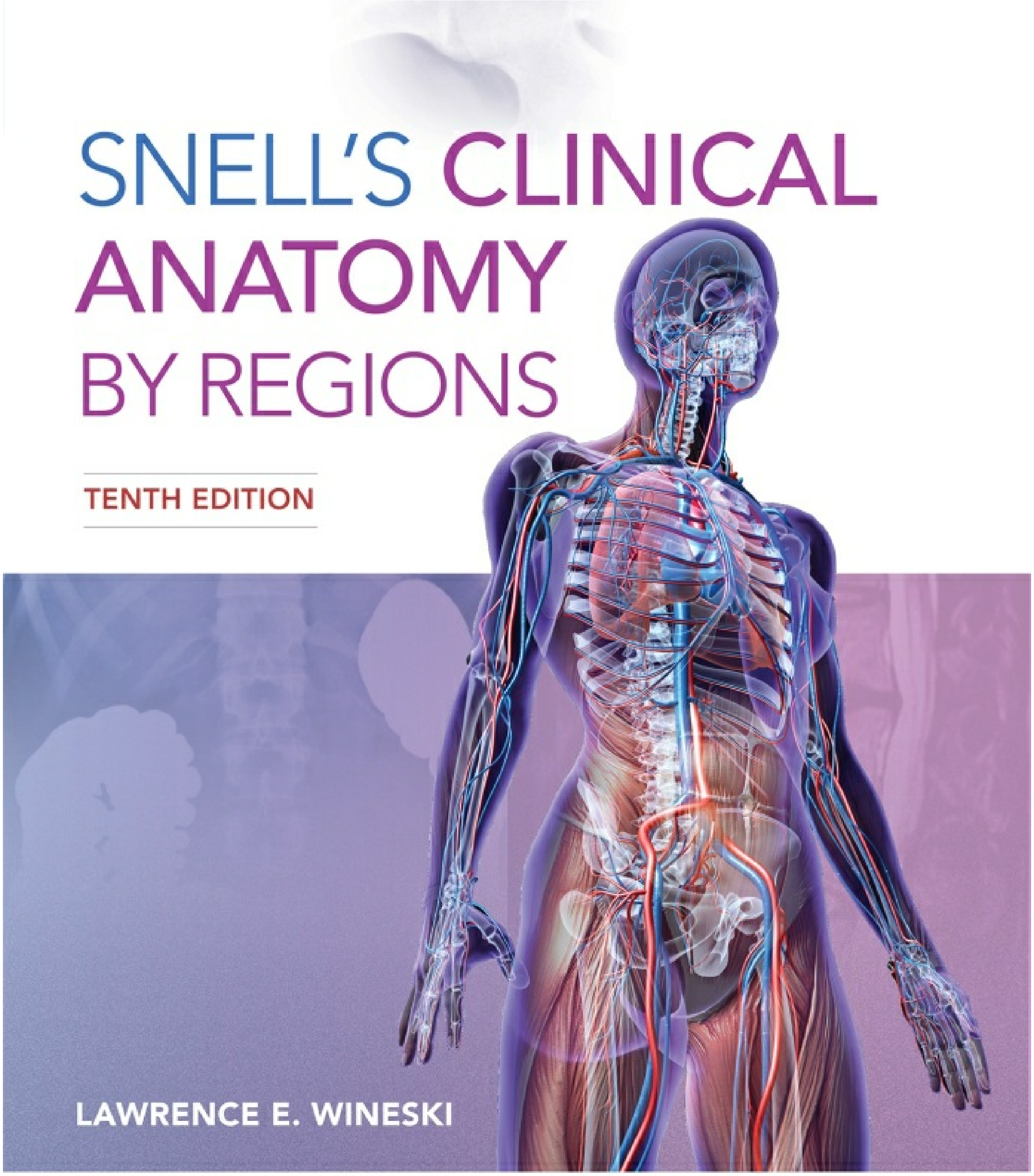
SNELL'S CLINICAL ANATOMY BY REGIONS

TENTH EDITION



LAWRENCE E. WINESKI

Wolters Kluwer

TENTH EDITION

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To Karen

For your understanding, extraordinary patience, and unconditional support.

To Anatomical Donors

With the deepest appreciation to our essential teachers for your remarkable gifts.

In Memoriam

Richard S. Snell, MRCS, LRCP, MB, MD, PhD

1925–2015

Clinical Anatomy by Regions

Clinical Anatomy by Systems

Clinical Neuroanatomy

Clinical Embryology for Medical Students

Preface

It is my great honor to continue the work of Dr. Richard S. Snell in this new edition of his text. I have always admired this book, having used earlier editions as a student and as an instructor, and I appreciated the opportunity to contribute in a small way to the ninth edition. I hope this 10th edition meets Dr. Snell's high standards and will continue his legacy of scholarship and clinical relevance in teaching.

This book provides health science students a review of basic anatomy in a strong clinical context. It includes the following changes:

1. The order of chapters is modified and now follows a standard medical school dissection sequence.
2. The progression of topics in each chapter is revised, beginning with foundational material and building to more complex relations.
3. Each chapter begins with a list of Learning Objectives and concludes with a set of Key Concepts. The Learning Objectives introduce the primary topics in the chapter, i.e., the anatomy most important to learn and understand. The Key Concepts summarize the critical points of anatomy covered in that chapter.
4. The text is largely reworked throughout and includes new material and updated terminology. New tables provide succinct summaries of information.
5. New and/or updated illustrations better demonstrate points of anatomy, especially surface anatomy.

Each chapter follows a similar format. This makes it easier to locate material and facilitates moving from one part of the book to another. Each chapter centers on the following categories:

1. **Clinical Example:** A short case report that dramatizes the relevance of anatomy in medicine introduces the chapter.
2. **Learning Objectives:** As described above, this section focuses the student on the primary anatomy that is most important to learn and

understand.

3. **Basic Clinical Anatomy:** The bulk of the chapter provides basic information on gross anatomic structures of clinical importance. Clinical and Embryology Notes supplement the core text, indicate clinical applications, and explain adult morphology and major congenital malformations.
4. **Radiographic Anatomy:** Each chapter includes numerous standard medical images (e.g., radiographs, CT scans, MRI studies, and sonograms) to demonstrate normal anatomy in the manner most often observed by clinicians. Labeled photographs of cross-sectional anatomy stimulate students to think in terms of three-dimensional anatomy, which is so important in the interpretation of imaging studies.
5. **Surface Anatomy:** This section outlines surface landmarks and palpation points of important anatomic structures fundamental to a thorough physical examination.
6. **Key Concepts:** This closing part of the chapter summarizes the major points of anatomy discussed in the chapter to reinforce the topics covered.
7. **Review Questions:** A collection of review questions is available online at www.thePoint.lww.com. The purpose of these questions is threefold: to focus attention on areas of importance, to enable students to assess their areas of strength and weakness, and to provide a form of self-evaluation for questions asked under examination conditions. The questions are in National Board format and center around a clinical problem that requires an anatomic answer.

As with previous editions, the book is heavily illustrated. Most figures have been kept simple in order to convey the fundamental floor plans that underlie the organization of body regions. Illustrations summarizing the nerve and blood supply of regions have been retained, as have overviews of the distribution of cranial nerves.

L.E.W.

Acknowledgments

I thank my teachers and colleagues who have contributed directly and indirectly to the development and completion of this book, whether they are aware of their contributions or not. I very much appreciate the time, input, mentoring, and general support and encouragement of the following individuals.

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Finally, I wish to express my deep gratitude to the staff of Wolters Kluwer for their great help and support in the preparation of this new edition. My special thanks to Crystal Taylor (Senior Acquisitions Editor) for the opportunity of authorship and the freedom to revise as I felt was appropriate, to Kelly Horvath (freelance Development Editor) for exceptional editing, and to Tim Rinehart (Editorial Coordinator) and Andrea Vosburgh (Development Editor) for steering this project to completion. I also thank Jen Clements for revisions to the artwork.

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1 Introduction

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A 65-year-old man was admitted to the emergency department complaining of the sudden onset of a severe crushing pain over the front of his chest spreading down his left arm and up into his neck and jaw. On questioning, he said that he had had several attacks of pain before and that they had always occurred when he was climbing stairs or digging in the garden. Previously, he found that the discomfort disappeared with rest after about 5 minutes. However, on this occasion, the pain was more severe and had occurred spontaneously while he was sitting in a chair. Additionally, the pain had not abated.

The initial episodes of pain were angina, a form of cardiac pain that occurs on exertion and disappears on rest. Insufficient blood flow to the cardiac muscle from narrowing of the coronary arteries causes the angina. The patient has now experienced myocardial infarction, in which the coronary blood flow is suddenly reduced or stopped, and the cardiac muscle degenerates or dies. Because myocardial infarction is the major cause of death in industrialized nations, knowledge of the blood supply to the heart and the arrangement of the coronary arteries is of paramount importance in making the diagnosis and treating this patient.

CHAPTER OUTLINE

General Orientation

Anatomic Terminology

Basic Anatomy

Skin
Fascia
Bone
Cartilage
Joints
Ligaments
Bursae and Synovial Sheaths
Muscle
Nervous System
Blood Vessels
Lymphatic System
Mucous and Serous Membranes
Effects of Sex, Age, and Race on Structure

Medical Imaging

Conventional Radiography (X-Rays)
Computed Tomography
Magnetic Resonance Imaging
Ultrasonography
Nuclear Medicine Imaging

LEARNING OBJECTIVES

The purpose of this chapter is to introduce the primary terminology used in describing the position and movement of the human body, some of the basic structures that compose the body (e.g., skin, fascia, muscles, bones), and the principles of medical imaging.

1. Define the anatomical position, the major planes of section, and the primary terms of direction used in anatomic descriptions.
2. Define the primary movements utilized in anatomic descriptions.
3. Identify the components of the skin and its appendages.
4. Identify the types and distributions of the fasciae of the body.

5. Identify the main structural features of bone. Describe the classification systems by which bones are organized. Describe the developmental processes by which bones are formed.
6. Identify the major forms of cartilage and the locations where each form is generally found.
7. Identify the major categories of joints and the structures that characterize each type of joint. Provide examples of each type of joint. Identify the structures responsible for maintaining the stability of joints.
8. Define and differentiate a bursa versus a synovial sheath.
9. Identify the three types of muscle and describe the basic structure of each type. Define the terms used to describe the actions of skeletal muscles. Describe the pattern of innervation of skeletal muscle. Describe the parameters used in naming skeletal muscles.
10. Identify the major subdivisions of the nervous system. Describe the components of a typical spinal nerve. Trace the distribution of a typical spinal nerve.
11. Describe the general organization of the autonomic nervous system. Differentiate between sympathetic and parasympathetic components and pathways, and preganglionic and postganglionic elements.
12. Define a dermatome. Contrast this with the cutaneous territory of a peripheral nerve.
13. Identify the main types of blood vessels and their functional roles in transporting blood.
14. Identify the components of the lymphatic system. Trace the major routes of lymph drainage in the body.
15. Identify and differentiate mucous and serous membranes.
16. Describe the general sex-, age-, and race-related differences in anatomic form.
17. Describe the major steps in development of the embryo. Differentiate ectoderm, endoderm, and mesoderm, and identify the main derivatives of each.
18. Identify the primary forms of medical imaging and the characteristics of images formed by each technique.

GENERAL ORIENTATION

Anatomy is the science of the structure and function of the body. **Clinical anatomy** is the study of the macroscopic structure and function of the body as it relates to the practice of medicine and other health sciences.

Anatomic Terminology

Understanding the terms used for describing the structures in different regions of the body is essential for students. Without these terms, describing the composition of the body in a meaningful way is impossible. Clinicians also need these terms so that anatomic abnormalities found on clinical examination of a patient can be accurately recorded. The accurate use of anatomic terms by medical personnel enables them to communicate with their colleagues both nationally and internationally.

With the aid of a medical dictionary, you will find that understanding anatomic terminology rather than memorizing rote nomenclature greatly assists you in the learning process. Without anatomic terms, abnormal functions of joints, the actions of muscles, the alteration of position of organs, or the exact location of swellings or tumors cannot be accurately discussed or recorded.

Terms Related to Position

Spatial orientation and organization are crucial concepts in anatomy, and understanding the standard geometric references that allow uniform, clear descriptions of locations, relations, and movements of structures is important. All descriptions of the human body are based on a conventional reference posture termed the **anatomical position**. In this, a person is standing erect and facing forward, the upper limbs are by the sides, the palms of the hands are directed forward, the lower limbs are together, the soles of the feet are on the ground, and the toes are pointing forward (Fig. 1.1). All directional and movement descriptions are based on this body position. Four geometric planes, three of which are at right angles to the others, are applied to the body in the anatomical position.

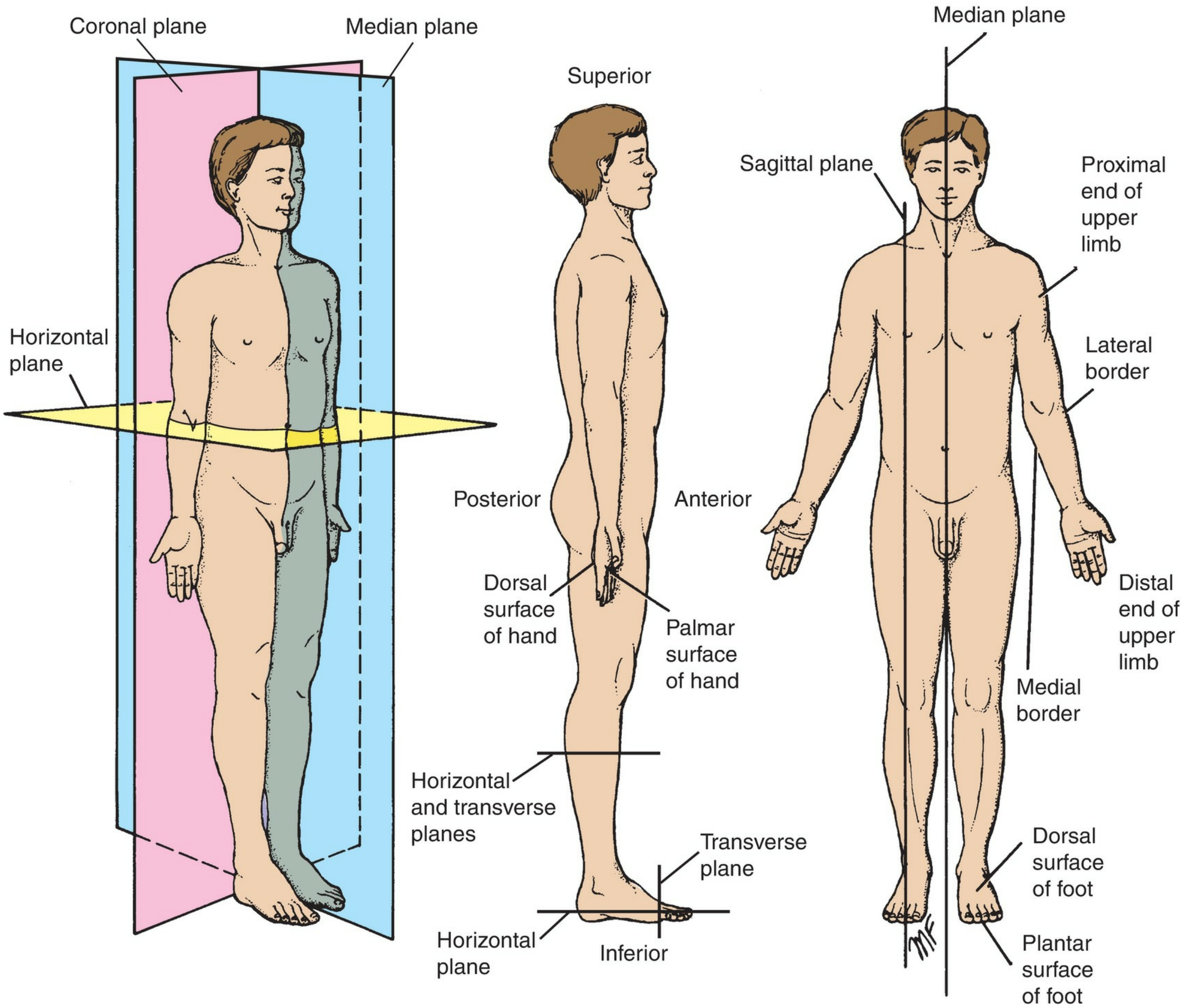


Figure 1.1 Anatomic terms used in relation to position. Note that the subjects are standing in the anatomical position. **A.** Illustration of the median, coronal, and horizontal planes. Note that these planes are aligned at 90° to one another. **B.** Lateral view, demonstrating anatomic planes and directional terms. Note that horizontal and transverse planes may or may not be equivalent. **C.** Anterior view, showing planes of section and anatomic directions.

- The **median plane** is a vertical plane passing through the center of the body, dividing it into equal right and left halves (see Fig. 1.1A).
- A **sagittal plane** is any plane parallel to the median plane that divides

the body into unequal right and left portions.

- The **coronal** (**frontal**) **plane** is a vertical plane situated at a right angle to the median plane. The coronal plane divides the body into anterior (front) and posterior (back) portions.
- The **horizontal plane** lies at right angles to both the median and the coronal planes. A horizontal plane divides the body into upper and lower parts.
- A **transverse plane** lies perpendicular to the long axis of a given structure and divides that structure in a cross-sectional orientation. The terms “transverse plane” and “horizontal plane” are often used interchangeably. However, they are not necessarily equivalent. Consider the difference between horizontal and transverse planes in the leg versus the foot and in the abdomen versus the gut tube. Understand that these planes in such regions produce very different orientations of the structures in question.

The terms **anterior** (**ventral**) and **posterior** (**dorsal**) are used to indicate the front and back of the body, respectively (see Fig. 1.1B). To describe the relationship of two structures, one is said to be anterior or posterior to the other, insofar as it is comparatively closer to the anterior or posterior body surface (e.g., the nose is on the anterior side of the head, whereas the buttocks are on the posterior side of the body). In describing the hand, the terms **palmar** and **dorsal** surfaces are used in place of anterior and posterior, respectively. In describing the foot, the term **plantar** surface refers to the sole of the foot and **dorsal** surface indicates the upper (top) surface (see Fig. 1.1C).

A structure situated nearer to the median plane of the body than another is said to be **medial** to the other. Similarly, a structure that lies farther away from the median plane than another is said to be **lateral** to the other (e.g., in the head, the eyes are lateral to the nose, and the nose is medial to the eyes).

The terms **superior** (**cranial**; **cephalic**) and **inferior** (**caudal**) denote levels relatively high or low with reference to the upper and lower ends of the body (e.g., the head is at the superior end of the body, whereas the feet are at the inferior end of the body).

The terms **proximal** and **distal** describe positions relative to the core, root, or attached end of a reference point. Proximal is closer to the core and distal is further away from the core (e.g., in the upper limb, the shoulder is proximal to the elbow, and the hand is distal to the elbow).

The terms **superficial** and **deep** denote positions relative to the surface of the body or a given structure. Superficial is closer to the surface, whereas deep is farther away from the surface (e.g., the skin is superficial to the ribs, but the heart is deep to the ribs).

The terms **internal** and **external** are used to describe locations relative to the center of a structure or space. Internal is inside the structure and external is outside the structure (e.g., the thoracic cavity is an internal space in the trunk of the body, whereas the skin is the external layer of the trunk).

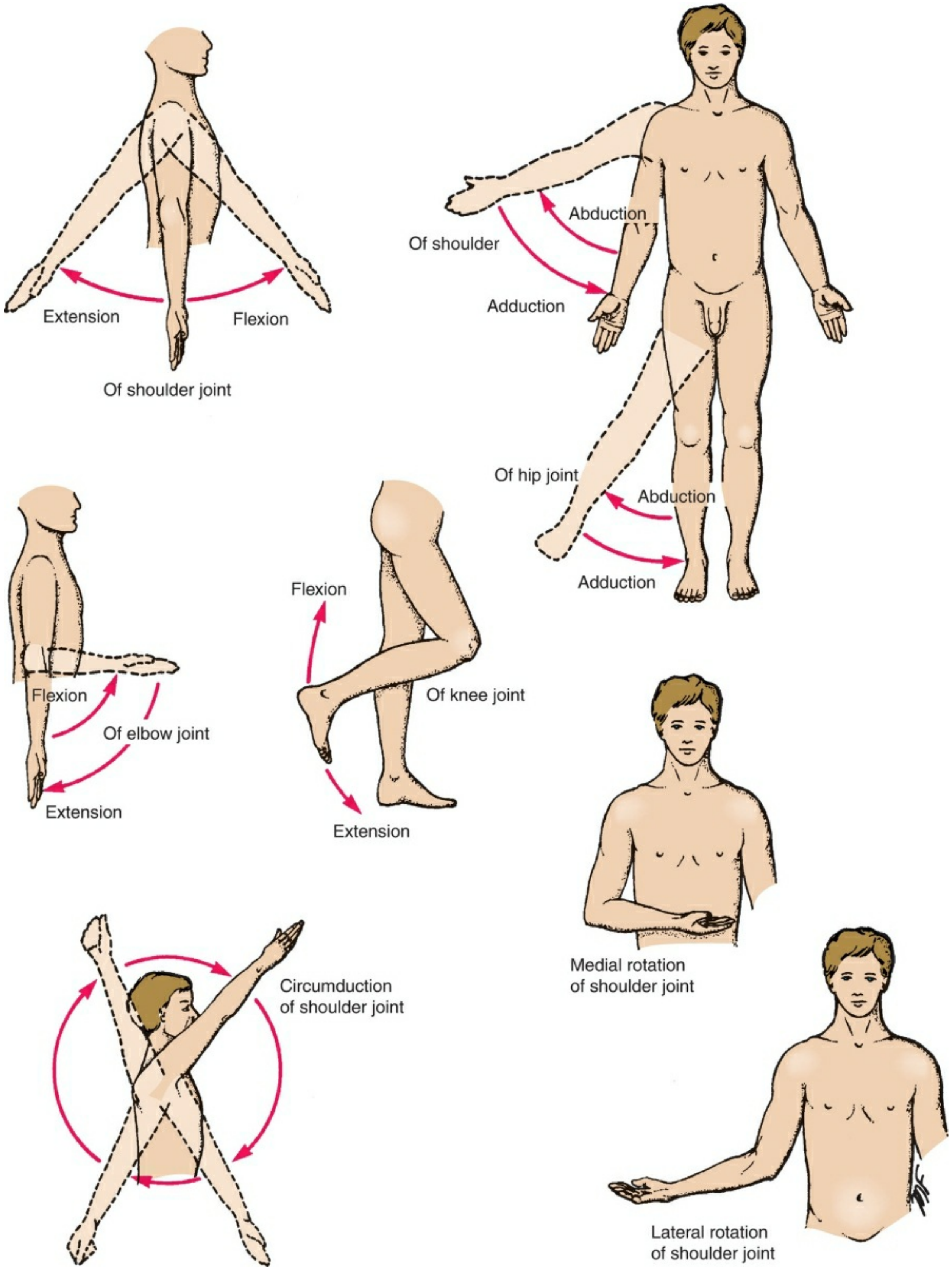
Ipsilateral and **contralateral** are terms referring to positions relative to a reference side of the body. Ipsilateral is on the same side as the reference point, and contralateral is on the opposite side from the reference point (e.g., the right eye is ipsilateral to the right ear; however, the right eye is contralateral to the left ear).

The **supine** position of the body is lying on the back. The **prone** position is laying face downward.

The terms **afferent** and **efferent** refer to the direction of flow relative to a reference point. Afferent is flow toward the reference point, whereas efferent is flow away from the reference (e.g., venous blood flow is afferent to the heart, and arterial blood flow is efferent to the heart).

Terms Related to Movement

In the musculoskeletal system, movement takes place at joints (Fig. 1.2). A joint is a site where two or more bones articulate, or come together. Some joints have no movement (e.g., sutures of the skull), some have only slight movement (e.g., superior tibiofibular joint), and some are freely movable (e.g., shoulder joint).



Extension
Flexion
Of shoulder joint
Abduction
Of shoulder
Adduction
Of hip joint
Abduction
Adduction
Flexion
Of elbow joint
Extension
Flexion
Of knee joint
Extension
Medial rotation
of shoulder joint
Circumduction
of shoulder joint
Lateral rotation
of shoulder joint

Figure 1.2 Some anatomic terms used in relation to movement. Note the difference between flexion of the elbow versus the knee.

Flexion is the movement in which a joint angle is decreased (closed) during motion occurring in a sagittal plane. **Extension** is the opposite movement in which the joint angle is increased (opened; straightened) in a sagittal plane (e.g., flexion of the elbow approximates the anterior surface of the forearm to the anterior surface of the arm; extension of the elbow is the reverse motion). Flexion usually is an anterior movement, but it is occasionally directed posteriorly, as in the case of the knee joint. Also, flexion typically implies a relatively more powerful, antigravity movement directed toward the embryonic ventral aspect of the body.

Dorsiflexion and **plantar flexion** are special terms used to simplify descriptions of the movements of the foot. Dorsiflexion (the equivalent to extension) refers to lifting the top of the foot superiorly, toward the shin. Plantar flexion (the equivalent to flexion) refers to moving the sole of the foot inferiorly, as in standing on the toes. These points will become clearer in the following chapters on the back and limbs. “Lateral flexion” is an imprecise term sometimes used in clinical settings that refers to a sideways bending movement of the trunk in the coronal plane (Fig. 1.3). However, “abduction” is the more correct term and the one that should be used.

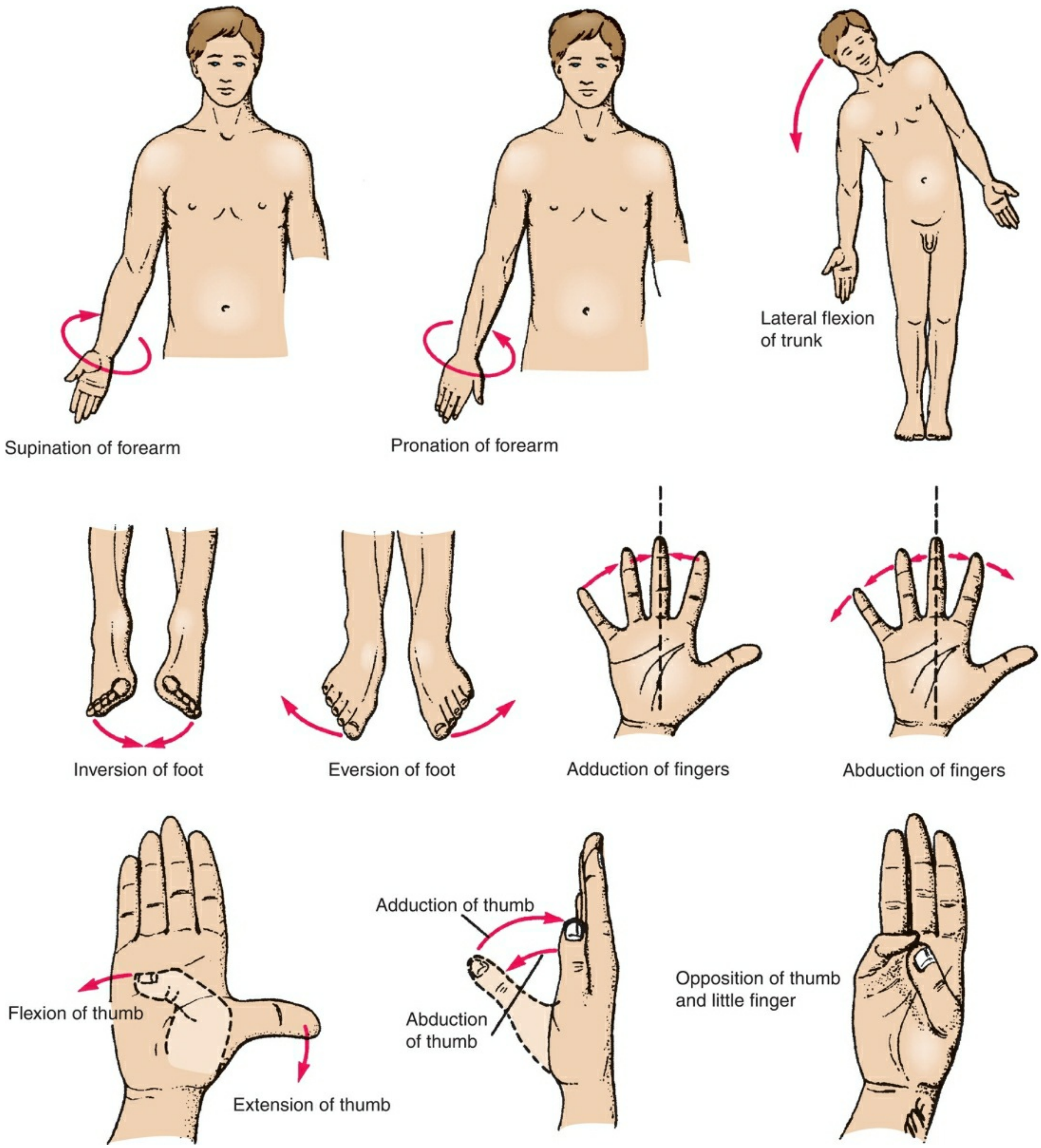


Figure 1.3 Additional anatomic terms used in relation to movement.

Abduction is movement away from the midline of the body in the coronal plane. **Adduction** is movement toward the midline of the body in the coronal plane (see Fig. 1.2). In the fingers and toes, abduction is applied to the spreading apart of the digits, and adduction is applied to the drawing together of these structures. The movements of the thumb, which are more complicated, are described in Chapter 3.

Inversion and **eversion** are special terms used to describe certain movements of the foot (see Fig. 1.3). Inversion is turning the sole of the foot so that the sole faces in a medial direction, toward the midline, and eversion is the opposite movement of the foot so that the sole faces in a lateral direction.

Rotation is the term applied to the movement of a part of the body around its long axis, with little to no movement through space. **Medial** (**internal**) **rotation** is the movement that results in the anterior surface of the part facing medially, and **lateral** (**external**) **rotation** is the movement that results in the anterior surface of the part facing laterally (see Fig. 1.2).

Circumduction is a complex sequence of movements combining flexion, extension, abduction, adduction, and rotation. The overall movement results in transcribing a cone through space, with the apex of the cone being the more proximal articular cavity of a joint and the base of the cone being the more distal end of a bone or limb segment. Circumduction is most easily envisioned at the shoulder.

Pronation and **supination** are special movements of the forearm in which the radius moves around the ulna (see Fig. 1.3). Pronation is turning the forearm medially in such a manner that the palm of the hand faces posteriorly, and supination is turning the forearm laterally from the pronated position so that the palm of the hand comes to face anteriorly. These movements are composed of both rotation (at the proximal end of the radius) and circumduction (at the distal end of the radius). Some references describe pronation/supination of the ankle and foot. Clinically defined, pronation and supination of the foot are complex movements of the ankle region that include plantar flexion, dorsiflexion, eversion, and inversion. Pronation and supination of the forearm and ankle are very different movements that should not be confused with one another.

Protraction is the term used to describe moving a body part forward. **Retraction** is to move a part backward. Examples of these movements are the forward and backward movement of the jaw at the temporomandibular joints (as when jutting the chin forward) and the forward/backward motion of the scapula across the rib cage (as when reaching forward).

Eponyms

International commissions reflecting the views of multiple professional anatomic societies determine official anatomic terminology. One of the guidelines used in producing this “Terminologica Anatomica” is that eponyms shall not be used. In a scientific context, an eponym is an identifying term formed from the name of a person (e.g., ampere, volt, foramen of Winslow, circle of Willis). However, eponyms are used randomly, conveying no information about the structure in question, and they are often historically misleading in that the person honored by the naming did not necessarily contribute the first description of the structure (e.g., Francois Poupart was not the first to describe the inguinal ligament). Unfortunately, eponyms remain in wide use in the biomedical sciences, especially in clinical settings. Newer generations of anatomists and other health science professionals should adopt current official terminology and avoid eponyms whenever possible to reverse this trend.

BASIC ANATOMY

Basic anatomy is the study of the minimal amount of anatomy consistent with the understanding of the overall structure and function of the body.

Skin

The skin is divided into two parts: the superficial part, the **epidermis**, and the deep part, the **dermis** (Fig. 1.4). The epidermis is a stratified epithelium with cells that flatten as they mature and rise to the surface. On the palms of the hands and the soles of the feet, the epidermis is extremely thick to withstand the wear and tear that occurs in these regions. In other areas of the body, such as on the anterior surface of the arm and forearm, it is thin. The dermis is composed of dense connective tissue containing many blood vessels, lymphatic vessels, and nerves. It shows considerable variation in thickness in different parts of the body, tending to be thinner on the anterior than on the posterior surface. It is thinner in women than in men. The dermis of the skin is connected to the underlying deep fascia or bones by the **superficial fascia**, otherwise known as *subcutaneous tissue*.

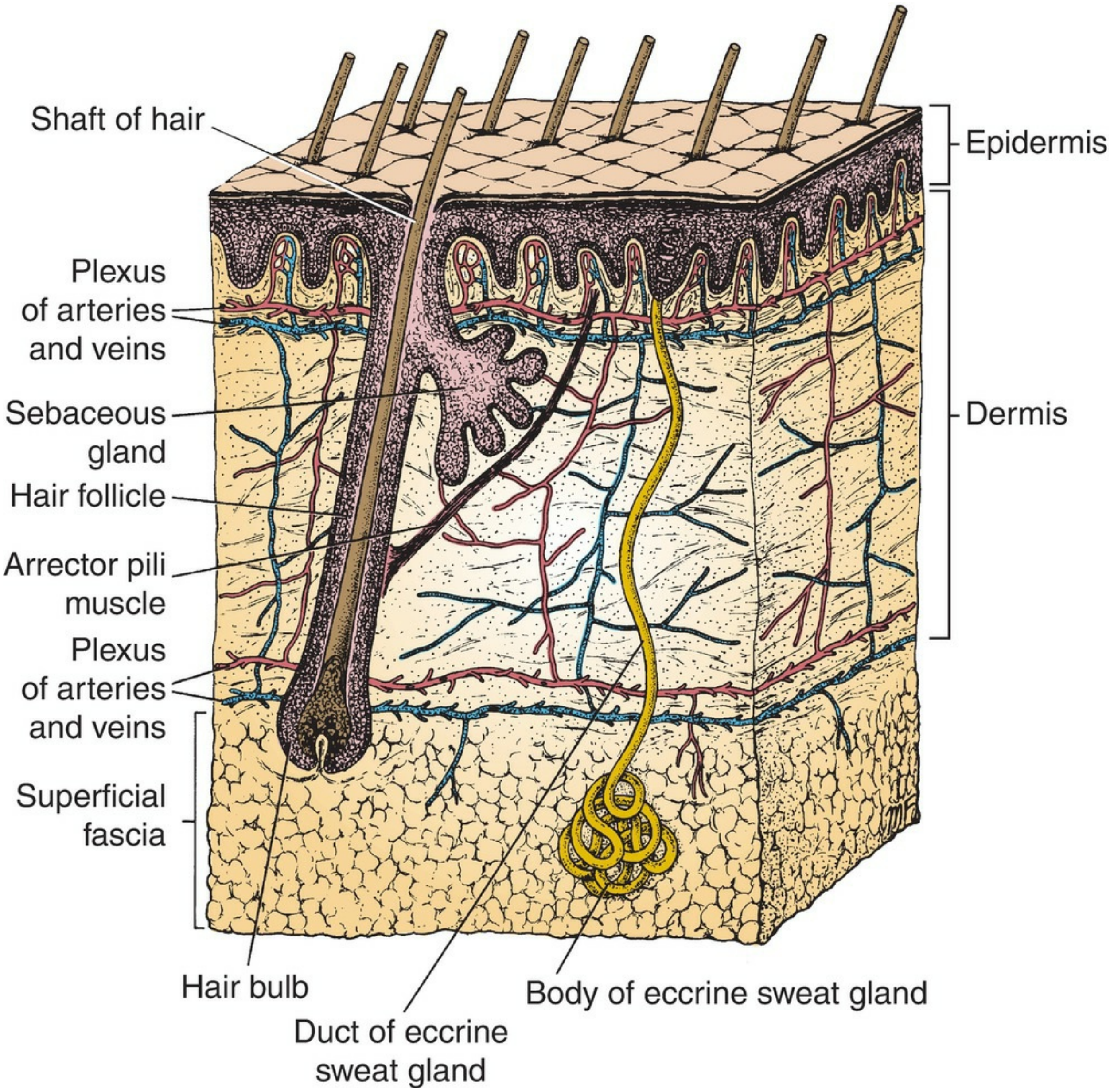
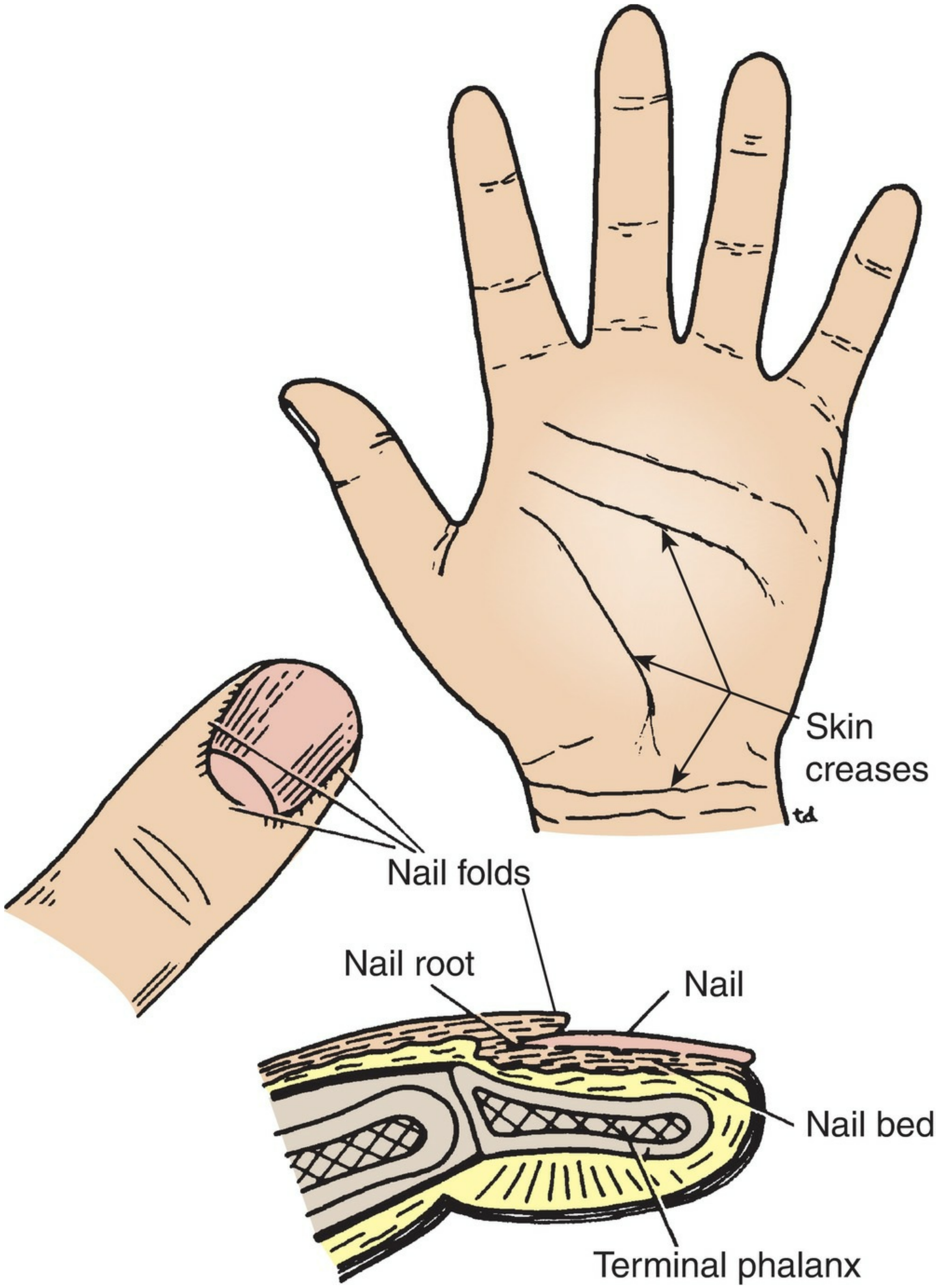


Figure 1.4 General structure of the skin and its relationship to the superficial fascia. Note that hair follicles extend into the deeper part of the dermis or into the superficial fascia, whereas sweat glands extend deeply into the superficial fascia.

The skin over joints always folds in the same place, the **skin creases** (Fig. 1.5). At these sites, the skin is thinner than elsewhere and is firmly tethered to underlying structures by strong bands of fibrous tissue.



Skin
creases
td
Nail folds
Nail root
Nail
Nail bed
Terminal phalanx

Figure 1.5 The various skin creases on the palmar surface of the hand and the anterior surface of the wrist joint. The relationship of the nail to other structures of the finger is also shown.

The appendages of the skin are the nails, hair follicles, sebaceous glands, and sweat glands.

The **nails** are keratinized plates on the dorsal surfaces of the tips of the fingers and toes. The proximal edge of the plate is the **root** of the nail. With the exception of the distal edge of the plate, the nail is surrounded and overlapped by folds of skin known as **nail folds**. The surface of skin covered by the nail is the **nail bed**.

Hairs grow out of **follicles**, which are invaginations of the epidermis into the dermis (see Fig. 1.4). The follicles lie obliquely to the skin surface, and their expanded extremities, called **hair bulbs**, penetrate to the deeper part of the dermis. Each hair bulb is concave at its end, and the concavity is occupied by vascular connective tissue called the **hair papilla**. A band of smooth muscle, the **arrector pili**, connects the undersurface of the follicle to the superficial part of the dermis. The muscle is innervated by sympathetic nerve fibers, and its contraction causes the hair to move into a more vertical position; it also compresses the sebaceous gland and causes it to extrude some of its secretion. The pull of the muscle also causes dimpling of the skin surface, so-called **gooseflesh** (or “goose pimples”). Hairs are distributed in various numbers over the whole surface of the body, except on the lips, the palms of the hands, the sides of the fingers, the glans penis and clitoris, the labia minora and the internal surface of the labia majora, and the soles and sides of the feet and the sides of the toes.

Sebaceous glands secrete **sebum** onto the **shafts of the hairs** as they pass up through the necks of the follicles. They are situated on the sloping undersurface of the follicles and lie within the dermis. Sebum is an oily material that helps preserve the flexibility of the emerging hair. It also oils the surface epidermis around the mouth of the follicle.

Sweat glands are long, spiral, tubular glands distributed over the surface of the body, except on the red margins of the lips, the nail beds, and the glans penis and clitoris. These glands extend through the full thickness of the dermis, and their extremities may lie in the superficial fascia. The sweat glands are therefore the most deeply penetrating structures of all the epidermal appendages.

Clinical Notes

Skin Infections

The nail folds, hair follicles, and sebaceous glands are common sites for pathogenic organisms such as *Staphylococcus aureus* to enter into the underlying tissues. Infection occurring between the nail and the nail fold is called a **paronychia**. Infection of the hair follicle and sebaceous gland is responsible for the common **boil**. A **carbuncle** is a staphylococcal infection of the superficial fascia that commonly occurs in the nape of the neck and usually starts as an infection of a hair follicle or a group of hair follicles.

Sebaceous Cyst

A **sebaceous cyst** is caused by obstruction of the mouth of a sebaceous duct and may be caused by damage from a comb or by infection. It occurs most frequently on the scalp.

Shock

A patient who is in a state of **shock** is pale and has gooseflesh as a result of overactivity of the sympathetic system, which causes vasoconstriction of the dermal arterioles and contraction of the arrector pili muscles.

Skin Burns

The depth of a **burn** determines the method and rate of healing. A partial-thickness burn heals from the cells of the hair follicles, sebaceous glands, and sweat glands as well as from the cells at the edge of the burn. A burn that extends deeper than the sweat glands heals slowly and from the edges only. The fibrous tissue at the margins of the burn causes considerable contracture of the wound. A deep burn often is grafted in order to speed up healing and reduce the incidence of contracture.

Skin Grafting

The two main types of skin grafts are split-thickness and full-thickness grafts. In a **split-thickness graft**, the greater part of the epidermis, including the tips of the dermal papillae, is removed from the donor site and placed on the recipient site. This leaves the epidermal cells on the sides of the dermal papillae and the cells of the hair follicles and sweat glands at the donor site for repair purposes.

A **full-thickness graft** includes both the epidermis and the dermis and requires rapid establishment of a new circulation within it at the recipient site to survive. The donor site is usually covered with a split-thickness graft. In certain circumstances, the full-thickness graft is made in the form of a pedicle graft, in which a flap of full-thickness skin is turned and stitched in position at the recipient site, leaving the base of the flap with its blood supply intact at the donor site. Later, when the new blood supply to the graft has been established, the base of the graft is cut across.

Fascia

Fascia is the connective tissue that encloses the body deep to the skin and also envelops and separates individual muscles and groups of muscles as well as deeper organs. Think of fascia as the connective tissue sheaths that hold the structures of the body together in organized arrangements. The fasciae of the body can be divided into two types, superficial and deep.

The **superficial fascia**, or **subcutaneous tissue**, is a mixture of loose areolar and adipose tissue that unites the dermis of the skin to the underlying deep fascia (Fig. 1.6). In the scalp, the back of the neck, the palms of the hands, and the soles of the feet, it contains numerous bundles of collagen fibers that hold the skin firmly to the deeper structures. In the eyelids, auricle of the ear, penis and scrotum, and clitoris, it is devoid of adipose tissue.

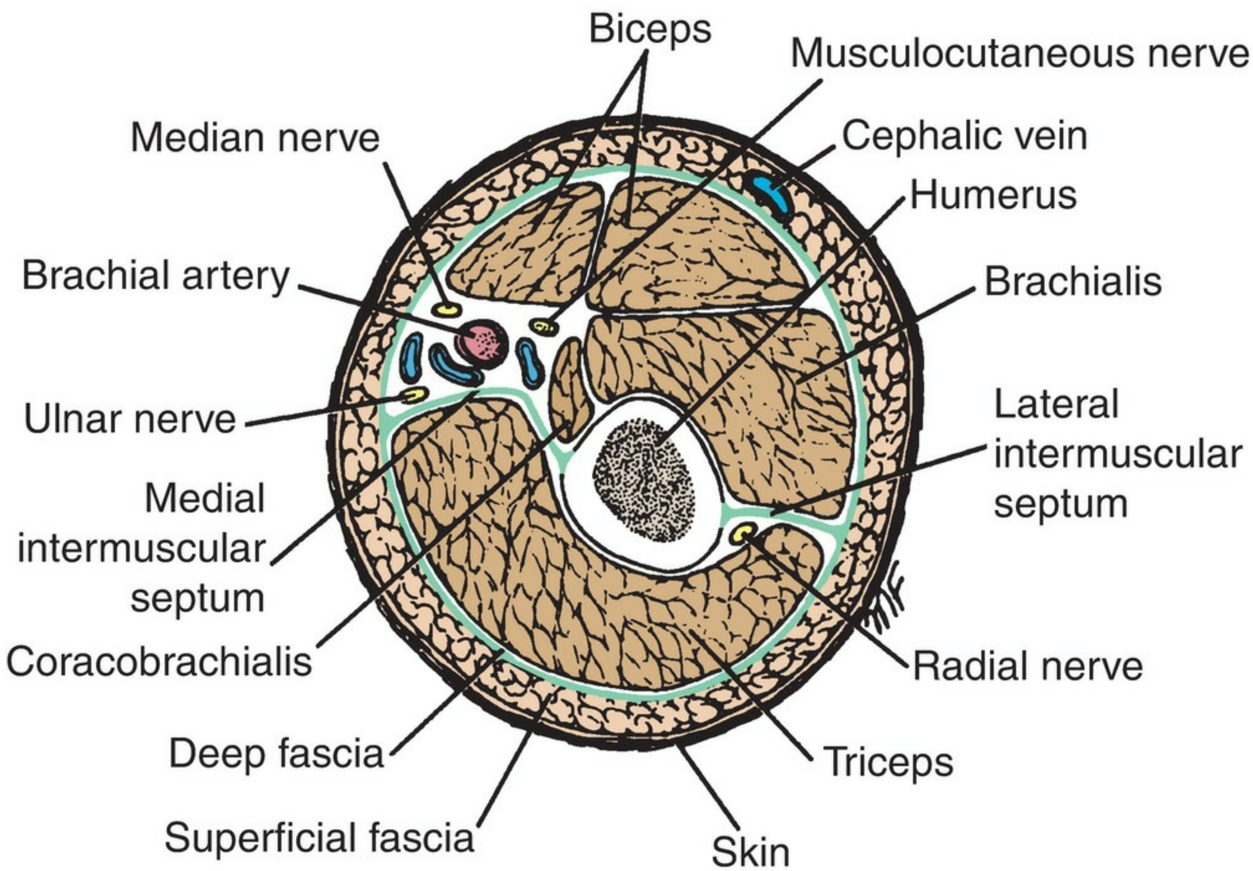


Figure 1.6 Section through the middle of the right arm showing the arrangement of the superficial and deep fascia. Note how deep extensions of the deep fascia extend between groups of muscles and form intermuscular septa, which divide the arm into fascial compartments.

The **deep fascia** (muscular fascia; visceral fascia) is a membranous layer of connective tissue that invests the muscles and other deep structures. In the neck, it forms well-defined layers that may play an important role in determining the path taken by pathogenic organisms during the spread of infection. In the thorax and abdomen, it is merely a thin film of areolar tissue covering the muscles and aponeuroses. In the limbs, it forms a definite sheath around the muscles and other structures, holding them in place. Fibrous septa extend from the deep surface of the membrane between the groups of muscles and, in many places, divide the interior of the limbs into compartments. In the region of joints, the deep fascia may be considerably thickened to form restraining bands called **retinacula** (Fig. 1.7). Their function is to hold underlying tendons in position or to serve as pulleys around which the tendons can move.

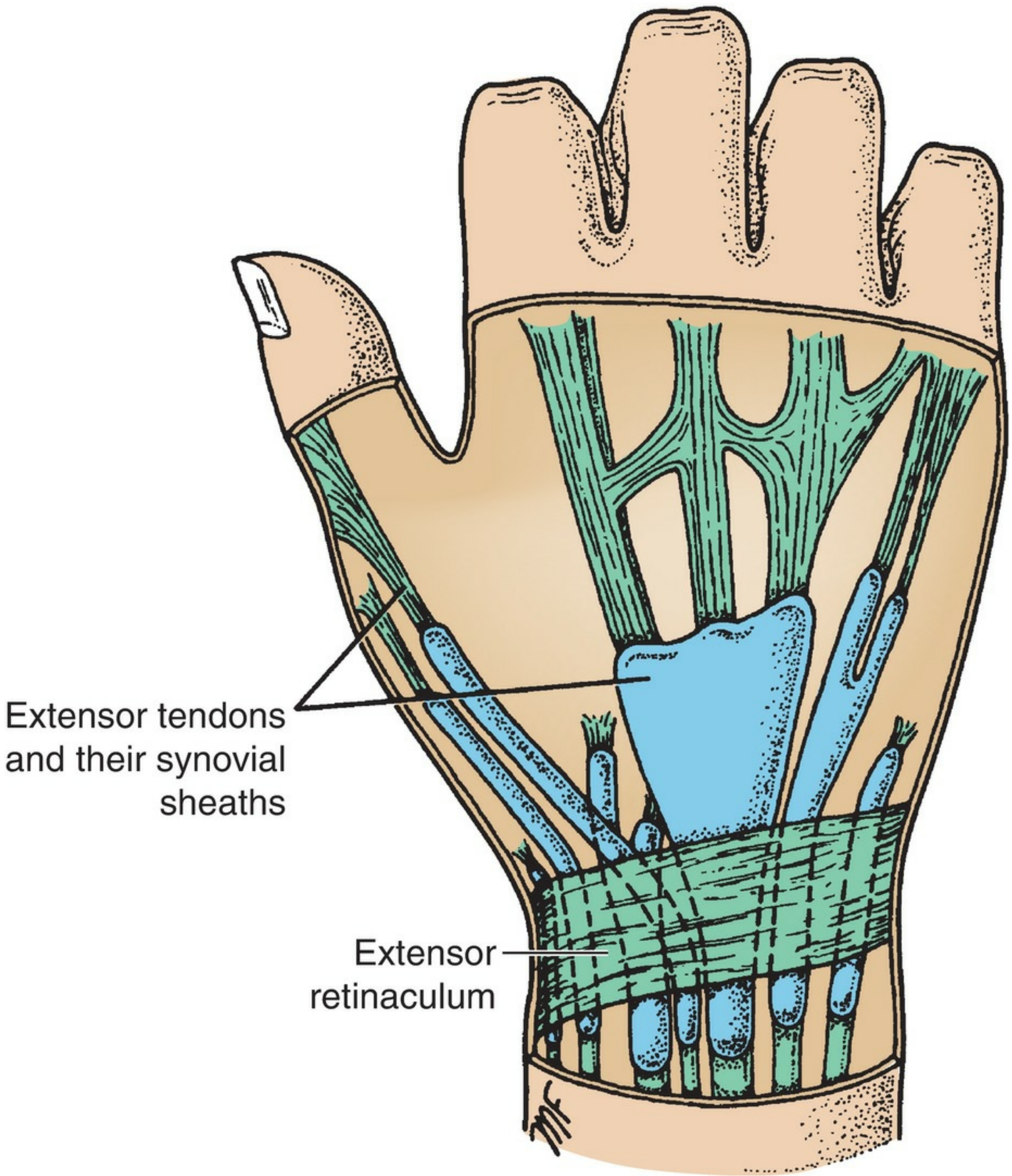


Figure 1.7 Extensor retinaculum on the posterior surface of the wrist holding the underlying tendons of the extensor muscles in position.

Clinical Notes

Fasciae and Infection

Knowledge of the arrangement of the deep fasciae often helps explain the path taken by an infection when it spreads from its primary site. For example, in the neck, the various fascial planes determine how infection can extend from the region of the floor of the mouth to the larynx or from the base of the skull into the thoracic cavity.

Bone

Bone is a living tissue capable of changing its structure when subjected to stresses. Like other connective tissues, bone consists of cells, fibers, and matrix. It is hard because of the calcification of its extracellular matrix and possesses a degree of elasticity because of the presence of organic fibers. Bone has a protective function; for example, the skull and vertebral column protect the brain and spinal cord from injury, and the sternum and ribs protect the thoracic and upper abdominal viscera (Fig. 1.8). It serves as a lever, as seen in the long bones of the limbs, and as an important storage area for calcium salts. Internally, bone houses and protects the delicate blood-forming bone marrow.

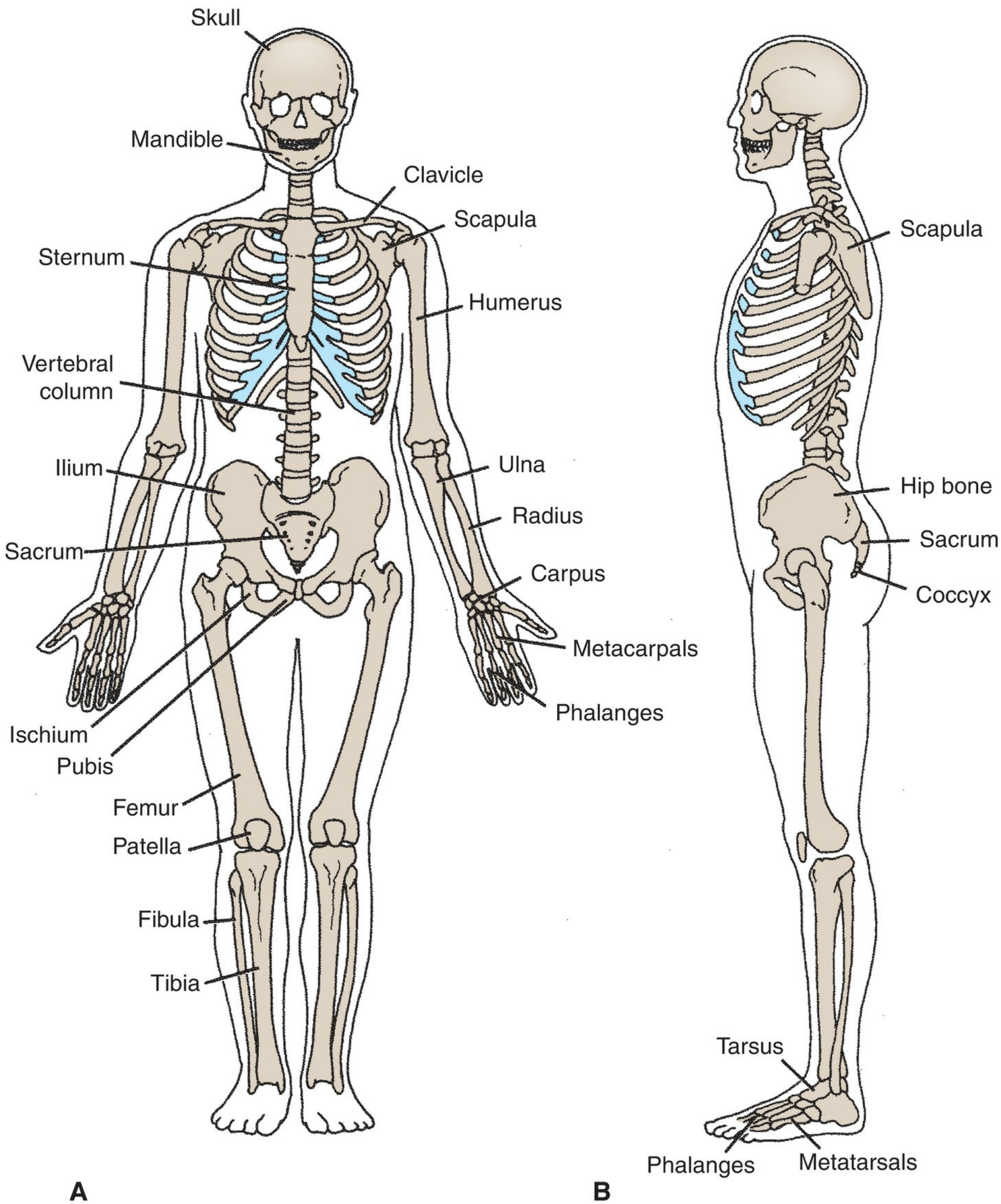


Figure 1.8 The skeleton. **A.** Anterior view. **B.** Lateral view with most of the upper limb removed.

A thick layer of fibrous tissue called the **periosteum** covers all bone surfaces, other than the articulating surfaces. The periosteum has an abundant vascular supply, and the cells on its deeper surface are osteogenic. The periosteum is particularly well united to bone at sites where muscles, tendons, and ligaments are attached to bone. Bundles of collagen fibers known as Sharpey's fibers extend from the periosteum into the underlying bone. The periosteum receives a rich nerve supply and is very sensitive to trauma.

Bone exists in two forms: compact and cancellous. Compact bone appears as a solid mass; cancellous bone consists of a branching network of **trabeculae** (Fig. 1.9). The trabeculae are arranged so as to provide resistance against mechanical stresses and strains.

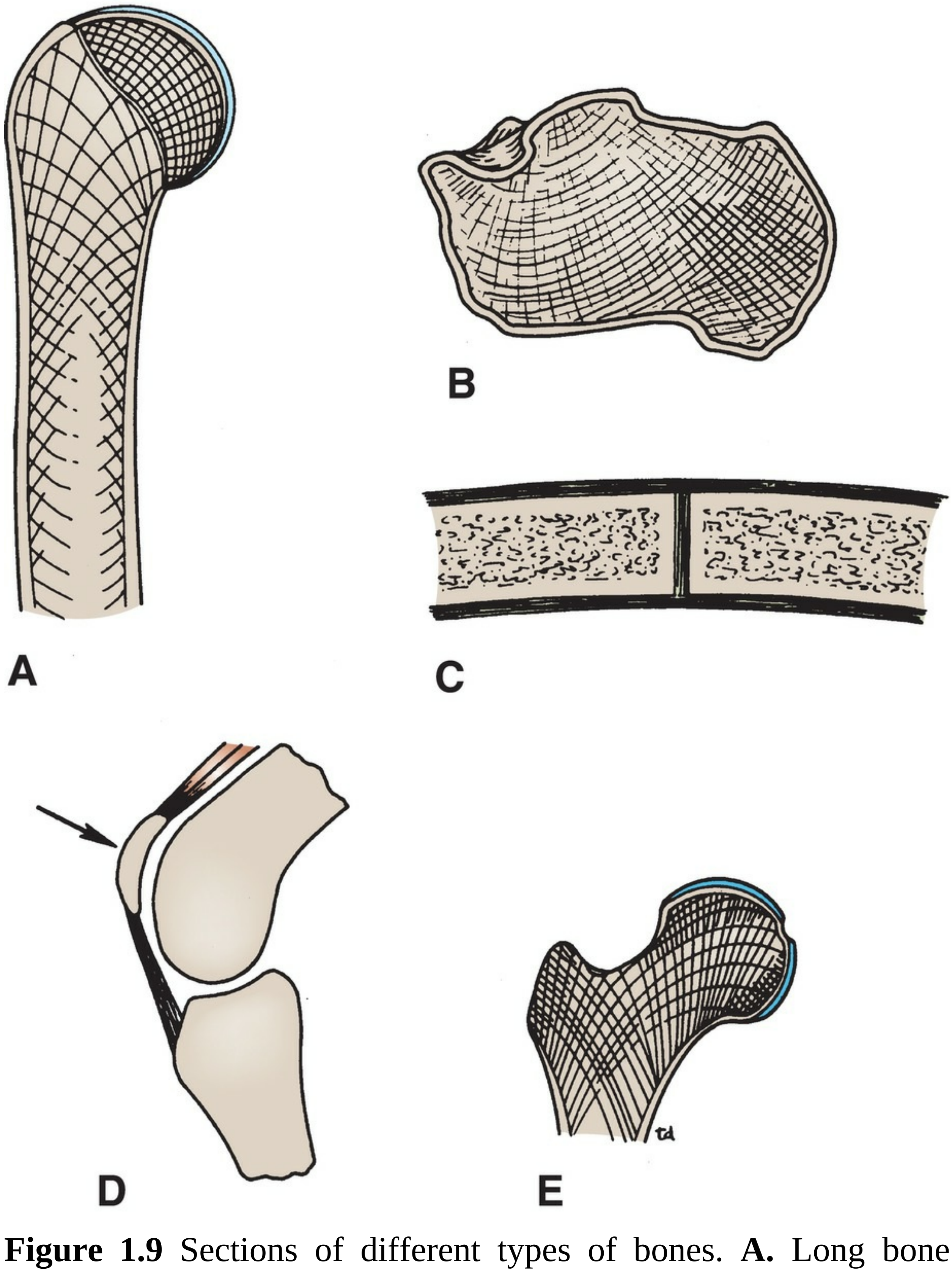


Figure 1.9 Sections of different types of bones. **A.** Long bone

(humerus). **B.** Irregular bone (calcaneum). **C.** Flat bone (two parietal bones separated by the sagittal suture). **D.** Sesamoid bone (patella). **E.** Note the arrangement of trabeculae to act as struts to resist both compression and tension forces in the upper end of the femur.

Bone Classification

Bones can be classified regionally or according to their general shape. In the regional classification scheme (Table 1.1), the bones are organized into two main groups: the axial and appendicular skeletons. The **axial skeleton** consists of the elements forming the central axis of the body. The **appendicular skeleton** consists of the bones forming the upper and lower limb girdles and extremities.

Table 1.1 Regional Classification of Bones

REGION OF SKELETON	NUMBER OF BONES (ADULT)
I. Axial skeleton	
Skull	
Cranium	8
Face	14
Auditory ossicles	6
Hyoid	1
Vertebrae (including sacrum and coccyx)	26
Sternum	1
Ribs	24
II. Appendicular skeleton	
Shoulder girdles	
Clavicle	2
Scapula	2
Upper extremities	
Humerus	2
Radius	2
Ulna	2
Carpals	16
Metacarpals	10
Phalanges	28
Pelvic girdle	
Os coxae	2
Lower extremities	
Femur	2
Patella	2
Fibula	2
Tibia	2
Tarsals	14
Metatarsals	10
Phalanges	28
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In the general shape classification scheme, bones are organized into five categories: long, short, flat, irregular, and sesamoid.

Long Bones

Long bones are found in the limbs (e.g., the humerus, femur, metacarpals, metatarsals, and phalanges). Their length is greater than their breadth (see Fig. 1.9A). They have a tubular shaft, the *diaphysis*, and usually an epiphysis at each end. During the growing phase, the diaphysis is separated from the epiphysis by an epiphyseal cartilage. The part of the diaphysis that lies adjacent to the epiphyseal cartilage is called the *metaphysis*. The shaft has a central marrow cavity containing bone marrow. The outer part of the shaft is composed of compact bone that is covered by periosteum. The ends of long bones are composed of cancellous bone surrounded by a thin layer of compact bone. The articular surfaces of the ends of the bones are covered by hyaline cartilage.

Short Bones

Short bones are found in the hand and foot (e.g., the scaphoid, lunate, talus, and calcaneum). They are roughly cuboidal in shape and are composed of cancellous bone surrounded by a thin layer of compact bone. Short bones are covered with periosteum, and the articular surfaces are covered by hyaline cartilage.

Flat Bones

Flat bones are found in the vault of the skull (e.g., the frontal and parietal bones). They are composed of thin inner and outer layers of compact bone, the **tables**, separated by a layer of cancellous bone, the **diploë** (see Fig. 1.9C). The scapulae, although irregular in shape, are included in this group.

Irregular Bones

Irregular bones include those not assigned to the previous groups (e.g., the bones of the skull, the vertebrae, and the pelvic bones). They are composed of a thin shell of compact bone with an interior made up of cancellous bone (see Fig. 1.9B).

Sesamoid Bones

A sesamoid bone is one formed within a tendon where the tendon passes over a joint. The greater part of a sesamoid bone is buried in the tendon, and the free surface is covered with cartilage. The largest sesamoid bone is the patella ("kneecap"), which is located in the tendon of the quadriceps femoris (see Fig. 1.9D). Other examples are found in the tendons of the flexor pollicis brevis (in the thumb) and flexor hallucis brevis (in the big toe). The function of a sesamoid bone is to reduce friction on the tendon; it can also alter the direction of pull of a tendon.

Bone Surface Markings

The surfaces of bones typically show various surface markings or irregular features. The surface is raised or roughened where bands of fascia, ligaments, tendons, or aponeuroses are attached to bone. These roughenings are not present at birth. They appear at puberty and become progressively more obvious during adult life. The pull of these fibrous structures causes the periosteum to elevate and new bone to be deposited beneath. In certain situations, the surface markings are large and are given special names. Some of the more important markings are summarized in Table 1.2.

Table 1.2 Bone Surface Markings

BONE MARKING	EXAMPLE
Linear elevation	
Line	Superior nuchal line of the occipital bone
Ridge	The medial and lateral supracondylar ridges of the humerus
Crest	The iliac crest of the hip bone
Rounded elevation	
Tubercle	Pubic tubercle
Protuberance	External occipital protuberance
Tuberosity	Greater and lesser tuberosities of the humerus
Malleolus	Medial malleolus of the tibia, lateral malleolus of the fibula
Trochanter	Greater and lesser tuberosities of the humerus
Sharp elevation	
Spine or spinous process	Ischial spine, spine of the vertebra
Styloid process	Styloid process of temporal bone
Expanded ends for articulation	
Head	Head of humerus, head of femur
Condyle	Medial and lateral condyles of femur (knuckle-like process)
Epicondyle (a prominence situated just above condyle)	Medial and lateral epicondyles of femur
Small flat area for articulation	
Facet	Facet on head of rib for articulation with vertebral body
Depressions	
Notch	Greater sciatic notch of hip bone
Groove or sulcus	Bicipital groove of humerus
Fossa	Olecranon fossa of humerus, acetabular fossa of hip bone
Openings	
Fissure	Superior orbital fissure
Foramen	Infraorbital foramen of the maxilla
Canal	Carotid canal of temporal bone
Meatus	External acoustic meatus of temporal bone

Each of the following chapters provides a comprehensive description of the bones of that region and their significant features. Do not relegate learning this material to a painful exercise in rote memorization of meaningless words. Try to understand the terminology in order to better appreciate the application of the anatomy. Most importantly, ask yourself functional questions when you examine the bones themselves, such as: Is this a right or left element? What articulates with this structure/area? What attaches to this structure? Is this structure palpable? Can this structure be identified in a standard radiographic image? Are there any important neurovascular relations to this region/structure?

Bone Marrow

Bone marrow occupies the marrow cavity in long and short bones and the interstices of the cancellous bone in flat and irregular bones. The marrow of all the bones of the body is red and hematopoietic at birth. This blood-forming activity gradually lessens with age, and the red marrow is replaced by yellow marrow. Yellow marrow begins to appear in the distal bones of the limbs at about age 7 years. This replacement of marrow gradually moves proximally, so that by the time the person becomes an adult, red marrow is restricted to the bones of the skull, the vertebral column, the thoracic cage, the girdle bones, and the head of the humerus and femur.

Bone Development

Bone develops by two processes: membranous and endochondral. In **membranous formation**, bone develops directly from a connective tissue membrane. In **endochondral formation**, a cartilaginous model is first laid down and is later replaced by bone. Consult a textbook of histology or embryology for details of the cellular changes involved.

The bones of the vault of the skull develop rapidly by membranous formation in the embryo, and this serves to protect the underlying developing brain. At birth, small areas of membrane persist between the bones. This is important clinically because it allows the bones a certain amount of mobility, so that the skull can undergo molding during its descent through the female genital passages.

The long bones of the limbs develop by endochondral ossification, in a slow process that is not completed until age 18 to 20 years or even later. The center of bone formation found in the shaft of the bone is the **diaphysis**; the centers at the ends of the bone are **epiphyses**. The plate of cartilage at each end, lying between the epiphysis and diaphysis in a growing bone, is the **epiphyseal plate**. The **metaphysis** is the part of the diaphysis that abuts onto the epiphyseal plate.

Clinical Notes

Bone Fractures

Immediately after a fracture, the patient suffers severe local pain and is not able to use the injured part. Deformity may be visible if the bone fragments have been displaced relative to each other. The degree of deformity and the directions taken by the bony fragments depend not only on the mechanism of injury but also on the pull of the muscles attached to the fragments. Ligamentous attachments also influence the deformity. In certain situations —for example, the ilium—fractures result in no deformity because the inner and outer surfaces of the bone are splinted by the extensive origins of muscles. In contrast, a fracture of the neck of the femur produces considerable displacement. The strong muscles of the thigh pull the distal fragment upward so that the leg is shortened. The very strong lateral rotators rotate the distal fragment laterally so that the foot points laterally.

Fracture of a bone is accompanied by a considerable hemorrhage of blood between the bone ends and into the surrounding soft tissue. The blood vessels and the fibroblasts and osteoblasts from the periosteum and endosteum take part in the repair process.

Rickets

Rickets is a defective mineralization of the cartilage matrix in growing bones. This produces a condition in which the cartilage cells continue to grow, resulting in excess cartilage and a widening of the epiphyseal plates. The poorly mineralized cartilaginous matrix and the osteoid matrix are soft, and they bend under the stress of bearing weight. The resulting deformities include enlarged costochondral junctions, bowing of the long bones of the lower limbs, and bossing of the frontal bones of the skull. Deformities of the pelvis may also occur.

Epiphyseal Plate Disorders

Epiphyseal plate disorders affect only children and adolescents. The epiphyseal plate is the part of a growing bone concerned primarily with growth in length. Trauma, infection, diet, exercise, and endocrine disorders can disturb the growth of the hyaline cartilaginous plate, leading to deformity and loss of function. In the femur, for example, the proximal epiphysis can slip because of mechanical stress or excessive loads. The length of the limbs can increase excessively because of increased vascularity in the region of the epiphyseal plate secondary to infection or in the presence of tumors. Shortening of a limb can follow trauma to the epiphyseal plate resulting from a diminished blood supply to the cartilage.

Cartilage

Cartilage is a form of connective tissue in which the cells and fibers are embedded in a gel-like matrix, the fibers lending firmness and resilience. A fibrous membrane called the **perichondrium** covers the cartilage except on the exposed surfaces in joints. Of the three types of cartilage, hyaline cartilage and fibrocartilage tend to calcify or even ossify in later life.

- **Hyaline cartilage** has a high proportion of amorphous matrix that has the same refractive index as the fibers embedded in it. Throughout childhood and adolescence, it plays an important part in the growth in length of long bones (epiphyseal plates are composed of hyaline cartilage). It has a great resistance to wear and covers the articular surfaces of nearly all synovial joints. Hyaline cartilage is incapable of repair when fractured; the defect is filled with fibrous tissue.
- **Fibrocartilage** has many collagen fibers embedded in a small amount of matrix and is found in the discs within joints (e.g., the

temporomandibular joint, sternoclavicular joint, and knee joint) and on the articular surfaces of the clavicle and mandible. Fibrocartilage, if damaged, repairs itself slowly in a manner similar to fibrous tissue elsewhere. Joint discs have a poor blood supply and therefore do not repair themselves when damaged.

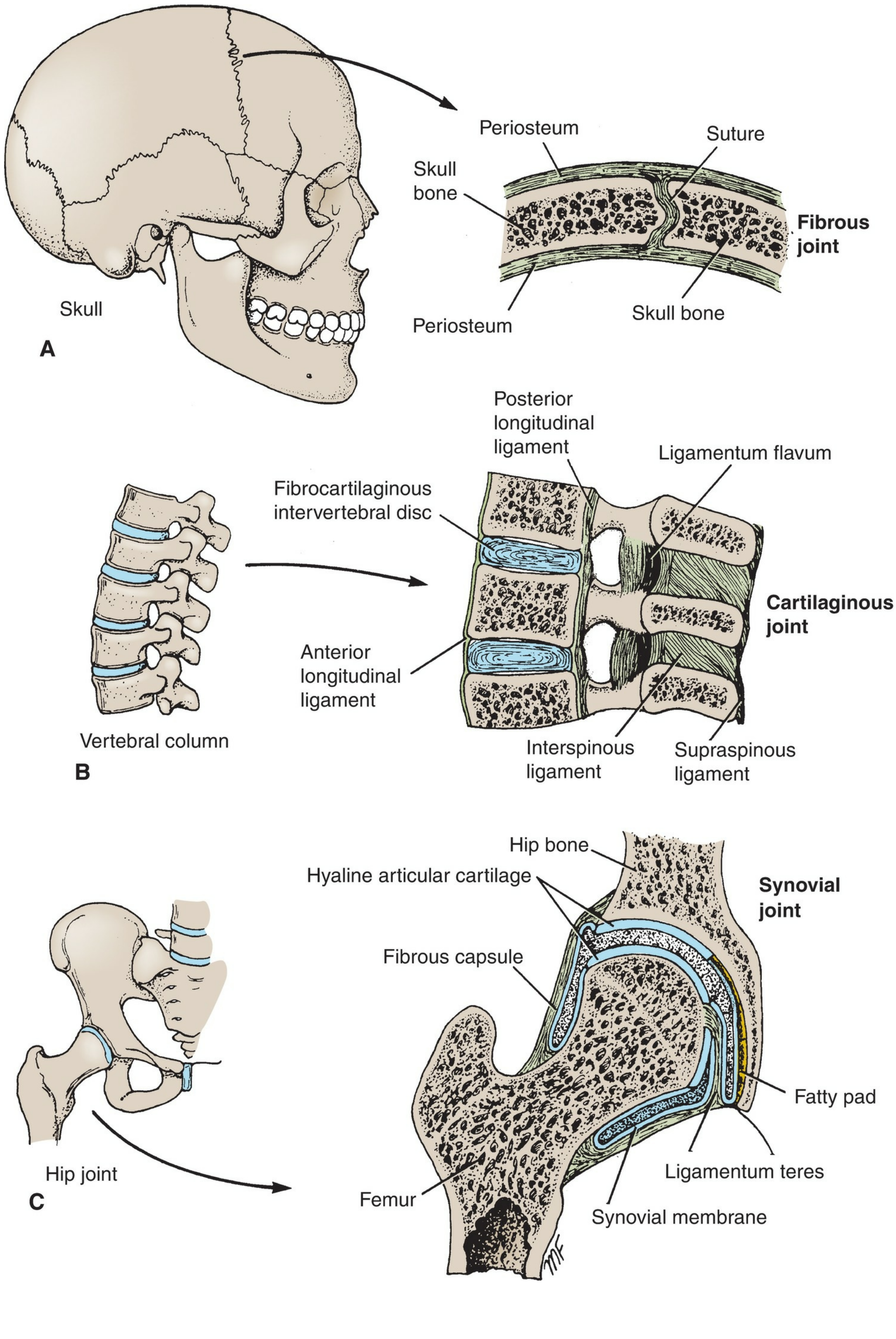
- **Elastic cartilage** possesses large numbers of elastic fibers embedded in matrix, making it flexible. It is found in the auricle of the ear, the external auditory meatus, the auditory tube, and the epiglottis. Elastic cartilage, if damaged, repairs itself with fibrous tissue.

Joints

A site where two or more bones come together, whether or not movement occurs between them, is termed a **joint**.

Joint Classification

The three main types of joints are based on the tissues that lie in the **joint space** between the bones: fibrous joints, cartilage joints, and synovial joints (Fig. 1.10).



Periosteum
Suture
Skull
bone
Fibrous
joint
Skull
Periosteum
Skull bone
A
Posterior
longitudinal
ligament
Ligamentum flavum
Fibrocartilaginous
intervertebral disc
Cartilaginous
joint
Anterior
longitudinal
ligament
Vertebral column
Interspinous
ligament
Supraspinous
ligament
B
Hip bone
Hyaline articular cartilage
Synovial
joint
Fibrous capsule
Fatty pad
Ligamentum teres
Hip joint
C
Femur
Synovial membrane

Figure 1.10 Examples of three types of joints. **A.** Fibrous joint (coronal suture of the skull). **B.** Cartilaginous joint (joint between two lumbar vertebral bodies). **C.** Synovial joint (hip joint).

Fibrous Joints

In fibrous joints, the articulating surfaces of the bones are tightly linked by fibrous tissue that fills the joint space (see Fig. 1.10A). Thus, very little movement is possible at these joints. The sutures of the vault of the skull and the inferior tibiofibular joints are examples of fibrous joints.

Cartilage Joints

In cartilage joints, the space between the articulating bony surfaces is filled with a cartilaginous pad. The two types of cartilage joints are synchondroses and symphyses. A **synchondrosis** is a cartilaginous joint in which the articulating bones are united by a plate or bar of hyaline cartilage. The epiphyseal plate between the epiphysis and diaphysis of a growing bone is a temporary form of a synchondrosis. The first sternocostal joint between the first rib and the manubrium sterni is a permanent synchondrosis. No movement occurs in synchondroses.

A **symphysis** is a cartilage joint in which the bones are united primarily by a pad or plate of fibrocartilage. Symphyses are located along the midline of the body. The intervertebral joints between the vertebral bodies (see Fig. 1.10B), the manubriosternal joint, and the symphysis pubis are symphyseal joints. A small amount of movement is possible in symphyses.

Synovial Joints

In synovial joints, the articular surfaces of the bones are covered by a thin layer of hyaline cartilage and are separated by a fluid-filled joint cavity (see Fig. 1.10C). This arrangement permits a great degree of freedom of movement. The cavity of the joint is lined by a **synovial membrane**, which extends from the margins of one articular surface to those of the other. A tough fibrous membrane referred to as the **capsule** of the joint protects the exterior of the synovial membrane. A viscous fluid called **synovial fluid**, which is produced by the synovial membrane, lubricates the articular surfaces. In certain synovial joints (e.g., the knee joint, the temporomandibular joint), discs or wedges of fibrocartilage are interposed between the articular surfaces of the bones. These are referred to as **articular discs**. Some synovial joints (e.g., the hip and knee joints) contain fatty pads lying between the synovial membrane and the fibrous capsule or bone.

The shape of the bones participating in the joint, the approximation of adjacent anatomic structures (e.g., the thigh against the anterior abdominal wall on flexing the hip joint), and the presence of fibrous ligaments uniting the bones all contribute to limiting the degree of movement in a synovial joint. Most ligaments lay outside the joint capsule and are referred to as **extracapsular ligaments**. However, some important ligaments (e.g., the cruciate ligaments in the knee) lie within the capsule and are termed **intracapsular ligaments**.

Synovial joints can be classified according to the shapes of the articular surfaces and the types of movements that are possible. Table 1.3 and Figure 1.11 summarize the types of synovial joints. The examples given are not necessarily the only joints of each type.

Table 1.3 Synovial Joint Types

JOINT TYPE	MORPHOLOGY	EXAMPLE(S)
Plane joint	The apposed articular surfaces are flat or almost flat, permitting the bones to slide on one another in multiple directions.	Joints between the articular processes of the vertebrae Sternoclavicular joint Acromioclavicular joint
Hinge joint	This resembles the hinge on a door, so that uniaxial flexion–extension movements are possible.	Humeroulnar joint in the elbow Interphalangeal joints in the hands and feet Ankle (talocrural) joint
Pivot joint	A central bony pivot is surrounded by a bony–ligamentous ring. Rotation is the only movement possible.	Median atlantoaxial joint Superior radioulnar joint
Condyloid joint	Two distinct convex surfaces that articulate with two concave surfaces. Biaxial movements (movements in two planes) are typical.	Metacarpophalangeal joints in the hands (knuckle joints) and feet
Ellipsoid joint	An elliptical convex articular surface fits into an elliptical concave articular surface. Mainly biaxial movements are allowed.	Radiocarpal (wrist) joint
Saddle joint	The articular surfaces are reciprocally concave–convex and resemble a saddle on a horse's back. Multiaxial movement allowance.	Carpometacarpal joint of the thumb
Ball-and-socket joint	A ball-shaped head of one bone fits into a socket-like concavity of another, allowing multiaxial movement.	Glenohumeral (shoulder) joint Hip joint

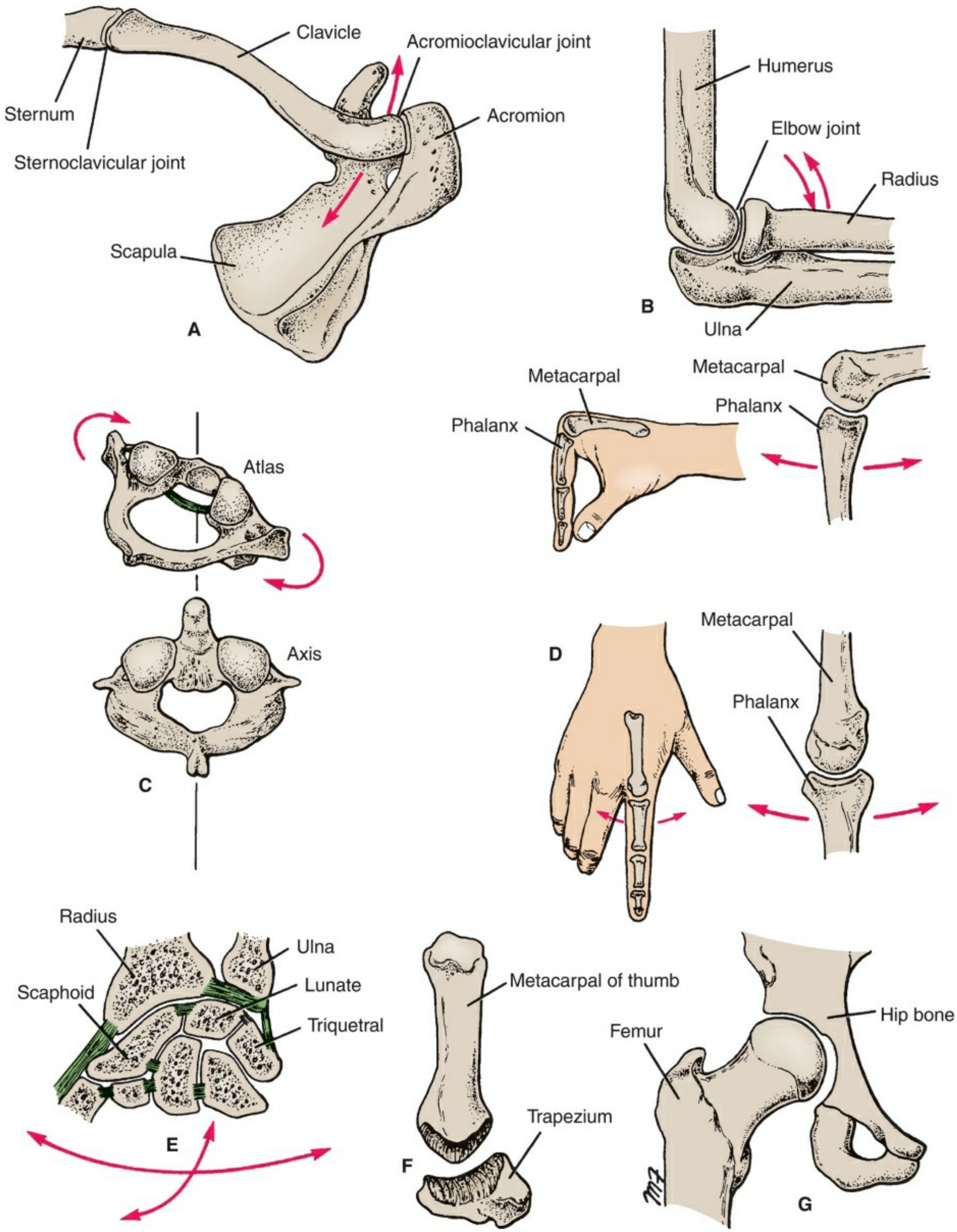


Figure 1.11 Examples of different types of synovial joints. **A.**

Plane joints (sternoclavicular and acromioclavicular joints). **B.** Hinge joint (humeroulnar part of the elbow joint). **C.** Pivot joint (medial atlantoaxial joint). **D.** Condyloid joint (metacarpophalangeal joint). **E.** Ellipsoid joint (radiocarpal part of the wrist joint). **F.** Saddle joint (carpometacarpal joint of the thumb). **G.** Ball-and-socket joint (hip joint).

Joint Stability

The stability of a joint depends on three main factors: the morphology of the bony articular surfaces, the ligaments, and the tone of the muscles around the joint (Fig. 1.12).

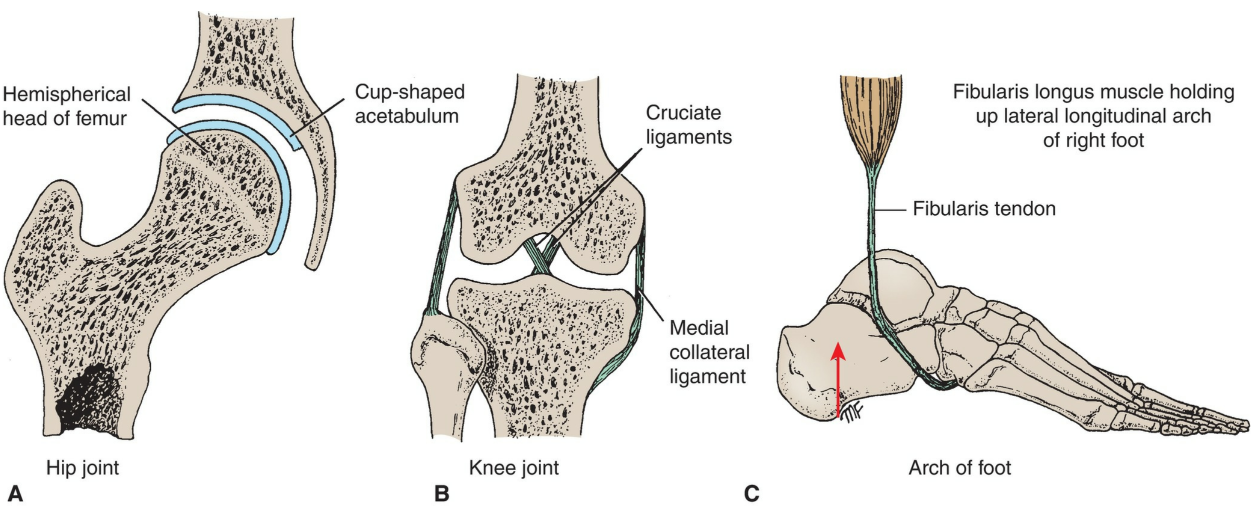


Figure 1.12 The three main factors responsible for stabilizing a joint. **A.** Shape of articular surfaces. **B.** Ligaments. **C.** Muscle tone.

Articular Surfaces

In certain joints, the shapes of the bones and their articulating surfaces cause the bones to form a relatively tight-fitting framework that imparts overall stability to the joint, such as the ball-and-socket arrangement of the hip joint (see Fig. 1.12A) and the mortise arrangement of the tarsal bones in the ankle joint. However, in some other joints, the shape of the bones contributes little or nothing to joint stability (e.g., the acromioclavicular, calcaneocuboid, and knee joints).

Ligaments

Fibrous ligaments prevent excessive movement in a joint (see Fig. 1.12B), but if the stress is continued for an excessively long period, then fibrous ligaments stretch. For example, the ligaments of the joints between the bones forming the arches of the feet will not support the weight of the body. Should the tone of the muscles that normally support the arches become impaired by fatigue, then the ligaments will stretch and the arches will collapse, producing flat feet. Elastic ligaments, conversely, return to their original length after stretching. The elastic ligaments of the auditory ossicles play an active part in supporting the joints and assisting in the return of the bones to their original position after movement.

Muscle Tone

In most joints, muscle tone is the major factor controlling stability. For example, the muscle tone of the short muscles around the shoulder joint keeps the hemispherical head of the humerus in the shallow glenoid cavity of the scapula. Without the action of these muscles, very little force would be required to dislocate this joint. The knee joint is very unstable without the tonic activity of the quadriceps femoris muscle. The joints between the small bones forming the arches of the feet are largely supported by the tone of the muscles of the leg, whose tendons are inserted into the bones of the feet (Fig. 1.12C).

Joint Nerve Supply

The joint capsule and ligaments receive an abundant sensory nerve supply. A sensory nerve supplying a joint also supplies the muscles moving the joint and the skin overlying the insertions of these muscles, a fact that has been codified as Hilton’s law.

Clinical Notes

Joint Examination

When examining a patient, the clinician should assess the normal range of movement of all joints. When the bones of a joint are no longer in their normal anatomic relationship with one another, then the joint is said to be **dislocated**. Some joints are particularly susceptible to dislocation because of lack of support by ligaments, the poor shape of the articular surfaces, or the absence of adequate muscular support. The shoulder joint, temporomandibular joint, and acromioclavicular joints are good examples. Dislocation of the hip is usually congenital, being caused by inadequate development of the socket that normally holds the head of the femur firmly in position.

The presence of cartilaginous discs within joints, especially weight-bearing joints, as in the case of the knee, makes the disc particularly susceptible to injury in sports. During a rapid movement, the disc loses its normal relationship to the bones and becomes crushed between the weight-bearing surfaces.

In certain diseases of the nervous system (e.g., syringomyelia), the sensation of pain in a joint is lost. This means that the warning sensations of pain felt when a joint moves beyond the normal range of movement are not experienced. This phenomenon results in the destruction of the joint.

Knowledge of the classification of joints is valuable because, for example, certain diseases affect only certain types of joints. Gonococcal arthritis affects large synovial joints such as the ankle, elbow, or wrist, whereas tuberculous arthritis also affects synovial joints and may start in the synovial membrane or in the bone.

Remember that more than one joint may receive the same nerve supply. For example, the obturator nerve supplies both the hip and knee joints. Thus, a patient with disease limited to one of these joints may experience pain in both.

Ligaments

A ligament is a cord or band of fibrous connective tissue uniting two or more structures. In the context of the musculoskeletal system, ligaments typically bind bones at joints. The two types of ligaments are fibrous and elastic. Most **fibrous ligaments** are composed of dense bundles of collagen fibers and are not stretchable under normal conditions (e.g., the iliofemoral ligament of the hip joint and the collateral ligaments of the elbow joint). **Elastic ligaments** are composed largely of elastic tissues and can therefore regain their original length after stretching (e.g., the ligamentum flavum of the vertebral column and the calcaneonavicular ligament of the foot).

Clinical Notes

Ligament Damage

Joint ligaments are very prone to excessive stretching, tearing, and rupture. A ligament **sprain** is an injury caused by abnormal or excessive force at a joint, but without dislocation of the joint or fracture of a bone. In treating damaged ligaments, if possible, the apposing damaged surfaces of the ligament are brought together by positioning and immobilizing the joint. In severe injuries, surgical approximation of the cut ends may be required. The blood clot at the damaged site is invaded by blood vessels and fibroblasts. The fibroblasts lay down new collagen and elastic fibers, which become oriented along the lines of mechanical stress.

Bursae and Synovial Sheaths

A **bursa** is a closed fibrous sac lined internally with synovial membrane. The synovial membrane secretes a film of viscous fluid that fills the sac. Bursae are typically found in areas subject to friction and serve to reduce friction (e.g., wherever tendons rub against bones, ligaments, or other tendons). They are commonly found close to joints where the skin rubs against underlying bony structures such as the prepatellar bursa (Fig. 1.13). Occasionally, the cavity of a bursa communicates with the cavity of a synovial joint (e.g., the suprapatellar bursa communicates with the knee joint, and the subscapularis bursa communicates with the shoulder joint).