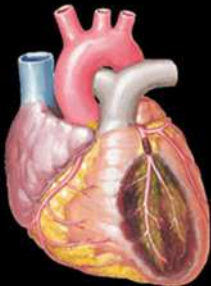


JOHN T. HANSEN



# NETTER'S CLINICAL ANATOMY



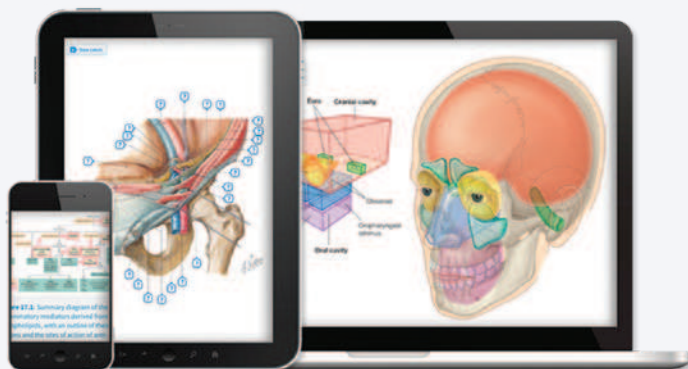
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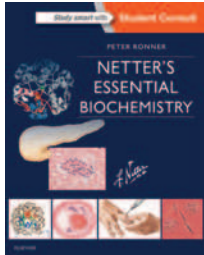


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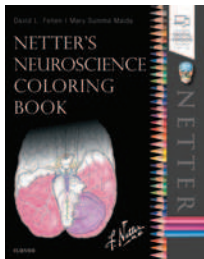
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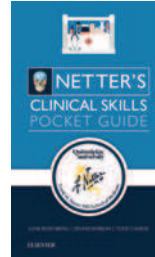
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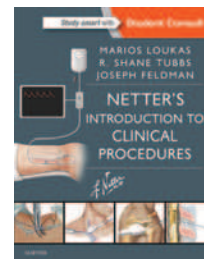


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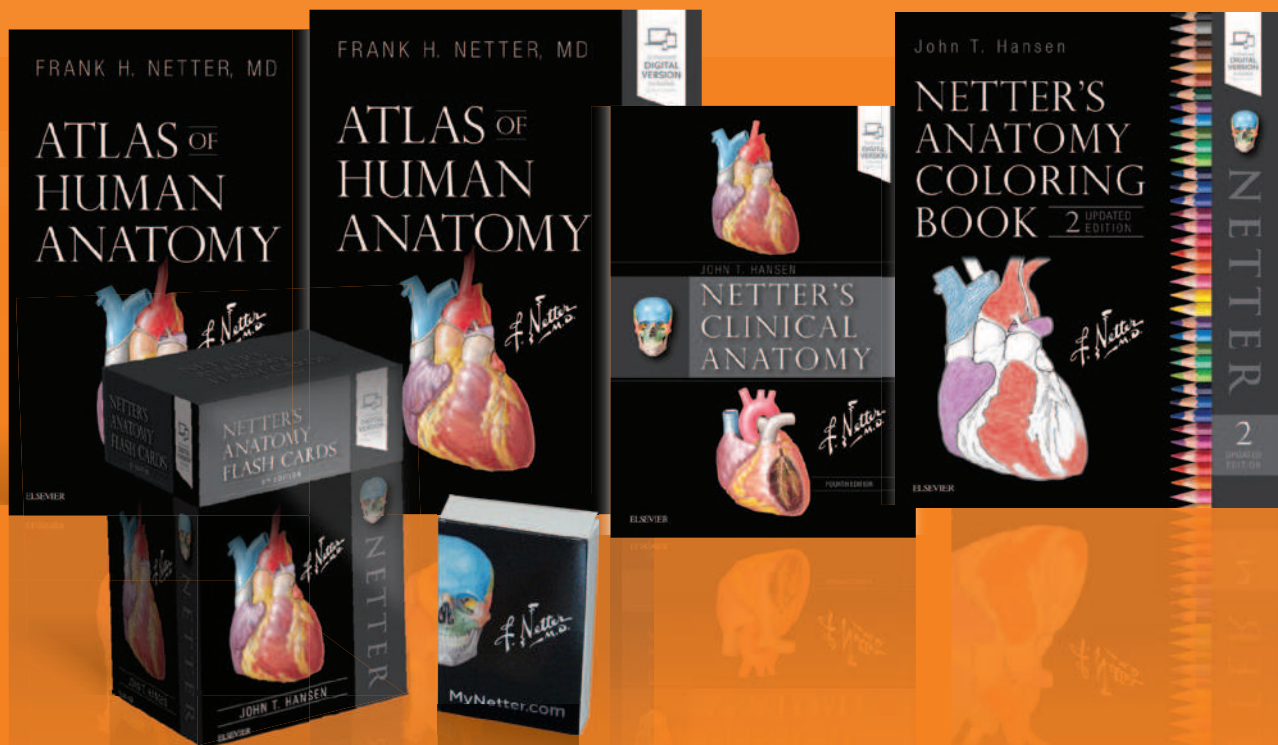
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*I dedicate this book to my wife*

***Paula,***

*and to my children*

***Amy and Sean,***

*and to my grandchildren*

***Abigail, Benjamin and Jonathan.***

*Without their unconditional love, presence, and encouragement, little would have been accomplished either personally or professionally. Because we've shared so much, this effort, like all the others, was multiauthored.*

# About the Artists

---

## Frank H. Netter, MD

Frank H. Netter was born in 1906, in New York City. He studied art at the Art Students' League and the National Academy of Design before entering medical school at New York University, where he received his medical degree in 1931. During his student years, Dr. Netter's notebook sketches attracted the attention of the medical faculty and other physicians, allowing him to augment his income by illustrating articles and textbooks. He continued illustrating as a sideline after establishing a surgical practice in 1933, but he ultimately opted to give up his practice in favor of a full-time commitment to art. After service in the United States Army during World War II, Dr. Netter began his long collaboration with the CIBA Pharmaceutical Company (now Novartis Pharmaceuticals). This 45-year partnership resulted in the production of the extraordinary collection of medical art so familiar to physicians and other medical professionals worldwide.

In 2005, Elsevier, Inc., purchased the Netter Collection and all publications from Icon Learning Systems. More than 50 publications featuring the art of Dr. Netter are available through Elsevier, Inc. (in the US: [www.us.elsevierhealth.com/Netter](http://www.us.elsevierhealth.com/Netter) and outside the US: [www.elsevierhealth.com](http://www.elsevierhealth.com)).

Dr. Netter's works are among the finest examples of the use of illustration in the teaching of medical concepts. The 13-book *Netter Collection of Medical Illustrations*, which includes the greater part of the more than 20,000 paintings created by Dr. Netter, became and remains one of the most famous medical works ever published. *The Netter Atlas of Human Anatomy*, first published in 1989, presents the anatomic paintings from the Netter Collection. Now translated into 16 languages, it is the anatomy atlas of choice among medical and health professions students the world over.

The Netter illustrations are appreciated not only for their aesthetic qualities, but, more important, for their intellectual content. As Dr. Netter wrote in 1949, "... clarification of a subject is the aim and goal of illustration. No matter how beautifully painted, how delicately and subtly rendered a subject may be, it is of little value as a *medical illustration* if it does not serve to make clear some medical point." Dr. Netter's planning, conception, point of view, and approach are what inform his paintings and what make them so intellectually valuable.

Frank H. Netter, MD, physician and artist, died in 1991.

Learn more about the physician-artist whose work has inspired the Netter Reference collection: <https://netterimages.com/artist-frank-h-netter.html>.

## Carlos A. G. Machado, MD

Carlos A. G. Machado was chosen by Novartis to be Dr. Netter's successor. He continues to be the main artist who contributes to the Netter collection of medical illustrations.

Self-taught in medical illustration, cardiologist Carlos Machado has contributed meticulous updates to some of Dr. Netter's original plates and has created many paintings of his own in the style of Netter as an extension of the Netter collection. Dr. Machado's photorealistic expertise and his keen insight into the physician/patient relationship informs his vivid and unforgettable visual style. His dedication to researching each topic and subject he paints places him among the premier medical illustrators at work today.

Learn more about his background and see more of his art at: <https://netterimages.com/artist-carlos-a-g-machado.html>.



# About the Author

---

**John T. Hansen, PhD**, is Professor of Neuroscience and former Associate Dean for Admissions at the University of Rochester Medical Center. Dr. Hansen served as Chair of the Department of Neurobiology and Anatomy before becoming Associate Dean. Dr. Hansen is the recipient of numerous teaching awards from students at three different medical schools. In 1999, he was the recipient of the Alpha Omega Alpha Robert J. Glaser Distinguished Teacher Award given annually by the Association of American Medical Colleges

to nationally recognized medical educators. Dr. Hansen's investigative career encompassed the study of the peripheral and central dopaminergic systems, neural plasticity, and neural inflammation. In addition to over 100 research publications, he is co-author of *Netter's Atlas of Human Physiology*; the lead consulting editor of *Netter's Atlas of Human Anatomy*; author of *Netter's Anatomy Flash Cards*, *Essential Anatomy Dissector*, and *Netter's Anatomy Coloring Book*; and co-author of the *TNM Staging Atlas with Oncoanatomy*.

# Acknowledgments

---

Compiling the illustrations for, researching, and writing *Netter's Clinical Anatomy*, fourth edition, has been both enjoyable and educational, confirming again the importance of lifelong learning in the health professions.

*Netter's Clinical Anatomy* is for all my students, and I am indebted to all of them who, like many others, yearn for a better view to help them learn the relevant essential anatomy that informs the practice of medicine. Anatomy is a visual science, and Netter's illustrations are the gold standard of medical illustration.

Thanks and appreciation belong to my colleagues and reviewers who provided encouragement and constructive comments that clarified many aspects of the book. Especially, I wish to acknowledge David Lambert, MD, Senior Associate Dean for Undergraduate Medical Education at Rochester, who co-authored the first edition of this book with me and remains a treasured colleague and friend.

At Elsevier, it has been a distinct pleasure to work with dedicated, professional people who massaged, molded, and ultimately nourished the dream beyond even my wildest imagination. I owe much to the efforts of Marybeth Thiel, Senior

Content Development Specialist, and John Casey, Senior Project Manager, both of whom kept me organized, focused, and on time. Without them, little would have been accomplished. Thanks and appreciation also to Patrick Ferguson, Designer and Karen Giacomucci, Illustration Manager. A special thank you to Madelene Hyde, Publishing Director, and Elyse O'Grady, Executive Content Strategist, for believing in the idea and always supporting my efforts. This competent team defines the word "professionalism," and it has been an honor to work with all of them.

Special thanks to Carlos Machado, MD, for his beautiful artistic renderings that superbly complemented, updated, and extended the Netter anatomy collection. Also, I wish to express my thanks to my faculty colleagues at Rochester for their generous and constructive feedback.

Finally, I remain indebted to Frank H. Netter, MD, whose creative genius lives on in generations of biomedical professionals who have learned clinical anatomy from his rich collection of medical illustrations.

To all of these remarkable people, and others, "Thank you."

JOHN T. HANSEN, PhD

# Preface

---

Human anatomy is the foundation upon which the education of our medical, dental, and allied health science students is built. However, today's biomedical science curriculum must cover an ever-increasing body of scientific knowledge, often in fewer hours, as competing disciplines and new technologies emerge. Many of these same technologies, especially those in the imaging science fields, have made understanding the anatomy even more important and have moved our discipline firmly into the realm of clinical medicine. It is fair to say that competent clinicians and allied health professionals can no longer simply view their anatomical training in isolation from the clinical implications related to that anatomy.

In this context, I am proud to introduce the fourth edition of *Netter's Clinical Anatomy*. Generations of students have used Dr. Frank H. Netter's elegant anatomical illustrations to learn anatomy, and this book combines his beautiful anatomical and embryological renderings with numerous clinical illustrations to help students bridge the gap between normal anatomy and its clinical application across each region of the human body.

This fourth edition provides succinct text, key bulleted points, and ample summary tables, which offer students a concise textbook description of normal human anatomy, as well as a quick reference and review guide for clinical practitioners. Additionally, 215 *Clinical Focus* boxes representing some of the more commonly encountered clinical conditions seen in medical practice are integrated within the textbook. These clinical correlations are drawn from a wide variety of medical fields including emergency medicine, radiology, orthopedics, and surgery, but also include relevant clinical anatomy related to the fields of cardiology, endocrinology, infectious diseases, neurology, oncology, reproductive biology, and urology. By design, the text and clinical correlations are not exhaustive but are meant to help students focus on the essential elements of anatomy and begin

to appreciate some of the clinical manifestations related to that anatomy. Other features of this edition include:

- An introductory chapter designed to orient students to the body's organ systems
- A set of end-of-chapter clinically oriented multiple choice review questions to help reinforce student learning of key concepts
- Basic embryology of each system that provides a contextual framework for human postnatal anatomy and several common congenital defects
- Online access with additional *Clinical Focus* boxes

My intent in writing this updated fourth edition of *Netter's Clinical Anatomy* was to provide a concise and focused introduction to clinical anatomy as a viable alternative to the more comprehensive anatomy textbooks, which few students read and often find difficult to navigate when looking for essential anatomical details. Moreover, this textbook serves as an excellent essential review text for students beginning their clinical clerkships or elective programs, and as a reference text that clinicians will find useful for review and patient education.

The text is by no means comprehensive but does provide the essential anatomy needed by the generalist physician-in-training that is commonly encountered in the first year of medical school. I have intentionally focused on the anatomy that a first-year student might be expected to grasp and carry forward into his or her clerkship training, especially in this day and age when anatomy courses are often streamlined and dissection exercises abbreviated. Those students, who by choice, choose to enter specialties where advanced anatomical training is required (e.g., surgical specialties, radiology, physical therapy, etc.) may encounter a need for additional anatomical expertise that will be provided by their graduate medical

or allied health education. By meeting the needs of the beginning student and providing ample detail for subsequent review or handy reference, my hope is that *Netter's Clinical Anatomy* will be the anatomy textbook of choice that will actually be read and used by students throughout their undergraduate medical or allied health careers.

I hope that you, the health science student-in-training or the physician-in-practice, will find *Netter's Clinical Anatomy* the valuable link you've searched for to enhance your understanding of clinical anatomy as only Frank Netter can present it.

JOHN T. HANSEN, PhD

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# Introduction to the Human Body

**1. TERMINOLOGY****2. SKIN****3. SKELETAL SYSTEM****4. MUSCULAR SYSTEM****5. CARDIOVASCULAR SYSTEM****6. LYMPHATIC SYSTEM****7. RESPIRATORY SYSTEM****8. NERVOUS SYSTEM****9. ENDOCRINE SYSTEM****10. GASTROINTESTINAL SYSTEM****11. URINARY SYSTEM****12. REPRODUCTIVE SYSTEM****13. BODY CAVITIES****14. OVERVIEW OF EARLY DEVELOPMENT****15. IMAGING THE INTERNAL ANATOMY****CHALLENGE YOURSELF QUESTIONS**

## 1. TERMINOLOGY

### Anatomical Position

The study of anatomy requires a clinical vocabulary that defines position, movements, relationships, and planes of reference, as well as the systems of the human body. The study of anatomy can be by **body region** or by **body organ systems**. Generally, courses of anatomy in the United States approach anatomical study by regions, integrating all applicable body systems into the study of a particular region. This textbook therefore is arranged regionally, and for those studying anatomy for the first time, this initial chapter introduces you to the major body systems that you will encounter in your study of anatomy. You will find it extremely helpful to refer back to this introduction as you encounter various body systems in your study of regional anatomy.

By convention, anatomical descriptions of the human body are based on a person in the **anatomical position** (Fig. 1.1), as follows:

- Standing erect and facing forward
- Arms hanging at the sides with palms facing forward
- Legs placed together with feet facing forward

### Terms of Relationship and Body Planes

Anatomical descriptions often are referenced to one or more of three distinct body planes (Fig. 1.2 and Table 1.1), as follows:

- **Sagittal plane:** a vertical plane that divides the body into equal right and left halves (median or midsagittal plane) or a plane parallel to the median sagittal plane (parasagittal) that divides the body into unequal right and left portions.

- **Frontal (coronal) plane:** a vertical plane that divides the body into anterior and posterior portions (equal or unequal); this plane is at right angles to the median sagittal plane.
- **Transverse (axial) plane:** a horizontal plane that divides the body into superior and inferior portions (equal or unequal) and is at right angles to both the median sagittal and the frontal planes (sometimes called *cross sections*).

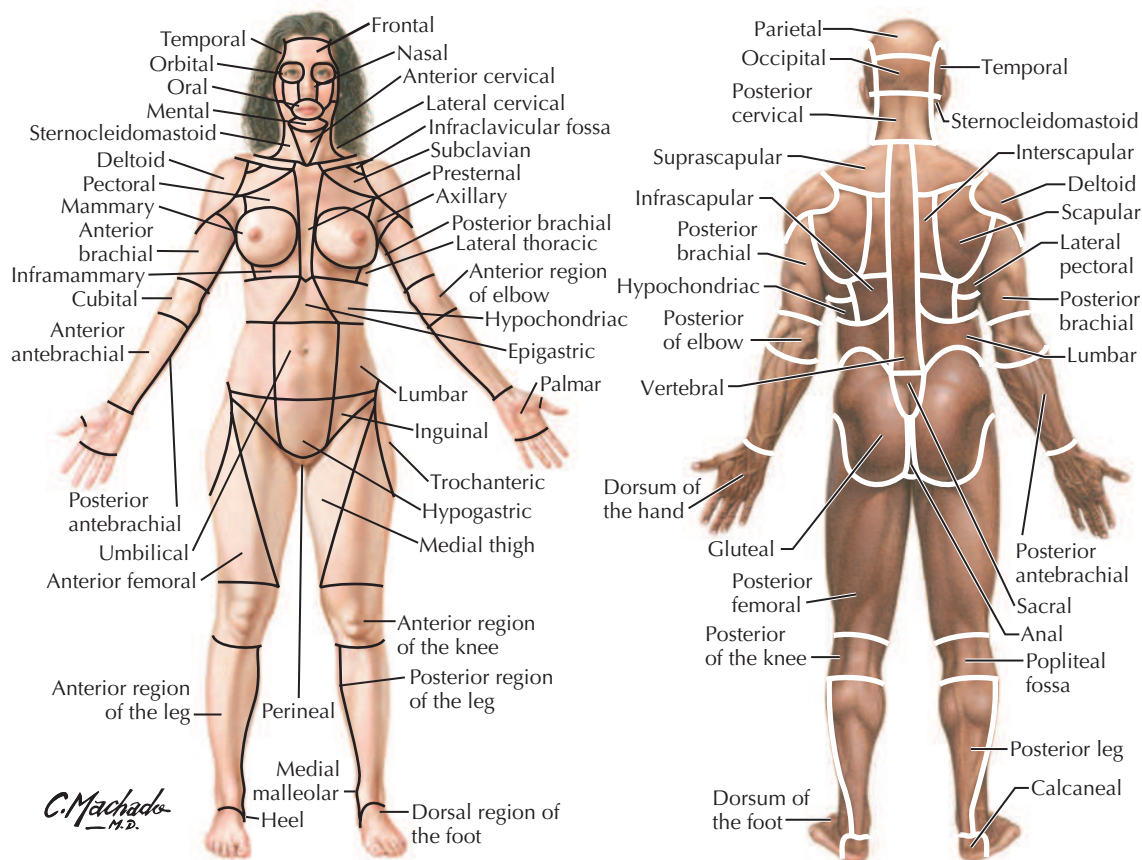
Key terms of relationship used in anatomy and the clinic are summarized in Table 1.1. A structure or feature closer to the front of the body is considered *anterior* (ventral), and one closer to the back is termed *posterior* (dorsal). The terms *medial* and *lateral* are used to distinguish a structure or feature in relationship to the midline; the nose is medial to the ear, and in anatomical position, the nose also is anterior to the ear. Sometimes these terms of relationship are used in combination (e.g., *superomedial*, meaning closer to the head and nearer the median sagittal plane).

### Movements

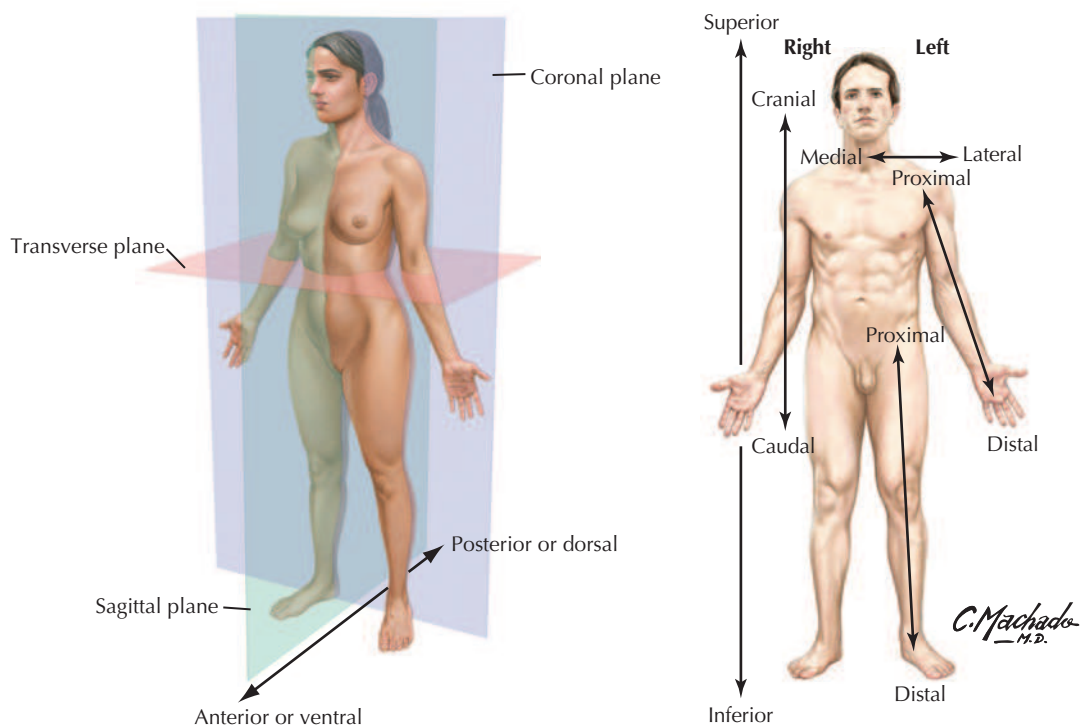
Body movements usually occur at the joints where two or more bones or cartilages articulate with one another. Muscles act on joints to accomplish these movements and may be described as follows: “The biceps muscle flexes the forearm at the elbow.” Fig. 1.3 summarizes the terms of movement.

### Anatomical Variability

The human body is remarkably complex and remarkably consistent anatomically, but normal variations do exist, often related to size, gender,



**FIGURE 1.1** Surface Anatomy: Regions (From *Atlas of human anatomy*, ed 7, Plates 2 and 3.)



**FIGURE 1.2** Body Planes and Terms of Anatomical Relationship. (From *Atlas of human anatomy*, ed 7, Plate 1.)

**TABLE 1.1 General Terms of Anatomical Relationship**

TERM	DEFINITION	TERM	DEFINITION
Anterior (ventral)	Near the front	Median plane	Divides body into equal right and left parts
Posterior (dorsal)	Near the back	Midsagittal plane	Median plane
Superior (cranial)	Upward, or near the head	Sagittal plane	Divides body into unequal right and left parts
Inferior (caudal)	Downward, or near the feet	Frontal (coronal) plane	Divides body into equal or unequal anterior and posterior parts
Medial	Toward the midline or median plane	Transverse plane	Divides body into equal or unequal superior and inferior parts (cross sections)
Lateral	Farther from the midline or median plane		
Proximal	Near a reference point		
Distal	Away from a reference point		
Superficial	Closer to the surface		
Deep	Farther from the surface		

**FIGURE 1.3** Terms of Movement.



age, number, shape, and attachment. Variations are particularly common in the following structures:

- **Bones:** the fine features of bones (processes, spines, articular surfaces) may be variable depending on the forces working on a bone.
- **Muscles:** they vary with size and fine details of their attachments (it is better to learn their actions and general attachments rather than focus on detailed exceptions).
- **Organs:** the size and shape of some organs will vary depending on their normal physiology or pathophysiologic changes that have occurred previously.
- **Arteries:** they are surprisingly consistent, although some variation is seen in the branching patterns, especially in the lower neck (subclavian branches) and in the pelvis (internal iliac branches).
- **Veins:** they are consistent, although variations, especially in size and number of veins, can occur and often can be traced to their complex embryologic development; veins generally are more numerous than arteries, larger, and more variable.

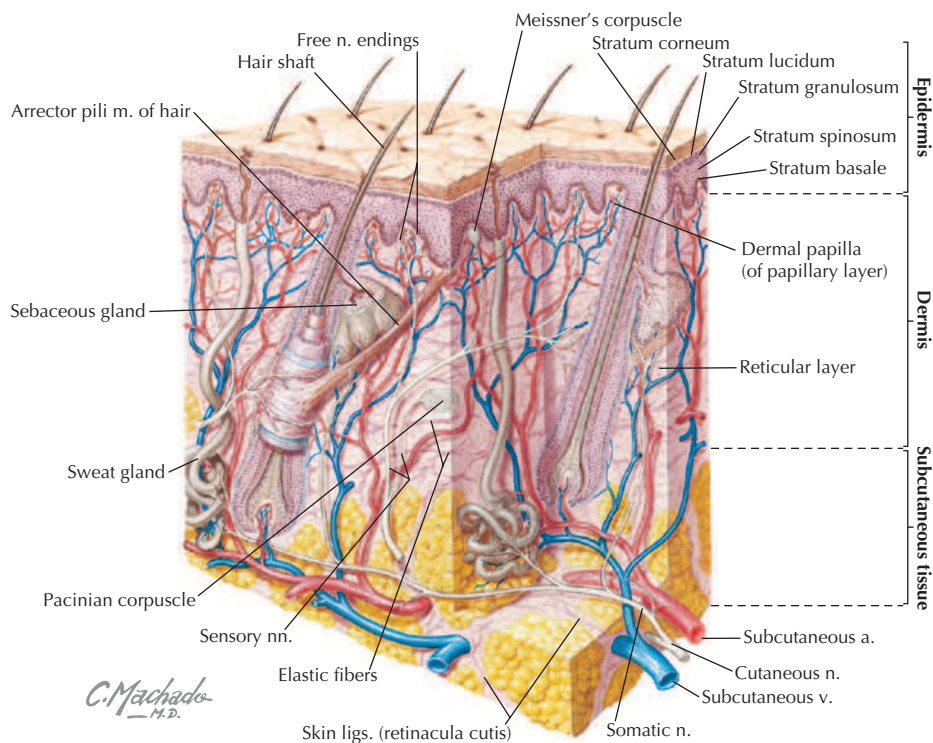
## 2. SKIN

The skin is the largest organ in the body, accounting for about 15% to 20% of the total body mass, and has the following functions:

- **Protection:** against mechanical abrasion and in immune responses, as well as prevention of dehydration.
  - **Temperature regulation:** largely through vasodilation, vasoconstriction, fat storage, or activation of sweat glands.
  - **Sensations:** to touch by specialized mechanoreceptors such as pacinian and Meissner's corpuscles; to pain by nociceptors; and to temperature by thermoreceptors.
  - **Endocrine regulation:** by secretion of hormones, cytokines, and growth factors, and by synthesis and storage of vitamin D.
  - **Exocrine secretions:** by secretion of sweat and oily sebum from sebaceous glands.
- The skin consists of two layers (Fig. 1.4):

- **Epidermis:** is the outer protective layer consisting of a keratinized stratified squamous epithelium derived from the embryonic ectoderm.
- **Dermis:** is the dense connective tissue layer that gives skin most of its thickness and support, and is derived from the embryonic mesoderm.

**Fascia** is a connective tissue sheet that may contain variable amounts of fat. It can interconnect structures, provide a conduit for vessels and nerves (termed **neurovascular bundles**), and provide a sheath around structures (e.g., muscles) that permits them to slide over one another easily. **Superficial**



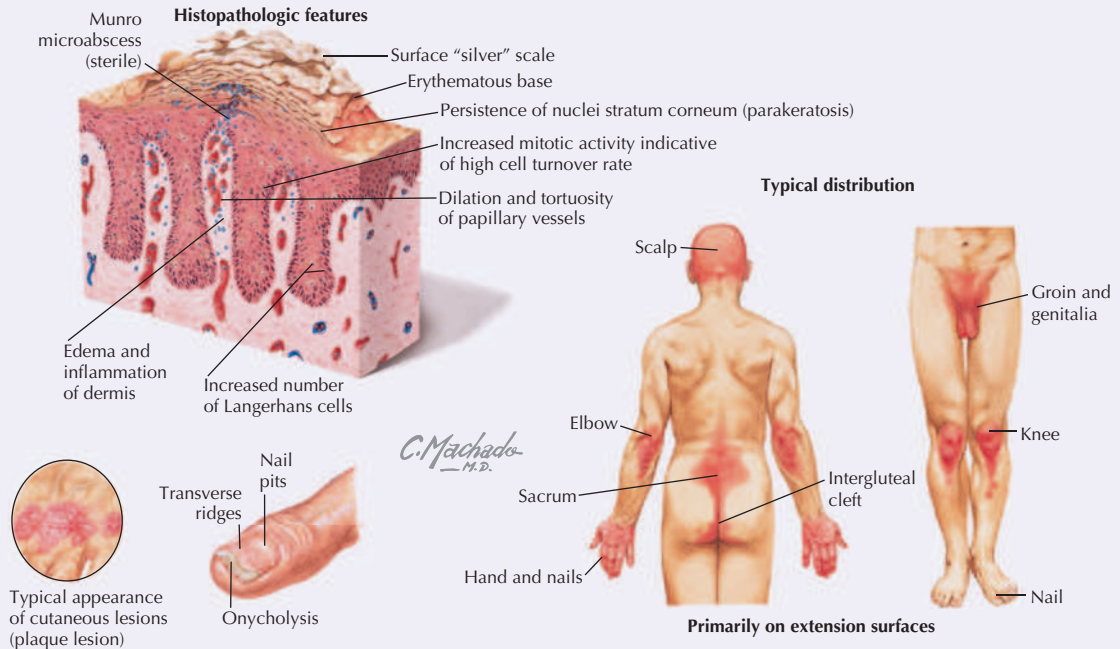
**FIGURE 1.4** Layers of the Skin.



## Clinical Focus 1-1

## Psoriasis

Psoriasis is a chronic inflammatory skin disorder that affects approximately 1% to 3% of the population (women and men equally). It is characterized by defined red plaques capped with a surface scale of desquamated epidermis. Although the pathogenesis is unknown, psoriasis seems to involve a genetic predisposition.



**fascia** is attached to and lies just beneath the dermis of the skin and can vary in thickness and density; it acts as a cushion, contains variable amounts of fat, and allows the skin to glide over its surface. **Deep fascia** usually consists of a dense connective tissue, is attached to the deep surface of the superficial fascia, and often ensheathes muscles and divides them into functional groupings. Extensions of the deep fascia encasing muscles also may course inward and attach to the skeleton, dividing groups of muscles with **intermuscular septa**. Common injuries to the skin include abrasions, cuts (lacerations), and burns. Burns are classified as follows:

- **First-degree:** burn damage that is limited to the superficial layers of the epidermis; termed a *superficial burn*, clinically it causes erythema (redness of the skin).
- **Second-degree:** burn damage that includes all of the epidermis and extends into the superficial dermis; termed a *partial-thickness burn*, it causes blisters but spares the hair follicles and sweat glands.

- **Third-degree:** burn damage that includes all the epidermis and dermis and may even involve the subcutaneous tissue and underlying deep fascia and muscle; termed a *full-thickness burn*, it causes charring.

## 3. SKELETAL SYSTEM

## Descriptive Regions

The human skeleton is divided into two descriptive regions (Fig. 1.5):

- **Axial skeleton:** includes the bones of the skull, vertebral column (spine), ribs, and sternum, which form the “axis” or central line of the body (80 bones).
- **Appendicular skeleton:** includes the bones of the limbs, including the pectoral and pelvic girdles, which attach the limbs to the body’s axis (134 bones).

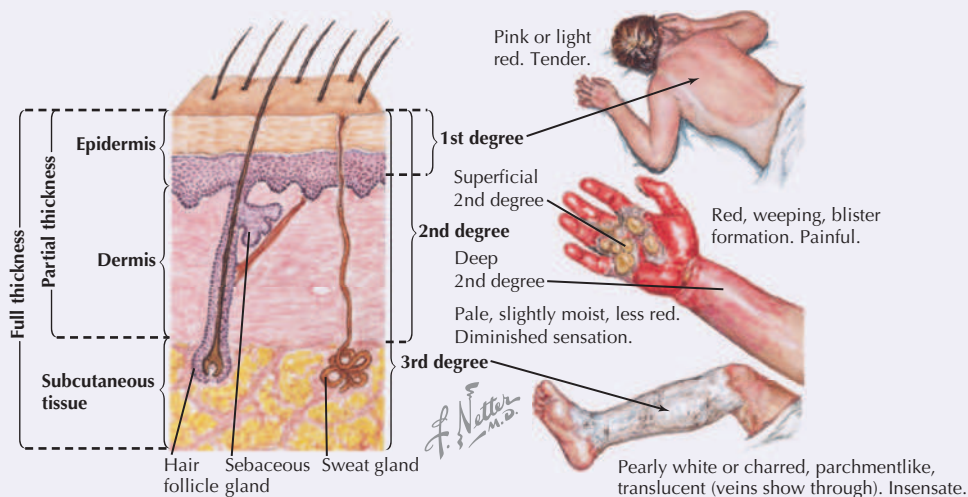
## Shapes and Function of Bones

The skeleton is composed of a living, dynamic, rigid connective tissue that forms the bones and cartilages.

## Clinical Focus 1-2

## Burns

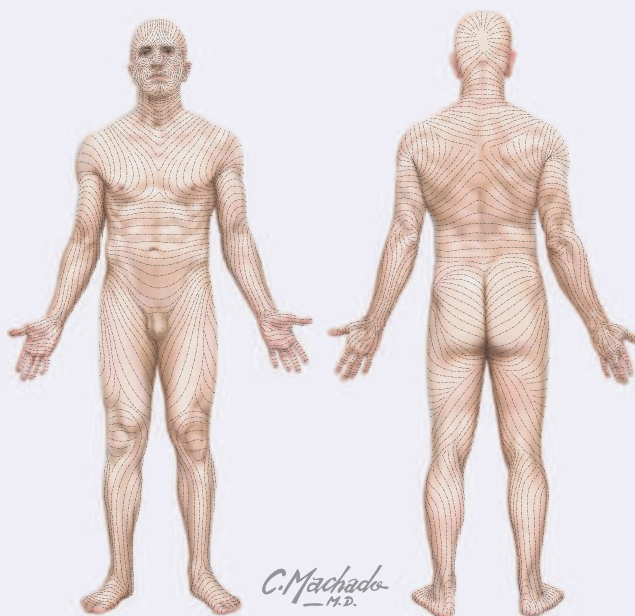
Burns to the skin are classified into three degrees of severity based on the depth of the burn:

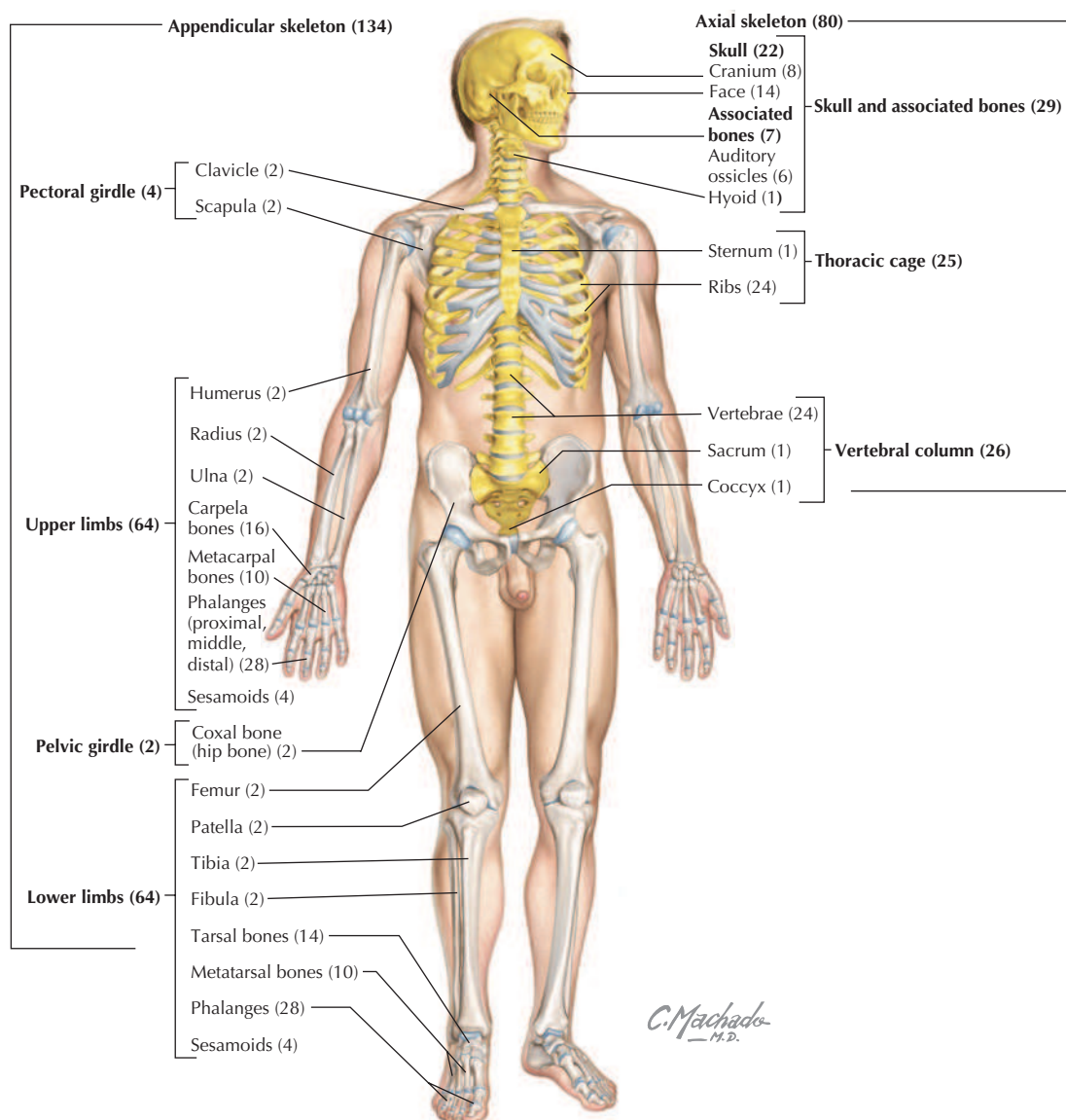


## Clinical Focus 1-3

## Langer's Lines

Collagen in the skin creates tension lines called *Langer's lines*. Surgeons sometimes use these lines to make skin incisions; other times, they may use the natural skin folds. The resulting incision wounds tend to gape less when the incision is parallel to Langer's lines, resulting in a smaller scar after healing. However, skin fold incisions also may conceal the scar following healing of the incision.





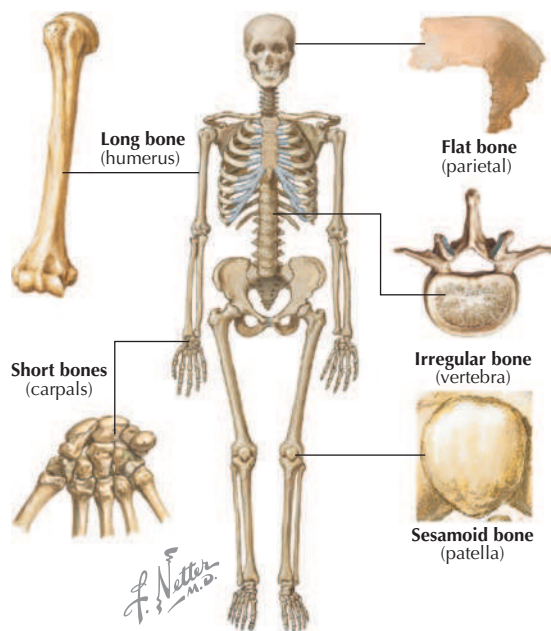
**FIGURE 1.5** Axial and Appendicular Regions of Skeleton.

Generally, humans have about 214 bones, although this number varies, particularly in the number of small sesamoid bones that may be present. (Many resources claim we have only 206 bones, but they have ignored the 8 sesamoid bones of the hands and feet.) Cartilage is attached to some bones, especially where flexibility is important, or covers the surfaces of bones at points of articulation. About 99% of the body's calcium is stored in bone, and many bones possess a central cavity that contains bone marrow—a collection of hemopoietic (blood-forming) cells. Most of the bones can be classified into one of the following five shapes (Fig. 1.6):

- Long.
- Short.
- Flat.
- Irregular.
- Sesamoid.

The functions of the skeletal system include:

- Support.
- Protection of vital organs.
- A mechanism, along with muscles, for movement.
- Storage of calcium and other salts, growth factors, and cytokines.
- A source of blood cells.



**FIGURE 1.6** Bone Classification Based on Shape.

There are two types of bone:

- **Compact:** is a relatively solid mass of bone, commonly seen as a superficial layer of bone, that provides strength.
- **Spongy** (trabecular or cancellous): is a less dense trabeculated network of bone spicules making up the substance of most bones and surrounding an inner marrow cavity.

Long bones also are divided into the following descriptive regions (Fig. 1.7):

- **Epiphysis:** the ends of long bones, which develop from secondary ossification centers.
- **Epiphysial plate:** the site of growth in length; it contains cartilage in actively growing bones.
- **Metaphysis:** the site where the bone's shaft joins the epiphysis and epiphysial plate.
- **Diaphysis:** the shaft of a long bone, which represents the primary ossification center and the site where growth in width occurs.

As a living, dynamic tissue, bone receives a rich blood supply from:

- **Nutrient arteries:** usually one or several larger arteries that pass through the diaphysis and supply the compact and spongy bone, as well as the bone marrow.
- **Metaphysial and epiphysial arteries:** usually arise from articular branches supplying the joint.
- **Periosteal arteries:** numerous small arteries from adjacent vessels that supply the compact bone.

## Markings on the Bones

Various surface features of bones (ridges, grooves, and bumps) result from the tension placed on them by the attachment of tendons, ligaments, and fascia, as well as by neurovascular bundles or other structures that pass along the bone. Descriptively, these features include the following:

- **Condyle:** a rounded articular surface covered with articular (hyaline) cartilage.
- **Crest:** a ridge (narrow or wide) of bone.
- **Epicondyle:** a prominent ridge or eminence superior to a condyle.
- **Facet:** a flat, smooth articular surface, usually covered with articular (hyaline) cartilage.
- **Fissure:** a very narrow "slitlike" opening in a bone.
- **Foramen:** a round or oval "hole" in the bone for passage of another structure (nerve or vessel).
- **Fossa:** a "cuplike" depression in the bone, usually for articulation with another bone.
- **Groove:** a furrow in the bone.
- **Line:** a fine linear ridge of bone, but less prominent than a crest.
- **Malleolus:** a rounded eminence.
- **Meatus:** a passageway or canal in a bone.
- **Process:** a bony prominence that may be sharp or blunt.
- **Protuberance:** a protruding eminence on an otherwise smooth surface.
- **Ramus:** a thin part of a bone that joins a thicker process of the same bone.
- **Spine:** a sharp process projecting from a bone.
- **Trochanter:** large, blunt process for muscle tendon or ligament attachment.
- **Tubercle:** a small, elevated process.
- **Tuberosity:** a large, rounded eminence that may be coarse or rough.

## Bone Development

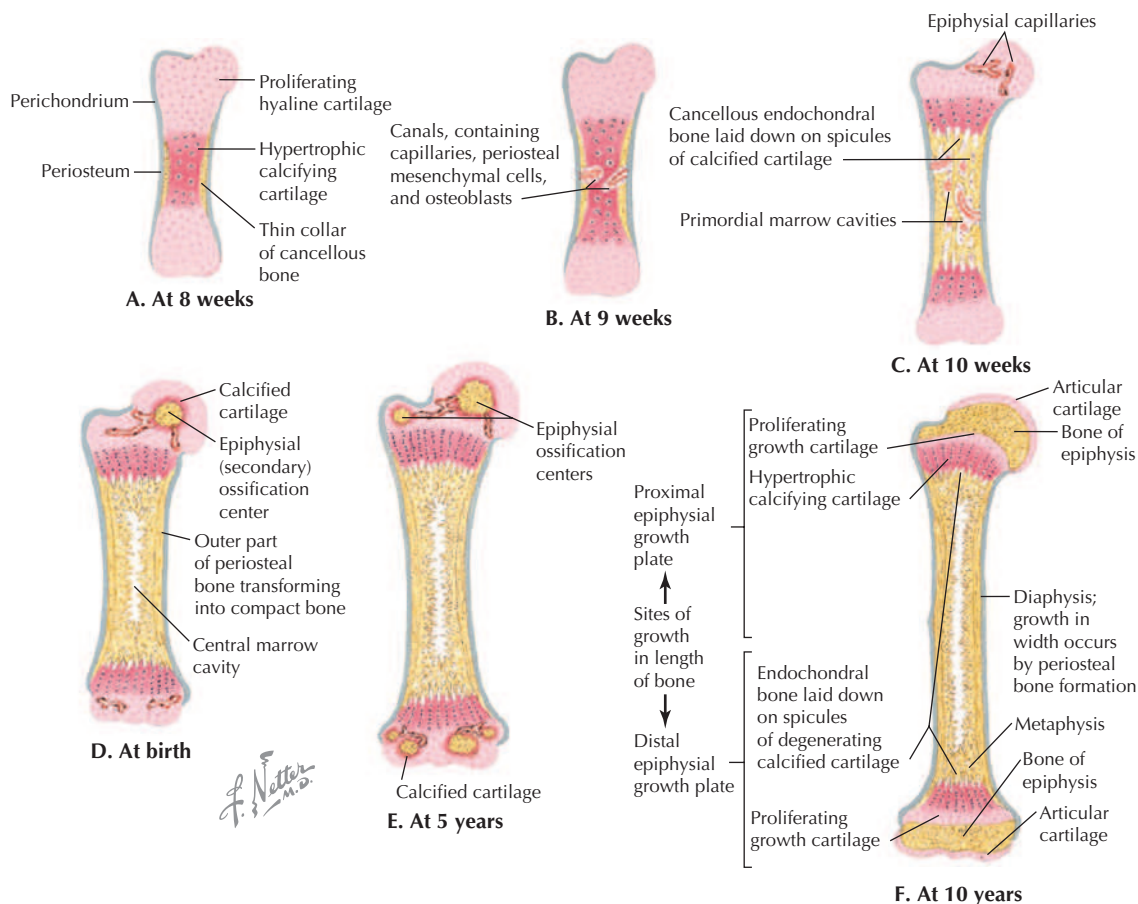
Bones develop in one of the following two ways:

- **Intramembranous formation:** most flat bones develop in this way by direct calcium deposition into a mesenchymal (primitive mesoderm) precursor or model of the bone.
- **Endochondral formation:** most long and irregularly shaped bones develop by calcium deposition into a cartilaginous model of the bone that provides a scaffold for the future bone.

The following sequence of events defines endochondral bone formation (Fig. 1.7, A-F):

- Formation of a thin collar of bone around a hyaline cartilage model.





**FIGURE 1.7** Growth and Ossification of Long Bones (Midfrontal Sections).

- Cavitation of the primary ossification center and invasion of vessels, nerves, lymphatics, red marrow elements, and osteoblasts.
- Formation of spongy (cancellous) endochondral bone on calcified spicules.
- Diaphysis elongation, formation of the central marrow cavity, and appearance of the secondary ossification centers in the epiphyses.
- Long bone growth during childhood.
- Epiphysal fusion occurring from puberty into maturity (early to mid-20s).

### Types of Joints

Joints are the sites of union or articulation of two or more bones or cartilages, and are classified into one of the following three types (Fig. 1.8):

- **Fibrous** (synarthroses): bones joined by fibrous connective tissue.
- **Cartilaginous** (amphiarthroses): bones joined by cartilage, or by cartilage and fibrous tissue.
- **Synovial** (diarthroses): in this most common type of joint, the bones are joined by a joint cavity filled with a small amount of synovial fluid

and surrounded by a capsule; the bony articular surfaces are covered with hyaline cartilage.

**Fibrous joints** include **sutures** (flat bones of the skull), **syndesmoses** (two bones connected by a fibrous membrane), and **gomphoses** (teeth fitting into fibrous tissue-lined sockets).

**Cartilaginous joints** include **primary** (synchondrosis) joints between surfaces lined by hyaline cartilage (epiphysal plate connecting the diaphysis with the epiphysis), and **secondary** (symphysis) joints between hyaline-lined articular surfaces and an intervening fibrocartilaginous disc. Primary joints allow for growth and some bending, whereas secondary joints allow for strength and some flexibility.

**Synovial joints** generally allow for considerable movement and are classified according to their shape and the type of movement that they permit (uniaxial, biaxial, or multiaxial movement) (Fig. 1.9), as follows:

- **Hinge** (ginglymus): are uniaxial joints for flexion and extension.
- **Pivot** (trochoid): are uniaxial joints for rotation.

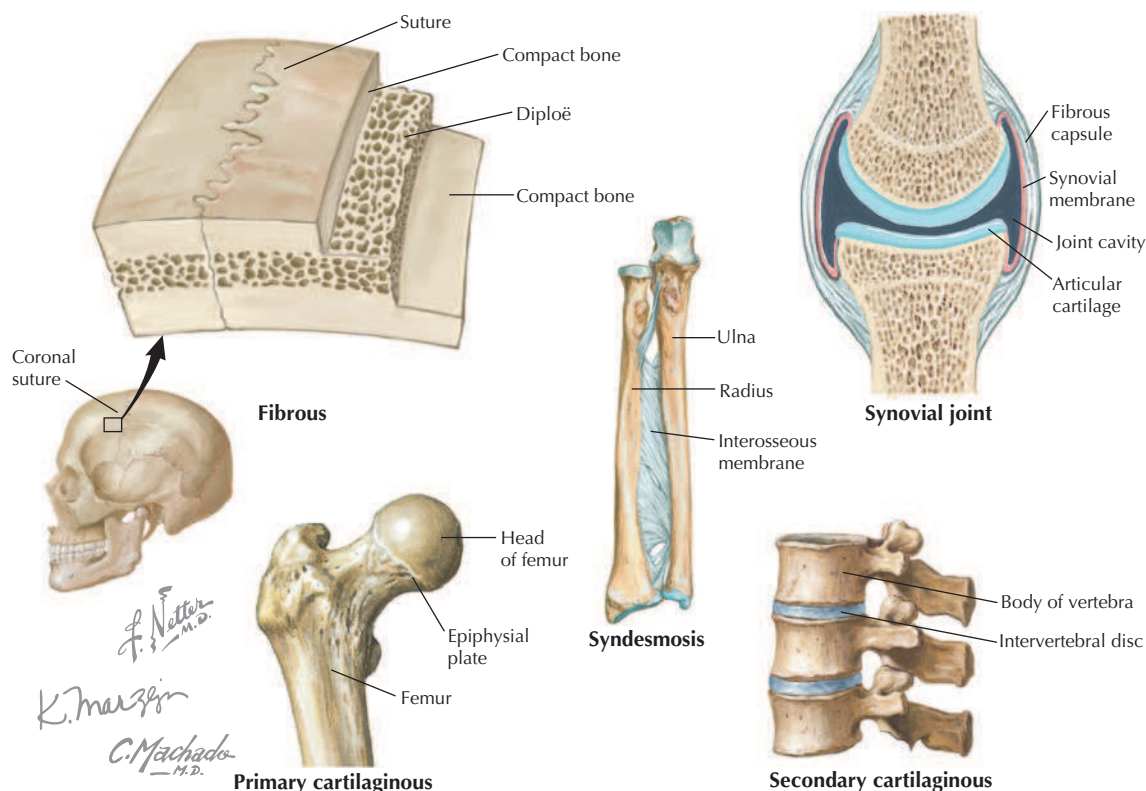


FIGURE 1.8 Types of Joints.

- **Saddle:** are biaxial joints for flexion, extension, abduction, adduction, and circumduction.
- **Condylloid** (ellipsoid; sometimes classified separately): are biaxial joints for flexion, extension, abduction, adduction, and circumduction.
- **Plane** (gliding): are joints that only allow simple gliding movements.
- **Ball-and-socket** (spheroid): are multiaxial joints for flexion, extension, abduction, adduction, mediolateral rotation, and circumduction.

#### 4. MUSCULAR SYSTEM

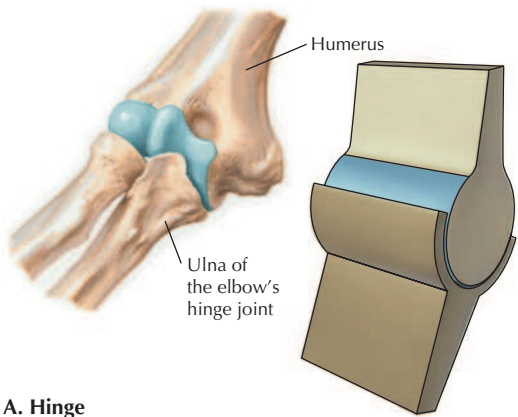
Muscle cells (fibers) produce contractions (shortenings in length) that result in movement, maintenance of posture, changes in shape, or the propulsion of fluids through hollow tissues or organs. There are three different types of muscle:

- **Skeletal:** striated muscle fibers that are attached to bone and are responsible for movements of the skeleton (sometimes simplistically referred to as *voluntary muscle*).
- **Cardiac:** striated muscle fibers that make up the walls of the heart and proximal portions of the great veins where they enter the heart.
- **Smooth:** nonstriated muscle fibers that line various organ systems (gastrointestinal, urogenital, respiratory), attach to hair follicles, and line the walls of most blood vessels (sometimes simplistically referred to as *involuntary muscle*).

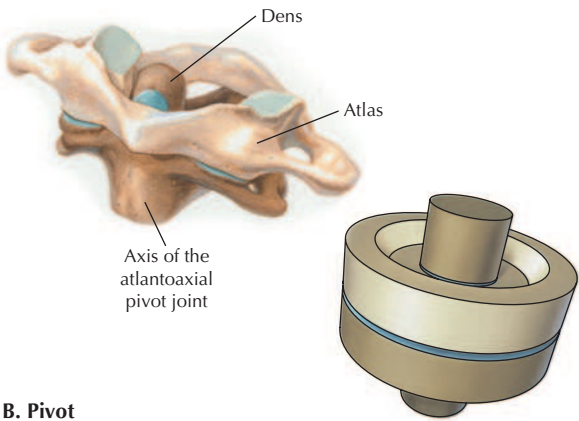
Skeletal muscle is divided into **fascicles** (bundles), which are composed of muscle fibers (muscle cells) (Fig. 1.10). The muscle fiber cells contain longitudinally oriented **myofibrils** that run the full length of the cell. Each myofibril is composed of many **myofilaments**, which are composed of individual **myosin** (thick filaments) and **actin** (thin filaments) that slide over one another during muscle contraction.

Skeletal muscle moves bones at their joints and possesses an **origin** (the muscle's fixed or proximal attachment) and an **insertion** (the muscle's movable or distal attachment). In a few instances, the muscle's origin moves more than its insertion. At the gross level, anatomists classify muscle on the basis of its shape:

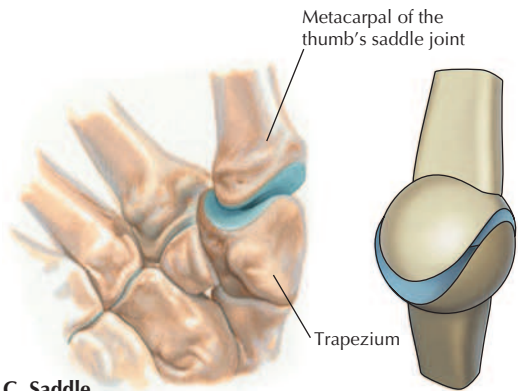
- **Flat:** muscle that has parallel fibers, usually in a broad flat sheet with a broad tendon of attachment called an *aponeurosis*.
- **Quadrilateral:** muscle that has a four-sided appearance.



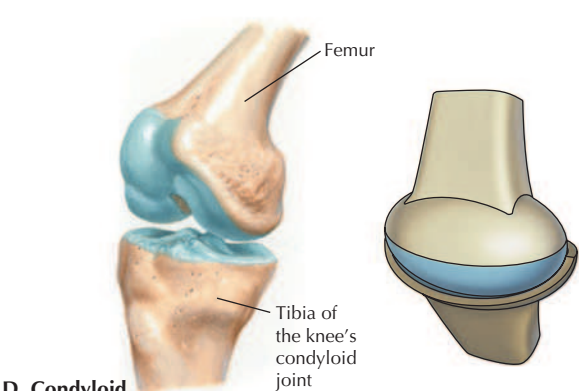
A. Hinge



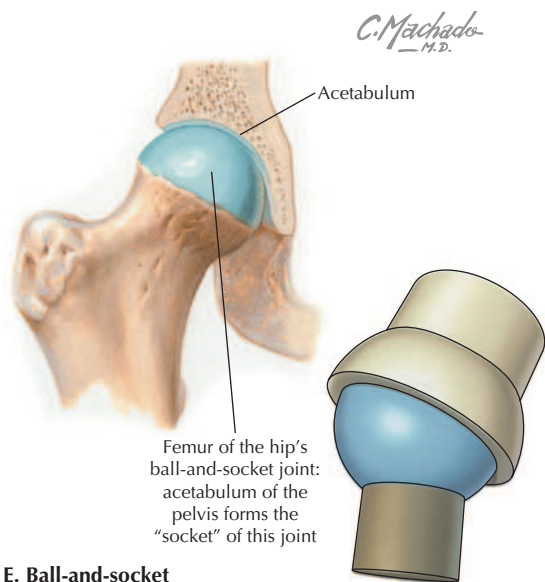
B. Pivot



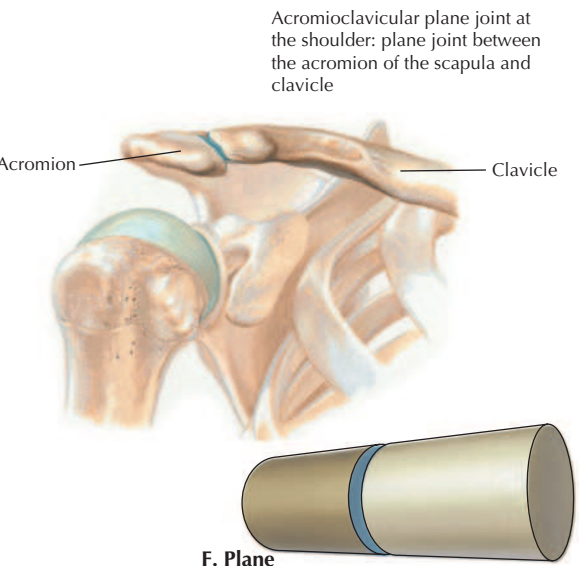
C. Saddle



D. Condylloid



E. Ball-and-socket



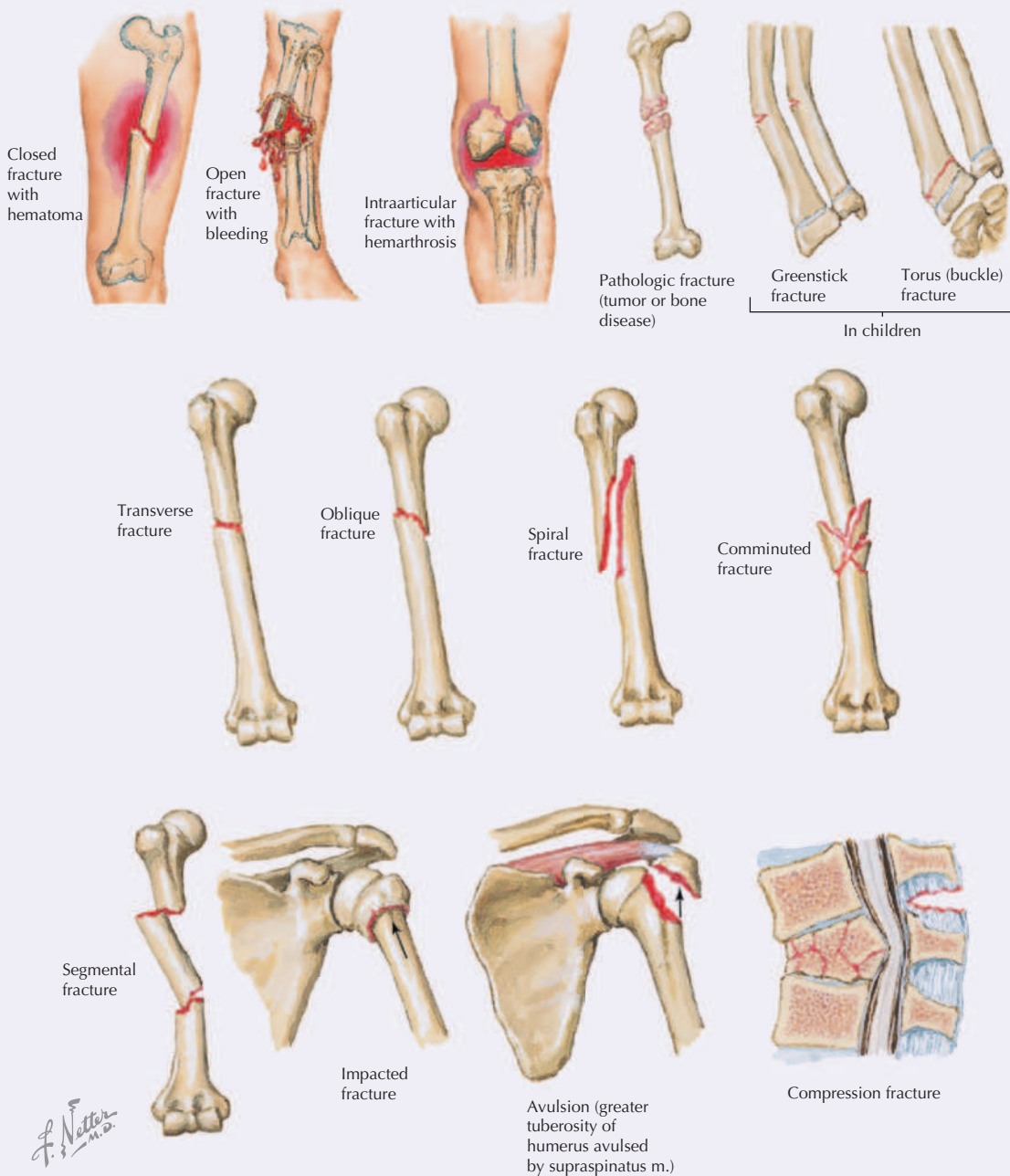
F. Plane

FIGURE 1.9 Types of Synovial Joints.

## Clinical Focus 1-4

## Fractures

Fractures are classified as either **closed** (the skin is intact) or **open** (the skin is perforated; often referred to as a *compound fracture*). Additionally, the fracture may be classified with respect to its anatomical appearance (e.g., transverse, spiral).

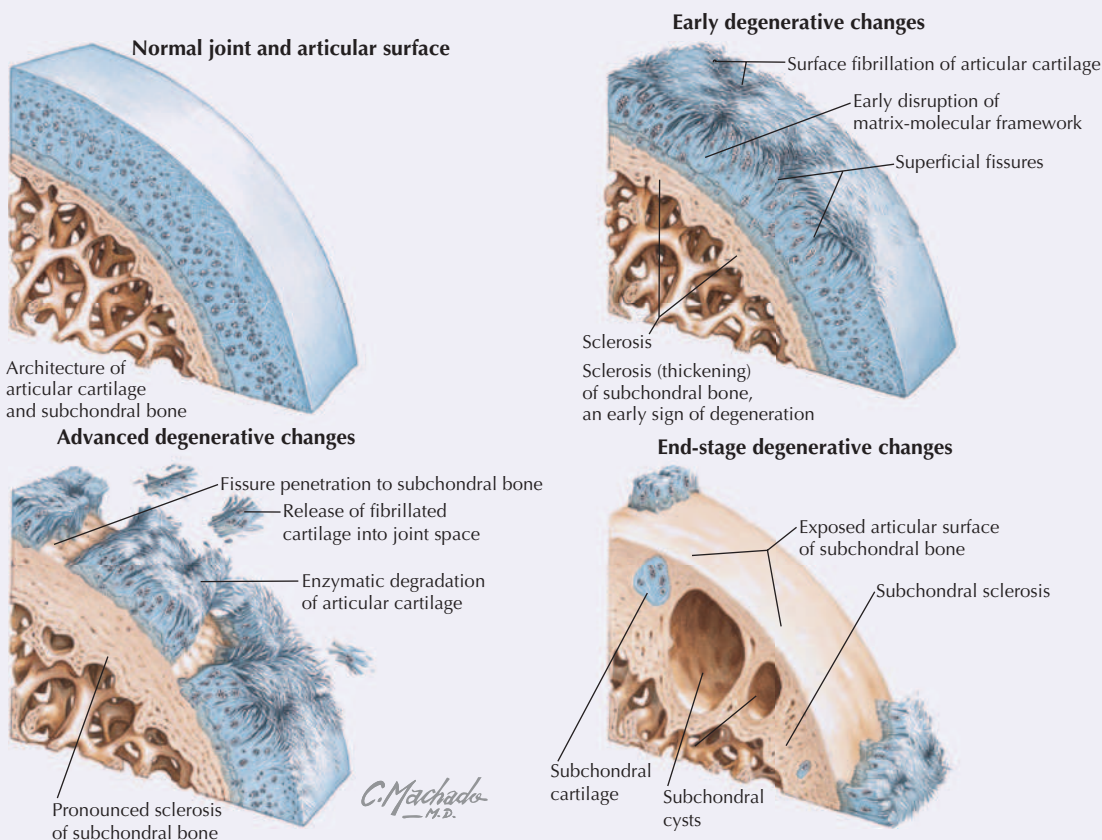




## Clinical Focus 1-5

## Degenerative Joint Disease

Degenerative joint disease is a catch-all term for osteoarthritis, degenerative arthritis, osteoarthrosis, or hypertrophic arthritis; it is characterized by progressive loss of articular cartilage and failure of repair. **Osteoarthritis** can affect any synovial joint but most often involves the foot, knee, hip, spine, and hand. As the articular cartilage is lost, the joint space (the space between the two articulating bones) becomes narrowed, and the exposed bony surfaces rub against each other, causing significant pain.



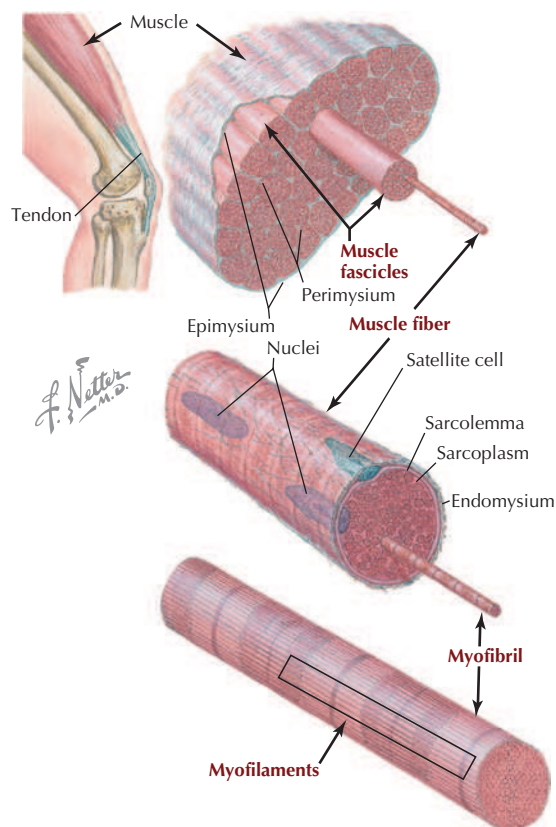
- **Circular:** muscle that forms sphincters that close off tubes or openings.
- **Fusiform:** muscle that has a wide center and tapered ends.
- **Pennate:** muscle that has a feathered appearance (unipennate, bipennate, or multipennate forms). Muscle contraction shortens the muscle. Generally, skeletal muscle contracts in one of three ways:
  - **Reflexive:** involuntary or through automatic contraction; seen in the diaphragm during respiration or in the reflex contraction elicited by tapping a muscle's tendon with a reflex hammer.
  - **Tonic:** maintains "muscle tone," a slight contraction that may not cause movement but allows

the muscle to maintain firmness necessary for stability of a joint and important in maintaining posture.

- **Phasic:** includes two types of contraction; isometric contraction, where no movement occurs but the muscle maintains tension to hold a position (stronger than tonic contraction), and isotonic contraction, where the muscle shortens to produce movement.

Muscle contraction that produces movements can act in several ways, depending on the conditions:

- **Agonist:** the main muscle responsible for a specific movement (the "prime mover").



**FIGURE 1.10** Structure of Skeletal Muscle.

- **Antagonist:** the muscle that opposes the action of the agonist; as an agonist muscle contracts, the antagonistic muscle relaxes.
- **Fixator:** one or more muscles that steady the proximal part of a limb when a more distal part is being moved.
- **Synergist:** a muscle that complements (works synergistically with) the contraction of the agonist, either by assisting with the movement generated by the agonist or by reducing unnecessary movements that would occur as the agonist contracts.

## 5. CARDIOVASCULAR SYSTEM

The cardiovascular system consists of (1) the **heart**, which pumps blood into the pulmonary circulation for gas exchange and into the systemic circulation to supply the body tissues; and (2) the **vessels** that carry the blood, including the arteries, arterioles, capillaries, venules, and veins. The blood passing through the cardiovascular system consists of the following formed elements (Fig. 1.11):

- Platelets.
- White blood cells (WBCs).
- Red blood cells (RBCs).
- Plasma.

**Blood** is a fluid connective tissue that circulates through the arteries to reach the body's tissues and then returns to the heart through the veins. When blood is "spun down" in a centrifuge tube, the RBCs precipitate to the bottom of the tube, where they account for about 45% of the blood volume. This is called the **hematocrit** and normally ranges from 40% to 50% in males and 35% to 45% in females. The next layer is a "**buffy coat**," which makes up slightly less than 1% of the blood volume and includes WBCs (leukocytes) and platelets. The remaining 55% of the blood volume is the **plasma** and includes water, plasma proteins, clotting factors, and various solutes (**serum** is plasma with the clotting factors removed). The functions of blood include:

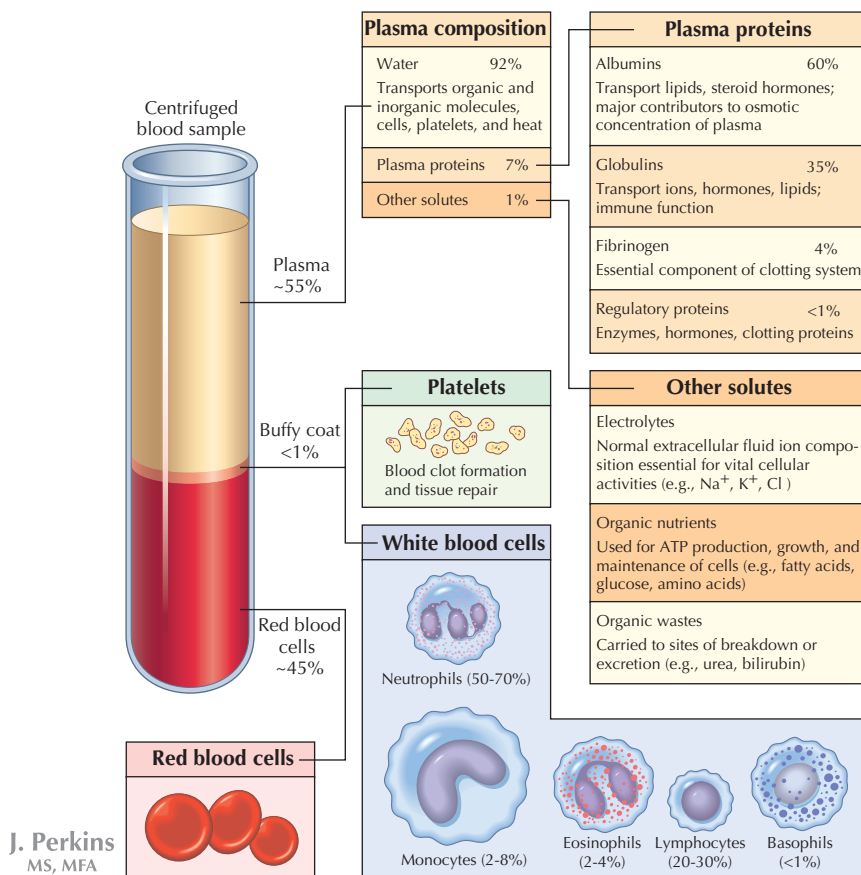
- Transport of dissolved gases, nutrients, metabolic waste products, and hormones to and from tissues.
- Prevention of fluid loss via clotting mechanisms.
- Immune defense.
- Regulation of pH and electrolyte balance.
- Thermoregulation through blood vessel constriction and dilation.

## Blood Vessels

Blood circulates through the blood vessels (Fig. 1.12). **Arteries** carry blood away from the heart, and **veins** carry blood back to the heart. Arteries generally have more smooth muscle in their walls than veins and are responsible for most of the vascular resistance, especially the small muscular arteries and arterioles. Alternatively, at any point in time, most of the blood resides in the veins (about 64%) and is returned to the right side of the heart; thus veins are the capacitance vessels, capable of holding most of the blood, and are far more variable and numerous than their corresponding arteries.

The major arteries are illustrated in Fig. 1.13. At certain points along the pathway of the systemic arterial circulation, large and medium-sized arteries lie near the body's surface and can be used to take a **pulse** by compressing the artery against a hard underlying structure (usually a bone). The most distal pulse from the heart is usually taken over the dorsalis pedis artery on the dorsum of the foot or by the posterior tibial artery pulse, at the medial aspect of the ankle.

**FIGURE 1.11**  
Composition of Blood.



The major veins are illustrated in Fig. 1.14. Veins are capacitance vessels because they are distensible and numerous and can serve as reservoirs for the blood. Because veins carry blood at low pressure and often against gravity, larger veins of the limbs and lower neck region have numerous valves that aid in venous return to the heart (several other veins throughout the body may also contain valves). Both the presence of valves and the contractions of adjacent skeletal muscles help to “pump” the venous blood against gravity and toward the heart. In most of the body, the veins occur as a superficial set of veins in the subcutaneous tissue that connects with a deeper set of veins that parallel the arteries. Types of veins include:

- **Venules:** these are very small veins that collect blood from the capillary beds.
- **Veins:** these are small, medium, and large veins that contain some smooth muscle in their walls, but not as much as their corresponding arteries.
- **Portal venous systems:** these are veins that transport blood between two capillary beds (e.g., the hepatic portal system draining the GI tract).

## Heart

The heart is a hollow muscular (cardiac muscle) organ that is divided into four chambers (Fig. 1.15):

- **Right atrium:** receives the blood from the systemic circulation via the superior and inferior venae cavae.
- **Right ventricle:** receives the blood from the right atrium and pumps it into the pulmonary circulation via the pulmonary trunk and pulmonary arteries.
- **Left atrium:** receives the blood from the lungs via pulmonary veins.
- **Left ventricle:** receives the blood from the left atrium and pumps it into the systemic circulation via the aorta.

The atria and ventricles are separated by atrio-ventricular valves (**tricuspid** on the right side and **mitral** on the left side) that prevent the blood from refluxing into the atria when the ventricles contract. Likewise, the two major outflow vessels, the pulmonary trunk from the right ventricle and the ascending aorta from the left ventricle, possess the