

GLOBAL  
EDITION 

# THE FUNDAMENTALS OF 12 ANATOMY & PHYSIOLOGY



**MARTINI NATH BARTHOLOMEW**





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# FUNDAMENTALS OF Anatomy & Physiology

TWELFTH EDITION  
GLOBAL EDITION

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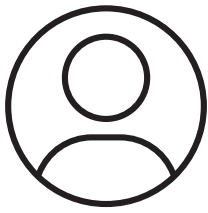
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Edwin F. Bartholomew received his undergraduate degree from Bowling Green State University and his M.S. from the University of Hawaii. Mr. Bartholomew has taught human anatomy and physiology at both the secondary and undergraduate levels. In addition, he has taught courses ranging from botany to zoology at Maui Community College (now the University of Hawaii Maui College). For 17 years, he taught at historic Lahainaluna High School, the oldest high school west of the Rockies, where he assisted in establishing a Health Occupations Students of America (HOSA) chapter. He is a coauthor of *Fundamentals of Anatomy & Physiology*, *Visual Anatomy & Physiology*, *Essentials of Anatomy & Physiology*, *Visual Essentials of Anatomy & Physiology*, *Structure and Function of the Human Body*, and *The Human Body in Health and Disease* (all published by Pearson). Mr. Bartholomew is a member of the Human Anatomy and Physiology Society (HAPS), the National Association of Biology Teachers, the National Science Teachers Association, the American Association for the Advancement of Science, and Lahaina Arts Society. He enjoys painting in oil, watercolor, and pastels, as well as growing tropical fish, aquarium plants, and orchids.



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*Illustrator*

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# Preface

The Twelfth Edition of *Fundamentals of Anatomy & Physiology* is a comprehensive textbook that fulfills the needs of today's students while addressing the concerns of their teachers. We focused our attention on these questions:

- How can we make this information meaningful, manageable, and comprehensible?
- How can we ensure that issues of diversity, equity, and inclusion are met?

During the revision process, we drew upon our content knowledge, research skills, artistic talents, and years of classroom experience to make this edition the best yet.

The broad changes to this edition are presented in the **New to the Twelfth Edition** section below, and the specific changes are presented in the **Chapter-by-Chapter Changes in the Twelfth Edition** section that follows.

## New to the Twelfth Edition

- We made a concerted effort to revise text and images to align with contemporary values related to diversity, equity, and inclusion. As teaching professors, authors, and humans, we strive for sensitivity to all people; as such, we deliberately addressed issues to better reflect the world in which we live. Like life itself, language is dynamic and evolving. With this edition we attempted to strike a balance between science and the language describing that science.
- Figures and figure legends were revised according to best practices for accessibility.
- Removed page references to topics previously covered.
- Changed Tips & Tools to Tips.
- All Clinical Notes have been revised and updated.
- Revised all homeostasis figures to enhance understanding.
- Revised selected Spotlights with a vertical orientation for best viewing on screens.
- Removed references to the Atlas.
- Boldfaced terms are used on the page to focus your attention on something important and to link the word to a corresponding structure in the art. Not all boldfaced terms will appear in the glossary.
- Students can access all media in the Study Area in Mastering A&P.

- Students can access 15 SmartArt Videos in the accompanying eTextbook and Study Area of Mastering A&P.

Be sure to view the  
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video for this figure.

## Chapter-by-Chapter Changes in the Twelfth Edition

This annotated table of contents provides examples of revision highlights in each chapter of the Twelfth Edition. For a more complete list of changes, please contact the publisher.

### Chapter 1: An Introduction to Anatomy and Physiology

- **Revised Anatomy of a Chapter section to be more useful for students**
- **Updated medical terminology section**
- **Replaced Figure 1–1 with a more meaningful student-centered image**
- **Revised Clinical Note: Diagnostic Imaging Techniques for eTextbook (images are enlarged to make scans easier to compare)**
- **Revised Spotlight Figure 1–2**

### Chapter 2: The Chemical Level of Organization

- **Revised Spotlight Figure 2–4**
- **Question added to Figure 2–4**
- **Revised Figure 2–11 by adding arrows pointing at the top of pH strip rather than plain lines to differentiate it from the pH scale at the bottom**
- **Revised Figure 2–20 by putting small arrowheads with little white highlights to clearly differentiate between bond lines and leader lines. This helps make it clearer that we are pointing at the grouping, too.**
- **Revised Figure 2–23 by making a bracket instead of two separate leader lines for the active site**
- **Revised Figure 2–25 by adding “backbone” label and adding pointed arrows for a few of the labels in places where the bond rules were the same as the lead lines**
- **Revised Figure 2–26 to show bonding with carbon in adenine**

### Chapter 3: The Cellular Level of Organization

- **New Clinical Case “Mohan Gets the Run”**
- **Revised Figure 3–1 separating nonmembranous organelles and membranous organelles; and the nucleus label is more prominent**
- **Revised Figures 3–10, 3–12 (corrected number of C-G H-bonds) and 3–13**
- **Revised Spotlight Figures 3–1, 3–7, 3–22, 3–23, and 3–24**



**Chapter 4: The Tissue Level of Organization**

- Retitled **Clinical Case to Rubber Joints**
- Revised Figure 4–2 by adding another leader line for plural cilia
- Revised **Spotlight Figure 4–21**

**Chapter 5: The Integumentary System**

- Revised **Spotlight Figure 5–3**
- Updated **Nips, Tucks, and Shots Clinical Note**

**Chapter 6: Bones and Bone Structure (formerly called Osseous Tissue and Bone Structure)**

- Revised **Spotlight Figure 6–11**
- Revised **Spotlight Figure 6–17**
- Revised Figures 6–13 and 6–16
- Deleted section on Ukrainian Chernobyl nuclear reactor incident

**Chapter 7: The Axial Skeleton**

- Revised **Spotlight Figure 7–4**
- Changed “costal process” to “anterior tubercle” in Figure 7–19b
- Revised **Clinical Note: Kyphosis, Lordosis, and Scoliosis** to remove language that focused on being abnormal

**Chapter 8: The Appendicular Skeleton**

- New **Clinical Case “Head Over Heals”**
- Revised text in Figure 8–9b
- Revised **Spotlight Figure 8–14**

**Chapter 9: Joints**

- Revised **Spotlight Figure 9–2**
- Revised definition of hyperextension. From a clinical perspective, hyperextension is the term used for extension of a limb beyond the normal anatomical limit. New Figure 9–3 reflects the changes.

**Chapter 10: Muscle Tissue**

- Revised text in Figure 10–9a
- Revised **Spotlight Figure 10–10**
- Revised **Spotlight Figure 10–11**
- Revised **Spotlight Figure 10–12**

**Chapter 11: The Muscular System**

- Revised **Spotlight Figure 11–3**

**Chapter 12: Nervous Tissue**

- Revised **Spotlight Figure 12–8**
- Revised **Spotlight Figure 12–13**
- Revised **Spotlight Figure 12–14**
- Added hyphen so term now reads “blood-brain barrier”

**Chapter 13: The Spinal Cord, Spinal Nerves, and Spinal Reflexes**

- Revised **Spotlight Figure 13–8**
- Revised Figure 13–11b: changed “Nerve to Subclavius” to “Subclavian” and “Subclavian” to “Suprascapular”
- Changed “fibular nerve” to “common fibular nerve”
- Revised **Spotlight Figure 13–14**

**Chapter 14: The Brain and Cranial Nerves**

- New **Clinical Case “The Bells!”**
- Revised **Spotlight Figure 14–4**
- Revised Figure 14–5 regarding thalamus

- Revised Figure 14–8c regarding anterior/posterior orientation
- Revised Figure 14–13 adding label for “retractor” and refining figure question
- Revised text in Figure 14–17a

**Chapter 15: Sensory Pathways and the Somatic Nervous System**

- Changed “pacinian” to “Pacinian”
- Revised Figure 15–5
- Revised **Spotlight Figure 15–8**
- Removed reference to Stephen Hawking in **Clinical Note on amyotrophic lateral sclerosis**

**Chapter 16: The Autonomic Nervous System and Higher-Order Functions**

- Revised Figure 16.1 to represent skeletal muscle with a skeletal muscle fiber
- Revised **Spotlight Figure 16.2**
- Changed “amyloid (A) protein” to “serum amyloid A protein”

**Chapter 17: The Special Senses**

- Revised **Spotlight Figure 17–2**
- Removed “umami” leader and label in Figure 17–3a
- Revised **Spotlight Figure 17–13**
- Revised **Spotlight Figure 17–16**
- Changed primary term to “taste receptor cell” and secondary term to “gustatory epithelial cell”
- Switched order of Figure 17–11a and b to match orientation of Figure 17–10
- Changed term from “magnocells” to “magnocellular neurons”
- Change term from “parvo cells” to “parvocellular neurons”
- Revised Figure 17–28

**Chapter 18: The Endocrine System**

- Revised **Spotlight Figure 18–2**
- Revised **Spotlight Figure 18–3**
- Added “Median eminence” labels to Figures 18–6 and 18–7
- Revised **Spotlight Figure 18–18**
- Revised **Spotlight Figure 18–20**
- Changed “prostate gland” to “prostate”
- Added information on the major forms of estrogens
- Added information on adipokines
- Revised section on gamma-hydroxybutyric acid (GHB) use
- Added a new **Clinical Note on Sex and Gender**
- Revised step-art text in Figure 18–11a, number 7 within running narrative
- Changed term from “pancreatic islet cells” to “pancreatic islets”
- Revised Table 18–8, including text change from “infantile” to “congenital” and descriptions with Estrogens (females) and Androgens (males) headings

**Chapter 19: Blood**

- Revised definition of hematocrit
- Revised **Spotlight Figure 19–1**
- Revised Figure 19–4 by darkening reticulocyte to better reflect hemoglobin content
- Revised **Spotlight Figure 19–8**
- Removed Table 19–2
- Revised Figure 19–11 for vertical orientation

**Chapter 20: The Heart**

- Changed “arch of aorta” to “aortic arch”
- **Revised Spotlight Figure 20–9**
- Removed hyphen from “broken heart syndrome” Clinical Note and added “takotsubo cardiomyopathy”
- Revised QRS complex, step 5 in Figure 20–11
- **Revised Spotlight Figure 20–13**

**Chapter 21: Blood Vessels and Circulation**

- **Revised Spotlight Figure 21–33**
- Changed “aortic sinus” to “aortic arch” in discussion and Figure 21–13 on baroreceptor reflexes
- Changed purple arrow to blue arrow for Pulmonary circuit in Figure 21–17
- Revised Figure 21–29

**Chapter 22: The Lymphatic System and Immunity**

- Added section on meningeal lymphatics.
- Revised Figure 22–1
- **Revised Spotlight Figure 22–21**
- Replaced AIDS Clinical Note with a new Clinical Note on various types of vaccinations currently available

**Chapter 23: The Respiratory System**

- **Revised Spotlight Figure 23–13**
- **Revised Spotlight Figure 23–25**
- Added hyphen so term now reads “blood-air barrier”
- Changed  $V_T$  to TV for tidal volume

**Chapter 24: The Digestive System**

- New Figure 24–4 to replace Peristalsis figure
- Changed “adult teeth” to “permanent teeth”
- **Revised Spotlight Figure 24–15**
- Changed Cirrhosis Clinical Note title to “Liver Disease”
- **Revised Spotlight Figure 24–27**

**Chapter 25: Metabolism, Nutrition, and Energetics (title changed to include nutrition)**

- **Revised Spotlight Figure 25–4**
- **Revised Spotlight Figure 25–10**
- Retitled 25–5 section heading
- Revised Figure 25–11

- **Revised and combined Clinical Notes on Alcohol**
- **Revised section on brown adipose tissue (formerly called brown fat)**

**Chapter 26: The Urinary System**

- **Revised Figure 26–11**
- **Revised Spotlight Figure 26–16**

**Chapter 27: Fluid, Electrolyte, and Acid–Base Balance**

- **Revised Spotlight Figure 27–18**

**Chapter 28: The Reproductive System**

- **Revised Figure 28–8 to clarify reductional and equational meiotic divisions**
- **Revised Figure 28–9**
- **Added hyphen so term now reads “blood-testis barrier”**
- **Revised Spotlight Figure 28–12**
- **Revised Figure 28–21**
- **Revised Spotlight Figure 28–24**
- **Revised Figure 28–26**
- **Changed “bulb of vestibule” to “vestibular bulb”**

**Chapter 29: Development and Inheritance**

- **Changed “differentiation” to “cellular differentiation”**
- **Revised Spotlight Figure 29–5**
- **Added new section and new Figure 29–8 on sexual differentiation**
- **Figure number changes: Figure 29–8 is now Figure 29–9; Figure 29–9 is now Figure 29–10; Figure 29–10 is now Figure 29–11; Figure 29–11 is now Figure 29–12; Figure 29–12 is now Figure 29–13; Figure 29–13 is now Figure 29–14; Figure 29–14 is now Figure 29–15; Figure 29–15 is now Figure 29–16; Figure 29–16 is now Figure 29–17; Figure 29–17 is now Figure 29–18; Figure 29–18 is now Figure 29–19; and Figure 29–19 is now Figure 29–20.**
- **Human Genome section updated**

**Appendices**

- **Revised title of Appendix B to Gas Pressure Measurements**
- **Appendix C is now Turnover Time for Selected Cells**
- **Appendix D is now Codon Chart**
- **Appendix E is now The Periodic Table**

# Acknowledgments

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No book is written and published in isolation. While authors may have their noses in the professional literature and their fingers on computer keyboards, there are many (many!)

people involved in the behind-the-scenes work before, during, and after publication. The next paragraphs attempt to express our appreciation for them.

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***Judi L. Nath***  
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# An Introduction to Anatomy and Physiology

## Learning Outcomes

These Learning Outcomes correspond by number to this chapter's sections and indicate what you should be able to do after completing the chapter.

- 1-1 ■ Describe how to use the text and art to master your learning.
- 1-2 ■ Define anatomy and physiology, explain the relationship between these sciences, and describe various specialties of each discipline.
- 1-3 ■ Identify the major levels of organization in organisms from the simplest to the most complex, and identify the major components of each organ system.
- 1-4 ■ Describe the origins of anatomical and physiological terms and explain the significance of standardizing terms.
- 1-5 ■ Use anatomical terms to describe body regions, body sections, and relative positions.
- 1-6 ■ Identify the major body cavities of the trunk and their subdivisions and describe the functions of each.
- 1-7 ■ Explain homeostasis.
- 1-8 ■ Describe how negative feedback and positive feedback are involved in homeostatic regulation.





## CLINICAL CASE

### Using A&P to Save a Life

An emergency medical technician (EMT) is on the way to the emergency department with a young victim of street violence. A knife with a 6-inch blade had been found next to the bleeding, unconscious man.

“We have a young male with multiple stab wounds. He has lost a lot of blood and we can barely get a blood pressure,” the EMT radios to the triage nurse in the emergency department as the ambulance squeals through traffic. “We started an IV and we are pouring in fluid as fast as we can.”

“Where are the wounds?” asks the receiving nurse.

“He has a deep wound in his right upper quadrant, just inferior to the diaphragm. I can see bruising from the hub of the knife around the wound, and there is another wound in his anterior



right thigh. His pulse is 120 and thready (weak). His blood pressure is 60 over 30.”

“How long has he been down?” questions the nurse.

“Less than a half hour. We intubated him (inserted a breathing tube) and started a large-bore IV as soon as we got there. We are 10 minutes out now.”

“Keep the fluids going wide open, keep pressure on the thigh, and take him directly to Trauma Room 1,” come the instructions. Meanwhile, the nurse orders the trauma team to Trauma Room 1, orders X-Ray to be

on standby in the room, and requests 4 units of type O negative whole blood—the universal donor blood—from the blood bank.

**Will the team be ready to save this young man? To find out, turn to the Clinical Case Wrap-Up at the end of the chapter.**

## An Introduction to Studying the Human Body

Welcome to the field of human anatomy and physiology—known simply as A&P! In this textbook, we introduce the inner workings of the human body, giving information about both its structure (anatomy) and its function (physiology). Many students who use this book are preparing for jobs in health-related fields; but regardless of career choice, the information within these pages is relevant to your future.

We focus on the human body, but the principles learned also apply to other living things. Our world contains an enormous diversity of living organisms, which vary widely in appearance and environment. One aim of *biology*—the study of life—is to discover the unity and the patterns that underlie this diversity. As we study human anatomy and physiology, three main concepts emerge: (1) the principle of complementarity of structure and function, (2) the hierarchy of structural relationships, and (3) homeostasis, the tendency toward internal balance. These principles are the foundation for learning about human organisms.

Before we begin with the science of human anatomy and physiology, let’s turn our attention to the science of learning and learning strategies. To make the most of your learning experience, apply these strategies, which were collected from educational research.

### 1-1 To make the most of your learning, read the text and view the art together

**Learning Outcome** Describe how to use the text and art to master your learning.

## Getting to Know Your Textbook

This first section of the book sets the stage for your success in this course and introduces you to the basic principles of learning. Just as there are three underlying concepts in A&P, there are two basic principles to using your textbook effectively to learn A&P. Practicing these principles helps you throughout your college career.

Let’s start. Think back to your first childhood book. You most likely began with a “picture book.” Then, as you learned the alphabet and developed speech, you progressed to “word books.” The next step was “chapter books.” Somewhere along the way, you quit looking at pictures and focused solely on the words (text). Maybe the shift in focus to text-based reading without looking at the pictures happened in high school. You began reading words—paragraph upon paragraph, page upon page of words. Now, you are in college, and we need to realign your focus.

In college, you are faced with lots of new terms, abstract concepts, and unfamiliar images. That’s great, because college is intended to increase your knowledge and expand your horizons. However, educational research has shown that undergraduate students tend to simply read the text (also called the *narrative*), without paying attention to the pictures (visuals, art, photos, diagrams, illustrations, figures, images, and tables). While you can certainly learn from this approach, further research shows that when students *read the text and then look at the corresponding picture, they learn the material better!*

Although this may sound quite intuitive, most students do not do that. So, we wrote a book that truly integrates text with art to help you learn A&P. Please continue reading as we walk you through the process of using a textbook to enhance your