

Hole's Human Anatomy & Physiology



DAVID SHIER
JACKIE BUTLER
RICKI LEWIS

Tenth edition
10

Hole's Human Anatomy & Physiology

DAVID SHIER

Washtenaw Community College

JACKIE BUTLER

Grayson County College

RICKI LEWIS

Contributing Editor to The Scientist



Higher Education

Boston Burr Ridge, IL Dubuque, IA Madison, WI New York San Francisco St. Louis
Bangkok Bogotá Caracas Kuala Lumpur Lisbon London Madrid Mexico City
Milan Montreal New Delhi Santiago Seoul Singapore Sydney Taipei Toronto

HOLE'S HUMAN ANATOMY & PHYSIOLOGY, TENTH EDITION

Published by McGraw-Hill, a business unit of The McGraw-Hill Companies, Inc., 1221 Avenue of the Americas, New York, NY 10020. Copyright © 2004, 2002, 1999, 1996 by The McGraw-Hill Companies, Inc. All rights reserved. No part of this publication may be reproduced or distributed in any form or by any means, or stored in a database or retrieval system, without the prior written consent of The McGraw-Hill Companies, Inc., including, but not limited to, in any network or other electronic storage or transmission, or broadcast for distance learning.

Some ancillaries, including electronic and print components, may not be available to customers outside the United States.

This book is printed on acid-free paper.

2 3 4 5 6 7 8 9 0 QPD/QPD 0 9 8 7 6 5 4

ISBN 0-07-291932-9

Publisher: *Martin J. Lange*
Sponsoring editor: *Michelle Watnick*
Senior developmental editor: *Patricia Hesse*
Director of development: *Kristine Tibbetts*
Marketing manager: *James F. Connely*
Senior project manager: *Jayne Klein*
Lead production supervisor: *Sandy Ludovissy*
Media project manager: *Sandra M. Schnee*
Senior media technology producer: *Barbara R. Block*
Designer: *K. Wayne Harms*
Cover/interior designer: *Christopher Reese*
Cover image: *Hoby Finn/Gettyimages*
Senior photo research coordinator: *John Leland*
Photo research: *Billie Porter*
Supplement producer: *Brenda A. Erzen*
Compositor: *Precision Graphics*
Typeface: *10/12 Melior*
Printer: *Quebecor World Dubuque*

The credits section for this book begins on page 1007 and is considered an extension of the copyright page.

Library of Congress Cataloging-in-Publication Data

Shier, David.

Hole's human anatomy & physiology / David Shier, Jackie Butler, Ricki Lewis. — 10th ed.

p. cm.

Includes index.

ISBN 0-07-291932-9 (hard copy : alk. paper)

1. Human physiology. 2. Human anatomy. I. Title: Hole's human anatomy and physiology. II. Title: Human anatomy & physiology. III. Title.

QP34.5 .H63 2004

612—dc21

2002015462

CIP



IMPORTANT:

HERE IS YOUR REGISTRATION CODE TO ACCESS
YOUR PREMIUM MCGRAW-HILL ONLINE RESOURCES.

For key premium online resources you need THIS CODE to gain access. Once the code is entered, you will be able to use the Web resources for the length of your course.

If your course is using WebCT or Blackboard, you'll be able to use this code to access the McGraw-Hill content within your instructor's online course.

Access is provided if you have purchased a new book. If the registration code is missing from this book, the registration screen on our Website, and within your WebCT or Blackboard course, will tell you how to obtain your new code.

Registering for McGraw-Hill Online Resources



to gain access to your mcgraw-hill web
resources simply follow the steps below:

- 1 USE YOUR WEB BROWSER TO GO TO: <http://www.mhhe.com/shier10>
- 2 CLICK ON **FIRST TIME USER**.
- 3 ENTER THE REGISTRATION CODE* PRINTED ON THE TEAR-OFF BOOKMARK ON THE RIGHT.
- 4 AFTER YOU HAVE ENTERED YOUR REGISTRATION CODE, CLICK **REGISTER**.
- 5 FOLLOW THE INSTRUCTIONS TO SET-UP YOUR PERSONAL UserID AND PASSWORD.
- 6 WRITE YOUR UserID AND PASSWORD DOWN FOR FUTURE REFERENCE.
KEEP IT IN A SAFE PLACE.

TO GAIN ACCESS to the McGraw-Hill content in your instructor's WebCT or Blackboard course simply log in to the course with the UserID and Password provided by your instructor. Enter the registration code exactly as it appears in the box to the right when prompted by the system. You will only need to use the code the first time you click on McGraw-Hill content.

thank you, and welcome
to your mcgraw-hill
online resources!

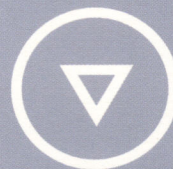


Higher
Education

* YOUR REGISTRATION CODE CAN BE USED ONLY ONCE TO ESTABLISH ACCESS. IT IS NOT TRANSFERABLE.
0-07-291931-0 SHIER: HOLE'S HUMAN ANATOMY AND PHYSIOLOGY, 10E

MCGRAW-HILL

ONLINE RESOURCES



BS5U-WX5J-Y2H4-8KNL-829Q

REGISTRATION CODE

Higher
Education
Mc
Graw
Hill

How's Your Math?

Do you have the math skills you need to succeed?



Why risk not succeeding because you struggle with your math skills?

Get access to a web-based, personal math tutor:

- Available 24/7, unlimited use
- Driven by artificial intelligence
- Self-paced
- An entire month's subscription **for much less** than the cost of one hour with a human tutor

ALEKS is an inexpensive, private, infinitely patient math tutor that's accessible any time, anywhere you log on.

ALEKS®

**Mc
Graw
Hill**

Log On for a
FREE 48-hour Trial

www.highedstudent.aleks.com

ALEKS is a registered trademark of ALEKS Corporation.

About the Authors

David Shier

David Shier has accumulated twenty-seven 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 Human Anatomy & Physiology* and *Hole's Essentials of Human Anatomy and Physiology*. David has published numerous papers and abstracts 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 conducting research on remission in leukemia patients. Now a popular educator 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 Human Anatomy & Physiology* and *Hole's Essentials of 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, author of the McGraw-Hill textbooks *Life* and *Human Genetics*, combines the skills of scientist and journalist. Since earning her Ph.D. in genetics from Indiana University in 1980, she has published more than 3,000 articles in scientific and popular publications. Today Ricki contributes regularly to *The Scientist* and *Biophotonics International*, and has published an essay collection, *Discovery: Windows on the Life Sciences*. She is a genetic counselor for a private medical practice in upstate New York. Ricki brings a molecular, cellular, and genetics perspective, with a journalistic flair, to *Hole's Human Anatomy & Physiology* and *Hole's Essentials of Human Anatomy and Physiology*.



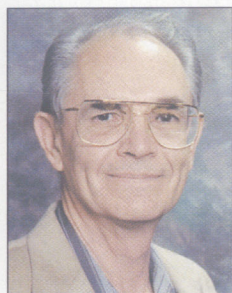
Ricki Lewis, David Shier, Jackie Butler

Preface

The Evolution of a Classic

In biological evolution, a population of organisms changes over time. Molded by natural selection, a successful species becomes the best suited that it can be for a particular environment. In a similar manner, this textbook has evolved over the past quarter century.

From its beginnings as a clear, concise, and exciting grand tour of the human body, John Hole's *Human Anatomy & Physiology* has matured into a modern exploration of the human, from its interacting organ systems to the cellular and molecular underpinnings of the functions of life. In our preface to the seventh edition, when we came on board to continue Dr. Hole's legacy, we termed his work "a classic." That it certainly is, with over one million copies sold worldwide over its 25-year history.



Dr. John W. Hole, Jr.

Dr. Hole tells of his book's origin:

"When I began teaching human anatomy and physiology 35 years ago, the nation was entering an era of increased space exploration, advances in civil rights, and influences of the women's movement. In the 1970s, the floppy disc appeared, rocks were the pets of choice, and *Star Wars* transported us to a galaxy far, far away. Despite the advances made during this era, the available anatomy and phys-

iology textbooks were lacking in some of the features I felt were desirable for my students.

The first edition of Hole's *Human Anatomy & Physiology*, published in 1978, reflected our efforts to prepare a textbook that would engage students and involve them actively in the learning process. The text included information of particular interest to allied health students and devices to help them relate their classroom knowledge to their future clinical practice. Boxed information illustrated how theory is applied to clinical practice, lists of terms and word parts expanded understanding of technical and medical terminology, and review activities within as well as at the end of each chapter aided the reader in evaluating his or her progress in achieving the chapter objectives.

As I think about the many years of work involved in preparing the first edition of the textbook, I am reminded of how much of it was a team effort, and I will be forever grateful for the help and support from all who were part of

the text's development and production. With each edition, the current authors continue to include, expand and improve the features that define this text."

Success came quickly for *Hole's Human Anatomy & Physiology*. One early adopter wrote, "I think it is one of the finest books of its kind I have ever seen. It is an excellent teaching text, the organization is superb, and its explanatory style is highly effective." Such praise is rare indeed for a first edition. By fall 1978, sales confirmed that John Hole's approach had struck a chord, and the publisher declared the textbook "an overwhelming success." Work began on the second edition, and the success exploded. With each revision, the textbook grew. Much of the black-and-white art evolved into full color, and certain chapters underwent a binary fission of sorts, the nervous system expanding into two chapters, and bones and joints given their own turf. New clinical case studies, practical applications, and laboratory applications continued to complement the trademark of clear explanations.

When we took over with the seventh edition a decade ago, space travel had become more common place, pet rocks had vanished, and the Internet was beginning to link us all together. Powerful imaging technologies added new views of anatomy and physiology, as nonstop discoveries in molecular and cellular biology and genetics revealed the mechanisms behind body functions. To embrace new knowledge while at the same time making the material accessible, we introduced a personal touch—compelling vignettes to open chapters and more tales of real people. Coverage of pathology ranged from the tragic to the commonplace to the quirky, usually offset in small boxes or sidebars so as not to interrupt the narrative flow. We delved into historical anecdotes where appropriate for understanding the present, while introducing new biomedical technologies. At the same time, increased coverage of homeostasis and a new feature to end the systems chapters, called *InnerConnections*, wove the text into a tighter fabric.

Other changes streamlined the learning process. We reorganized the chapter sequence, and placed the clinical case studies, practical applications, and laboratory applications under the umbrella heading of clinical applications. Improvements in art, text, as well as content updating, continued through the eighth edition. The ninth edition introduced a "life-span changes" section at the ends of the systems chapters, and a "reconnect" fea-

ture throughout to help the reader integrate the information, and more extensive on-line student resources. The final chapter evolved to become “Genetics and Genomics” to reflect the sequencing of the human genome and the emergence of a new field.

Just as world events helped to inspire the first edition of the book, so too have they influenced this anniversary edition. The vignette for the integumentary system chapter addresses a possible reintroduction of smallpox; that for the respiratory system chapter examines air quality concerns at the World Trade Center site in the months following September 11, 2001. This edition also introduces a developmental backdrop by considering how stem cells contribute to tissues, including two spectacularly redone illustrations, vignettes, a basic section in the Cells chapter, and relevant mentions throughout. Stem cells also star in three of the *From Science to Technology* boxes, which highlight the origins of medical and biotechnologies.

Audience

The tenth edition brings new awareness and reveals a new set of rules. In our evolution as authors we are evolving as teachers. What we and our reviewers do in class is reflected more in this than in previous editions. 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. We have never included detail for its own sake, but we have felt free to include extra detail if the end result is to clarify.

The level of this text is geared toward students in two-semester courses in anatomy and physiology who are pursuing careers in allied health fields and who have minimal background in physical and biological sciences. The first four chapters cover the chemistry and processes. Students who have studied this material previously will view it as a welcomed review, but newcomers will not find it intimidating.

What's New?

Over 25 years have passed, and *Hole's Human Anatomy & Physiology* is still *Hole's Human Anatomy & Physiology*—but with a sharper focus and appearance.

- **Design**—The revitalized text design injects new life into the study of Anatomy and Physiology. Bright, bold, modern colors are used throughout the feature boxes, tables, and chapter openers, making them easy to recognize.
- **Illustrations**—All illustrations have been revised. New art incorporates cutting-edge technology

offering vivid depictions of complex processes while maintaining the conceptual base that has established Hole as the most effective “instructional tool” on the market, with a unique focus on the fundamentals. Hole’s art focuses on the main concepts by using concise labeling methodology that keeps students from getting bogged down with excessive detail. Difficult concepts are broken down into easy-to-understand illustrations.

- **Chapter Openers**—Chapter opener images give you a closer look inside the wonders of the human body through the technology of scanning electron micrographs, endoscopic photography, and immunofluorescent light micrographs. The authors provide interesting, creative, and thought-provoking vignettes that introduce the chapter topics with readings on such topics as smallpox, heart transplants, and defibrillator implants.
- **From Science to Technology**—The new “From Science to Technology” readings cover topics such as *Cloning to Produce Therapeutic Stem Cells* and *Replacing the Liver*.
- **Clinical Applications**—New topics have been added to the Clinical Application boxes in several chapters. Read updates on Parkinson disease treatment, asthma, and food supplements.
- **Review Exercises and Critical Thinking**—Updated end-of-chapter review exercises help the student check their understanding of the chapter’s major ideas. Critical thinking questions encourage the student to apply information to clinical situations.
- **Online Learning Center**—New OLC activities and resources are available for students and instructors.
- **Digital Content Manager**—The *Digital Content Manager*, a multimedia collection of visual resources, allows instructors to utilize artwork from the text in multiple formats to create customized classroom presentations, visually-based tests and quizzes, dynamic course website content, or attractive printed support materials. The digital assets on this cross-platform CD-ROM are grouped by chapter within easy-to-use folders.

Updates and Additions

Chapter 1 reorders topics to provide a more solid foundation for understanding by presenting the internal environment in more detail with unique figures and introducing hierarchy of organization and various organ systems first. New figures on homeostatic mechanisms have also been added.

Chapter 2 features a revised presentation of dissociation of salts in water, a revised presentation of protein structure, and an improved explanation of electron shells and octet rule, and polar bonds. The explanation of saturated/unsaturated fatty acids and fats has also been reordered.

Chapter 3 presents a revised figure on osmosis, which now allows for equilibrium to be reached, thus better illustrating the relationship between intracellular and extracellular fluids. A new section covers stem and progenitor cells.

Chapter 4 offers additional steps shown in translation and a better representation of the relationship between chromosome structure and DNA.

Chapter 5 presents a new vignette on building a blood vessel plus the addition of a *From Science to Technology* reading on tissue engineering. The “types of membranes” topic from chapter 6 has been moved to chapter 5.

Chapter 6 introduces a new, boxed reading on the causes as well as the anatomical and physiological effects of sunburn. A new vignette on smallpox has been added at the beginning of the chapter.

Chapter 7 features revised skeletal figures that present a consistent right side orientation. *Skeletons From the Past* is the new chapter opener vignette.

Chapter 9 presents a clearer relationship between thick and thin filaments, striation pattern, and the explanation of the sliding filament model. A new figure on muscle contraction shows the crossbridge cycle and the relationship to relaxed state. New art for muscles has been added throughout. Terminology is now more consistent with *Terminologia Anatomica*, except when such convention conflicts with current clinical usage.

Chapter 10 introduces a new figure showing the relationship between CNS and PNS, including motor and sensory divisions of PNS and the somatic and autonomic divisions of the motor portion. Unipolar neurons are now shown to have an axon with a central process and a peripheral process.

Chapter 11 features a revised presentation of neuroanatomy distinguishing between gray matter and white matter.

Chapter 12 offers new illustrations of the inner ear.

Chapter 13 provides a new illustration and a new table that compare the nervous and endocrine systems and highlights the importance of target cells.

Chapter 14 introduces the topic of blood with a new vignette on blood substitutes.

Chapter 15 provides added and expanded information on the control of blood pressure; end-diastolic volume, end-systolic volume, and preload. A new vignette on defibrillator implants opens the chapter.

Chapter 16 presents a new section on *Natural Killer Cells (NK)*, includes expanded information on MHC classes, and a new table on the comparison of T cells and B cells. The topic of peanut allergies is featured in the chapter-opening vignette.

Chapter 17 *From Science to Technology 17.1* features a new reading on liver replacement, and the introductory chapter vignette covers a brief history of constipation.

Chapter 18 features an expanded section on appetite control and a new vignette on preventing vitamin D deficiency.

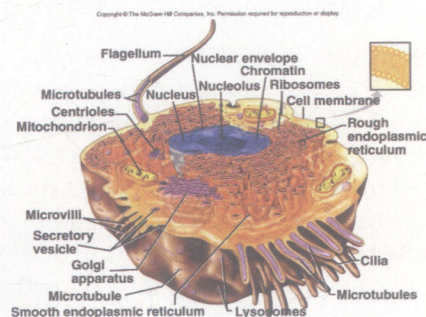
Chapter 20 has improved art pieces presenting kidney anatomy, the countercurrent mechanism, and the mechanism of urine concentration.

Chapter 23 presents a new vignette on multiple births and a new table on the stages and events of early human prenatal development. Pregnancy, the birth process and milk production are now included in this chapter.

Chapter 24 provides an update on human genome sequencing results and chromosomal abnormalities.

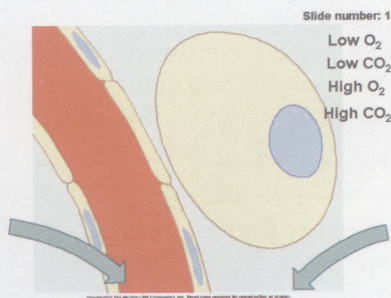
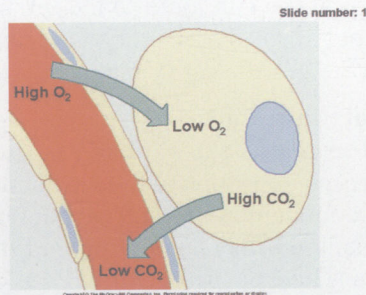
Teaching and Learning Supplements

McGraw-Hill offers various tools and teaching products to support the tenth edition of *Hole's Human Anatomy & Physiology*. Students can order supplemental study materials by contacting your local bookstore. Instructors can obtain teaching aids by calling the Customer Service Department at 800-338-3987, visiting our A&P website at www.mhhe.com, or contacting your local McGraw-Hill sales representative.

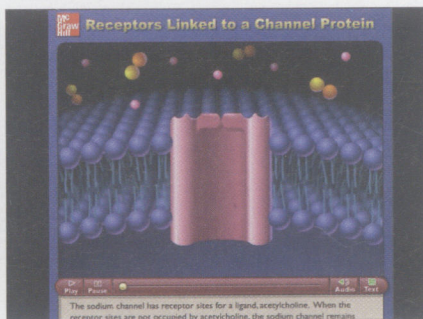


The **Digital Content Manager**, 0-07-243895-9, is a multimedia collection of visual resources that

allows instructors to utilize artwork from the text in multiple formats to create customized classroom presentations, visually-based tests and quizzes, dynamic course website content, or attractive printed support materials. The digital assets on this cross-platform CD-ROM are grouped by chapter within the following easy-to-use folders.



- **Active Art Library** Key Process Figures from the text are saved in manipulable layers that can be isolated and customized to meet the needs of the lecture environment.



- **Animations Library** Numerous full-color animations of key physiological processes are provided. Harness the visual impact of processes in motion by importing these files into classroom presentations or course websites.
- **Art Libraries** Full-color digital files of all illustrations in the book, plus the same art saved in unlabeled and gray scale versions, can be readily incorporated into lecture presentations, exams, or custom-made

classroom materials. These images are also pre-inserted into blank PowerPoint slides for ease of use.

- **Photo Libraries** Digital files of instructionally significant photographs from the text—including cadaver, bone, histology, and surface anatomy images—can be reproduced for multiple classroom uses.
- **PowerPoint Lectures** Ready-made presentations that combine art and lecture notes have been specifically written to cover each of the 24 chapters of the text. Use the PowerPoint lectures as they are, or tailor them to reflect your preferred lecture topics and sequences.
- **Tables Library** Every table that appears in the text is provided in electronic form. You can quickly preview images and incorporate them into PowerPoint or other presentation programs to create your own multimedia presentations. You can also remove and replace labels to suit your own preferences in terminology or level of detail.

Instructor Testing and Resource CD-ROM,

0-07-282738-6, is a cross-platform CD-ROM providing a wealth of resources for the instructor. Supplements featured on this CD-ROM include a computerized test bank utilizing Brownstone Diploma® testing software to quickly create customized exams. This user-friendly program allows instructors to search for questions by topic, format, or difficulty level; edit existing questions or add new ones; and scramble questions and answer keys for multiple versions of the same test.

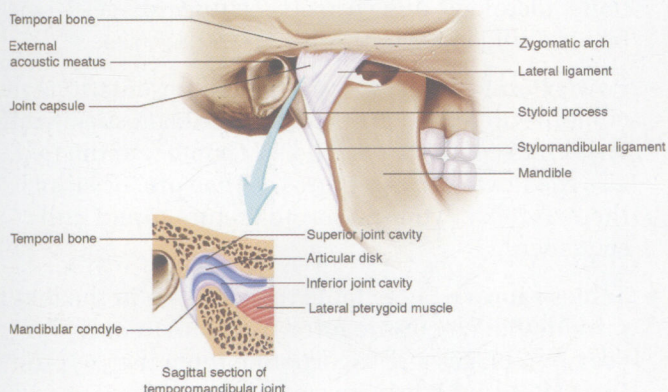
Other assets on the Instructor's Testing and Resource CD-ROM are grouped within easy-to-use folders. The Instructor's Manual and the Instructor's Manual to accompany the Laboratory Manual are available in both Word and PDF formats. Word files of the test bank are included for those instructors who prefer to work outside of the test generator software.

The ***Instructor's Manual***, by Michael F. Peters includes supplemental topics and demonstration ideas for your lectures, suggested readings, critical thinking questions, and teaching strategies. The Instructor's Manual is available through the Instructor Resources of the Online Learning Center and the Instructor Testing and Resource CD-ROM.

McGraw-Hill provides **Overhead Transparencies, Labeled** 0-07-243894-0, of all text line art and numerous photos and **Unlabeled** 0-07-284222-9, of key line art and photos.

English/Spanish Glossary for Anatomy and Physiology, 0-07-283118-9, is a complete glossary that includes every key term used in a typical two-semester

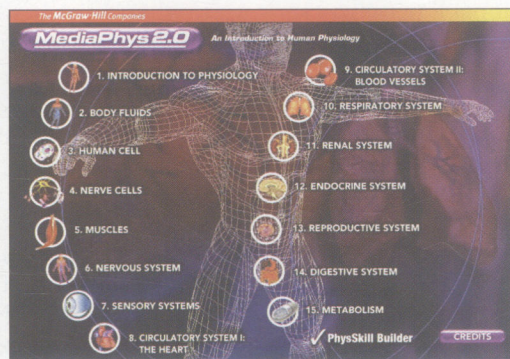
anatomy and physiology course. Definitions are provided in both English and Spanish. A phonetic guide to pronunciation follows each word in the glossary.



A Visual Guide for Anatomy and Physiology, 0-07-286378-1, is a visual atlas containing key gross anatomy illustrations that have been enlarged in size to make it easier for students to learn anatomy.

Course Delivery Systems With help from our partners, WebCT, Blackboard, TopClass, eCollege, and other course management systems, professors can take complete control over their course content. These course cartridges also provide online testing and powerful student tracking features. *Hole's Human Anatomy & Physiology* Online Learning Center is available within all of these platforms.

For the Student



MediaPhys 2.0 CD-ROM

This interactive tool offers detailed explanations, high quality illustrations and animations to provide students with a thorough introduction to the world of physiology—giving them a virtual tour of physiological processes. MediaPhys is filled with interactive activities and quizzes to help reinforce physiology concepts that are often difficult to understand.

Online Learning Center (<http://www.mhhe.com/shier10>)

The OLC offers an extensive array of learning and teaching tools. The site includes quizzes for each chapter, links to websites related to each chapter, clinical applications, interactive activities, art labeling exercises, and case studies. Students can click on a diagram of the human body and get case studies related to the regions they select. Instructor resources at the site include lecture outlines, technology resources, clinical applications, and case studies.

• Essential Study Partner

The ESP contains 120 animations and more than 800 learning activities to help your students grasp complex concepts. Interactive diagrams and quizzes will make learning stimulating and fun for your students. The Essentials Study Partner can be accessed via the Online Learning Center.

• Live News Feeds

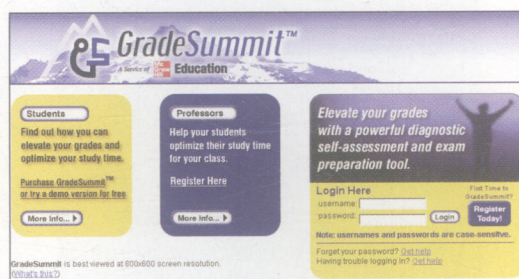
The OLC offers course specific real-time news articles to help students stay current with the latest topics in anatomy and physiology.

• Tutorial Service

This free “homework hotline” offers students the opportunity to discuss text questions with our A&P consultant.

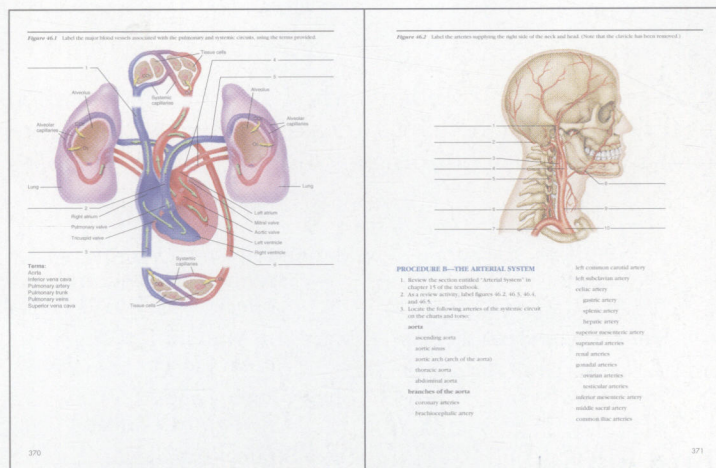
• GetBody Smart.com is an online examination of human anatomy and physiology.

• Access Science is the online version of McGraw-Hill's Encyclopedia of Science & Technology. Link to this site free of charge from the Online Learning Center.

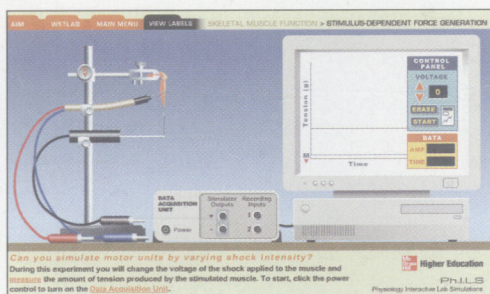


GradeSummit (www.gradesummit.com)

This Internet-based self-assessment service provides students and instructors with diagnostic information about subject strengths and weaknesses. This detailed feedback and direction enables learners and teachers to focus study time on areas where it will be most effective. GradeSummit also enables instructors to measure their students' progress and assess that progress relative to others in their classes and worldwide.



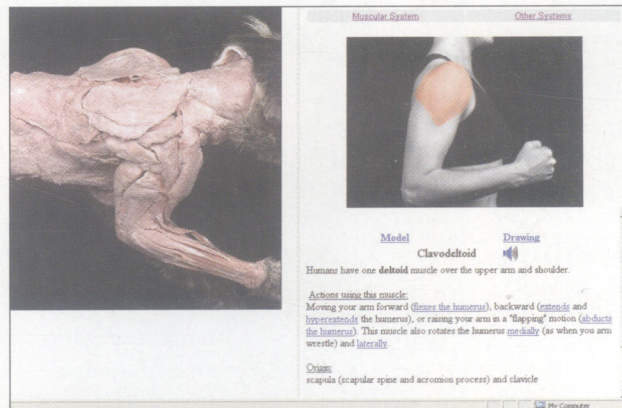
The Laboratory Manual for Hole's Human Anatomy & Physiology, Tenth Edition, 0-07-243891-6, by Terry R. Martin, Kishwaukee College
This lab manual is designed to accompany the tenth edition of *Hole's Human Anatomy and Physiology*.



Physiology Interactive Lab Simulations (Ph.I.L.S.)
The Ph.I.L.S. CD-ROM contains eleven laboratory simulations that allow students to perform experiments without using expensive lab equipment or live animals. This easy-to-use software offers students the flexibility to change the parameters of every lab experiment, with no limit to the amount of times a student can repeat experiments or modify variables. This power to manipulate each experiment reinforces key physiology concepts by helping students to view outcomes, make predictions, and draw conclusions.

Student Study Guide, 0-07-243893-2, by Nancy A. Sickles Corbett contains chapter overviews, chapter objectives, focus questions, mastery tests, study activities, and mastery test answers.

Anatomy and Physiology Laboratory Manual—Fetal Pig, Second Edition, 0-07-243814-2, by Terry R. Martin, provides excellent full-color photos of the dissected fetal pig with corresponding labeled art. It includes World Wide Web activities for many chapters.



Virtual Anatomy Dissection Review, CD-ROM, 0-07-285621-1, by John Waters, Pennsylvania State University
This multimedia program contains vivid, high quality labeled cat dissection photographs. The program helps students easily identify and review the corresponding structures and functions between the cat and the human body.

Life Science Animation CD-ROM, 0-07-234296-X, contains 125 animations of major biological concepts and processes such as the sliding filament mechanism, active transport, genetic transcription and translation, and other topics that may be difficult for students to visualize.

Laboratory Atlas of Anatomy and Physiology, fourth edition, 0-07-243810-X, by Eder et al., is a full-color atlas containing histology, human skeletal anatomy, human muscular anatomy, dissections, and reference tables.

Acknowledgments

Any textbook is the result of hard work by a large team. Although we directed the revision, many "behind-the-scenes" people at McGraw-Hill were indispensable to the project. We would like to thank our editorial team of Michael Lange, Marty Lange, Kris Tibbetts, Michelle Watnick, and Pat Hesse; our production team, which included Jayne Klein, Sandy Ludovissy, Wayne Harms, John Leland, Sandy Schnee, Barb Block; Joanne Bales, art director, Precision Graphics; and most of all, John Hole, for giving us the opportunity and freedom to continue his classic work. We also thank our wonderfully patient families for their support.

David Shier

Jackie Butler

Ricki Lewis

Reviewers

We would like to acknowledge the valuable contributions of all professors and their students who have provided detailed recommendations for improving chapter content and illustrations throughout the revision process for each edition. Hundreds of professors from the U.S., Canada, and Europe have played a vital role in building a solid foundation for *Hole's Human Anatomy & Physiology*.

First Edition

Edward Barnett, *Kellogg Community College*
Nancy Corbett, *Thomas Jefferson University*
Jesse Dolson, *Delta College*
John Frehn, *Illinois State University*
John Harley, *Eastern Kentucky University*
Theodore Hollis, *Penn State University*
Ann Lesak, *Moraine Community College*
Robert Nabors, *Tarrant County Junior College*
Richard Pflanzner, *Indiana University*
John Childrey, *Purdue University*
Judy Best, *Purdue University*
Mary Dorhman, *University of Northern Iowa*

Second Edition

Edward M. Barnett, *Kellogg Community College*
William Bednar, *C.S. Mott Community College*
Colin Campbell, *Pima Community College*
Jessie Dolson, *Delta College*
Hester Fassel, *Iowa State University*
Yola Forbes, *Iowa State University*
John Frehn, *Illinois State University*
Cecilia Valle Gonzales, *St. Philip's College*
Terry E. Greathouse, *Cuyahoga Community College*
Joe Harbor, *San Antonio College*
John P. Harley, *Eastern Kentucky University*
Eugene S. Horowitz, *Queensborough Community College*
Anne Lesak, *Moraine Valley Community College*
Robert E. Nabors, *Tarrant County Junior College*
Richard Northrup, *Delta College*

Joseph R. Powell, *Florida Junior College*
Margaret Howarth Przyogda, *Middlesex County College*
Ed Reschke, *Muskegon Community College*
Ethel Sloane, *University of Wisconsin, Milwaukee*
Jane McNamara Bieber, *Virginia Commonwealth University*
Anne Denner, *Indiana State University, Evansville*
Joyce M. Dungan, *University of Evansville*
Jerry O. Erkert, *Santa Fe Community College*
James Ezell, *J. Sargeant Reynolds Community College*
William Garretson, *Valencia Community College*
Mary Etta Hight, *Marshall University*
Edward C. Hurlbut, *Mesa College*
Kenneth L. Jones, *Mt. San Antonio College*
Thomas S. Kaufman, *Montgomery College*
Jack Kildebeck, *Bakersfield College*
Donald S. Kisiel, *Suffolk County Community College*
Mary Linda Lungren, *Community College of Denver*
Margaret May, *Virginia Commonwealth University*
Mary Lou Mulvihill, *William Rainey Harper College*
Patricia M. O'Mahoney, *University of Southern Maine*
Harry S. Reasor, *Miami-Dade Community College*
Jo Ann Robertson, *Western Illinois University*
Curtis Robinson, *Milwaukee Area Technical College*
Maggie Sample, *Valencia Community College*
Elise Schoenfeld, *University of Albuquerque*
Louis Squitieri, *Bronx Community College*

G. Arthur Stephens, *Arapahoe Community College*
Michael J. Timmons, *Moraine Valley Community College*
Kent. M. Van De Graff, *Brigham Young University*

Third Edition

Allan L. Abati, *California State University Long Beach*
Lucille Aulsebrook, *Vanderbilt University*
Shirley Bishel, *Rio Hondo College*
Mary Jane Burge, *Cuyahoga Community College*
Warren Burggren, *University of Massachusetts*
Robert Catlett, *University of Colorado, Colorado Springs*
Philip L. Cooper, *Suffolk County Community College*
Ruthanna Dyer, *Seneca College*
David E. Grosland, *Iowa Central Community College*
William C. Kleinelp, Jr., *Middlesex County College*
Brenda H. Knight, *Catawba Valley Technical College*
Roxine McQuitty, *Milwaukee Area Technical College*
John A. Martin, *Clark College*
T. Pavlovitch, *Pasadena City College*
Frank C. Salter, *Jacksonville State University*
Donald A. Wheeler, *Cuyahoga Community College*
Louis Wigginton, *St. Clair County Community College*
Calvin G. Beams, Jr., *Oklahoma State University*
Donna Edwards, *Olympia Technical Community College*
Steve Hager, *University of Scranton*
Roy Hyle, *Thomas Nelson Community College*
Paula Holloway, *Lewis and Clark Community College*

Mariana Holson, *Olympia Technical Community College*
Mary Lou Mulvihill, *William Rainey Harper College*
Sherry Stair, *Thomas Nelson Community College*
Dave Straley, *University of Dubuque*

Fourth Edition

Thomas S. Kaufman, *Montgomery College*
Robert E. Nabors, *Tarrant County Junior College*
James W. Russell, *Georgia Southwestern College*
Louise Squitieri, *Bronx Community College*
Howard M. Fuld, *Bronx Community College*
Gerald R. Dotson, *Front Range Community College*
Robert D. Morden, *University of Wisconsin-Superior*
Ahmad Kamal, *Olive-Harvey College*
Karen A. Koos, *Rio Hondo College*

Fifth Edition

Richard Anderson, *Modesto Junior College*
Helene Auld, *Northeast Iowa Technical Institute*
Paul Badaracco, *Yuba College*
Phil J. Costa, *Queensborough College of the City University of New York*
Paul R. Holmgren, *Northern Arizona University*
Dennis D. Kalichstein, *Ocean County College*
Anne E. Lesak, *Moraine Valley Community College*
Ronald A. Markle, *Northern Arizona University*
Constance R. Martin, *Hunter College of the City University of New York*
Richard L. Myers, *Southwest Missouri State University*

Fredrick Prince, *Plymouth State College*
 Cecelia Thomas, *Hinds Community College*
 Carol B. Veil, *Anne Arundel Community College*

Sixth Edition

David Logan, *York University*
 Terry R. Martin, *Kishwaukee College*
 Aaron E. James, *Gateway Community College*
 Dr. Louis A. Giacinti, *Milwaukee Area Technical College*
 Clarence C. Wolfe, *Northern Virginia Community College*
 Dale A. DesLauriers, *Chaffey College*
 Jean S. Helgeson, *Collin County Community College*
 Nancy Ann S. Corbett, *Camden College of Arts, & Sciences*
 Edwin J. Bessler, *Franciscan University of Steubenville*
 Ed Krol, *Henry Ford Community College*
 Dwight Kamback, *Northhampton Community College*
 Robert Smith, *Forest Park Community College*
 John H. Dustman, *Indiana University Northwest*

Seventh Edition

Susan M. Behling, *Concordia University Wisconsin*
 Charles H. Bennett, *Kentucky State University*
 Barbara A. Bernardi, *Springfield College in Illinois*
 Moges Bizuneh, *IVY Tech State College*
 Brenda C. Blackwelder, *Central Piedmont Community College*
 Stanton Braude, *Washington University, University of Missouri at St. Louis*
 Wanda L. Buckland, *Dabney S. Lancaster Community College*
 Judith Carpenter, *Columbus State Community College*
 Melvin C. Chambliss, *Michigan State University*
 F. Jeffrey Chyatte, *University of Maryland*
 Karen M. Cianci, *Houghton College*

Rosanne M. Ciccio, *D'Youville College*
 Nancy A. Sickles Corbett, *Rutgers The State University of New Jersey*
 James E. Cordes, *Louisiana State University at Eunice*
 Michael Corral, *Darrow School*
 Jean Cremins, *Massachusetts Bay Community College*
 Opal H. Dakin, *Hinds Community College*
 Patricia R. Daron, *Northern Virginia Community College*
 Winifred B. Dickinson, *Franciscan University of Steubenville*
 Michael A. Dorset, *Cleveland State Community College*
 Victor P. Eroschenko, *University of Idaho*
 L. Fleming Fallon, *Jameson Hospital, Columbia University School of Public Health*
 Bruce A. Fisher, *Roane State Community College*
 Kate Fleury, *Lake Washington Technical College*
 Pamela B. Fouché, *Walters State Community College*
 Ralph F. Fregosi, *The University of Arizona*
 William S. Garlick, *Arizona State University*
 Phyllis Gee, *University of Manitoba*
 Mike Gehner, *Xavier University*
 H. R. Giesman, *North Iowa Area Community College*
 Sister Terence Glum, *University of Mary*
 Keith R. Graham, *Lutheran College of Health Professions*
 Darryl V. Grennell, *Alcorn State University*
 Kevin Jon Gyolai, *North Dakota State College of Science*
 Ruth L. Hays, *Clemson University*
 Jimmie F. Hughey, *St. John's University*
 Robert L. Jochen, *Blue Ridge Community College*
 Jerry M. Johnson, *Western Baptist College*
 Ronald L. Johnson, *Arkansas State University*

Drusilla B. Jolly, *Forsyth Technical Community College*
 Joan H. Jones, *Naugatuck Valley Community-Technical College*
 Brian E. Jordan, *Lansing Community College*
 Kamal I. Kamal, *Valencia Community College-West Campus*
 Dwight Kamback, *Northampton Community College*
 Judith Kasperek, *Pitt Community College*
 Gary Kennedy, *Lethbridge Community College*
 Frank G. Kitakis, *Wayne County Community College*
 John E. Kovaleski, *Indiana State University*
 Jeffrey R. LaDuca, *Canisius College*
 Billie S. Lane, *Chattanooga State Technical Community College*
 Gina Langley, *Eastern New Mexico University-Ruidoso*
 Mary T. Leonard, *University of Dayton*
 Mary Katherine Lockwood, *University of New Hampshire*
 D. M. Logan, *York University*
 Bonita L. Longo, *Community Hospital School of Nursing*
 Charmayne Mack, *Rosary College*
 Dennis Malek, *Triton College*
 Terry R. Martin, *Kishwaukee College*
 William J. Mathena, *Kaskaskia College*
 Pamela S. McLaughlin, *Madisonville Community College*
 Michael C. Meyers, *Montana State University*
 Robert D. Muckel, *Doane College*
 Shirley Mulcahy, *San Diego Mesa College*
 Tara Narayansingh, *University of Manitoba*
 J. Felix Palmer, *Tulane University*
 Brian K. Paulson, *California University of Pennsylvania*
 Carlos F. A. Pinkham, *Norwich University*
 Pam Rhyne, *Kennesaw State College*

Kristi Sather-Smith, *Hinds Community College*
 Robert A. Sharp, *Aquinas College*
 Clyde F. Smith, *Odessa College*
 Jean E. Smith, *Carroll College*
 Shirley N. Smith, *Lansing Community College*
 Paulette R. Snyder, *Erie Community College, North*
 Janet E. Steele, *University of Nebraska at Kearney*
 Stuart S. Sumida, *California State University-San Bernardino*
 Donald L. Terpening, *Ulster County Community College*
 William R. Tobin, Jr., *Erie Community College South Campus*
 Robin Vance, *Union College*
 Dianne L. Vermillion, *University of Rochester*
 Margaret G. Wade, *Midland College*
 Robert C. Wall, *Lake-Sumter Community College*
 Garry M. Wallace, *Northwest College*
 Leslie Jayne Wallace, *Baker College of Owosso*
 Alan R. Wasmoen, *Iowa Central Community College*
 Carl F. Wellstead, *West Virginia Institute of Technology*
 Philip C. Whitford, *Capital University*
 Barbara Wineinger, *Vincennes University Jasper*
 Clarence C. Wolfe, *Northern Virginia Community College-Annandale Campus*
 Ricky K. Wong, *Los Angeles Trade-Technical College*
 Diana L. Wyman, *New Hampshire Technical College*

Special Contributors

Louis A. Giacinti, *Milwaukee Area Technical College*
 Charles J. Grossman, *Xavier University, Research Service, Veterans Affairs Medical Center*
 Virginia Rivers, *Truckee Meadows Community College*
 Kenneth S. Saladin, *Georgia College*

D. M. Van Wynsberghe,
*University of Wisconsin-
Milwaukee*

Leslie J. Wiemerslage, *Belleville
Area College*

Eric A. Wise, *Santa Barbara City
College*

Eighth Edition

Janice Asel, *Mitchell Community
College*

Beth M. Atkin, *Washington State
Community College*

Gordon Atkins, *Andrews
University*

Stephanie Sajdak Baiyasi, *Delta
College*

Anna Bartosh, *Howard County
Junior College*

William R. Belzer, *Clarion
University of
Pennsylvania-
Venango Campus*

Edwin Bessler, *Franciscan
University of Steubenville*

E. Beth Bonner, *Delgado
Community College*

Ray D. Burkett, *Shelby State
Community College*

Rebecca M. Burt, *Southeast
Community College-
Beatrice Campus*

Jennifer Carr Burtwistle,
*Northeast Community
College*

Michael S. Capp, *Carlow College*

Holly Carmichael, *Wilson
Technical Community
College*

Melvin C. Chambliss, *Michigan
State University's
Veterinary Technology
Program*

William H. Chrouser, *Warner
Southern College*

Lu Anne Clark, *Lansing
Community College*

Barbara J. Cohen, *Delaware
County Community
College*

Mary Catharine Cox, *Wingate
University*

Allen R. Crooker, Jr., *Hartwick
College*

Lin Doyle, *Northwest College*

Duane A. Dreyer, *Durham
Technical Community
College*

Peter I. Ekechukwu, *Horry-
Georgetown Technical
College*

Barbara F. Ensley, *Haywood
Community College*

Gary Estep, *Lubbock Christian
University*

Louis A. Giacinti, *Milwaukee
Area Technical College*

William A. Gibson, *University
of New Orleans*

Susan K. Gilmore, *University
of Pittsburgh at Bradford
Jamestown Community
College*

David E. Harris, *Lewiston-
Auburn College,
University of Southern
Maine*

George E. Heath, *University
of Maryland Eastern Shore*

Drusilla Beal Jolly, *Forsyth
Technical Community
College*

Beverly W. Juett, *Midway College*

Kamal I. Kamal, *Valencia
Community College, West
Campus*

Gary M. Kiebzak, *Miller
Orthopaedic Clinic,
Charlotte, NC*

Glenn E. Kietzmann, *Wayne
State College*

Alan Knowles, *Pensacola
Christian College*

Kristin Krause, *Saint Thomas
Aquinas College*

Gopal Krishna, *Moberly Area
Community College*

Barbara Lax, *Community College
of Allegheny County*

Nancy Longlet, *Concordia
College*

Lisa Lupini, *Baker College
of Flint*

Bradford D. Martin, *La Sierra
University*

William J. Mathena, *Kaskaskia
College*

Julie A. Medlin, *Northwestern
Michigan College*

Jim Miller, *College of the
Southwest*

Eli C. Minkoff, *Bates College*

Robert Moldenhauer, *Washtenaw
Community College*

James (Jym) C. Moon, *Western
Iowa Technical
Community College*

David Mork, *Saint Cloud State
University*

C. Aubrey Morris, *Pensacola
Junior College*

Tony E. Morris, *Fairmont State
College*

Steve C. Nunez, *Sauk Valley
Community College*

Nicole J. Okazaki, *Southeastern
Louisiana University*

Charles M. Page, *El Camino
College*

Mark A. Paulissen, *McNeese
State University*

Mary S. Rea, *Sage Junior College*

Donald Rodd, *University
of Evansville*

Connie E. Rye, *Bevill State
Community College*

David A. Sandmire, *University
of New England*

Soma Sanyal, *Penn
State-Altoona*

Marilyn Shopper, *Johnson
County Community
College*

Richard Sims, *Jones County
Junior College*

Katherine Smalley, *Emporia
State University*

Denise L. Smith, *Skidmore
College*

Michael E. Smith, *Valdosta State
University*

Paul M. Spannbauer, *Hudson
Valley Community College*

Marian Spozio, *Jefferson
Community College*

Sarah Anne Staples, *Andrew
College*

John R. Steele, *Ivy Tech State
College*

Dennis M. Sullivan, *Cedarville
College*

P. Alleice Summers, *Dyersburg
State Community College*

Patricia J. Thomas, *Delgado
Community College*

William R. Tobin, *West Valley
Central School*

Don Varnado, *Southern Ohio
College-Northern
Kentucky Campus*

Dianne L. Vermillion, *School
of Nursing-University
of Rochester*

Garry M. Wallace, *Northwest
College*

Norma J. Weekly, *Wilkes
Community College*

Christine A. Wilson, *Community
College of Allegheny
County-Boyce Campus*

Barbara Wineinger, *Vincennes
University Jasper*

Clarence C. Wolfe, *Northern
Virginia Community
College Annandale
Campus*

Ninth Edition

Marion Alexander, *University
of Manitoba*

Angela J. Andrews, *Redlands
Community College*

Martha W. Andrus, *Grambling
State University*

Timothy A. Ballard, *University
of North Carolina
at Wilmington*

Brenda C. Blackwelder, *Central
Piedmont Community
College*

James Bridger, *Prince George's
Community College*

Carolyn Burroughs, *Bossier
Parish Community College*

Edward W. Carroll, *Marquette
University*

Margaret Chad, *Saskatchewan
Institute of Applied
Science & Technology*

Lynda B. Collins, *Mississippi
College*

Shirley A. Colvin, *Gadsden State
Community College*

Wilfrid DuBois, *D'Youville
College*

Sondra Dubowsky, *Allen County
Community College*

John Erickson, *Ivy Tech State
College*

Marilyn Ziegler Franklin,
*Grambling State
University*

Brent M. Graves, *Northern
Michigan University*

Mary Guise, *Mohawk College
of Applied Arts
& Technology*

Michael J. Harman, *North Harris
Montgomery Community
College*

Alan G. Heath, *Virginia
Polytechnic Institute
& State University*

Julie A. Huggins, *Arkansas State
University*

Marsha Jones, *Southwestern
Community College*

Beverly W. Juett, *Midway College*

Jeffrey S. Kiggins, *Blue Ridge
Community College*

Nancy G. Kincaid, *Troy State University Montgomery*

Alan C. Knowles, *Pensacola Christian College*

Donna A. Kreft, *Iowa Central Community College*

Mary Katherine Lockwood, *University of New Hampshire*

Josephine Macias, *West Nebraska Community College*

Qian Frances Moss, *Des Moines Area Community College*

Sheila A. Murray, *Berkshire Community College*

Steve Nunez, *Sauk Valley Community College*

Augustine I. Okonkwo, *Norfolk State University*

Amy Griffin Ouchley, *University of Louisiana at Monroe*

David J. Pierotti, *Northern Arizona University*

John Romanowicz, *International School of Amsterdam*

David K. Saunders, *Emporia State University*

Melvin Schmidt, *McNeese State University*

Brian Shmaefsky, *Kingwood College*

Bharathi P. Sudarsanam, *Labette Community College*

Gary Lee Tieben, *University of Saint Francis*

John M. Wakeman, *Louisiana Tech University*

Murray B. Weinstein, *Erie Community College, City Campus*

Eddie L. Whitson, *Gadsden State Community College*

Tenth Edition

Pegge Alciatore, *University of Louisiana Lafayette*

Vivian T. Anderson, *Oakland Community College—Auburn Hills*

Sharon R. Barnewall, *Columbus State Community College*

Charles J. Biggers, *University of Memphis*

Jennifer Borash, *Horry-Georgetown Technical College*

Karen Borg, *Midlands Technical College*

Sara Brenizer, *Shelton State Community College*

Joseph Cameron, *Hinds Community College*

Kenneth Carpenter, *Southwest Tennessee Community College*

Sandra I. Caudle and students, *Calhoun Community College*

W. Wade Cooper, *Shelton State Community College*

Larry G. DeLay, *Waubensee Community College*

Nichol Dolby, *Amarillo College*

Ardath Egle, *University of Texas—Pan American*

Mary Catherine Flath and students of Anatomy I and II, *Ashland Community College*

Tom M. Graham, *University of Alabama*

Kathryn Gronlund, *Edison Community College*

Linden C. Haynes, *Hinds Community College*

Jacqueline A. Homan, *South Plains College*

Dale R. Horeth, *Tidewater Community College*

Dianne M. Jedlicka, *The School of the Art Institute of Chicago*

Narinder Kapoor, *Concordia University*

Mary Katherine Lockwood, *University of New Hampshire*

Jane R. Marone, *University of Illinois—Chicago*

William J. Mathena, *Kaskaskia College*

Richard McCloskey, *Boise State University*

W. J. McCracken, *Tallahassee Community College*

Robert C. McReynolds, *San Jacinto College Central*

Stephen H. McReynolds, *Tarleton State University*

Sharon Miles, *Itawamba Community College*

John E. Moore, *Parkland College*

Jesse J. Myers, student, *Oregon State University*

Augustine Okonkwa, *Norfolk State University*

Linda Nichols, *Sante Fe Community College*

Justicia Opoku, *University of Maryland, College Park*

Margaret (Betsy) Ott, *Tyler Junior College*

Julie C. Pilcher, *University of Southern Indiana*

Linda Powell, *Community College of Philadelphia*

Mattie Roig, *Broward Community College*

Melvin Schmidt, *McNeese State University*

Michael Squires, *Columbus State Community College*

Sarah Strong, *Austin Community College*

Mark Wygoda, *McNeese State University*

Canadian Reviewers

Mary T. Guise, *Mohawk College of Applied Arts and Technology*

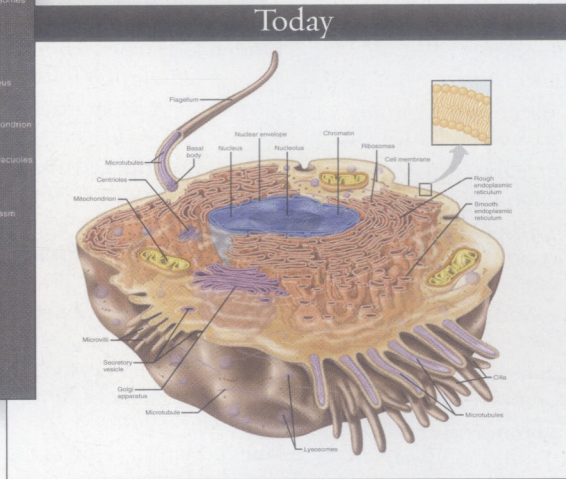
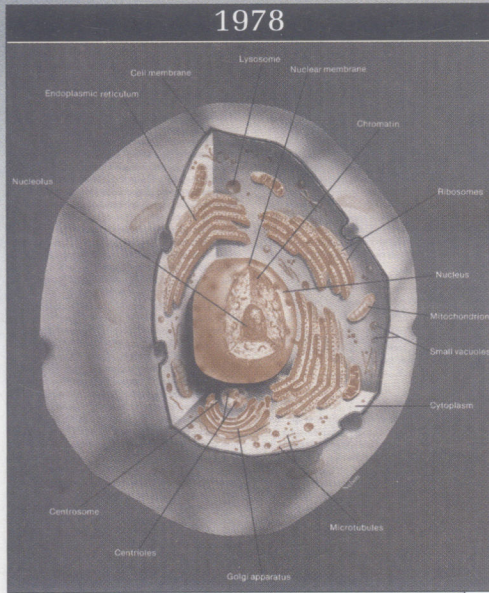
William (Bill) Magill, *Humber College*

Donna Newhouse, *Lakehead University*

Delia Roberts, *Selkirk College*

Hole's Human Anatomy & Physiology

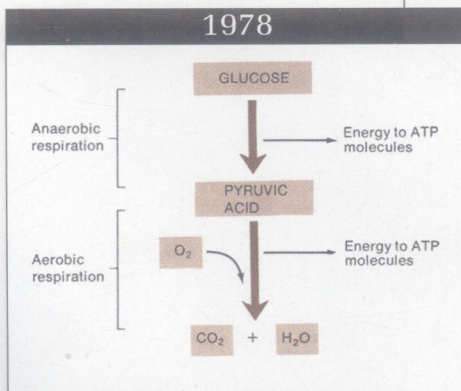
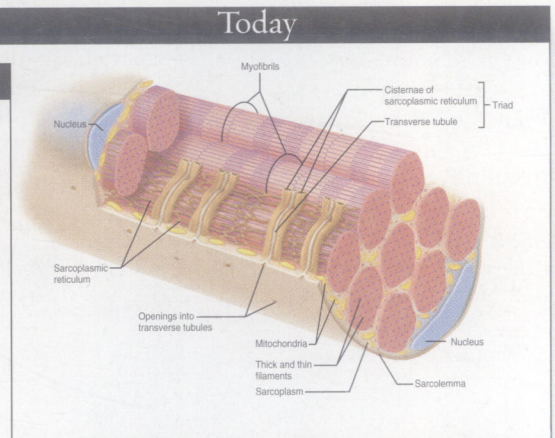
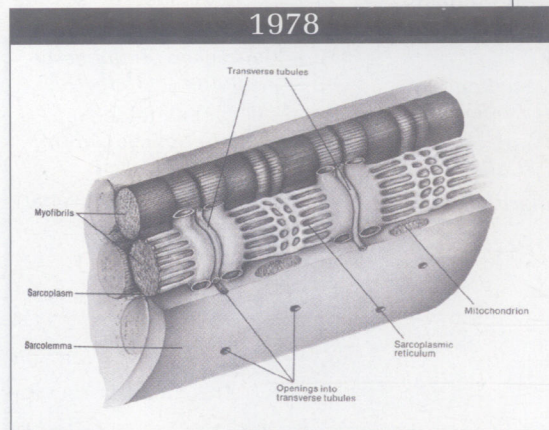
Over 25 years have passed, and *Hole's Human Anatomy & Physiology* is still *Hole's Human Anatomy & Physiology*—but with a sharper focus and appearance.



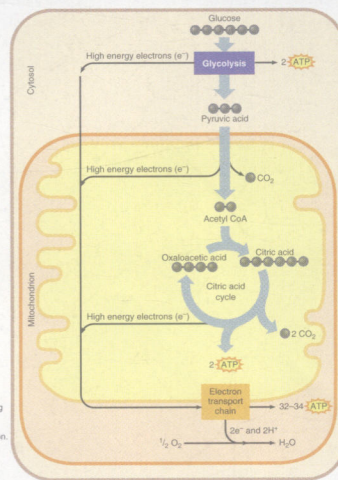
New and Revised Art

incorporates cutting-edge technology offering vivid depictions of complex processes while maintaining the conceptual base that has established Hole as the most effective “instructional tool” on the market with a unique focus on the fundamentals.

Hole's art is focused on the main concepts by using concise labeling methodology that keeps students from getting bogged down with excessive detail.



- Glycolysis**
- The 6-carbon sugar glucose is broken down into two 3-carbon pyruvic acid molecules with a net gain of 2 ATP and the release of high energy electrons.
- Citric Acid Cycle**
- The 3-carbon pyruvic acids generated by glycolysis enter the mitochondria. Each loses a carbon (generating CO_2) and is combined with a coenzyme to form a 2-carbon acetyl coenzyme A (acetyl CoA). More high energy electrons are released.
 - Each acetyl CoA combines with a 4-carbon oxaloacetic acid to form the 6-carbon citric acid, for which the cycle is named. For each citric acid a series of reactions removes 2 carbons (generating 2 CO_2), synthesizes 1 ATP and releases more high energy electrons. The figure shows 2 ATP, resulting directly from 2 turns of the cycle per glucose molecule that enters glycolysis.
- Electron Transport Chain**
- The high energy electrons still contain most of the chemical energy of the original glucose molecule. Special carrier molecules bring the high energy electrons to a series of enzymes that convert much of the remaining energy to more ATP molecules. The other products are heat and water. The requirement of oxygen in this last step is why the overall process is called aerobic respiration.



Difficult concepts are illustrated as a step-by-step process.