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 seventh edition with this privilege, and the responsibility for content integrity, in mind.

The preparation of the seventh 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 seventh 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 previous editions was well received by users as being less expensive and easily adapted to a one-semester course format. The seventh 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 and sixth editions, 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 seventh 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. 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, a second set of themed boxed readings (in addition to "Wildlife Alerts") entitled "Evolutionary Insights" was added to the sixth edition and has been expanded in this new edition. 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, the debates that occur among taxonomists who try to sort out evolutionary relationships within animal groups, and the evolution of animal organ systems.

To help students understand that science is a process, not just a body of facts, a new type of boxed reading has been added to the seventh edition. These "How Do We Know" boxes highlight research results that provide insight into biological processes. For example, chapter 3 has a box entitled "How Do We Know About the Function of Genes—Mutagenesis Screening?" This box discusses how biologists use mutations as a tool for investigating the function of genes. Chapter 14 has a box entitled "How Do We Know about Spider Silk?" This box discusses methods for measuring the tensile strength and elasticity of spider silk and the possible uses of engineered silk. The boxed readings in each chapter are listed following the table of contents.

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 Seventh 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 Seventh Edition

Major additions to the seventh 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 to 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.

- "How Do We Know" boxes appear in most chapters. These boxes provide insight into how biologists have arrived at conclusions regarding a variety of biological processes.
- "Evolutionary Insights" boxes have been expanded into Part Three. These boxes describe ideas regarding the evolution of animal organ systems and processes.
- All chapters have been carefully edited. All chapter revisions include minor to substantial changes in wording, artwork, photographs, and content. The following chapters have substantial changes.
  - Chapter 4 has expanded coverage of molecular biology and phylogeny.
  - Chapter 5 has expanded coverage of the role of mutations in evolutionary change and documentation of sympatric speciation events.
  - Chapter 8 has been completely reorganized by the inclusion of the most recent taxonomic relationships among protists as revealed by molecular studies. A new figure has been developed that shows the tentative phylogeny of the protozoan-like eukaryotes based on 18S rRNA sequence comparisons.
  - Chapter 11 has been revised to reflect the division of the aschelminths into lophotrochozoan and ecdysozoan groupings.
  - Chapter 18 has updated taxonomy and coverage of the evolution of tetrapod limbs, including evidence from both paleontology and Hox studies.
  - Chapter 19 now includes expanded coverage of amphibian skin glands and feeding.
  - Chapter 20 includes updated taxonomy, an expanded discussion of turtle navigation, and new information on endangered turtles.
  - Chapter 21 has been revised to include more information on the evolution of birds and feathered dinosaurs. It also includes the latest information on feather development and evolution. The new title of this chapter, "Birds: Reptiles by Another Name," reflects the content revisions present in this chapter.
  - Chapter 22 has undergone major revision with the addition of a new section on human evolution. New information on the evolution of mammary glands is also included.
  - Chapter 23 includes new information on the function of vitamin D_3 in the skin, the molecular basis of ameboid movement, and animal movement.
  - Chapter 24 contains new information on the role of graded potentials in the nervous system. The section on the sense of smell has been completely rewritten based on new findings in the physiology of olfaction.
  - Chapter 25 has a new section on autocrine and paracrine agents, and newly discovered hormones have been added to the table that describes major mammalian tissues and hormones.
- 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/millerharley7e

Acknowledgments

We wish to thank the reviewers who provided detailed analysis of the text during its 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 the seventh edition.

Reviewers

Steve K. Alexander, *University of Mary Hardin-Baylor*
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Elise Van Ginkel, *Madison Area Technical College*

The publication of a textbook 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, our Publisher, has helped shaped

Zoology from its earliest planning stages. Her wisdom and skill are evident in the seventh edition. Debra Henricks, Developmental Editor, worked with this textbook on the latest revision. We are grateful for her skill in coordinating many of the tasks involved with publishing this edition of *Zoology*. Debra kept us on schedule and kept the production moving in the plethora of directions that are nearly unimaginable to us. April Southwood served as Project Manager for this edition. We appreciate her efficiency and organization. We also thank Carrie Barker for proofreading the entire textbook.

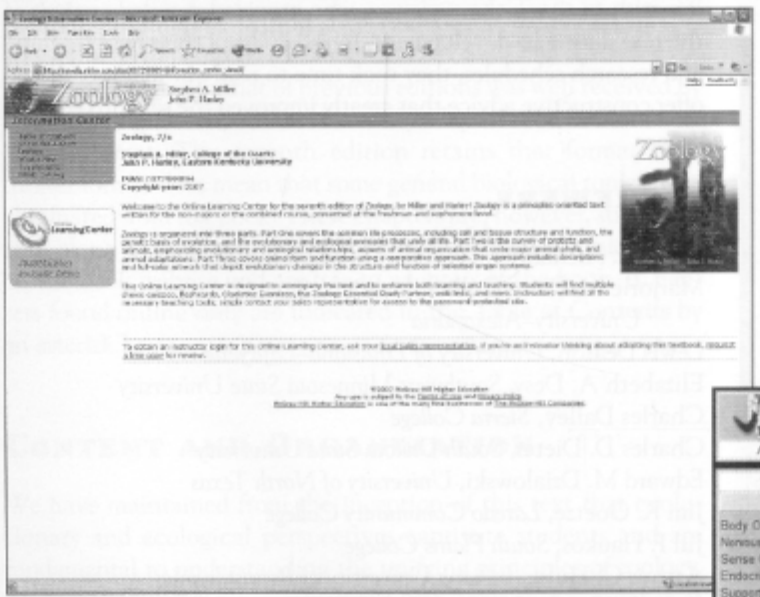
Finally, but most importantly, we wish to extend appreciation to our families for their patience and encouragement. Janice A. Miller lived with this text through many months of planning and writing. She died suddenly two months before the first edition was released. Our wives, Carol A. Miller and Donna L. 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

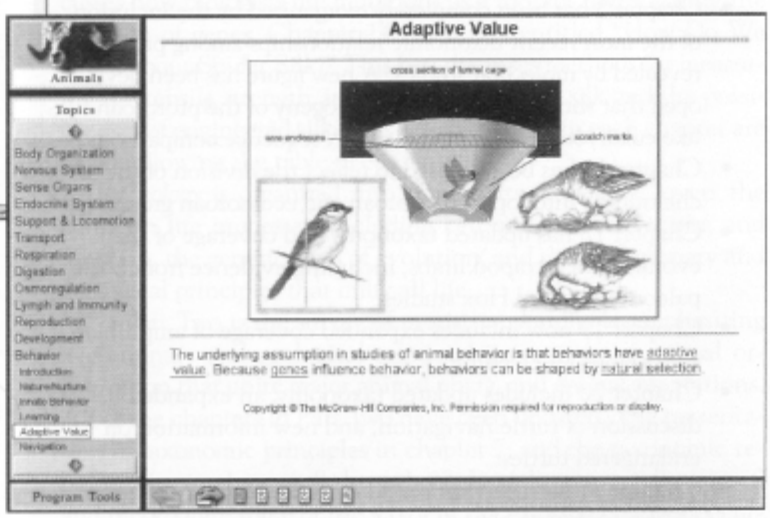
Supplementary Materials

Zoology Online Learning Center www.mhhe.com/millerharley7e

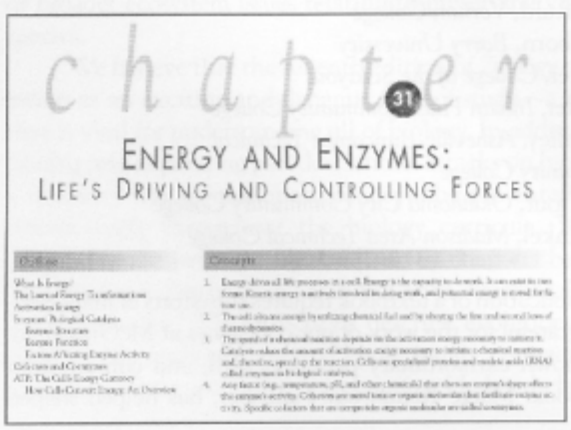


This convenient website takes studying to a whole new level. **Students** will find multiple choice quizzing, key term flashcards, web links, interactive cladistics exercises, boxed readings, and more!

Instructors will appreciate a password-protected **Instructor's Manual**, **Laboratory Resource Guide**, and access to all of the **illustrations, photographs, and tables** from the text organized by chapter in convenient PowerPoint files.



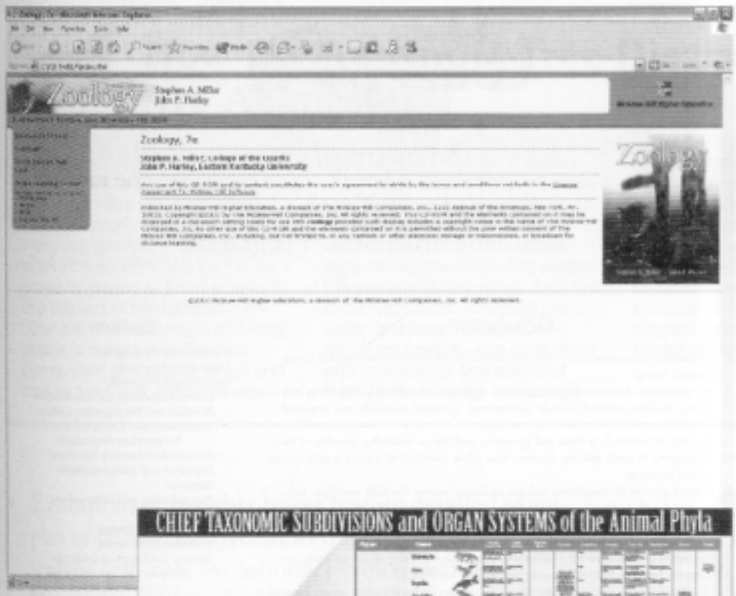
The *Zoology* Online Learning Center is also home to the **Essential Study Partner.** This unique learning tool allows students to test their understanding of important zoology concepts through the use of animations, learning activities, quizzing, and interactive diagrams.



Additional Chapters

The following chapters (not printed in the text) are available in PDF format:

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



Instructor's Manual

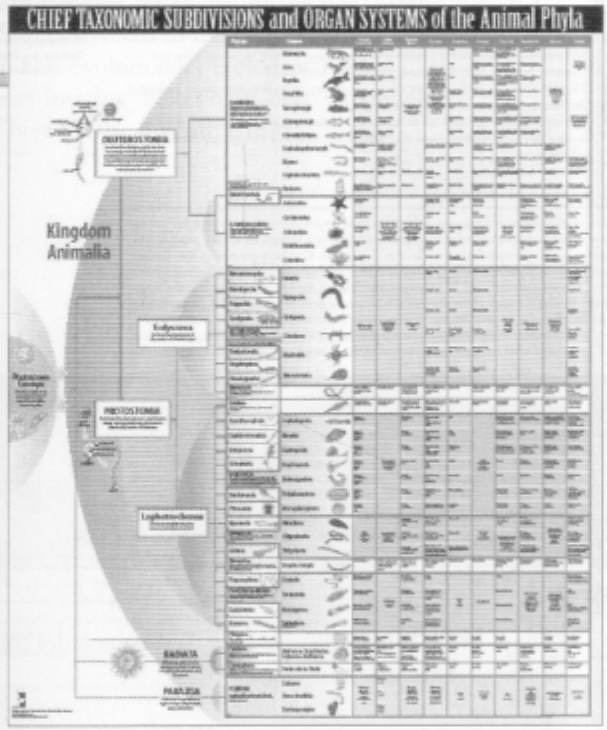
Instructors will find lecture outlines and enrichment, teaching suggestions, and suggested readings for each chapter. The Instructor's Manual can be accessed via the password-protected portion of the *Zoology* Online Learning Center as well as the Instructor's Testing & Resource CD-ROM. (Prepared by Jim Goetze, *Laredo Community College*.)

Instructor's Testing & Resource CD-ROM

This cross-platform CD-ROM includes an Instructor's Manual and test bank utilizing McGraw-Hill's EZ Test software. EZ Test is a flexible and easy-to-use electronic testing program that allows instructors to create tests in a wide variety of question types. Instructors may use the test questions provided by McGraw-Hill, add their own questions, create multiple versions of a test, and export tests for use with course management systems such as WebCT, BlackBoard, or PageOut.

General Zoology Laboratory Manual

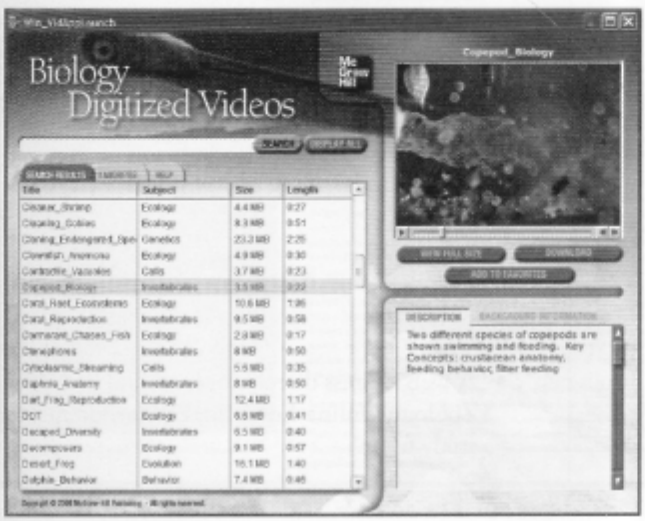
Fifth Edition, by Stephen A. Miller, is an excellent corollary to the text. This laboratory manual includes photographs and illustrations, activities on the scientific method, cladistics, ecological and evolutionary principles, and animal structure and function. A **Laboratory Resource Guide** with information on materials and procedures as well as answers to worksheet questions accompanying the lab exercises can be found in the *Zoology* Online Learning Center.



Additional Resources

Study Aid/Poster

This 30″ × 36″ poster presenting the Chief Taxonomic Subdivisions and Organ Systems of the Animal Phyla is a great reference/study tool for students!



NEW! McGraw-Hill: *Biology Digitized Video Clips*

McGraw-Hill is pleased to offer digitized biology video clips on DVD! Licensed from some of the highest-quality science video producers in the world, these brief clips illustrate key biological concepts and processes. Video segments include: alligator predation, clam locomotion, Darwin's finches, frog metamorphosis, mitosis, parasitic wasps, and much more! ISBN-13: 978-0-07-312155-0 (ISBN-10: 0-07-312155-X)

Guided Tour

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

- **Chapter Concepts** highlight the main points of the chapter.

Chapter 22

Mammals:

Specialized Teeth, Hair, Endothermy, and Viviparity

Concepts

1. Mammalian characteristics evolved gradually over a 200-million-year period in the synapsid lineage.
2. Two subclasses of mammals evolved during the Mesozoic era—the Prototheria and the Theria. Modern mammals include monotremes, marsupial mammals, and placental mammals.
3. The skin of mammals is thick and protective and has an insulating covering of hair.
4. Adaptations of teeth and the digestive tract allow mammals to exploit a wide variety of food resources.
5. Efficient systems for circulation and gas exchange support the high metabolic rate associated with mammalian endothermy.
6. The brain of mammals has an expanded cerebral cortex that processes information from various sensory structures.
7. Metanephric kidneys permit mammals to excrete urea without excessive water loss.
8. Complex behavior patterns enhance mammalian survival.
9. Most mammals are viviparous and have reproductive cycles that help ensure internal fertilization and successful development.
10. Primate evolution included the evolution of the apes and humans. Human evolution is documented by evidence from the fossil record, molecular biology, and numerous other sources.

Outline

Evolutionary Perspective
Diversity of Mammals
Evolutionary Pressures
External Structure and Locomotion
Nutrition and the Digestive System
Circulation, Gas Exchange, and Temperature Regulation
Nervous and Sensory Functions
Excretion and Osmoregulation
Behavior
Reproduction and Development
Human Evolution
Who Are the Primates
Evolution of Hominins
Cultural Evolution—A Distinctly Human Process of Change

Evolutionary Perspective

The fossil record that documents the origin of the mammals from ancient reptilian ancestors is very complete and relatively uncontroversial. It is being used to test, and has confirmed, many macroevolutionary theories (*see chapter 4*). The beginning of the Tertiary period, about 70 million years ago, was the start of the "age of mammals." It coincided with the extinction of many reptilian lineages, which led to the adaptive radiation of the mammals. Tracing the roots of the mammals, however, requires returning to the Carboniferous period, when the synapsid lineage diverged from other amniote lineages (*see figure 20.3*).

Mammalian characteristics evolved gradually over a period of 200 million years (figure 22.13). Most of what we know about early synapsids is based on skeletal characteristics. The

development of regions of the brain that supported the capacity for instruction, discussion, and bargaining. As populations grew, humans learned that natural resources are not unlimited. Small campsites became permanent communities as humans learned to cultivate grain crops to supplement hunting and gathering. This was the beginning of the agricultural revolution, which was in full swing in the Fertile Crescent of the Mideast 10,000 years ago. These technologies quickly spread to China about seven thousand years ago and to Central America about five thousand years ago. The domestication of animals and the advent of metallurgy about eight thousand years ago made both agriculture and warfare more efficient. Bountiful agricultural harv
fewer people to supply the needs of large p
in a new direction, one that has changed
for all times. Industrialization has prod
scars, like the imminent extinction of ma
trial Revolution is a reminder that big
cultural evolution do share a common fe
guaranteed by either. Finally, we are in
revolution—the genetic revolution. We
experience its influence. Only the adv
perspective will reveal its full impact.

Summary

1. Mammalian characteristics evolved from the synapsid lineage over a period of about 200 million years. Mammals evolved from a group of synapsids called therapsids.
2. Modern mammals include the monotremes, marsupials, and placental mammals.
3. Hair is uniquely mammalian. It functions in sensory perception, temperature regulation, and communication.
4. Mammals have sebaceous, sudoriferous, scent, and mammary glands.
5. The teeth and digestive tracts of mammals are adapted for different feeding habits. Flat, grinding teeth and fermentation structures for digesting cellulose characterize herbivores. Predatory mammals have sharp teeth for killing and tearing prey.
6. The mammalian heart has four chambers, and circulatory patterns are adapted for a vigorous development.
7. Mammals possess a diaphragm that alters intrathoracic pressure, which helps ventilate the lungs.
8. Mammalian thermoregulation involves metabolic heat production, insulating pelage, and behavior.
9. Mammals react to unfavorable environments by migration, winter sleep, and hibernation.
10. The nervous system of mammals is similar to that of other vertebrates. Olfaction and hearing were important for early mammals. Vision, hearing, and smell are the dominant senses in many modern mammals.
11. The nitrogenous waste of mammals is urea, and the kidney is adapted for excreting a concentrated urine.
12. Mammals have complex behavior to enhance survival. Visual cues, pheromones, and auditory and tactile cues are important in mammalian communication.
13. Most mammals have specific times during the year when reproduction occurs. Female mammals have estrus or menstrual cycles. Monotremes are oviparous. All other mammals nourish young by a placenta.
14. Apes diverged from other primates about 25 million years ago. The human lineage is traced back about 7 million years to its divergence from that of chimpanzees. An excellent fossil record documents the changes that took place in our evolutionary history.

Selected Key Terms

cecum (p. 368)
delayed fertilization (p. 375)
dental formula (p. 367)
diaphragm (p. 369)
embryonic diapause (p. 375)
estrus cycle (p. 373)
gestation period (p. 375)
heterodont (p. 366)
hibernation (p. 371)
homodont (p. 366)
mammary glands (p. 365)
placenta (p. 362)
scent or musk glands (p. 365)
sebaceous (oil) glands (p. 365)
sudoriferous (sweat) glands (p. 365)
winter sleep (p. 371)

Critical Thinking Questions

1. Why is tooth structure important in the study of mammals?
2. What does the evolution of secondary palates have in common with the evolution of completely separated, four-chambered hearts?
3. Why is classifying mammals by feeding habits not particularly useful to phylogenetic studies?
4. Under what circumstances is endothermy disadvantageous for a mammal?
5. Discuss the possible advantages of embryonic diapause for marsupials that live in climatically unpredictable regions of Australia.
6. What is induced ovulation? Why might it be adaptive for a mammal?
7. Do you think tool use selected for increased intelligence or increased intelligence (perhaps selected for by social behaviors) promoted tool use? Explain.

Online Learning Center

The Zoology Online Learning Center is a great place to check your understanding of chapter material. Visit www.mhhe.com/miller-harley7e for access to a variety of helpful learning tools!

- A list of **Selected Key Terms** includes page references for further review.

- **Critical Thinking Questions** help students to synthesize chapter information.

- A web address directs students and instructors to the **Zoology Online Learning Center** for chapter-specific study tools.

How Do We Know Tree Diagrams Are Accurate?

The grouping of organisms by characters is not arbitrary. If one were to classify screws based on length, head type, and metal composition, one would begin at an arbitrary starting point, for example by placing all brass screws in one pile and all steel screws in another pile. Then one might arbitrarily decide to subgroup within each composition grouping by length and then by head type. Someone else could reclassify the same screws using length as a starting point and end up with an entirely different set of nesting relationships. Neither classification would be incorrect because the characteristics used in this exercise do not reflect ancestral or derived states. Biological classification is unique. Not all starting points are correct—one must begin with an ancestral character and work upward through increasingly derived characters. Modern taxonomic methods involve testing and retesting data from different sources (e.g., morphological and various molecular sources). The relationships derived from all sources of evidence should be very similar. This congruence is evidence that a tree diagram accurately depicts evolutionary relationships.

- **NEW! How Do We Know** boxes provide an understanding of how biologists have arrived at conclusions regarding a variety of biological processes.

- **Evolutionary Insights** boxes feature detailed examples of principles covered in the chapter and offer insight into how evolutionary biology works. "Evolutionary Insights" boxes have been expanded into Part Three for the seventh edition.

EVOLUTIONARY INSIGHTS

The Early Evolution of the Vertebrate Limb

Nowhere are evolutionary transitions more clearly documented than in the vertebrate lineage. It is important to remember that documenting evolutionary transitions does not necessarily mean that we trace the exact animal species involved in a series of evolutionary changes. Instead, paleontologists and biologists look for transitional stages in the development of structures represented in fossil and developmental records. One example is the documentation of changes in limb structure in the fish-to-amphibian transition.

The basic arrangement of bones in the limbs of terrestrial vertebrates was presented in chapter 4 (see figure 4.10) as an example of the concept of homology. In the vertebrate limb, a single proximal element, the humerus (femur in the hindlimb), articulates with two distal elements, the radius (fibula) and ulna (tibia). These are followed more distally by the wrist bones, the carpals (ankle, tarsals), and then the bones of the hand, the metacarpals (foot, metatarsals) and phalanges. With the exception of the bones of the hand, this basic pattern can be observed in

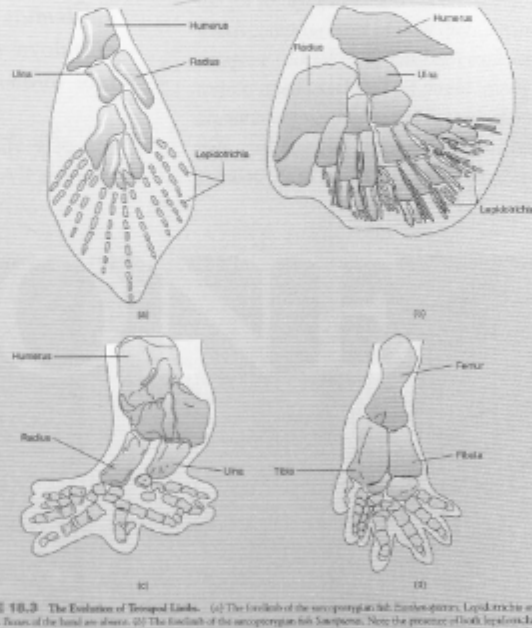


FIGURE 15.3 The Evolution of Tetrapod Limbs. (a) The forelimb of the sarcopterygian fish Eusthenopteron. Lepidotrichia are dermal elements not in tetrapods. Bones of the hand are absent. (b) The forelimb of the sarcopterygian fish Sauripterus. Note the presence of both lepidotrichia and eight digit-like elements in the distal portion of the fin. (c) The forelimb of the tetrapod Acanthostega had eight digits. (d) The hindfoot of the tetrapod Ichthyostega had seven. The forelimb structure is unknown.

(Continued)

- **Wildlife Alert** boxes discuss issues related to endangered and threatened species of animals.

WILDLIFE ALERT

The Karner Blue Butterfly (*Lycaeides melissa samuelis*)

VITAL STATISTICS

Classification: Phylum Arthropoda, class Hexapoda, order Lepidoptera

Range: New England to the Great Lakes Region (historical); West to Great Lakes Region (current)

Habitat: Sand plains, oak savannas, or pine barrens in association with wild lupine

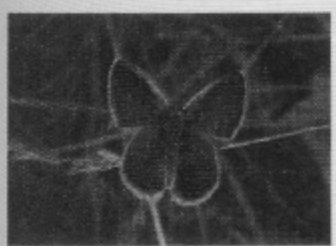
Number remaining: Less than 1% of its population in 1900

Status: Endangered

NATURAL HISTORY AND ECOLOGICAL STATUS

The male Karner blue butterfly is silvery or dark blue with a narrow black margin on the upper surface of the wing (box figure 15.1). The female has grayish brown wings with a dark border and orange lunules.

The Karner blue butterfly lives in sand plains, oak savannas, or pine barrens. These habitats are patchily distributed across the northeastern and midwestern parts of the United States (box figure 15.2). They consist of grassland areas with scattered trees and are maintained in their natural state by periodic disturbances from fire. Without fire disturbance, shrub and tree vegetation soon overtakes these habitats. These grassy islands are the home of a plant called wild lupine (*Lupinus perennis*), which is the sole food source for caterpillars of the Karner blue butterfly.



BOX FIGURE 15.1 Male Karner Blue Butterfly (*Lycaeides melissa samuelis*).

BOX FIGURE 15.2 Approximate Distribution of Karner Blue Butterfly (*Lycaeides melissa samuelis*).

In the spring, Karner blue eggs, which have overwintered, hatch, and the larvae feed on wild lupine. By the end of May, the larvae have grown and pupated. Adults emerge and mate, and the females lay eggs on or near wild lupine. Eggs quickly hatch, and the larvae feed, grow, and pupate. By the end of July, the second generation of adults emerges and mates. This generation of females lays eggs among the plant litter near wild lupine. These eggs remain dormant until the following April. After August, no adults or larvae of the Karner blue butterfly are found.

The endangered status of the Karner blue butterfly is a result of habitat loss. As humans develop land, they quickly bring fires under control. Fire control allows a wild lupine habitat to overgrow with shrubs and trees, making it no longer suitable for wild lupine or the Karner blue butterfly. Habitat loss is devastating for a species, especially if habitat distribution is patchy. Patchy distribution does not provide corridors for movement and dispersal to new areas. When a patch of habitat is lost, the species present in that patch usually have no place to go. Even when patches of habitat are not entirely lost, but simply broken up by human development, dispersal within the habitat may be nearly impossible. The construction of roads, buildings, and off-road vehicle trails presents formidable obstacles for a species as fragile and specialized as the Karner blue butterfly.

This example vividly illustrates an organism's dependence on habitat preservation. The struggle of the Karner blue butterfly is a subtle reminder that something is wrong in our treatment of the land. Protecting pine barrens and oak savannas will improve the chances for the survival of wild lupine, the Karner blue butterfly, and other species specialized for life in these fragile habitats.