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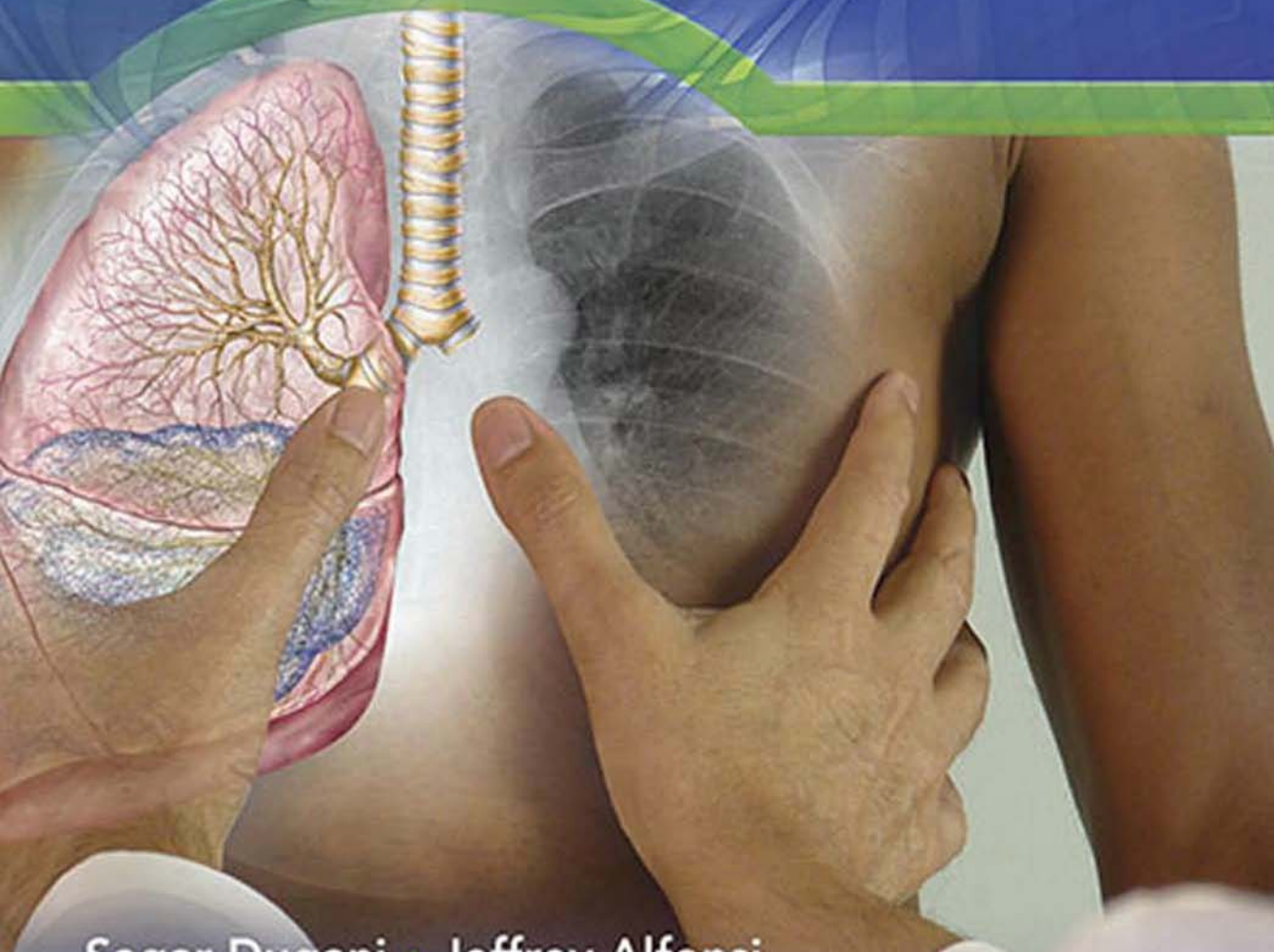

Sagar Dugani • Jeffrey Alfonsi
Anne M. R. Agur • Arthur F. Dalley

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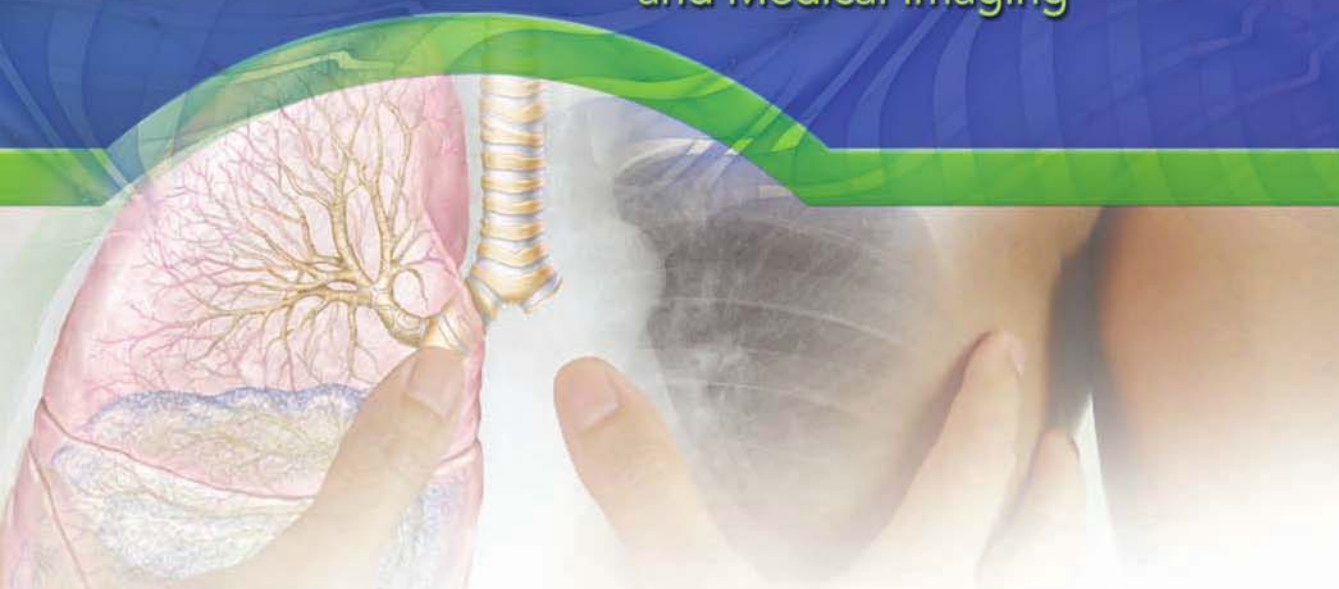

Sagar Dugani, MD, PhD

Clinical Fellow, General Internal Medicine
St. Michael's Hospital and University of Toronto
Toronto, Ontario, Canada

Anne M. R. Agur, BSc (OT), MSc, PhD

Professor, Division of Anatomy, Department of Surgery, Faculty of Medicine
Division of Physical Medicine and Rehabilitation, Department of Medicine
Department of Physical Therapy, Department of Occupational Science and Occupational Therapy
Division of Biomedical Communications, Institute of Medical Science
Rehabilitation Sciences Institute, Graduate Department of Dentistry
University of Toronto
Toronto, Ontario, Canada

Jeffrey E. Alfonsi, BASc, MD

Clinical Fellow, Department of Medicine
Schulich School of Medicine and Dentistry
Western University
London, Ontario, Canada

Arthur F. Dalley II, PhD, FAAA

Professor, Department of Cell and Developmental Biology
Adjunct Professor, Department of Orthopaedic Surgery
Vanderbilt University School of Medicine
Adjunct Professor of Anatomy
Belmont University School of Physical Therapy
Nashville, Tennessee

Wolters Kluwer

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And…

…to the anatomical donors:

With sincere appreciation for all those who donate their bodies for anatomical study and research, without whom much anatomical study would not be possible.

CONTRIBUTORS

Anne M. R. Agur, BSc (OT), MSc, PhD
Professor, Division of Anatomy, Department of Surgery, Faculty of Medicine
Division of Physical Medicine and Rehabilitation, Department of Medicine
Department of Physical Therapy, Department of Occupational Science and Occupational Therapy
Division of Biomedical Communications, Institute of Medical Science
Rehabilitation Sciences Institute, Graduate Department of Dentistry
University of Toronto
Toronto, Ontario, Canada

Jeffrey E. Alfonsi, BASc, MD
Clinical Fellow, Department of Medicine
Schulich School of Medicine and Dentistry
Western University
London, Ontario, Canada

Shamik Bhattacharyya, MD, MS
Clinical Fellow
Department of Neurology
Harvard Medical School
Neurology Resident
Department of Neurology
Massachusetts General Hospital and Brigham and Women's Hospital
Boston, Massachusetts

Nickolaus Biasutti, HBSc
MD Candidate, QMed 2018
Faculty of Health Sciences
Queen's University
Kingston, Ontario, Canada

Tanya Chawla, RCP, FRCR, FRCPC
Assistant Professor
Department of Medical Imaging
University of Toronto
Staff Radiologist
Department of Medical Imaging
Mount Sinai Hospital
Toronto, Ontario, Canada

Ernest Chiu, MD
Clinical Fellow, Division of Nephrology
Department of Medicine
University of Toronto
Toronto, Ontario, Canada

Kenneth B. Christopher, MD, SM
Assistant Professor
Department of Medicine
Harvard Medical School
Associate Physician
Division of Renal Medicine
Brigham and Women's Hospital
Boston, Massachusetts

Christine J. Chung, MD
Department of Medicine, Division of Cardiology
Columbia University Medical Center
New York City, New York

Arthur F. Dalley II, PhD, FAAA
Professor, Department of Cell and Developmental Biology
Adjunct Professor, Department of Orthopaedic Surgery
Vanderbilt University School of Medicine
Adjunct Professor of Anatomy
Belmont University School of Physical Therapy
Nashville, Tennessee

Sagar Dugani, MD, PhD
Clinical Fellow, General Internal Medicine
St. Michael's Hospital and University of Toronto
Toronto, Ontario, Canada

Sebastian Heaven, MBBCh
Postgraduate Surgical Trainee
Department of Surgery, Orthopaedic Division
McMaster University
Orthopaedic Surgery Resident
Department of Orthopaedic Surgery
Hamilton Health Sciences
Hamilton, Ontario, Canada

Marilyn Heng, MD, FRCSC
Instructor
Department of Orthopaedic Surgery
Harvard Medical School
Orthopaedic Surgeon
Department of Orthopaedic Surgery
Massachusetts General Hospital
Boston, Massachusetts

Aaron Izenberg, MD, FRCPC
Lecturer
Division of Neurology, Department of Medicine
University of Toronto
Staff Neurologist
Sunnybrook Health Sciences Centre
Toronto, Ontario, Canada

R. Phelps Kelley, AB, MD
Resident
Department of Radiology and Biomedical Imaging
University of California, San Francisco
San Francisco, California

Joshua P. Klein, MD, PhD
Associate Professor
Department of Neurology
Harvard Medical School
Chief, Division of Hospital Neurology
Department of Neurology
Brigham and Women's Hospital
Boston, Massachusetts

Kristen M. Krysko, MD, BSc
Resident Physician
Department of Neurology
University of Toronto
Toronto, Ontario, Canada

Joshua M. Liao, MD
Department of Medicine
Perelman School of Medicine
University of Pennsylvania
Philadelphia, Philadelphia

Kelsey E. Mills, MD
Obstetrician and Gynecologist
Department of Obstetrics and Gynecology
Victoria General Hospital
Victoria, British Columbia

Tri H. Nguyen, MD, MSc
Resident
Physical Medicine and Rehabilitation
University of Toronto
Toronto, Ontario, Canada

Gavin J. le Nobel, MD
Resident
Otolaryngology Head and Neck Surgery
University of Toronto
Toronto, Ontario, Canada

Sunita Sharma, MD, MPH
Associate Professor
Department of Medicine
University of Colorado School of Medicine
Aurora, Colorado

Samuel A. Silver, MD, FRCPC
University of Toronto
Toronto, Ontario, Canada

Laura E. Smith, MD
Instructor in Medicine
Harvard Medical School
Instructor in Medicine
Internal Medicine
Brigham and Women's Hospital
Boston, Massachusetts

Daniel Souza, MD, MSc
Instructor
Department of Radiology
Harvard Medical School
Staff Radiologist
Department of Radiology
Brigham and Women's Hospital
Boston, Massachusetts

Devraj Sukul, MD
Fellow, Cardiovascular Medicine
Department of Internal Medicine
University of Michigan Health System
Ann Arbor, Michigan

Piero Tartaro, MD, MScCH
Lecturer
Department of Medicine
University of Toronto
Staff Gastroenterologist
Division of Gastroenterology
Sunnybrook Health Sciences Centre
Toronto, Ontario, Canada

Sarah M. Troster, MD
Clinical Fellow, Division of Rheumatology
Department of Internal Medicine
University of Toronto
Toronto, Ontario, Canada

Janice Wong, MD, MS
Clinical Fellow
Department of Neurology
Harvard Medical School
Neurology Resident
Department of Neurology
Brigham and Women's Hospital, Massachusetts General Hospital
Boston, Massachusetts

Michelle J. Yu, MD, PhD
Pulmonary and Critical Care Medicine
University of California, San Francisco
San Francisco, California

Jonathan S. Zipursky, MD
Resident
Department of Medicine
St. Michael's Hospital
University of Toronto
Toronto, Ontario, Canada

Molly Zirkle, MD, MED
Assistant Professor
Department of Otolaryngology
University of Toronto
Toronto, Ontario, Canada

REVIEWERS

FACULTY

Francine Anderson, PhD, PT
Chair of Anatomy
School of Osteopathic Medicine
Campbell University
Buies Creek, North Carolina

Rebecca Brown, MPAS, PA-C
Assistant Coordinator
Le Moyne College
Syracuse, New York

Thomas R. Gest, PhD
Professor of Anatomy
Department of Medical Education
Texas Tech University Health Sciences Center
El Paso, Texas

Douglas J. Gould, PhD
Professor of Neuroscience and Vice Chair
Department of Biomedical Sciences
Oakland University William Beaumont
School of Medicine
Rochester, Michigan

Robert Hage, MD, PhD, DLO, MBA
Professor
St. George's University
St. George's, Grenada, West Indies

Jon Jackson, PhD
Visiting Professor
St. George's University
St. George's, Grenada, West Indies

Eileen Kalmar, PhD
Assistant Professor—Clinical
College of Medicine
The Ohio State University
Columbus, Ohio

H. Wayne Lambert, PhD
Professor
Department of Neurobiology and Anatomy
West Virginia University School of Medicine
Morgantown, West Virginia

Octavian Calin Lucaciu, MD, PhD
Associate Professor
Canadian Memorial Chiropractic College
Toronto, Ontario

Andrew F. Payer, PhD
Professor
Medical Education
College of Medicine
University of Central Florida
Orlando, Florida

Danielle Royer, PhD
Assistant Professor
Department of Cell and Developmental Biology
University of Colorado Denver
Denver, Colorado

Brett Szymik, PhD
Assistant Professor
Georgia Regents University/University of Georgia
Medical Partnership
Athens, Georgia

Ljubisa Terzic, MD
Associate Professor
Canadian College of Naturopathic Medicine
Toronto, Ontario

Shanna Williams, PhD
Assistant Professor
School of Medicine
University of South Carolina
Greenville, South Carolina

STUDENTS

Joshua Agranat
Boston University School of Medicine

Amier Ahmad
University of Southern Florida College of Medicine

David Ballard
Louisiana State University Health
Shreveport School of Medicine

William Blair
Lake Erie College of Osteopathic Medicine

Lucas Carlson
University of Maryland School of Medicine

William Gentry
Oceania University of Medicine

Benjamin Heyen
University of Kansas Medical School

Christopher Jacob
Becker Professional Education
Ross University School of Medicine

Christen Johnson
Wright State University Boonshoft School of Medicine

Zuhal Kadhim
University of Toronto

Bryan Klosky
Shenendoah University School of Pharmacy

Porcha Leggett
Ross University School of Medicine

Jason Lipof
George Washington University School of Medicine

Julianne Matthews
Northeastern Ohio Medical University

Francesca Nichols
University of Utah School of Medicine

Jennifer Townsend
UCSF School of Medicine

Samuel Windham
University of Missouri–Columbia School of Medicine

Kristen Wilde
Indiana University School of Medicine

Michael Wu
University of Hawaii, John A. Burns School of Medicine

PREFACE

Medical education is evolving. Yet, today, many topics are often taught in isolation, and trainees are presented with the daunting task of integrating various concepts in medicine. Several years ago, we experienced that three key topics—anatomy, physical examination, and medical imaging—were fragmented through different stages of medical education and that trainees lacked a single resource to integrate these topics. This fragmentation gave rise to the idea of *Clinical Anatomy Cases* as a way to amalgamate all three concepts into a single resource.

Clinical Anatomy Cases uses a highly graphical approach to describe seven anatomical regions. The introductory chapter outlines our integrated approach and provides the fundamentals of the physical examination, medical imaging modalities, and commonly used statistical concepts. The seven anatomical regions continue this integrated approach and lead the reader through several common clinical presentations and diseases. Where relevant, we also include a concise list of differential diagnoses and high-yield clinical pearls.

We decided to create this resource as it addresses a gap in our approach to education. We remain confident that this integrated resource will appeal to medical students, residents, and students in health disciplines including nursing, physical therapy, occupational therapy, dentistry, and physician assistants program. In addition to being beneficial to students, this book will also serve as a convenient resource for faculty members to include in their courses or integrated curricula. Further, the topics presented here complement the clinical focus of related Wolters Kluwer publications such as *Clinically Oriented Anatomy* and *Essential Clinical Anatomy*. We hope that this book generates additional resources that integrate various aspects of medical education.

KEY TO ICONS USED IN CLINICAL CASES

 = Family Medicine

 = Emergency Medicine

 = Obstetrics and Gynecology

 = Surgery

 = Internal Medicine

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Several years ago, we started out with the idea of integrating anatomy, physical examination, and medical imaging, and the creation of this first edition of *Clinical Anatomy Cases* would not have been possible without the guidance and advice of several outstanding individuals in the United States and Canada. We are extremely grateful to Dr. Joseph Loscalzo (Chairman of the Department of Medicine, and Physician-in-Chief at Brigham and Women's Hospital, Boston), Dr. Joel T. Katz (Director, Internal Medicine Residency Program, Brigham and Women's Hospital, Boston), Dr. Maria Yialamas (Associate Program Director, Internal Medicine Residency Program, Brigham and Women's Hospital, Boston), Dr. Vivian Gonzalez Mitchell (Assistant Program Director, Internal Medicine Residency Program, Brigham and Women's Hospital, Boston), and Dr. Stephen Ledbetter (Chief of Radiology at Brigham and Women's Faulkner Hospital, Boston) for their timely and generous advice in developing this book and in identifying faculty contributors. We thank Dr. Heather McDonald-Blumer (Division of Rheumatology, Mount Sinai Hospital/University Health Network and University of Toronto, Toronto) and Dr. Vincent Chien (Division of General Internal Medicine, St. Michael's Hospital and University of Toronto, Toronto) for supporting this initiative and for identifying faculty collaborators. We remain grateful to all of our authors (residents, fellows, and faculty members) at Brigham and Women's Hospital (Boston), University of Toronto (Toronto), and other hospitals in the United States and Canada, who took time out of their busy clinical and nonclinical schedules to be part of this project and help bring our idea to fruition.

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Integrated Approach to Clinical Encounters

1

JEFFREY E. ALFONSI • SAGAR DUGANI •
ANNE M. R. AGUR • ARTHUR F. DALLEY II

INTRODUCTION TO AN INTEGRATED APPROACH TO MEDICINE

The practice of medicine is the art and science of evaluating and optimizing the health of a patient. According to the World Health Organization, health is "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" and is determined by biologic, psychological, and social factors. To evaluate a patient's health, the clinician must integrate knowledge in anatomy, physical examination, biochemistry, and medical imaging to characterize the etiology of the presenting symptoms. During undergraduate and postgraduate education, many of these concepts are often taught in isolation. This book aims to facilitate the process of thinking clinically and critically by integrating the fundamentals of anatomy, physical examination, and medical imaging into the clinical evaluation of a patient. We begin this chapter with the clinical case of Mr. John Smith.

> *Mr. Smith is a 30-year-old male who visits his primary care provider with a chief complaint of right knee pain. Four days prior, he developed sudden-onset knee pain that has made it difficult to ambulate. Mr. Smith has also experienced abdominal discomfort and diarrhea over the last week. He has not taken any medications and does not have drug allergies. As his primary care provider, you are aware that Mr. Smith has experienced intermittent episodes of abdominal pain and diarrhea in the past that have resolved without intervention. As his provider, you consider if the two presenting symptoms—right knee pain and abdominal discomfort with diarrhea—are related or independent of each other.*

How should the clinician approach this situation?

INITIAL EVALUATION

Based on the chief complaint, the clinician develops a *differential diagnosis* and, throughout the history, physical examination, and interpretation of tests (also called *investigations*), attempts to narrow the differential diagnosis to arrive at the most likely etiology. In medical emergencies, the clinician may obtain a brief history, stabilize the patient, and then obtain additional information from the patient or collateral sources such as family members, witnesses, and emergency responders.

The initial evaluation begins with the clinician observing the patient and focuses on four components: general appearance and grooming, greeting, behavior and expression, and posture and gait.

The general appearance and grooming provide information on the patient's overall health.

1. Does the patient appear well or sick? If the patient appears sick, does this reflect an acute change or is this consistent with the patient's chronic illnesses?
2. Does the patient's appearance match his or her stated age?
3. Does the patient look malnourished, or is there an obvious change (increase or decrease) in weight? Is this change uniform, or is it restricted to a specific part of the body?
4. Is the patient wearing appropriate clothing and footwear, or is there a risk of weather-related injuries?
5. Are the patient's hair, nails, and skin well groomed? Does the patient have body odor, which along with other factors may suggest inadequate self-care and hygiene?

During the greeting, the clinician assesses the appropriateness of the patient's initial interaction.

1. Does the patient make appropriate eye contact?
2. When the patient shakes hands, do the hands feel warm or cool/clammy?
3. Do the patient's facial gestures match his or her verbal expressions, or is there discordance?

The third component is evaluation of the patient's behavior and expression, which provides information on the overall physical and psychological state.

1. Does the patient appear to be breathing normally, or is it labored?
2. Does the patient appear to be in obvious distress or pain?
3. Does the patient maintain appropriate eye contact throughout the interview?
4. Does the patient appear to have involuntary movements, tremors, or facial twitching?

The final component is the evaluation of posture and gait, which helps identify possible impairment in the neurological, musculoskeletal, or endocrine systems.

1. Does the patient have normal gait? (Chapter 6)
2. Does the patient swing his or her arms while ambulating, or are the arms locked in a particular position?
3. Does the patient maintain normal posture while ambulating and while sitting?

Returning to the case, the initial evaluation revealed that Mr. Smith was well groomed and appropriately dressed. He appeared his stated age, but was frail, and his facial expression showed he was in discomfort. Despite his discomfort, he greeted the clinician pleasantly. While walking into the examination room, Mr. Smith maintained a normal posture, but had difficulty bearing weight on his right leg.

DETAILED EVALUATION

The detailed evaluation involves obtaining a detailed history, performing a physical examination, and ordering laboratory tests and imaging. History taking will not be covered in this book, and we will begin with the physical examination.

PHYSICAL EXAMINATION

A complete physical examination involves evaluation of the following components, most of which will be addressed in the relevant chapters:

- General appearance, behavior, and vital signs (Chapter 1)
- Cardiovascular examination (Chapter 2)
- Respiratory examination (Chapter 2)
- Abdominal and retroperitoneal examination (Chapter 3)
- Peripheral vascular examination (Chapter 6)
- Musculoskeletal examination (Chapter 6)
- Neurologic examination (Chapters 5, 6, and 7)
- Head and neck examination (Chapter 7)

In special circumstances, dermatologic, gynecologic (Chapter 4), urologic (Chapter 4), psychiatric, ophthalmologic, and otolaryngologic examinations may also be performed.

The clinician should obtain consent prior to performing a physical examination. Exact definitions of consent vary based on the state, province, or country of practice, but, in general, it involves informing the patient or his or her substitute decision maker about the planned examination/intervention, the benefits and risks of the examination/intervention, and available reasonable alternatives. Consent is intervention specific and, in emergency situations, can be overridden as long as the patient's interests and wishes are kept in mind.

Here is one approach to preparing a patient for an examination (although several are possible):

- *Positioning and Appropriate Lighting*: It is important that the patient be positioned appropriately, for example, sitting upright in an examination chair or lying supine on an examination table. Further, ensuring that there is appropriate lighting to examine the relevant system(s) is also important.
- *Supervision and Draping*: The clinician should perform maneuvers that are within his or her scope of practice and expertise and ensure appropriate supervision, when necessary. Further, the clinician should clarify the patient's preference for having a chaperone in the room during the examination. For example, a patient may prefer to have a female chaperone in the room during a breast or pelvic examination. Finally, the patient should be appropriately draped such that only

essential areas are exposed. For example, while performing an abdominal examination, a drape is placed over the pelvic area and lower extremities; while performing a breast examination, only the breast being examined is exposed, while the other breast should be covered with a drape.

- *Equipment*: The clinician should have all necessary equipment (e.g., stethoscope, reflex hammer, eye chart) for the physical examination.

Vital Signs

After performing an initial evaluation, the clinician obtains vital signs. Vital signs provide essential information on the stability of the patient. There are four vital signs: body temperature, blood pressure (BP), heart rate (HR), and respiratory rate (RR). Abnormalities in these signs may occur when one or more anatomic systems are affected by disease, trauma, or medications. In some instances, the following parameters are also measured and reported with vital signs: arterial oxygen saturation (O_2 sat), height, weight, body-mass index (BMI), and pain index; however, these are not classically regarded as "vital signs."

Temperature

There are at least four approaches to measuring temperature: oral, aural (tympanic membrane), axillary, and rectal. The average oral temperature is 98.6°F (37°C) and fluctuates from 96.4°F (35.8°C) in the morning (usually at 6:00 AM) to 99.1°F (37.3°C) in the afternoon or evening (usually between 4 and 6 PM).

CLINICAL PEARL

Compared to oral temperature:

Rectal temperature is higher by 0.4°C–0.5°C.
Aural temperature is higher by 0.8°C–1°C.
Axillary temperature is lower by 1°C.

Body temperature is regulated by the hypothalamus, which, in turn, is affected by several intrinsic and extrinsic factors. Temperatures within the normal range are considered *normothermia*, temperatures below 95.0°F (35°C) are considered *hypothermia*, and temperatures above 98.9°F (37.3°C) or an afternoon temperature above 99.9°F (37.7°C) fall into one of three pathologic groups: fever, hyperthermia, or hyperpyrexia. The presence of fever suggests an underlying infection, inflammatory process, autoimmune condition, malignancy, hemolysis, venous thrombosis, or medication side effect, among other etiologies. Fever may also result from alterations in the hypothalamus' *set point;* as a result, there is a central drive to raise the body's temperature. *Hyperthermia* increases body temperature without altering the hypothalamus' set point. This usually occurs in the presence of extrinsic factors such as heat stroke, use of stimulants such as cocaine, or as a side effect of medications (resulting in neuroleptic malignant syndrome [NMS] or malignant hyperthermia). Hyperpyrexia is characterized by temperatures above 106°F (41.1°C) and can result from CNS hemorrhage, underlying infection, or as a side effect of medications (namely, NMS or malignant hyperthermia). Hyperpyrexia requires urgent attention as it can be life threatening.

CLINICAL PEARL

NMS is a combination of hyperthermia, rigidity, and autonomic dysregulation and is a possible side effect of antipsychotic medications. Malignant hyperthermia is hypermetabolism of skeletal muscle that occurs in susceptible patients after exposure to certain inhaled anesthetic medications and muscle relaxant medications such as succinylcholine.

Serotonin syndrome is caused by excessive serotonin in the body from illicit drugs such as ecstasy or from polypharmacy. Patients may be hyperthermic with associated rigidity, hyperreflexia, myoclonus, confusion, diaphoresis, and autonomic instability.

Blood Pressure

BP is a functional measure of the circulatory system and is affected by the volume of fluid in the circulatory system, ability of the heart to effectively pump blood to the body, systemic inflammation associated with infections, and the ability of the nervous system to relax or constrict blood vessels. In addition, the patient's age, sex, medical comorbidities, medications, and social stressors can affect BP.

BP fluctuates throughout the day. The goal is to obtain numerous measurements to approximate the true BP, and there are various methods to do so:

- *Ambulatory BP monitoring* requires a patient to wear a BP cuff for 24–48 hours. The patient's BP is automatically measured every 15–20 minutes during the day and every 30–60 minutes at night. Ambulatory monitoring has several advantages: it normalizes natural physiologic BP variation that might incidentally be captured during a clinic visit, it eliminates "white coat hypertension" associated with clinic settings, it can uncover "masked hypertension," and it reduces the number of clinic visits a patient has to make. Although ambulatory monitoring requires a patient to wear a BP cuff for 24–48 hours and is considered to be cumbersome, it is regarded as the reference standard to diagnose hypertension.
- *Home blood pressure monitoring* requires a patient to check his or her BP 10–15 times over a 1-week period in order to estimate the average BP. This approach has similar advantages to the ambulatory monitoring approach.
- *Office blood pressure monitoring* requires one or more BP measurements to be taken during a single office visit. Office measurements are more likely to vary from the patient's true BP compared to ambulatory or home monitoring. **Figure 1.1** summarizes the technique of obtaining a BP manually.

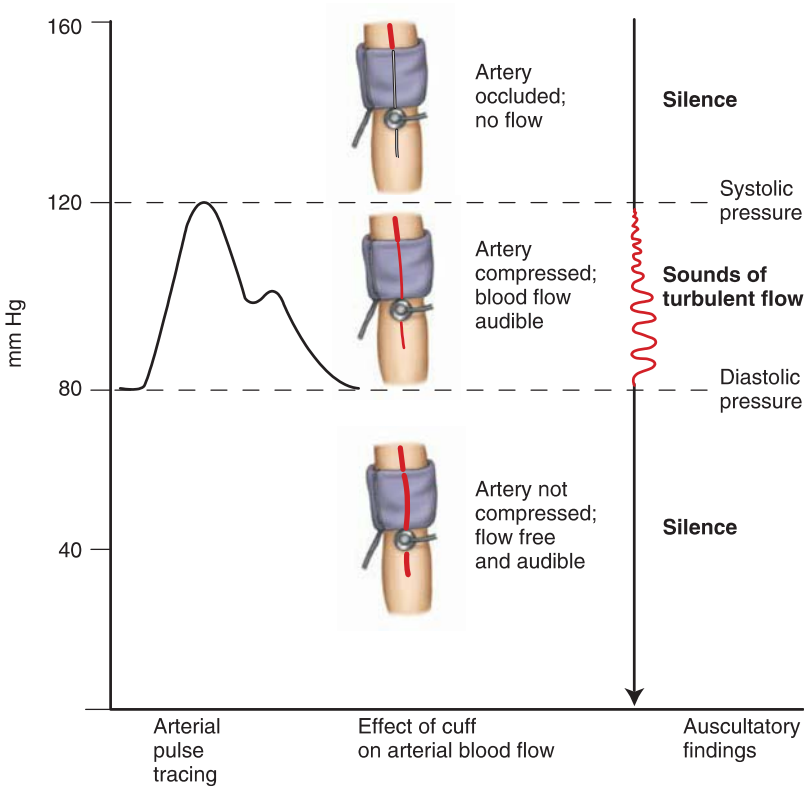


FIGURE 1.1. Measuring blood pressure. An appropriately sized blood pressure cuff is inflated around the arm of the patient to compress and occlude arterial blood flow. Next, the cuff is deflated while auscultating for Korotkoff sounds, and the first instance of this marks the systolic pressure. As the cuff is further deflated, sounds of turbulent blood flow remain audible, until they become inaudible. The first instance of this marks the diastolic blood pressure.

TABLE 1.1. Pulse pressure (PP) and asymmetry in measurement of blood pressure (BP)

Definition	Causes
Wide PP is a PP > 50% of the systolic pressure.	Hyperdynamic states such as hyperthyroidism, aortic insufficiency (or regurgitation), fever, anemia, and pregnancy
Narrow PP is a PP < 25% of the systolic pressure.	Cardiac tamponade, constrictive pericarditis, aortic stenosis, and shock
Asymmetric BP is a difference of more than 10 mm Hg in the systolic pressure between the right and left extremities.	Aortic dissection, peripheral artery disease, subclavian stenosis, and errors in measurement

PP is the difference between the systolic and diastolic BP. Blood pressure should be measured in both arms, and the readings are normally within 5–10 mm Hg of each other. Several conditions are associated with asymmetric BP measurements as described in **Table 1.1** and in Chapter 2.

Several factors can complicate BP readings, including the presence of weak Korotkoff sounds; body habitus of the patient, particularly if the wrong type/size of cuff is used; type of equipment used (manual vs. automatic); and arrhythmias.

Heart Rate and Rhythm

HR and rhythm are important signs related to the circulatory system and are affected by the respiratory, endocrine, and nervous systems as well as by drugs and fever, among other etiologies. In addition to the HR, the clinician documents if the heart rhythm is regular or irregular and if the arterial pulse is weak or bounding.

Normal hearts have a regular HR of 60–100 beats per minute (bpm). HRs below 60 bpm are termed *bradycardia*, and HRs above 100 bpm are termed *tachycardia*. The differential diagnosis for bradycardia and tachycardia is presented below.

Sinus Bradycardia	Sinus Tachycardia
Normal finding in some athletes	Hyperthyroidism
Acute myocardial ischemia	Acute myocardial ischemia
Increased intracranial pressure	Fever, volume depletion, and sepsis
Hypothyroidism	Stimulants including caffeine, toxins, anxiety, recreational drugs, and exercise
Sick sinus syndrome	Anemia, hypoxia, and chronic obstructive pulmonary disease (COPD)
Medication side effect	Heart failure Pulmonary embolism

Orthostatic Vital Signs

When the clinician suspects blood loss or dehydration, and the patient's resting BP is within the normal range, orthostatic vital signs should be measured. With the patient supine, the clinician measures the BP and HR. The patient is then asked to stand for 2–3 minutes, following which the BP and HR are again measured. A symptomatic patient or a drop in diastolic BP of 10 mm Hg or more, drop in systolic BP of 20 mm Hg or more, or an increase in HR of 30 bpm or more is indicative of orthostatic changes and suggests low circulating blood volume.

Respiratory Rate

The RR is an important vital sign affected by the respiratory, circulatory, renal, and nervous systems. The normal adult RR is 12–18 breaths per minute. The clinician assesses if the patient's breathing

pattern is normal and quiet or if it is labored and requires the use of accessory respiratory muscles. The clinician also monitors the breathing pattern for the presence of respiratory pauses and for the duration of the expiratory phase, as these can be altered in conditions such as asthma and COPD.

Oxygen Saturation

Arterial O_2 sat is a measure of arterial oxygenation and is normally 95% or higher on room air (or *ambient air*, in which O_2 concentration is 21%). O_2 sat was initially measured using arterial puncture and chemical analysis, but now it can be calculated noninvasively using pulse oximetry. Pulse oximetry may be unreliable in the presence of hemoglobin-based abnormalities such as sickle cell anemia, carbon monoxide poisoning, or anemia. In such cases, co-oximetry can be performed in the laboratory to determine the true O_2 sat.

Body Mass Index

$$\text{BMI} = [\text{weight, measured in kg}]/[\text{height, measured in meters}]^2$$

Different cutoff points may be used for different ethnicities:

<18.5 kg/m^2	underweight
18.5–24.9 kg/m^2	normal
25.0–29.9 kg/m^2	overweight
≥30.0 kg/m^2	obese

Vital Signs in an Anatomic Context

As described above, vital signs are affected by numerous anatomic systems. Many of these systems are interrelated, such that changes in one can affect the others. Here, we describe how the circulatory, respiratory, renal, nervous, and endocrine systems interact to alter the vital signs.

The *circulatory system* consists of the cardiovascular and lymphatic systems, which serve to transport blood and lymph in the body. The cardiovascular system comprises the *pulmonary* and *systemic circulations* (**Fig. 1.2**). BP and HR are direct measures of the circulatory system. The

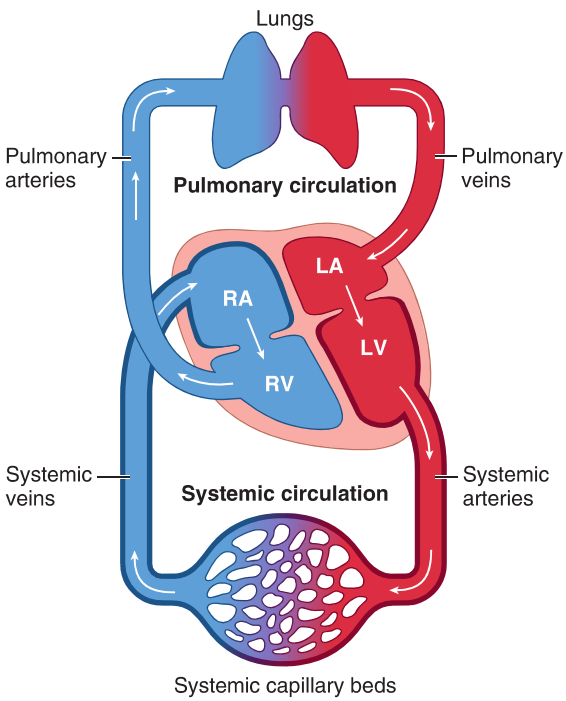


FIGURE 1.2. The circulatory system. Schematic representation of right and left heart pumping blood to the pulmonary and systemic circulation systems, respectively. *RA,* right atrium; *LA,* left atrium; *RV,* right ventricle; *LV,* left ventricle.

circulatory system also regulates temperature by increasing blood flow to dilated vessels near the skin where heat can be exchanged with the environment. If the circulatory system fails to adequately pump blood (e.g., in the setting of heart failure), then fluid accumulates in the lungs causing an increase in RR and a decrease in arterial O_2 sat. HR can be regulated by the nervous system via the vagal nerve and BP via the autonomic nervous system.

The *lymphatic system* is closely related to the circulatory system. During a 24-hour period, ~20 L of plasma is filtered out of the circulatory system into the interstitial space. Approximately 17 L is reabsorbed into the circulatory system, leaving 3 L in the interstitial space that is transported to the circulatory system via the lymphatic system (**Fig. 1.3**). In addition to its circulatory function, the lymphatic system is important to the body's immune system. As shown in **Figure 1.3**, several superficial lymphatic vessels track along the venous system and eventually drain into deep lymphatic vessels, which, in turn, drain into the right lymphatic duct or the thoracic duct. The right lymphatic duct drains lymph from the right side of the head, neck, thorax, and right upper limb into the venous circulation at the junction of the right internal jugular vein and the right subclavian vein (blue shaded area in **Fig. 1.3**). The thoracic duct receives lymph from the rest of the body and empties it in the venous circulation at the junction (also known as *left venous angle*) of the left internal jugular vein and left subclavian veins.

The *respiratory* (or *pulmonary*) *system* comprises airways, lungs, and the diaphragm (innervated by the phrenic nerve) and is responsible for transporting and exchanging oxygen and carbon dioxide between the environmental air and the circulating blood (**Fig. 1.4**). The respiratory system directly impacts O_2 sat. The respiratory system works in conjunction with the renal system to regulate blood pH. The circulatory system delivers blood to the kidneys where it passes through *nephrons* and undergoes filtration to remove waste material and excess electrolytes that are subsequently expelled in urine through the ureters, bladder, and urethra. The kidney is also responsible for the regulation of fluids (BP), pH, calcium, and electrolytes and for the production of erythropoietin to stimulate red blood cell (RBC) production. As a result, the renal and respiratory systems can affect RR. The renal system also helps regulate BP.

In addition to being affected by the circulatory, respiratory, and renal systems, vital signs are also affected by hormones. The *endocrine system* consists of structures that produce and secrete hormones into the bloodstream that then exert a physiologic or pathologic response throughout the body. For example, in hyperthyroidism, the thyroid gland produces an excess of thyroid hormone (triiodothyronine [T_3] and thyroxine [T_4]), which, in turn, can increase the HR, body temperature, BP, and RR.

Returning to the case, Mr. Smith's vital signs were assessed and recorded as follows:

Aural temperature: 97.2°F
Blood Pressure: 125/85 (right arm) and 130/90 (left arm)
Heart Rate: 72 bpm and regular rhythm
Respiratory Rate: 14 breaths per minute and without pauses or evidence of distress
Oxygen saturation: 98% on room air (ambient air, and not using supplemental oxygen)
BMI: 28.1 kg/m^2, calculated at a visit 1 month ago, and was not repeated

Focused Physical Examination

After recording Mr. Smith's vital signs, the clinician next performs a focused physical examination while keeping in mind the underlying anatomy. One approach for performing an examination is based on the IPPA method: inspection, palpation, percussion, and auscultation. The IPPA method is a general framework and has some notable exceptions. One, during an abdominal examination, the clinician first auscultates the abdomen as palpation and percussion can affect bowel sounds. Two, during a musculoskeletal examination (e.g., of the knee or hip), percussion and auscultation are not necessary. Finally, in addition to IPPA, some physical examinations include maneuvers specific to an anatomic region. For example, the knee examination will include assessment of gait, range of motion (ROM), motor power, and joint stability. The details on how to perform a specific physical examination along with special tests or maneuvers are described in the relevant chapter.

During inspection and palpation, the first organ system to be encountered is the *integumentary system*. The integumentary system consists of the skin (epidermis and dermis), hair, nails, and the

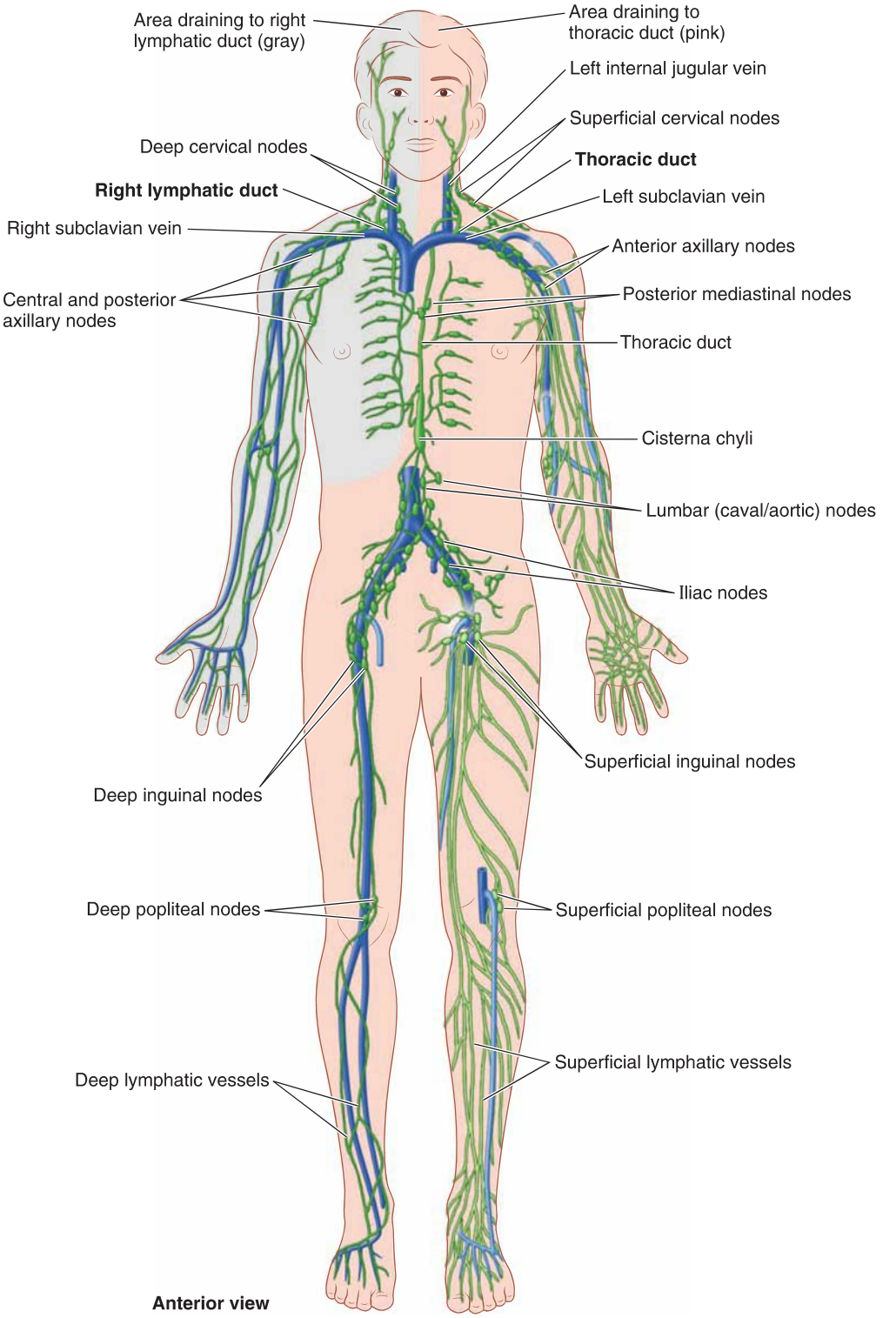
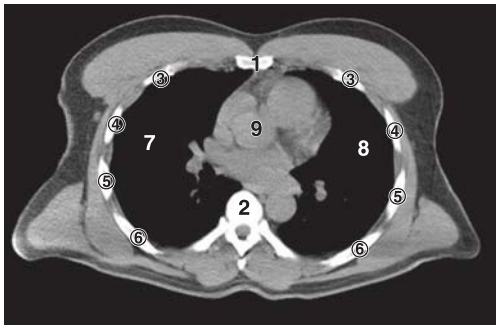
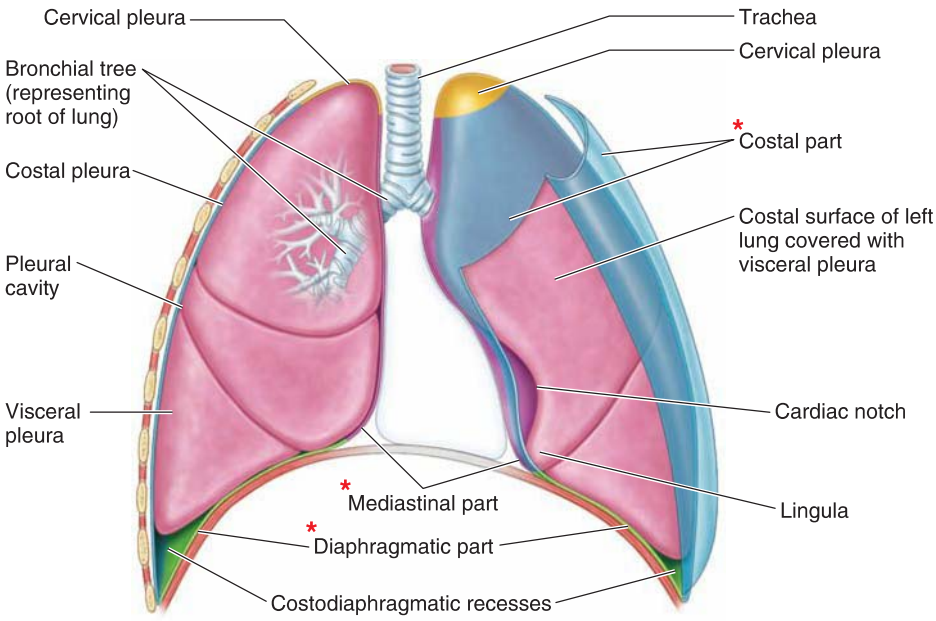


FIGURE 1.3. The lymphoid system. Pattern of lymphatic drainage. The right superior quadrant (depicted in *gray*) drains to the right venous angle, usually via the right lymphatic duct. The rest of the body (depicted in *pink*) ultimately drains into the left venous angle via the thoracic duct.



Transverse CT scan
1 Sternum
2 Vertebral body
3–6 Ribs
7 Right pulmonary cavity
8 Left pulmonary cavity
9 Mediastinum

(A) Inferior view



(B) Anterior view

FIGURE 1.4. The thoracic cavity. A. CT scan of transverse cross-sectional view of the thoracic cavity. B. Coronal cross section of the thoracic cavity. The lung invaginates a continuous membranous pleural sac; the visceral pleura covers the lungs, and the parietal pleura lines the thoracic cavity. The *asterisks* denotes that these structures are part of the parietal pleura.

subcutaneous tissue just beneath it. The integumentary system protects the viscera from the external environment, stores fat, regulates temperature, and synthesizes vitamin D. The *epidermis* is a *keratinized epithelium* composed of a tough *superficial* epithelial layer overlying a deep, *basal* layer that is pigmented and has regenerative potential. The epidermis is devoid of blood vessels and lymphatics and relies on the underlying, vascularized dermis for nutrition. As shown in **Figure 1.5**, the *dermis* has vascular and lymphatic beds and nerve terminals that convey sensory information including pain and temperature. Although the vast majority of nerve fibers terminate in the dermis, a few also penetrate the epidermis. The dermis is composed of a dense layer of collagen and elastic fibers. Below the dermis is *subcutaneous tissue* (superficial fascia), which is composed of loose connective tissue, fat, sweat glands, superficial blood and lymphatic vessels, and cutaneous nerves. Subcutaneous tissue is the primary site where body fat is stored; therefore, the thickness of this layer varies from person to person and among different body parts in the same person.

The integumentary system is inspected for swelling (*tumor*), redness (*rubor*), scars and lesions, dryness, hair loss, and pigmentation and color changes such as pallor, cyanosis, and jaundice. Next,