ВОЛГОГРАДСКИЙ ГОСУДАРСТВЕННЫЙ МЕДИЦИНСКИЙ УНИВЕРСИТЕТ

The introduction in clinical anatomy.

(Educational manual)

Department of operative surgery and topographic anatomy, VSMU

O.D. Chulkov, A.S. Mazunov, E.E. Pisareva, E.A. Barinova

There are three main approaches to studying human gross anatomy:

- **regional**
- **systemic**
- **clinical (applied).**

The main approaches

- **Systemic anatomy** is an approach to anatomical study organized by *organ systems* that work together to carry out complex functions. None of the organ systems functions in isolation. For example, much of the skeletal, articular, and muscular systems constitute the *locomotor system*. And although the structures directly responsible for locomotion are the muscles, bones, joints, and ligaments, other systems are involved as well. The arteries and veins of the circulatory system supply oxygen to them and remove waste from them,and the nerves of the nervous system stimulate them to act.

The main approaches

- **Regional anatomy** is based on the organization of the body into parts: head, neck, trunk (further subdivided into thorax, abdomen, pelvis/perineum, and back), and paired upper and lower limbs. Emphasis is placed on the relationships of various systemic structures (e.g., muscles, nerves, and arteries) within the region. Each region is not an isolated part and must be put into the context of adjacent regions and of the body as a whole.

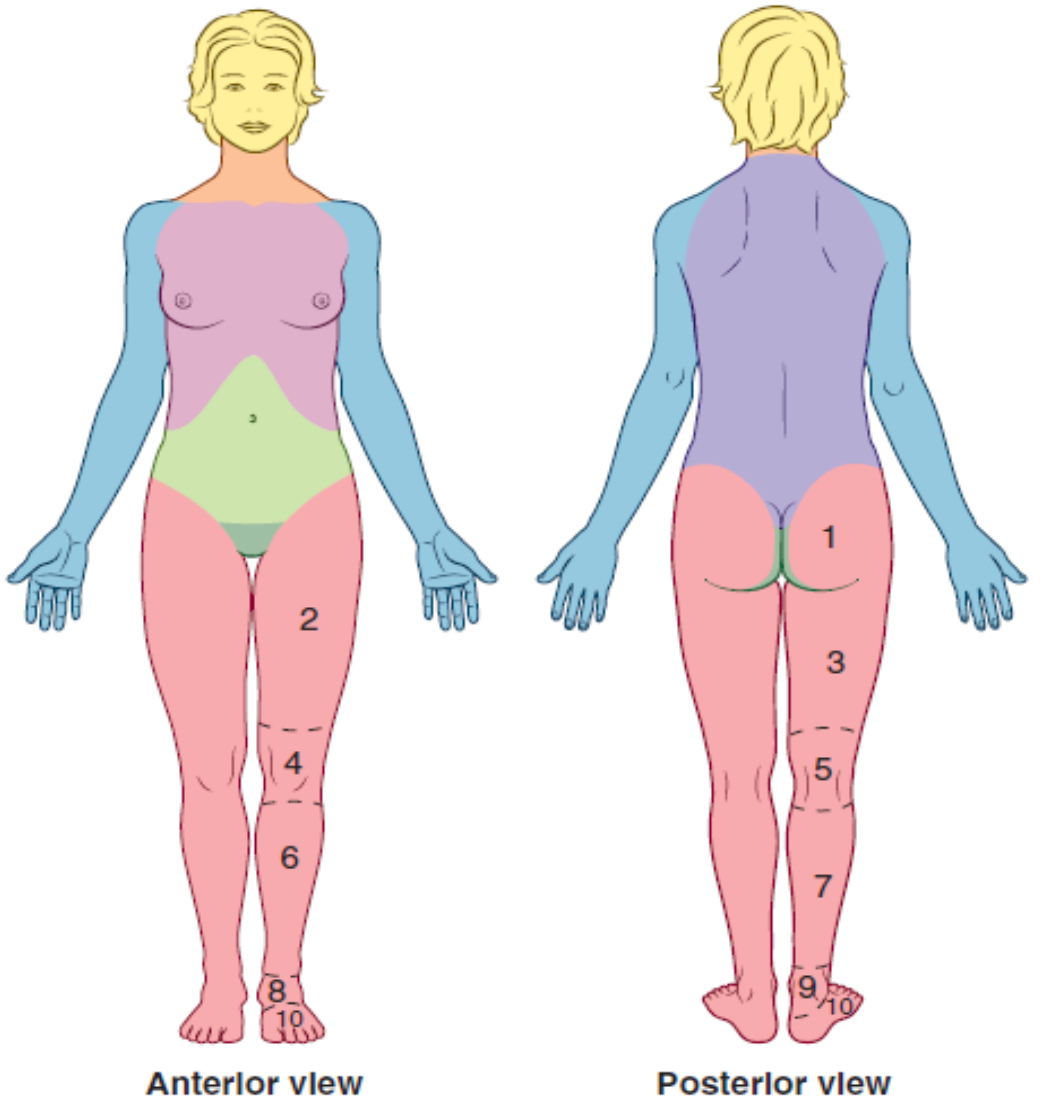
The main approaches

- **Surface anatomy** is an essential part of the regional approach, providing a knowledge of what structures are visible and/or palpable (perceptible to touch) in the living body at rest and in action. The physical examination of patients is the clinical extension of surface anatomy. In people with stab wounds, for example, the healthcare worker must be able to visualize the deep structures that might be injured.

Regions of lower limb

1 = Gluteal region	6 = Anterior leg region
2 = Anterior thigh region	7 = Posterior leg region
3 = Posterior thigh region	8 = Anterior talocrural (ankle) region
4 = Anterior knee region	9 = Posterior talocrural region
5 = Posterior knee region	10 = Foot region

The divisions and subdivisions of human body



Brief descriptions of the systems of the body and their fields of study (in parentheses) follow:

- *Integumentary system* (dermatology): consists of the skin (integument) and its appendages, such as the hair and nails. The skin, an extensive sensory organ, forms a protective covering for the body.
- *Skeletal system* (osteology, orthopedics): consists of bones and cartilage. It provides support for the body and protects vital organs. The muscular system acts on the skeletal system to produce movements.

- *Articular system* (arthrology): consists of joints and their associated ligaments. It connects the bony parts of the skeletal system and provides the sites at which movements occur.

- *Muscular system (myology):* consists of muscles that act (contract) to move or position parts of the body (e.g., the bones that articulate at joints)

• Nervous system (neurology): consists of the central nervous system (brain and spinal cord) and the peripheral *nervous system* (nerves and ganglia, together with their motor and sensory endings). The nervous system controls and coordinates the functions of the organ systems.

• *Circulatory system* (angiology): consists of the cardiovascular and lymphatic systems, which function in parallel to distribute fluids within the body

• *Cardiovascular system* (cardiology): consists of the heart and blood vessels that propel and conduct blood through the body

• *Lymphoid system*: consists of a network of lymphatic vessels that withdraws excess tissue fluid (lymph) from the body's interstitial (intercellular) fluid compartment, filters it through lymph nodes, and

• *Digestive* or *alimentary system* (gastroenterology): consists of the organs and glands associated with the ingestion, mastication (chewing), deglutition (swallowing), digestion, and absorption of food and the elimination of feces (solid wastes) after the nutrients have been absorbed

• *Respiratory system* (pulmonology): consists of the air passages and lungs that supply oxygen and eliminate carbon dioxide. The control of airflow through the system produces tone, which is further modified into speech

- *Urinary system (urology):* consists of the kidneys, ureters, urinary bladder, and urethra, which filter blood and subsequently produce, transport, store, and intermittently excrete liquid waste (urine)

- *Reproductive system (obstetrics and gynecology for females, andrology for males):* consists of the gonads (ovaries and testes) that produce oocytes (eggs) and sperms and the other genital organs concerned with reproduction

- *Endocrine system* (endocrinology): consists of discrete ductless glands (e.g., thyroid gland) as well as cells of the intestine and blood vessel walls and specialized nerve endings that secrete hormones. Hormones are distributed by the cardiovascular system to reach receptor organs in all parts of the body. These glands influence metabolism and coordinate and regulate other processes (e.g., the menstrual cycle).

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

Anatomical position

All anatomical descriptions are expressed in relation to the anatomical position to ensure that the descriptions are not ambiguous. The anatomical position refers to people—regardless of the actual position they may be in—as if they were standing erect, with their

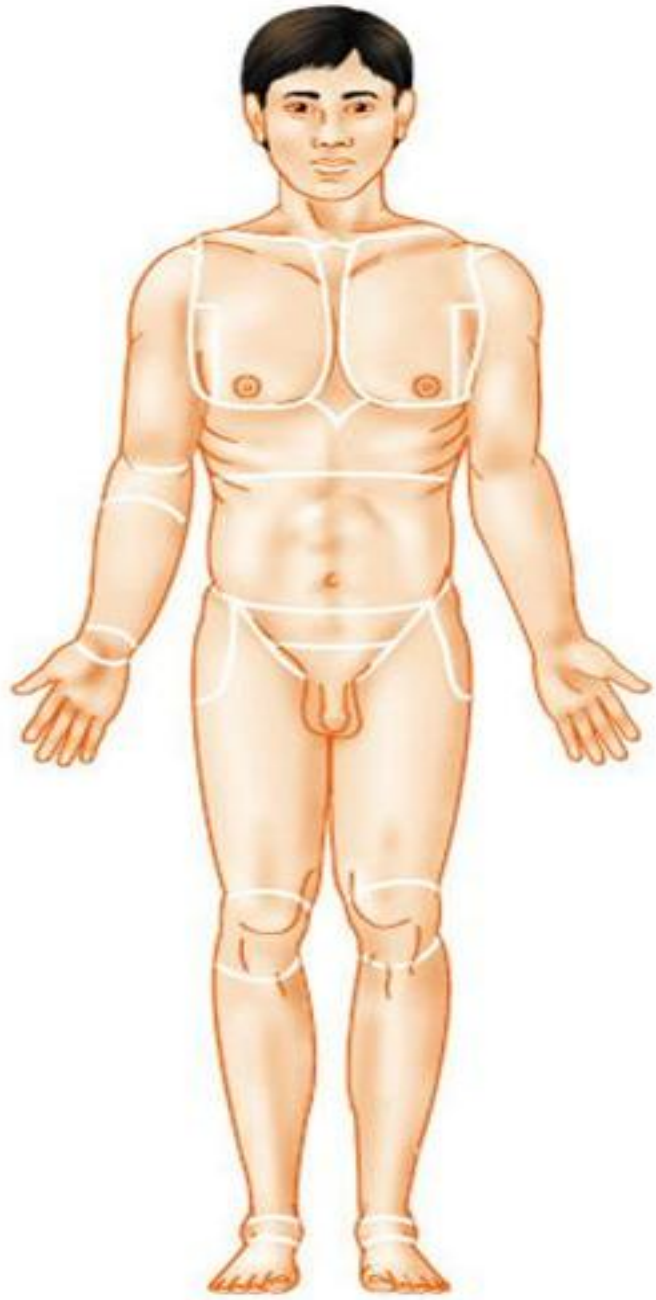
- Head, eyes (gaze), and toes directed anteriorly (forward)
- Upper limbs by the sides with the palms facing anteriorly
- Lower limbs close together with the feet parallel and the toes directed anteriorly

Anatomical Position

1. Body erect
2. Feet slightly apart
3. Palms facing forward
4. Thumbs point away from body
5. Similar to "standing at attention"

Supine – person laying down in anatomical position face up

Prone – face down

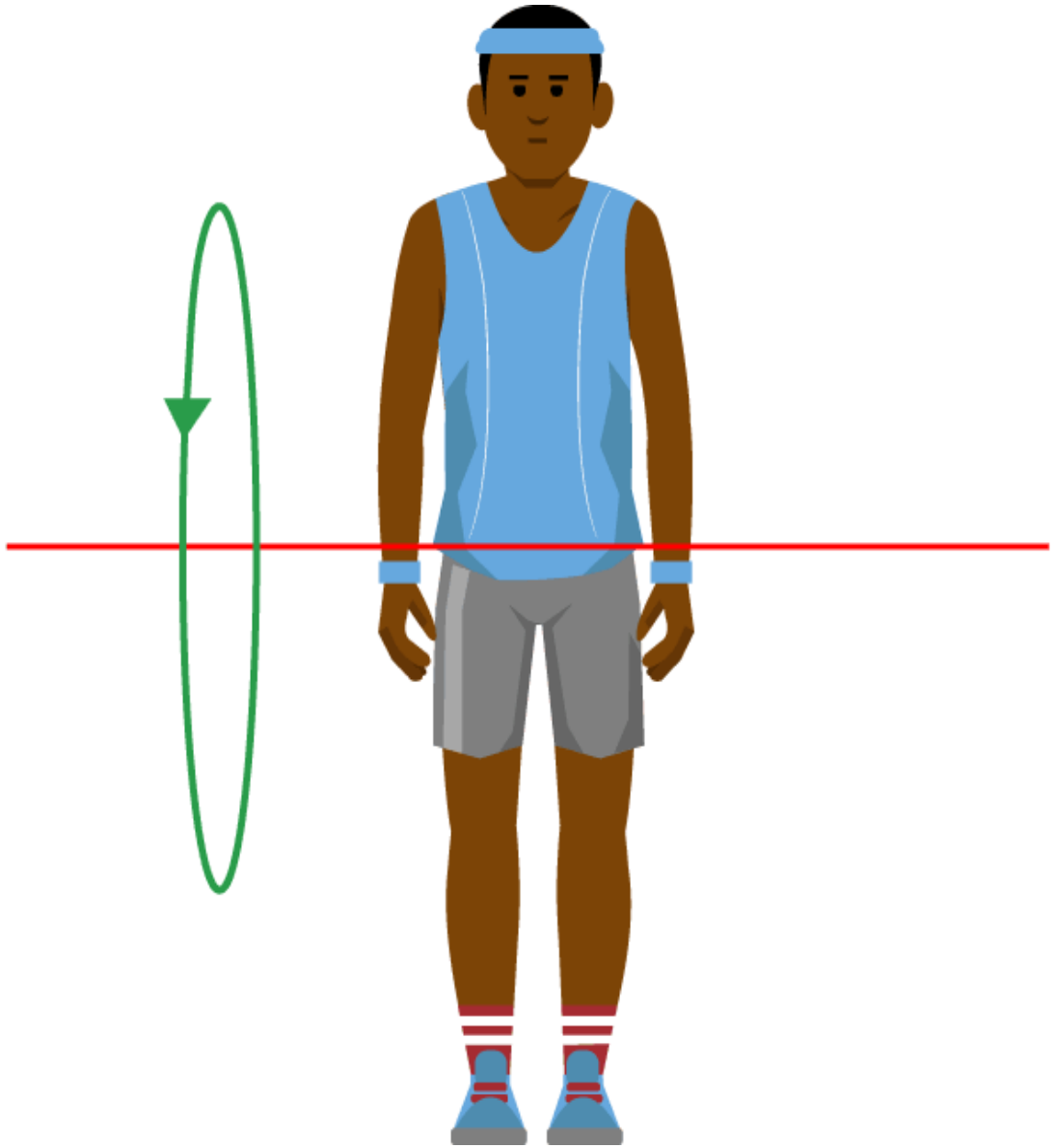


Axes of movement

- An axis is an imaginary line at right angles to the plane, about which the body rotates or spins.
- There are three axes of movement around which the body or body parts rotate:

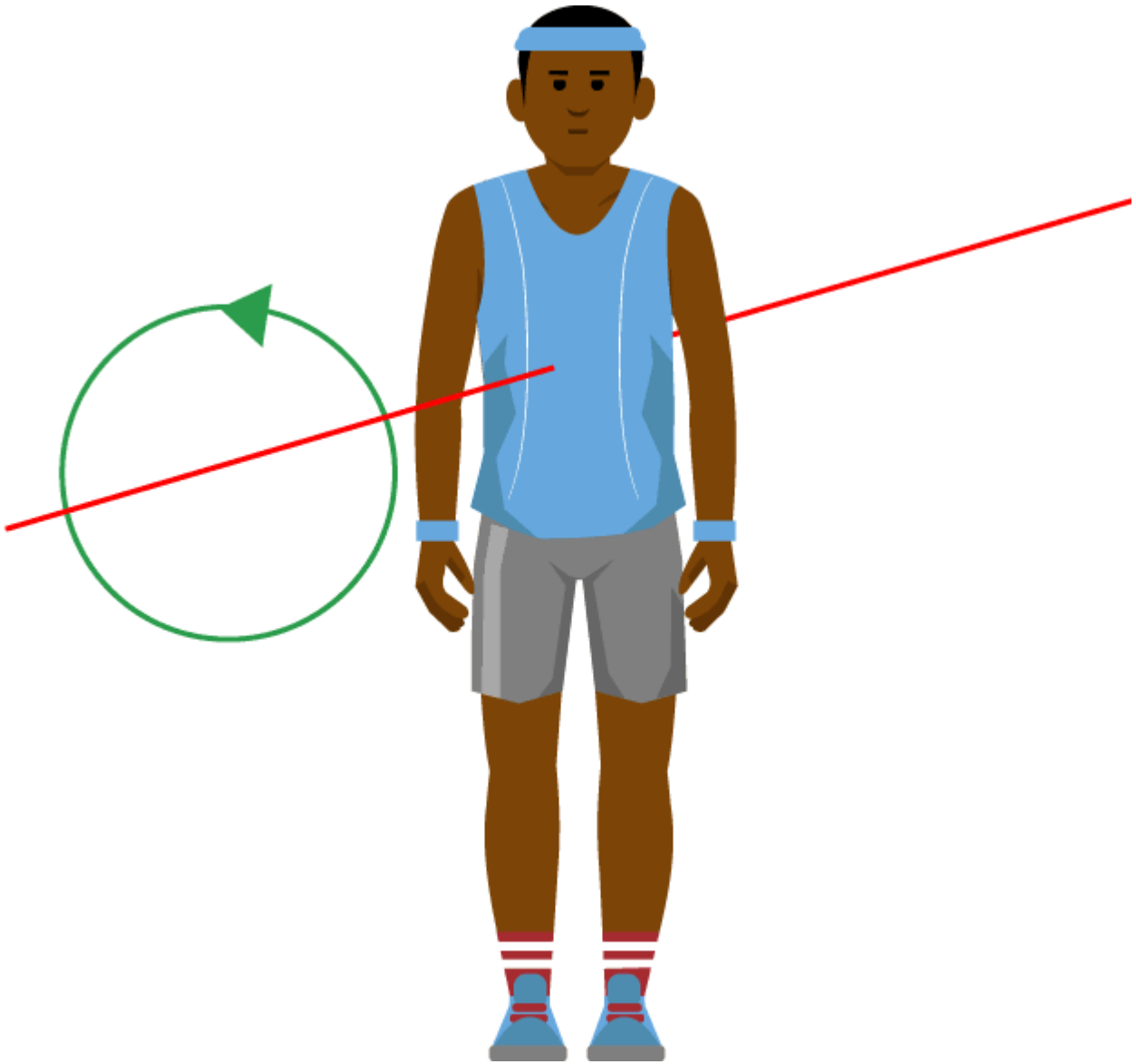
1. **Frontal axis** - this line runs from left to right through the center of the body. For example, when a person performs a somersault they rotate around this axis.
2. **Sagittal (also known as the antero-posterior) axis** - this line runs from front to back through the center of the body. For example, when a person performs a cartwheel they are rotating about the sagittal axis.
3. **Vertical axis** - this line runs from top to bottom through the center of the body. For example, when a skater performs a spin they are rotating around the vertical axis.

Axes of movement



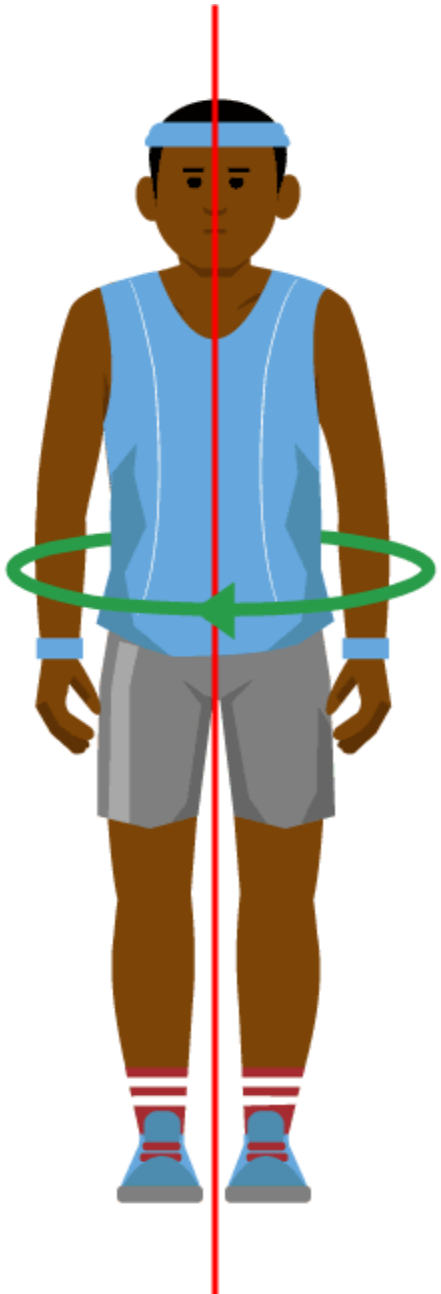
Frontal axis - this line runs from left to right through the center of the body. For example, when a person performs a somersault they rotate around this axis.

Axes of movement



Sagittal (also known as the antero-posterior) axis - this line runs from front to back through the center of the body. For example, when a person performs a cartwheel they are rotating about the sagittal axis.

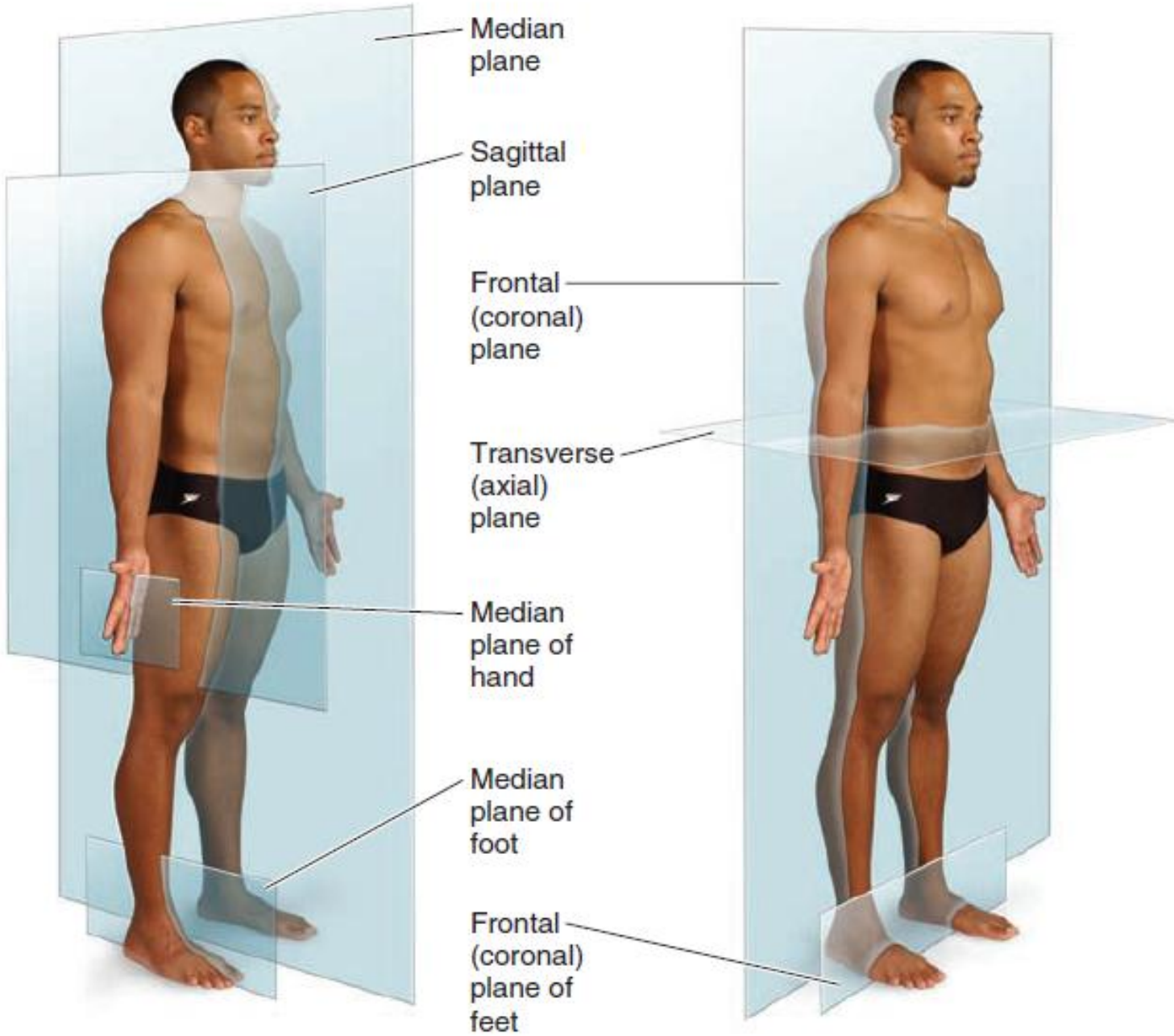
Axes of movement

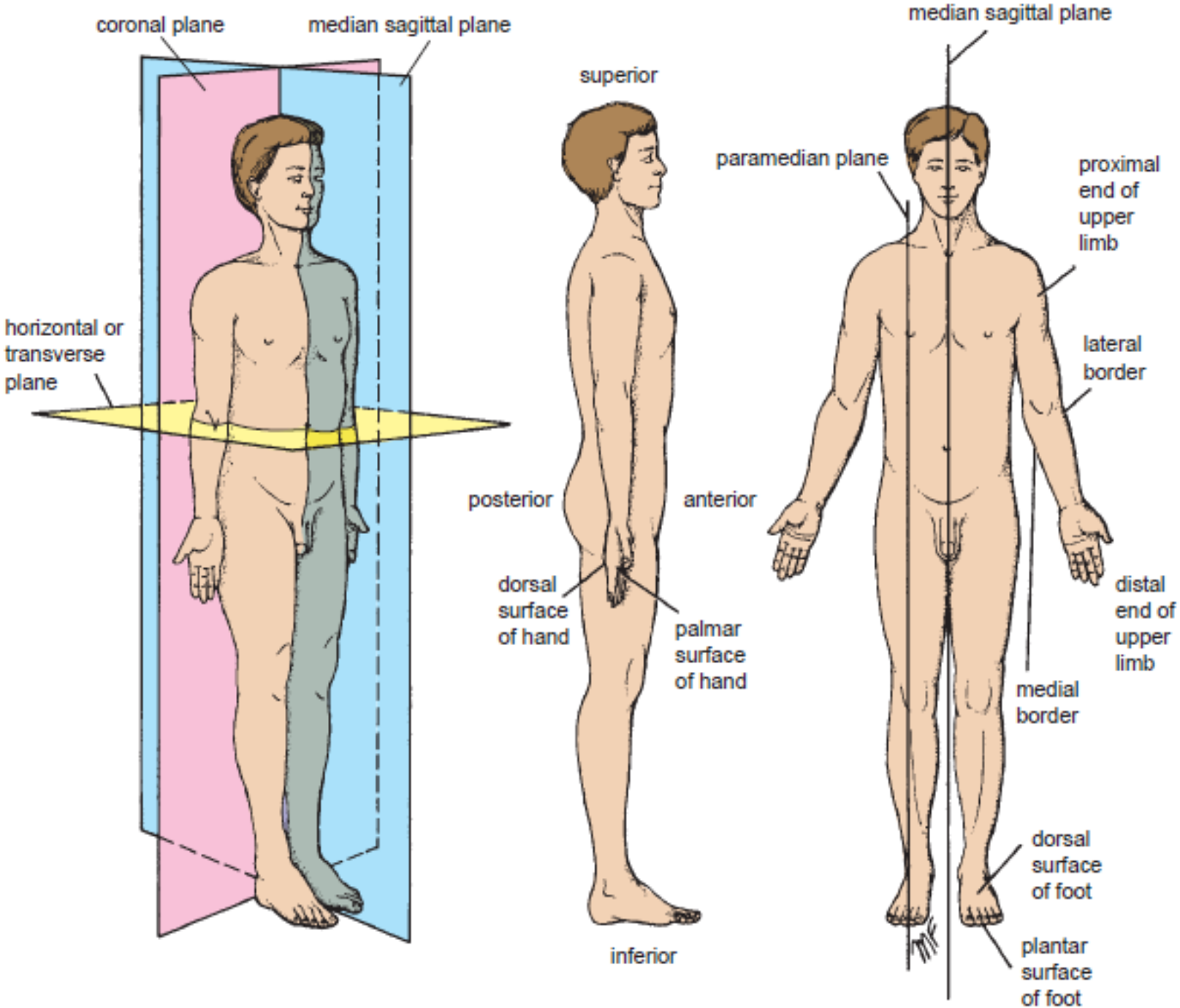


Vertical axis - this line runs from top to bottom through the center of the body. For example, when a skater performs a spin they are rotating around the vertical axis.

Anatomical planes

Anatomical descriptions are based on four imaginary planes that intersect the body in the anatomical position. There are many sagittal, frontal, and transverse planes, but there is only one median plane.


Median plane
Sagittal plane
Frontal (coronal) plane
Transverse (axial) plane
Median plane of hand
Median plane of foot
Frontal (coronal) plane of feet


coronal plane
median sagittal plane
horizontal or transverse plane
superior
posterior
anterior
dorsal surface of hand
palmar surface of hand
inferior
median sagittal plane
paramedian plane
proximal end of upper limb
lateral border
distal end of upper limb
medial border
dorsal surface of foot
plantar surface of foot

Anatomical planes

- **Median (median sagittal)** plane is the vertical plane passing longitudinally through the center of the body, dividing it into right and left halves.

Anatomical planes

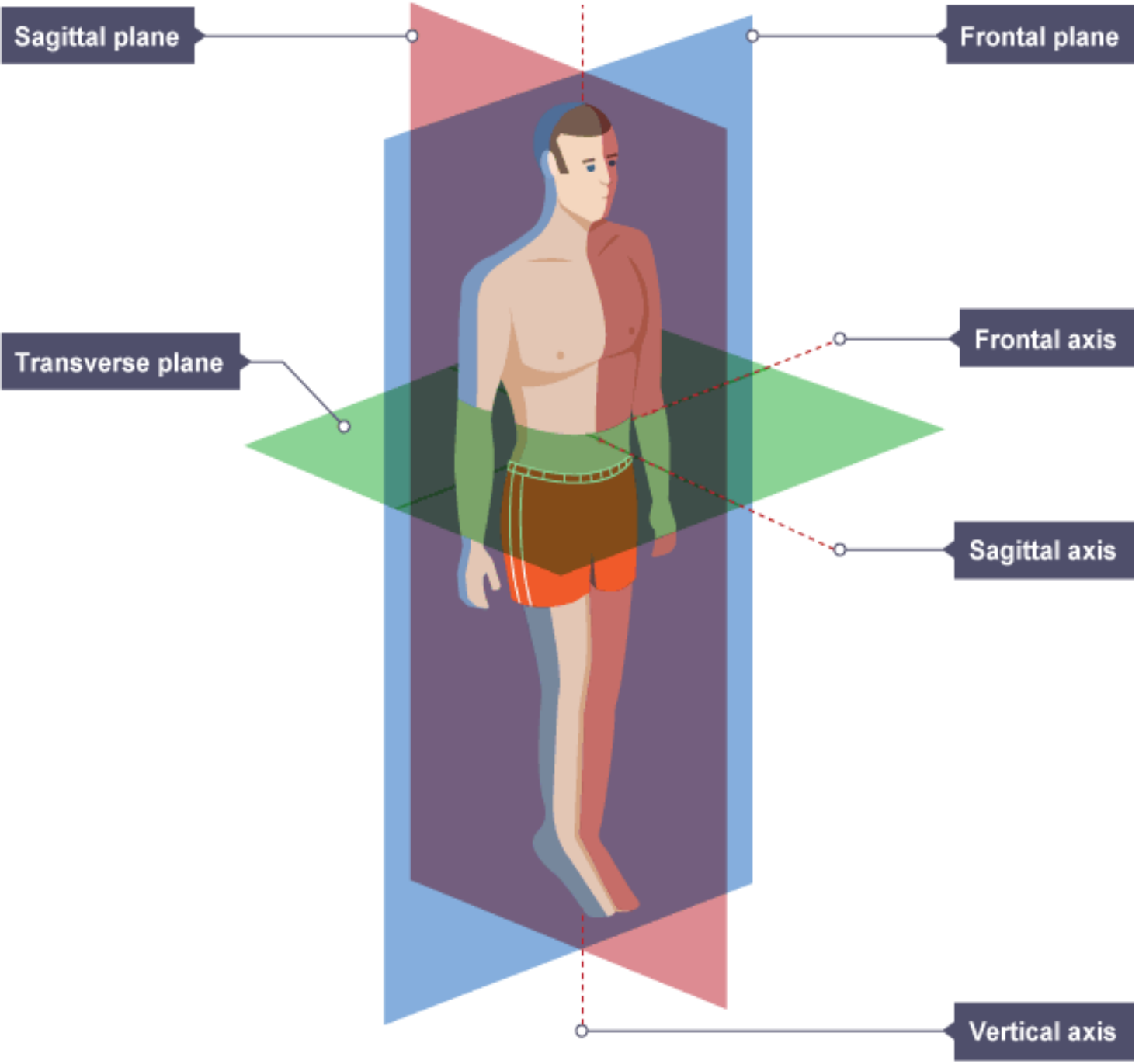
- **Sagittal planes** are vertical planes passing through the body parallel to the median plane. It is helpful to give a point of reference to indicate the position of a specific plane—for example, a sagittal plane through the midpoint of the clavicle. A plane parallel to and near the median plane may be referred to as a paramedian plane.

Anatomical planes

- **Frontal (coronal)** planes are vertical planes passing through the body at right angles to the median plane, dividing it into anterior (front) and posterior (back) portions—for example, a frontal plane through the heads of the mandible.

Anatomical planes

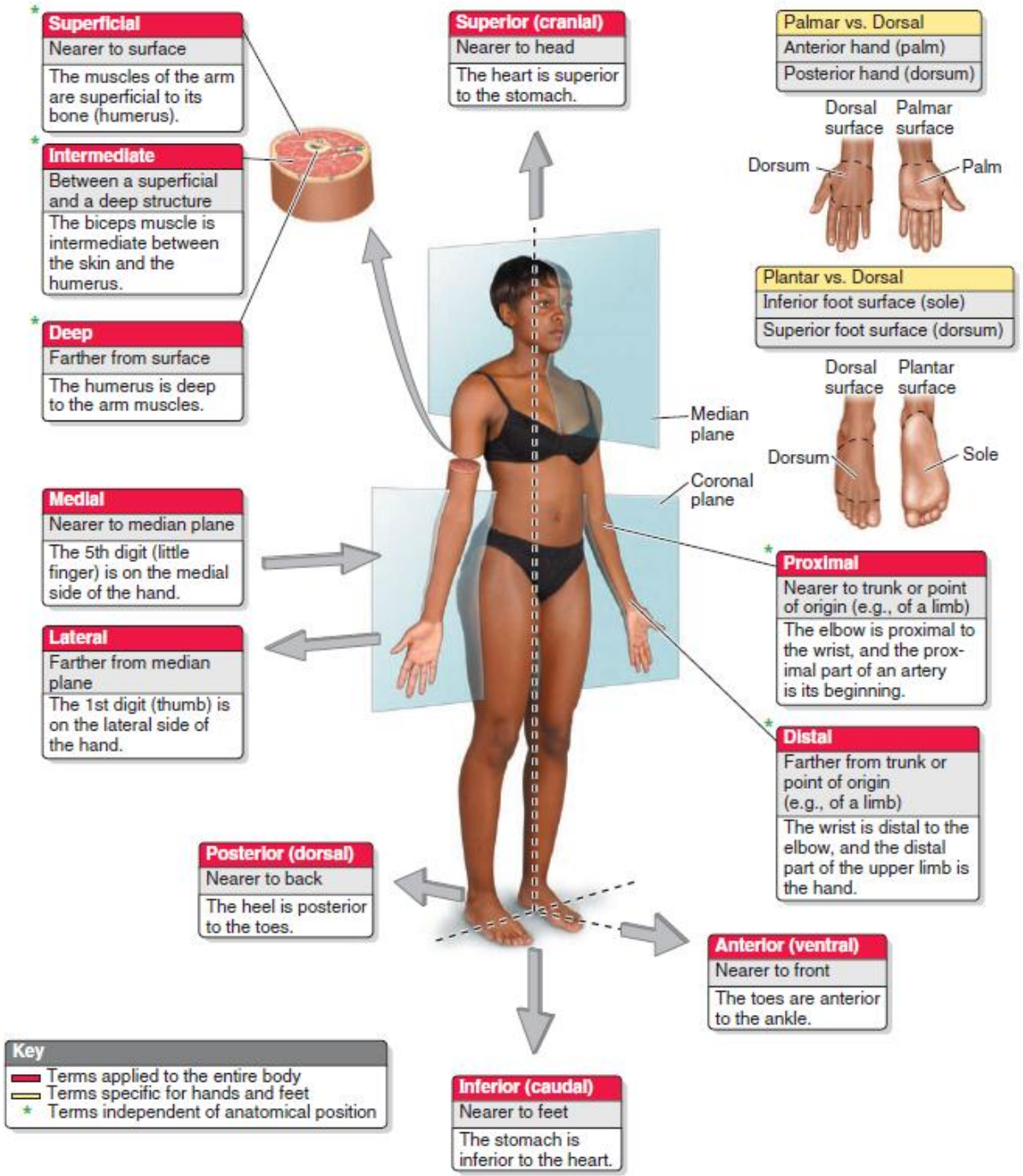
- **Transverse planes** are planes passing through the body *at right angles to the median and frontal planes*. A transverse plane divides the body into superior (upper) and inferior (lower) parts—for example, a transverse plane through the umbilicus. Radiologists refer to transverse planes as *transaxial planes* or simply *axial planes*.



Planes and axes of movement

Terms of relationship and comparison

Various adjectives, arranged as pairs of opposites, describe the relationship of parts of the body in the anatomical position and compare the position of two structures relative to each other.



Terms of relationship and comparison

Terms of relationship and comparison

For example, the eyes are superior to the nose, whereas the nose is inferior to the eyes.

Combined terms describe intermediate positional arrangements:

- **Inferomedial** means nearer to the feet and closer to the median plane—for example, the anterior parts of the ribs run inferomedially.
- **Superolateral** means nearer to the head and farther from the median plane.

Terms of relationship and comparison

Proximal and distal are directional terms used when describing positions—for example, whether structures are nearer to the trunk or point of origin (i.e., proximal). Dorsum refers to the superior or dorsal (back) surface of any part that protrudes anteriorly from the body, such as the dorsum of the foot, hand, penis, or tongue. It is easier to understand why these surfaces are considered dorsal if one thinks of a quadrupedal plantigrade animal that walks on its soles, such as a dog.

Terms of relationship and comparison

The sole indicates the inferior aspect or bottom of the foot, much of which is in contact with the ground when standing barefoot. The palm refers to the flat anterior aspect of the hand, excluding the five digits, and is the opposite of the dorsum of the hand.

Terms of laterality

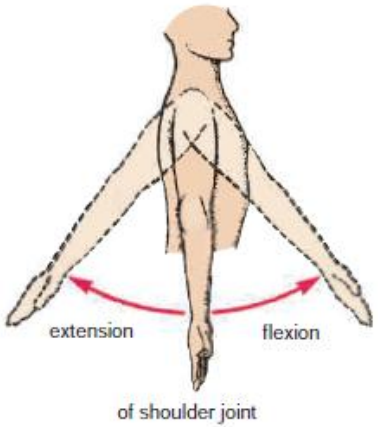
Paired structures having right and left members (e.g., the kidneys) are **bilateral**, whereas those occurring on one side only (e.g., the spleen) are **unilateral**. **Ipsilateral** means occurring on the same side of the body; the right thumb and right great toe are ipsilateral, for example. **Contralateral** means occurring on the opposite side of the body; the right hand is contralateral to the left hand.

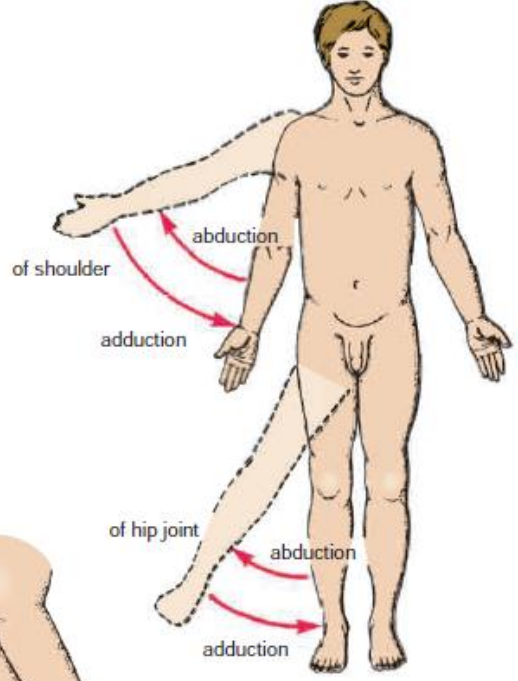
Terms of movement

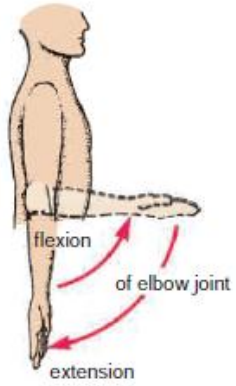
Various terms describe movements of the limbs and other parts of the body. Although most movements take place at joints where two or more bones or cartilages articulate with one another, several nonskeletal structures exhibit movement (e.g., tongue, lips, and eyelids).

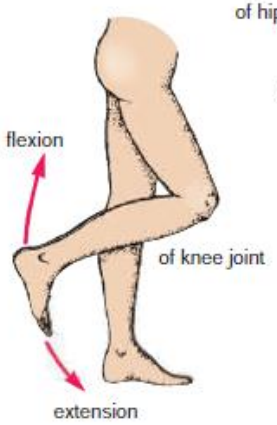
Terms of movement

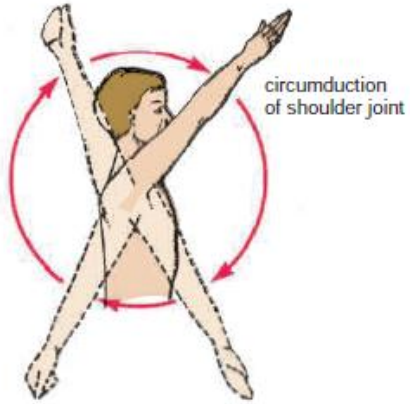
Movements taking place at joints are described relative to the axes around which the part of the body moves and the plane in which the movement takes place—for example, flexion and extension of the shoulder take place in the sagittal plane around a frontal (coronal) axis.

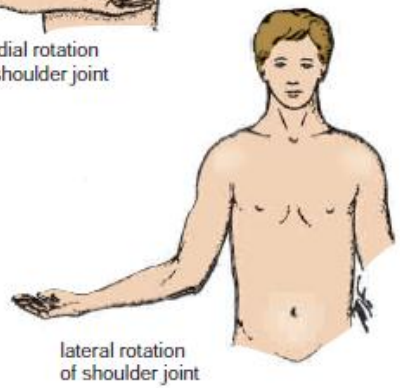






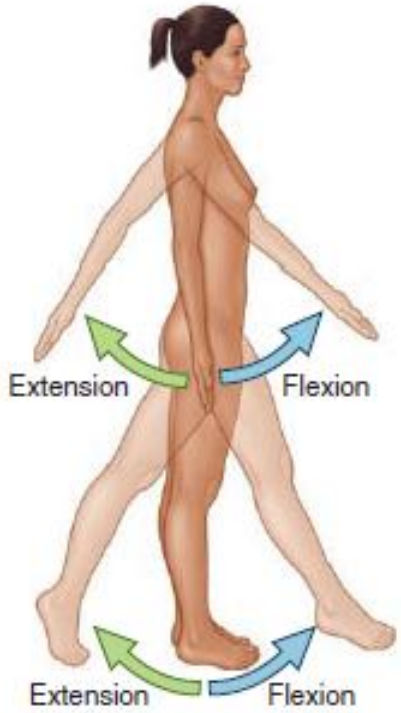






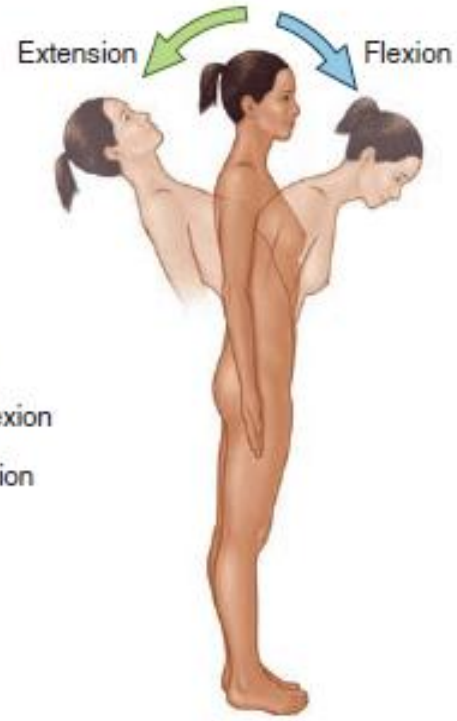
Terms of movement

Note the difference between flexion of the elbow and that of the knee.



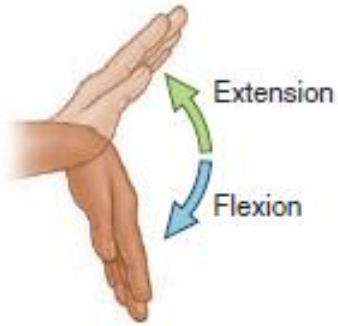
(A) Flexion and extension of upper limb at shoulder joint and lower limb at hip joint

Flexion and extension of forearm at elbow joint and of leg at knee joint



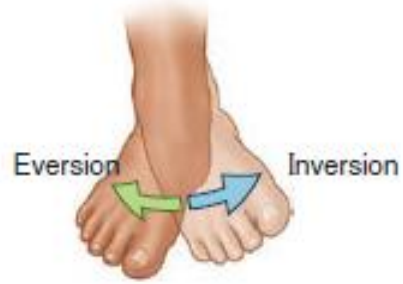
Flexion and extension of vertebral column at intervertebral joints

(B) Pronation and supination of forearm at radio-ulnar joints

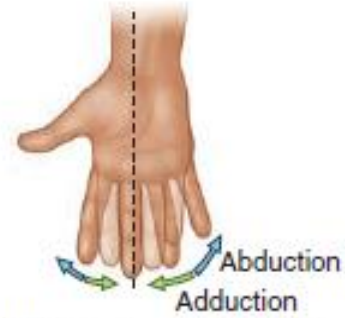


(C) Flexion and extension of hand at wrist joint

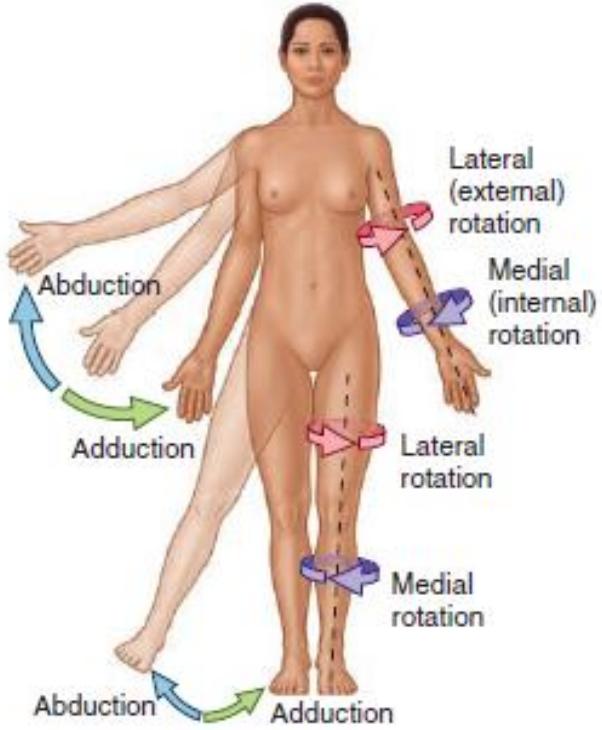
(D) Dorsiflexion and plantarflexion of foot at ankle joint



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

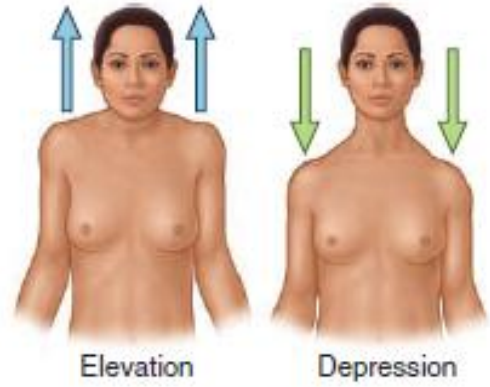


(F) Abduction and adduction of 2nd, 4th, and 5th digits at metacarpo-phalangeal joints

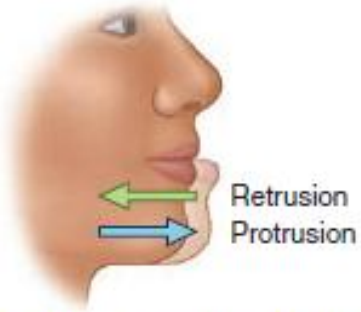


(G) Abduction and adduction of right limbs and rotation of left limbs at glenohumeral and hip joints

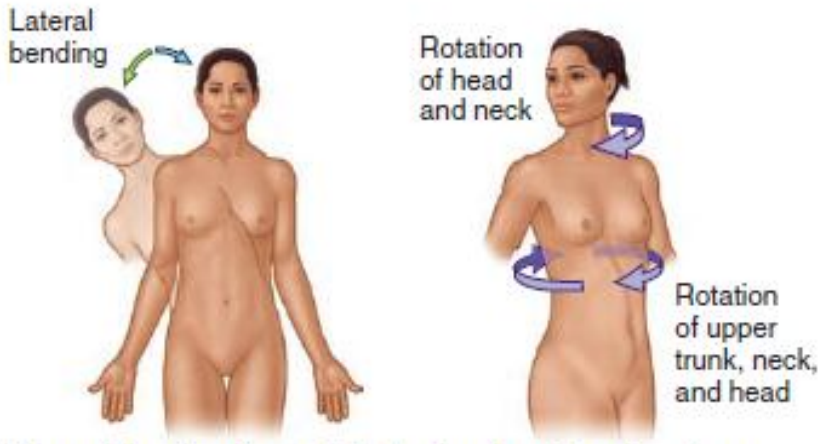
(H) Circumduction (circular movement) of lower limb at hip joint



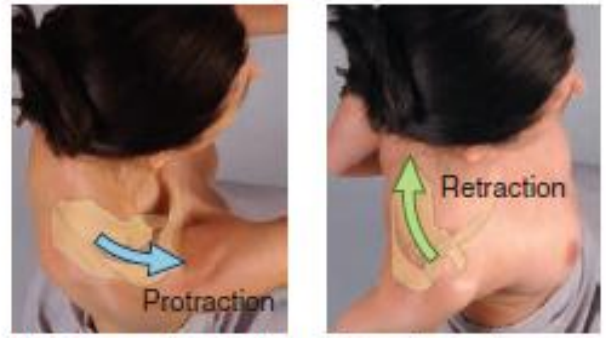
(I) Elevation and depression of shoulders



(K) Protrusion and retrusion of mandible (jaw) at temporomandibular joints

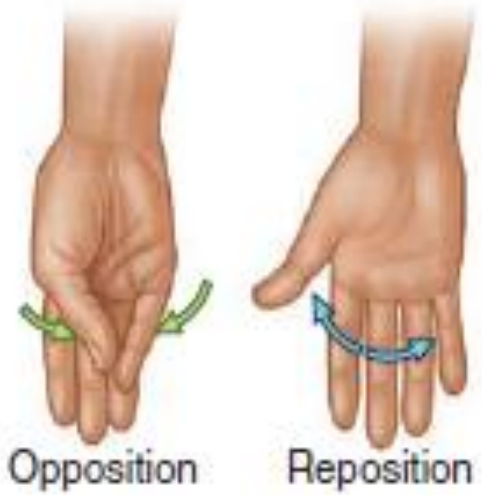


(J) Lateral bending (lateral flexion) of trunk and rotation of upper trunk, neck, and head

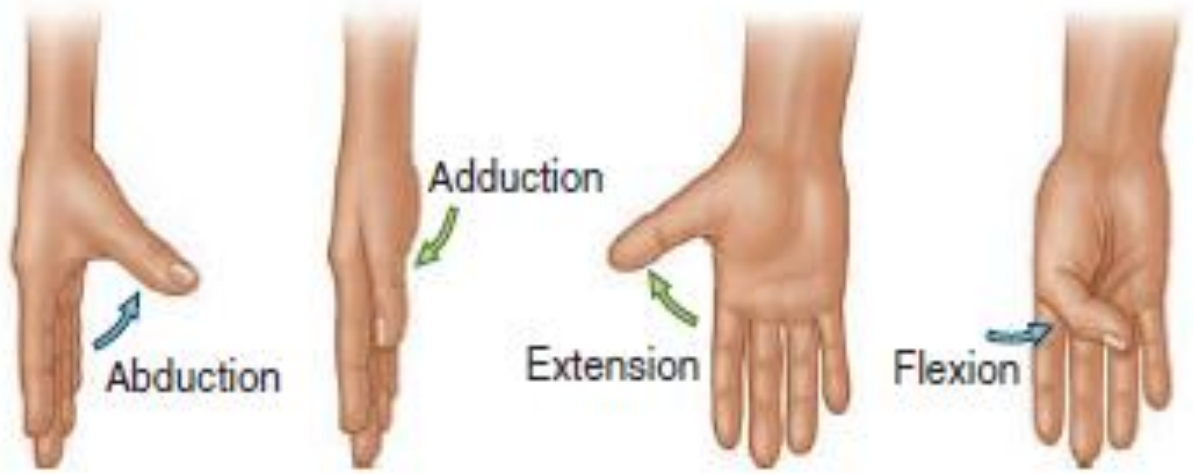


(L) Protraction and retraction of scapula on thoracic wall

Terms of movement for hand



(M) Opposition and reposition of thumb and little finger at carpometacarpal joint of thumb combined with flexion at metacarpophalangeal joints



(N) The thumb is rotated 90° relative to other structures. Abduction and adduction at metacarpophalangeal joint occurs in a sagittal plane; flexion and extension at metacarpophalangeal and interphalangeal joints occurs in frontal planes, opposite to these movements at other joints.

Anatomical variations

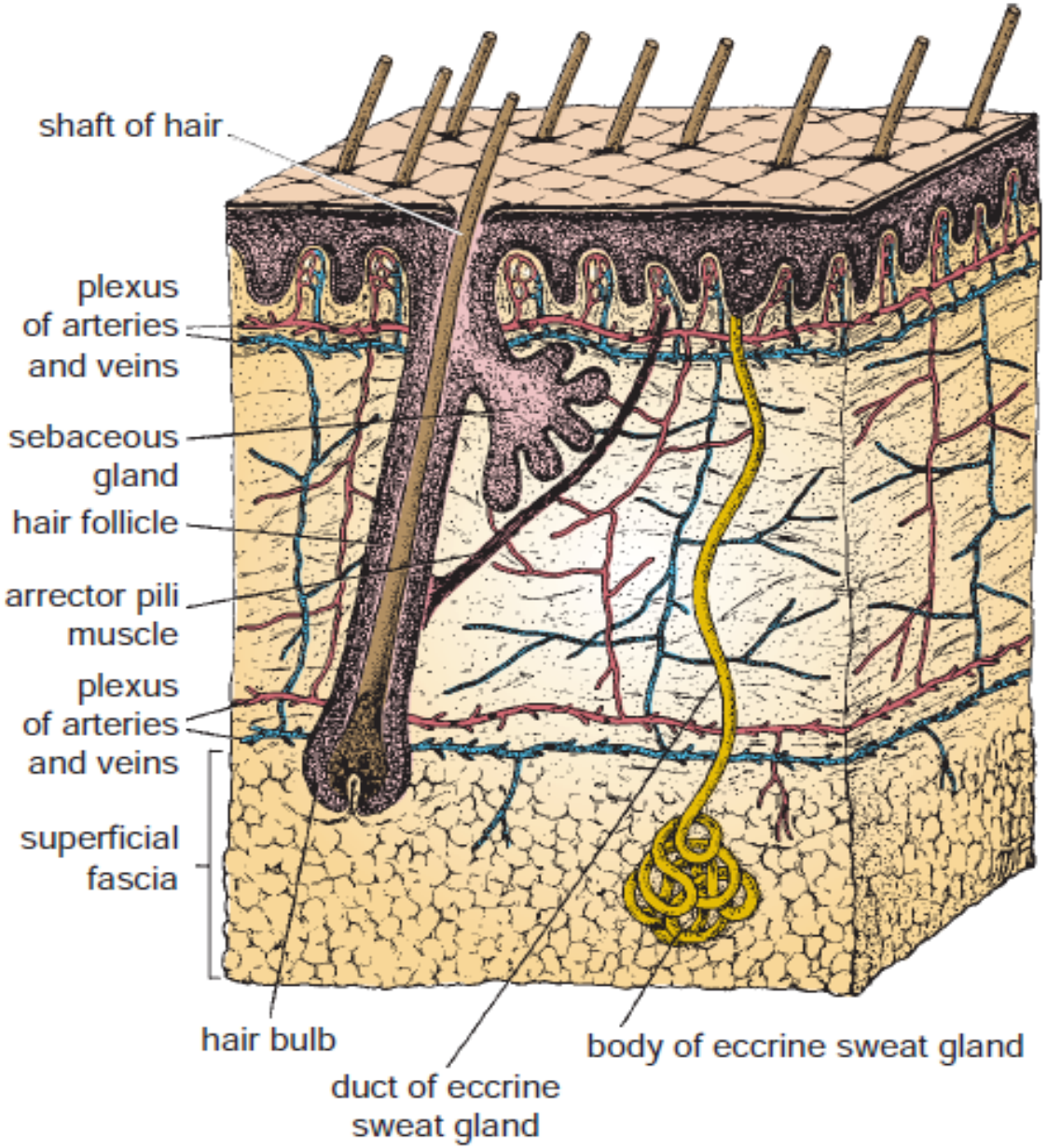
Although anatomy books describe the structure of the body observed in most people (i.e., the most common pattern), the structure of individuals varies considerably in the details. Students are often frustrated because the bodies they are examining or dissecting do not conform to the atlas or textbook they are using. Students should expect anatomical variations when dissecting or studying prosected specimens.

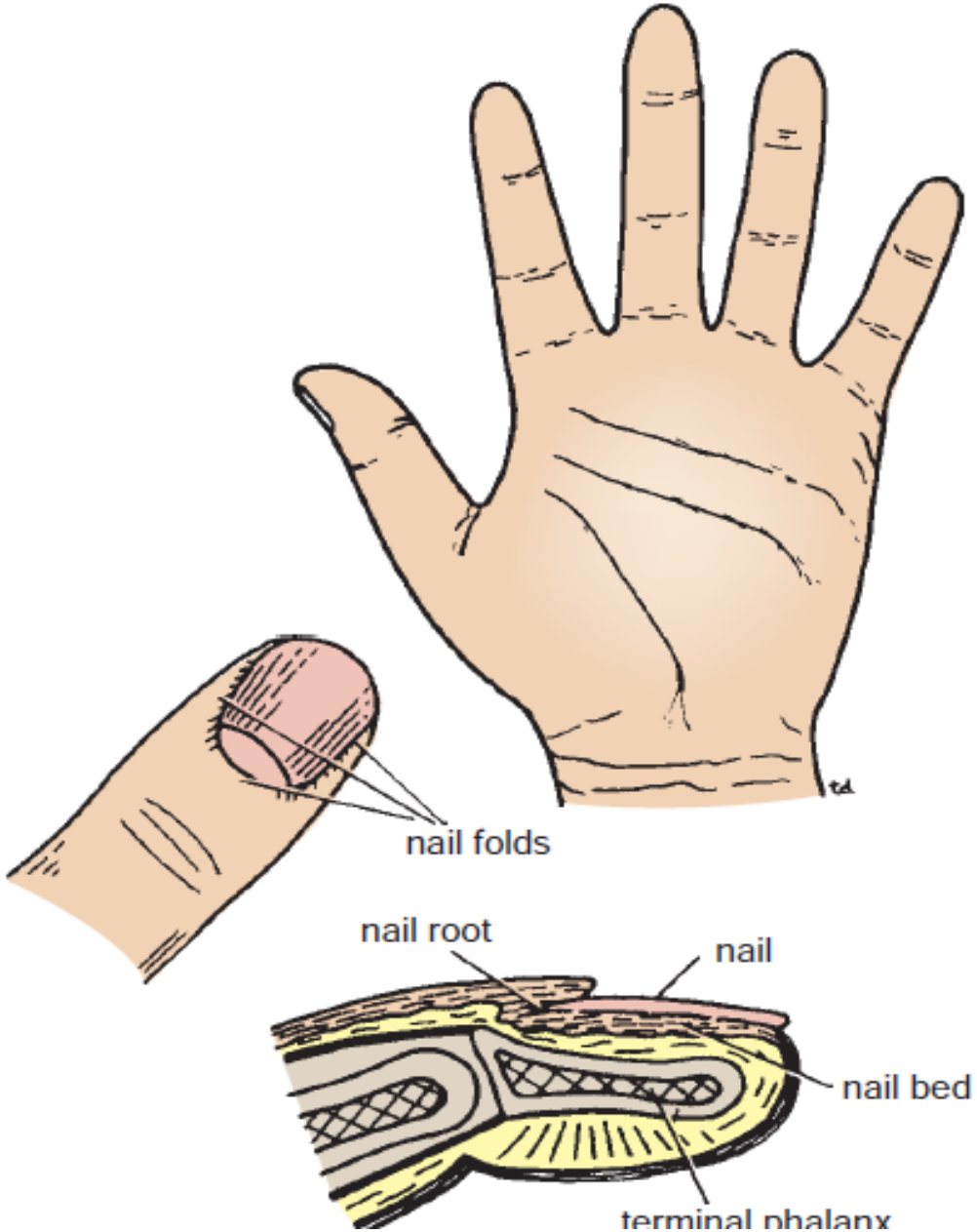
Integumentary system

The skin, the largest organ of the body, is readily accessible and is one of the best indicators of general health. *The skin provides*

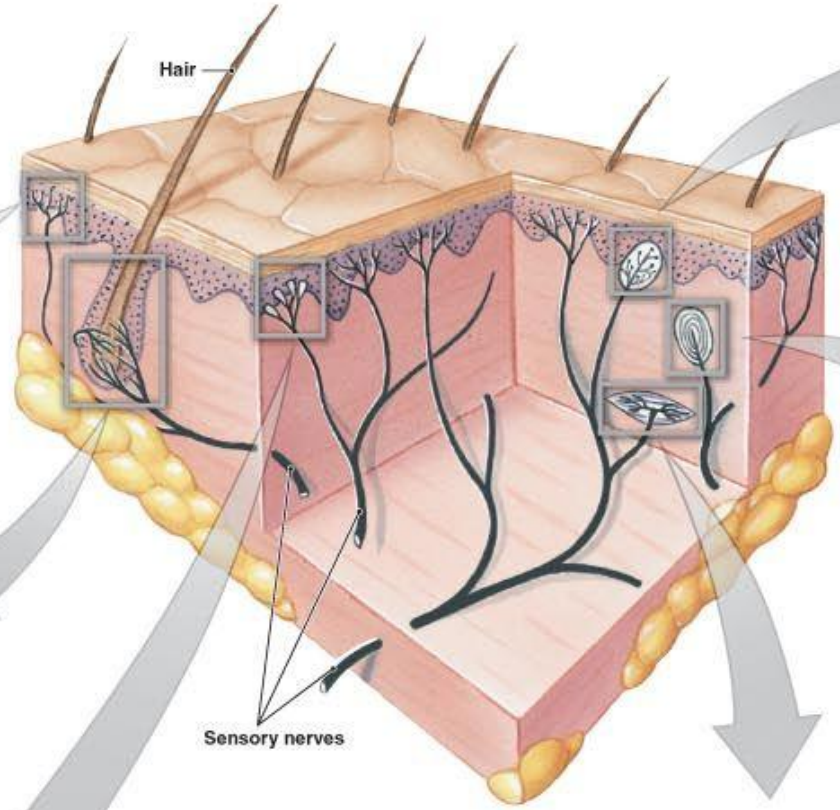
- *Protection* for the body from environmental effects, such as abrasions and harmful substances
- *Containment* of the tissues, organs, and vital substances of the body, preventing dehydration
- *Heat regulation* through sweat glands, blood vessels, and fat deposits
- *Sensation* (e.g., pain) by way of superficial nerves and their sensory endings
- *Synthesis and storage* of vitamin D

Integumentary system



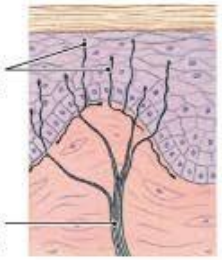


The types of receptors in the skin



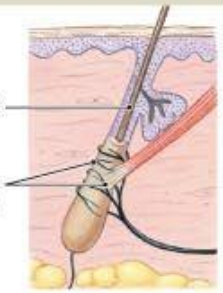
Free Nerve Endings

Are the branching tips of sensory neurons; are unprotected and nonspecific; can respond to tactile, pain, and temperature stimuli



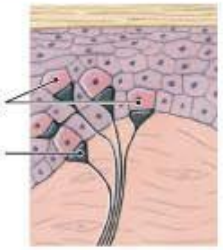
Root Hair Plexus

Monitor distortions and movements across the body surface; adapt rapidly

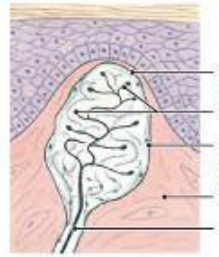


Tactile Discs and Merkel Cells

Tactile discs: fine touch and pressure receptors; are extremely sensitive tonic receptors with very small receptive fields. Merkel cells: unusually large epithelial cells in the stratum basale of the skin

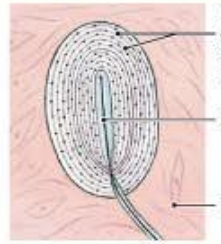


Tactile Corpuscles



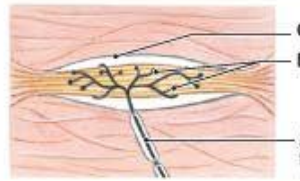
Provide sensations of fine touch and pressure and low-frequency vibration; also called Meissner corpuscles

Lamellated Corpuscles



Are sensitive to deep pressure, especially pulsing or high-frequency vibrating stimuli; are fast-adapting receptors

Ruffini Corpuscles



Are sensitive to pressure and distortion of the deep dermis

Integumentary system

The skin consists of a superficial cellular layer, the epidermis, which creates a tough protective outer surface, and a basal (deep) regenerative and pigmented connective tissue layer, the dermis. The epidermis is a keratinized stratified (layered) epithelium with a tough outer surface composed of keratin (a fibrous protein). The outer layer of the epidermis is continuously “shed” or rubbed away with replacement of new cells from the basal layer. This process renews the epidermis of the entire body every 25 to 45 days. The epidermis is avascular (no blood vessels or lymphatics) and is nourished by the vessels in the underlying dermis.

Integumentary system

The skin is supplied by afferent nerve endings that are sensitive to touch, irritation(pain), and temperature. Most nerve terminals are in the dermis, but a few penetrate the epidermis. The dermis is formed by a dense layer of interlacing collagen and elastic fibers. These fibers provide skin tone and account for the strength and toughness of the skin. The primary direction of collagen fibers in a particular region determines the characteristic tension lines (cleavage lines) and wrinkle lines in the skin.

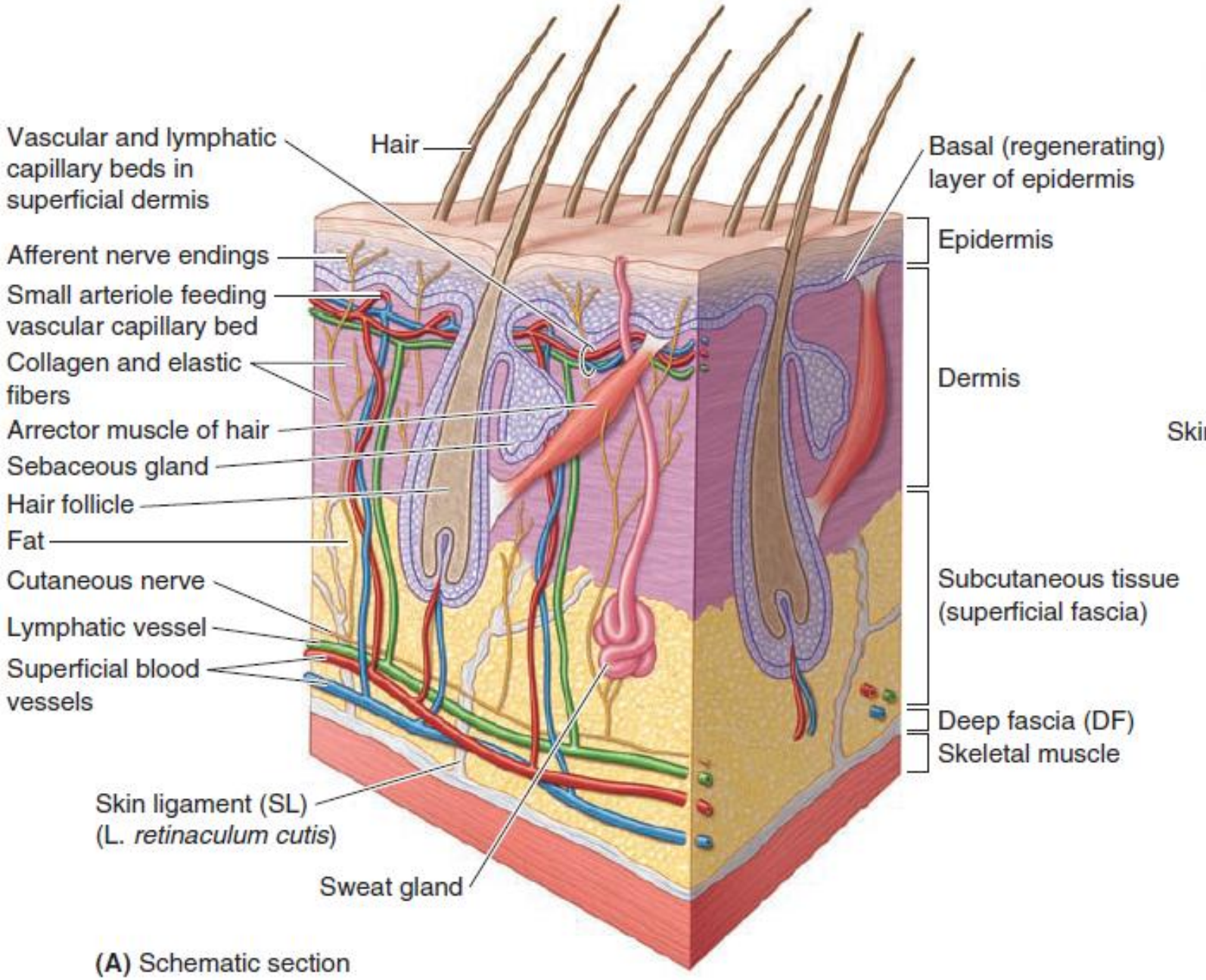
Integumentary system

The deep layer of the dermis contains hair follicles, with their associated smooth arrector (L. arrector pili) muscles and sebaceous glands. Contraction of the arrector muscles erects the hairs (causing goose bumps), thereby compressing the sebaceous glands and helping them secrete their oily product onto the skin. Other integumentary structures include the hair, nails, mammary glands, and the enamel of teeth.

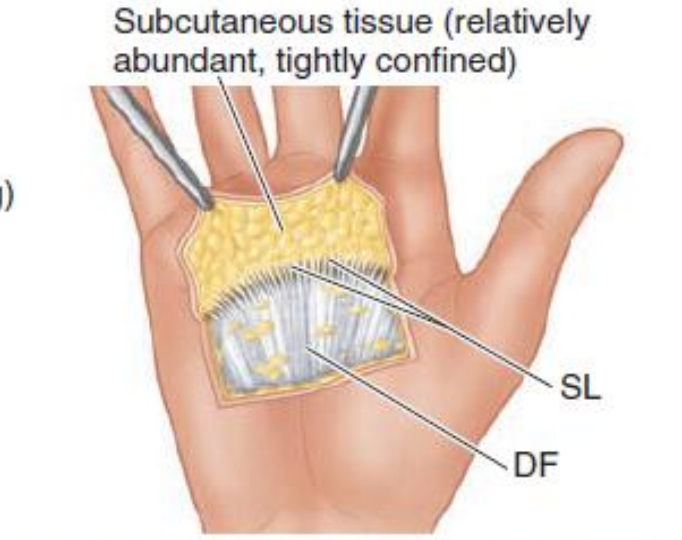
Integumentary system

The subcutaneous tissue (superficial fascia) is composed of loose connective tissue and fat. Located between the dermis and underlying deep fascia, the subcutaneous tissue contains the deepest parts of the sweat glands, the blood and lymphatic vessels, and cutaneous nerves. The subcutaneous tissue provides for most of the body's fat storage, so its thickness varies greatly depending on the person's nutritional state.

Integumentary system



(A) Schematic section



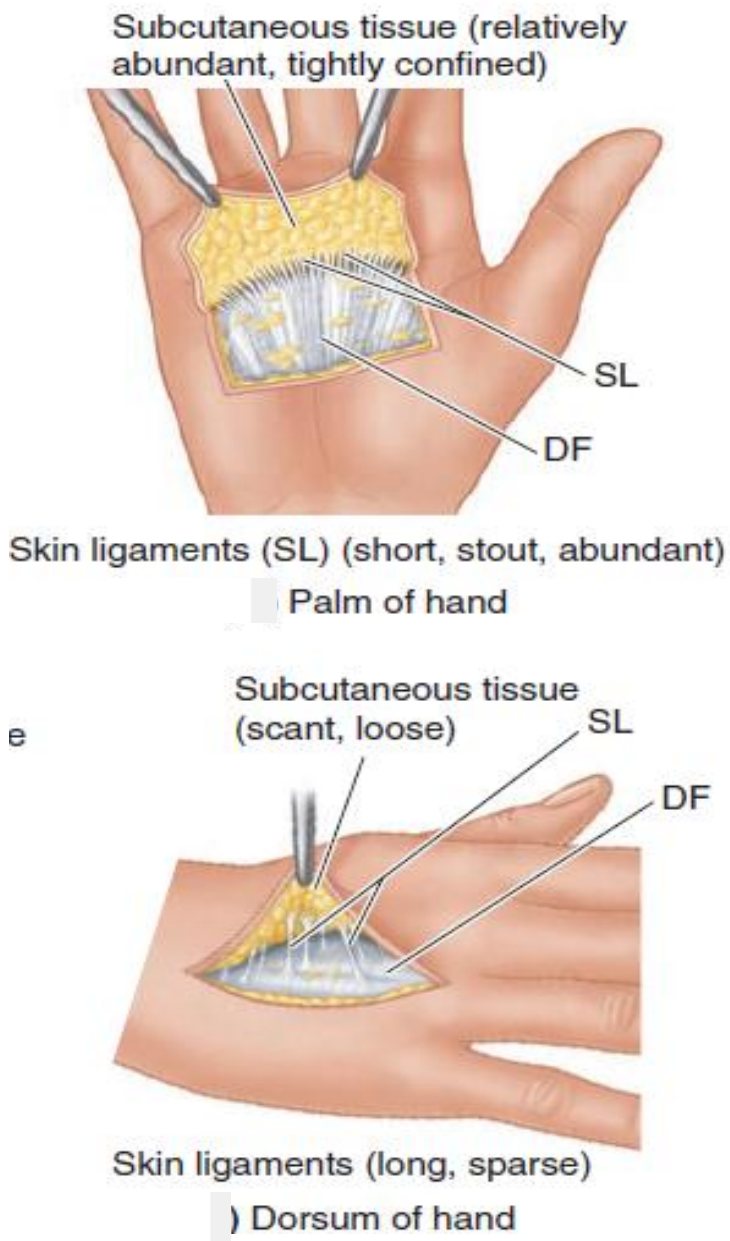
Skin ligaments (SL) (short, stout, abundant)

(B) Palm of hand

Skin ligaments (long, sparse)

(C) Dorsum of hand

Integumentary system



Skin ligaments (L. retinacula cutis), consisting of numerous small fibrous bands, extend through the subcutaneous tissue and attach the deep surface of the dermis to the underlying deep fascia. The length and density of these ligaments determine the mobility of the skin over deep structures.

Integumentary system

The deep fascia is a dense, organized connective tissue layer, devoid of fat, that envelops most of the body deep to the skin and subcutaneous tissue. Extensions from its internal surface

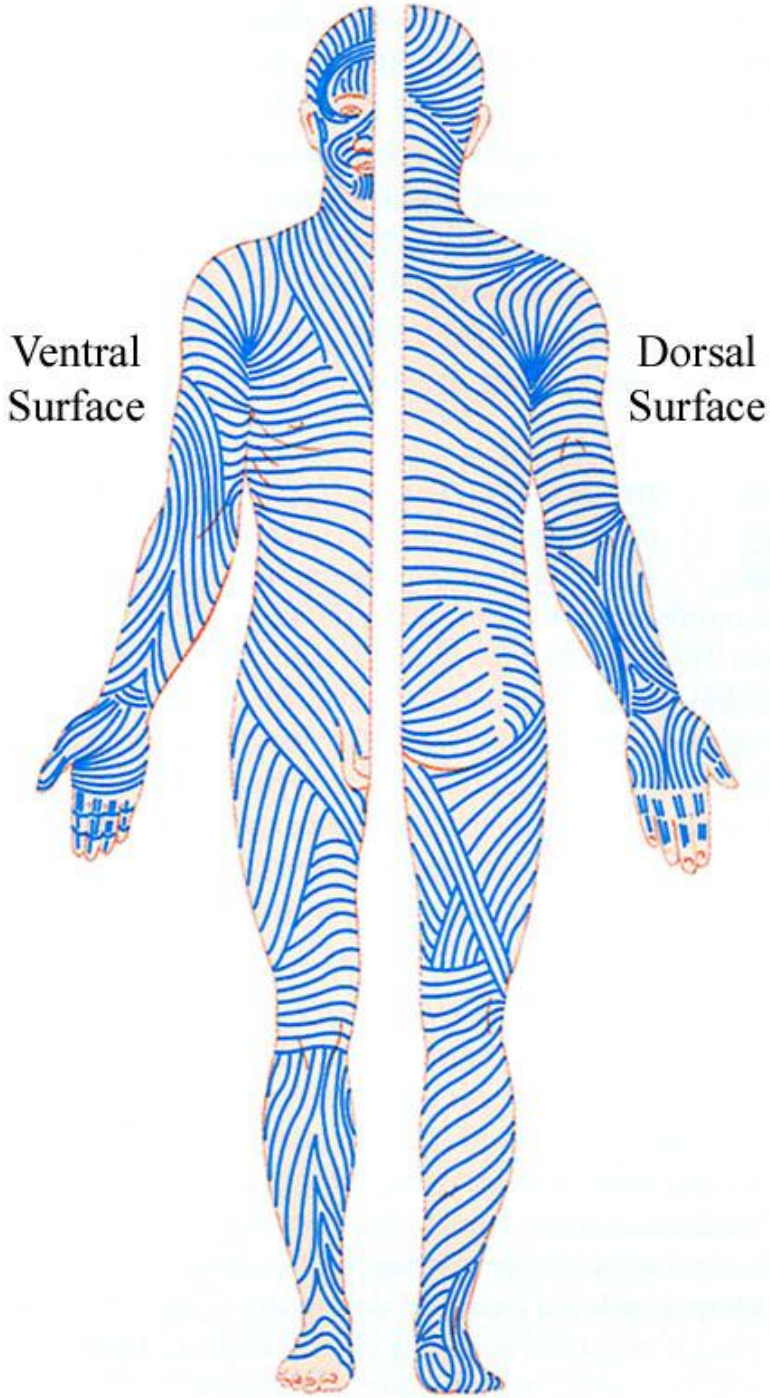
- Invest deeper structures, such as individual muscles and neurovascular bundles (investing fascia)
- Divide muscles into groups or compartments (intermuscular septa)
- Lie between the musculoskeletal walls and the serous membranes lining body cavities (subserous fascia)

Integumentary system

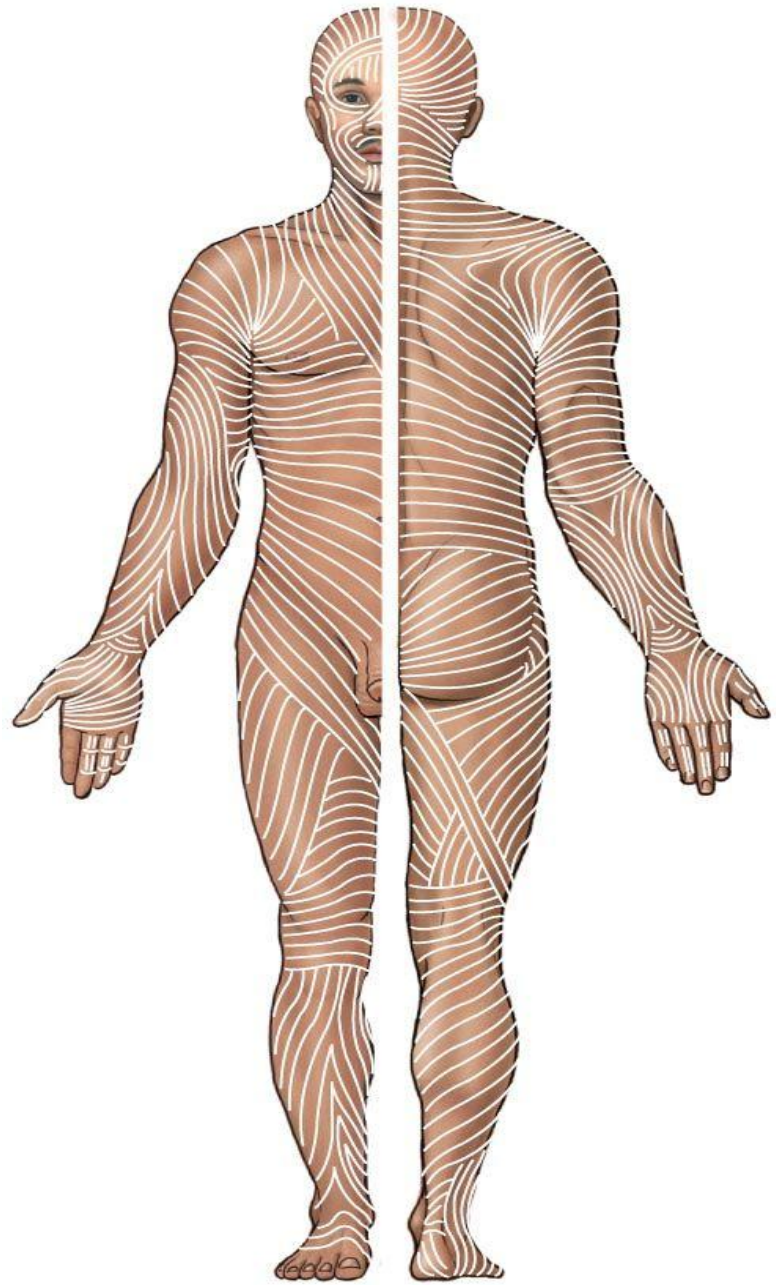
The deep fascia also forms (1) retinacula, which hold tendons in place during joint movement, and (2) bursae (closed sacs containing fluid), which prevent friction and enable structures to move freely over another. In living people, fascial planes (interfascial and intrafascial) are potential spaces between adjacent fascias or fascia-lined structures. During operations, surgeons take advantage of these planes, separating structures to create actual spaces that allow access to deeply placed structures.

Integumentary system

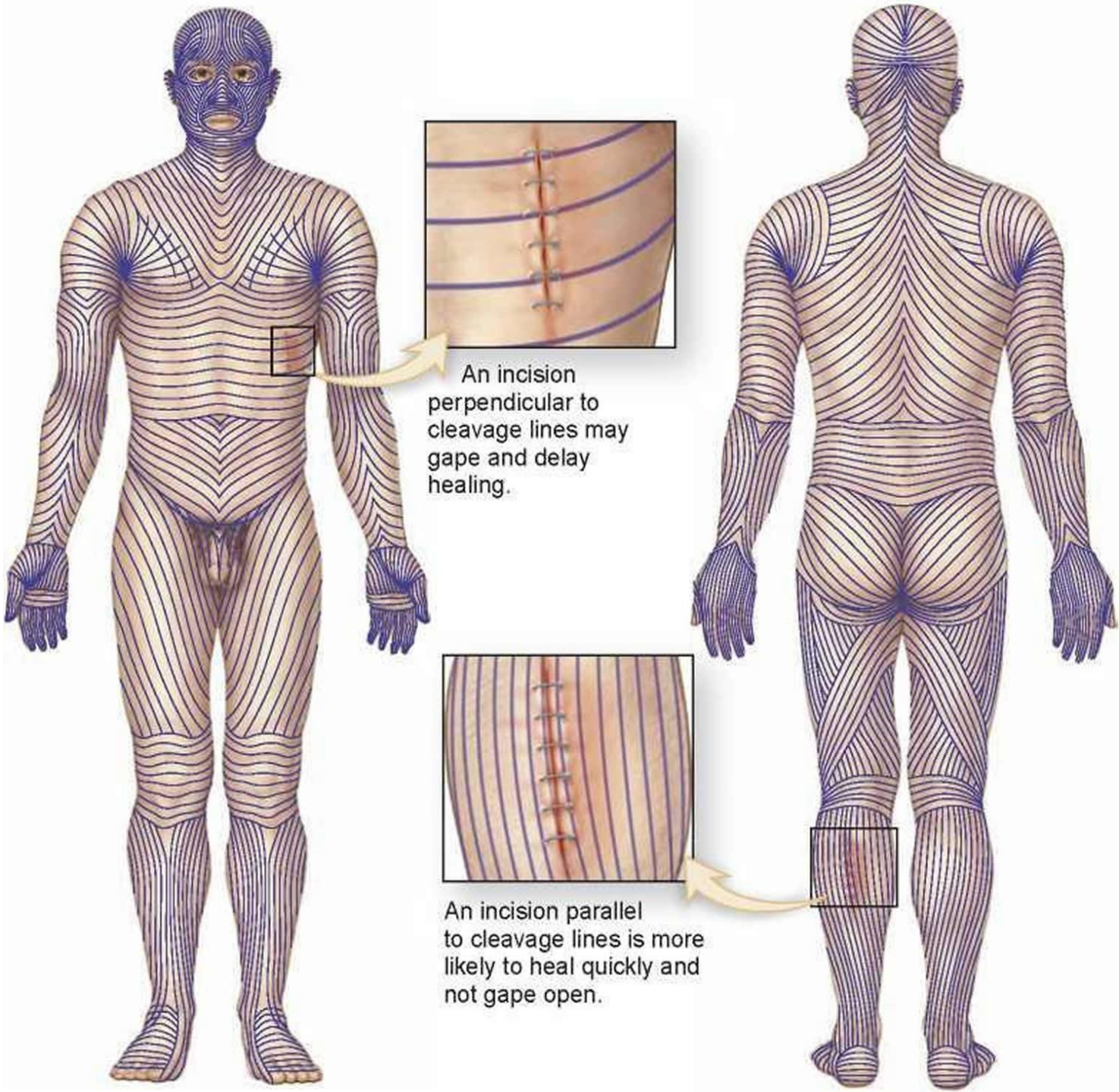
Tension lines (cleavage lines), Langer's lines, Langer lines of skin tension, keep the skin taut, yet allow for creasing with movement. Lacerations or surgical incisions that parallel the tension lines usually heal well with little scarring because there is minimal disruption of the collagen fibers. An incision or laceration across tension lines disrupts a greater number of collagen fibers, causing the wound to gape and possibly heal with excessive (keloid) scarring. Surgeons make their incisions parallel with the tension lines when other considerations (e.g., adequate exposure, avoiding nerves) are not of greater importance.



The lines of cleavage in the skin



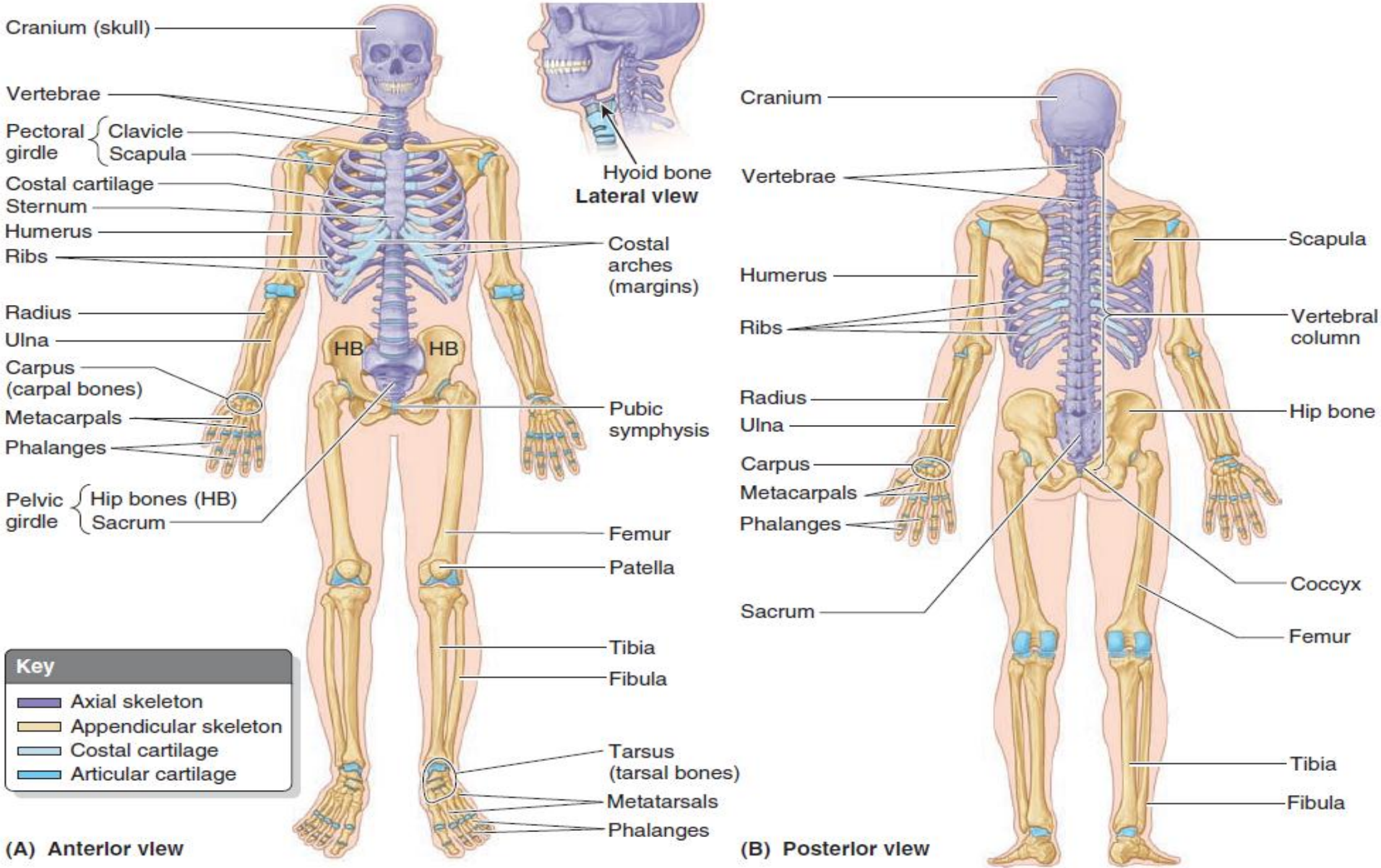
Langer's lines, **Langer lines of skin tension**, or sometimes called **cleavage lines.**



Skeletal system

The skeleton of the body is composed of bones and cartilages and has two main parts :

- The axial skeleton consists of the bones of the head (cranium or skull), neck (cervical vertebrae), and trunk (ribs, sternum, vertebrae, and sacrum).
- The appendicular skeleton consists of the bones of the limbs, including those forming the pectoral (shoulder) and pelvic girdles.


Cranium (skull)
Vertebrae
Pectoral girdle
Clavicle
Scapula
Costal cartilage
Sternum
Humerus
Ribs
Radius
Ulna
Carpus (carpal bones)
Metacarpals
Phalanges
Pelvic girdle
Hip bones (HB)
Sacrum
Hyoid bone
Lateral view
Costal arches (margins)
HB
HB
Pubic symphysis
Femur
Patella
Tibia
Fibula
Tarsus (tarsal bones)
Metatarsals
Phalanges
Key
Axial skeleton
Appendicular skeleton
Costal cartilage
Articular cartilage
(A) Anterior view
Cranium
Vertebrae
Scapula
Humerus
Ribs
Vertebral column
Radius
Ulna
Hip bone
Carpus
Metacarpals
Phalanges
Coccyx
Sacrum
Femur
Tibia
Fibula
(B) Posterior view

Skeletal system

Bone, a living tissue, is a highly specialized, hard form of connective tissue that makes up most of the skeleton and is the chief supporting tissue of the body. Bones provide

- Protection for vital structures
- Support for the body and its vital cavities
- The mechanical basis for movement
- Storage for salts (e.g., calcium)
- A continuous supply of new blood cells (produced by the marrow in the medullary cavity of many bones)

Skeletal system

Cartilage is a resilient, semirigid, avascular type of connective tissue that forms parts of the skeleton where more flexibility is necessary (e.g., the costal cartilages that attach the ribs to the sternum). The articulating surfaces of bones participating in a synovial joint are capped with articular cartilage, which provides smooth, low-friction gliding surfaces for free movement of the articulating bones. Cartilage is avascular and therefore its cells obtain oxygen and nutrients by diffusion. The proportion of bone and cartilage in the skeleton changes as the body grows; the younger a person is, the greater the contribution of cartilage.

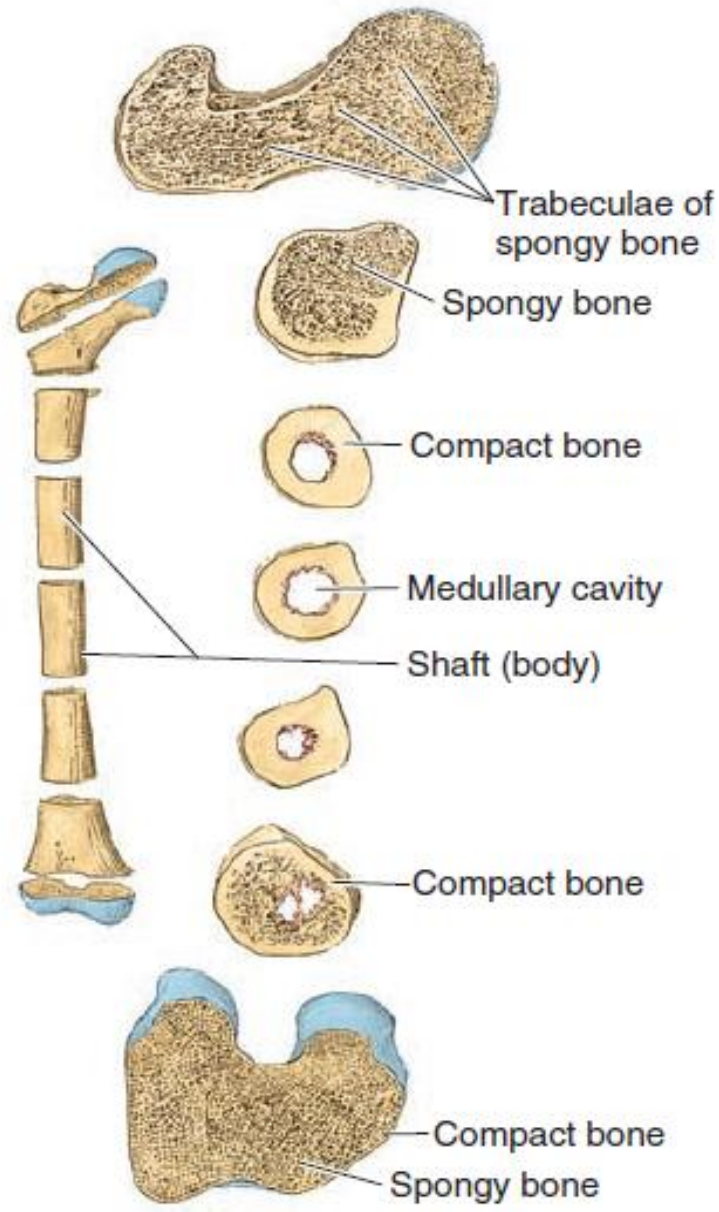
Skeletal system

The fibrous connective tissue covering that surrounds bone is periosteum; that surrounding cartilage elements, excluding articular cartilage, is perichondrium. The periosteum and perichondrium help nourish the tissue, are capable of laying down more cartilage or bone (particularly during fracture healing), and provide an interface for attachment of tendons and ligaments.

Skeletal system

There are two types of bone: compact bone and spongy (trabecular or cancellous) bone. The differences between these types of bone depend on the relative amount of solid matter and the number and size of the spaces they contain. All bones have a superficial thin layer of compact bone around a central mass of spongy bone, except where the latter is replaced by a medullary (marrow) cavity. Within this cavity of adult bones and between the spicules of spongy bone, blood cells and platelets are formed. The architecture of spongy and compact bone varies according to function.

Skeletal system



Transverse sections of femur (thigh bone).

Observe the trabeculae (tension and pressure lines) related to the weight-bearing function of this bone.

Skeletal system

Compact bone provides strength for weight bearing. In long bones, designed for rigidity and attachment of muscles and ligaments, the amount of compact bone is greatest near the middle of the shaft (body) of the bone, where it is liable to buckle. Living bones have some elasticity (flexibility) and great rigidity (hardness).

Skeletal system

Classification of bones

Bones are classified according to their shape :

- Long bones are tubular structures (e.g., humerus in the arm, phalanges in the fingers).
- Short bones are cuboidal and are found only in the ankle (tarsus) and wrist (carpus).

Skeletal system

Classification of bones

- Flat bones usually serve protective functions (e.g., those of the cranium protect the brain).
- Irregular bones, such as those in the face, have various shapes other than long, short, or flat.
- Sesamoid bones (e.g., patella, or kneecap) develop in certain tendons. These bones protect the tendons from excessive wear and often change the angle of the tendons as they pass to their attachments.

Skeletal system

Vasculature and innervation of bones

Bones are richly supplied with blood vessels. The arterial supply is from

- Nutrient arteries (one or more per bone) that arise outside the periosteum, pass through the shaft of a long bone via nutrient foramina, and split in the medullary cavity into longitudinal branches. These vessels supply the bone marrow, spongy bone, and deeper portions of the compact bone.

Skeletal system

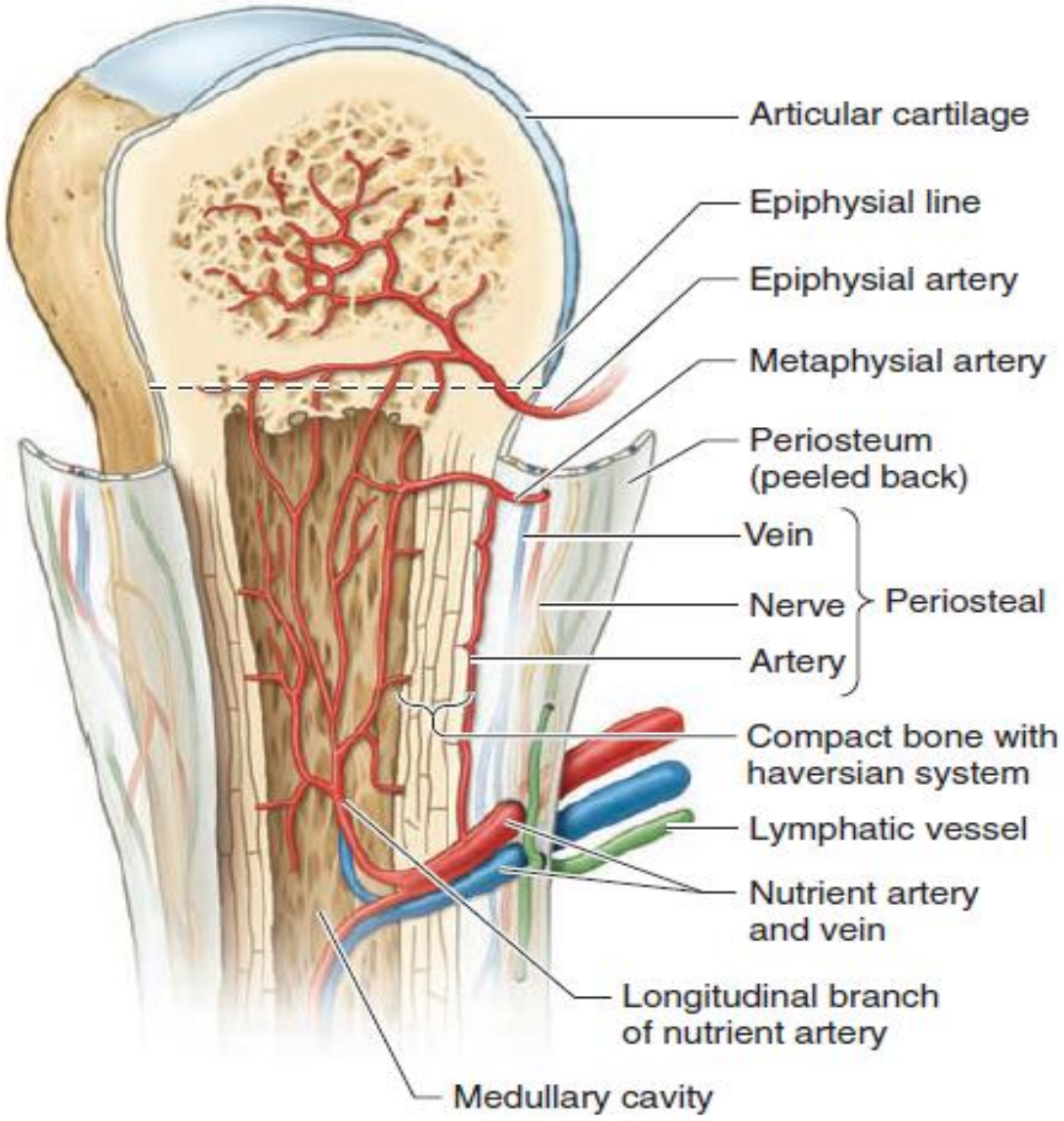
Vasculature and innervation of bones

• Small branches from the periosteal arteries of the periosteum supply most of the compact bone. Consequently, if the periosteum is removed, the bone will die.

• Metaphysial and epiphysial arteries supply the ends of the bones. These vessels arise mainly from the arteries that supply the joints.

Veins accompany arteries through the nutrient foramina. Many large veins leave through foramina near the articular ends of the bones. Lymphatic vessels are abundant in the periosteum.

Skeletal system



Vasculature and innervation of long bone.

The bulk of compact bone is composed of haversian systems (osteons). The haversian canal in the system houses one or two small blood vessels for nourishing the osteocytes (bone cells).

Skeletal system

Nerves accompany the blood vessels supplying bones. The periosteum is richly supplied with sensory nerves— periosteal nerves—that carry pain fibers. The periosteum is especially sensitive to tearing or tension, which explains the acute pain from bone fractures. Bone itself is relatively sparsely supplied with sensory endings. Within bones, vasomotor nerves cause constriction or dilation of blood vessels, regulating blood flow through the bone marrow.

Joints

A joint is an articulation, or the place of union or junction, between two or more rigid components (bones, cartilages, or even parts of the same bone). Joints exhibit a variety of forms and functions. Some joints have no movement, others allow only slight movement, and some are freely movable, such as the glenohumeral (shoulder) joint.

Joints

Classification of joints

The three types of joints (fibrous, cartilaginous, and synovial) are classified according to the manner or type of material by which the articulating bones are united:

- The articulating bones of fibrous joints are united by fibrous tissue.

The amount of movement occurring at a fibrous joint depends in most cases on the length of the fibers uniting the articular bones.

Joints

Classification of joints.

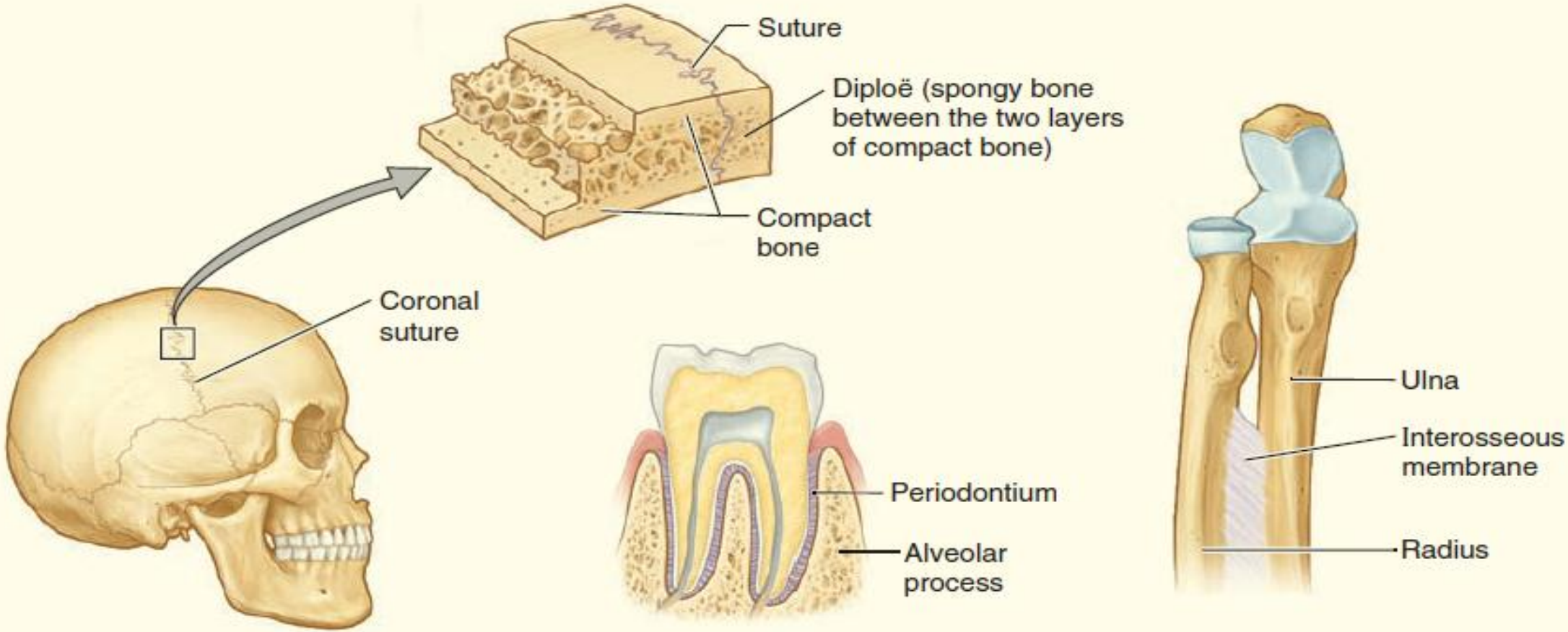
A syndesmosis type of fibrous joint unites the bones with a sheet of fibrous tissue, either a ligament or fibrous membrane. Consequently, this type of joint is partially movable. A gomphosis (dento-alveolar syndesmosis) is a type of fibrous joint in which a peg-like fibrous process stabilizes a tooth and provides proprioceptive information (e.g., about how hard we are chewing or clenching our teeth).

Joints

- The articulating structures of cartilaginous joints are united by hyaline cartilage or fibrocartilage. Primary cartilaginous joints (synchondroses) are united by hyaline cartilage. These joints permit growth of the length of the bone and allow slight bending during early life until the epiphysial plate converts to bone and the epiphyses fuse with the diaphysis. Secondary cartilaginous joints (symphyses) are strong, slightly mobile joints united by fibrocartilage.

Joints

- The articular cavity of synovial joints is a potential space that contains a small amount of synovial fluid. Synovial fluid serves the dual function of nourishing the articular cartilage and lubricating the joint surfaces. Synovial joints, the most common type of joint, are usually reinforced by accessory ligaments that either are separate (extrinsic) or are a thickened part of the joint capsule (intrinsic).

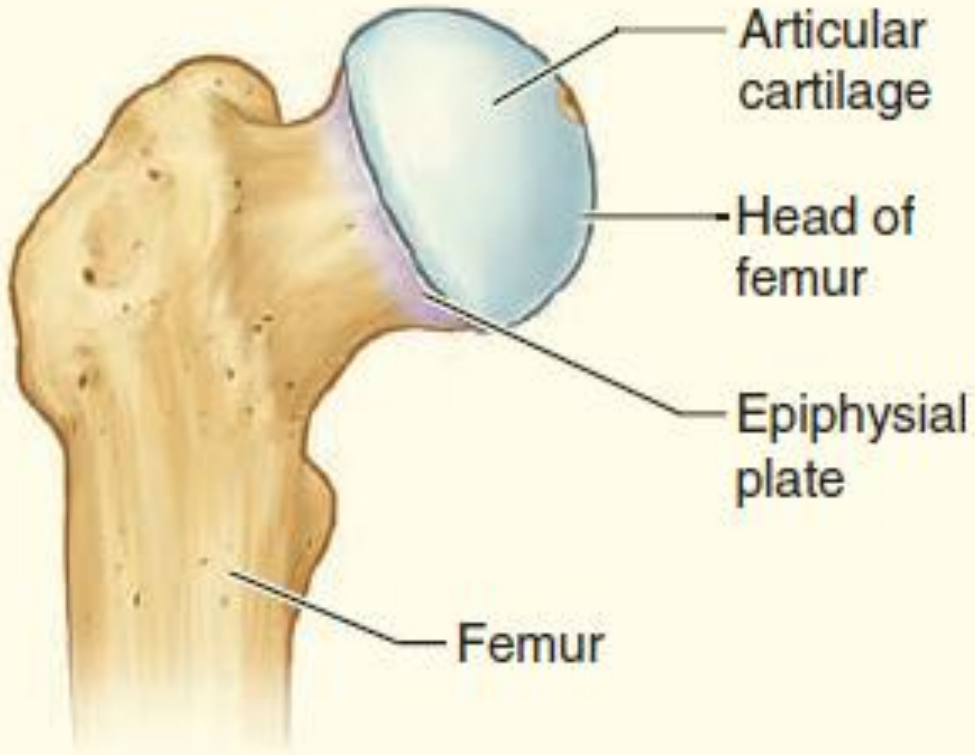


Lateral view
Suture

Gomphosis
(Dento-alveolar syndesmosis)

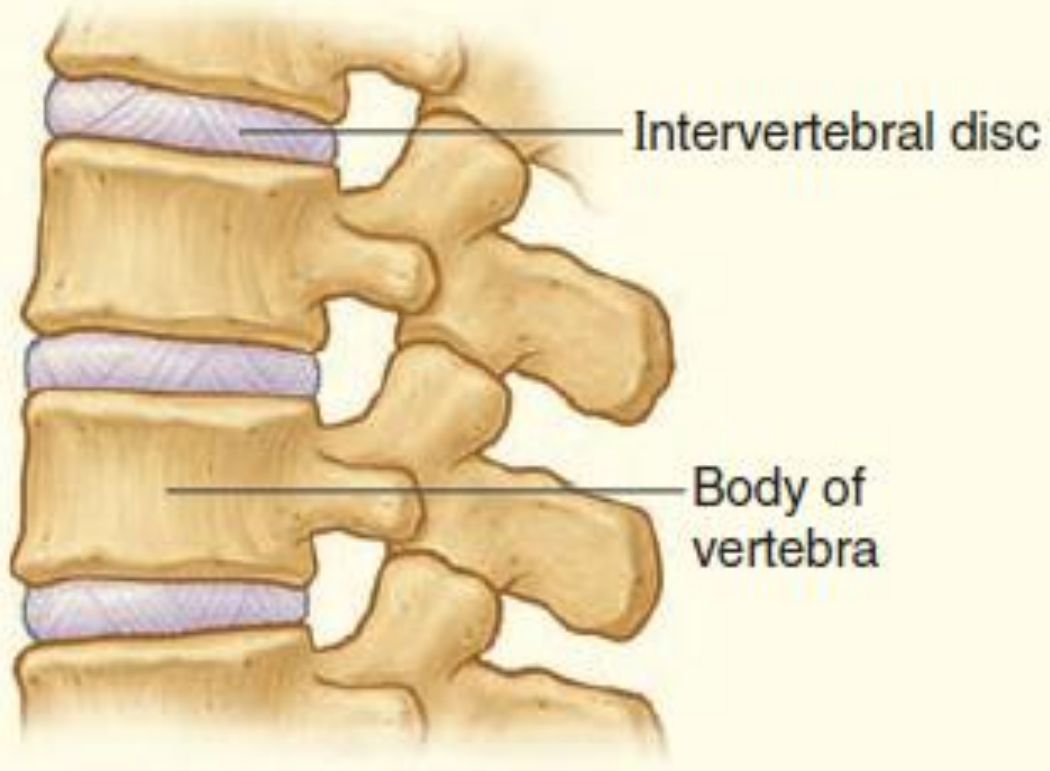
Anterior view
Syndesmosis

In **fibrous joints,** articulating bones are joined by fibrous tissue. Sutures of the cranium are fibrous joints in which bones are close together and united by fibrous tissue, often interlocking along a wavy line. Flat bones consist of two plates of compact bone separated by spongy bone and marrow (diploë). In a **syndesmosis joint,** the bones are joined by an interosseous ligament or a sheet of fibrous tissue (e.g., the interosseous membrane joining the forearm bones). In a **gomphosis joint,** a peg-like process fits into a socket (e.g., the articulation between the root of the tooth and the alveolar process). Fibrous tissue, the periodontium, anchors the tooth in the socket.



Anterior view

Primary cartilaginous (Synchondrosis)

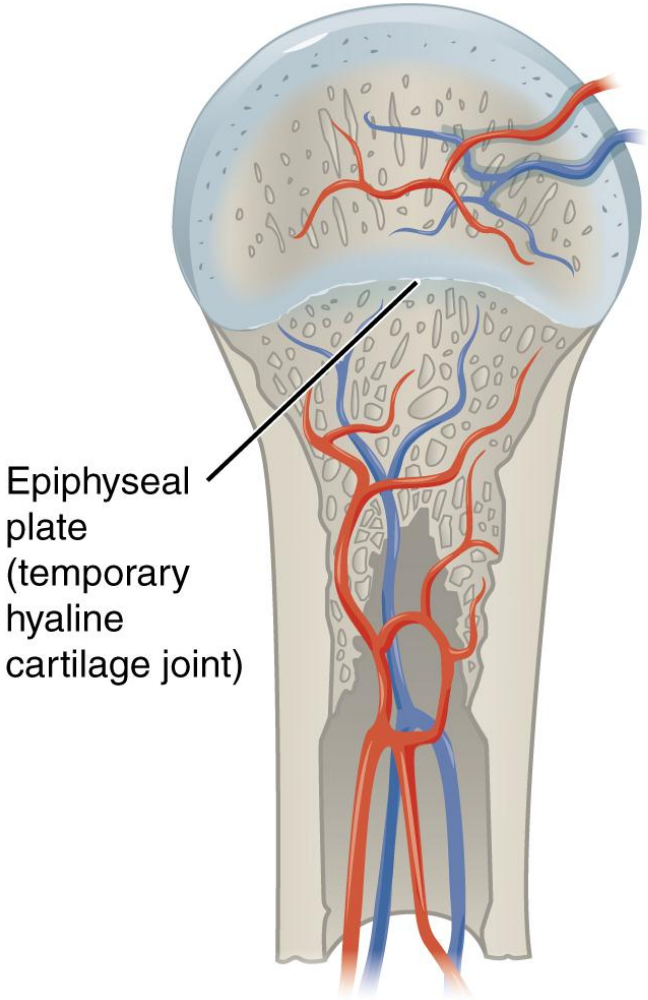


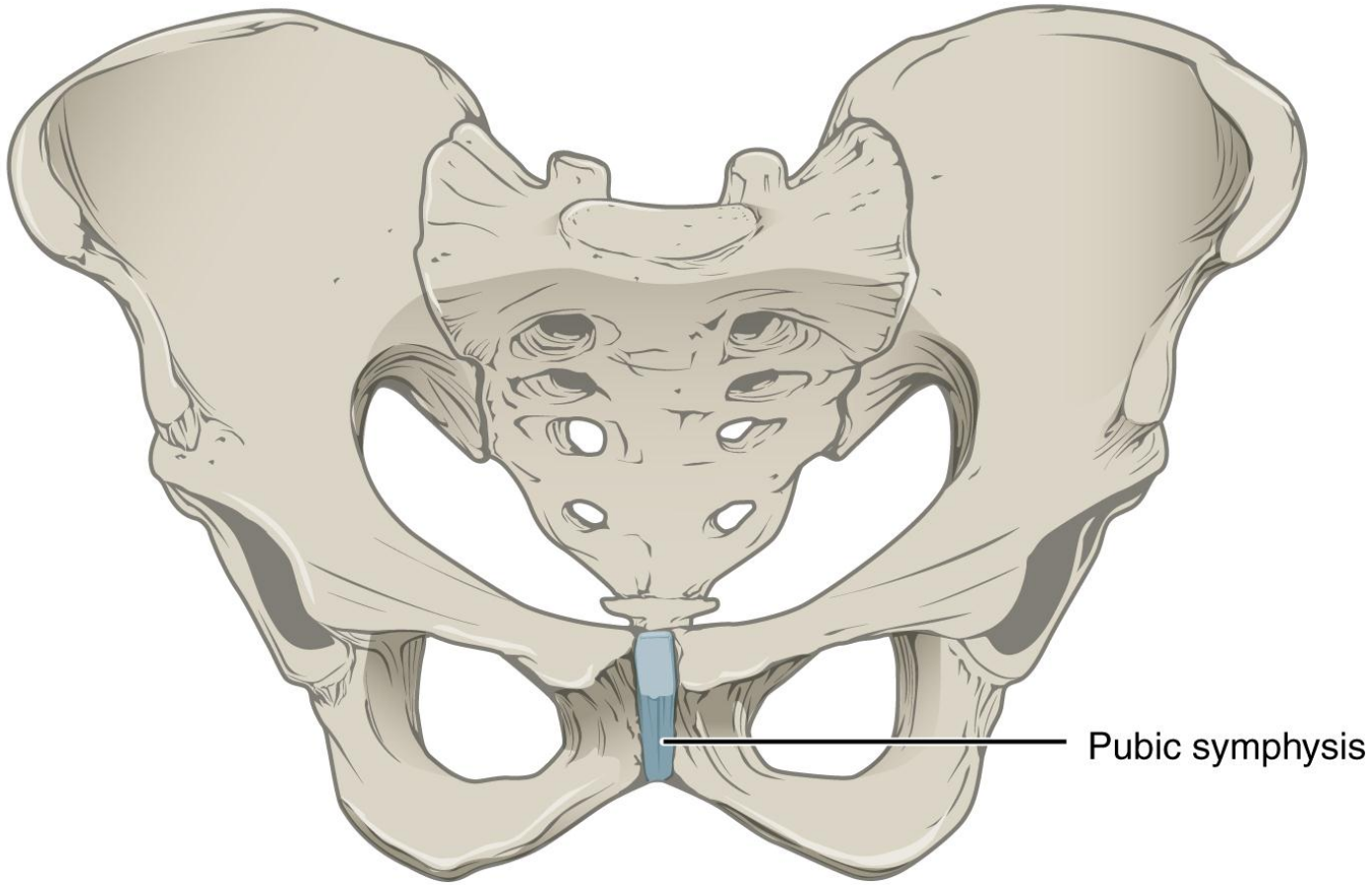
Lateral view

Secondary cartilaginous (Symphysis)

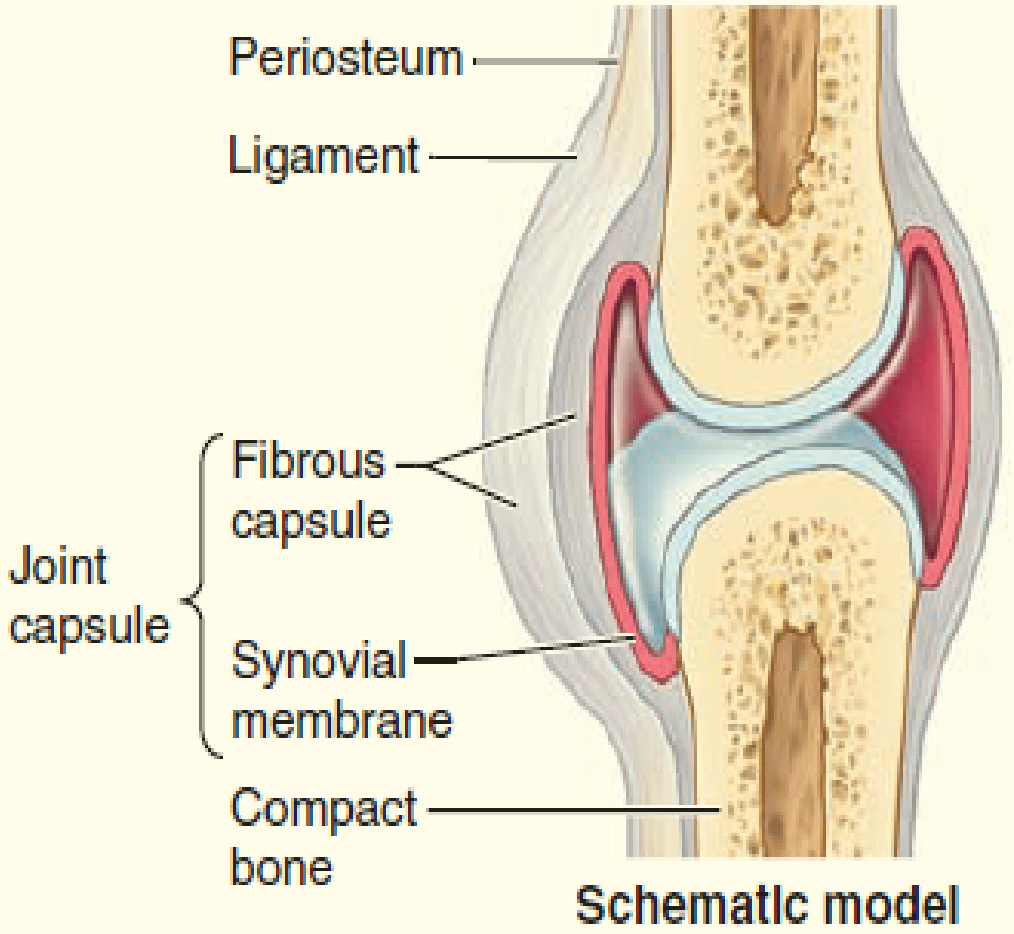
In **cartilaginous joints**, articulating bones are united by fibrocartilage or hyaline cartilage. In a **synchondrosis**, such as that in a developing long bone, the bony epiphysis and body are joined by an epiphysial plate (hyaline cartilage). In a **symphysis**, the binding tissue is a fibrocartilaginous disc (e.g., between two vertebrae).

Cartilaginous joints





In a **synovial joint** (articulation), the two bones are separated by the characteristic joint cavity (containing synovial fluid) but are joined by an articular capsule (fibrous capsule lined with synovial membrane). The bearing surfaces of the bones are covered with articular cartilage. Synovial joints are functionally the most common and important type of joint. They provide free movement between the bones they join and are typical of nearly all joints of the limbs.

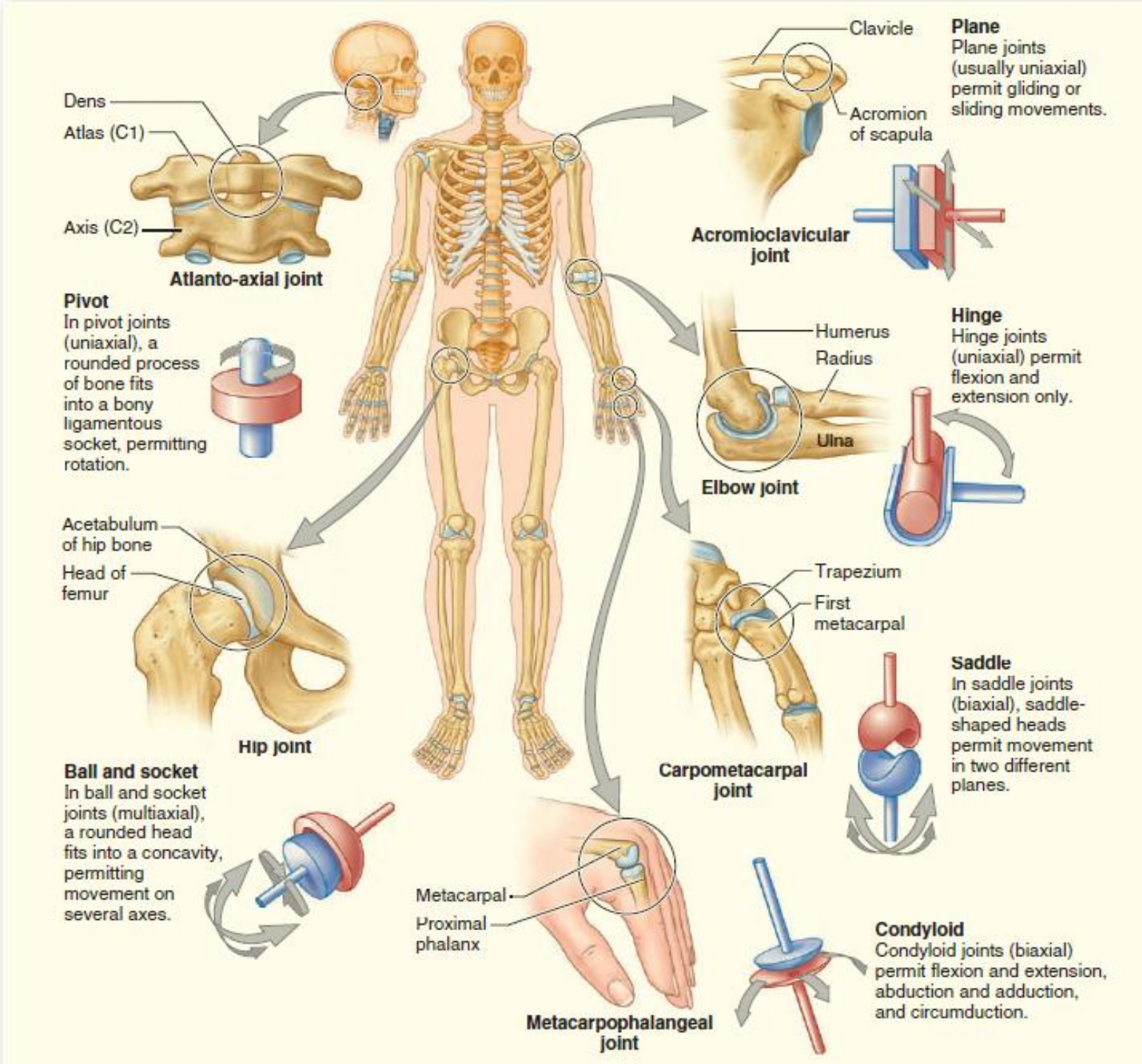


Schematic model

Joints

Some synovial joints have other distinguishing features, such as fibrocartilaginous articular discs or menisci, which are present when the articulating surfaces of the bones are incongruous. The six major types of synovial joints are classified according to the shape of the articulating surfaces and/or the type of movement they permit

Types of synovial joints



Joints

Vasculature and innervation of joints

Joints receive blood from articular arteries that arise from vessels around the joint. The arteries often anastomose(communicate) to form networks (peri-articular arterial anastomoses), which ensure a continuous blood supply to a joint throughout its range of movement. Articular veins are communicating veins that accompany the arteries (L. venae comitantes) and, like the arteries, are located in the joint capsule, mostly in the synovial membrane.

Joints

Vasculature and innervation of joints

Joints have a rich nerve supply; the nerve endings are numerous in the joint capsule. In the distal parts of limbs, the articular nerves are branches of the cutaneous nerves supplying the overlying skin. Otherwise, most articular nerves are branches of nerves that supply the muscles that cross and therefore move the joint. Hilton law states that the nerves supplying a joint also supply the muscles moving the joint and the skin covering their attachments.

Muscular system

Muscle cells, often called muscle fibers because they are long and narrow when relaxed, are specialized contractile cells organized into tissues that move body parts or temporarily alter the shape of internal organs. The associated connective tissue conveys nerve fibers and capillaries to the muscle fibers as it binds them into bundles or fascicles. Muscles also give form to the body and provide heat.

Muscular system

There are **three types** of muscle :

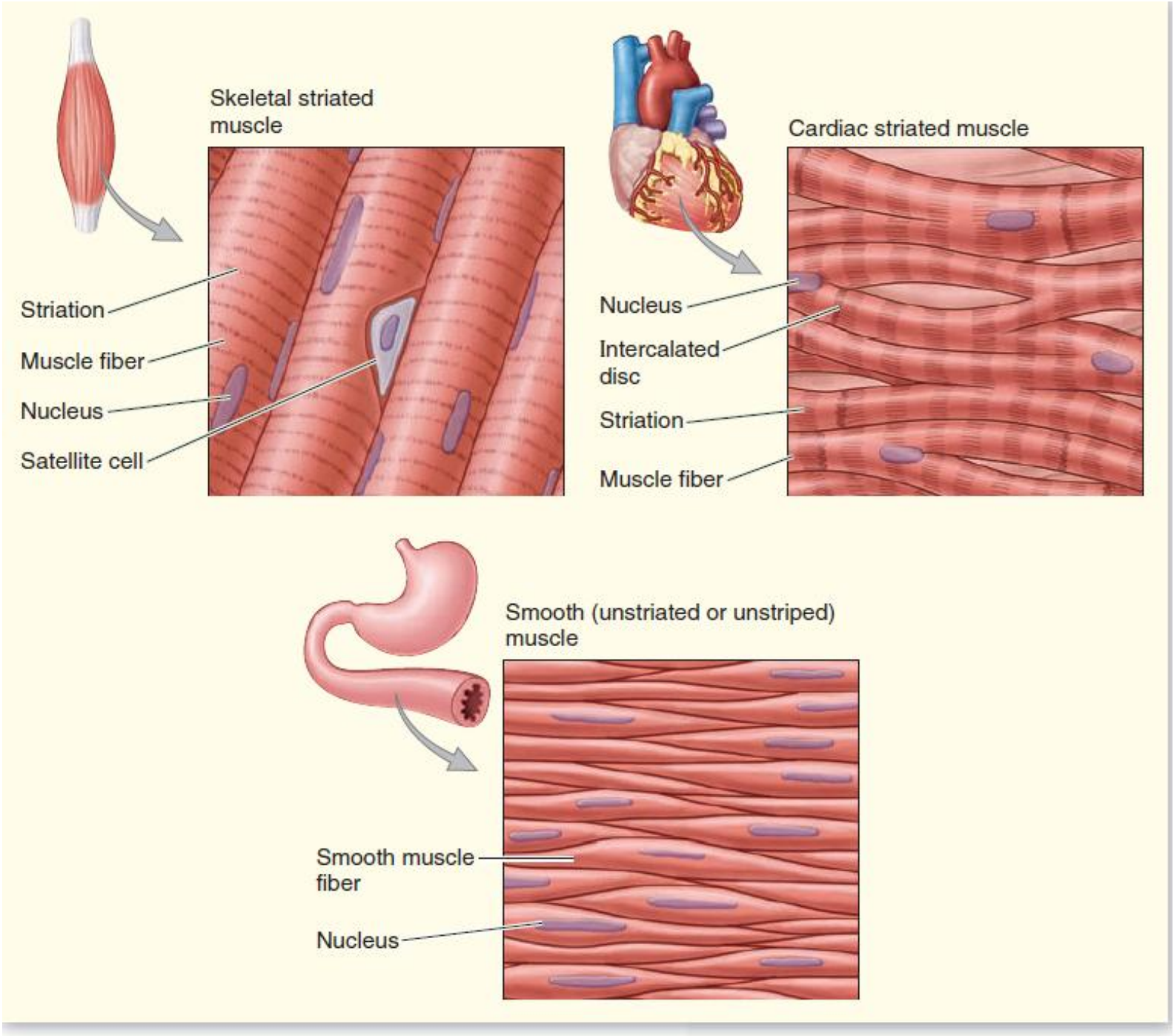
(1) skeletal muscle, which moves bones and other structures (e.g., the eyes);

(2) cardiac striated muscle, which forms most of the walls of the heart and adjacent parts of the great vessels; and

(3) smooth muscle, which forms part of the walls of most vessels and hollow organs, moves substances through viscera such as the intestine, and controls movement through blood vessels.

Muscular system

Types of muscle



Muscular system

Skeletal muscle

All skeletal muscles have a fleshy contractile portion (one or more heads or bellies) composed of skeletal striated muscle and a noncontractile portion composed mainly of collagen bundles: tendons (rounded) and aponeuroses (flat sheets). When referring to the length of a muscle, both the belly and the tendons are included.

Muscular system

Skeletal muscle

Most skeletal muscles are attached directly or indirectly through tendons and aponeuroses to bones, cartilages, ligaments, or fascia or to some combination of these structures; however, some muscles are attached to organs (e.g., the eyeball), to skin (e.g., facial muscles), and to mucous membranes (e.g., intrinsic tongue muscles). Muscles are organs of movement, but they also provide static support and give form to the body and provide heat.

Muscular system

Muscles may be described according to their shape and architecture.

For example

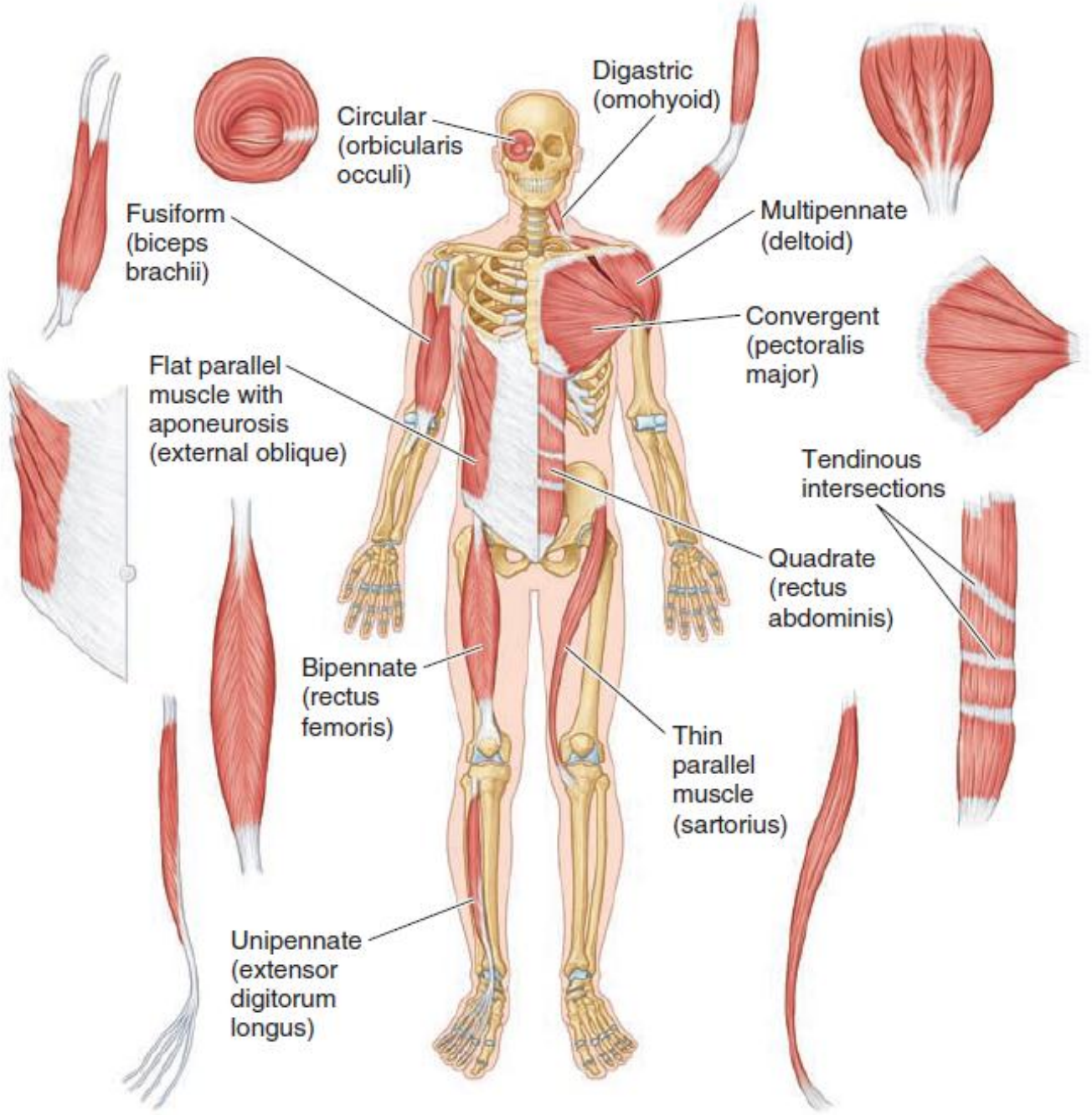
- Pennate muscles are feather-like in the arrangement of their fascicles (fiber bundles): unipennate, bipennate, or multipennate (L. pennatus, feather).
- Fusiform muscles are spindle-shaped (round, thick belly, and tapered ends).

Muscular system

- In parallel muscles, the fascicles lie parallel to the long axis of the muscle; flat muscles with parallel fibers often have aponeuroses.
- Convergent muscles have a broad attachment from which the fascicles converge to a single tendon.
- Circular muscles surround a body opening or orifice, constricting it when contracted.
- Digastric muscles feature two bellies in series, sharing a common intermediate tendon.

Muscular system

Architecture and shape of **skeletal muscles**. Various types of muscles are shown whose shapes depend on the arrangement of fibers.



Muscular system

Contraction of muscles

When muscles contract, the fibers shorten to about 70% of their resting length. Muscles with a long parallel fascicle arrangement shorten the most, providing considerable range of movement at a joint, but are not powerful. Muscle power increases as the total number of muscle cells increases. Therefore, the shorter, wide pennate muscles that “pack in” the most fiber bundles shorten less but are most powerful.

Muscular system

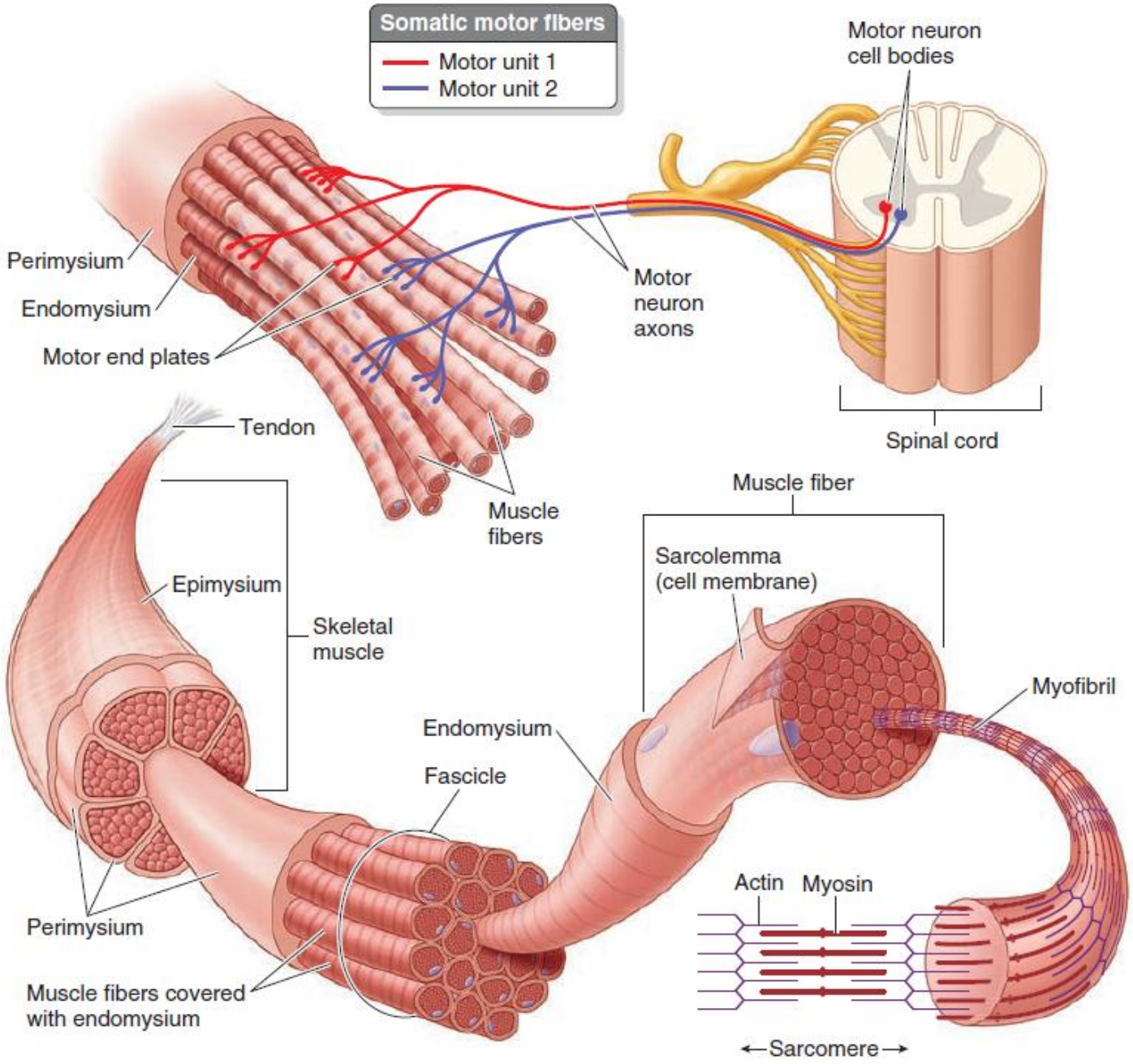
When a muscle contracts and shortens, one of its attachments usually remains fixed and the other one moves. Attachments of muscles are commonly described as the origin and insertion; the origin is usually the proximal end of the muscle, which remains fixed during muscular contraction, and the insertion is usually the distal end of the muscle, which is movable. However, some muscles can act in both directions under different circumstances.

Muscular system

The structural unit of a muscle is a muscle fiber. Connective tissue covering individual muscle fibers is called endomysium, a group of fibers (fiber bundles) is invested by perimysium, and the entire muscle is surrounded by epimysium. The functional unit of a muscle, consisting of a motor neuron and the muscle fibers it controls, is a motor unit. When a motor neuron in the spinal cord is stimulated, it initiates an impulse that causes all the muscle fibers supplied by that motor unit to contract simultaneously.

Muscular system

Structure of skeletal muscle and motor unit. A motor unit consists of a single motor neuron and all the muscle fibers innervated by it.



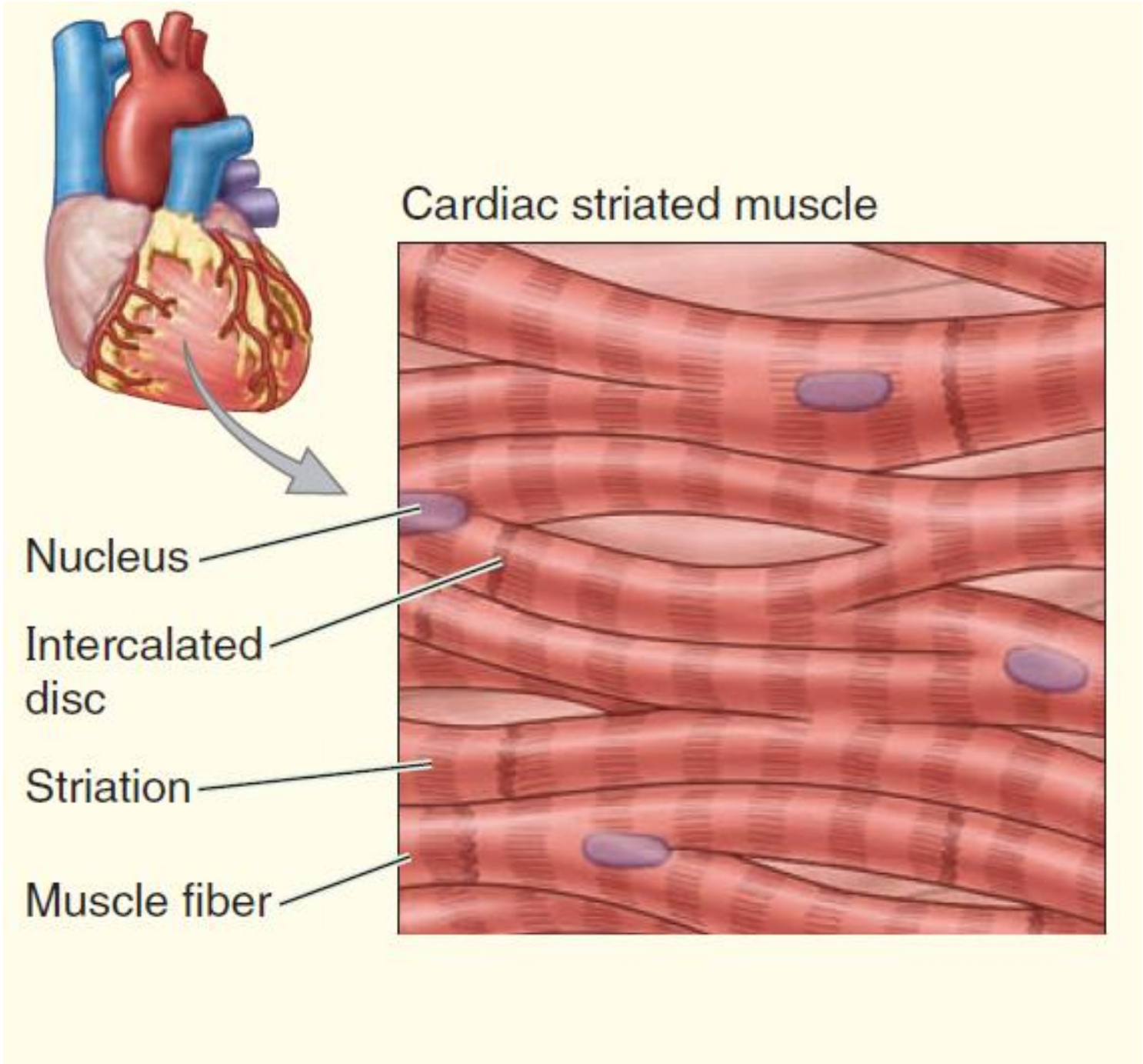
Muscular system

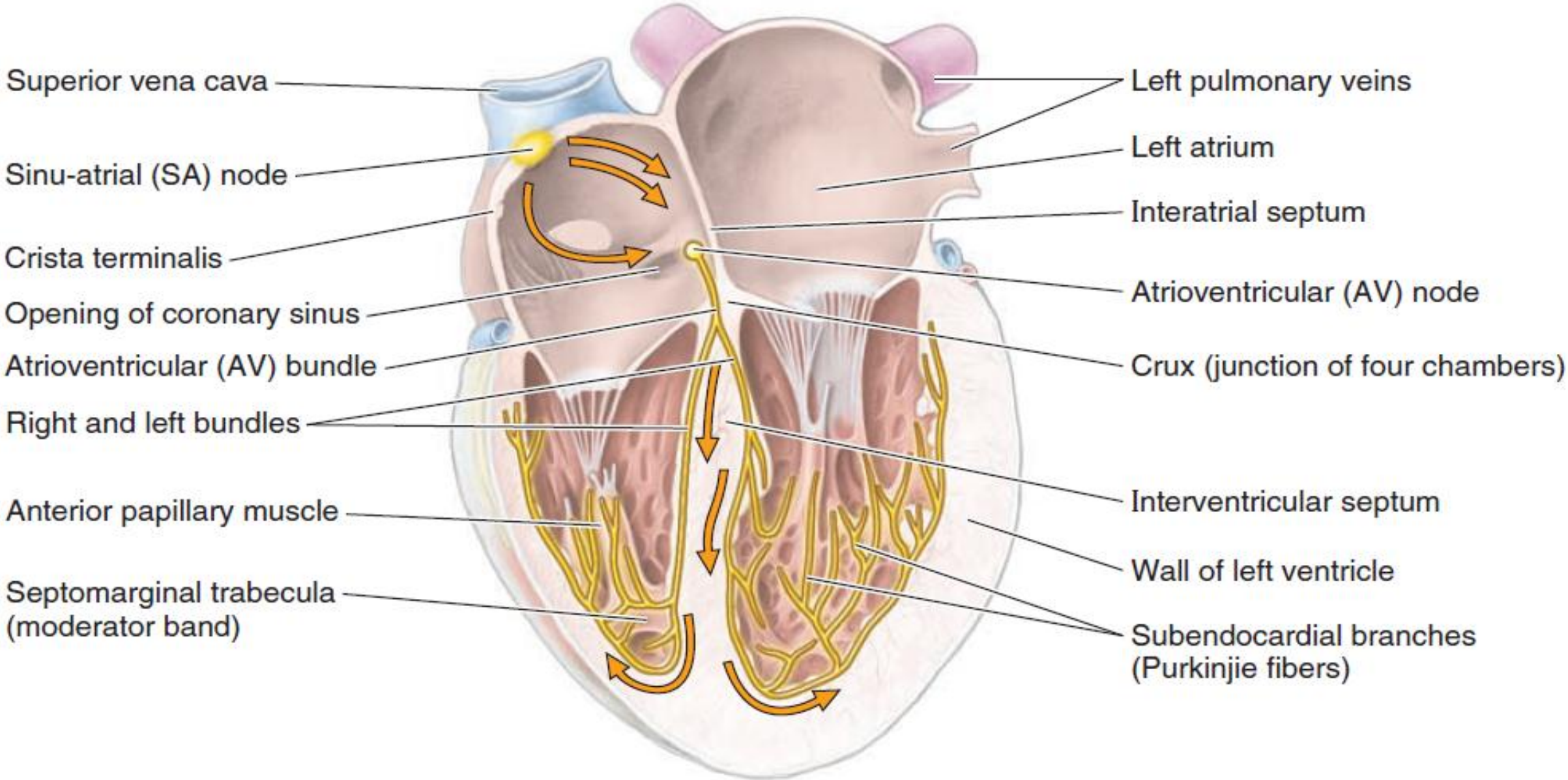
Cardiac striated muscle

Cardiac striated muscle forms the muscular wall of the heart — the myocardium . Some cardiac muscle is also present in the walls of the aorta, pulmonary vein, and superior vena cava. Cardiac muscle contractions are not under voluntary control. Heart rate is regulated intrinsically by a pacemaker composed of special cardiac muscle fibers that are influenced by the autonomic nervous system.

Muscular system

Cardiac striated muscle




Superior vena cava
Sinu-atrial (SA) node
Crista terminalis
Opening of coronary sinus
Atrioventricular (AV) bundle
Right and left bundles
Anterior papillary muscle
Septomarginal trabecula
(moderator band)
Left pulmonary veins
Left atrium
Interatrial septum
Atrioventricular (AV) node
Crux (junction of four chambers)
Interventricular septum
Wall of left ventricle
Subendocardial branches
(Purkinjie fibers)

Muscular system

Smooth Muscle

Smooth muscle, named for the absence of microscopic striations, forms a large part of the middle coat or layer (tunica media) of the walls of most blood vessels and the muscular part of the wall of the digestive tract and ducts. Smooth muscle is also found in skin (arrector muscles associated with hair follicles) and in the eyeball (to control lens thickness and pupil size). Like cardiac muscle, smooth muscle is innervated by the autonomic nervous system; hence, it is an involuntary muscle that can undergo partial contraction for long periods.

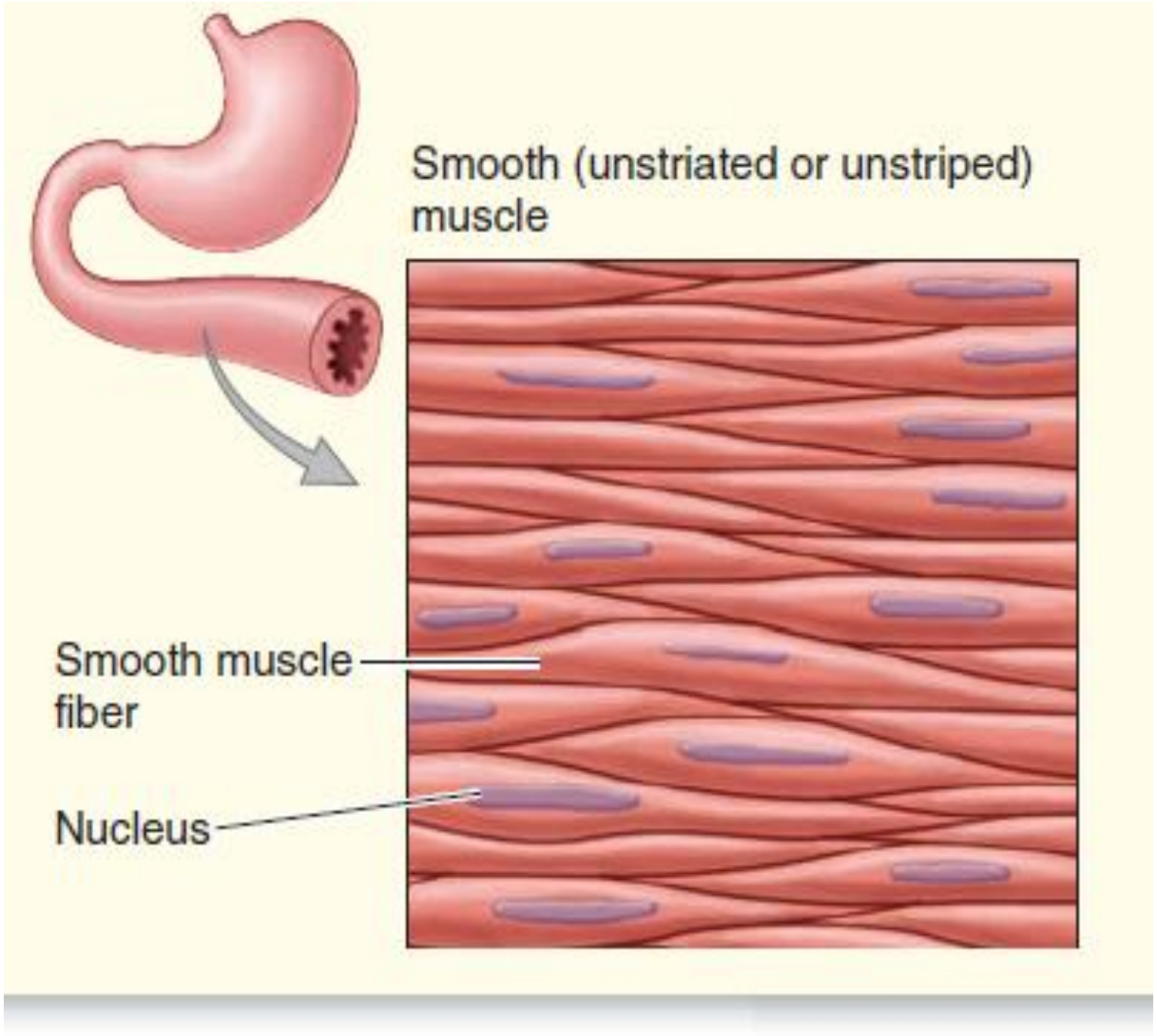
Muscular system

Smooth Muscle

This is important in regulating the size of the lumen of tubular structures; in the walls of the digestive tract, uterine tubes, and ureters, the smooth muscle cells undergo rhythmic contractions (peristaltic waves). This process (peristalsis) propels the contents along these tubular structures.

Muscular system

Smooth Muscle



Cardiovascular system

The circulatory system transports fluids throughout the body; it consists of the cardiovascular and lymphatic systems. The heart and blood vessels form the blood transportation network, the cardiovascular system . The heart pumps blood through the body's vast system of vessels. The blood carries nutrients, oxygen, and waste products to and from cells.

Cardiovascular system

The heart consists of two muscular pumps that, although adjacently located, act in a series, dividing the cardiovascular system into two circulations.

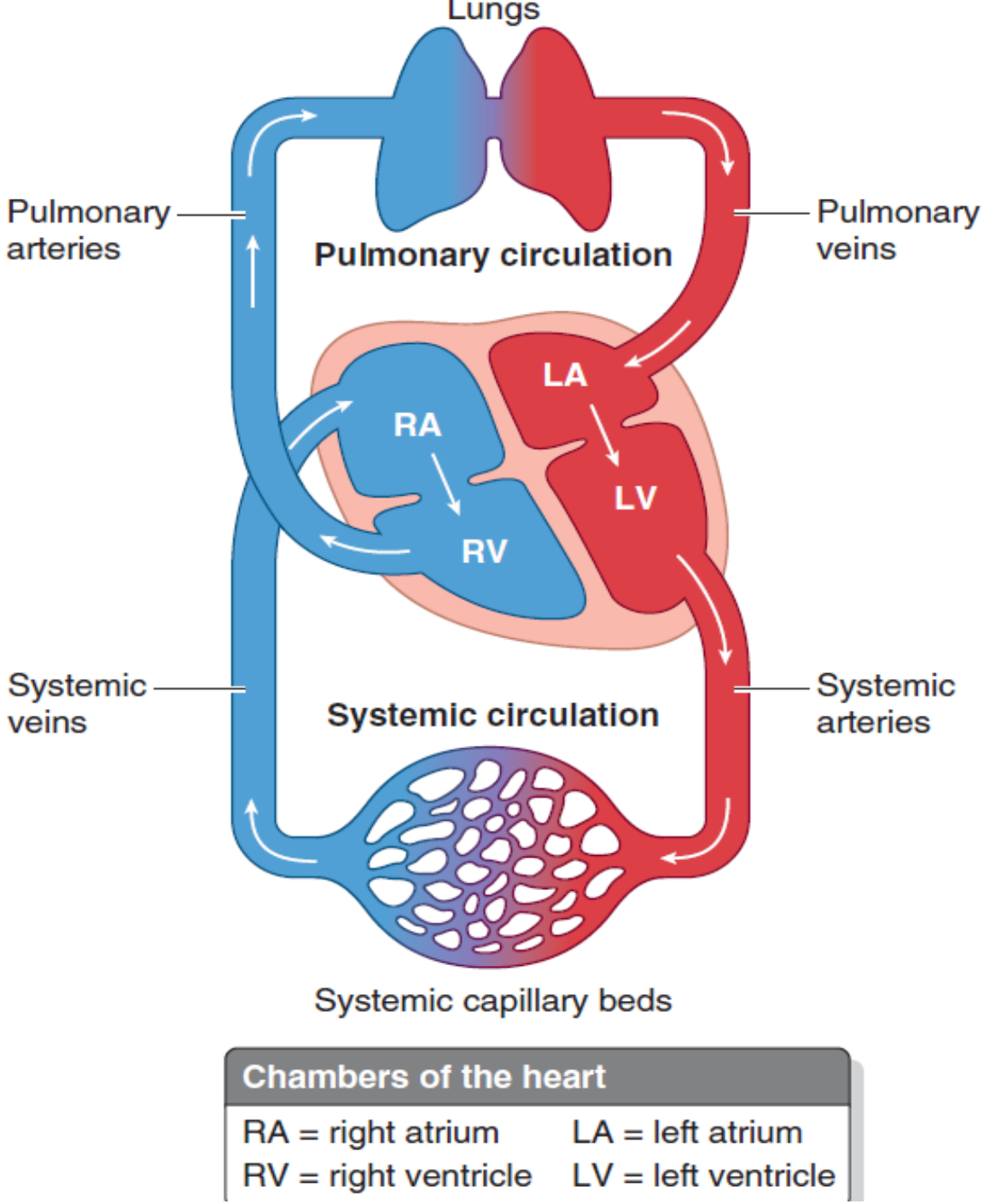
In the pulmonary circulation, the right heart propels low-oxygen blood returned to it into the lungs, where carbon dioxide is exchanged for oxygen.

In the systemic circulation, oxygen-rich blood returned to the left heart is pumped to the remainder of the body, exchanging oxygen and nutrients for carbon dioxide.

Cardiovascular system

Schema of cardiovascular system.

The continuous circuit consists of two loops: the pulmonary and systemic circulations, served by separate halves of the heart.



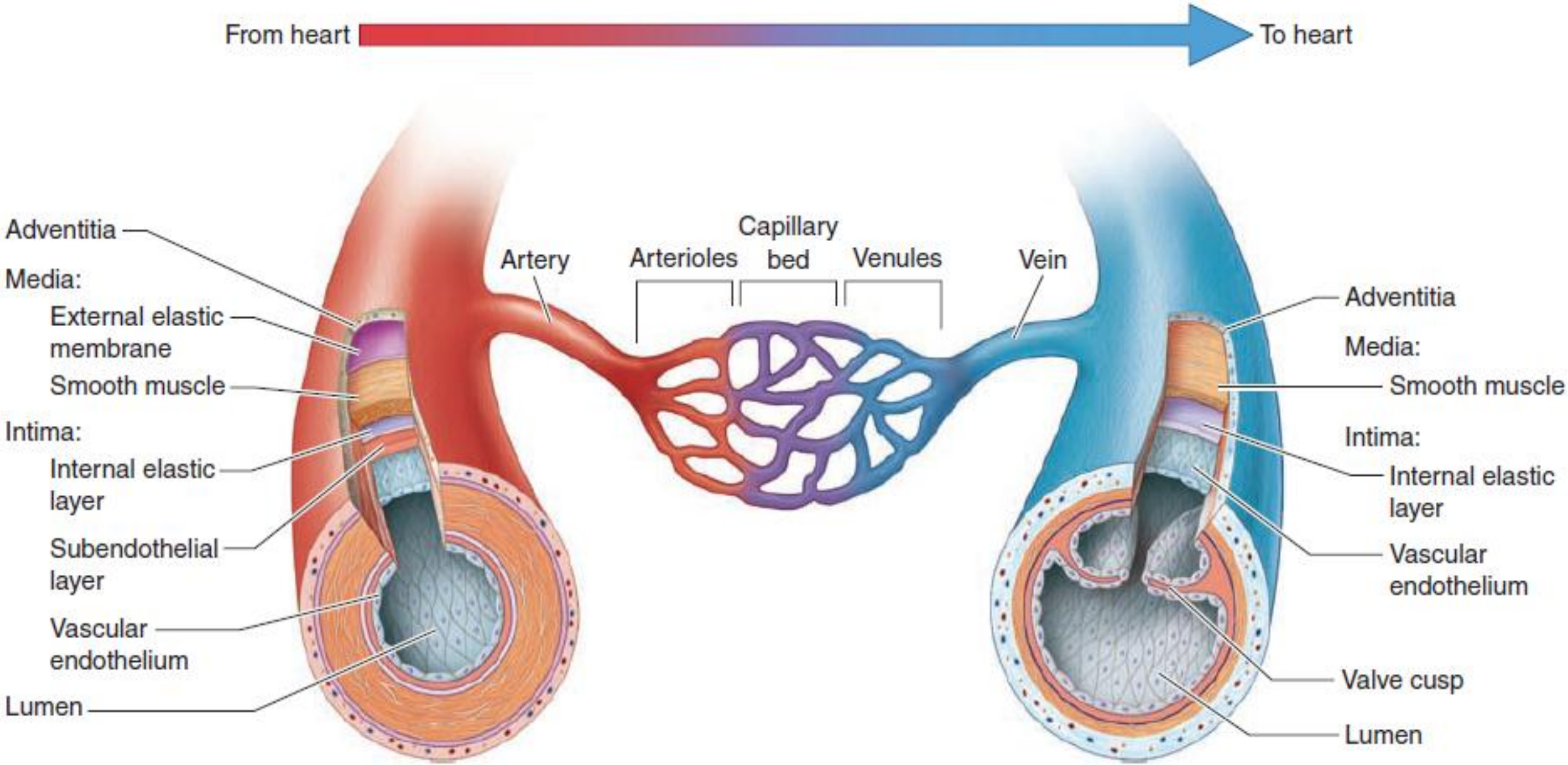
Cardiovascular system

There are three types of blood vessels: **arteries, veins, and capillaries**. Blood under high pressure leaves the heart and is distributed to the body by a branching system of thick-walled arteries. The final distributing vessels, arterioles, deliver oxygenated blood to capillaries. Capillaries form a capillary bed, where the interchange of oxygen, nutrients, waste products, and other substances with the extracellular fluid occurs.

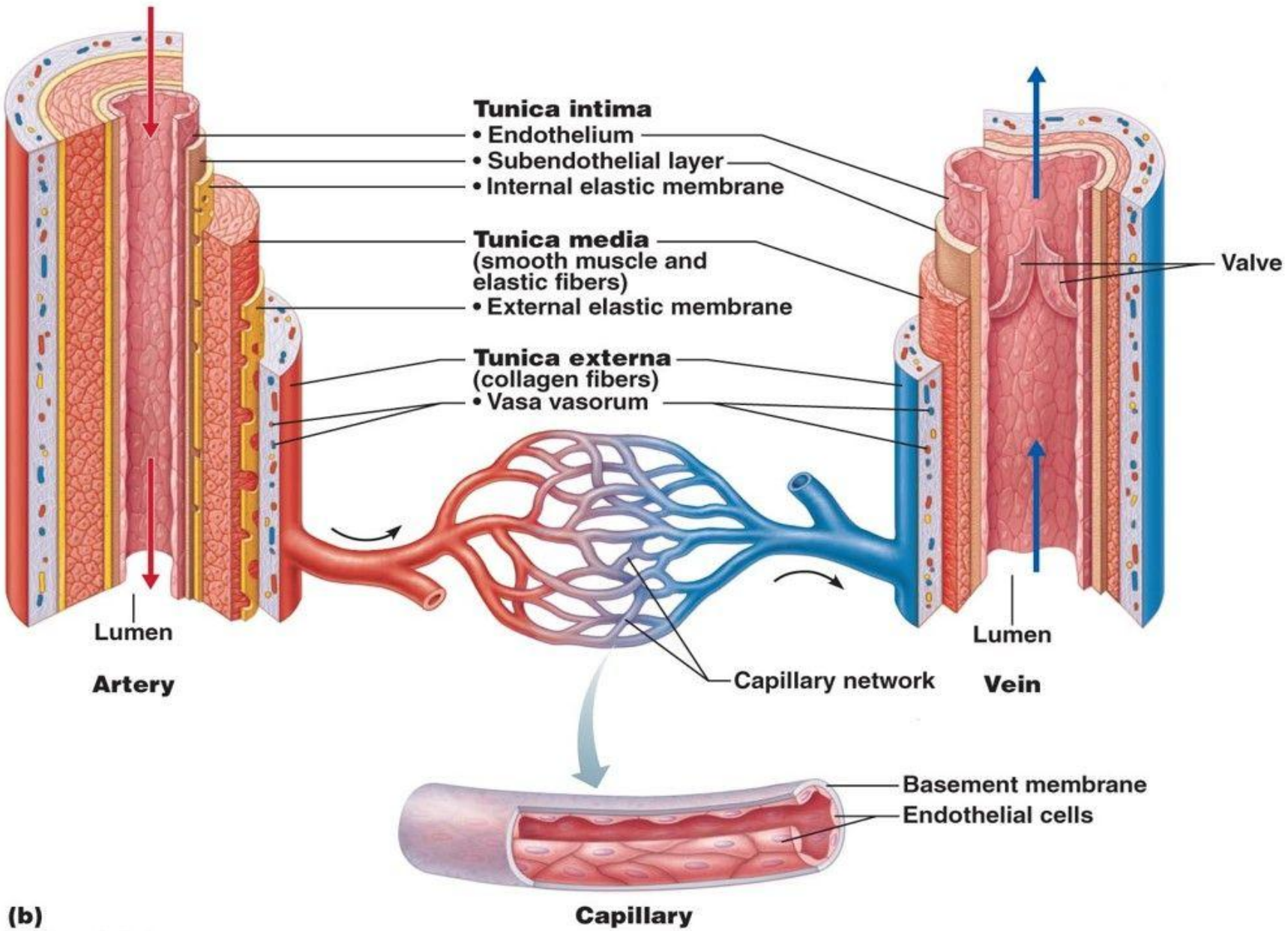
Cardiovascular system

Blood from the capillary bed passes into thin-walled venules, which resemble wide capillaries. Venules drain into small veins that open into larger veins. The largest veins, the superior vena cava (SVC) and inferior vena cava (IVC), return poorly oxygenated blood to the heart.

Cardiovascular system



Cardiovascular system



Cardiovascular system

Most vessels of the circulatory system have three tunics or coats: tunica intima, the thin endothelial lining of vessels; tunica media, the middle smooth muscle layer; and tunica adventitia, the outer connective tissue coat.

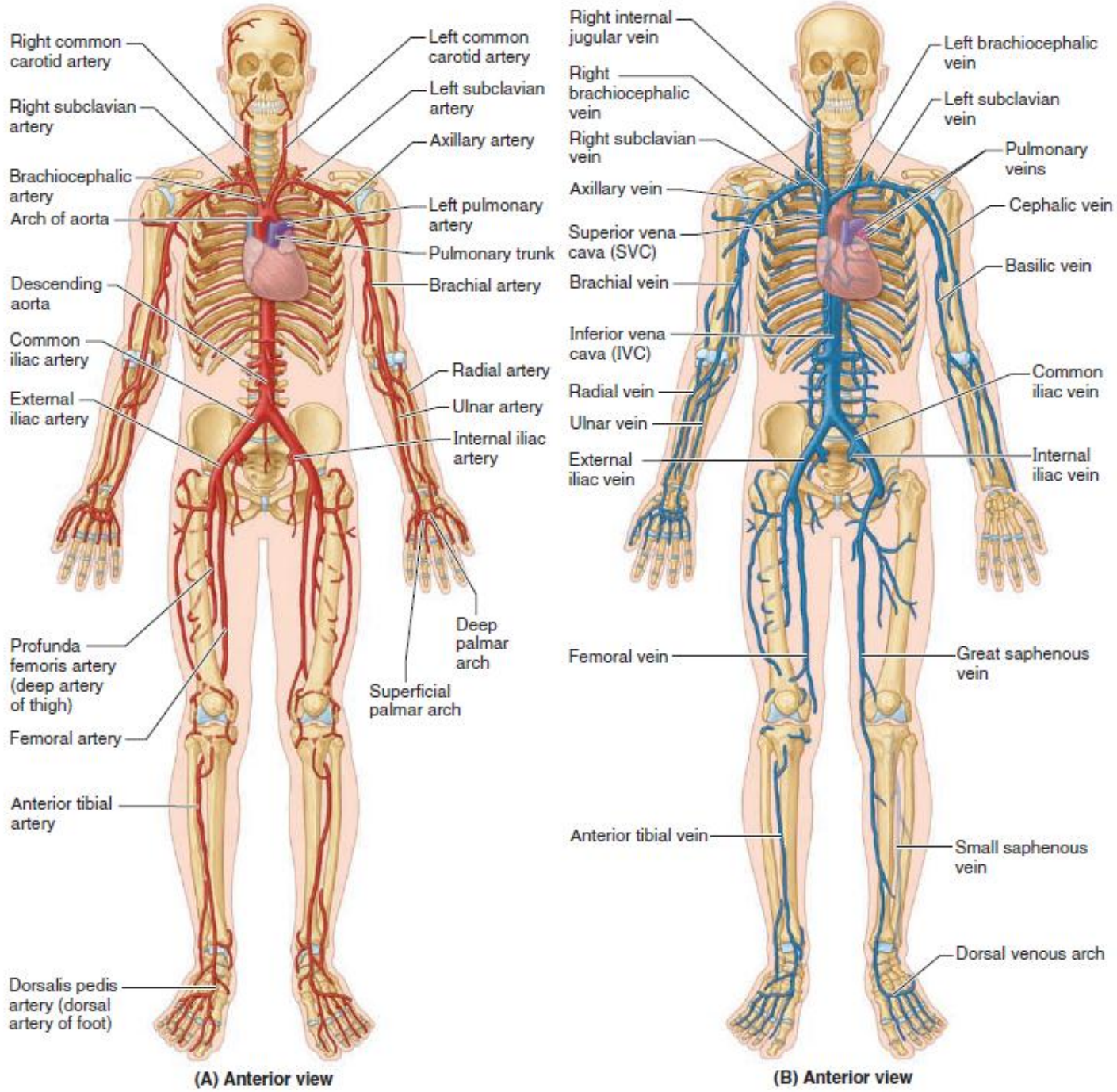
Cardiovascular system

Systemic portion of cardiovascular system.

A. Principal arteries.

B. B. Principal veins.

Superficial veins are shown in the left limbs; deep veins are shown in the right limbs.



Cardiovascular system

Arteries

Arteries carry blood away from the heart and distribute it to the body. Blood passes from the heart through arteries of ever-decreasing caliber. The different types of arteries are distinguished from each other on the basis of overall size, relative amounts of elastic tissue or muscle in the tunica media, and the thickness of the wall relative to the lumen.

Cardiovascular system

Anastomoses (communications) between the multiple branches of an artery provide numerous potential detours for blood flow in case the usual pathway is obstructed by compression, the position of a joint, pathology, or surgical ligation. If a main channel is occluded, the smaller alternate channels can usually increase in size, providing a collateral circulation that ensures the blood supply to structures distal to the blockage.

Cardiovascular system

Veins.

Veins return poorly oxygenated blood to the heart from the capillary beds. The large pulmonary veins are atypical in that they carry well-oxygenated blood from the lungs to the heart. Because of the lower blood pressure in the venous system, the walls of veins are thinner than those of their companion arteries. The smallest veins, venules, unite to form larger veins that usually form venous plexuses.

Cardiovascular system

Veins.

Medium veins in the limbs and other locations where the flow of blood is opposed by the pull of gravity have ***valves*** that permit blood to flow toward the heart but not in the reverse direction. Large veins, such as the SVC and IVC, are characterized by wide bundles of longitudinal smooth muscle and a well- developed tunica adventitia. Systemic veins are more variable than the arteries and more frequently form anastomoses.

Cardiovascular system

Veins

The limbs have superficial and deep veins; the superficial veins are in the subcutaneous tissue, and the deep veins are deep to the deep fascia and accompany the major arteries. Superficial and deep veins have valves, but they are more numerous in deep veins.

Cardiovascular system

Veins

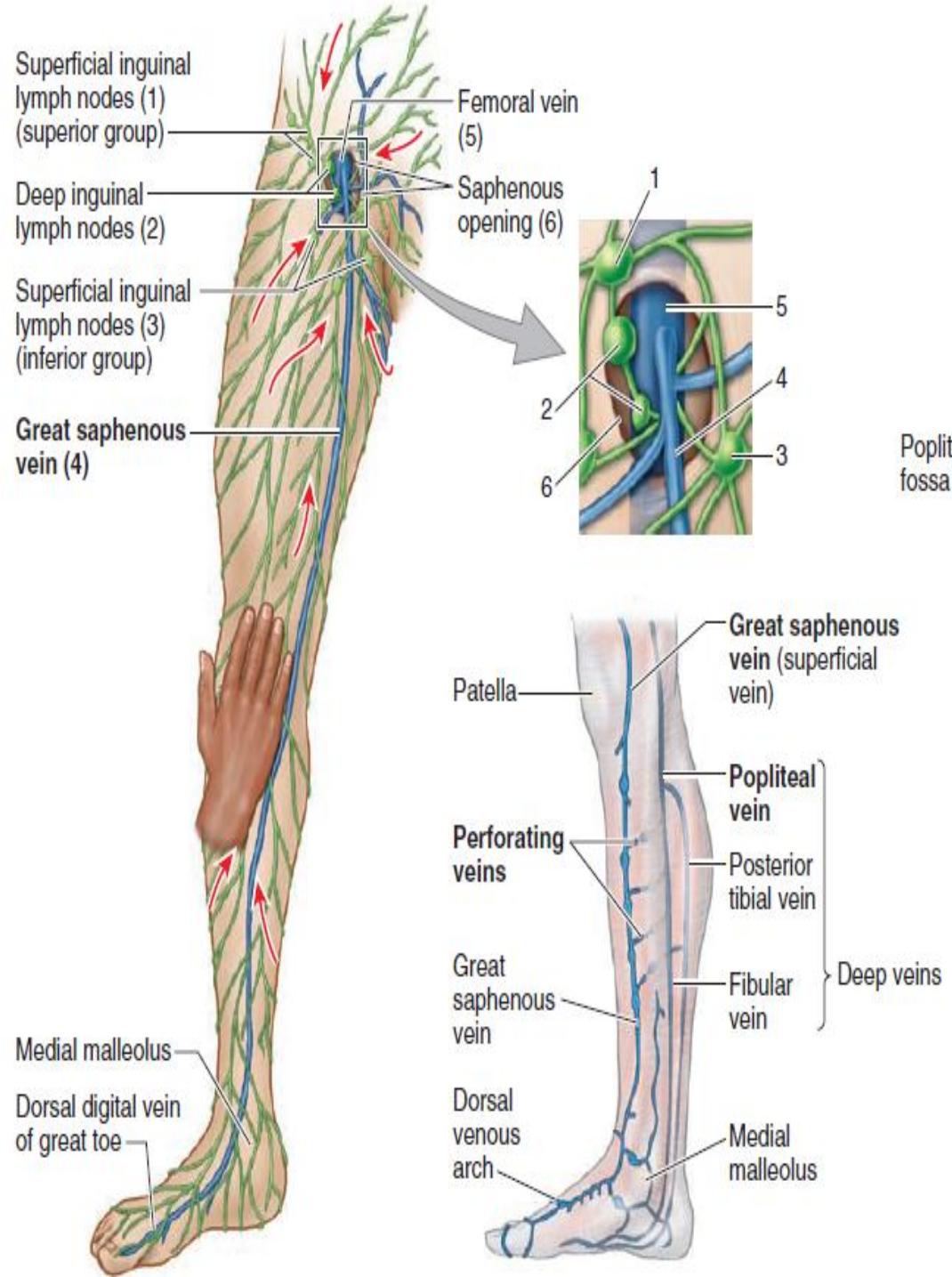
The two major superficial veins of lower limb are the great and small saphenous veins. The great saphenous vein is formed by the union of the dorsal digital vein of the

great toe and the dorsal venous arch of the foot. The great saphenous vein

- Ascends anterior to the medial malleolus
- Passes posterior to the medial condyle of the femur (about a hand's breadth posterior to the medial border of the patella)

Cardiovascular system

Veins of the lower limb



Cardiovascular system

Veins.

The small saphenous vein arises on the lateral side of the foot from the union of the dorsal digital vein of the 5th digit with the dorsal venous arch. The small saphenous vein

- Ascends posterior to the lateral malleolus as a continuation of the lateral marginal vein
- Passes along the lateral border of the calcaneal tendon
- Inclines to the midline of the fibula and penetrates the deep fascia
- Ascends between the heads of the gastrocnemius muscle
- Empties into the popliteal vein in the popliteal fossa

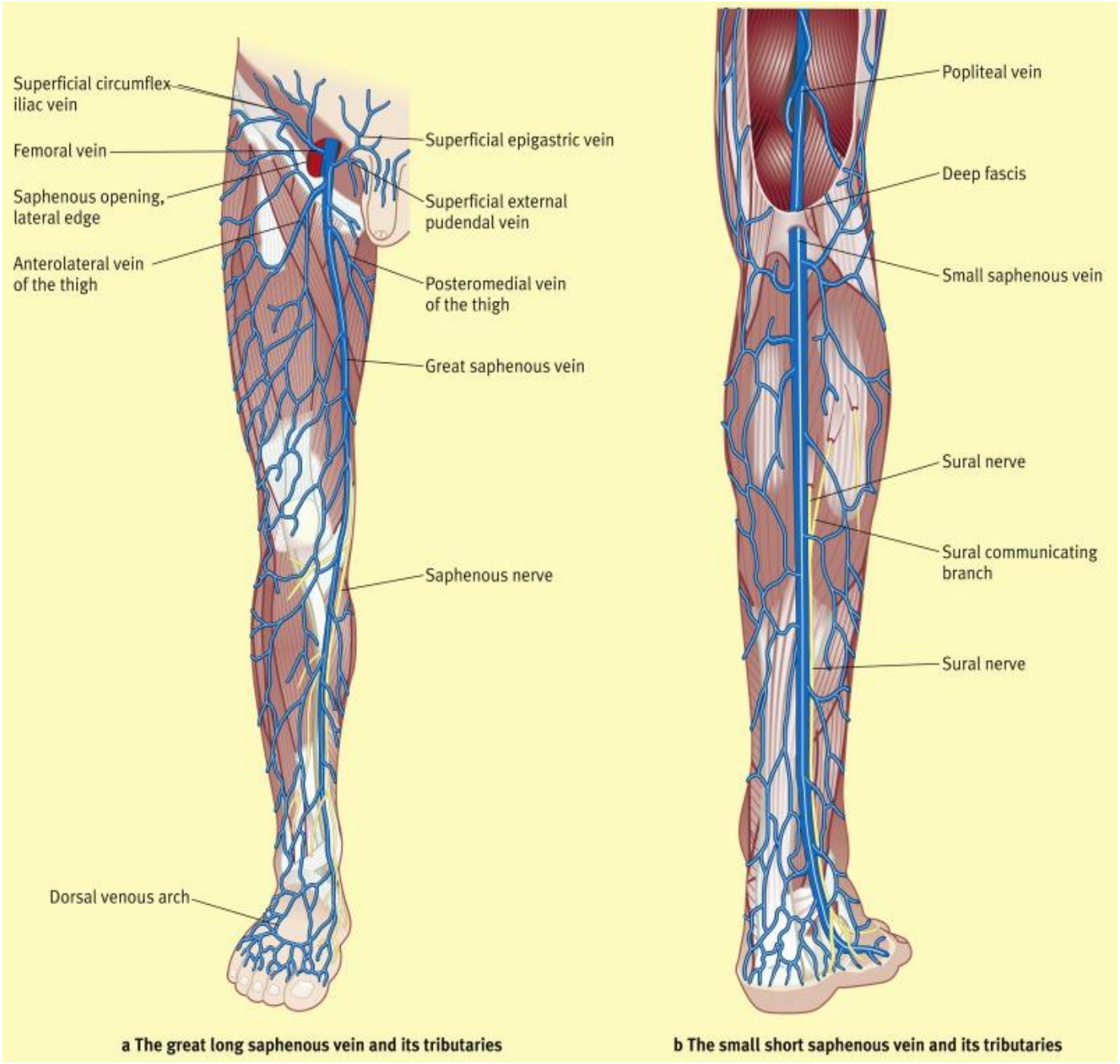
Cardiovascular system

Veins

Abundant perforating veins penetrate the deep fascia as they pass between the superficial and deep veins. They contain valves that allow blood to flow only from the superficial to the deep veins. The perforating veins penetrate the deep fascia at oblique angles so that when muscles contract and pressure increases inside the deep fascia, the perforating veins are compressed, preventing blood from flowing from the deep to the superficial veins.

Cardiovascular system

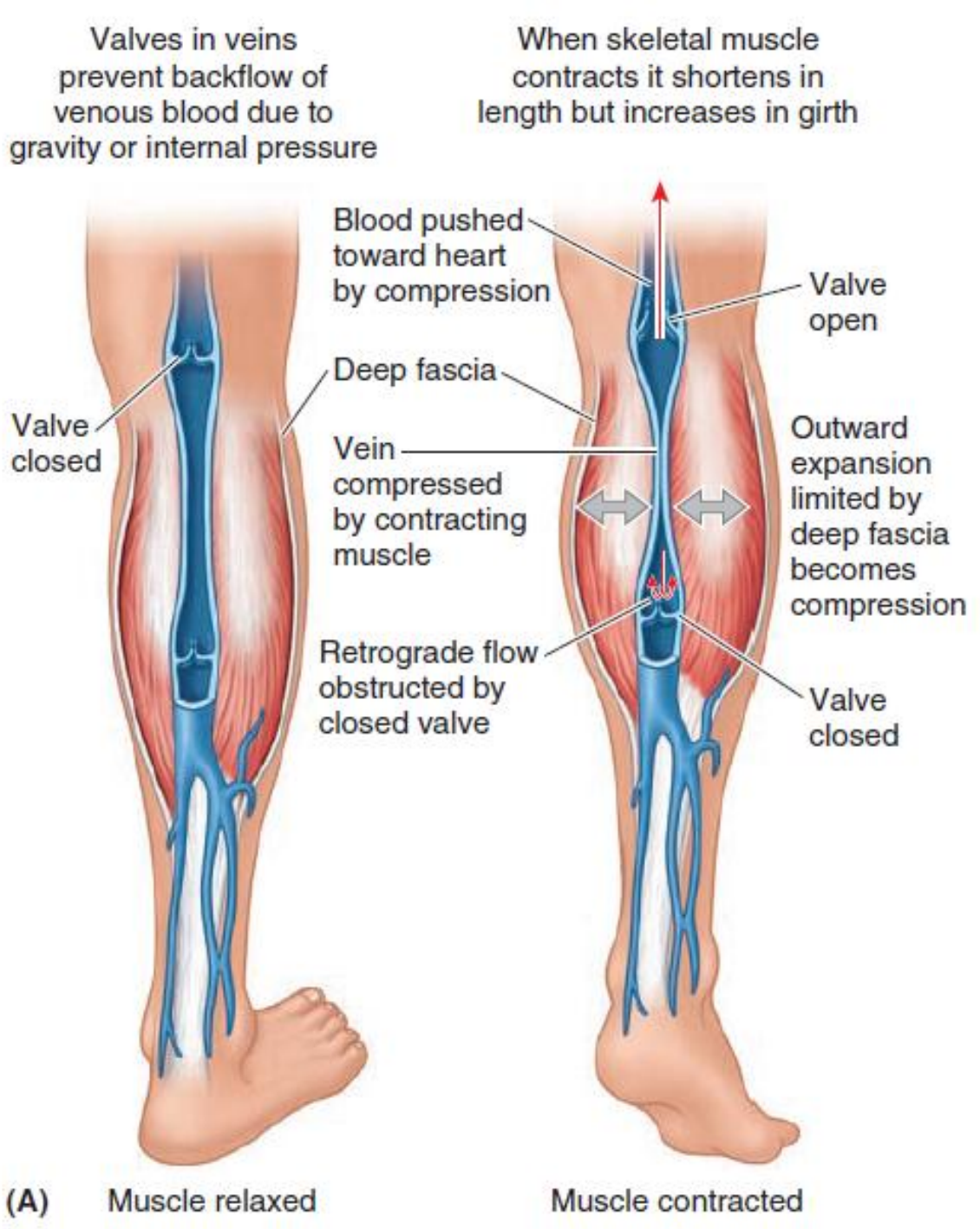
Veins. Superficial venous drainage of lower limb.



Cardiovascular system

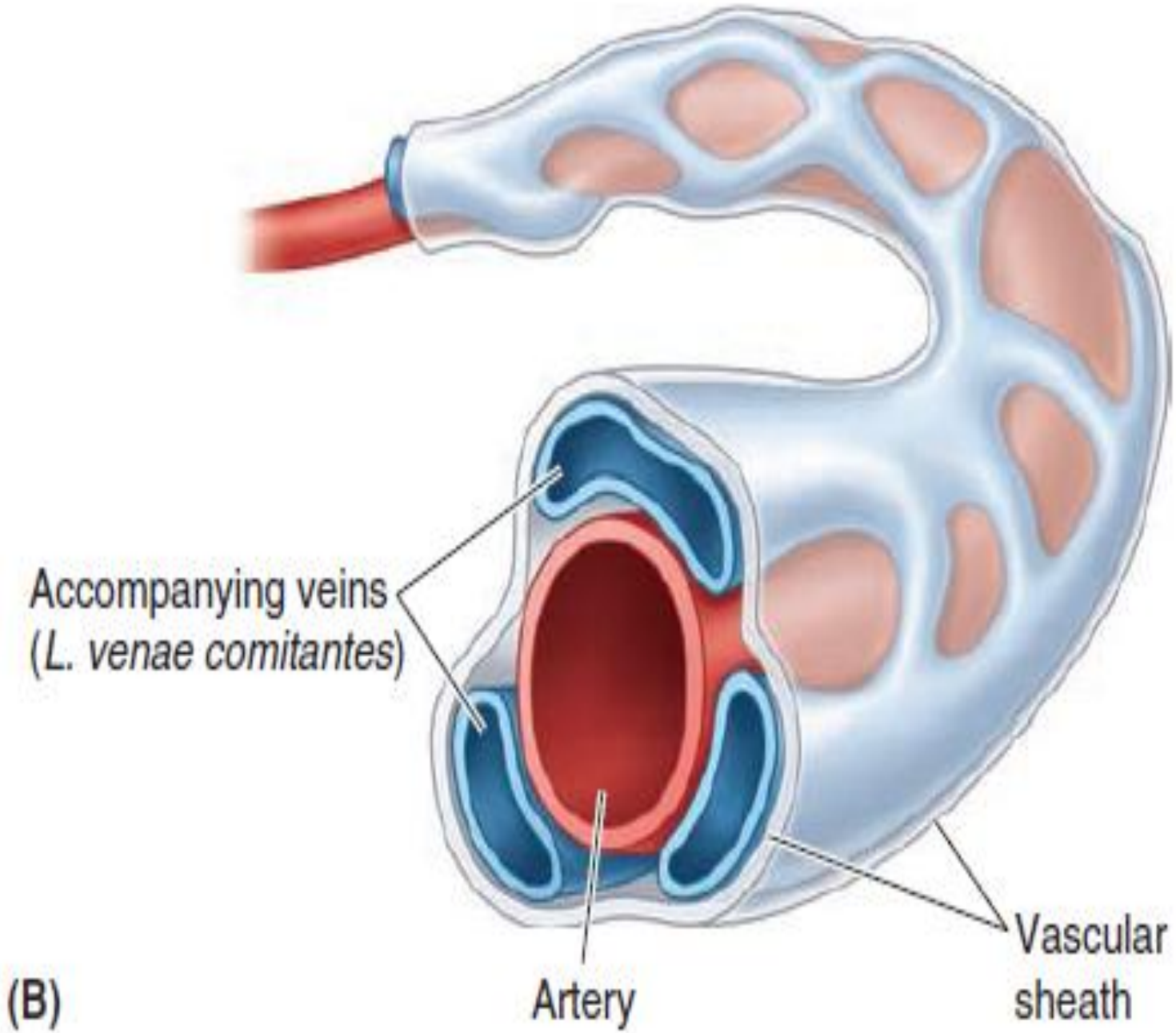
Veins.

The musculovenous pump. Muscular contractions in the limbs function with the venous valves to move blood toward the heart.



Cardiovascular system

Veins. Although often depicted as single vessels, veins tend to be double or multiple. The veins that accompany deep arteries (accompanying veins) surround them in a branching network and occupy a relatively unyielding vascular sheath with the artery they accompany. As a result, they are stretched and flattened as the artery expands during contraction of the heart, which assists in driving the venous blood toward the heart.



Cardiovascular system

Capillaries

Capillaries are simple endothelial tubes connecting the arterial and venous sides of the circulation. They are generally arranged in networks (capillary beds) between the arterioles and venules .

Lymphoid system

The lymphatic system provides for the drainage of surplus tissue fluid and leaked plasma proteins to the bloodstream and for the removal of cellular debris and infection. This system collects surplus extracellular tissue fluid as lymph. Lymph is usually clear and watery and is similar in composition to blood plasma.

Lymphoid system

The lymphoid system consists of

- Lymphatic plexuses, networks of small lymphatic vessels, lymphatic capillaries, that originate in the extracellular spaces of most tissues
- Lymphatic vessels (lymphatics), a nearly body-wide network of thin-walled vessels with abundant valves originating from lymphatic plexuses along which lymph nodes are located.

Lymphoid system

- Lymph nodes, small masses of lymphatic tissue through which lymph is filtered on its way to the venous system
- Lymphocytes, circulating cells of the immune system that react against foreign materials
- Lymphoid organs, sites that produce lymphocytes, such as that found in the walls of the digestive tract; in the spleen, thymus, and lymph nodes; and in myeloid tissue in red bone marrow

Lymphoid system

Lymphatic vessels occur almost everywhere blood capillaries are found, except, for example, teeth, bone, bone marrow, and the entire central nervous system (excess fluid here drains into the cerebrospinal fluid). Superficial lymphatic vessels in the skin and subcutaneous tissue eventually drain into deep lymphatic vessel. The deep vessels accompany the major blood vessels.

Lymphoid system

After traversing one or more lymph nodes, lymph enters larger lymphatic vessels, called lymphatic trunks, which unite to form either the right lymphatic duct or the thoracic duct.

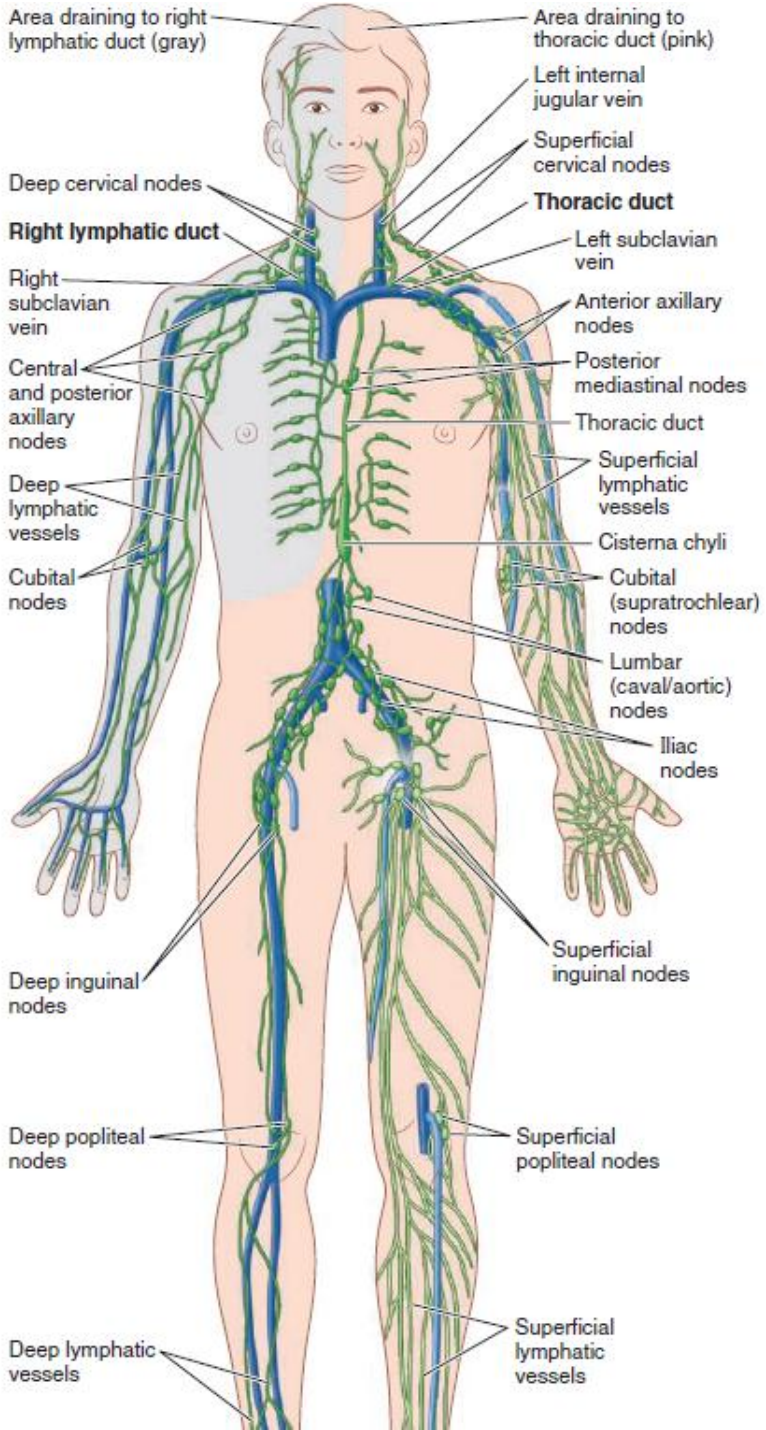
- The right lymphatic duct drains lymph from the body's right upper quadrant (right side of head, neck, and thorax and the entire right upper limb). The duct ends in the right subclavian vein at its angle of junction with the right internal jugular vein, called the right venous angle.

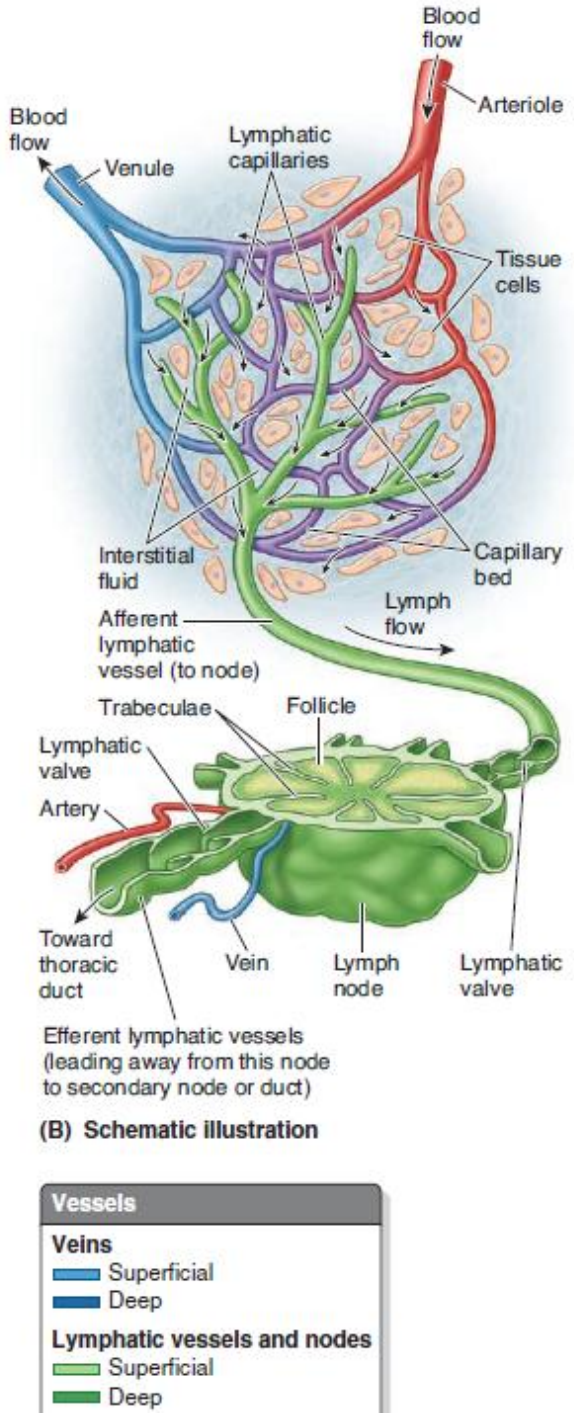
Lymphoid system

- The thoracic duct drains lymph from the remainder of the body. This duct begins in the abdomen as a sac, the cisterna chyli, and ascends through the thorax and enters the junction of the left internal jugular and left subclavian veins, called the left venous angle.

Lymphoid system

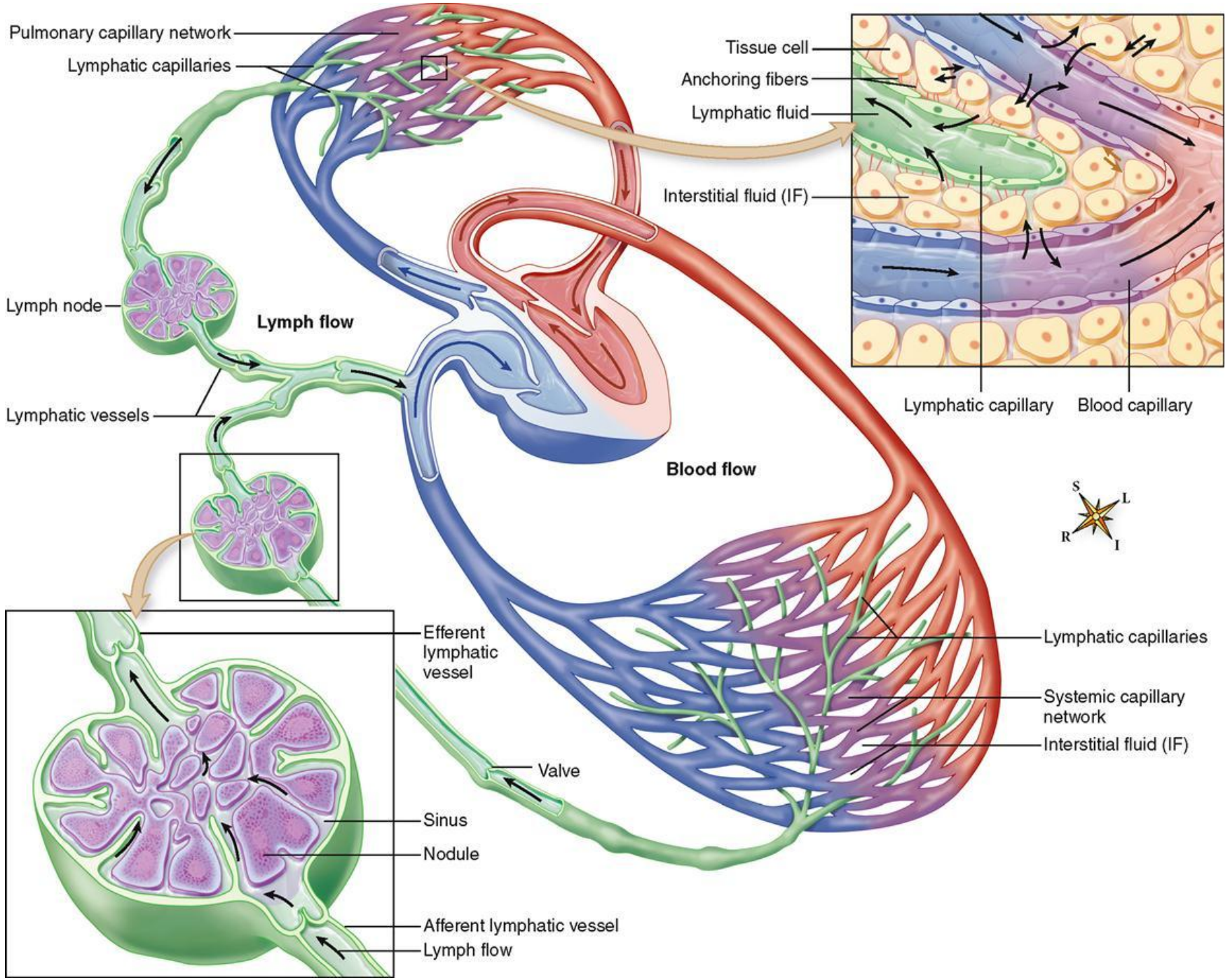
The right lymphatic duct drains lymph from the right side of the head and neck and the right upper limb (shaded). The thoracic duct drains the remainder of the body. Deep lymphatic vessels are shown on the right, and superficial lymphatic vessels are shown on the left. B. Lymph flow from extracellular spaces through a lymph node. Small black arrows indicate the flow of interstitial fluid out of blood capillaries into the lymphatic capillaries.





Lymphoid system

The lymphatic system in relation to the cardiovascular system (scheme).



Nervous system

The nervous system enables the body to react to continuous changes in its external and internal environments. It controls and integrates various activities of the body, such as circulation and respiration. Nervous tissue consists of two main cell types: neurons (nerve cells) and neuroglia (glial cells).

Nervous system

Neurons are the structural and functional units of the nervous system specialized for rapid communication. Neuroglia (glial cells or glia) are approximately five times as abundant as neurons and are nonneuronal, nonexcitable cells that form a major component (scaffolding) of nervous tissue. Neuroglia support, insulate, and nourish the neurons.

Nervous system

For descriptive purposes, the human nervous system is divided as follows:

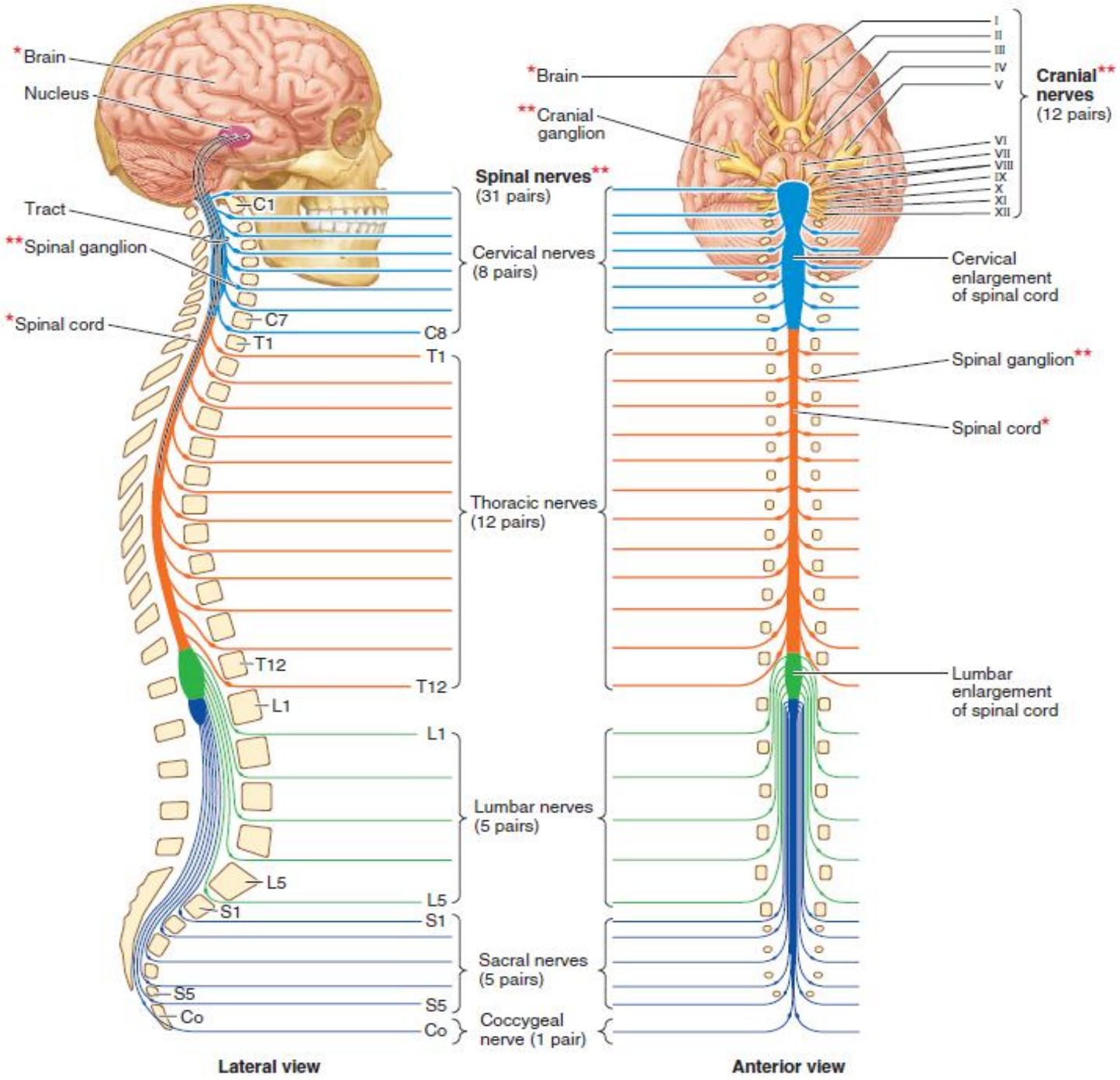
- Structurally into the central nervous system (CNS), made up of the brain and spinal cord, and the peripheral nervous system, consisting of nerve fibers and cell bodies outside the CNS that conduct impulses to or away from the CNS

Nervous system

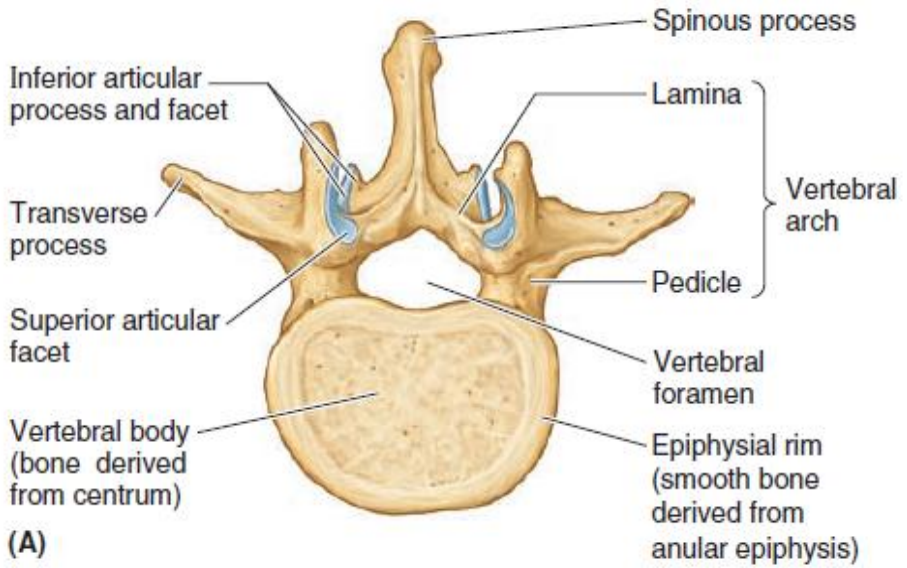
- Functionally into the somatic nervous system (SNS), the voluntary nervous system, which carries sensation (e.g., pain) from the skin and joints (e.g., position sense) and supplies skeletal muscle, and the autonomic nervous system, the involuntary/visceral nervous system, which supplies smooth muscle (e.g., in the wall of blood vessels), glands (e.g., sweat glands), and viscera (internal organs) in the body cavities (e.g., heart, stomach, and bladder)

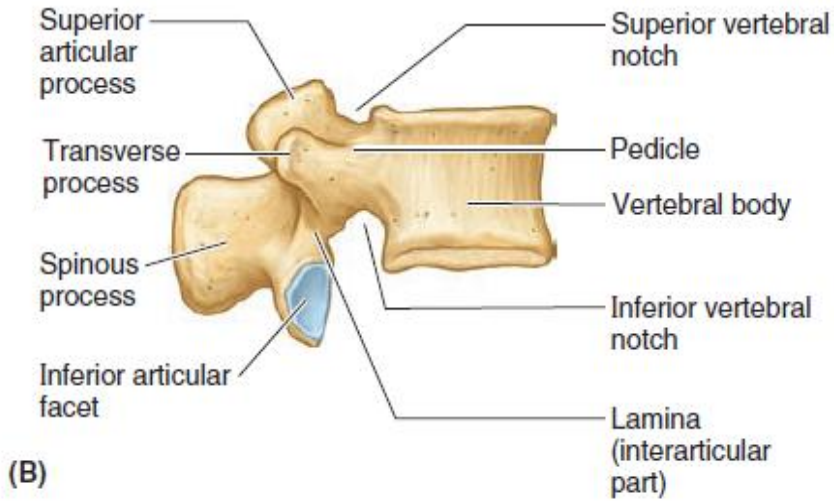
Nervous system

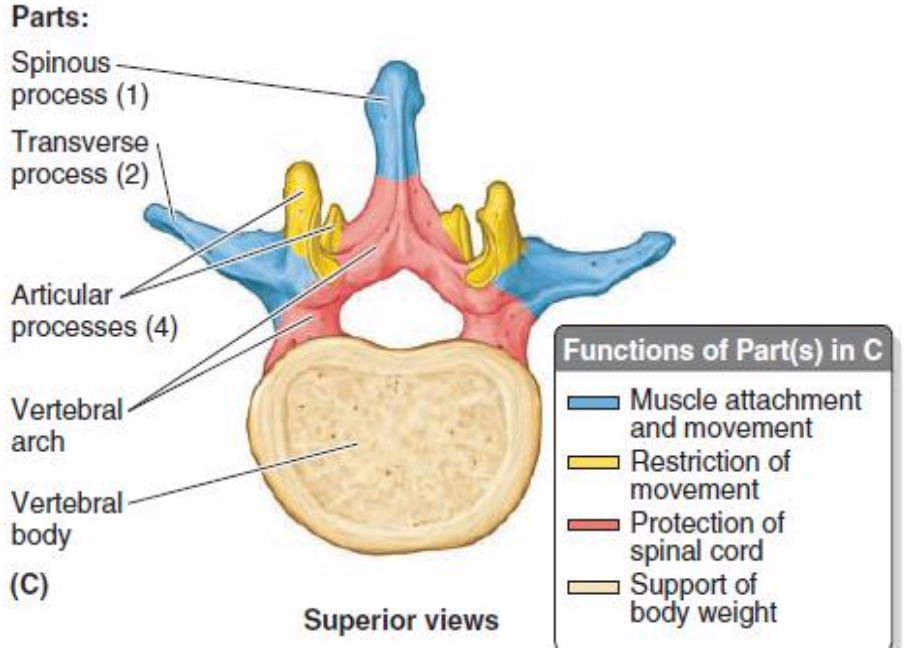
The **central nervous system** consists of the brain and spinal cord. The principal roles of the CNS are to integrate and coordinate incoming and outgoing neural signals and to carry out higher mental functions, such as thinking and learning.

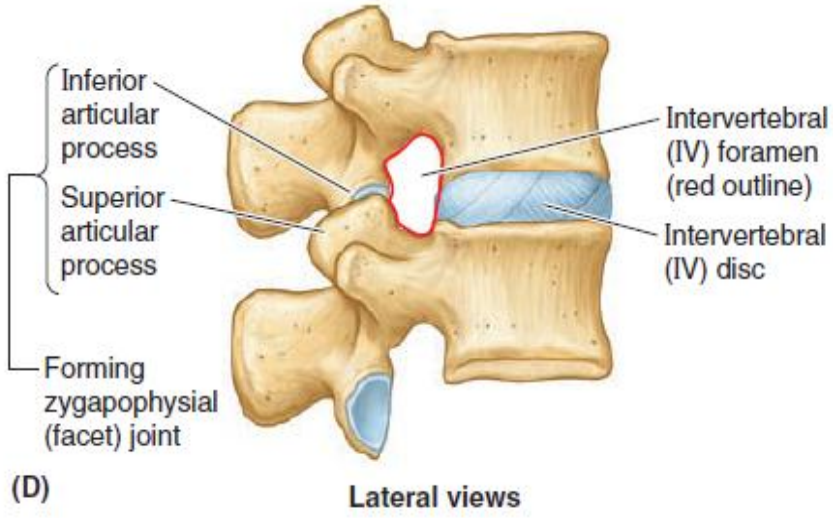


Typical vertebra, represented by second lumbar vertebra







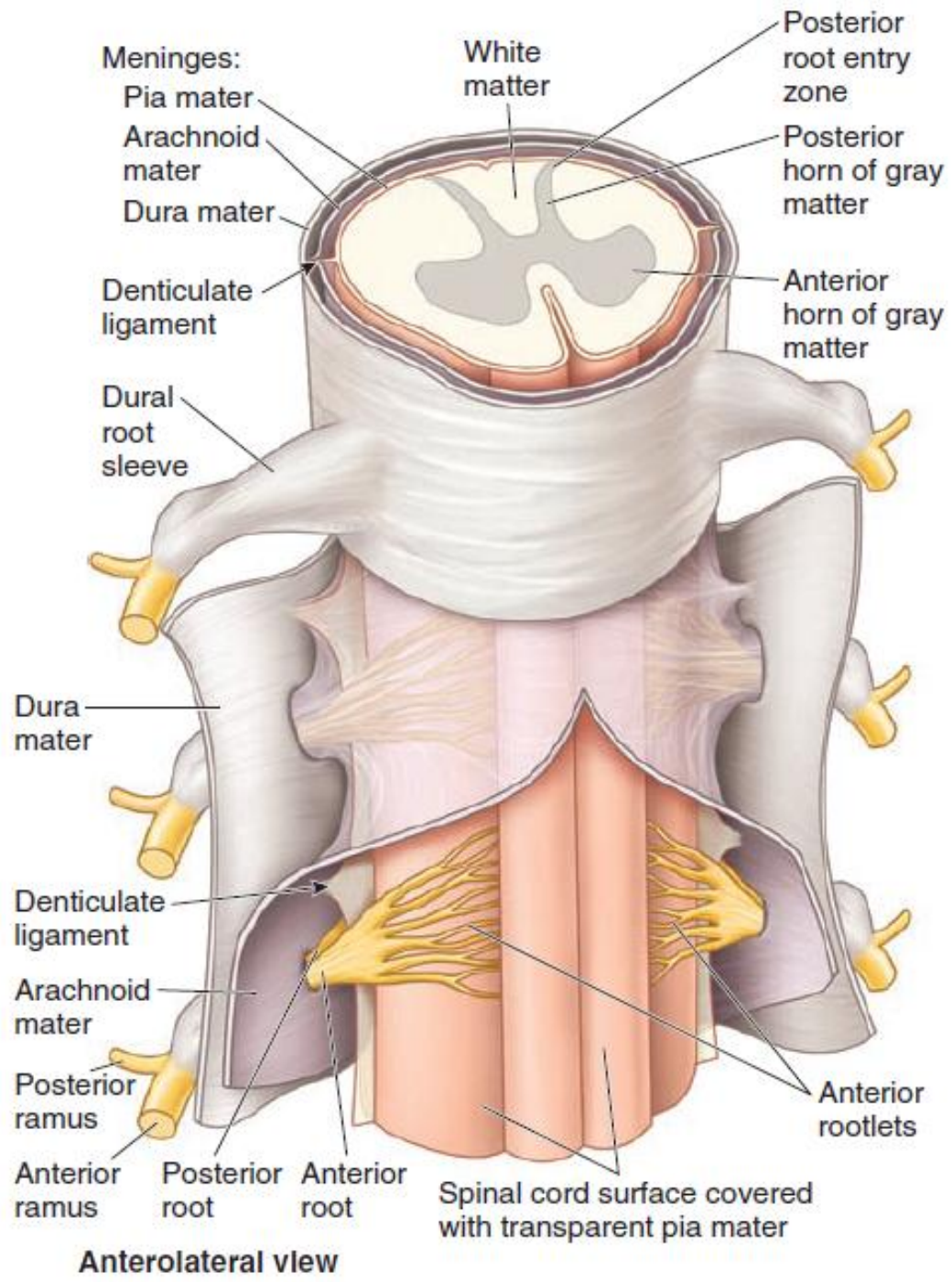


Nervous system

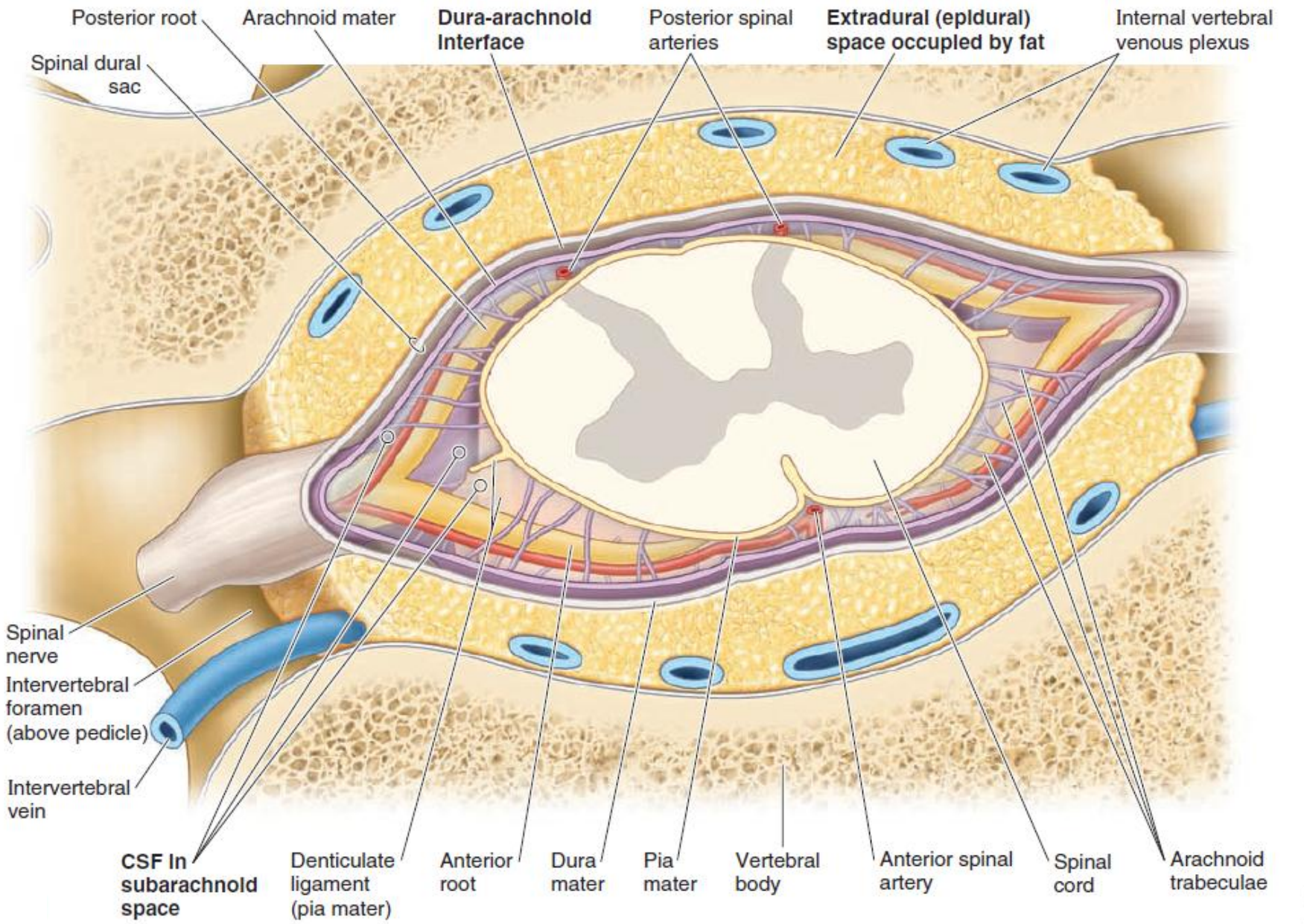
The nerve cell bodies lie within and constitute the gray matter; the interconnecting fiber tract systems form the white matter. In transverse sections of the spinal cord, the gray matter appears roughly as an H-shaped area embedded in a matrix of white matter. The struts (supports) of the H are horns; therefore, there are right and left posterior (dorsal) and anterior (ventral) gray horns.

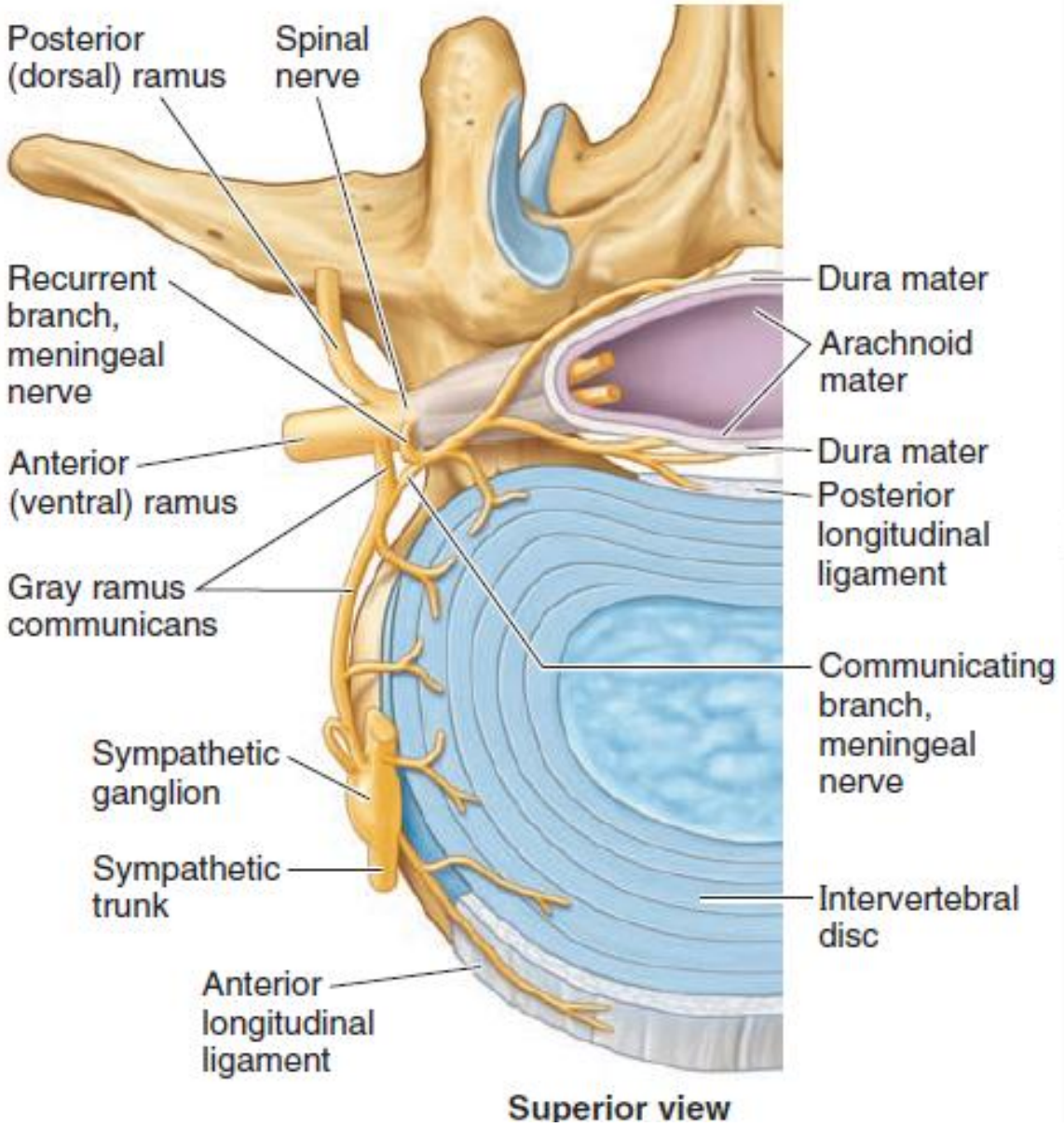
Nervous system

Three membranous layers — pia mater, arachnoid mater, and dura mater — collectively constitute the meninges. The meninges and the cerebrospinal fluid (CSF) surround and protect the CNS

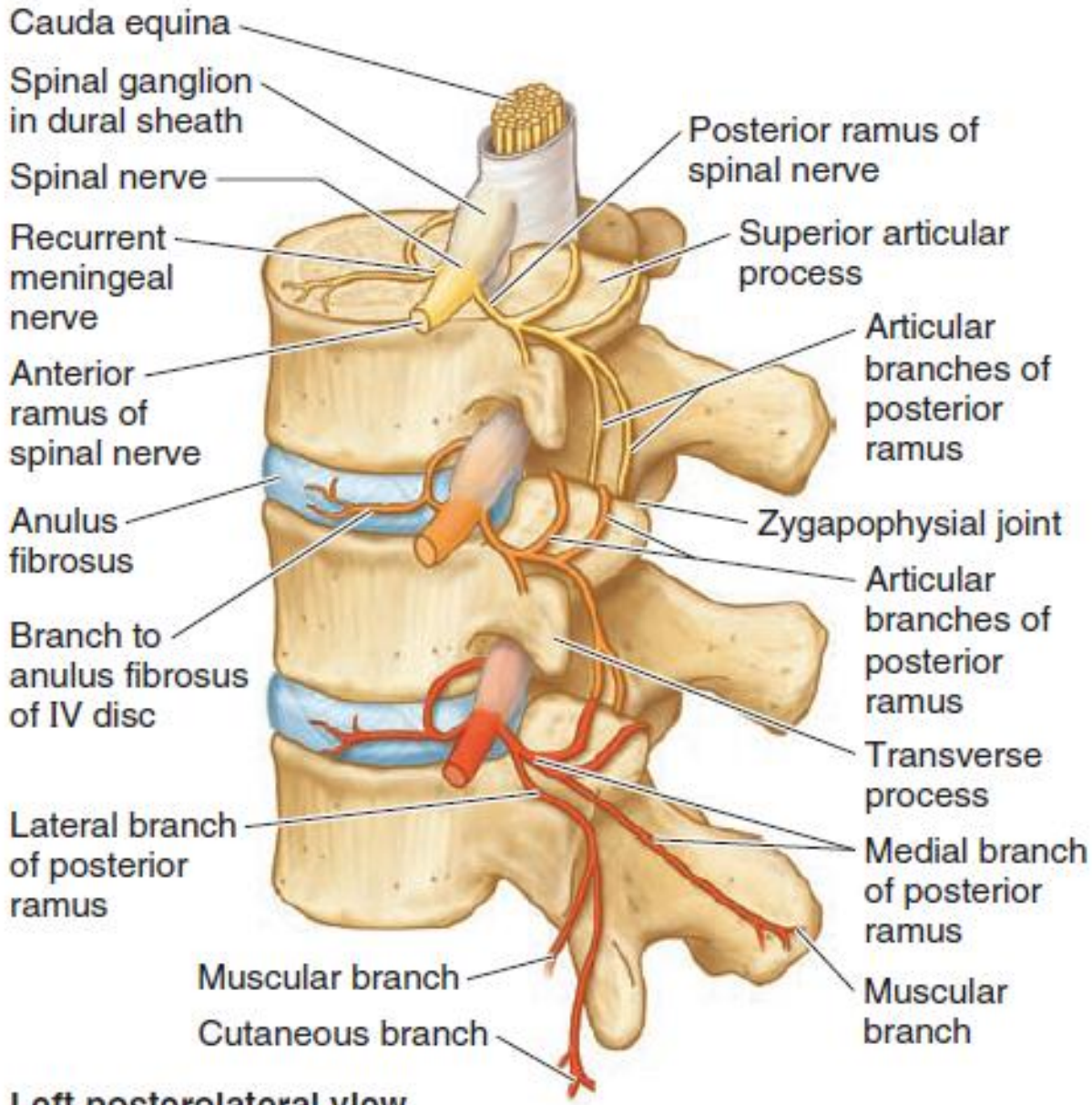


Spinal cord and spinal meninges





Superior view

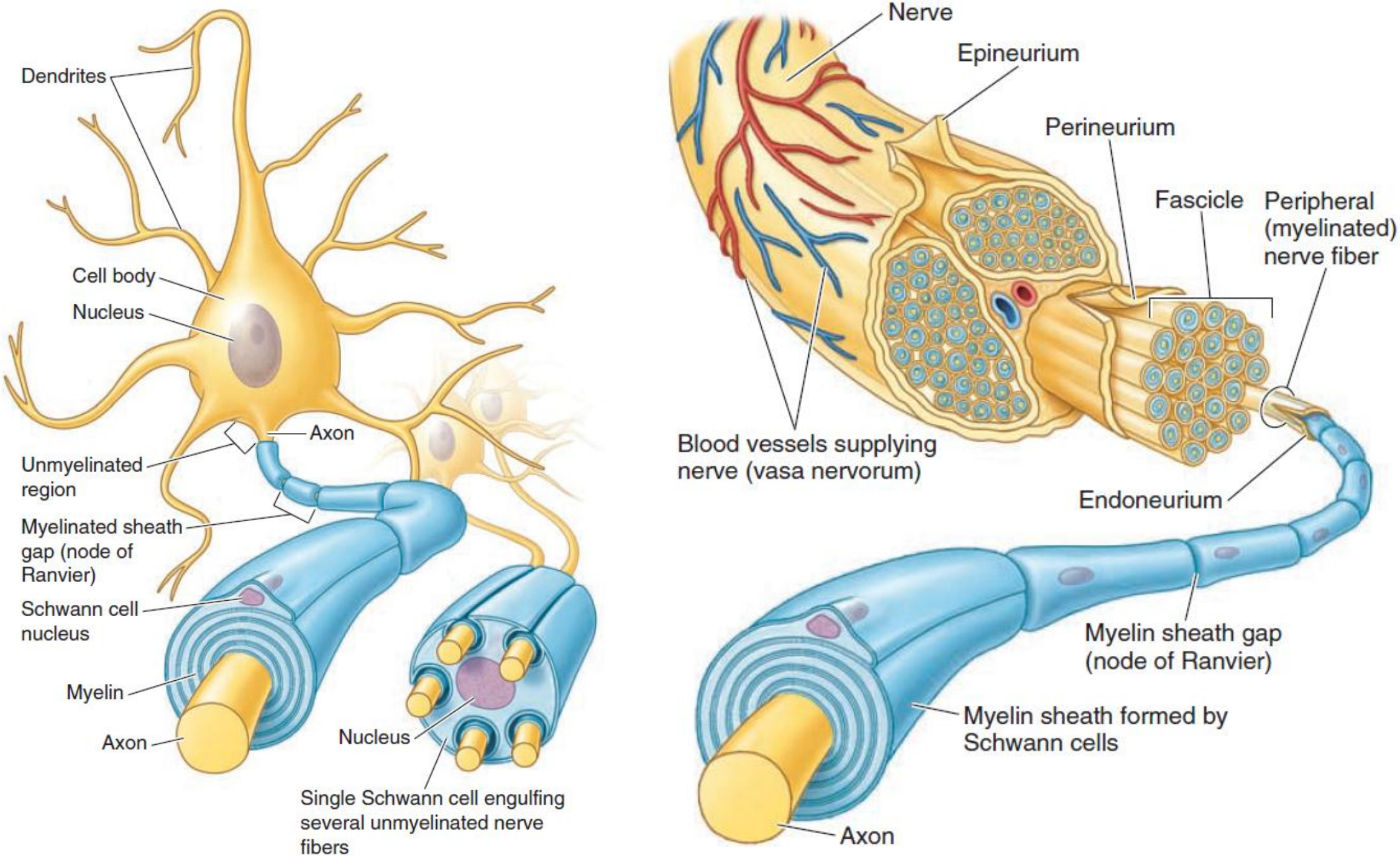


Left posterolateral view

Nervous system

Peripheral Nervous System

The peripheral nervous system (PNS) consists of nerve fibers and nerve cell bodies that connect the CNS with peripheral structures. Peripheral nerves consist of bundles of nerve fibers, their connective tissue coverings, and blood vessels, the vasa nervorum. A nerve fiber consists of an axon, the single process of a neuron; its neurolemma, the cell membranes of Schwann cells that immediately surround the axon, separating it from other axons; and its endoneurium, a connective tissue sheath.


Dendrites
Cell body
Nucleus
Axon
Unmyelinated region
Myelinated sheath gap (node of Ranvier)
Schwann cell nucleus
Myelin
Axon
Nucleus
Single Schwann cell engulfing several unmyelinated nerve fibers
Nerve
Epineurium
Perineurium
Fascicle
Peripheral (myelinated) nerve fiber
Blood vessels supplying nerve (vasa nervorum)
Endoneurium
Myelin sheath gap (node of Ranvier)
Myelin sheath formed by Schwann cells
Axon

Nervous system

Peripheral nerves are either cranial or spinal nerves. Of the 12 pairs of cranial nerves (CN), 11 pairs arise from the brain; 1 pair (CN XI) arises mostly from the superior part of the spinal cord. All CNs exit the cranial cavity through foramina in the cranium (G. kranion, skull). All 31 pairs of spinal nerves—8 cervical (C), 12 thoracic (T), 5 lumbar (L), 5 sacral (S), and 1 coccygeal (Co)—arise from the spinal cord and exit through intervertebral foramina in the vertebral column.

Nervous system

Structure and Components of a Typical Spinal Nerve

A typical spinal nerve arises from the spinal cord by nerve rootlets, which converge to form two nerve roots . The anterior (ventral) root consists of motor (efferent) fibers passing from nerve cell bodies in the anterior horn of the spinal cord gray matter to effector organs located peripherally. The posterior (dorsal) root consists of sensory (afferent) fibers that convey neural impulses to the CNS from sensory receptors in various parts of the body (e.g., in the skin).

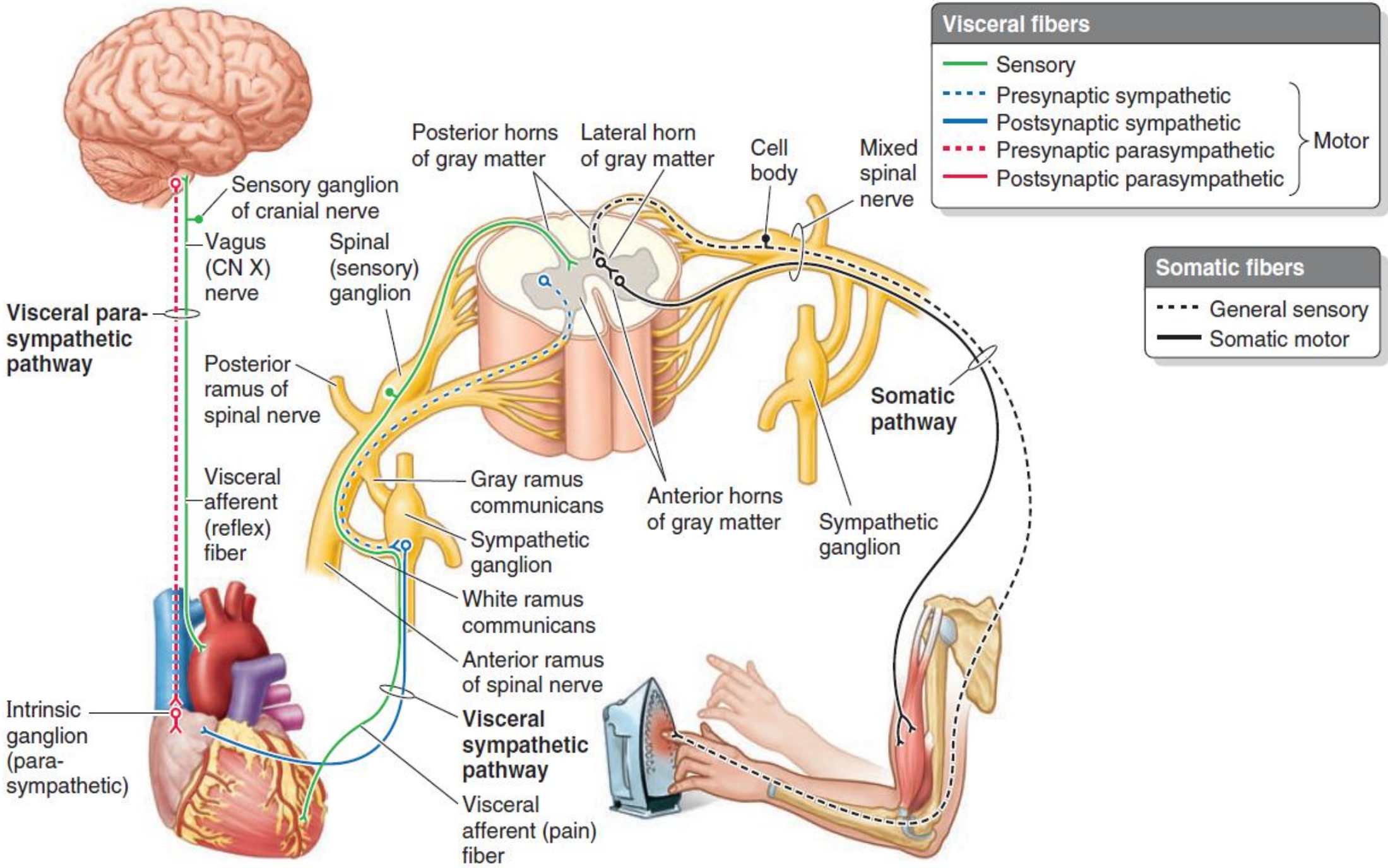
Nervous system

The posterior root carries general sensory fibers to the posterior horn of the spinal cord. The anterior and posterior roots unite at the intervertebral foramen to form a spinal nerve, which immediately divides into two rami (branches): a posterior ramus and an anterior ramus.

Nervous system

As branches of a mixed spinal nerve, the anterior and posterior rami also carry both motor and sensory nerves, as do all their branches.

- The posterior rami supply nerve fibers to synovial joints of the vertebral column, deep muscles of the back, and the overlying skin.
- The anterior rami, forming the somatic plexuses, supply nerve fibers to the much larger remaining area, consisting of anterior and lateral regions of the trunk and the upper and lower limbs arising from them.


Visceral fibers
Sensory
Presynaptic sympathetic
Postsynaptic sympathetic
Presynaptic parasympathetic
Postsynaptic parasympathetic
Motor
Somatic fibers
General sensory
Somatic motor
Posterior horns of gray matter
Lateral horn of gray matter
Cell body
Mixed spinal nerve
Sensory ganglion of cranial nerve
Vagus (CN X) nerve
Spinal (sensory) ganglion
Visceral para-sympathetic pathway
Posterior ramus of spinal nerve
Somatic pathway
Visceral afferent (reflex) fiber
Gray ramus communicans
Anterior horns of gray matter
Sympathetic ganglion
Sympathetic ganglion
White ramus communicans
Anterior ramus of spinal nerve
Intrinsic ganglion (para-sympathetic)
Visceral sympathetic pathway
Visceral afferent (pain) fiber

Nervous system

The components of a typical spinal nerve include

Somatic sensory fibers and motor fibers

- General sensory (general somatic afferent) fibers transmit sensations from the body to the CNS; they may be exteroceptive sensations (pain, temperature, touch, and pressure) from the skin or pain and proprioceptive sensations from muscles, tendons, and joints.

Nervous system

The components of a typical spinal nerve

- Somatic motor (general somatic efferent) fibers transmit impulses to skeletal (voluntary) muscles. The unilateral muscle mass receiving innervation from the somatic motor fibers conveyed by a single spinal nerve is a myotome. Each skeletal muscle is usually innervated by the somatic motor fibers of several spinal nerves; therefore, the muscle myotome will consist of several segments

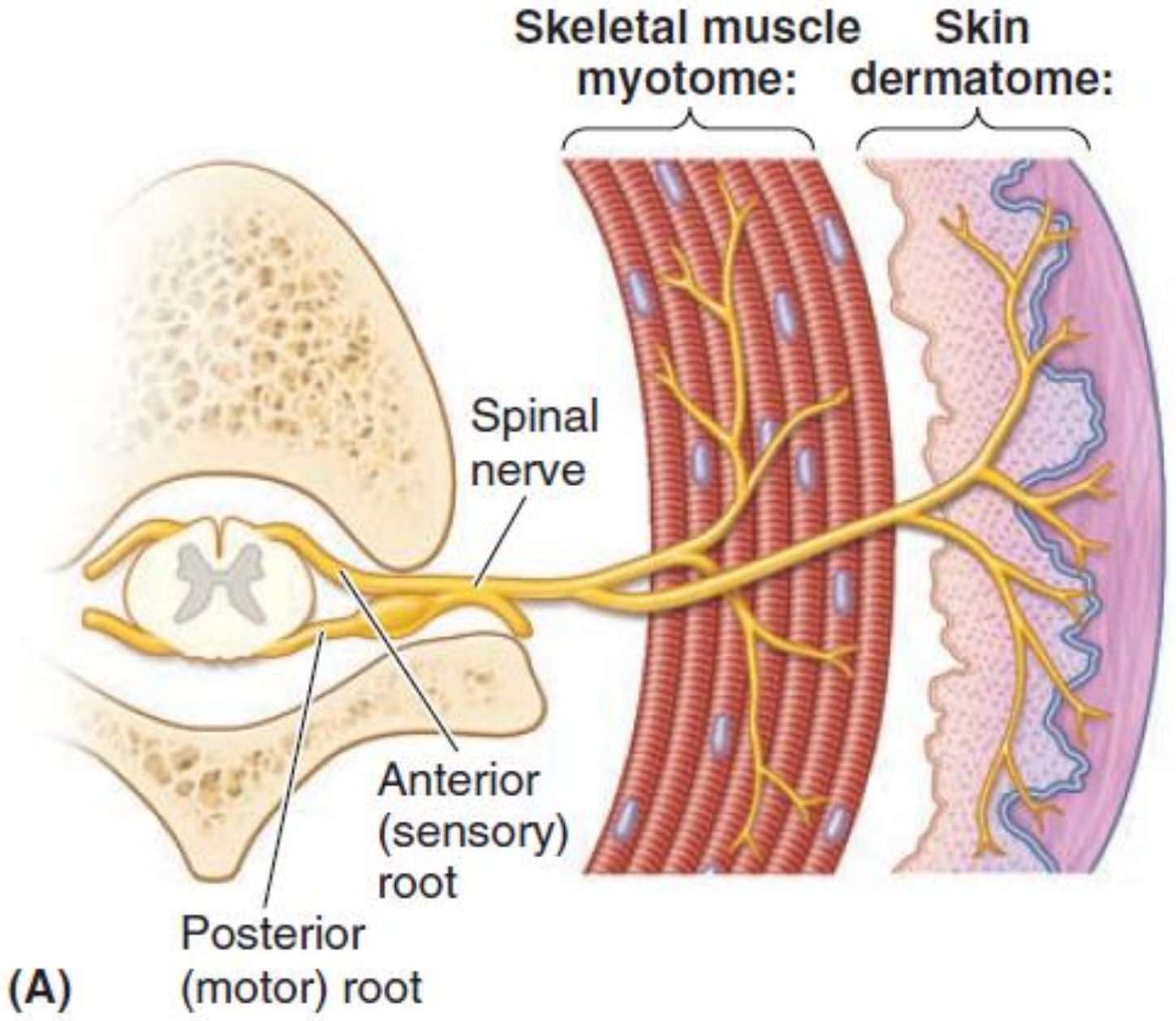
Nervous system

The components of a typical spinal nerve

- Visceral motor fibers of the sympathetic part of the autonomic nervous system are conveyed by all branches of all spinal nerves to the smooth muscle of blood vessels and to sweat glands and arrector pili muscles of the skin.
- Connective tissue coverings
- Vasa nervorum, blood vessels supplying the nerves

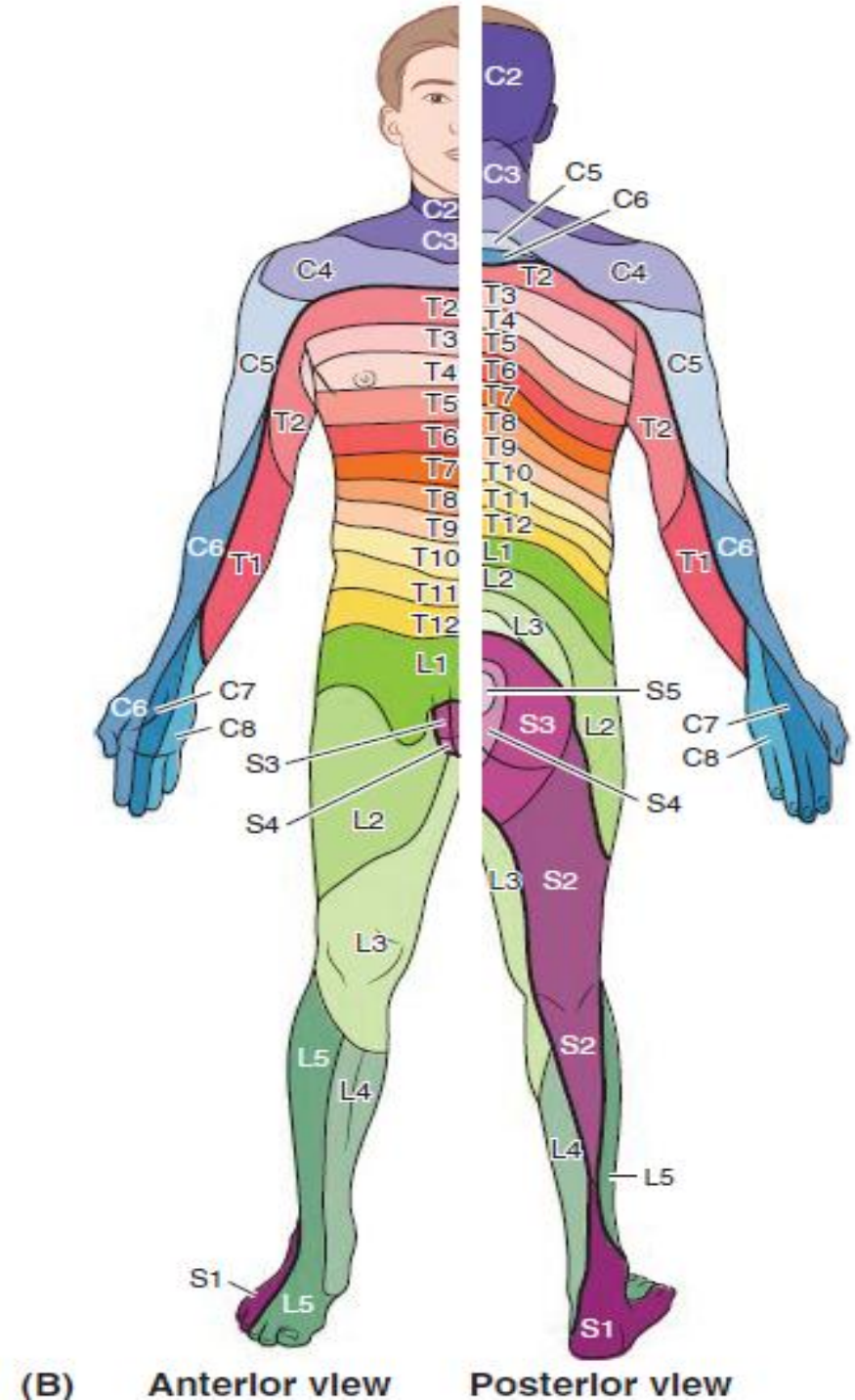
Nervous system

Dermatomes and myotomes. A. Schematic representation of a dermatome (the unilateral area of skin) and a myotome (the unilateral portion of skeletal muscle) receiving innervation from a single spinal nerve.



Nervous system

The unilateral area of skin innervated by the general sensory fibers of a single spinal nerve is called a dermatome. From clinical studies of lesions of the posterior roots or spinal nerves, dermatome maps have been devised that indicate the typical pattern of innervation of the skin by specific spinal nerves.



Nervous system

Autonomic Nervous System

The autonomic nervous system (ANS), classically described as the visceral nervous system or visceral motor system, consists of visceral efferent (motor) fibers that stimulate smooth(involuntary) muscle in the walls of blood vessels and organs, modified cardiac muscle (the intrinsic stimulating and conducting tissue of the heart), and glands. The visceral efferent fibers of the ANS serving viscera of the body cavities are accompanied by visceral afferent (sensory) fibers.

Nervous system

The efferent nerve fibers and ganglia of the ANS are organized into two systems or divisions:

1. **Sympathetic** (thoracolumbar) division. In general, the effects of sympathetic stimulation are catabolic (preparing the body for “flight or fight”).

2. **Parasympathetic** (craniosacral) division. In general, the effects of parasympathetic stimulation are anabolic (promoting normal function and conserving energy).

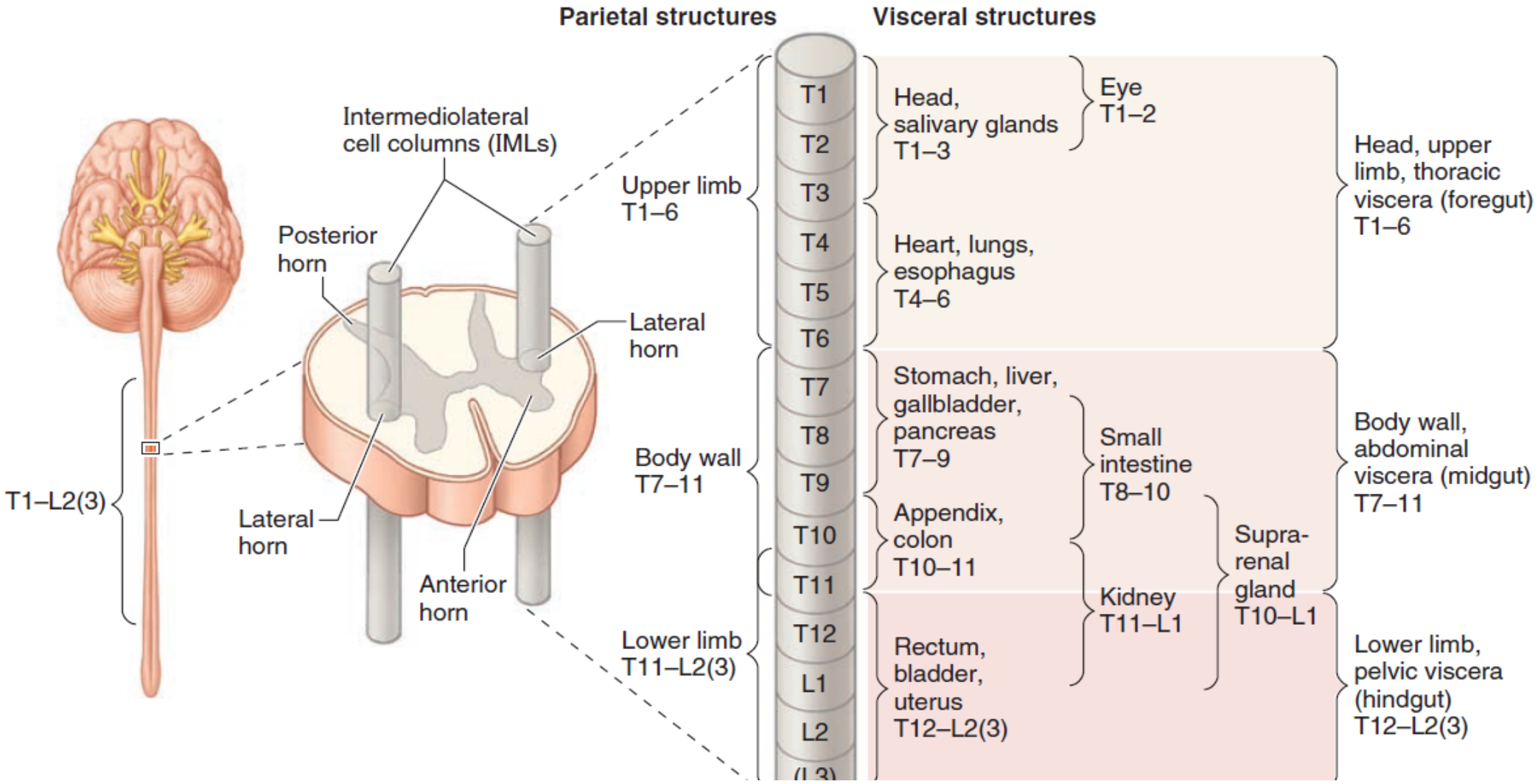
Nervous system

Conduction of impulses from the CNS to the effector organ involves a series of two neurons in both sympathetic and parasympathetic systems. The cell body of the presynaptic (preganglionic) neuron (first neuron) is located in the gray matter of the CNS. Its fiber (axon) synapses on the cell body of a postsynaptic (postganglionic) neuron, the second neuron in the series (Fig. I.25). The cell bodies of such second neurons are located in autonomic ganglia outside the CNS, and the postsynaptic fibers terminate on the effector organ.

Nervous system

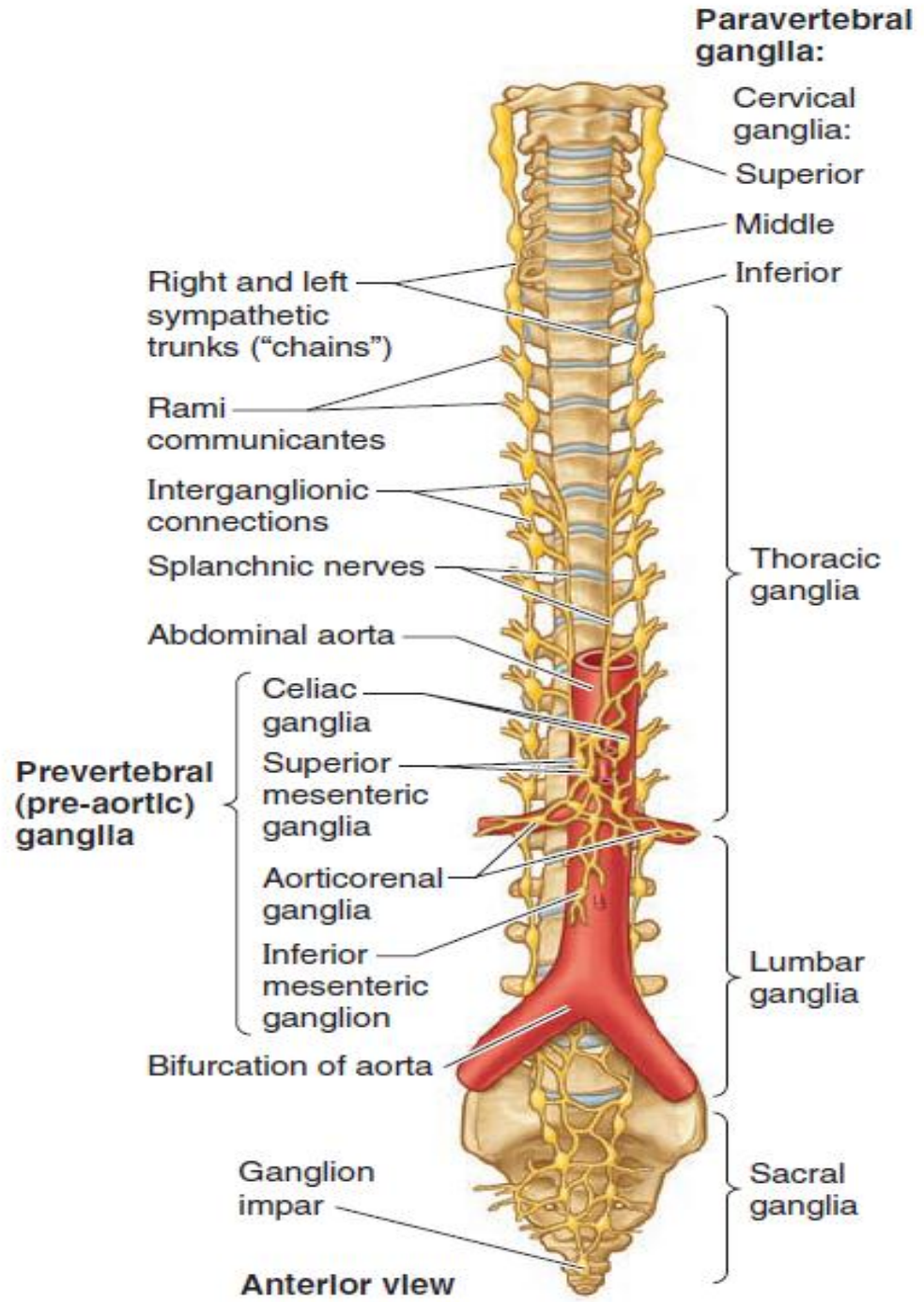
The cell bodies of presynaptic neurons of the sympathetic division of the ANS are located in the intermediolateral cell columns (IMLs) or nuclei of the spinal cord. The paired (right and left) IMLs are a part of the gray matter, extending between the 1st thoracic (T1) and the 2nd or 3rd lumbar (L2 or L3) segments of the spinal cord.

Nervous system



Nervous system

The cell bodies of postsynaptic neurons of the **sympathetic nervous system** occur in two locations, the paravertebral and prevertebral ganglia.

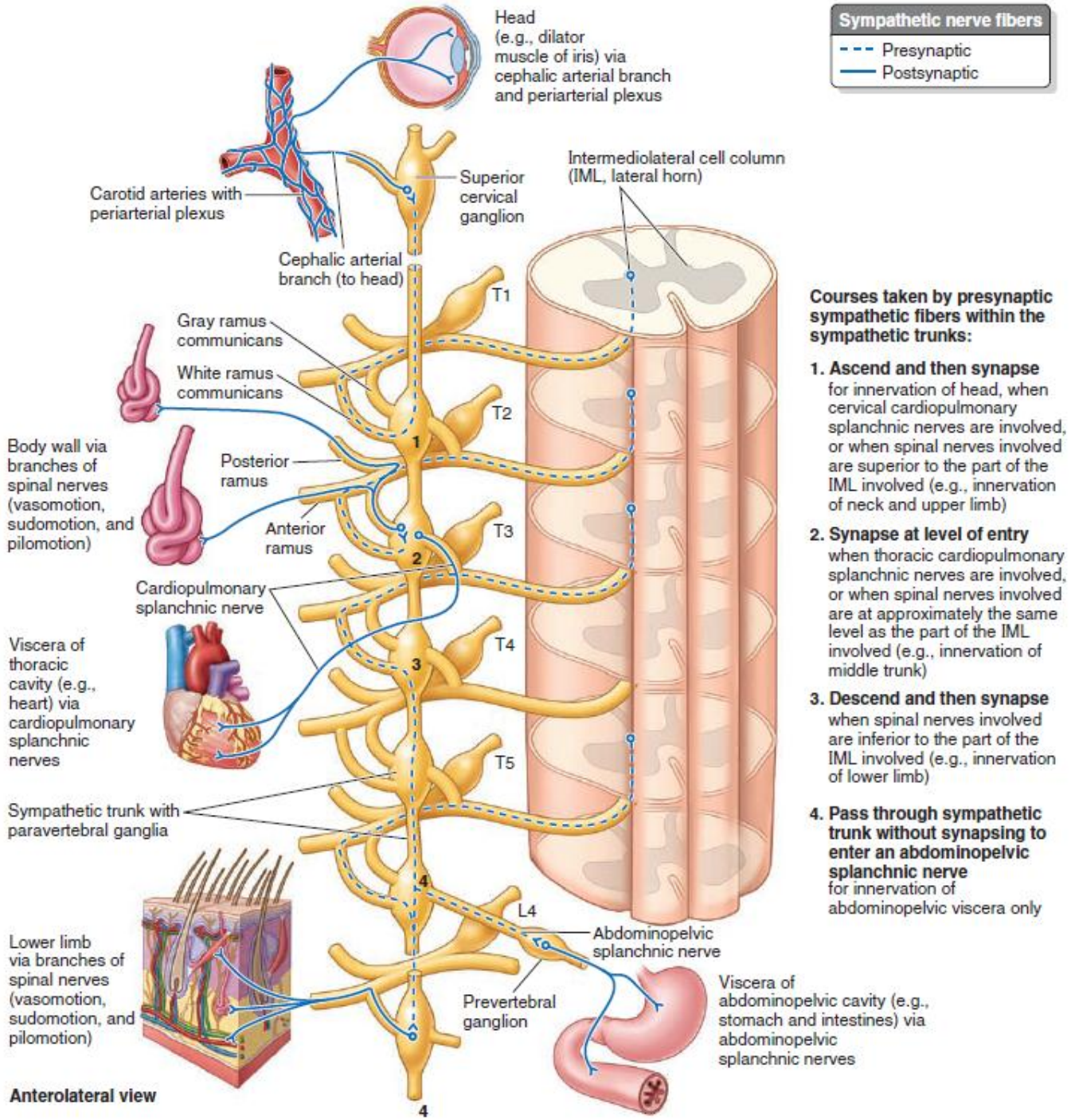


Nervous system

- Paravertebral ganglia are linked to form right and left sympathetic trunks (chains) on each side of the vertebral column that extend essentially the length of this column. The superior cervical ganglion of each sympathetic trunk lies at the base of the cranium. The ganglion impar forms inferiorly, where the two trunks unite at the level of the coccyx.
- Prevertebral ganglia are in the plexuses that surround the origins of the main branches of the abdominal aorta

Nervous system

Courses taken by sympathetic motor fibers.



Organ, Tract, or System		Effect of Sympathetic Stimulation	Effect of Parasympathetic Stimulation
Eyes	Pupil	Dilates pupil (admits more light for increased acuity at a distance)	Constricts pupil (protects pupil from excessively bright light)
	Ciliary body		Contracts ciliary muscle, allowing lens to thicken for near vision (accommodation)
Skin	Arrector muscle of hair	Causes hairs to stand on end (gooseflesh or goose bumps)	No effect (does not reach)[a]
	Peripheral blood vessels	Vasoconstricts (blanching of skin and lips; turning fingertips blue)	No effect (does not reach)[a]
	Sweat glands	Promotes sweating[b]	No effect (does not reach)[a]
Other glands	Lacrimal glands	Slightly decreases secretion[c]	Promotes secretion
	Salivary glands	Secretion decreases, becomes thicker, more viscous[c]	Promotes abundant, watery secretion
Heart		Increases rate and strength of contraction; inhibits effect of parasympathetic system on coronary vessels, allowing them to dilate[c]	Decreases rate and strength of contraction (conserving energy); constricts coronary vessels in relation to reduced demand
Lungs		Inhibits effect of parasympathetic system, resulting in bronchodilation and reduced secretion, allowing for maximum air exchange	Constricts bronchi (conserving energy) and promotes bronchial secretion
Digestive tract		Inhibits peristalsis and constricts blood vessels to digestive tract so blood is available to skeletal muscle; contracts internal anal sphincter to aid fecal continence	Stimulates peristalsis and secretion of digestive juices; contracts rectum and inhibits internal anal sphincter to cause defecation
Liver and gallbladder		Promotes breakdown of glycogen to glucose (for increased energy)	Promotes building/conservation of glycogen; increases secretion of bile
Urinary tract		Vasoconstriction of renal vessels slows urine formation; internal sphincter of bladder contracted to maintain urinary continence.	Inhibits contraction of internal sphincter of bladder, contracts detrusor muscle of bladder wall, causing urination
Genital system		Causes ejaculation and vasoconstriction, resulting in remission of erection	Produces engorgement (erection) of erectile tissues of external genitals
Suprarenal medulla		Release of adrenaline into blood	No effect (does not innervate)

Nervous system

a) The parasympathetic system is restricted in its distribution to the head, neck, and body cavities (except for erectile tissues of genitalia); otherwise, parasympathetic fibers are never found in the body wall and limbs. Sympathetic fibers, by comparison, are distributed to all vascularized portions of the body.

b) With the exception of the sweat glands, glandular secretion is parasympathetically stimulated.

c) With the exception of the coronary arteries, vasoconstriction is sympathetically stimulated; the effects of sympathetic stimulation on glands (other than sweat glands) are the indirect effects of vasoconstriction.

Nervous system

Presynaptic parasympathetic neuron cell bodies are located in two sites within the CNS (craniosacral); their fibers exit by two routes. This accounts for the alternate name of the parasympathetic (craniosacral) division of the ANS.

• In the gray matter of the brainstem, the fibers exit the CNS within CN III, CN VII, CN IX, and CN X; these fibers constitute the cranial parasympathetic outflow.

• In the gray matter of the sacral segments of the spinal cord (S2–S4), the fibers exit the CNS through the anterior roots of spinal nerves S2–S4 and the pelvic splanchnic nerves that arise from their anterior rami; these fibers constitute the sacral parasympathetic outflow.

Nervous system

Presynaptic parasympathetic fibers synapse with postsynaptic cell bodies, which occur singly in or on the wall of the target organ (intrinsic or enteric ganglia). Most presynaptic parasympathetic fibers are long, extending from the CNS to the effector organ, whereas the postsynaptic fibers are short, running from a ganglion located near or embedded in the effector organ.

Nervous system

Distribution of parasympathetic nerve fibers.