THIRD EDITION

ANATOMY AND
PHYSIOLOGY
FOR HEALTH PROFESSIONALS

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JONES & BARTLETT LEARNING
This book is dedicated to my wonderful and amazing wife, Hengameh, and two beautiful daughters, Mahkameh and Morvarid.

It is also dedicated to my granddaughters, Laila Jade and Annabelle Jasmine Mabry.
# Brief Contents

<table>
<thead>
<tr>
<th>Preface</th>
<th>xiii</th>
</tr>
</thead>
<tbody>
<tr>
<td>About the Author</td>
<td>xv</td>
</tr>
<tr>
<td>Acknowledgments</td>
<td>xvi</td>
</tr>
<tr>
<td>Reviewers</td>
<td>xvii</td>
</tr>
<tr>
<td>A Visual Walkthrough</td>
<td>xix</td>
</tr>
</tbody>
</table>

## SECTION I  Levels of Organization

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction to Human Anatomy and Physiology</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Chemical Basics of Life</td>
<td>28</td>
</tr>
<tr>
<td>3</td>
<td>Cells</td>
<td>52</td>
</tr>
<tr>
<td>4</td>
<td>Cellular Metabolism</td>
<td>84</td>
</tr>
<tr>
<td>5</td>
<td>Tissues</td>
<td>102</td>
</tr>
</tbody>
</table>

## SECTION II  Support and Movement

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Integumentary System</td>
<td>128</td>
</tr>
<tr>
<td>7</td>
<td>Bone Tissues and the Skeletal System</td>
<td>151</td>
</tr>
<tr>
<td>8</td>
<td>Articulations</td>
<td>197</td>
</tr>
<tr>
<td>9</td>
<td>Muscle Tissue</td>
<td>219</td>
</tr>
<tr>
<td>10</td>
<td>Muscular System</td>
<td>240</td>
</tr>
</tbody>
</table>
### SECTION III  Control and Coordination  271

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>Neural Tissue</td>
<td>272</td>
</tr>
<tr>
<td>12</td>
<td>Central Nervous System</td>
<td>296</td>
</tr>
<tr>
<td>13</td>
<td>Peripheral Nervous System and Reflex Activity</td>
<td>327</td>
</tr>
<tr>
<td>14</td>
<td>Autonomic Nervous System</td>
<td>347</td>
</tr>
<tr>
<td>15</td>
<td>Special Senses</td>
<td>364</td>
</tr>
<tr>
<td>16</td>
<td>Endocrine System</td>
<td>391</td>
</tr>
</tbody>
</table>

### SECTION IV  Transport  421

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>Blood</td>
<td>422</td>
</tr>
<tr>
<td>18</td>
<td>The Heart</td>
<td>449</td>
</tr>
<tr>
<td>19</td>
<td>Vascular System</td>
<td>472</td>
</tr>
<tr>
<td>20</td>
<td>Lymphatic System and Immunity</td>
<td>508</td>
</tr>
</tbody>
</table>

### SECTION V  Environmental Exchange  537

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>Respiratory System</td>
<td>538</td>
</tr>
<tr>
<td>22</td>
<td>Urinary System</td>
<td>571</td>
</tr>
<tr>
<td>23</td>
<td>Fluid, Electrolyte, and Acid-Base Balance</td>
<td>595</td>
</tr>
<tr>
<td>24</td>
<td>Digestive System</td>
<td>617</td>
</tr>
</tbody>
</table>

### SECTION VI  Continuity of Life  657

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>Reproductive System</td>
<td>658</td>
</tr>
<tr>
<td>26</td>
<td>Pregnancy and Development</td>
<td>690</td>
</tr>
<tr>
<td>27</td>
<td>Heredity</td>
<td>714</td>
</tr>
</tbody>
</table>
Appendix A  Common Abbreviations and Symbols  732
Appendix B  Medical Terminology  740
Appendix C  The Metric System  744
Appendix D  Reference Laboratory Values – Blood and Urine  746
Glossary  750
Index  809
Contents

Preface .......................................................... xiii
About the Author .............................................. xv
Acknowledgments ............................................. xvi
Reviewers ......................................................... xvii
A Visual Walkthrough ........................................ xix

SECTION I  Levels of Organization  1

Chapter 1  Introduction to Human Anatomy and Physiology .... 2
Overview ......................................................... 3
Organization Levels of the Body ............................... 4
Essentials for Life .............................................. 5
Homeostasis ..................................................... 7
Organization of the Body ...................................... 9
Summary ........................................................ 24
Key Terms ....................................................... 24
Learning Goals .................................................. 24
Critical Thinking Questions ................................... 25
Review Questions ............................................... 26
Essay Questions ................................................ 27

Chapter 2  Chemical Basics of Life ............... 28
Overview ........................................................ 29
Basic Chemistry .............................................. 29
Atoms, Molecules, and Chemical Bonds .................... 29
Biochemistry ................................................... 37
Adenosine Triphosphate ...................................... 47
Summary ........................................................ 48
Key Terms ....................................................... 49
Learning Goals .................................................. 49
Critical Thinking Questions ................................... 50
Review Questions ............................................... 50
Essay Questions ................................................ 51

Chapter 3  Cells .............................................. 52
Overview ......................................................... 53
Structure of the Cell .......................................... 53
Movements Through Cell Membranes ...................... 68
Cell Cycle ....................................................... 74
Summary ........................................................ 79
Key Terms ....................................................... 80
Learning Goals .................................................. 81
Critical Thinking Questions ................................... 82
Review Questions ............................................... 82
Essay Questions ................................................ 83

Chapter 4  Cellular Metabolism ................. 84
Overview ......................................................... 85
Metabolic Reactions .......................................... 85
Control of Metabolic Reactions ............................. 87
Oxidation-Reduction Reactions ............................. 88
Chemical Energy .............................................. 88
Cellular Respiration and Metabolism of Carbohydrates... 88
Metabolism of Lipids .......................................... 96
Metabolism of Proteins ....................................... 97
Summary ........................................................ 98
Key Terms ....................................................... 99
Learning Goals .................................................. 99
Critical Thinking Questions ................................... 100
Review Questions ............................................... 100
Essay Questions ................................................ 101

Chapter 5  Tissues ................................. 102
Overview ......................................................... 103
Types of Tissues .............................................. 103
Tissue Membranes .......................................... 120
Tissue Repair .................................................. 122
Effects of Aging on Various Tissues ....................... 122
Summary ........................................................ 123
## Contents

Key Terms ................................................. 124  
Learning Goals ........................................ 124  
Critical Thinking Questions ...................... 125  
Review Questions ..................................... 125  
Essay Questions ....................................... 126  

**SECTION II Support and Movement 127**  

### Chapter 6 Integumentary System ........... 128  
Overview .............................................. 129  
Skin ..................................................... 129  
Accessory Structures ............................... 136  
Functions of the Integumentary System ........ 141  
Response of the Integument to Injuries and Wounds .................. 142  
Effects of Aging on the Integumentary System ... 143  
Skin Cancer ......................................... 144  
Burns ................................................... 145  
Summary .............................................. 147  
Key Terms ............................................ 147  
Learning Goals ...................................... 148  
Critical Thinking Questions ...................... 149  
Review Questions ................................... 149  
Essay Questions ..................................... 150  

### Chapter 7 Bone Tissues and the Skeletal System .......... 151  
Overview .............................................. 152  
Classifications of Bones ......................... 152  
Structures of Bones ................................. 154  
Growth and Development of Bones ............ 159  
Functions of Bones ................................ 162  
Bone Homeostasis .................................. 163  
Bone Homeostatic Imbalance .................... 167  
Skeletal Organization ............................... 168  
Effects of Aging on the Skeletal System ...... 191  
Summary .............................................. 192  
Key Terms ............................................ 193  
Learning Goals ...................................... 194  
Critical Thinking Questions ...................... 195  
Review Questions ................................... 195  
Essay Questions ..................................... 196  

### Chapter 8 Articulations ......................... 197  
Overview .............................................. 198  
Classifications of Joints ............................ 198  
Types of Joint Movements ........................ 208  
Intervertebral Joints ................................ 210  
Intervertebral Ligaments .......................... 211  
Joint Injuries ......................................... 211  
Effects of Aging on the Joints .................... 212  
Summary .............................................. 215  
Key Terms ............................................ 215  
Learning Goals ...................................... 216  
Critical Thinking Questions ...................... 217  
Review Questions ................................... 217  
Essay Questions ..................................... 218  

### Chapter 9 Muscle Tissue ......................... 219  
Overview .............................................. 220  
Classification of Muscle Tissues ................. 220  
Characteristics of Muscle Tissue ................ 221  
Functions of the Muscles .......................... 222  
Coverings of Connective Tissue ................. 222  
Blood Supply and Nerve Attachments .......... 222  
Structure of Skeletal Muscle Fibers ............ 223  
Contraction Stimulus ............................... 225  
Neuromuscular Junction ........................... 226  
Action Potential ..................................... 227  
Sarcoplasmic Reticulum and Transverse Tubules ... 227  
Somatic Motor Neurons ............................ 228  
Motor Units ......................................... 229  
Muscle Twitch ....................................... 230  
Energy Sources for Contraction ................. 231  
Smooth Muscle ...................................... 233  
Effects of Aging on Muscle Tissue ............. 235  
Summary .............................................. 236  
Key Terms ............................................ 236  
Learning Goals ...................................... 237  
Critical Thinking Questions ...................... 238  
Review Questions ................................... 238  
Essay Questions ..................................... 239
Chapter 10  Muscular System          240
Overview ........................................ 241
Lever Systems ................................ 244
Effects of Aging on the Muscular System ... 267
Summary ........................................ 268
Key Terms ..................................... 268
Learning Goals ................................ 268
Critical Thinking Questions ................. 269
Review Questions ............................. 269
Essay Questions ............................... 270

SECTION III  Control and Coordination  271

Chapter 11  Neural Tissue .............. 272
Overview ........................................ 273
Divisions of the Nervous System .......... 273
Cells of the Nervous System ............. 274
Classification of Nerve Fibers .......... 279
Cell Membrane Potential ................. 281
Nerve Impulses ............................... 284
Synapses ...................................... 285
Processing of Impulses ..................... 290
Effects of Aging on the Nervous System .... 290
Summary ........................................ 291
Key Terms ..................................... 292
Learning Goals ................................ 293
Critical Thinking Questions ............... 294
Review Questions ............................. 294
Essay Questions ............................... 295

Chapter 12  Central Nervous System .... 296
Overview ........................................ 297
The Brain ....................................... 297
Higher Brain Functions .................... 306
Brain Protection ............................ 309
Spinal Cord .................................... 312
Spinal Neuronal Pathways ............... 315
Imbalances of the CNS ...................... 316
Effects of Aging on the Brain .............. 320
Summary ........................................ 321
Key Terms ..................................... 322
Learning Goals ................................ 323
Critical Thinking Questions ............... 325
Review Questions ............................. 325
Essay Questions ............................... 326

Chapter 13  Peripheral Nervous System and Reflex Activity .... 327
Overview ........................................ 328
Sensory Receptors ........................... 328
General Senses ................................ 330
Peripheral Nerves ............................ 332
Peripheral Motor Endings ................. 340
Somatic Nervous System ................. 340
Imbalances of the PNS ...................... 342
Effects of Aging on the PNS ............... 342
Summary ........................................ 343
Key Terms ..................................... 343
Learning Goals ................................ 344
Critical Thinking Questions ............... 345
Review Questions ............................. 345
Essay Questions ............................... 346

Chapter 14  Autonomic Nervous System .... 347
Overview ........................................ 348
Comparison of the Somatic Nervous System and Autonomic Nervous System .... 348
Major ANS Neurotransmitters ............ 350
Autonomic Nerve Fibers ................... 350
Divisions of the ANS ....................... 352
Cholinergic Receptors ...................... 355
Adrenergic Receptors ....................... 356
Control of Autonomic Activity .......... 358
Somatic and Autonomic Function Overlap .... 358
Higher Levels of Autonomic Control .... 358
Imbalances of the ANS ..................... 359
Effects of Aging on the ANS .............. 359
Summary ........................................ 360
Key Terms ..................................... 360
Learning Goals ............................... 360
In 35 years of teaching anatomy and physiology, I have utilized numerous books related to the subject. Some were very high level while others were very low level, and I could not find a “middle ground” book that really taught the subject to allied health students; surprising, given that this is a time when the field is growing exponentially. Therefore, I undertook the writing of this book for all allied health professionals. Anatomy and physiology are two of the major core subjects for almost all allied health professionals—they must understand the structures and normal functions of the body in the simplest possible terms. This book strives to make that possible.

Organization of This Text

This text is based on levels of organization within the body and becomes more multifaceted as the student incorporates the understanding of basic, then intermediate, and finally more complex subjects.

In total, the text consists of six units:

- **Unit I, Levels of Organization**: This unit begins by providing a general introduction to human anatomy and physiology along with the organization levels through which the body is understood. It then delves into the atomic, molecular, and chemical interactions on which life is based before moving on to discussions of the cells and tissues that comprise the body.

- **Unit II, Support and Movement**: This unit focuses on the body systems that support the body and allow for a range of motion. It first considers the integumentary system, composed of the skin and its accessory structures; these are the body’s first line of defense against the environment. The text then approaches the bones and joints that comprise the skeletal system before discussing the muscular system.

- **Unit III, Control and Coordination**: This unit tackles the critical components of the body that control all body functions. The text considers the all-important nervous system across four chapters on neural tissue, the central nervous system, the peripheral nervous system, and the senses. The unit then ends with a chapter on the endocrine system, which works along with the nervous system to regulate the functions of the human body to maintain homeostasis.

- **Unit IV, Transport**: This unit focuses on the cardiovascular and lymphatic systems, which keep the body running. The first three chapters discuss the major components of the cardiovascular system: the heart, blood, and blood vessels. The last chapter in this unit focuses on the lymphatic system. Like the cardiovascular system, it transports fluids through a network of vessels; without the lymphatic system, fluid would accumulate in tissue spaces.

- **Unit V, Environmental Exchange**: This unit considers the systems and processes that balance what the body intakes with what it expels. The unit first examines the respiratory system, which intakes oxygen and removes carbon dioxide from the body, before shifting focus to the urinary system, which eliminates wastes and maintains homeostatic regulation of the volume and solute concentration of blood plasma. The text then surveys fluid, electrolyte, and acid-base balance before moving on to the digestive system, which in simplest terms supplies nutrients for body cells.

- **Unit VI, Continuity of Life**: In this unit, the focus shifts to the male and female reproductive systems, which, while not essential to the survival of an individual, are needed to ensure the continued existence of the human species. The final chapter, then, discusses pregnancy before delving into a brief discussion of genetics.

In addition to the recurring features that guide the student through each chapter (of which an overview is given in the “How to Use This Book” section), the body systems chapters contained in this text address the effects of aging on each specific system, information
that is especially critical at a time when the number of older adults is on the rise.

New to This Edition

This Third Edition has been updated to take into account both advancements in medical knowledge in the last several years as well as feedback from valued users of the First and Second Editions.

For the Third Edition, the text was expanded from 24 to 27 chapters. Changes include:

- **NEW! Case Studies** are included for instructors and students as part of the Teaching and Learning Package as interactive or printable PDFs to help students apply concepts to real-world scenarios.
- **NEW! Chapter 7, Muscle Tissue**: This chapter focuses on the more basic concepts of the various types of muscle tissues, including structures and functions.
- **REVISED! Chapter 8, Muscular System**: This chapter focuses on the actual muscles of the body and their functions. Lever systems is a topic that has been added, and this chapter includes discussion of skeletal, smooth, and cardiac muscles.
- **NEW and REVISED! Chapter 14, Autonomic Nervous System**: This chapter has been separated from the second edition's “Peripheral Nervous System” chapter, and both these new chapters have been greatly expanded.
- **NEW! Chapter 27, Heredity**: This is a new chapter that explains how our genes and chromosomes influence every facet of life. It focuses on various types of inheritance and genetic screening.
- **NEW! There are four new Appendices in this edition. They include:**
  - Common Abbreviations
  - Medical Terminology
  - The Metric System
  - Reference Values for Blood and Urine

New tables and figures have been added as appropriate.

The Teaching and Learning Package

The Teaching and Learning packages for instructors and students encourage going beyond the content of the text as well as driving home key concepts within the text.

Instructor Teaching Package

Qualified instructors can receive a full suite of extensive Instructor Resources, including:

- **Slides in PowerPoint format**: Featuring more than 2,000 slides. At the bottom of each slide, Lecture Notes have been added to assist instructors in better explanations of the concepts summarized on the slides as well as to provide students in the form of study notes.
- **Test Bank**: Containing more than 1,000 questions
- **Instructor's Manual**: Including teaching strategies, lecture outlines, discussion topics, and answers to end of chapter questions as well as answers to Case Studies
- **Image Bank**: Supplying key figures from the text
- **Sample Syllabus**: Showing how a course can be structured around this text
- **Transition Guide**: Providing guidance in switching from the previous edition

Student Learning Package

The Student Learning Package includes:

- **Interactive eBook**: Featuring more than 20 animations to help students conceptualize key points of interest
- **Lab Exercises**: Interactive or printable PDFs, which students can use to visually apply the concepts learned
- **Practice Activities**: To test student understanding for each chapter
- **Case Studies**: Available as interactive or printable PDFs to help students apply concepts to real-world scenarios
- **Flash Cards**: For self-study
Dr. Jahangir Moini is currently a professor at Eastern Florida State College, where he teaches anatomy and physiology as well as other science courses. He was previously assistant professor at Tehran University School of Medicine for nine years, where he taught medical and allied health students. Dr. Moini is a former professor and director (for 15 years) of allied health programs at Everest University. In total, he served at Everest University for 24 years.

As a physician and instructor for the past 45 years, he advocates that all health professionals must understand the structures and functions of the human body. Other sciences such as pathology, pharmacology, and chemistry are correlated with the knowledge of anatomy and physiology.

Dr. Moini is actively involved in teaching and helping students prepare for service in various health professions. He has been an internationally published author of 25 allied health books since 1999.
I would like to acknowledge the following individuals for their time and efforts in aiding with this book:

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A Visual Walkthrough

Anatomy and Physiology for Health Professionals, Third Edition incorporates a number of engaging pedagogical features to aid in the students’ understanding and retention of the material. A colorful and engaging layout enables easy reading and supports the retention of important concepts. Hundreds of full-color photographs and medically accurate illustrations provide valuable insight into human anatomy and physiology.

Objectives and Outline

Each chapter begins with a framework for learning the most important topics by presenting Objectives that list the chapter’s desired outcomes and an Outline indicating the material to be discussed.

Overview

The science of genetics is the study of heredity. In the mid-1980s, Craig Venter was the first scientist to propose basic principles of heredity. Today’s geneticists are able to engineer and manipulate human genes in order to modify the ways in which they are expressed. The Human Genome Project was undertaken to determine the actual human DNA sequence. As the field of genetic screening develops, many futures medical outcomes are now envisioned.

Genes

Children inherit traits from their parents and relatives as determined by DNA. Individual segments of DNA are known as genes. When a gene’s DNA sequence changes or mutates, an illness or other condition may result. Spontaneous mutations occur because of errors in DNA replication or transcription. The field of genomics investigates how genes result in certain characteristics affecting health or contributing to natural variation. It also focuses on how genes are passed from generation to generation. Today, familial chromosome analyses provide clues to a child’s future health.

All human cells, except gametes, have a diploid number of chromosomes (46). This number consists of 22 pairs of autosomes and 1 pair of sex chromosomes. One pair is from the father (the sperm) and the other pair is from the mother (the egg). Homologous chromosomes appear similar, carrying genes for the same traits. However, they do not always bring about the same expressions of those traits. Autosomes are pairs 1 through 22 and do not carry genetic determinants, but function to guide the expressions of most other traits. Only pair 23, the X and Y chromosomes, are sex chromosomes. Females have two X chromosomes and males have one X and one Y chromosome. A six-chromosome pair may be very different in size. The Y chromosome, however, is much shorter and carries fewer genes than the X chromosome. A Y chromosome is actually an individual gene (Y-CHNA) that encodes a protein that influences male sexual development.

Genetic Variation

Cytogenetic and molecular analyses are used to identify the specific genetic changes that cause inherited diseases. These changes can occur when a gene is altered or inactivated by a mutation or when an abnormal gene is inserted into the genome. The most frequent mutations are deletions and insertions. Other frequent mutations are duplications and losses of genetic material. Mutations can also occur in the chromosome structure, including translocations and inversions. The most frequent mutations are deletions and insertions. Other frequent mutations are duplications and losses of genetic material. Mutations can also occur in the chromosome structure, including translocations and inversions.

Patterns of Inheritance

Dominant Inheritance

Recessive Inheritance

Multiple Inheritance

Environmental Factors

Infectious Disease

Mechanical Inheritance

Gender-Related Factors

Sex Determination

Chromosome Disorders
A Visual Walkthrough

Focus on Pathology

Focus on Pathology boxes connect the book's coverage of anatomy and physiology to important topics in pathology or the study of disease.

Test Your Understanding

Each chapter contains Test Your Understanding boxes scattered throughout, which present open-ended questions that reinforce key content covered in the preceding sections.
Extensive Art Program

The extensive art program has been revised to include a number of new photos and illustrations to provide additional visual support for student comprehension.
At the end of each chapter, the **Summary** recaps the most important points in the chapter and connects it to the student’s overall journey.

**Key Terms**

*Key Terms* list the most important new terms covered in the chapter; correlating definitions can be found in the end of text glossary.
Learning Goals

Learning Goals encapsulate how each Objective has been addressed over the course of the chapter.

Critical Thinking Questions

A range of questions are also included at the end of each chapter; the student can use these for self-study or submit their answers to the instructor. A case is presented at the end of each chapter, with Critical Thinking Questions that cause the student to reflect on the situation described.

Review Questions

Review Questions provide students with a chance to answer multiple choice questions.

Essay Questions

Finally, Essay Questions ask students to delve deeply into the content.
CHAPTER 1

Introduction to Human Anatomy and Physiology

**OUTLINE**

**OVERVIEW**
- Classifications of Anatomy
- Classifications of Physiology

**ORIENTATION LEVELS OF THE BODY**

**ESSENTIALS FOR LIFE**
- Boundaries
- Movement
- Responsiveness
- Digestion
- Metabolism
- Excretion
- Reproduction
- Growth
- Survival

**HOMEOSTASIS**
- Homeostatic Control
- Homeostatic Imbalance

**ORGANIZATION OF THE BODY**
- Body Cavities and Membranes
- Diagnostic Imaging
- Organ Systems

**Anatomic Planes**
- Directional Terms
- Abdominal Regions
- Body Regions

**SUMMARY**

**KEY TERMS**

**LEARNING GOALS**

**CRITICAL THINKING QUESTIONS**

**REVIEW QUESTIONS**

**ESSAY QUESTIONS**
OBJECTIVES

After studying this chapter, readers should be able to

1. Define anatomy and physiology.
2. Name the components that make up the organization levels of the body.
3. Describe the major essentials of life.
4. Define homeostasis and describe its importance to survival.
5. Describe the major body cavities.
6. List the systems of the body and give the organs in each system.
7. Describe directions and planes of the body.
8. Discuss the membranes near the heart, lungs, and abdominal cavity.
9. List the nine abdominal regions.
10. Compare positive and negative feedback mechanisms.

Overview

The study of anatomy and physiology is vital for all health professionals and it involves many different areas of science to understand how the human body works and how it is structured. The study of anatomy and physiology provides answers to many questions about the functions of the body in both health and disease. As a result of this understanding, it is possible to see what happens to the body when it is injured, stressed, or contracts a disease or infection. It is important for all allied health students to be familiar with the terminology used in anatomy and physiology. In this chapter, the focus is on a complete introduction to anatomy and physiology.

The structures and functions of the human body are closely related. Anatomy is the study of the structure of body parts and how they are organized. This term is derived from the Greek words meaning to cut apart. Physiology is the study of how body parts work. Every body part functions to assist the human body in different ways. It is not easy to separate the topics of anatomy and physiology because the structures of body parts are so closely associated with their functions. Each part has its own unique substructures that allow it to perform its needed functions. Pathophysiology is the study of changes associated with, or resulting from, disease or injury. It is also concerned with biological and physical manifestations of disease as they relate to underlying abnormalities and physiological disturbances. Pathophysiology explains the processes within the body that result in disease signs and symptoms but does not focus directly on the treatment of disease.

The human body has been studied for hundreds of years. Even though its inner workings are well understood, new discoveries are being made even today. In 2003, the human genome (instructions that allow the body to operate) was deciphered for the first time. There are more than 20,000 genes in the human body, and this substantial discovery took many years to complete. Researchers frequently discover new information about physiology, particularly at the molecular level, but basic human anatomy changes very slowly.

Classifications of Anatomy

The many subdivisions of anatomy include gross (macroscopic) anatomy, microscopic anatomy, and developmental anatomy. These can be further broken down as follows:

- **Gross (macroscopic) anatomy:** The study of large body structures that can be seen without a microscope. These include the brain, heart, kidneys, lungs, and skin. Studies conducted to understand gross anatomy made use of dissected animals and their organs.
  - **Regional anatomy:** All structures in a certain body region are examined at the same time. For example, for an arm, the structures being examined would include skin, muscles, bones, nerves, blood vessels, and others.
  - **Systemic anatomy:** Each body system is examined. For example, the heart would be examined when studying the cardiovascular system, but so would all the blood vessels in the body.
  - **Surface anatomy:** This is the examination of internal structures related to overlying skin surfaces. Surface anatomy is used, for example, to locate the correct blood vessels used for phlebotomy.

- **Microscopic anatomy:** The study of small body structures that require a microscope to be seen.
This requires making thin slices of tissues, which are then stained and affixed (mounted) to glass slides for microscopic examination.

- **Cytology:** A subdivision of microscopic anatomy that focuses on body cells.
- **Histology:** A subdivision of microscopic anatomy that focuses on body tissues.
- **Developmental anatomy:** The study of structural changes in anatomy throughout the life span.
- **Embryology:** A subdivision of developmental anatomy that focuses on developmental changes occurring before birth.

For medical diagnosis, scientific research, and other highly specialized needs, *pathological* or *radiographic* anatomy may be used. Pathological anatomy focuses on disease and the structural changes that are a result of the disease, whereas radiographic anatomy focuses on internal structures via the use of X-rays or specialized scanning equipment such as magnetic resonance imaging (MRI) or computed tomography (CT). *Molecular anatomy* focuses on the structure of chemical substances (biological molecules). Although formally considered a branch of *biology*, molecular anatomy is still part of the overall study of anatomy as it focuses on subcellular particles of the body.

Anatomical studies require a combination of many different skills. These include anatomic terminology, observation, *auscultation* (using a stethoscope to listen to organ sounds), manipulation, and *palpation* (feeling body organs for normal or abnormal conditions by using the hands).

### Classifications of Physiology

Physiology is concerned with how the body functions, often focusing on cellular or molecular activities. There are also many subdivisions of physiology, which are primarily focused on certain organ systems. Examples of physiology classifications are as follows:

- **Respiratory physiology:** Focuses on the functions of the respiratory system
- **Cardiovascular physiology:** Focuses on the heart and blood vessels
- **Neurophysiology:** Focuses on the nervous system
- **Renal physiology:** Focuses on the functions of the kidneys, including urine production

The physiology of the human body is based on chemical reactions that affect the actions of cells at the molecular level. Physiology is also linked to the study of physics, which takes into account body functions such as blood pressure, electrical currents, and muscular movement.

### TEST YOUR UNDERSTANDING

1. Describe the difference between gross anatomy and developmental anatomy.
2. Compare cytology and histology.
3. Explain the classifications of physiology.

### Organization Levels of the Body

Every body structure is made up of smaller structures, which are, likewise, made up of even smaller components. Chemicals compose every material found in the human body. They contain microscopic *atoms* combined into structures known as *molecules*. Many molecules may be combined into macromolecules. These macromolecules, in turn, form *organelles*, which help to complete the intended functions of a *cell*, the basic unit of both structure and function in the human body.

Cells are microscopic structures that can vary in size, shape, and function. Cells are grouped together to form *tissues*, which, in turn, are grouped together to form *organs*. Groups of similarly functioning organs form *organ systems*, which then combine to form a living *organism* (*Figure 1-1*). Body parts are organized into different levels of complexity, including the *atomic level*, *molecular level*, and *cellular level*. Atoms are the most simple in structure, with complexity increasing in molecules, organelles, tissues, and organs.

At *tissue level*, the tissues work together and perform one or more specific functions. For example, cardiac muscle cells interact within the heart with other types of cells. They also interact with extracellular materials, forming cardiac muscle tissue. At the *organ level*, the tissues of an organ work together, performing several functions. For example, layers of cardiac muscle tissue work with connective tissue to form most of the wall of the heart, which is a hollow, three-dimensional organ. At the *organ system level*, groups of organs interact and perform particular functions. For example, each contraction of the heart pushes blood into the blood vessel network. The heart, along with the blood and blood vessels, comprise the cardiovascular system. This is one of the 11 organ systems of the human body.

### TEST YOUR UNDERSTANDING

1. Describe the major levels of organization of the body.
2. Identify the tissue level and the organ system level.
Essentials for Life

Humans and other animals share many similar traits. All body cells are interdependent as we are multicellular organisms. Vital body functions occur over various organ systems, which contribute to overall body health.

Boundaries

The body’s boundaries are maintained to keep the internal environment distinct from the external environment. All body cells are surrounded by selectively permeable membranes. The skin encloses and protects the body as a whole from factors such as dryness, bacteria, heat, sunlight, and chemicals.

Movement

Movement of the body is achieved via the muscular and skeletal systems. Inside the body, the cardiovascular, digestive, and urinary systems too use movement to transport blood, food materials, and urine. Even cells move, such as when muscle cells move by shortening, which is known as contractility.

Responsiveness

The ability to sense and respond to environmental stimuli (changes) is known as responsiveness, which is also referred to as excitability. An example is the way we quickly withdraw our hands from a hot saucepan. Nerve cells are highly excitable. They communicate with rapid electrical impulses, and, therefore, the nervous system is the most responsive of all body systems. However, all body systems have some degree of excitability.

Digestion

Humans require specific nutrients to remain healthy and to grow and develop normally. Energy is gained from the breakdown, digestion, absorption, and assimilation of food. Digestion breaks down food materials to simple, more easily absorbed molecules. Absorbed nutrients move throughout the body’s circulation. Nutrient-rich blood is distributed, via the cardiovascular system, to the entire body. Respiration brings in oxygen that works with nutrients to grow and repair body parts. The unusable parts of these processes are then excreted as waste.

Metabolism

The body’s metabolism controls all these processes. It includes all chemical reactions inside body cells, the breaking down of substances into simpler forms (catabolism), creating more complex cellular components from simpler substances (anabolism), and the use of nutrients and oxygen to produce energy-rich adenosine triphosphate (ATP) molecules (via cellular respiration).
In metabolism, nutrients and oxygen from the digestive and respiratory systems are circulated to all body cells. Hormones from the endocrine system glands have strong regulatory control over metabolism.

**Excretion**
The process of removing wastes from the body is known as *excretion*. Nonessential substances that are produced during digestion and metabolism must be removed. The digestive system removes food components that cannot be digested via the feces. The urinary system removes urea and other metabolic wastes containing nitrogen via the urine. The blood carries carbon dioxide to the lungs for it to be exhaled.

**Reproduction**
*Reproduction* is a process that occurs at several levels. At the cellular level, reproduction means cell division. Cells divide to produce two identical daughter cells, which the body uses for growth and repair. At the organism level, the human reproduction system unites a sperm with an egg. A fertilized egg is formed, developing into a baby inside the body of the mother. The function of the production of offspring is controlled by endocrine system hormones. Reproductive structures differ between the sexes, with the female structures providing a fertilization site for the male sperm cells. The female reproductive structures protect the developing fetus and nurture its growth until birth.

**Growth**
An increase in the size of an organism or its body parts is called *growth*. Most often, growth is achieved by an increase in the amount of cells. In fact, even when the cells do not divide, they can increase in size. True growth occurs when constructive activities occur more quickly than destructive activities. The various characteristics of life are listed in **TABLE 1-1**.

**Survival**
Human beings need several substances for survival: food (nutrients), water, oxygen, pressure, and heat in specific quantities and with specific qualities.

**Nutrients**
Food provides nutrients for energy, growth, and regulation of the chemical reactions in the body. Some of these chemicals are used as energy sources or supply the raw materials needed for building new living matter; other chemicals help to regulate vital chemical reactions. Plant-based foods contain high levels of carbohydrates, vitamins, and minerals. Carbohydrates are the primary energy fuel for body cells. Certain vitamins and minerals are needed for chemical reactions inside cells and for oxygen transport in the blood. Calcium is a mineral that assists in making bones harder and is needed for blood clotting. Animal-based foods contain high levels of proteins and fats. Proteins

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### TABLE 1-1 Characteristics of Human Life

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Movement</td>
<td>Change in positions of the body or its parts; motion of internal organs</td>
</tr>
<tr>
<td>Responsiveness</td>
<td>Reaction to changes, inside or outside the body</td>
</tr>
<tr>
<td>Digestion</td>
<td>Breakdown of foods into simpler forms for absorption and usage</td>
</tr>
<tr>
<td>Excretion</td>
<td>Removal of wastes from metabolic reactions</td>
</tr>
<tr>
<td>Growth</td>
<td>Increases in body size, without changes in shape</td>
</tr>
<tr>
<td>Respiration</td>
<td>Obtaining oxygen and removing carbon dioxide; releasing energy from foods</td>
</tr>
<tr>
<td>Absorption</td>
<td>Movement of substances through membranes into body fluids</td>
</tr>
<tr>
<td>Circulation</td>
<td>Movement of substances in body fluids</td>
</tr>
<tr>
<td>Assimilation</td>
<td>Change of absorbed substances into various chemical forms</td>
</tr>
</tbody>
</table>
are the most essential component required for building cell structures. Fats assist in this process and are a great source of energy-providing fuel for the body.

**Water**

Water is required for metabolic processes and makes up most of the body’s actual structure, transporting substances and regulating temperature. It accounts for 60% to 80% of body weight and is the most abundant chemical in the body. Water allows chemical reactions to occur and is also the fluid base for secretions and excretions. Water is mostly obtained from ingested liquids or foods, and is lost in the urine, by evaporation from the lungs and skin, and also in other body excretions.

**Oxygen**

Oxygen is a gas that drives metabolic processes by releasing energy from food that is consumed and by bringing nutrients to cells throughout the body. This energy release involves oxidative reactions, for which oxygen is required. Therefore, all nutrients require oxygen for them to be effectively used. Human cells only survive for a few minutes without oxygen. Oxygen makes up approximately 20% of the air that we breathe. It is made available to the blood and body cells by both the respiratory and cardiovascular systems. Appropriate amounts of oxygen sustain life, but even oxygen may be toxic in excessive quantities.

**Atmospheric Pressure**

Appropriate pressure, specifically atmospheric pressure, is essential for breathing and gas exchange. Blood pressure is a form of hydrostatic pressure that forces the blood through the veins and arteries. Atmospheric pressure may be defined as the force that air exerts upon the body’s surface. Gas exchange, in higher altitudes, may be insufficient to support cellular metabolism because at these altitudes, atmospheric pressure is lower and the air is thinner. At sea level, the average atmospheric pressure is 760 mm of mercury (Hg).

**Body Temperature**

Heat energy is produced from metabolic reactions, influencing their speed. The muscular system generates the most body heat. Body heat is measured as temperature. Normal body temperature must be maintained if chemical reactions are to sustain life continually. If the temperature is too high, chemical reactions occur very quickly, and proteins in the body change shape and cease functioning. If body temperature drops below 98.6°F (37°C), metabolic reactions slow down and eventually stop. Death may occur also because of either variation in temperature.

### TEST YOUR UNDERSTANDING

1. What factors are necessary to sustain life in humans?
2. What elements are needed by the body for survival?
3. Describe metabolism and the effect of atmospheric pressure on the body.

### Homeostasis

The internal environment of the human body must stay relatively stable for the person to survive. **Homeostasis** is a term that describes a stable internal body environment. It requires a constant balance. There must be normal concentrations of nutrients, oxygen, and water. Heat and pressure must be regulated at tolerable levels. **Homeostatic mechanisms** regulate the body by negative or **positive feedback**.

### Homeostatic Control

For homeostasis to occur, the body primarily uses the nervous and endocrine systems. These systems allow forms of communication that control homeostasis to occur. The nervous system uses neural electrical impulses for these activities, whereas the endocrine system uses blood borne hormones. The nervous system handles rapid, short-term, extremely specific responses. The endocrine system responds more slowly, but its effects last for a longer duration. The event or factor that is being controlled (regulated) is referred to as the **variable**.

The two basic components of homeostatic control are as follows:

- **Autoregulation**: Also known as **intrinsic regulation**, this occurs when a body structure or system adjusts its activities because of some change in its environment. For example, declining tissue oxygen levels cause cells to release chemicals that widen local blood vessels, thereby increasing blood flow rate, which provides more oxygen to the local area of the body.

- **Extrinsic regulation**: Related to nervous or endocrine system activity, these systems influence activities of many other body systems simultaneously. For example, increased exercise causes the nervous system to increase the heart rate and circulate
blood more quickly. It also reduces blood flow to the digestive tract and other less active organs. Oxygen in the circulating blood is then available to the active muscles, which need it the most.

All mechanisms used for homeostatic control involve at least three components:

- **Receptors**: These are “sensors” that monitor the internal body environment and respond to stimuli. Receptors send information to the control center along the afferent pathway. You can remember this more easily because the afferent pathway carries information that is “approaching” the control center.

- **Control center**: This is a point in the body that determines the set point (the range or level at which a variable must be maintained). It analyzes the input from the receptors to determine appropriate responses or actions. It then sends information to effectors via the efferent pathway. You can remember this more easily because the efferent pathway carries information that is “exiting” the control center (FIGURE 1-2). The set point for the average body temperature, for example, is 98.6°F (37°C). Another set point is normal adult blood pressure, which is ideally below 120 (systolic) and under 80 (diastolic).

- **Effectors**: These are components of homeostatic control that allow the control center to respond to stimuli. The control center’s response involves negative (reducing) or positive (enhancing) feedback. Basically, negative feedback shuts off the control process, whereas positive feedback makes it occur at a faster rate.

**Negative Feedback**

A **negative feedback** mechanism is one that prevents the correction of deviations from doing too much (which could possibly harm the body). Most of the feedback mechanisms of the human body use negative feedback. Examples of negative feedback are blood pressure regulation, erythropoiesis (the production of red blood cells), body temperature regulation (thermoregulation), and control of blood glucose levels. The hypothalamus of the brain maintains homeostatic control of body temperature. Information is received from temperature receptors in the skin and within the hypothalamus itself. The normal set point of body temperature is approximately 98.6°F (37°C). When temperature rises above this normal, hypothalamic activity targets muscle tissue in walls of blood vessels that supply the skin, and also targets the sweat glands. This causes blood flow to increase near the body surface, and acceleration of sweat gland secretion. The skin loses heat to the environment, and sweat evaporation speeds up this process. As temperature lowers back to normal, hypothalamic activity declines, and all processes reverse.

Negative feedback is the main controller of homeostasis, providing long-term control over internal systems and body conditions. Minor variations are usually ignored, while normal body ranges are maintained instead of exact, fixed values. The regulatory process works dynamically since set points vary with changes in environment and activity. While sleeping, thermoregulation has a lower set point than when you are awake and active. Therefore, temperature varies because of small fluctuations around the set point, or change in the set point. Similar variations occur throughout all body physiology.

Set points differ between individuals based on age, gender, genetic factors, overall health, and the environment. There are no actual precise homeostatic conditions. Basically, homeostatic values are either based on average between large amounts of people, or as a range including 95% (or more) of those people being sampled. While most healthy adults have body temperature between 98.1°F and 98.9°F (between 36.7°C and 37.2°C), 5% have resting body temperatures above or below this range.

**Positive Feedback**

A **positive feedback** mechanism is one that makes conditions move away from the normal state to stimulate further changes. They are usually short-lived and extremely specific actions, producing extreme responses. A positive feedback mechanism is defined as one that results in or responds in an enhanced way.
to the original stimulus, accelerating the result or response. Examples of positive feedback are the onset of contractions before childbirth, the process of blood clotting, lactation, the secretion of estrogen during the follicular phase of menstruation, and the generation of nerve signals.

In positive feedback, cycles *escalate* and are often referred to as being part of a **positive feedback loop**. These loops are usually found when a possibly stressful or dangerous body process must be completed quickly prior to homeostasis being restored. One example is a severe laceration, which may lower blood pressure and reduce the heart's effectiveness. As the clotting process attempts to combat the loss of blood, a positive feedback loop occurs, which increases the clotting activities.

**Homeostatic Imbalance**

Most diseases occur because of **homeostatic imbalance** (meaning the disturbance of homeostasis). Aging causes body systems to become less efficient and more uncontrollable, resulting in instability in the internal body environment and increasing the risk for illness. Also, when helpful negative feedback mechanisms become overwhelmed, certain destructive positive feedback mechanisms can dominate (such as those seen in some forms of heart failure). Additional examples of homeostatic imbalance include abdominal injury due to physical trauma (and lack of protective bones in this body region), sepsis (resulting in severe pain, such as in **peritonitis**), and metabolic acidosis or alkalosis (which can affect all body systems and lead to death). Trauma may involve hemorrhage and perforation of abdominal organs. Any cause of homeostatic imbalance can result in death if untreated.

**Organization of the Body**

The human body is composed of distinct body parts, cavities, membranes, and organ systems that include various body systems. All of these are discussed in greater detail in the following sections.

**Body Cavities and Membranes**

The body is divided into two main cavities, the dorsal cavity and the ventral cavity. These two main cavities are divided into smaller subcavities. The dorsal cavity protects the organs of the nervous system. Its two subdivisions include the **cranial cavity** of the skull, which encases the brain, and the **vertebral (spinal) cavity**, located inside the vertebral column, which encases the spinal cord. The vertebral cavity is also referred to as the **vertebral canal**. The cranial and spinal cavities are in continuation with each other. The ventral cavity contains most of the body's organs. More anterior and larger than the dorsal cavity, it houses the **viscera** (visceral organs). The ventral cavity is divided into the **thoracic cavity** and the **abdominopelvic cavity**.

**Thoracic Cavity**

The thoracic cavity is surrounded by the chest muscles and ribs, and contains the lungs and heart; organs of the cardiovascular, respiratory, and lymphatic systems; inferior esophagus; and the thymus. It is subdivided into lateral **pleural cavities**, which surround each lung, and the medial **mediastinum**, which is a tissue mass that separates the cavities. Each pleural cavity is lined by a **serous membrane**, which is shiny and slippery, and functions to reduce friction as the lung expands and recoils during breathing. The **pleura** is the serous membrane lining a pleural cavity. The **visceral pleura** covers the outer lung surfaces. The **parietal pleura** covers the inner body wall and mediastinal surface.

The mediastinum is a mass of connective tissue surrounding and protecting the esophagus, trachea, thymus, and major blood vessels originating or ending at the heart. It also contains a small chamber surrounding the heart, which is called the **pericardial cavity**. The attached portion of the heart is called the **base**. The serous membrane of the heart is the **pericardium**, subdivided into the **visceral pericardium** (covering the heart) and its opposing surface, the **parietal pericardium**. As the heart changes size and shape while beating, the pericardial cavity also changes. Friction is prevented by the slipper
pericardial lining, between the heart and thoracic cavity structures.

**Abdominopelvic Cavity**

The thoracic cavity and abdominopelvic cavity are separated internally by the **diaphragm**, which is a flat sheet of muscle. The major cavities of the body are shown in **FIGURE 1-3**.

In the **abdominopelvic cavity**, which extends from the diaphragm to the pelvis, there are subdivisions known as the superior **abdominal cavity**, and the inferior **pelvic cavity**. The abdominopelvic cavity contains the **peritoneal cavity** (**FIGURE 1-4**). This is a potential space that is lined by a serous membrane called the **peritoneum**. The **peritoneal membranes** include the **parietal peritoneum** lining the walls and the **visceral peritoneum** covering each organ. Movement of the digestive organs, while able to cause rumbling or gurgling sounds, does not cause damage because the peritoneum allows them to slide across each other.

The abdominal cavity extends from the inferior surface of the diaphragm to the level of the superior edges of the pelvis. It contains the liver, stomach, spleen, small intestine, and the majority of the large intestine. These organs are completely or partially enclosed by the peritoneal cavity. However, certain organs such as the kidney and pancreas lie in between the peritoneal lining and the muscular abdominal cavity wall. Organs lying behind the peritoneum are called **retroperitoneal**. Organs lying inside the peritoneum are called **intraperitoneal**. **TABLE 1-2** lists intraperitoneal and retroperitoneal organs.
Diagnostic Imaging

Diagnostic or “medical” imaging was developed in order to view the internal organs and body structures, in both normal and abnormal conditions. It began in the first decade of the 1900s when physicist Wilhelm Roentgen discovered X-rays. Until the 1950s, X-rays were the exclusive method of imaging available. In its early days, X-rays took much longer to produce and exposed the patient to significantly higher amounts of radiation. An example of an X-ray is shown in FIGURE 1-5.

Additional medical imaging developments are as follows:

- The development of fluorescent screens that were used with special glasses allowed real-time viewing of X-ray images but also exposed physicians to radiation.
- Contrast agents barium and iodine help to improve viewing of the esophagus, stomach, coronary arteries, and other structures. Examples of procedures that use contrast agents include intravenous pyelogram and angiogram (FIGURE 1-6).
In 1955, X-ray image intensifiers allowed moving X-rays to be viewed by using television cameras and monitors.

Radionuclide scanning, or nuclear medicine, was developed in the 1950s. This type of scan uses special gamma cameras and low-level radioactive chemicals introduced into the body, allowing the evaluation of functional activity of organs. Results of nuclear medicine are recorded as a nuclear isotope scan (FIGURE 1-7).

Ultrasound scanning appeared in the 1960s, using high-frequency sound waves to penetrate the body, bounce off the internal structures, and then be reconstructed into live pictures by a computer (FIGURE 1-8). Ultrasound is most useful for soft tissues and body fluids and is commonly used to view the gallbladder, urinary bladder, and uterus.

Digital imaging came along in the 1970s with the development of CT. All preexisting technologies were upgraded to digital forms. Digital X-ray detectors are replacing previous analog technologies, allowing better imaging and less health risks. CT acquires an image in less than a second and instantly reconstructs it. It offers detailed cross-sectional images of body structures. FIGURE 1-9 shows a CT machine and FIGURE 1-10 shows a CT scan of the abdomen.

MRI, first offered in 1984, allows detailed imaging without exposure to radiation (FIGURE 1-11). Images are produced by displacing protons in atomic nuclei with radiofrequency signals. However, it cannot be used on a patient who has any metal implants because of its extremely powerful magnetization. Also, the person must remain completely still for a long period of time in a small, confined space. MRI is often used for bone, joint, brain, and nerve imaging.

Organ Systems

In each organ system of the human body, the organs work together to maintain homeostasis. These organ systems include the integumentary, skeletal, muscular, nervous, endocrine, cardiovascular, lymphatic, digestive, respiratory, urinary, and reproductive systems (FIGURE 1-12).

Integumentary System

The integumentary system includes the skin, hair, nails, sebaceous (oil) glands, and sweat glands. The system protects the underlying tissues of the body,
assists in the regulation of body temperature, contains various sensory receptors, and manufactures certain substances (such as vitamin D).

**Skeletal System**

The skeletal system supports and protects the soft tissues of the body and helps the body to move. It consists of bones, which are bound together by ligaments and cartilages. The skeletal system shields soft tissues and attaches to muscles. The bones also help in blood formation and provide storage of mineral salts.

**Muscular System**

The muscular system works with the skeletal system in helping the body to move. Body parts are moved by muscle contraction. Posture and body heat are maintained by the muscular system. The muscular system also includes the tendons.

**Nervous System**

The nervous system, along with the endocrine system, controls and coordinates various organ functions, helping to maintain homeostasis. The nervous system consists of the brain, spinal cord, nerves, and sensory organs. *Nerve impulses* are electrochemical signals used by nerve cells to communicate with each other.
and with the glands and muscles of the body. Certain nerve cells (called sensory receptors) detect internal and external changes that affect the body. Other nerve cells interpret and respond to these stimuli. Additional nerve cells carry impulses from the brain or spinal cord to the glands and muscles. These nerves are able to stimulate the muscles to contract and cause the glands to secrete their products. The characteristics of the nervous system include short-term effects, rapid responses, and very specific responses, as well as a variety of other responses.

**Endocrine System**

The endocrine system consists of hormone-secreting glands. Hormones affect specific target cells, altering their metabolism. Hormones have a relatively long duration of action compared with nerve impulses and can last for several days or longer. The endocrine system also produces a slower response regarding body changes than the nervous system. The organs of the endocrine system include the hypothalamus (in the brain), pituitary gland, pineal gland, thyroid gland, parathyroid glands, adrenal glands, pancreas, and thymus. Other organs with endocrine function include the ovaries and testes, which are also the parts of the reproductive system. The endocrine system can produce effects involving several organs or tissues at the same time.

**Cardiovascular System**

The cardiovascular system includes the heart, blood, arteries, veins, and capillaries. The heart muscle pumps blood through the arteries, transporting gases, hormones, nutrients, and wastes. Blood returns to the heart via the veins. Oxygen is carried from the lungs to the body, and nutrients are carried from the digestive system. The blood also transports biochemicals required for metabolism. Wastes are carried in the blood from body cells to the excretory organs.
Lymphatic System
The lymphatic system is composed of the lymphatic vessels, lymph nodes, thymus, spleen, and lymph fluid. It works with the cardiovascular system, transporting tissue fluid back into the bloodstream. It also carries specific fats from digestive organs into the bloodstream. Lymphatic cells (lymphocytes) defend the body against infection. The lymphatic vessels have two ducts in the chest, known as the thoracic duct and the right lymphatic duct.

Digestive System
The digestive system takes in food from outside the body, breaks it down and absorbs the nutrients. It then excretes wastes from its various processes. The digestive system also produces certain hormones and works in conjunction with the endocrine system. The structures of the digestive system include the mouth, teeth, salivary glands, tongue, esophagus, stomach, liver, gallbladder, pancreas, small intestine, large intestine, rectum, and anus. The pharynx is part of both the digestive and respiratory systems.

Respiratory System
The respiratory system takes in and expels air, exchanging oxygen and carbon dioxide via the lungs and bloodstream. The structures of the respiratory system include the nose, nasal cavity, larynx, trachea, bronchi, and lungs. Again, the pharynx is part of both the respiratory and digestive systems.

Urinary System
The urinary system functions to remove liquid wastes from the body. It consists of the kidneys, ureters, urinary bladder, and urethra; it is through the urethra that urine is expelled. The female urethra is located just above the vagina, while the male urethra runs through the penis. The kidneys filter wastes from the blood and maintain electrolyte concentrations. The urinary bladder stores the urine and the urethra carries it to outside the body.

Reproductive System
The reproductive system in females consists of the ovaries, uterine tubes, uterus, vagina, clitoris, and vulva. The female sex cells are called oocytes or eggs. They are fertilized by male sex cells (sperm or spermatozoa). When a female is impregnated, the embryo develops within the uterus. The male reproductive system includes the scrotum, testes, epididymides, ductus deferentia, seminal vesicles, prostate gland, bulbourethral glands, penis, and urethra. Reproduction is the process of producing offspring. As embryonic cells divide, they grow and produce new cells, and the process is continued.

Test Your Understanding
1. Describe the general functions of the digestive system.
2. List the organs of the respiratory system.

Anatomic Planes
The body can be visually divided into specific areas, called planes. These planes “divide” the body at particular angles and in particular directions (FIGURE 1-13 and TABLE 1-3). They are also referred to as slices or sections. There are three sectional planes, as follows:

- Transverse (horizontal) plane: It lies at right angles to the long axis of the body and divides the body into superior and inferior portions. A cut in this plane is called a transverse (cross) section.
- Frontal (coronal) plane: It is parallel to the long axis of the body and extends vertically, dividing the body into anterior and posterior portions.
- Sagittal plane: Also parallel to the long axis of the body, this plane, however, divides the body into left and right portions. A cut passing along the midline, dividing the body into equal left and right halves, is called a midsagittal (median) section and a cut parallel to the midsagittal line is called a parasagittal section.

Directional Terms
Directional terms used in the study of anatomy include words that describe relative positions of body parts as well as imaginary anatomical divisions. The term anatomical position describes the body standing erect, facing forward, with the arms held to the sides of the body, palms of the hands facing forward. When the terms right and left are used, they refer to those specific sides of the body when it is in the anatomical position. Important directional terms used in anatomy are listed in TABLE 1-4.

Abdominal Regions
Anatomists have divided the abdomen and pelvis into nine imaginary regions that are helpful in identifying the location of particular abdominal organs.