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.

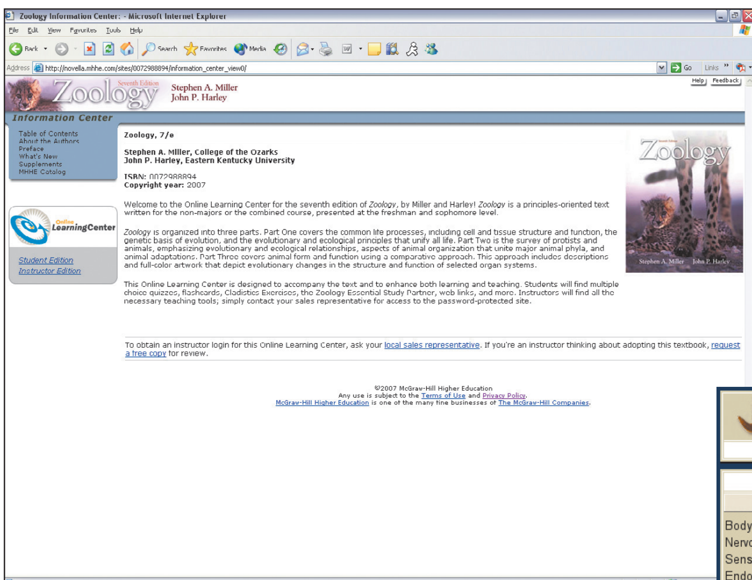
Finally, but most importantly, we wish to extend appreciation to our families for their patience and encouragement. Janice A. Miller lived with this text through many months of planning and writing. She died suddenly two months before the first edition was released. Our wives, Carol A. Miller and Donna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

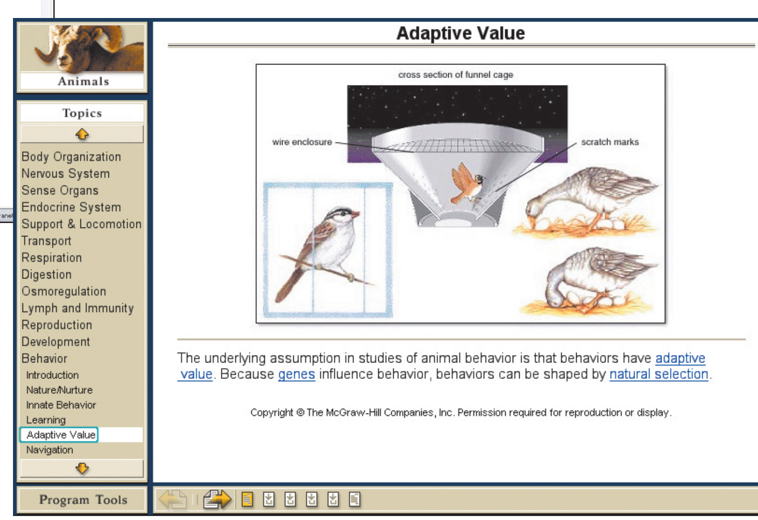
Zoology Online Learning Center www.mhhe.com/millerharley7e

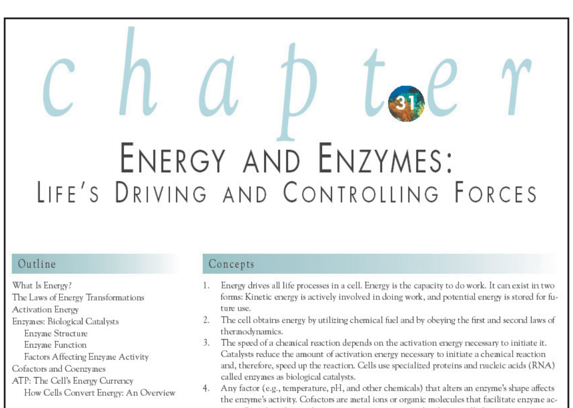


This convenient website takes studying to a whole new level. **Students** will find multiple choice quizzing, key term flashcards, web links, interactive cladistics exercises, boxed readings, and more!

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:

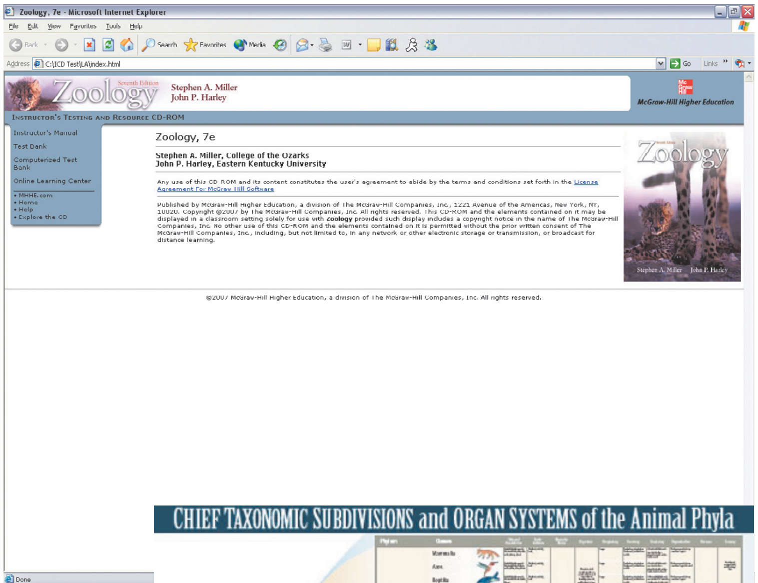
Chapter 30: The Chemical Basis of Animal Life

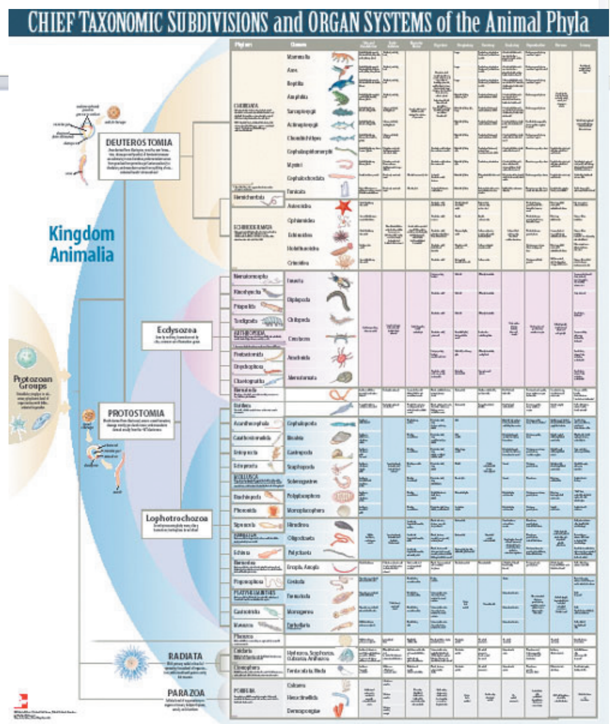
Chapter 31: Energy and Enzymes: Life's Driving and Controlling Forces

Chapter 32: How Animals Harvest Energy Stored in Nutrients

Chapter 33: Embryology

Chapter 34: Animal Behavior





Title	Subject	Size	Length
Cleaner_Shrimp	Ecology	4.4 MB	0:27
Cleaning_Gobies	Ecology	8.3 MB	0:51
Cloning_Endangered_Spe	Genetics	23.3 MB	2:25
Clownfish_Anemone	Ecology	4.9 MB	0:30
Contractile_Vacuoles	Cells	3.7 MB	0:23
Copepod_Biology	Invertebrates	3.6 MB	0:22
Coral_Reef_Ecosystems	Ecology	10.6 MB	1:06
Coral_Reproduction	Invertebrates	9.5 MB	0:58
Cormorant_Chases_Fish	Ecology	2.8 MB	0:17
Ctenophores	Invertebrates	8 MB	0:50
Cytoplasmic_Streaming	Cells	5.6 MB	0:35
Daphnia_Anatomy	Invertebrates	8 MB	0:50
Dart_Frog_Reproduction	Ecology	12.4 MB	1:17
DDT	Ecology	6.6 MB	0:41
Decapod_Diversity	Invertebrates	6.5 MB	0:40
Decomposers	Ecology	9.1 MB	0:57
Desert_Frog	Evolution	16.1 MB	1:40
Dolphin_Behavior	Behavior	7.4 MB	0:46

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.

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

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 22.1). Most of what we know about early synapsids is based on skeletal characteristics. The

CHAPTER 22 Mammals: Specialized Teeth, Hair, Endothermy, an

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 produ scars, like the imminent extinction of ma trial Revolution is a reminder that bio cultural evolution do share a common fe guaranteed by either. Finally, we are in revolution—the *genetic revolution*. We a 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 viviparous 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/millerharley7e 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

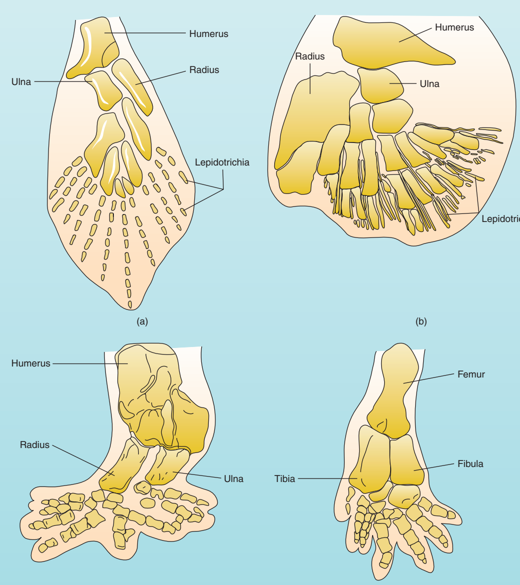


FIGURE 18.3 The Evolution of Tetrapod Limbs. (*a*) The forelimb of the sarcopterygian fish *Eusthenopteron*. Lepidotrichia are dermal elements not in tetrapods. Bones of the hand are absent. (*b*) The forelimb of the sarcopterygian fish *Sauripterus*. Note the presence of both lepidotrichia and eight digit-like elements in the distal portion of the fin. (*c*) The forelimb of the tetrapod *Acanthostega* had eight digits. (*d*) The hindlimb of the tetrapod *Icthyostega* had seven The forelimb structure is unknown.

(Continued)

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), Western Great Lakes Region (current)

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

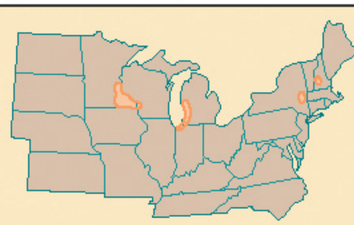
Number remaining: Less than 1% of its population in 1900

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 bands.

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 overruns 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 15.2 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.

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

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