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Seeley's  
ESSENTIALS OF  
**ANATOMY**  
&  
**PHYSIOLOGY**

Cinnamon VanPutte • Jennifer Regan • Andrew Russo



Mc  
Graw  
Hill

Eleventh Edition

**ELEVENTH EDITION**

Seeley's Essentials of

# **Anatomy & Physiology**

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SEELEY'S ESSENTIALS OF ANATOMY & PHYSIOLOGY, ELEVENTH EDITION

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## **DEDICATION**

This text is dedicated to our families. Without their uncompromising support and love, this effort would not have been possible. Our spouses and children have been more than patient while we've spent many nights at the computer surrounded by mountains of books. We also want to acknowledge and dedicate this edition to the previous authors as we continue the standard of excellence that they have set for so many years. For each of us, authoring this text is a culmination of our passion for teaching and represents an opportunity to pass knowledge on to students beyond our own classrooms; this has all been made possible by the support and mentorship we in turn have received from our teachers, colleagues, friends, and family.

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## About the Authors



Courtesy of Leanna Rolla



Courtesy of Bridget Reeves

### **Cinnamon L. VanPutte**

**Associate Professor of Applied Dental  
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***Southern Illinois University School of  
Dental Medicine***

Cinnamon has been teaching biology and human anatomy and physiology for over two decades. At SIU School of Dental Medicine she teaches first year dental students and participates in dental-based physiology research. Cinnamon is an active member of several professional societies, including the Human Anatomy & Physiology Society (HAPS). Her Ph.D. in zoology, with an emphasis in endocrinology, is from Texas A&M University. She worked in Dr. Duncan MacKenzie's lab, where she was indoctrinated in the major principles of

### **Jennifer L. Regan**

**Assistant Teaching Professor**  
***University of Southern Mississippi***

For over twenty years, Jennifer has taught introductory biology, human anatomy and physiology, and genetics at the university and community college level. She has received the Instructor of the Year Award at both the departmental and college level while teaching at USM. In addition, she has been recognized for her dedication to teaching by student organizations such as the Alliance for Graduate Education in Mississippi and Increasing Minority Access to Graduate Education. Jennifer has dedicated much of her career to improving lecture and laboratory instruction at her institutions. Critical thinking and lifelong learning are two

physiology and the importance of critical thinking. The critical thinking component of *Seeley's Essentials of Human Anatomy & Physiology* epitomizes Cinnamon's passion for the field of human anatomy and physiology; she is committed to maintaining this tradition of excellence. Cinnamon and her husband, Robb (also a biology professor), have two children: a daughter, Savannah, and a son, Ethan. Savannah is studying to become a child life specialist. Ethan is involved in 4-H and shows steers and lambs. He is pursuing his undergraduate education at Lindenwood University. Cinnamon and her family live on a farm with her parents, Tom and Bobbie, where they raise sheep and cattle.

characteristics Jennifer hopes to instill in her students. She appreciates the Seeley approach to learning and is excited about contributing to further development of the textbook. She received her Ph.D. in biology at the University of Houston, under the direction of Edwin H. Bryant and Lisa M. Meffert. She is an active member of several professional organizations, including the Human Anatomy and Physiology Society. Jennifer is married to Hobbie, a GIS supervisor. They have two sons, Patrick and Nicholas. Jennifer and Hobbie enjoy spending time on their small farm, tending the bees and the chickens, and their spoiled Boston Terrier, Sally.

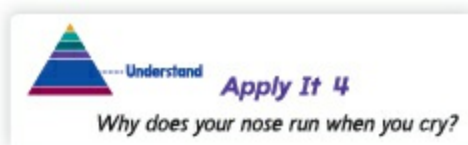
# Preface

*Seeley's Essentials of Anatomy & Physiology* is designed to help students develop a solid, basic understanding of essential concepts in anatomy and physiology without an encyclopedic presentation of detail. Our goal as authors is to offer a textbook that provides enough information to allow students to understand basic concepts, and from that knowledge, make reasonable predictions and analyses. We have taken great care to select critically important information and present it in a way that maximizes understanding.


## EMPHASIS ON CRITICAL THINKING

Critical thinking skills help students build a knowledge base for solving problems. An emphasis on critical thinking is integrated throughout this textbook. This approach is found in questions at the beginning of each chapter, and embedded within the narrative; in clinical material that is designed to bridge concepts explained in the text with real-life applications and scenarios; in Process Figure questions that apply physiological processes to practical situations, to promote applied understanding; in end-of-chapter questions that go beyond rote memorization; and in a visual program that presents material in understandable, relevant images.

- Pedagogy builds student comprehension from knowledge to application (Apply It questions, Critical Thinking questions, and Learn to Apply It Answers)



**Apply It Questions** challenge students to use their understanding of new concepts to solve a problem. Answers to the questions are provided at the end of the book, allowing students to evaluate their responses and to understand the logic used to arrive at the correct answer.



1. An elderly male with normal vision developed cataracts. A surgeon treated his condition by removing the lenses of his eyes. What aspect of his vision will be most affected by the removal of the lenses? Explain your answer.

2. On a camping trip, Stephanie was admiring the stars in the night sky. She noticed a little cluster of dim stars at the edge of her vision, but when she looked directly at that part of the sky, she could not see the cluster. On the other hand, when she looked toward the stars but not directly at them, she could see them. Explain what was happening.

3. SCUBA divers are subject to increased pressure as they descend toward the bottom of the ocean. Sometimes this pressure can lead to damage to the ear and loss of hearing. Describe the normal mechanisms that adjust for changes in pressure. Explain how increased pressure might cause reduced hearing, and suggest at least one other common condition that might interfere with this pressure adjustment.

4. If a vibrating tuning fork were placed against the mastoid process of your temporal bone, you would perceive the vibrations as sound, even if the external auditory canal were plugged. Explain how this happens.

5. The main way that people “catch” colds is through their hands. After touching an object contaminated with the cold virus, the person transfers the virus to the nasal cavity, where it causes an infection. Other than the obvious entry of the virus through the nose, how could the virus get into the nasal cavity?

*Answers to this chapter's odd-numbered critical thinking questions appear in Appendix D*

**Critical Thinking** These innovative exercises encourage students to apply chapter concepts to solve a problem. Answering these questions helps students build a working knowledge of anatomy and physiology while developing reasoning skills. Answers are provided in Appendix D.

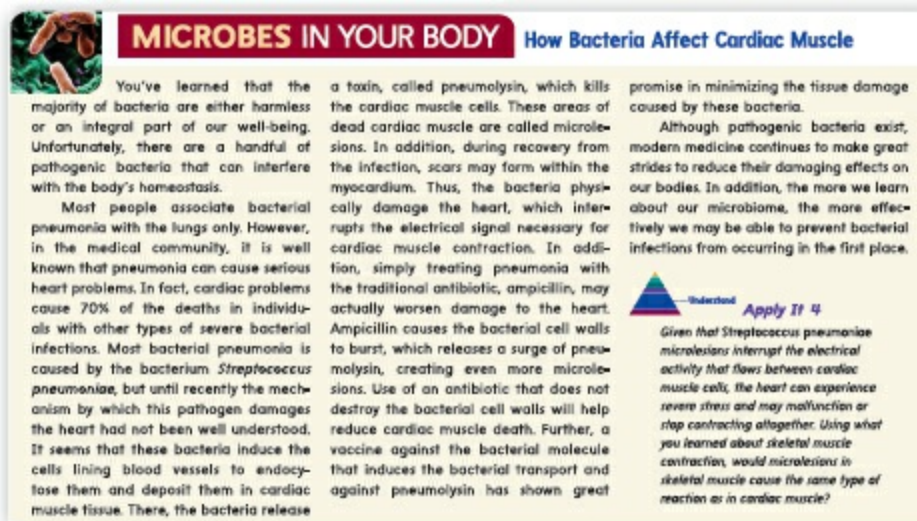
## **Clinical Emphasis—Case Studies Bring Relevance to the Reader**

When problems in structure and/or function of the human body occur, this is often the best time to comprehend how the two are related. Clinical Impact boxes provide a thorough clinical education that fully supports the surrounding textual material. Systems Pathology boxes provide a modern and systems interaction approach to clinical study of the materials presented.


- Clinical Impact essays (placed at key points in the text)
- Chapter-opening clinical scenarios/vignettes
- Learn to Apply It and chapter Apply It questions with unique Learn to Apply It Answers
- Systems Pathology Boxes



Pathology box begins with a patient history followed by background information about the featured topic.



**MICROBES IN YOUR BODY** How Bacteria Affect Cardiac Muscle


 You've learned that the majority of bacteria are either harmless or an integral part of our well-being. Unfortunately, there are a handful of pathogenic bacteria that can interfere with the body's homeostasis.

Most people associate bacterial pneumonia with the lungs only. However, in the medical community, it is well known that pneumonia can cause serious heart problems. In fact, cardiac problems cause 70% of the deaths in individuals with other types of severe bacterial infections. Most bacterial pneumonia is caused by the bacterium *Streptococcus pneumoniae*, but until recently the mechanism by which this pathogen damages the heart had not been well understood. It seems that these bacteria induce the cells lining blood vessels to endocytose them and deposit them in cardiac muscle tissue. There, the bacteria release

a toxin, called pneumolysin, which kills the cardiac muscle cells. These areas of dead cardiac muscle are called microlesions. In addition, during recovery from the infection, scars may form within the myocardium. Thus, the bacteria physically damage the heart, which interrupts the electrical signal necessary for cardiac muscle contraction. In addition, simply treating pneumonia with the traditional antibiotic, ampicillin, may actually worsen damage to the heart. Ampicillin causes the bacterial cell walls to burst, which releases a surge of pneumolysin, creating even more microlesions. Use of an antibiotic that does not destroy the bacterial cell walls will help reduce cardiac muscle death. Further, a vaccine against the bacterial molecule that induces the bacterial transport and against pneumolysin has shown great

promise in minimizing the tissue damage caused by these bacteria.

Although pathogenic bacteria exist, modern medicine continues to make great strides to reduce their damaging effects on our bodies. In addition, the more we learn about our microbiome, the more effectively we may be able to prevent bacterial infections from occurring in the first place.

 **Apply It 4**

Given that *Streptococcus pneumoniae* microlesions interrupt the electrical activity that flows between cardiac muscle cells, the heart can experience severe stress and may malfunction or stop contracting altogether. Using what you learned about skeletal muscle contraction, would microlesions in skeletal muscle cause the same type of reaction as in cardiac muscle?

**Microbes in Your Body** helps students to understand the important role microbes play in helping various systems of the body to maintain homeostasis.

**EFFECTS OF AGING ON THE LYMPHATIC SYSTEM AND IMMUNITY**

Aging appears to have little effect on the lymphatic system's ability to remove fluid from tissues, absorb lipids from the digestive tract, or remove defective red blood cells from the blood. However, aging has a severe impact on the immune system.

With age, people eventually lose the ability to produce new, mature T cells in the thymus. By age 40, much of the thymus has been replaced with adipose tissue, and after age 60, the thymus decreases in size to the point that it can be difficult to detect. While the number of T cells remains stable in most individuals due to the replication (not maturation) of T cells in lymphatic tissues, the T cells are less functional. In many individuals, the ability of helper T cells to proliferate in response to antigens decreases. Thus, antigen exposure produces fewer helper T

cells, which results in less stimulation of B cells and cytotoxic T cells. Consequently, both antibody-mediated immunity and cell-mediated immunity responses to antigens decrease with age.

Both primary and secondary antibody responses decrease with age. More antigen is required to produce a response, the response is slower, less antibody is produced, and fewer memory cells result. Thus, a person's ability to resist infections and develop immunity decreases.

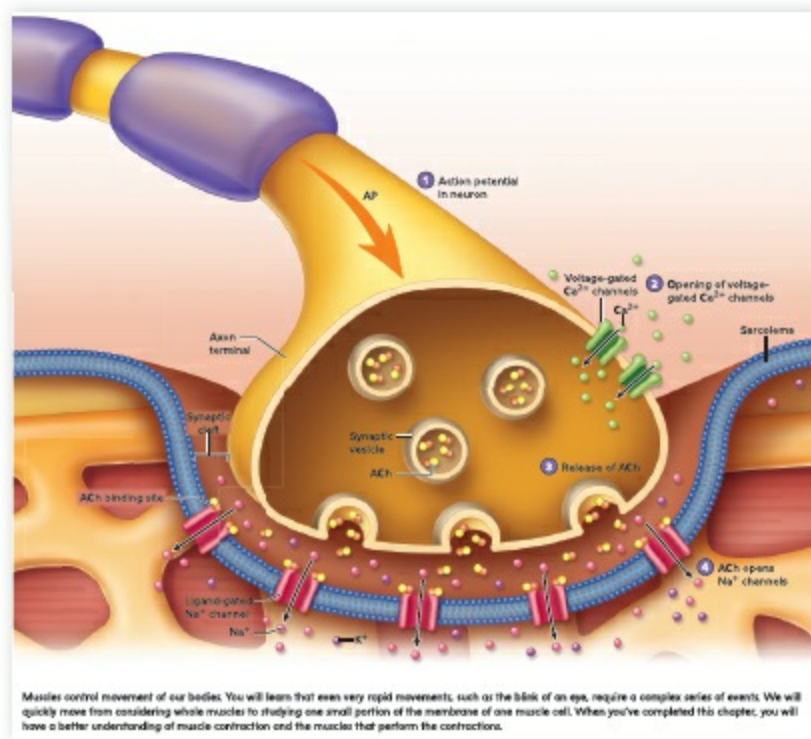
The ability of cell-mediated immunity to resist intracellular pathogens also decreases with age. For example, the elderly are more susceptible to influenza (flu) and should be vaccinated every year. Some pathogens cause disease but are not eliminated from the body; with age, decreased immunity can lead to reactivation of the pathogen. An example is the virus that causes chickenpox in children, which can remain latent within nerve cells, even though the disease seems to have disappeared. Later in life, the virus can leave the nerve cells and infect skin cells, causing painful lesions known as herpes zoster, or shingles.

Autoimmune disease occurs when immune responses destroy otherwise healthy tissue. There is very little increase in the number of new-onset autoimmune diseases in the elderly. However, the chronic inflammation and immune responses that began earlier in life have a cumulative, damaging effect. Likewise, the increased incidence of cancer in the elderly is likely to be caused by a combination of repeated exposure to and damage from cancer-causing agents and decreased immunity.

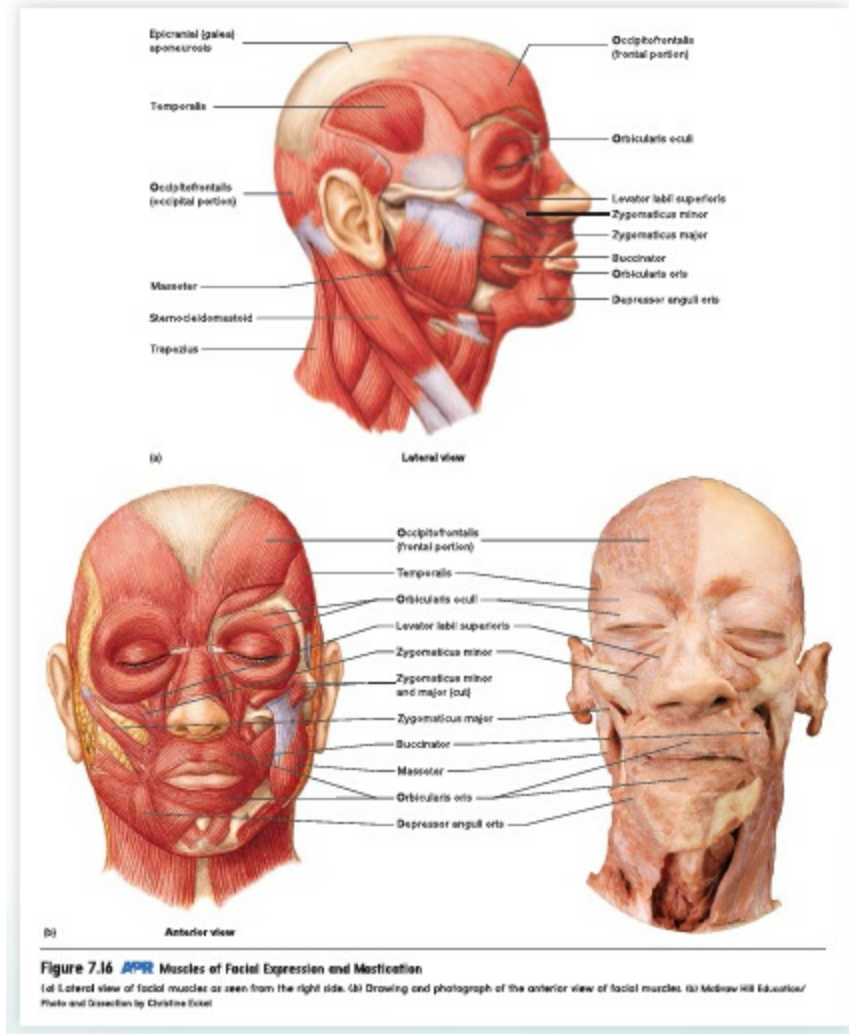
**Effects of Aging** describes changes that occur as a person ages. Each reading focuses on the changes that occur in a specific body system.

## Exceptional Art—*Instructive Artwork Promotes Interest and Clarifies Ideas*

A picture is worth a thousand words—especially when you're learning anatomy and physiology. Brilliantly rendered and carefully reviewed for accuracy and consistency, the precisely labeled illustrations and photos provide concrete, visual reinforcement of important topics discussed throughout the text.



**Chapter-opener** figures provide a visual overview of major concepts of the chapter, highlighting the components of systems, tissues, or mechanisms that will be explored.

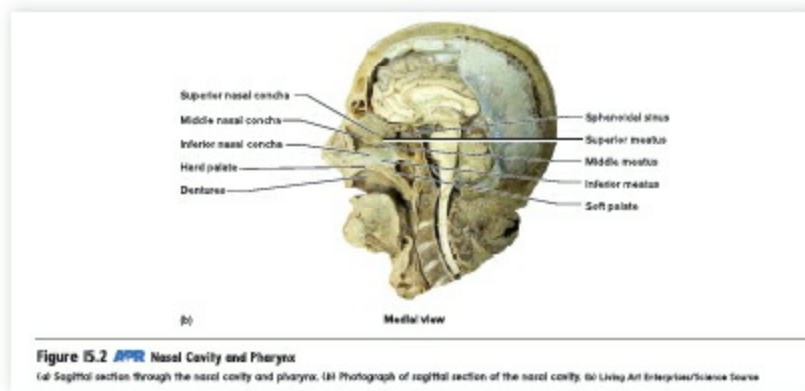


**Realistic Anatomical Art** The anatomical figures in *Seeley's Essentials of Anatomy & Physiology* have been carefully drawn to convey realistic, three-dimensional detail. Richly textured bones and artfully shaded muscles, organs, and vessels lend a sense of realism to the figures that helps students envision the appearance of actual structures within the body.

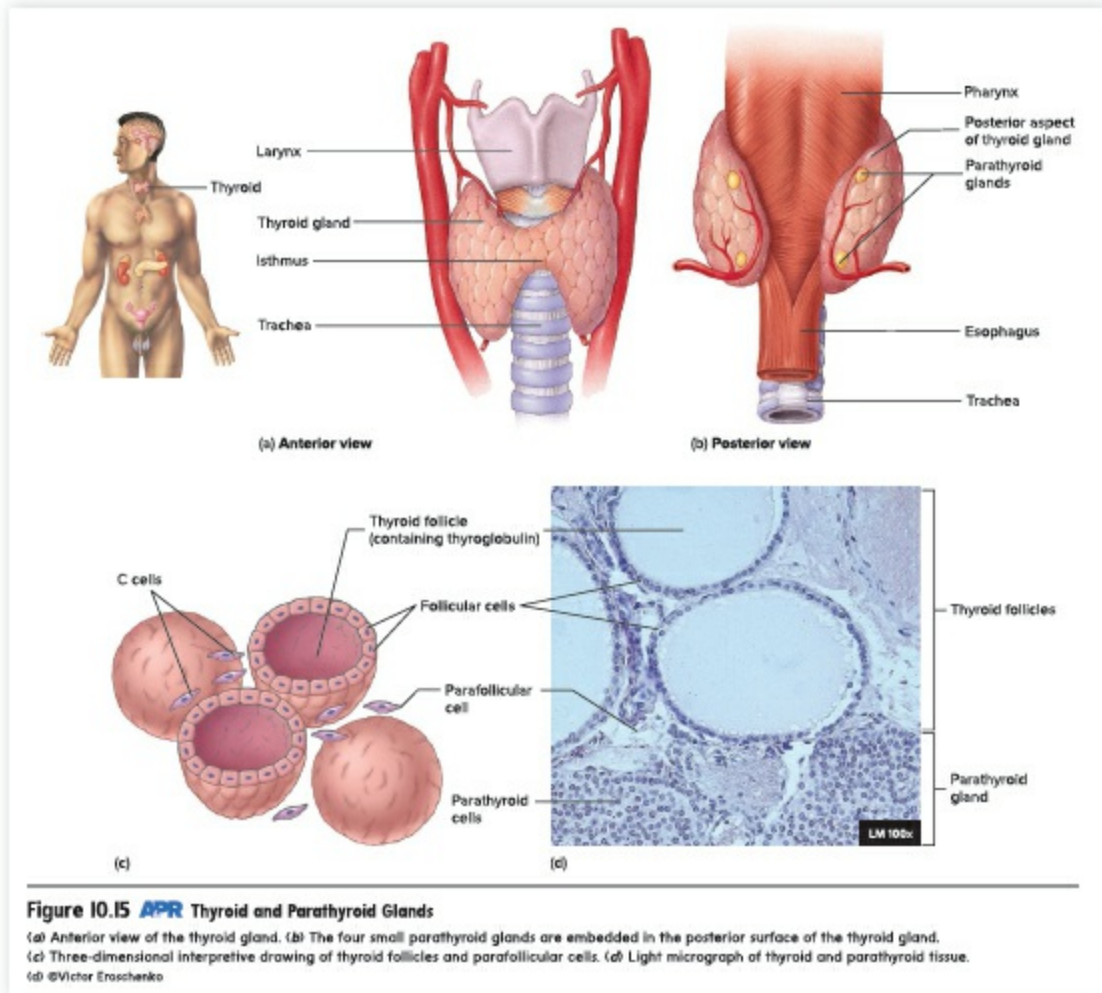
**Atlas-Quality Cadaver Images** Clearly labeled photos of dissected human cadavers provide detailed views of anatomical structures, capturing the intangible characteristics



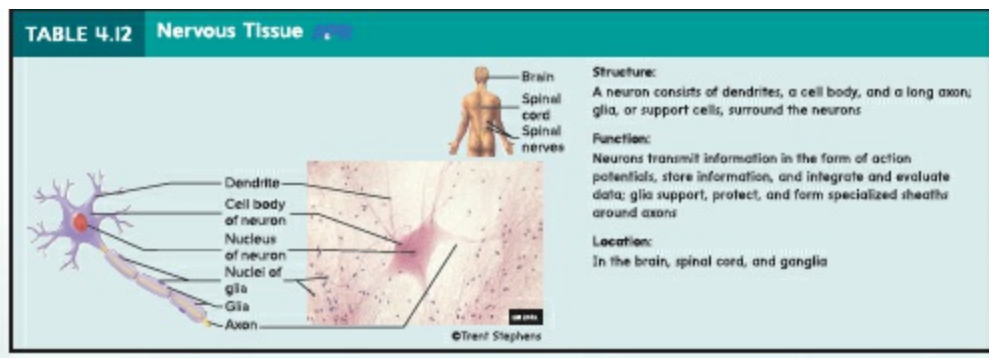
of actual human anatomy that can be appreciated only when viewed in human specimens.



**Multi-level Perspective** Illustrations depicting complex structures or processes combine macroscopic and microscopic views to help students see the relationships between increasingly detailed drawings. Drawings are often paired with photographs to enhance the visualization of the structures.



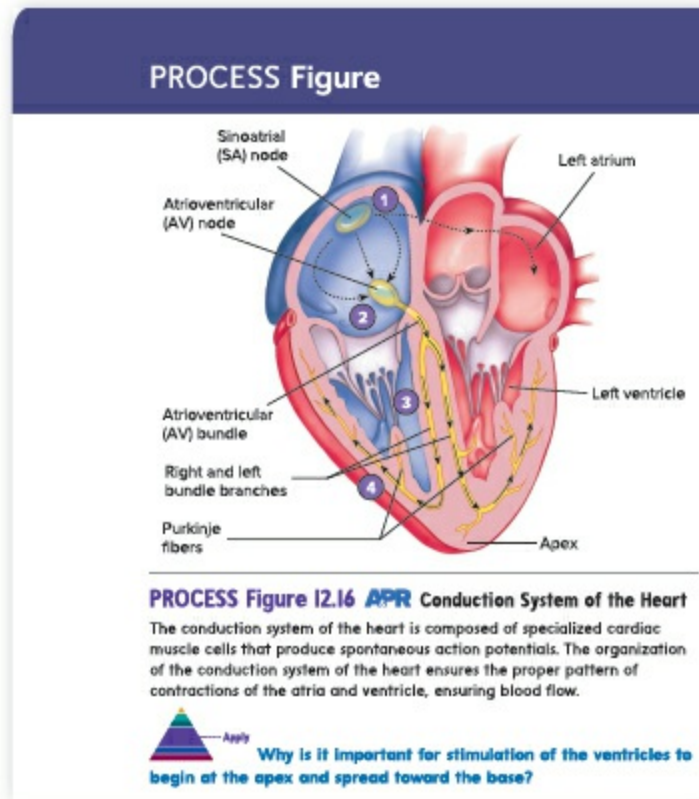
**Histology Micrographs** Light micrographs, as well as scanning and transmission electron micrographs, are used in conjunction with illustrations to present a true picture of anatomy and physiology from the cellular level.



## Specialized Figures Clarify Tough Concepts

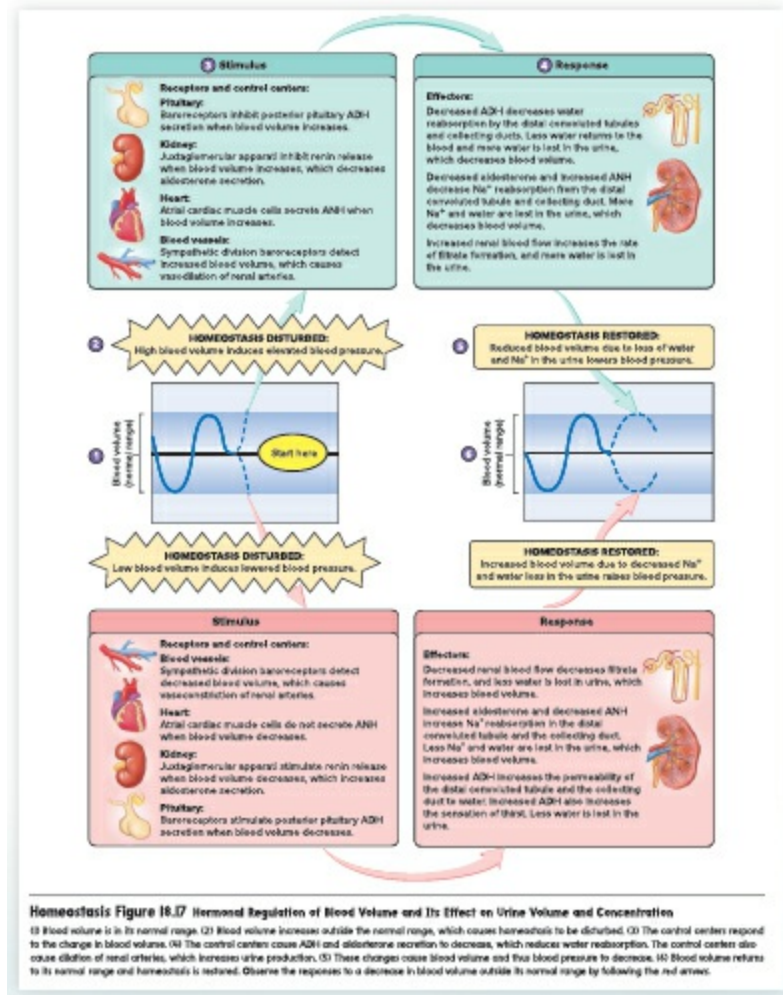
Studying anatomy and physiology does not have to be an intimidating task mired in memorization. *Seeley's Essentials of Anatomy & Physiology* uses two special types of illustrations to help students not only learn the steps involved in specific processes, but also apply the knowledge as they predict outcomes in similar situations. Process Figures organize the key occurrences of physiological processes in an easy-to-follow format. Process Figure questions that follow each figure legend apply physiological processes to practical situations, to promote applied understanding. Homeostasis Figures summarize the mechanisms of homeostasis by diagramming how a given system regulates a parameter within a narrow range of values.

**Step-by-Step Process Figures** Process Figures break down physiological processes into a series of smaller steps, allowing readers to build their understanding by learning each important phase. Numbers are placed carefully in the art, permitting students to zero right in to where the action described in each step takes place.



## Correlated with APR! Homeostasis Figures with in-art explanations and organ icons

- These specialized flowcharts illustrating the mechanisms that body systems employ to maintain homeostasis have been refined and improved in the ninth edition.
- More succinct explanations
- Small icon illustrations included in boxes depict the organ or structure being discussed.



## Learn to Apply It and Learn to Apply It Answer—Helping students learn how to think critically

- A *Learn to Apply It* question begins each chapter, which links the chapter opener scenario and photo to the topics covered within the chapter. *Apply It* questions appear throughout each chapter, to reinforce critical thinking.

## LEARN TO APPLY IT

Chase and Christina were studying for their last anatomy and physiology exam of the semester. After reviewing his notes on meiosis, Chase said, "Well, since meiosis is the same in males and females, I don't need to study the meiosis notes from the female reproductive system lecture." Christina quickly pointed out that he was mistaken and that if he reviewed his notes he would see that meiosis is very different in males and females.



**After reading chapter 19, explain the major differences between meiosis in males and meiosis in females. Describe any advantages to the differences between male and female meiosis.**

*Answers to this question and the chapter's odd-numbered Apply It questions can be found in Appendix E.*

- The answers to Learn to Apply It teach students step-by-step how to answer the chapter-opening critical thinking question. These answers to odd-numbered Apply It questions can be found in Appendix E. This is foundational to real learning and is a crucial part of helping students put facts together to reach that "Aha" moment of true comprehension.

## Chapter 1

### Learn to Apply It

The Learn to Apply It feature in every chapter of this text is designed to help you develop the skills to successfully answer critical thinking questions. The first step in the process is always to analyze the question itself. In this case, the question asks you to evaluate the mechanisms governing Renzo's blood sugar levels, and it provides the clue that there's a homeostatic mechanism involved. In addition, the question describes a series of events that helps create an explanation: Renzo doesn't feel satisfied after eating, has elevated blood sugar, and then is prescribed an insulin pump. In chapter 1, we learn that homeostasis is the maintenance of a relatively constant internal environment. Renzo experienced hunger despite eating, and his blood sugar levels were higher than normal. In this situation, we see a disruption in homeostasis because his blood sugar stayed too high after eating. Normally an increased blood sugar after a meal would return to the normal range due to the activity of insulin secreted by the pancreas. When blood sugar returns to normal, insulin secretion stops. In Renzo's case, his

cool water, the thermoreceptors would cause the hypothalamus to initiate shivering. Simply preventing sweating was insufficient to keep body temperature from dropping out of its normal range. If shivering continued to be ineffective, the body would conserve heat through loss of consciousness and severe hypothermia could set in.

3. In order to recognize which correct term to use here, you must first realize that directional terms are relative terms to the body. Therefore, it doesn't matter what position your body is in compared to the earth, body parts always have the same relationship to each other. Thus the nose is always referred to as being superior to the mouth.
5. The first step is to define the abdominopelvic and peritoneal cavities. The abdominopelvic cavity is located inferiorly to the diaphragm and superiorly to the pubic symphysis. The peritoneal cavity is located between the visceral peritoneum, which covers organs in the abdominopelvic cavity, and the parietal peritoneum, which lines the wall of

## PEDAGOGICAL FEATURES ENSURE SUCCESS

Learning Outcomes are closely linked with in-chapter Apply It and Learn to Apply It questions as well as the Summary, Critical Thinking, and Review and Comprehension questions. These carefully designed learning aids assist students in reviewing chapter content, evaluating their grasp of key concepts, and utilizing what they've learned.

### 14.1 FUNCTIONS OF THE LYMPHATIC SYSTEM

**Learning Outcomes** After reading this section, you should be able to

- A. Describe the functions of the lymphatic system.
- B. Explain how lymph is formed.

**Studying Anatomy and Physiology does not have to be intimidating**

**Chapter Summary** The summary is now conveniently linked by section and page number while it briefly states the important facts and concepts covered in each chapter.



## SUMMARY

### 14.1 Functions of the Lymphatic System

The lymphatic system maintains fluid balance in tissues, absorbs lipids from the small intestine, and defends against pathogens.

### 14.2 Anatomy of the Lymphatic System

The lymphatic system consists of lymph, lymphocytes, lymphatic vessels, lymph nodes, tonsils, the spleen, and the thymus.

#### Lymphatic Capillaries and Vessels

1. Lymphatic vessels carry lymph away from tissues. Valves in the vessels ensure the one-way flow of lymph.
2. Skeletal muscle contraction, contraction of lymphatic vessel smooth muscle, and thoracic pressure changes move the lymph through the vessels.
3. The thoracic duct and right lymphatic duct empty lymph into the blood.

#### Lymphatic Organs

1. Lymphatic tissue produces lymphocytes when exposed to foreign substances, and it filters lymph and blood.
2. The tonsils protect the openings between the nasal and oral cavities and the pharynx.
3. Lymph nodes, located along lymphatic vessels, filter lymph.
4. The white pulp of the spleen responds to foreign substances in the blood, whereas the red pulp phagocytizes foreign substances and worn-out red blood cells. The spleen also functions as a reservoir for blood.
5. The thymus processes lymphocytes that move to other lymphatic

3. Macrophages are large phagocytic cells that are active in the latter part of an infection. Macrophages are positioned at sites where pathogens may enter tissues.
4. Basophils and mast cells promote inflammation. Eosinophils also play a role in inflammation associated with allergic reactions.
5. Natural killer cells lyse tumor cells and virus-infected cells.

#### Inflammatory Response

1. Chemical mediators cause vasodilation and increase vascular permeability, allowing chemicals to enter damaged tissues. Chemicals also attract phagocytes.
2. The amount of chemical mediators and phagocytes increases until the cause of the inflammation is destroyed. Then the tissues undergo repair.
3. Local inflammation produces redness, heat, swelling, pain, and loss of function. Symptoms of systemic inflammation include an increase in neutrophil numbers, fever, and shock.

### 14.5 Adaptive Immunity

1. Antigens are molecules that stimulate adaptive immunity.
2. B cells are responsible for antibody-mediated immunity; T cells are involved with cell-mediated immunity.

#### Origin and Development of Lymphocytes

1. B cells and T cells originate in red bone marrow. T cells are processed in the thymus, and B cells are processed in red bone marrow.
2. B cells and T cells move to lymphatic tissue from their processing sites. They continually circulate from one lymphatic tissue to another.

**Remembering and Understanding** These practice questions cover the main points presented in the chapter. Completing this self-test helps students gauge their mastery of the material.



## REMEMBERING AND UNDERSTANDING

1. Define tissue and histology.
2. In what areas of the body is epithelium located? What are four characteristics of epithelial tissue?
3. Explain how epithelial tissue is classified according to the number of cell layers and the shape of the cells. What are pseudostratified columnar and transitional epithelium?
4. What kinds of functions does a single layer of epithelium perform? A stratified layer? Give an example of each.
5. Contrast the functions performed by squamous cells with those of cuboidal or columnar cells. Give an example of each.
6. What is the function of an epithelial free surface that is smooth? of one that has microvilli? of one that has cilia?
7. Name the ways in which epithelial cells may be connected to one another, and give the function for each way.
8. Define gland. Distinguish between an exocrine and an endocrine gland.
9. Explain the differences among connective tissue cells that are termed blast, cyte, and elast cells.
10. What are the functions of connective tissues?
11. What are the major connective tissue types? How are they used to classify connective tissue?
12. Describe areolar connective tissue, and give an example.
13. How is adipose tissue different from other connective tissues? List the functions of adipose tissue.
14. Describe dense collagenous connective tissue and dense elastic connective tissue, and give two examples of each.
15. Describe the components of cartilage. Give an example of hyaline cartilage, fibrocartilage, and elastic cartilage.
16. Describe the components of bone.
17. Describe the cell types and matrix of blood, and list the functions of blood.
18. Functionally, what is unique about muscle? Which of the muscle types is under voluntary control? What tasks does each type perform?
19. Functionally, what is unique about nervous tissue? What do neurons and glia accomplish? What is the difference between an axon and a dendrite?
20. Compare mucous and serous membranes according to the type of cavity they line and their secretions. Name the serous membranes associated with the lungs, heart, and abdominopelvic organs.
21. What is the function of the inflammatory response? Name the five symptoms of inflammation, and explain how each is produced.
22. Define tissue repair. What is the difference between regeneration and fibrosis?
23. Describe the process of tissue repair when the edges of a wound are close together versus when they are far apart.
24. Describe the effect of aging on cell division and the formation of



**Critical Thinking Questions** These innovative exercises encourage students to apply chapter concepts to solve problems. Answering these questions helps build their working knowledge of anatomy and physiology while developing reasoning and critical thinking skills.



### CRITICAL THINKING

1. A patient is suffering from edema in the right lower limb. Explain why elevation and massage of the limb help remove the excess fluid.
2. If the thymus of an experimental animal is removed immediately following birth, the animal exhibits the following characteristics:
  - a. increased susceptibility to infections
  - b. decreased numbers of lymphocytes
  - c. greatly decreased ability to reject graftsExplain these observations.
3. Adjuvants are substances that slow, but do not stop, the release of an antigen from an injection site into the blood. Suppose injection A of a given amount of antigen is given without an adjuvant and injection B of the same amount of antigen is given with an adjuvant that caused the release of antigen over a period of 2 to 3 weeks. Does injection A or injection B result in the greater amount of antibody production? Explain.



# Chapter-by-Chapter Changes

## Global Changes

- Added Chapter 0, a student study resource guide with text-specific figure symbols and format guide
- Added figures spanning two pages that tie together multiple steps of a single process or several ideas into one complete figure
- Increased vibrancy, clarity, and vividness of colors in the art program
- Descriptions of process figure events are now within the text with a bullet linking the text to the corresponding portion of the figure to help the student better follow the text
- Gender-neutral language throughout with use of biological sex pronouns throughout the entire book
- Bloom's levels were added to all in-text questions
- Word pronunciations guides have all been converted to the phonetic pronunciation rather than symbols
- Throughout, numbering has been added to lists of terms to help reduce cognitive load for the student

## Chapter 1

- Added a situational process figure to illustrate negative and positive feedback
- Figure 1.8 updated to include the gallbladder
- Definition of “variable” within homeostasis discussion has been updated to be more accurate

- Added an analogy to illustrate the importance of body temperature maintenance
- Modified the definition of positive feedback to be more clear
- Reorganized the discussion of positive feedback to flow more logically
- Updated the definition of etymology for clarity
- Reworded the definition of ventral and dorsal to be more clear
- Reorganized section on body cavities to include dorsal body cavity, a term commonly used within the allied health fields
- Reorganized the body membranes section to flow more logically
- Integrated clinical information into the body cavities section

## Chapter 2

- Added a figure demonstrating the relationship between electronegativity and bond formation (fig 2.2)
- Added figures demonstrating electron distribution between atoms, depending on bond type (figs 2.4 and 2.5)
- Added figure depicting electron position within a molecule with polar bonds (2.5)
- Added figure demonstrating the relationship between pH and  $H^+$  and the connection to household items (fig 2.10)
- Figure 2.11 on buffers has been revised for clarity
- Added definition of an “electron cloud”
- Per a reviewer’s suggestion, added definition of isotope
- Updated the definition of ionic bonding for clarity
- Simplified the discussion of chemical bonds by integrating a stepwise association with the corresponding process figure; it is now more logical
- Rearranged the order of the discussion of energy for simplicity and clarity

- Added the definition of “gene” to nucleic acid discussion

## Chapter 3

- New chapter-opener figure
- New figure 3.1 highlighting the components of a cell
- Added headings to distinguish between passive membrane transport processes and active membrane transport processes
- Description of transcytosis added

## Chapter 4

- Revised tables that list tissue types to make it easy to compare one tissue to another tissue
- Added two 2-page figures illustrating the distribution of epithelial and connective tissues throughout the body
- Updated the description of epithelial tissue for clarity
- Changed the descriptions of the epithelial tissue types to be more succinct
- Reorganized the discussion of epithelial tissue types to be more logical
- Reorganized the discussion of secretory glands for logic and clarity
- Added a table organizing gland type by structure and mode of secretion
- Per reviewer suggestion, added a new Apply It question to the muscle tissue section
- Reorganized the discussion of inflammation to correspond with the accompanying process figure
- Reorganized the discussion of tissue repair to correspond with the accompanying process figure

## Chapter 5

- New chapter-opener figure
- List of five epidermal strata added
- Description of thick skin versus thin skin added  
Page xvi
- Added term *friction ridge* and explained its relationship to fingerprints
- Added explanation of why different types of injections are used
- Description of fourth-degree burns added

## Chapter 6

- Added a figure illustrating the anatomy of spongy bone
- Updated the figure depicting the process of intramembranous ossification for clarity
- Updated the figure depicting the process of endochondral ossification to include a timeline for when each event occurs
- Updated the figure of the overview of skeletal anatomy to visually differentiate between axial skeleton and appendicular skeleton
- Added a figure of the superior view of the skull for better visualization of skull sutures
- Updated multiple figures throughout the chapter to have more distinct detail and more vivid coloration
- Revised the introduction to bone matrix section to better illustrate the relationship between form and function, with a reference to chapter 4
- Reorganized the order of chapter sections for more logical flow
- Added a new figure comparing the three bone-cell types

- Rewrote the section on bone histology to clarify the function of each bone cell
- Reorganized the section on bone development to correlate with the process figures
- Reorganized the section on bone repair to correlate with the process figure
- Rewrote the section on  $\text{Ca}^{2+}$  homeostasis to flow more logically and to be more clear
- Replaced figure 6.10 with a homeostasis figure to simplify the visual representation of  $\text{Ca}^{2+}$  homeostasis
- The skull bone anatomy has been rearranged to be organized by bone rather than by view of skull to streamline this information and reduce redundancy
- The section on appendicular bone anatomy has been reorganized by girdle, then by bone
- The section on joints has been reorganized to be more logical

## Chapter 7

- The art has been updated to be more vivid and realistic
- The physiology art is reorganized with new figures that help the students keep track of what portion of the process they learning and how it relates to the other steps in the sequence as well as the location within the cell
- Updated the figure illustrating energy sources for muscle contraction to be more streamlined and logical
- Reorganized section 7.3 on skeletal muscle anatomy to be more logical and to be more clear
- Added an organizing principle to skeletal muscle fiber anatomy and its role in muscle contraction
- Added a figure illustrating the resting membrane potential
- Reorganized the section on action potentials to correlate with the corresponding process figure

- Reorganized the section on the neuromuscular junction to correlate with the corresponding process figure
- Rewrote the portion of this section that describes the link between the action potential and muscle shortening
- Incorporated an active learning tip for the cross-bridge cycle
- Rewrote the portion of this section describing the cross-bridge cycle to correlate with the corresponding process figure
- Reorganized the section on whole-muscle physiology to flow more logically
- The term *recovery oxygen consumption* is replaced with *excess post-exercise consumption*
- Updated the section on energy sources for contraction to reflect more current terminology
- Added a study tip for approaching the learning of skeletal muscle anatomy
- Reorganized the anatomy section to include more separate sections of muscles for clarity
- Updated the description of the pelvis diaphragm for accuracy

## Chapter 8

- New chapter-opener figure
- New figure representing the organization of the nervous system
- Added description of satellite cells in the discussion of PNS glial cells
- Revised the section “Resting Membrane Potential” for clarity
- New figure highlighting the phase of nerve cell communication: stimulation of action potential, action potential propagation, and synaptic communication
- Added active learning prompts (action potential propagation)
- Moved the description of reflexes to discussion of spinal cord to eliminate redundancy



- Changed to “dorsal” and “ventral” in reference to horns in spinal segment description  
Page xvii
- Statement added about the function of the insula (taste perception)
- Replaced the term “primary somatic sensory cortex” with the term “primary somatosensory cortex”

## Chapter 9

- New chapter-opener figure
- Additional information concerning proprioception and the righting reflex added
- Section on “Pain” revised for clarity
- Description of photoreceptor function moved to the section “Function of the Eye” so that physiological processes are grouped together
- New figure highlighting the process of vision added

## Chapter 10

- Added a figure comparing transport of water-soluble hormones to lipid-soluble hormones
- Updated figure 10.3 for clarity
- Updated figure 10.10 for clarity
- Updated the discussion of binding proteins to be more clear
- Rewrote the section on water-soluble hormone transport to be more logical
- Reorganized the discussion of control of hormone secretion to correlate with the corresponding process figure
- Deleted figure 10.9 and incorporated some of that information into figure 10.10 to be clearer and less visually detailed

- Updated information on prolactin-inhibiting hormone for accuracy
- Reorganized the discussion on the adrenal cortex to be more logical
- Deleted figure 10.20 to be more in line with the level of detail throughout the chapter; this topic is discussed further in chapter 18

## Chapter 11

- New chapter-opener figure
- Updated description of red blood cell structure to accurately relate to function
- Updated figure 11.2 to reflect level of detail in the text
- New figure of life history of red blood cell added
- Revised figure detailing the breakdown of hemoglobin for clarity
- New figure illustrating blood typing added

## Chapter 12

- New chapter-opener figure
- New two-page figure highlighting the Cardiac Cycle
- Section 12.5, “Stimulation of the Heart,” has been updated with a introduction to prepare students for the detailed description of action potentials and cardiac muscle activity
- Panel labels have been added to figure 12.19, Events of the Cardiac Cycle, to correlate with references in the text, which will help the reader interpret the multiple graphs
- Clear descriptions of extrinsic regulation and intrinsic regulation added to the introduction of section 12.8, “Regulation of Cardiac Function”

## Chapter 13

- New chapter-opener figure
- Figure 13.24 revised for clarity
- New figure 13.21 summarizes the regulation of blood flow

## Chapter 14

- New chapter-opener figure
- New figure 14.8 summarizes the components of immunity
- Revised description of specificity in section 14.3 for clarity
- Revised description of self antigen for accuracy
- Revised the section “Antigen Recognition” for accuracy and clarity
- Figure 14.11 revised to include memory helper T cells

## Chapter 15

- This chapter has been completely reorganized and rewritten for more coherent flow of information
- The discussion of ventilation and gas laws has been combined
- Organized the physiology discussion into respiration versus gas transport with a separate section on metabolic factors affecting gas transport
- Figure 15.13 was updated to depict O<sub>2</sub> molecules bound to the hemoglobin molecule
- Added an overview figure of CO<sub>2</sub> transport mechanisms

## Chapter 16

- Rearranged figure 16.9 to better illustrate each of the three

- phases of swallowing
- Added a part (e) to figure 16.11 to illustrate the specific location of nutrient absorption
  - Updated figure 16.23 to include images of the nutrient molecules
  - Updated figure 16.24 with a better representation of digestive actions in each region of the digestive tract
  - Updated figures 16.25 and 16.26 to be more realistic
  - Updated the anatomy description of the stomach to be more clear
- Page xviii
- Reorganized the text in section 16.4 to correlate with the corresponding process figure
  - Rewrote the anatomy description of the liver to better illustrate the relationships among its components
  - Rewrote the description of bile to be more clear
  - Reorganized the section on functions of the liver to correlate with the corresponding figure
  - Rewrote the section on the anatomy of the pancreas to be more clear
  - Rewrote the section on the defecation reflex to be more coherent

## **Chapter 17**

- New chapter-opener figure
- New figure 17.4 illustrates the pathways of macromolecule breakdown for ATP production
- Updated the numbers of ATP produced from glucose metabolism

## **Chapter 18**

- Added a figure depicting urine flow through the urinary system (figure 18.4)
- Added a flowchart depicting blood flow through the kidney (figure 18.7)
- Edited figure 18.8 to show the urine formation process with a more realistic relationship to the nephron
- Figure 18.9 was revised to be clearer and to link to other corpuscle images
- Figure 18.10 was revised as a two-page spread highlighting the reabsorption of solutes and water
- Figure 18.13 was recast as a two-page spread to illustrate water conservation and filtrate flow
- Figure 18.15 was edited to include details of the collecting duct
- Per reviewer request, a photomicrograph of transitional epithelium was added to figure 18.18
- Per reviewer request, figure 18.20 as added to review the principles of osmosis
- Rewrote the section on urine flow to correspond to the new portion of figure 18.4
- Throughout the chapter, the text was reorganized to correlate with the corresponding process figures
- Per reviewer request, added a discussion of countercurrent mechanism to help provide context for the ability of the kidney to conserve water
- Rewrote the section on renin-angiotensin-aldosterone to be more logical
- Rewrote the section on intracellular fluid compartments and extracellular fluid compartments
- Rewrote the section on  $\text{Na}^+$  regulation for clarity
- Rewrote the section on  $\text{Ca}^{2+}$  homeostasis to be clearer
- Simplified the section on buffers

## Chapter 19

- Figure 19.5 revised as a two-page figure outlining the process of spermatogenesis
- Figure 19.11 revised as a two-page figure outlining the maturation of the oocyte and follicle
- Rewrote the section on meiosis to be clearer
- Meiosis discussion now correlates with the corresponding process figure
- Added a new Clinical Impact box, “Gender and Sex,” introducing the concept of the difference between biological sex and gender identity
- Rewrote the section on the anatomy of the scrotum to clarify the relationship between temperature and sperm development
- Rewrote the text on spermatogenesis to correlate with the corresponding process figure
- Used biological sex terms rather than gender terms throughout the chapter
- Rewrote the section on infertility in males for clarity
- Integrated the discussion on follicle development and oocyte development to reduce redundancy
- Revised the statement on the length of the menstrual cycle to be more general
- Updated the section on birth control to be more current

## Chapter 20

- New chapter-opener figure
- Introduction to section 20.1, “Prenatal Development,” revised to include list of prenatal and postnatal life stages
- Discussions of neural tube and neural crest formation revised for clarity
- Description of formation of the heart revised to better reflect the detail in figure 20.13

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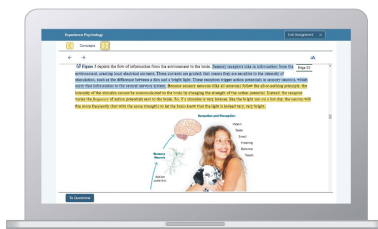
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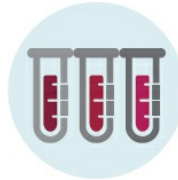
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\*Statistic courtesy of The New England Journal of Higher Education

# Acknowledgments

In today's world, no textbook is brought to fruition through the work of the authors alone. Without the support of friends, family, and colleagues, it would not have been possible for us to complete our work on this text. The final product is truly a team effort. We want to express sincere gratitude to the staff of McGraw Hill for their help and encouragement. We sincerely appreciate Senior Portfolio Manager Matt Garcia and Product Developer Melisa Seegmiller for their hours of work, suggestions, patience, and undying encouragement. We also thank Content Project Manager Ann Courtney, Content Licensing Specialist Lori Hancock, Buyer Laura Fuller, and Designer David Hash for their hours spent turning a manuscript into a book; Assessment Project Manager Brent dela Cruz for his assistance in building the various products that support our text; and Marketing Manager Valerie Kramer for her enthusiasm in promoting this book. The McGraw Hill LLC employees with whom we have worked are extremely professional, but more than that, they are completely dedicated to their role as part of the content team.

Finally, we sincerely thank the reviewers and the teachers who have provided us with excellent constructive criticism. The remuneration they received represents only a token payment for their efforts. To conscientiously review a textbook requires a true commitment and dedication to excellence in teaching. Their helpful criticisms and suggestions for improvement were significant contributions that we greatly appreciate. We acknowledge them by name in the next section.

*Cinnamon VanPutte  
Jennifer Regan  
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CHAPTER

0

# How to Be Successful in A&P



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Page 2

Hello, Students! Author Cinnamon VanPutte would like to share something with you: she failed her college organic chemistry course. Later, she retook it and earned an “A.” Why does this matter to you? We hope this helps you understand that your authors have been there. Yes, we’ve earned an “A” in hard classes—but we also know what it is to struggle in a class. We’ve had to retool our study habits; we’ve had to learn how to effectively use a textbook. These experiences have helped inform our approach to this textbook, and we hope this helps you. We know that many of you will sail right through A&P and would

have done so even without reading this success guide, while others may be retaking A&P for the second or third time. By taking the time to read this guide, you have already taken a positive first step to being able to succeed in A&P. You have entered a partnership with your instructor and us, the authors. If you utilize the tips, techniques, and information that we, as well as your instructors, are providing to you, we know you will learn a lot of information and you will be positioned to succeed in this course.

## 0.1 THE WORLD OF A&P

If you search online for “hardest classes in college,” A&P will show up on many lists. But don’t worry! We are here to help! We have each taught A&P for more than 20 years and have seen countless students, who were very nervous on the first day, successfully move through the course—all the while gaining self-assurance, confidence, and a deep understanding of the fundamental concepts needed to perform well in the course.

The study of A&P entails a lot of information. Depending on the particular course, the first semester of A&P may start with a discussion of matter and chemical bonds, and end with the complexities of the nervous system (such as action potentials). Truthfully, this means progressing from introductory material to more advanced material within a single semester.

In addition, you will be learning the vocabulary of A&P, which means you are essentially learning a foreign language—you might even feel like you’re learning more new vocabulary than if you were actually learning a foreign language! In an effort to make this task easier, our textbook provides phonetic pronunciations of these vocabulary terms, similar to those found on Facebook for people’s names. For example, the gluteus maximus pronunciation would be: GLOO-tee-us MAX-ih-mus. We think this type of guide will help you learn the terminology very readily and be more confident speaking the language—if you can say it out loud, then you can probably spell it and are better poised to remember it.

It’s also important to realize that the information in A&P cannot be effectively understood through memorization alone. Much of the physiology material requires that you use critical thinking skills. Many

of you may be planning careers in science or health professions, such as nursing or pharmacy—professions in which the ability to problem solve is essential. In this book we will help you develop critical thinking skills and thus a deep understanding of complex concepts.

## 0.2 DEVELOPING CRITICAL THINKING SKILLS

So, what is required to develop critical thinking skills? What even are critical thinking skills? To understand these questions, we need to explore the difference between simple memorization—what you may have always called “studying”—and **conceptual learning**. Many of you have enjoyed much success in high school and in some of your early introductory-level college classes through “studying.” However, to be successful in most A&P classes, you will also need to develop skills for conceptual learning. The basis for this difference is best described using Bloom’s taxonomy, originally published by B. Bloom and colleagues in 1956. Over time, Bloom’s taxonomy has been modified and can be best thought of as a model for the gradual increase in the amount of abstract thought required to achieve a particular level of learning. The simplest, most concrete level of learning is *remembering*, or simply memorizing. As you climb the levels of Bloom’s, your ability to put ideas into your own words (*understanding*) and then to solve problems you’ve never seen before (*applying*) increases. Thus, as you gain these skills, you are now *learning* the material and can answer **how** and **why** a particular process happens, and you can predict outcomes to unfamiliar scenarios. This textbook will guide you in developing those skills.

To do this, you will begin to use **metacognition** in your learning. Metacognition was first defined by Flavell in 1976 as “thinking about your own thinking”—in other words, deciding whether you truly understand and can apply fundamental physiological and anatomical principles. We are going to provide you with five metacognitive learning strategies to ensure your success in A&P.

## 0.3 FIVE METACOGNITIVE LEARNING STRATEGIES

What will you need to do to achieve the goal of being successful in A&P? There are five specific tasks you can employ to be successful in A&P. These tasks are adapted from the book *Teach Students How to*

*Learn* by S. Y. McGuire. They are the following:

1. Attend every class session and take notes with a pen and paper.
2. Read, read, read!
3. Work with other students.
4. Do homework as if it were the test.
5. Engage in concentrated study sessions.

We will address each of these tasks in the remainder of this success guide with specific information on how to use this textbook.

Page 3

## 0.4 USING THE FIVE METACOGNITIVE LEARNING STRATEGIES WITH THIS TEXTBOOK

1. *Attendance and Note-Taking.* It is essential that you attend each class session. As you can see, this book has 20 chapters, each of which covers a topic for which you could take an entire semester class, or more! Your instructor will decide what material they will cover. Some instructors may expect you to glean specific information directly from the book. Therefore, to make sure you hear, firsthand, all the information and messages your instructor presents in class, it is critical you be in class. Then, while in class, take notes by hand! Students who handwrite their notes outperform students who take notes with their laptops. The difference is that taking notes by hand requires you to use your own words, which helps you remember the information better. After the class session, it is also helpful to take notes by hand directly from the assigned chapters.
2. *Read, Read, Read!* Possibly one of the biggest misconceptions regarding reading a textbook is that it is no different from reading a novel—which couldn't be farther from the truth. Reading a science textbook involves a slow and systematic process. There are three types of reading strategies you'll need to employ to get the most information from each chapter: (1) preview, (2) prepare for active reading, (3) actively read.



a. Preview

Previewing a chapter is like watching a movie trailer or reading the description of a book to see what it's about and whether it interests you. Skim the section headings. Each system chapter of this textbook is laid out in the following way:

Anatomy of the System

Organs

Histology

Functions of the System

Major Functions

Integration of Functions for Homeostasis

Some sections are further subdivided into specialized topics to walk you through a process step-by-step.

While you're previewing the chapter, pay attention to bolded terms, phonetic pronunciations, and word origins. Root words tell a lot of information about a process or structure; for example, *hyper-* indicates higher or above, and *hypo-* indicates lower or below, and they are used both anatomically and physiologically.

b. Prepare for Active Reading

As you're previewing, or as a next step, write out questions you'd like answered as you read. The bold terms can be used as a guide to the questions.

c. Actively Read

After you've previewed the chapter and have done the preparations for active reading, the next step is to actively read. This can be done one paragraph, or one concept in SmartBook 2.0, at a time. Write notes in your own words as you read. Add a paragraph, or concept, at a time, all the while adding ideas from the previous paragraph. In this way, you're "taking one bite at a time" of the chapter's information. This helps your brain integrate information and keeps it from suffering information overload. As you actively read, there are several features that are consistent throughout this text that can serve as guideposts for you. We present these features in the section "Textbook Features and Figure Colors and Symbols."

3. *Work with Other Students Enrolled in the Same Class.* Author C. VanPutte would like to share something else with you: she did not fully comprehend the concept of osmosis until she taught her first college-level class. Once she had to explain the concept out loud and in her own words, a light clicked on! So, form study groups! Assign each other topics on which to lecture to the group. Write practice exams for each other. Sometimes your peers can help you as much as, or perhaps more than, the instructor.
4. *Do Homework as if It Were the Test.* For most lecture exams you will not be allowed to use your notes, the textbook, or the internet. So you need to practice for that situation. Don't simply copy answers onto your homework assignments. Instead, study first, then do the homework without assistance. Then, if you get stuck, use your resources. For example, you could do a "recharge" in SmartBook 2.0, or visit your instructor during their office hours.
5. *Utilize Multiple, Intense, Short Study Sessions.* Our brains work more efficiently when we stay focused for a relatively brief period of time: approximately 30–50 minutes. Staring blankly at your notes for 3 hours is not helpful. Therefore, decide what you're going to focus on, then study with intent for 30–50 minutes. Studying with intent involves actively engaging with the material. This can include making a concept map, expanding on your notes and rephrasing them, writing out a summary and simply thinking about the material. Take a short 10- to 15-minute break, then briefly review what you just studied. Do this 3–5 times a day for each class in which you're enrolled.

## 0.5 TEXTBOOK FEATURES AND FIGURE COLORS AND SYMBOLS

Throughout this textbook you will see certain repeating features and symbols. These symbols are always a particular color; however, for our students with vision disabilities, these colored symbols are also uniquely labeled.

### 1. In-Text Numbering

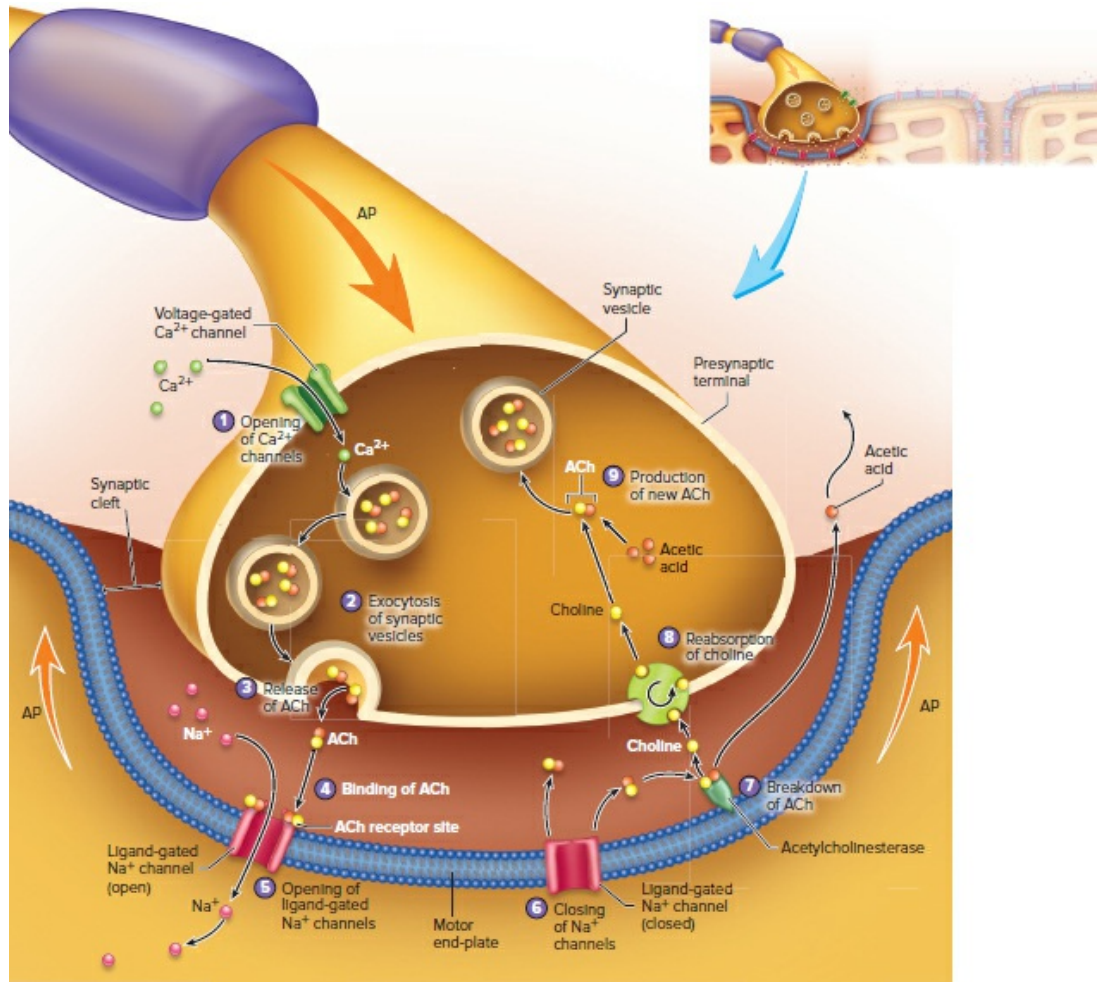
As you're reading, look for areas where we've tried to make complex topics clearer by numbering steps or components. This ensures that you don't miss a step or a part.

In an unstimulated cell, this charge difference is called the **resting membrane potential**. Although we call it the resting membrane potential, the cell is more like a sprinter in starting blocks; it is ready to respond at a moment's notice. The resting membrane potential is the result of three factors: (1) The concentration of  $K^+$  inside the cell membrane is higher than that outside the cell membrane, (2) the concentration of  $Na^+$  outside the cell membrane is higher than that inside the cell membrane, and (3) the cell membrane is more permeable to  $K^+$  than to  $Na^+$ .

Page 4

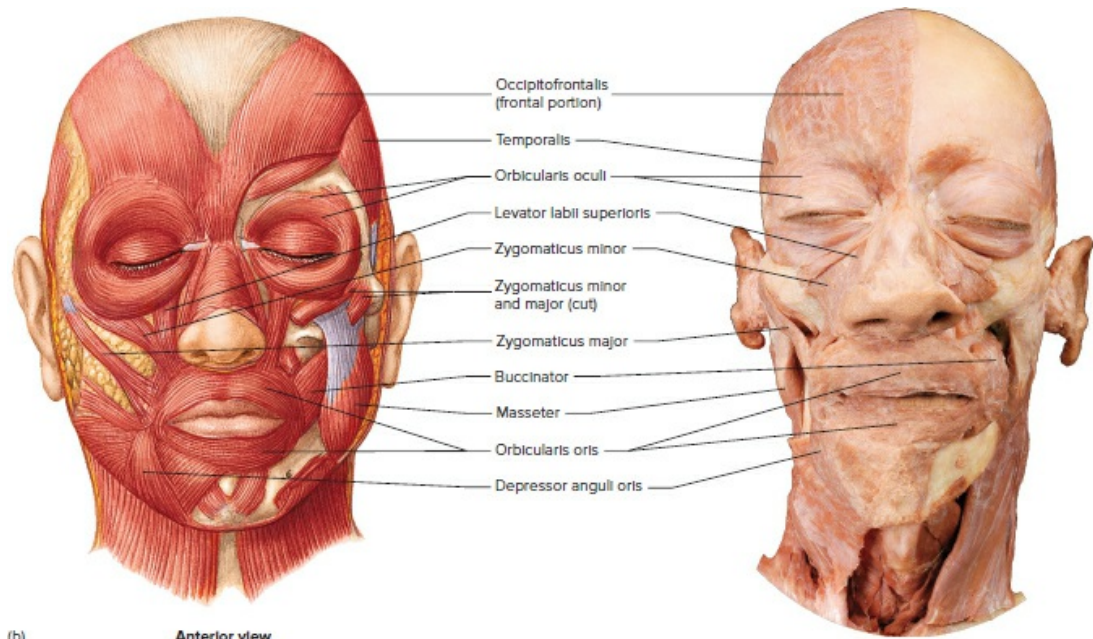
### 2. Process Figures

For complex processes, we have process figures that break down the step-by-step sequence of events. The in-text explanations directly correlate to portions of the figure by the use of purple circle numbers.



### 3. Side-by-Side Anatomy Figures

In certain anatomy figures, we have placed a photograph next to an artistic rendering. This allows for accurate interpretation of artist-generated figures.

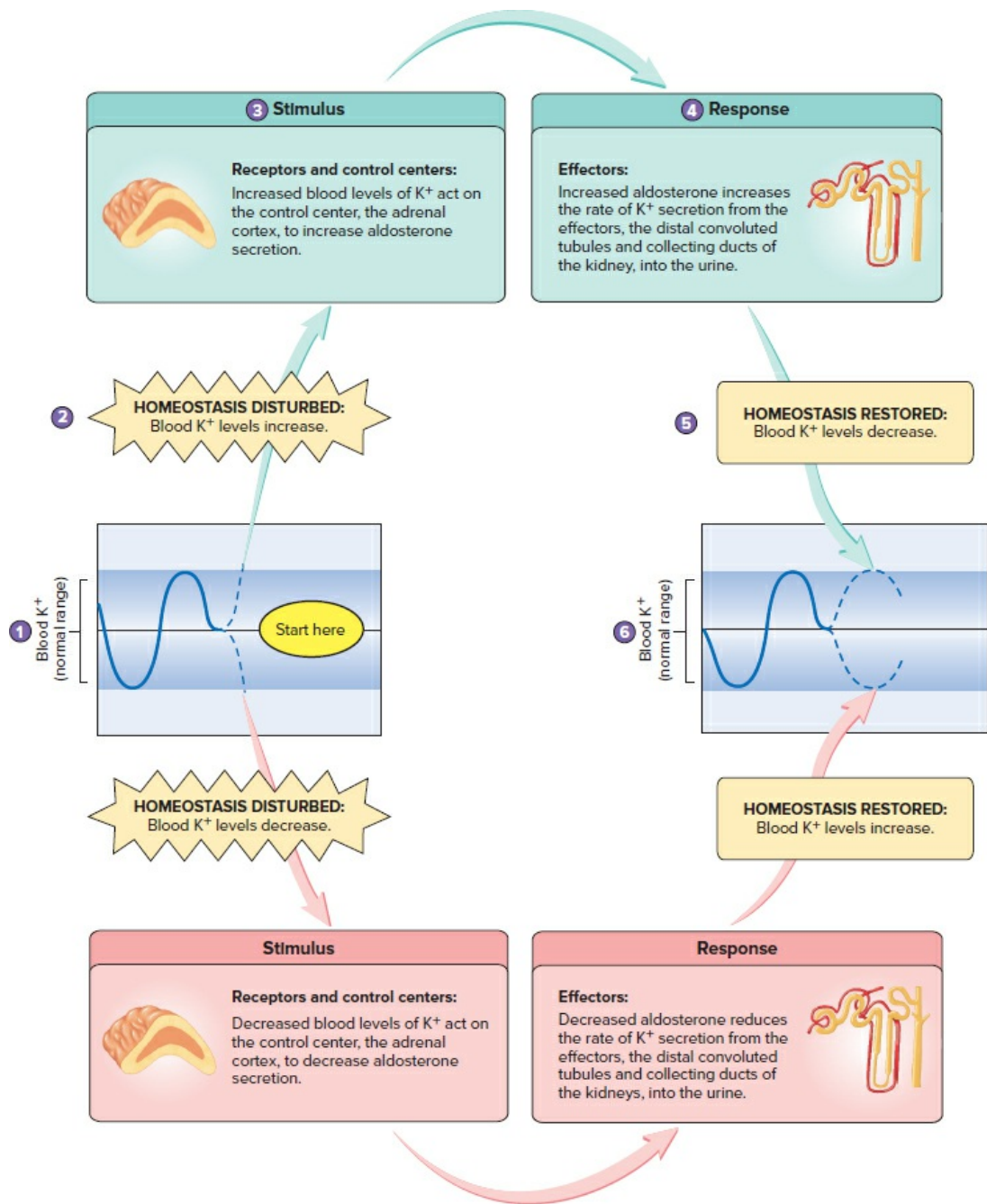


(b) Anterior view

McGraw Hill Education/Photo and Dissection by Christine Eckel

#### 4. Homeostasis Figures

These figures walk you through certain critical physiological mechanisms involved in the maintenance of homeostasis. Icons depict the particular organs discussed, in order to help strengthen associations between anatomy and physiology.



## 5. Clinical Content

- a. Clinical Impact: explore interesting clinical aspects of the body system being discussed



## CLINICAL IMPACT Gender and Sex

At birth, people are assigned one of three biological sexes based solely on the anatomy of their external genitalia. Males have a penis, females have a vagina, and intersex people can have a wide variation in sexual characteristics. However, anatomy does not always dictate a person's gender identity. Gender identity is how people view and express themselves in the world. Biological sex also does not determine a person's sexual orientation. Sexual orientation is the interpersonal interactions people have with others with regard to physical, emotional, and romantic attraction. Sexual orientation also does not determine sexual preference. Sexual preference refers to the way a person wishes to receive and participate in physically intimate acts.

Until about the 1990s, the societal norm for humans in the United States consisted of a gender binary. The gender binary is the system of viewing gender as consisting of only two identities and two sexes: male and female. However, since the 1990s, it has been recognized that gender exists along a gender spectrum, sometimes referred to as nonbinary. The gender spectrum is a continuum of gender identity that includes male and female, but does not assert male and female as absolutes or as polar opposites.

For parents of a gender-expansive child, one who goes against societal norms based on gender identity, the first source of information is usually a medical professional. This means that physicians, nurses, and all medical professionals are put into a pivotal role of helping to provide understanding and resources to parents.

An immense set of terms exists to describe gender identity, sexual orientation, and sexual preference. Here, we provide a brief introduction to some of these terms:

1. Gender identity—how individuals view themselves; gender identity can be the same or different than the sex assigned to them at birth
2. Gender expression—how individuals present themselves in terms of appearance, behavior, clothing, haircut, etc.
3. Gender nonconforming—behaving in a way that does not conform to societal expectation of biological sex
4. Queer—a previously derogatory term used for certain sexual orientations, but now is used to express fluid identities and orientations; usually used by people who do not identify as straight (heterosexual)
5. Transgender—individuals whose gender identity and/or gender

expression is not the same as societal expectations based on their assigned biological sex. Although this does not imply a particular sexual orientation, it can be described as an FtM (F2M), female to male, transition or an MtF (M2F), a male to female, transition when individuals begin to express the knowledge of their internal identity by their outward appearance.

6. Gender dysphoria—the term used to describe the long-term distress individuals experience when their assigned biological sex does not align with their gender identity
7. Gay—the sexual attraction and affectional orientation between members of the same gender (assigned or expressed); refers to males and females
8. Pansexual—not limited in attraction to an individual with regard to biological sex, gender, or gender identity
9. Lesbian—the sexual attraction and affectional orientation between two females (assigned or expressed)
10. Bisexual—being sexually, emotionally, and physically attracted to people of both the same gender and another gender

b. Microbes in Your Body: highlight the role of microbes in maintaining homeostasis



## MICROBES IN YOUR BODY Hormonal Regulation of Nutrient Metabolism is Influenced by Gut Microbes

Obesity has increased at an alarming rate over the last three decades. It is estimated that over 50 billion adults worldwide are overweight or obese. In the United States, 1/3 of adults are obese. As obesity rates have increased, so have the rates of obesity-related health conditions such as insulin resistance, diabetes, and cardiovascular disease. Why this dramatic increase? There are two main reasons for obesity: diet/lifestyle and gut bacteria; it seems these two may be related.

The most familiar cause of obesity is diet and lifestyle. The "typical" Western diet consists of frequent large meals high in refined grains, red meat, saturated fats, and sugary drinks. Combined with a reduction in physical activity and less sleep for many Americans, the Western diet and lifestyle can lead to obesity and poor health.

However, could humans' gut microbiota be just as responsible (or even more responsible) for obesity? Comparisons

between the gut microbiota of lean versus obese individuals seem to suggest the possibility of an important link between gut microbiota and our weight. The human gut, like other animals, is densely populated with microbiota. The majority (90%) of human gut bacteria fall into two groups: Firmicutes and Bacteroidetes. Lean people have more Bacteroidetes than Firmicutes, while the opposite is true for obese people.

We now know that gut microbiota affect nutrient processing and absorption, hormonal regulation of nutrient use by body cells, and even our hunger level.

Changes in gut microbiota alter the hormonal regulation of nutrient use. Inflammation-promoting effects of an imbalanced gut microbiota is thought to induce obesity via promoting insulin resistance, a known autoimmune malfunction. Normal gut microbiota metabolism is critical for secretion of several anti-

hunger hormones, and anti-depressive neurotransmitters and neurochemicals. Shifts in normal gut microbiota, as related to diet, may very well disrupt normal anti-hunger signals and gut permeability, leading to over-eating and inflammation related to obesity.

Can gut microbiota in obese people be manipulated to cause them to become leaner? Several possibilities exist, including the distinct possibility that prescribing antibiotics against bacteria associated with obesity could shift the metabolism of an obese person to become leaner. Another possibility is the use of prebiotics—non-digestible sugars that enhance the growth of beneficial microbiota. Finally, probiotic use is another possible intervention for obesity. Probiotics are nonpathogenic live bacteria that confer a health benefit to the host. This is a rapidly expanding field that holds much promise, but it is still in its beginning stages of our understanding.

c. Aging: describe changes to the body systems as we age

## EFFECTS OF AGING ON THE ENDOCRINE SYSTEM

Age-related changes to the endocrine system include a gradual decrease in the secretion of some, but not all, endocrine glands. Some of the decreases in secretion may be due to the fact that older people commonly engage in less physical activity.

GH secretion decreases as people age. However, regular exercise offsets this decline. Older people who do not exercise have significantly lower GH levels than older people who exercise regularly. Decreasing GH levels may explain the gradual decrease in bone and muscle mass and the increase in adipose tissue seen in many elderly people. So far, administering GH to slow or prevent the consequences of aging has not been found to be effective, and unwanted side effects are possible.

A decrease in melatonin secretion may influence age-related changes in sleep patterns, as well as the decreased secretion of some hormones, such as GH and testosterone.

The secretion of thyroid hormones decreases slightly with age. Age-related damage to the thyroid gland by the immune system can occur. Approximately 10% of elderly women experience some reduction in thyroid hormone secretion; this tendency is less common in men.

The kidneys of the elderly secrete less renin, reducing the ability to respond to decreases in blood pressure.

Reproductive hormone secretion gradually declines in elderly men, and women experience menopause (see chapter 19).

Secretion of thymosin from the thymus decreases with age. Fewer functional lymphocytes are produced, and the immune system becomes less effective in protecting the body against infections and cancer.

Parathyroid hormone secretion increases to maintain blood calcium levels if dietary  $\text{Ca}^{2+}$  and vitamin D levels decrease, as they often do in the elderly. Consequently, a substantial decrease in bone matrix may occur.

In most people, the ability to regulate blood glucose does not decrease with age. However, there is an age-related tendency to develop type 2 diabetes mellitus for those who have a familial tendency, and it is correlated with age-related increases in body weight.

- d. Systems Pathologies: discuss a disorder or disruption in a particular body system

## SYSTEMS PATHOLOGY

### Burns

#### Background Information

Sam is a 23-year-old male who fell asleep while smoking. His burning cigarette started a fire. Burns can damage the body in many ways (figure 5.11). Sam received partial-thickness and full-thickness burns to his face, arms, upper torso, and legs (figure 5.12). When large areas of skin are severely burned, the resulting systemic effects can be life-threatening. Within minutes of a major burn injury, there is increased permeability of small blood vessels called capillaries. This increased permeability occurs at the burn site and throughout the body. As a result, fluid and ions are lost from the burn wound and into tissue spaces. The loss of fluid decreases blood volume, which decreases the heart's ability to pump blood. The resulting decrease in blood delivery to tissues can cause tissue damage, shock, and even death. Treatment consists of administering intravenous fluid at a faster rate than it leaks out of the capillaries. Although this fluid replacement can reverse the shock and prevent death, fluid continues to leak into tissue spaces, causing pronounced edema (swelling). Typically, after 24 hours, capillary permeability returns to normal, and the amount of intravenous fluid administered can be greatly decreased.

Substances released from the burn may also play a role in causing cells to function abnormally. Burn injuries result in an almost immediate hypermetabolic state, resulting from an increase in body temperature and changes in hormone secretion. Compared with a normal body temperature of approximately  $37^{\circ}\text{C}$  ( $98.6^{\circ}\text{F}$ ), a typical burn patient may

have a body temperature of  $38.5^{\circ}\text{C}$  ( $101.3^{\circ}\text{F}$ ), despite the higher loss of water by evaporation from the burn.

In severe burns, the increased metabolic rate can result in loss of as much as 30–40% of the patient's preburn weight. To help compensate, treatment may include doubling or tripling the patient's caloric intake. In addition, the need for protein, which is necessary for tissue repair, is greater.

Normal skin maintains homeostasis by preventing microorganisms from entering the body. Because burns damage and sometimes completely destroy the skin, microorganisms can cause infections. For this reason, burn patients are maintained in an aseptic (sterile) environment (figure 5.13), which attempts to prevent the entry of microorganisms into the wound. They are also given antimicrobial drugs, which kill microorganisms or suppress their growth. Debridement (deh-STRID-ment), the removal of dead tissue from the burn, helps prevent infections by cleaning the wound and removing tissue in which infections could develop. Skin grafts, performed within a week of the injury, also help close the wound and prevent the entry of microorganisms.

Despite these efforts, however, infections are still the major cause of death for burn victims. Depression of the immune system during the first or second week after the injury contributes to the high infection rate. First, the thermally altered tissue is recognized as a foreign substance, which stimulates the immune system. Then, the immune system is overwhelmed as immune system cells become less effective and the production of the chemicals that normally provide resistance to infections decreases (see chapter 14). The greater the magnitude of the burn, the greater the depression of the immune system, and the greater the risk of infection.

TABLE 5.1 REPRESENTATIVE DISEASES AND DISORDERS: Skin

Condition	Description
Ringworm	Fungal infection that produces patchy scaling and inflammatory response in the skin
Eczema and dermatitis	Inflammatory conditions of the skin caused by allergy, infection, poor circulation, or exposure to chemical or environmental factors
Psoriasis	Chronic skin disease characterized by thicker than normal epidermal layer (stratum corneum) that sloughs to produce large, silvery scales; bleeding may occur if the scales are scraped away
<b>Bacterial Infections</b>	
Impetigo	Small blisters containing pus; easily rupture to form a thick, yellowish crust; usually affects children
Decubitus ulcers (bedsores or pressure sores)	Develop in people who are bedridden or confined to a wheelchair; compression of tissue and reduced circulation result in destruction of the subcutaneous tissue and skin, which later become infected by bacteria, forming ulcers
<b>Viral Infections</b>	
Shingles (zoster)	Skin lesions; caused by a virus contracted through the respiratory tract; may develop into pneumonia or infect the brain, causing damage
Shingles (German measles)	Skin lesions; usually mild viral disease contracted through the respiratory tract; may be dangerous if contracted during pregnancy because the virus can cross the placenta and damage the fetus
Chicken pox	Skin lesions; usually mild viral disease contracted through the respiratory tract
Shingles	Painful skin lesions that can occur when the dormant virus is activated by trauma, stress, or another illness; caused by the chicken pox virus after childhood infection
Cold sores (fever blisters)	Skin lesions; caused by herpes simplex I virus; transmitted by oral or respiratory routes; lesions recur
Genital herpes	Genital lesions; caused by herpes simplex II virus; transmitted by sexual contact



## 6. Critical Thinking Practice

The textbook presents you with multiple opportunities to practice applying the information you've learned to particular situations. Critical Thinking questions require a higher-order level of thinking than simple fact-based questions. The Bloom's Taxonomy icon indicates the level at which a given question is ranked.



### a. Learn to Apply It

This feature appears at the beginning of each chapter and integrates information from earlier chapters or asks you to think about a scenario as you read the chapter. Answers to odd-numbered questions are provided online or in the appendices. The answers are written in a solution-style format. We walk you through the logic of each answer.

## LEARN TO APPLY IT

Rafael is playing the soccer match of his life. However, hot weather conditions are making this match one of his hardest yet. As the game began, Rafael noticed himself sweating, which was helping to keep him cool. However, he had been ill the night before and had not been able to hydrate as was normal for him. Toward the end of the second half, he realized he was no longer sweating and he began to feel overheated and dizzy.

### Chapter 2

#### Learn to Apply It (Answer)

In this question, you learn that Rafael had not been able to properly hydrate the night before the soccer match and the weather is hot. The question also tells you that Rafael was cool when he was sweating and became overheated when he stopped sweating. Sweat consists mainly of water, and as you learned in section 2.1, water molecules are polar, allowing them to hydrogen-bond together. Later, in section 2.4, you learned that hydrogen bonds stabilize water, allowing it to absorb large amounts of heat. Thus, sweating.

## b. Apply It

Apply It questions are distributed throughout each chapter and pertain to information presented prior to each question. The same solution-style format answers to the odd-numbered questions are provided.



Provide the correct directional term for the following statement:  
When a boy is standing on his head, his nose is \_\_\_\_\_ to his mouth.

## c. Critical Thinking

Critical Thinking questions typically require a higher-order level of thinking than the Apply It questions. Solution-style-format answers are also provided for these.

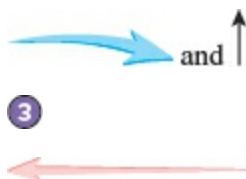


1. A male has lost blood as a result of a gunshot wound. Even though the bleeding has been stopped, his blood pressure is low and dropping, and his heart rate is elevated. Following a blood transfusion, his blood pressure increases and his heart rate decreases. Propose a physiological explanation for these changes.
2. During physical exercise, the respiration rate increases. Two students are discussing the mechanisms involved. Student A claims they are positive-feedback mechanisms, and student B claims they are negative-feedback mechanisms. Do you agree with student A or student B, and why?
3. Of the six characteristics of life, why is organismal reproduction a characteristic of life?
4. Describe, using as many directional terms as you can, the relationship between your kneecap and your heel.

## 7. Figure Colors and Symbols

Following are symbols used consistently to indicate the same structure or event in all chapters. If in some chapter a symbol is given a different usage, that usage for the symbol is always labeled or defined.

### Symbol

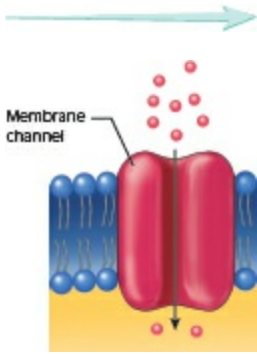


### Meaning

Information and level flow

Describe steps in a process

To decrease or inhibit

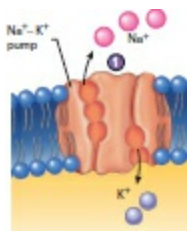


To increase or stimulate  
Channel proteins and ions

Pink: Na<sup>+</sup>  
Purple: K<sup>+</sup>  
Green: Ca<sup>2+</sup>



Blue: Phospholipid bilayer of cell membrane  
Yellow: Cytoplasm/inside of cell



Sodium/potassium pump



Acetylcholine



Sympathetic nervous system



Parasympathetic nervous system



Action potential



Generic ligand



Generic ligand receptor



G Protein



Veins with deoxygenated blood



Arteries with oxygenated blood

CONCLUSIONS

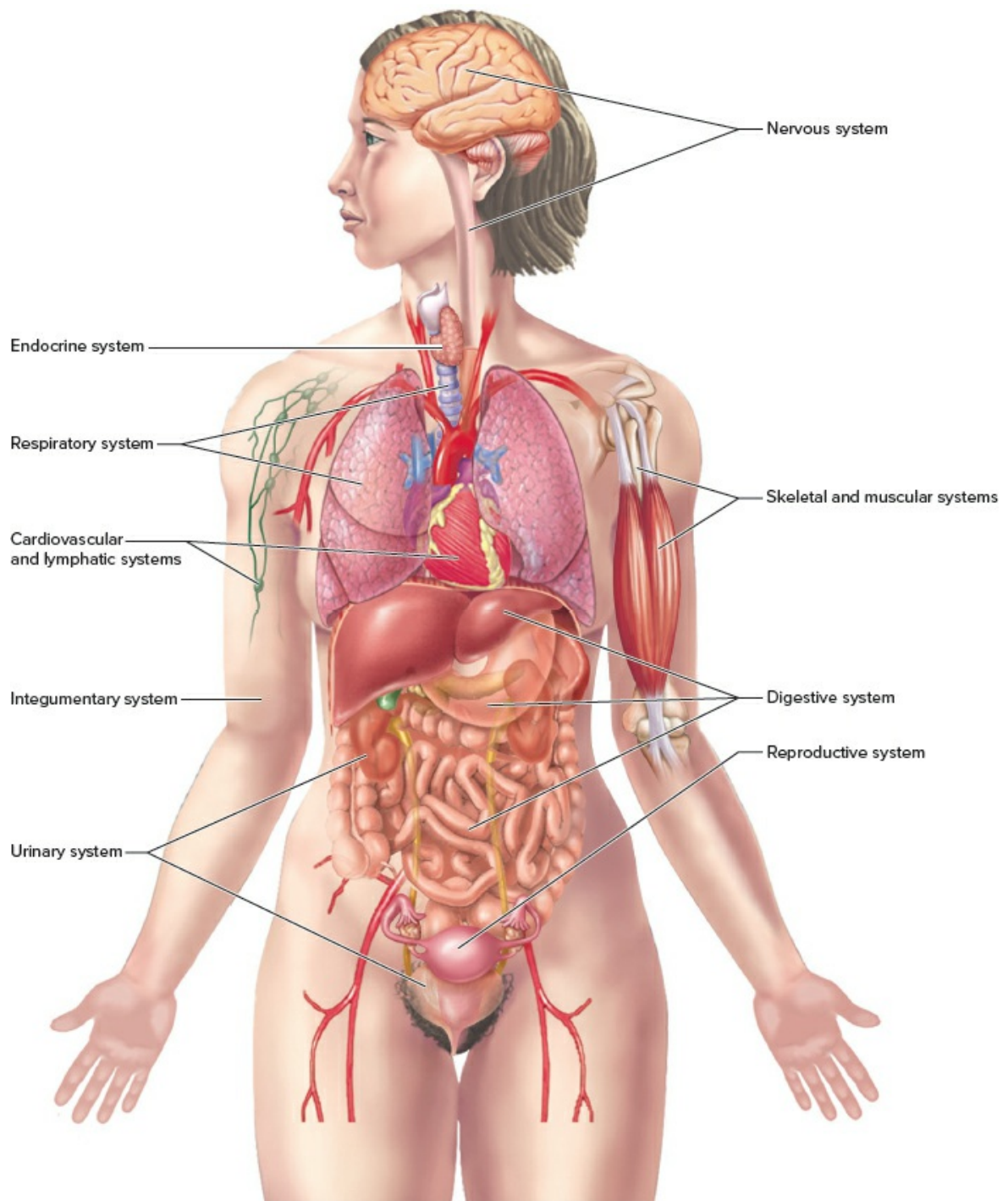
In our teaching we have seen, time and time again, that the students who put in the effort and utilize the activities described in this guide consistently outperform the students who do not. Thus, it will be your perseverance, sometimes called *grit*—and not how “smart” you are—that will enable your success. Encourage yourself, believe in yourself, and never quit.

**Design Elements:** (Microbes in Your Body): Janice Haney Carr/CDC; (Clinical Impact): Comstock/Alamy Stock Photo

CHAPTER

**1**

**The Human Organism**



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The human body is a complex system. The structures in the body work in concert to maintain homeostasis, a balance in the body's internal environment.

## LEARN TO APPLY II

Renzo, a dancer, can move his body such that it is perfectly balanced, yet a slight movement in any direction would cause him to adjust his position. The human body adjusts its balance among all its parts through a process called homeostasis.

Let's imagine that Renzo is suffering from a blood sugar disorder. Earlier, he'd eaten an energy bar. As an energy bar is digested, blood sugar rises. Normally, tiny collections of cells embedded in the pancreas respond to the rise in blood sugar by secreting the chemical insulin. Insulin increases the movement of sugar from the blood into the cells. However, Renzo did not feel satisfied from his energy bar. He felt dizzy and was still hungry, all symptoms he worried could be due to a family history of diabetes. Fortunately, the on-site trainer tested his blood sugar and noted that it was much higher than normal. After a visit to his regular physician, Renzo was outfitted with an insulin pump and his blood sugar levels are more consistent.



**What is a good explanation for Renzo's blood sugar levels before and after his visit to the doctor?**

*Answers to this question and the chapter's odd-numbered Apply It questions can be found in Appendix E.*



**Module 1** Body Orientation

### 1.1 ANATOMY AND PHYSIOLOGY

**Learning Outcomes** *After reading this section, you should be able to*

- A.** Define anatomy and describe the levels at which anatomy can be studied.
- B.** Explain the importance of the relationship between structure and function.
- C.** Define physiology and describe the levels at which physiology can be studied.

What lies ahead is a fantastic adventure—learning about the structure and function of the human body and the intricate checks and balances that regulate it. Perhaps you have had the experience of oversleeping, rushing to your 8 a.m. class, and missing breakfast. Afterward, on the way to your Anatomy & Physiology class, you bought an energy bar from the vending machine. Eating the energy bar helped you feel

better. The explanation for this experience is the process of homeostasis, the maintenance of a relatively constant internal environment despite fluctuations in the external environment. For you, homeostasis was maintained, but for Renzo, the dancer in this chapter's Learn to Apply It feature, there was a disruption in homeostasis. Throughout this book, the major underlying theme is homeostasis. As you think about Renzo's case, you will come to realize just how capable the human body is of an incredible coordination of thousands upon thousands of processes.

Learning about human anatomy and physiology is important for understanding disease. The study of human anatomy and physiology is important for students who plan a career in the health sciences because health professionals need a sound knowledge of structure and function in order to perform their duties. In addition, understanding anatomy and physiology prepares all of us to evaluate recommended treatments, critically review advertisements and reports in the popular literature, and rationally discuss the human body with health professionals and nonprofessionals.

**Anatomy** (ah-NAT-oh-mee) is the scientific discipline that investigates the structure of the body—for example, the parts and chambers of the heart. The word *anatomy* means to dissect, or cut apart and separate, the parts of the body for study. In addition, anatomy examines the relationship between the structure of a body part and its function. For example, the structure of a hammer informs us of its primary use of driving nails into wood. Similarly, the fact that bone tissue is a hard, mineralized substance enables the bones to provide strength and support. Understanding the relationship between structure and function makes it easier to understand and appreciate anatomy.

There are two basic approaches to the study of anatomy: (1) systemic anatomy and (2) regional anatomy. **Systemic anatomy** is the study of the body by systems, such as the cardiovascular, nervous, skeletal, and muscular systems. It is the approach taken in this textbook. **Regional anatomy** is the study of the organization of the body by areas. Within each region, such as the head, abdomen, or arm, all systems are studied simultaneously. This is the approach taken in many medical and dental schools.