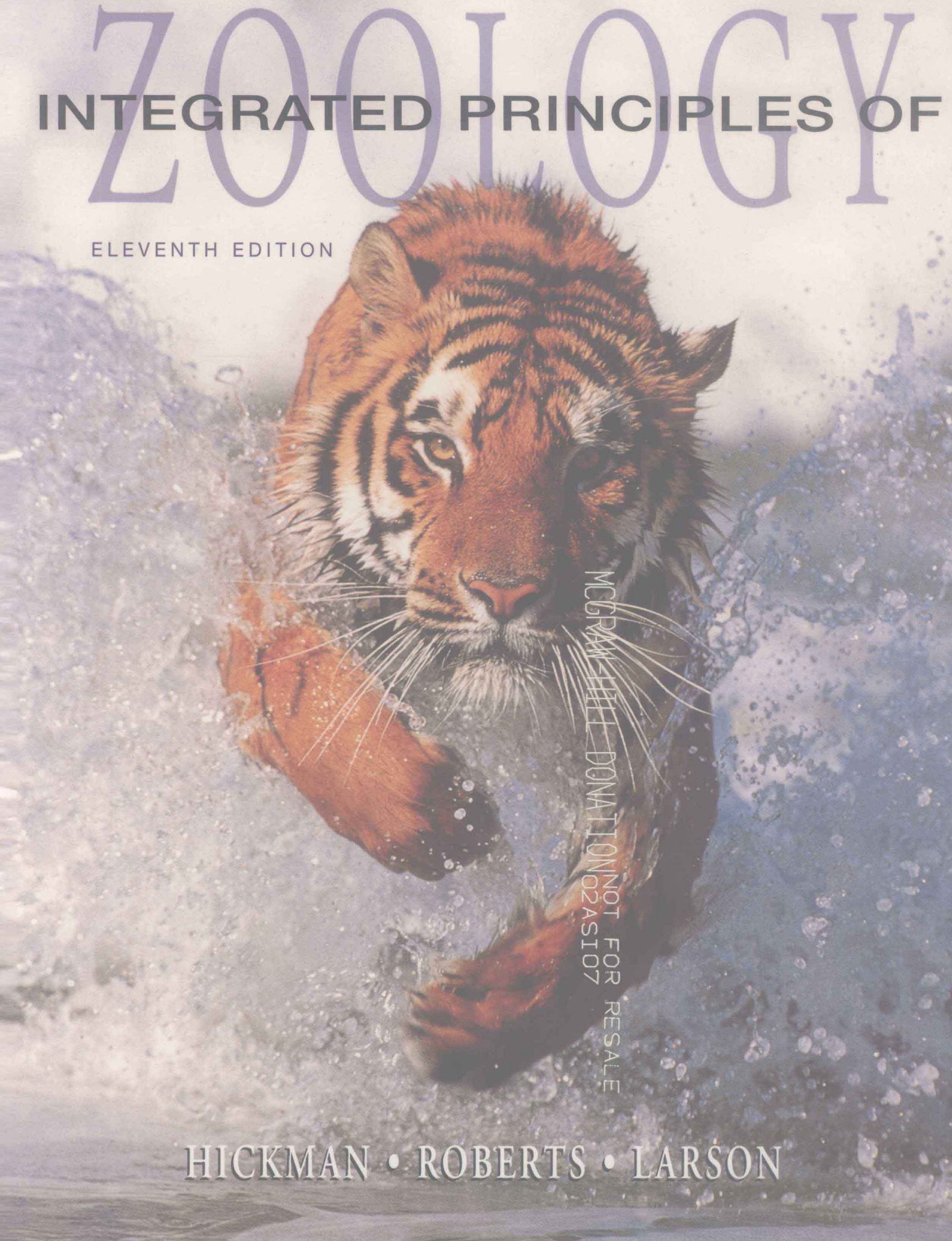
INTEGRATED PRINCIPLES OF ZOOLOGY

ELEVENTH EDITION



HICKMAN • ROBERTS • LARSON

INTEGRATED PRINCIPLES OF ZOOLOGY

ELEVENTH EDITION

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Over the years, Dr. Hickman has led many field trips to the Galápagos Islands. His current research is on intertidal zonation and marine invertebrate systematics in the Galápagos. He has published two field guides in the Galápagos Marine Life Series for the identification of echinoderms and marine molluscs. His interests include scuba diving, woodworking, and participating in chamber music ensembles.

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Dr. Larson has an active research laboratory that uses DNA sequences to examine evolutionary relationships among vertebrate species, especially in salamanders, lizards, fishes, and primates. The students in Dr. Larson's laboratory have participated in zoological field studies around the world, including projects in Africa, Asia, Australia, Madagascar, North America, South America, and the Caribbean Islands. Dr. Larson has authored numerous scientific publications, and has edited for the journals *Evolution*, *Molecular Phylogentics* and *Evolution, and Systematic Biology.* Dr. Larson serves as an academic advisor to undergraduate students and supervises the undergraduate biology curriculum at Washington University.

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PREFACE

PREAMBLE

How does one direct the revision of a classic? As the Editor faced with the responsibility of instructing authors to improve further an incredibly successful and comprehensive text, I thought the answer to be a special focus on "contemporary." The eleventh edition is a bridge to the twenty-first century in teaching general zoology. It combines classical coverage of animal biology with new research, new phylogenies, and new technologies.

Students using this text will be exposed to the most current coverage of zoology in addition to being the first to have integrated multimedia as part of their studies. ***Integrated Principles of Zoology*** is supported by a tutorial CD-ROM, the Essential Study Partner; an Online Learning Center Web site with additional readings, animations, and quizzing; and a Visual Resource Library CD-ROM that contains 1,000 line drawings and photos to enhance lecture presentations.

Along with the authors, our editorial team strives to produce the finest educational resources to support your instructional and educational objectives. I invite you to read, enjoy, and respond to a classic of the twenty-first century!

Margaret J. Kemp
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Integrated Principles of Zoology is a college text adaptable to any introductory course in zoology. This eleventh edition, as with previous editions, describes the diversity of animal life and the fascinating adaptations that enable animals to inhabit nearly all conceivable ecological niches. We retain in this revision the basic organization of the tenth edition and its distinctive features, especially emphasis on the principles of evolution and zoological science. Also retained are several pedagogical features that have made previous editions easily accessible to students: opening chapter dialogues drawn from the chapter's theme; chapter summaries and review questions to aid student comprehension and study; accurate and visually appealing illustrations; in-text derivations of generic names; chapter notes and essays that enhance the text by offering interesting sidelights to the narrative; and an extensive glossary providing pronunciation, derivation, and definition of terms used in the text.

New to the Eleventh Edition

Many of the changes in this edition were guided by the suggestions of more than 60 zoology instructors who read and commented on sections of the tenth edition. In addition, the vertebrate chapters of Part Three, and several chapters on functional systems (Part Four) were revised by invited Contributors, all experienced zoologists who were solicited for their interest and expertise in the subject matter of specific chapters. In general, all chapters were revised to make the text current while eliminating excessive detail, and to place more emphasis on experimentation and comparative studies in zoology.

Chapter Organization

- Separate treatments of the origin of life and chemistry of life are condensed into a single chapter (Chapter 2), thus streamlining the presentation by discussing basic chemistry in the context of the origin of life.
- The order of chapters in Part Two is altered to offer a better study sequence for students, providing a grounding in genetics and evolutionary theory before undertaking the chapters on reproduction and development. There are numerous places in the development chapter in which an understanding of genetics is crucial.
- A completely new chapter on immunology (Chapter 37) was developed, covering both vertebrate and invertebrate immunology and embracing many new discoveries in this fast-moving field.

New Pedagogy

- Throughout the text we updated references, revised or replaced many illustrations, and rewrote many of the Review Questions to provoke thought and reduce emphasis on rote memorization.

- Suggested Internet topics are added at the end of each chapter; hyperlinks are available on this text's Online Learning Center web site at www.mhhe.com/zoology.
- The end paper on Origin of Life and Geologic Time Table has been replaced with a revised version in full color.

The principal revisions are explained below.

Part One: Introduction to the Living Animal

- Chapters 2 (Chemistry) and 3 (Origin of Life) now form an integrated review of the kinds of organic molecules found in living systems and their origins in the earth's primitive reducing atmosphere. A review of basic chemistry (atoms, elements, and molecules; bonding theory; acids, bases, salts, and buffers) is available for reference; it will be found at our Online Learning Center web site www.mhhe.com/zoology).
- For Chapter 3, on cells as units of life, we revised the discussion of cell structure and cell junctions, and reorganized the sequence of certain topics. Several illustrations in this and the following chapter on cellular metabolism were redrawn for this edition.

Part Two: Continuity and Evolution of Animal Life

- Chapter 5, Principles of Genetics, features a revised section on molecular genetics, adding a new coverage of genomics and a new subsection on molecular systematics. The increasing ease with which genes can be sequenced and compared to sequences of the same gene in other taxa has led to a great many revisions of phylogenies based on sequence analysis. Such findings have made necessary many changes in the diversity chapters in Part Three of this book.
- Chapter 7, The Reproductive Process, was revised to clarify relationships among bisexual reproduction, hermaphroditism, and parthenogenesis. A new section on sex determination summarizes the most recent understanding of the male determining gene and masculinizing hormones, and discovery of the sex reversing X region on the X chromosome and its role in promoting ovary formation. The final section on endocrine events that orchestrate reproduction was rewritten and updated.
- Chapter 8, Principles of Development, was extensively revised in both text and line art. The order in which material on cleavage is presented was reorganized to clarify relationships among principal topics of yolk amount and distribution, cleavage type, cleavage pattern, and subtopics of direct and indirect development, mosaic versus regulative development, and differences between protostomes and deuterostomes. Cleavage of centrolecithal eggs was added. The section on gastrulation now compares the process in sea stars, reptiles, birds, and mammals. Among other sections revised and updated were those on cytoplasmic specification and homeotic genes.

Part Three: The Diversity of Animal Life

- Chapter 9 provides a concise presentation on animal architecture as an introduction to animal diversity, which is the core of most zoology courses. Several sections of this chapter were revised: complexity and body size, muscular tissue, animal body plans, body cavities, and terminology used in specifying aspects of symmetry.
- Chapter 10, Classification and Phylogeny of Animals, explains the principles of animal taxonomy and how they are applied by the competing schools of evolutionary taxonomy and cladistics. Because classification pervades every course in zoology, students should understand that systematics provides the evolutionary basis for zoological study. Changes include revision of systematics of great apes to use a cladistic classification, and updating of the material on classification of the Bilateria to incorporate results of new molecular phylogenetic studies.
- The title of Chapter 11 was changed from "The Animal-like Protista" to "Protozoan Groups." Although both Protozoa and Protista no longer are considered valid taxa, we continue to use the terms "protozoa" and "protozoan" informally to distinguish these animal-like phyla. Among sections revised in the protozoan chapter are pseudopodial movement, mechanism of contractile vacuole action, and the final sections on phylogeny and classification.
- For Chapter 12 (Mesozoa and Parazoa) we revised the sections on origin and phylogeny of Metazoa, and deleted reference to class Sclerospongiae, which is no longer recognized as a valid taxon.
- We made several changes in Chapters 14 and 15 on acoelomate and pseudocoelomate animals, including reorganization of the material on class Turbellaria, and revision of the phylogeny sections for both chapters. There is evidence now that acoels (order Acoela) are not flatworms but form the sister group for all other Bilateria. All remaining acoelomates are now placed in the newly erected protostome superphylum Lophotrochozoa.
- Each of the pseudocoelomate phyla is assigned to either Lophotrochozoa or to the alternative superphylum Ecdysozoa. Phylogeny sections for mollusc, annelid, and arthropod chapters also were revised to embrace new

information from sequence analysis, which places Mollusca and Annelida in superphylum Lophotrochozoa, and Arthropoda in superphylum Ecdysozoa. We point out, however, that analysis upon which the Lophotrochozoa/Ecdysozoa hypothesis is based fails to support monophyly of Mollusca and Annelida. Nevertheless, few if any zoologists believe molluscs and annelids are not monophyletic groups.

- In Chapter 20, on terrestrial mandibulates, we introduce the term parasitoid and emphasize the importance of parasitoids in controlling populations of other insects. Among other changes in this chapter we strengthened coverage of pheromones, including use of pheromone baits in insect traps and importance of such use in monitoring insects of economic importance.
- Lophophorate animals (Chapter 22) are now assigned to Protostomia, forming an important group in superphylum Lophotrochozoa. If lophophorates are protostomes as most recent evidence suggests, the trimerous coelomic arrangement must have evolved independently in protostomes and deuterostomes.
- Chapter 25 (chordates) received minor revision, including reworking sections on ancestry and evolution, chordate fossil discoveries, and position of amphioxus in speculations on chordate ancestry.
- Chapter 26 on fishes was extensively revised. With Osteichthyes no longer considered a valid taxon, Actinopterygii and Sarcopterygii are elevated to class; this change is accompanied by a discussion of the origin and radiation of ray-finned fishes, radiation of the neopterygians, and morphological trends that permitted great diversification of the teleosts. Introductory sections on ancestry, relationships, and biology of fishes were rewritten to clarify relationships among major fish groups. Revisions in the section on sharks include discussions of sensory systems, shark attacks, and reproduction. Several changes were made in the art program, including corrections in synapomorphies in the cladogram of fishes.
- The title of Chapter 28 was changed to Reptilian Groups to emphasize paraphyly in class Reptilia. Topics revised in this chapter include lung breathing in turtles, viviparity, and characteristics that distinguish reptiles from amphibians.
- In the bird chapter (Chapter 29) we added a note on recent fossil bird discoveries, and revised discussions of skeletal weight comparisons in birds and mammals, bird kidney function, and sun-azimuth orientation of bird migration. We reorganized the treatment of forms of bird wings for flight and added a new illustration to show hovering flight in hummingbirds.
- Chapter 30, Mammals, includes an updated discussion of the first hominids to summarize recent fossil finds, and a revised illustration of hominid skulls. Other changes: adoption of a cladistic classification for primates, and revision of discussions of horns and antlers, glands, feeding specializations, body weight and food consumption, and reproductive patterns.

Part Four: Activity of Life

- The revisions for Chapter 31, Support, Protection, and Movement, include discussions of skin cancer from sunlight, mechanisms of ciliary movement, energy for muscle contraction, fast and slow fibers, and description of dermal derivative in vertebrates.
- Chapter 32, Homeostasis, was updated throughout. Treatments revised include hyperosmotic regulation in invertebrates, hypoosmotic regulation in fishes, shark kidney function, mechanism of contractile vacuole function, and glomerular filtration.
- A major improvement in flow and unity of Chapter 33, Internal Fluids and Respiration, was transfer of defense mechanisms and immunity to a separate chapter (Chapter 37).
- Chapter 34, Digestion and Nutrition, includes a discussion on nutritional requirements to embrace new understanding of relationships among the hunger center, brown fat, the protein thermogenin, and the recently discovered hormone leptin. We also updated statistics on world meat consumption, malnutrition, and world population. The discussion on gastrointestinal hormones, previously included in the endocrine chapter, was moved to this chapter.
- The chapter on nervous coordination (Chapter 35) was revised throughout. The most important revisions appear in sections dealing with nature of the nerve impulse, synapses, evolution of invertebrate nervous systems, reflex acts and reflex arcs, autonomic nervous systems, odor reception, and color vision.
- Chapter 36, Chemical Coordination, features an updated section on second messenger system, and new sections that describe the role of growth hormone as a diabetogenic hormone, and action of the most recently discovered hormone, leptin, in regulating eating behavior and energy balance.
- Chapter 37, Immunity, is *new* and covers the topics of susceptibility and resistance, innate defense mechanisms, acquired immune response in vertebrates, blood group antigens, and immunity in invertebrates. The section on acquired immune response in vertebrates includes descriptions of self–nonself discrimination (MHC proteins), recognition molecules (antibodies and T-cell receptors), cytokines, humoral response (T_H2 arm), and cell-mediated response (T_H1 arm).
- Chapter 38 concludes this unit with a discussion of animal

behavior. It features an expanded explanation of the ritualization of behavior, and new sections on diversity of mating systems, altruistic behavior and kin selection, and animal cognition. The latter describing the remarkable studies of the Gardners with the chimpanzee Washoe, and Pepperberg's work with an African grey parrot.

Part Five: The Animal and Its Environment

- Chapter 39, The Biosphere and Animal Distribution, includes an updated discussion of the proposed effect of carbon dioxide on the earth's climate. It also provides an expanded explanation of the earth's heat engine, with accompanying new art, and added mean annual temperature and rainfall values to all biome descriptions.
- Chapter 40, Animal Ecology, was completely rewritten to provide much greater emphasis on populational and community ecology. It features expanded explanations of niche, characteristics of population (age structure, growth rates, survivorship), population regulation, and interactions among populations in communities.

Teaching and Learning Aids

To help students in **vocabulary development**, as in previous editions we have boldfaced key words, and provided the derivations of technical and zoological terms, and generic names of animals where they first appear in the text. In this way students gradually become familiar with the more common roots that comprise many technical terms. An extensive glossary of almost 1,100 terms provides pronunciation, derivation, and definition of each term. Many new terms were added to the glossary or rewritten for this edition.

A distinctive feature of this text is a **chapter prologue** for each chapter that draws out some theme or fact relating to the subject of the chapter. Some present biological, particularly evolutionary, principles; others (especially those in the survey sections) illuminate distinguishing characteristics of the group treated in the chapter. Each is intended to present an important concept drawn from the chapter in an interesting manner that will facilitate learning by students, as well as engage their interest and pique their curiosity.

Chapter notes, which appear throughout the book, augment the text material and offer interesting sidelights without interrupting the narrative. We prepared many new notes for this edition and revised several of the existing notes.

To assist students in chapter review, each chapter ends with a **concise summary,** a list of **review questions,** and **annotated selected references.** The review questions enable the student to self-test retention and understanding of the more important chapter material.

The **historical appendix,** unique to this textbook, lists key discoveries in zoology, and separately describes books and publications that have greatly influenced the development of zoology. Many readers have found this appendix an invaluable reference to be consulted long after their formal training in zoology. The historical appendix will be found on this textbook's Online Learning Center web site at www.mhhe.com/zoology.

Again, William C. Ober and Claire W. Garrison have enhanced the **art program** for this text with many new full color paintings that replace older art, or that illustrate new material. Bill's artistic skills, knowledge of biology, and experience gained from an earlier career as a practicing physician, have enriched this text through seven of its editions. Claire practiced pediatric and obstetric nursing before turning to scientific illustration as a full-time career. Texts illustrated by Bill and Claire have received national recognition and won awards from the Association of Medical Illustrators, American Institute of Graphic Arts, Chicago Book Clinic, Printing Industries of America, and Bookbuilders West. They are also recipients of the Art Directors Award.

Supplements

The **Instructor's Manual and Test Item File** provides annotated chapter outlines, chapter-specific changes for this edition, lecture enrichment suggestions, commentaries and lesson plans, questions for advanced classes, and a listing of resource references for each chapter. Also included is a listing of transparencies and slides available with the book, and a comprehensive test bank offering 35 to 50 objective questions per chapter. We trust this will be of particular value to first-time users of the text, although experienced teachers may also find much of value.

The **Laboratory Manual** by Cleveland P. Hickman, Jr., Frances M. Hickman, and Lee B. Kats, *Laboratory Studies in Integrated Zoology*, has been revised to include new exercises on molecular techniques. This manual can be adapted conveniently for two semester, one semester, or term courses by judicious selection of exercises.

Test questions contained in the Instructor's Manual and Test File are also available as a **Computerized Test Bank,** a test-generation system for IBM and Macintosh computers. Using this system, instructors can create tests or quizzes quickly and easily. Questions can be sorted by type or level of difficulty, and instructors also can add their own material to the bank of questions provided.

A set of 150 full-color **transparency acetates** of important textual illustrations are available with this edition of *Integrated Principles of Zoology*. Labeling is clear, dark, and bold for easy reading.

A set of 148 animal diversity slides, photographed by the authors and Bill Ober on their various excursions, are offered in this unique textbook supplement. Both invertebrates and vertebrates are represented.

Descriptions, including specific names of each animal and brief overview of the animal's ecology and/or behavior, accompany the slides.

A **Zoology Visual Resource Library CD-ROM,** containing 1,000 line drawings and photos, is now available to instructors to enhance lecture presentations (see page xxiv for more details).

A tutorial CD-ROM, the **Essential Study Partner,** will be available soon to aid students in their study of zoology (see page xxi for more details).

An **Online Learning Center web site** is available with this edition, and contains additional readings, animations, quizzing, key terms flashcards, cladogram exercises, and much more (see page xix for specific information). Check it out at www.mhhe.com/zoology.

By the end of 2000, this text will also be available in a CD-ROM format, complete with hyperlinks to the Online Learning Center, an interactive glossary, and animations (see page xxii for more details).

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Chapter 35 Nervous Coordination
Chapter 36 Chemical Coordination
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Sharyn Marks, Humboldt State University
Chapter 8 Principles of Development
Ron Meyers, Weber State University
Chapter 28 Reptilian Groups
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Although we make every effort to bring to you an error-free text, errors of many kinds inevitably find their way into a textbook of this scope and complexity. We will be grateful to readers who have comments or suggestions concerning content to send their remarks to Donna Nemmers, Developmental Editor, 2460 Kerper Boulevard, Dubuque, IA 52001. Donna may also be contacted by e-mail: donna_nemmers@mcgraw-hill.com, or through this textbook's web site: www.mhhe.com/zoology.

Cleveland P. Hickman, Jr.
Larry S. Roberts
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The Online Learning Center

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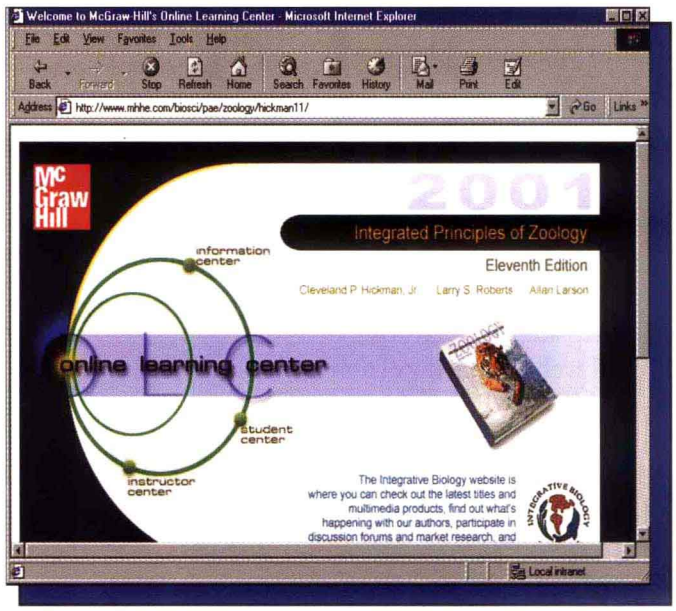
This text-specific web site allows students and instructors from all over the world to communicate. Instructors can create a more interactive course with the integration of this site, and students will find tools such as practice quizzing, key term flashcards, and animations that will help them improve their grades and learn that zoology can be fun.

Student Resources

Chapter Synopsis
Tips for chapter mastery
Quizzing with immediate feedback
Hyper links to chapter-related web sites
Key Term Flashcards
Animations
Interactive Cladogram Exercise
"Development of Zoology" timeline
"Basic Structure of Matter" appendix



Instructor Resources

Instructor's Manual
- Chapter outlines
- Eleventh edition changes
- Lecture enrichment
- Commentary/lesson plan
- Advanced class questions
- Source materials

Links to related web sites to expand on particular topics
List of Visual Resource Library (VRL) images
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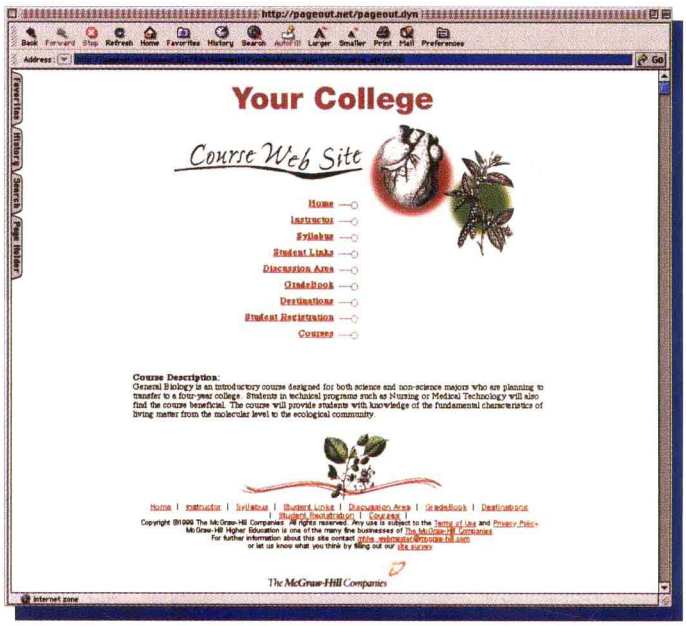

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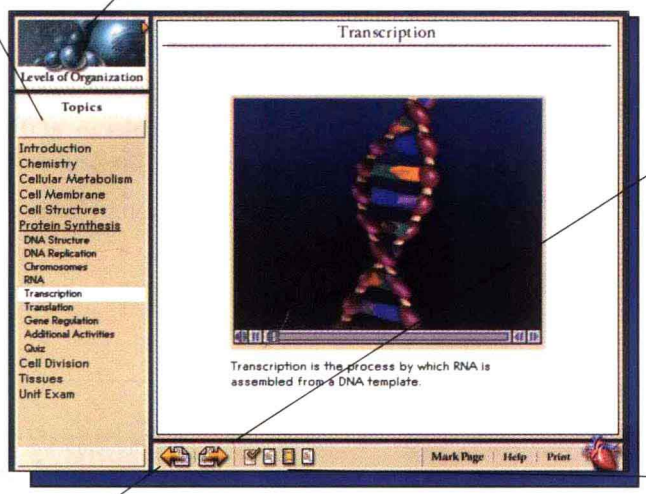
Essential Study Partner CD-ROM

A study partner that engages, investigates, and reinforces what you are learning from your textbook. You'll find the **Essential Study Partner** for *Zoology* to be a complete, interactive student study tool packed with hundreds of animations and learning activities. From quizzes to interactive diagrams, you'll find that there has never been a better study partner to ensure the mastery of core concepts.

The topic menu contains an interactive list of the available topics. Clicking on any of the listings within this menu will open your selection and will show the specific concepts presented within this topic. Clicking any of the concepts will move you to your selection. You can use the UP and DOWN arrow keys to move through the topics.

The unit pop-up menu is accessible at any time within the program. Clicking on the current unit will bring up a menu of other units available in the program.



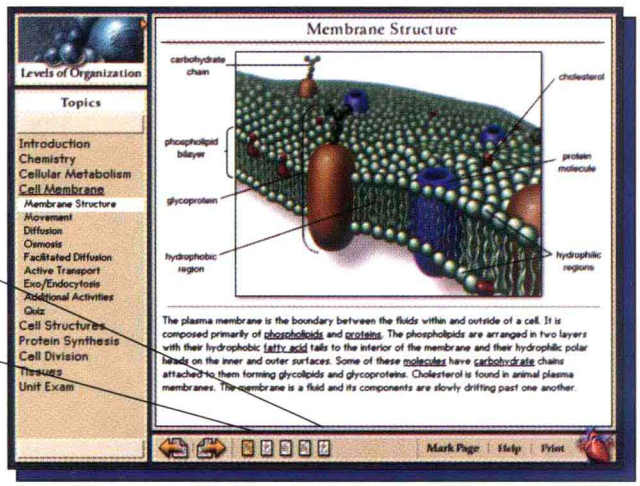
To the right of the arrows is a row of icons that represent the number of screens in a concept. There are three different icons, each representing different functions that a screen in that section will serve. The screen that is currently displayed will highlight yellow and visited ones will be checked.

The film icon represents an animation screen.

Along the bottom of the screen you will find various navigational aids. At the left are arrows that allow you to page forward and backward through text screens or interactive exercise screens. You can also use the LEFT and RIGHT arrows on your keyboard to perform the same function.

The activity icon represents an interactive learning activity.

The page icon represents a page of informational text.



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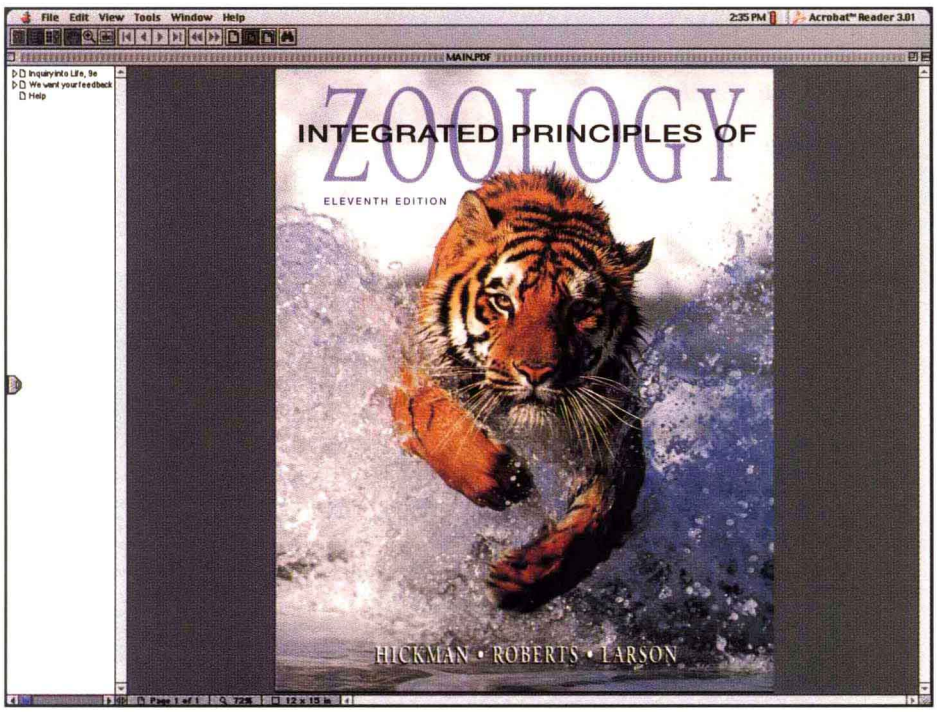
New from McGraw-Hill Higher Education

e-TEXT

E-TEXT is an exciting student resource that combines McGraw-Hill print, media, study, and web-based materials into one easy-to-use CD-ROM. This invaluable resource provides cutting-edge technology that accommodates all learning styles, and complements the printed text. The CD provides a truly non-linear experience by using video and art, as well as web-based and other course materials to help students organize their studies.

The following features illustrate, in depth, the benefits of e-TEXT.

- **Full textbook and study guide PDF files are interlinked.** This includes all narrative, art and photos, PLUS expertly crafted animations.
- Targeted web links encourage **focused web research.**
- A **Search feature** enables students to improve studying by locating targeted content quickly and easily.
- This hybrid CD is **compatible with both Macintosh and Windows** platforms.
- Required programs **Acrobat Reader and QuickTime are supplied** on the CD-ROM.
- **Bookmarks**—appearing on the left side of the screen—list all of the links available on that page.
- **Thumbnails** of the other pages within the chapter are shown for quick navigation.
- **Main menu links** are at the bottom of every screen as well as in the bookmark section.
- An explanation of features is provided on the **Help Page**.
- **Boldface terms** are linked to definitions in the glossary.



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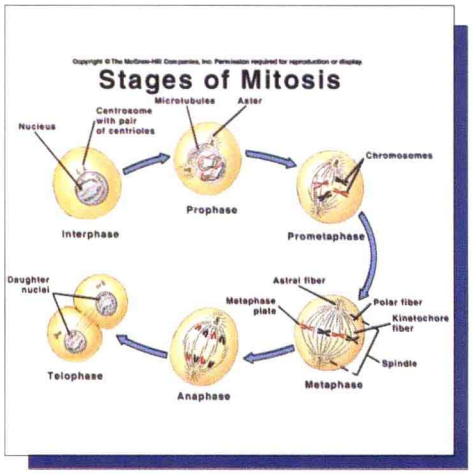
Visual Resource Library CD-ROMs

These CD-ROMs are electronic libraries of educational presentation resources that instructors can use to enhance their lectures. View, sort, search, and print catalog images, play chapter-specific slideshows using PowerPoint, or create customized presentations when you:

- Find and sort thumbnail image records by name, type, location, and user-defined keywords
- Search using keywords or terms
- View images at the same time with the Small Gallery View.
- Select and view images at full size.
- Display all the important file information for easy file identification.
- Drag and place or copy and paste into virtually any graphics, desktop publishing, presentation, or multimedia application

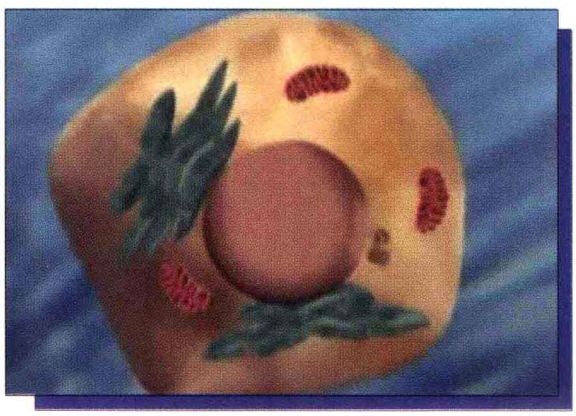


Life Science Animations Visual Resource Library CD-ROM

This instructor's tool, containing more than 125 animations of important biological concepts and processes—found in the *Essential Study Partner* and *Dynamic Human CD-ROMs*—is perfect to support your lecture. The animations contained in this library are not limited to subjects covered in the text, but include an expansion of general life science topics.

Zoology Visual Resource Library CD-ROM

This helpful CD-ROM contains 1,000 photographs and illustrations from the text as well as from several other McGraw-Hill Zoology texts. You'll be able to create interesting multimedia presentations with the use of these images, and students will have the ability to easily access the same images in their texts to later review the content covered in class.



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