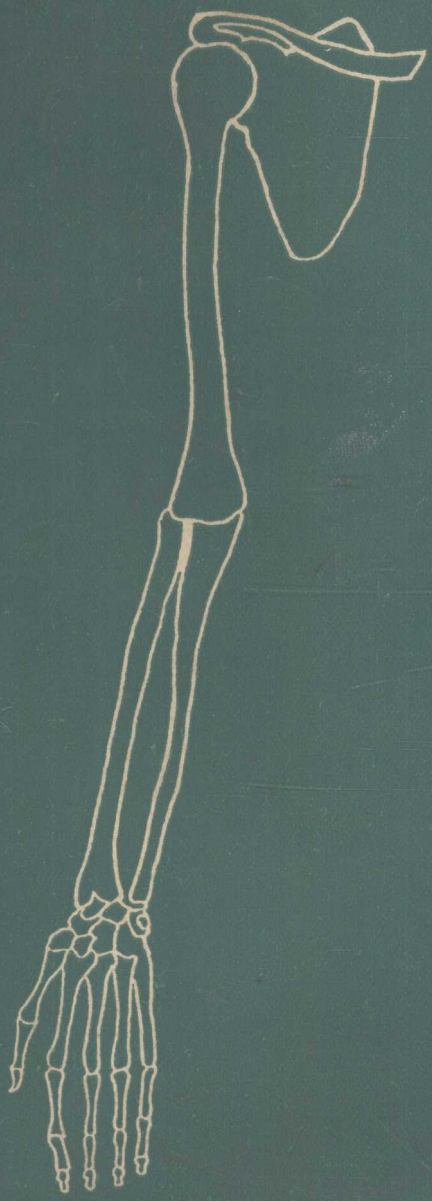
Functional Anatomy of the LIMBS AND BACK



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Fifth Edition

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Preface to the Fifth Edition

In this edition of *Functional Anatomy of the Limbs and Back* the aging but not yet senile original author welcomes a colleague as a co-author.

We have not changed the format: various facts and concepts that need to be understood before any serious study is undertaken are presented in the first section, and thereafter the emphasis is primarily on the musculoskeletal system. Following this are brief discussions of some of the more important features of the head, neck, and trunk.

Electromyographic findings that were not available at the time of the previous edition have been incorporated in the present one. In response to welcome suggestions, material has been added on levers and their application to the forces bearing upon joints; on the strength of bone, muscle and tendon; and on the courses of nerves and arteries. More practical and clinical applications have been added, especially in regard to the effect of various lesions of nerves. A number of illustrations have been enlarged, and there are twelve new figures.

The senior author is entirely responsible for any errors of facts or concepts that may appear in this book. However, beginning students should be aware that even in the old science of anatomy there are still differences of opinion and gaps in our knowledge. They should therefore not be surprised if their instructor sometimes disagrees with statements found here.

Our thanks are due to the Medical Department, Harper and Row, for allowing us to use figures from the senior author's *Anatomy for Surgeons* and *Textbook of Anatomy*; to our secretary, Mrs. Brenda Kendig, for her cheerful cooperation; and to our publisher, the W. B. Saunders Company,

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Anatomic Terminology 1

The beginning student of anatomy is confronted with the necessity of mastering a largely new, cumbersome and complicated vocabulary. The difficulties are increased by the fact that, in common with most scientific terminology, anatomic names are given a Latin form. It is now agreed that each language group may use the vernacular as it deems proper, therefore we depart from the strict Latin by anglicizing many expressions or using a direct English translation; however, the Latin terminology is the foundation upon which our scientific vocabulary is built. The problem is further complicated for most of us through the fact that, regardless of their endings, most anatomic terms have Greek or Latin roots. As most of them convey very definite meanings it is well worth the effort to consult a medical dictionary, when necessary, to discover the original meaning of the word and thus translate it in one's mind from a term that must be merely memorized to one that is understood. If the student will make a conscientious effort to understand the terminology of anatomy, he will find it much easier to learn the facts and concepts of anatomy.

A further difficulty in anatomic terminology is the abundance of synonyms that have accumulated for generations. The international anatomic terminology (NA, or Nomina Anatomica, adopted in 1955) recognizes practically no synonyms, but even anatomists, because they are used to an older terminology, have difficulty in eliminating synonyms from their talking and writing. Certainly, many of the clinicians with whom the therapist will come in contact will use the synonyms with which they are most familiar, and it is impossible to eliminate synonyms from older texts and figures that the student may consult. In this book the use of synonyms has been reduced to an approximate minimum. Only where it seemed obvious that the student might be handicapped through ignorance of another commonly employed although officially outdated term has that term been given

as a synonym. Some of the more common synonyms are listed beginning on page 384.

The major subdivisions of the body are the head, neck, trunk, and limbs. Although it is perfectly proper to use these English names, they also have Latin names that are used in many terms that the student will meet. Thus the head is "caput," and "capitis" therefore means "of the head." The neck is "collum"; cervix also means neck, especially its anterior part, and nucha means its posterior part. Thus "colli" means "of the neck," and we also find the terms "cervical" and "nuchal" or "nuchae" used in referring to structures in the neck.

Our word "trunk" is obviously the same as the Latin "truncus," but we have no particular reason to use the latter word. However, the subdivisions of the trunk need to be understood. The Latin word for chest is thorax, and this word will be met often both in this form, in its possessive "thoracis," which means "of the chest," and in its adjectival form "thoracic." The abdomen is the part of the trunk with muscular walls that lies below the thorax. It is most easily translated into our word "belly," but since this is considered inelegant we are left with no acceptable translation, and therefore use the words "abdomen" and "abdominal." ("Stomach," commonly used and understood to mean the abdomen, means no such thing; the stomach is one of many organs in the abdominal cavity.) The lowest part of the trunk is the pelvis (meaning "basin"), and the Latin term is always used for this; "pelvic" is the adjective pertaining to the pelvis.

The Latin for the limbs is "membra" (member), but has no common usage. "Appendage" is a term long used by zoologists to describe limbs in general, and sometimes appears in human anatomy in the adjectival form "appendicular." Names of smaller subdivisions of the limbs are best reserved for the times when the limbs are studied.

Since anatomy is a descriptive science, many anatomic terms are in themselves descriptive, referring to shape, size, location or function of a part, or its fancied resemblance to some nonanatomic structure. Muscles, especially, are usually so named, but since many muscles may have a given shape or a given function it is usual to use more than one descriptive adjective in naming a muscle. Thus there are two muscles called biceps, or muscles with two heads of origin, so we distinguish one as the biceps brachii, or two-headed muscle of the arm, the other as the biceps femoris, or two-headed muscle of the thigh. Similarly, the pronator quadratus is a quadrilateral muscle that pronates or turns the palm of the horizontally held hand downward, the quadratus lumborum is a quadrilateral muscle located in the lumbar region; the rectus abdominis is a muscle running vertically (rectus means straight) in the abdominal wall, the rectus capitis anterior is an anteriorly situated muscle running vertically to attach to the caput, or head, and so forth.

In addition to the various technical names of structures in the body there are also certain general terms describing surfaces of the body, planes through the body, relative positions of one structure to another, and so forth, that must be understood from the very beginning. The surfaces of the trunk may be conveniently described as the

dorsum, or back, the ventral or belly surface, and the two sides, or lateral surfaces. The cranium is the skull, and cephalon is the Greek word for head, so cranial and cephalic both mean toward the head; similarly, caudal means toward the tail, or in man toward where the tail would be had it persisted from embryonic life.

The above-defined terms are all understandable regardless of the position of the body, but there are others that require agreement as to what position of the body we are referring to before they can be understood. For instance, superior, meaning up or upward, implies a relation to gravity, and therefore might differ entirely in meaning according to whether one was erect, lying upon one's back, or standing upon one's head. For this reason, anatomists have agreed that such terms of relative position should always be used in relation to a fixed position of the body termed the anatomic position; the anatomic position is the erect one, with the heels together and the feet pointing somewhat outward, the arms by the sides and the palms facing forward. With reference, then, to the anatomic position, superior always means toward the head, and is therefore used interchangeably with cephalic or cranial; similarly, inferior means toward the feet, and is usually synonymous with caudal. Anterior, referring to the part of the body habitually carried forward in progression, is thus synonymous with ventral in the human being, and posterior and dorsal are also synonymous. Even in the new anatomic terminology there is some inconsistency in the use of the terms "anterior" and "ventral," and similarly in "posterior" and "dorsal"; in essence, however, dorsal and ventral are used in human anatomy only in referring to parts of spinal nerves and of the hand and foot (compare our English "back of the hand"). Elsewhere anterior and posterior are preferred, so what was once, for example, the dorsal interosseous artery is now the posterior interosseous artery. The term "ventral" was rarely used in regard to the limbs (except in developmental stages), the more common term here being "volar" (vola = the palm or sole); this has now been abandoned as the antithesis of posterior, so what was once the volar interosseous artery is now called the anterior interosseous artery.

Other terms of relative position are medial and lateral, that is, toward the midline or toward a side. In the case of the limbs, however, some confusion might exist as to whether these terms refer to the body as a whole or to the limb itself; thus the little finger is medial to the other fingers in regard to the midline of the hand, but is lateral, as is the thumb, in regard to the midline of the body. It is best in this case, therefore, to use medial and lateral only when referring to the limb as a whole, and its relation to the body in the anatomic position; if relative mediolateral relationships of structures within the limb are to be described, radial and ulnar, and tibial and fibular are the terms best employed. These terms refer to the paired bones of the limbs. In the upper limb, the radius is on the thumb side, the ulna on the little finger side, and in the lower limb the tibia is on the side of the big toe while the fibula is on that of the little toe; the sides of the limbs are thus named from the positions of these bones. Additional terms especially useful in regard to the limbs are proximal, meaning toward the

attachment of the limb to the trunk; distal, or away from the base of the limb; palmar, referring to the palm of the hand; and plantar, referring to the sole of the foot.

In regard to the planes of the body (fig. 1-1), the sagittal plane is either one passing through the midline of the body so as to divide it into right and left halves or one (often called parasagittal) parallel to but to one side of it. A coronal or frontal plane is one dividing the body into an anterior and a posterior (ventral and dorsal) portion, thus running roughly parallel with the front of the body and with a suture of

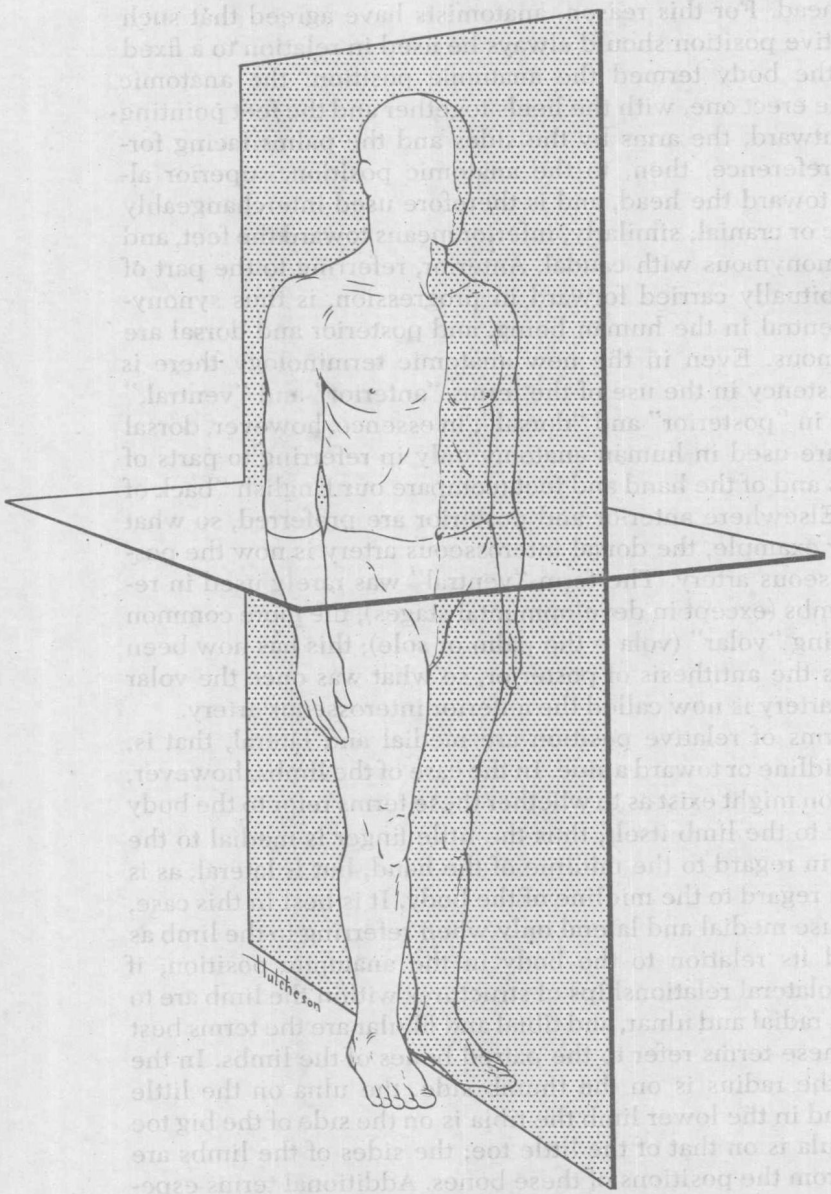

Figure 1–1. Planes of the body — sagittal and transverse.

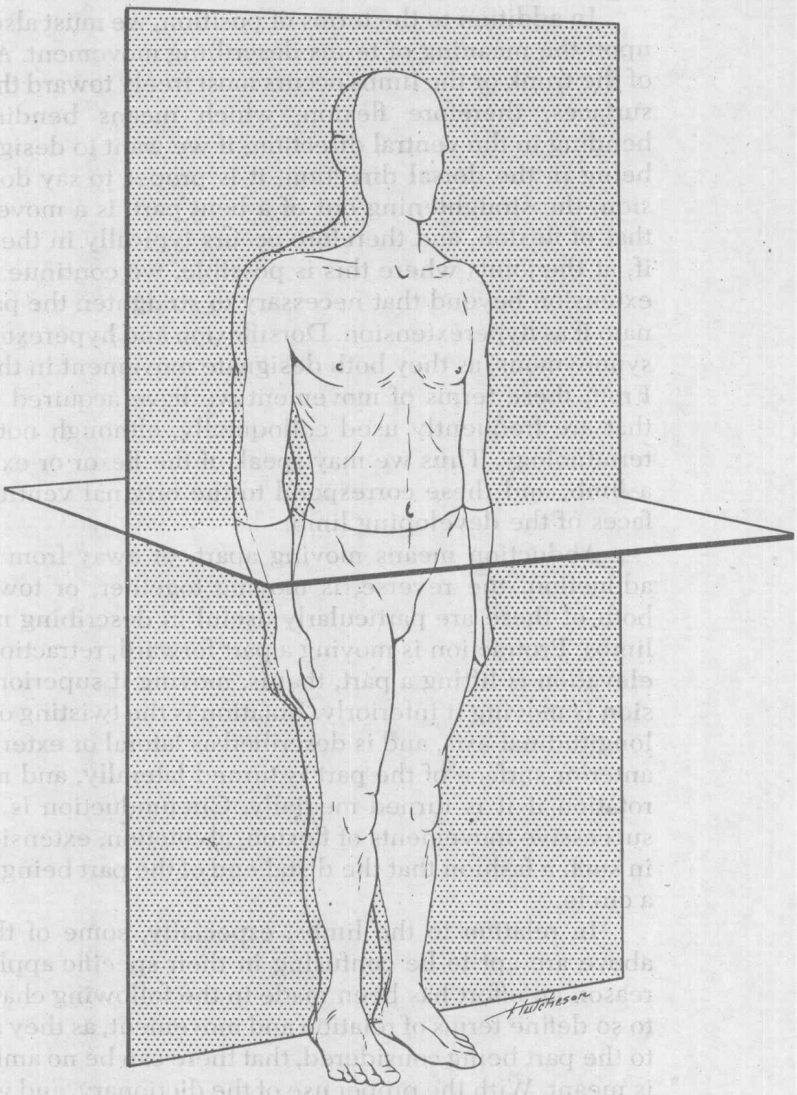

Figure 1–1. *Continued.* Coronal and transverse planes.

the skull called the coronal suture. A horizontal or transverse plane divides the body or limbs into upper and lower parts, in relation to gravity and the anatomic position.

In describing movements we may refer to them as being toward or away from a given plane, or we may find it convenient to speak of the axis of motion. For any given movement the axis of motion is an imaginary line about which a part describes a rotatory movement. These axes of motion typically make angles with one of the chief planes of the body. For instance, the axis for bringing the forearm up against the arm ("bending" the arm) is a line passing through the elbow region from lateral to medial sides, and is therefore at approximate right angles to the sagittal plane, and correspondingly approximately parallel to the frontal plane.

In addition to the terms of position, we must also agree in general upon the meaning of terms describing movement. As a rule, bending of the trunk or the limbs occurs most freely toward the original ventral surfaces, therefore flexion, which means bending, is usually a bending in the ventral direction; if we want to designate a bending as being in the dorsal direction, it is proper to say dorsiflexion. Extension, the straightening out of a bent part, is a movement opposed to that of flexion, and therefore occurs typically in the dorsal direction; if, at the joints where this is possible, we continue the movement of extension beyond that necessary to straighten the part, we can designate it as hyperextension. Dorsiflexion and hyperextension are plainly synonymous, as they both designate movement in the same direction. From these terms of movement we have acquired terms of position that are frequently used colloquially, although not a part of official terminology. Thus we may speak of the flexor or extensor surfaces of a limb, and these correspond to the original ventral and dorsal surfaces of the developing limb.

Abduction means moving apart, or away from the midline, and adduction, the reverse, is moving together, or toward the midline; both of these are particularly useful in describing movements of the limbs. Protraction is moving a part forward, retraction moving it back; elevation is lifting a part, that is, moving it superiorly, while depression is moving it inferiorly. Rotation is the twisting of a part around its longitudinal axis, and is described as lateral or external rotation if the anterior surface of the part is turned laterally, and medial or internal rotation if it is turned medially. Circumduction is a combination of successive movements of flexion, abduction, extension and adduction in such a fashion that the distal end of the part being moved describes a circle.

In relation to the limbs, especially, some of the terms defined above are apt to be confusing in their specific applications. For this reason an effort has been made in the following chapters of this book to so define terms of relation and movement, as they apply specifically to the part being considered, that there can be no ambiguity as to what is meant. With the proper use of the dictionary, and with due regard to the correct usage of anatomic terms as displayed by your instructor and in textbooks, the bugaboo of anatomic terminology can be largely overcome, and what may seem at first an almost incomprehensible jargon will become a useful part of your scientific language.

2 The Tissues of the Body

The human body, like most of the better-organized forms of animal life, consists of various types of specialized cells and a varying amount of intercellular substance; much of the actual weight of the body is water, both within the cells and without. The cells represent the living portion of the organism, while the intercellular substance, regardless of its nature, represents nonliving material that owes its existence to the activities of the cells.

Most types of cells tend to occur in groups in which the constituents are somewhat similar both in appearance and in function; such organized groups of cells are known as tissues. The tissues of the body are in turn not independent of one another but, rather, various types of tissues are interwoven to form more complex anatomic and functional units known as organs or organ systems.

According to their general appearance and functions, the various tissues of the body are usually classified into a few great groups: epithelial tissue, connective tissue, muscular tissue, nervous tissue, and blood.

EPITHELIA

Epithelial tissue (fig. 2-1) occurs most commonly in sheets, and is adapted especially for covering other tissues. It serves the general functions of protection, absorption and secretion. An epithelium is characterized by the fact that its cells are closely packed together with a minimum of inert intercellular cement substance between them. The cells may vary in shape from extremely flat ones resembling paving stones (called squamous cells; squama means a scale, such as that

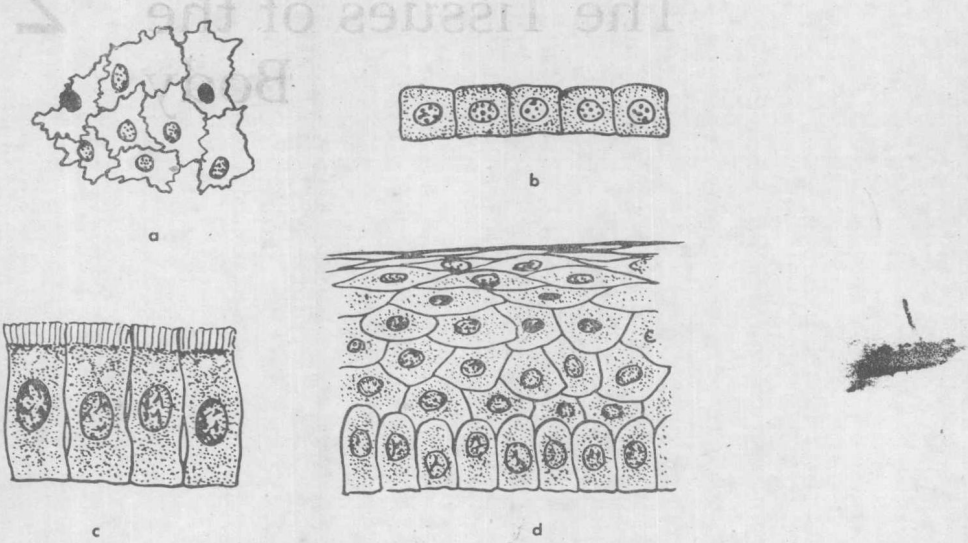

Figure 2–1. Several types of epithelium. *a*. Simple squamous, surface view. *b*. Simple cuboidal. *c*. Ciliated columnar. *d*. Stratified squamous. *b*, *c*, and *d* represent views of sections.

of a fish), to cuboidal ones shaped somewhat like children's blocks, to tall columnar ones. There are many subvarieties in shape, general appearance and function.

An epithelium may take the form of a single-layered sheet of cells, a multilayered sheet, or of essentially tubular outgrowths (glands) from such sheets. One type of epithelium covers the external surface of the body where, as the outer layer of the skin, a stratified or multilayered epithelium with dead outer cells protects the more delicate deeper-lying cells and serves as a membrane to seal off intercellular spaces from contact with the outside. Another type of epithelium, adapted for absorption and secretion, lines the digestive tract, and outgrowths from this epithelium form the digestive glands, including also the characteristic cells of such large organs as the liver and pancreas. Other types of epithelium line the tubules of the kidneys, the ureters, and the urinary bladder, and of course continue along the urethra (the tube leading from the bladder) to unite with the epithelium of the skin. Thus epithelium occurs primarily either on the outside of the body or as a lining of those cavities of the body that communicate with the exterior.

Two specialized types of epithelium are also found lining closed cavities within the body. Mesothelium, a single-layered very flattened epithelium of the pavement or squamous type, lines the four great cavities of the trunk, namely, the two pleural cavities surrounding the lungs, the pericardial cavity surrounding the heart, and the peritoneal cavity surrounding the abdominal viscera. Endothelium, essentially similar to mesothelium in appearance, forms the inner lining of the heart, of all blood vessels, and of the lymphatics.

CONNECTIVE TISSUE

Connective tissue, in sharp contrast to epithelial tissue, has cells that are more or less widely dispersed and separated from each other by nonliving intercellular material; it is the presence and character of this intercellular material that give connective tissue its specific characteristics.

The most pervasive type of connective tissue in the body is **fibrous connective tissue** (fig. 2-2). In this type the spaces between the cells are occupied by numerous fibers that make the tissues tough and capable of withstanding distortions and strains. The fibers between the cells may be of several types, and may occur either in the form of a loosely woven net with large quantities of fluid in the interstices of the net, or as an apparently solid structure such as a tendon, with closely packed fibers and very little interfibrillar space. The most common type of fiber found in connective tissues is the collagenous fiber. These fibers are essentially nonelastic; therefore, when they occur in places in which some deformation must be possible they are arranged in wavy bundles that allow movement until the slack of these bundles is taken up. Elastic fibers are the other important type of intercellular fibers; these fibers are actually elastic as their name implies: they may be stretched, and when the tension upon them is relaxed, they will shorten again. Their cut ends often curl. They are frequently mixed with more numerous collagenous fibers, but in certain locations great bundles of almost pure elastic tissue are found. At intervals, in the interstices between connective tissue fibers, connective tissue cells occur. Some of these, known as fibroblasts, are responsible for the formation and repair of the connective tissue fibers. Others possess the property of ingesting formed material; in this duty they may be aided by cells from the blood, some of which pass freely into the fibrous connective tissues as a part of the reaction of inflammation.

Collagenous tissue, with or without the admixture of elastic fibers, is the most ubiquitous of all tissues. Taking various forms, it permeates and surrounds practically all the tissues of the body, serving as a binding agent for these tissues. Indeed, it has been aptly said that if it were possible to dissolve out all the tissues of the body so as to

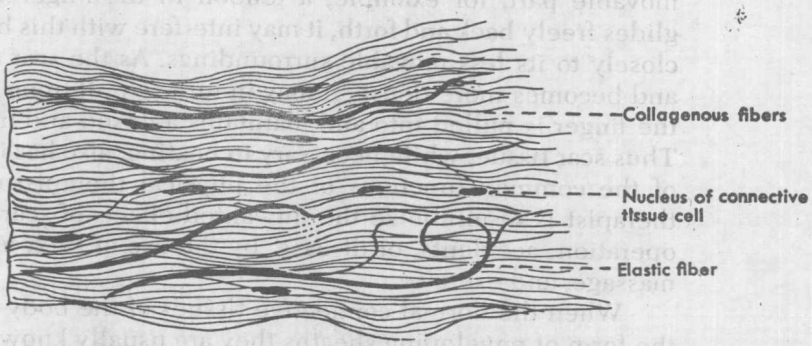

Figure 2–2. Connective tissue consisting largely of collagenous fibers, but with some admixture of elastic fibers.

leave only the fibrous connective tissues, the essential organization of the body would still be represented and recognizable through the arrangement of this fibrous tissue.

Where fibrous connective tissue forms the deep layer (the dermis or corium) of the skin it consists of densely matted fibers running in all directions. Most of these are collagenous, but there are also elastic fibers to lend resiliency to the skin. The dermis of animals is the source of leather. Deep to the skin, elastic and collagenous fibers are more loosely woven to form a subcutaneous layer, the tela subcutanea (subcutaneous network) that allows movement of the skin over the deeper structures. To a varying extent in different parts of the body and in different individuals this subcutaneous connective tissue contains modified tissue cells that are filled with fat. If these fat cells are sufficiently numerous the tissue is known as adipose tissue or fat. Varying amounts of loose connective tissue, often containing fat, occur elsewhere throughout the body, where this type of tissue forms padding between various organs, about blood vessels, and so forth. Special accumulations of connective tissue form the outer wall of blood vessels, and surround and permeate nerves to bind their nerve fibers together. Epithelia are rather regularly supported by connective tissue; muscles are surrounded and their cells are held together by connective tissue; and bone contains large quantities of connective tissue fibers. Thus fibrous tissue permeates practically all the organs of the body.

Because of its ubiquity, fibrous connective tissue is almost always involved in any injury to the body. It normally plays an important part in the healing process, for new connective tissue fibers form in the injured area and reunite the parts that have been separated by the injury. Connective tissue formed in an attempt to repair an injury is known as scar tissue. If the injury has been unduly severe or of long duration, more scar tissue is formed than is needed to repair the defect (nature's way of insuring at least enough is to overdo it somewhat). As this newly formed tissue grows older the fibers shorten and become more densely packed together, and may thus form a hard mass of considerable size which may—on a finger, for instance—interfere with movement of the part. Moreover, if the scar tissue is attached to a movable part, for example, a tendon in the finger which normally glides freely back and forth, it may interfere with this by binding it too closely to its less movable surroundings. As the scar tissue contracts and becomes more dense, it may in turn so pull upon the tendon that the finger is pulled into and maintains a flexed and useless position. Thus scar tissue, while necessary to healing, also has its dangers. One of the common functions of the physical therapist or occupational therapist is to minimize the unwanted effects of scar formation after operation, accidents, or disease, by the use of such methods as heat, massage, and exercise.

When the normal connective tissues of the body are arranged in the form of enveloping sheaths they are usually known as **fascias** (fascia means a bandage or band, and thus connotes a layer enveloping or binding together other structures). Thus the subcutaneous tissue or

tela subcutanea is frequently called the superficial fascia; numerous examples of well-developed, tough, deep fascias occur, especially in the limbs where fascia forms heavy membranes surrounding the limb as a whole. Individual muscles are also surrounded by thin fascia, called perimysium, and separated from each other by looser connective tissue. This is especially well developed where two adjacent muscles cross each other rather than running parallel, and the fluid between the fibers of the tissue then acts as a lubricant to allow free movement of one muscle upon the other. In some locations between muscles or between muscles or tendon and bone, or even beneath the skin over bony prominences, connective tissue spaces coalesce to form pocket-like accumulations of fluid known as **bursae** (bursa = a purse). From the fascia surrounding a muscle, connective tissue septa pass into the muscle and subdivide it into bundles; these septa in turn divide until delicate connective tissue fibers surround each muscle fiber within a muscle.

The connective tissue fibers of a fascia, although arranged in approximately the same plane to form membranes, run in various directions within this plane so that they appear interwoven, with no main direction of fibers predominating as a rule. In tendons and ligaments, in contrast, connective tissue fibers are arranged roughly parallel to one another, and are closely packed to form definite cords or bands that are especially adapted to resist movement in one direction. **Tendons** are formed of heavy collagenous bundles and delicate cross fibers; a tendon is defined as such a bundle that attaches muscle to bone or, occasionally, to some other structure. In the abdomen the tendons of the lateral abdominal muscles form broad flattened membranes known as aponeuroses. The tendons of most muscles are, however, more narrow bands, or frequently, as is true of many of the tendons of the limbs, rounded cords. The fibers of which tendons are composed are attached firmly to the muscle cells at one end, while at the other end they enter the bone and blend both with the connective tissue surrounding the bone (periosteum) and with the fibers within the bone itself.

Although most of the collagenous fibers composing a tendon run in the same direction, they are not strictly parallel, but intertwine to form small bundles that in turn intertwine to form the larger parallel bundles that give tendons their distinctive appearance. As the tendon nears its attachment to the bone the larger tendon bundles also intertwine with each other. The end result, therefore, is that the pull of any part of the muscle, instead of being limited to a tendon bundle originating in that part, is widely spread through the tendon; also, although in a broad tendon different fibers are in the direct line of pull as the bone is moved, a large part of the muscle constantly acts on these fibers.

Ligaments represent another type of dense connective tissue, frequently similar to tendons in appearance but uniting bone to bone rather than muscle to bone. Most ligaments are composed of dense collagenous tissue, but a very few are almost pure elastic tissue.

A type of connective tissue that at first sight appears to have little