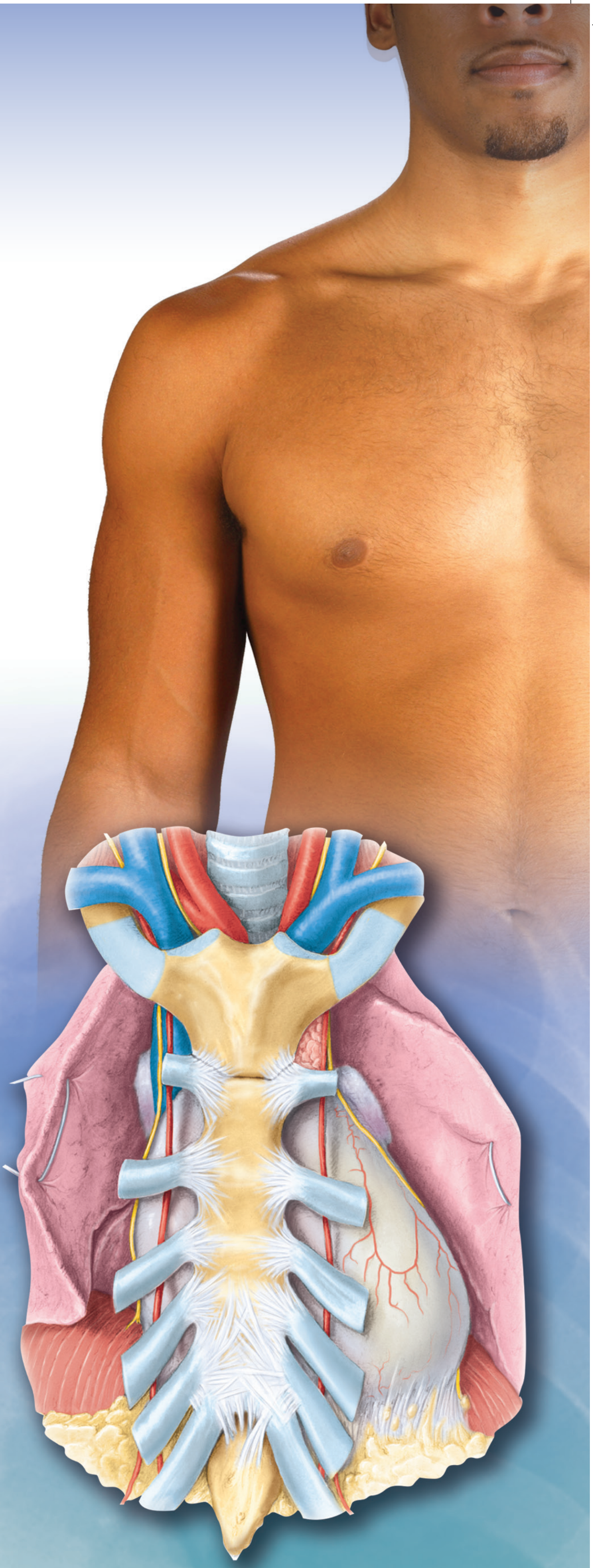
MOORE'S

Clinically Oriented Anatomy

NINTH EDITION



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In Loving Memory of My Bride of 50 years, Muriel

Devoted mother and grandmother

And to Our Family

Tristan, Lana, Elijah, Finley, Sawyer, and Dashiell
Denver, Samantha, and Olin
Skyler, Sara, Dawson, Willa, and Foster
with great appreciation for their support, humor, and patience • **(AFD)**

To Enno and Our Family

To my husband, Enno, and to my family, Erik, Amy, Kristina, and Christian,
for their support and encouragement • **(AMRA)**

To Our Students

We hope you will enjoy reading this book, increase your understanding of clinically oriented anatomy, pass your exams, and be excited and well prepared for your careers in patient care, research, and teaching. You will remember some of what you hear, much of what you read, more of what you see, and almost all of what you experience and understand.

To Professors

May our book be a helpful resource for you. We appreciate the numerous constructive comments we have received over the years from you. Your remarks have been invaluable to us in improving this edition.

To Anatomical Donors

With sincere appreciation to all those who donate their bodies for anatomical study and research, without whom anatomical textbooks and atlases and anatomical study in general would not be possible

Dr. Keith Leon Moore (1925–2019)

by Dr. Arthur F. Dalley II and Dr. Anne M. R. Agur

Dr. Keith Leon Moore
BA, MSc, PhD, Hon. DSc (OSU), Hon. DSc (WU)
FIAC, FRSM, FAAA

One of the most world-renowned anatomists of our time, Dr. Keith Leon Moore, passed away at age 94 on November 25, 2019. Keith was the founding author of *Clinically Oriented Anatomy* (COA) in 1980 and founding co-author, with Anne Agur, of *Essential Clinical Anatomy* (ECA) in 1996, both in the vanguard of *Clinically Oriented Anatomy* textbooks. Keith was the sole author for the first three editions of COA, bringing on Arthur Dalley as co-author starting with the fourth edition and Anne starting with the sixth edition. Keith and Anne brought me on as co-author for ECA starting with the fourth edition. Keith mentored Anne and me well, with COA now in its ninth edition, and ECA in its sixth. The retitling of COA and ECA as "Moore's" pays tribute to Keith's foundational work on the books and the legacy they represent. Keith was also the author/co-author of four clinically oriented embryology texts.

Anne Agur, Art Dalley, and Keith Moore

Keith and Marion Moore

Dr. Moore was born in Brantford, Canada, on October 5, 1925. Keith joined the Canadian Navy during World War II. He was a Sick Birth Attendant on Vancouver Island and was trained as a radiology technician. When the war was over, he went to the Western University, where he received his BA, MSc, and PhD degrees. Keith married Marion McDermid in 1949, and together they had five children and nine grandchildren. Marion was the typist, offering the "initial critique" for the first three editions of COA.

In 1956, Keith accepted the position of assistant professor at the University of Manitoba in Winnipeg. In 1965, he was promoted to the Head of Anatomy. In 1976, he became the chair of anatomy and then the associate dean of the Basic Medical Sciences at the University of Toronto. After retirement in 1991, Keith continued to work on his textbooks, give guest lectures, and attend anatomy meetings for more than two decades.

Keith was the recipient of many prestigious awards and recognitions. He received the highest awards for excellence in human anatomy education at the medical, dental, graduate, and undergraduate levels—and for his remarkable record of textbook publications in *Clinically Oriented Anatomy* and *Embryology*—from both the American Association of Anatomists (Henry Gray Distinguished Educator Award, 2007) and the American Association of Clinical Anatomists (AACA Honored Member Award, 1994). In 2012, Dr. Moore received honorary Doctor of Science degrees from The Ohio State University and the University of Western Ontario, the Queen Elizabeth II Diamond Jubilee Medal honoring significant contributions and achievements by Canadians, and the R. Benton Adkins, Jr., Distinguished Service Award for his outstanding record of service to the AACA.

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Anne and I are saddened by the loss of our mentor, co-author, and friend. Keith will continue to have an impact on the education of currently training, practicing, and future health care professionals around the world. Dr. Keith Leon Moore was *truly* an anatomy/embryology legend that will be greatly missed by us and all those in the anatomical community.

Preface

A third of a century has passed since the first edition of *Clinically Oriented Anatomy* appeared on bookstore shelves. Although the factual basis of anatomy is remarkable among basic sciences for its longevity and consistency, this book has evolved markedly since its inception. This is a reflection of changes in the clinical application of anatomy, new imaging technologies that reveal living anatomy in new ways, and improvements in graphic and publication technology that enable superior demonstration of this information. Efforts continue to make this book even more student friendly and authoritative. The ninth edition has been thoroughly reviewed by students, anatomists, and clinicians for accuracy and relevance and revised with significant new changes and updates.

KEY FEATURES

Clinically Oriented Anatomy has been widely acclaimed for the relevance of its clinical correlations. As in previous editions, the ninth edition places clinical emphasis on anatomy that is important in physical diagnosis for primary care, interpretation of diagnostic imaging, and understanding the anatomical basis of emergency medicine and general surgery. Special attention has been directed toward assisting students in learning the anatomy they will need to know in the 21st century, and to this end, new features have been added and existing features updated.

EXTENSIVE ART PROGRAM

Revision of the art program that began with the seventh edition continues into the ninth edition. Most illustrations were revised for the seventh edition, improving accuracy and consistency and giving classical art derived from *Grant's Atlas of Anatomy* a fresh, vital, new appearance. The ninth edition includes further updates to figures and labeling to maximize clarity and efficiency. The figures of muscles accompanying the tables have been extensively revised for the ninth edition, and overviews of arteries, with pulse points, and innervation of limbs have been added. Efforts started with the fourth edition continue to ensure that all the anatomy presented and covered in the text are also illustrated. The text and illustrations were developed to work together for optimum pedagogical effect, aiding the learning process, and markedly reducing the amount of searching required to find structures. The great majority of the clinical conditions are supported by photographs and/or color illustrations; multipart illustrations often combine dissections, line art, and medical images; and tables are accompanied by illustrations to aid the student's understanding of the structures efficiently described.

CLINICAL BLUE BOXES

Widely known as "blue boxes," the highlighted clinical correlations are now titled "Clinical Blue Boxes." They have evolved with changes in practice and many of them are supported by photographs and/or dynamic color illustrations to help with understanding the practical value of anatomy. In this edition, the clinical boxes have undergone extensive review and revision and reflect many recent medical advances. Topics in the Clinical Blue Boxes are classified by the following icons to indicate the type of clinical information covered:

Anatomical variations feature anatomical variations that may be encountered in the dissection lab or in practice, emphasizing the clinical importance of awareness of such variations.

Life cycle boxes emphasize prenatal developmental factors that affect postnatal anatomy and anatomical phenomena specifically associated with stages of life—childhood, adolescence, adult, and advanced age.

Trauma boxes feature the effects of traumatic events—such as fractures of bones or dislocations of joints—on normal anatomy and the clinical manifestations and dysfunction resulting from such injuries.

Diagnostic procedures discuss the anatomical features and observations that play a role in physical diagnosis.

Surgical procedures address such topics as the anatomical basis of surgical procedures, such as the planning of incisions, and the anatomical basis of regional anesthesia.

Pathology boxes cover the effects of disease on normal anatomy, such as cancer of the breast, and anatomical structures or principles involved in the confinement or dissemination of disease within the body.

THE BOTTOM LINE SUMMARIES

Frequent "The Bottom Line" boxes summarize the preceding information, ensuring that primary concepts do not become lost in the many details necessary for thorough understanding. These summaries provide a convenient means of ongoing review and underscore the "big picture" point of view.

ANATOMY DESCRIBED IN A PRACTICAL, FUNCTIONAL CONTEXT

A more realistic approach to the musculoskeletal system emphasizes the action and use of muscles and muscle groups in daily activities, emphasizing gait and grip. The eccentric contraction of muscles, which accounts for much of their activity, is now discussed along with the concentric contraction that is typically the sole focus in anatomy texts. This perspective is important to most health professionals, including the growing number of physical and occupational therapy students using this book.

SURFACE ANATOMY AND MEDICAL IMAGING

Surface anatomy and medical imaging, formerly presented separately, are integrated into the chapter, presented at the time each region is being discussed, clearly demonstrating anatomy's relationship to physical examination and diagnosis. Both natural views of unobstructed surface anatomy and illustrations superimposing anatomical structures on surface anatomy photographs are components of each regional chapter. Medical images, focusing on normal anatomy, include plain and contrast radiographic, MRI, CT, and ultrasonography studies, often with correlative line art as well as explanatory text, to help prepare future professionals who need to be familiar with diagnostic images.

VIDEOS, CASE STUDIES, AND BOARD REVIEW-STYLE QUESTIONS

Clinical Blue Box videos, case studies, and interactive multiple-choice questions are available to students online. These resources provide a convenient and comprehensive means of review and self-testing.

TERMINOLOGY

The terminology fully adheres to *Terminologia Anatomica: International Anatomical Nomenclature* (1998), generated by the Federative International Program on Anatomical Terminology (FIPAT) and approved by the International Federation of Associations of Anatomists (IFAA). Although the official English-equivalent terms are used throughout the book, when new terms are introduced, the Latin form, used in Europe, Asia, and other parts of the world, is often provided. The roots and derivations of terms are provided to help students understand meaning and increase retention. Eponyms, although not endorsed by the IFAA, appear in parentheses in this edition—for example, sternal angle (angle of Louis)—to assist students who will hear eponymous terms during their clinical studies. The terminology is available online at http://www.unifr.ch/ifaa.

RETAINED AND IMPROVED FEATURES

Students and faculty have told us what they want and expect from *Clinically Oriented Anatomy*, and we listened:

- A comprehensive text enabling students to fill in the blanks, as time allotted for lectures continues to decrease, laboratory guides and curricula become exclusively instructional, and multiauthored lecture notes develop inconsistencies in comprehension, fact, and format
- A resource capable of supporting areas of special interest and emphasis within specific anatomy courses that serves the anatomy needs of students during both the basic science and the clinical phases of their studies
- Updated organization of the chapters to match that of *Grant's Atlas of Anatomy* and *Grant's Dissector*
- A thorough introductory chapter (Chapter 1, Overview and Basic Concepts) that covers important systemic information and concepts basic to the understanding of the anatomy presented in the subsequent regional chapters. Students from many countries and backgrounds have written to express their views of this book—gratifyingly, most are congratulatory. Health professional students have more diverse backgrounds and experiences than ever before. Curricular constraints often result in unjustified assumptions concerning the prerequisite information necessary for many students to understand the presented material. The introductory chapter includes efficient summaries of functional systemic anatomy. Students' comments specifically emphasized the need for a systemic description of the nervous system and the peripheral autonomic nervous system (ANS) in particular. *Clinically Oriented Anatomy* was the first anatomy textbook to acknowledge and describe the structure and function of the enteric nervous system and its unique role in the innervation of the digestive tract.
- In this ninth edition, a section on Sex and Gender has been added to Chapter 1, Overview and Basic Concepts as well as a Clinical Box on Gender Transitioning in Chapter 6, Pelvis and Perineum.
- Routine facts (such as muscle attachments, innervations, and actions) presented in tables organized to demonstrate shared qualities and illustrated to demonstrate the

provided information. *Clinically Oriented Anatomy* provides more tables than any other anatomy textbook.

- Illustrated clinical correlations that not only describe but also show anatomy as it is applied clinically
- Illustrations that reflect the diversity of both those using the textbook and the patients they will be treating
- Illustrations that facilitate orientation. Many orientation figures have been added, along with arrows to indicate the locations of the inset figures (areas shown in close-up views) and viewing sequences. Labels have been placed to minimize the distance between label and object, with leader lines running the most direct course possible.
- Equitable focus on female as well as male anatomy. Traditionally, texts have been thorough regarding the presentation of the male phallus and insufficient on treatment of the female external genitalia, implying that the clitoris is merely a much smaller version of the penis. This edition provides a thorough presentation of the anatomy of the clitoris, showing that its anatomy is distinct and clearly not a miniature version of the penis.
- **Boldface type** indicates the main entries of anatomical terms, when they are introduced and defined. In the index, the page numbers of these main entries also appear in boldface type, so that the main entries can be easily located. Boldface type is also used to introduce clinical terms in the clinical blue boxes.
- *Italic type* indicates anatomical terms important to the topic and region of study or labeled in an illustration that is being referenced.
- Useful content outlines appear at the beginning of every chapter.

COMMITMENT TO EDUCATING STUDENTS

This book is written for health science students, keeping in mind those who may not have had a previous acquaintance with anatomy. We have tried to present the material in an interesting way so that it can be easily integrated with what will be taught in more detail in other disciplines such as physical diagnosis, medical rehabilitation, and surgery. We hope this text will serve two purposes: to educate and to excite. If students develop enthusiasm for clinical anatomy, the goals of this book will have been fulfilled.

Arthur F. Dalley II

Anne M. R. Agur

Acknowledgments

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Arthur F. Dalley II

Anne M. R. Agur

Abbreviations

a., aa.	artery, arteries
abd.	abdomen, abductor
acc.	accessory
ACL	anterior cruciate ligament
add.	adductor
ANS	autonomic nervous system
ant.	anterior
ASIS	anterior superior iliac spine
AV	atrioventricular
C	cervical
CCA	common carotid artery
CN	cranial nerve
CNS	central nervous system
Co	coccygeal
CSF	cerebrospinal fluid
ECA	external carotid artery
e.g.	for example
EJV	external jugular vein
ENS	enteric nervous system
et al.	and others
ext.	extensor, external
flex.	flexor
Fr.	French
G.	Greek
GI	gastrointestinal
ICA	internal carotid artery
i.e.	that is
IJV	internal jugular vein
inf.	inferior
int.	internal
IVC	internal vena cava
l.	left
L	liter, lumbar
L.	Latin
LA	left atrium
lat.	lateral
LCA	left coronary artery
lev.	levator
LLQ	left lower quadrant
LRV	left renal vein
LUQ	left upper quadrant
LV	left ventricle
m., mm.	muscle, muscles
med.	medial
PCL	posterior cruciate ligament
PNS	peripheral nervous system
post.	posterior
PSIS	posterior superior iliac spine
PSNS	parasympathetic nervous system
PV	hepatic portal vein
r.	right
RA	right atrium
RCA	right coronary artery
RLQ	right lower quadrant
RUQ	right upper quadrant
RV	right ventricle
S	sacral
SA	sinu-atrial
SCM	sternocleidomastoid
SNS	sensory nervous system
sp.	spinal
SPNS	sympathetic nervous system
sup.	superior
supf.	superficial
SV	sinoventricular
SVC	superior vena cava
T	thoracic
TA	Terminologia Anatomica
TMJ	temporomandibular joint
v., vv.	vein, veins
vs.	versus
yo	years old

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Figure Credits

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1 OVERVIEW AND BASIC CONCEPTS

Fig. 1.20 Based on Hamill JH, Knutzen KM, Derrick TR. *Biomechanical Basis of Human Movement*, 4th ed. Philadelphia, PA: Lippincott Williams & Wilkins, 2015.

Fig. 1.22C Based on Silverthorn DU. *Human Physiology*, 4th ed. Tappan, NJ: Pearson Education, 2007:459.

Fig. 1.23B&C Cormack DH. *Essential Histology*, 2nd ed. Philadelphia, PA: Lippincott Williams & Wilkins, 2001.

Fig. 1.35C Courtesy of Dr. Bradley R. Smith, Center for In Vivo Microscopy, Duke University Medical Center, Durham, NC. From Moore KL, Persaud TVN, Shiota K. *Color Atlas of Clinical Embryology*, 2nd ed. Philadelphia, PA: Saunders, 2000.

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Fig. 1.50 Daffner RH, Hartman MS. *Clinical Radiology: The Essentials*, 4th ed. Philadelphia, PA: Lippincott Williams & Wilkins, 2014.

Fig. 1.52 Courtesy of Dr. J. Heslin, University of Toronto, Ontario, Canada.

Fig. 1.53C Courtesy of D. Armstrong, University of Toronto, Ontario, Canada.

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Fig. 1.55 Castillo M. *Neuroradiology Companion: Methods, Guidelines, and Imaging Fundamentals*, 4th ed. Philadelphia, PA: Lippincott Williams & Wilkins, 2012.

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Fig. 2.7C Courtesy of Dr. J. Heslin, University of Toronto, Ontario, Canada.

Fig. 2.8E Courtesy of D. Salonen, University of Toronto, Ontario, Canada.

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Fig. B2.22F Dr. P. Marazzi/Science Photo Library.

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Fig. 3.41C Courtesy of Dr. D. Armstrong, University of Toronto, Ontario, Canada.

Fig. 3.49C Courtesy of Dr. W. Kucharczyk, Professor of Neuroradiologist Senior Scientist, Department of Medical Resonance Imaging, University Health Network, Toronto, Ontario, Canada.

Fig. 3.58A Courtesy of Dr. J. Heslin, University of Toronto, Ontario, Canada.

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Fig. 3.95B Courtesy of Dr. E. L. Lansdown, Professor of Medical Imaging, University of Toronto, Toronto, Ontario, Canada.

Fig. 3.97C Courtesy of Dr. W. Kucharczyk, Professor of Medical Imaging, University of Toronto, and Clinical Director of Tri-Hospital Resonance Centre, Toronto, Ontario, Canada.

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Fig. 3.108A&B Courtesy of Dr. J. Heslin, University of Toronto, Ontario, Canada.

Fig 3.109A Courtesy of Dr. E. L. Lansdown, Professor of Medical Imaging, University of Toronto, Toronto, Ontario, Canada.

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Fig. 5.49C Courtesy of Dr. J. Heslin, University of Toronto, Ontario, Canada.

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Fig. 5.55A Courtesy of Dr. E. L. Lansdown, Professor of Medical Imaging, University of Toronto, Ontario, Canada.

Fig. 5.55B Courtesy of Dr. D. K. Sniderman, University of Toronto, Ontario, Canada.

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Fig. 5.63B Courtesy of Dr. W. Kucharczyk, Professor of Medical Imaging, University of Toronto, and Clinical Director of Tri-Hospital Resonance Centre, Toronto, Ontario, Canada.

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Fig. 5.81 Courtesy of Dr. John Campbell, Department of Medical Imaging, Sunnybrook Medical Centre, University of Toronto, Ontario, Canada.

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Fig. B5.7 (radiograph) Courtesy of G. B. Haber, University of Toronto, Ontario, Canada.

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6 PELVIS AND PERINEUM

Fig. 6.2B Courtesy of Dr. E. L. Lansdown, Professor of Medical Imaging, University of Toronto, Ontario, Canada.

Fig 6.5B&C Courtesy of Dr. E. Becker, Department of Medical Imaging, University of Toronto, Ontario, Canada.

Fig. 6.7B Courtesy of Dr. E. L. Lansdown, Professor of Medical Imaging, University of Toronto, Ontario, Canada.

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Fig. 6.38B (ultrasound) Courtesy of Dr. A. M. Arenson, Assistant Professor of Medical Imaging, University of Toronto, Ontario, Canada.

Fig. 6.40 (ultrasound) Courtesy of Dr. A. M. Arenson, Assistant Professor of Medical Imaging, University of Toronto, Ontario, Canada.

Fig. 6.44A Courtesy of Dr. Donald R. Cahill, Department of Anatomy, Mayo Medical School, Rochester, MN.

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Fig. 6.62C Courtesy of Dr. Donald R. Cahill, Department of Anatomy, Mayo Medical School, Rochester, MN.

Fig. 6.72B–E Courtesy of Dr. M. A. Haider, University of Toronto, Ontario, Canada.

Fig. 6.73B&D Courtesy of Dr. Shirley McCarthy, Department of Diagnostic Radiology, Yale University and Yale-New Haven Hospital, New Haven, CT.

Fig. 6.74B&D Courtesy of Dr. M. A. Haider, University of Toronto, Ontario, Canada.

Fig. B6.2B Based on Hall-Craggs ECB. *Anatomy as the Basis of Clinical Medicine*, 3rd ed. Baltimore, MD: Williams & Wilkins, 1995.

Fig. B6.4C Courtesy of Dr. E. Becker, Department of Medical Imaging, University of Toronto, Ontario, Canada.

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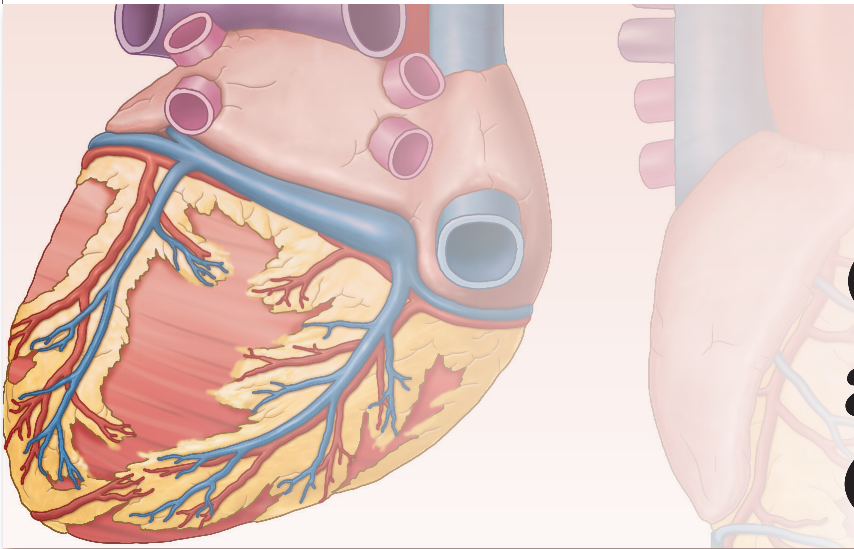
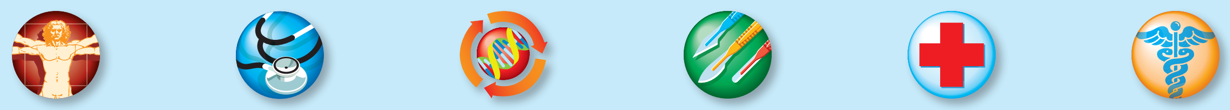


1

Overview and Basic Concepts

CLINICAL BOX KEY



Anatomical Variations | Diagnostic Procedures | Life Cycle | Surgical Procedures | Trauma | Pathology

APPROACHES TO STUDYING ANATOMY

Anatomy is the setting (structure) in which the events (functions) of life occur. This book deals mainly with functional human gross anatomy—the examination of structures of the human body that can be seen without a microscope. The three main approaches to studying anatomy are regional, systemic, and clinical (or applied), reflecting the body's organization and the priorities and purposes for studying it.

Regional Anatomy

Regional anatomy (topographical anatomy) considers the organization of the human body as major parts or segments (Fig. 1.1): a main body, consisting of the head, neck, and trunk (subdivided into thorax, abdomen, back, and pelvis/perineum), and paired upper limbs and lower limbs. All the major parts may be further subdivided into areas and regions. Regional anatomy is the method of studying the body's structure by focusing attention on a specific part (e.g., the head), area (the face), or region (the orbital or eye region); examining the arrangement and relationships of the various systemic structures (muscles, nerves, arteries, etc.) within it; and then usually continuing to study adjacent regions in an ordered sequence.

This book follows a regional approach, and each chapter addresses the anatomy of a major part of the body. This is the approach usually followed in anatomy courses that have a laboratory component involving dissection. When studying anatomy by this approach, it is important to routinely put the regional anatomy into the context of that of adjacent regions, of parts, and of the body as a whole.

Regional anatomy also recognizes the body's organization by layers: skin, subcutaneous tissue, and deep fascia covering the deeper structures of muscles, skeleton, and cavities, which contain viscera (internal organs). Many of these deeper structures are partially evident beneath the body's outer covering and may be studied and examined in living individuals via surface anatomy.

Surface anatomy is an essential part of the study of regional anatomy. It is integrated into each chapter of this book in "surface anatomy sections" that provide knowledge of what lies under the skin and what structures are perceptible to touch (palpable) in the living body at rest and in action. We can learn much by observing the external form and surface of the body and by observing or feeling the superficial aspects of structures beneath its surface. The aim of this method is to *visualize* (recall distinct mental images of) structures that confer contour to the surface or are palpable beneath it and, in clinical practice, to distinguish any unusual or abnormal findings. In short, surface anatomy requires a thorough understanding of the anatomy of the structures beneath the surface. In people with stab wounds, for example, a physician must be able to visualize the deep structures that may be injured. Knowledge of surface anatomy can also decrease the need to memorize facts because the body is always available to observe and palpate.

Physical examination is the clinical application of surface anatomy. *Palpation* is a clinical technique, used with *observation* and *listening* for examining the body. Palpation of arterial pulses, for instance, is part of a physical examination.

Radiographic and sectional imaging (*radiographic anatomy*) provides useful information about normal structures in living individuals, demonstrating the effect of muscle tone, body fluids and pressures, and gravity that cadaveric study does not. *Diagnostic radiology* reveals the effects of trauma, pathology, and aging on normal structures. In this book, most radiographic and many sectional images are integrated into the chapters where appropriate. The medical imaging sections at the end of each chapter provide an introduction

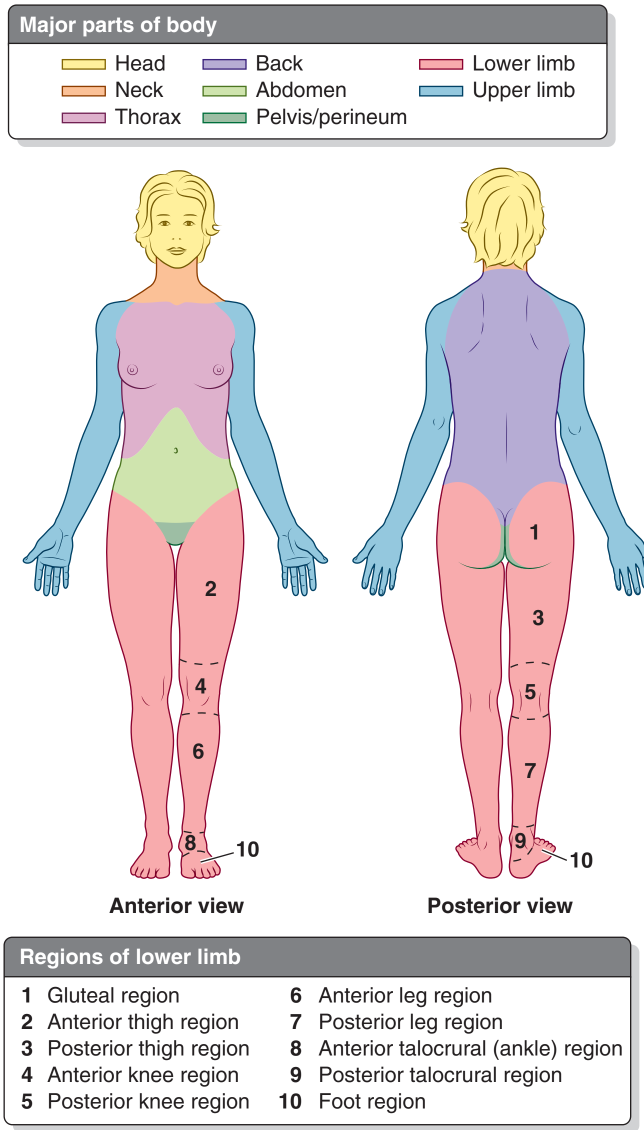


FIGURE 1.1. Major parts of body and regions of lower limb. Anatomy is described relative to the anatomical position illustrated here.

to the techniques of radiographic and sectional imaging and include series of sectional images that apply to the chapter. *Endoscopic techniques* (using a flexible fiber-optic device inserted into one of the body's orifices or through a small surgical incision ["portal"] to examine internal structures, such as the interior of the stomach) also demonstrate living anatomy. The detailed and thorough learning of the three-dimensional anatomy of deep structures and their relationships is best accomplished initially by dissection. In clinical practice, surface anatomy, radiographic and sectional images, endoscopy, and your experience from studying anatomy will combine to provide you with knowledge of your patient's anatomy.

The computer is a useful adjunct in teaching regional anatomy because it facilitates learning by allowing interactivity and manipulation of two- and three-dimensional graphic models. **Prosections**, carefully prepared dissections for the demonstration of anatomical structures, are also useful. However, learning is most efficient and retention is highest when didactic study is combined with the experience of firsthand dissection—that is, learning by doing. During **dissection**, you observe, palpate, move, and sequentially reveal parts of the body. In 1770, Dr. William Hunter, a distinguished Scottish anatomist and obstetrician, stated: "Dissection alone teaches us where we may cut or inspect the living body with freedom and dispatch."

Systemic Anatomy

Systemic anatomy is the study of the body's organ systems that work together to carry out complex functions. The basic systems and the field of study or treatment of each (*italics* in parentheses) are as follows:

- The **integumentary system** (*dermatology*) consists of the skin (L. *integumentum*, a covering) and its appendages—hairs, nails, and sweat glands, for example—and the subcutaneous tissue just beneath it. The skin, an extensive sensory organ, forms the body's outer, protective covering and container.
- The **skeletal system** (*osteology*) consists of bones and cartilage; it provides our basic shape and support for the body and is what the muscular system acts on to produce movement. It also protects vital organs such as the heart, lungs, and pelvic organs.
- The **articular system** (*arthrology*) consists of joints and their associated ligaments, connecting the bony parts of the skeletal system and providing the sites at which movements occur.
- The **muscular system** (*myology*) consists of skeletal muscles that act (contract) to move or position parts of the body (e.g., the bones that articulate at joints), or smooth and cardiac muscle that propels, expels, or controls the flow of fluids and contained substance.
- The **nervous system** (*neurology*) consists of the central nervous system (brain and spinal cord) and the peripheral nervous system (nerves and ganglia, together with their motor and sensory endings). The nervous system controls and coordinates the functions of the organ systems, enabling the body's responses to and activities within its environment. The sense organs, including the olfactory organ (sense of smell), eye or visual system (*ophthalmology*), ear (sense of hearing and balance—*otology*), and gustatory organ (sense of taste), are often considered with the nervous system in systemic anatomy.
- The **circulatory system** (*angiology*) consists of the cardiovascular and lymphatic systems, which function in parallel to transport the body's fluids.
  - The **cardiovascular system** (*cardiology*) consists of the heart and blood vessels that propel and conduct blood through the body, delivering oxygen, nutrients, and hormones to cells and removing their waste products.
  - The **lymphatic system** is a network of lymphatic vessels that withdraws excess tissue fluid (lymph) from the body's interstitial (intercellular) fluid compartment, filters it through lymph nodes, and returns it to the bloodstream.
- The **alimentary** or **digestive system** (*gastroenterology*) consists of the digestive tract from the mouth to the anus, with all its associated organs and glands that function in ingestion, mastication (chewing), deglutition (swallowing), digestion, and absorption of food and the elimination of the solid waste (feces) remaining after the nutrients have been absorbed.
- The **respiratory system** (*pulmonology*) consists of the air passages and lungs that supply oxygen to the blood for cellular respiration and eliminate carbon dioxide from it. The diaphragm and larynx control the flow of air through the system, which may also produce tone in the larynx that is further modified by the tongue, teeth, and lips into speech.
- The **urinary system** (*urology*) consists of the kidneys, ureters, urinary bladder, and urethra, which filter blood and subsequently produce, transport, store, and intermittently excrete urine (liquid waste).
- The **genital (reproductive) system** (*gynecology* for females; *andrology* for males) consists of the gonads (ovaries and testes) that produce oocytes (eggs) and sperms, the ducts that transport them, and the genitalia that enable their union. After conception, the female reproductive tract nourishes and delivers the fetus.
- The **endocrine system** (*endocrinology*) consists of specialized structures that secrete hormones, including discrete ductless endocrine glands (such as the thyroid gland), isolated and clustered cells of the gut and blood vessel walls, and specialized nerve endings. Hormones are organic molecules that are carried by the circulatory system to distant effector cells in all parts of the body. The influence of the endocrine system is thus as broadly distributed as that of the nervous system. Hormones influence metabolism and other processes, such as the menstrual cycle, pregnancy, and parturition (childbirth).

None of the systems functions in isolation. The passive skeletal and articular systems and the active muscular system collectively constitute a super system, the **locomotor system** or **apparatus** (*orthopedics*), because they must work together to produce locomotion of the body. Although the structures directly responsible for locomotion are the muscles, bones, joints, and ligaments of the limbs, other systems are indirectly involved as well. The brain and nerves of the nervous system stimulate them to act; the arteries and veins of the circulatory system supply oxygen and nutrients to and remove waste from these structures; and the sensory organs (especially vision and equilibrium) play important roles in directing their activities in a gravitational environment.

In this chapter, an overview of several systems significant to all parts and regions of the body is provided before Chapters 2 through 9 cover regional anatomy in detail. Chapter 10 also presents systemic anatomy in reviewing the cranial nerves.

Clinical Anatomy

Clinical anatomy (applied anatomy) emphasizes aspects of bodily structure and function important in the practice of medicine, dentistry, and the allied health sciences. It incorporates the regional and systemic approaches to studying anatomy and stresses clinical application.

Clinical anatomy often involves inverting or reversing the thought process typically followed when studying regional or systemic anatomy. For example, instead of thinking, "The action of this muscle is to . . . ," clinical anatomy asks, "How would the absence of this muscle's activity be manifest?" Instead of noting, "The . . . nerve provides innervation to this area of skin," clinical anatomy asks, "Numbness in this area indicates a lesion of which nerve?"

Clinical anatomy is exciting to learn because of its role in solving clinical problems. The Clinical Boxes (popularly called "blue boxes," appearing on a blue background) throughout this book describe practical applications of anatomy. Case studies, demonstrating the application of anatomy in clinical practice, are integral parts of the clinical approach to studying anatomy.

SEX AND GENDER

Sex, male or female, is assigned genetically. Females have 46 chromosomes that include two X chromosomes, and males have 46 chromosomes that include both an X and a Y chromosome. There are also uncommon genetically based conditions where the number of chromosomes varies, such as Klinefelter syndrome, which includes 47 chromosomes (XXY) and Jacob syndrome, which includes 47 chromosomes (XYY).

Gender identity is an individual's intrinsic sense of their own gender, which may or may not be consistent with the sex assigned chromosomally (or genetic sex). Gender is not binary but rather a spectrum that may be expressed through appearance, personality, behaviors, and relationships or not be outwardly expressed at all.

The difference between sex and gender is important for clinical practice in order to be able to understand and form a trusting relationship with patients. Clinically, gender dysphoria is the significant distress an individual may undergo due to a mismatch between their gender identity and their genetic sex. While some children see their anatomy as having a different meaning to the way society sees it, many individuals may not express related feelings and behaviors until puberty or much later.

ANATOMICOMEDICAL TERMINOLOGY

Anatomical terminology introduces and makes up a large part of medical terminology. To be understood, you must express yourself clearly, using the proper terms in the correct way. Although you are familiar with common, colloquial terms for parts and regions of the body, you must learn the international anatomical terminology (e.g., axillary fossa instead of armpit and clavicle instead of collarbone) that enables precise communication among health care professionals and scientists worldwide. Health professionals must also know the common and colloquial terms people are likely to use when they describe their complaints. Furthermore, you must be able to use terms people will understand when explaining their medical problems to them.

The terminology in this book conforms to the new *International Anatomical Terminology*. *Terminologia Anatomica* (TA) and *Terminologia Embryologica* (TE) list terms both in Latin and as English equivalents (e.g., the common shoulder muscle is musculus deltoideus in Latin and deltoid in English). Most terms in this book are English equivalents. Official terms are available at the International Federation of Associations of Anatomists website (https://www4.unifr.ch/ifaa). Unfortunately, the terminology commonly used in the clinical arena may differ from the official terminology. Because this discrepancy may be a source of confusion, this text clarifies commonly confused terms by placing the unofficial designations in parentheses when the terms are first used—for example, *pharyngotympanic tube* (auditory tube, eustachian tube) and *internal thoracic artery* (internal mammary artery). *Eponyms*, terms incorporating the names of people, do not conform to an international standard, provide no information about the type or location of the structures involved, and are frequently historically inaccurate in terms of identifying the original person to describe a structure or assign its function. Notwithstanding, commonly used eponyms appear in parentheses throughout the book when these terms are first introduced—such as sternal angle (angle of Louis)—since you will surely encounter them in your clinical years.

Structure of terms. Anatomy is a descriptive science and provides names for the many structures and processes of the body. Because most terms are derived from Latin and Greek, medical language may seem difficult at first; however, as you learn the origin of terms, the words will make sense.

Many terms provide information about a structure's shape, size, location, or function or about the resemblance of one structure to another. For example, some muscles have descriptive names to indicate their main characteristics. The *deltoid muscle*, which covers the point of the shoulder, is triangular, like the symbol for delta, the fourth letter of the Greek alphabet. The suffix *-oid* means "like"; therefore, deltoid means like delta. *Biceps* means two-headed and *triceps* means three-headed. Some muscles are named according to their shape—the *piriformis muscle*, for example, is pear shaped (L. *pirum*, pear + L. *forma*, shape or form). Other muscles are named according to their location. The *temporalis muscle* is in the temporal region (temple) of the cranium (skull). In some cases, actions are used to describe muscles—for example, the *levator scapulae* elevates the scapula (L. for shoulder blade). If you learn the derivations of anatomical terms and consider them as you read and dissect, it will be easier to remember them.

Abbreviations. Abbreviations of terms are used for brevity in medical histories and in this and other books, such as in tables of muscles, arteries, and nerves. Clinical abbreviations are used in discussions and descriptions of signs and symptoms. Learning to use these abbreviations also speeds note taking. Common anatomical and clinical abbreviations are provided in this text when the corresponding term is introduced—for example, temporomandibular joint (TMJ). Lists of common medical abbreviations can be found online.

Anatomical Position

All anatomical descriptions are expressed in relation to one consistent position, ensuring that descriptions are not ambiguous (Figs. 1.1 and 1.2). One must visualize this position in the mind when describing patients (or cadavers), whether they are lying on their sides, **supine** (recumbent, lying on the back, face upward), or **prone** (lying on the abdomen, face downward). The **anatomical position** refers to the body position as if the person were standing upright with the:

- Head, gaze (eyes), and toes directed anteriorly (forward)
- Arms adjacent to the sides with the palms facing anteriorly
- Lower limbs close together with the feet parallel

This position is adopted globally for anatomicomedical descriptions. By using this position and appropriate terminology, you can relate any part of the body precisely to any other part. It should also be kept in mind, however, that gravity causes a downward shift of internal organs (viscera) when the upright position is assumed. Since people are typically examined in the supine position, it is often necessary to describe the position of the affected organs when supine, making specific note of this exception to the anatomical position.

Anatomical Planes

Anatomical descriptions are based on four imaginary planes (median, sagittal, frontal, and transverse) that intersect the body in the anatomical position (Fig. 1.2):

- The **median plane** (*median sagittal plane*) is the *vertical anteroposterior plane* passing longitudinally *through the midlines of the head, neck, and trunk* where it intersects the surface of the body, dividing it into right and left halves (Fig. 1.2A). Midline is often erroneously used as a synonym for the median plane.
- **Sagittal planes** are *vertical planes* passing through the body *parallel to the median plane*. "Parasagittal" is commonly used but is unnecessary because any plane parallel to and on either side of the median plane is sagittal by definition. However, a plane parallel and near to the median plane may be referred to as a *paramedian plane*.
- **Frontal (coronal) planes** are *vertical planes* passing through the body *at right angles to the median plane*, dividing the body into anterior (front) and posterior (back) parts (Fig. 1.2B, C).
- **Transverse planes** are *horizontal planes* passing through the body *at right angles to the median and frontal planes*, dividing the body into superior (upper) and inferior (lower) parts (Fig. 1.2C). Radiologists refer to transverse planes as *transaxial*, which is commonly shortened to *axial planes*.

Since the number of sagittal, frontal, and transverse planes is unlimited, a reference point (usually a visible or palpable landmark or vertebral level) is necessary to identify the location or level of the plane, such as a "transverse plane through the umbilicus." Sections of the head, neck, and trunk in precise frontal and transverse planes are symmetrical, passing through both the right and left members of paired structures, allowing some comparison.

The main use of anatomical planes is to describe *sections* (Fig. 1.3):

- **Longitudinal sections** run lengthwise or parallel to the long axis of the body or of any of its parts, and the term applies regardless of the position of the body (Fig. 1.3A). Although median, sagittal, and frontal planes are the standard (most commonly used) longitudinal sections, there is a 180° range of possible longitudinal sections.
- **Transverse sections**, or cross sections, are slices of the body or its parts that are cut at right angles to the longitudinal axis of the body or of any of its parts (Fig. 1.3B). Because the long axis of the foot runs horizontally, a transverse section of the foot lies in the frontal plane (Fig. 1.2C).
- **Oblique sections** are slices of the body or any of its parts that are not cut along the previously listed anatomical planes (Fig. 1.3C). In practice, many radiographic images

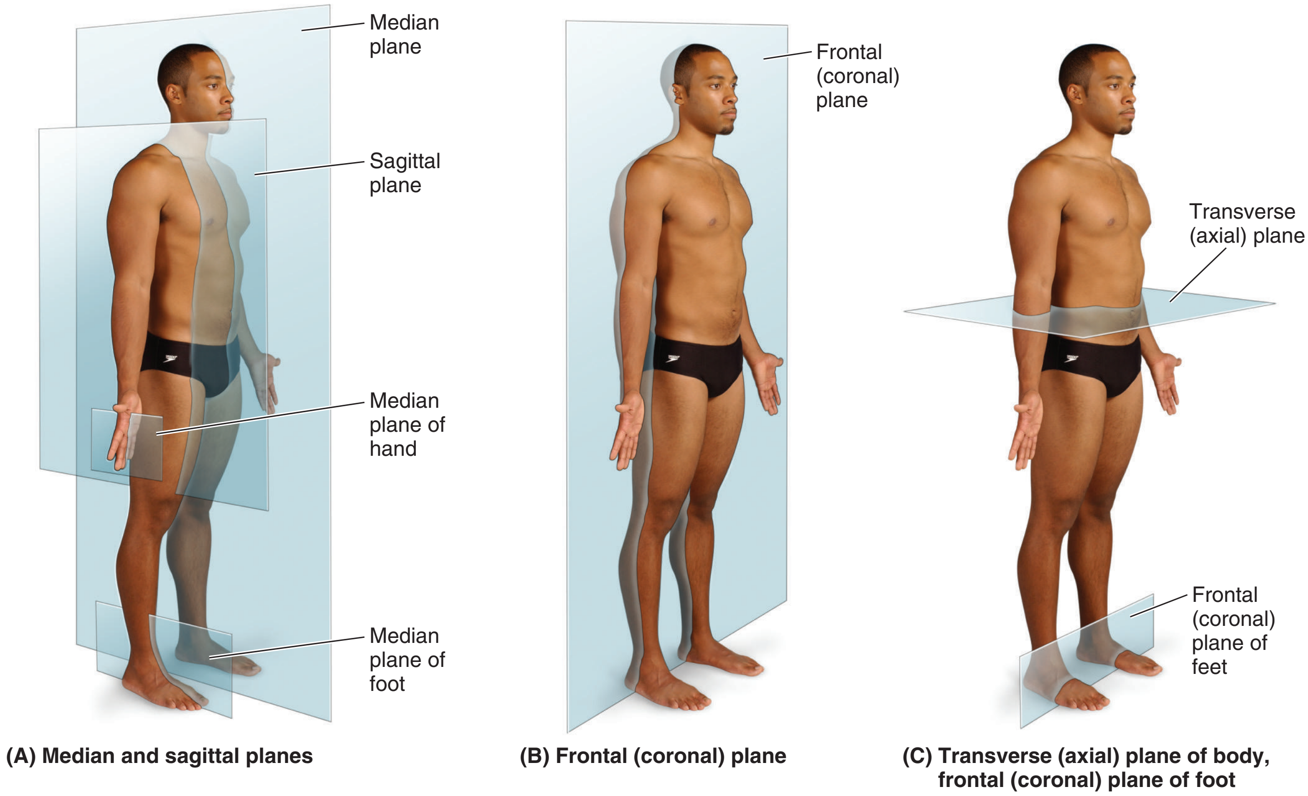


FIGURE 1.2. Anatomical position and anatomical planes. The main planes of the body.

and anatomical sections do not lie precisely in sagittal, frontal, or transverse planes; often, they are slightly oblique.

Anatomists create sections of the body and its parts anatomically, and clinicians create them by planar imaging technologies, such as computed tomography (CT), to describe and display internal structures.

Terms of Relationship and Comparison

Various adjectives, arranged as pairs of opposites, describe the relationship of parts of the body or compare the position of two structures relative to each other (Fig. 1.4). Some of these terms are specific for comparisons made in the

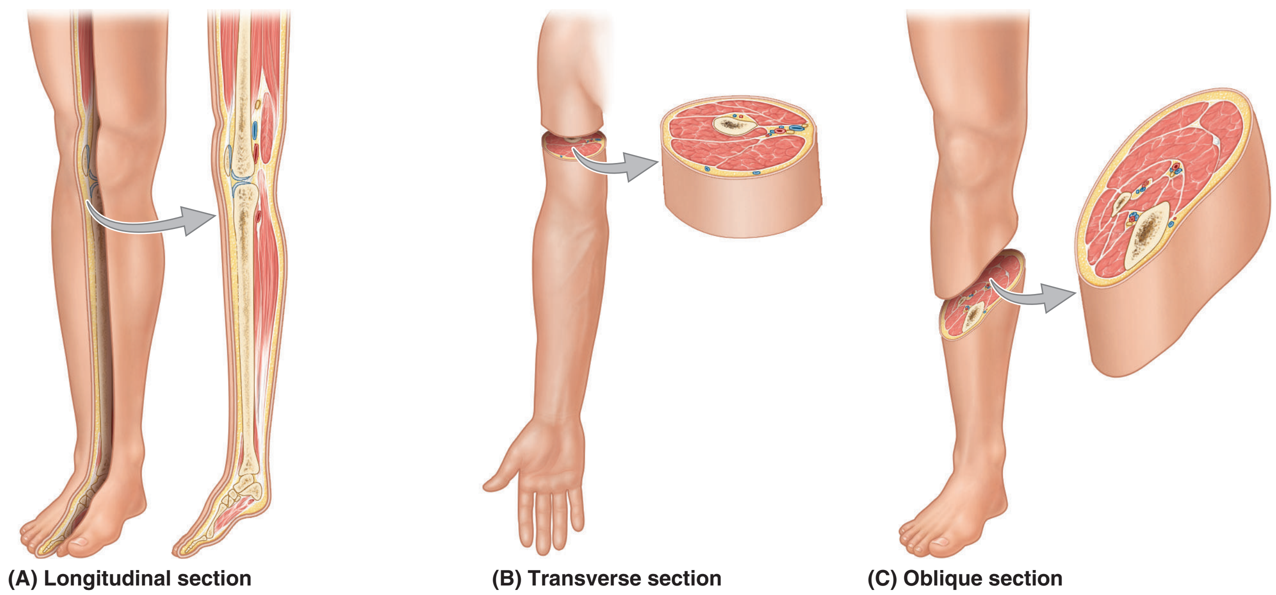


FIGURE 1.3. Sections of limbs. Sections may be obtained by anatomical sectioning or medical imaging techniques.

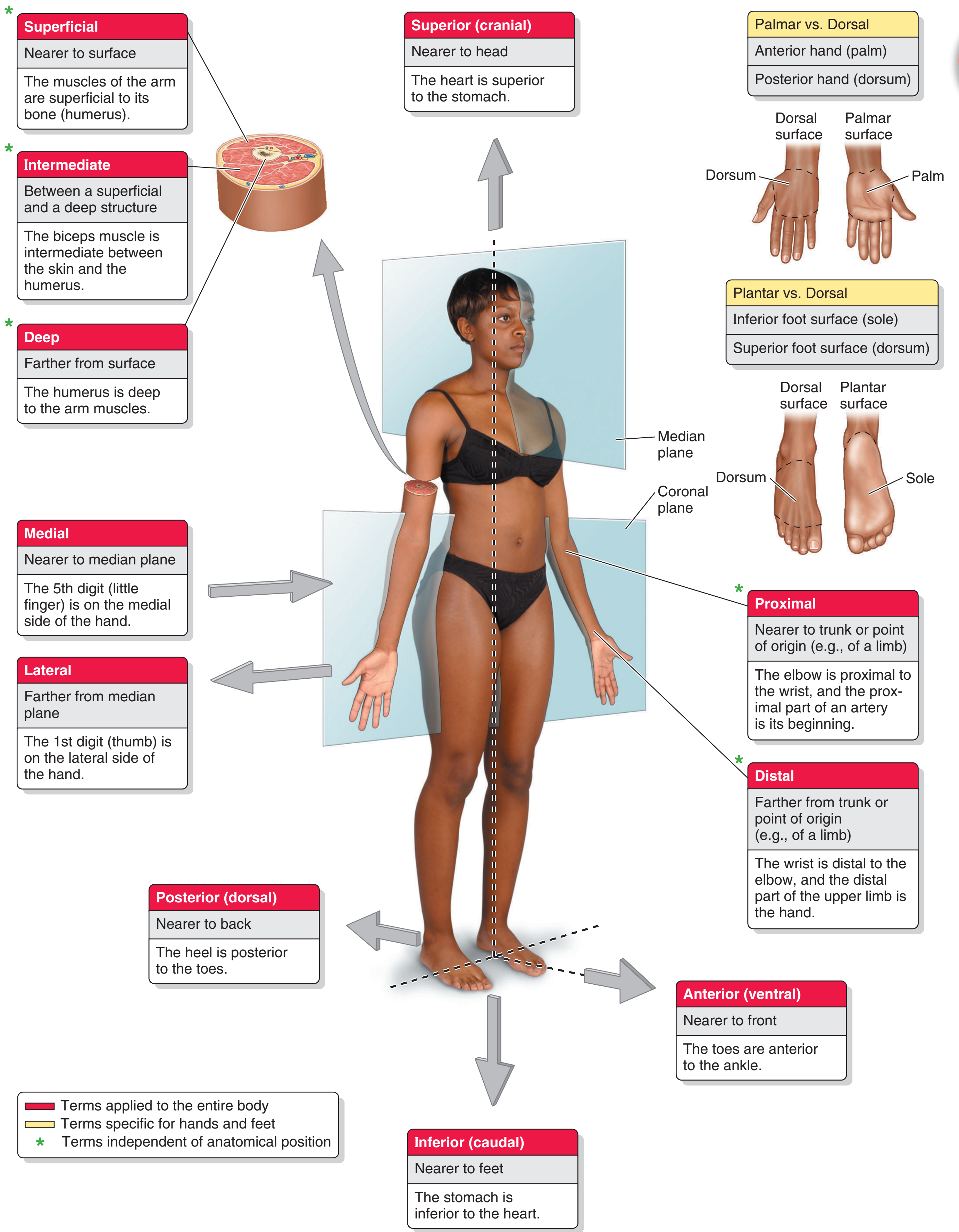


FIGURE 1.4. Anatomical position and terms of relationship and comparison. These terms describe the position of one structure relative to another.

anatomical position, or with reference to the anatomical planes:

Superior refers to a structure that is nearer the **vertex**, the topmost point of the cranium (Mediev. L., skull). **Cranial** relates to the cranium and is a useful directional term, meaning toward the head or cranium. **Inferior** refers to a structure that is situated nearer the sole of the foot. **Caudal** (L. *cauda*, tail) is a useful directional term that means toward the feet or tail region, represented in humans by the coccyx (tail bone), the small bone at the inferior (caudal) end of the vertebral column.

Posterior (dorsal) denotes the back surface of the body or nearer to the back. **Anterior** (ventral) denotes the front surface of the body. **Rostral** is often used instead of anterior when describing parts of the brain; it means toward the rostrum (L., beak); however, in humans, it denotes nearer the anterior part of the head (e.g., the frontal lobe of the brain is rostral to the cerebellum).

Medial is used to indicate that a structure is nearer to the median plane of the body. For example, the 5th digit of the hand (little finger) is medial to the other digits. Conversely, **lateral** stipulates that a structure is farther away from the median plane. The 1st digit of the hand (thumb) is lateral to the other digits.

Dorsum usually refers to the superior aspect of any part that protrudes anteriorly from the body, such as the dorsum of the tongue, nose, penis, or foot. It is also used to describe the posterior surface of the hand, opposite the *palm*. Because the term *dorsum* may refer to both superior and posterior surfaces in humans, the term is easier to understand if one thinks of a quadrupedal plantigrade animal that walks on its palms and soles, such as a bear. The *sole* is the inferior aspect or bottom of the foot, opposite the dorsum, much of which is in contact with the ground when standing barefoot. The surface of the hands, the feet, and the digits of both corresponding to the dorsum is the **dorsal surface**, the surface of the hand and fingers corresponding to the palm is the **palmar surface**, and the surface of the foot and toes corresponding to the sole is the **plantar surface**.

Combined terms describe intermediate positional arrangements: **Inferomedial** means nearer to the feet and median plane—for example, the anterior parts of the ribs run inferomedially; **superolateral** means nearer to the head and farther from the median plane.

Other terms of relationship and comparisons are independent of the anatomical position or the anatomical planes, relating primarily to the body's surface or its central core:

- **Superficial**, **intermediate**, and **deep** describe the position of structures relative to the surface of the body or the relationship of one structure to another underlying or overlying structure.
- **External** means outside of or farther from the center of an organ or cavity, while **internal** means inside or closer to the center, independent of direction.
- **Proximal** and **distal** are used when contrasting positions nearer to or farther from the attachment of a limb or the central aspect of a linear structure, respectively.

Terms of Laterality

Paired structures having right and left members (e.g., the kidneys) are **bilateral**, whereas those occurring on one side only (e.g., the spleen) are **unilateral**. Designating whether you are referring specifically to the right or left member of bilateral structures can be critical and is a good habit to begin at the outset of one's training to become a health professional. Something occurring on the same side of the body as another structure is **ipsilateral**; the right thumb and right great (big) toe are ipsilateral, for example. **Contralateral** means occurring on the opposite side of the body relative to another structure; the right hand is contralateral to the left hand.

Terms of Movement

Various terms describe movements of the limbs and other parts of the body (Fig. 1.5). Most movements are defined in relationship to the anatomical position, with movements occurring within, and around axes aligned with, specific anatomical planes. While most movements occur at joints where two or more bones or cartilages articulate with one another, several nonarticulated structures exhibit movement (e.g., tongue, lips, eyelids, and hyoid bone in the neck). It is often advantageous to consider movements in antagonistic (opposing) pairs.

Flexion and extension movements generally occur in sagittal planes around a transverse axis (Fig. 1.5A, B). **Flexion** indicates bending or decreasing the angle between the bones or parts of the body. For joints above the knee, flexion involves movement in an anterior direction. **Extension** indicates straightening or increasing the angle between the bones or parts of the body. Extension usually occurs in a posterior direction. The knee joint, rotated 180° to more superior joints, is exceptional in that flexion of the knee involves posterior movement and extension involves anterior movement. **Dorsiflexion** describes flexion at the ankle joint, as occurs when walking uphill or lifting the front of the foot and toes off the ground (Fig. 1.5I). **Plantarflexion** bends the foot and toes toward the ground, as when standing on your toes. Extension of a limb or part beyond the normal limit—**hyperextension** (overextension)—can cause injury, such as "whiplash" (i.e., hyperextension of the neck during a rear-end automobile collision).

Abduction and adduction movements generally occur in a frontal plane around an anteroposterior axis (Fig. 1.5E, G). Except for the digits, **abduction** means moving away from the median plane (e.g., when moving an upper limb laterally away from the side of the body) and **adduction** means moving toward it. In *abduction of the digits* (fingers or toes), the term means spreading them apart—moving the other fingers away from the neutrally positioned 3rd (middle) finger or moving the other toes away from the neutrally positioned 2nd toe. The 3rd finger and 2nd toe medially or laterally abduct away from the neutral position. *Adduction of the digits* is the opposite—bringing the spread fingers or toes together, toward the neutrally positioned 3rd finger or 2nd toe.

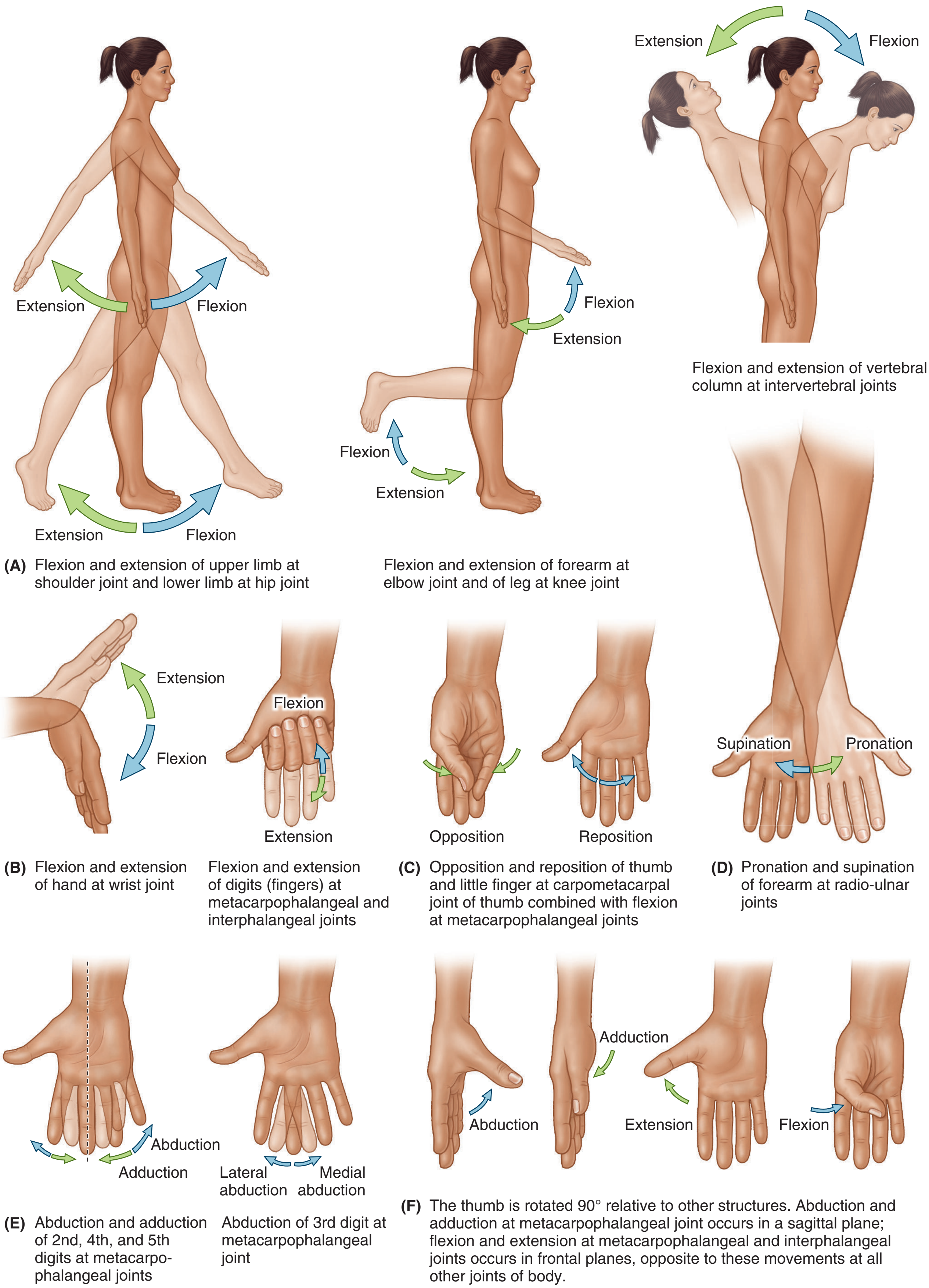
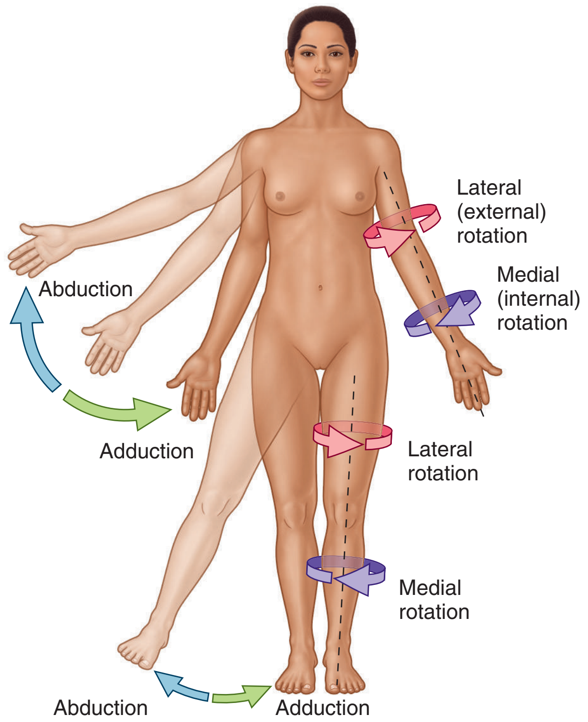
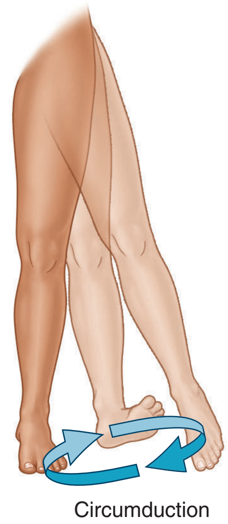


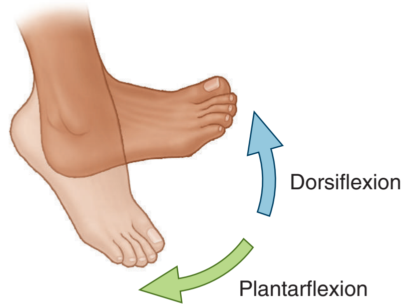
FIGURE 1.5. Terms of movement. A–M. Terms describing movements of the limbs and other parts of the body. Most movements take place at joints, where two or more bones or cartilages articulate with one another.



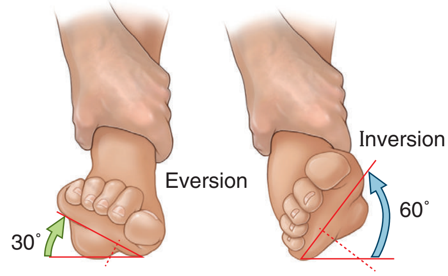
(G) Abduction and adduction of right limbs and rotation of left limbs at glenohumeral and hip joints, respectively



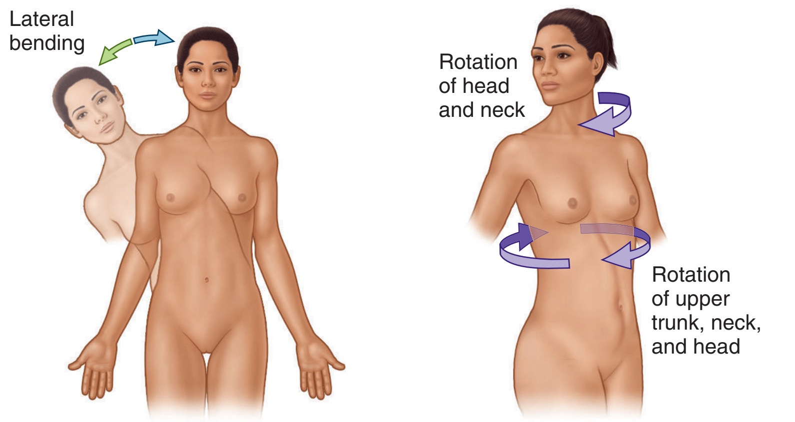
(H) Circumduction (circular movement) of lower limb at hip joint



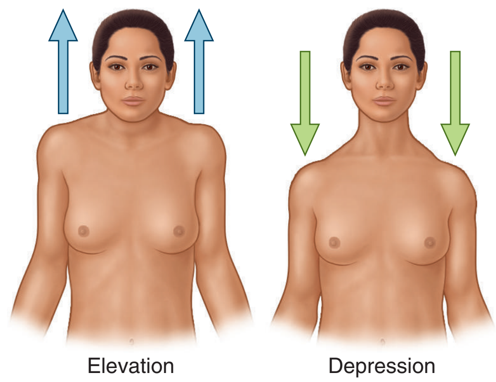
Dorsiflexion and plantarflexion of foot at ankle joint



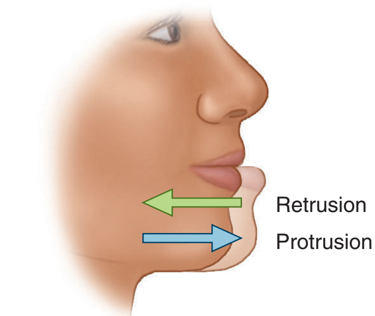
(I) Inversion and eversion of foot at subtalar and transverse tarsal joints



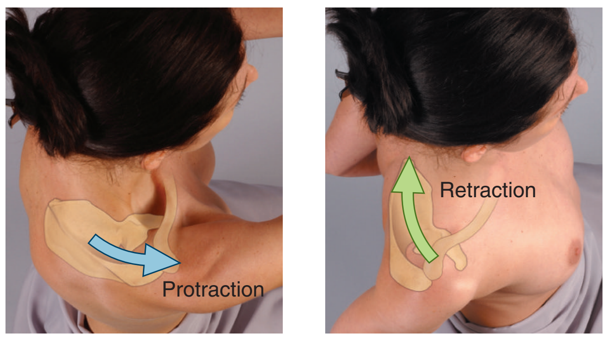
(J) Lateral bending (lateral flexion) of trunk and rotation of upper trunk, neck, and head



(K) Elevation and depression of shoulders



(L) Protrusion and retrusion of jaw at temporomandibular joints



(M) Protraction and retraction of scapula on thoracic wall

FIGURE 1.5. **(Continued)**

Right and left **lateral flexion** (lateral bending) are special forms of abduction for only the neck and trunk (Fig. 1.5J). The face and upper trunk are directed anteriorly as the head and/or shoulders tilt to the right or left side, causing the midline of the body itself to become bent sideways. This is a compound movement occurring between many adjacent vertebrae.

As you can see by noticing the way the thumbnail faces (laterally instead of posteriorly in the anatomical position), the thumb is rotated 90° relative to the other digits (Fig. 1.5F). Therefore, *the thumb flexes and extends in the frontal plane and abducts and adducts in the sagittal plane*.

Circumduction is a circular movement that involves sequential flexion, abduction, extension, and adduction (or in the opposite order) in such a way that the distal end of the part moves in a circle (Fig. 1.5H). Circumduction can occur at any joint at which all the above-mentioned movements are possible (e.g., the shoulder and hip joints).

Rotation involves turning or revolving a part of the body around its longitudinal axis, such as turning one's head to face sideways (Fig. 1.5J). **Medial rotation** (internal rotation) brings the anterior surface of a limb closer to the median plane, whereas **lateral rotation** (external rotation) takes the anterior surface away from the median plane (Fig. 1.5G).

Pronation and supination are the rotational movements of the forearm and hand that swing the distal end of the radius (the lateral long bone of the forearm) medially and laterally around and across the anterior aspect of the ulna (the other long bone of the forearm) while the proximal end of the radius rotates in place (Fig. 1.5D). **Pronation** rotates the radius medially so that the palm of the hand faces posteriorly and its dorsum faces anteriorly. When the elbow joint is flexed, pronation moves the hand so that the palm faces inferiorly (e.g., placing the palms flat on a table). **Supination** is the opposite rotational movement, rotating the radius laterally and uncrossing it from the ulna, returning the pronated forearm to the anatomical position. When the elbow joint is flexed, supination moves the hand so that the palm faces superiorly. (Memory device: You can hold *soup* in the palm of your hand when the flexed forearm is *sup*inated but are *prone* [likely] to spill it if the forearm is then *pron*ated!)

Eversion moves the sole of the foot away from the median plane, turning the sole laterally (Fig. 1.5I). When the foot is fully everted, it is also dorsiflexed. **Inversion** moves the sole of the foot toward the median plane (facing the sole medially). When the foot is fully inverted, it is also plantarflexed. *Pronation of the foot* actually refers to a combination of eversion and abduction that results in lowering of the medial margin of the foot (the feet of an individual with flat feet are pronated), and *supination of the foot* generally implies movements resulting in raising the medial margin of the foot, a combination of inversion and adduction.

Opposition is the movement by which the pad of the 1st digit (thumb) is brought to another digit pad (Fig. 1.5C). This movement is used to pinch, button a shirt, and lift a teacup by the handle. **Reposition** describes the movement of the 1st digit from the position of opposition back to its anatomical position.

Protrusion is a movement anteriorly (forward) as in protruding the mandible (chin), lips, or tongue (Fig. 1.5L). **Retrusion** is a movement posteriorly (backward), as in retruding the mandible, lips, or tongue. The similar terms **protraction** and **retraction** are used most commonly for anterolateral and posteromedial movements of the scapula on the thoracic wall, causing the shoulder region to move anteriorly and posteriorly (Fig. 1.5M).

Elevation raises or moves a part superiorly, as in elevating the shoulders when shrugging, the upper eyelid when opening the eye, or the tongue when pushing it up against the palate (roof of mouth) (Fig. 1.5K). **Depression** lowers or moves a part inferiorly, as in depressing the shoulders when standing at ease, the upper eyelid when closing the eye, or pulling the tongue away from the palate.

ANATOMICAL VARIATIONS

Structural variation occurs to differing degrees of severity ranging from normal to incompatible with life. **Anatomical variation** usually has no effect on normal function. Anatomical variations are often discovered during imaging or surgical procedures, at autopsy, or during anatomical study in individuals who had no awareness of or adverse effects from the variation. A **congenital anomaly** or **birth defect** is a variation often evident at birth or soon afterward due to aberrant form or function. Birth defects also can range from mild to severe. Although many birth defects can be treated, others are fatal. It is important to know how such variations and anomalies may influence physical examinations, diagnosis, and treatment.

Anatomy textbooks describe (initially, at least) the structure of the body as it is most often observed in people, that is, the most common pattern. However, occasionally, a particular structure demonstrates so much variation within the normal range that the most common pattern is found less than half the time! Beginning students are frequently frustrated because the bodies they are examining or dissecting do not conform to the atlas or text they are using (https://www.anatomyatlases.org; Tubbs et al., 2016). Often, students ignore the variations or inadvertently damage them by attempting to produce conformity. However, you should *expect anatomical variations* when you dissect or inspect prosected specimens.

In a random group of people, individuals obviously differ superficially from each other in physical appearance. The bones of the skeleton vary not only in size but more subtly in their basic shape and in lesser details of surface structure. A wide variation is found in the size, shape, and form of the attachments of muscles. Similarly, considerable variation exists in the patterns of branching of neurovascular structures (veins, arteries, and nerves). *Veins demonstrate the greatest degree of variation and nerves the least*. Individual variation must be considered in physical examination, diagnosis, and treatment.

CLINICAL BOX

ANATOMICAL VARIATIONS

Clinically Significant Variations and Birth Defects

Most descriptions in this text assume a normal range of variation. However, the frequency of variation often differs among human groups, and variations collected in one population may not apply to members of another population. Some variations, such as those occurring in the origin and course of the cystic artery to the gallbladder, are clinically significant (see Chapter 5, Abdomen). Being aware of these variations is essential in medical practice, particularly surgery. Clinically significant variations are described in clinical correlation (blue) boxes identified with an Anatomical Variation icon (at left above).

Humans exhibit considerable genetic variation beyond sexual and racial differences, such as polydactyly (extra digits) or dextrocardia (heart on left). Approximately 3% of newborns show one or more significant birth defects (Moore et al., 2020). Other defects (e.g., atresia or blockage of the intestine) are not detected until symptoms occur. Discovering anatomical variations in cadavers is actually one of the many benefits of firsthand dissection because it enables students to develop an awareness of the occurrence of variations and a sense of their frequency.

INTEGUMENTARY SYSTEM

Because the **skin** (L. *integumentum*, a covering) is readily accessible and is one of the best indicators of general health, careful observation of it is important in physical examinations. It is considered in the differential diagnosis of almost every disease. The skin provides:

- *Protection* of the body from environmental effects, such as abrasions, fluid loss, harmful substances, ultraviolet radiation, and invading microorganisms
- *Containment* for the body's structures (e.g., tissues and organs) and vital substances (especially extracellular fluids), preventing dehydration, which may be severe when extensive skin injuries (e.g., burns) are experienced
- *Thermal regulation* through the evaporation of sweat and/or the dilation or constriction of superficial blood vessels
- *Sensation* (e.g., pain) by way of superficial nerves and their sensory endings
- *Synthesis and storage* of vitamin D

The skin, the body's largest organ, consists of the epidermis, a superficial cellular layer, and the dermis, a deep connective tissue layer (Fig. 1.6).

The **epidermis** is a *keratinized epithelium*—that is, it has a tough, horny *superficial layer* that provides a protective outer surface overlying its regenerative and pigmented deep or *basal layer*. The epidermis has no blood vessels or lymphatics. The *avascular epidermis* is nourished by the underlying *vascularized dermis*. The dermis is supplied by arteries that enter its deep surface to form a cutaneous plexus of anastomosing arteries. The skin is also supplied with afferent nerve endings that are sensitive to touch, irritation (pain), and temperature. Most nerve terminals are in the dermis, but a few penetrate the epidermis.

The **dermis** is a dense layer of interlacing *collagen* and *elastic fibers*. These fibers provide skin tone and account for the strength and toughness of skin. The dermis of animals is removed and tanned to produce leather. Although the bundles of collagen fibers in the dermis run in all directions to produce a tough felt-like tissue, in any specific location most fibers run in the same direction. The predominant pattern of collagen fibers determines the characteristic tension and wrinkle lines in the skin.

The **tension lines** (also called cleavage lines or Langer lines) tend to spiral longitudinally in the limbs and run transversely in the neck and trunk (Fig. 1.7). Tension lines at the elbows, knees, ankles, and wrists are parallel to the transverse creases that appear when the limbs are flexed. The elastic fibers of the dermis deteriorate with age and are not replaced; consequently, in older people, the skin wrinkles and sags as it loses its elasticity.

The skin also contains many specialized structures (Fig. 1.6). The deep layer of the dermis contains *hair follicles*, with associated smooth arrector muscles and sebaceous glands. Contraction of the **arrector muscles of hairs** (L. *musculi arrector pili*) erects the hairs, causing goose bumps. Hair follicles are generally slanted to one side, and several *sebaceous glands* lie on the side the hair is directed toward ("points to") as it emerges from the skin. Thus, contraction of the arrector muscles causes the hairs to stand up straighter, thereby compressing the sebaceous glands and helping them secrete their oily product onto the skin surface. The evaporation of the watery secretion (*sweat*) of the *sweat glands* from the skin provides a thermoregulatory mechanism for heat loss (cooling). Also involved in the loss or retention of body heat are the small arteries (arterioles) within the dermis. They dilate to fill *superficial capillary beds* to radiate heat (skin appears red) or constrict to minimize surface heat loss (skin, especially of the lips and fingertips, appears blue). Other skin structures or derivatives include the nails (fingernails, toenails), the mammary glands, and the enamel of teeth.

Located between the overlying skin (dermis) and underlying deep fascia, the **subcutaneous tissue** (superficial fascia) is composed mostly of *loose connective tissue and stored fat* and contains sweat glands, superficial blood vessels, lymphatic vessels, and cutaneous nerves (Fig. 1.6). The neurovascular structures of the integument (*cutaneous nerves*, *superficial vessels*) course in the subcutaneous tissue, distributing only their terminal branches to the skin.

The subcutaneous tissue provides for most of the body's fat storage, so its thickness varies greatly, depending on the person's nutritional state. In addition, the distribution of subcutaneous

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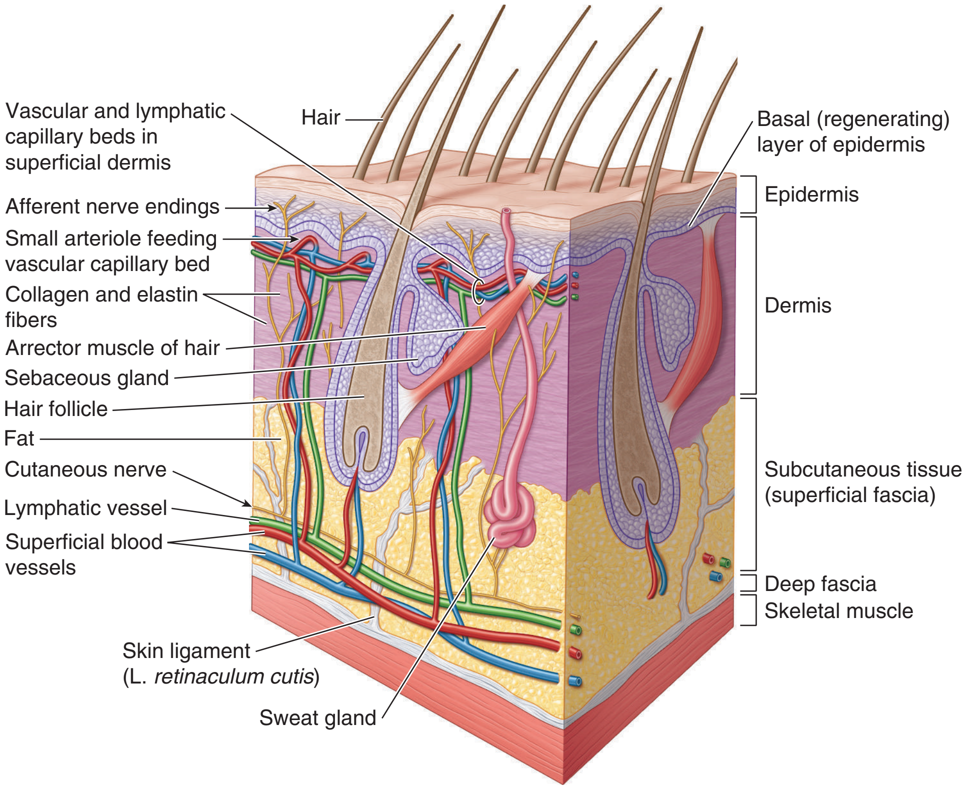


FIGURE 1.6. Skin. Layers of the skin and some of its specialized structures.

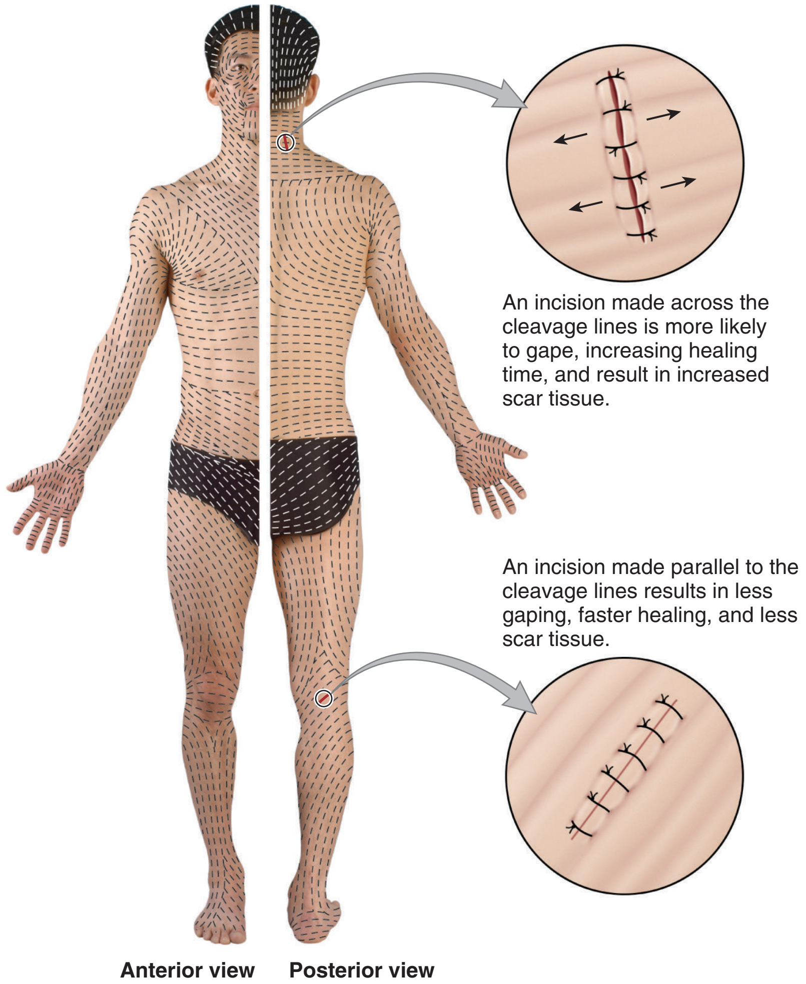


FIGURE 1.7. Tension lines of skin. The *dashed lines* indicate the predominant direction of the collagen fibers of the dermis.

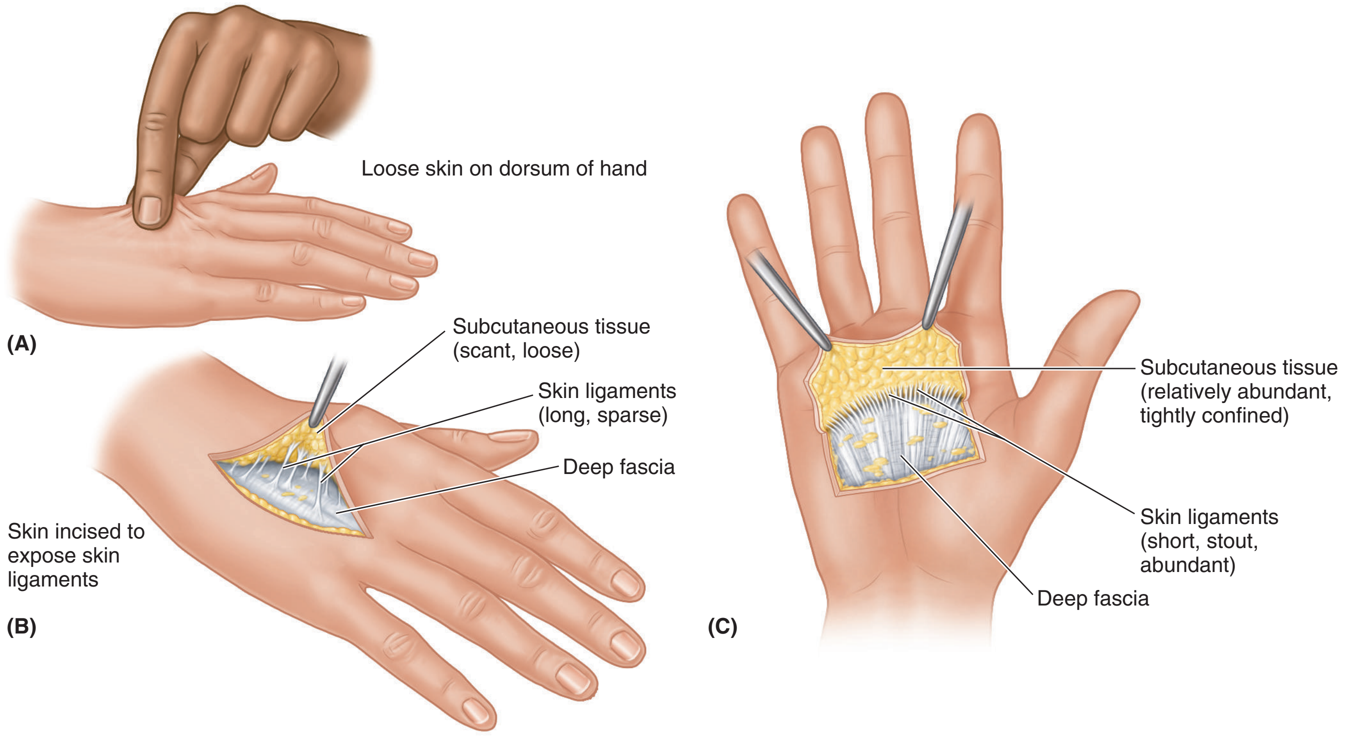


FIGURE 1.8. Skin ligaments in subcutaneous tissue. A. Estimating thickness of subcutaneous tissue. The thickness of subcutaneous tissue can be estimated as being approximately half that of a pinched fold of skin (i.e., a fold of skin includes a double thickness of subcutaneous tissue). The dorsum of the hand has relatively little subcutaneous tissue. **B.** Long, relatively sparse skin ligaments. Such ligaments allow the mobility of the skin demonstrated in part **A**. **C.** Short, abundant skin ligaments. The skin of the palm (like that of the sole) is firmly attached to the underlying deep fascia by relatively short, dense skin ligaments.

tissue varies considerably in different sites in the same individual. Compare, for example, the relative abundance of subcutaneous tissue evident by the thickness of the fold of skin that can be pinched at the waist or thighs with the anteromedial part of the leg (the shin, the anterior border of the tibia) or the back of the hand, the latter two being nearly devoid of subcutaneous tissue. Also consider the distribution of subcutaneous tissue and fat between the sexes: In mature females, it tends to accumulate in the breasts and thighs, whereas in males, subcutaneous fat accumulates especially in the lower abdominal wall.

Subcutaneous tissue participates in thermoregulation, functioning as insulation, retaining heat in the body's core. It also provides padding that protects the skin from compression by bony prominences, such as those in the buttocks.

Skin ligaments (L. *retinacula cutis*), numerous small fibrous bands, extend through the subcutaneous tissue and attach the deep surface of the dermis to the underlying deep fascia (Fig. 1.6). The length and density of these ligaments determine the mobility of the skin over deep structures. Where skin ligaments are longer and sparse, the skin is more mobile, such as on the back of the hand (Fig. 1.8A, B). Where ligaments are short and abundant, the skin is firmly attached to the underlying deep fascia, such as in the palms and soles (Fig. 1.8C). In dissection, removal of skin where the skin ligaments are short and abundant requires use of a sharp scalpel. The skin ligaments are long but particularly well developed in the breasts, where they form weight-bearing *suspensory ligaments* (see Chapter 4, Thorax).

CLINICAL BOX

INTEGUMENTARY SYSTEM

Skin Color Signs in Physical Diagnosis

Blood flow through the superficial capillary beds of the dermis (Fig. 1.6) affects the color of skin and can provide important clues for diagnosing certain clinical conditions. When the blood is not carrying enough oxygen from the lungs, such as in a person who has stopped breathing or whose circulation is unable to send adequate amount of blood through the lungs, the skin can appear bluish (cyanotic). Cyanosis occurs because the oxygen-carrying hemoglobin of blood appears bright red when carrying oxygen (as it does in arteries and usually does in capillaries) and appears deep, purplish blue when depleted of oxygen, as it does in veins. Cyanosis is especially evident where skin is thin, such as the lips, eyelids, and deep to the transparent nails. Skin injury, exposure to excess heat, infection, inflammation, or allergic reactions may cause the superficial capillary beds to become engorged, making the skin look abnormally red, a sign called erythema. In certain liver disorders, a yellow pigment called bilirubin builds up in the blood, giving a yellow appearance to the whites of the eyes and skin, a condition called jaundice. Skin color changes are most readily observed in people with light-colored skin and may be difficult to discern in people with dark skin, in which case examination of the delicate underside of the tongue may be helpful.

Skin Incisions and Scarring

The skin is always under tension. In general, lacerations or incisions that parallel the tension lines usually heal well with little scarring because there is minimal disruption of collagen fibers (Fig. 1.7, lower inset). The uninterrupted fibers tend to retain the cut edges in place. However, a laceration or incision across the tension lines disrupts more collagen fibers. The disrupted lines of force cause the wound to gape (Fig. 1.7, upper inset), and it may heal with excessive (keloid) scarring. When other considerations, such as adequate exposure and access or avoidance of nerves, are not of greater importance, surgeons attempting to minimize scarring for cosmetic reasons may use surgical incisions that parallel the tension lines.

Stretch Marks in Skin

The collagen and elastic fibers in the dermis form a tough, flexible meshwork of tissue. Because the skin can distend considerably, a relatively small incision can be made during surgery compared with the much larger incision required to attempt the same procedure in an embalmed cadaver, which no longer exhibits elasticity. The skin can stretch and grow to accommodate gradual increases in size. However, marked and relatively fast size increases, such as the abdominal enlargement and weight gain accompanying pregnancy, can stretch the skin too much, damaging the collagen fibers in the dermis (Fig. B1.1). During pregnancy, stretch marks (L. *striae gravidarum*)—bands of thin wrinkled skin, initially red but later becoming purple or white—may appear on the abdomen, buttocks, thighs, and breasts. Stretch marks also form outside of pregnancy (L. *striae cutis distensae*) in obese individuals and in certain diseases (e.g., hypercortisolism or Cushing syndrome); they occur along with distension and loosening of the deep fascia due to protein breakdown leading to reduced cohesion between the collagen fibers. Stretch marks generally fade after pregnancy and weight loss, but they never disappear completely.

Skin Injuries and Wounds

Lacerations. Accidental cuts and skin tears are superficial or deep. Superficial lacerations penetrate the epidermis and perhaps the superficial layer of the dermis; they bleed but do not interrupt the continuity of the dermis. Deep lacerations penetrate the deep layer of the dermis, extending into the subcutaneous tissue or beyond; they gape and require approximation of the cut edges of the dermis (by suturing, or stitches) to minimize scarring.

Burns. Burns are caused by thermal trauma, ultraviolet or ionizing radiation, or chemical agents. Burns are classified, in increasing order of severity, based on the depth of skin injury and the need for surgical intervention. The current classification system does not use numerical designations except for fourth-degree burns (the most severe) (Fig. B1.2):

- Superficial burn (e.g., sunburn): Damage is limited to the epidermis; symptoms are erythema (hot red skin), pain, and edema (swelling); desquamation (peeling) of the

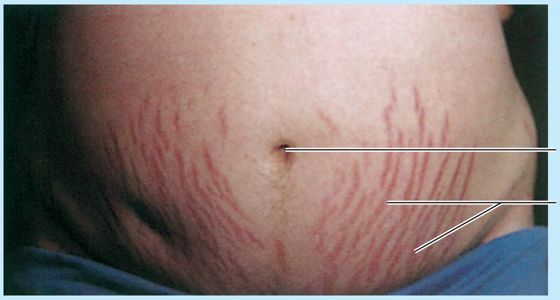
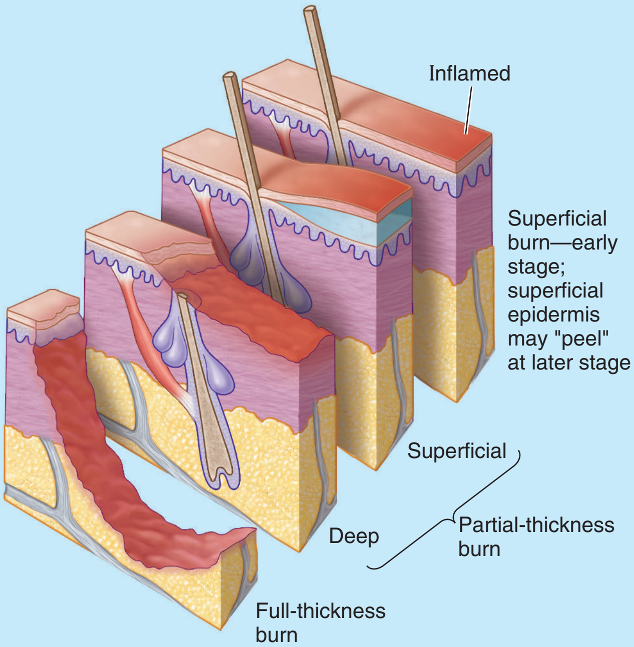


FIGURE B1.1. Stretch marks.



Partial-thickness burn

FIGURE B1.2. Skin burns.

superficial layer usually occurs several days later, but the layer is quickly replaced from the basal layer of the epidermis without significant scarring.

- Partial-thickness burn: Epidermis and superficial dermis are damaged with blistering (superficial partial thickness) or loss (deep partial thickness); nerve endings are damaged, making this variety the most painful; except for their most superficial parts, the sweat glands and hair follicles are not damaged and can provide the source of replacement cells for the basal layer of the epidermis along with cells from the edges of the wound; healing occurs slowly (3 weeks to several months), leaving scarring and some contracture, but it is usually complete.
- Full-thickness burn: The entire thickness of the skin is damaged and often the subcutaneous tissue; there is marked edema and the burned area is numb since sensory endings are destroyed; minor degree of healing may occur at the edges, but the open, ulcerated portions require skin grafting: Dead material (eschar) is removed and replaced (grafted) over the burned area with skin harvested (taken) from a nonburned location (autograft) or using skin from human cadavers or pigs or cultured or artificial skin.
- Fourth-degree burn: Damage extends through the entire thickness of the skin into underlying fascia, muscle, or bone; these injuries are life threatening.

Burns are classified as severe if they cover 20% or more of the total body surface area (excluding superficial burns like sunburn), are complicated by trauma or inhalation injury, or are caused by chemicals or high-voltage electricity. One way to estimate the surface area affected by a burn in an adult is to apply the "rule of nines," in which the body is divided into areas that are approximately 9% or multiples of 9% of the total body surface (Fig. B1.3). Three factors that increase the risk of death from burn injury are (1) age older than 60 years, (2) partial-thickness and full-thickness burns of over 40% body surface area, and (3) the presence of inhalation injury.

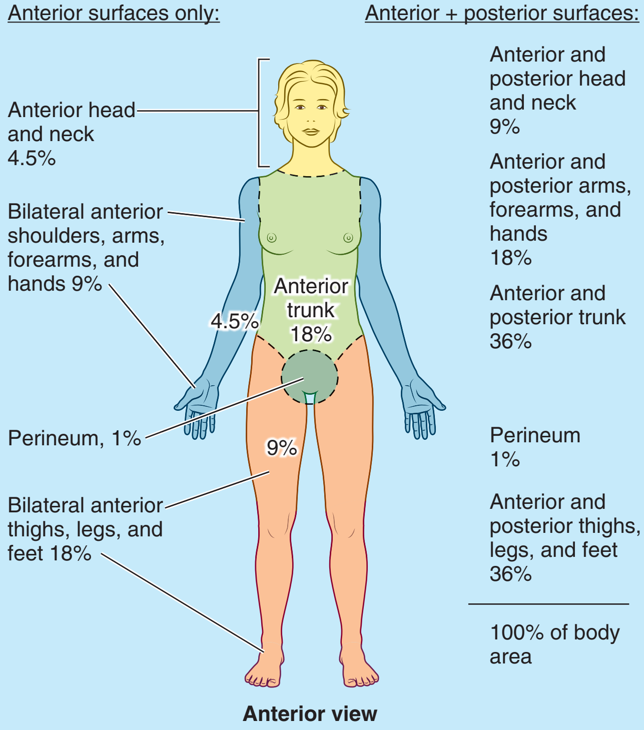


FIGURE B1.3. **Estimating body surface area.**

FASCIAS, FASCIAL COMPARTMENTS, BURSAE, AND POTENTIAL SPACES

Fascias (L. *fasciae*) constitute the wrapping, packing, and insulating materials of the deep structures of the body. Underlying the subcutaneous tissue (superficial fascia) almost everywhere is the deep fascia (Fig. 1.9). The **deep fascia** is a dense, organized connective tissue layer, devoid of fat, that covers most of the body parallel to (deep to) the skin and subcutaneous tissue. Extensions from its internal surface invest deeper structures, such as individual muscles (when it may also be called *epimysium*—see Fig. 1.21) and neurovascular bundles, as **investing fascia**. Its thickness varies widely. For example, in most of the face, distinct layers of deep fascia are absent.

In the limbs, groups of muscles with similar functions, usually sharing the same nerve supply, are located in **fascial compartments**. These compartments are separated by thick sheets of deep fascia, called **intermuscular septa**, that extend centrally from the surrounding fascial sleeve to attach to bones. These compartments may contain or direct the spread of an infection or a tumor.

In a few places, the deep fascia gives attachment (origin) to the underlying muscles (although it is not usually included in lists or tables of origins and insertions); but in most places, the muscles are free to contract and glide deep to it. However, the deep fascia itself never passes freely over bone; where deep fascia contacts bone, it blends firmly with the periosteum (bone covering). The relatively unyielding deep fascia investing muscles, and especially that surrounding the fascial compartments in the limbs, limits the outward expansion of the bellies of contracting skeletal muscles. Blood is thus pushed out as the veins of the muscles and compartments are compressed. Valves within the veins allow the blood to flow only in one direction (toward the heart), preventing the backflow that might occur as the muscles relax. Thus, deep fascia, contracting muscles, and venous valves work together as a musculovenous pump to return blood to the heart, especially in the lower limbs where blood must move against the pull of gravity (see Fig. 1.26).

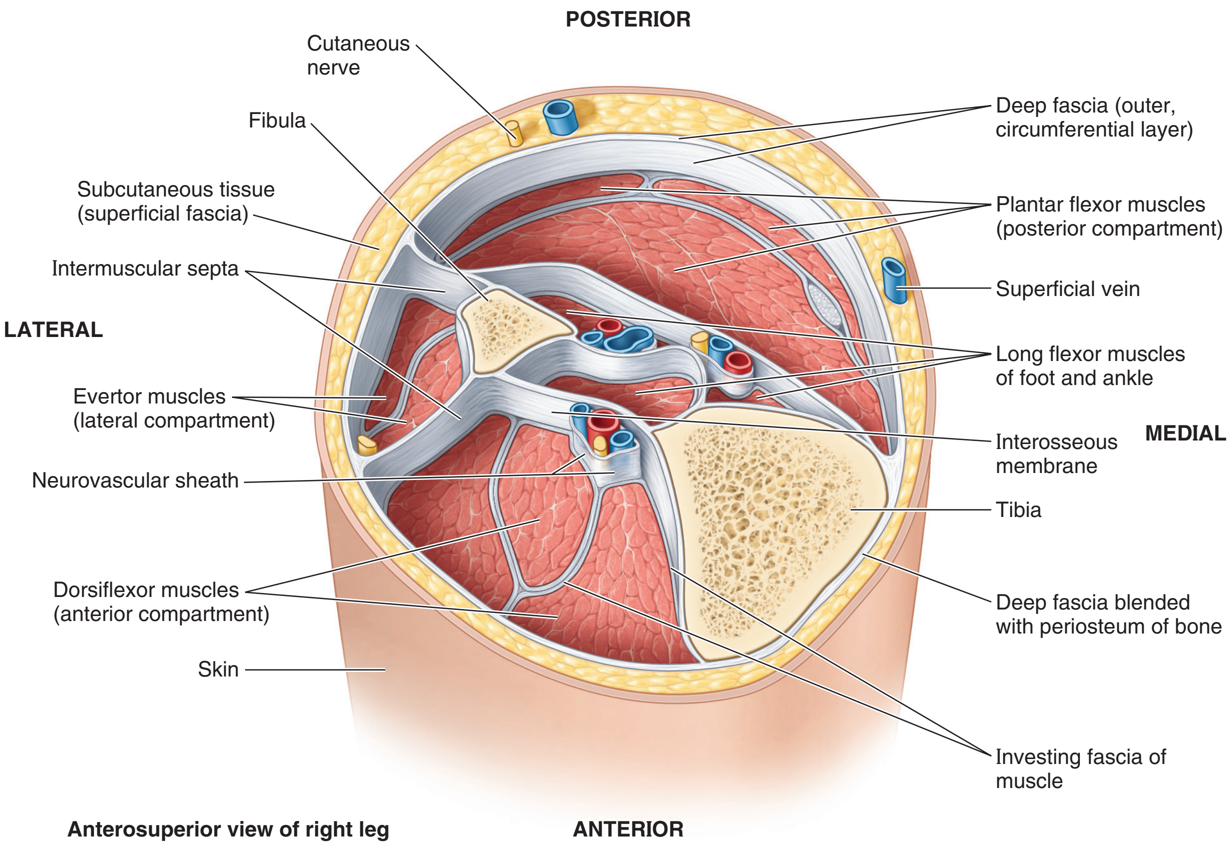


FIGURE 1.9. Excavated section of leg. The deep fascia and fascial formations are demonstrated.

Near certain joints (e.g., wrist and ankle), the deep fascia becomes markedly thickened, forming a **retinaculum** (plural = retinacula) to hold tendons in place where they cross the joint during flexion and extension, preventing them from taking a shortcut, or *bow stringing*, across the angle created (see Fig. 1.19).

Subserous fascia, with varying amounts of fatty tissue, lies between the internal surfaces of the musculoskeletal walls and the serous membranes lining the body cavities. These are the *endothoracic*, *endoabdominal*, and *endopelvic fascias*; the latter two may be referred to collectively as *extraperitoneal fascia*.

Bursae (singular = bursa; Mediev. L., a purse) are closed sacs or envelopes of **serous membrane** (a delicate connective tissue membrane capable of secreting fluid to lubricate a smooth internal surface). Bursae are normally collapsed. Unlike three-dimensional realized or actual spaces, these potential spaces have no depth; their walls are apposed with only a thin film of lubricating fluid between them that is secreted by the enclosing membranes. When the wall is interrupted at any point, or when a fluid is secreted or formed within them in excess, they become realized spaces; however, this condition is abnormal or pathological.

Usually occurring in locations subject to friction, bursae enable one structure to move more freely over another. **Subcutaneous bursae** occur in the subcutaneous tissue between the skin and bony prominences, such as at the elbow or knee; **subfascial bursae** lie beneath deep fascia; and **subtendinous bursae** facilitate the movement of tendons over bone. **Synovial tendon sheaths** are a specialized type of elongated bursae that wrap around tendons, usually enclosing them as they traverse osseofibrous tunnels that anchor the tendons in place (Fig. 1.10A).

Bursae occasionally communicate with the synovial cavities of joints. Because they are formed by delicate, transparent serous membranes and are collapsed, bursae are not easily noticed or dissected in the laboratory. It is possible to display bursae by injecting and distending them with colored fluid.

Collapsed bursal sacs surround many important organs (e.g., the heart, lungs, and abdominal viscera) and structures (e.g., portions of tendons). This configuration is much like wrapping a large but empty balloon around a structure, such as a fist (Fig. 1.10B). The object is surrounded by the two layers of the empty balloon but is not inside the balloon; the balloon itself remains empty. For an even more exact comparison, the balloon should first be filled with water and then emptied, leaving the empty balloon wet inside. In exactly this way, the heart is surrounded by—but is not inside—the *pericardial sac*. Each lung is surrounded by—but is not inside—a pleural sac, and the abdominal viscera are surrounded by—but are not inside—the *peritoneal sac*. In such cases, the inner layer of the balloon or serous sac (the one adjacent to the fist, viscus, or viscera) is called the **visceral layer**; the outer layer of the balloon (or the one in contact with the body wall) is called the **parietal layer**.