1 Introduction to Anatomic Systems and Terminology

Anatomy of the human body can be studied by inspection of all the systems that occupy a specific region or by considering the global aspects of a particular system throughout the entire body. The first approach tends to focus on anatomic relationships while the second is better suited to studying physiologic influences. Most systems, however, are conveniently confined to one or two regions, and in this text are discussed in the units devoted to those regions. Some systems, however, (those included in this chapter) are more pervasive throughout the body, and a fundamental understanding of their basic organization is important before undertaking the study of the systems they support.

1.1 Structural Design of the Human Body

The most preliminary inspection of the human body reveals that it is structurally divided into a head and neck region, a trunk, and paired upper and lower extremities (limbs). Each is further divided into smaller regions **(Fig. 1.1; Table 1.1)**. These house the structures that make up the functional organ systems that perform the basic bodily functions **(Table 1.2)**. Although the primary organ of a system is often confined to a single anatomic region (e.g., the brain resides in the head), systems extend beyond regional borders, both anatomically and physiologically, to integrate their influences on normal function and growth.

Table 1.1 Regional Subdivisions of the Body

Head (Caput)
Neck (Collum)
Trunk (Truncus) • Thorax (chest) • Abdomen • Pelvis
Upper limb (Membrum superius) • Shoulder girdle (Cingulum membri superioris) • Free upper limb (Pars libera membri superioris)
Lower limb (Membrum inferius) • Pelvic girdle (Cingulum membri inferioris) • Free lower limb (Pars libera membri inferioris)

Table 1.2 Functional Subdivisions by Organ Systems

Locomotor system (musculoskeletal system) • Skeleton and skeletal connections (passive part) • Striated skeletal musculature (active part)
Viscera • Cardiovascular system • Hemolymphatic system • Endocrine system • Respiratory system • Digestive system • Urinary system • Male and female reproductive system
Nervous system • Central and peripheral nervous system • Sensory organs
The skin and its appendages

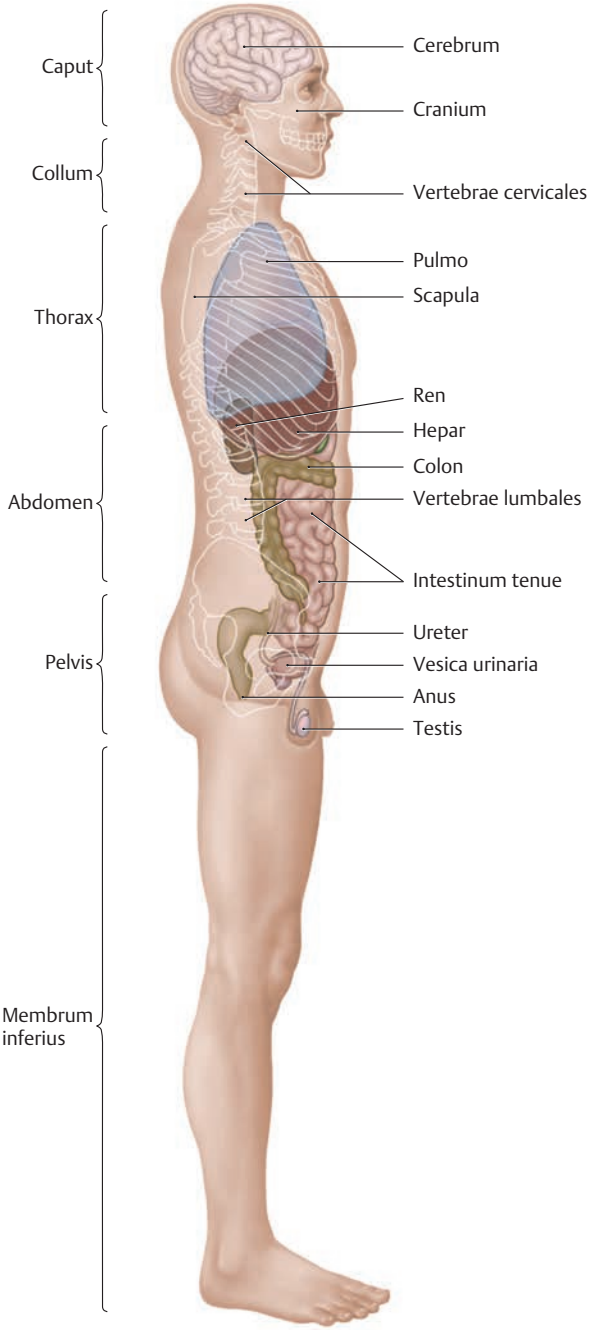


Fig. 1.1 Structural design of the human body: location of the internal organs
(From Schuenke M, Schulte E, Schumacher U. THIEME Atlas of Anatomy, Vol 1. Illustrations by Voll M and Wesker K. 3rd ed. New York: Thieme Publishers; 2020.)

1.2 Terms of Location and Direction, Cardinal Planes, and Axes

- All locational and directional terms used in anatomy, and in medical practice, refer to the human body in the **anatomic position,** in which the body is upright, arms at the side, with the eyes, palms of the hands, and feet directed forward **(Fig. 1.2, Table 1.3)**.
- Three perpendicular cardinal planes and three axes based on the three spatial coordinates can be drawn through the body **(Fig. 1.3)**.
  - The **plana sagittalia** passes through the body from front to back, dividing it into right and left sides.

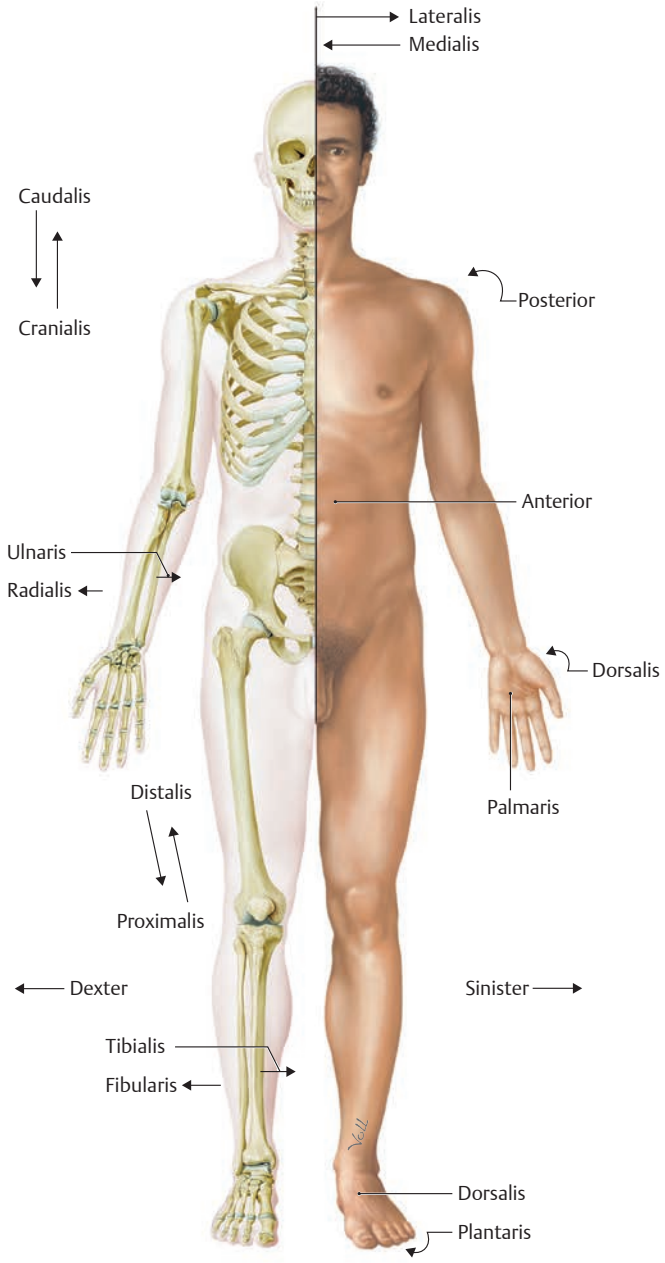


Fig. 1.2 Anatomic position
Anterior view. (From Schuenke M, Schulte E, Schumacher U. THIEME Atlas of Anatomy, Vol 1. Illustrations by Voll M and Wesker K. 3rd ed. New York: Thieme Publishers; 2020.)

Table 1.3 General Terms of Location and Direction

Term	Explanation
Upper Body (Caput, Collum, and Truncus)	
Cranialis	Pertaining to, or located toward, the head
Caudalis	Pertaining to, or located toward, the tail
Anterior	Pertaining to, or located toward, the front; synonym: ventralis (used for all animals)
Posterior	Pertaining to, or located toward, the back; synonym: dorsalis (used for all animals)
Superior	Upper or above
Inferior	Lower or below
Axialis	Pertaining to the axis of a structure
Transversus	Situated at right angles to the long axis of a structure
Longitudinalis	Parallel to the long axis of a structure
Horizontalis	Parallel to the plane of the horizon
Verticalis	Perpendicular to the plane of the horizon
Medialis	Toward the median plane
Lateralis	Away from the median plane (toward the side)
Medianus	Situated in the median plane or midline
Peripheralis	Situated away from the center
Superficialis	Situated near the surface
Profundus	Situated deep beneath the surface
Externus	Outer or lateral
Internus	Inner or medial
Apicalis	Pertaining to the top or apex
Basalis	Pertaining to the bottom or base
Sagittalis	Situated parallel to the sutura sagittalis
Coronalis	Situated parallel to the sutura coronalis (pertaining to the crown of the head)
Limbs	
Proximalis	Close to, or toward, the truncus, or toward the point of origin
Distalis	Away from the truncus (toward the end of the limb), or away from the point of origin
Radialis	Pertaining to the radius or the lateral side of the antebrachium
Ulnaris	Pertaining to the ulna or the medial side of the antebrachium
Tibialis	Pertaining to the tibia or the medial side of the crus
Fibularis	Pertaining to the fibula or the lateral side of the crus
Palmaris (volaris)	Pertaining to the palma
Plantaris	Pertaining to the planta
Dorsalis	Pertaining to the dorsum manus or dorsum pedis

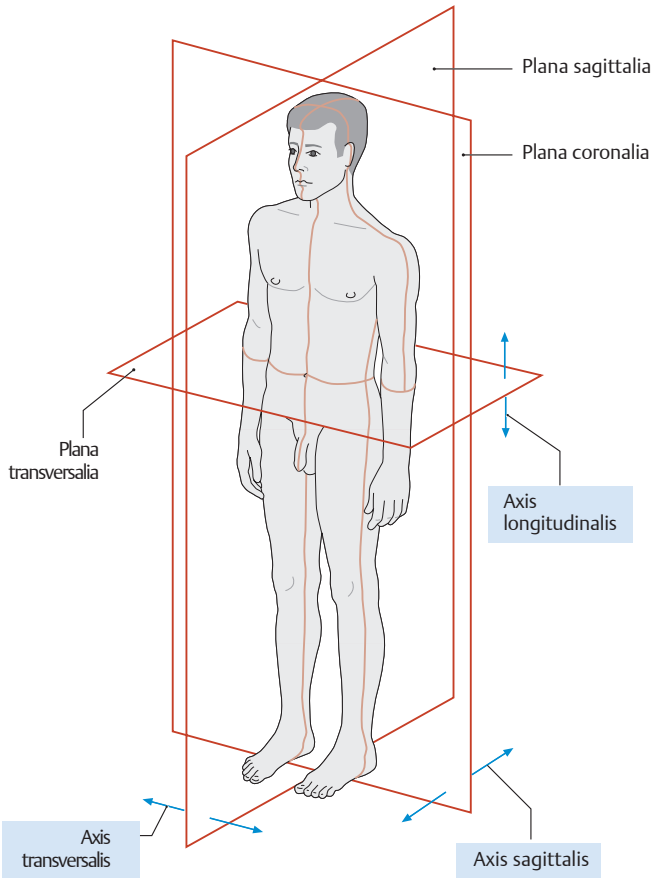
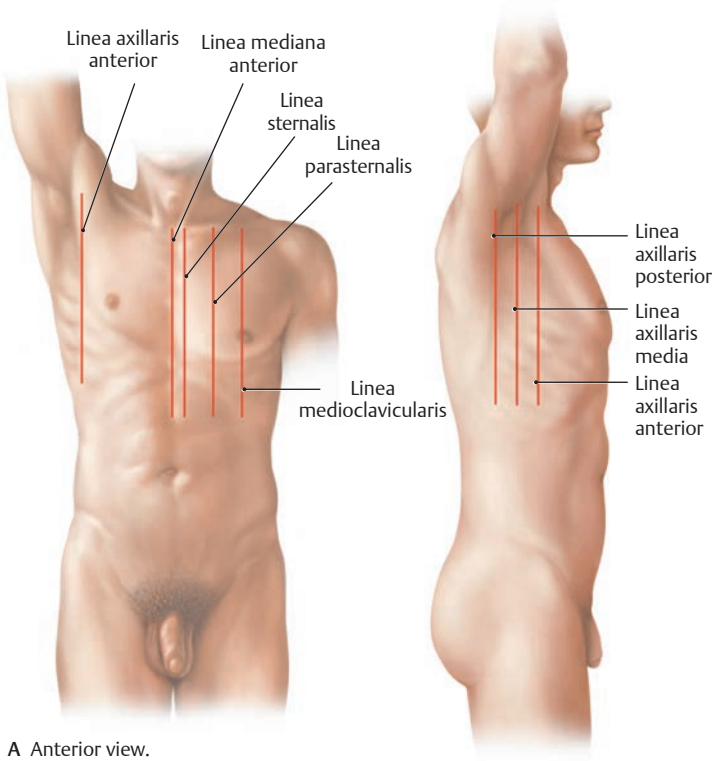


Fig. 1.3 Cardinal planes and axes
Neutral position, left anterolateral view. (From Schuenke M, Schulte E, Schumacher U. THIEME Atlas of Anatomy, Vol 1. Illustrations by Voll M and Wesker K. 3rd ed. New York: Thieme Publishers; 2020.)

- The **plana coronalia** passes through the body from side to side, dividing it into front (anterior) and back (posterior) parts.
- The **plana transversalia** (axial, horizontal, cross-sectional planes) divides the body into upper and lower parts. A particular transverse section is often given the designation of the corresponding vertebral level, such as *T IV,* which passes through vertebra thoracica T IV.
- The **axis longitudinalis** passes along the height of the body in a craniocaudal direction.
- The **axis sagittalis** passes from the front to the back (or the back to the front) of the body in an anteroposterior direction.
- The **axis transversalis** (horizontal axis) passes through the body from side to side.

1.3 Landmarks and Reference Lines

— In surface anatomy, palpable structures or visible markings on the surface of the body are used to identify the location of underlying structures. **Reference lines** are vertical or transverse planes that connect palpable structures or markings (**Tables 1.4, 1.5,** and **1.6;** see also **Fig. 1.5**).



A Anterior view.

B Right lateral view.

Table 1.4 Anterior and Lateral Reference Lines on the Trunk
(From Schuenke M, Schulte E, Schumacher U. THIEME Atlas of Anatomy, Vol 1. Illustrations by Voll M and Wesker K. 3rd ed. New York: Thieme Publishers; 2020.)

Linea mediana anterior	Passes through the center of the sternum
Linea sternalis	Passes along the lateral border of the sternum
Linea medioclavicularis	Passes through the midpoint of the clavicula
Linea parasternalis	Passes through a point midway between the linea sternalis and linea medioclavicularis
Linea axillaris anterior	Marks the anterior axillary fold formed by the m. pectoralis major
Linea axillaris posterior	Marks the posterior axillary fold formed by the m. teres major
Linea axillaris media	Marks the midpoint between the linea axillaris anterior and linea axillaris posterior

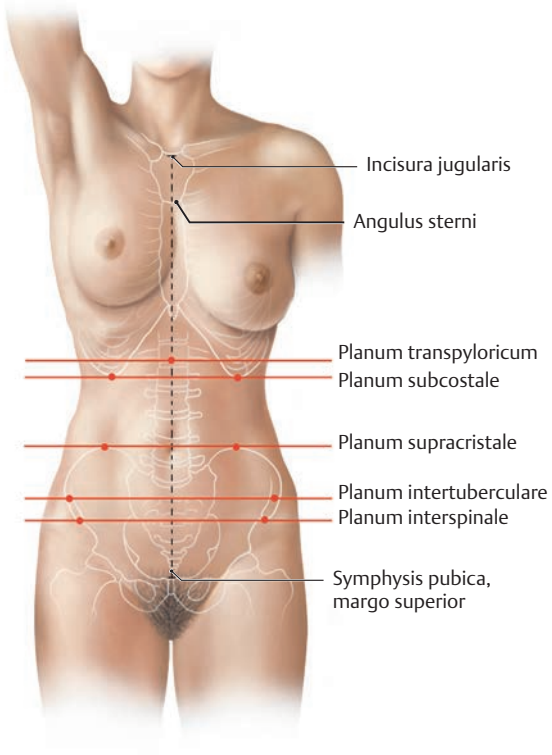


Table 1.5 Landmarks and Transverse Planes on the Anterior Trunk
(From Schuenke M, Schulte E, Schumacher U. THIEME Atlas of Anatomy, Vol 1. Illustrations by Voll M and Wesker K. 3rd ed. New York: Thieme Publishers; 2020.)

Incisura jugularis	Marks the superior border of the manubrium sterni
Angulus sterni	Marks the junction of manubrium and corpus sterni
Planum transpyloricum	Passes through the midpoint between the incisura jugularis and symphysis pubica
Planum subcostale	Marks the lowest level of the cavea thoracis, cartilago costalis X
Planum supracristale	Connects the top of the cristae iliacae
Planum intertuberculare	Passes through the tubercula iliaca
Planum interspinale	Connects the cristae iliacae anterior superior

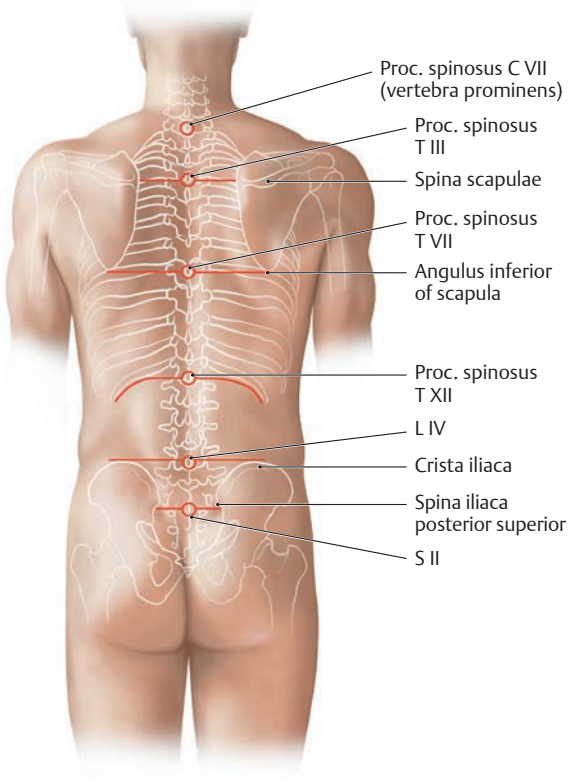


Table 1.6 Vertebral Spinous Processes and Posterior Landmarks
(From Schuenke M, Schulte E, Schumacher U. THIEME Atlas of Anatomy, Vol 1. Illustrations by Voll M and Wesker K. 3rd ed. New York: Thieme Publishers; 2020.)

C VII	Vertebra prominens
T III	Level of the medial edge of spinae scapulae
T VII	Level of the anguli inferiores scapulae
T XII	Level of the lower limit of cavitas thoracis
L IV	Level of the cristae iliacae
S II	Level of the spinae iliacae posteriores superiores

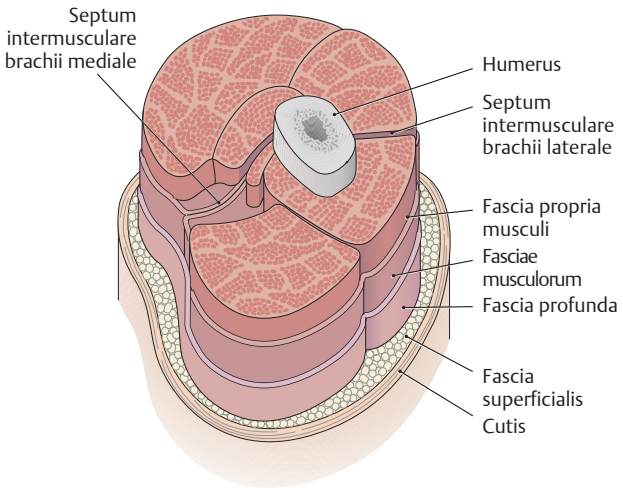


Fig. 1.4 Fascia
Cross section through the brachium dexter, proximal view. (From Schuenke M, Schulte E, Schumacher U. THIEME Atlas of Anatomy, Vol 1. Illustrations by Voll M and Wesker K. 3rd ed. New York: Thieme Publishers; 2020.)

1.4 Connective and Supporting Tissues

— Connective tissue comprises a variety of forms that are found throughout the body. Its common characteristic is a predominance of extracellular material made up largely of fibrous proteins and an amorphous ground substance and widely spaced cells that may include adipocytes, fibroblasts, and mesenchymal stem cells as well as macrophages and lymphocytes. Bone and cartilage are specialized types of connective tissue.
— The classification of connective tissue types is based on the degree to which the fibrous components are organized.
  - Irregular types include
    - Loose, or areolar, connective tissue, which is widely distributed around vessels and nerves and within organs, where it binds lobes and groups of muscle fascicles. It provides support while allowing movement of structures.
    - Dense connective tissue, which supports structures under mechanical stress. It ensheathes muscles and nerves and forms the capsules of organs such as the testis.
    - Adipose tissue, or fat, which is found in specialized areas such as the subcutaneous tissue of the skin, the female breast (mamma), and padding on the soles of the feet and in the renal bed surrounding the kidneys (renes).
  - Regular connective tissue, which is largely fibrous but may also contain elastin fibers, makes up the tendons, ligaments, and aponeuroses as well as fascial layers that enclose muscles and underlie the skin.
— Fascia is a general term that has been redefined in recent years to describe any easily discernable connective tissue sheet or sheath. The most common usages pertain to the connective tissue layers between the skin and muscle, formerly known as the fasciae superficialis and fasciae profunda. New terminology refers to these layers as the **subcutaneous connective tissue** with two layers (**Fig. 1.4**):
  - A **fatty layer** of varying thickness that lies deep to the skin, composed of loose connective tissue and fat, traversed by superficial nerves and vessels.
  - A **membranous layer** of dense connective tissue layer that lies under (deep to) the fatty layer and is devoid of fat. It forms an investing layer, which envelops neurovascular structures and muscles of the limbs, trunk wall, head, and neck. Invaginations of this layer form intermuscular septa that compartmentalize limb musculature into functional groups.

1.5 The Integumentary System

The skin (integument), the largest organ of the body, protects underlying tissue from biologic, mechanical, and chemical injury; regulates body temperature; and participates in metabolic processes, such as the synthesis of vitamin D.
— The skin is composed of
  - an outer waterproof avascular layer, the **epidermis,** which has a superficial layer of keratinized cells that shed continuously and a deep basal layer of regenerating cells, and
  - an inner richly vascularized and innervated layer, the **dermis,** which supports the epidermis and contains hair follicles.

1.6 The Skeletal System

The bones and cartilages of the body, which make up the skeletal system, provide leverage for muscles and protect the internal organs. Bone is also the site for calcium storage and blood cell production.

— There are two anatomic divisions of the skeleton **(Fig. 1.5)**:
  - The **axial skeleton,** which consists of the skull, vertebrae, os sacrum, os coccygis, ribs (costae), and sternum
  - The **appendicular skeleton,** which includes the clavicle and scapula of the pectoral girdle, the coxal bones of the pelvic girdle, and the bones of the upper and lower limbs

— **Periosteum** is a thin layer of fibrous connective tissue that coats the outer surface of each bone **(Fig. 1.6)**. **Perichondrium** forms a similar layer around cartilaginous structures. These tissues nourish and assist in the healing of the underlying bone.

— All bones have a superficial layer of dense **compact** (cortical) **bone** that surrounds a less dense **cancellous** (spongy) **bone.** In some areas of the bone, a **medullary cavity** contains yellow (fatty) or red (blood cell or platelet-forming) **bone marrow.**

— Bones develop from **mesenchyme** (embryonic connective tissue) through two processes of ossification (bone formation).

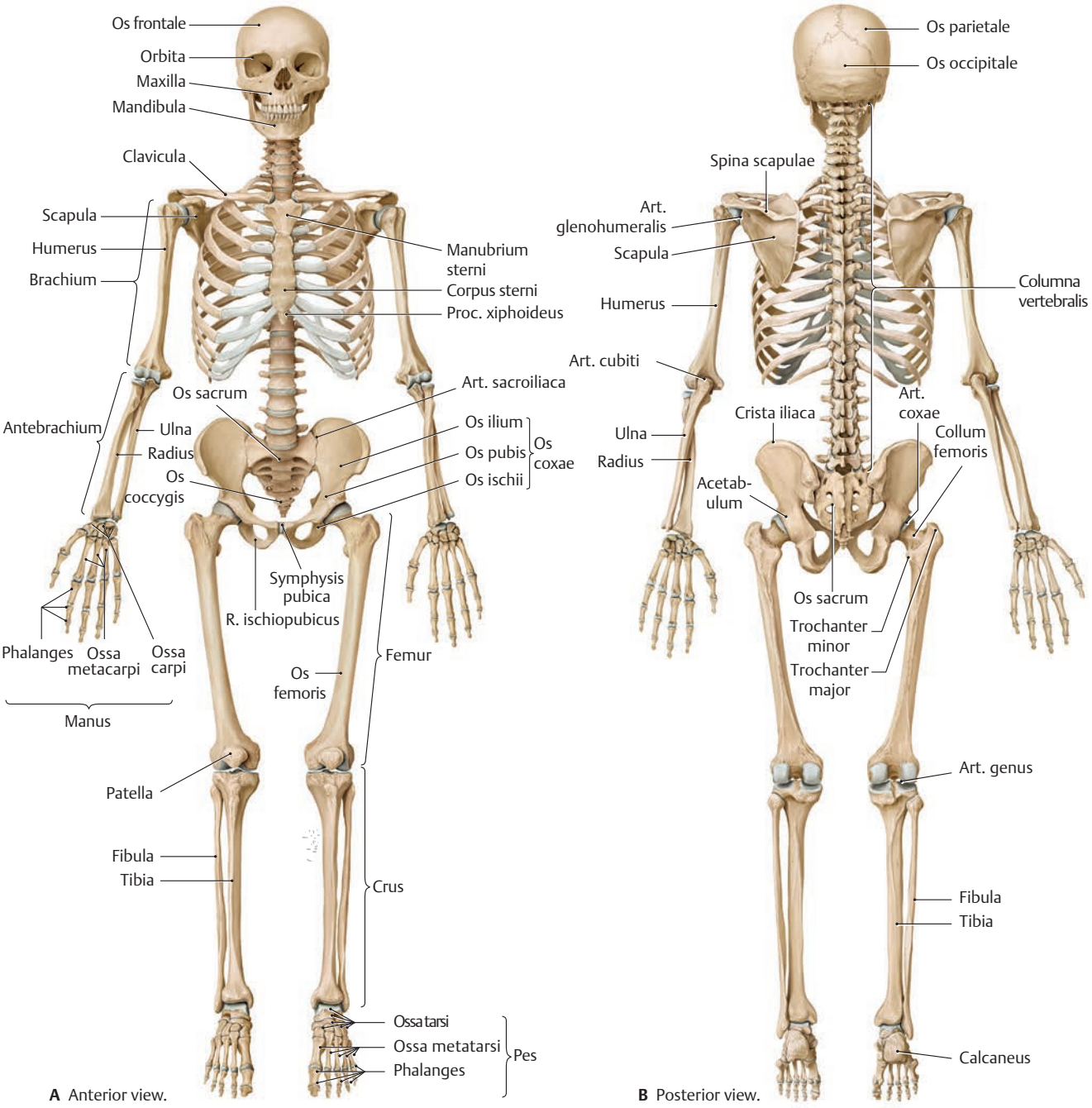


Fig. 1.5 Human skeleton
Left forearm is pronated, and both feet are in plantarflexion. (From Schuenke M, Schulte E, Schumacher U. THIEME Atlas of Anatomy, Vol 1. Illustrations by Voll M and Wesker K. 3rd ed. New York: Thieme Publishers; 2020.)

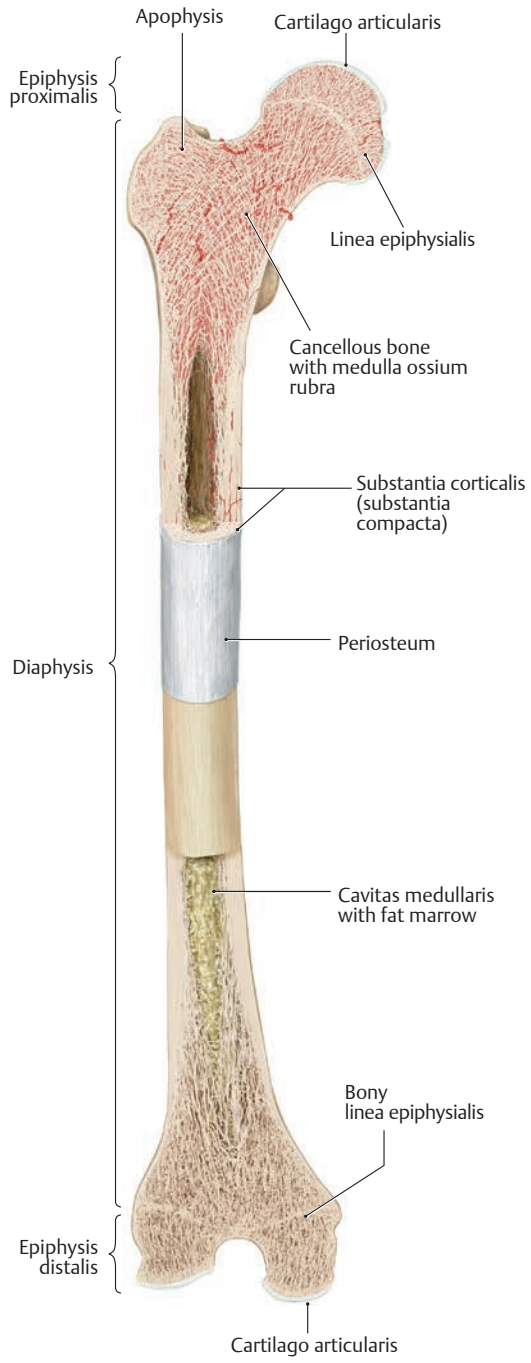


Fig. 1.6 Structure of a typical long bone
Illustrated for the femur. Coronal cuts through the proximal and distal parts of an adult femur. (From Schuenke M, Schulte E, Schumacher U. THIEME Atlas of Anatomy, Vol 1. Illustrations by Voll M and Wesker K. 3rd ed. New York: Thieme Publishers; 2020.)

- The clavicle and some bones of the skull develop by **membranous ossification,** in which the bones form through direct ossification of mesenchymal templates that are set down during the embryonic period.
- Most bones, including the long bones of the limbs, develop by **endochondral ossification,** in which a cartilaginous template, formed from mesenchyme, is laid down during the fetal period. Over the first and second decades of life, bone replaces most of the cartilage.
  - Within each bone undergoing endochondral ossification, bone formation occurs first at a **primary ossification center,** which is in the **diaphysis** (shaft) of the long bones. **Secondary ossification centers** appear later at the **epiphyses** (growing ends) of the bones.

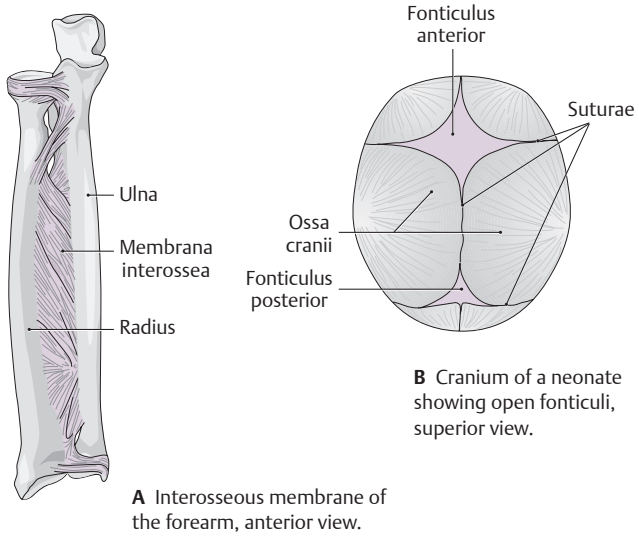
— Long bones of the skeleton increase in length through growth of the epiphyses and diaphysis on either side of the **lamina epiphysialis,** an intervening cartilaginous area. During childhood and adolescence the laminae epiphysiales gradually shorten as they are replaced by bone. In the adult these areas are completely ossified, and only thin **linea epiphysialis** remain.

— **Apophyses,** bony outgrowths that lack their own growth center, serve as attachment sites for ligaments or tendons. Specific apophyses are referred to as condyles, tubercles, spines, crests, trochanters, or processes.

— **Ligaments** are connective tissue bands that connect bones to each other or to cartilage. (Within the body cavities, the term *ligament* refers to folds or condensations of a serous or fibrous membrane that support visceral structures.)

— Joints are classified according to the type of tissue that connects the bones.

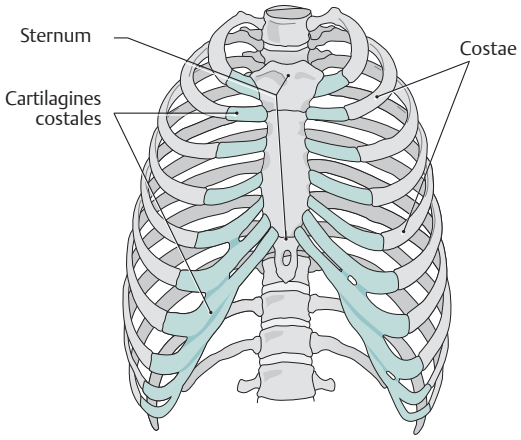
- **Syndesmoses** (fibrous joints), such as those found in the sutures of the skull and interosseous membrane of the forearm, are united by fibrous tissue and allow minimal movement **(Fig. 1.7)**.
- **Synchondroses** (cartilaginous joints) are united either by fibrocartilaginous segments, such as the cartilago costalis of costae, disci intervertebrales, and symphysis pubica **(Fig. 1.8A,B)**, or by cartilago articularis, often found in



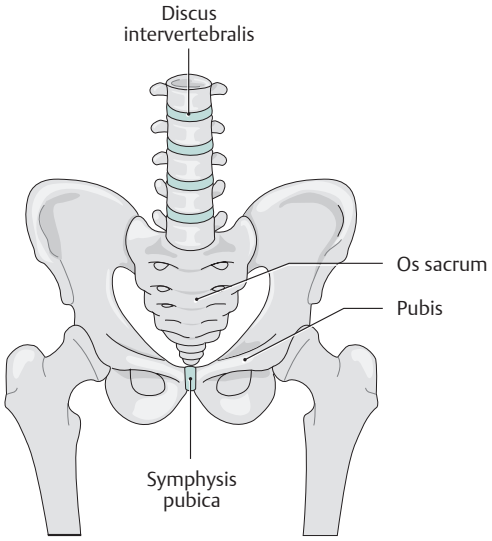
A Interosseous membrane of the forearm, anterior view.

B Cranium of a neonate showing open fonticuli, superior view.

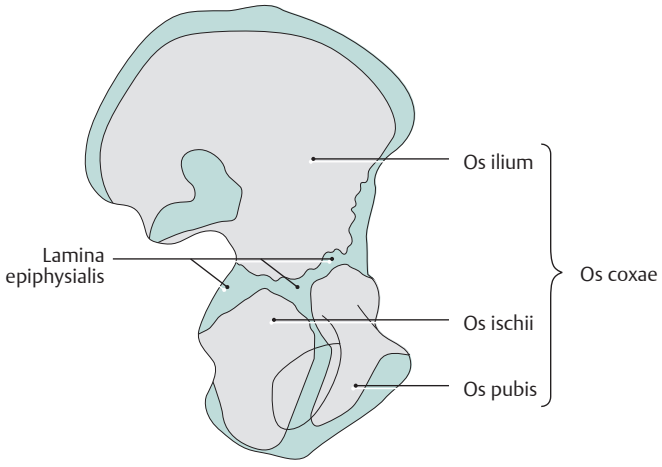
Fig. 1.7 Syndesmoses
(From Schuenke M, Schulte E, Schumacher U. THIEME Atlas of Anatomy, Vol 1. Illustrations by Voll M and Wesker K. 3rd ed. New York: Thieme Publishers; 2020.)



A Cartilago costalis.



B Symphysis pubica and disci intervertebrales.



C Os coxae before closure of laminae epiphysiales.

Fig. 1.8 Synchondroses
(From Schuenke M, Schulte E, Schumacher U. THIEME Atlas of Anatomy, Vol 1. Illustrations by Voll M and Wesker K. 3rd ed. New York: Thieme Publishers; 2020.)

temporary joints, such as those that join the ilium, ischium, and pubis of the hip bone **(Fig. 1.8C)**. Subsequent fusion of these temporary joints creates **synostoses** (sites of bony fusion) **(Fig. 1.9)**.

- **Synovial joints,** the most common type of joint, allow free movement **(Fig. 1.10)** and typically have
  - a **cavitas articularis** that is enclosed by a fibrous **capsula articularis** and lined by a **synovial membrane,** which secretes a thin film of lubricating **synovial fluid;**
  - articulating ends of the bones that are covered by cartilago epiphysialis; and
  - extrinsic ligaments on the outer surface, which reinforce the joints.
  - Some synovial joints also contain intrinsic ligaments and intra-articular fibrocartilaginous structures.

— **Bursae** are closed sacs that contain a thin film of fluid and are lined with a synovial membrane. Commonly found around joints of the limbs, bursae cushion prominent bony processes from external pressure and prevent friction where tendons cross bony surfaces.

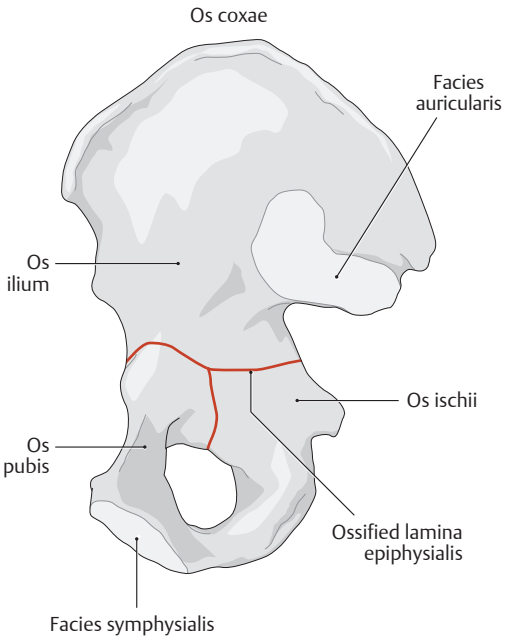
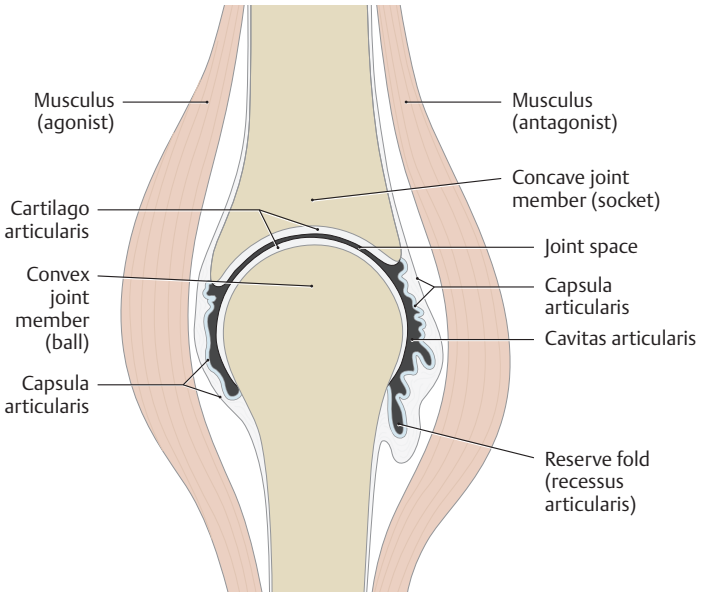
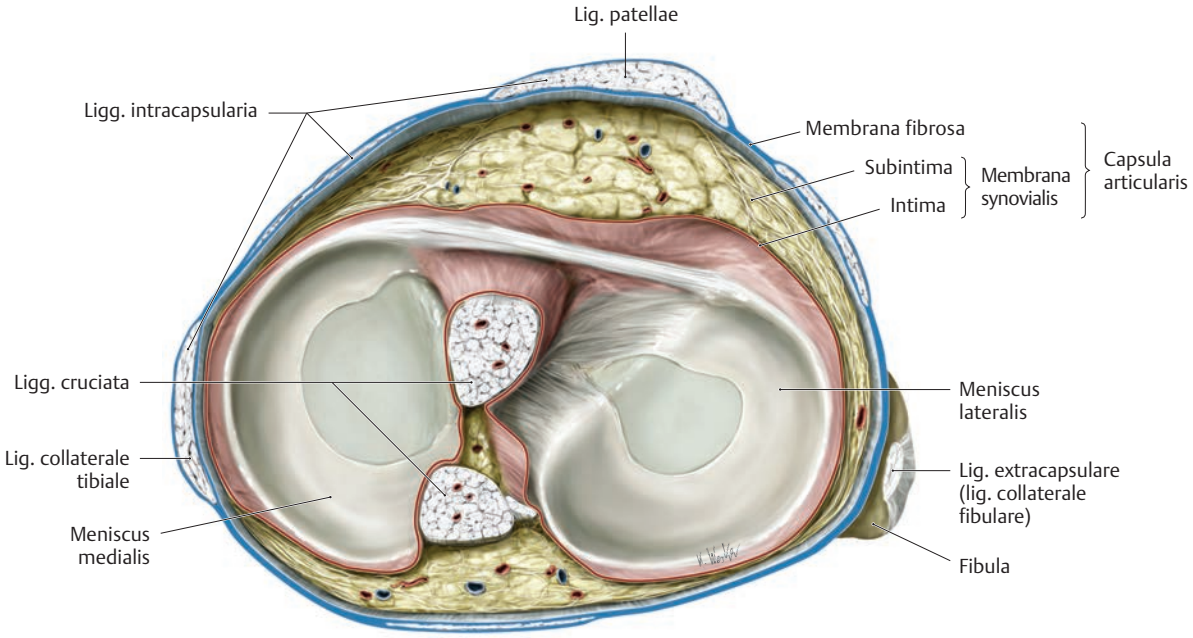


Fig. 1.9 Synostoses
Os coxae (fusion of ischium, ilium, and pubis). (From Schuenke M, Schulte E, Schumacher U. THIEME Atlas of Anatomy, Vol 1. Illustrations by Voll M and Wesker K. 3rd ed. New York: Thieme Publishers; 2020.)



A Schematic.



B Intracapsular structures of the art. genus.

Fig. 1.10 Structure of a synovial joint
(From Schuenke M, Schulte E, Schumacher U. THIEME Atlas of Anatomy, Vol 1. Illustrations by Voll M and Wesker K. 3rd ed. New York: Thieme Publishers; 2020.)

BOX 1.1: ANATOMIC NOTES

EXTRA-ARTICULAR AND INTRA-ARTICULAR STRUCTURES OF SYNOVIAL JOINTS (SEE FIG. 1.10)

The joint capsule of a synovial joint is composed of an outer fibrous membrane and an inner synovial membrane. The intima (innermost lining) of the synovial membrane produces the synovial fluid, which lubricates and nourishes intra-articular structures.

— Ligaments of synovial joints act as primary joint stabilizers. They may be:
  - Extra-capsular (e.g., lig. collaterale fibulare of the knee), which lie outside the fibrous capsule.
  - Intra-capsular, which run either within the fibrous membrane (e.g., lig. collaterale tibiale of the art. genus) or between the fibrous and synovial membranes (e.g., ligg. cruciata).

— Menisci, articular disks, and articular labra are intra-articular structures composed of connective tissue and fibrocartilage:
  - Menisci are crescent-shaped structures found in the art. genus. They act as shock absorbers and modify the incongruity of the articulating surfaces.
  - Articular disks divide joints into separate chambers and are found in the artt. sternoclavicularis and radiocarpea.
  - Articular labra are wedge-shaped structures that line the glenoid of the scapula and acetabulum of the os coxae, thus enlarging the articular surfaces of the shoulder and hip joints.

1.7 The Muscular System

The muscular system is composed of muscles and their tendons, which produce movement through contraction of muscle cells.

- **Muscle cells** are the structural units of the muscular system. Connective tissue binds muscle cells (fibers) together to form bundles, which in turn are bound together to form muscles **(Fig. 1.11)**.
- A **motor unit** is the functional unit of muscles and describes the group of muscle fibers innervated by a single motor neuron. Motor units are relatively small in muscles that perform fine movements but larger in muscles that are responsible for maintaining posture or performing gross movements.
- Muscles function through tensing and contraction of the muscle fibers, which provide movement and stability
  - **Phasic contractions** can change the length of the muscle through shortening **(concentric contractions)**, or lengthening **(eccentric contractions)**, or simply increasing the muscle tension **(isometric contractions)**.
  - **Tonic contractions** contribute to stability of joints and position but do not provide any movements.
  - **Reflexive contractions** are involuntary and are responsive to muscle stretch.
- Muscle tissue is classified by location (somatic or visceral), appearance (striated or nonstriated), and innervation (voluntary or involuntary).
- **Somatic**, or **skeletal muscles**, the most prevalent type, are found in the neck, trunk wall, and limbs, where they move and support the skeleton **(Fig. 1.12)**. They are multinucleated, striated, and voluntary.
  - Somatic muscle fibers are interwoven with three sheaths of connective tissue including the **endomysium**, the innermost sheath, which surrounds and condenses muscle fibers into primary bundles; the **perimysium,** which surrounds and condenses primary bundles into secondary bundles; and the **epimysium**, a loose connective tissue layer that surrounds the muscle and lies deep to the muscle fascia.
  - **Muscle fascia** is the tough connective tissue sheath that encloses the muscle, maintains its shape, and allows frictionless movement between muscles and muscle groups.
  - **Tendons**, dense fibrous bands, connect muscles to their bony attachments. **Aponeuroses** are tendons that form flat sheets, which attach the muscle to the skeleton, other muscles, or organs.
  - Muscles shapes are described according to the arrangement of the muscle fibers as pennate (uni-, bi-, multi-), fusiform, circular, convergent, or parallel.
  - **Tendon (synovial) sheaths**, such as those found in the wrist and ankle, facilitate the movement of tendons over bone. Similar to a capsula articularis, they are composed of an outer vagina fibrosa lined with a two-layered synovial membrane. The space between the synovial layers is filled with synovial fluid.
- **Visceral muscles,** considered involuntary**,** alter the shape of internal structures, such as the heart (cor) and gastrointestinal tract. There are two types:
  - **Cardiac muscle**, which makes up the thick muscular layer (myocardium) of the heart, is striated.
  - **Smooth muscle,** which is found in the walls of blood vessels and hollow internal organs, is nonstriated.

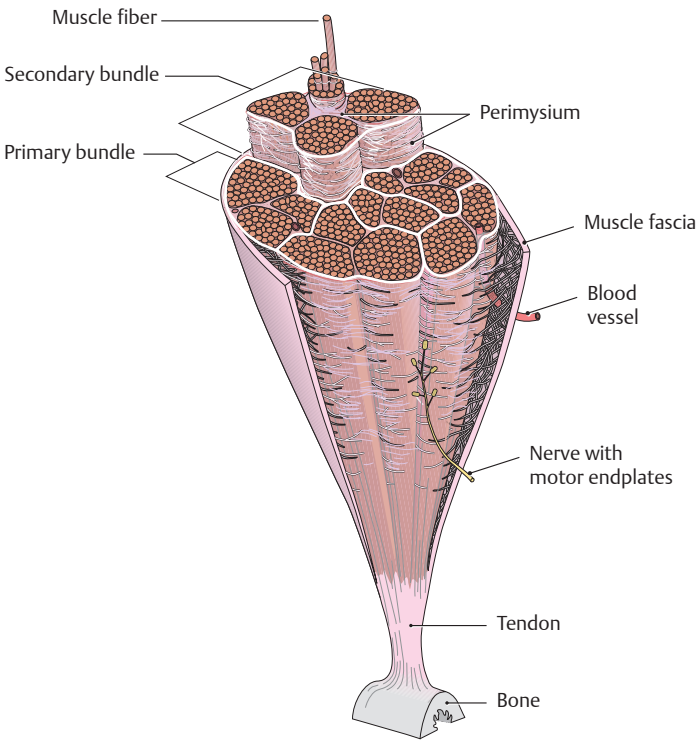


Fig. 1.11 Structure of a skeletal muscle
Cross section through a skeletal muscle. (From Schuenke M, Schulte E, Schumacher U. THIEME Atlas of Anatomy, Vol 1. Illustrations by Voll M and Wesker K. 3rd ed. New York: Thieme Publishers; 2020.)