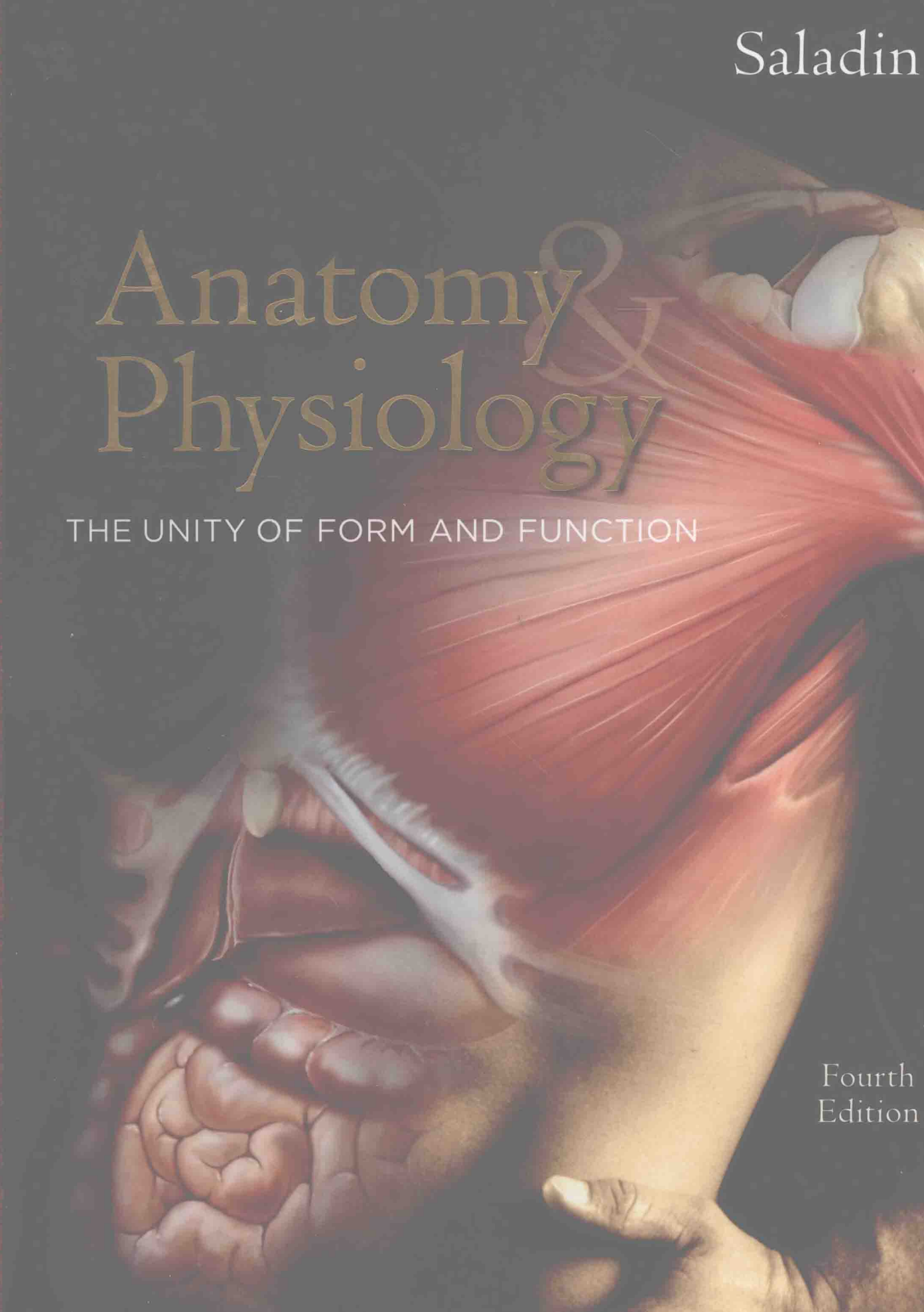


Saladin

Anatomy & Physiology

THE UNITY OF FORM AND FUNCTION

Fourth
Edition



ANATOMY & PHYSIOLOGY

The Unity of Form and Function

Kenneth S. Saladin

Georgia College and State University

fourth edition



ANATOMY AND PHYSIOLOGY: THE UNITY OF FORM AND FUNCTION, FOURTH EDITION

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CIP

KEN SALADIN has taught since 1977 at Georgia College and State University, a public liberal arts university in Milledgeville, Georgia. He earned his B.S. in zoology at Michigan State University and Ph.D. in parasitology at Florida State University. In addition to human anatomy and physiology, his courses have included histology, parasitology, animal behavior, sociobiology, introductory biology, general zoology, biological etymology, and a study abroad course in the Galápagos Islands. Nine times over the years, outstanding students inducted into Phi Kappa Phi have tapped Ken for recognition as their most significant undergraduate mentor. He received the university's Excellence in Research and Publication Award for the first edition of this book, and was named Distinguished Professor in 2001.

Ken is an active member of the Human Anatomy and Physiology Society, the Society for Integrative and Comparative Biology, the American Association of Anatomists, and the American Association for the Advancement of Science. He served as a developmental reviewer and wrote supplements for several other McGraw-Hill anatomy and physiology textbooks for a number of years before beginning this book.

Ken's avocational interests include philanthropic support of the Big Brothers/Big Sisters program for single-parent children, the Charles Darwin Research Station in the Galápagos, and several student scholarships, and he occasionally acts in college theatrical productions. Ken is married to Diane Saladin, a registered nurse. Their son, Emory, is a student in architectural design and their daughter, Nicole, is a graduate student in marine conservation ecology.



Ken Saladin (left) and Les Greene.

DEDICATION

All professions depend on good teachers. I dedicate this edition to one of the very best

LES GREENE

my first biology teacher and a friend ever since.

Preface

My students come to anatomy and physiology full of idealism, hoping to work in one of the health professions from nursing or therapy to fitness training and health education. They quickly discover that it is a tremendous task just to master the prerequisites for the clinical phase of their training. One of the greatest challenges they face is to understand the structural complexity of the human body and its intricate functional mechanisms.

My profession is to help them along the way by making this overwhelming amount of information manageable and, ideally, even stimulating. My students have long inspired me to spare no effort in presenting human form and function in a lucid, well-organized, and interesting way in my classes. Nearly 15 years ago, I accepted an invitation to put my approach on paper, with the result you are holding in your hands. I was pleasantly surprised at how quickly the first edition of this book rose to success—a gratifying validation of the way I had written and illustrated it and framed it in helpful pedagogic devices.

As enjoyable as this success has been, I've never been fully satisfied with the book. I view perfection as an asymptote, a standard to be approached more and more closely but perhaps never quite attained. The ink never dries on a new edition before I'm already compiling a list of how the next one could be better. Here is the fourth avatar, still reaching for that asymptote.

Audience

This book is meant for a two-semester course in combined human A&P, primarily for beginning college students who need it as a prerequisite for admission to a clinical curriculum. I assume no prior college coursework; the first five chapters provide all the basic concepts of chemistry and cell biology that a student needs in order to understand the subsequent chapters on the human organ systems. The introductory chapters also serve as a refresher for those returning to college after raising a family or pursuing another career.

I also keep in mind that many A&P students, being very early in their college careers, are still developing the

intellectual skills and study habits necessary for success in a health science curriculum, and that there also are many whose original language was other than English. I think of them as I choose my words and craft the structure of a sentence or paragraph. I try to avoid talking over the heads of beginning college students, but also to avoid “dumbing down” the text to an insulting level. I'm wary of idioms that may be obscure to international readers. I sprinkle the narrative with review activities such as self-testing questions; self-teaching prompts such as palpations and simple experiments the reader can do sitting at a desk; and learning aids such as pronunciation guides and insights into the roots and origins of medical terms. I try to conceive of enlightening ways to illustrate each major idea, often in ways that no other textbook has illustrated them before. To enliven the facts of science, I offer analogies, clinical insights, historical notes, biographical vignettes, and other seasoning that will make the book not only enjoyable to students, but interesting even to experienced instructors who may have “heard it all before,” yet may not have heard of some of the facts and perspectives offered in these pages.

What Sets This Book Apart?

Honored as I felt at being invited to write a textbook, I deliberated for more than a year before I accepted. There were many other A&P books already on the market, some of them very good. I didn't want to write a “me too” book, a mere imitation of the others. If I were going to write at all, it would be to provide something that other textbooks were not—a point of view, a clarity of exposition, new illustrative concepts, or content more accurate than many of the oft-repeated, but false, textbook clichés. I stake my claim to originality in the following aspects of this book.

ORGANIZATION

Some chapters and topics are presented in a nontraditional sequence that I feel is more instructive than the conventional order. This has been well received, so I've

made no changes in it since the previous edition. For those who have not used the book before, a brief explanation is in order.

Heredity

The most fundamental principles of heredity are presented in the last few pages of chapter 4 rather than at the back of the book. I do not see how students can adequately understand such genetic traits and conditions as cystic fibrosis, color blindness, blood types, hemophilia, cancer genes, or sickle cell disease, if they do not first understand such concepts as dominant and recessive alleles, genotype and phenotype, sex linkage, and pleiotropy. It has always seemed to me a mistake to put these at the back of the book, as others do, in a chapter that many instructors never reach as we try to cover such a big subject in such a short semester. The most monumental development in medical science now taking place is genomic medicine, and textbooks can no longer defensibly make genetics take a back seat to all the rest of A&P. The next few years seem certain to demand an earlier and stronger presentation of genomics to health-care students.

Muscle Anatomy and Physiology

I treat the functional morphology of the skeleton, joints, and muscles in three consecutive chapters, 8 through 10. Therefore, when students learn muscle origins and insertions from this book, it is only two chapters after the names of the relevant bone features; when they learn muscle actions, it is in the first chapter after learning the terms for the joint movements. This means presenting muscle anatomy and physiology in an order opposite from the one that other A&P books follow. It also brings another advantage: the physiology of muscle and nerve cells is treated in two consecutive chapters (11 and 12), which are thus closely integrated in their treatment of synapses, neurotransmitters, and membrane potentials.

The Urinary System

Most textbooks place this system near the end of the book because of its anatomical and developmental relationships with the reproductive system. I feel, however, that its physiological ties to the circulatory and respiratory systems are much more important. The lungs and kidneys collaborate to regulate the pH of the blood; the kidneys have more impact than any other organ on blood pressure; and students should study glomerular filtration and tubular reabsorption before they have long forgotten the basic principles of capillary fluid exchange. I cannot see reason for the anatomical association between the urinary tract and reproductive system to override these important physiological ties to the car-

diovascular and respiratory systems. Therefore, except for a necessary digression on lymphatics and immunity, I follow the circulatory system (chapters 18–20) almost immediately with the respiratory and urinary systems (chapters 22–24).

WRITING STYLE

Next to scientific accuracy, the most important quality of an effective textbook is writing style. Over my years of teaching from other college textbooks, I've seen styles to admire and emulate, and others to avoid. Some are very correct and formal, but students find them aloof; such books do not "speak" to them, they say. Beginning college students get a stronger sense of engagement in the discipline from a more personal approach on the part of an author. Other writers go for such a chummy style that they appear a bit too cute and leave a student feeling patronized. My inclination has always been a middle course: a tone that is semiconversational, neither stuffy nor condescending; one that uses an occasional colloquialism without straying into baffling idioms; one that uses everyday events and innovative analogies to enable students to visualize and relate to a process; one that favors simple language and syntax over convoluted paragraphs and a needlessly multisyllabic, graduate school vocabulary.

No writer can be an objective judge of his own effectiveness, but I feel I've hit my mark when students write to me from other colleges (where I do not determine their grades) saying they enjoy the book because "it feels as if the author is talking to me," or because they can understand it so much more easily than other A&P books they've used. And when reviewers make comments like the following, I'm encouraged to preserve and enhance this tone from edition to edition:

This book is the clearest and most direct read in the field. His strong narrative style holds the students' interest and is an important strong area in his writing. He tends to avoid pointless and ego-centric digressions that spoil many other anatomy and physiology texts. I find myself drawn into reading his text more as I would a decent novel. One particularly difficult area is immunology: so many texts are scattered and confused that I often wonder if that author understands the topic. Saladin, on the other hand, is clear and straightforward on that topic.

—David L. Evans, Pennsylvania College of Technology

Students who have used other textbooks rave about this one. This text has been written to simplify things for students, not to mystify them.

—Lawrence N. Killian, Clark State Community College

Compared to [other textbooks I have used], this is the absolute best. I love the way Saladin writes and I think the students do as well. His powers of explanation are sometimes extraordinary. His analogies and interesting snippets scattered throughout the book are fascinating and greatly facilitate absorption of the material. I don't think that any other text is as "user friendly" to the students.

—Nikki Privacky, Palm Beach Community College

ILLUSTRATIONS

Captivating art and photography were especially important in stimulating my interest in the life sciences when I was a boy, and they are no less important in reinforcing a college student's interest in human structure and function. I brought several original illustrative concepts to this project, as well as a vision of the kind of art and photographs that an outstanding A&P book should have. McGraw-Hill spared no expense to commission an art package in a league of its own. In this edition, the scientific and medical illustrators at Precision Graphics have produced another quantum leap forward. I'm confident that a prospective user can compare the art in this book with the corresponding figures of others and clearly see the advantage of this one for both instructor and student. Reviewers agree:

The artwork in Saladin is head and shoulders above all the other anatomy and physiology books on the market today....the others have not been able to come close.

—Robert Moldenhauer, St. Clair County Community College

I must say I was completely blown away by this text. The graphics in [a leading text I've been using] don't come close to the graphics in Saladin, which have an extraordinary 3-D quality.

—Bill Schutt, Long Island University

One of the major strengths of the Saladin text, one that prompted me to adopt it, was the quality and quantity of the illustrations. In my view, this text is a hands-down winner in this area.

—Richard A. Symmons, California State University at Hayward

AN EVOLUTIONARY FLAVOR

The human body can never be fully understood without a sense of how and why it came to be as it is. Since the mid-1990s, medical literature has shown an increasing interest in evolutionary medicine. Several

books have recently been published on it, as have many articles in the leading medical journals. Even the first chapter of *Gray's Anatomy* is devoted mainly to the relevance of evolution for human anatomy, and Gray's reinforces this with numerous evolutionary insights from cover to cover. Yet most A&P textbooks continue to ignore it.

I briefly introduce the concept of natural selection as applied to humans in chapter 1. Later chapters have nine boxed essays (Insights) on evolutionary medicine, and many evolutionary remarks in the main body of the narrative. Students will find novel and intriguing ways of looking at such topics as mitochondria (p. 121), body hair (p. 200), skeletal anatomy (p. 284), body odors (p. 597), the taste for sweets (p. 1006), the nephron loop (p. 914), lactose intolerance (p. 985), menopause (p. 1077), and senescence (p. 1134).

I must say that I strongly support the [evolutionary] approach. The more students hear about evolution, selection and adaptation, the better. These three variables are crucial for understanding physiology.... It is a nice idea to provide them with the underpinnings of the terms adaptation and selection.

—Ralph F. Fregosi, University of Arizona

I am particularly impressed with Saladin's inclusion of evolution and the history of medicine. I often try to interject this information into my lectures, and find most modern texts lacking in these areas. Kudos to you!

—Mary E. Dawson, Kingsboro Community College

HISTORICAL INSIGHTS— HUMANIZING HUMAN A&P

I found long ago that students especially enjoy lectures in which I remark on the personal dramas that enliven the history of medicine, so I've incorporated that into my writing as well. In these pages, I share such favorite stories as William Beaumont's digestive experiments on Alexis St. Martin, "the man with the hole in his stomach" (p. 995); Crawford Long's discovery of the surgical benefit of a popular party drug, ether (p. 630); Phineas Gage's dramatic personality changes following his remarkable brain injury (p. 539); and the testy relationship between the two men who shared a Nobel Prize for the discovery of insulin, Frederick Banting and J. J. R. MacLeod (p. 672). There's drama and poignancy in the struggles and unkind ironies of the careers of Rosalind Franklin (p. 130), Marie Curie (p. 57), and Charles Drew (p. 693); we can take inspiration from the way that Santiago Ramón y Cajal (p. 453), William

Harvey (p. 754), and Rita Levi-Montalcini (p. 454) triumphed over privation, ridicule, and even ethnic persecution.

Some say they simply don't have time in their A&P courses to cover any evolution or scientific history. Neither my book nor my semesters are longer than anyone else's, yet I find, as my students seem to do, that an occasional evolutionary remark or historical drama make the teaching and learning of A&P a lot more fun. More than a few distinguished scientists and clinical practitioners say they found their inspiration in reading of the lives of their predecessors.

What's New?

What distinguishes this edition from the previous one? It certainly is not just the old book in a new cover. My personal list of changes runs to 95 pages of 10-point type, so obviously only the most important ones can be listed here.

ILLUSTRATIONS

The most extensive change in this edition is a thorough revision of its 809 illustrations. The editor and I put a great deal of thought into how every piece of art might be improved, and McGraw-Hill engaged a team of talented scientific and medical illustrators at Precision Graphics, in Champaign, Illinois, to enhance, revamp, or replace almost every item of line art. The improvements are too numerous to list more than a few, but users of the previous edition will find conspicuous improvements in such figures as the plasma membrane (p. 95), endochondral ossification (p. 223), gross anatomy of the spinal cord (p. 483), the eye (p. 615), capillary histology (pp. 758 and 759), neutrophil diapedesis (p. 826), the cardiac myocyte (p. 729), neural control of respiration (p. 868), the nephron (p. 903), and histology of the teeth (p. 961) and liver (p. 976).

The illustrators' flair for human portraiture has greatly humanized and beautified such figures as wound healing (p. 181), the paranasal sinuses (p. 248), the hyoid (p. 257), the facial nerve (p. 553), and others. More realistic figure drawings also now grace the "icons" that we use to identify the bodily location of a close-up view, a dissection, or a section—for example at pages 47, 350, and 898.

Several illustrative concepts are entirely new to this edition: intervertebral disc herniation (p. 262), axes of joint rotation (p. 300), the knee menisci (p. 313), knee injuries (p. 314), CNS myelination (p. 451), the relationship of the Schwann cell to unmyelinated nerve fibers (p. 452), cross-sectional anatomy of the pons and medulla (p. 525), the sleep cycle (p. 537), the hepatic sinusoid (p. 976), development of T and B cells (p. 830), the

endometrial cycle (p. 1084), and the histology of intramembranous ossification (p. 222), the thymus (p. 816), and red bone marrow (p. 814).

Numerous figures have been enlarged and their color schemes brightened. In laying out the pages, we took great pains to ensure that in nearly every case, an illustration is placed on the same page as the text that first references and describes it, or on the facing page, so there can be a minimum of page turning between reading about a figure and looking at it.

In many cases, I have moved brief descriptions such as "Mediastinal surface, right lung" from the figure legends into the body of the figure itself (p. 862). This shortens the legends so there is less need to look up and down repeatedly between the legend and art.

I have also brought more uniformity to the "process figures": those which present a series of events. Yellow-highlighted numbers indicate the steps in a process and correspond to a numbered descriptive list of the events, placed within the figure (see p. xv) or at least on the same page (as on pp. 457 and 658). In multipart figures that show different perspectives on the same subject, such as views at levels of increasing detail, we box the area of interest and connect the figure elements with arrows (as on p. 816). Such changes give the art a stronger sense of action and a clearer sense of relationship among the figure elements.

The photographs also came under close scrutiny. Several cadaver photographs have been replaced with new ones that depict better specimens, cleaner dissections, or sharper photography (abdominal muscles, p. 345; leg muscles, p. 375; lymph nodes, p. 817; kidney, p. 899). Several other replacement photos are more stunning or instructive than the old ones (some of the joint movements, pp. 302–307; ovarian follicle, p. 635; spina bifida, p. 485; kwashiorkor, p. 684; capillary bed, p. 753; glomerular podocytes, p. 905; thalidomide effects, p. 1124). A few photos of subjects entirely new to this edition include platelet structure (p. 703), twin fetuses (p. 1110), and some of the fetal development series (pp. 1120–1121).

REWRITES AND UPDATES

One of my most important tasks as author is to keep the science current, which I do through more than a dozen journal subscriptions, updating my library of medical books, attending conferences, monitoring and participating in online discussions of A&P, and receiving very helpful feedback from reviewers and users of the book. I have rewritten numerous passages to update the scientific content, correct errors, and improve readability. Such changes are too numerous to list in entirety, but the most significant ones in each chapter are as follows.

Chapter 1, Major Themes of Anatomy and Physiology.

A more multicultural look at early medical history; corrections in the chronology of microscopy; update on the evolution of modern *Homo sapiens*.

Chapter 2, The Chemistry of Life.

New discussion of the role of van der Waals forces in protein folding and molecular associations.

Chapter 3, Cellular Form and Function.

Rewritten sections on osmosis and peroxisomes.

Chapter 4, Genetics and Cellular Function.

Rewritten sections on chromatin coiling, mitosis, and cancer. Updates on changing concepts of the gene, alternative RNA splicing and protein diversity, genomic medicine, and the Human Genome Project.

Chapter 5, Histology.

New sections on stem cells and tissue engineering.

Chapter 6, The Integumentary System.

Reorganized section on the skin; new content on epidermal stem cells and dendritic cells; updates on epidermal tight junctions, eumelanin and pheomelanin, and the malignant melanoma oncogene.

Chapter 7, Bone Tissue.

Reorganized sections on bone function, general bone structure, and the composite nature of the bone matrix. Expanded treatment of intramembranous ossification. Sections on endochondral ossification, bone growth, and bone remodeling rewritten for clarity. Wolff's law introduced. Scientific updates on osteocyte function, RANKL (formerly osteoclast-stimulating factor), and the diagnosis and treatment of osteoporosis.

Chapter 8, The Skeletal System.

New content on the mechanical function of interosseous membranes and rotation of the embryonic limbs as a basis for understanding adult limb orientation. All bone features introduced in chapter 10 as muscle attachments are now explained here.

Chapter 9, Joints.

Substitution of functional discussion for anatomical detail; deletion of jaw and ankle anatomy, replaced by an extensive rewrite on joint biomechanics to provide a better background for study in kinesiology and physical therapy. Reorganized section on types of synovial joint movements, with introduction of kinesiologic terminology.

Chapter 10, The Muscular System.

Narratives on muscle anatomy condensed and moved into the tables. All muscle origins and insertions, previously from multiple sources, now conformed to *Gray's Anatomy*. Some minor and variable muscles deleted (procerus, plantaris, and deep and superficial perineal) and table entries on some other muscles divided or expanded. More everyday examples used for muscle actions.

Chapter 11, Muscular Tissue.

Rewrites and updates on the elastic components of muscle, dystrophin and other accessory muscle proteins, energy metabolism of muscle, muscle strength, morphology of cardiac myocytes, and muscular dystrophy.

Chapter 12, Nervous Tissue.

Enhanced discussion of astrocyte function, nerve regeneration, and the labeled line code. New historical notes on Camillo Golgi and Ramón y Cajal, and essay on Rita Levi-Montalcini.

Chapter 13, The Spinal Cord, Spinal Nerves, and Somatic Reflexes.

Updates on spina bifida and folic acid, muscle spindle physiology, and shingles. Rewrites on the spinoreticular, tectospinal, and vestibulospinal tracts, and explanation of their related brainstem nuclei. Reorganized tables of spinal nerve plexuses with simplified lists of their muscle innervations.

Chapter 14, The Brain and Cranial Nerves.

New concepts of cerebellar function, and other rewrites on pain modulation, sleep, and functions of the mammillary nuclei, thalamus, limbic system, basal nuclei, sensory cortex, and orbitofrontal cortex. A new format for the cranial nerve tables.

Chapter 15, The Autonomic Nervous System and Visceral Reflexes.

Rewrites on the splanchnic nerve route, glossopharyngeal nerve, nitric oxide, cholinergic receptors, and autonomic brainstem nuclei.

Chapter 16, Sense Organs.

Rewrites on the general properties of receptors; lamellated corpuscles; spinal gating of pain; and projection pathways for pain, olfaction, and vestibular function. Updates on olfactory sensory transduction and central processing, retinal circuitry, and inhalation anesthesia. Enhanced treatments of the auditory ossicles and physiology of hearing. Simplified treatment of retinal rod and ganglion cell function.

Chapter 17, The Endocrine System.

Rewrites on the adrenal catecholamines and synthesis of thyroid hormones. Update on hepatic hormones including hepcidin.

Chapter 18, The Circulatory System: Blood.

Hemopoiesis reorganized, with only general principles presented early, and details of erythropoiesis now presented in the section on RBCs, leukopoiesis with the WBCs, and thrombopoiesis with the platelets. Rewrites on plasma, blood osmolarity, blood antigens and antibodies, leukocyte functions, and platelet structure. New Insight on the complete blood count.

Chapter 19, The Circulatory System: The Heart.

Rewrites on cardiac anatomy, cardiac myocyte morphology, angina and heart attack, blood pressure and

flow, chronotropic chemicals, and myocardial contractility. Introduction of clinical terms for the coronary blood vessels.

Chapter 20, The Circulatory System: Blood Vessels and Circulation. Rewrites on blood vessel histology; capillary types; blood pressure, resistance, and flow relationships; and capillary fluid exchange.

Chapter 21, The Lymphatic and Immune Systems. An extensively rewritten chapter with new treatments of the classic three lines of defense, leukocyte functions, interferons, the complement system, the membrane attack complex, immune surveillance, perforins and granzymes, inflammation, penicillin allergy, lymphocyte development, T cell classes, antibody diversity, and AIDS chemotherapy. Addition of the structure of red bone marrow as a lymphatic organ, and a new Insight on lymph nodes and cancer. Updated and simplified cytokine terminology and deletion of some obsolete cytokine nomenclature.

Chapter 22, The Respiratory System. Expanded treatment of respiratory muscles and pulmonary ventilation, brainstem respiratory centers, and neural control of breathing. Rewrites on respiratory gross anatomy, restrictive and obstructive lung disorders, pressure and airflow relationships, and pulmonary surfactant.

Chapter 23, The Urinary System. Update on hormonal control of nephron function; enhanced discussion of ureter and bladder histology; rewrite on the neural control of micturition; and deletion of renal diabetes.

Chapter 24, Water, Electrolyte, and Acid–Base Balance. Rewrite on disorders of acid–base homeostasis.

Chapter 25, The Digestive System. Rewrites on the enteric nervous system; histology of the jejunum, ileum, and colon; tongue musculature; emesis; lactose intolerance; and micelle formation. Update on bacterial flora. Addition of gluten-sensitive enteropathy (sprue) to the table of digestive disorders.

Chapter 26, Nutrition and Metabolism. Extensive rewrite and update on appetite control, hunger and satiety hormones, and obesity. New Insight on hepatitis and cirrhosis. Update on thermoregulation and heat stroke.

Chapter 27, The Male Reproductive System. Reorganized discussion of gross anatomy for better sequencing of illustrations. Rewrites on cryptorchidism, descent of the testes, testicular thermoregulation; neural control of coital physiology; the role of voluntary muscles in erection; and treatment of erectile dysfunction.

Chapter 28, The Female Reproductive System. Updates on the staging of Pap smears; the role of leptin in menarche and menstruation; the relation-

ship of oocyte count to the onset of menopause; the grandmother hypothesis for menopause; the role of plasmin in ovulation; preeclampsia; and contraception. Improved descriptions of the mesovarium, ovarian blood vessels, and cyclic histology of the uterus. Extensive rewrite on the ovarian cycle, with modified terminology and deletion of popular textbook truisms that are untrue.

Chapter 29, Human Development. Extensive rewrite of the entire section on prenatal development, introducing developmental trimesters and embryonic folding. Improved treatment of embryonic germ layers and gastrulation. Rewrite on the trisomies and other aneuploid conditions.

ISSUES OF TERMINOLOGY

Aside from these chapter-specific changes, some anatomical terminology throughout the book has been updated in conformity to the *Terminologia Anatomica (TA)*, although I depart from the TA in cases where it seems that it would create more confusion than enlightenment for the beginning student. As in the previous edition, I follow the general trend of the TA and the American Medical Association in eliminating the possessive form for medical terms (such as Down's syndrome and Peyer's patches); using English terms when they have become accepted as alternatives to the Latin (such as *piloerector muscle* in place of *arrector pili*); and using descriptive terms in place of eponyms (such as *pancreatic islets* in place of *islets of Langerhans*). The older Latin and eponymous terms are given only as parenthetical synonyms where new terms are first introduced.

Guided Tour

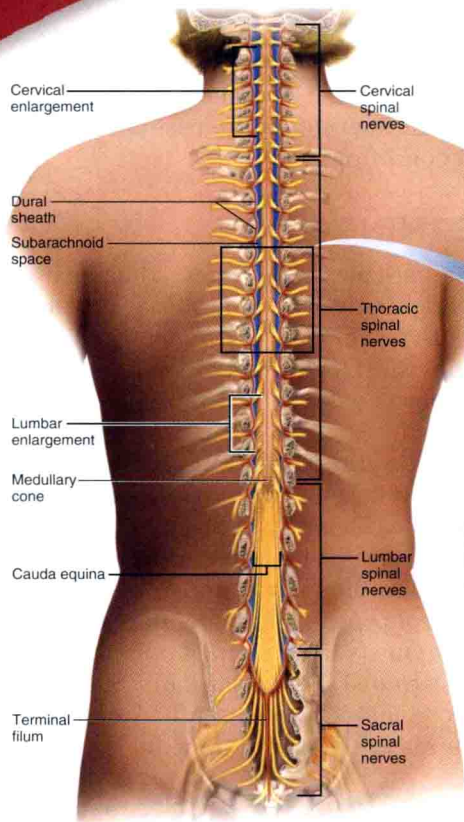
Students and instructors can become acquainted with the key features of this book by browsing through the Guided Tour starting on the next page. These pages constitute a visual exposition of the book's art program and the pedagogical framework around which each chapter is organized.

Suggestions Always Welcome

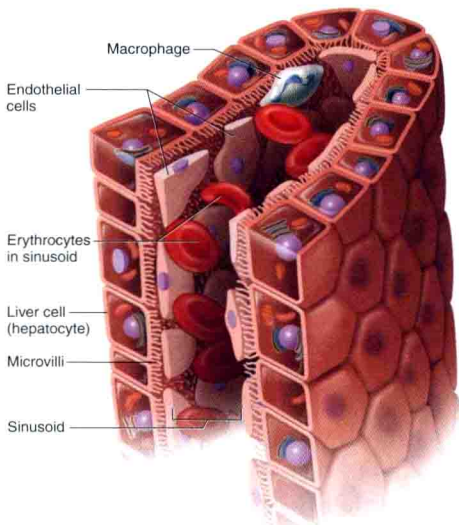
I invite my colleagues and students everywhere to continue offering their valuable and stimulating feedback as I plan the next edition.

Ken Saladin
Dept. of Biology
Georgia College & State University
Milledgeville, GA 31061 (USA)
478-445-0816
ken.saladin@gcsu.edu

Guided Tour

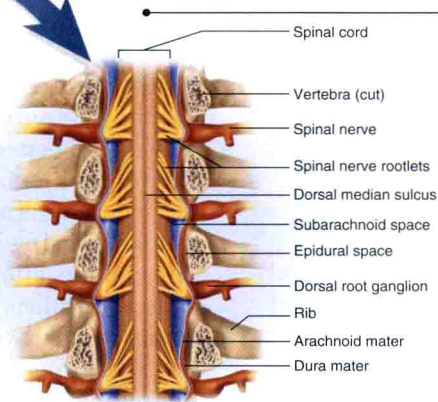


(a)



NEW AND VIVID ILLUSTRATIONS

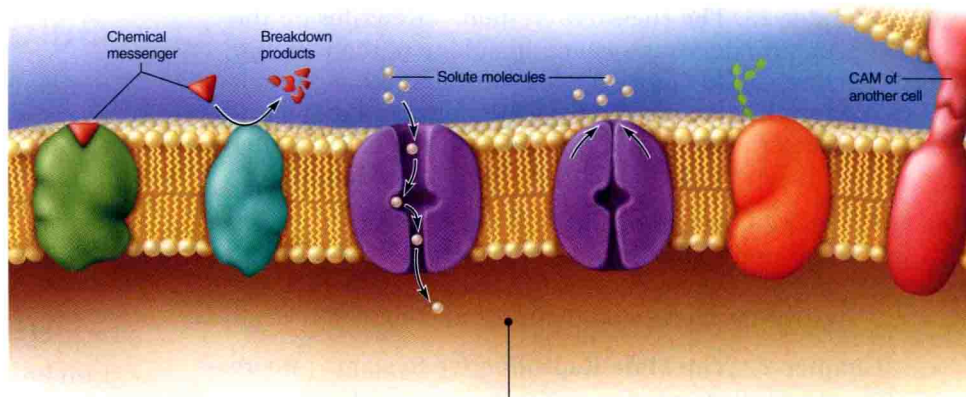
Saladin's all-new illustration program is unsurpassed among A&P texts! Dynamic illustrations harmonize with Saladin's clear and engaging writing style to create an A&P textbook that is visually captivating and fun to read. Colorful, precise anatomical illustrations lend a realistic view of body structures and three-dimensional details help students envision the cellular-level events of physiological processes.



(b)

BRIGHT, BOLD COLORS

A bright color palette provides contrast for easy distinction of structures.



THREE-DIMENSIONAL DETAIL

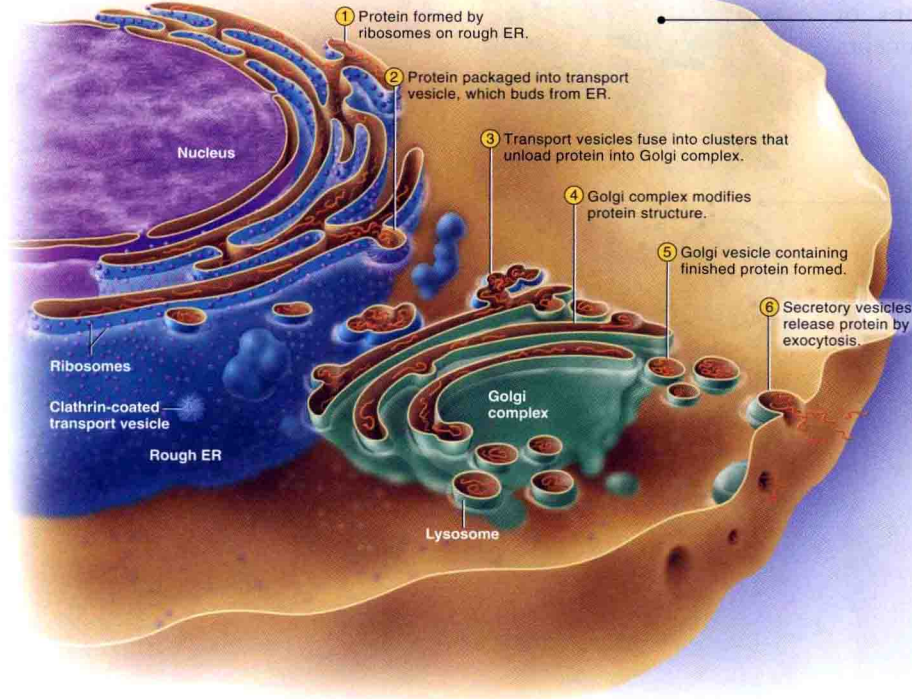
Rich textures and shading provide the visual depth and dimension that bring structures to life.

CONSISTENT COLOR PALETTE

Colors used to indicate specific structures are applied consistently for a cohesive art program from cover to cover.

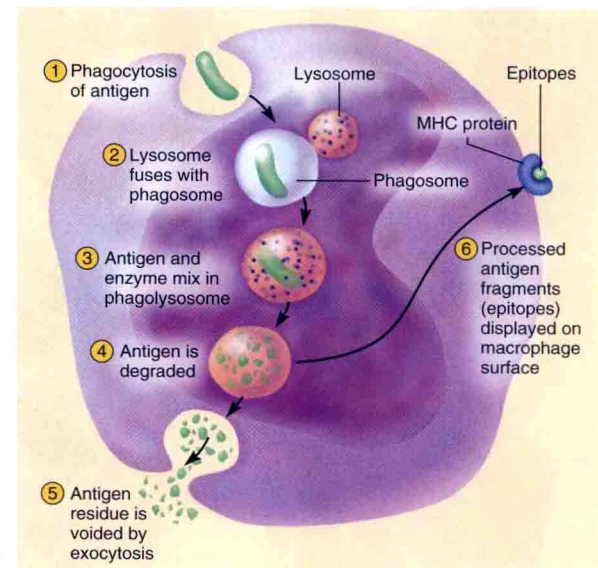
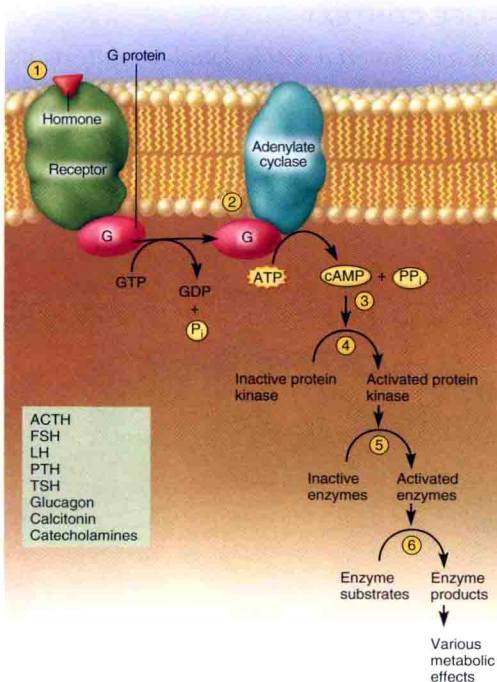
STEPPED-OUT PROCESS FIGURES

Saladin presents physiological concepts in an easy-to-follow stepwise format. Numbered steps within figures trace the sequence of events, and brief explanations describe what is happening in each step. Combining process descriptions with artwork creates a self-contained snapshot that summarizes concepts in a convenient and consistent format.



STEP-BY-STEP FORMAT

Numbered steps embedded in the artwork guide students through complex processes.

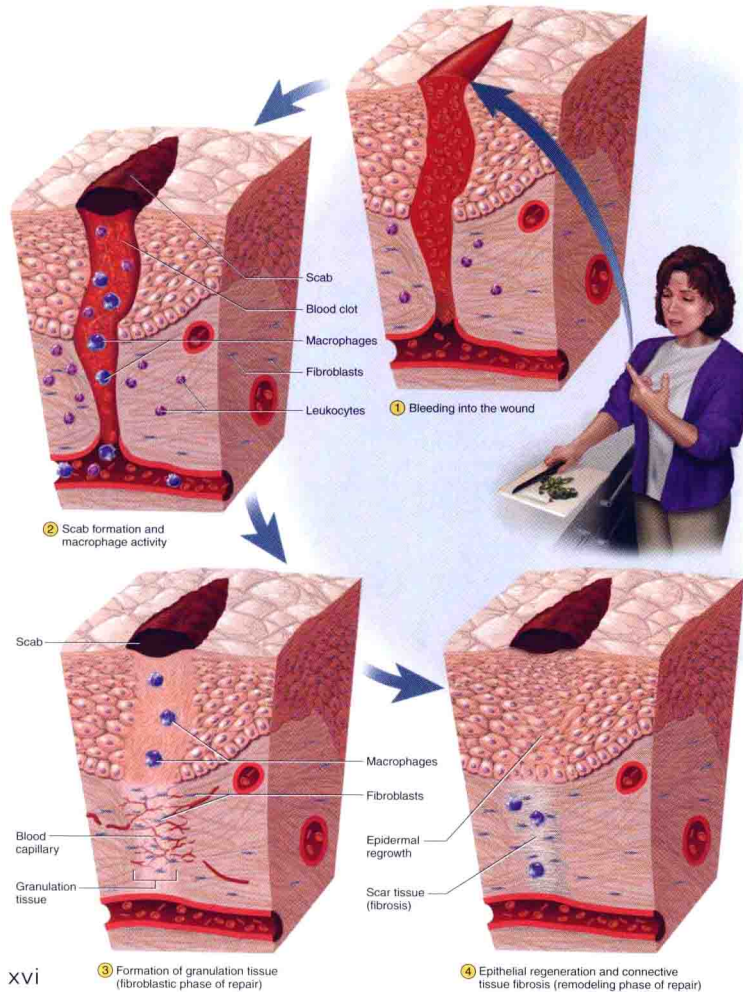
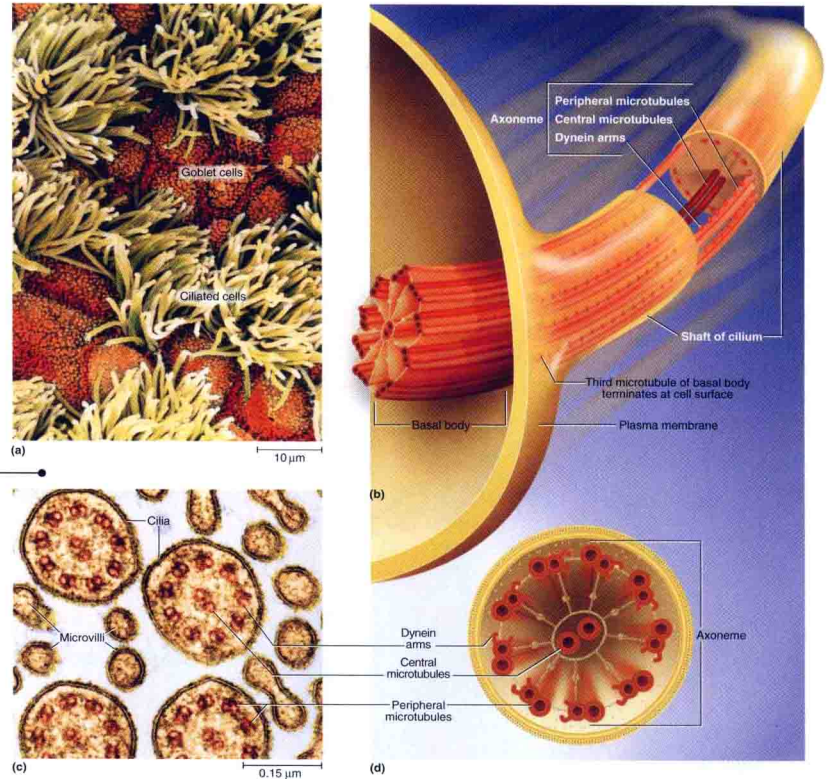


MESSAGE-DRIVEN LAYOUTS

Creating effective, educational artwork that conveys a clear message to students requires careful consideration of the relationship of the parts to the whole, as well as a little creativity. Saladin's figures are organized in meaningful displays in which individual figure parts interact with one another to create big-picture explanations. Figures are often accented with depictions of everyday items or situations to frame concepts within familiar contexts.

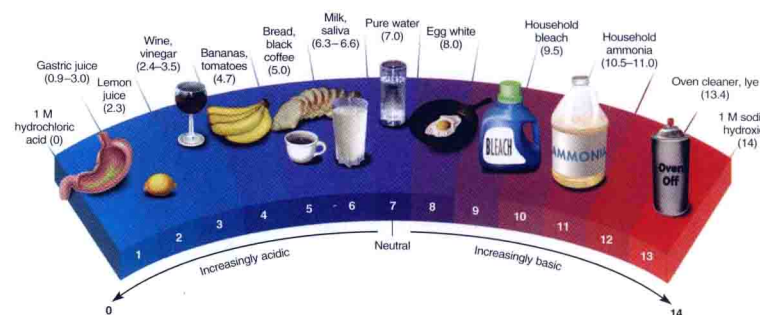
ENGAGING FIGURE PRESENTATIONS

Figures are arranged in cohesive layouts that emphasize relationships among figure parts. For example, sharing labels between photos and drawings allows for easy comparison of structure appearance between the two mediums.



REAL-LIFE CONTEXT

Framing new material within familiar contexts makes learning relevant to life. Many figures incorporate visual cues or artistic analogies that draw upon everyday experiences to facilitate understanding. This artistic technique is paralleled throughout the book by Saladin's analogy-rich writing style.

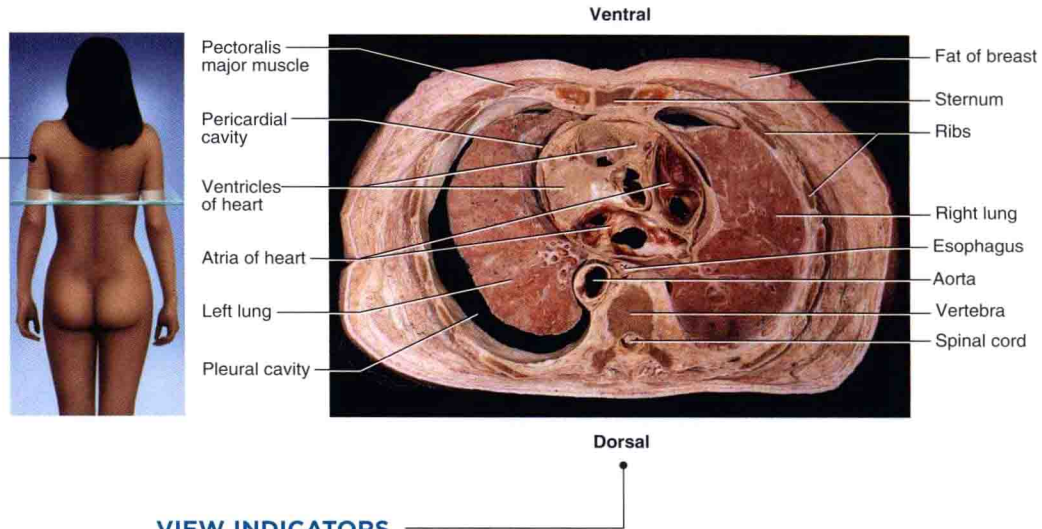


INFORMATION-RICH VISUALS

Interpreting anatomical views can be difficult, so Saladin's figures have been designed with students in mind. Special helps like view indicators, orientation icons, and clear figure navigation paths make the focus of each figure readily apparent. Descriptive information previously confined to figure legends has been embedded directly into the artwork to make figures understandable at first glance.

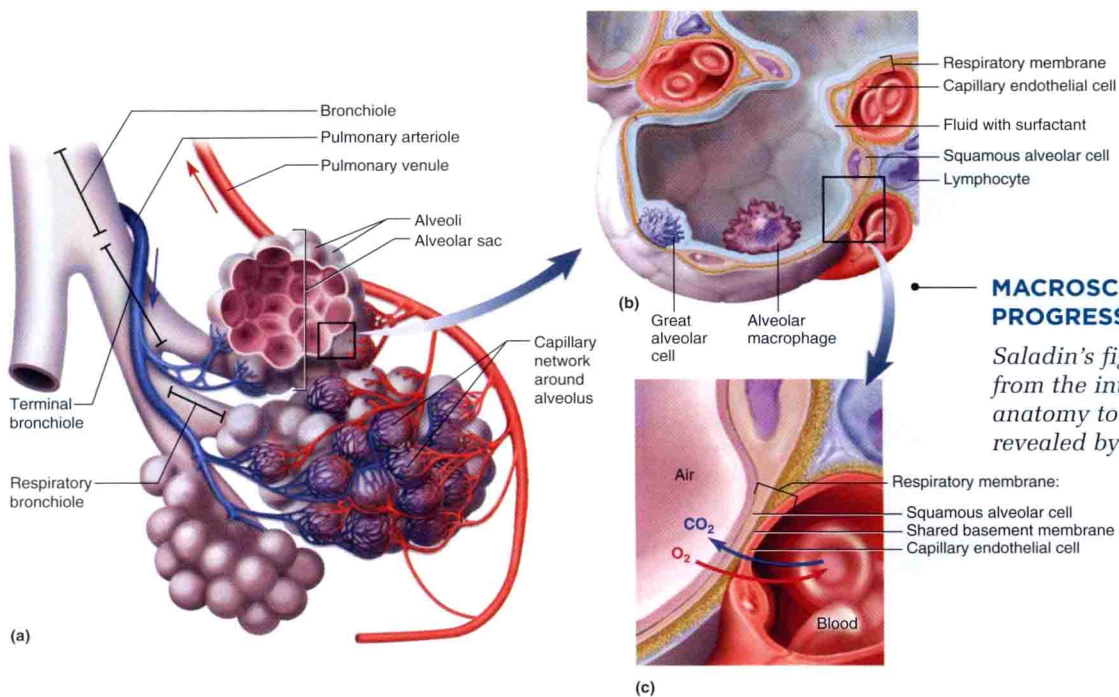
ORIENTATION ICONS

Reference diagrams clarify the view or plane an illustration represents.



VIEW INDICATORS

Descriptive labeling indicating figure views facilitates easy interpretation of what is shown.



MACROSCOPIC TO MICROSCOPIC PROGRESSION

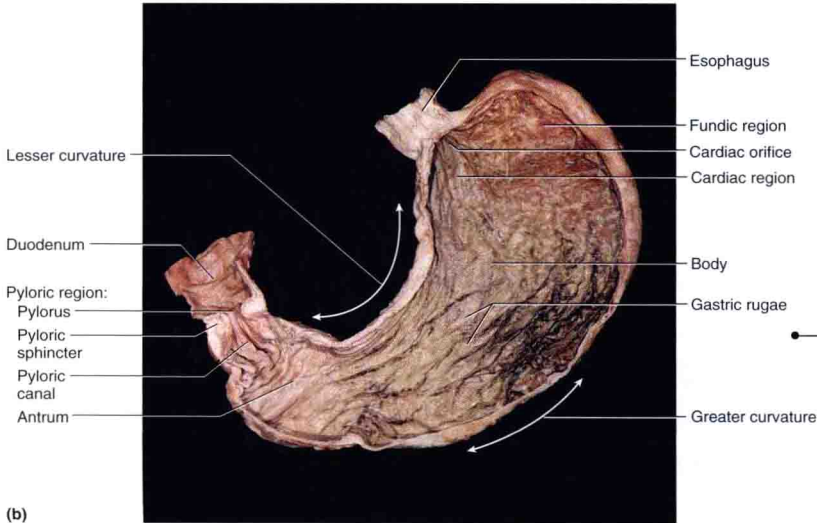
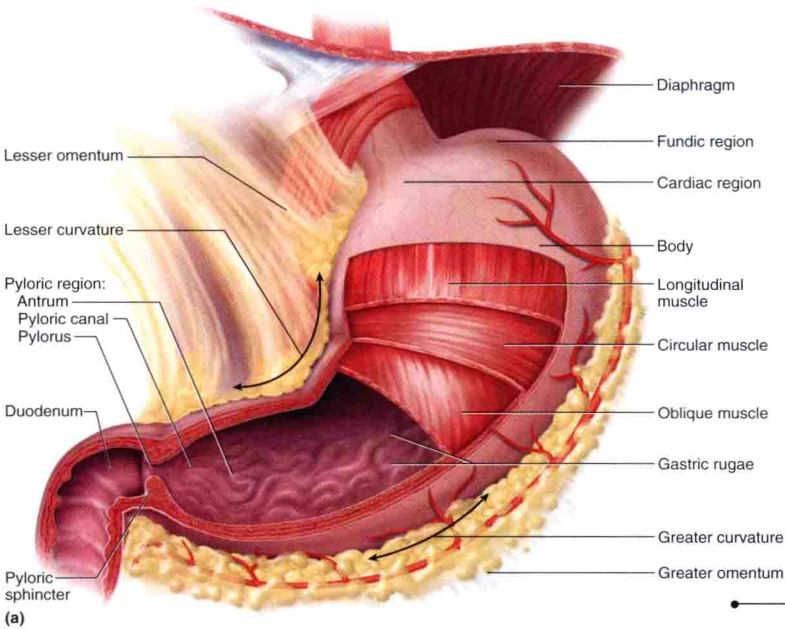
Saladin's figures guide students fluidly from the intuitive level of gross anatomy to the functional foundations revealed by microscopic anatomy.

ATLAS-QUALITY PHOTOGRAPHS

Photographs capture the truest appearance of gross and microscopic anatomy, and familiarize students with actual structures they may encounter in laboratory activities. Saladin's stunning collection of cadaver dissection images and light, TEM, and SEM photomicrographs balances the simplified clarity of illustrations with the realism of photos.

CADAVER DISSECTIONS

High-quality photographs of expertly dissected cadaver specimens capture the texture and detail of real human structures, and emphasize their anatomical relationships.

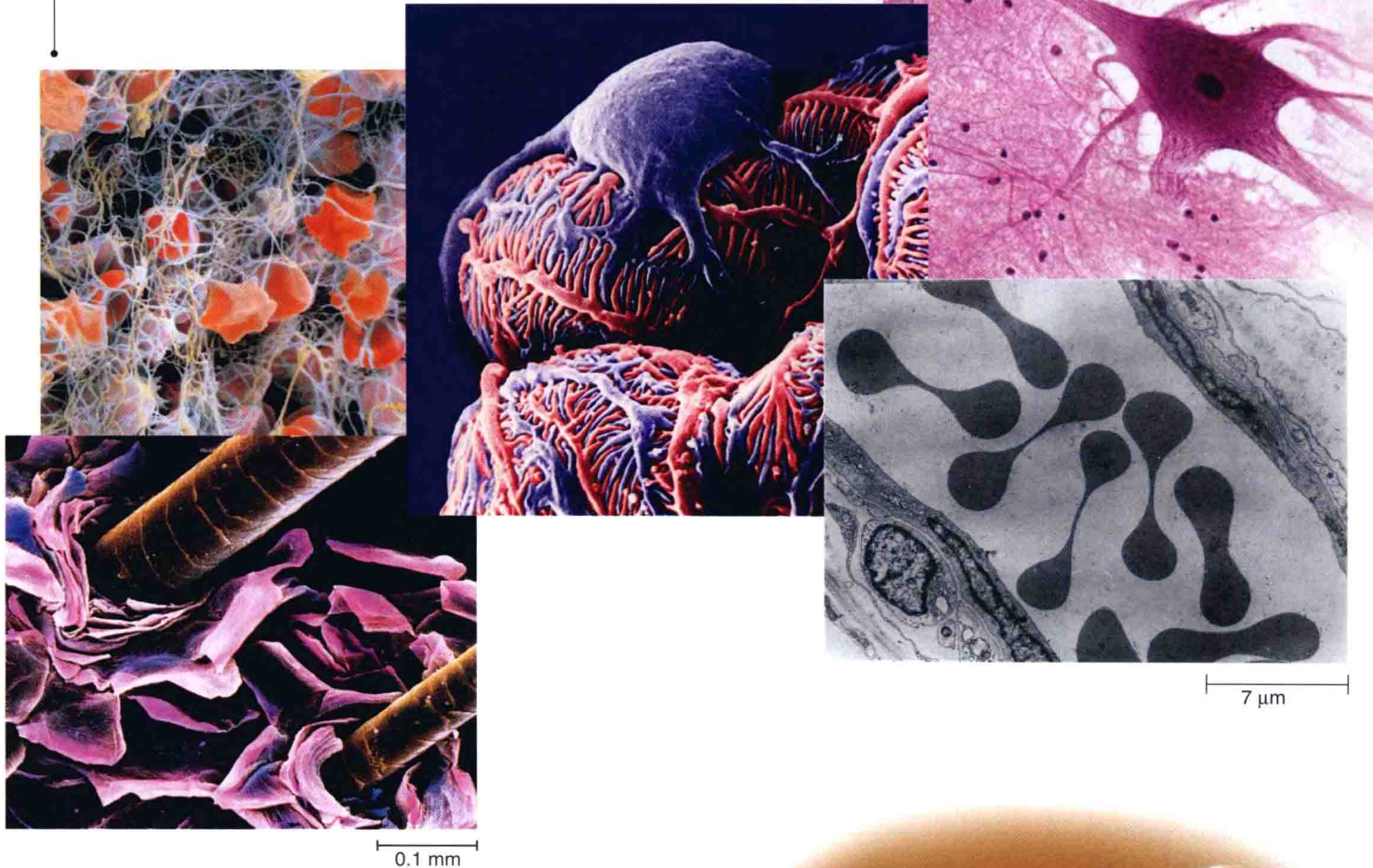


COMPLEMENTARY VIEWS

Drawings paired with photographs enhance visualization of structures. Labeling of art and photo mirror each other whenever possible, making it easy to correlate structures between views.

MICROGRAPHS

A carefully researched collection of LM, SEM, and TEM photomicrographs reveal the intricate detail of microscopic structures.

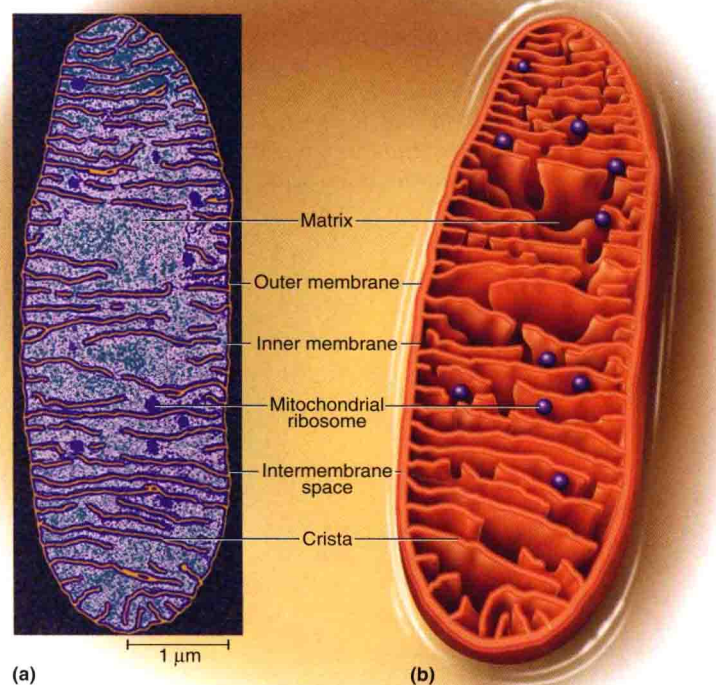


SCALE BARS


Scale bars are used whenever possible to provide a reference point for estimating the sizes of structures shown in micrographs.

PHOTOMICROGRAPHS CORRELATED WITH ILLUSTRATIONS

Photomicrographs are often paired with illustrations to give students the best of both perspectives: the realism of photos and the explanatory clarity of drawings.



CHAPTER
18



A red blood cell, white blood cells, and four platelets (TEM)

THE CIRCULATORY SYSTEM: BLOOD

CHAPTER OUTLINE

Introduction 680

- Functions of the Circulatory System 680
- Components and General Properties of Blood 680
- Blood Plasma 681
- Blood Viscosity and Osmolarity 683
- How Blood Is Produced 684

Erythrocytes 685

- Form and Function 685
- Hemoglobin 686
- Quantities of Erythrocytes and Hemoglobin 686
- The Erythrocyte Life Cycle 687
- Erythrocyte Disorders 690

Blood Types 692

- The ABO Group 692
- The Rh Group 695
- Other Blood Groups 696

Leukocytes 697

- Form and Function 697
- Types of Leukocytes 697
- The Leukocyte Life Cycle 700
- Leukocyte Disorders 702

Platelets and Hemostasis—The Control of Bleeding 703

- Platelet Form and Function 703
- Platelet Production 704
- Hemostasis 704
- The Fate of Blood Clots 708
- Prevention of Inappropriate Clotting 708
- Clotting Disorders 709

Chapter Review 711

Brushing Up

To understand this chapter, it is important that you understand or brush up on the following concepts:

- Polypeptides and conjugated proteins (p. 76)
- Filtration (p. 102)
- Osmosis and osmolarity (pp. 103–105)
- Dominant and recessive alleles (p. 144)
- Sex linkage (p. 146)

INSIGHTS

18.1 Clinical Application: Starvation and Plasma Protein Deficiency 684


18.2 Evolutionary Medicine: The Packaging of Hemoglobin 687

18.3 Medical History: Charles Drew—Blood Banking Pioneer 693

18.4 Clinical Application: The Complete Blood Count 700

18.5 Clinical Application: Liver Disease and Blood Clotting 708

18.6 Clinical Application: Clinical Management of Blood Clotting 710



Volume 3 Cardiovascular System

SYSTEMATIC PEDAGOGY

Saladin structures each chapter around a consistent and unique framework of pedagogic devices. Whatever the subject matter of a chapter, students can develop a consistent learning strategy. Orienting features such as chapter outlines and learning objectives help students organize study time and set goals, while self-testing questions in various formats and difficulty levels challenge students to recall terms and facts, to describe concepts, to analyze and apply ideas, and to relate concepts across chapters. Each chapter is seasoned with boxed discussions of clinical or scientific relevance that demonstrate application of concepts and add interest.

BRUSHING UP

A page-referenced list of previously covered concepts integral to understanding topics explained in the chapter at hand prompts students to review this material and reminds them that all organ systems are conceptually related.

ANATOMY & PHYSIOLOGY REVEALED

Chapters covering systems presented in McGraw-Hill's Anatomy & Physiology Revealed series include an icon indicating which volume of this software coincides with the chapter.

CHAPTER OUTLINE

A chapter outline provides a quick overview of the chapter contents and organization.

LEARNING OBJECTIVES AND BEFORE YOU GO ON

Saladin divides each chapter typically into five or six short, digestible segments of just a few pages each, with a list of learning objectives at the beginning and a list of Before You Go On content review questions at the end of each one. This enables students to set tangible goals for short study periods and to assess their progress before moving on.

CHAPTER 18 The Circulatory System: Blood 703

Before You Go On

Answer the following questions to test your understanding of the preceding section.

- What is the overall function of leukocytes?
- List the five kinds of leukocytes in order of abundance, identify whether each is a granulocyte or agranulocyte, and describe how to identify each one.
- What does leukopenia have in common with erythropoiesis? How does it differ?
- What can cause an abnormally high or low WBC count?
- WBCs fight infection, and leukemia is an abnormally high WBC count. Yet leukemia patients are very vulnerable to infection. Explain this seeming paradox.

Platelets and Hemostasis—The Control of Bleeding

Objectives

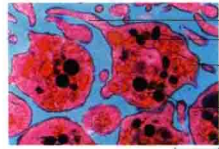
When you have completed this section, you should be able to:

- describe the body's mechanisms for controlling bleeding;
- list the functions of platelets;
- describe two reaction pathways that produce blood clots;
- explain what happens to blood clots when they are no longer needed;
- explain what keeps blood from clotting in the absence of injury; and
- describe some disorders of blood clotting.

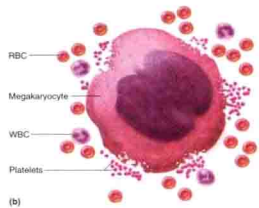
Circulatory systems developed very early in animal evolution, and with them evolved mechanisms for stopping leaks, which are potentially fatal. **Hemostasis**¹³ is the cessation of bleeding. Although hemostatic mechanisms may not stop a hemorrhage from a large blood vessel, they are quite effective at closing breaks in small ones. Platelets play multiple roles in hemostasis, so we begin with a consideration of their form and function.

PLATELET FORM AND FUNCTION

Platelets are not cells but small fragments of marrow cells called **megakaryocytes**. Platelets are the second most abundant formed elements, after erythrocytes; a normal platelet count in blood from a fingerstick ranges from 130,000 to 400,000 platelets/ μ L (averaging about 250,000). The platelet count can vary greatly, however, under different physiological conditions and in blood



(a)



(b)

FIGURE 18.20 Platelets. (a) Structure of blood platelets (TEM). (b) Platelets being produced by a megakaryocyte in the bone marrow. Note the enormous size of the megakaryocyte compared with RBCs and WBCs.

samples taken from various places in the body. In spite of their numbers, platelets are so small (2 to 4 μ m in diameter) that they contribute even less than the WBCs to the blood volume.

Platelets have a complex internal structure that includes lysosomes, mitochondria, microtubules and microfilaments, **granules** filled with platelet secretions, and a system of channels called the **open canalicular system**, which opens onto the platelet surface (Fig. 18.20a). They have no nucleus. When activated, they form pseudopods and are capable of amoeboid movement.

Despite their small size, platelets have a greater variety of functions than any of the true blood cells:

- They secrete **vasoconstrictors**, chemicals that cause spasmodic constriction of broken vessels and thus help reduce blood loss.
- They stick together to form temporary **platelet plugs** to seal small breaks in injured blood vessels.