

Preface

"There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved." —Charles Darwin, last line of *The Origin of Species*.

Even though the authors of this text have been teaching biology for many years, we continue to be awed by the grandeur of life as so eloquently expressed by Charles Darwin. As animal physiologists, we are continually amazed by the wondrously intricate functions that mesh together to sustain an animal's body. As biologists, we are also fascinated by the powerful and yet quirky mechanisms of evolution, which have allowed life to adapt from the bitter cold of Antarctica to the scalding heat of hydrothermal vents. Moreover, the fact that we humans have structures, processes, and genes in our cells that connect us to every life form on this planet is both humbling and inspiring. It is the grand view of life that we try to convey to our students.

This second edition of *Animal Physiology: From Genes to Organisms* focuses on the mechanisms and evolutionary histories of animal body functions from genes to organ systems to the whole organism interacting with its environment. This text is designed for mid- to upper-level undergraduate courses. Because this book may be the only exposure many undergraduate students will have to physiology beyond the introductory level, all aspects of physiology and many types of animals are covered. This text serves for general biology and zoology programs, preprofessional programs in animal husbandry, veterinary medicine and science, marine biology, and wildlife and fisheries biology, as well as for human health sciences.

We have three major goals in writing this second edition. First, to better understand scientific knowledge, students should realize that our knowledge is incomplete and yet continually advancing, and they should know how that knowledge is obtained. Therefore, pertinent information based on recent discoveries, as well as new research methodologies, has been included in all chapters, with new controversial ideas and hypotheses presented to illustrate that physiology is a dynamic, changing discipline. Students can be assured of the timeliness and accuracy of the material presented. Our second goal has been to clarify and modify figures and text as needed to strengthen our coverage of physiological features and to ensure that the text and art work well together. Third, we have sought to strengthen our comparative, evolutionary approach with greater emphasis on some nonmammalian systems as some of the more remarkable recent discoveries have been made in this arena.

Even the most tantalizing subject can be difficult to comprehend if not effectively presented. Thus, this book has a logical, understandable format with an emphasis on how each concept is an integral part of the entire subject. Too often, students view the components and functions of an animal as isolated entities; by understanding how each component depends on the others, students can appreciate the integrated functioning of the whole organism. Moreover, this text is designed to promote understanding of the basic principles and concepts of physiology rather than memorization of details. The text is written in simple, straightforward language, and every effort has been made to ensure smooth reading through good transitions, logical reasoning, and integration of ideas throughout the text.

Major Organizing Principles

This text follows an "integrative systems" approach, which involves both vertical and horizontal integration. *Vertical integration* concerns the hierarchical nature of physiology, in which organ systems and their functions arise from cells and their molecular components, and from the evolutionary forces that gave rise to those components. After an introduction to the major themes of physiology, the chapters proceed from molecular and cellular physiology to classical organ systems. Organ systems are grouped according to universal functions of whole-body regulation and integration, support and movement, maintenance, and reproduction. For each organ system, both the evolutionary forces and the cellular and molecular underpinnings are discussed, including new research in genomics, which is having a major impact on all areas of biology. Where necessary, sufficient relevant anatomy is included to make the inseparable relation between structure and function meaningful.

Horizontal integration concerns the interactions of all organ systems to yield a whole functioning organism. As we noted earlier, it is all too easy to view each system as an isolated entity. This text works to overcome this in two ways. First, this text's central themes are homeostasis and other integrated forms of regulation—how processes from the genetic to the behavioral level allow an animal's body to meet changing demands while maintaining the internal consistency necessary for all cells and organs to function. Each chapter not only emphasizes these themes but also indicates interactions with other systems. Second, special integrative chapters—Fluid and Acid-Base Balance and Energy Balance and Thermal Physiology—focus on crucial whole-body phenomena that are dependent on more than one organ system.

In addition to an integrated systems organization, this text also incorporates a *comparative approach* throughout

that illustrates respective solutions animals have evolved to cope with the environment. Mechanisms used by major and exemplary groups of vertebrates, insects, and other illustrative groups are included for three purposes. First, comparisons among types of animals are selected to illuminate important universal functions and principles, emphasizing the unity of life. Second, unique or striking adaptations that reveal the diversity that can result from evolutionary adaptation are featured. Finally, this text incorporates detailed coverage of animal species of relevance to those preparing for animal-related careers, especially vertebrates.

The scope of this text has been limited by judicious selection of pertinent content that students can reasonably be expected to assimilate in a one-semester course. To keep pace with today's rapid advances in the biological sciences, students interested in careers related to animal physiology must be able to draw on their overall understanding of concepts instead of merely recalling isolated facts. For this reason, this text is designed to promote understanding of the basic principles and concepts of physiology rather than the memorization of details. Yet depth, where needed, is not sacrificed. All aspects of physiology receive coverage, including separate chapters on immune and reproductive systems and detailed coverage of pregastric and postgastric digestion.

Learning Aids and High-Interest Features

Pedagogical Illustrations Anatomic illustrations, schematic representations, photographs, tables, and graphs complement and reinforce the written material. Widespread use of integrated descriptions within figures, including numerous process-oriented figures with step-by-step descriptions, allows visually oriented students to review processes through figures. Flow diagrams are used extensively to help students integrate the written information. In the flow diagrams, lighter and darker shades of the same color denote a decrease or increase in a controlled variable, such as blood pressure or the concentration of blood glucose. Physical entities, such as body structures and chemicals, are distinguished visually from actions.

Feedforward Statements as Subsection Titles Instead of traditional short topic titles for each major subsection (for example, "Heart valves"), feedforward statements alert students to the main point of the subsection to come (for example, "Heart valves ensure that the blood flows in the proper direction through the heart"). These headings also break up large concepts into smaller, more manageable pieces for the student, and as an added bonus, the listing of these headings in the Contents at the beginning of the book serves as a set of objectives for each chapter.

Cross-Referencing Many chapters build on material presented in preceding chapters, yet each chapter is designed to stand on its own to allow the instructor flexibility in curriculum design. With extensive cross-references provided, the

sequence of presentation can be varied at the instructor's discretion.

Unanswered Questions The physiological sciences are changing constantly due to new discoveries and challenges of old ideas. In most chapters, *Unanswered Questions* present short overviews and questions on controversial ideas and new hypotheses to illustrate the dynamic nature of physiology research and to stimulate students to propose their own ideas. Many of these have been updated for the second edition.

Boxed Features More detailed boxed features are inserted where appropriate within chapters. *Beyond the Basics* exposes students to high-interest, tangentially relevant information on diverse topics, including historical perspectives, environmental issues, and common diseases. *Challenges and Controversies* boxes introduce the frontiers of physiological research with new hypotheses and unsolved questions, going in more depth than in the *Unanswered Questions*. *A Closer Look at Adaptation* illustrates the scope and limits of evolutionary adaptation with selected illustrative examples. *Molecular Biology and Genomics* provides examples of cutting-edge research resulting from the animal genome projects and related research to uncover the physiological functions of newly discovered genes. Most of these boxes are new or updated in this second edition.

Evolutionary Foundations Most chapters have an overview of major evolutionary events and selective forces, typically at the chapter start. All topics are placed in a true biological context that melds both the proximate (mechanistic) approach of traditional physiology with the evolutionary explanations behind them; this helps explain not only the power of natural selection but also the often quirky and even illogical features of life.

Cellular, Molecular, and Genomic Foundations Even though this text is primarily organized according to body systems, it provides coverage of cellular, molecular, and genomic topics in early chapters and incorporates these throughout as a basis for understanding organ function. The current tools used to explore molecular physiology are also outlined in most chapters. This is the cutting edge of physiology research.

Pathophysiology This text is also designed to help students realize that they are learning worthwhile and applicable material. Because many students using this text will have a clinical component to their careers, reference to important pathophysiological issues demonstrates the content's relevance to their professional goals. For example, this text includes the effects of environmental toxins on some body systems, an issue of increasing concern.

Key Terms, Word Derivations, and Glossary with Phonetic Pronunciations Key terms are defined as they appear in the text. A glossary at the end of the book, which includes phonetic pronunciations of the entries, enables students to quickly review key terms. Because physiology is laden with new vocabulary words, many of which are rather intimidating at first glance, word derivations are often provided to enhance understanding.

Integration Following our integrated systems approach, each chapter includes a *Making Connections* section that helps students put into perspective how the system just discussed contributes to the whole animal and important regulatory functions.

Chapter Summaries Each chapter now ends with a *Chapter Summary* of the key concepts as a bulleted list.

Review Questions Two new features help the student retain information. First, *Check Your Understanding* questions have been added after each major section to help review the main ideas just discussed. Answers to these questions appear in an appendix at the end of the book. Second, at each chapter's end are *Review, Synthesize, and Analyze* essay questions that integrate the chapter material or delve deeper into a topic and challenge the student on a higher level.

Suggested Readings Each chapter concludes with a list of both recent and classic articles as well as books that give important details on the chapter material.

Online Review The following online materials are designed to help students review foundation concepts presumably covered in prerequisite courses:

- **A Review of Chemical Principles:** This review is offered online at CengageBrain.com as a reference for students who need to go over basic chemistry concepts that are essential to understanding physiology.
- **Storage, Replication, and Expression of Genetic Information:** This review includes a discussion of DNA and chromosomes, protein synthesis, cell division, and mutations and is also offered online at CengageBrain.com.

New to the Second Edition

This edition has undergone extensive revision. Some of the changes are as follows:

New and Enhanced Artwork More than 90% of the art has been upgraded in this edition, with more three-dimensional art; many conceptually redesigned figures to enhance student understanding; brighter, more contemporary, and more visually appealing colors; and more consistent style throughout. New pictures of various animals that illustrate key physiological adaptations have been added. Also, icons of physical entities are incorporated into many of the flow diagrams to aid students in learning what structures are involved in specific actions.

In addition, many new figures have been added, such as those on the following topics: a cell's response to oxidative stress under normal and pathological states and the effects of chronic stress on cellular aging; the mechanism by which new synaptic connections are formed in association with long-term memory; cephalopod eye formation; pineal function in seasonally breeding animals; new insights into the mechanism by which the "catch state" is generated in bivalves; lipid transport for insects and mammals; a possible acquired immune response in insects; crosscurrent flow in a bird lung; protein and carbohydrate metabolism in the rumen; and global warming and animal metabolism.

New and Updated Content We have incorporated appropriate, timely material throughout, as the following examples illustrate: Chapter 2 has a new section on generating stem cells and new findings on microRNAs and small interfering RNAs; Chapter 5 contains updated material on learning and a new section on sleep; Chapter 6 includes updates on TRP-type receptor channels in most types of sensory cells; Chapter 7 contains new material on TSH in seasonally breeding animals, updates on nonvertebrate hormones, and new coverage of epigenetics; Chapter 8 includes updates on the role of titin and new concepts in muscle fatigue; Chapter 9 contains new information on genes in the evolution of the four-chambered heart; Chapter 10 has updates on dendritic cells, regulatory T cells, nanotubes, lamprey immunity, and insect immunity; Chapter 11 includes recent findings on insect respiration, birdlike crocodile lungs, and mammoth hemoglobin; Chapter 12 includes recent findings on insect (anti)diuretic hormones and exciting new hypotheses on the mammalian renal countercurrent mechanism; Chapter 13 has a new section on the effects of ocean acidification on animals; Chapter 14 presents updated material on methane production in ruminants and climate change; Chapter 15 includes a major new section on the effects of climate change on thermal physiology and updates on hypotheses about metabolic scaling and on gastrointestinal hormones in energy regulation; and Chapter 16 includes novel material on seasonal breeding in mammals, the female sexual act, and more depth on the topic of reproduction in nonvertebrates as well as new information on the rut in deer and the multiple roles of prolactin.

Increased Evolutionary and Comparative Aspects We have added additional detail on physiological adaptations, including the following examples: Chapter 1 has added information on vestigial features, cost-benefit trade-offs in evolution, and the Krogh principle; Chapter 6 contains new material on the use of infrasound and ultrasound in various animals, Pax6 genes in animal eye evolution, electroreception and magnetoreception mechanisms and electric organs, and color and UV vision in fish, reptiles, birds, mammals (including whales), and mantis shrimp; Chapter 7 has incorporated additional comparative aspects of thyroid function; Chapter 9 contains new material on hemolymph proteins in arthropods, the evolution of clotting in mammals, and cardiac output in various endotherms and ectotherms; Chapter 10 has been extensively rewritten with an evolutionary overview of universal and nonvertebrate immune functions; Chapter 11 has been extensively rewritten with an evolutionary overview of respiratory functions and more comparative and evolutionary details such as dinosaur and bird connections, nonhemoglobin respiratory pigments, hemoglobin oxygen affinities in various species, and comparisons of high flyers and deep divers; Chapter 12 includes more comparative examples on urea excretion and vertebrate renal development and evolution, and the entire chapter has been reorganized to reflect a more explicit evolutionary framework; Chapter 13 includes a table comparing water balance in humans and kangaroo rats and a new box on the evolution of osmoregulation in vertebrates; and Chapter 15 includes a new table comparing energy metabolism in humans and hummingbirds and new boxes on the evolution of endothermy and the thermal maximum for animal life.

Instructor and Student Ancillaries

PowerLecture This convenient tool makes it easy for instructors to create customized lectures. Each chapter includes the following features, all organized by chapter:

- Lecture slides
- All chapter art and photos
- Animations and videos
- *Test Bank*, which includes more than 900 questions in multiple-choice, true/false, matching, fill-in-the-blank, and essay formats

This single disc places all the media resources at your fingertips.

CourseMate Cengage Learning's Biology CourseMate brings course concepts to life with interactive learning, study, and exam preparation tools that support the printed textbook or the included eBook. With CourseMate, professors can use the included Engagement Tracker to assess student preparation and engagement either for the class as a whole or for individual students. Students can access an interactive eBook, chapter-specific interactive learning tools, including flash cards, quizzes, videos, and more in their Biology CourseMate, accessed through CengageBrain.com.

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