Hole's ESSENTIALS OF HUMAN ANATOMY & PHYSIOLOGY

eleventh edition

DAVID SHIER
Washtenaw Community College

JACKIE BUTLER
Grayson County College

RICKI LEWIS
Alden March Bioethics Institute

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HOLE'S ESSENTIALS OF HUMAN ANATOMY & PHYSIOLOGY, ELEVENTH EDITION

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Brief Contents

About the Authors

David Shier

David Shier has more than thirty years of experience teaching anatomy and physiology, primarily to premedical, nursing, dental, and allied health students. He has effectively incorporated his extensive teaching experience into another student-friendly revision of *Hole's Essentials of Human Anatomy and Physiology* and *Hole's Human Anatomy and Physiology.* David has published in the areas of renal and cardiovascular physiology, the endocrinology of fluid and electrolyte balance, and hypertension. A faculty member in the Life Science Department at Washtenaw Community College, he is actively involved in a number of projects dealing with assessment, articulation, and the incorporation of technology into instructional design. David holds a Ph.D. in physiology from the University of Michigan.

Jackie Butler

Jackie Butler's professional background includes work at the University of Texas Health Science Center conducting research about the genetics of bilateral retinoblastoma. She later worked at Houston's M. D. Anderson Hospital investigating remission in leukemia patients. A popular educator for more than twenty-five years at Grayson County College, Jackie teaches microbiology and human anatomy and physiology for health science majors.

Her experience and work with students of various educational backgrounds have contributed significantly to another revision of *Hole's Essentials of Human Anatomy and Physiology* and *Hole's Human Anatomy and Physiology.* Jackie Butler received her B.S. and M.S. degrees from Texas A&M University, focusing on microbiology, including courses in immunology and epidemiology.

Ricki Lewis

Ricki Lewis's career communicating science began with earning a Ph.D. in genetics from Indiana University in 1980. It quickly blossomed into writing for newspapers and magazines, and writing the introductory textbook *Life.* Since then she has taught a variety of life science courses and published the textbook *Human Genetics: Concepts and Applications,* an essay collection, and a novel about stem cells.

Since 1984 Ricki has been a genetic counselor for a large ob/gyn practice. She is active with the American Society of Human Genetics, and teaches an online course in "Genethics" at Albany Medical College.

A Note from the Authors

To the Student

Welcome! As you read this (with your eyes) and understand it (with your brain), perhaps turning to the next page (with muscle actions of your fingers, hand, forearm, and arm), you are using the human body to do so. In this eleventh edition of *Hole's Essentials of Human Anatomy and Physiology,* our goal is to provide you with an interesting and readable introduction to how all of this works! It is not simple, and there are times when it may not seem easy, but it is always fascinating, and understanding how your body works can be fun!

Many of you are on a path toward a career in health care, athletics, science, or education. We understand that many of you face the challenges of balancing family, work, and academics. Always remember that your course is not so much a hurdle along your way as it is a stepping stone. We have written this book to help you succeed in your coursework and to help prepare you to make that journey.

To the Teacher

We are authors, but first and foremost we are teachers, active in the classroom. What we and our reviewers do in class is reflected in this new edition. Students have always come first in our approach to teaching and textbook authoring, but we now feel more excited than ever about the student-oriented, teacher-friendly quality of this text.

Along with updated versions of the extra resources that students and teachers alike have found so helpful over the years (Anatomy and Physiology Revealed®, text websites, and so on), we are especially pleased to present the new Learn, Practice, Assess approach. Each chapter opens with Learning Outcomes, contains many opportunites to Practice throughout, and closes with Assessments that are closely tied to the learning outcomes. Students can use this new feature not only to focus their study efforts, but also to take an active role in monitoring their own progress toward mastering the material. All of these resources are described in more detail in the Chapter Preview beginning on page xviii.

David Shier, Jackie Butler, Ricki Lewis

New to this Edition

Global Changes

- End-of-chapter Integrative Assessments/Critical Thinking questions include reference to previous chapters.
- Practice Questions are added to the legends of selected figures.
- Clinical Terms are on the book website.
- Complex figures include the legend content in the artwork, paralleling the text.
- Many new vignettes and small boxes.
- All boxed material updated, with a more clinical focus.

Specific Changes At-a-Glance

Chapter	Topic	Change	Rationale
1	Head cavities (fig. 1.9)	Improved depth	Accuracy
1	Directional terms (fig. 1.13)	Rewritten	Clarity
1	Anatomical terms (fig. 1.14)	Rewritten	Clarity, consistency
1	Anatomical terms	Rewritten	Clarity, consistency
2	Matter and mass	Rewritten	Clarity
2	Ionically-bonded substances	Dissociate, not dissolve	Accuracy
3	Reprogrammed cells	New vignette	Update
3	Gene expression	New material	Update
3	Cell membrane (fig. 3.3)	Lipid bilayer inset added	Clarity
3	Osmosis	Rewritten	Clarity
3	Organelles	Functions added	Update, balance
4	Enzyme-substrate complex	New fig. 4.5	Clarity
4	Fate of pyruvic acid	Redrawn	Clarity
4	Catabolism of macronutrients (fig. 4.9)	Redrawn	Update
4	DNA replication (fig 4.11)	Redrawn	Accuracy, detail
5	Tissues (figs. 5.1c, d; 5.2; 5.3; 5.4; 5.5; 5.6; 5.7; 5.13; 5.14; 5.15; 5.16; 5.17; 5.18; 5.19; 5.20; 5.21; 5.22; 5.23; 5.24)	Many new micrographs and corresponding line art	Clarity, an attempt to more closely resemble the microscope slides the students will be observing in lab
5	Extracellular matrix Clinical Application	Rewritten, new figure	Update, more clinical approach
6	Itching	New vignette	New information
6	Skin (figs. 6.1; 6.2; 6.5; 6.7)	Many new micrographs and corresponding line art	Clarity
6	Skin cancer	Rewritten	Update, more clinical approach
6	Fingerprints	Rewritten	Clarity, update
6	Burns	Rule of nines added to Clinical Application	More clinical approach

Continued next page—

New to this Edition

Specific Changes At-a-Glance *—Continued*

Chapter	Topic	Change	Rationale
6	Botox	New small box	More clinical approach
7	Skeletal system (figs. 7.1; 7.9; 7.38; 7.39; 7.40)	Many figures improved	Update, clarity
7	Joint movements	Photos of people added	More clinical approach
7	Arthritis	Box expanded into Clinical Application	Update, more clinical approach
8	Thick and thin muscle filaments	Figs. 8.1 and 8.2 redone	Accuracy, clarity
8	Motor end plate, motor units, and recruitment	Reorganized and rewritten	Clarity
9	Vegetative brain	Vignette rewritten	Update
9	Nerve impulse conduction and synaptic transmission	Distinguished better	Clarity, consistency
9	Relationship of CNS/PNS, sensory/motor	Fig. 9.2 redone	Clarity
9	Membrane and action potentials	Figs. 9.12 and 9.13	Clarity
9	Meninges	Figs. 9.21 and 9.22 redone	Clarity
9	Nerve impulse, nerve tract, axons, fibers, nerve fibers	Redundancy eliminated	Clarity, consistency
9	Lateral horn	New micrograph and line art	Clarity
9	Sensory and motor speech areas	Rewritten	Update
10	Sensation and perception	Rewritten	Clarity
10	Sound volume perception in terms of action potentials	Rewritten	Clarity
10	Clinical Applications on synesthesia and migraines	Rewritten	Update
11	Hormone secretion regulation	Rewritten	Accuracy
11	Clinical Application on diabetes	A1c testing, new glucose monitoring methods	Update, more clinical approach
12	Collection and centrifugation of blood sample	Photos added to fig. 12.1	Update, clarity
12	Blood components	Fig. 12.12 moved up	Clarity
12	Genetics Connection	Factor V Leiden replaces ITP, which is not genetic; also includes coagulation disorders	Accuracy, update
12	Blood cell formation (fig. 12.4), rbc life cycle (fig. 12.6), platelet plug (fig. 12.13)	Reworked	Update
12	Artery cross section (fig. 12.15)	New micrographs	Clarity
13	Human heart and major vessels	New photo for fig. 13.3	Clarity
13	Tachycardia/bradycardia	New small box	More clinical information
13	SA node and depolarization pathway	Fig. 13.11 redrawn	Clarity
13	Blood color	Fig. 13.21 lightened	Clarity
13	Venous valves	Fig. 13.23 colors lightened	Arrows more visible
13	Varicose veins	Rewritten and moved to veins section	Clarity
13	Major vein figures show paired veins	Figs. 13.33 and 13.35 redone	Accuracy, clarity
14	Lymphatic vessel valve	Micrograph in fig 14.3 replaced	Clarity
14	Lymphatic pathway	Detail added to fig. 14.5	Clarity, update
14	Thymus and spleen	New micrographs for figs. 14.9b and 14.10b	Clarity

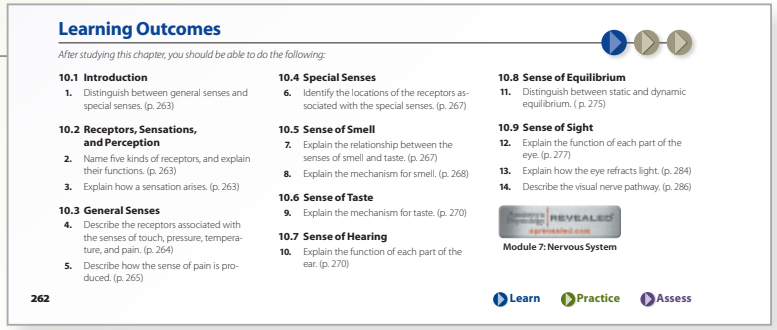
Specific Changes At-a-Glance —*Continued*

Chapter	Topic	Change	Rationale
14	T cell/B cell activation	Fig. 14.13 redone and corresponding text rewritten	Clarity
14	Complement	Agglutination and neutralization added	More information
14	Primary and secondary immune response	Graphs in fig. 14.16 separated	Clarity
15	Gut microbiome	Vignette expanded	Update
15	Gastric gland cells and hepatic lobules	New micrographs for figs. 15.12b and 15.17c	Clarity
15	Movements in alimentary canal (fig. 15.4), mouth (fig. 15.6), skull (fig. 15.7), salivary glands (fig. 15.10) and stomach (fig. 15.11)	Redrawn	Clarity
15	Inflammatory bowel disease	Clinical Application rewritten	Update
16	Mechanics of inspiration	Rewritten	Clarity
16	Spirometry	Cannot measure residual volume	Clarity
16	Basic breathing rhythm	Figs. 16.16 and 16.17 redone and corresponding text rewritten	Update
16	Cystic fibrosis	Clinical Application rewritten	Update
17	Hemolytic uremic syndrome	Vignette rewritten	Update
17	Macula densa	Location, new fig. 17.7	Accuracy
17	Afferent and efferent arterioles	Anatomical differences moved to part on glomerular filtration	Accuracy, clarity
17	Net filtration pressure	Fig. 17.10 matches fig. 13.21 on capillary filtration	Consistency
18	Heatstroke	New vignette	More clinical approach
18	Water intoxication	New information in Clinical Application	Update
19	Seminiferous tubules	New micrograph in fig. 19.2c	Clarity
19	Spermatogonia and sperm	New micrograph in fig. 19.4	Clarity
19	Prostate cancer	Clinical Application rewritten	Update
19	Uterus	Fundus added	More information
19	Breast cancer	Clinical Application rewritten	Update
19	Contraceptives	Fig. 19.15 redone	Update
19	Sexually transmitted diseases	Changed to sexually transmitted infections	Update, accuracy
20	Postmortem sperm retrieval	New vignette	Update
20	Critical period	Added to discussion, new orange box	More information
20	Teratogens	Clinical Application 20.2 rewritten	Update
20	Aging	Added	More information
Appendix B	Metrics	New	Students need help making conversations to/from metric measurements.
Appendix E	Figure Questions Answers	New	Provides answers to the new figure questions

Learn, Practice, Assess!

Learn

Learning Outcomes open chapters, and are closely linked to Chapter Assessments and Integrative Assessments/Critical Thinking questions found at the end of each chapter.



Learning Outcomes

After studying this chapter, you should be able to do the following:

10.1 Introduction
1. Distinguish between general senses and special senses. (p. 263)

10.2 Receptors, Sensations, and Perception
2. Name five kinds of receptors, and explain their functions. (p. 263)
3. Explain how a sensation arises. (p. 263)

10.3 General Senses
4. Describe the receptors associated with the senses of touch, pressure, temperature, and pain. (p. 264)
5. Describe how the sense of pain is produced. (p. 265)

10.4 Special Senses
6. Identify the locations of the receptors associated with the special senses. (p. 267)

10.5 Sense of Smell
7. Explain the relationship between the senses of smell and taste. (p. 267)
8. Explain the mechanism for smell. (p. 268)

10.6 Sense of Taste
9. Explain the mechanism for taste. (p. 270)

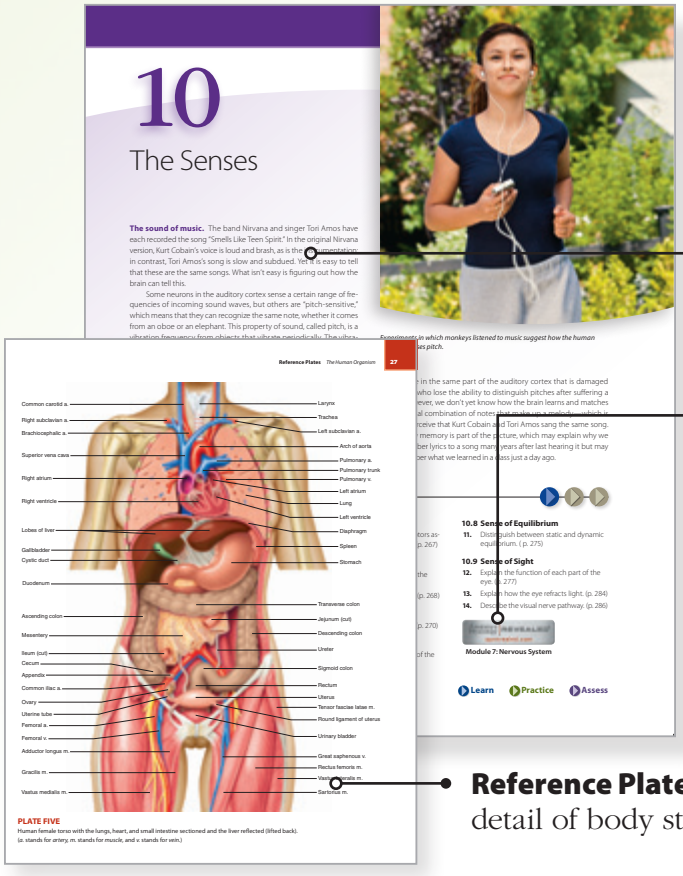
10.7 Sense of Hearing
10. Explain the function of each part of the ear. (p. 270)

10.8 Sense of Equilibrium
11. Distinguish between static and dynamic equilibrium. (p. 275)

10.9 Sense of Sight
12. Explain the function of each part of the eye. (p. 277)
13. Explain how the eye refracts light. (p. 284)
14. Describe the visual nerve pathway. (p. 286)

Module 7: Nervous System

262 Learn Practice Assess



10
The Senses

The sound of music. The band Nirvana and singer Tori Amos have each recorded the song "Smells Like Teen Spirit." In the original Nirvana version, Kurt Cobain's voice is loud and brash, as is the [illegible]; in contrast, Tori Amos's song is slow and subdued. Yet it is easy to tell that these are the same songs. What isn't easy is figuring out how the brain can tell this.

Some neurons in the auditory cortex sense a certain range of frequencies of incoming sound waves, but others are "pitch-sensitive," which means that they can recognize the same note, whether it comes from an oboe or an elephant. This property of sound, called pitch, is a

Experiments in which monkeys listened to music suggest how the human [illegible] pitch.

in the same part of the auditory cortex that is damaged who lose the ability to distinguish pitches after suffering a ever, we don't yet know how the brain learns and matches al combination of notes that make up a melody—which is ceive that Kurt Cobain and Tori Amos sang the same song. memory is part of the picture, which may explain why we ber lyrics to a song many years after last hearing it but may ber what we learned in a class just a day ago.

10.8 Sense of Equilibrium
11. Distinguish between static and dynamic equilibrium. (p. 275)

10.9 Sense of Sight
12. Explain the function of each part of the eye. (p. 277)
13. Explain how the eye refracts light. (p. 284)
14. Describe the visual nerve pathway. (p. 286)

Module 7: Nervous System

Learn Practice Assess

Reference Plates The Human Organism 27

Common carotid a.
Right subclavian a.
Brachiocephalic a.
Superior vena cava
Right atrium
Right ventricle
Lobes of liver
Gallbladder
Cystic duct
Duodenum
Ascending colon
Mesentery
Ileum (cut)
Cecum
Appendix
Common iliac a.
Ovary
Uterine tube
Femoral a.
Femoral v.
Adductor longus m.
Gracilis m.
Vastus medialis m.
Larynx
Trachea
Left subclavian a.
Arch of aorta
Pulmonary a.
Pulmonary trunk
Pulmonary v.
Left atrium
Lung
Left ventricle
Diaphragm
Spleen
Stomach
Transverse colon
Jejunum (cut)
Descending colon
Ureter
Sigmoid colon
Rectum
Uterus
Tensor fasciae latae m.
Round ligament of uterus
Urinary bladder
Great saphenous v.
Rectus femoris m.
Sartorius m.

PLATE FIVE
Human female torso with the lungs, heart, and small intestine sectioned and the liver reflected (lifted back).
(a. stands for artery, m. stands for muscle, and v. stands for vein.)

Learning tools to help you succeed. . .

Check out the Chapter Preview, Foundations for Success, on page xviii. The Chapter Preview was specifically designed to help you **LEARN** how to study. It provides helpful study tips.
NEW! for this edition is a section on learning styles!

Vignettes lead into chapter content. They connect you to many areas of health care including technology, physiology, medical conditions, historical perspectives, and careers.

NEW! Anatomy and Physiology Revealed (APR) icon at the beginning of each chapter tells you which system in APR applies to this chapter.

Aids to Understanding Words help you remember scientific word meanings. Examine root words, stems, prefixes, suffices, pronunciations, and build a solid anatomy and physiology vocabulary.

Reference Plates offer vibrant detail of body structures.

Practice

Practice with a question or series of questions after major sections. They will test your understanding of the material.

Practice

1. What factors probably stimulated an early interest in the human body?
2. What kinds of activities helped promote the development of modern medical science?

Interesting applications help you practice and apply their knowledge. . .

NEW! Anatomy and Physiology Revealed icons found in figure legends. These icons indicate that there is a direct link to APR available in the eBook provided with Connect Plus for this title!

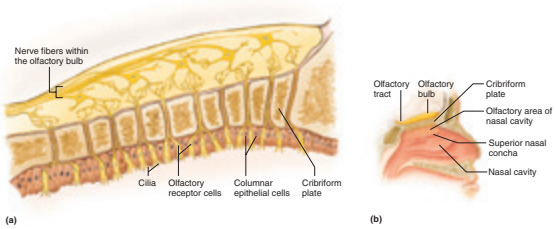


Figure 10.4 APR

Olfactory receptors convey the sense of smell. **(a)** Columnar epithelial cells support olfactory receptor cells, which have cilia at their distal ends. The actual olfactory receptors, which are proteins, are on the cilia. Binding of odorants to these receptors in distinctive patterns conveys the information that the brain interprets as an odor. **(b)** The olfactory area is associated with the superior nasal concha.

Q: NEW! Figure Questions allow an additional assessment. Found on key figures throughout the chapter.

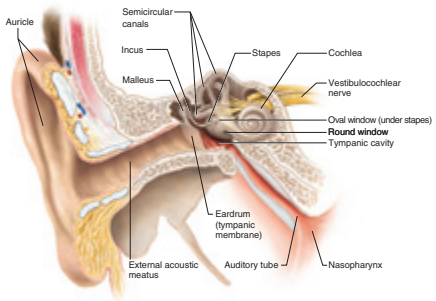


Figure 10.6 APR

Major parts of the ear. The outer ear includes the auricle, external acoustic meatus, and eardrum. The middle ear includes the auditory ossicles (malleus, incus, and stapes) and the oval window. The inner ear includes the semicircular canals and the cochlea.

Q: *How do the action potentials generated along auditory pathways compare with those on taste and smell pathways?*

Answer can be found in Appendix E on page 568.

The fovea centralis of the human eye has 150,000 cones per square millimeter. In contrast, a bird of prey's eye has about a million cones per square millimeter.

Facts of Life provides interesting bits of anatomy and physiology information, adding a touch of wonder to chapter topics.

Boxed information applies ideas and facts in the narrative to clinical situations.

As a person ages, tiny, dense clumps of gel or deposits of crystal-like substances form in the vitreous humor. When these clumps cast shadows on the retina, the person sees small, moving specks in the field of vision, called *floaters*.

NEW! Clinical Applications present disorders, physiological responses to environmental factors, and other topics of general interest.

Genetics Connections explore the molecular underpinnings of familiar as well as not so familiar illnesses. Read about such topics as ion channel disorders, muscular dystrophy, and cystic fibrosis.

Clinical Application 10.1

Synesthesia: Connected Senses

"The song was full of glittering orange diamonds."
"The paint smelled blue."
"The sunset was salty."
"The pickle tasted like a rectangle."

About 1 in 2,000 people have a condition called synesthesia ("joined sensation"), in which sensation and perception mix, so that the brain perceives [illegible] from another. Most comm[illegible] of time evoke specific col[illegible] tary, are very specific, and [illegible] a person might report th[illegible] Thursday as a very dark, shiny [illegible]

Synesthesia runs in fa[illegible] ated the condition with ir[illegible] ferent genes. Female "syn[illegible] one. Creative individuals a[illegible] with the condition. They i[illegible] Mayer, Tori Amos, and Fran[illegible]

and physicist Richard Feynman, who used to include the hues with which he visualized chemical equations on the chalkboard, to the amusement of his students. One of the co-authors of this book has it—to her, days are colors. The earliest recorded mention of synesthesia is an essay from John Locke in 1690. More and more people with synesthesia are recog-

Genetics Connection 8.1

Inherited Diseases of Muscle

A variety of inherited conditions affect muscle tissue. These disorders differ in the nature of the genetic defect, the type of protein that is abnormal in form or function, and the particular muscles in the body that are impaired.

The Muscular Dystrophies—Missing Proteins

A muscle cell is packed with filaments of actin and myosin. Much less abundant, but no less important, is a protein called *dystrophin*. It holds skeletal muscle cells together by linking actin in the cell to glycoproteins in the cell membrane, which helps attach the cell to the extracellular matrix. Missing or abnormal dystrophin or the glycoproteins cause muscular dystrophies. These illnesses vary in severity and age of onset, but in all cases, muscles weaken and degenerate. Eventually, fat and connective tissue replace muscle.

Duchenne muscular dystrophy (DMD) is the most severe type of the illness (fig. 8B). Symptoms begin by age five and affect only boys. By age thirteen, the person cannot walk, and by early adulthood he usually dies from failure of the respiratory muscles. In DMD, dystrophin is often missing. In Becker muscular dystrophy, symptoms begin in early adulthood, are less severe, and result from underproduction of dystrophin.

Figure 8B

This young man has Duchenne muscular dystrophy. The condition has not yet severely limited his activities, but he shows the hypertrophied (overdeveloped) calf muscles that result from his inability to rise from a sitting position the usual way—an early sign of the illness.

Charcot-Marie-Tooth Disease—A Duplicate Gene

Charcot-Marie-Tooth disease causes a slowly progressing weakness in the muscles of the hands and feet and a decrease in tendon reflexes in these parts. In this illness, an extra gene impairs the insulating sheath around affected nerve cells, so that nerve cells cannot adequately stimulate muscles. Physicians perform two tests—electromyography and nerve conduction velocity—to diagnose Charcot-Marie-Tooth disease. It is also possible to test for the gene mutation to confirm a diagnosis based on symptoms.

Hereditary Idiopathic Dilated Cardiomyopathy—A Tiny Glitch

This very rare inherited form of heart failure usually begins in a person's forties and is lethal in 50% of cases within five years of diagnosis, unless a heart transplant can be performed. The condition is caused by a tiny genetic error in a form of actin found only in cardiac muscle, where it is the predominant component of the thin filaments. The mutation disturbs actin's ability to anchor to the Z lines in heart muscle cells, preventing actin from effectively transmitting the force of contraction. As a result, the heart chambers enlarge and eventually fail.

Learn, Practice, Assess!

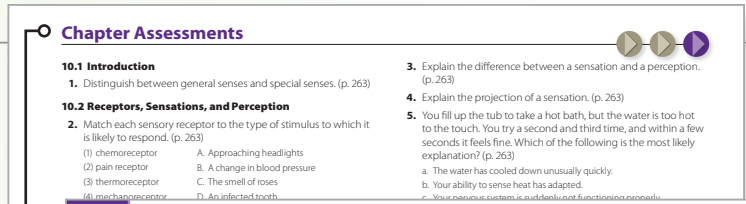
Assess

Tools to help you make the connection and master anatomy & physiology!

Chapter Assessments check your understanding of the chapter's learning outcomes.

Integrative Assessments/Critical Thinking questions allow you to connect and apply information from previous chapters as well as information within the current chapter.

Chapter Summary Outlines help you review the chapter's main ideas.



Chapter Assessments

10.1 Introduction

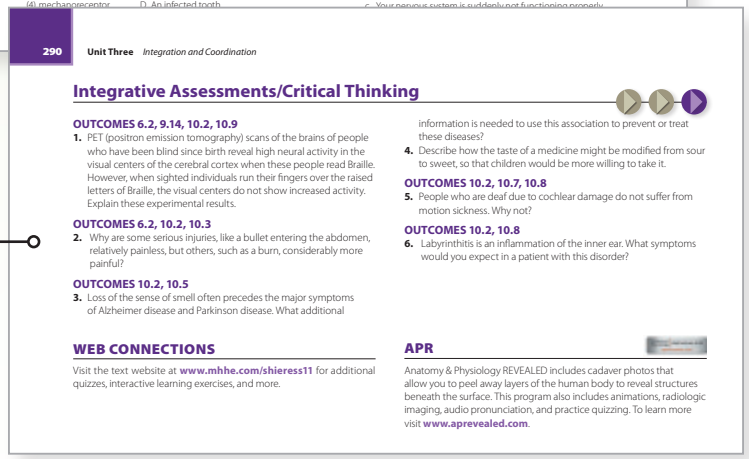
1. Distinguish between general senses and special senses. (p. 263)

10.2 Receptors, Sensations, and Perception

2. Match each sensory receptor to the type of stimulus to which it is likely to respond. (p. 263)

(1) chemoreceptor	A. Approaching headlights
(2) pain receptor	B. A change in blood pressure
(3) thermoreceptor	C. The smell of roses
(4) mechanoreceptor	D. An infected tooth

3. Explain the difference between a sensation and a perception. (p. 263)
4. Explain the projection of a sensation. (p. 263)
5. You fill up the tub to take a hot bath, but the water is too hot to the touch. You try a second and third time, and within a few seconds it feels fine. Which of the following is the most likely explanation? (p. 263)
   a. The water has cooled down unusually quickly.
   b. Your ability to sense heat has adapted.
   c. Your nervous system is suddenly not functioning properly.



290 Unit Three *Integration and Coordination*

Integrative Assessments/Critical Thinking

OUTCOMES 6.2, 9.14, 10.2, 10.9

1. PET (positron emission tomography) scans of the brains of people who have been blind since birth reveal high neural activity in the visual centers of the cerebral cortex when these people read Braille. However, when sighted individuals run their fingers over the raised letters of Braille, the visual centers do not show increased activity. Explain these experimental results.

OUTCOMES 6.2, 10.2, 10.3

2. Why are some serious injuries, like a bullet entering the abdomen, relatively painless, but others, such as a burn, considerably more painful?

OUTCOMES 10.2, 10.5

3. Loss of the sense of smell often precedes the major symptoms of Alzheimer disease and Parkinson disease. What additional information is needed to use this association to prevent or treat these diseases?
4. Describe how the taste of a medicine might be modified from sour to sweet, so that children would be more willing to take it.

OUTCOMES 10.2, 10.7, 10.8

5. People who are deaf due to cochlear damage do not suffer from motion sickness. Why not?

OUTCOMES 10.2, 10.8

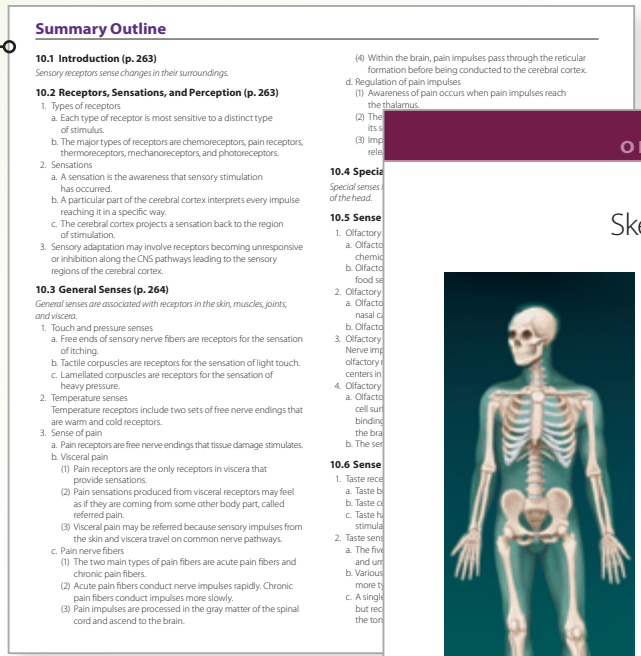
6. Labyrinthitis is an inflammation of the inner ear. What symptoms would you expect in a patient with this disorder?

WEB CONNECTIONS

Visit the text website at **www.mhhe.com/shieress11** for additional quizzes, interactive learning exercises, and more.

APR

Anatomy & Physiology REVEALED includes cadaver photos that allow you to peel away layers of the human body to reveal structures beneath the surface. This program also includes animations, radiologic imaging, audio pronunciation, and practice quizzing. To learn more visit **www.aprevealed.com**.



Summary Outline

10.1 Introduction (p. 263)

Sensory receptors sense changes in their surroundings.

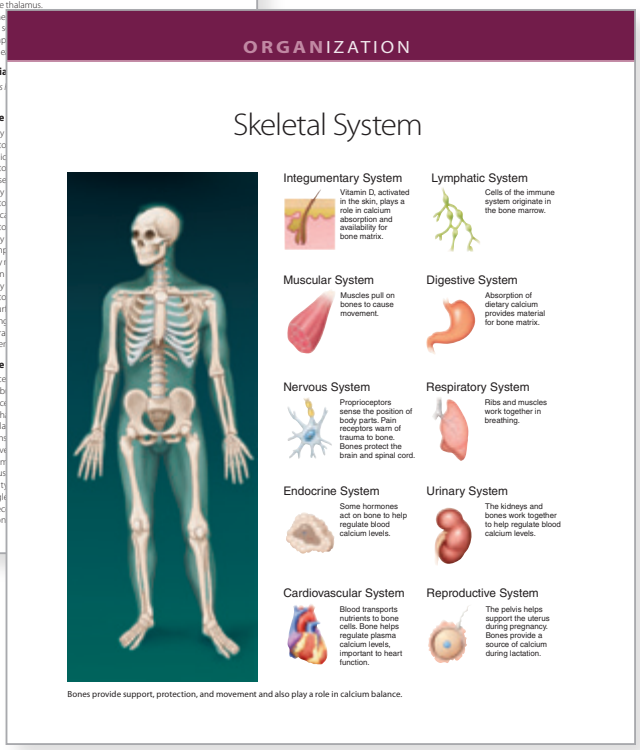
10.2 Receptors, Sensations, and Perception (p. 263)

1. Types of receptors
   a. Each type of receptor is most sensitive to a distinct type of stimulus.
   b. The major types of receptors are chemoreceptors, pain receptors, thermoreceptors, mechanoreceptors, and photoreceptors.
2. Sensations
   a. A sensation is the awareness that sensory stimulation has occurred.
   b. A particular part of the cerebral cortex interprets every impulse reaching it in a specific way.
   c. The cerebral cortex projects a sensation back to the region of stimulation.
3. Sensory adaptation may involve receptors becoming unresponsive or inhibition along the CNS pathways leading to the sensory regions of the cerebral cortex.

10.3 General Senses (p. 264)

General senses are associated with receptors in the skin, muscles, joints, and viscera.

1. Touch and pressure senses
   a. Free ends of sensory nerve fibers are receptors for the sensation of itching.
   b. Tactile corpuscles are receptors for the sensation of light touch.
   c. Lamellated corpuscles are receptors for the sensation of heavy pressure.
2. Temperature senses
   Temperature receptors include two sets of free nerve endings that are warm and cold receptors.
3. Sense of pain
   a. Pain receptors are free nerve endings that tissue damage stimulates.
   b. Visceral pain
      (1) Pain receptors are the only receptors in viscera that provide sensations.
      (2) Pain sensations produced from visceral receptors may feel as if they are coming from some other body part, called referred pain.
      (3) Visceral pain may be referred because sensory impulses from the skin and viscera travel on common nerve pathways.
   c. Pain nerve fibers
      (1) The two main types of pain fibers are acute pain fibers and chronic pain fibers.
      (2) Acute pain fibers conduct nerve impulses rapidly. Chronic pain fibers conduct impulses more slowly.
      (3) Pain impulses are processed in the gray matter of the spinal cord and ascend to the brain.
      (4) Within the brain, pain impulses pass through the reticular formation before being conducted to the cerebral cortex.
   d. Regulation of pain impulses
      (1) Awareness of pain occurs when pain impulses reach the thalamus.



Bones provide support, protection, and movement and also play a role in calcium balance.

ORGANIZATION
Illustrations
found at the end of selected chapters conceptually link the highlighted body system to every other system and reinforce the dynamic interplay among systems. These illustrations help you review chapter concepts and reinforce the big picture in learning and applying the principles of anatomy and physiology.

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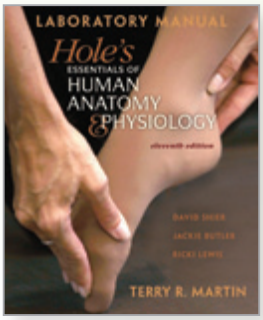

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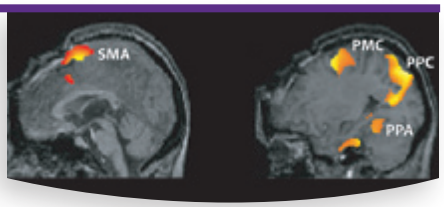
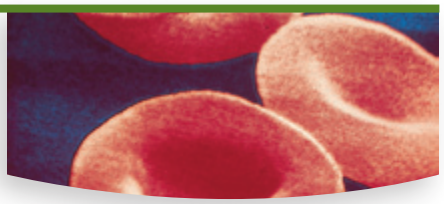
David Shier
Jackie Butler
Ricki Lewis

Contents

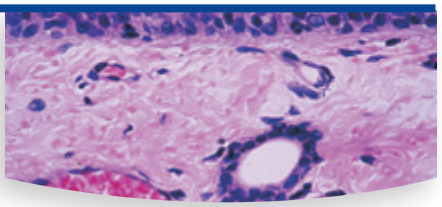
Unit 3
Integration and Coordination



Unit 4
Transport



Unit 5
Absorption and Excretion



Unit 6
The Human Life Cycle

The Chapter Preview not only provides great study tips to offer a foundation for success, but it also offers tips on how to utilize this particular text.

Chapter Preview

Foundations for Success

A photo on the opening page for each chapter generates interest.

OPENING VIGNETTE
Beginning each chapter is a vignette that discusses current events or research news relating to the subject matter in the chapter. These vignettes demonstrate applications of the concepts learned in the study of anatomy and physiology.

It is a beautiful day. You can't help but stare wistfully out the window, the scent of spring blooms and sound of birds making it impossible to concentrate on what the instructor is saying. Gradually, the lecture fades as you become aware of your own breathing, the beating of your heart, and the sweat that breaks out on your forehead in response to the radiant heat from the glorious day. Suddenly your reverie is cut short—the instructor has dropped a human anatomy and physiology textbook on your desk. You jump. Your heart hammers and a flash of fear grips your chest—but you soon realize what has happened and recover.

The message is clear: pay attention. So you do, tuning out the great outdoors and focusing on the lecture. In this course, you will learn all about the events that you have just experienced, including your response to the sudden stimulation of the instructor's wake-up call. This is a good reason to learn about how to stay focused in the course.

Learning Outcomes

After studying this chapter, you should be able to do the following:

Each chapter begins with a list of outcomes indicating the knowledge you should gain as you work through the chapter. (Note the blue learn arrow.) These outcomes are intended to help you master the similar outcomes set by your instructor. The outcomes will be tied directly to assessments of knowledge gained.

P.1 Introduction

1. Explain the importance of an individualized approach to learning.

P.2 Strategies for Your Success

2. Summarize what you should do before attending class.
3. Identify student activities that enhance classroom experience.
4. List and describe several study techniques that can facilitate learning new material.

Aids to Understanding Words *(Appendix A on page 564 has a complete list of Aids to Understanding Words.)*

This section introduces building blocks of words that your instructor may assign. Learning them is a good investment of your time, because they can be used over and over and apply to many of the terms you will use in your career. Appendix A (p. 564) has a comprehensive list of these prefixes, suffixes, and root words.

ana- [up] *ana*tomy: the study of breaking up the body into its parts.

multi- [many] *multi*tasking: performing several tasks simultaneously.

physio- [relationship to nature] *physio*logy: the study of how body parts function.

P.1 INTRODUCTION

Each chapter begins with an overview that tells you what to expect and why the subject matter is important.

Studying the human body can be overwhelming at times. The new terminology, used to describe body parts and how they work, can make it seem as if you are studying a foreign language. Learning all the parts of the body, along with the composition of each part, and how each part fits with the other parts to make the whole requires memorization. Understanding the way each body part works individually, as well as body parts working together, requires a higher level of knowledge, comprehension, and application. Identifying underlying structural similarities, from the macroscopic to the microscopic levels of body organization, taps more subtle critical thinking skills. This chapter will catalyze success in this active process of learning. (Remember that while the skills and tips discussed in this chapter relate to learning anatomy and physiology, they can be applied to other subjects.)

Learning occurs in different ways or modes. Most students use several modes (multimodal), but are more comfortable and use more effectively one or two learning styles. Some students prefer to read the written word to remember it and the concept it describes or to actually write the words; others learn best by looking at visual representations, such as photographs and drawings. Still others learn most effectively by hearing the information or explaining it to someone else. For some learners, true understanding remains elusive until a principle is revealed in a laboratory or clinical setting that provides a memorable context and engages all of the senses.

This text is balanced among the learning styles; read-write learners will appreciate the lists, definitions (glossary), and tables; visual learners will discover in the pages of text many diagrams, flow charts, and figures, all with consistent and purposeful use of color (in figures where bones are color-coded, for example, a particular bone is always the same color); auditory learners will find pronunciations whenever new scientific terms are introduced, so that they may "sound out" the new vocabulary; and kinesthetic learners will appreciate real-life examples and applications to relate to their own activities.

After each major section, a question or series of questions tests your understanding of the material and enables you to practice using the information. (Note the green practice arrow.) If you cannot answer the question(s), you should reread that section, being particularly on the lookout for the answer(s).

Check Your Recall

1. List some difficulties a student may experience when studying the human body.
2. List the ways that people learn.

P.2 STRATEGIES FOR YOUR SUCCESS

Major divisions within a chapter are called "A-heads." They are numbered sequentially in very large, purple type and identify major content areas.

Many strategies for academic success are common sense, but it might help to review them. You may encounter new and helpful methods of learning.

Before Class

The major divisions are subdivided into "B-heads," which are identified by large, black type. These will help you organize the concepts upon which the major divisions are built.

Before attending class, prepare by reading and outlining or taking notes on the assigned pages of the text. If outlining, leave adequate space between entries to allow room for note-taking during lectures. Or, fold each page of notes taken before class in half so that class notes can be written on the blank side of the paper across from

the reading notes on the same topic. This introduces the topics of the next class lecture, as well as new terms. Some students team a vocabulary list with each chapter's notes. The outline or notes from the reading can be taken to class and expanded during the lecture. At a minimum, the student should at least skim through the text, reading A-heads, B-heads, and the summary outline to become acquainted with the topics and vocabulary in advance of class attendance.

As you read, you may feel the need for a "study break" or to "chill out." Other times, you may just need to shift gears. Try the following. Throughout the book are shaded boxes that present sidelights to the main text. Indeed, some of these may cover topics that your instructor chooses to highlight. Read them! They are interesting, informative, and a change of pace.

Health-care workers repeatedly monitor patients' *vital signs*—observable body functions that reflect essential metabolic activities. Vital signs indicate that a person is alive. Assessment of vital signs includes measuring body temperature and blood pressure and monitoring rates and types of pulse and breathing movements. Absence of vital signs signifies death. A person who has died displays no spontaneous muscular movements, including those of the breathing muscles and beating heart. A dead body does not respond to stimuli and has no reflexes, such as the knee-jerk reflex and the pupillary reflexes of the eye. Brain waves cease with death, as demonstrated by a flat electroencephalogram (EEG), which signifies a lack of electrical activity in the brain.

The skeleton of an average 160-pound body weighs about 29 pounds.

Genetics Connection 16.1

Cystic Fibrosis

"Woe to that child which when kissed on the forehead tastes salty. He is bewitched and soon must die." So went a seventeenth-century British saying about a child with cystic fibrosis (CF). Until recently, salty skin, foul stools, and poor weight gain ("failure to thrive") were typically the first symptoms of CF. Today most new cases are detected before birth, using genetic tests. The disease, inherited from two carrier parents, affects about 30,000 people in the United States and 70,000 worldwide. It isn't known how many people have mild forms of the disease, merely with symptoms of frequent respiratory infection. More than 1,000 mutations can cause CF, so severity varies widely.

In 1938, physicians first described CF as a defect in channels leading from certain glands. This causes formation of extremely thick, sticky mucus, which encourages infections by microorganisms not otherwise common in the lungs. A clogged pancreas prevents digestive juices from reaching the intestines and thus impairs absorption of nutrients.

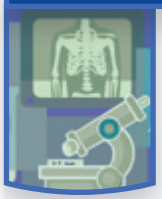
In the 1930s, life expectancy for a child with CF was five years, but by 1960 it became possible to treat the symptoms. Antibiotics control the respiratory infections, and daily "bronchial drainage" exercises shake the stifling mucus free from the lungs of infants. Older children and adults wear a vibrating vest for half-hour stretches two to four times a day to shake the mucus free. Some people multitask, taking daily antibiotics in a nebulizer as they wear the vest. Digestive enzymes mixed into soft foods enhance nutrient absorption.

The gene that is mutant in CF normally encodes a protein called the "cystic fibrosis transmembrane regulator," or CFTR for short. It is an ion channel that controls chloride transport out of cells. In severe CF, the chloride channel is missing one crucial amino acid, and is so deformed that it fails to function. The abnormal handling of chloride ions thickens the mucus. Organs become clogged.

Discovery of the most common CFTR mutation in 1989 enabled development of more targeted treatments. Some drugs allow more chloride to leave the cells lining the lungs. Two new drugs, still experimental, are small molecules that escort abnormal CFTR protein to the cell surface, where it apparently functions. The drugs act as "correctors," saving the errant CFTR proteins from being dismantled before they can reach the cell surface.

Life with severe CF is difficult. One little girl did not mind the twice-daily vibrating vest, or even the feeding tube she needed at night to pack in nutrients. But she hated the measures to avoid respiratory infections, especially in summertime. She had to stay away from hoses, which harbor lung-loving *Pseudomonas* bacteria. Bonfires or cookouts could expose her to lung-clogging particulates in the air. She couldn't even go into a pool—too little chlorine would invite bacterial infections, and too much would irritate her lungs. But unlike children of a generation ago, her disease is controlled enough that she will likely live well into adulthood.

Clinical Application 15.1



Dental Caries

Sticky foods, such as caramel, lodge between the teeth and in the crevices of molars, feeding bacteria such as *Actinomyces, Streptococcus mutans,* and *Lactobacillus.* These microorganisms metabolize carbohydrates in the food, producing acid by-products that destroy tooth enamel and dentin. The bacteria also produce sticky substances that hold them in place.

If a person eats a candy bar but does not brush the teeth soon afterward, the acid-forming bacteria may decay tooth enamel, creating a condition called *dental caries.* Unless a dentist cleans and fills the resulting cavity that forms where enamel is destroyed, the damage will spread to the underlying dentin.

Dental caries can be prevented in several ways:

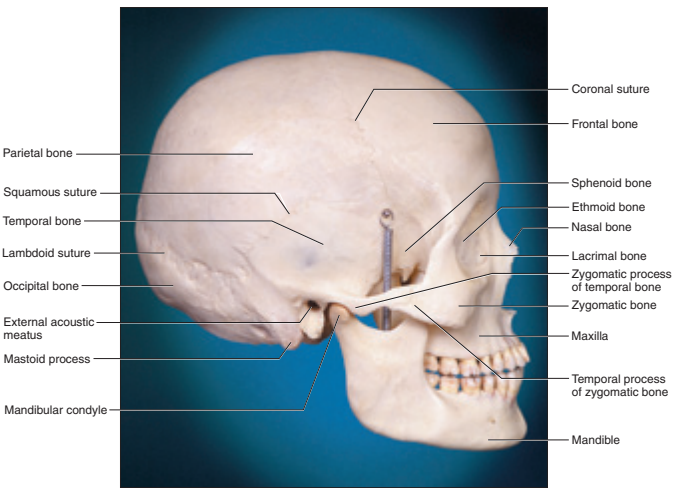
1. Brush and floss teeth regularly.
2. Have regular dental exams and cleanings.
3. Talk with your dentist about receiving a fluoride treatment. Fluoride is added to the water supply in many communities. Fluoride is incorporated into the enamel's chemical structure, strengthening it.
4. The dentist may apply a sealant to children's and adolescents' teeth where crevices might hold onto decay-causing bacteria. The sealant is a coating that keeps acids from eating away at tooth enamel.

Remember when you were very young and presented with a substantial book for the first time? You were likely intimidated by its length, but were reassured that there were "a lot of pictures." This book has many illustrations too, all designed to help you master the material and become that person who you would want treating you.

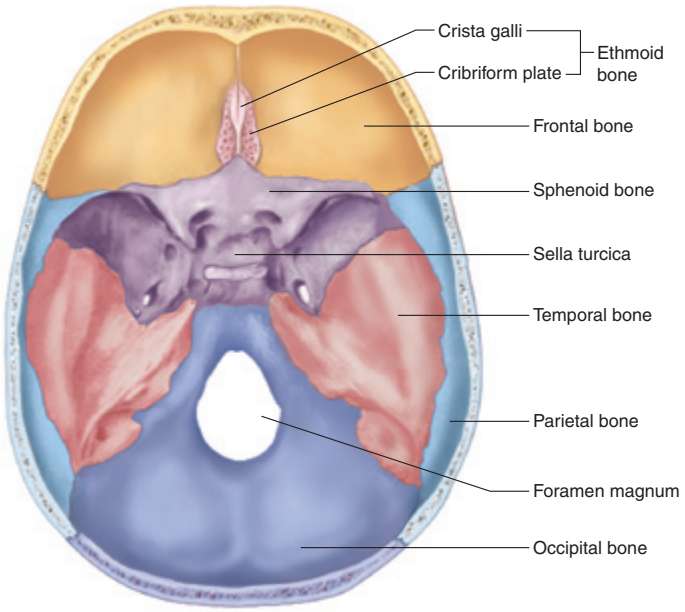
Photographs and Line Art

The heading above this box is a "C-head." Sometimes subdivisions have so many parts that the book goes to this third level of organization. This heading is presented in a slightly smaller, italicized font.

Photographs provide a realistic view of anatomy.

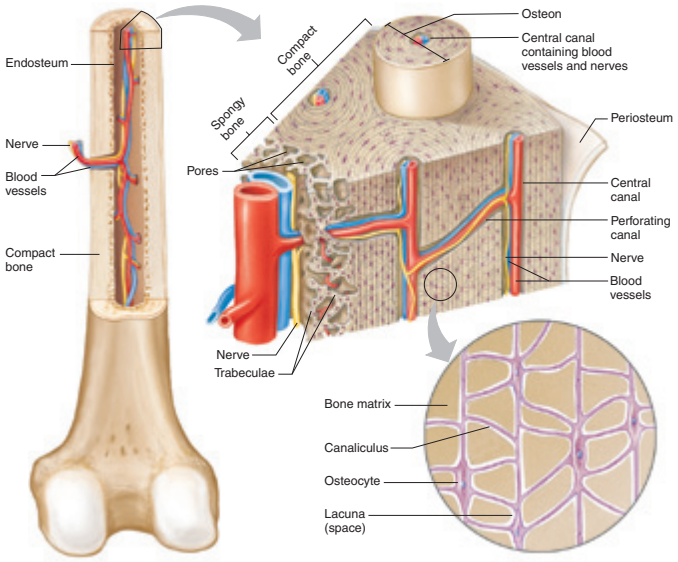


Because line art can present different positions, layers, or perspectives, it can provide a unique view.



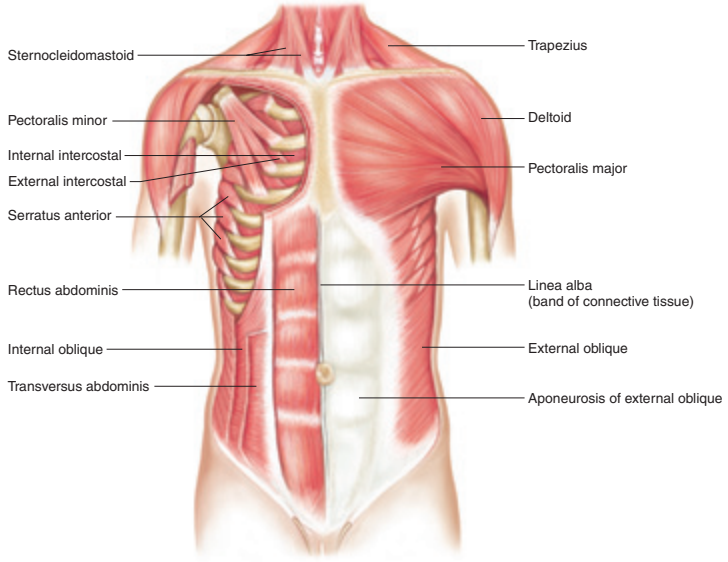
Macroscopic to Microscopic

Many figures show anatomical structures in a manner that is macroscopic to microscopic (or vice versa).



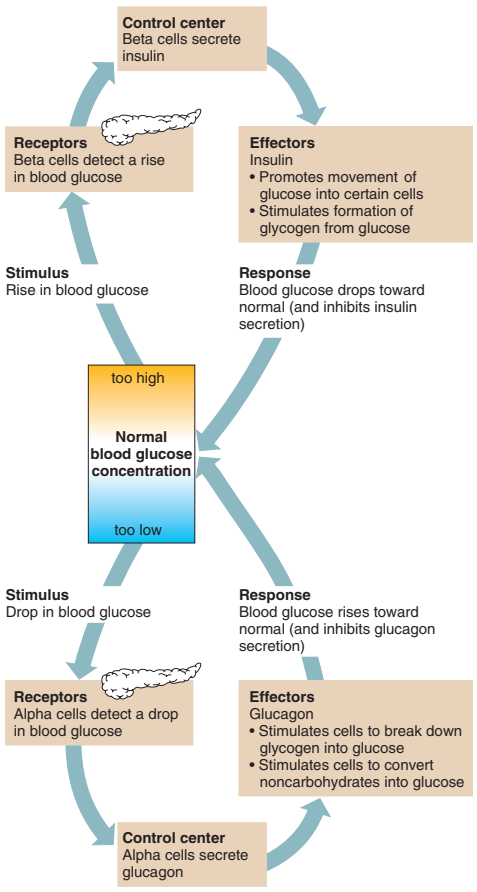
Anatomical Structures

Some figures illustrate the locations of anatomical structures.

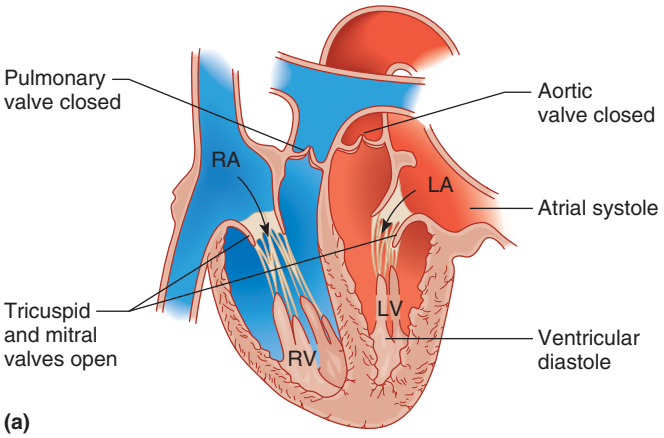


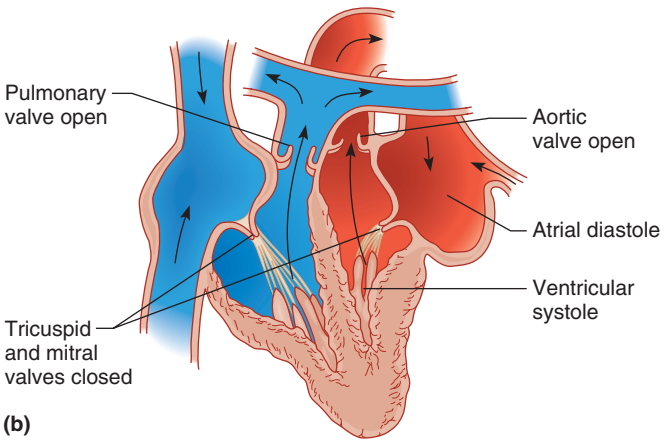
Flow Charts

Flow charts depict sequences of related events, steps of pathways, and complex concepts, easing comprehension. Other figures may show physiological processes.



Other figures illustrate the functional relationships of anatomical structures.





Organizational Tables

Organizational tables can help "put it all together," but are not a substitute for reading the text or having good lecture notes.

Table 5.6 Muscle and Nervous Tissues

Type	Function	Location
Skeletal muscle tissue (striated)	Voluntary movements of skeletal parts	Muscles usually attached to bones
Smooth muscle tissue (lacks striations)	Involuntary movements of internal organs	Walls of hollow internal organs
Cardiac muscle tissue (striated)	Heart movements	Heart muscle
Nervous tissue	Sensory reception and conduction of electrical impulses	Brain, spinal cord, and peripheral nerves

It is critical that you attend class regularly, and be on time—even if the instructor's notes are posted on the Web, and the information is in the textbook. For many learners, hearing and writing new information is a better way to retain facts than just scanning notes on a computer screen. Attending lectures and discussion sections also provides more detailed and applied analysis of the subject matter, as well as a chance to ask questions.

During Class

Be alert and attentive in class. Take notes by adding to either the outline or notes taken while reading. Auditory learners benefit from recording the lectures and listening to them while driving or doing chores. This is called **multitasking**—doing more than one activity at a time.

Participate in class discussions, asking questions of the instructor and answering questions he or she poses. All of the students are in the class to learn, and many will be glad someone asked a question others would not be comfortable asking. Such student response can alert the instructor to topics that are misunderstood or not understood at all. However, respect class policy. Due to time constraints and class size, asking questions may be more appropriate after a large lecture class or during tutorial (small group) sessions.

After Class

In learning complex material, expediency is critical. Organize, edit, and review notes as soon after class as possible, fleshing out sections where the lecturer got ahead of the listener. Highlighting or underlining (in color, for visual learners) the key terms, lists, important points and major topics make them stand out, which eases both daily reviews and studying for exams.

Lists

Organizing information into lists or categories can minimize information overload, breaking it into manageable chunks. For example, when studying the muscles of the thigh it is easier to learn the insertion, origin, action, and nerve supply of the four muscles making up the quadriceps femoris as a group, because they all have the same insertion, action, and nerve supply . . . they differ only in their origins.

Mnemonic Devices

Another method for remembering information is the **mnemonic device.** One type of mnemonic device is a list of words, forming a phrase, in which the first letter of each word corresponds to the first letter of each word that must be remembered. For example, ***Frequent parade often tests soldiers' endurance*** stands for the skull bones **f**rontal, **p**arietal, **o**ccipital, **t**emporal, **s**phenoid, and **e**thmoid. Another type of mnemonic device is a word formed by the first letters of the items to be remembered. For example, ***ipmat*** represents the stages in the cell cycle: **i**nterphase, **p**rophase, **m**etaphase, **a**naphase, and **t**elophase.

Study Groups

Forming small study groups helps some students. Together the students review course material and compare notes. Working as a team and alternating leaders allows students to verbalize the information. Individual students can study and master one part of the assigned material, and then explain it to the others in the group, which incorporates the information into the memory of the speaker. Hearing the material spoken aloud also helps the auditory learner. Be sure to use anatomical and physiological terms, in explanations and everyday conversation, until they become part of your working vocabulary, rather than intimidating jargon. Most important of all—the group must stay on task, and not become a vehicle for social interaction. Your instructor may have suggestions or guidelines for setting up study groups.

Flash Cards

Flash cards may seem archaic in this computer age, but they are still a great way to organize and master complex and abundant information. The act of writing or drawing on a note card helps the tactile learner. Master a few new cards each day, and review cards from previous days, and use them all again at the end of the semester to prepare for the comprehensive final exam. They may even come in handy later, such as in studying for exams for admission to medical school or graduate school. Divide your deck in half and flip half of

the cards so that the answer rather than the question is showing. Mix and shuffle them. Get used to identifying a structure or process from a description as well as giving a description when provided with a process or structure. This is more like what will be expected of you in the real world of the health-care professional.

Manage Your Time

For each hour in the classroom, most students will spend at least three hours outside of class studying. Many of you have important obligations outside of class, such as jobs and family responsibilities. As important as these are, you still need to master this material on your path to becoming a health-care professional. Good time management skills are therefore essential in your study of human anatomy and physiology. In addition to class, lab, and study time, multitask. Spend time waiting for a ride, in a doctor's office, or on line reviewing notes or reading the text.

Daily repetition is helpful, so scheduling several short study periods each day can replace an end-of-semester crunch to cram for an exam. This does not take the place of time to prepare for the next class. Thinking about these suggestions for learning now can maximize study time throughout the semester, and, hopefully, lead to academic success. A working knowledge of the structure and function of the human body provides the foundation for all careers in the health sciences.

Check Your Recall

3. Why is it important to prepare before attending class?
4. Name two ways to participate in class discussions.
5. List several aids for remembering information.

Summary Outline

A summary of the chapter provides an outline to review major ideas and is a tool for organizing thoughts.

P.1 Introduction (page xix)

Try a variety of methods to study the human body.

P.2 Strategies for Your Success (page xix)

While strategies for academic success seem to be common sense, you might benefit from reminders of study methods.

1. Before class
   Read the assigned text material prior to the corresponding class meeting.
   a. Photographs give a realistic view and line art shows different perspectives.
   b. Macroscopic to microscopic show increase in detail.
   c. Flow charts depict sequences and steps.
   d. Figures of anatomical structures show locations.
   e. Organizational charts/tables summarize text.
2. During class
   Take notes and participate in class discussions.
3. After class
   a. Organize, edit, and review class notes.
   b. Mnemonic devices aid learning.
      (1) The first letters of the words to remember begin words of an easily recalled phrase.
      (2) The first letters of the items to be remembered form a word.
   c. Small study groups reviewing and vocalizing material can divide and conquer the learning task.
   d. Making flash cards helps the tactile learner.
   e. Time management skills encourage scheduled studying, including daily repitition instead of cramming for exams.

Chapter Assessments

Chapter assessments that are tied directly to the learning outcomes allow you to assess your mastery of the material. (Note the purple assess arrow.)

P.1 Introduction

1. Explain why the study of the human body can be overwhelming. (p. xix)

P.2 Strategies for Success

2. Methods to prepare for class include: (p. xix)
   a. reading the chapter.
   b. outlining the chapter.
   c. taking notes on the assigned reading.
   d. making a vocabulary list.
   e. all of the above.
3. Describe how you can participate in class discussions. (p. xxiii)
4. Forming the phrase "*I passed my anatomy test*" to remember the cell cycle (interphase, prophase, metaphase, anaphase, telophase) is a _____ device. (p. xxiii)
5. Name a benefit and a drawback of small study groups. (p. xxiii)
6. Explain the value of repetition in learning and preparation for exams. (p. xxiv)

Integrative Assessments/Critical Thinking

A textbook is inherently linear. This text begins with Chapter 1 and ends with Chapter 20. Understanding physiology and the significance of anatomy, however, requires you to be able to recall previous concepts. Toward this end, we have included in the Integrative Assessments/Critical Thinking section references to sections from earlier chapters. Making connections is what it is all about!

OUTCOME P.1

1. Which study methods are most successful for you?

OUTCOMES P.1, P.2

2. Design a personalized study schedule.

Check out the text website at **www.mhhe.com/shieress11** for additional study tools. There is also information about the applicable Anatomy & Physiology Revealed® CD-ROM.

WEB CONNECTIONS

Visit the text website at **www.mhhe.com/shieress11** for additional quizzes, interactive learning exercises, and more.

APR

Anatomy & Physiology REVEALED® includes cadaver photos that allow you to peel away layers of the human body to reveal structures beneath the surface. This program also includes animations, radiologic imaging, audio pronunciations, and practice quizzing. To learn more visit **www.aprevealed.com**.