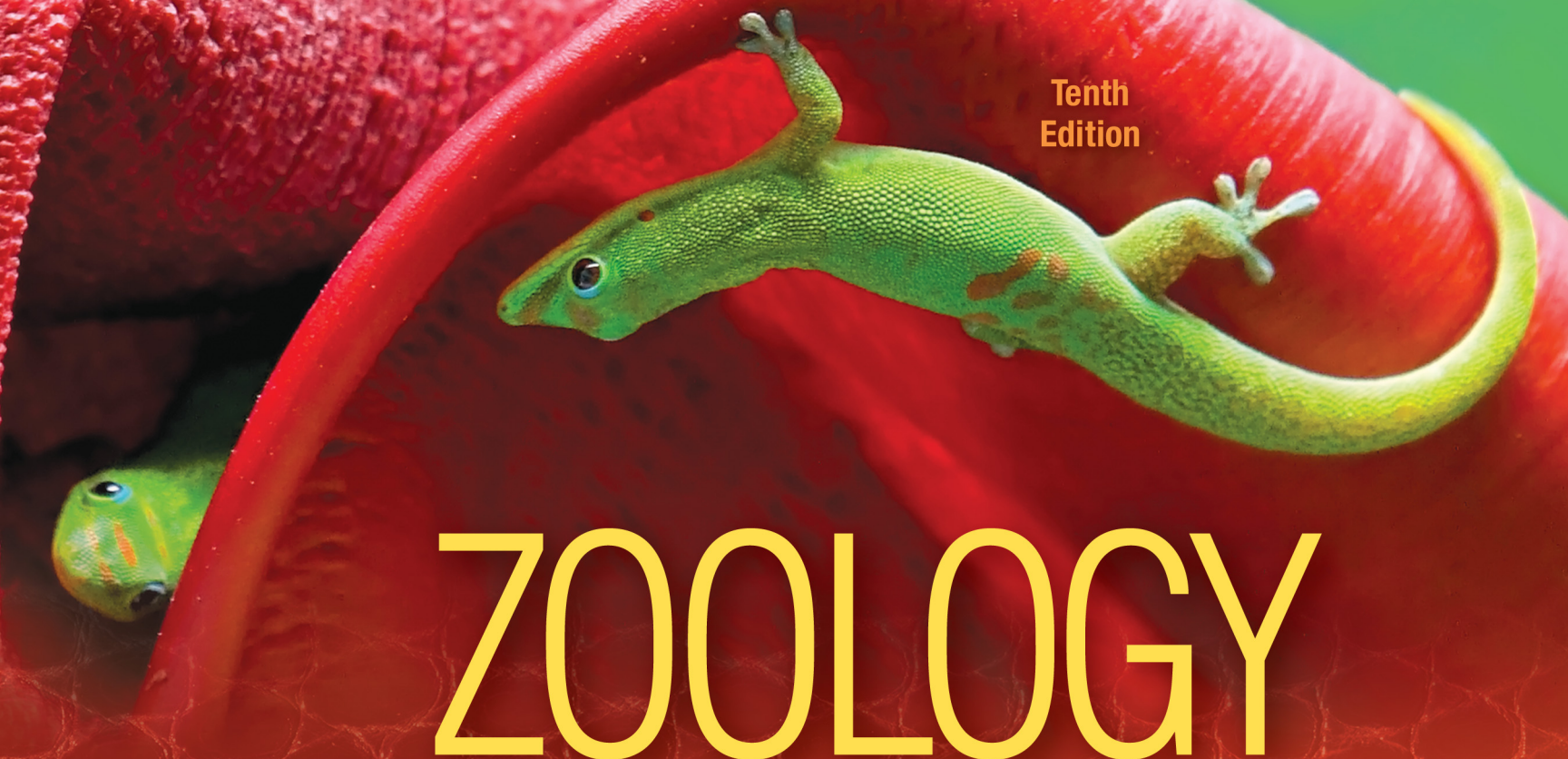

Tenth Edition

# ZOOLOGY

Stephen A. Miller
John P. Harley

Mc Graw Hill Education

# Zoology

**Tenth Edition**


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# BRIEF CONTENTS

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# PREFACE

Beginning with the first outlines in 1986, we have envisioned *Zoology* as a general zoology textbook for use in one-semester courses. Our plan was that *Zoology* should be adaptable to a variety of course organizations; that it should be filled with relevant, up-to-date zoological information; and that it should not overwhelm introductory-level students with unnecessary terminology. As teachers with over 80 years of combined experience in college and university classrooms and laboratories, we know that a book is good only if it is read. Feedback from reviewers, professors, teachers, and students tells us that *Zoology's* informative and friendly writing does encourage its use by students in ways that other textbooks do not.

We are honored that this book has had a part in the development of students we will never know personally. We recognize that our part in the training of future zoologists and biologists is modest. A general zoology course is as good as the professors and teachers who inspire their students to delve into a book's pages. Over the life of *Zoology* we have been a team of two authors, numerous editors, zoology teachers and professors, and students who have contributed to keeping this textbook alive and lively into its 10th edition. In preparing for the 10th edition of *Zoology*, we have taken seriously the feedback we have received. Every chapter has been carefully scrutinized, and many of the changes incorporated into the revisions summarized later in this preface are the result of reviewer, instructor, and student comments. Preparation for the 11th edition begins now, and we welcome your comments. We can be reached at the following email addresses: Stephen Miller at zoology.miller@gmail.com and John Harley at zoology.harley@gmail.com.

Every edition of *Zoology* brings something new and exciting from McGraw-Hill. As authors and teachers, we are excited about the **LearnSmart** and **SmartBook** adaptive learning features that are available with this edition. LearnSmart and SmartBook allow students to progress through chapters with greater confidence knowing that they understand concepts being studied. We have found these tools user friendly, and we encourage you to take time to investigate how they can enhance student learning in your course. More information is presented on LearnSmart and SmartBook in "Teaching and Learning Resources."

## CONTENT AND ORGANIZATION

We have maintained from the inception of this text that evolutionary and ecological perspectives captivate students. These perspectives are fundamental to students understanding the unifying principles of zoology. Chapters 1 through 6 present cellular, evolutionary, and ecological concepts that unite zoology to biology as a whole. These chapters have been updated with new population statistics, examples, illustrations, and photographs.

Major content changes in the 10th edition of *Zoology* reflect the changes in our understanding of animal phylogeny that have come to light in the past few years. These changes should not surprise anyone given the dynamic and vital state of affairs in modern animal phylogenetics. A comparison of the expanded table of contents from the 9th edition to that of the 10th edition will highlight some of the changes in chapters 7 through 22. Most noticeably, chapters 10 and 13 have been completely reorganized. Chapter 10 is now devoted to the smaller lophotrochozoan phyla, and chapter 13 is devoted to the ecdysozoans other than the Panarthropoda. Chapter 12 is reorganized to reflect new interpretations of phylogeny within the annelids. Chapters 14 and 15 are reorganized in recognition of the validity of the Pancrustacea. Chapters 16 and 17 are reorganized to group echinoderms and hemichordates into a single ambulacrarian chapter.

In addition to organizational changes, chapters 7 through 22 contain many new photographs, newly drawn cladograms, revised illustrations, and content additions and revisions. For example, we have added more information on vertebrate teeth in chapters 18 through 22, new material on the reptiliomorphs and the basal tetrapod/reptile transition in chapter 19, and new information on human evolution in chapter 22.

In previous editions, some small phyla were omitted from the survey chapters to keep the size of the book manageable. We have found a way to introduce descriptions and phylogenetic relationships of these "lesser-known phyla" without adversely affecting the book's length. These phyla are presented in tables at the end of chapters 9, 12, and 16, and we hope that these tables will help students understand more of the amazing diversity within the animal kingdom.

Chapters 23 through 29 retain their clear, concise, system-by-system coverage of animal organ systems. These chapters contain new photographs and text revisions that illustrate comparative aspects of animal structure and function. For example, chapter 25 describes insulin production within bivalve intestines, and chapter 26 has expanded coverage of the evolution of the sinus venosus and the SA node.

## PEDAGOGY

### Integrated Learning Outcomes and Critical Thinking

We have retained pedagogical elements useful to science faculty in identifying measurable learning outcomes. **Learning Outcomes** and **Section Reviews,** including section review

questions, have been retained in the 10th edition for each major section of each chapter. Answers for section review questions are available to instructors on the *Zoology* website. These elements allow students to self-test and instructors to document student learning. In addition, instructors and students using Connect Zoology can access auto-gradable and interactive assessment material tied to learning outcomes from the text. These Connect features include the new LearnSmart and SmartBook adaptive learning tools and are described under "Teaching and Learning Resources."

Each chapter ends with a set of **Concept Review Questions** and **Analysis and Application Questions**. These questions have been carefully reviewed and revised as needed. They allow students to test their understanding of chapter concepts and to apply concepts they have learned in each chapter. Suggested answers to these questions are available to instructors through Connect. The glossary has been moved to the Connect site as well. In the mobile information age, it seems students are quicker to check a definition electronically than to flip to the back of the book. The glossary will also be available in SmartBook.

## An Evolutionary and Ecological Focus

*Zoology* emphasizes ecological and evolutionary concepts and helps students understand the process of science through elements of chapter organization and boxed readings. Each chapter in chapters 8 through 22 begins with a section entitled **Evolutionary Perspective**. This section discusses the relationship of the phylum or phyla covered in the current chapter to the animal kingdom as a whole and to animals discussed in previous chapters. Students are frequently reminded to consult the animal kingdom cladogram on the inside front cover and the geological time chart on the inside back cover. Similarly, each survey chapter ends with a section entitled **Further Phylogenetic Considerations**. This section discusses phylogenetic relationships of groups (subphyla or classes) within the phylum or phyla being studied and is a point of transition between chapters. The discussion in this section is usually supported by a cladogram illustrating important phylogenetic relationships.

To further explain and support evolutionary concepts, a set of themed boxed readings entitled **Evolutionary Insights** is present throughout the book. 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 speciation of Darwin's finches that illustrates how speciation can occur. Chapter 18 has a reading on the evolution of the vertebrate limb, and chapter 25 has a reading on the evolution of hormone receptors.

The ecological perspective of *Zoology* is stressed throughout chapters 1 to 22. Human population and endangered species statistics have been updated. Ecological problems are discussed including an assessment of eight critical environmental processes: biodiversity loss, nitrogen cycling, phosphorus cycling, climate change, ocean acidification, land and freshwater use, and ozone depletion. The ecological perspective is reinforced by boxed readings entitled **Wildlife Alerts**. Wildlife Alerts first appeared in the 4th edition and have been very well received by students and professors. Each boxed reading depicts the plight of selected animal species or broader ecosystem issues relating to preserving animal species. These readings have been revised, and some new readings have been added. Chapter 6 has a new reading on species translocation as a tool in conservation biology. Chapter 18 has a new reading on the problem of invasive species. Chapter 20 has a new reading on the plight of the Eastern diamondback rattlesnake (*Crotalus adamanteus*). Students who read and study this book should have an enhanced understanding of ecological principles and how human ignorance and misplaced values have had detrimental effects on our environment in general and on specific animal groups in particular.

## The Process of Science

To help students understand that science is a process, not just a body of facts, **How Do We Know** boxed readings are retained in this edition and they highlight research results that provide insight into biological processes. Chapter 9 has a boxed reading entitled "How Do We Know about Sponge Defenses?" This reading describes how zoologists investigated sponge defense mechanisms. Chapter 19 has a boxed reading entitled "How Do We Know about Amphibian Skin Toxins?" This reading describes how scientists are studying antibacterial and anticancer effects of amphibian skin toxins. Students learn that these studies have implications for studying naturally occurring compounds that may aid in the development of novel pharmaceutical drugs.

## Digital Assets and Media Integration

Beginning with the 9th edition of *Zoology,* digital resources were integrated into the book through the Connect Zoology site. Many of the sections within most chapters are linked to animations of biological processes and to MP3 files. This media integration is indicated within the printed text by the icons shown below. These media assets are available through Connect.


**MP3 files.** These short three-to-five minute audio files serve as a review of material in certain sections of the book and help students with the pronunciation of scientific terms and processes.

**Animations.** The authors have selected animations from McGraw-Hill's library of animations that will enhance students' understanding of the material within the chapter.

## NEW TO THE TENTH EDITION

As with earlier revisions of *Zoology*, the focus for this revision has been on presenting evolutionary and ecological concepts clearly and accurately using examples from current literature as convincingly as possible. The revisions highlighted below should impress students with the excitement experienced in zoology as new information clarifies zoological concepts and informs our understanding of phylogenetic relationships.

- **Chapter 1 (Zoology: An Evolutionary and Ecological Perspective)**
  Table 1.1 has been updated with the addition of comparative genomics and bioinformatics as a specialization in zoology. The use of cichlid fish as an example of the importance of evolutionary and ecological perspectives within zoology has been expanded. The concept of evolutionary plasticity is introduced. Population, world resource, rainforest depletion, and threatened and endangered species statistics have been updated with figures from 2014. Table 1.5 is new and compares human population projections in major world regions.

- **Chapter 2 (Cells, Tissues, and Organ Systems of Animals)**

  This chapter, including table 2.3, has been updated to include discussion of a newly discovered organelle, the exosome. New information is presented on hydrogen peroxide as a metabolite that induces oxidative damage and mediates aging.

- **Chapter 3 (Cell Division and Inheritance)**

  Coverage of the cell cycle has been expanded, including the discussion of the $G_0$ phase. Figure 3.3 is replaced to accompany this expanded discussion. The discussion of mitotic cell division now includes a discussion of prometaphase, and figure 3.5 has been revised to more clearly illustrate the concepts of mitotic cell division. Figure 3.6 has been revised to include an illustration of crossing-over in meiosis. Figure 3.15 has been redrawn to clearly illustrate primary and secondary nondisjunction. A new "How Do We Know" box on Thoroughbred horse inbreeding illustrates the dangers of reducing genetic diversity through inbreeding. The "Wildlife Alert" on preserving genetic diversity provides new information on the endangered status of the cheetah (*Panthera uncia*).

- **Chapter 4 (Evolution: History and Evidence)**

  New information is presented on the evolution of the horse, and figure 4.10 has been revised to support this coverage.

- **Chapter 5 (Evolution and Gene Frequencies)**

  The discussion of genetic drift has been revised and now includes the concept of fixation of an allele. "Founder Effect" and "Bottleneck Effect" are organized into subheadings to more clearly define their relationship to the larger genetic drift concept. Cichlid fish are used as an additional example of rapid evolutionary change in "Rates of Evolution."

- **Chapter 6 (Ecology: Preserving the Animal Kingdom)**

  The discussion of density-dependent factors influencing populations has been expanded. The discussion of crypsis has been expanded. New examples illustrate chemical, auditory, and visual crypsis. The section "Ecological Problems" has been revised. It has been updated with population statistics from 2014 and new statistics on rates of population growth. Problems associated with the aging of the human population are now included. The human age pyramids in figure 6.13 have been revised to support this updated discussion. A new "Wildlife Alert" that discusses species translocation as a tool in ecosystem restoration has been added. It points out the usefulness of species introductions and reintroductions as well as the risks associated with introducing nonnative species into ecosystems (*see the new "Wildlife Alert" in chapter 20*).

- **Chapter 7 (Animal Taxonomy, Phylogeny, and Organization)**

  The discussion in the section "Animal Systematics" is expanded. It now includes a comparison of the concepts of homology and homoplasy. The discussion of phylogenetic systematics (cladistics) has been revised. The terms "plesiomorphies" and "apomorphies" are discussed. The hypothetical cladogram (formerly figure 7.5) used to illustrate cladistic principles has been replaced by a simplified vertebrate cladogram (now figure 7.4). The new figure depicts familiar character states that are used to support the discussion of cladistics. After studying figure 7.4, students can "graduate to" figure 7.5—a more detailed version of vertebrate phylogeny. The discussion of evolutionary systematics is also expanded, including the "adaptive zone" concept. The phylogenetic species concept is discussed in more detail. In "Higher Animal Taxonomy," figure 7.12 has been redrawn and is an abbreviated version of the larger, highly revised cladogram on the inside front cover of the textbook. Figure 7.12 (and the expanded cladogram) reflects the taxonomic revisions that will be described in chapters 8 through 22.

- **Chapter 8 (Animal-Like Protists: The Protozoa)**

  Figure 8.1 has been replaced with a new cladogram showing the phylogeny of six protist supergroups.

- **Chapter 9 (Multicellular and Tissue Levels of Organization)**

  Chapter 9 opens with a revised discussion of the origin of multicellularity, including selective advantages of multicellularity and requirements for the evolution of multicellularity. Colonial and coenocytial hypotheses are discussed. Figure 9.1 has been revised to reflect updated animal

phylogeny. "Animal Origins" has additional detail on animal/choanocyte relationships. "Further Phylogenetic Relationships" presents new evidence that suggests that the Ctenophora, not the Porifera, is a sister taxon to all other animals. Table 9.4 is new and features two lesser-known basal animal phyla: Placozoa and Acoelomorpha.

- **Chapter 10 (The Smaller Lophotrochozoan Phyla)**

  Chapter 10 has received major revisions and now describes lophotrochozoan phyla other than Mollusca (chapter 11) and Annelida (chapter 12). The "Evolutionary Perspective" has been rewritten to explain why the new chapter organization makes phylogenetic sense, and it also describes the lophophore and the trochophore larval stage—the two features that unite the lophotrochozoans. Members of the clade Platyzoa (Platyhelminthes, Gastrotricha, Micrognathozoa, Gnathostomulida, Rotifera, and Acanthocephala) are described first. They are followed by Cycliophora, Nemertea, Ectoprocta, and Brachiopoda. Three of these phyla have not been featured in previous editions of this textbook. "Further Phylogenetic Considerations" has been rewritten to focus on lophotrochozoan relationships. The questionable validity of the clade Platyzoa and the paraphyly of Turbellaria are discussed. Figure 10.29 is a new cladogram depicting lophotrochozoan relationships.

- **Chapter 11 (Molluscan Success)**

  New information on bivalve burrowing and cephalopod sensory perception is provided.

- **Chapter 12 (Annelida: The Metameric Body Form)**

  Chapter 12 has received extensive revision that reflects recent changes in our understanding of the phylogenetic relationships within the Annelida. The "Evolutionary Perspective" describes the traditional class "Polychaeta" as paraphyletic, and it explains the reinstatement of "Errantia" and "Sedentaria" as two major clades within Annelida. An updated discussion of annelid structure and function is then followed by descriptions of the clades Errantia and Sedentaria. *Nereis* and *Glycera* are used as representative errantians. Various tubeworms, siboglinids, echiurians, and clitellates are described as representative sedentarians. Chaetopteridae and Sipuncula are described as basal annelid groups. The reinterpretation of annelid phylogeny is described in a revised "Further Phylogenetic Considerations" and shown in a revised cladogram in figure 12.24. A new table 12.2 presents descriptions and phylogenetic relationships of three lesser-known lophotrochozoan phyla: Entoprocta, Phoronida, and Mesozoa.

- **Chapter 13 (The Smaller Ecdysozoan Phyla)**

  Chapter 13 has received major organizational revisions. It covers the ecdysozoan phyla other than Arthropoda, Onycophora, and Tardigrada. The five phyla discussed in chapter 13 (Nematoda, Nematomorpha, Kinorhyncha, Priapulida, and Loricifera) are described as members of the clade Cycloneuralia. The relationships of these phyla to the Panarthropoda are described in a revised "Further Phylogenetic Considerations" and presented in a cladogram in figure 13.16.

- **Chapter 14 (The Arthropods: Blueprint for Success)**

  Chapter 14 has received major organizational revisions that reflect arthropod phylogeny. Coverage of the Crustacea has been moved to chapter 15, and coverage of the Myriapoda has been moved to chapter 14.

- **Chapter 15 (Pancrustacea: Crustacea and Hexapoda)**

  Chapter 15 is devoted to the clade Pancrustacea. Discussion of the clade Panarthropoda is described in "Further Phylogenetic Considerations" and includes brief descriptions of Tardigrada and Onychophora. The discussion of arthropod phylogeny includes new information supporting the validity of the mandulate and chelicerate lineages. It also presents new information that suggests that the traditional subphylum Crustacea is paraphyletic. Hexapoda is presented as a monophyletic lineage within the crustacean phylogeny.

- **Chapter 16 (Amulacraria: Echinoderms and Hemichordates)**

  Chapter 16 has received organizational revisions that reflect our current understanding of deuterostome phylogeny. The discussion of the hemichordates has been moved from chapter 17 to reflect their closer ties to the Echinodermata. The "Evolutionary Perspective" has been revised to include more information on the clade Ambulacraria and deuterostome evolution in general. "Further Phylogenetic Considerations" has been revised to include discussion of the growing body of evidence of the ancestral status of pharyngeal slits in the deuterostome lineage. The cladogram in figure 16.19 has been revised to support the discussion of deuterostome phylogeny. Table 16.2 is a new table that provides information on two lesser-known phyla. The Chaetognatha and Xenoturbellida are described as "Phyla of Uncertain Affinities."

- **Chapter 17 (Chordata: Urochordata and Cephalochordata)**

  Chapter 17 has received minor revisions apart from moving the Hemichordata into chapter 16. The recognition that pharyngeal slits arose early in deuterostome evolution means that these structures are not unique to the chordates, but they are adapted for important functions in most chordates. "Further Phylogenetic Considerations" presents a revised discussion of the relationships between the chordate subphyla. The cladogram in figure 17.10 has been revised to support this discussion.

- **Chapter 18 (The Fishes: Vertebrate Success in Water)**

  Chapter 18 has received minor revisions. It includes a new boxed reading "Wildlife Alert: Invasive Species—A

Growing Problem in a Shrinking World." This reading uses the red lionfish (*Pterois volitans*) as an example to alert students to the risks associated with accidental or intentional release of species into nonnative ecosystems.

- **Chapter 19 (Amphibians: The First Terrestrial Vertebrates)**

  New information is presented on amphibian phylogeny in the "Evolutionary Perspective." "Evolutionary Pressures" contains expanded coverage of amphibian teeth, heart structure, and heart function. "Further Phylogenetic Considerations" has been expanded to include discussion of the reptiliomorph lineage and evolution of the synapsid lineage from ancient tetrapods. This discussion is supported by the revised cladogram in figure 19.3 and a photograph of a diadectomorph fossil in figure 19.19.

- **Chapter 20 (Reptiles: Diapsid Amniotes )**

  The organization of chapter 20 better reflects diapsid phylogeny. The evolutionary perspective and the revised cladogram in figure 20.3 complement the reptiliomorph discussion in chapter 19. The survey of reptiles is organized into three headings: Testudines, Archosauria, and Lepidosauria. While the traditional reptilian order names are retained, the new organization reflects reptilian phylogeny and makes very clear the position of Aves within the reptilian lineage. The birds are still covered in a separate chapter 21 out of respect for zoological tradition and in recognition of the importance of distinctive avian characteristics. "Evolutionary Pressures" contains expanded coverage of reptilian teeth and temperature regulation. A new "Wildlife Alert: The Eastern Diamondback Rattlesnake (*Crotalus adamanteus*)" has been added to chapter 20. It was written by guest contributors actively working to preserve this magnificent reptile.

- **Chapter 21 (Birds: Reptiles by Another Name)**

  New information has been added to chapter 21 on ancient theropods and the evolution of flight. The blurred distinction between bird and nonbird within the theropod lineage is emphasized. The presentation of avian taxonomy reflects recent genome-scale findings. In "Evolutionary Pressures" new information has been added on the unidirectional air flow through crocodylian lungs, reinforcing the archosaurian affinities of birds and crocodylians. The coverage of thermoregulation has been reorganized for clarity of presentation.

- **Chapter 22 (Mammals: Synapsid Amniotes)**

  "Evolutionary Pressures" has new information on mammalian teeth. The description of mammalian placentas has been clarified. The presentation of human evolution has been updated to reflect our current understanding of the very bush-like hominin phylogeny. The coverage emphasizes that adaptations for bipedal locomotion probably occurred more than once within our lineage. It also points out that different hominin species were contemporaries of one another and may have interacted. Table 22.3 (Significant Events in Hominin Evolution) and Figure 22.20 (Human Evolution) have been updated to support the revised discussion of human evolution.

- **Chapter 25 (Communication II: The Endocrine System and Chemical Messengers)**

  A short discussion has been added on the possible role of insulin in carbohydrate regulation in bivalves. Table 25.1 (Some Major Endocrine Tissues and Hormones) now lists additional hormones and their principal functions: peptide $YY_{3\text{-}36}$, adiponectin, irisin, and ghrelin. The "Evolutionary Insights" box has been expanded to include discussion of the evolutionary conservation of hormonal control of parental behavior and the effects of the resultant parental behavior on infant development.

## ACKNOWLEDGMENTS

We wish to thank reviewers who provided feedback and analysis of the revision plan for the 10th edition. In the midst of their busy teaching and research schedules, they took time to consider the revisions we were making to the table of contents and offer constructive advice that greatly improved the 10th edition. One person in particular has become a friend and valued advisor for us. As the 9th edition was being released, we began an ongoing email dialog with Todd Tupper of Northern Virginia Community College. His feedback, and feedback and questions from his students, have been especially valuable in the development of the 10th edition of *Zoology*. His comments and photographs were particularly valuable in the revisions for chapters 19 and 20, and he should receive most of the credit for the new "Wildlife Alert" on the Eastern diamondback rattlesnake in chapter 20. Thank you, Todd!

## REVIEWERS

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Jennifer Skillen, *Sierra College*
Todd Tupper, *Northern Virginia Community College*

## SPECIAL THANKS AND DEDICATIONS

The publication of a textbook requires the efforts of many people. We are grateful for the work of our colleagues at McGraw-Hill Education who have shown extraordinary patience, skill, and commitment to this textbook. Rebecca Olson, our Brand Manager, has helped shape *Zoology* through its recent editions and has skillfully managed *Zoology's* transition into the interactive electronic world. Her wisdom and

skill are evident in the 10th edition. Elizabeth Sievers, Lead Product Developer, coordinated all of the tasks involved with publishing this edition. We learned to expect her emails at all hours of the day, and we are still amazed at her ability to guide reviews, manuscript, figure and table revisions, and new photographs into their proper places in the final version you have in front of you. Thank you for your patience with us on the many occasions that we submitted revised material and then resubmitted the same with additional changes. We know that we must have caused you moments of frustration beyond words. Lisa A. Bruflodt served as Content Project Manager for this edition. We appreciate her efficiency and organization.

Most importantly, we wish to extend appreciation to our families for their patience and encouragement. Janice A. Miller lived through many months of planning and writing of the 1st edition of *Zoology*. She died suddenly two months before it was released. Our wives, Carol A. Miller and Donna L. Harley, have been supportive throughout the revision process. Carol, an accomplished musician, spent many hours proofreading *Zoology* for grammatical errors. Over the past 20 years, she has become a much better zoologist than her husband has become a musician—something about practicing got in his way. We appreciate the sacrifices that our families have made during the writing and revision of this text. We dedicate this book to our families.

# TEACHING AND LEARNING RESOURCES

## Help Your Students Prepare for Class

Digital resources can help you achieve your instructional goals—making your students more responsible for learning outside of class by meeting your students where they live: on the go and online. Use the text and digital tools to empower students to come to class more prepared and ready to engage!

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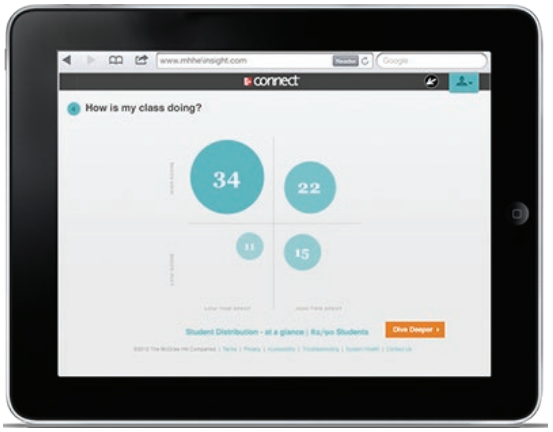


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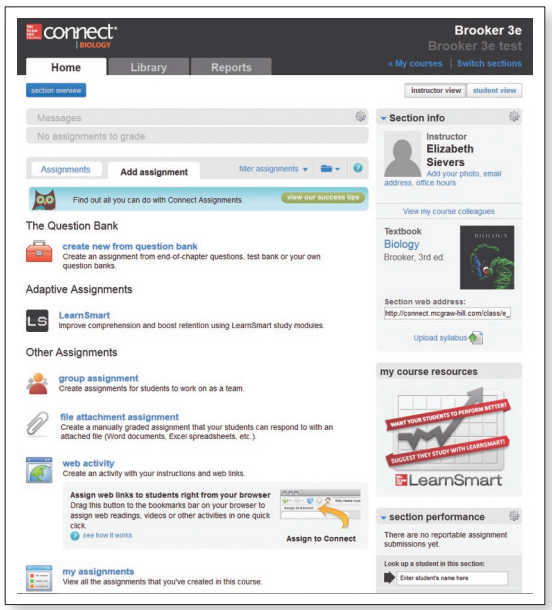


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Connect content can be assigned as homework before class to help students with basic concepts so they can better understand classroom presentations and projects. Quizzes taken after class can also evaluate their comprehension. These assignments support the rich assessment presented in the text so that students and professors can gauge the level of understanding of concepts and the mastery of skills.

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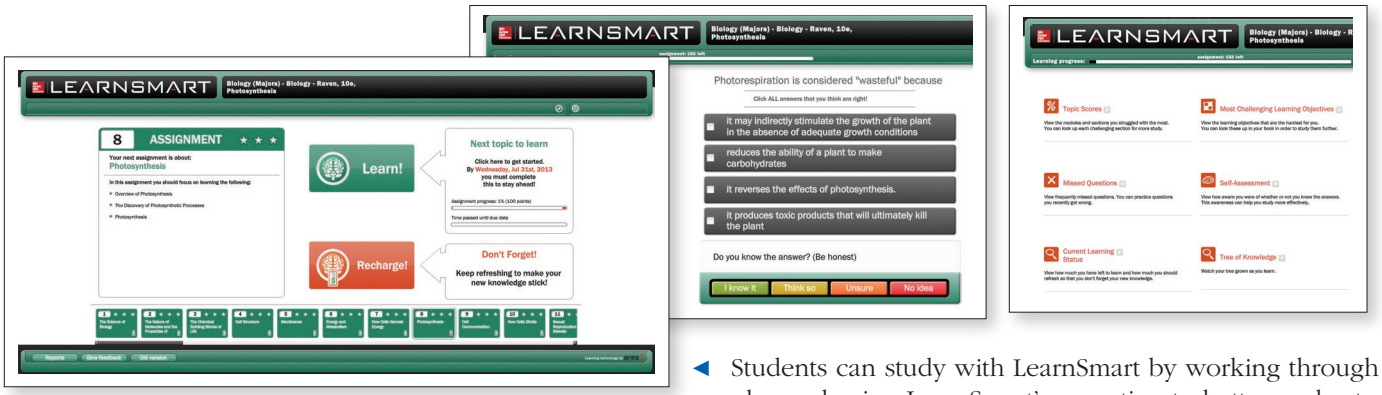


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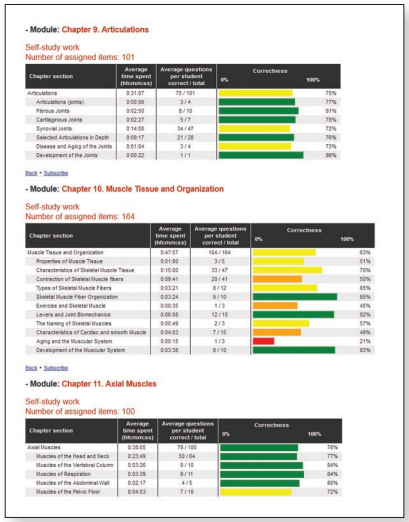


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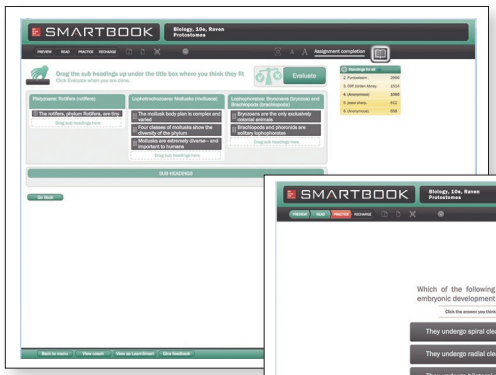
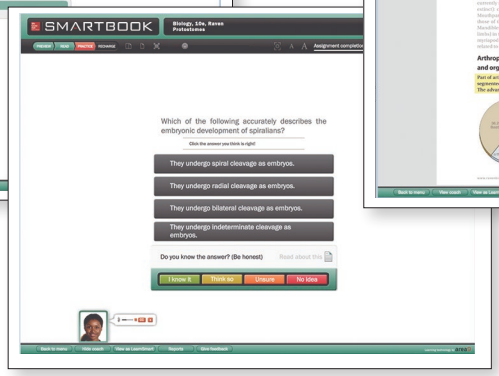
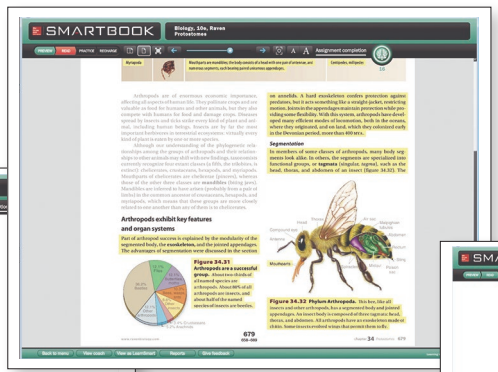


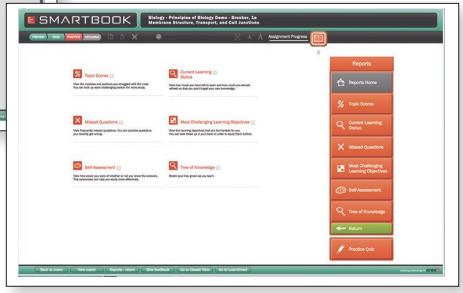

The Smartbook experience starts by previewing key concepts from the chapter and ensuring that you understand the big ideas.




SmartBook asks you questions that identify gaps in your knowledge. The reading experience then continuously adapts in response to the assessments, highlighting the material you need to review based on what you don't know.




The reports in SmartBook help identify topics where you need more work.



## Instructor's Resources

Within Connect you will find presentation materials and other resources for your course including:

- **Color Art** Full-color digital files of ALL illustrations in the text can readily be incorporated into lecture presentations, exams, or custom-made classroom materials.
- **Photos** Digital files of ALL photographs from the text can be reproduced for multiple classroom uses.
- **Animations** Full-color animation files that illustrate many different concepts covered in the study of zoology are available for use in creating classroom lectures, testing materials, or online course communication.
- **PowerPoint Lecture Outlines** Ready-made presentations that combine art, photos, and lecture notes are provided for each of the 29 chapters of the text. These outlines can be used as they are, or tailored to reflect your preferred lecture topics and sequences.
- **PowerPoint Figure Slides** For instructors who prefer to create their lectures from scratch, all illustrations, photos, and tables are preinserted by chapter into blank PowerPoint slides for convenience.

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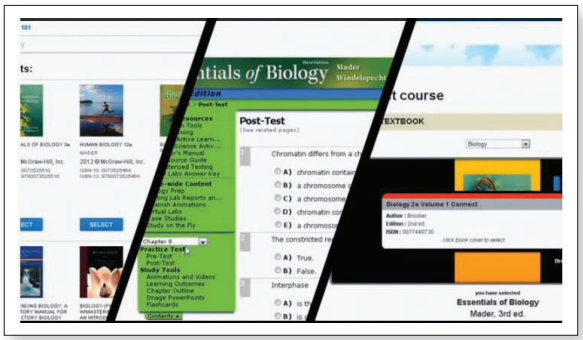
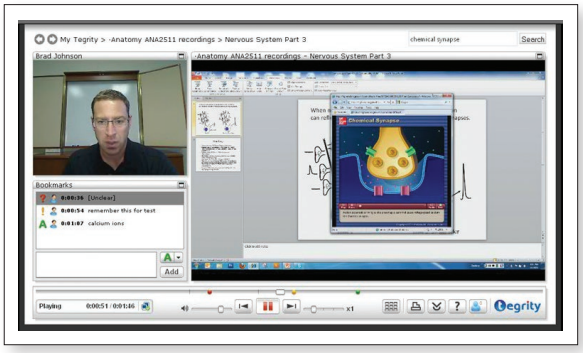
MH Campus® integrates all of your digital products from McGraw-Hill Education with your school LMS for quick and easy access to best-in-class content and learning tools.




Mc Graw Hill Education tegrity

Tegrity Campus is a fully automated lecture capture solution used in traditional, hybrid, "flipped classes" and online courses to record lessons, lectures, and skills. Its personalized learning features make study time incredibly efficient, and its ability to affordably scale brings this benefit to every student on campus. Patented search technology and real-time LMS integrations make Tegrity the market-leading solution and service. More than just a recorded lecture, Tegrity lets you search and bookmark content, take notes, and work with fellow classmates in order to make learning incredibly efficient.



## *GENERAL ZOOLOGY LABORATORY MANUAL*
**ISBN: 0-07-747929-7**

Seventh Edition, by Stephen A. Miller, is an excellent corollary to the text. This laboratory manual includes photographs and illustrations, activities on the scientific method, cladistics, ecological and evolutionary principles, and animal structure and function. The Seventh Edition includes major content updates in animal taxonomy and evolution. The pedagogy includes learning outcomes and numbered section headings. Learning outcomes are correlated with Learning Outcome Reviews and Analytical Thinking questions in worksheets. The pedagogy makes this laboratory manual more interactive and student learning more easily assessed. A **Laboratory Resource Guide** with information on materials and procedures as well as answers to worksheet questions accompanying the lab exercises can be found in the *Zoology* website.

*Generations of Luo fishermen on Lake Victoria, Africa have caught cichlid fish, including tilapia, as a mainstay of their economy. Recent introductions of the Nile perch* (Lates niloticus) *has changed the Lake Victoria ecosystem and the fishing economy of the lake.*

# 1

# Zoology: An Evolutionary and Ecological Perspective

## Chapter Outline



**Zoology** (Gr. *zoon,* animal + *logos,* to study) is the study of animals. It is one of the broadest fields in all of science because of the immense variety of animals and the complexity of the processes occurring within animals. There are, for example, more than 28,000 described species of bony fishes and more than 400,000 described (and many more undescribed) species of beetles! It is no wonder that zoologists usually specialize in one or more of the subdisciplines of zoology. They may study particular functional, structural, or ecological aspects of one or more animal groups (table 1.1), or they may choose to specialize in a particular group of animals (table 1.2).

Ichthyology, for example, is the study of fishes, and ichthyologists work to understand the structure, function, ecology, and evolution of fishes. These studies have uncovered an amazing diversity of fishes. One large family of bony fish, Cichlidae, contains 2,000 to 3,000 species. Members of this family include the familiar *Tilapia* species that grace our dinner plates and a host fish that hobbyists maintain in freshwater aquaria. Cichlid species range in length from 2.5 cm to 1 m and have an enormous variety of color patterns (figure 1.1), habitats, and body forms. Ichthyologists have described a wide variety of feeding habits in cichlids. These fish include algae scrapers like *Eretmodus* that nip algae with chisel-like teeth; insect pickers like *Tanganicodus;* and scale eaters like *Perissodus*. All cichlids have two pairs of jaws. The mouth jaws are used for scraping or nipping food, and the throat jaws are used for crushing or macerating food before it is swallowed.

Many cichlids mouth brood their young. A female takes eggs into her mouth after the eggs are spawned. She then inhales sperm released by the male, and fertilization and development take place within the female's mouth! Even after the eggs hatch, young are taken back into the mouth of the female if danger threatens (figure 1.2). Hundreds of variations in color pattern, body form, and behavior in this family of fishes illustrate the remarkable diversity present in one relatively small branch of the animal kingdom. Zoologists are working around the world to understand and preserve this enormous diversity.

**TABLE 1.1**
**EXAMPLES OF SPECIALIZATIONS IN ZOOLOGY**

| SUBDISCIPLINE | DESCRIPTION |
|---|---|
| Anatomy | Study of the structure of entire organisms and their parts |
| Cytology | Study of the structure and function of cells |
| Comparative Genomics and Bioinformatics | Study of the structure, function, and evolution of the genetic composition of groups of animals using computer-based computational methods |
| Ecology | Study of the interaction of organisms with their environment |
| Embryology | Study of the development of an animal from the fertilized egg to birth or hatching |
| Genetics | Study of the mechanisms of transmission of traits from parents to offspring |
| Histology | Study of tissues |
| Molecular biology | Study of subcellular details of structure and function |
| Parasitology | Study of animals that live in or on other organisms at the expense of the host |
| Physiology | Study of the function of organisms and their parts |
| Systematics | Study of the classification of, and the evolutionary interrelationships among, animal groups |

**TABLE 1.2**
**EXAMPLES OF SPECIALIZATIONS IN ZOOLOGY BY TAXONOMIC CATEGORIES**

| SUBDISCIPLINE | DESCRIPTION |
|---|---|
| Entomology | Study of insects |
| Herpetology | Study of amphibians and reptiles |
| Ichthyology | Study of fishes |
| Mammalogy | Study of mammals |
| Ornithology | Study of birds |
| Protozoology | Study of protozoa |

# 1.1 ZOOLOGY: AN EVOLUTIONARY PERSPECTIVE

## LEARNING OUTCOMES

1. Formulate a hypothesis regarding the evolutionary origin of contrasting color patterns in two closely related species of fish.
2. Explain how our taxonomic system is hierarchical.

(a)

(b)

**FIGURE 1.1**

**Cichlids.** Cichlids of Africa exist in an amazing variety of color patterns, habitats, and body forms. (*a*) This dogtooth cichlid (*Cynotilapia afra*) is native to Lake Malawi in Africa. The female of the species broods developing eggs in her mouth to protect them from predators. (*b*) The fontosa (*Cyphontilapia fontosa*) is native to Lake Tanganyika in Africa.

Animals share a common evolutionary past and evolutionary forces that influenced their history. Evolutionary processes are remarkable for their relative simplicity, yet they have had awesome effects on life-forms. These processes have resulted in an estimated 4 to 10 million species of animals living today. (Over 1 million animal species have been described.) Many more, about 90%, existed in the past and have become extinct. Zoologists must understand evolutionary processes if they are to understand what an animal is and how it originated.

## Evolutionary Processes

**Organic evolution** (L. *evolutus,* unroll) is change in the genetic makeup of populations of organisms over time. It is the source of animal diversity, and it explains family relationships within animal groups. Charles Darwin published convincing evidence of evolution in 1859 and proposed a

**FIGURE 1.2**

**A Scale-Eating Cichlid.** Scale-eaters (*Perissodus microlepis*) attack from behind as they feed on scales of prey fish. Two body forms are maintained in the population. In one form, the mouth is asymmetrically curved to the right and attacks the prey's left side. The second form has the mouth curved to the left and attacks the prey's right side. Both right- and left-jawed forms are maintained in the population and prey do not become wary of being attacked from one side. *Perissodus microlepis* is endemic (found only in) to Lake Tanganyika. A male with its brood of young is shown here.


**FIGURE 1.3**

**Lakes Victoria, Kivu Tanganyika, and Malawi.** These lakes have cichlid populations that have been traced by zoologists to an ancestry that is approximately 200,000 years old. Cichlid populations originated in Lake Kivu and Lake Tanganyika and then spread to the other lakes.

mechanism that could explain evolutionary change. Since that time, biologists have become convinced that evolution occurs. The mechanism proposed by Darwin has been confirmed and now serves as the nucleus of our broader understanding of evolutionary change (*see chapters 4 and 5*).

Understanding how the diversity of animal structure and function arose is one of the many challenges faced by zoologists. For example, the cichlid scale eaters of Africa feed on the scales of other cichlids. They approach a prey cichlid from behind and bite a mouthful of scales from the body. The scales are then stacked and crushed by the second set of jaws and sent to the stomach and intestine for protein digestion. Michio Hori of Kyoto University found that there were two body forms within the species *Perissodus microlepis*. One form had a mouth that was asymmetrically curved to the right, and the other form had a mouth that was asymmetrically curved to the left. The asymmetry results in right-jawed fish approaching and biting scales from the left side of their prey and the left-jawed fish approaching and biting scales from the right side of their prey. Both right- and left-jawed fish have been maintained in the population; otherwise, the prey would eventually become wary of being attacked from one side. The variety of color patterns within the species *Topheus duboisi* has also been explained in an evolutionary context. Different color patterns arose as a result of the isolation of populations among sheltering rock piles separated by expanses of sandy bottom. Breeding is more likely to occur within their isolated populations because fish that venture over the sand are exposed to predators.

## Animal Classification and Evolutionary Relationships

Evolution not only explains why animals appear and function as they do, but also explains family relationships within the animal kingdom. Zoologists have worked for many years to understand the evolutionary relationships among the 2,000 to 3,000 cichlid species. Groups of individuals are more closely related if they share more of their genetic material (DNA) with each other than with individuals in other groups. (You are more closely related to your brother or sister than to your cousin for the same reason. Because DNA determines most of your physical traits, you will more closely resemble your brother or sister.) Genetic studies suggest that the oldest populations of African cichlids are found in Lakes Tanganyika and Kivu, and from these the fish invaded African rivers and Lakes Malawi, Victoria, and other smaller lakes (figure 1.3). The history of these events is beginning to be understood and represents the most rapid known origin of species of any animal group. For example, the origin of Lake Victoria's cichlid species has been traced to an invasion of ancestral cichlids, probably from Lake Kivu approximately 100,000 years ago. Today, Lake Kivu has only 15 species of cichlids. This invasion continued up to about 40,000 years ago when volcanic eruptions isolated the fauna of Lakes Kivu and Victoria. That time period is long from the perspective of a human lifetime, but it is a blink of the eye from the perspective of evolutionary time. There is firm geological evidence that Lake