Respiratory Care

Cardiopulmonary Anatomy & Physiology

Margaret V. Clark, MSc, RN, RRT-NPS, CMPP

JONES & BARTLETT
LEARNING

World Headquarters
Jones & Bartlett Learning
5 Wall Street
Burlington, MA 01803
978-443-5000
info@jblearning.com
www.jblearning.com

Jones & Bartlett Learning books and products are available through most bookstores and online booksellers. To contact Jones & Bartlett Learning directly, call 800-832-0034, fax 978-443-8000, or visit our website, www.jblearning.com.

Substantial discounts on bulk quantities of Jones & Bartlett Learning publications are available to corporations, professional associations, and other qualified organizations. For details and specific discount information, contact the special sales department at Jones & Bartlett Learning via the above contact information or send an email to specialsales@jblearning.com.

43024-0

Production Credits
VP, Product Management: Amanda Martin
Director of Product Management: Cathy L. Esperti
Content Strategist: Rachael Souza
Product Coordinator: Elena Sorrentino
Manager, Project Management: Lori Mortimer
Project Specialist: Kathryn Leeber
Senior Digital Project Specialist: Angela Dooley
Marketing Manager: Dani Burford
Production Services Manager: Colleen Lamy
VP, Manufacturing and Inventory Control: Therese Connell
Composition: S4Carlisle Publishing Services
Cover Design: Scott Moden
Text Design: Kristin E. Parker
Senior Media Development Editor: Troy Liston
Media Development Editor: Faith Brosnan
Rights Specialist: Rebecca Damon
Cover Image (Title Page, Chapter Opener): © Golatckii Nikolai/Shutterstock.
Printing and Binding: LSC Communications

Library of Congress Cataloging-in-Publication Data
Names: Clark, Margaret Varnell, author.
Title: Cardiopulmonary anatomy & physiology / Margaret Clark.
Other titles: Cardiopulmonary anatomy and physiology
Description: First edition. | Burlington, MA : Jones & Bartlett Publishing, [2022] | Includes bibliographical references and index.
Identifiers: LCCN 2020009965 | ISBN 9781284164848 (paperback)
Subjects: MESH: Respiratory System--anatomy & histology | Respiratory Physiological Phenomena | Cardiovascular System--anatomy & histology | Cardiovascular Physiological Phenomena
Classification: LCC QP123 | NLM WF 101 | DDC 612.2--dc23
LC record available at https://lccn.loc.gov/2020009965

6048

Printed in the United States of America
24 23 22 21 20 10 9 8 7 6 5 4 3 2 1

For Bijoux and Jamie

Brief Contents

Contents

Preface

A thorough understanding of anatomy and physiology is the foundation of any career in health care. The complex interactions of the respiratory and cardiac systems affect the entire body. Today's student needs a textbook and resources that provide more than just the basics of how our heart beats and how we breathe in order to understand how the different organs and systems of the body, including the heart, lungs, kidneys, nervous system, and musculoskeletal system, interact. Students need this information presented in both print and an accessible electronic format. This text and the accompanying digital content is designed to facilitate students' understanding of cardiopulmonary anatomy and physiology and serve as an ongoing reference. This text was also written with an understanding of the National Board for Respiratory Care Examination Matrix to help applicants prepare for the successful completion of their examinations.

Organization of this Text

Most college-level semesters are 18-weeks in length. Academic institutions on the quarterly system generally utilize a 9-week instructional format. This text is organized into 18 chapters to align with these teaching calendars. Institutions utilizing the 18-week semester format should use one chapter per week for instruction. Educational Institutions utilizing quarterly calendars may use Chapters 1 through 9 per week for the first quarter and Chapters 10 through 18 per week for the second quarter. If the institution utilizes a shorter educational calendar, Chapters 1 and 2 and 15 and 16 may be easily combined. The text consists of:

- **Chapters 1, 2, and 3**: These chapters provide an introduction to the organization and function of the upper airway, lower airway, and the lungs. The structure and main function of the lungs, including the lobes, segments, and subsegments of the left and right lungs, and abnormal physiologic processes of the lungs and airways are discussed. This section concludes with a *Putting It All Together* review that helps students understand how the airways and lungs work together.
- **Chapter 4**: Three circulatory systems move blood through the lungs and throughout the body. This chapter helps outlines the pulmonary circulation, bronchial circulation, and systemic circulation. The chapter provides an overview of the blood and some common blood disorders.
- **Chapter 5**: This chapter focus on the normal anatomy and physiology of the thoracic cavity, which provides the basis for understanding the pathophysiologic mechanisms of disease, how to assess work of breathing, and how to successfully provide care for individuals with respiratory disorders.
- **Chapter 6**: This chapter presents the structure and function of the nervous system, the nerves that innervate the pulmonary system, and the receptors in the pulmonary system that control breathing. The similarities and differences among asthma, chronic obstructive disease (COPD), and asthma–chronic obstructive disease overlap (ACO) are introduced.
- **Chapter 7**: The mucociliary escalator enables the body to remove unwanted particles and debris from the lungs so that respiration can occur efficiently. This chapter presents the structure and function of the respiratory mucosal epithelium, the development of airway secretions, and mucociliary clearance mechanisms in the airways. The importance of humidity in the airway, particle size and deposition in the lungs, and postural drainage are also presented.
- **Chapter 8**: This chapter presents the interactions of the pulmonary vasculature with the heart and lungs, which forms the basis for optimizing gas exchange and ventilation. Pulmonary hemodynamics and the etiologies of pulmonary edema and other alterations related to fluid dynamics are also explained.
- **Chapter 9**: This chapter introduces the gas laws and the factors that affect oxygen and carbon dioxide diffusion in the pulmonary alveoli. The chapter concludes with a *Putting It All Together* section that offers a quick reference to the gas laws commonly used in respiratory therapy and pulmonary medicine.
- **Chapter 10**: This chapter discusses the physiology supporting ventilation as both an involuntary and a voluntary process. The locations and functions of the central chemoreceptors, the peripheral chemoreceptors, and the lung receptors and their role in ventilation are presented along with the

clinical importance of the ventilation–perfusion ratio ($\dot{V}/\dot{Q}$) and mechanisms that may contribute to the development of hypoxemia and/or $\dot{V}/\dot{Q}$ mismatch.

- **Chapter 11**: This chapter discusses the relationship between ventilation, lung compliance, and airway resistance. The difference between positive pressure ventilation, negative pressure ventilation, and intermittent abdominal pressure ventilation are discussed and examples of conditions that may cause shifts in pulmonary pressure–volume curves are presented.
- **Chapter 12**: This chapter discusses the physiology of oxygen and carbon dioxide in the body along with examples of conditions that may cause shifts in the oxyhemoglobin dissociation curve and the carbon dioxide dissociation curve. The chapter examines the role of hemoglobin in oxygen transport and the differences between hypoxia and hypoxemia. The chapter also explains how to calculate the total capacity of the blood to carry oxygen.
- **Chapter 13**: This chapter explains static lung volumes and capacities, how to calculate lung capacities, and the pathophysiologic differences between obstructive and restrictive lung disorders. This chapter also includes a *Putting It All Together* section and explanation of pulmonary function testing.
- **Chapter 14**: This chapter explains acid-base balance, arterial blood gases, and the role of the pulmonary system and the renal system in maintaining acid-base balance in the body. Examples of conditions that may cause respiratory acidosis, respiratory alkalosis, metabolic acidosis, and metabolic alkalosis are presented and normal values for arterial blood gas, venous blood gas, and capillary blood gases are discussed.
- **Chapter 15**: The structure, function, and interactions of the atria, ventricles, valves of the heart, pericardium, heart nodes, and coronary arteries are discussed. Also included is a discussion of the conditions that may affect the heart and how to calculate the cardiac output (CO) and cardiac index (CI).
- **Chapter 16**: This chapter presents the electrophysiology of the heart and how to identify common cardiac arrhythmias. The chapter includes a *Putting It All Together* section on electrocardiogram interpretation. This chapter may be combined with Chapter 15 to adapt to academic calendars.
- **Chapter 17**: This chapter discusses fetal development, fetal circulation, and common congenital conditions that affect the cardiopulmonary system. The utilization of APGAR scores for rapidly assessing the clinical status of a newborn infant is also presented.
- **Chapter 18**: This chapter builds on the previous material and presents the definition, prevalence, signs and symptoms, diagnosis, and treatment of common respiratory diseases/disorders. This chapter not only introduces students to common respiratory diseases but demonstrates how the study of anatomy and physiology provides the foundation for safe, effective medical care.

How to Use This Book

- Each chapter of the book begins with a list of **Chapter Objectives** to help you focus on the most important concepts in that chapter.

CHAPTER OBJECTIVES

After completing this chapter, you will be able to:

1. Identify the structures, physiologic processes, and functions of the upper airway.
2. Explain the difference between breathing and respiration.
3. Discuss the filtration, humidification, and warming of inhaled gases.
4. Describe the histology of the upper airway.
5. Provide examples of abnormal physiologic processes of the nose, sinuses, oral cavity, and pharynx.
6. Describe the structure and function of the larynx.
7. Discuss the use of bronchoscopy.
8. Identify different types of artificial airways.

- **Tables** are used to highlight important information, such as **Table 6-2**, Primary Physiologic Activities of the Sympathetic and Parasympathetic Nervous Systems.

TABLE 6-2
Primary Physiologic Activities of the Sympathetic and Parasympathetic Nervous Systems

Sympathetic Nervous System	Parasympathetic Nervous System
Dilates pupils.	Constricts pupils.
Increases heart rate.	Decreases heart rate.
Increases respiratory rate.	Decreases respiratory rate.
Decreases secretions (salivary glands).	Increases secretions (salivary glands).
Reduces blood flow to the surface areas of the body and increases blood flow to the muscles, brain, legs, and arms.	Returns blood flow to the surface areas of the body and normalizes blood pressure.

- This text is **highly illustrated** with diagrams and photos demonstrating a variety of concepts, as seen with **Figure 3-11**.

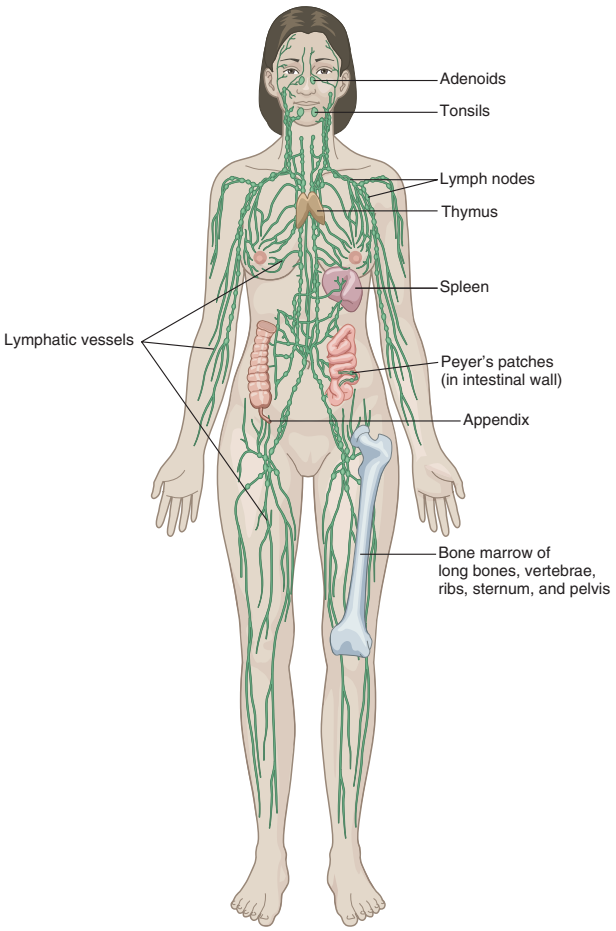

FIGURE 3-11 The lymphatic system includes the lymphatic vessels and ducts, lymph nodes, tonsils, adenoids, thymus gland, and the spleen.

- Throughout the text, key points are illustrated and important information is highlighted in **Clinical Focus** and **Did You Know?** boxes to ensure comprehension and to aid the study of critical materials.

CLINICAL FOCUS: Aortic Aneurysms, Tracheal Tugging, and the Suprasternal Notch

The suprasternal, or jugular, notch is easily visible and/or palpated on most individuals. Although this notch may seem to be a simple depression at the base of the neck, because of its anatomic position it allows access to a variety of structures in the upper thoracic cavity. In individuals experiencing a **thoracic aneurysm**, a pulsatile swelling may be seen in the jugular arch. This can create pressure on the vagus, phrenic, and spinal nerves; the thoracic veins; and the trachea. Pressure from the aneurysm may partially occlude the trachea, resulting in cyanosis and dyspnea. If the aneurysm obstructs the trachea completely, the individual will not be able to breathe. In some instances, when the aneurysm is in the arch of the aorta, the trachea is pulled down with each beat of the heart. This is known as the **tracheal tugging**, suprasternal retractions, or Oliver's sign. The condition was first described in 1878 by Canadian physician William Silver Oliver (1836–1908).

The suprasternal notch may also be used for diagnostic procedures. Assessment of the aortic arch via echocardiography can be accomplished by placing the echocardiography transducer in and just above the suprasternal notch. Intrathoracic pressures may also be measured in a similar way by using a transducer held over the soft tissue located above the suprasternal notch.

Did You Know?

Mucous Membranes

Mucous membranes are found throughout the body in any cavity that has some type of contact with the outside environment. This includes the upper and lower respiratory airways, digestive tract, reproductive tract, and urinary tract. These mucous membranes are called mucosae. Their role is to protect the various tracts of the body from debris and toxins. The structures of these membranes are basically the same throughout the body. They include some type of epithelial tissue with or without goblet cells, a basement membrane, and a thin layer of loose areolar connective tissue called the lamina propria. This layer of connective tissue contains blood vessels; nerves; and, in some areas of the body, glands. In the lungs, the lamina propria directly connects to the pulmonary parenchyma.

- Every chapters concludes with a **Case Study** and **Review Questions** to help the reader review and put into practice what they have learned.

Case Study

A 27-year-old male is brought to the emergency department (ED) by emergency medical services. He was mountain biking in a nearby state park, and it appears he was thrown from his bike, hitting some rocks. He was found by hikers partially covered in mud and semiconscious, with the bike was lying approximately 150 yards away. The time of his accident is not known. It is also not known if he lost complete consciousness for any period of time. He appears to be in pain and is breathing rapidly. Assessment in the ED reveals the following: temperature 37.3° C, heart rate 124 beats/min, respiratory rate 36 breaths/min, blood pressure 156/116 mm Hg, and Spo_2 on room air 72%. His laboratory report shows the following: white blood cell (WBC) 6.2 K/mcL, red blood cell (RBC) 5.6 million/mcL, hemoglobin (Hb) 15.9 g/dL, hematocrit (HCT) 40.7%, mean cell volume (MCV) 87 fl, mean cell hemoglobin (MCH) 30.4 pg, mean cell hemoglobin concentration (MCHC) 33.8 g/dL, red cell distribution width (RDW) 12.7 %, platelet count 378 K/mcL, and mean platelet volume 9.60 fl.

1. **Information provided by the hikers who found the biker suggests that he may have been thrown against some rocks. What sorts of injuries may result from blunt trauma to the thoracic cavity from such an occurrence?**
2. **During the physical examination, the provider notes an abrasion to the left anterior chest and that a portion of the patient's rib cage is moving paradoxically from the rest of the chest wall. A chest radiograph confirms that the third through sixth vertebrosternal ribs on the left side have broken and are separated from the rest of the rib cage. What is this condition called?**
3. **The man is being prepared for emergency surgical stabilization of his chest wall. He is placed on 100% oxygen and will be intubated by anesthesia in the operating room. You note that he is still breathing shallowly and appears to be splinting on his left side. What complications can result from splinting if this is left untreated?**

Review Questions

1. The thoracic vertebrae increase in size as you move down the spinal column. How many thoracic vertebrae are there?
   a. 4
   b. 8
   c. 12
   d. 16
2. Which of the following is considered the primary muscle(s) of ventilation?
   a. Scalene muscles
   b. Pectoralis major muscles
   c. Trapezius muscles
   d. Diaphragm
3. Which muscle(s) are considered the most variable muscle(s) in the human body?
   a. Pectoralis major muscles
   b. Trapezius muscles
   c. Sternomastoid muscles
   d. Transversus thoracis muscle
4. Which muscles are strongest of the three intercostal muscle groups?
   a. Internal intercostal muscles
   b. External intercostal muscles
   c. Subcostal muscles
   d. Deep intercostal muscles

Instructor and Student Resources

Qualified instructors will receive a full suite of instructor resources.

For the Instructor

- A comprehensive chapter-by-chapter PowerPoint deck
- A test bank containing questions on a chapter-by-chapter basis
- Answers to the Case Studies and end-of-chapter Review Questions

For the Student

- Case Studies available online as writeable PDFs
- Each text comes with access to our Anatomy & Physiology Review Module, which includes the Heart & Lung Sounds Module

About the Author

Margaret V. Clark, MSc, RN, RRT-NPS, CMPP

Margaret V. Clark has more than 30 years of experience as a medical writer, editor, and educator. Clark has specialized in writing for medical education, clinical practice guidelines, quality improvement initiatives, clinical research studies, and publication planning. She was a reviewer for the National Guidelines Clearinghouse and the National Quality Measures Clearinghouse on behalf of the Agency for Healthcare Research and Quality (AHRQ). She has also written for *Advance News Magazine*, WebMD, and Reuters Health. Miss Clark was the Editorial Director for Medscape from WebMD for Pulmonary Medicine, Allergy and Immunology, Emergency Medicine, and Critical Care Medicine. She was the inaugural Pulmonary/Critical Care Editor of the peer-reviewed journal *MedGenMed*. Additionally, her textbook, *Asthma: A Clinician's Guide*, has been translated into multiple languages and is used worldwide.

Miss Clark was the Clinical Coordinator for Pulmonary Medicine and Respiratory Care at Boston Medical Center/Boston University Medical School and as the Special Studies Coordinator for the Georgia Medical Care Foundation, a Quality Improvement Organization for the Centers for Medicare & Medicaid Services. She has served as an investigator for national and international trials and also written several other books and monographs.

Miss Clark holds a Master of Science in International Health from Touro University. She is the 1996 recipient of the Bird Award given by the Bird Institute of Biomedical Technology for her extensive writing in Pulmonary Medicine and in 2010 she was awarded the D. Robert McCaffree, MD, Master FCCP Humanitarian Award given by the Chest Foundation–American College of Chest Physicians for her volunteer work with inner-city children.

Acknowledgments

I would like to acknowledge the following individuals for their time and assistance in developing this book: Charles F. Kearns, PhD; Judith Lenhart, PhD; Susan Steinbis, RN, MSN, APRN-BC; Helen B. Wilson, MA; Abigail H. Goben, MLS; Doug McIntyre, MS, RRT, FAARC; Terry J. Lirette, RRT; and Christi Leigh DeFrancesco, LCSW.

I would like to thank the team at Jones & Bartlett Learning for making this possible, especially Cathy Esperti, Rachael Souza, Kathryn Leeber, Rebecca Damon, and Troy Liston.

I would also like to thank the reviewers who gave their time and guidance in preparing this book.

Reviewers

Charity Bowling, MA, RRT
Program Chair Respiratory Therapy
Ivy Tech Community College
Indianapolis, Indiana

Adam Lavis, MS, ACSM-CEP
Professor/Lab Manager
University of North Carolina at Charlotte
Charlotte, North Carolina