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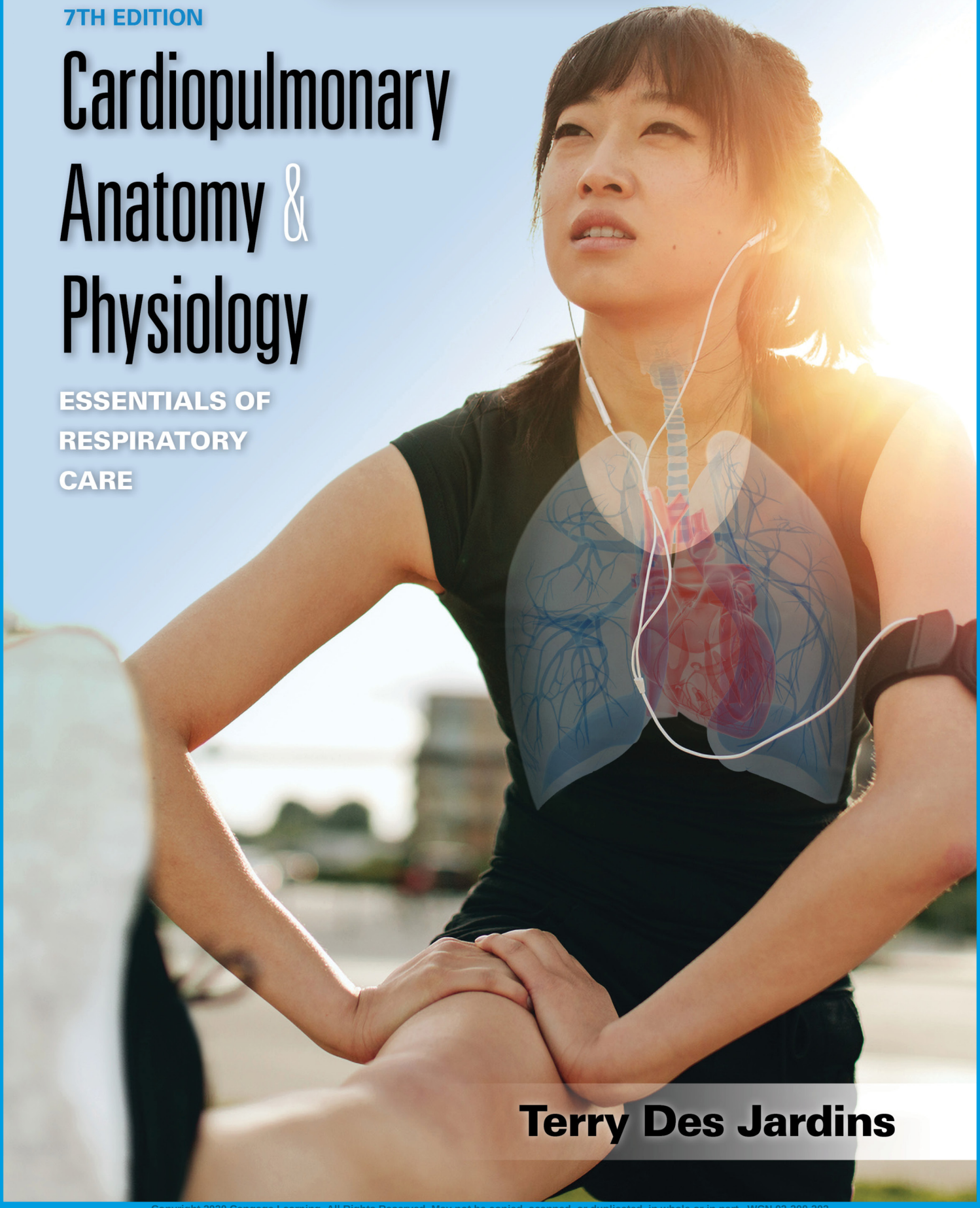
Cardiopulmonary Anatomy & Physiology

ESSENTIALS OF RESPIRATORY CARE



Terry Des Jardins

Cardiopulmonary Anatomy & Physiology

ESSENTIALS OF RESPIRATORY CARE

Seventh Edition

To
Katherine, Alexander, Destinee, Ashley, and Jax
The Next Generation
Grandpa T

Cardiopulmonary Anatomy & Physiology

ESSENTIALS OF RESPIRATORY CARE

Seventh Edition

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Cardiopulmonary Anatomy & Physiology – Essentials of Respiratory Care
Seventh Edition
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Foreword

As an educator, it is so delightful to use a book that the students love. This is the case with Terry Des Jardins' *Cardiopulmonary Anatomy & Physiology—Essentials of Respiratory Care.* The new 7th edition expands upon the well proven qualities that make it so "student friendly." First and foremost, this is far more than a standard anatomy and physiology textbook. Students don't complain, "Why do I have to learn this? Is this important?" Terry has tied the essentials of "A&P" to the students' exciting new experiences with patient care. He does this by cross-connecting normal A&P to common pathological conditions that affect the body and real patient situations. For example, in Chapter 1, the discussion of the oral cavity and laryngeal structures is augmented by discussing croup syndrome and endotracheal intubation. Terry brings the normal, the abnormal, and the patient application together in this example and throughout the book.

The text is clearly written and succinctly explains complex topics. Students easily understand what is described to them. Full color art and color photographs further guide the students' visualization of the topic. When appropriate, chest and other radiographs and other medical images are added. As the saying goes, "A picture is worth a thousand words."

Since the anatomy and physiology course typically precedes the pathology course, the Clinical Connections and Clinical Application Cases offer insight into patient care situations. When the pathology course instructor is presenting a disease or condition, croup syndrome for example, it is easy to refer the students back to their earlier learning from this book. The reinforcement of past learning to the present discussion to the future application with a real patient will help guide the students to be knowledgeable and prepared respiratory therapists. A solid understanding of cardiopulmonary anatomy and physiology is the foundation upon which safe, effective patient care is built. Terry's excellent book does just that.

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Preface

Overview

It is important to emphasize that knowledge of an anatomic *structure* is essential to the understanding of the *function* of that structure. It therefore makes little sense to present students with physiologic details without first establishing a solid foundation in anatomy. Because most college-level anatomy courses spend only a limited amount of time on the cardiopulmonary system, respiratory therapy educators generally need to cover this subject themselves. In addition, with regard to a good textbook, respiratory educators usually find the cardiopulmonary section of the college-level anatomy and physiology texts too introductory in nature for the future respiratory therapist's needs.

As a solution to this problem, this book is designed to provide students of cardiopulmonary anatomy and physiology with the most accurate and complete information essential for respiratory care. It is assumed that the student has no previous knowledge of respiratory anatomy or physiology. Great efforts have been made to present a comprehensive overview of the subject matter in an organized, interesting, and readable manner. The organization of this book is based on my experiences as an educator of respiratory anatomy and physiology since 1973—and the countless things I have learned from my students and fellow colleagues. In response to these personal experiences and helpful suggestions, the following pedagogic approach is used in this book.

Organization

The seventh edition of this book is divided into three major sections. **Section 1, *The Cardiopulmonary System—The Essentials,*** consists of Chapters 1 through 11. **Chapter 1** provides the student with a thorough discussion of anatomic structures associated with the respiratory system. This chapter also features a large number of colorful illustrations. The visual impact of this chapter is intended to (1) stimulate interest in the subject under discussion, (2) facilitate the rapid visualization of anatomic structures, and (3) help the student relate classroom knowledge to clinical experiences.

Chapters 2 through 9 cover the major concepts and mechanisms of respiratory physiology. The discussions are comprehensive, logically organized, and, most importantly, presented at a level suitable for the average college student. When appropriate, anatomic and physiologic principles are applied to common clinical situations to enhance understanding and retention (e.g., the gas transport calculations and their clinical application to the patient's hemodynamic status). In addition, a large number of colorful line drawings and tables appear throughout these chapters to assist in the understanding of various concepts and principles.

Chapters 2, 3, 6, 7, and 8 feature several unique line drawings that relate familiar visual concepts to standard graphs and nomograms. While I have found that the types of graphs and nomograms presented in this book are often (at first) difficult for students to understand, it is important to stress that the "physiology literature" uses these items extensively. **The student must understand how to read every graph and nomogram in this book to comprehend its contents fully!**

Chapter 10 covers the major anatomic structures and physiologic mechanisms associated with fetal and newborn gas exchange and circulation. It presents the basic cardiopulmonary foundation required to understand fetal and neonatal respiratory disorders. **Chapter 11** describes changes that occur in the cardiopulmonary system with age. Because the older age groups are expected to increase each year until

about the year 2050, basic knowledge of this material will become increasingly important to respiratory care practitioners.

Section 2, *Advanced Cardiopulmonary Concepts and Related Areas—The Essentials,* consists of **Chapters 12 through 17. Chapter 12** covers the essential electrophysiology of the heart required for ECG interpretation, **Chapter 13** presents the major components of the standard 12-ECG lead system, and **Chapter 14** provides a systematic approach to ECG interpretation and the major cardiac dysrhythmias seen by the respiratory care practitioner. **Chapter 15** gives the reader the essential knowledge foundation required for hemodynamic measurements and interpretations.

Chapter 16 presents the structure and function of the renal system and the major cardiopulmonary problems that develop when the renal system fails. This chapter is particularly important for respiratory therapist working with patients in the critical care unit. **Chapter 17** presents sleep physiology and its relationship to the cardiopulmonary system. During the past few years, there has been a tremendous increase in the demand for sleep medicine care services. Many of these sleep care centers are staffed with respiratory therapists who work routinely with patients who have various sleep-related disorders that adversely impact the cardiopulmonary system, such as obstructive sleep apnea.

Section 3, *The Cardiopulmonary System during Unusual Environmental Conditions,* consists of Chapters 18, 19, and 20. **Chapter 18** presents the effects of exercise on the cardiopulmonary system. During heavy exercise, the components of the cardiopulmonary system may be stressed to their limits. Cardiac patients involved in exercise training after myocardial infarction demonstrate a significant reduction in mortality and major cardiac mishaps. As our older population increases, cardiovascular rehabilitation programs will become increasingly more important to respiratory care practitioners.

Chapter 19 describes the effects of high altitude on the cardiopulmonary system. It provides a better understanding of chronic oxygen deprivation, which can then be applied to the treatment of chronic hypoxia caused by lung disease.

Chapter 20 provides an overview of high-pressure environments and their profound effect on the cardiopulmonary system. The therapeutic administration of oxygen at increased ambient pressures (hyperbaric medicine) is commonly used to treat a number of pathologic conditions.

Finally, at the end of each chapter there is a set of review questions designed to facilitate learning and retention. In addition, at the end of Chapters 2 through 10 and 15, 16, and 17, the reader is provided with a clinical application section. In this part of the chapters, one or two clinical scenarios are presented that apply several of the concepts, principles, or formulas that are presented in the chapter to actual clinical situations. These clinical scenarios are flagged throughout the chapters—in the form of abbreviated Clinical Connections (see description of Clinical Connections below)—to help highlight important points or concepts as they appear in the chapter. This feature further facilitates the transfer of classroom material to the clinical setting. Following the clinical applications are related questions to facilitate the development of critical thinking skills.

A **glossary** is included at the end of the text that further defines many of the key terms that are bolded throughout the textbook. Not all the bolded key terms in the textbook appear in the glossary. This is because, oftentimes, certain terms and phrases are bolded in the text to emphasize certain anatomic structures, concepts, and relationships to enhance the readability of the text.

The glossary is followed by **appendices** that cover symbols, abbreviations, and units of measurement commonly used in respiratory physiology. Also included is a nomogram that can be copied and laminated for use as a handy clinical reference tool in the interpretation of specific arterial blood gas abnormalities. Finally, the **answers** to the chapter review questions appear in the last appendix.

Clinical Connections

Over 140 **Clinical Connections** are interspersed throughout each chapter. The Clinical Connections provide the reader with a direct link between the topics being discussed and, importantly, how they may be applied to the clinical setting and to everyday "real-life" situations. In addition to enhancing the transfer of classroom material to the clinical setting, the Clinical Connections are designed to (1) further stimulate classroom discussions; (2) provide a brief preview (i.e., coming attractions) of more advanced cardiopulmonary topics—such as respiratory disorders, pharmacology, and the benefits and hazards or mechanical ventilation; (3) help in clarifying important cardiopulmonary concepts; and (4) further stimulate the student's excitement—and anticipation—of ultimately working and caring for patients in the profession of respiratory care.

The Clinical Connections are also intended to help the student—the early apprentice of respiratory care—answer the following types of commonly asked questions:

- "Why am I learning this material?"
- "When will I ever see this information in the clinical setting?"
- "How will this material ever be used in my 'real life'—when I am working as a licensed respiratory therapist?"

With the addition of the Clinical Connections, these types of questions are appropriately addressed—the student is now provided with commonly seen relationships between what is being studied in the classroom and how this material may be used in clinical setting.

New to the Seventh Edition

- 150 new or re-rendered colored figures have been added to the text—for a total of over 380 illustrations. These colored illustrations further highlight the important features and concepts associated with the content under discussion.
- 13 new Clinical Connections have been added to the text—for a total of 141 Clinical Connections. The Clinical Connections help to provide a direct link between the chapter content and the clinical setting—and, to "real-life," "everyday" situations. In addition, the Clinical Connections further enhance the student's classroom discussions and critical thinking skills.
- Revised and updated chapter content throughout the entire textbook.

MindTap

MindTap is a personalized teaching experience with relevant assignments that guide students to analyze, apply, and improve thinking, allowing you to measure skills and outcomes with ease.

- Personalized Teaching: Becomes yours with a Learning Path that is built with key student objectives. Control what students see and when they see it. Use it as-is or match to your syllabus exactly–hide, rearrange, add and create your own content.
- Guide Students: A unique learning path of relevant readings and activities that move students up the learning taxonomy from basic knowledge and comprehension to analysis and application.
- Promote Better Outcomes: Empower instructors and motivate students with analytics and reports that provide a snapshot of class progress, time in course, engagement and completion rates.

The MindTap for *Cardiopulmonary Anatomy & Physiology, 7e* features a complete integrated course combining additional quizzing and assignments, and application activities along with the enhanced ebook to further facilitate learning.

Instructor Companion Website

Spend Less Time Planning and More Time Teaching!
With Cengage's Instructor Resources to Accompany *Cardiopulmonary Anatomy & Physiology*, preparing for class and evaluating students has never been easier! As an instructor, you will find this tool offers invaluable assistance by giving you access to all of your resources—anywhere and at any time.

Features:

- Each chapter in the **Instructor's Manual** provides (1) an overview of the content of the chapter; (2) instructional objectives; (3) key terms; (4) instructor and student resources; and (5) a chapter lesson plan and overview—which includes each instructional objective, where in the textbook it is discussed, and what PowerPoint® slides can be used to facilitate the presentation and discussion of the material.
- The **Computerized Testbank** in **Cognero®** makes generating tests and quizzes a snap. With over 1000 questions and different styles to choose from, including multiple choice, true/false, and short answer, you can create customized assessments for your students with the click of a button. Add your own unique questions and print answers for easy class preparation. All questions have been thoroughly updated to reflect content updates made to the seventh edition. Questions have also been edited to provide more correlation to the NBRC exam format.
- Customizable instructor support slide presentations in **PowerPoint®** format focus on key points for each chapter and have been fully updated to correlate to the content updates made to the seventh edition.

Acknowledgments

Several people have provided important contributions to the development of the seventh edition of this textbook. First, a very special thank you goes out to Gayle Carr for the many hours she spent for the research, development, and final edits of the of 13 new Clinical Connections that appear throughout the book. In addition, Gayle provided many important edits and updates throughout the entire textbook. For his outstanding input and wine expertise regarding the clinical connection that discusses the inert gases used to preserve partially filled bottles of wine, a special thank you goes out to Rich Blazier. For the 63 pieces of new or re-rendered artwork for this textbook, a very big shout-out again goes out to Joe Chovan. Joe's outstanding artistic skills continue to enhance the visualization and understanding of the content presented throughout the textbook. For their work and editorial support for the production of the 7th edition of this text, my gratitude goes out to the following from the Cengage Learning staff: Debbie Bordeaux, Mark Peplowski, Sharib Asrar, and Charu Verma. Great job!

SECTION 1

The Cardiopulmonary System

The Essentials

CHAPTER 1

The Anatomy and Physiology of the Respiratory System

OBJECTIVES

By the end of this chapter, the student should be able to:

1. Describe the four major components and the primary functions of the upper airways.
2. Identify the structures and the three primary functions of the nose.
3. Identify the structures and function of the upper airways and pharynx.
4. Describe the structure and function of the larynx.
5. Discuss the structure and function of the tracheobronchial tree.
6. Identify the location (generation) and structure of the cartilaginous and noncartilaginous airways.
7. Describe the structure and function of the bronchial blood supply.
8. Describe the sites of gas exchange including the structure and function.
9. Describe the structure and function of the pulmonary vascular system.
10. Discuss the structure and function of the lymphatic system.
11. Identify the effects of sympathetic and parasympathetic nervous systems have on the following: heart, bronchial smooth muscle, bronchial glands, salivary glands, stomach, intestines, and eyes.
12. Identify the structures of the lungs and lung segments from the anterior, posterior, lateral, and medial views.
13. Identify the components of the mediastinum.
14. Identify the components of the pleural membranes.
15. Identify the components of the bony thorax.
16. Describe the structure and function of the diaphragm.
17. Describe the structure and function of the accessory muscles of expiration and inspiration.

The Airways

The passageways between the ambient environment and the gas exchange units of the lungs (the alveoli) are called the **conducting airways**. Although no gas exchange occurs in the conducting airways, they are, nevertheless, important to the overall process of ventilation. The conducting airways are divided into the **upper airways** and the **lower airways**.

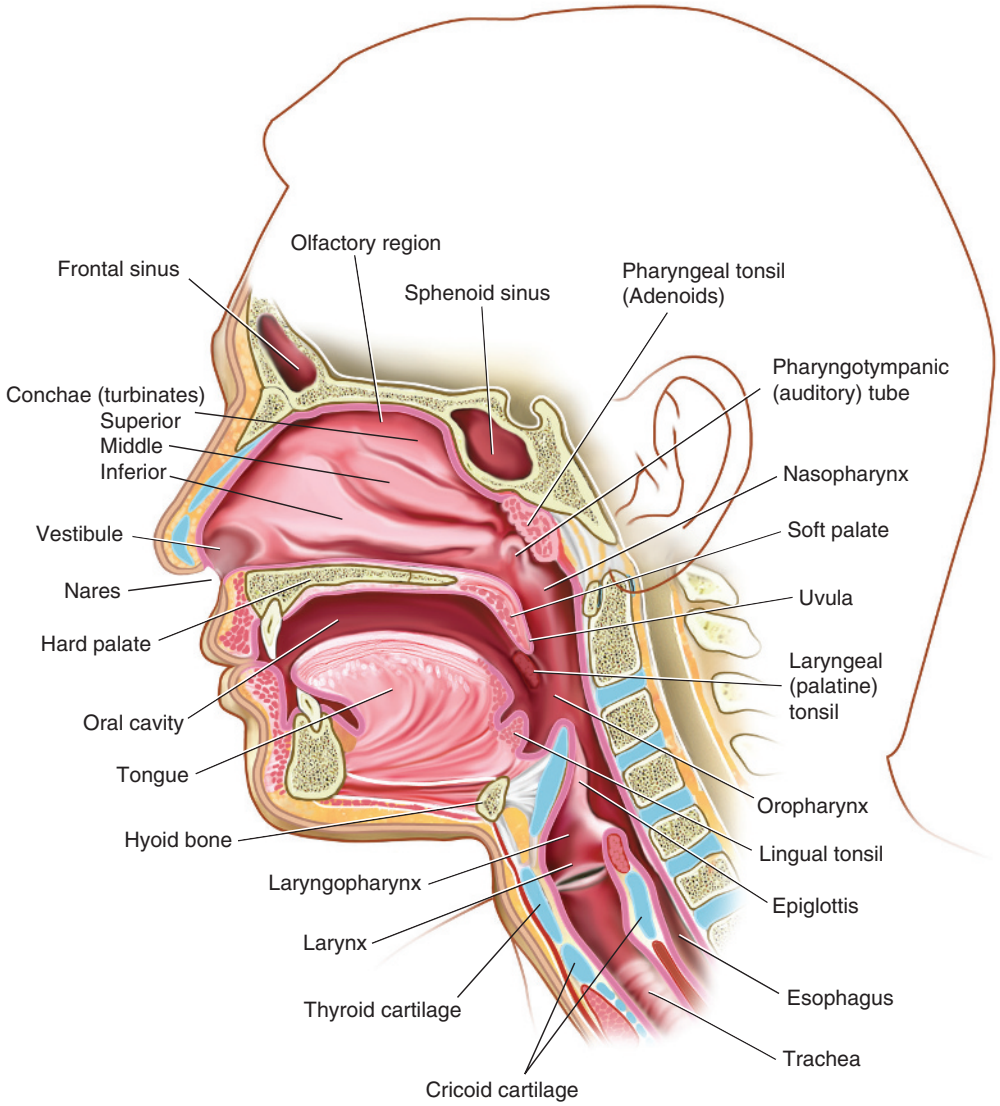
The Upper Airways

The upper airways consist of the **nose**, **oral cavity**, **pharynx**, and **larynx** (Figure 1–1). The primary functions of the upper airways are to (1) act as a conductor of air, (2) humidify and warm or cool the inspired air, (3) prevent foreign materials from entering the tracheobronchial tree, and (4) serve as an important area involved in speech and smell.

The Nose

The primary functions of the nose are to *filter, humidify,* and *condition (warm or cool)* inspired air. The nose is also important as the site for the sense of smell and to generate resonance in phonation.

FIGURE 1–1 Sagittal section of human head, showing the upper airways.



The outer portion of the nose is composed of bone and cartilage. The upper third of the nose (the bridge) is formed by the **nasal bones** and the **frontal process** of the **maxilla**. The lower two-thirds consist of the **lateral nasal cartilage**, the **greater alar cartilage**, the **lesser alar cartilages**, the **septal cartilage**, and some **fibrous fatty tissue** (Figure 1–2).

In the internal portion of the nose, a partition, the **nasal septum**, separates the nasal cavity into two approximately equal chambers. Posteriorly, the nasal septum is formed by the **perpendicular plate** of the **ethmoid bone** and by the **vomer**. Anteriorly, the septum is formed by the **septal cartilage**. The roof of the nasal cavity is formed by the **nasal bones**, the **frontal process of the maxilla**, and the **cribriform plate of the ethmoid bone**. The floor is formed by the **palatine process of the maxilla** and by the **palatine bones**—the same bones that form the hard palate of the roof of the mouth. The posterior section of the nasal cavity floor is formed by the superior portion of the **soft palate** of the oral cavity, which consists of a flexible mass of densely packed collagen fibers (Figure 1–3).

Air enters the nasal cavity through the two openings formed by the septal cartilage and the alae nasi, called the **nares**, or **nostrils**. Initially, the air passes through a slightly dilated area called the **vestibule** (see Figure 1–1), which contains hair follicles called **vibrissae**. The vibrissae function as a filter and are the tracheobronchial tree's first line of defense. **Stratified squamous epithelium** (nonciliated) lines the anterior one-third of the nasal cavity (Figure 1–6A). The posterior two-thirds of the nasal cavity are lined with **pseudostratified ciliated columnar epithelium** (Figure 1–6B). The cilia propel mucous toward the nasopharynx.

FIGURE 1–2 Structure of the nose.

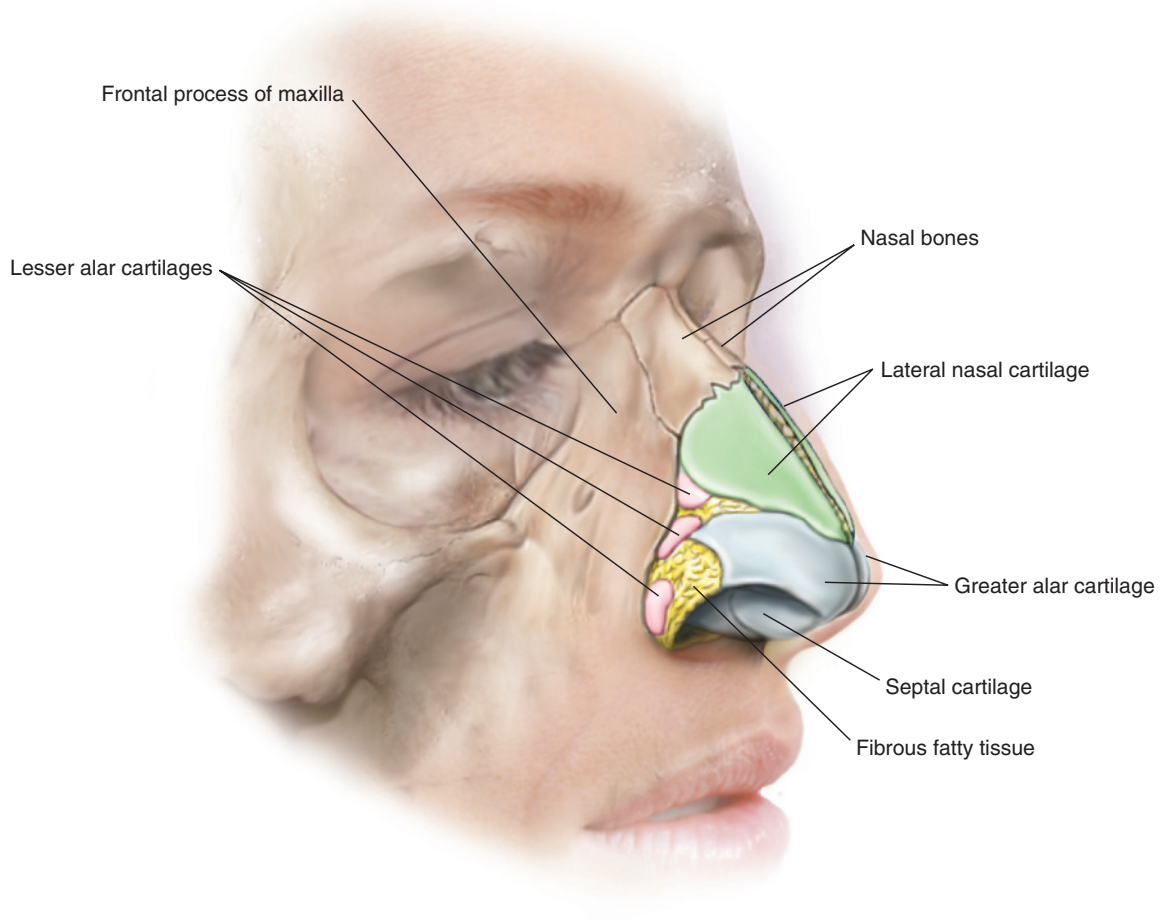
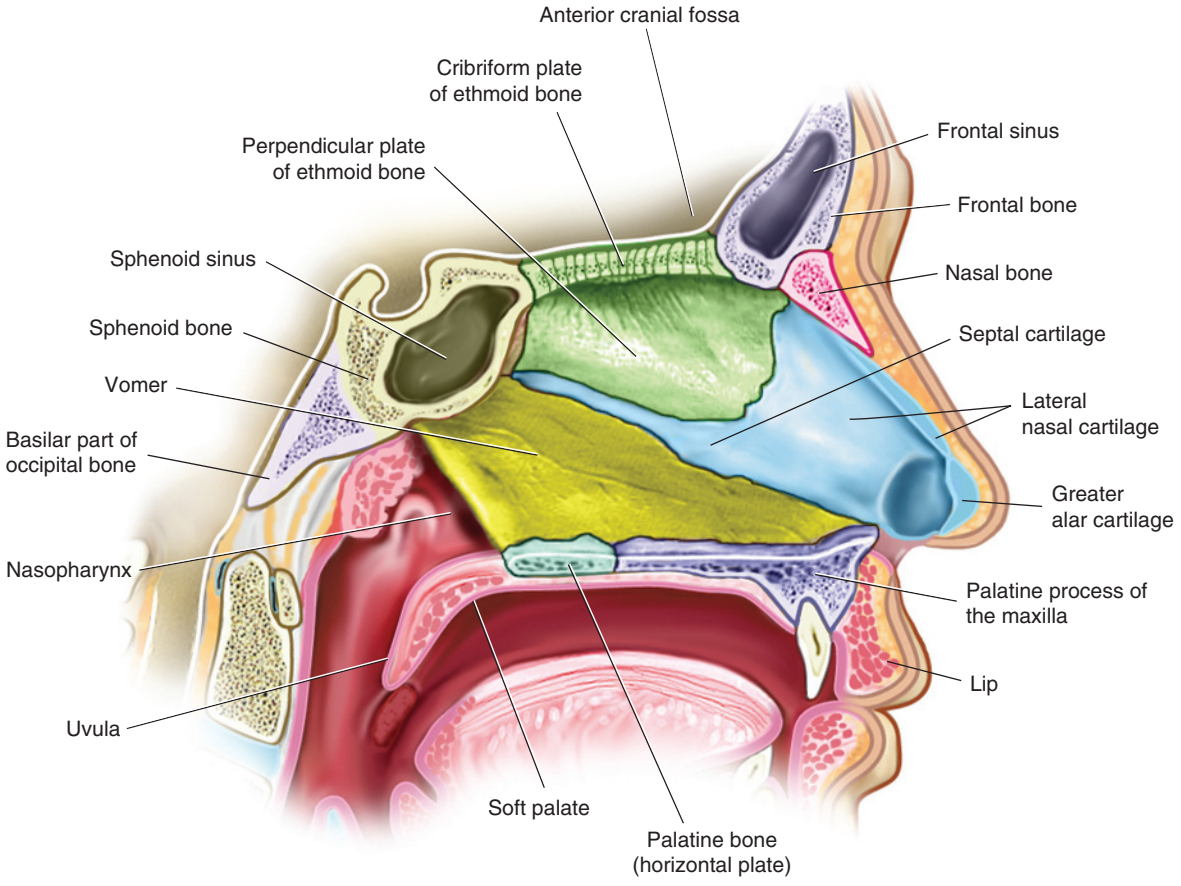


FIGURE 1–3 Sagittal section through the nose, showing the parts of the nasal septum.



Clinical Connection 1-1

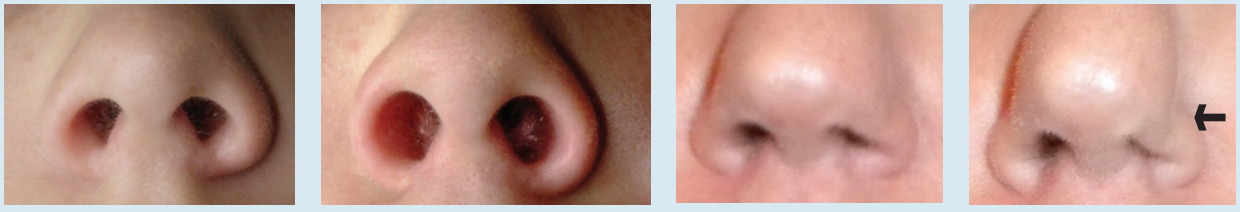
Nasal Flaring and Alar Collapse

Nasal flaring is the widening of the nostrils during periods of respiratory difficulty. The identification of nasal flaring is considered a classic sign of respiratory discomfort—especially in the newborn infant. During periods of respiratory distress—caused by (1) increased airways resistance (e.g., asthma) or (2) lungs that are stiffer than normal (e.g., pneumonia)—the patient commonly generates a greater than normal negative pressure during each inspiration to pull air into the airways more rapidly. The widening of the nostrils further augments the movement of gas flow into the nasal passage during each inspiration (Figure 1–4A and B). Common respiratory disorders associated with nasal flaring include respiratory distress syndrome of the newborn infant, pneumonia, acute asthma, and any airways obstruction. Clinically, aggressive respiratory therapy modalities should be activated to increase the patient's arterial blood oxygen level.

The reverse of nasal flaring is called **alar collapse** and is an important sign of nasal obstruction (Figure 1–4C and D). Nasal obstruction causes the victim to be an obligate mouth breather, and it is one of the causes of snoring and obstructive sleep apnea (refer to Chapter 17).

Clinical Connection 1-1, Continued

FIGURE 1-4 **A.** Normal nostrils. **B.** Nasal flaring. **C.** Patient with alar collapse during exhalation. **D.** Patient with alar collapse during inspiration.



A B C D

Courtesy T. Des Jardins, WindMist LLC

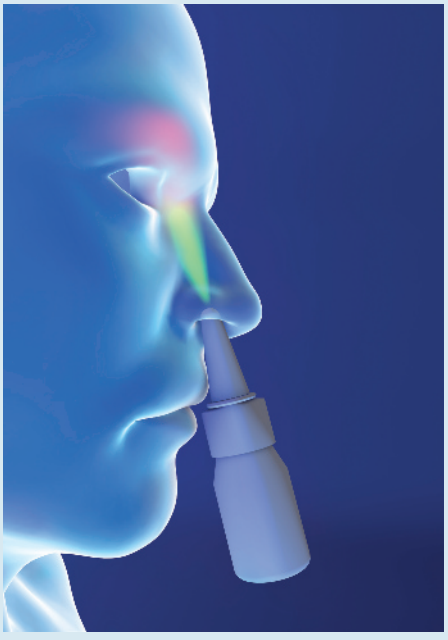
Clinical Connection 1-2

The Nose—A Route of Administration for Topical Agents

Because of the large quantity of blood vessels located near the surface of the nasal mucosa, the nose serves as an excellent route of administration for a variety of topical drugs in the form of nasal sprays or nasal drops (Figure 1–5). Such drugs can be applied directly to the mucous membranes to produce a local effect, with little or no systemic absorption. For example, in cold remedies, medications such as Neo-Synephrine® (phenylephrine) are commonly applied for their sympathomimetic, alpha-stimulating, and vasoconstriction effects to treat nasal congestion. Abuse of this class of drugs is, unfortunately, common. Overuse of topical nasal decongestants can result in the undesired effect of engorgement of the nasal membranes.

Synthetic corticosteroids—such as budesonide—are used to treat nasal mucosa inflammation. Ipratropium bromide, an anticholinergic agent, is used to treat nasal congestion, sneezing, and itchy, runny nose. In addition, other medications, including influenza vaccines, can be delivered by intranasal administration.

FIGURE 1-5 Nasal spray.



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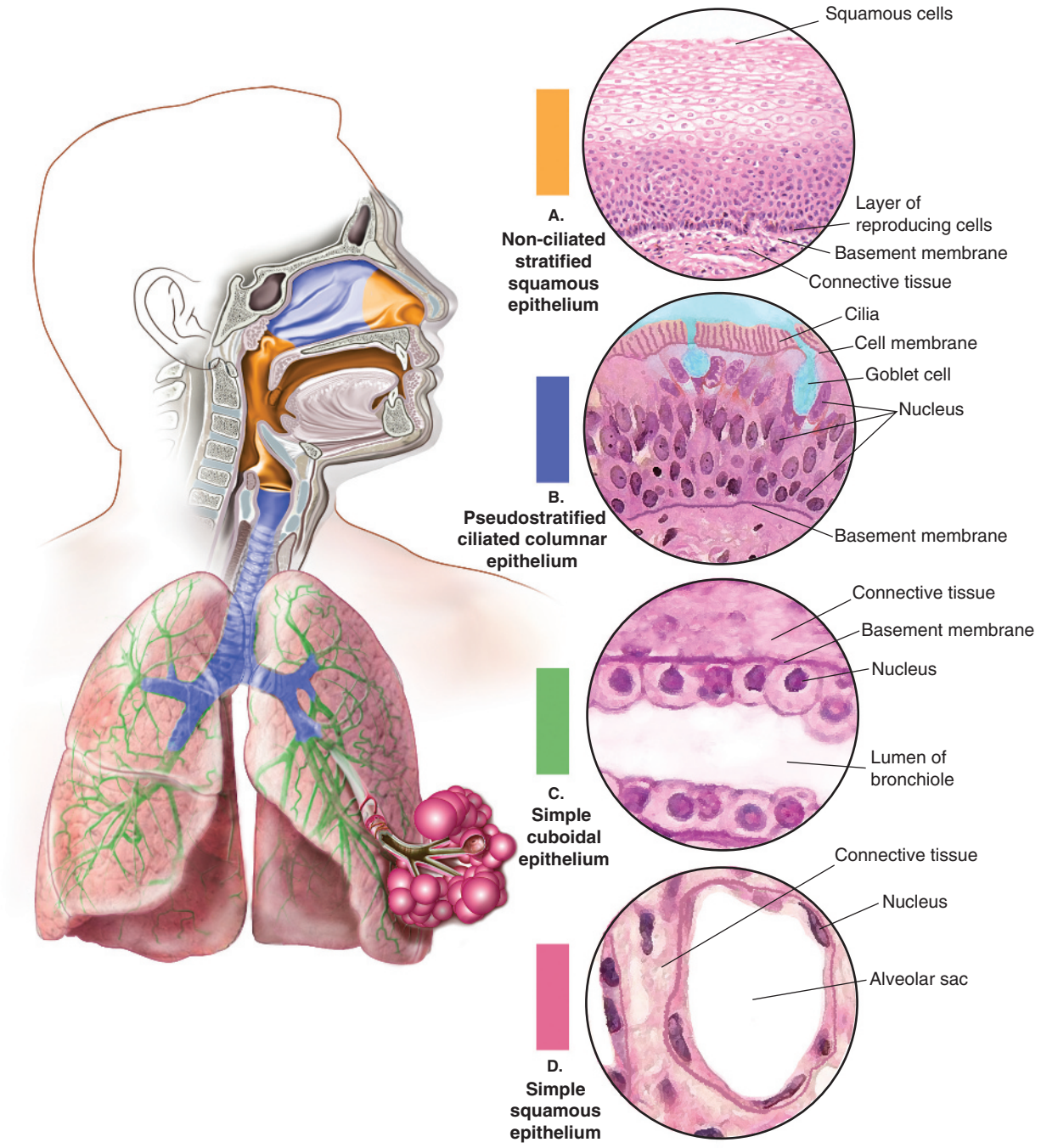
There are three bony protrusions on the lateral walls of the nasal cavity called the **superior**, **middle**, and **inferior nasal turbinates**, or **conchae** (see Figure 1–1). The turbinates separate inspired gas into several different airstreams—this action increases the contact area between the inspired air and the warm, moist surface of the nasal mucosa. The nasal mucosa has a rich supply of blood vessels and nerve endings. When the inspired air is cold, the vascular system becomes engorged with blood and warms the air. The turbinates

FIGURE 1–6 Epithelium of the conducting airways. **A. Stratified squamous epithelium** consists of several layers of cells. This tissue is found in the anterior portion of the nasal cavity, oral cavity, oropharynx, and laryngopharynx. **B. Pseudostratified ciliated columnar epithelium** appears stratified because the nuclei of the cells are located at different levels. These cells have microscopic hairlike projections called cilia that extend from the outer surface. Mucous-producing goblet cells are also found throughout this tissue. Pseudostratified columnar ciliated epithelium lines the posterior two-thirds of the nasal cavity and the tracheobronchial tree. **C. Simple cuboidal epithelium** consists of a single layer of cube-shaped cells. These cells are found in the bronchioles. **D. Simple squamous epithelium** consists of a single layer of thin, flattened cells with broad and thin nuclei. Substances such as oxygen and carbon dioxide readily pass through this type of tissue. These cells form the walls of the alveoli and the pulmonary capillaries that surround the alveoli.



play a major role in the humidification and warming of inspired air. The receptors for the sense of smell are located in the **olfactory region**, which is near the superior and middle turbinates. When the nasal mucosa nerve endings are irritated with particles—such as powder, dust, or pollen—a sneeze reflex is triggered. The two nasal passageways between the nares and the nasopharynx are also called the **choanae**.

Clinical Connection 1-3

Nosebleeds (Epistaxis)

Because of the abundance and superficial location of the vascular system throughout the mucosa of the nasal cavity—especially the anterior septum area—nosebleeds are commonly seen both in and out of the hospital setting (Figure 1–7). The nosebleed may be profuse or merely a minor complication. Nosebleeds tend to occur more often during the winter months, when the air is dry and warmed by household heaters. Nosebleeds can also occur in a hot and dry climate with low humidity. In other words, nosebleeds tend to occur during periods of low humidity. Although nosebleeds may occur at any age, they are most commonly seen in children between 2 and 10 years of age and in adults between 50 and 80 years of age.

Nosebleeds are classified as either *anterior,* originating from the highly vascularized anterior septum of the nose, or *posterior,* originating from the back of the nose. **Anterior nosebleeds** make up more than 90 percent of nosebleeds and are usually stopped at home by simply pinching the nostrils closed or packing them with cotton. **Posterior nosebleeds** are much less common. The bleeding usually originates from an artery located in the back of the nasal cavity. Blood usually flows down the back of the pharynx—even when the person is sitting or standing. Posterior nosebleeds tend to occur more often in the elderly and are usually more complicated. Posterior nosebleeds can be very serious and may require hospitalization for management.

Common causes of anterior nosebleeds include trauma (e.g., a hard blow or smack to the nose), nose-picking and trauma from foreign bodies (common in children), a difficult nasal intubation, exposure to cold and dry climates with low humidity, exposure to a hot and dry climate with low humidity, high altitudes, head colds and allergies, and certain medications. For example, individuals are more susceptible to nosebleeds when they are taking the anti-blood-clotting medication warfarin (Coumadin® or Panwarfarin®), aspirin, or any anti-inflammatory medications. Significant nosebleeds can result in these cases.

FIGURE 1–7 Nosebleed.

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When the nosebleed is caused by dry nasal mucosa, a little water-soluble jelly, applied about 0.5 inch into the nose using a Q-tip, two to four times a day, may be helpful. Although a room humidifier may be helpful, caution must be taken to prevent the growth of molds and other allergens. Do not use a petroleum-based product (e.g., Vaseline). A petroleum-based product will dry, not moisten, the nose. In the hospital setting, the respiratory therapist adds humidity to oxygen therapy when flow rates exceed 4 liters per minute.

Common causes of posterior nosebleeds include serious nose trauma (e.g., displaced broken nose from a motor vehicle accident or fall), nasal mucosal infections, high blood pressure, nasal tumors, atherosclerosis, drug abuse (e.g., cocaine), and leukemia. Treatment includes packing the nose with cotton or inserting an inflatable balloon to stop the bleeding. Cauterization of the ruptured blood vessels may be required.