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, he teaches histology, neuroanatomy, biomedical etymology, animal behavior, sociobiology, and other biological and interdisciplinary courses. Ken is a six-time recipient of the Honor Professor award from Phi Kappa Phi for outstanding mentoring of his undergraduate students. He received the university’s 1998 Excellence in Research and Publication Award for the first edition of this book, and partly in recognition of its growing success, he was named Distinguished Professor in 2001. Ken is an active member of the Human Anatomy and Physiology Society and the Society for Integrative and Comparative Biology. He served as a developmental reviewer and wrote instructor’s supplements for several other McGraw-Hill anatomy and physiology textbooks for a number of years before beginning this book. Ken is married to Diane Saladin, a registered nurse. They regard their major joint achievement as having maintained their faculties moderately intact while raising two children through adolescence.

I dedicate this edition of Anatomy & Physiology to my daughter

Nicole

becoming a marine biologist at the University of Miami and making her dad proud.
Brief Contents

Part One
Organization of the Body
1  Major Themes of Anatomy and Physiology  1
   *Atlas A General Orientation to Human Anatomy*  29
2  The Chemistry of Life  55
3  Cellular Form and Function  93
4  Genetics and Cellular Function  129
5  Histology  157

Part Two
Support and Movement
6  The Integumentary System  191
7  Bone Tissue  217
8  The Skeletal System  243
9  Joints  293
10  The Muscular System  325
    *Atlas B Surface Anatomy*  391
11  Muscular Tissue  407

Part Three
Integration and Control
12  Nervous Tissue  443
13  The Spinal Cord, Spinal Nerves, and Somatic Reflexes  481
14  The Brain and Cranial Nerves  515
15  The Autonomic Nervous System and Visceral Reflexes  563
16  Sense Organs  585
17  The Endocrine System  635

Part Four
Regulation and Maintenance
18  The Circulatory System: Blood  679
19  The Circulatory System: The Heart  715
20  The Circulatory System: Blood Vessels and Circulation  747
21  The Lymphatic and Immune Systems  799
22  The Respiratory System  841
23  The Urinary System  879
24  Water, Electrolyte, and Acid-Base Balance  915
25  The Digestive System  939
26  Nutrition and Metabolism  985

Part Five
Reproduction and Development
27  The Male Reproductive System  1017
28  The Female Reproductive System  1049
29  Human Development  1089

Appendix A  Periodic Table of the Elements  A–1
Appendix B  Answers to Chapter Review Questions  A–2
Appendix C  Lexicon of Biomedical Word Elements  A–6
Glossary  G–1
Credits  C–1
Index  I–1
## Contents

Preface viii

### Part One

**Organization of the Body**

#### Chapter 1

Major Themes of Anatomy and Physiology 1
- The Scope of Anatomy and Physiology 2
- The Origins of Biomedical Science 3
- Scientific Method 7
- Human Origins and Adaptations 9
- Human Structure 12
- Human Function 14
- The Language of Medicine 19
- Review of Major Themes 21
- Chapter Review 25

#### Atlas A

General Orientation to Human Anatomy 29
- Anatomical Position 30
- Anatomical Planes 31
- Directional Terms 31
- Surface Anatomy 32
- Body Cavities and Membranes 36
- Organ Systems 38
- A Visual Survey of the Body 39
- Chapter Review 52

#### Chapter 2

The Chemistry of Life 55
- Atoms, Ions, and Molecules 56
- Water and Mixtures 63
- Energy and Chemical Reactions 68
- Organic Compounds 71
- Chapter Review 88

#### Chapter 3

Cellular Form and Function 93
- Concepts of Cellular Structure 94
- The Cell Surface 98
- Membrane Transport 106
- The Cytoplasm 115
- Chapter Review 125

#### Chapter 4

Genetics and Cellular Function 129
- The Nucleic Acids 130
- Protein Synthesis and Secretion 134
- DNA Replication and the Cell Cycle 139
- Chromosomes and Heredity 145
- Chapter Review 152

#### Chapter 5

Histology 157
- The Study of Tissues 158
- Epithelial Tissue 160
- Connective Tissue 166
- Nervous and Muscular Tissue—Excitable Tissues 175
- Intercellular Junctions, Glands, and Membranes 178

### Part Two

**Support and Movement**

#### Chapter 6

The Integumentary System 191
- Structure of the Skin and Subcutaneous Tissue 192
- Functions of the Skin 198
- Hair and Nails 200
- Hair Growth and Loss 203
- Cutaneous Glands 205
- Diseases of the Skin 208
- Connective Issues 212
- Chapter Review 213

#### Chapter 7

Bone Tissue 217
- Tissues and Organs of the Skeletal System 218
- Histology of Osseous Tissue 221
- Bone Development 225
- Physiology of Osseous Tissue 229
- Bone Disorders 234
- Chapter Review 240

#### Chapter 8

The Skeletal System 243
- Overview of the Skeleton 244
- The Skull 246
- The Vertebral Column and Thoracic Cage 262
- The Pectoral Girdle and Upper Limb 270
- The Pelvic Girdle and Lower Limb 277
- Connective Issues 288
- Chapter Review 289

Tissue Growth, Development, Death, and Repair 183
- Chapter Review 187
Chapter 9
Joints 293
Joints and Their Classification 294
Fibrous, Cartilaginous, and Bony Joints 295
Synovial Joints 298
Anatomy of Selected Diarthroses 310
Chapter Review 322

Chapter 10
The Muscular System 325
The Structural and Functional Organization of Muscles 326
Muscles of the Head and Neck 330
Muscles of the Trunk 345
Muscles Acting on the Shoulder and Upper Limb 352
Muscles Acting on the Hip and Lower Limb 369
Connective Issues 387
Chapter Review 388

Atlas B
Surface Anatomy 391
The Importance of External Anatomy 392
Head and Neck 393
Trunk 394
Upper Limb 398
Lower Limb 400
Muscle Test 406

Chapter 11
Muscular Tissue 407
Types and Characteristics of Muscular Tissue 408
Microscopic Anatomy of Skeletal Muscle 409
The Nerve-Muscle Relationship 412
Behavior of Skeletal Muscle Fibers 416
Behavior of Whole Muscles 423
Muscle Metabolism 427
Cardiac and Smooth Muscle 432
Chapter Review 438

Part Three
Integration and Control

Chapter 12
Nervous Tissue 443
Overview of the Nervous System 444
Nerve Cells (Neurons) 445
Supportive Cells (Neuroglia) 449
Electrophysiology of Neurons 455
Synapses 463
Neural Integration 468
Chapter Review 476

Chapter 13
The Spinal Cord, Spinal Nerves, and Somatic Reflexes 481
The Spinal Cord 482
The Spinal Nerves 490
Somatic Reflexes 503
Chapter Review 510

Chapter 14
The Brain and Cranial Nerves 515
Overview of the Brain 516
Meninges, Ventricles, Cerebrospinal Fluid, and Blood Supply 519
The Hindbrain and Midbrain 524
The Forebrain 529
Higher Brain Functions 536
The Cranial Nerves 546
Chapter Review 558

Chapter 15
The Autonomic Nervous System and Visceral Reflexes 563
General Properties of the Autonomic Nervous System 564
Anatomy of the Autonomic Nervous System 567
Autonomic Effects on Target Organs 574
Central Control of Autonomic Function 578
Connective Issues 581
Chapter Review 582

Chapter 16
Sense Organs 585
Properties and Types of Sensory Receptors 586
The General Senses 588
The Chemical Senses 592
Hearing and Equilibrium 597
Vision 610
Chapter Review 629

Chapter 17
The Endocrine System 635
Overview of the Endocrine System 636
The Hypothalamus and Pituitary Gland 637
Other Endocrine Glands 646
Hormones and Their Actions 652
Stress and Adaptation 662
Eicosanoids and Paracrine Signaling 664
Endocrine Disorders 666
Connective Issues 673
Chapter Review 674

Part Four
Maintenance

Chapter 18
The Circulatory System: Blood 679
Functions and Properties of Blood 680
Plasma 683
Blood Cell Production 684
Erythrocytes 689
Blood Types 694
Leukocytes 699
Hemostasis—The Control of Bleeding 702
Chapter Review 709

Chapter 19
The Circulatory System: The Heart 715
Gross Anatomy of the Heart 716
Cardiac Muscle and the Cardiac Conduction System 726
Electrical and Contractile Activity of the Heart 728
Blood Flow, Heart Sounds, and the Cardiac Cycle 733
Cardiac Output 737
Chapter Review 743
Chapter 20
The Circulatory System: Blood Vessels and Circulation 747
General Anatomy of the Blood Vessels 748
Blood Pressure, Resistance, and Flow 753
Capillary Exchange 761
Venous Return and Circulatory Shock 763
Special Circulatory Routes 766
Anatomy of the Pulmonary Circuit 767
Anatomy of the Systemic Arteries 767
Anatomy of the Systemic Veins 781
Connective Issues 794
Chapter Review 795

Chapter 21
The Lymphatic and Immune Systems 799
The Lymphatic System 800
Nonspecific Resistance 808
General Aspects of Specific Immunity 815
Cellular Immunity 818
Humoral Immunity 822
Immune System Disorders 827
Connective Issues 834
Chapter Review 835

Chapter 22
The Respiratory System 841
Anatomy of the Respiratory System 842
Mechanics of Ventilation 850
Neural Control of Ventilation 857
Gas Exchange and Transport 859
Blood Chemistry and the Respiratory Rhythm 867
Respiratory Disorders 868
Connective Issues 873
Chapter Review 874

Chapter 23
The Urinary System 879
Functions of the Urinary System 880
Anatomy of the Kidney 881
Urine Formation I: Glomerular Filtration 886
Urine Formation II: Tubular Reabsorption and Secretion 891
Urine Formation III: Water Conservation 897
Urine and Renal Function Tests 899
Urine Storage and Elimination 903
Connective Issues 909
Chapter Review 910

Chapter 24
Water, Electrolyte, and Acid-Base Balance 915
Water Balance 916
Electrolyte Balance 921
Acid-Base Balance 926
Chapter Review 934

Chapter 25
The Digestive System 939
General Anatomy and Digestive Processes 940
The Mouth Through Esophagus 943
The Stomach 949
The Liver, Gallbladder, and Pancreas 958
The Small Intestine 964
Chemical Digestion and Absorption 968
The Large Intestine 974
Connective Issues 979
Chapter Review 980

Chapter 26
Nutrition and Metabolism 985
Nutrition 986
Carbohydrate Metabolism 996
Lipid and Protein Metabolism 1004
Metabolic States and Metabolic Rate 1007
Body Heat and Thermoregulation 1009
Chapter Review 1013

Part Five
Reproduction and Development

Chapter 27
The Male Reproductive System 1017
Sexual Reproduction 1018
Sex Determination and Development 1019
Male Reproductive Anatomy 1023
Puberty and Climacteric 1030
Sperm and Semen 1032
Male Sexual Response 1037
Chapter Review 1043

Chapter 28
The Female Reproductive System 1049
Reproductive Anatomy 1050
Puberty and Menopause 1058
Oogenesis and the Sexual Cycle 1061
Female Sexual Response 1068
Pregnancy and Childbirth 1070
Lactation 1076
Connective Issues 1082
Chapter Review 1083

Chapter 29
Human Development 1089
Fertilization and Preembryonic Development 1090
Embryonic and Fetal Development 1094
The Neonate 1101
Aging and Senescence 1107
Chapter Review 1117

Appendix A Periodic Table of the Elements A–1
Appendix B Answers to Chapter Review Questions A–2
Appendix C Lexicon of Biomedical Word Elements A–6
Glossary G–1
Credits C–1
Index I–1
Thank you to the colleagues and students who have made this textbook so successful and helped to ensure its staying power in a very competitive textbook niche. Several people have asked me, with this book doing so well, why I don’t retire from the classroom. The answer is that not only do I find classroom teaching the most fulfilling aspect of my profession, but also that it is my students who teach me how to write. I work continually at finding more and more effective ways of getting concepts across to them, at turning on the light of insight. The best ideas for communicating difficult physiological ideas often come to mind during my face-to-face interactions with students, and many are the times that I have dashed back from the lecture room to the drawing pad or keyboard to sketch concepts for new illustrations or write down new explanations. Grading exams and homework assignments also continually gives me new impressions of whether I have effectively taught an idea through my writing. Thus, my students are my unwitting writing teachers. This pertains also to the students in my “extended classroom”—students worldwide who use the book and write to ask my help in understanding difficult concepts.

What are the improvements in this edition? I continue to aim for ever-better clarity, brevity, currency, and accuracy. Physiology, especially, is a complex subject to explain to beginning students, and I am always working in both the lecture room and textbook to find clearer ways to explain it. Physiology also is a fast-growing field, and it’s a challenge to keep a book up to date without it growing longer and longer. After all, our lecture periods and semesters aren’t getting any longer! So, while updating information, I have looked for ways to make my discussions more concise in each edition. I also continue to correct errors as students and content experts have sent me queries, corrections, and suggestions. Accuracy is, of course, an advantage of a seasoned textbook over a newcomer, and this book has gained a lot of seasoning and a little spice from my extensive correspondence with students and colleagues.

This preface describes the book’s intended audience, how we determined what students and instructors want in the ideal A&P textbook, what has changed in this edition to best meet your needs, how this book differs from others, and what supplements are available to round out the total teaching package.

### Audience

This book is meant especially for students who plan to pursue such careers as nursing, therapy, health education, medicine, and other health professions. It is designed for a two-semester combined anatomy and physiology course and assumes that the reader has taken no prior college chemistry or biology courses. I also bear in mind that many A&P students return to college after interruptions to raise families or pursue other careers. For returning students and those without college prerequisites, the early chapters will serve as a refresher on the necessary points of chemistry and cell biology.

Many A&P students also are still developing the intellectual skills and study habits necessary for success in a health science curriculum. There are many, too, for whom English was not their original language. Therefore, I endeavor to write in a style that is clear, concise, and enjoyable to read, and to enliven the facts of science with analogies, clinical remarks, historical notes, biographical vignettes, and other seasoning that will make the book enjoyable to students and instructors alike. Each chapter is built around pedagogic strategies that will make the subject attainable for a wide range of students and instill the study and thinking habits conducive to success in more advanced courses.

### How We Evaluated Your Needs

This book has evolved through extensive research on the needs and likes of A&P students and instructors. In developing its three editions so far, we have collected evaluative questionnaires from reviewers; commissioned detailed reviews from instructors using this book and those using competing books; held focus groups from coast to coast in the United States, in which instructors and students studied the book in advance, then met with us to discuss it in depth for several hours, including how it compared to other leading A&P textbooks; and created panels of A&P instructors to thoroughly analyze the entire book and its art program. These efforts have involved many hundreds of faculty and students and generated thousands of pages of reviews, all of which I have read carefully in developing my revision plans. In a less formal
way, the book has improved because of the many e-mails I receive from instructors and students worldwide who not only tell me what they like about it, but also raise suggestions for correction or improvement. I’ve responded generously to these e-mails because I learn a great deal looking up answers to readers’ questions, finding sources to substantiate the book’s content, and sometimes finding that I need to update, clarify, or correct a point.

How We’ve Met Your Needs

Our research has consistently revealed that the three qualities instructors value most in a textbook are, in descending order of importance, writing style, illustration quality, and teaching supplements. I have focused my attention especially on the first two of these and on pedagogic features, while McGraw-Hill Higher Education has continually engaged other authors and software developers to produce a more diverse package of superb supplements for students and instructors.

Writing Style

Students benefit most from a book they enjoy reading, a book that goes beyond presenting information to also tell an interesting story and engage the reader with a somewhat conversational tone. That was my guiding principle in finding the right voice for the first edition, and it remains so in this one. I try to steer a middle course, avoiding rigid formality on one hand or a chatty descending tone on the other. I feel I have succeeded when students describe the tone as friendly, engaging, colloquial, almost as if the author is talking to them, but not talking down to them.

In devising ways to make the writing more concise without losing the qualities that make it interesting and enjoyable, I have been guided by reviewers who identified areas in need of less detail and by students who cited certain areas as especially engrossing and pleasurable to read. In this edition, I somewhat reduced the number of boldfaced terms and the amount of vocabulary, and fine-tuned such mechanics as sentence length, paragraph breaks, and topic and transitional sentences for improved flow. In such difficult topics as action potentials, blood clotting, the countercurrent multiplier, or aerobic respiration, I think this book will compare favorably in a side-by-side reading of competing textbooks.

Illustrations

When I was a child, it was the art and photography in biology books that most strongly inspired me to want to learn about the subject. So it comes as no surprise that students and instructors rate the visual appeal of this book as second only to writing style in importance. I developed many illustrative concepts not found in other books. Professional medical illustrators and graphic artists have rendered these, as well as the classic themes of A&P, in a vivid and captivating style that has contributed a lot to a student’s desire to learn.

As the book has evolved through these three editions, I have used larger figures and brighter colors; adopted simpler, uncluttered labeling; and continued to incorporate innovative illustrative concepts. A good illustration conveys much more information than several times as much space filled with verbiage, and I have cut down on the word count of the book to allow space for larger and more informative graphics.

The illustration program is more than line art. I continue to incorporate better histological photography and cadaver dissections, including many especially clear and skillful dissections commissioned specifically for this book.

Several of my students have modeled for photographs in this book. As much as possible with the volunteers who came forth, I have represented an ethnic variety of subjects, getting away from the unfortunate stereotype in some other textbooks in which the photo models are all white.

Supplements

The third most highly rated quality is the package of learning supplements for the student and teaching aids for the instructor. Instructors have rated overhead transparencies the most important of all supplements, and we now include transparencies of every item of line art in the book, and some of the photographs and tables. Included are unlabeled duplicates of many anatomical figures, useful for testing or labeling to fit one’s individual teaching approach. A full set of both labeled and unlabeled illustrations is also available in the Instructor’s Presentation CD-ROM.

Students have expressed growing enthusiasm and appreciation for the Online Learning Center and the Essential Study Partner. We have continued to enrich these media with an abundance of learning aids and resources. These and other student and instructor supplements are listed and described on page xiii.

What Sets This Book Apart?

Those who have not used or reviewed previous editions will want to know how this book differs from others.

Organization

The sequence of chapters and placement of some topics in this book differ from others. While I felt it was risky to depart from tradition in my first edition, reviewer comments have overwhelmingly supported my intuition that these represent a more logical way of presenting the
human A&P. Indeed, some have written that they are changing their teaching approach because of this book.

**Heredity**

I treat the most basic concepts of heredity in chapter 4 rather than waiting, as most books do, until the last chapter. Students would be ill-prepared to understand color blindness, blood types, hemophilia, sex determination, and other topics if they didn’t already know about such concepts as dominant and recessive alleles, sex chromosomes, and sex linkage.

**Muscle Anatomy and Physiology**

I treat gross anatomy of the muscular system (chapter 10) immediately after the skeletal system and joints in order to tie it closely to the structures on which the muscles act and to relate muscle actions to the terminology of joint movements. This is followed by muscle physiology and then neurophysiology so that these two topics can be closely integrated in their discussions of synapses, neurotransmitters, and membrane potentials.

**Nervous System Chapters**

Many instructors cite the nervous system as the most difficult one for students to understand, and in many courses, it is presented in a hurry before the clock runs out on the first semester. Other A&P textbooks devote six chapters or more to this system. It is overwhelming to both the instructor and student to cover this much material at the end of the course. I present this system in five chapters, and notwithstanding my assignment of a separate chapter to the autonomic nervous system in this edition, this is still the most concise treatment of this system among the similar two-semester textbooks.

**Urinary System**

Most textbooks place the urinary system near the end because of its anatomical association with the reproductive system. I feel that its intimate physiological ties with the circulatory and respiratory systems are much more important than this anatomical issue. The respiratory and urinary systems collaborate to regulate the pH of the body fluids; the kidneys have more impact than any other organ on blood volume and pressure; and the principles of capillary fluid exchange should be fresh in the mind of a student studying glomerular filtration and tubular reabsorption. Except for an unavoidable detour to discuss the lymphatic and immune systems, I treat the respiratory and urinary systems as soon as possible after the circulatory system.

**"Insight" Sidebars**

Each chapter has from two to six special topic sidebars called Insights, listed by title and page number on the opening page of each chapter. These fall into three categories: 101 clinical applications, 13 on medical history, and 9 on evolutionary medicine. For a quick survey of their subject matter, see the lists under these three phrases in the index.

**Clinical Applications**

It is our primary task in A&P to teach the basic biology of the human body, not pathology. Yet students want to know the relevance of this biology—how it relates to their career aims. Furthermore, disease often gives us our most revealing window on the importance of normal structure and function. What could better serve than cystic fibrosis, for example, to drive home the importance of membrane ion pumps? What better than brittle bone disease to teach the importance of collagen in the osseous tissue? The great majority of Insight sidebars therefore deal with the clinical relevance of the basic biology. Clinical content has also been enhanced by the addition of a table for each organ system that describes common pathologies and page-references others.

**Medical History**

I found long ago that students especially enjoyed lectures in which I remarked on the personal dramas that enliven the history of medicine. Thus, I incorporated that approach into my writing as well, emulating something that is standard fare in introductory biology textbooks but has been largely absent from A&P textbooks. Reviews have shown that students elsewhere, like my own, especially like these stories. I have composed 13 historical and biographical vignettes to have an especially poignant or inspiring quality, give students a more humanistic perspective on the field they’ve chosen to study, and, I hope, to cultivate an appropriately thoughtful attitude toward the discipline. Historical remarks are also scattered through the general text.

Profiles of Marie Curie (p. 58), Rosalind Franklin (p. 132), and Charles Drew (p. 694) tell of the struggles and unkind ironies of their scientific careers. Some of my favorite historical sidebars are the accounts of William Beaumont’s digestive experiments on “the man with a hole in his stomach” (p. 977); Crawford Long’s pioneering surgical use of ether, until then known mainly as a party drug (p. 628); the radical alteration of Phineas Gage’s personality by his brain injury (p. 538); and the testy relationship between the men who shared a Nobel Prize for the discovery of insulin, Frederick Banting and J. J. R. MacLeod (p. 671).

**Evolutionary Medicine**

The human body can never be fully appreciated without a sense of how and why it came to be as it is. Medical literature since the mid-1990s has shown increasing interest in “evolutionary medicine,” but most A&P textbooks continue to disregard it. Chapter 1 briefly introduces the con-
cept of natural selection and how certain human adaptations relate to our biological past. Later chapters have nine Evolutionary Medicine insights and shorter evolutionary remarks in the main body of text. Students will find novel and intriguing ways of looking at such topics as mitochondria (p. 124), hair (p. 204), skeletal anatomy (p. 286), body odors (p. 595), the taste for sweets (p. 990), the nephron loop (p. 897), lactose intolerance (p. 970), menopause (p. 1060), and senescence (p. 1114).

**Pedagogy**

Several features of this book are designed to facilitate the student’s learning.

**Learning Objectives**

I divide each chapter into typically five or six 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.

**Vocabulary Aids**

A&P students must assimilate a large working vocabulary. This is far easier and more meaningful if they can pronounce words correctly and if they understand the roots that compose them. Chapter 1 now has a section, “The Language of Medicine,” which I hope will help get students into the habit of breaking new words into familiar roots, and help them appreciate the importance of precision in spelling and word use. Pronunciation guides are given parenthetically when new words are introduced, using a “pro-NUN-see-AH-shun” format that is easy for students to interpret. New terms are accompanied by footnotes that identify their roots and origins, and a lexicon of about 400 most commonly used roots and affixes appears in appendix C (p. A-87).

**Self-Testing Questions**

Each chapter has about 75 to 90 self-testing questions in various formats and three levels of difficulty: recall, description, and analysis or application. The ability to recall terms and facts is tested by 20 multiple choice and sentence completion questions in the chapter review. The ability to describe concepts is tested by the “Before You Go On” questions at the ends of the chapter subdivisions, totaling about 20 to 30 such questions per chapter. The ability to analyze and apply ideas and to relate concepts in different chapters to each other is tested by an average of 5 “Think About It” questions at intervals throughout each chapter, 10 “True/False” questions in the chapter review that require the student to analyze why the false statements are untrue, and usually 5 questions per chapter in the figure legends, prompting the student to analyze or extrapolate from information in the illustrations. A great number and variety of additional questions are available to students at the Online Learning Center.

**System Interrelationships**

Most instructors would probably agree on the need to emphasize the interrelationships among organ systems and to discourage the idea that a system can be put out of one’s mind after a test is over. This book reinforces the interdependence of the organ systems in three ways.

1. Beginning with chapter 3 (p. 93), each chapter has a “Brushing Up” box that lists concepts from earlier chapters that one should understand before moving on. This may also be useful to students who are returning to college and need to freshen up concepts studied years before, and to instructors who teach the systems in a different order than the book does. It also reinforces the continuity between A&P I and II.

2. For each organ system, there is a “Connective Issues” feature (p. 212, for example) that summarizes ways in which that system influences all of the others of the body, and how it is influenced by them in turn.

3. Chapter 29 includes a section, “Senescence of the Organ Systems,” which can serve as a “capstone lesson” that compellingly shows how the age-related degeneration of each system influences, and is influenced by, the others. Senescence is an increasingly important topic for health-care providers as the population increases in average age. This section should sensitize readers not only to the issues of gerontology, but also to measures they can take at a young age to ensure a better quality of life later on. For instructors who prefer to treat senescence of each organ system separately throughout the course, earlier chapters cite the relevant pages of this senescence discussion.

**What’s New?**

I’ve been cautious about reorganizing the book and tampering with a structure that has been responsible for its success. Nevertheless, the voices of many reviewers have convinced me that a few changes were in order.

**Changes in Chapter Sequence**

I made two changes in chapter sequencing and numbering:
Nervous System Chapters

The most frequent request has been to give the autonomic nervous system a chapter of its own, with slightly deeper coverage. I have done so at chapter 15. Another common request I've accommodated has been to discuss the spinal cord and spinal nerves together in one chapter (now chapter 13) and the brain and cranial nerves together in another (now chapter 14).

Chemistry

To compensate for the added nervous system chapter without making the book longer, and because many reviewers felt that the book could do without two full chapters of chemistry, I condensed the coverage of chemistry by about 25% and combined the two former chemistry chapters into one (now chapter 2). This results in a change of chapter numbers from 3 through 15, but from chapter 16 to the end, the numbers are the same as in the previous editions.

Changes Within Chapters

In three cases, I felt that a subject could be presented more effectively by rearrangements and content substitutions within a chapter. Other chapters continue to be organized as they were in the second edition.

Chapter 1, Major Themes of Anatomy and Physiology

Here I replaced the section on human taxonomic classification with sections on anatomical and physiological variability. This gives the chapter a less zoological and more clinical flavor. Also, I feel it is important at the outset of such a course to instill a sense of the familiar roots of biomedical terms, the importance of precision in spelling, and other aspects of vocabulary. Thus I moved the former appendix B, which introduced students to medical etymology, to chapter 1 (“The Language of Medicine,” p. 19).

Chapter 17, The Endocrine System

As many reviewers desired, I have separated endocrine pathology from normal physiology and placed the pathology at the end of the chapter.

Chapter 21, The Lymphatic and Immune Systems

I have found it more effective to present cellular immunity before humoral immunity, since humoral immunity depends on some concepts such as helper T cells usually introduced in the context of cellular immunity.

Content Changes

I have strengthened the coverage of the following topics (indicating chapter numbers in parentheses): mitochondrial diseases (3), autoimmune diseases (5), the stages of hair growth (6), biomechanics of bone tissue (7), the enteric nervous system (15), receptive fields of sensory neurons (16), hormone-transport proteins (17), the blood-thymus barrier (21), clonal deletion and anergy (21), renal autoregulation (23), lipostats and leptin (26), and the trisomies (29).

I have updated information on the following, drawing on research and review literature as recent as April 2002, even as the book was in production: genetic translation in the nucleus (4), signal peptides (4), stem cell research (5), hair analysis (6), osteoporosis treatments (7), knee surgery (9), muscle–connective tissue relationships (11), mitosis in cardiac muscle (11), astrocyte functions (12), surgical treatment of parkinsonism (12), amyotrophic lateral sclerosis (13), memory consolidation (14), functional MRI (14), the sensory role of filiform papillae (16), a new class of retinal photoreceptors (16), the history of anesthesia (16), the relationship of growth hormone to somatomedins (17), cytotoxic T cell activation (21), asthma (21), neuroimmunology (21), atrial natriuretic peptide (23), hunger and body weight homeostasis (26), heritability of alcoholism (26), the functions of relaxin (28), contraceptive options (28), the fate of sperm mitochondria (29), Werner syndrome (29), telomeres (29), and theories of aging (29).

Issues of Terminology

In 1999, the Terminologia Anatomica (TA) replaced the Nomina Anatomica as the international standard for anatomical terminology. I have updated the terminology in this edition accordingly, except in cases where TA terminology is, as yet, so unfamiliar that it may be more of a hindrance than a help for an introductory anatomy course. For example, I use the unofficial femur rather than the official os femoris or femoral bone.

The TA no longer recognizes eponyms, and I have avoided using them when possible and practical (using tactile disc instead of Merkel disc, for example). I do introduce common eponyms parenthetically when a term is first used. Some eponyms are, of course, unavoidable (Alzheimer disease, Golgi complex) and in some cases it still seems preferable to use the eponyms because of familiarity and correlation with other sources that students will read (for example, Schwann cell rather than neurilemmocyte).

I follow the recommendation of the American Medical Association Manual of Style (ninth edition, 1998) to delete the possessive forms of nearly all eponyms. There are people who take offense at the possessive form Down’s syndrome and yet may be equally insistent that Alzheimer’s disease be in the possessive. The AMA has grappled with such inconsistencies for years, and I accept
its recommendation that the possessives be dropped whenever possible. I make exception for a few cases such as Broca’s area (which would be awkward to pronounce without the ‘s) and I retain the possessive form for natural laws (Boyle’s law).

**Pedagogic Changes**

I have made the following changes in pedagogy; see the referenced pages for examples of each:

- Added icons to the histological illustrations in chapter 5 to show a place where each tissue can be found (pp. 162–163).
- Added thought questions to some figure legends (usually five per chapter) and provided answers to these at the end of the chapter (p. 91).

**Figure 12.9 Ionic Basis of the Resting Membrane Potential.**

Note that sodium ions are much more concentrated in the extracellular fluid (ECF) than in the intracellular fluid (ICF), while potassium ions are more concentrated in the ICF. Large anions unable to penetrate the plasma membrane give the cytoplasm a negative charge relative to the ECF. If we suddenly increased the concentration of Cl⁻ ions in the ICF, would the membrane potential become higher or lower than the RMP?

- For each organ system, added a table of pathologies which briefly describes several of the most common dysfunctions and cites pages where other dysfunctions of that system are mentioned elsewhere in the book (p. 208).
- Changed the chapter reviews from an outline to a narrative format that briefly restates the key points of the chapter (p. 125).
- Shortened the end-of-chapter vocabulary lists, which no longer list all boldfaced terms in a chapter, but only those terms that I deemed most important (p. 126).
- Added 10 true/false questions to each chapter review, with a prompt to explain why the false questions are untrue (p. 127). The answers to these are in appendix B (p. 1122).

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**Suggestions Still Welcome!**

Many features of this book, and many refinements in the writing, illustrations, and factual content, came about because of suggestions and questions from instructors and their students. In addition, many things that were tried experimentally in the first edition have been retained in the later editions because of positive feedback from users. But perfection in textbook writing seems to be an asymptote, ever approached but never fully reached. I invite my colleagues and students everywhere to continue offering such valuable and stimulating feedback as I continue the approach.

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**Teaching and Learning Supplements**

McGraw-Hill offers various tools and technology products to support the third edition of Anatomy & Physiology. Students can order supplemental study materials by contacting their local bookstore. Instructors can obtain teaching aids by calling the Customer Service Department, at 800-338-3987, visiting our A&P website at www.mhhe.com/ap, or contacting their local McGraw-Hill sales representative.

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**Instructor’s Presentation CD-ROM**

This multimedia collection of visual resources allows instructors to utilize artwork from the text in multiple formats to create customized classroom presentations, visually based tests and quizzes, dynamic course website content, or attractive printed support materials. The digital assets on this cross-platform CD-ROM are grouped by chapter within the following easy-to-use folders:

- **Art Library** Full-color digital files of all illustrations in the book, plus the same art saved in unlabeled and gray scale versions, can be readily incorporated into lecture presentations, exams, or custom-made classroom materials. These images are also pre-inserted into blank PowerPoint slides for ease of use.
- **Photo Library** Digital files of instructionally significant photographs from the text—including...
cadaver, bone, histology, and surface anatomy images—can be reproduced for multiple classroom uses.

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In addition to the content found within each chapter, the Instructor’s Presentation CD-ROM for Anatomy & Physiology contains the following multimedia instructional materials:

- **Active Art Library** Active Art consists of art files from key figures from the book that have been converted to a format that allows the artwork to be edited inside of Microsoft PowerPoint. Each piece of art inside an Active Art presentation can be broken down to its core elements, grouped or ungrouped, and edited to create customized illustrations.

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- **Instructor’s Testing and Resource CD-ROM** This cross-platform CD-ROM provides a wealth of resources for the instructor. Supplements featured on this CD-ROM include a computerized test bank utilizing Brownstone Dipoma@ testing software to quickly create customized exams. This user-friendly program allows instructors to search for questions by topic, format, or difficulty level; edit existing questions or add new ones; and scramble questions and answer keys for multiple versions of the same test. Although few textbook authors write their own test banks, this test bank, written by the author himself better reflects the textbook than one contracted out to an independent writer.

Other assets on the Instructor’s Testing and Resource CD-ROM are grouped within easy-to-use folders. The Instructor’s Manual and the Instructor’s Manual to accompany the Laboratory Manual are available in both Word and PDF formats. Word files of the test bank are included for those instructors who prefer to work outside of the test-generator software.

**Laboratory Manual**

The Anatomy & Physiology Laboratory Manual by Eric Wise of Santa Barbara City College is expressly written to coincide with the chapters of Anatomy & Physiology. This lab manual has been revised to include clearer explanations of physiology experiments and computer simulations that serve as alternatives to frog experimentation. Other improvements include a greatly expanded set of review questions at the end of each lab, plus numerous new photographs and artwork.

**Transparencies**

This exhaustive set of over 1,000 transparency overheads includes every piece of line art in the textbook, tables, and several key photographs. An additional set of 150 unlabeled line art duplicates is also available for testing purposes or custom labeling. Images are printed with better visibility and contrast than ever before, and labels are large and bold for clear projection.

**English/Spanish Glossary for Anatomy and Physiology**

This complete glossary includes every key term used in a typical 2-semester anatomy and physiology course. Definitions are provided in both English and Spanish. A phonetic guide to pronunciation follows each word in the glossary.

**A Visual Atlas for Anatomy and Physiology**

This visual atlas contains key gross anatomy illustrations that have been blown up in size to make it easier for students to learn anatomy.
Clinical Applications Manual

Expands on Anatomy and Physiology's clinical themes, introduces new clinical topics, and provides test questions and case studies to develop the student's ability to apply his or her knowledge to realistic situations.

Course Delivery Systems

With help from our partners, WebCT, Blackboard, TopClass, eCollege, and other course management systems, professors can take complete control over their course content. These course cartridges also provide online testing and powerful student tracking features. The Saladin Online Learning Center is available within all of these platforms!

For the Student: MediaPhys CD-ROM

This interactive tool offers detailed explanations, high-quality illustrations, and animations to provide students with a thorough introduction to the world of physiology—giving them a virtual tour of physiological processes. MediaPhys is filled with interactive activities and quizzes to help reinforce physiology concepts that are often difficult to understand.

GradeSummit

GradeSummit, found at www.gradesummit.com, is an Internet-based self-assessment service that provides students and faculty with diagnostic information about subject strengths and weaknesses. This detailed feedback and direction enables learners and teachers to focus study time on areas where it will be most effective. GradeSummit also enables instructors to measure their students’ progress and assess that progress relative to others in their classes and worldwide.

Student Study Guide

This comprehensive study guide written by Jacque Homan, South Plains College, in collaboration with Ken Saladin, contains vocabulary-building and content-testing exercises, labeling exercises, and practice exams.

Acknowledgments

A textbook and supplements package on this scale is the product of a well coordinated effort by many dedicated people. I am deeply indebted to the team at McGraw-Hill Higher Education who have shown continued faith in this book and invested so generously in it.

For their unfailing encouragement and material support, I thank Vice President and Editor-in-Chief Michael Lange and Publisher Marty Lange. My appreciation likewise goes out to Michelle Watnick for her years of energetic promotion of the book and lately her role as Sponsoring Editor, and to the legion of sales managers and sales representatives who work so hard to get the book into the hands of my fellow instructors and their students.

Kristine Tibbetts, Director of Development, has been a wonderful editor with whom I’ve been very fortunate to
work for the past decade. The appearance of this book owes a great deal to Kris’s attention to detail and her uncompromising commitment to quality, accuracy, and esthetics. Were it not for e-mail, our voluminous correspondence would have required the razing of entire forests and probably would have detectably enhanced employment statistics for lumberjacks and postal carriers. Working closely with Kris and me, Designer K. Wayne Harms also deserves a great deal of credit for the esthetic appeal and readability of these pages.

Mary E. Powers, Senior Project Manager, has been responsible for monitoring all aspects of the project, keeping me and its many other contributors coordinated and moving toward the book’s timely release. She, too, has been a very alert reader of the entire manuscript and has spared no effort to incorporate last-minute corrections and to change page layouts for better figure placement and flow of text.

A good copyeditor makes one a better writer, and I have learned a great deal from my copyeditors on all editions of this book. On this edition, it was Cathy Conroy’s assiduous attention to detail, ranging from consistency in anatomical synonyms down to the humblest punctuation mark, that spared me from committing numerous embarrassing errors and inconsistencies.

And always high on my list at McGraw-Hill, I am especially grateful to Colin Wheatley for his conviction, over a decade ago, that I had a book in me, and for persuading me to give it a go. Few people have changed my life so profoundly.

The line art in this edition was beautifully executed by the medical illustrators and graphic artists of Imagineering STA Media Services in Toronto, under the watchful and knowledgeable eye of Jack Haley, Content/Art Director. Imagineering illustrator Dustin Holmes produced the award-winning cover art for the previous edition and, not surprisingly, I was delighted with his execution of the new cover art for this edition. For the visual appeal of this book, credit is also due to McGraw-Hill Photo Coordinator John Leland and Photo Researcher Mary T. Reeg, who worked hard to acquire photographs that are clear, informative, and esthetically appealing. I must also repeat my earlier thanks to anatomists Don Kincaid and Rebecca Gray of the Ohio State University Department of Anatomy and Medical Education Morgue for producing at my behest such clean, instructive dissections and clear cadaver photographs.

For photographs of living subjects, whenever possible I employed volunteers from among my own students at Georgia College and State University. For kindly lending their bodies to the service of science, I thank my students, colleagues, friends, and family members: Laura Ammons, Sharesia Bell, Elizabeth Brown, Amy Burmeister, Mae Carpenter, Valeria Champion, Kelli Costa, Adam Fraley, Yashica Marshall, Diane Saladin, Emory Saladin, Nicole Saladin, Dilanka Seimon, Natalie Spires, Xiaodan Wang, Nathan Williams, and Danielle Wychoff. The improved photographs of joint movements in this edition (chapter 9), with their multiple-exposure effects, are by Milledgeville photographer Tim Vacula.

Thanks once again to my colleagues David Evans and Eric Wise for their fine work in producing the Instructor’s Manual and Laboratory Manual, respectively. New thanks to Leslie Miller, M. S. N., for reviewing the manuscript from a clinical perspective and offering many helpful suggestions.

The factual content and accuracy of this edition owe a great deal to colleagues who are more knowledgeable than I in specific areas of human anatomy and physiology, and to both colleagues and inquisitive students whose e-mails and other queries sent me to the library to dig still deeper into the literature. I have gained especially from the lively and fruitful discussions on HAPP-L, the e-mail list of the Human Anatomy and Physiology Society (http://www.hapsweb.org); my heartfelt thanks go to the many colleagues who have made HAPP-L such a stimulating and informative site, and to Jim Pendley for maintaining the list.

Once again, and first in my appreciation, I thank my wife Diane, my son Emory, and my daughter Nicole, not only for sharing with me in the rewards of writing, but also for bearing up so graciously under the demands of having a full-time author cloistered in the inner sanctum of the house.

Reviewers

No words could adequately convey my indebtedness and gratitude to the hundreds of A&P instructors and experts who have reviewed this book in all its editions, and who have provided such a wealth of scientific information, corrections, suggestions for effective presentation, and encouragement. For making the book beautiful, I am indebted to the team described earlier. For making it right, I am thankful to the colleagues listed on the following pages.
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Saladin’s Anatomy and Physiology brings key concepts to life with its unique style of biomedical illustration. The digitally rendered images have a vivid three-dimensional look that will not only stimulate your students’ interest and enthusiasm, but also give them the clearest possible understanding of important concepts.

**Unparalleled Art Program**
Saladin’s illustration program includes digital line art, numerous cadaver photographs, and light, TEM, and SEM photomicrographs. Larger images and brighter colors in the third edition will help draw your students into the subject.

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
The art program in Saladin’s text is superb. Students today are more “picture oriented” and gain much of their information from the figures rather than from the text material. The figures in Saladin are clearly and accurately presented.

W. Walther, Lake Erie College
Atlas Quality Cadaver Images
Color photographs of cadavers dissected specifically for this book allow students to see the real texture of organs and their relationships to each other. This anatomical realism combines with the simplified clarity of line art to give your students a holistic view of bodily structure.

The cadaver photos are excellent! My students (and friends who have taught or taken anatomy class) love them.

-Michael Angilletta, Jr., Indiana State University, Terre Haute

Students have liked the excellent artwork, the charts and tables, and the clinical insights. The photographs of cadaver dissections and the electron microscopy are excellent.

- Robert Moldenhauer, St. Clair County Community College
Physiology Focused Art
Saladin illustrates many difficult physiological concepts in steps that students find easy to follow. For students who are "visual learners," illustrations like these teach more than a thousand words.

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

R. Symmons, California State University at Hayward
Micrographs
All life processes are ultimately cellular processes. Saladin drives this point home with a variety of histological micrographs in LM, SEM, and TEM formats, including many colorized electron micrographs.

Photomicrographs Correlated with Line Art
Saladin juxtaposes histological photomicrographs with line art. Much like the combination of cadaver gross photographs and line art, this gives students the best of both perspectives: the realism of photos and the explanatory clarity of line drawings.

From Macroscopic to Microscopic
Saladin’s line art guides students from the intuitive level of gross anatomy to the functional foundations revealed by microscopic anatomy.

The artwork in Saladin is one of its major strengths. I applaud this; it really seems to help hold the interest of a wide variety of students.

D. Farrington, Russell Sage College
Anatomy and Physiology is fundamentally a textbook of the basic science of the human body. However, students always want to know why all the science is relevant to their career aims. Clinical examples and thought questions make it so. Students can see how the science relates to well-known dysfunctions, and why it is important to know the basics. Dysfunctions also provide windows of insight into the basic concepts, such as the insight that cystic fibrosis gives on the importance of membrane ion channels, or that antidepressants give on the synaptic reuptake of neurotransmitters.

Pathology Tables
For each organ system, Saladin presents a table that briefly describes several well-known dysfunctions and comprehensively lists the pages where students can find comments on other disorders of that system.

There are many tidbits of clinical information that are in this book, but not in others that I have seen. I think that's great! I have learned a thing or two. I also think that the author has tried to choose clinical examples that are commonly dealt with and therefore most useful to the student.

L. Steele, Ivy Tech State College
erection. In males, the bulbospongiosus (bulbocavernosus) forms a sheath around the base (bulb) of the penis; it expels semen during ejaculation. In females, it encloses the vagina like a pair of parentheses and tightens on the penis during intercourse. Voluntary contractions of this muscle in both sexes also help void the last few milliliters of urine. The superficial transverse perineus extends from the ischial tuberosities to a strong central tendon of the perineum.

In the middle compartment, the urogenital triangle is spanned by a thin triangular sheet called the urogenital diaphragm. This is composed of a fibrous membrane and two muscles—the deep transverse perineus and the external urethral sphincter (fig. 10.20c, d). The anal triangle contains the external anal sphincter. The deepest compartment, called the pelvic diaphragm, is similar in both sexes. It consists of two muscle pairs shown in figure 10.20c—the levator ani and coccygeus.

Insight 10.3 Clinical Application

Hernias
A hernia is any condition in which the viscera protrude through a weak point in the muscular wall of the abdominopelvic cavity. The most common type to require treatment is an inguinal hernia. In the male fetus, each testis descends from the pelvic cavity into the scrotum by way of a passage called the inguinal canal through the muscles of the groin. This canal remains a weak point in the pelvic floor, especially in infants and children. When pressure rises in the abdominal cavity, it can force part of the intestine or bladder into this canal or even into the scrotum. This also sometimes occurs in men who hold their breath while lifting heavy weights. When the diaphragm and abdominal muscles contract, pressure in the abdominal cavity can soar to 1,500 pounds per square inch—more than 100 times the normal pressure and quite sufficient to produce an inguinal hernia, or “rupture.” Inguinal hernias rarely occur in women.
Connective Issues

The human organ systems do not exist in isolation from each other. Diseases of the circulatory system can lead to failure of the urinary system and aging of the skin can lead to weakening of the skeleton. For each organ system, a page called Connective Issues shows how it affects other systems of the body and is affected by them.

Think About It
Success in health professions requires far more than memorization. More important is your insight and ability to apply what you remember in new cases and problems. Think About It questions, which can be found strategically distributed throughout each chapter, encourage stopping and thinking more deeply about the meaning or broader significance.

873 Part Four Regulation and Maintenance

Control Centers in the Brainstem
The medulla oblongata contains the respiratory (R) neurons, which fire during forced expiration (but not during auscultation). Fibers from these neurons travel down the spinal cord and synapse with lower motor neurons in the cervical to thoracic regions. From here, the fibers travel in the phrenic nerves to the diaphragm and intercostal muscles. No pacemaker neurons have been found that are analogous to the autorhythmic cells of the heart, and the exact mechanism for setting the rhythm of respiration remains unknown despite intensive research. One of the centers in the medulla oblongata that is involved in respiratory control is the pneumotaxic center (fig. 22.15). The pneumotaxic center is composed primarily of R neurons, which stimulate the muscles of inspiration. The more frequently they fire, the more motor units are recruited and the more deeply you inhale. If they fire longer than usual, each breath is prolonged and the respiratory rate slows. When they stop firing, elastic recoil of the lungs becomes faster and shallower, pulse frequency declines, and breathing is shallower, with inspiration lasting as long as 5 seconds.

Think About It
Do you think the fibers from the pneumotaxic center produce EPSPs or IPSPs at their synapses in the inspiratory center? Explain.

References
The clinical application approach seems much more consistently and richly in evidence in Saladin.

- D. Plantz, Mohave Community College
Pedagogical Aids Promote Systematic Learning
Saladin structures each chapter around a consistent and unique framework of pedagogic devices. No matter what the subject matter of a chapter, this enables students to develop a consistent learning strategy, making Anatomy and Physiology a superior learning tool.

Chapter Outline
An outline of the first chapter of each page provides a broad overview of what is covered. Page-referenced to facilitate later review and study. Saladin often presents concepts as bulleted or numbered lists. Students find they can absorb key points more easily from these than from a continuous narrative.

Insights
Each chapter has from three to six special topic Insight essays on the history behind the science, the evolution behind human form and function, and especially the clinical implications of the basic science. Insight sidebars lend the subject deeper meaning, intriguing perspectives, and career relevance to the student.

Brushing Up
A Brushing Up list at the beginning of the chapter ties chapters together and reminds students that all organ systems are conceptually related to each other. They discourage the habit of forgetting about a chapter after the exam is over. Brushing Up lists are also useful to instructors who present the subject in a different order from the textbook.

Control Centers in the Brainstem
The medulla oblongata contains inspiratory (I) neurons, which fire during inspiration, and expiratory (E) neurons, which fire during expiration. The medulla is composed of two main nuclei: the pneumotaxic center and the apneustic center. Fibers from these neurons travel down the spinal cord and synapse with lower motor neurons in the spinal cord to thoracic regions. From here, nerve fibers travel in the phrenic nerves to the diaphragm and intercostal nerves to the intercostal muscles. No parameter neurons have been found that are analogous to the autorhythmic cells of the heart, and the exact mechanism for setting the rhythm of respiration remains unknown despite intensive research.

The medulla has two respiratory nuclei (fig. 22.15).

- Inspiratory center
  - neurons in the upper pons
  - neurons in the lower pons

- Expiratory center
  - neurons in the lower pons
  - neurons in the medulla

Figure 22.15 Respiratory Control Centers. Functions of the respiratory centers. Arrows indicate the direction of impulse transmission. Each center is involved in one or more respiratory nuclei and produces EPSPs or IPSPs at their synapses in the inspiratory center neurons.

Before You Go On
Saladin divides each chapter into short "digestible" segments of about three to five pages each. Each segment ends with a few content review questions, so students can pause to evaluate their understanding of the previous few pages before going on.

Objectives
Each new section of a chapter begins with a list of learning objectives. Students and instructors find this more useful than a single list of objectives at the beginning of a chapter, where few students ever refer back to them as they progress with their reading.
Chapter Review

Briefly restates the key points of the chapter.

Testing Your Recall

Multiple choice and short answer questions allow students to check their knowledge.

Testing Your Comprehension

Questions that go beyond memorization to require a deeper level of analysis and clinical application. Scenarios from Morbidity and Mortality Weekly Reports and other sources prompt students to apply the chapter's basic science to real-life case histories.

True or False

Saladin’s True or False questions are more than they appear. They also require the student to explain why the false statements are untrue, thus challenging the student to think more deeply into the material and to appreciate and express subtle points. Answers can be found in the appendix.

Answers to Figure Legend Questions

Thought questions have been added to around five figures per chapter. Answers to these questions are found in this section.

Web Address

Located at the end of the Chapter Review is a reminder that additional study questions and other learning activities for anatomy and physiology appear on the Online Learning Center.

The “Testing Your Recall” questions and the “Testing Your Comprehension” questions provide and excellent opportunity for students to review the material in the chapter as a whole, testing not only recall of information, but also the student’s ability to apply the information they recall.

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