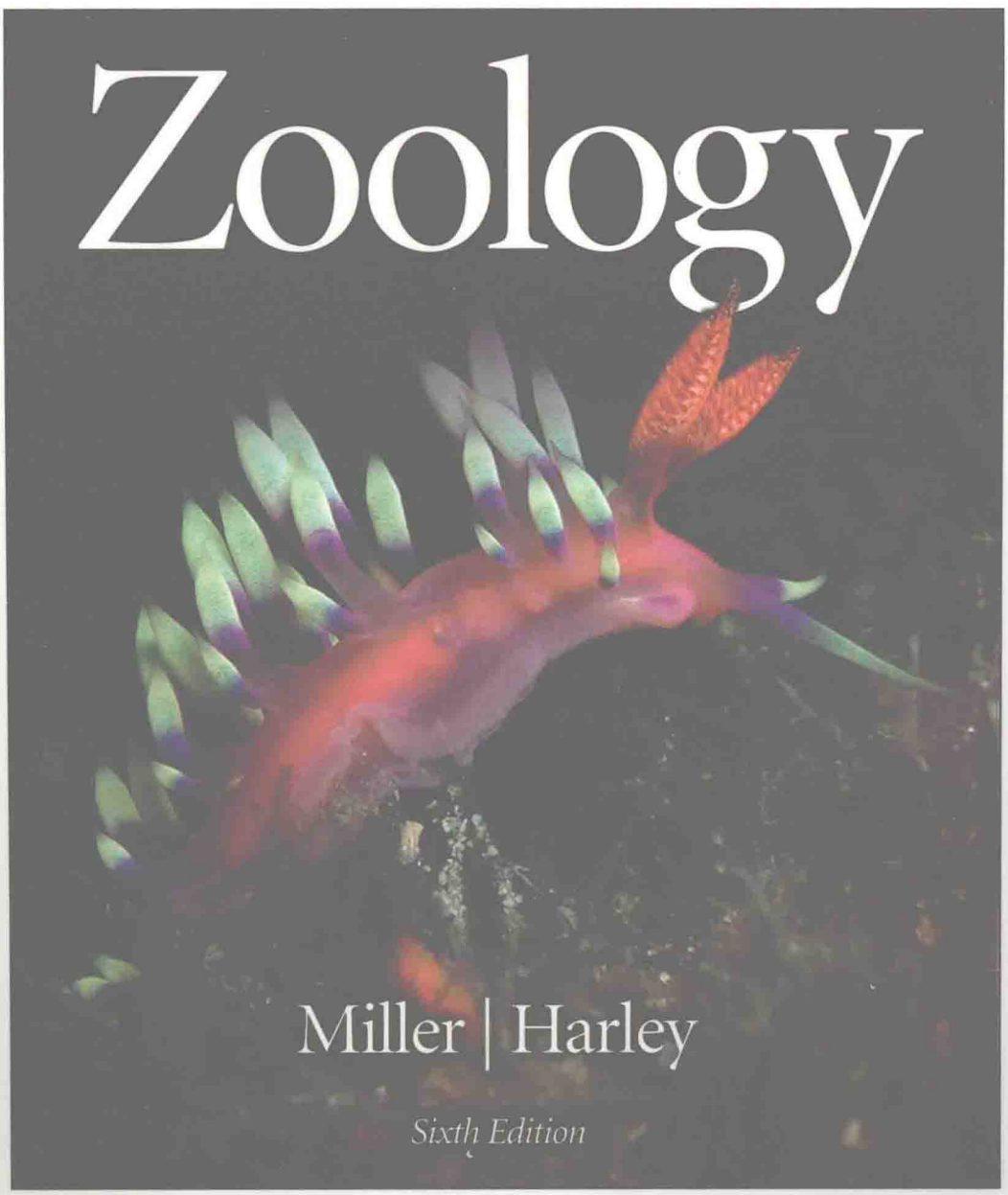
INTERNATIONAL EDITION

Zoology



Miller | Harley

Sixth Edition

McGRAW-HILL

Zoology

Sixth Edition

Stephen A. Miller
College of the Ozarks

John P. Harley
Eastern Kentucky University

Higher Education

Boston Burr Ridge, IL Dubuque, IA Madison, WI New York San Francisco St. Louis
Bangkok Bogotá Caracas Kuala Lumpur Lisbon London Madrid Mexico City
Milan Montreal New Delhi Santiago Seoul Singapore Sydney Taipei Toronto

The McGraw-Hill Companies

Mc Graw Hill **Higher Education**

ZOOLOGY, SIXTH EDITION

Published by McGraw-Hill, a business unit of The McGraw-Hill Companies, Inc., 1221 Avenue of the Americas, New York, NY 10020.

This book is printed on recycled, acid-free paper containing 10% postconsumer waste.

1 2 3 4 5 6 7 8 9 0 VNH/VNH 0 9 8 7 6 5 4

ISBN 0–07–252836–2

Publishers: *Martin J. Lange/Colin H. Wheatley*
Developmental editor: *Fran Schreiber*
Marketing manager: *Heather K. Wagner*
Senior project manager: *Jayne Klein*
Production supervisor: *Sherry L. Kane*
Senior media project manager: *Tammy Juran*
Senior media technology producer: *John J. Theobald*
Senior designer: *David W. Hash*
Cover designer: *Rokusek Design*
Cover photo: *©2003 Nishina Masayoshi/Jun Imamoto* www.umiushi.info
Senior photo research coordinator: *Lori Hancock*
Photo research: *LouAnn K. Wilson*
Compositor: *The GTS Companies/Los Angeles, CA Campus*
Typeface: *10/12 Goudy*
Printer: *Von Hoffmann Corporation*

The credits section for this book begins on page 531 and is considered an extension of the copyright page.

Library of Congress Cataloging-in-Publication Data

Miller, Stephen A.
Zoology / Stephen A. Miller, John P. Harley. — 6th ed.
p. cm.
Includes bibliographical references (p.) and index.
ISBN 0–07–252836–2 (hard copy : alk. paper)
1. Zoology. I. Harley, John P. II. Title.

QL47.2M55 2005
590—dc22 2003024621
CIP

www.mhhe.com

PREFACE

As authors, we are honored to play a key role in the instruction of future generations of zoologists, ecologists, wildlife managers, and other life scientists. We undertook the revision for the sixth edition with this privilege, and the responsibility for content integrity, in mind.

The preparation of the sixth edition of *Zoology* involved careful evaluation of the previous editions and the features that contributed to the understanding of zoology as an exciting and dynamic scientific field. Our goal in preparing the sixth edition of *Zoology*, as in previous editions, was to prepare an introductory general zoology textbook that we believe is manageable in size and adaptable to a variety of course formats. We have retained the friendly, informative writing style that has attracted instructors and students to previous editions.

The shorter format of the fifth edition was well received by users as being less expensive and easily adapted to a one-semester course format. The sixth edition retains that format. The shorter format does mean that some general biological topics were eliminated from the book. These chapters are, however, still available, along with numerous other resources, in an electronic format on the book website and are free to adopters of the book. (Chapters found online only are indicated in the Table of Contents by an asterisk.)

CONTENT AND ORGANIZATION

We have maintained from the inception of this text that evolutionary and ecological perspectives captivate students and are fundamental to understanding the unifying principles of zoology. These perspectives are incorporated into *Zoology* in a number of ways. For example, animal structure and function are considered in the context of the environment, the animal phyla are described in the context of their roles in ecosystems, and most of the "Wildlife Alerts" that first appeared in the fourth edition, and were expanded in the fifth edition, have been retained. These boxed readings depict the plight of selected animal species or broader ecosystem issues relating to preserving various animal species.

We believe that the sixth edition of *Zoology* presents evolution as an exciting and dynamic field of study—a field of study that is vital for understanding all of biology. In addition, the continuing and expanding pseudoscientific attacks on biology make it a necessity that evolutionary concepts be presented clearly and convincingly throughout the biology curricula. We have attempted to do just that. A special font highlights important evolutionary concepts. Animal survey chapters begin with an "Evolutionary Perspective" and end with "Further Phylogenetic Considerations." These sections describe evolutionary relationships within each phylum and evolutionary connections to animals of previous and following chapters. Updated cladograms are used to depict taxonomic relationships. Evolutionary connections and animal adaptations are stressed in the structure and function sections.

To further explain and support evolutionary concepts, this sixth edition has a second set of themed boxed readings (in addition to "Wildlife Alerts") entitled "Evolutionary Insights." These boxes provide detailed examples of principles covered in a chapter and provide insight into how evolutionary biology works. For example, chapter 4 includes a reading on big-cat biogeography that illustrates how a variety of sources of evidence are used to paint a picture of the history of one group of animals. Chapter 5 has a reading on the speciation of Darwin's finches that illustrates how and why speciation occurs. Other readings describe ideas regarding animal origins and the debates that occur among taxonomists who try to sort out evolutionary relationships within animal groups.

Zoology is organized into three parts. Part One covers the common life processes, including cell and tissue structure and function, the genetic basis of evolution, and the evolutionary and ecological principles that unify all life.

Part Two is the survey of protists and animals, emphasizing evolutionary and ecological relationships, aspects of animal organization that unite major animal phyla, and animal adaptations. All of the chapters in Part Two have been updated. The presentation of taxonomic principles in chapter 7, and the taxonomic relationships in chapters 8 through 22, have been carefully revised and incorporate some of the flavor of the exciting changes occurring in the field of taxonomy. You will see some of these changes listed under "New to the Sixth Edition." Cladograms have been updated and, as in previous editions, full-color artwork, photographs, and lists of phylum characteristics are used to highlight each phylum.

Part Three covers animal form and function using a comparative approach. This approach includes descriptions and full-color artwork that depict evolutionary changes in the structure and function of selected organ systems. Part Three includes an appropriate balance between invertebrate and vertebrate descriptions.

NEW TO THE SIXTH EDITION

Major additions to the sixth edition focus on evolutionary principles and taxonomy. Evolutionary concepts must be presented clearly and convincingly in biology courses. We believe that changes we have made will help instructors accomplish that goal by providing more evidence of evolution, more examples to illustrate evolutionary principles, and more detail on evolutionary mechanisms. Recent, fast-paced changes in animal taxonomy require constant reevaluation of the presentation of evolutionary

relationships between animal taxa. Because the taxonomy of many animal groups is unsettled, we have tried to take a conservative, yet up-to-date, position on taxonomic revisions. The following are major additions to this edition.

- "Evolutionary Insights" boxes appear in selected chapters. These readings present students with further information and examples of how evolutionary biology works.
- Chapter 4 is reorganized and presents new information on the distinction between microevolution and macroevolution. The coverage of the evidence for macroevolution includes an expanded discussion of paleontology, a reorganized and expanded discussion of homology and analogy from the perspectives of both comparative anatomy and molecular biology, and a new presentation of evidence from developmental biology. A new section on phylogeny and common descent caps this chapter.
- Chapter 5 begins with an expanded presentation of populations and gene pools. The sections on sources of variation and gene flow are enhanced with more information and new examples.
- Chapter 9 presents new information on the evolutionary relationships of the Porifera, Cnidaria, and Ctenophora.
- Chapter 13 provides an updated taxonomy of the Annelida, including the presentation of the oligochaetes and leeches as members of a single class Clitellata.
- Chapters 14 and 15 include an extensive update on arthropod taxonomy. Arthropods are presented as a monophyletic group, and recent thinking regarding crustacean ancestry for the phylum is discussed. There is expanded coverage of the hemocoel and insect nutrition and digestion.
- Chordate taxonomy in chapters 17 through 22 has been updated. Chapter 18 includes an expanded discussion of the evolution of jaws and paired appendages and the fish-to-amphibian transition. Chapter 19 introduces more coverage of the early evolution of the Stegocephalia and Tetrapoda. Chapter 21 has expanded coverage of bird evolution.

SUPPLEMENTARY MATERIALS

Supplementary materials are available to assist instructors with their presentations and course management and to augment student learning. The usefulness of these supplements is now greatly enhanced with the availability of online, digital, and printed resources. A Digital Content Manager is available as a CD-ROM. It contains PowerPoint slides of most line art and photographs from the textbook, which can be used in customizing classroom presentations.

ONLINE LEARNING CENTER

As with the previous edition, chapters on cell chemistry, energy and enzymes, embryology, and animal behavior—along with numerous boxed readings and pedagogical elements—have been moved to the Online Learning Center. This content-rich website is located at www.mhhe.com/zoology—just click on this book's cover. Both instructors and students can take advantage of numerous teaching and learning aids within this book's Online Learning Center.

Instructor Resources:

- Instructor's Manual
- Instructor Resource Guide
- Link to Digital Zoology

Student and Instructor Resources:

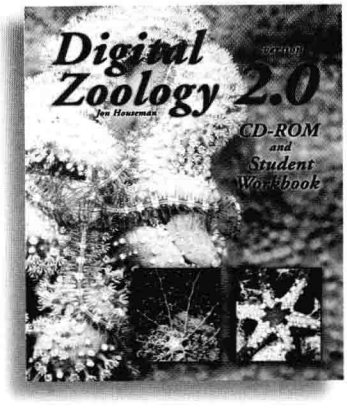
- Interactive Cladistics Exercises
- Chapters on:
  - Chapter 30: The Chemical Basis of Animal Life
  - Chapter 31: Energy and Enzymes: Life's Driving and Controlling Forces
  - Chapter 32: How Animals Harvest Energy Stored in Nutrients
  - Chapter 33: Embryology
  - Chapter 34: Animal Behavior
- Quizzing
- Flashcards
- Suggested Readings
- Boxed Readings
- Animation Exercises
- Zoology Lab Correlations
- Zoology Essential Study Partner (ESP)

OTHER RESOURCES

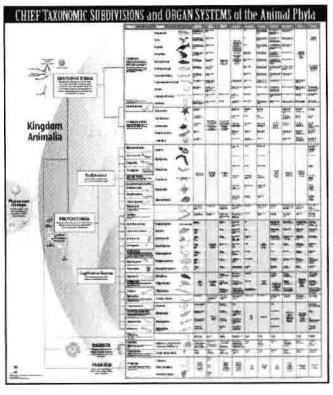
The following items may accompany *Zoology*. Please consult your McGraw-Hill representative for policies, prices, and availability.

- An **Instructor's Manual,** prepared by Susan L. Keen, is available for instructors within the Online Learning Center. It provides items such as a lecture outline, lecture enrichments, research discussion topics, teaching suggestions, and/or suggested readings for each chapter.
- A ***Zoology* Test Item CD-ROM** is also available for instructors. This contains approximately 50 multiple-choice questions and the instructor's manual for each chapter.
- **General Zoology Study Guide,** prepared by Jane Aloi and Gina Erickson, contains subject-by-subject summaries, questions, and learning activities.
- A set of 100 full-color acetate transparencies is available to supplement classroom lectures.
- **General Zoology Laboratory Manual,** Fifth Edition, by Stephen A. Miller, is an excellent corollary to the text and incorporates many learning aids. It includes illustrations and photographs, plus activities on scientific method, cladistics, ecological and evolutionary principles, and animal structure and function. A Laboratory Resource Guide, available within the Online Learning Center, provides information about materials and procedures and answers to worksheet questions that accompany the lab exercises.

- **Digital Zoology CD-ROM** is an exciting interactive product designed to help you make the most of your zoology classes and laboratory sessions. This program contains interactive cladograms, laboratory modules, video, interactive quizzes, hundreds of photographs, a full glossary, and much detailed information about the diversity and evolution of the animals that we find on the planet. To find out the latest news on this ever-expanding product, log on to www.digitalzoology.com and find out how to incorporate this valuable resource into your course.



- **Study Aid/Poster: Chief Taxonomic Subdivisions & Organ Systems of the Animal Phyla**—This 30- × 36-inch poster is a great reference/study tool for students.



- Available through the Zoology Online Learning Center or on a free CD-ROM, the **Zoology Essential Study Partner** is a complete, interactive study tool offering animations and learning activities to help students understand complex zoology concepts. This valuable resource also includes self-quizzing to help students review each topic.
- PageOut® is the solution for professors who need to build a course website. The following features are now available to professors:
  - The PageOut Library offers instant access to fully loaded course websites with no work required on the instructor's part.
  - Courses can now be password protected.
  - Professors can now upload, store, and manage up to 10 MB of data.
  - Professors can copy their course and share it with colleagues or use it as a foundation for next semester. Short on time? Let us do the work. Our McGraw-Hill service team is ready to build your PageOut website and to provide content and any necessary training. Learn more about PageOut and other McGraw-Hill digital solutions at www.mhhe.com/solutions.

ACKNOWLEDGMENTS

We wish to thank the reviewers who provided detailed analysis of the text during development. In the midst of their busy teaching and research schedules, they took time to read our manuscript and offer constructive advice that greatly improved this sixth edition.

REVIEWERS

Barbara J. Abraham, Hampton University
Marc C. Albrecht, University of Nebraska at Kearney
Donald I. Anadu, South Carolina State University
Joe Arruda, Pittsburg State University
Amir M. Assadi-Rad, San Joaquin Delta College
Kris Burnell, Santa Barbara City College
Vincent A. Cobb, Northeastern State University
Marjorie M. Collier, Louisiana State University at Alexandria
D. Charles Dailey, Sierra College
Lewis Deaton, University of Louisiana at Lafayette
Elizabeth A. Desy, Southwest State University
Charles D. Dieter, South Dakota State University
Phillip Eichman, University of Rio Grande
David J. Eisenhour, Morehead State University
Bruce E. Felgenhauer, University of Louisiana at Lafayette
Jim Goetze, Laredo Community College
Glenn A. Gorelick, Citrus College
Edward J. Greding, Jr., Del Mar College
Ann Grens, Indiana University–South Bend
Leon E. Hallacher, University of Hawaii at Hilo
Jenna Jo Hellack, University of Central Oklahoma
J. L. Henriksen, Bellevue University
Gary W. Hunt, Tulsa Community College
Arthur B. Jantz, Western Oklahoma State College
Ritin Khan, Armstrong Atlantic State University
Scott L. Kight, Montclair State University
Shelley A. Kirkpatrick, Saint Francis University
Robert A. Krebs, Cleveland State University
Mary Jane Krotzer, Stillman College
Kevin Lyon, Jones County Junior College
Kelly M. Mack, University of Maryland Eastern Shore
Neal F. McCord, Stephen F. Austin State University

Bonnie McCormick, University of the Incarnate Word
Michael B. McDarby, Fulton-Montgomery Community College
Emily C. McDuffee, Freed-Hardeman University
William R. Miller, Chestnut Hill College
Devonna Sue Morra, Saint Francis University
Charles M. Page, El Camino College
Louis L. Pech, Carroll College
Polly K. Phillips, Miami-Dade Community College
Karen E. Plucinski, Defiance College
Michelle A. Priest, College of the Canyons
William M. Saidel, Rutgers University–Camden
Allen Sanborn, Barry University
Neil Schanker, College of the Siskiyous
Doug Schexnayder, Copiah-Lincoln County College
Fred Schindler, Indian Hills Community College
Shari Snitovsky, Skyline College
Ken Spitze, University of Miami
Annie M. Talley, Asheville-Buncombe Technical College
Michael E. Toliver, Eureka College
Richard E. Trout, Oklahoma City Community College
Elise M. Van Ginkel, Madison Area Technical College
Scott E. Walter, University of Wisconsin–Richland
Danny B. Wann, Carl Albert State College
MaryJo A. Witz, Monroe Community College
Jeffery S. Wooters, Pensacola Junior College
Robert W. Yost, Indiana University/Purdue University at Indianapolis
David D. Zeigler, University of North Carolina at Pembroke
Brenda Zink, Northeastern Junior College

The publication of a text requires the efforts of many people. We are grateful for the work of our colleagues at McGraw-Hill who have shown extraordinary patience, skill, and commitment to this textbook. Marge Kemp has helped shape *Zoology* from its earliest planning stages. Although she has moved up to other responsibilities within McGraw-Hill, her wisdom and skill is still evident in this sixth edition. Donna Nemmers, Senior Developmental Editor, has worked with this textbook through the last two revisions. We are grateful for her skill in coordinating many of the tasks involved with publishing previous editions of *Zoology*. Our Developmental Editor, Fran Schreiber, helped make the production of the sixth edition remarkably smooth. Fran kept us on schedule and the production moving in the plethora of directions that are nearly unimaginable to us. Jayne Klein served as Senior Project Manager for this edition. We appreciate her efficiency and organization. We also thank Rose Kramer for proofreading the entire textbook.

Finally, but most importantly, we wish to extend appreciation to out families for their patience and encouragement. Janice A. Miller lived with this text through many months of planning and writing. She died suddenly two months before the first edition was released. Our wives, Carol A. Miller and Donna Dailey Harley, have been supportive throughout the revision process. We appreciate the sacrifices that our families have made during the writing and revision of this text. We dedicate this book to the memory of Jan and to our families.

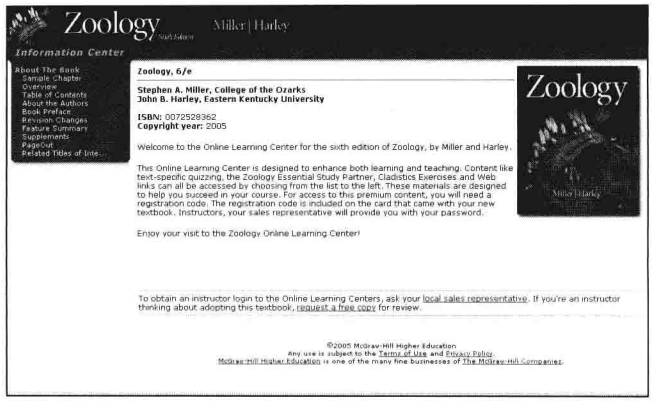
STEPHEN A. MILLER

JOHN P. HARLEY

ONLINE LEARNING CENTER

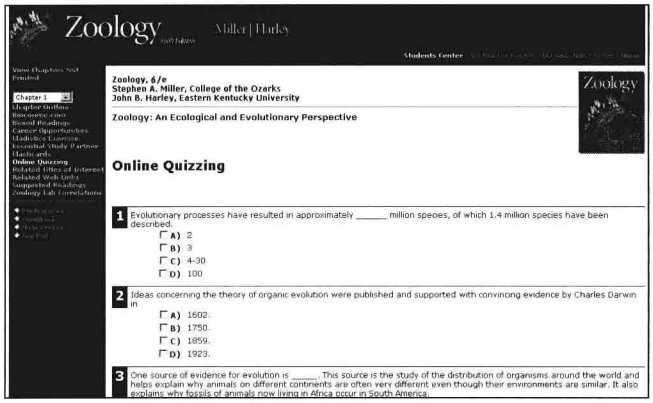
www.mhhe.com/zoology (click on this book's cover)

Students: You'll appreciate extensive self-quizzing opportunities; interactive activities; and related weblinks in addition to the Zoology Essential Study Partner—a web-based review of major zoology topics—hosted on this site.



Instructor Resources:

- Instructor's Manual
- Instructor Resource Guide
- Link to Digital Zoology

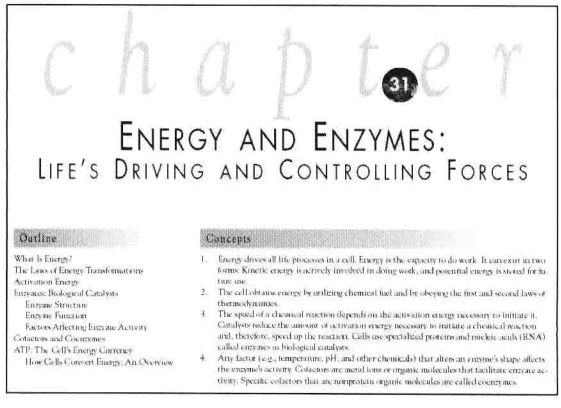


Student & Instructor Resources:

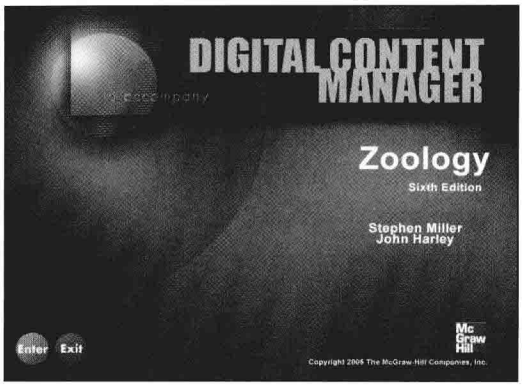
- Interactive Cladistics Exercises
- Quizzing
- Flashcards
- Suggested Readings
- Boxed Readings
- Animation Exercises
- Zoology Lab Correlations
- Zoology Essential Study Partner (ESP)

Additional Chapters:

- Chapter 30: The Chemical Basis of Animal Life
- Chapter 31: Energy and Enzymes: Life's Driving and Controlling Forces
- Chapter 32: How Animals Harvest Energy Stored in Nutrients
- Chapter 33: Descriptive Embryology
- Chapter 34: Animal Behavior



Digital Content Manager CD-ROM

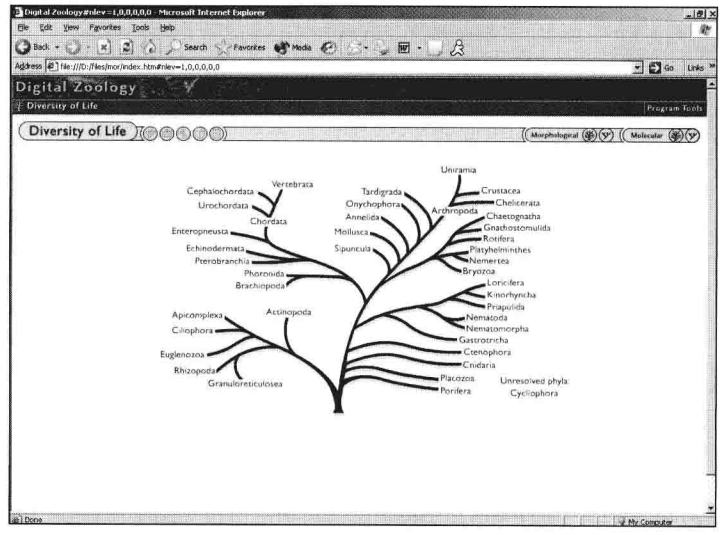


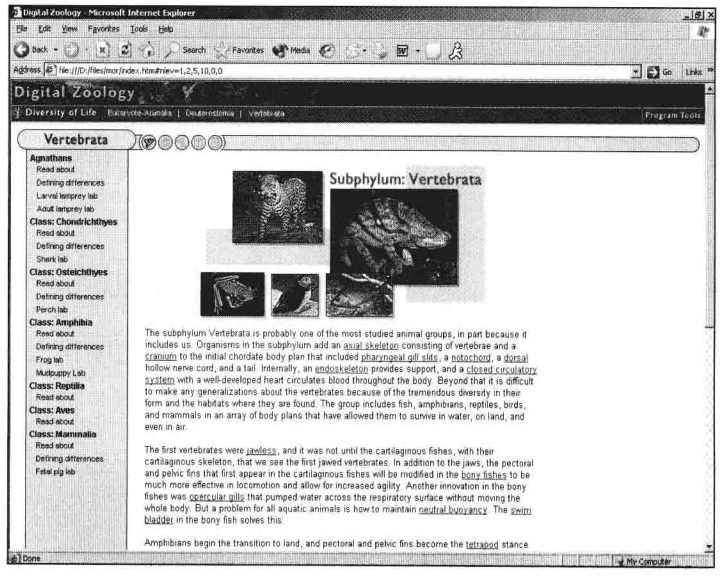
For the first time, *Zoology* will have a **text-specific Digital Content Manager CD-ROM.** This powerful and easy-to-use tool is designed to help instructors easily incorporate text-specific illustrations and photos into lecture presentations and printed classroom materials. Organized by chapter, this cross-platform CD-ROM contains a collection of visual resources that can be imported and reproduced in multiple formats to create customized lectures, visually based tests and quizzes, dynamic course website content, or attractive printed materials.

Digital Zoology CD-ROM and Student Work Book

Digital Zoology is an interactive guide that will help reinforce what students are learning in their zoology lecture and laboratory sessions. Here is what you will find on this easy-to-use CD-ROM.

- Laboratory modules containing illustrations, photographs, annotations of the major structures of organisms, interactive quizzes, and over 70 video clips of animal diversity, habitats, and behaviors.
- Interactive cladograms and dendograms within lab modules, along with links to interactive synapomorphies of the various animal groups.
- Key terms with links to an interactive glossary of over 750 definitions.
- Taxon "Read Abouts" that include information on over 100 taxa, the number of living and extinct species, habitats, and how they function.
- Updated taxonomy of the animal phyla that allows for easy comparison of the differences between traditional morphological phylogenies and those created with molecular data.
- Image galleries available for many of the major phyla, providing photos that detail diversity within the phyla.
- An accompanying student workbook with self-tests, crossword puzzles, and a website to provide additional study tips, exercises, and phyla characteristics.





GUIDED TOUR

The organization and features of this book have been planned with students' learning and comprehension in mind.

CHAPTER CONCEPTS

The concepts most important to the understanding of each chapter are highlighted on the first page of each chapter.

CHAPTER 24

COMMUNICATION I:

NERVOUS AND SENSORY SYSTEMS

Outline

Concepts

1. The nervous system helps to communicate, integrate, and coordinate the functions of the various organs and organ systems in the animal body.
2. Information flow through the nervous system has three main steps: (1) the collection of information from outside and inside the body (sensory activities), (2) the processing of this information in the nervous system, and (3) the initiation of appropriate responses.
3. Information is transmitted between neurons directly (electrically) or by means of chemicals called neurotransmitters.
4. The evolution of the nervous system in invertebrates has led to the elaboration of organized nerve cords and the centralization of responses in the anterior portion of the animal.
5. The vertebrate nervous system consists of the central nervous system, made up of the brain and spinal cord, and the peripheral nervous system, composed of the nerves in the rest of the body.
6. Nervous systems evolved through the gradual layering of additional nervous tissue over reflex pathways of more ancient origin.
7. Sensory receptors or organs permit an animal to detect changes in its body, as well as in objects and events in the world around it. Sensory receptors collect information that is then passed to the nervous system, which determines, evaluates, and initiates an appropriate response.
8. Sensory receptors initiate nerve impulses by opening channels in sensory neuron plasma membranes, depolarizing the membranes, and causing a generator potential. Receptors differ in the nature of the environmental stimulus that triggers an eventual nerve impulse.
9. Many kinds of receptors have evolved among invertebrates and vertebrates, and each receptor is sensitive to a specific type of stimulus.
10. The nature of its sensory receptors gives each animal species a unique perception of its body and environment.

The two forms of communication in an animal that integrate body functions to maintain homeostasis are: (1) neurons, which transmit electrical signals that report information or initiate a quick response in a specific tissue; and (2) hormones, which are slower, chemical signals that initiate a widespread, prolonged response, often in a variety of tissues. This chapter focuses on the function of the neuron, the anatomical organization of the nervous system in animals, and the ways in which the senses collect information and transmit it along nerves to the central nervous system. To conclude the study of communication, chapter 25 examines how hormones affect long-term changes in an animal's body.

This chapter contains evolutionary concepts, which are set off in this font.

379

CRITICAL THINKING QUESTIONS

Students can synthesize the chapter information by applying it to the Critical Thinking Questions in each chapter.

SUMMARY

1. The kingdom Protista is a polyphyletic group that arose about 1.5 billion years ago from the Archaea. The evolutionary pathways leading to modern protozoa are uncertain.
2. Protozoa are both single cells and entire organisms. Organelles specialized for the unicellular lifestyle carry out many protozoan functions.
3. Many protozoa live in symbiotic relationships with other organisms, often in a host-parasite relationship.
4. Members of the phylum Sarcomastigophora possess pseudopodia and/or one or more flagella.
5. Members of the class Phytomastigophorea are photosynthetic and include the genera *Euglena* and *Volvox*. Members of the class Zoomastigophorea are heterotrophic and include *Trypanosoma*, which causes sleeping sickness.
6. Amoebae use pseudopodia for feeding and locomotion.
7. Members of the subphylum Sarcodina include the freshwater genera *Amoeba*, *Arcella*, and *Difflugia*, and the parasitic genus *Entamoeba*. Foraminiferans and radiolarians are common marine amoebae.
8. Members of the phylum Apicomplexa are all parasites. The phylum includes *Plasmodium* and *Toxoplasma*, which cause malaria and toxoplasmosis, respectively. Many apicomplexans have a three-part life cycle involving schizogony, gametogony, and sporogony.
9. The phylum Microspora consists of small protozoa that are intracellular parasites of every major animal group. They are transmitted from one host to the next as a spore, the form from which the group obtains its name.
10. The phylum Acetospora contains protozoa that produce spores lacking polar capsules. These protozoa are primarily parasitic in molluscs.
11. The phylum Myxozoa consists entirely of parasitic species, usually found in fishes. One to six polar filaments characterize the spore.
12. The phylum Ciliophora contains some of the most complex of all protozoa. Its members possess cilia, a macronucleus, and one or more micronuclei. Mechanical coupling of cilia coordinates their movements, and cilia can be specialized for different kinds of locomotion. Ciliates reproduce sexually by conjugation. Diploid ciliates undergo meiosis of the micronuclei to produce haploid pronuclei that two conjugants can exchange.
13. Precise evolutionary relationships are difficult to determine for the protozoa. The fossil record is sparse, and what does exist is not particularly helpful in deducing relationships. However, ribosomal RNA sequence comparisons indicate that each of the seven protozoan phyla probably had separate origins.

SELECTED KEY TERMS

ectoplasm (p. 112)
endoplasm (p. 112)
host (p. 113)
macronucleus (p. 123)
micronuclei (p. 123)
multiple fission (schizogony) (p. 113)
pellicle (p. 112)
protozoa (p. 112)
protozoologists (p. 114)
trichocysts (p. 123)

CRITICAL THINKING QUESTIONS

1. If knowing for certain the evolutionary pathways that gave rise to protozoa and animal phyla is impossible, is it worth constructing hypotheses about those relationships? Why or why not?
2. In what ways are protozoa similar to animal cells? In what ways are they different?
3. If sexual reproduction is unknown in *Euglena*, how do you think this lineage of organisms has survived through evolutionary time? (Recall that sexual reproduction provides the genetic variability that allows species to adapt to environmental changes.)
4. The use of DDT has been greatly curtailed for ecological reasons. In the past, it has proved to be an effective malaria deterrent. Many organizations would like to see this form of mosquito control resumed. Do you agree or disagree? Explain your reasoning.
5. If you were traveling out of the country and were concerned about contracting amoebic dysentery, what steps could you take to avoid contracting the disease? How would the precautions differ if you were going to a country where malaria is a problem?

ONLINE LEARNING CENTER

Visit our Online Learning Center (OLC) at www.mhhe.com/zoology (click on this book's title) to find the following chapter-related materials:

- CHAPTER QUIZZING
- RELATED WEB LINKS
  - Phylum Sarcomastigophora
  - Phylum Apicomplexa
  - Phylum Ciliophora
  - Other Protozoan Phyla
- BOXED READINGS ON
  - Giardiasis: "Backpacker's Disease" in the Rocky Mountains
  - Malaria Control—A Glimmer of Hope
- SUGGESTED READINGS
- LAB CORRELATIONS

Check out the OLC to find specific information on these related lab exercises in the *General Zoology Laboratory Manual*, 5th edition, by Stephen A. Miller:

Exercise 8 *Animal-like Protists*

ONLINE LEARNING CENTER

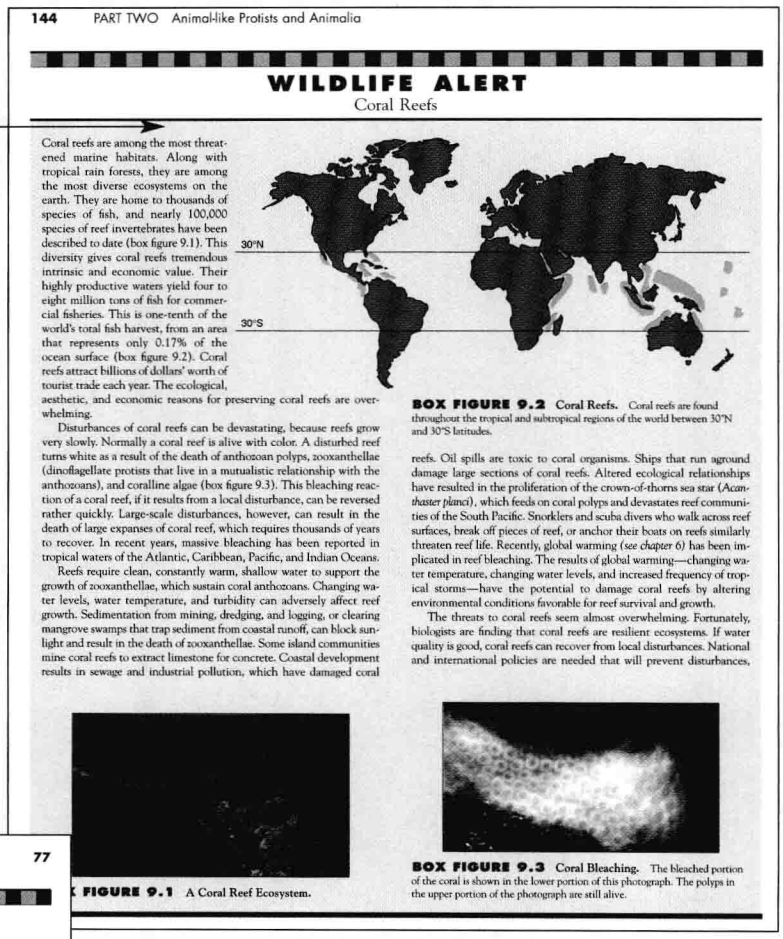
The Online Learning Center hosts specific study tools for each chapter, which are summarized at the end of each text chapter.

KEY TERMS

The most important terms from each chapter are linked to the text pages where they are defined, for further study.

WILDLIFE ALERT BOXES

These boxes feature issues related to endangered and threatened species of animals.



144 PART TWO Animal-like Protists and Animalia

WILDLIFE ALERT

Coral Reefs

Coral reefs are among the most threatened marine habitats. Along with tropical rain forests, they are among the most diverse ecosystems on the earth. They are home to thousands of species of fish, and nearly 100,000 species of reef invertebrates have been described to date (box figure 9.1). This diversity gives coral reefs tremendous intrinsic and economic value. Their highly productive waters yield four to eight million tons of fish for commercial fisheries. This is one-tenth of the world's total fish harvest, from an area that represents only 0.17% of the ocean surface (box figure 9.2). Coral reefs attract billions of dollars' worth of tourist trade each year. The ecological, aesthetic, and economic reasons for preserving coral reefs are overwhelming.

Disturbances of coral reefs can be devastating, because reefs grow very slowly. Normally a coral reef is alive with color. A disturbed reef turns white as a result of the death of anthozoan polyps, zooxanthellae (dinoflagellate protists that live in a mutualistic relationship with the anthozoans), and coralline algae (box figure 9.3). This bleaching reaction of a coral reef, if it results from a local disturbance, can be reversed rather quickly. Large-scale disturbances, however, can result in the death of large expanses of coral reef, which requires thousands of years to recover. In recent years, massive bleaching has been reported in tropical waters of the Atlantic, Caribbean, Pacific, and Indian Oceans.

Reefs require clean, constantly warm, shallow water to support the growth of zooxanthellae, which sustain coral anthozoans. Changing water levels, water temperature, and turbidity can adversely affect reef growth. Sedimentation from mining, dredging, and logging, or clearing mangrove swamps that trap sediment from coastal runoff, can block sunlight and result in the death of zooxanthellae. Some island communities mine coral reefs to extract limestone for concrete. Coastal development results in sewage and industrial pollution, which have damaged coral reefs. Oil spills are toxic to coral organisms. Ships that run aground damage large sections of coral reefs. Altered ecological relationships have resulted in the proliferation of the crown-of-thorns sea star (*Acanthaster planci*), which feeds on coral polyps and devastates reef communities of the South Pacific. Snorklers and scuba divers who walk across reef surfaces, break off pieces of reef, or anchor their boats on reefs similarly threaten reef life. Recently, global warming (*see chapter 6*) has been implicated in reef bleaching. The results of global warming—changing water temperature, changing water levels, and increased frequency of tropical storms—have the potential to damage coral reefs by altering environmental conditions favorable for reef survival and growth.

The threats to coral reefs seem almost overwhelming. Fortunately, biologists are finding that coral reefs are resilient ecosystems. If water quality is good, coral reefs can recover from local disturbances. National and international policies are needed that will prevent disturbances,

30°N

30°S

BOX FIGURE 9.2 Coral Reefs. Coral reefs are found throughout the tropical and subtropical regions of the world between 30°N and 30°S latitudes.

FIGURE 9.1 A Coral Reef Ecosystem.

BOX FIGURE 9.3 Coral Bleaching. The bleached portion of the coral is shown in the lower portion of this photograph. The polyps in the upper portion of the photograph are still alive.

CHAPTER 5 Evolution and Gene Frequencies 77

EVOLUTIONARY INSIGHTS

Speciation of Darwin's Finches

When Charles Darwin visited the Galápagos Islands in 1835, he observed the dark-bodied finches whose adaptive radiation has become a classic example of speciation (box figure 5.1). Studies of these finches have provided insight into some of the ways in which speciation can occur. Peter R. and B. Rosemary Grant have been studying these finches for more than 30 years. They have directly observed microevolutionary change reflected in bill morphology in response to change in rainfall and food availability. Other molecular studies have also contributed to our knowledge of the adaptive radiation of this group of birds.

Molecular studies have identified the most likely South American relatives of Darwin's finches, members of the grassquit genus *Tiaris*. Comparisons of the mitochondrial DNA of this group with Darwin's finches suggest that the latter colonized some of the Galápagos Islands not more than 3 million years ago. A very rapid adaptive radiation occurred, with the number of finch species doubling approximately every 750,000 years. No other group of birds studied has undergone a more rapid evolutionary diversification (*see figure 4.4*). Darwin's finches have served as a model to answer questions of how and why species diverge.

The traditional explanation of speciation within Darwin's finches is based on the allopatric model discussed in this chapter. This explanation is based upon differences in food resources, and the observations of the Grants have provided support for this model. Geographic isolation of populations of finches on different islands promoted speciation as these populations were influenced by natural selection and genetic drift. Each population adapted to the food resources available in their habitat (*see figure 4.6*). Most of these adaptations are reflected in bill morphology.

The Grants have discovered, however, that the allopatric model is not the entire explanation for finch adaptive radiation. Three million years ago, the Galápagos Islands were much simpler than they are today. In fact, there were fewer islands when they were first colonized by finches. Apparently the number of finch species increased as the number of islands increased as a result of volcanic activity. The increasing number of islands and oscillations in temperature and precipitation naturally affected vegetation. Habitats available for finches became more diverse and complex. The original warm, wet islands favored long, narrow bills that were used in gathering nectar and insects. The islands' moisture now fluctuates and the climate is more seasonal. The increasing diversity in habitats and food supply over 3 million years apparently promoted very rapid speciation among the finch populations.

The Grants have also discovered that sympatric forces probably have also promoted speciation. Different species of finches that live on the same island rarely hybridize. Lack of hybridization promotes isolation and speciation. Genetic incompatibility of gametes is apparently not the factor that discourages hybridization. Courtship behaviors of different species are similar, so courtship differences are not responsible.

(a) (b)

BOX FIGURE 5.1 Speciation of Darwin's Finches. Speciation and adaptive radiation of Darwin's finches has been used as a classic example of allopatric speciation. Isolation of finches on different islands, and differences in food resources on those islands, selected for morphological differences in finch bills. For example, (*a*) the warbler finch (*Certhidea olivacea*) has a bill that is adapted for probing for insects, and (*b*) the large ground finch (*Geospiza magnirostris*) has a bill that is adapted for crushing seeds. Recent studies show that increasing numbers of islands over the last 3 million years and changes in temperature and precipitation resulted in very rapid speciation. In addition, sympatric influences regarding the role of the males' song and bill shape probably also promoted speciation.

EVOLUTIONARY INSIGHTS

These new boxes provide detailed examples of principles covered in a chapter and provide insight into how evolutionary biology works.

BRIEF CONTENTS

*This chapter is available at www.mhhe.com/zoology (click on this book's cover).

CONTENTS