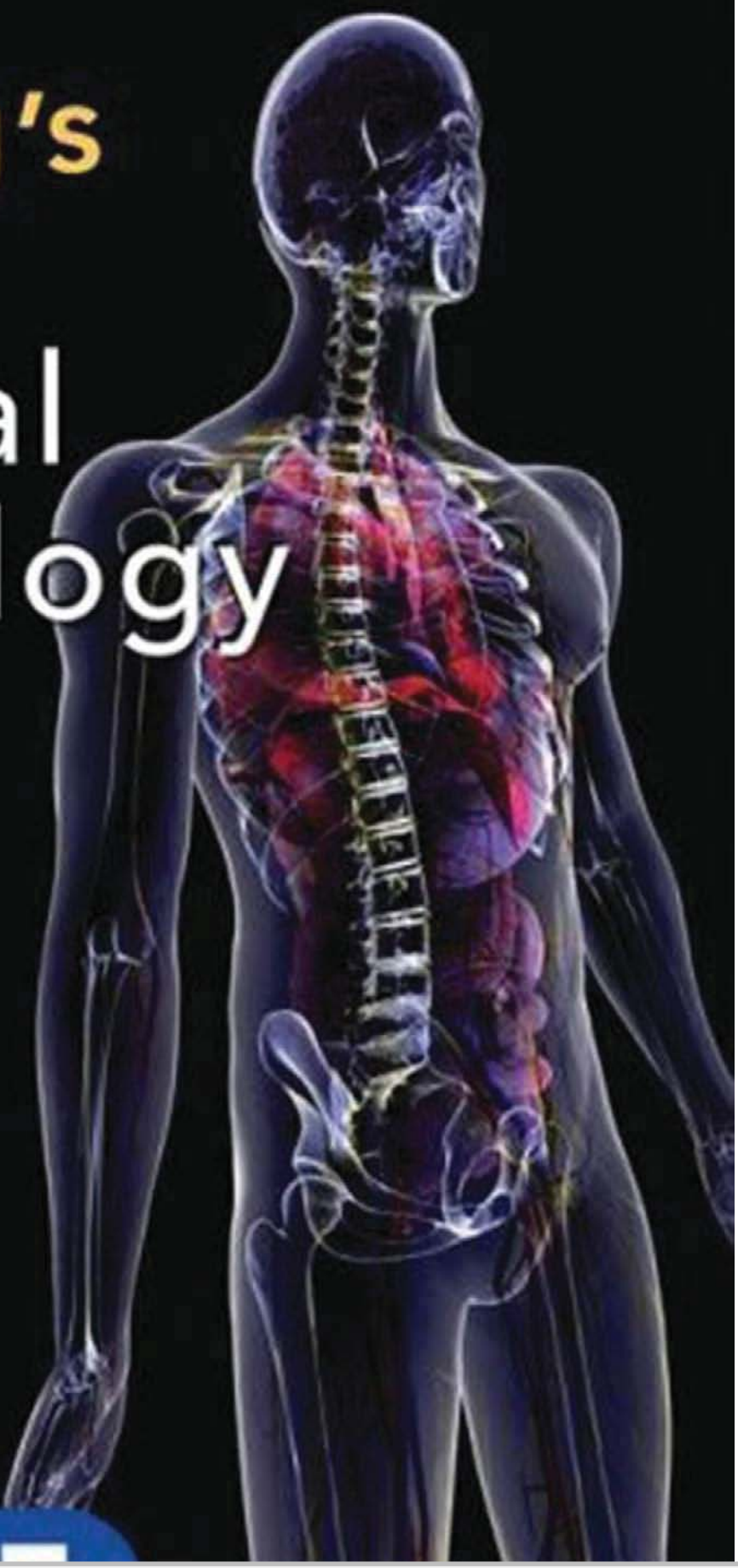


Ganong's

Review of

Medical Physiology



23rd Edition

Kim Barrett
Heddwen Brooks
Scott Boitano
Susan Barman

a LANGE medical book

Ganong's Review of Medical Physiology

Twenty-Third Edition

Kim E. Barrett, PhD

*Professor
Department of Medicine
Dean of Graduate Studies
University of California, San Diego
La Jolla, California*

Scott Boitano, PhD

*Associate Professor, Physiology
Arizona Respiratory Center
Bio5 Collaborative Research Institute
University of Arizona
Tucson, Arizona*

Susan M. Barman, PhD

*Professor
Department of Pharmacology/Toxicology
Michigan State University
East Lansing, Michigan*

Heddwen L. Brooks, PhD

*Associate Professor
Department of Physiology
College of Medicine
University of Arizona
Tucson, Arizona*



New York Chicago San Francisco Lisbon London Madrid Mexico City

DOCKET
A L A R M

Find authenticated court documents without watermarks at docketalarm.com.

Copyright © 2010 by The McGraw-Hill Companies, Inc. All rights reserved. Except as permitted under the United States Copyright Act of 1976, 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 permission of the publisher.

ISBN: 978-0-07-160568-7

MHID: 0-07-160568-1

The material in this eBook also appears in the print version of this title: ISBN: 978-0-07-160567-0, MHID: 0-07-160567-3.

All trademarks are trademarks of their respective owners. Rather than put a trademark symbol after every occurrence of a trademarked name, we use names in an editorial fashion only, and to the benefit of the trademark owner, with no intention of infringement of the trademark. Where such designations appear in this book, they have been printed with initial caps.

McGraw-Hill eBooks are available at special quantity discounts to use as premiums and sales promotions, or for use in corporate training programs. To contact a representative please e-mail us at bulksales@mcgraw-hill.com.

Medicine is an ever-changing science. As new research and clinical experience broaden our knowledge, changes in treatment and drug therapy are required. The authors and the publisher of this work have checked with sources believed to be reliable in their efforts to provide information that is complete and generally in accord with the standards accepted at the time of publication. However, in view of the possibility of human error or changes in medical sciences, neither the authors nor the publisher nor any other party who has been involved in the preparation or publication of this work warrants that the information contained herein is in every respect accurate or complete, and they disclaim all responsibility for any errors or omissions or for the results obtained from use of the information contained in this work. Readers are encouraged to confirm the information contained herein with other sources. For example and in particular, readers are advised to check the product information sheet included in the package of each drug they plan to administer to be certain that the information contained in this work is accurate and that changes have not been made in the recommended dose or in the contraindications for administration. This recommendation is of particular importance in connection with new or infrequently used drugs.

TERMS OF USE

This is a copyrighted work and The McGraw-Hill Companies, Inc. ("McGraw-Hill") and its licensors reserve all rights in and to the work. Use of this work is subject to these terms. Except as permitted under the Copyright Act of 1976 and the right to store and retrieve one copy of the work, you may not decompile, disassemble, reverse engineer, reproduce, modify, create derivative works based upon, transmit, distribute, disseminate, sell, publish or sublicense the work or any part of it without McGraw-Hill's prior consent. You may use the work for your own noncommercial and personal use; any other use of the work is strictly prohibited. Your right to use the work may be terminated if you fail to comply with these terms.

THE WORK IS PROVIDED "AS IS." MCGRAW-HILL AND ITS LICENSORS MAKE NO GUARANTEES OR WARRANTIES AS TO THE ACCURACY, ADEQUACY OR COMPLETENESS OF OR RESULTS TO BE OBTAINED FROM USING THE WORK, INCLUDING ANY INFORMATION THAT CAN BE ACCESSED THROUGH THE WORK VIA HYPERLINK OR OTHERWISE, AND EXPRESSLY DISCLAIM ANY WARRANTY, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. McGraw-Hill and its licensors do not warrant or guarantee that the functions contained in the work will meet your requirements or that its operation will be uninterrupted or error free. Neither McGraw-Hill nor its licensors shall be liable to you or anyone else for any inaccuracy, error or omission, regardless of cause, in the work or for any damages resulting therefrom. McGraw-Hill has no responsibility for the content of any information accessed through the work. Under no circumstances shall McGraw-Hill and/or its licensors be liable for any indirect, incidental, special, punitive, consequential or similar damages that result from the use of or inability to use the work, even if any of them has been advised of the possibility of such damages. This limitation of liability shall apply to any claim or cause whatsoever whether such claim or cause arises in contract, tort or otherwise.

SECTION VII RESPIRATORY PHYSIOLOGY

C H A P T E R

35

Pulmonary Function

OBJECTIVES

After studying this chapter, you should be able to:

- Define partial pressure and calculate the partial pressure of each of the important gases in the atmosphere at sea level.
- List the passages through which air passes from the exterior to the alveoli, and describe the cells that line each of them.
- List the major muscles involved in respiration, and state the role of each.
- Define the basic measures of lung volume and give approximate values for each in a normal adult.
- Define compliance, and give examples of diseases in which it is abnormal.
- Describe the chemical composition and function of surfactant.
- List the factors that determine alveolar ventilation.
- Define diffusion capacity, and compare the diffusion of O₂ with that of CO₂ in the lungs.
- Compare the pulmonary and systemic circulations, listing the main differences between them.
- Describe basic lung defense and metabolic functions.

INTRODUCTION

Respiration, as the term is generally used, includes two processes: **external respiration**, the absorption of O₂ and removal of CO₂ from the body as a whole; and **internal respiration**, the utilization of O₂ and production of CO₂ by cells and the gaseous exchanges between the cells and their fluid medium. Aspects of external respiratory physiology are presented throughout this section. In this chapter, the processes

responsible for the uptake of O₂ and excretion of CO₂ in the lungs are explored. The next chapter is concerned with the transport of O₂ and CO₂ to and from the tissues. The final chapter in this section examines some key factors that regulate respiration. Throughout each chapter, clinical implications of specific physiology will be presented.

PROPERTIES OF GASES

The pressure of a gas is proportional to its temperature and the number of moles per volume:

$$P = \frac{nRT}{V} \quad (\text{from equation of state of ideal gas})$$

where

P = Pressure

n = Number of moles

R = Gas constant

T = Absolute temperature

V = Volume

PARTIAL PRESSURES

Unlike liquids, gases expand to fill the volume available to them, and the volume occupied by a given number of gas molecules at a given temperature and pressure is (ideally) the same regardless of the composition of the gas. Therefore, the pressure exerted by any one gas in a mixture of gases (its **partial pressure**) is equal to the total pressure times the fraction of the total amount of gas it represents.

The composition of dry air is 20.98% O₂, 0.04% CO₂, 78.06% N₂, and 0.92% other inert constituents such as argon and helium. The barometric pressure (PB) at sea level is 760 mm Hg (1 atmosphere). The partial pressure (indicated by the symbol P) of O₂ in dry air is therefore 0.21 × 760, or 160 mm Hg at sea level. The PN₂ and the other inert gases is 0.79 × 760, or 600 mm Hg; and the PCO₂ is 0.0004 × 760, or 0.3 mm Hg. The water vapor in the air in most climates reduces these percentages, and therefore the partial pressures, to a slight degree. Air equilibrated with water is saturated with water vapor, and inspired air is saturated by the time it reaches the lungs. The PH₂O at body temperature (37 °C) is 47 mm Hg. Therefore, the partial pressures at sea level of the other gases in the air reaching the lungs are PO₂, 149 mm Hg; PCO₂, 0.3 mm Hg; and PN₂ (including the other inert gases), 564 mm Hg.

Gas diffuses from areas of high pressure to areas of low pressure, with the rate of diffusion depending on the concentration gradient and the nature of the barrier between the two areas. When a mixture of gases is in contact with and permitted to equilibrate with a liquid, each gas in the mixture dissolves in the liquid to an extent determined by its partial pressure and its solubility in the fluid. The partial pressure of a gas in a liquid is the pressure that, in the gaseous phase in equilibrium with the liquid, would produce the concentration of gas molecules found in the liquid.

METHODS OF QUANTITATING RESPIRATORY PHENOMENA

Modern spirometers permit direct measurement of gas intake and output. Since gas volumes vary with temperature and

TABLE 35–1 Standard conditions to which measurements involving gas volumes are corrected.

STPD	0 °C, 760 mm Hg, dry (standard temperature and pressure, dry)
BTPS	Body temperature and pressure, saturated with water vapor
ATPD	Ambient temperature and pressure, dry
ATPS	Ambient temperature and pressure, saturated with water vapor

pressure and since the amount of water vapor in them varies, these devices have the ability to correct respiratory measurements involving volume to a stated set of standard conditions. The four most commonly used standards and their abbreviations are shown in Table 35–1. It should be noted that correct measurements are highly dependent on the ability for the practitioner to properly encourage the patient to fully utilize the device. Modern techniques for gas analysis make possible rapid, reliable measurements of the composition of gas mixtures and the gas content of body fluids. For example, O₂ and CO₂ electrodes, small probes sensitive to O₂ or CO₂, can be inserted into the airway or into blood vessels or tissues and the PO₂ and PCO₂ recorded continuously. Chronic assessment of oxygenation is carried out noninvasively with a **pulse oximeter**, which is usually attached to the ear.

ANATOMY OF THE LUNGS

THE RESPIRATORY SYSTEM

The respiratory system is made up of a gas-exchanging organ (the lungs) and a “pump” that ventilates the lungs. The pump consists of the chest wall; the respiratory muscles, which increase and decrease the size of the thoracic cavity; the areas in the brain that control the muscles; and the tracts and nerves that connect the brain to the muscles. At rest, a normal human breathes 12 to 15 times a minute. About 500 mL of air per breath, or 6 to 8 L/min, is inspired and expired. This air mixes with the gas in the alveoli, and, by simple diffusion, O₂ enters the blood in the pulmonary capillaries while CO₂ enters the alveoli. In this manner, 250 mL of O₂ enters the body per minute and 200 mL of CO₂ is excreted.

Traces of other gases, such as methane from the intestines, are also found in expired air. Alcohol and acetone are expired when present in appreciable quantities in the body. Indeed, over 250 different volatile substances have been identified in human breath.

AIR PASSAGES

After passing through the nasal passages and pharynx, where it is warmed and takes up water vapor, the inspired air passes