

Anatomy and *Understanding the Human Body* Physiology

Robert K. Clark



Anatomy and Physiology

Understanding the Human Body

Robert K. Clark



JONES AND BARTLETT PUBLISHERS

Sudbury, Massachusetts

BOSTON TORONTO LONDON SINGAPORE

World Headquarters

Jones and Bartlett Publishers
40 Tall Pine Drive
Sudbury, MA 01776
978-443-5000
info@jbpub.com
www.jbpub.com

Jones and Bartlett Publishers
Canada
2406 Nikanna Road
Mississauga, ON L5C 2W6
CANADA

Jones and Bartlett Publishers
International
Barb House, Barb Mews
London W6 7PA
UK

Copyright © 2005 by Jones and Bartlett Publishers, Inc.

All rights reserved. No part of the material protected by this copyright may be reproduced or utilized in any form, electronic or mechanical, including photocopying, recording, or by any information storage and retrieval system, without written permission from the copyright owner.

Production Credits

Chief Executive Officer: Clayton Jones
Chief Operating Officer: Don W. Jones, Jr.
President, Higher Education and Professional Publishing: Robert W. Holland, Jr.
V.P., Design and Production: Anne Spencer
V.P., Sales and Marketing: William Kane
V.P., Manufacturing and Inventory Control: Therese Bräuer
Executive Editor, Science: Stephen L. Weaver
Managing Editor, Science: Dean W. DeChambeau
Associate Editor, Science: Rebecca Seastrong
Senior Production Editor: Louis C. Bruno, Jr.
Marketing Manager: Matthew Payne
Marketing Associate: Laura M. Kavagian
Text and Cover Design: Anne Spencer
Photo Researcher: Kimberly Potvin
Illustrations: Elizabeth Morales
Printing and Binding: Courier Kendallville
Cover Printing: John Pow Company

About the Cover: A racing scull is propelled through the water by the coordinated action of the oars. Likewise, the contraction of muscle requires the coordinated activities of the proteins present in myofilaments within muscle cells. These molecular activities can be understood by considering rowing technique. In this textbook, this and similar analogies will help you to understand the molecular and cellular processes that occur in the human body.

Library of Congress Cataloging-in-Publication Data

Clark, Robert K., 1958–

Anatomy and physiology: understanding the human body / Robert K. Clark.

p. cm.

ISBN 0-7637-4816-1 (alk. paper)

1. Human physiology. 2. Human anatomy. 3. Physiology, Pathological. 1. Title.

QP34.5C537 2004

612—dc22

2004051586

Printed in the United States of America

09 08 07 06 05 10 9 8 7 6 5 4 3 2 1

Preface

Anatomy and Physiology: Understanding the Human Body was designed to meet the needs of a diverse group of students. We are living in an era of amazing technological advancements, and those of our health care system are perhaps the most astonishing of all. Those preparing for careers in the allied health sciences, including careers involving direct patient care and the many allied technologies, need to understand the human body in greater detail than ever before. I wrote *Anatomy and Physiology: Understanding the Human Body* at the depth and detail these students require, while not losing sight of their overriding need for conceptual understanding and critical thinking skills.

Many students preparing for careers outside of the biomedical field also need to understand the human body. The range of disciplines that this is true for increases yearly, but includes such diverse fields as the social sciences, criminal justice, preschool through secondary education, athletics and fitness training and in some cases, the visual and performing arts. This book provides the pedagogic tools these students need to ensure their learning.

Additionally, many people today face difficult decisions about their own health and the health care of their loved-ones. Many of these people recognize that an understanding of the human body enables them to ask the types of questions of their health care providers that help them make informed decisions; decisions they will be comforted by. Increasingly, people enroll in basic biomedical science courses at community colleges for just this reason. This book has been prepared with these people in mind as well. The text was written in a way that will encourage these students to continue reading and stick with their course even if they have not previously been successful in the sciences.

Students who do not have a strong background in the sciences or who may be intimidated by science courses often report that their textbooks are dry, difficult to follow and more than a little daunting. *Anatomy and Physiology: Understanding the Human Body* was written using a conversational style and an informal manner, much the way a friend would explain anatomy and physiology to them. It builds confidence as it teaches.

Much of what we learn in anatomy and physiology requires an understanding of processes at the cellular and molecular level, the very processes that are often the most difficult to grasp. Without this knowledge, the functions of the organ systems become merely words to mem-

orize, or “magical” activities that are beyond comprehension. When students see that they can understand molecular and cellular activities, their interest in their studies increases greatly. This text makes these processes easy to understand because it relates them to objects and activities that students see daily, or can easily imagine. These teaching analogies are clear and simple and sometimes humorous. This increases reader enjoyment, encouraging continued reading and studying. When difficult concepts are presented, the text directly encourages the reader and offers learning strategies, just as many effective educators do in the classroom. This helps to build student confidence and encourages those who might otherwise become frustrated and abandon their studies.

Pedagogical features that aid student success abound. The entire first chapter is aimed at helping students to become effective learners and to develop life-long learning skills. By teaching students how to evaluate the biomedical information they encounter in their daily lives, it also prepares them to be effective at the kind of critical thinking skills our information era requires. Each chapter begins with a *What You Will Learn* feature, a set of goals for that chapter. It presents, as simple statements, the types of information students should expect to learn from their reading of the chapter. A similar, but longer and more detailed feature called *What You Should Know* can be found at the end of each chapter. This too contains information from the chapter in the form of simple statements. An understanding of these statements is one way to assess accomplishment of the goals of the chapter.

Learning outcomes or student success can be further determined by using the questions in the *What Did You Learn?* feature that follows each chapter. Notice that Appendix B contains the answers to the multiple choice questions so students can quickly evaluate their progress.

Although this book primarily presents the normal activities of the body, pathologic processes (disease, injury, and the body's response to these conditions) are presented where it aids understanding of normal activities. This is done in two ways: short descriptions within the text and slightly longer discussions called *Breaching Homeostasis . . . When Things Go Wrong* strategically placed at the end of key chapters. These discussions are not intended as a complete presentation on these conditions but as a starting point from which student understanding can grow. Appendix C helps the instructor to locate the pathologies that are of interest. As students explore these diseases, they should keep in mind the material presented in Chapter 1 on how to find and evaluate biomedical information. This helps them to avoid the pitfalls of the misinformation about diseases that is so abundant today.

The chemistry and cell biology chapters have been kept very simple, just enough to get these students started. Often our students are frustrated early in the course when they have to learn so much material that they don't consider to be "real" anatomy and physiology. Some of the larger concepts (i.e., the details of protein syntheses) are moved further into the text for inclusion after students have gained confidence and interest. Also included is a separate chapter specifically presenting the concept of electrical activity in cells. In this way, students learn the basics of this fascinating but sometimes challenging topic before moving into the specific activities of muscle cells or neurons. Instructors may choose to adopt the order of topics as presented here or to adapt the order of text chapters to follow their own syllabus. The text is flexible enough to instructors to do what works best for their students.

As you examine and use this text, I believe that you will find it distinctly different from others you have tried. I hope you enjoy using *Anatomy and Physiology: Understanding the Human Body*.

Ancillaries

Instructor's Tool Kit CD-ROM Compatible with Windows and Macintosh platforms, this CD-ROM provides instructors with the following traditional ancillaries.

The Instructor's Manual, provided as a text file, includes goals and objectives suitable to use as handouts and classroom exercises.

The Test Bank is available as text files and as part of the

Diploma™ Test Generator software included on the CD. The Test Generator software enables you to choose an appropriate variety of questions, create multiple versions of tests, even administer and grade tests on-line.

The PowerPoint™ Lecture Outline Slides presentation package provides lecture notes and images for each chapter of *Anatomy and Physiology: Understanding the Human Body*. A PowerPoint™ viewer is provided on the CD. Instructors with the Microsoft PowerPoint™ software can customize the outlines, art, and order of presentation.

The Kaleidoscope Media Viewer provides a library of all the art, tables, and photographs in the text to which Jones and Bartlett Publishers holds the copyright or that are in the public domain. The Kaleidoscope Media Viewer uses your browser—Internet Explorer or Netscape Navigator—so you may project images from the text in the classroom, insert images into PowerPoint presentations, or print your own acetates.

Anatomy and Physiology On Line This text's Web site, www.bioscience.jbpub.com/anatomy, provides additional resources to expand the scope of the textbook and make sure students have access to the most up-to-date information in anatomy and physiology. Students can find a variety of study aids in the eLearning area, such as chapter outlines, flash cards, and review questions. Carefully chosen links to relevant Web sites enable students to explore specific topics in anatomy and physiology in more detail. A brief description of each link places the site in context before the student connects to it.

Acknowledgments

I would like to thank the many people who assisted and encouraged me in the preparation of this textbook. The administration and faculty of Cumberland County College in Vineland, New Jersey have been very supportive. Special thanks go to the following members of our college community: President Dr. Kenneth Ender, Vice President of Academic Affairs and Enrollment Services Dr. Thomas Isekenegbe, former Academic Dean Dr. Jack Lobb, and Health and Science Division Chair Ms. Jane Leggieri. I express special thanks to my esteemed humanities colleague, Professor John Adair, who bravely read and red inked an entire early draft. Thanks also go to Mr. Amar Madineni for his tireless answers to my endless technology questions.

The great people at Jones and Bartlett Publishers who worked hard to convert my manuscript into this text also

deserve thanks and congratulations. These include Stephen Weaver, Executive Editor; Dean DeChambeau, Managing Editor; Rebecca Seastrong, Associate Editor; and Anne Spencer, Vice President of Design and Production. Art editor and illustrator Elizabeth Morales has done a remarkable job and was a real joy to work with. Photo researcher Kimberly Potvin deserves special thanks for her willingness to shoot photos even when special courage was required. Senior Production Editor Louis Bruno's impressive organizational skills, positive outlook, and great humor made this project a real pleasure. Special congratulations and thanks go to Lou. Thanks go to copyeditor Ellice Gerber, proofreader Debbie Liehs, indexer Sherri Dietrich, and to the compositor Circle Graphics who did a beautiful job setting the text and art. I would also like to acknowledge the valuable contribution of the anatomy and physiology faculty from across the country, who reviewed this text. Their hard work demonstrates a special dedication to their discipline and improves the teaching done by each of us.

Bert Atsma
Union County College, New Jersey

Judy Cunningham
Montgomery County Community
College, Pennsylvania

Chaya Gopalan
St. Louis Community College-
Florissant Valley, Missouri

Susan Klarr
Washtenaw Community College,
Michigan

Scott Layton
Cowley College, Kansas

Stephen Lebsack
Linn Benton Community College,
Oregon

Wendy McCullen-Vermillion
Columbus State Community
College, Ohio

Margaret Ott
Tyler Junior College, Texas

Cynthia Prentice
Chemeketa Community College,
Oregon

Cynthia Schauer
Kalamazoo Valley Community
College, Michigan

Michael Squires
Columbus State Community
College, Ohio

Jeffery Thompson
Hudson Valley Community College,
New York

Patricia Torrence
Seattle Central Community College,
Washington

Finally, I would like to thank my closest collaborator, Lise Desquenne Clark, V.M.D., Ph.D., for her ongoing support and specifically for her critical reading of the manuscript and extensive work on Chapter 21.

The writing of this textbook was aided, in part, by a sabbatical leave from Cumberland County College, Vineland, New Jersey.

Robert K. Clark
Pilesgrove, New Jersey
January, 2005

About the Author



Dr. Clark is an associate professor in the Health and Science Division of Cumberland County College in Vineland, New Jersey, where he teaches Anatomy and Physiology I and II, Human Biology, Pathology, and Genetics and has been awarded the President's Award for Excellence in Leadership, Service and Scholarship. He was named 2001 New Jersey Professor of the Year by the Carnegie Foundation for the Advancement of Teaching.

He earned a Bachelor of Science Degree in Marine Biology from the University of New England and a Ph.D. from Hahnemann University (now part of Drexel

University) in Experimental Pathology. His extensive research experience has led to numerous publications in the fields of cancer, stroke, and HIV/AIDS.

Commercial farmers for more than 21 years, Bob and Lise Clark raise specialty produce and goats on their southern New Jersey farm. He is shown here with week-old triplets, the results of the Clark's tinkering with goat coat-color genetics.

Brief Contents

PART I Foundations for Understanding the Human Body 1

- CHAPTER 1** Foundations for Success 2
- CHAPTER 2** Developing a Common Chemical Language 10
- CHAPTER 3** Understanding Your Cells 30
- CHAPTER 4** Tissues: Construction Materials of the Body 57
- CHAPTER 5** Viewing the Body as a Whole 74

PART II Our Journey Continues 87

- CHAPTER 6** Your Living Bones 88
- CHAPTER 7** The Ankle Bone's Connected to the...: The Anatomy of Your Skeleton 103
- CHAPTER 8** The Body Electric: Electrical Activities in Your Body 126
- CHAPTER 9** Your Contracting Muscles 138
- CHAPTER 10** Your Body in Motion: The Gross Anatomy of Your Muscle System 155

PART III Regulating Your Body 171

- CHAPTER 11** Your Neurons and their Electrical Activity 172
- CHAPTER 12** Fast-Acting Regulation of Your Body: Your Nervous System 185
- CHAPTER 13** Slow-Acting Regulation of Your Body: Your Endocrine System 228

PART IV Reproducing Your Body 253

- CHAPTER 14** Your Body's Blueprint: The Genetic Code 254
- CHAPTER 15** Your Reproductive System 267

PART V Moving Fluids and Gases 286

- CHAPTER 16** The River Within: Your Cardiovascular System 288
- CHAPTER 17** Every Breath You Take: Your Respiratory System 319

PART VI Management of Nutrients and Wastes 341

- CHAPTER 18** Your Gastrointestinal System 342
- CHAPTER 19** Your Urinary System 371

PART VII Defending Your Body 389

- CHAPTER 20** The Great Wall and More: Your Integumentary System 390
- CHAPTER 21** Surveillance and Defense: Your Immune System 402
- APPENDIX A** The Metric System 421
- APPENDIX B** Answers to Multiple Choice Questions 424
- APPENDIX C** Pathologic Conditions Presented in Anatomy and Physiology: Understanding the Human Body 426
- APPENDIX D** Aerobic Cellular Metabolism/Oxidative Phosphorylation 428

- Glossary 433
- Index 455

Contents

PART

Foundations for Understanding the Human Body 1

Why Must We Learn These Foundations? 1

CHAPTER 1 Foundations for Success 2

1.1 Anatomy and Physiology: What Are We Studying? 2

Why Study Two Disciplines At One Time? 3

How This Material May Benefit You 3

1.2 How to Succeed in Your Study of Anatomy and Physiology 3

Relax, You Can Succeed! 3

Tips for Successful Studying 4

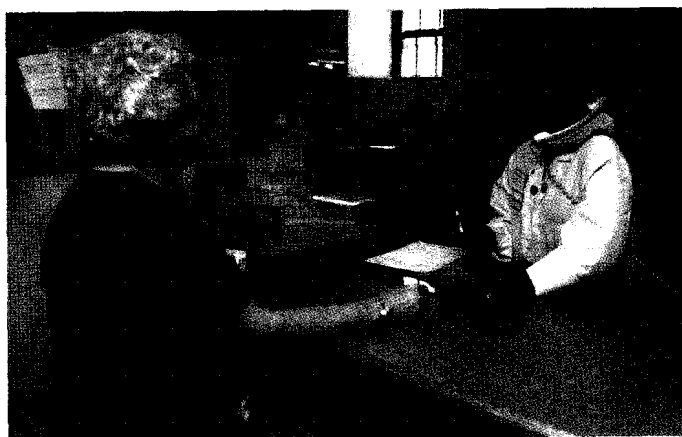
Tips for Successful Examinations 4

1.3 Reliable Sources of Biomedical Information:

Where You Can Find Them 7

Finding and Evaluating Biomedical Information 7

The Peer-Review Process 7



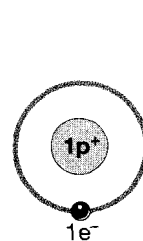
CHAPTER 2 Developing a Common Chemical Language 10

2.1 Why is Knowledge of Chemistry Necessary? 10

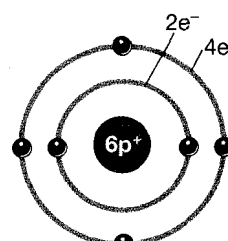
2.2 Atoms and Molecules 11

Electron Energy Levels: Like a Trip to a Carnival 11

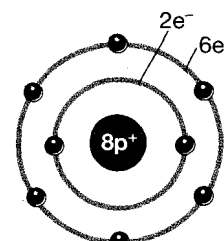
2.3 Chemical Bonds: How We Are Held Together 13



Hydrogen (H)



Carbon (C)



Oxygen (O)

And Now for a Bonding Experience 13

Ionic Bonds: Like Magnetic Toys 13

Covalent Bonds: Shared Riches 14

Hydrogen Bonds: The Serving Line at the Banquet 15

2.4 Organic Compounds 16

What's with All the Carbon? 16

Carbohydrates: Energy, Identification, and More 16

Lipids: Everybody's Favorite 17

Proteins: Of First Importance 19

Nucleic Acids: Why All the Excitement? 20

2.5 Inorganic Compounds 21

Water: Its Importance to Us 21

Acids, Bases, and Salts Made Easy 24

CHAPTER 3 Understanding Your Cells 30

3.1 Introducing: Your Cells! 30

Who Studies Cells? 30

A Naming Dilemma 31

3.2 The Organelles: Organs for Your Cells 31

Your Cells' Membranes 31

The Nucleus: Your Cell's Most Prominent Organelle 37



The Nucleolus: A Potential Source of Confusion 39

Ribosomes: Two Subunits, One Organelle 39

Endoplasmic Reticulum: Seeded or Plain? 39

Golgi Apparatus: Like a Stack of Pita 40

Lysosomes: They Really Are Organelles 40

Mitochondria: Let's Get Energized 41
A Slight Detour 45

3.3 The Cytoskeleton: A Skeleton for Your Cells 45

Three Major Cytoskeletal Components 45

3.4 Cytoplasmic Inclusions 46

3.5 Cell Division: Reproducing Your Cells 46

Mitosis and Cytokinesis:
Two Big Events 47

The Cell Cycle: Taking a
Larger View 47

The Phases of Mitosis: I Prefer My
Anatomy Teacher 48

3.6 Differentiation: How Your Cells Become All That They Can Be 48

Breaching Homeostasis . . . When Things Go Wrong: Disease and Injury at the Cellular Level 52

CHAPTER 4 Construction Materials of Your Body: The Tissues 57

4.1 Why Are We Interested in Tissues? 57

4.2 How to Learn This Information 58

4.3 The Five Classes of Tissue 58

How Did We Settle on Five Classes? 58
Epithelial Tissues: Linings 59

Mesenchymal Derivatives: A Fancy
Term for Some Simple Tissues 64

Other Tissues: Beyond Lining and
Packing 68



4.4 Parenchyma and Stroma: Useful Concepts 69

Breaching Homeostasis . . . When Things Go Wrong: Histotechnology: How Microscope Slides Are Prepared 70

CHAPTER 5 Viewing the Body As a Whole 74

5.1 Organ Systems: A System for Organizing Your Organs 74

5.2 Homeostasis: What a Concept! 75

Stress and its Consequences 76

Regulation of Homeostasis 77

Mechanisms in the Maintenance of
Homeostasis 77

The Role of Negative Feedback 78

5.3 The Language of the Anatomist: Why It Is Important 79

Locational Terminology 80

Planes of Section 82

Body Cavities 83

PART II Our Journey Continues 87

CHAPTER 6 Your Living Bones 88

6.1 The Many Functions of Your Bones 88

6.2 Bone as a Connective Tissue 90

The Cells of Bone 91

The Structure of Bone 91

6.3 A Typical Bone: Naming the Parts of a Long Bone 93

The Membranes of Bone 93

6.4 Life as a Bone: Osteogenesis, Growth, and Remodeling 93

Osteogenesis: Formation
of Your Bones 94





Growth: Enlarging Your Bones 94

Remodeling: Keeping Your
Bones New 96

**Breaching Homeostasis . . . When Things Go
Wrong: Osteoporosis 99**

CHAPTER 7 The Ankle Bone's Connected to the...: The Anatomy of Your Skeleton 103

**7.1 How to Know the Bones: A Strategy
for Learning 103**

7.2 The Skeleton: Subdivisions 104

The Axial Skeleton 105

The Appendicular Skeleton 112

7.3 The Generic Features of Bones 118

**7.4 The Articulations: What Kind of a
Joint Is This Anyway? 118**

Functional Classification of the
Articulations 118

Structural Classification of the
Articulations 118

CHAPTER 8 The Body Electric: Electrical Activities in Your Body 126

8.1 What...Electricity in My Body?!!! 126

**8.2 Ions and Gradients: Membrane
Polarization 126**

It's All about Cats and Dogs 127

Meanwhile Back at the Ions 127

**8.3 Molecular Pumps: That's Some
Fancy Enzyme 129**

**8.4 Membrane Depolarization and
Repolarization 130**

Lightning Strikes: Initiating the
Electrical Event 132

**8.5 Synapses and Neuroeffector
Junctions 133**

**8.6 How Your Electrical Cells
Are Like Toilets: The All-or-None
Principle 134**

CHAPTER 9 Your Contracting Muscles 138

**9.1 Functions of the Muscle
System 138**

9.2 The Three Types of Muscle 139

9.3 A Skeletal Muscle Cell 140

Special Features of Muscle Cells 140

The Contractile Machinery 142

The Sliding-Filament Theory: It's Just
Like Rowing a Boat 144

Twitches and Tetany: The Types of
Contractions 147

Contractions Involving Multiple Muscle
Fibers 148

Energy for Contraction
and Relaxation 148

**9.4 Making the Leap to the Gross
Anatomy of Muscles 149**

**Breaching Homeostasis . . . When Things Go
Wrong: Postmortem Changes: What
Happens to Your Cells After Death 151**

CHAPTER 10 Your Body in Motion: The Gross Anatomy of Your Muscle System 155

**10.1 The Parts of an Individual
Muscle 155**

**10.2 How Your Muscles Cooperate to
Move You: Group Actions 156**

10.3 Naming the Muscles 157

How Skeletal Muscles Are Named 157

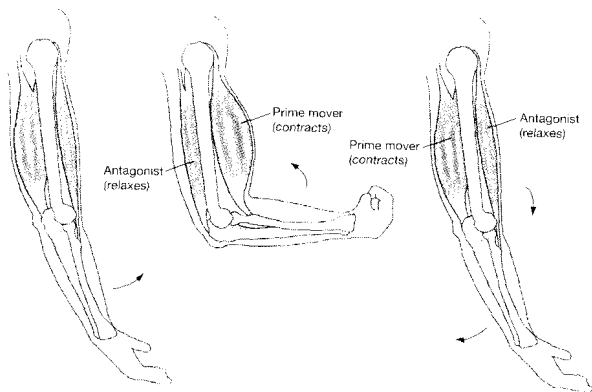
How to Know the Muscles: A Strategy
for Learning 157

**10.4 An Atlas of the Superficial
Muscles 160**

The Superficial Muscles of the Face and
Anterior Trunk 160

The Superficial Muscles of the Anterior
Shoulder and Arm 162

The Superficial Muscles of the Posterior
Trunk, Shoulder, and Arm 164



The Superficial Muscles of the Anterior Hip and Leg 166

The Superficial Muscles of the Posterior Hip and Leg 166

PART

Regulating Your Body 171

The Nervous and Endocrine Systems: Two Great Systems That Go Great Together 171

CHAPTER 11 Your Neurons and Their Electrical Activity 172

11.1 Your Fascinating Neurons 172

The Neuron Cell Body 173

The Dendrites 173

The Axon 174

Nerve Fibers 175

Classification of Neurons 177

11.2 Synapses Revisited: Interconnections Between Neurons 178

11.3 Glia: The Stroma of the Nervous System 180

Astrocytes: Genuine Glia 180

Oligodendrocytes: Fewer, Shorter Branches 180

Microglia: Macrophages of the CNS 180

Ependyma: True Epithelia 182

Neurolemmocytes: Not Really Glia at All 182

CHAPTER 12 Fast-Acting Regulation of Your Body: Your Nervous System 185

12A Your Amazing Nervous System 186

12A.1 Your Amazing Nervous System: An Overview 186

12A.2 Subdivisions of Your

Nervous System: Structural and Functional 186

12A.3 Support and Protection for Your Central Nervous System 188

Your Meninges 189

Your Cerebrospinal Fluid 189

The Blood Supply of

Your Brain 192

Your Blood-Brain Barrier 192

12B The Structure and Function of Your Brain 195

12B.1 Your Brainstem 195

Your Medulla Oblongata 195

Your Pons 196

Your Midbrain 196

12B.2 Your Diencephalon 196

Your Thalamus 197

Your Hypothalamus 197

12B.3 Your Cerebrum: Its Anatomy and Physiology 199

Cerebral Gray Matter 199

Cerebral White Matter 200

The Functional Areas of the Cortex 200

12B.4 Your Cerebellum: Its Anatomy and Physiology 204

A Brief Word of Caution 204

The Gross Anatomy of Your Cerebellum 204

Cerebellar Gray and White Matter: Leaves on the Trees 204

Functions of Your Cerebellum 204

12B.5 Your Limbic System: Emotion and Memory 205



- 12B.6** Your Autonomic Nervous System 205
 - Two Antagonistic Components: One Caveman 206

- 12B.7** The Anatomic Arrangement of Your Motor Nerves 208

- 12B.8** Your Cranial Nerves 208

- 12B.9** Your Neurotransmitters 208

12C Your Spinal Cord 213

- 12C.1** The Anatomy of Your Spinal Cord 213
 - Your Spinal Nerves 213
 - Your Spinal Cord in Cross Section 213

12D Reflexes and Senses 217

- 12D.1** Reflexes: Your Nervous System in Action 217

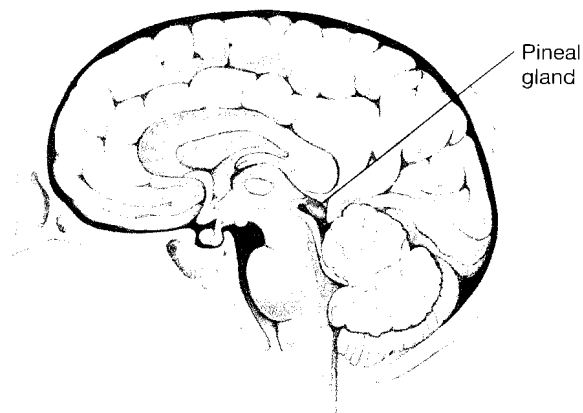
- 12D.2** Your Senses 217
 - Your Amazing Eyes 217
 - Your Amazing Ears 219
 - Your Senses of Taste and Smell 221

- 12D.3** Take Some Time to Comprehend the Beauty of Your Nervous System 223

- Breaching Homeostasis . . . When Things Go Wrong: Stroke** 226

CHAPTER 13 Slow-Acting Regulation of Your Body: Your Endocrine System 228

- 13.1** Two Regulatory Systems: The Body as a Department Store 229
- 13.2** The Endocrine Glands: A Few Quick Questions and Answers 229
- 13.3** Classes of Hormones: Some Simple Chemistry 230



- 13.4** Target Cells Are Like Students with Radios 231

- Mechanisms of Receptor Activity 232

- 13.5** Control of Hormone Secretion 234

- 13.6** Hormone Interactions 235

- 13.7** Your Endocrine Glands: Their Anatomy and Physiology 235

- Your Pituitary Gland 235

- Your Adrenal Gland: Two Glands in One 240

- Your Pancreas 242

- Your Thyroid 244

- Your Parathyroid Glands 246

- Your Pineal Gland 247

- Other Endocrine Glands 247

- Breaching Homeostasis . . . When Things Go Wrong: Diabetes** 248

PART IV Reproducing Your Body 253

CHAPTER 14 Your Body's Blueprint: The Genetic Code 254

- 14.1** Let's Review 254

- 14.2** Complementarity: Like Singing in Harmony 255

- 14.3** DNA Replication: Like Teaching a Friend a Song 256

- 14.4** Your DNA Code: What It Actually Encodes 256

- 14.5** The DNA Code and Protein Synthesis 257

- Transcription 258

- Translation 259





An Example of Protein Synthesis:
Insulin 260

14.6 Meiosis: The Generation of Variability 261

Breaching Homeostasis . . . When Things Go Wrong: Genetic Mutations 264

CHAPTER 15 Your Reproductive System 267

15.1 An Unusual System 268

15.2 The Male Reproductive System 268

The Male Primary Sex Organ:
The Testes 268

Secondary Sex Organs of the Male:
Ducts for the Passage of Sperm and Fluids 271

Secondary Sex Organs of the Male:
Accessory Glands 271

Secondary Sex Organs of the Male: The
Penis 272

15.3 The Female Reproductive System 273

“And Now For Something Completely
Different . . .” 273

The Female Primary Sex Organ: The
Ovary 273

Secondary Sex Organs
of the Female 276

The Female Reproductive Cycle: Putting
It All Together 279

The Mammary Glands 279

Breaching Homeostasis . . . When Things Go Wrong: Testicular Cancer 282

PART V Moving Fluids and Gases 286

Why Study the Cardiovascular and Respiratory Systems Together? 286

CHAPTER 16 The River Within: Your Cardiovascular System 288

16.1 Blood as a Moving Fluid 289

16.2 Your Heart 289

The Great Vessels and the Path Your
Blood Follows 289

Heart Valves 291

Electrical Impulse Generation and
Conduction 295

The Cardiac Cycle 297

Cardiac Output 297

16.3 Your Blood Vessels 300

The Types of Vessels 300

16.4 The Gross Anatomy of Your Cardiovascular System: A Brief Atlas 303

16.5 Fluids in Motion: Your Blood 303

How Your Blood Moves:
Axial Flow 303

A Balance of Pressures: Starling's
Hypothesis 308

Lymphatic Vessels 309

16.6 Your Blood as a Connective Tissue 309

The Cells of Your Blood 309

Plasma as an Extracellular Matrix 313

16.7 Hemostasis 313

Breaching Homeostasis . . . When Things Go Wrong: Atherosclerosis 315

CHAPTER 17 Every Breath You Take: Your Respiratory System 319

17.1 A Partnership 319

17.2 The Anatomy of Your Respiratory System 320

Your Nose 320

Your Pharynx 322

Your Larynx 322

Your Trachea 322

Your Bronchi 323

Your Alveoli 325

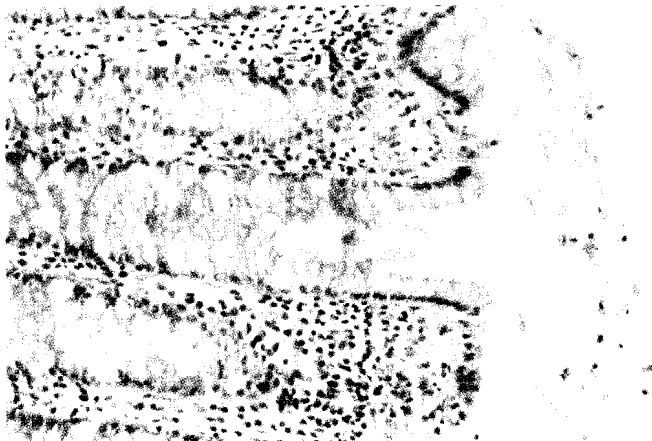
- 17.3 Pulmonary Ventilation: It's As Easy As Breathing In and Out 325**
 The Muscles of Respiration: Eupnea and Forced Breathing 327
 Elastic Recoil and Surfactant 328
- 17.4 Behavior of Respiratory Gases: Exchange and Transport 330**
 External Respiration 330
 Internal Respiration 321
 Transportation of Gases in Your Blood 331
- 17.5 Regulation of Breathing 334**
 A Cautionary Tale 335
Breaching Homeostasis . . . When Things Go Wrong: Chronic Bronchitis and Emphysema: COPD 336

PART VI Management of Nutrients and Wastes 341

Why Study the Gastrointestinal and Urinary Systems Together? 341

CHAPTER 18 Your Gastrointestinal System 342

- 18.1 One System: Two Basic Components 343**
- 18.2 Your Alimentary Canal 343**
 Some Definitions 344
 An Architectural Plan 344
 Your Mouth 345
 Your Pharynx 346
 Your Esophagus 346
 Your Stomach 347
 Your Small Intestine 349
 Your Large Intestine 353



18.3 Accessory Organs of Digestion 356

- Your Salivary Glands 356
 Your Pancreas 357
 Your Liver 359

18.4 Lipid Metabolism: We Saved the Best for Last 362

- Lipid Digestion and Absorption 362
Breaching Homeostasis . . . When Things Go Wrong: How Laxatives Work 366

CHAPTER 19 Your Urinary System 371

19.1 Functions of the Urinary System 371

- Nitrogenous Wastes: Where Do They Come From? 372

19.2 Anatomy of Your Urinary System 372

- The Nephron: Functional Unit of Your Kidneys 373

- Gross Anatomy of the Kidney 376

19.3 How to Make Urine in Three Easy Steps 376

- Glomerular Filtration 376
 Tubular Resorption 377
 Tubular Secretion 380

19.4 Acid Base Balance and Renal Influence on Blood pH 380

19.5 Renal Control of Fluid and Electrolyte Balance 381

- Renal Control of Fluid Volume 381
 Control of Ion Concentrations:
 Mechanisms You Already Understand 383

Breaching Homeostasis . . . When Things Go Wrong: Urolithiasis: Urinary Stones
385

VII Defending Your Body 389

The Integumentary and Immune Systems: Why Study Them Together? 389

CHAPTER 20 The Great Wall and More: Your Integumentary System 390

20.1 Like the Wall of a Mighty Fortress: The Functions of Your Integumentary System 390

Specialized Functions of Your Skin 391

20.2 The Anatomy of Your Skin 392

Your Epidermis 392

Your Dermis 395

Your Hypodermis: The Subcutaneous Tissues 395

20.3 Integumentary Appendages: The Structures Associated with Your Skin 396

Your Hair 396

Your Nails: Finger and Toe 397

Skin-Associated Glands 397

Breaching Homeostasis . . . When Things Go Wrong: Skin Cancer 399

CHAPTER 21 Surveillance and Defense: Your Immune System 402

21.1 Fences, Guard Dogs, and an Elite Security Force 402

21.2 Fences and Guard Dogs: Natural Immunity 403

Acute Inflammation 404

Chronic Inflammation 407

Natural Killer Cells 409

21.3 Your Elite Security Force: Acquired Immunity 409



Preparation for Defense: Lymphoid Organs and Lymphocyte 410

A Call To Arms: Acquired Immunity in Action 411

Breaching Homeostasis . . . When Things Go Wrong: Immunodeficiency and Autoimmune Diseases 417

Appendix A The Metric System 421

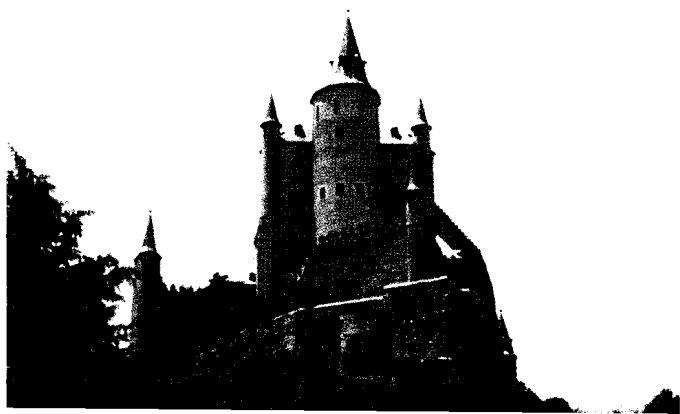
Appendix B Answers to Multiple Choice Questions 424

Appendix C Pathologic Conditions Presented in Anatomy and Physiology: Understanding the Human Body 426

Appendix D Aerobic Cellular Metabolism/Oxidative Phosphorylation 428

Glossary 433

Index 455



Foundations For Understanding The Human Body

Why Must We Learn These Foundations?

We are about to embark on a study of the basic anatomy (form) and physiology (function) of the human body. These disciplines can be highly complex and we will need to develop a common language to understand what happens within the body. Some students approach these topics with a thorough background in the sciences. Others have not yet had the opportunity to develop this science foundation. In the first section of this text, we will work at developing a common level of science literacy. This will allow us to discuss the human body with the language of science and some basic knowledge of science as we move into the disciplines in which we are specifically interested: anatomy and physiology. We will also spend some time learning study skills and examination techniques that may help you to be more successful in your studies. Whether you are reading this book as part of a course or reading on your own to increase your understanding of your body, these techniques may assist you in reaching your goal.

Some students may be tempted to skip over this early information and move right into the chapters dealing with the organs or systems that interest them. That would be a mistake. We can only understand the organs if we understand the cells of which they are composed. We can only understand how these cells work if we have some knowledge of basic chemistry. Without this knowledge, the functions of our organs appear to be magic and beyond our comprehension. Rather than developing an understanding of the body, you would merely memorize a lot of terminology that you would quickly forget. The fact that you are reading this text shows that you have a desire to understand your body. Do not cheat yourself of this understanding by not laying a suitable foundation for it. Please spend some time on the chapters in this section now, and trust that this information will help you to develop the understanding you seek.