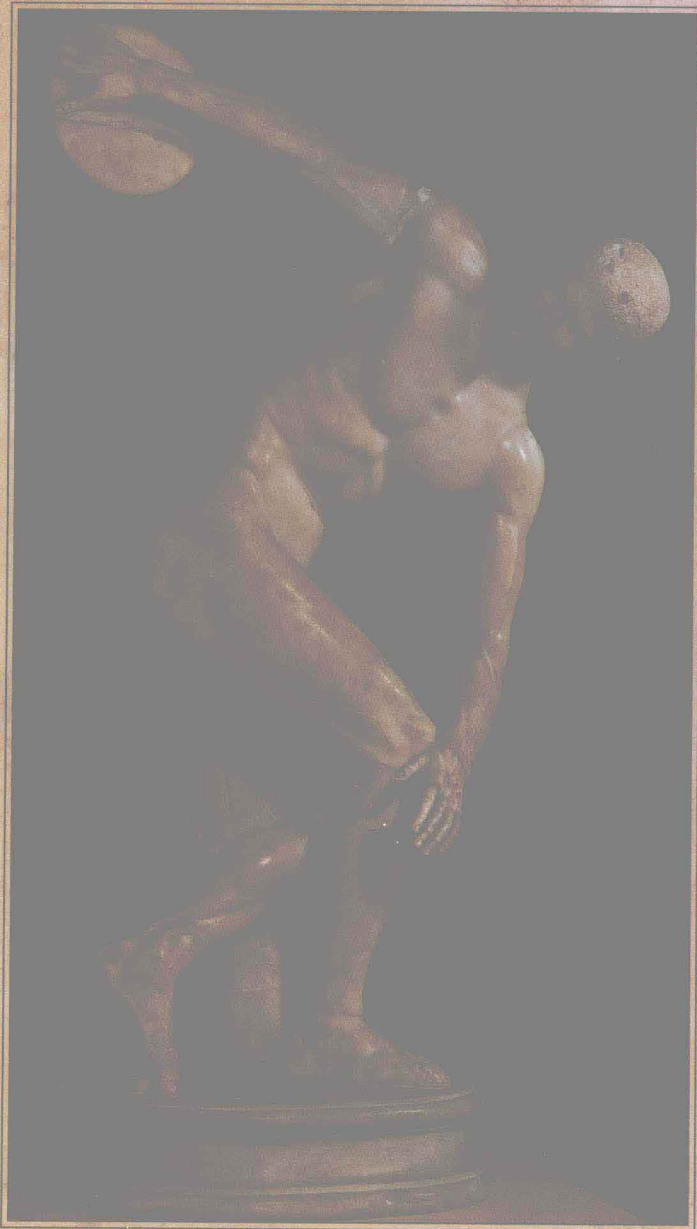


FOURTH EDITION

Human Anatomy and Physiology



Alexander P. Spence Elliott B. Mason

FOURTH EDITION

Human Anatomy and Physiology



Alexander P. Spence, Ph.D.

STATE UNIVERSITY OF NEW YORK COLLEGE AT CORTLAND

Elliott B. Mason, Ph.D.

STATE UNIVERSITY OF NEW YORK COLLEGE AT CORTLAND

WEST PUBLISHING COMPANY

Saint Paul New York Los Angeles San Francisco

**To my wife Marion
and our children Mark, Carol, and Cindy**
ALEXANDER P. SPENCE

**To my wife Marsha
and our children Jennifer, Julie, and Jessica**
ELLIOTT B. MASON

**Their love, patience, encouragement, and understanding
made this book possible**



PRODUCTION CREDITS

Composition: Parkwood Composition
Copyediting: Patricia Lewis
Indexing: E. Virginia Hobbs
Illustrations: Rolin Graphics
Interior design: K. M. Weber
Cover design: K. M. Weber
Cover photograph: Myron, Discobolos, Firenze, Pal. Vecchio.
Scala/Art Resource, New York
Appendix 1 photographs: Reproduced by permission from
Photographic Atlas of the Human Body by Drs. B. Vidić and
F. R. Suarez. Copyright © 1984 by Mosby Year Book, Inc.



COPYRIGHT © 1992 by WEST PUBLISHING COMPANY
50 W. Kellogg Boulevard
P.O. Box 64526
St. Paul, MN 55164-0526

All rights reserved

Printed in the United States of America
99 98 97 96 95 94 93 92 8 7 6 5 4 3 2 1 0

Library of Congress Cataloging-in-Publication Data

Spence, Alexander, P., 1929—
Human anatomy and physiology/Alexander P. Spence, Elliott B.
Mason.—4th ed.
p. cm.
Includes index.
ISBN 0-314-87693-6 (hard)
1. Human physiology. 2. Human anatomy. I. Mason, Elliott B.,
1943-. II. Title.
[DNLM: 1. Anatomy. 2. Physiology. O\$ 4 S744h]
QP34.5.S72 1992
612-dc20
DNLM/DLC
for Library of Congress

91-21622
CIP



P R E F A C E

Working on a new edition of a textbook is always a rewarding experience. A new edition provides the opportunity to update information and revise the manner in which it is presented. This fourth edition of *Human Anatomy and Physiology* is especially exciting because we are working with a new publisher. West Publishing Company has committed themselves to a major upgrading of our book and stimulated a renewed vigor for the project.

Our major goal for this edition remains the same as in previous editions: To provide a textbook that is written at the introductory level and yet is comprehensive enough to meet the needs of diverse groups of human anatomy and physiology students. We have found that courses in human anatomy and physiology vary considerably in length, depth, and objectives. However, we believe our book provides enough information, without being overwhelming, to make it suitable for most courses.

Our book is written primarily for students who are preparing for careers in physical education, nursing, or various health-related professions. The book is also well suited for students majoring in the liberal arts. Because students taking anatomy and physiology courses have such diverse backgrounds and goals, we have assumed that the students using our text will have only a general familiarity with science. All the information needed to understand anatomy and physiology at the introductory level is presented in the text. In some instances we have placed certain topics in special boxes (entitled “A Closer Look”) and examined them in greater detail than is generally done in anatomy and physiology texts. We consider this in-depth information to be optional, but believe it will be of interest to the more motivated students.

As the book’s title indicates, it is designed for courses that teach anatomy and physiology at the same time. Consequently, we have made a concerted effort to integrate structure and function throughout the text. In

addition, we emphasize that structure and function complement one another. It is important for students to realize that the structures of the various organs and other components of the body are specifically suited to contribute to their optimal functioning.



New in This Edition

New Art Program

This edition contains an entirely new art program. Every figure has been redrawn, and most photomicrographs are new. The art program from the previous three editions has been carefully modified so that each illustration depicts precisely what it is designed to show. In many cases, the new figures closely follow the detail shown in the figures in previous editions, which were generally well received. Retaining the detail of these proven figures while presenting them in an entirely new style has been a rare opportunity.

Increased Use of Color

The art program has been expanded to full color throughout the book. We have chosen pastel colors to avoid the rather garish appearance of some recent textbooks. We have also worked closely with the artists to ensure that color is used in a functional manner that serves as a learning aid—that is, to focus attention, differentiate related structures, or guide the viewer through a complex illustration—rather than simply for its own sake.

The use of color is consistent throughout the book. The color used to illustrate a particular structure in early chapters is used to illustrate the same structure in later chapters.

Updated Physiology

The sections of the text dealing with physiology have been extensively rewritten and updated. Many of the sections have been modified to make them more easily understood by students in an introductory course.

Aspects of Exercise Physiology

Many students enrolled in human anatomy and physiology courses are preparing for careers in physical education. In addition, the general public is increasingly aware of the value of exercise for the maintenance of health. To provide some interesting and pertinent information about the effects of exercise on specific body systems, we have included *Aspects of Exercise Physiology* boxes in most chapters. Each box discusses an effect of exercise that is probably familiar to most people and explains why the body responds to the exercise in the manner that it does.

Special Features

This edition retains several special features that were well received in the previous editions. These features enhance the text's usefulness as a teaching tool and increase student interest.

Integration of Embryology

We have found that structural and functional relationships within the body are understood better when students have some knowledge of embryonic development. For this reason, the discussion of each body system begins with a brief consideration of the embryonic development of the system. These discussions are self-contained and, if the instructor chooses, may be omitted without detracting from the remainder of the text.

Conditions of Clinical Significance

The emphasis throughout the text is on normal human anatomy and physiology. However, brief discussions of diseases, dysfunctions, and aging are included when they enhance and reinforce an understanding of normal structure and function. These discussions appear in separate *Conditions of Clinical Significance* boxes. This special treatment allows instructors to emphasize or deemphasize these discussions according to the objectives of their particular courses.

Clinical Correlations

In several chapters, we have included *Clinical Correlation* boxes that are of special interest to students majoring in nursing, premedicine, and the allied health sciences. Each box presents an actual case history of a patient suffering from a condition that illustrates basic physiological principles.

Regional Anatomy Appendix

Regional relationships are a significant aspect of human anatomy. Consequently, a regional anatomy appendix composed of full-color, labeled photographs of dissected cadavers appears at the end of the book (Appendix 1, page A1). This appendix will be valuable to anyone wishing to study regional anatomy, especially those with access to a cadaver in the laboratory.

In-Text Learning Aids

Different students learn in different ways. We have, therefore, provided various pedagogical aids to assist the diverse groups of students who take courses in human anatomy and physiology.

Learning Objectives

Each chapter begins with a list of learning objectives that direct the student toward significant aspects of the chapter.

Chapter Contents

Chapter contents placed at the beginning of each chapter list the major topics included in the chapter.

In-Text Pronunciations

When a scientific or technical term is first used in the text, it is accompanied by a phonetic pronunciation.

Study Outline

A study outline at the end of each chapter provides a summary of the chapter. Page references are included in the outline to help students locate information they may want to review.

Self-Quiz

A list of questions in the form of a self-quiz is included at the end of each chapter to help students determine how well they have learned the information in the chapter. The answers to the questions are listed in Appendix 2 (page A26).

Glossary

A glossary, which provides phonetic pronunciations and definitions for over 1,500 terms, is located on page G1.

Metric Appendix

A metric appendix, on page A34, provides metric/English conversion constants.

Supplements

Instructor's Manual/Test Bank

This supplement includes an extensive testing program to accompany *Human Anatomy and Physiology*, fourth edition. Each chapter includes 75 multiple choice, fill-in-the-blank, or true-false questions, some with anatomical line art, and at least five essay/thought questions, all arranged by level of difficulty. Also included is an extensive and newly updated guide to resources for teaching the course and course related media. This supplement is prepared by Professor Beth Howard of Rutgers University.

Computerized Testing

WESTEST is a full-featured microcomputer implementation of the test bank, which is available to qualified adopters. Available on both the Macintosh and IBM formats, WESTEST for Spence and Mason, fourth edition is fully editable, and is accompanied by clip art of line drawings based on anatomical illustrations in the text.

Study Guide

Newly developed for this edition by Alease Bruce of the University of Massachusetts at Lowell, this book is an interactive ancillary for sale to students, providing them with skills for self-study, drill exercises with answers, and "coloring exercises" to reinforce comprehension of the textual material.

Transparencies

This edition includes 200 full-color acetates based on art and tables from the text, with type reset for effective in-class use. It is available to qualified adopters.

Laboratory Manuals

Two versions of the laboratory manuals are available. Designed to parallel the text, they can be used independently with *any* book. Each of the laboratory manuals is accompanied by an instructor's manual outlining procedures, equipment, and suggested answers to exercises.

Laboratory Manual for Anatomy and Physiology with Dissection Guide for the Cat, by Katherine Malone and Jane Schneider, is a comprehensive manual designed to cover all aspects of the course. Qualified adopters can also receive a 20-minute videotape of a cat dissection, produced by Carolina Biological Supply Company.

Laboratory Manual for Anatomy and Physiology with Dissection Guide for the Fetal Pig, by Katherine Malone, Jane Schneider, and Eileen Walsh, is a comprehensive manual designed to cover all aspects of the course. Qualified adopters can also receive a 20-minute videotape of a pig dissection, produced by Carolina Biological Supply Company.

Video Library for Class Use

Qualified adopters have access to the extensive library of the film series: "The Human Body," developed by Films for the Humanities and Sciences.

Videodisc

Developed specifically for the fourth edition of Spence and Mason, this videodisc contains extensive visual resources to allow instructors to draw together all aspects of this course into coherent and integrated presentations. Included on the disc are all the images from the parent text, human cadaver dissection photos, all the images from the lab manuals, images from "The Human Body" produced by Films for the Humanities and Sciences, Mayo Clinic images utilizing the ANALYZE system, highly animated sequences of anatomical and physiological processes, histology slides, and more. To facilitate ease of use, the videodisc is accompanied by a guide to its use and bar code labels. It is available to qualified adopters.



Acknowledgments

We believe that one reason our text has been so successful for the past twelve years is that each edition has been extensively reviewed, and we have taken the reviewers' suggestions seriously. More than 45 people read all or part of the manuscript for this fourth edition, and their suggestions have been extensively incorporated into it. We are very grateful to the following for their thorough reviews and their many helpful suggestions;

Donna Alder
Roberts Wesleyan College

Barry Anderson
University of Scranton

Tom Baldus
North Dakota State College of Science

William Belzer
Clarion University

Jeffrey H. Black
East Central University

Robert J. Boettcher
Lane Community College

James A. Bridger
Prince George's Community College

Alan H. Brush
University of Connecticut

Ray D. Burkett
Shelby State Community College

Jerry Button
Portland Community College

Cynthia Carey
University of Colorado-Boulder

A. Carey Carpenter
Mt. Hood Community College

Anthony Chee
Houston Community College

Jean Cons
College of San Mateo

Philip Cooper
Suffolk Community College

Irene M. Cotton
Lorain County Community College

Darrell Davies
Kalamazoo Valley Community College

Gerald Dotson
Front Range Community College

William E. Dunscombe
Union County College

Douglas B. Fonner
Ferris State University

George Fortunato
Nassau Community College

John L. Frehn
Illinois State University

Greg Garman
Centralia College

Norman Goldstein
California State University-Hayward

Judy Goodenough
University of Massachusetts-Amherst

Donald W. Green
New Mexico Junior College

James E. Hall
Central Piedmont Community College

Ann Harmer
Orange Coast College

H. Kendrick Holden
Northern Essex Community College

Reinhold Hutz
University of Wisconsin-Milwaukee

R. Bruce Judd
Edison Community College

Jerry T. Justus
Arizona State University

Kenneth Kaloustian
Quinnipiac College

Joseph R. Koke
Southwest Texas State University

Linda Kollett
Massasoit Community College

Alan S. Kolok
University of Colorado-Boulder

Charles Leavell
Fullerton College

Harvey Liftin
Broward Community College

Linda L. MacGregor
Bucks County Community College

Kathryn Malone
Westchester Community College

Joseph W. McDaniel
Vermont College

Randall M. McKee
University of Wisconsin-Parkside

A. Kenneth Moore
Seattle Pacific University

Robert Nabors
Tarrant County Junior College

W. Brian O'Connor
University of Massachusetts-Amherst

Ann Marie Olson
Bunker Hill Community College

Patricia O'Mahoney-Damon
University of Southern Maine

Steven J. Person
Lake Superior State University

Michael Postula
Parkland College

Ralph E. Reiner
College of the Redwoods

James W. Russell
Georgia Southwestern College

Mary Schwanke
University of Maine-Farmington

David S. Smith
San Antonio College

Carol Spaulding
University of Maryland

Eugene Volz
Sacramento City College

Elizabeth Walker
West Virginia University

Edith Wallace
William Paterson College

Edward P. Wallen
University of Wisconsin-Parkside

James F. Waters
Humboldt State University

Richard E. Welton
Southern Oregon State College

Barry J. Wicklow
St. Anselm College

Clarence C. Wolfe
Northern Virginia Community College

One improvement in this edition that will be noticed immediately by anyone familiar with our previous edi-

tions is the beautiful full-color art program. We are delighted with the work done by Rolin Graphics, and we appreciate the patience shown by their artists as we made, what must have seemed to them, endless revisions in the artwork.

We also want to express our appreciation to Dr. Rachel Yeater, professor, Sports Exercise Program, and director, Human Performance Laboratory, School of Physical Education, West Virginia University for providing the Aspects of Exercise Physiology boxes used in the text. They indeed add a new dimension to the study of anatomy and physiology.

It has been our good fortune to work with West Publishing Company, a truly outstanding publisher. The people at West are enthusiastic, energetic, and full of ideas. We are particularly indebted to Ron Pullins, acquiring editor, for professionally and expertly overseeing all aspects of the preparation of this fourth edition. We thank Denise Bayko, developmental editor, for organizing the most effective reviewing process we have ever encountered, and Pat Lewis, freelance copyeditor, for her efficient editing of the manuscript. We are grateful to Laura Nelson, who conducted the photo research, for finding just the right photos to complement the text, and to Kristen Weber, freelance interior designer, for giving the book such a pleasing and effective appearance. We extend our very special thanks to the production editor, Deanna Quinn. We stand in awe of her ability to handle the many details and difficulties involved in the preparation of this book and still keep the project on schedule. To all these people, it seems inadequate to merely say thanks. Each one has contributed in a significant way to this text.

Alexander P. Spence
Elliott B. Mason

Department of Biological Sciences
State University of New York College at Cortland

CHAPTER 1

Introduction to Anatomy and Physiology





CONTENTS IN BRIEF

Preface xxi

**CHAPTER 1 Introduction to Anatomy
and Physiology 1**

**CHAPTER 2 The Chemical and Physical
Basis of Life 22**

CHAPTER 3 The Cell 58

CHAPTER 4 Tissues 108

**CHAPTER 5 The Integumentary
System 132**

CHAPTER 6 The Skeletal System 152

CHAPTER 7 Articulations 216

**CHAPTER 8 The Muscular System:
General Structure and
Physiology 242**

**CHAPTER 9 The Muscular System: Gross
Anatomy 278**

**CHAPTER 10 The Nervous System: Its
Organization and Components 334**

**CHAPTER 11 Neurons, Synapses, and
Receptors 356**

**CHAPTER 12 The Central Nervous
System 382**

**CHAPTER 13 The Peripheral Nervous
System 426**

**CHAPTER 14 The Autonomic Nervous
System 454**

**CHAPTER 15 Integrative Functions of the
Nervous System 468**

CHAPTER 16 The Special Senses 486

**CHAPTER 17 The Endocrine
System 536**

**CHAPTER 18 The Cardiovascular System:
The Blood 570**

**CHAPTER 19 The Cardiovascular System:
The Heart 592**

**CHAPTER 20 The Cardiovascular System:
Blood Vessels 626**

**CHAPTER 21 The Lymphatic
System 674**

**CHAPTER 22 Defense Mechanisms of the
Body 686**

**CHAPTER 23 The Respiratory
System 716**

CHAPTER 24 The Digestive System 754

**CHAPTER 25 Metabolism, Nutrition, and
Temperature Regulation 802**

CHAPTER 26 The Urinary System 832

**CHAPTER 27 Fluid and Electrolyte
Regulation and Acid-Base
Balance 866**

**CHAPTER 28 The Reproductive
System 884**

**CHAPTER 29 Pregnancy, Embryonic
Development, and Inheritance 924**

APPENDIX 1 Regional Anatomy A1

APPENDIX 2 Self-Quiz Answers A26

**APPENDIX 3 Word Roots, Prefixes,
Suffixes, and Combining Forms A31**

**APPENDIX 4 Units of the Metric
System A34**

GLOSSARY G1

INDEX II

CREDITS C1

CONTENTS

Preface xxi

CHAPTER 1 Introduction to Anatomy and Physiology 1

FIELDS OF ANATOMY	2
FIELDS OF PHYSIOLOGY	2
MEDICAL IMAGING METHODS	2
Tomography	2
Dynamic Spatial Reconstructor	3
Magnetic Resonance Imaging	3
Ultrasonography	4
Positron-emission Tomography	4
INTERRELATIONSHIP OF STRUCTURE AND FUNCTION	4
LEVELS OF STRUCTURAL ORGANIZATION	5
Chemical Level	5
Cellular Level	5
Tissue Level	5
<i>Epithelial Tissues</i>	5
<i>Muscular Tissues</i>	6
<i>Nervous Tissues</i>	6
<i>Connective Tissues</i>	6
Organ Level	6
Organ System Level	6
ANATOMICAL AND PHYSIOLOGICAL TERMINOLOGY	7
BODY POSITIONS	8
DIRECTIONAL TERMS	8
REGIONAL TERMS	8
BODY PLANES	10
BODY CAVITIES	10
MEMBRANES OF THE VENTRAL BODY CAVITIES	12
HOMEOSTASIS	15
HOMEOSTATIC MECHANISMS	17
Negative Feedback	17
POSITIVE FEEDBACK	19
◆ Aspects of Exercise Physiology: What Is Exercise Physiology?	17

CHAPTER 2 The Chemical and Physical Basis of Life 22

CHEMICAL ELEMENTS AND ATOMS	24
ELECTRON ENERGY LEVELS	24
ATOMIC NUMBER, MASS NUMBER, AND ATOMIC WEIGHT	25
◆ A Closer Look: Isotopes and Radiation	26
CHEMICAL BONDS	27
Covalent Bonds and Molecules	27
<i>Nonpolar Covalent Bonds</i>	27
<i>Polar Covalent Bonds</i>	28
Ionic Bonds and Ions	28
Hydrogen Bonds	30
◆ A Closer Look: Electronegativity	30
CARBON CHEMISTRY	31
Carbohydrates	31
Lipids	31
Proteins	34
Nucleic Acids	38
Adenosine Triphosphate	40
ENZYMES AND METABOLIC REACTIONS	41
Action of Enzymes	42
Regulation of Enzymatic Activity	44
<i>Control of Enzyme Production and Destruction</i>	44
<i>Control of Enzyme Activity</i>	44
Cofactors	44
SOLUTIONS	44
Properties of Water	45
◆ A Closer Look: Expressing the Concentration of a Solution	46
SUSPENSIONS	48
COLLOIDS	48
ACIDS, BASES, AND pH	48
GRADIENTS	49
DIFFUSION	50
OSMOSIS	51

DIALYSIS	52
BULK FLOW	53
FILTRATION	53

◆ CHAPTER 3 ◆

The Cell 58

CELL COMPONENTS	60
Plasma Membrane	61
<i>Movement of Materials across the Plasma Membrane</i>	62
◆ A Closer Look: Active Transport and the Sodium-Potassium Pump	66
<i>Tonicity</i>	70
<i>Signaling Molecules and Plasma-Membrane Receptors</i>	70
◆ A Closer Look: G Protein-Linked Receptors and Intracellular Mediators	72
<i>Electrical Conditions at the Plasma Membrane</i>	75
The Nucleus	77
<i>RNA Synthesis (Transcription)</i>	78
<i>Messenger RNA</i>	80
<i>Transfer RNA</i>	80
<i>Ribosomal RNA</i>	81
Ribosomes	81
<i>Basic Features of Polypeptide and Protein Synthesis (Translation)</i>	81
◆ A Closer Look: Ribosomes and Protein Synthesis	83
Endoplasmic Reticulum	85
Golgi Apparatus	86
Endosomes, Endolysosomes, and Lysosomes	87
Peroxisomes	88
Mitochondria	88
Cytoskeleton	90
<i>Microtubules</i>	90
<i>Intermediate Filaments</i>	91
<i>Microfilaments</i>	91
Cilia, Flagella, and Basal Bodies	91
Centrosome and Centrioles	92
Inclusion Bodies	92
EXTRACELLULAR MATERIALS	92
CELL DIVISION	93
Interphase	93
<i>Centriole Replication</i>	94
<i>DNA Replication</i>	95
Mitosis	95
<i>Prophase</i>	95
<i>Prometaphase</i>	96
<i>Metaphase</i>	97
<i>Anaphase</i>	97
<i>Telophase</i>	97
Cytokinesis	97
Meiosis	97
<i>Phases of Meiosis</i>	98
<i>Genetic Diversity</i>	100
◆ Conditions of Clinical Significance: The Cell	101
Genetic Disorders	101

Cancer	102
Aging and Cells	102

◆ CHAPTER 4 ◆

Tissues 108

EPITHELIAL TISSUES	110
Specialization of Epithelial Cell Surfaces	110
Specializations for Cell Attachments	110
<i>Junctional Complexes</i>	110
<i>Gap Junctions</i>	112
Classification of Epithelia	112
<i>According to Cell Layers</i>	112
<i>According to Cell Shape</i>	112
<i>General Classification</i>	112
<i>Epithelial Membranes</i>	115
<i>Glandular Epithelium</i>	117
CONNECTIVE TISSUES	118
Intercellular Matrix	119
<i>Collagenous Fibers</i>	120
<i>Elastic Fibers</i>	120
<i>Reticular Fibers</i>	120
Types of Connective Tissue	120
<i>Loose Connective Tissue</i>	121
<i>Adipose Tissue</i>	121
<i>Reticular Connective Tissue</i>	120
<i>Dense Irregular Connective Tissue</i>	122
<i>Dense Regular Connective Tissue</i>	122
<i>Elastic Connective Tissue</i>	122
<i>Cartilage</i>	122
<i>Bone</i>	125
<i>Blood</i>	125
MUSCLE TISSUE	126
Skeletal Muscle	126
Cardiac Muscle	127
Smooth Muscle	127
NERVOUS TISSUE	127
TISSUE REPAIR	128

◆ CHAPTER 5 ◆

The Integumentary System 132

EPIDERMIS	134
Epidermal Layers	135
<i>Stratum Basale</i>	135
<i>Stratum Spinosum</i>	136
<i>Stratum Granulosum</i>	136
<i>Stratum Lucidum</i>	136
<i>Stratum Corneum</i>	136
Nourishment of the Epidermis	136
DERMIS	137
Papillary Layer	137
Reticular Layer	137
HYPODERMIS	137
◆ Aspects of Exercise Physiology: What the Scales Don't Tell You	138

SKIN COLOR	138
GLANDS OF THE SKIN	139
Sweat Glands	139
Sebaceous Glands	139
HAIR	140
NAILS	141
FUNCTIONS OF THE INTEGUMENTARY SYSTEM	141
Protection	141
Body Temperature Regulation	142
Excretion	142
Sensation	142
Vitamin D Production	142
◆ Conditions of Clinical Significance: The Integumentary System	143
Acne	143
Warts	143
Dermatitis and Eczema	143
Psoriasis	143
Impetigo	143
Moles	144
Herpes Simplex	144
Shingles	144
Cancers	144
Burns	144
Wound Healing in Skin	146
Effects of Aging	148
Metastatic Calcification	167
Spina Bifida	167
Osteoporosis	167
Osteomyelitis	167
Tuberculosis of Bone	168
Rickets and Osteomalacia	168
Tumors of Bone	168
Abnormal Growth Patterns	168
Effects of Aging	168
INDIVIDUAL BONES OF THE SKELETON	169
AXIAL SKELETON	169
Skull	169
<i>Calvarium</i>	169
<i>Bones That Form the Floor of the Cranial Cavity</i>	173
<i>Facial Skeleton</i>	176
<i>Bones That Form the Nasal Cavity</i>	178
<i>Bones That Form the Hard Palate</i>	178
<i>Bones That Form the Orbital Cavity</i>	178
<i>Paranasal Sinuses</i>	178
<i>Auditory Ossicles</i>	179
<i>Hyoid Bone</i>	179
Vertebral Column	181
<i>Curvatures of the Vertebral Column</i>	181
<i>Functions of the Vertebral Column</i>	182
<i>Characteristics of a Typical Vertebra</i>	184
<i>Regional Differences in Vertebrae</i>	186
Thorax	186
<i>Sternum</i>	186
<i>Ribs</i>	190
<i>Costal Cartilages</i>	191
APPENDICULAR SKELETON	191
Upper Limbs	193
<i>Pectoral Girdle</i>	193
◆ Aspects of Exercise Physiology: Osteoporosis: The Bane of Brittle Bones	195
<i>Arm</i>	196
<i>Forearm</i>	197
<i>Hand</i>	199
Lower Limbs	201
<i>Pelvic Girdle</i>	201
<i>Pelvic Cavities</i>	201
<i>Thigh</i>	203
<i>Leg</i>	203
<i>Foot</i>	206
Sesamoid Bones	207

◆ CHAPTER 6 ◆

The Skeletal System 152

FUNCTIONS OF THE SKELETON	154
Support	154
Movement	154
Protection	154
Mineral Reservoir	154
Blood-Cell Formation (Hemopoiesis)	154
CLASSIFICATION OF BONES	154
Long Bones	154
Short Bones	154
Flat Bones	154
Irregular Bones	154
STRUCTURE OF BONE	155
Gross Anatomy	155
Microscopic Anatomy	156
COMPOSITION AND FORMATION OF BONE	157
DEVELOPMENT OF BONE	158
Early Development of Bone	158
<i>Intramembranous Ossification</i>	159
<i>Endochondral Ossification</i>	159
Increase in Long Bone Length and Diameter	161
Remodeling of Bone	161
Factors That Affect Bone Development	162
<i>Mechanical Stress</i>	162
<i>Hormones</i>	164
◆ Conditions of Clinical Significance: The Skeletal System	164
Fractures	164
<i>Types of Fractures</i>	164
<i>Healing of Fractures</i>	164

◆ CHAPTER 7 ◆

Articulations 216

CLASSIFICATION OF JOINTS	218
FIBROUS JOINTS	218
Sutures	218
Syndesmoses	219
Gomphoses	219
CARTILAGINOUS JOINTS	219
Synchondroses	219
Symphyses	219

SYNOVIAL JOINTS	219
Bursae and Tendon Sheaths	221
Movements of Synovial Joints	222
<i>Gliding</i>	222
<i>Angular Movements</i>	223
<i>Circumduction</i>	225
<i>Rotation</i>	225
<i>Special Movements</i>	225
Types of Synovial Joints	226
<i>Nonaxial Joints</i>	226
<i>Uniaxial Joints</i>	226
<i>Biaxial Joints</i>	226
<i>Triaxial Joints</i>	226
Ligaments of Selected Synovial Joints	227
<i>Ligaments of the Shoulder Joint</i>	228
<i>Ligaments of the Elbow Joint</i>	229
<i>Ligaments of the Hip Joint</i>	231
<i>Ligaments of the Knee Joint</i>	231
◆ Conditions of Clinical Significance:	
Articulations	235
Sprains	235
Dislocations	235
Bursitis	235
Tendinitis	235
Herniated (Slipped) Disc	235
Torn Menisci	235
Arthritis	236
<i>Osteoarthritis</i>	236
<i>Rheumatoid Arthritis</i>	237
<i>Gouty Arthritis</i>	238
Effects of Aging	238

◆ **CHAPTER 8** ◆

The Muscular System:

General Structure and Physiology 242

MUSCLE TYPES	244
Skeletal Muscle	244
Smooth Muscle	244
Cardiac Muscle	244
EMBRYONIC DEVELOPMENT OF MUSCLE	244
Skeletal Muscle	244
Smooth Muscle	245
Cardiac Muscle	245
GROSS ANATOMY OF SKELETAL MUSCLE	245
Connective-Tissue Coverings	245
Skeletal Muscle Attachments	245
Skeletal Muscle Shapes	245
MICROSCOPIC ANATOMY OF SKELETAL MUSCLE	247
Composition of the Myofilaments	247
Transverse Tubules and Sarcoplasmic Reticulum	248
CONTRACTION OF SKELETAL MUSCLE	249
Contraction of a Skeletal Muscle Fiber	249
<i>The Neuromuscular Junction</i>	250
<i>Excitation of a Skeletal Muscle Fiber</i>	250
<i>Excitation-Contraction Coupling</i>	252
<i>Mechanism of Contraction</i>	253
<i>Regulation of the Contractile Process</i>	253

Sources of ATP for Muscle Contraction	253
<i>Creatine Phosphate</i>	255
<i>Nutrients</i>	256
Muscle Fatigue	257
Oxygen Debt	257
◆ Aspects of Exercise Physiology: Exercising Muscles	
Increases Their Uptake of Glucose	258
The Motor Unit	259
Responses of Skeletal Muscle	259
<i>Muscle Twitch</i>	259
<i>Graded Muscular Contractions</i>	259
Factors Influencing the Development of Muscle	
Tension	261
<i>Contractile and Series Elastic Elements</i>	261
<i>Influence of Length on the Development of Muscle</i>	261
Relation of Load to Velocity of Shortening	263
MUSCLE ACTIONS	263
RELATIONSHIP BETWEEN LEVERS AND MUSCLE ACTIONS	264
Classes of Levers	264
<i>Class I Levers</i>	264
<i>Class II Levers</i>	264
<i>Class III Levers</i>	264
Effects of Levers on Movements	264
TYPES OF SKELETAL MUSCLE FIBERS	265
Slow Twitch, Fatigue-Resistant Fibers	266
Fast Twitch, Fatigue-Resistant Fibers	266
Fast Twitch, Fatigable Fibers	266
UTILIZATION OF DIFFERENT FIBER TYPES	266
EFFECTS OF EXERCISE ON SKELETAL MUSCLE	268
◆ Conditions of Clinical Significance: Skeletal Muscle	268
Muscle Atrophy	268
Cramps	268
Muscular Dystrophy	268
Myasthenia Gravis	268
Effects of Aging	269
◆ Clinical Correlation: Skeletal Muscle Contracture during Sustained Activity	267
SMOOTH MUSCLE	269
Smooth Muscle Arrangements	270
<i>Single-Unit Smooth Muscle</i>	270
<i>Multiunit Smooth Muscle</i>	270
Influence of External Factors on Smooth Muscle Contraction	271
Smooth Muscle Contraction	271
Smooth Muscle Contraction Speed and Energy Supply	271
Stress-Relaxation Response	272
Ability to Contract When Stretched	272
Degree of Shortening during Contraction	273
Smooth Muscle Tone	273

◆ **CHAPTER 9** ◆

The Muscular System:

Gross Anatomy 278

MUSCLES OF THE HEAD AND NECK	282
Muscles of the Face	282

Muscles of Mastication	284
Muscles of the Tongue	285
Muscles of the Neck	285
Muscles of the Throat	286
MUSCLES OF THE TRUNK	286
Muscles of the Vertebral Column	287
Deep Muscles of the Thorax	288
Muscles of the Abdominal Wall	293
Muscles That Form the Floor of the Abdominopelvic Cavity	294
Muscles of the Perineum	294
MUSCLES OF THE UPPER LIMBS	296
Muscles That Act on the Scapula	296
Muscles That Act on the Arm (Humerus)	299
Muscles That Act on the Forearm (Radius and Ulna)	301
Muscles That Act on the Hand and Fingers	303
Intrinsic Muscles of the Hand	306
MUSCLES OF THE LOWER LIMBS	311
Muscles That Act on the Thigh (Femur)	312
Muscles That Act on the Leg (Tibia and Fibula)	316
Muscles That Act on the Foot and Toes	321
Intrinsic Muscles of the Foot	327
◆ Aspects of Exercise Physiology: Adverse Effects of Steroid Use	329

◆ CHAPTER 10 ◆

The Nervous System: Its Organization and Components 334

ORGANIZATION OF THE NERVOUS SYSTEM	337
Central Nervous System	337
Peripheral Nervous System	338
<i>Afferent Division</i>	338
<i>Efferent Division</i>	338
EMBRYONIC DEVELOPMENT OF THE NERVOUS SYSTEM	338
COMPONENTS OF THE NERVOUS SYSTEM	340
Neurons	340
<i>Structure of a Neuron</i>	341
<i>Locations of the Cell Bodies of Neurons</i>	341
<i>Processes of Neurons</i>	342
<i>Formation of Myelinated Neurons</i>	342
<i>Types of Neurons</i>	344
Nerves	345
Specialized Endings of Peripheral Neurons	346
<i>Endings of Motor Neurons</i>	346
<i>Endings of Sensory Neurons</i>	346
Types of Receptors	349
<i>Classification According to Location of Stimulus</i>	349
<i>Classification According to Type of Stimulus</i>	350
◆ Aspects of Exercise Physiology: Back Swings and Pre-Jump Crouches: What Do They Have in Common?	350
Neuroglial Cells	350
<i>Astrocytes</i>	351
<i>Oligodendrocytes</i>	351
<i>Microglia</i>	353
<i>Ependymal Cells</i>	353
EFFECTS OF AGING ON THE NERVOUS SYSTEM	353

◆ CHAPTER 11 ◆

Neurons, Synapses, and Receptors 356

RESTING MEMBRANE POTENTIAL	358
Development of the Resting Membrane Potential	359
MOVEMENT OF IONS ACROSS THE UNSTIMULATED NEURONAL MEMBRANE	359
Potassium Ions	359
Sodium Ions	359
Chloride Ions	360
ROLE OF ACTIVE-TRANSPORT MECHANISMS IN MAINTAINING THE RESTING MEMBRANE POTENTIAL	360
GATED ION CHANNELS	360
GRADED POTENTIALS	361
ACTION POTENTIAL	361
Depolarization and Polarity Reversal	362
Return to the Original Membrane Potential	363
Maintenance of Sodium and Potassium Ion Concentrations	364
THE NERVE IMPULSE	364
Refractory Periods	365
All-or-None Response	365
Direction of Nerve Impulse Conduction	366
Conduction Velocities	366
SYNAPSES	366
Electrical Synapses	367
Chemical Synapses	367
<i>Chemical Synapses Involving Chemically Gated Ion Channels</i>	367
◆ Aspects of Exercise Physiology: Relation between Excitatory Postsynaptic Potentials and Muscle Strength	373
<i>Chemical Synapses Involving Non-Channel-Linked Receptors</i>	368
<i>Kinds of Neurotransmitters</i>	369
<i>Neuromodulators</i>	370
NEURAL INTEGRATION	371
Divergence and Convergence	371
Summation	371
<i>Temporal Summation</i>	371
<i>Spatial Summation</i>	371
Facilitation	372
Determination of Postsynaptic Neuron Activity	372
Presynaptic Inhibition and Presynaptic Facilitation	373
RECEPTORS	374
Generator Potentials	374
Receptor Potentials	374
Discrimination of Differing Stimulus Intensities	375
Adaptation	375
EFFECTORS	375
Effects of Aging on Neuromuscular Junctions	376
◆ Clinical Correlation: Myasthenia Gravis	376

◆ CHAPTER 12 ◆

The Central Nervous System 382

THE BRAIN	384
------------------	-----

Forebrain	384
<i>Telencephalon</i>	384
<i>Diencephalon</i>	393
Midbrain	397
<i>Cerebral Peduncles</i>	398
<i>Corpora Quadrigemina</i>	398
Hindbrain	399
<i>Metencephalon</i>	399
<i>Myelencephalon</i>	399
Ventricles of the Brain	400
<i>Lateral Ventricles</i>	401
<i>Third Ventricle</i>	401
<i>Fourth Ventricle</i>	401
The Meninges	402
<i>Dura Mater</i>	402
<i>Arachnoid</i>	404
<i>Pia Mater</i>	404
Cerebrospinal Fluid	404
THE SPINAL CORD	404
General Structure of the Spinal Cord	404
Meninges of the Spinal Cord	407
Composition of the Spinal Cord	407
<i>Gray Matter of the Spinal Cord</i>	408
<i>Dorsal and Ventral Roots of Spinal Nerves</i>	408
<i>White Matter of the Spinal Cord</i>	409
The Spinal Reflex Arc	412
<i>Stretch Reflex</i>	414
<i>Tendon Reflex</i>	416
◆ Aspects of Exercise Physiology: Swan Dive or Belly Flop: It's a Matter of CNS Control	417
NEURON POOLS	417
◆ Conditions of Clinical Significance: The Central Nervous System	418
Spinal Cord Dysfunctions	418
<i>Paralysis</i>	418
<i>Lesions of Sensory Tracts of the Spinal Cord</i>	418
<i>Specific Dysfunctions of the Spinal Cord</i>	418
Dysfunctions of the Brain Stem	419
Dysfunctions of the Cerebellum	419
Dysfunctions of the Basal Nuclei	419
<i>Parkinsonism</i>	419
<i>Huntington's Chorea</i>	420
Inflammatory Diseases of the Central Nervous System	420
<i>Encephalitis and Myelitis</i>	420
<i>Meningitis</i>	420
Tumors of the Central Nervous System	420

◆ CHAPTER 13 ◆

The Peripheral Nervous System 426

CRANIAL NERVES	428
I: Olfactory Nerves	429
II: Optic Nerves	429
III: Oculomotor Nerves	430
IV: Trochlear Nerves	430
V: Trigeminal Nerves	431
VI: Abducens Nerves	433
VII: Facial Nerves	433
VIII: Vestibulocochlear Nerves	433

IX: Glossopharyngeal Nerves	435
X: Vagus Nerves	435
XI: Accessory Nerves	436
XII: Hypoglossal Nerves	437
SPINAL NERVES	437
Formation of Spinal Nerves	440
Branches of Spinal Nerves	440
Distribution of Spinal Nerves	441
Plexuses and Peripheral Nerves	441
<i>Cervical Plexus</i>	441
<i>Brachial Plexus</i>	442
<i>Lumbosacral Plexus</i>	448
◆ Aspects of Exercise Physiology: Loss of Muscle Mass: A Problem of Space Flight	443
◆ Conditions of Clinical Significance: The Peripheral Nervous System	449
Injury and Regeneration of Peripheral Nerves	449
Neuritis	449
Neuralgia	450
Shingles	451

◆ CHAPTER 14 ◆

The Autonomic Nervous System 454

ANATOMY OF THE AUTONOMIC NERVOUS SYSTEM	456
Sympathetic Division	456
Parasympathetic Division	459
Anatomical Differences between the Divisions	460
NEUROTRANSMITTERS OF THE AUTONOMIC NERVOUS SYSTEM	460
RECEPTORS FOR AUTONOMIC NEUROTRANSMITTERS	461
FUNCTIONS OF THE AUTONOMIC NERVOUS SYSTEM	462
◆ Aspects of Exercise Physiology: Exercise and Autonomic Effects on Heart Rate	464
◆ Conditions of Clinical Significance: The Autonomic Nervous System	465
Biofeedback	465
Raynaud's Disease	465
Achalasia	465
Hirschsprung's Disease	465

◆ CHAPTER 15 ◆

Integrative Functions of the Nervous System 468

INTEGRATIVE SPINAL REFLEXES	470
MENTAL PROCESSES	471
The Electroencephalogram	471
Consciousness	472
<i>The Aroused Brain</i>	472
<i>Sleep</i>	472
<i>Sleep-Wakefulness Cycle</i>	472
Attention	474
Emotions and Behavior	474

Pain	475
<i>Pain Modulation</i>	475
<i>Referred Pain</i>	477
<i>Phantom Pain</i>	477
Memory	478
<i>Short-Term Memory</i>	478
<i>Long-Term Memory</i>	479
Learning	479
CONTROL OF BODY MOVEMENTS	480
Support of the Body against Gravity	480
<i>Reflexes</i>	480
<i>Higher Centers</i>	480
Locomotion	480
The Cerebellum and the Coordination of Movement	480
Skilled Movements	481
LANGUAGE	481
◆ Clinical Correlation: Alzheimer's Disease	482

◆ CHAPTER 16 ◆

The Special Senses 486

THE EYE—VISION	488
Embryonic Development of the Eye	488
Structure of the Eye	489
<i>Fibrous Tunic</i>	489
<i>Vascular Tunic</i>	489
<i>Retina</i>	489
<i>Lens</i>	491
<i>Cavities and Humors</i>	491
Accessory Structures of the Eye	491
<i>Eyelids</i>	491
<i>Conjunctiva</i>	492
<i>Lacrimal Apparatus</i>	492
<i>Extrinsic Eye Muscles</i>	493
Light	494
Optics	494
Focusing of Images on the Retina	496
<i>Emmetropia</i>	496
<i>Accommodation</i>	496
<i>Near and Far Points of Vision</i>	498
Control of Eye Movements	498
Binocular Vision and Depth Perception	498
<i>Diplopia (Double Vision)</i>	498
<i>Strabismus</i>	499
Photoreceptors of the Retina	499
<i>Rods</i>	499
<i>Cones</i>	501
Neural Elements of the Retina	503
Visual Pathways	504
Processing of Visual Signals	504
Light and Dark Adaptation	506
Pupillary Light Reflex	506
Visual Acuity	506
◆ Conditions of Clinical Significance: The Eye	507
Myopia	507
Hypermetropia	507
Astigmatism	508
Cataract	508

Glaucoma	508
Color Blindness	508
Effects of Aging	508
THE EAR—HEARING AND HEAD POSITION AND MOVEMENT	510
Embryonic Development of the Ear	510
Structure of the Ear	510
<i>External Ear</i>	511
<i>Middle Ear</i>	511
<i>Inner Ear</i>	513
Mechanisms of Hearing	513
<i>Sound Waves</i>	513
<i>Sound Waves and the Loudness, Pitch, and Timbre of Sounds</i>	516
<i>Transmission of Sound Waves to the Inner Ear</i>	517
<i>Function of the Cochlea</i>	517
<i>Auditory Pathways</i>	519
<i>Determination of Pitch</i>	519
<i>Determination of Loudness</i>	520
<i>Sound Localization</i>	520
<i>The Stapedius and Tensor Tympani Muscles</i>	521
<i>Central Nervous System Influences on the Spiral Organ</i>	521
Head Position and Movement	521
◆ Clinical Correlation: Hearing Loss Due to Aging	522
<i>Function of the Utricle</i>	522
<i>Function of the Sacculle</i>	524
<i>Function of the Semicircular Ducts</i>	525
<i>Nystagmus</i>	525
Maintenance of Equilibrium	525
◆ Conditions of Clinical Significance: The Ear	527
Middle-Ear Infections	527
Deafness	527
Effects of Aging	527
SMELL (OLFACTION)	525
TASTE (GUSTATION)	529

◆ CHAPTER 17 ◆

The Endocrine System 536

BASIC ENDOCRINE FUNCTIONS	538
Hormones	538
Transport of Hormones	538
Mechanisms of Hormone Action	539
<i>Binding of Hormones to Plasma-Membrane Receptors</i>	539
<i>Binding of Hormones to Receptors within Cells</i>	539
Hormonal Interrelationships	539
Relationship between the Endocrine System and the Nervous System	540
PITUITARY GLAND	540
Embryonic Development and Structure	540
<i>Neurohypophysis</i>	540
<i>Adenohypophysis</i>	540
Relationship to the Brain	541