and varying amounts of space. Near the end of the term, we will count the number of larvae, pupae, and adults in each container and compare age distribution and resulting densities.

T. confusum develops from egg to adult in about 28 days as follows: egg stage 5 days, larval stages 17 days, pupal stage 6 days (Figure 1-1). The average life span of adult beetles is roughly 200 days.

Work in groups of four students each. Each group should prepare:

- A. One low-density, high-food jar, containing 50 g of resource (95% whole wheat flour; 5% brewer's yeast)
- B. One medium-density, medium-food jar, containing 10 g of resource
- C. One high-density jar, low-food jar, containing 3 g of resource
- D. One low-density, medium-food jar, containing 10 g of resource with filler (such as vermiculite

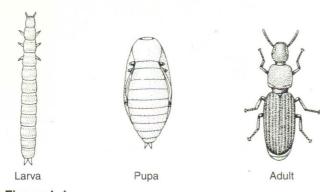


Figure 1-1 Appearance of Tribolium confusum at larval, pupal, and adult stages.

- screened to standardize the size) added to bring the total volume to that of jar A.
- E. One low-density, low-food jar, containing 3 g of resource with filler added to bring the total volume to that of jar A.

Next, sort through the culture that has been provided to you. Be careful not to damage the animals. Use a fine brush or small spatula to push them around. Each group should sort and count 250 healthy looking adults, and put 50 into each of the half-pint Mason canning jars. We will assume that within each group of 50 there are plenty of both males and females. Cover jar with the precut wire mesh (window screen), then a piece of paper towel, then screw on the top ring. Place the jars in a cabinet with a light (for warmth; about 30° C) and an open container of water (for humidity).

You and your lab instructor may decide to try other variations on this experimental setup. For example, you might try to see if temperature is important. How would you do this?

Why don't we use just one jar at each density for the whole class? If there were only one jar, it would be difficult to say, because of biological variation and experimental error, that the results from that jar are representative of any jars the class might start with the same density. For example, what if only the jar your class had used for its medium-density culture had previously contained a toxic chemical? That could invalidate your results. However, if each group of four students prepares one jar at each density, then a class of 24 students would have a total of six jars at the same density (known as replicates). If all six give approximately the same result, then we can have substantial confidence that those jars are representative of all jars at that density.

During the term, make occasional observations on beetle behavior, and record those observations in your notebook. For example, do the beetles live on top of the flour or within it? Do the beetles congregate or space themselves out?



At the end of the experiment, sort through each jar and count live adults, dead adults, pupae, and large (final instar) larvae. For the purposes of this experiment we will count neither the eggs nor the early instar larvae. Compile data for the whole class and calculate averages for each age class for each jar. Construct an age distribution for each treatment.

This is a time to try your hand at "playing with the data." Look for interesting patterns such as correlations between variables. Try to think of patterns you would expect to occur if the hypothesis is correct.

Questions

- 1. Comparison between which jars will test what hypotheses? For example, what hypothesis can be tested by comparing jars A, D, and E? What would you conclude if they had the same densities of beetles?
- 2. What other hypotheses can you formulate to explain the observation that populations do not grow indefinitely? What predictions can you derive from these hypotheses and what tests could you perform?
- 3. Two life stages (eggs and pupae) are not mobile, and so are particularly vulnerable to cannibalism. Do you see evidence of this when comparing jars, for example, jar A with jar C?
- 4. An attitude commonly encountered in undergraduate science labs is that if you did not get the result the instructor expected, then the experiment "did not work." What do you think of this view?
- 5. Given the results thus far, what would be your next step in this study, if your goal is to understand what determines the abundance of flour beetles?

Written Report



For your report prepare the suggested graphs and write a summary statement of the experimental approach and an explanation of the results. Answer any of the preceding questions that your instructor may request.

Alternatively, your instructor may want you to follow the format of a scientific paper for your report: introduction, materials and methods, results, discussion, and literature cited. These questions are designed to bring up possible topics that might be included in the report. Be sure to think about your results and look at your data in original ways before writing the report.

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