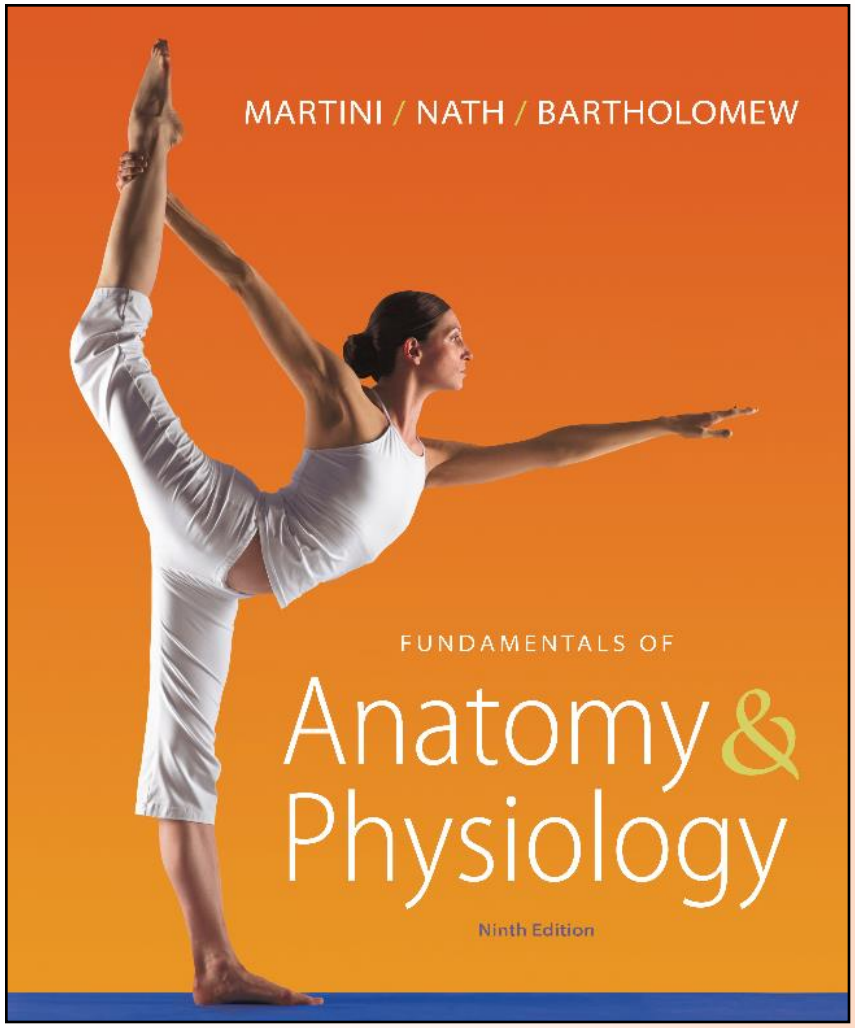


13

The Spinal Cord, Spinal Nerves, and Spinal Reflexes

PowerPoint® Lecture Presentations prepared by Jason LaPres

Lone Star College—North Harris

An Introduction to the Spinal Cord, Spinal Nerves, and Spinal Reflexes

- Learning Outcomes
  - **13-1** Describe the basic structural and organizational characteristics of the nervous system.
  - **13-2** Discuss the structure and functions of the spinal cord, and describe the three meningeal layers that surround the central nervous system.
  - **13-3** Explain the roles of white matter and gray matter in processing and relaying sensory information and motor commands.
  - **13-4** Describe the major components of a spinal nerve, and relate the distribution pattern of spinal nerves to the regions they innervate.

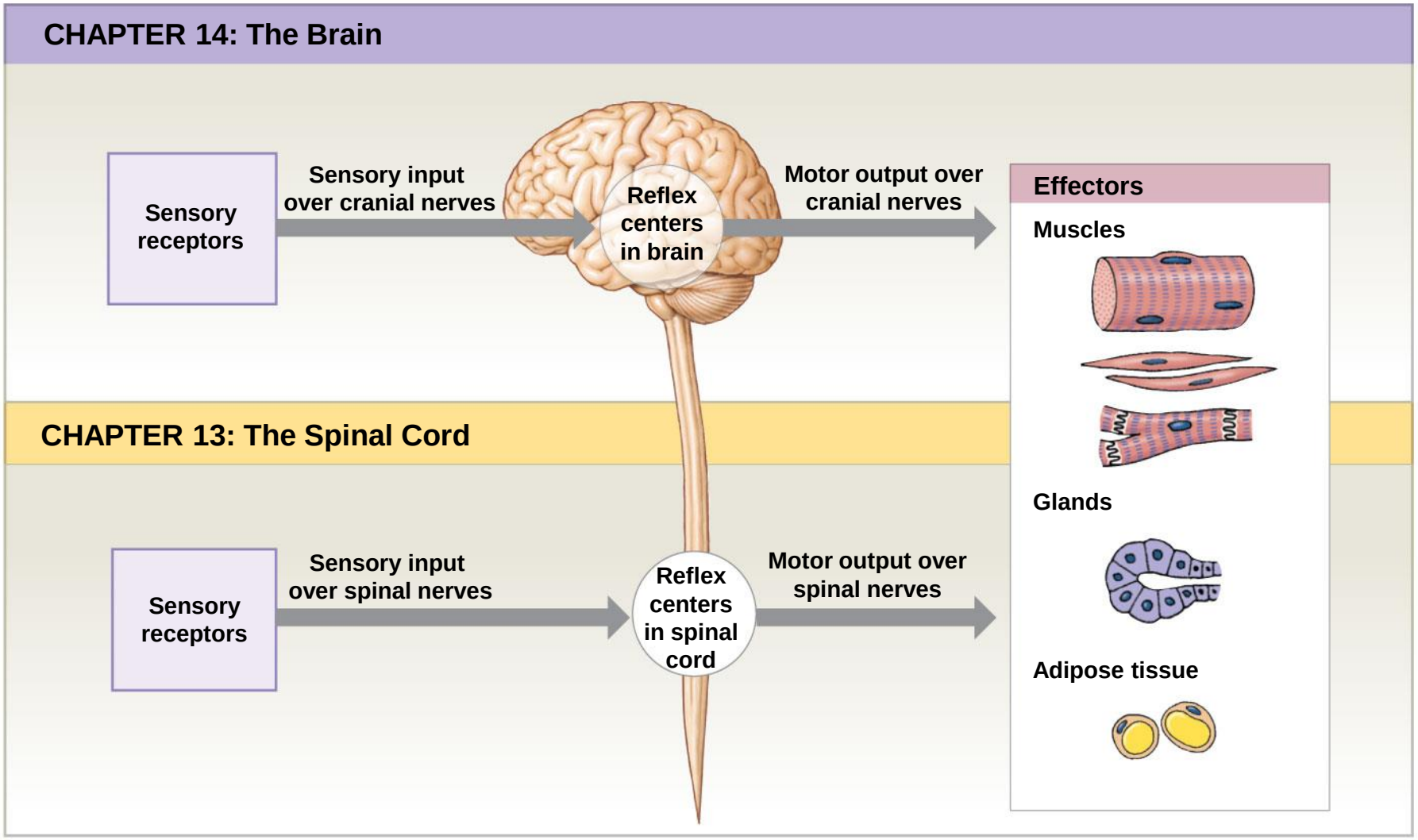
An Introduction to the Spinal Cord, Spinal Nerves, and Spinal Reflexes

- Learning Outcomes
  - **13-5** Discuss the significance of neuronal pools, and describe the major patterns of interaction among neurons within and among these pools.
  - **13-6** Describe the steps in a neural reflex, and classify the types of reflexes.
  - **13-7** Distinguish among the types of motor responses produced by various reflexes, and explain how reflexes interact to produce complex behaviors.
  - **13-8** Explain how higher centers control and modify reflex responses.

An Introduction to the Spinal Cord, Spinal Nerves, and Spinal Reflexes

- Spinal Reflexes
  - Rapid, automatic nerve responses triggered by specific stimuli
  - Controlled by spinal cord alone, not the brain

Figure 13-1 An Overview of Chapters 13 and 14



13-2 Spinal Cord

- Gross Anatomy of the Spinal Cord
  - About 18 inches (45 cm) long
  - 1/2 inch (14 mm) wide
  - Ends between vertebrae L_1 and L_2
  - Bilateral symmetry
    - Grooves divide the spinal cord into left and right
      - **Posterior median sulcus** – on posterior side
      - **Anterior median fissure** – deeper groove on anterior side

13-2 Spinal Cord

Distinguish between white and gray matter

- **Enlargements** of the Spinal Cord
  - Caused by:
    - Amount of gray matter in segment
    - Involvement with sensory and motor nerves of limbs
  - **Cervical enlargement**
    - Nerves of shoulders and upper limbs
  - **Lumbar enlargement**
    - Nerves of pelvis and lower limbs

13-2 Spinal Cord

- Gross Anatomy of the Spinal Cord
  - The distal end (away from the brain)
    - **Conus medullaris**
      - Thin, conical spinal cord below lumbar enlargement
    - **Filum terminale**
      - Thin thread of fibrous tissue at end of conus medullaris
      - Attaches to *coccygeal ligament*
    - **Cauda equina**
      - Nerve roots extending below conus medullaris

Figure 13-2 Gross Anatomy of the Adult Spinal Cord

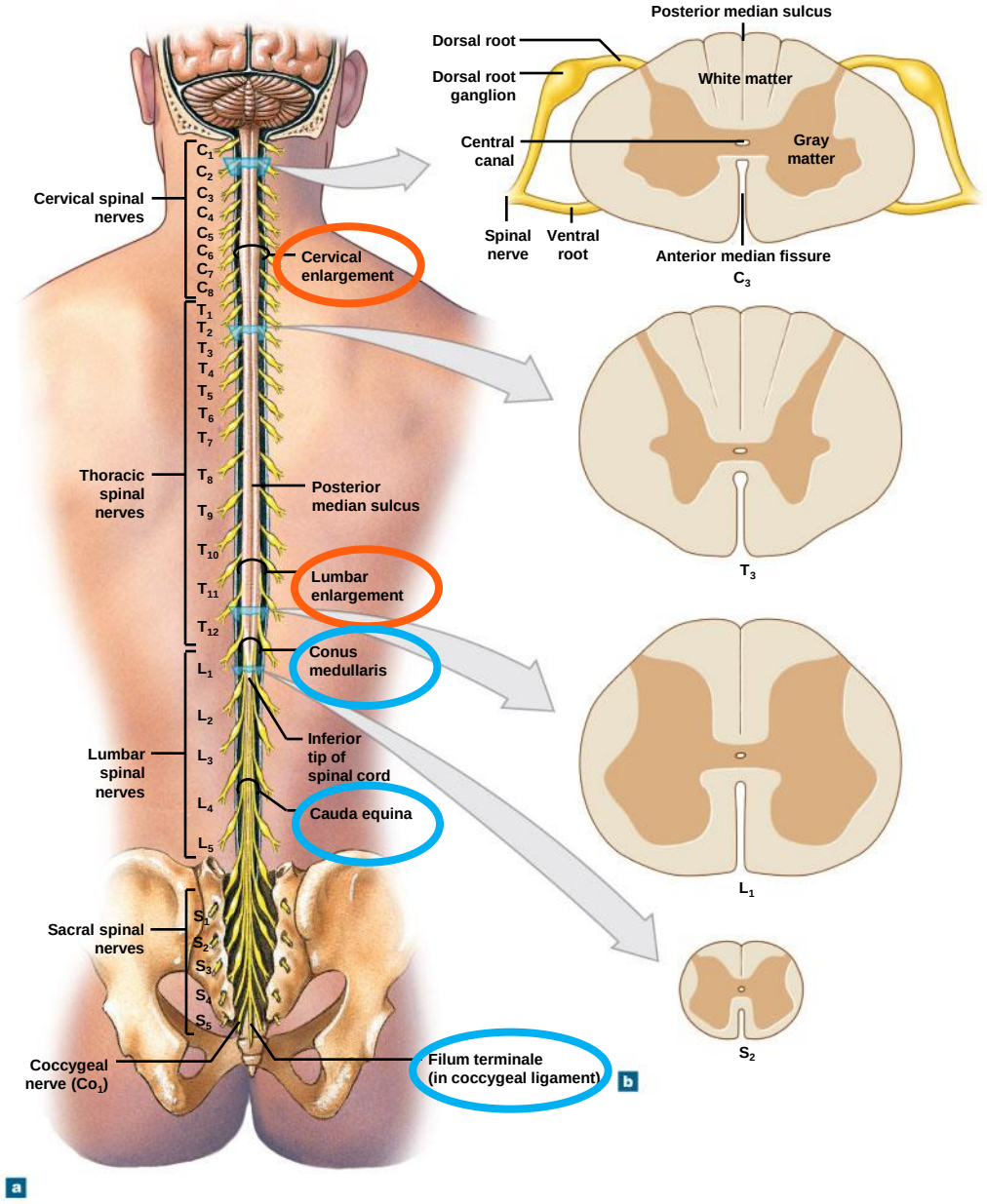
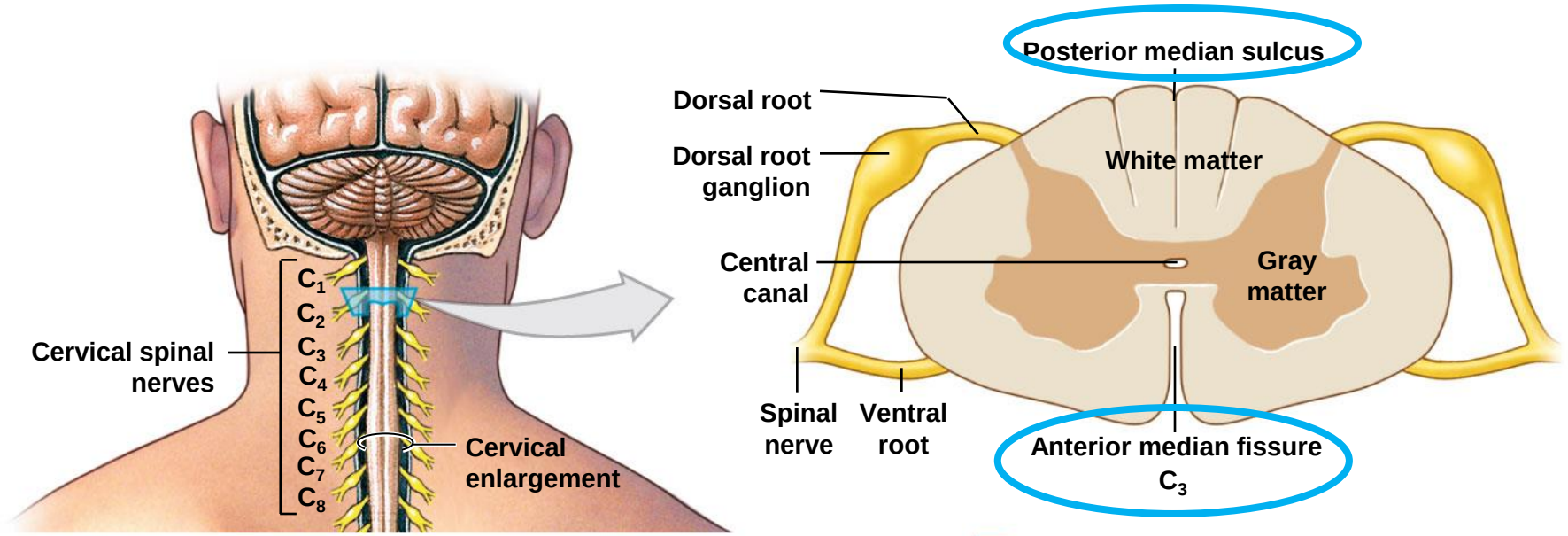


Figure 13-2 Gross Anatomy of the Adult Spinal Cord



a The superficial anatomy and orientation of the adult spinal cord. The numbers to the left identify the spinal nerves and indicate where the nerve roots leave the vertebral canal. The spinal cord extends from the brain only to the level of vertebrae L_1–L_2; the spinal segments found at representative locations are indicated in the cross sections.

b Inferior views of cross sections through representative segments of the spinal cord, showing the arrangement of gray matter and white matter.

Figure 13-2 Gross Anatomy of the Adult Spinal Cord

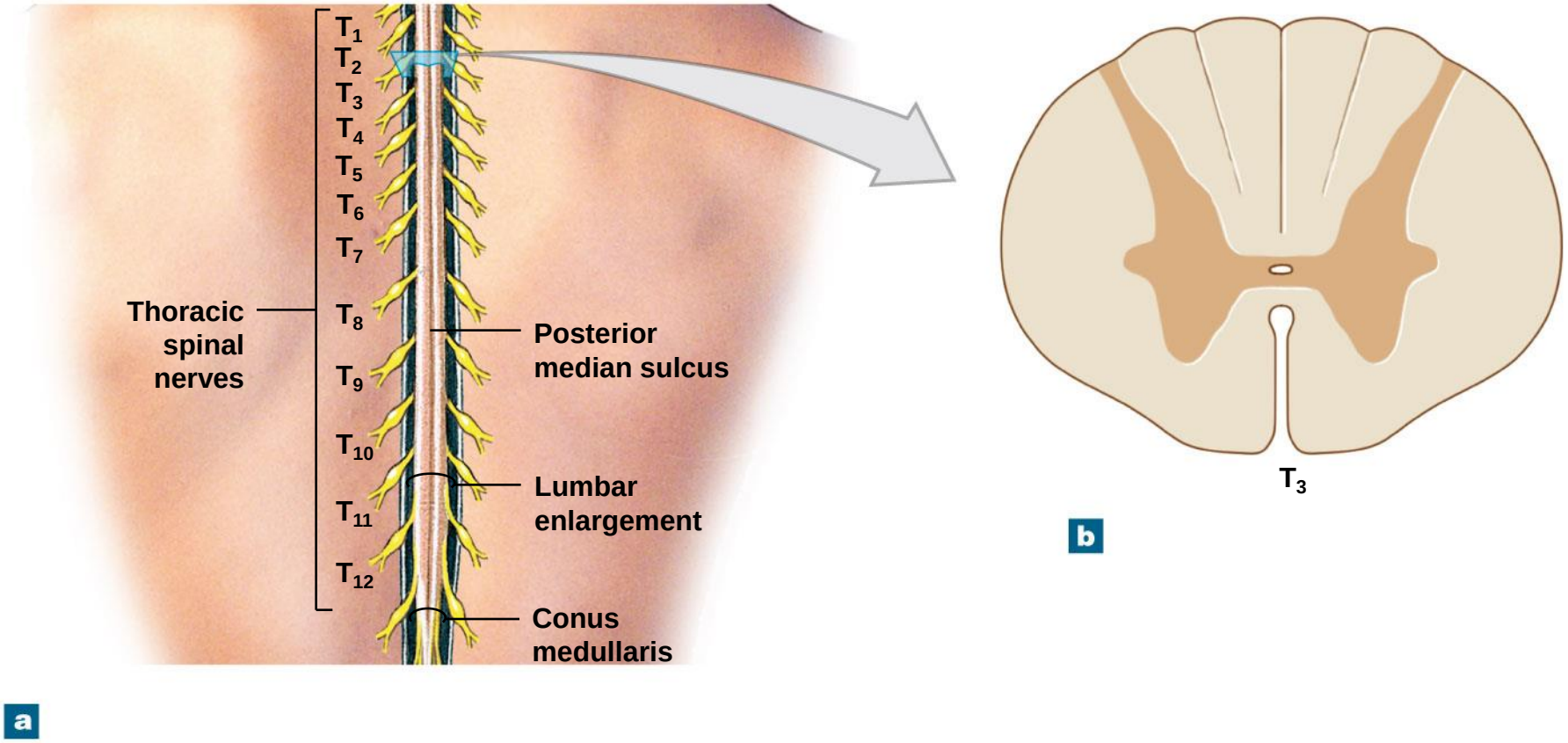


Figure 13-2 Gross Anatomy of the Adult Spinal Cord

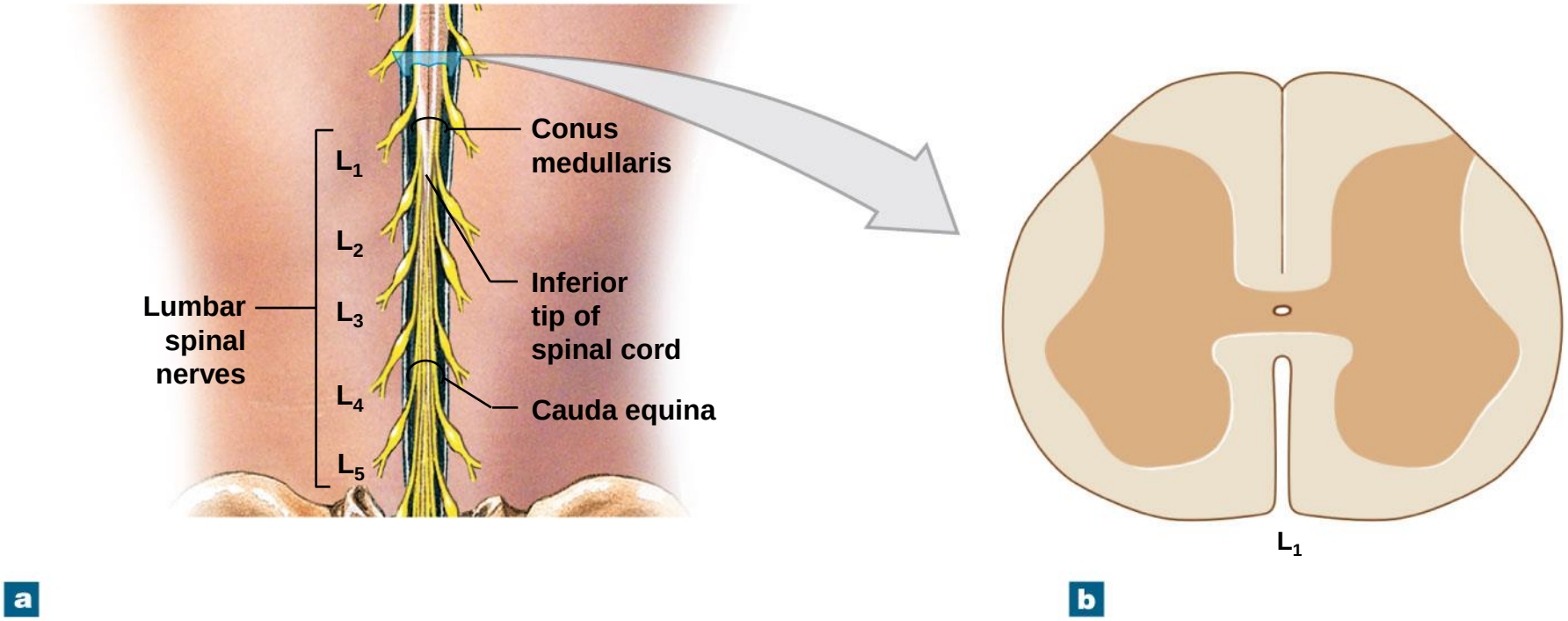
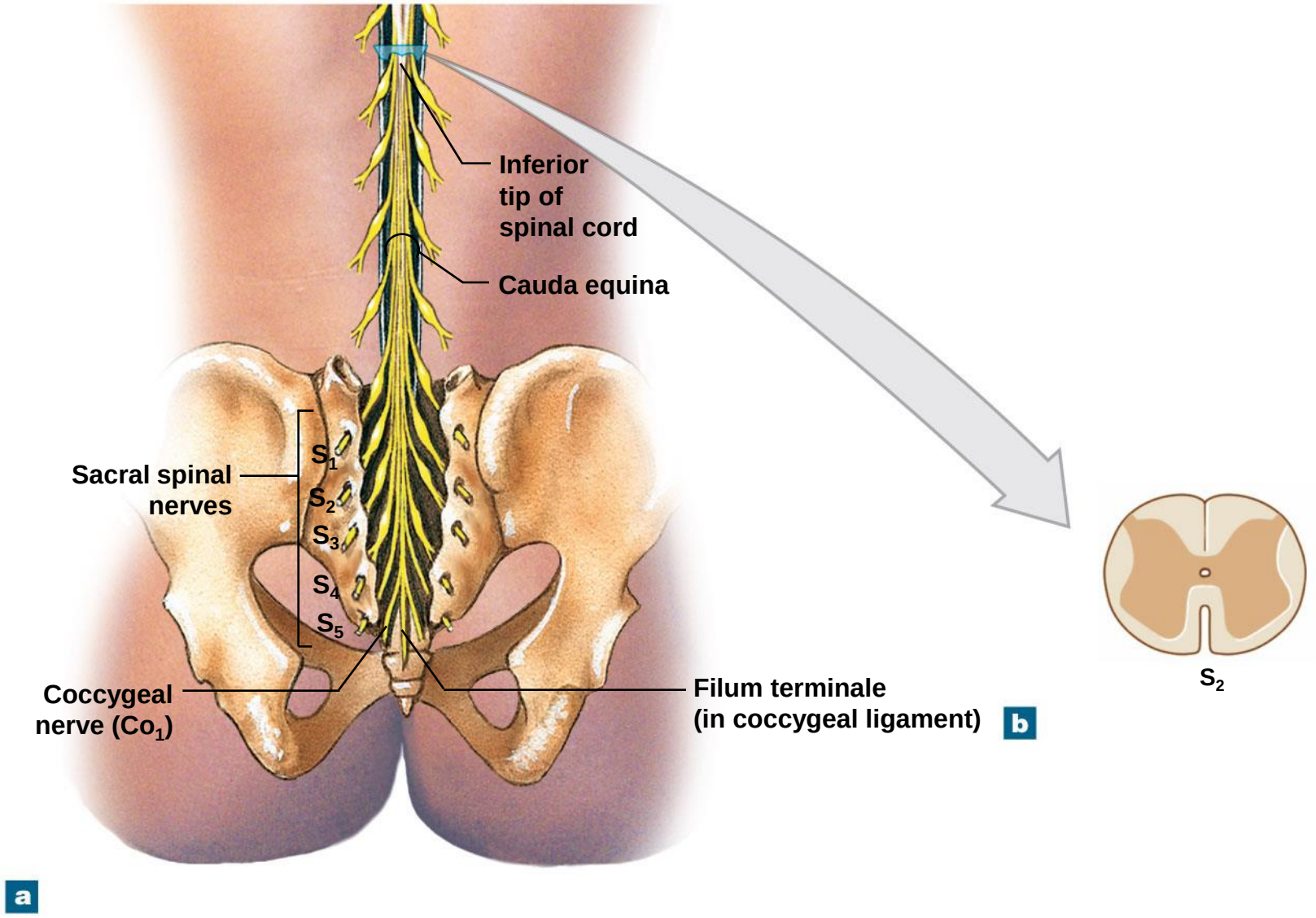


Figure 13-2 Gross Anatomy of the Adult Spinal Cord



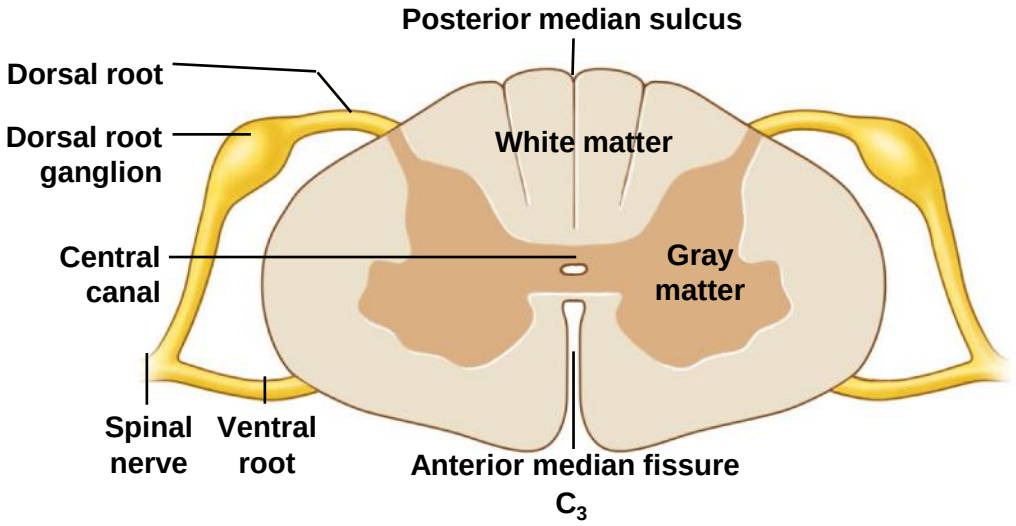
13-2 Spinal Cord

- 31 Spinal Cord Segments
  - Based on vertebrae where spinal nerves originate
  - Positions of spinal segment and vertebrae change with age
    - Cervical nerves
      - Are named for inferior vertebra
    - All other nerves
      - Are named for superior vertebra

13-2 Spinal Cord

- **Dorsal root ganglia**
  - Every spinal segment is associated with a pair of dorsal root ganglia, located near the spinal cord.
  - The axons of the neurons form the dorsal roots, which bring sensory information into the spinal cord.
  - A pair of ventral roots contains the axons of motor neurons that extend into the periphery to control somatic and visceral effectors.
  - On both sides, the dorsal and ventral roots of each segment pass between the vertebral canal and the periphery at the intervertebral foramen between each vertebrae.

13-2 Spinal Cord

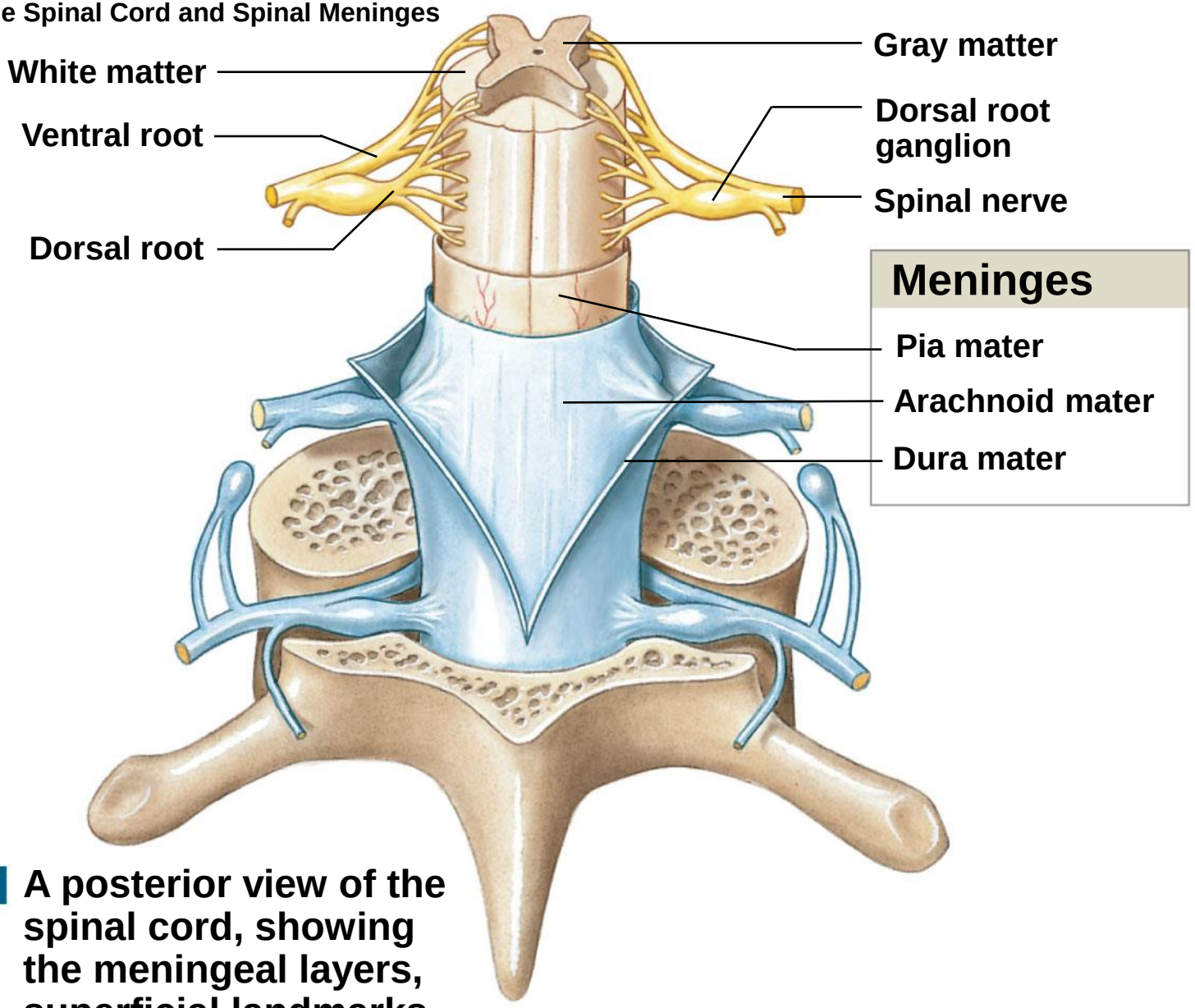


- Roots
  - Two branches of spinal nerves
    1. **Ventral root**
       - Contains axons of motor neurons
    2. **Dorsal root**
       - Contains axons of sensory neurons
  - **Dorsal root ganglia**
    - Contain cell bodies of sensory neurons

13-2 Spinal Cord

- The **Spinal Nerve**
  - Each side of spine
    - Dorsal and ventral roots join
    - To form a spinal nerve
  - **Mixed Nerves**
    - Carry both afferent (sensory) and efferent (motor) fibers

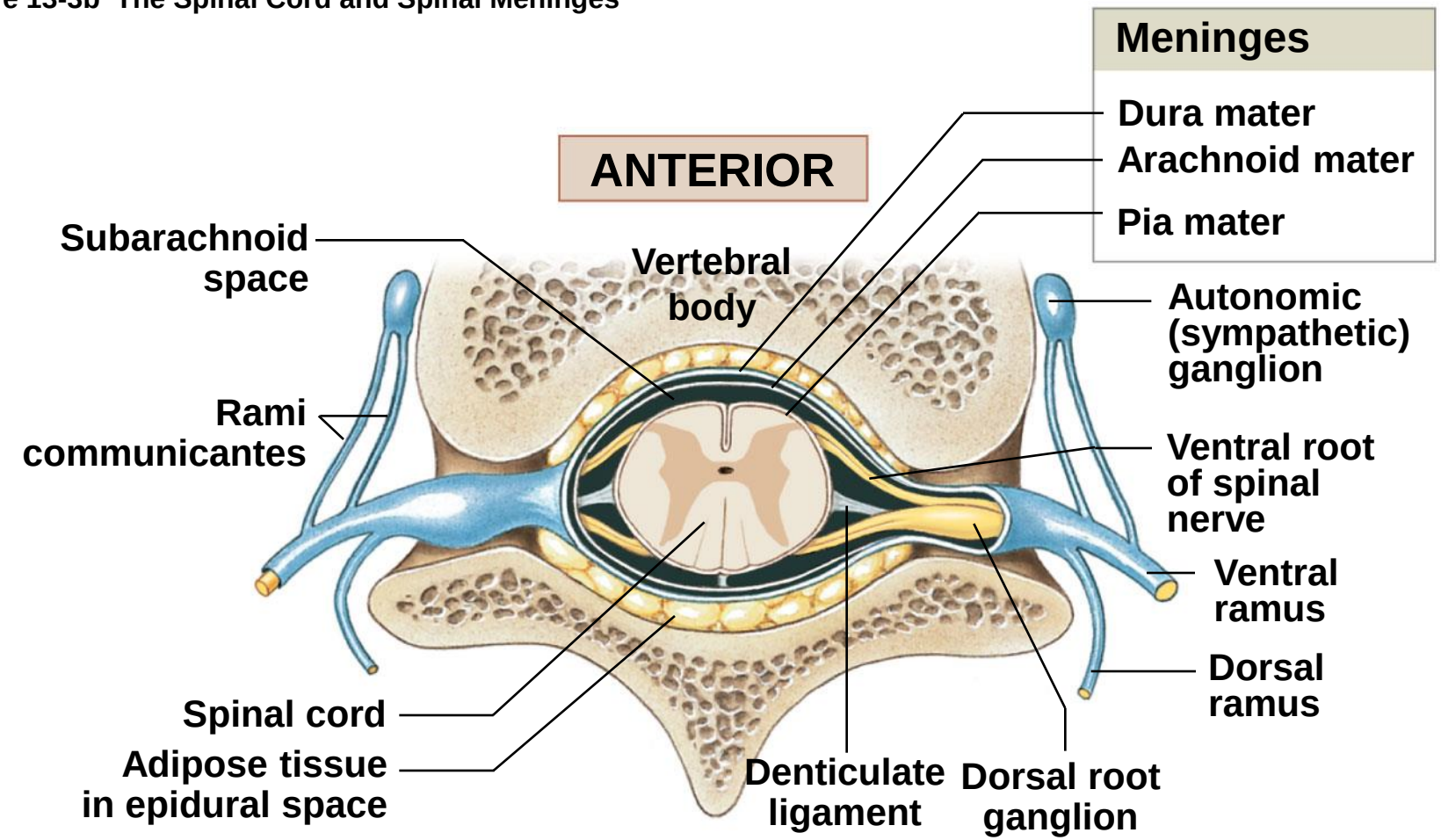
Figure 13-3a The Spinal Cord and Spinal Meninges



a A posterior view of the spinal cord, showing the meningeal layers, superficial landmarks, and distribution of gray matter and white matter

- The spinal cord is continuous with the brain and is located inside the vertebral column. It is surrounded by 3 protective layers called the meninges.
- The outermost is the dura mater, the middle is the arachnoid mater, and the innermost is the pia mater.
- The pia mater extends from the tip of the spinal cord, merges with the dura mater, and forms filum terminale which anchors the cord to the first coccygeal vertabrae.

Figure 13-3b The Spinal Cord and Spinal Meninges



b A sectional view through the spinal cord and meninges, showing the peripheral distribution of spinal nerves

13-2 Spinal Cord

- The **Spinal Meninges**
  - Specialized membranes isolate spinal cord from surroundings
  - Functions of the spinal meninges include:
    - Protecting spinal cord
    - Carrying blood supply
    - Continuous with **cranial meninges**
  - **Meningitis**
    - Viral or bacterial infection of meninges

13-2 Spinal Cord

- The Three Meningeal Layers
  1. **Dura mater**
     - Outer layer of spinal cord
  2. **Arachnoid mater**
     - Middle meningeal layer
  3. **Pia mater**
     - Inner meningeal layer

13-2 Spinal Cord

- The **Dura Mater**
  - Tough and fibrous
  - Cranially
    - Fuses with periosteum of occipital bone
    - Is continuous with cranial dura mater
  - Caudally
    - Tapers to dense cord of collagen fibers
    - Joins filum terminale in **coccygeal ligament**

13-2 Spinal Cord

- The **Dura Mater**
  - The **Epidural Space**
    - Between spinal dura mater and walls of vertebral canal
    - Contains loose connective and adipose tissue
    - Anesthetic injection site

13-2 Spinal Cord

- The **Arachnoid Mater**
  - Middle meningeal layer
  - Arachnoid membrane
    - Simple squamous epithelia
    - Covers arachnoid mater

13-2 Spinal Cord

- The Interlayer Spaces of Arachnoid Mater
  - **Subdural space**
    - Between arachnoid mater and dura mater
  - **Subarachnoid space**
    - Between arachnoid mater and pia mater
    - Contains collagen/elastin fiber network (arachnoid trabeculae)
    - Filled with **cerebrospinal fluid (CSF)**

13-2 Spinal Cord

- The Interlayer Spaces of Arachnoid Mater
  - **Cerebrospinal Fluid (CSF)**
    - Carries dissolved gases, nutrients, and wastes
    - **Lumbar puncture** or **spinal tap** withdraws CSF

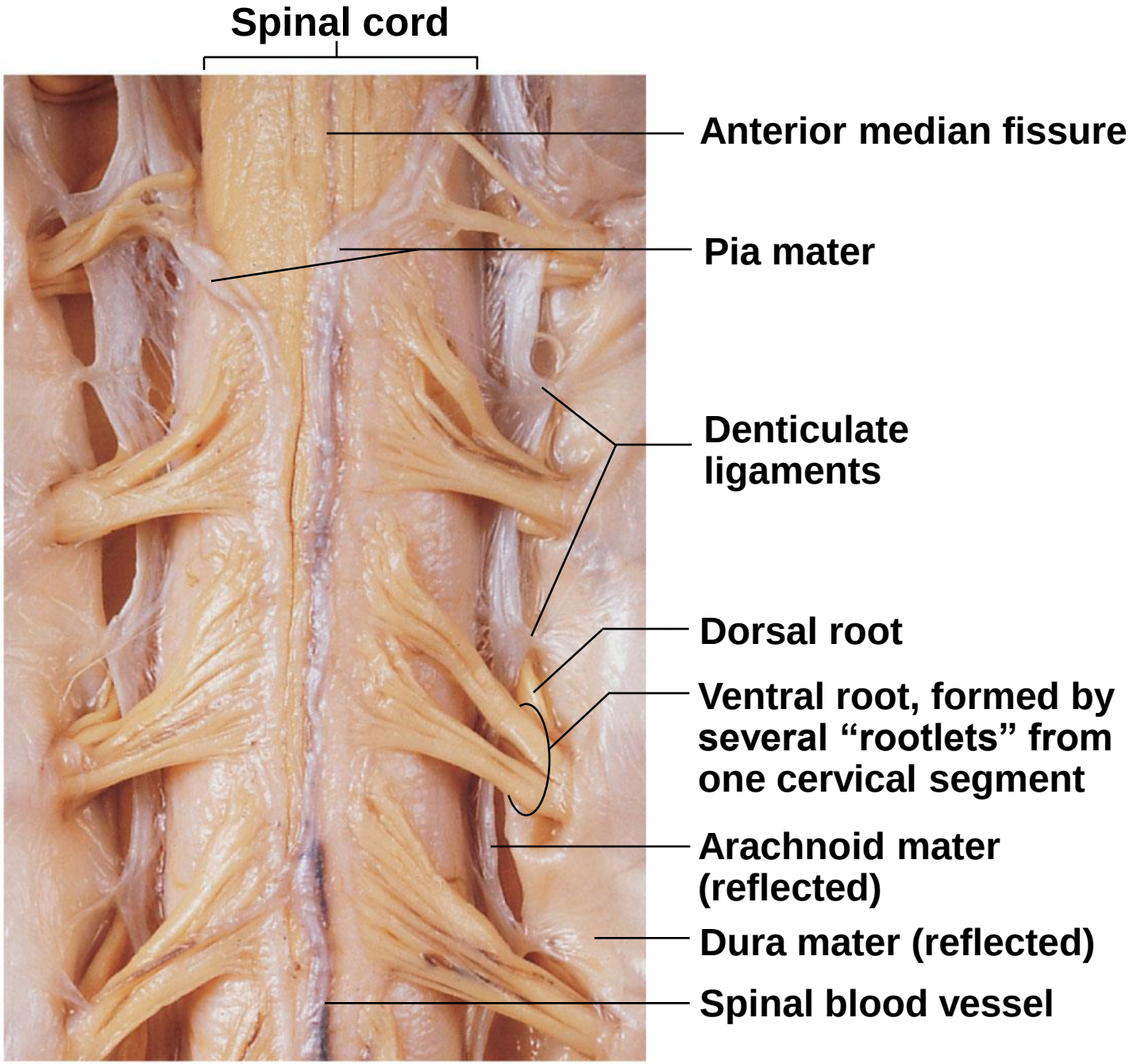
13-2 Spinal Cord

- The **Pia Mater**
  - Is the innermost meningeal layer
  - Is a mesh of collagen and elastic fibers
  - Is bound to underlying neural tissue

13-2 Spinal Cord

- Structures of the Spinal Cord
  - Paired **denticulate ligaments**
    - Extend from pia mater to dura mater
    - Stabilize side-to-side movement
  - Blood vessels
    - Along surface of spinal pia mater
    - Within subarachnoid space

Figure 13-4 The Spinal Cord and Associated Structures



13-3 Gray Matter and White Matter

- The spinal cord plays a major role in spinal reflex activities and provides a communication link between the brain and the rest of the body.
- In cross section, an inner butterfly shaped region of gray matter is surrounded by anterior, lateral, and posterior white columns.
- Within these columns, ascending and descending bundles of myelinated axons called tracts carry information to and from the brain.

13-3 Gray Matter and White Matter

- Sectional Anatomy of the Spinal Cord
  - **White matter**
    - Is superficial
    - Contains myelinated and unmyelinated axons
  - **Gray matter**
    - Surrounds **central canal** of spinal cord
    - Contains neuron cell bodies, neuroglia, unmyelinated axons
    - Has projections (gray **horns**)

13-3 Gray Matter and White Matter

- Organization of Gray Matter
  - The gray horns
    - **Posterior gray horns** contain somatic and visceral sensory nuclei
    - **Anterior gray horns** contain somatic motor nuclei
    - **Lateral gray horns** are in thoracic and lumbar segments; contain visceral motor nuclei
  - **Gray commissures**
    - Axons that cross from one side of cord to the other before reaching gray matter

13-3 Gray Matter and White Matter

- Organization of Gray Matter
  - The cell bodies of neurons form functional groups called **nuclei**
    - **Sensory nuclei**
      - Dorsal (posterior)
      - Connect to peripheral receptors
    - **Motor nuclei**
      - Ventral (anterior)
      - Connect to peripheral effectors

13-3 Gray Matter and White Matter

- Control and Location
  - Sensory or motor nucleus location within the gray matter determines which body part it controls

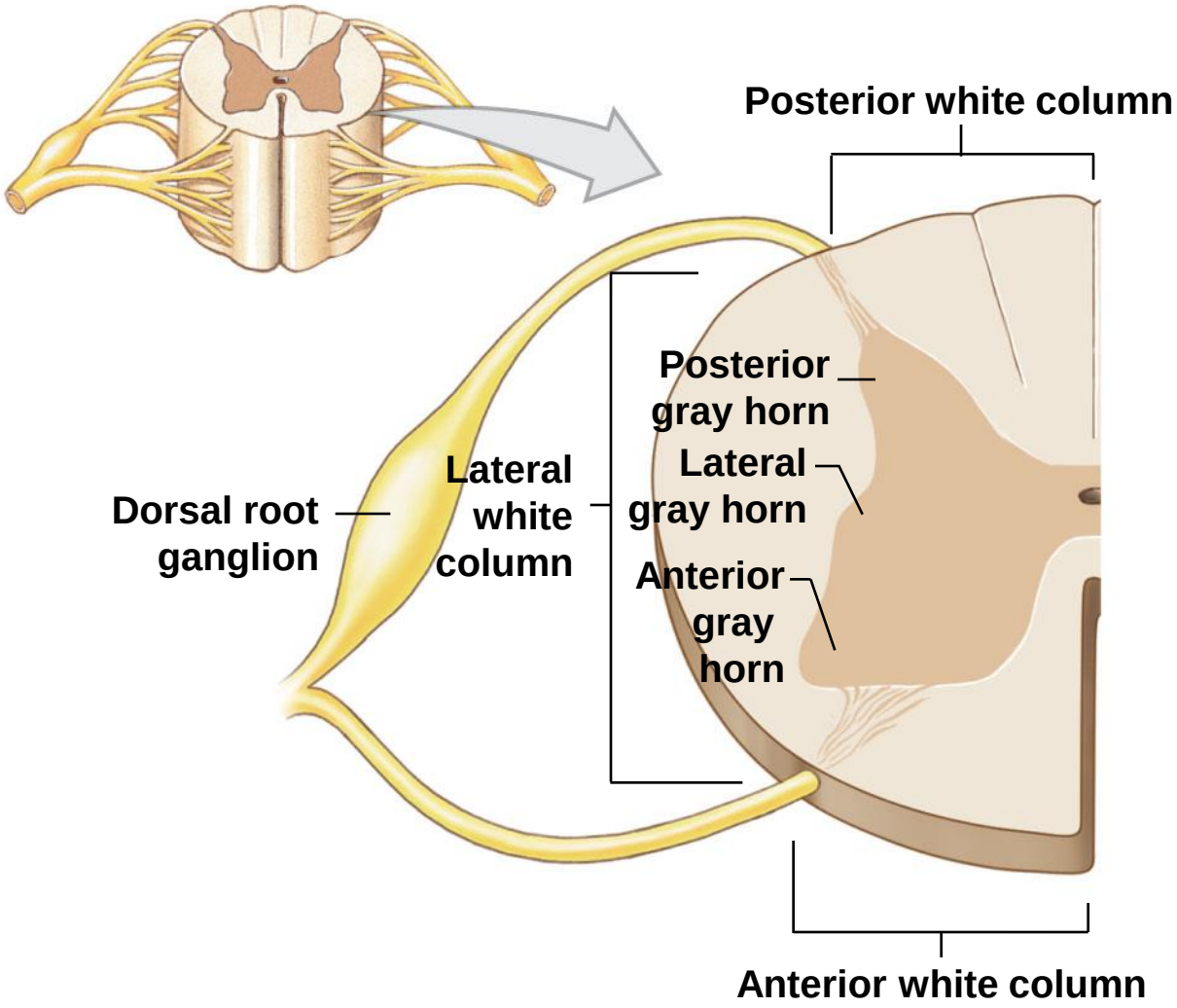
13-3 Gray Matter and White Matter

- Organization of White Matter
  - **Posterior white columns** lie between posterior gray horns and posterior median sulcus
  - **Anterior white columns** lie between anterior gray horns and anterior median fissure
    - **Anterior white commissure** area where axons cross from one side of spinal cord to the other
  - **Lateral white columns** located on each side of spinal cord between anterior and posterior columns

13-3 Gray Matter and White Matter

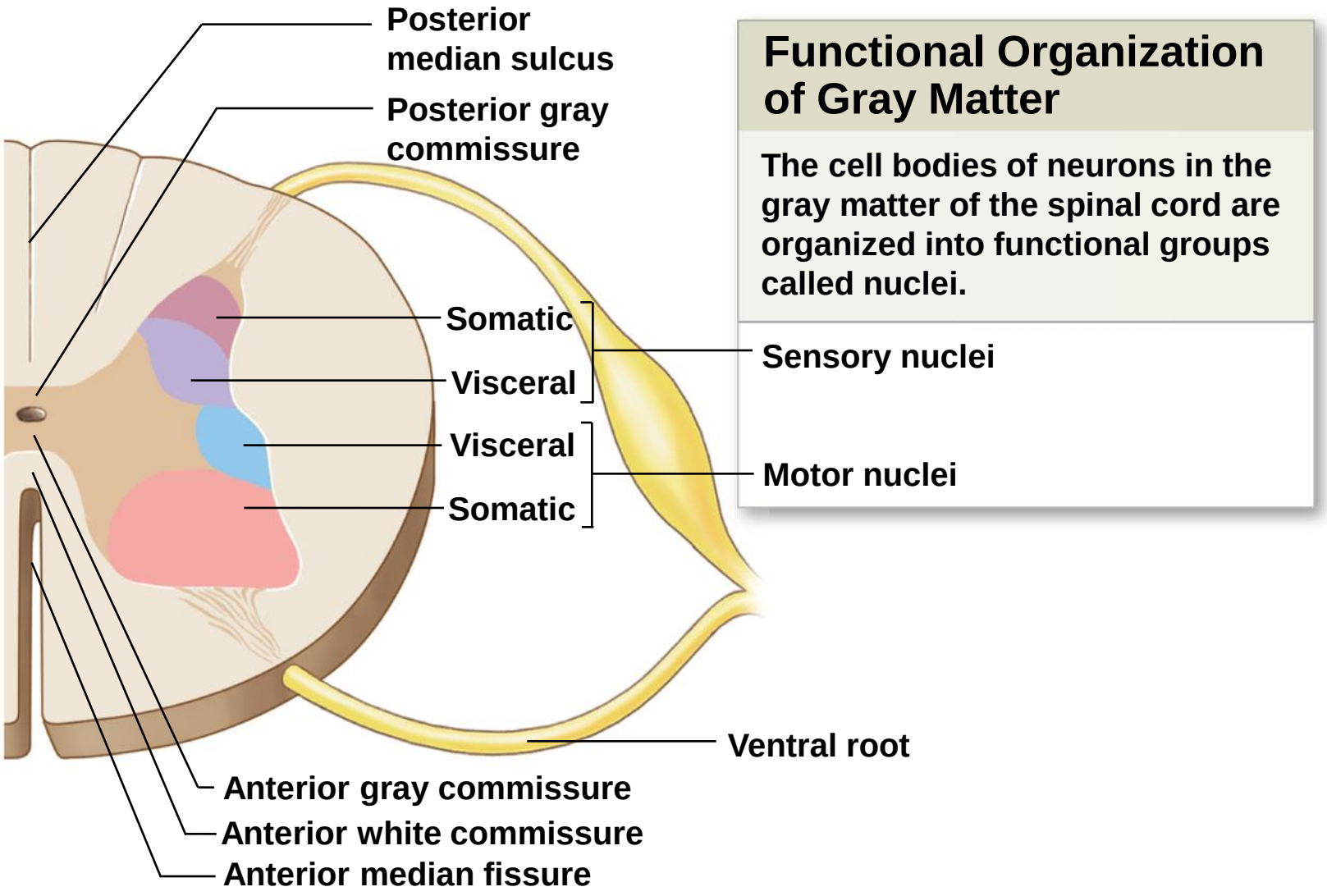
- Organization of White Matter
  - **Tracts** or ***fasciculi***
    - In white columns
    - Bundles of axons
    - Relay same information in same direction
    - **Ascending tracts**
      - Carry information to brain
    - **Descending tracts**
      - Carry motor commands to spinal cord

Figure 13-5a The Sectional Organization of the Spinal Cord



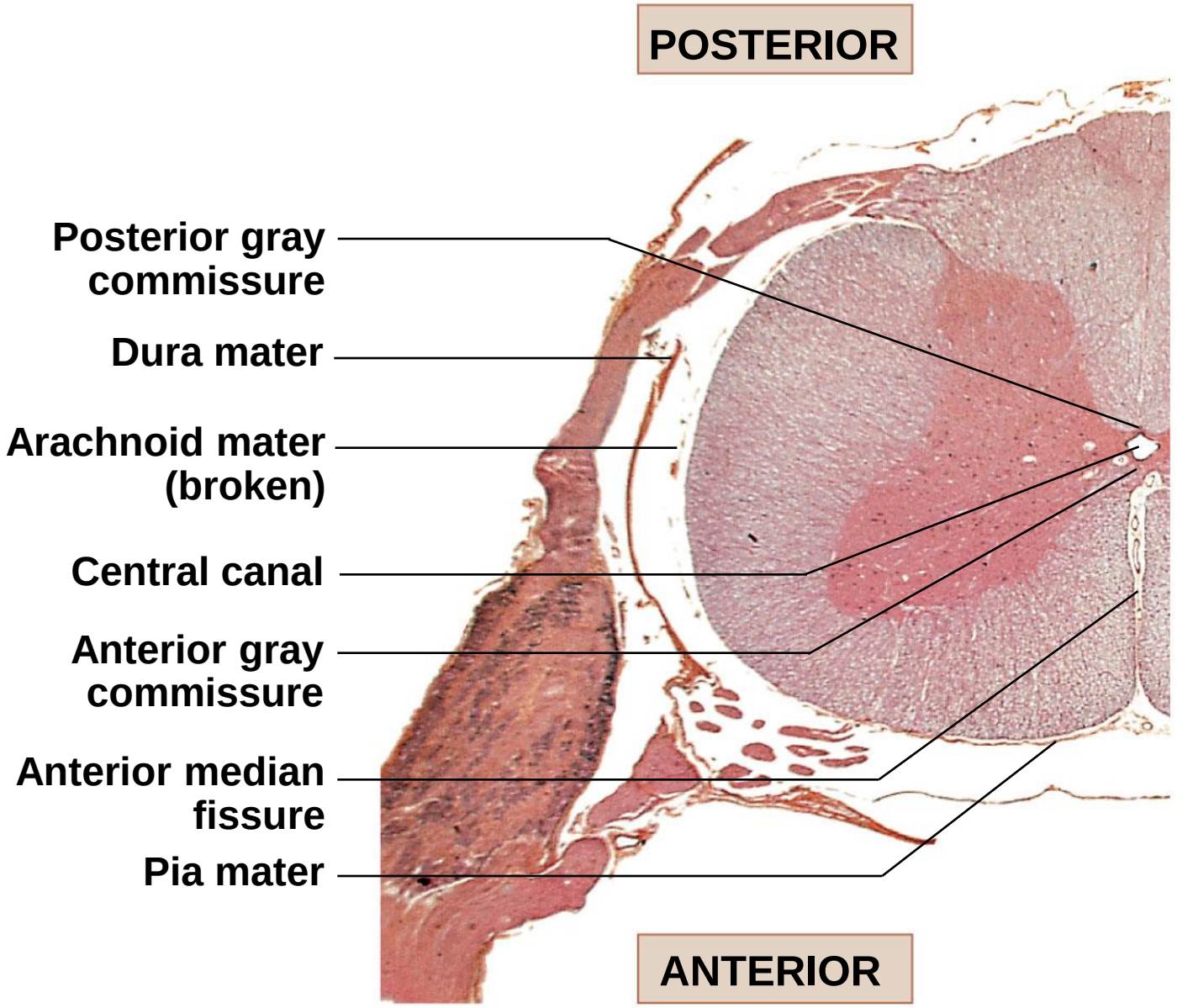
a **The left half of this sectional view shows important anatomical landmarks, including the three columns of white matter. The right half indicates the functional organization of the nuclei in the anterior, lateral, and posterior gray horns.**

Figure 13-5a The Sectional Organization of the Spinal Cord



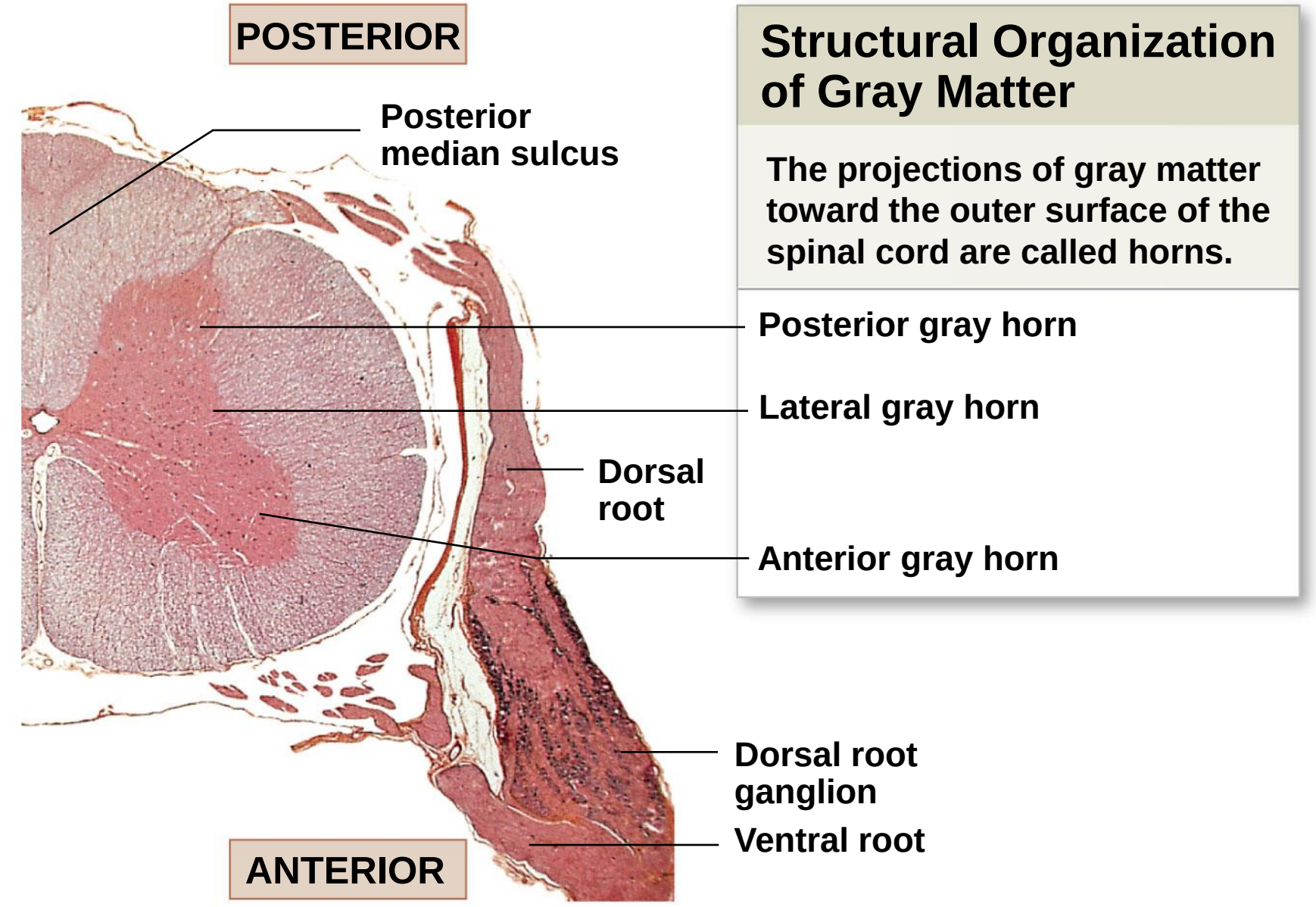
a The left half of this sectional view shows important anatomical landmarks, including the three columns of white matter. The right half indicates the functional organization of the nuclei in the anterior, lateral, and posterior gray horns.

Figure 13-5b The Sectional Organization of the Spinal Cord



b **A micrograph of a section through the spinal cord, showing major landmarks in and surrounding the cord.**

Figure 13-5b The Sectional Organization of the Spinal Cord



b A micrograph of a section through the spinal cord, showing major landmarks in and surrounding the cord.

13-3 Gray Matter and White Matter

- Spinal Cord Summary
  - Spinal cord has a narrow **central canal**
    - Surrounded by gray matter
    - Containing sensory and motor nuclei
      - Sensory nuclei are dorsal
      - Motor nuclei are ventral

13-3 Gray Matter and White Matter

- Spinal Cord Summary
  - Gray matter
    - Is covered by a thick layer of white matter
  - White matter
    - Consists of ascending and descending axons
    - Organized in columns
    - Contains axon bundles with specific functions
  - Spinal cord is so highly organized
    - It is possible to predict results of injuries to specific areas

Spinal Nerves Summary

- 31 pairs of spinal nerves originate from the spinal cord.
- Each section of the spinal cord and its pair of spinal nerves is called a segment.
- Each spinal emerges from the cord as posterior (sensory) and anterior (motor) roots.
- These roots merge to form the spinal nerve which emerges from the vertebral column through an intervertabral formina.

Spinal Nerves Summary

- Each nerve immediately divides into 3 branches of rami: posterior, anterior, and meningeal.
- At some levels of the cord, the anterior rami for nerve plexus that provide innervation for the neck, shoulders and diaphragm (cervical plexus), the upper extremities (brachial plexus), the abdominal wall, genitalia, and anterior thigh (lumbar plexus), and the reminader of the lower extremity (sacral plexus) and the skin over the coccys (coccygeal plexus)

13-4 Spinal Nerves and Plexuses

- Anatomy of Spinal Nerves
  - Every spinal cord segment
    - Is connected to a pair of spinal nerves
  - Every spinal nerve
    - Is surrounded by three connective tissue layers
    - That support structures and contain blood vessels

13-4 Spinal Nerves and Plexuses

- **Nerve Plexuses**
  - Complex, interwoven networks of nerve fibers
  - Formed from blended fibers of ventral rami of adjacent spinal nerves
  - Control skeletal muscles of the neck and limbs

13-4 Spinal Nerves and Plexuses

- The Four Major Plexuses of Ventral (anterior) Rami

1. **Cervical plexus**
2. **Brachial plexus**
3. **Lumbar plexus**
4. **Sacral plexus**

Figure 13-10 Peripheral Nerves and Nerve Plexuses

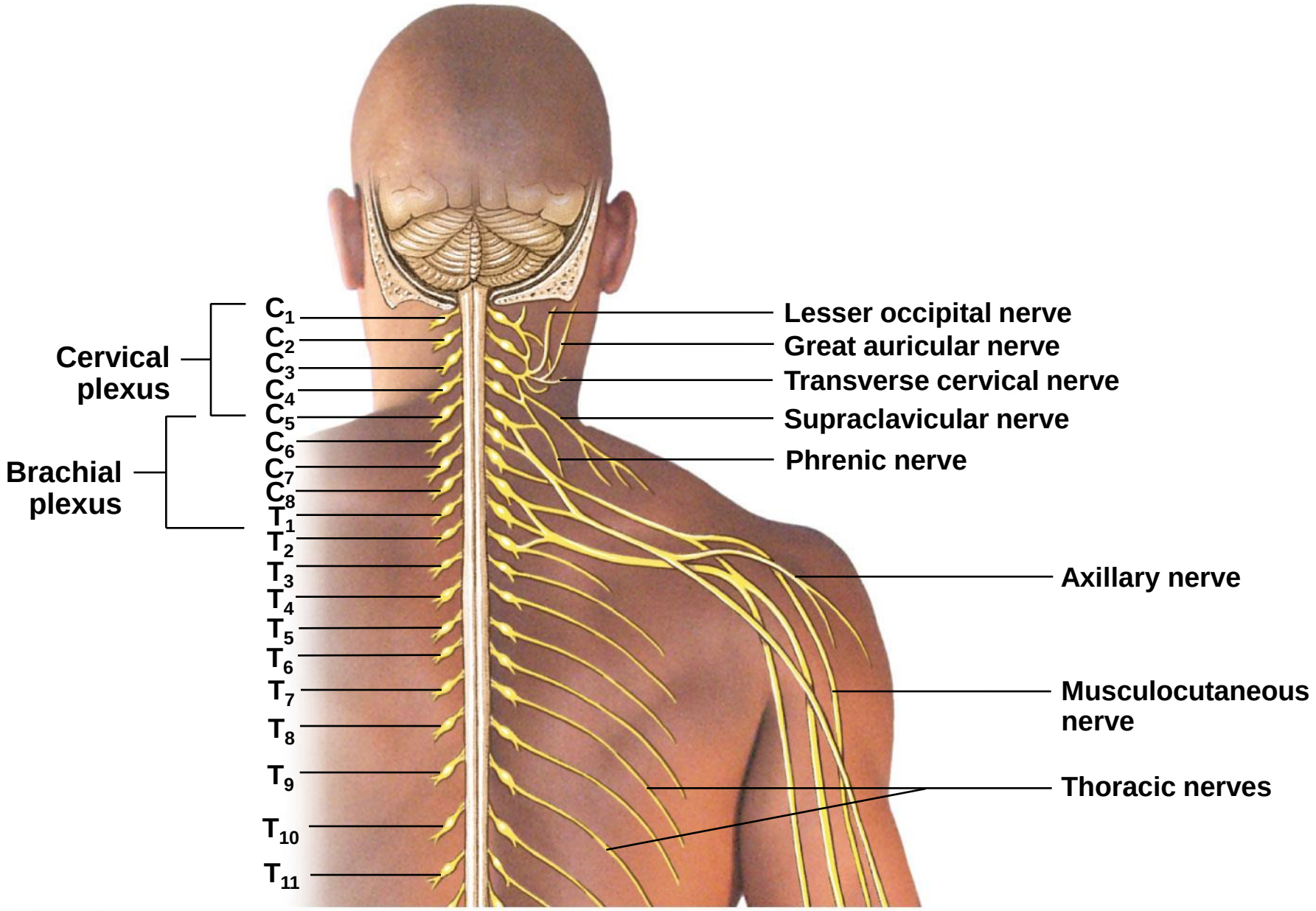
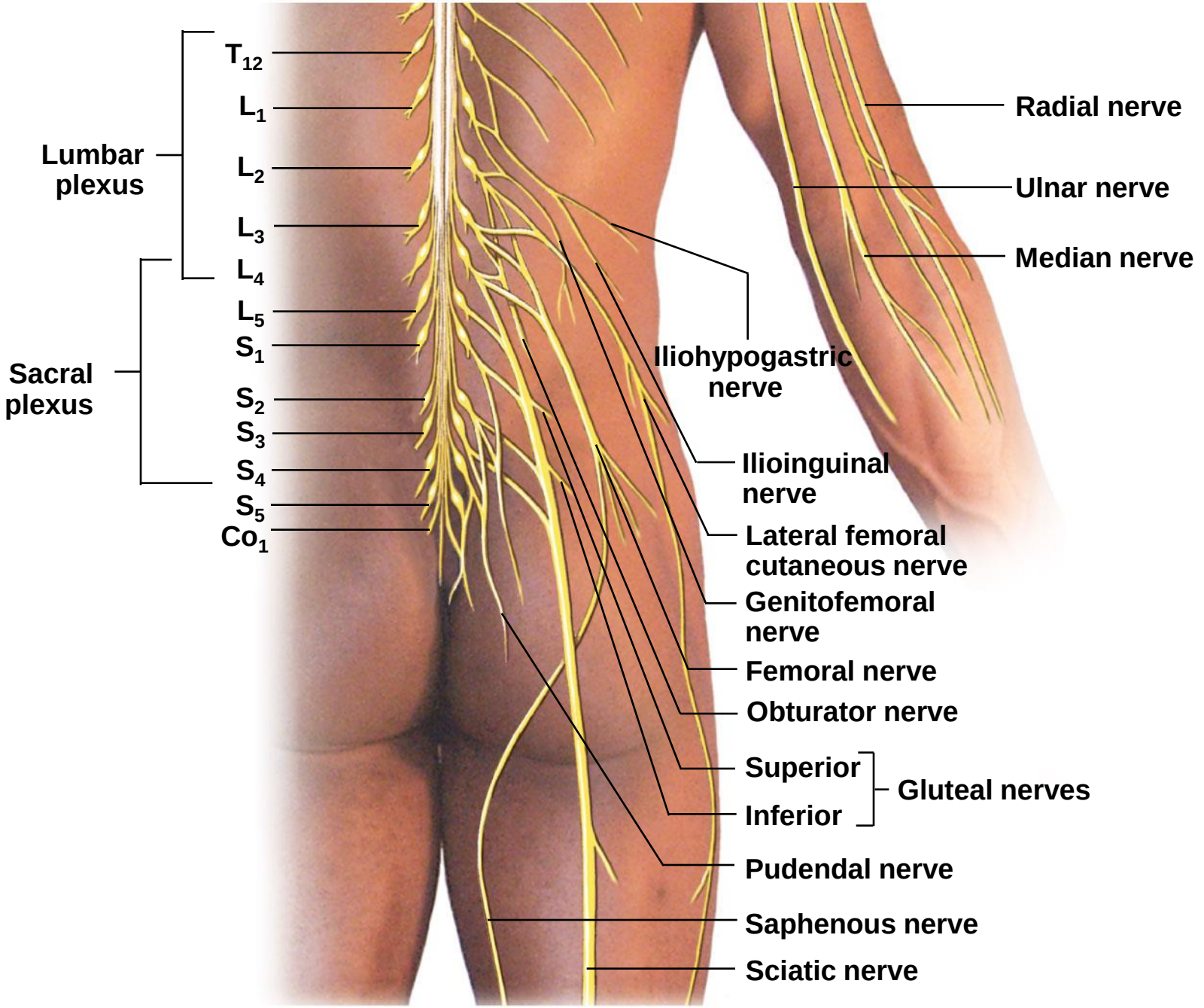


Figure 13-10 Peripheral Nerves and Nerve Plexuses



13-4 Spinal Nerves and Plexuses

- The **Cervical Plexus**
  - Includes ventral rami of spinal nerves C_1–C_5
  - Innervates neck, thoracic cavity, diaphragmatic muscles
  - Major nerve
    - **Phrenic nerve** (controls diaphragm)

Figure 13-11 The Cervical Plexus

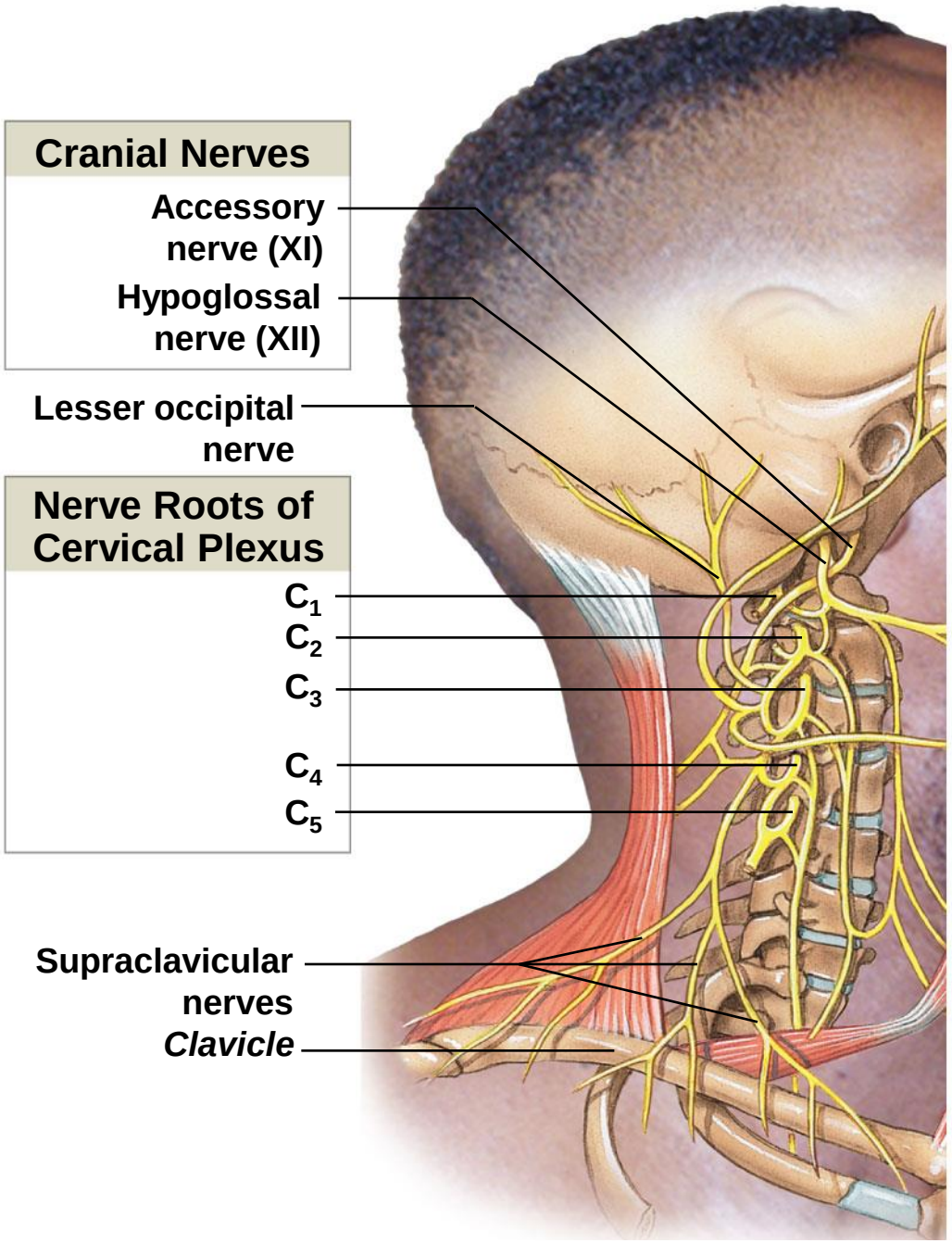


Figure 13-11 The Cervical Plexus

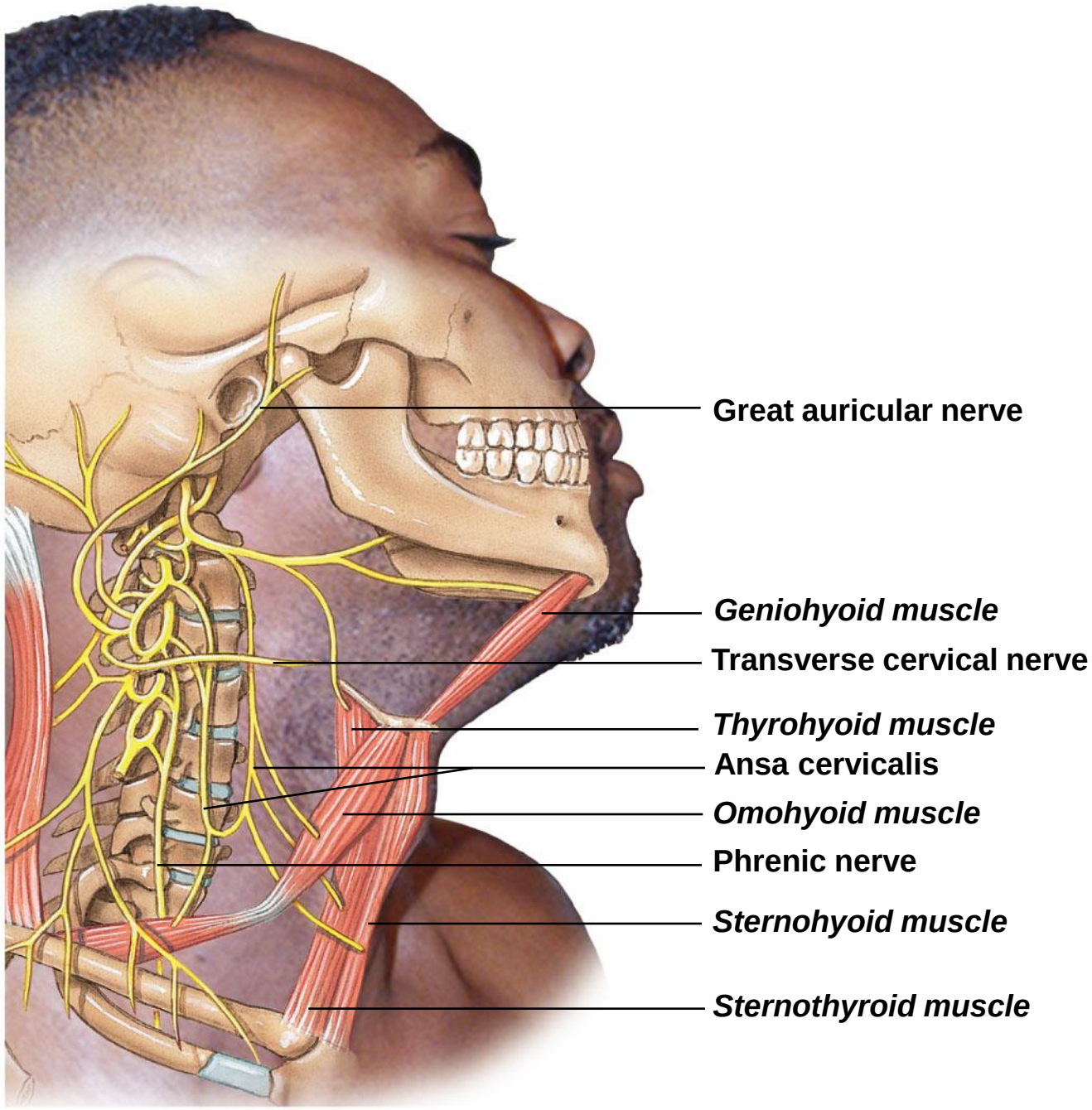


Table 13-1 The Cervical Plexus

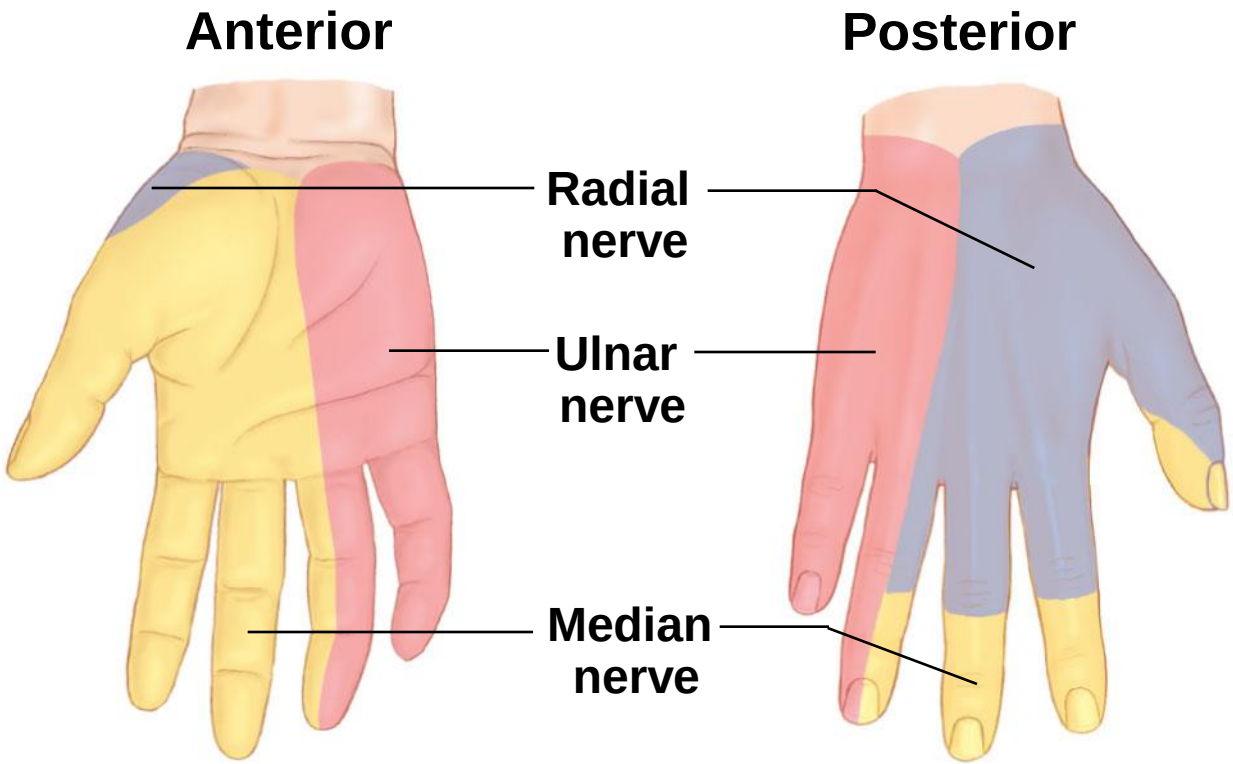
Table 13–1 The Cervical Plexus

Nerve	Spinal Segments	Distribution
Ansa cervicalis (superior and inferior branches)	C_1–C_4	Five of the extrinsic laryngeal muscles: sternothyroid, sternohyoid, omohyoid, geniohyoid, and thyrohyoid muscles (via N XII)
Lesser occipital, transverse cervical, supraclavicular, and great auricular nerves	C_2–C_3	Skin of upper chest, shoulder, neck, and ear
Phrenic nerve	C_3–C_5	Diaphragm
Cervical nerves	C_1–C_5	Levator scapulae, scalene, sternocleidomastoid, and trapezius muscles (with N XI)

13-4 Spinal Nerves and Plexuses

- The **Brachial Plexus**
  - Includes ventral rami of spinal nerves C_5–T_1
  - Innervates pectoral girdle and upper limbs
  - Nerves that form brachial plexus originate from:
    - Superior, middle, and inferior trunks
    - Large bundles of axons from several spinal nerves
    - Lateral, medial, and posterior cords
    - Smaller branches that originate at trunks

Figure 13-12b The Brachial Plexus



b Areas of the hands serviced by nerves of the right brachial plexus

Table 13-2 The Brachial Plexus

Table 13–2 The Brachial Plexus		
Nerve	**Spinal Segments**	**Distribution**
Nerve to subclavius	C_4–C_6	Subclavius muscle
Dorsal scapular nerve	C_5	Rhomboid and levator scapulae muscles
Long thoracic nerve	C_5–C_7	Serratus anterior muscle
Suprascapular nerve	C_5, C_6	Supraspinatus and infraspinatus muscles; sensory from shoulder joint and scapula
Pectoral nerves (medial and lateral)	C_5–T_1	Pectoralis muscles
Subscapular nerves	C_5, C_6	Subscapularis and teres major muscles
Thoracodorsal nerve	C_6–C_8	Latissimus dorsi muscle
Axillary nerve	C_5, C_6	Deltoid and teres minor muscles; sensory from the skin of the shoulder
Medial antebrachial cutaneous nerve	C_8, T_1	Sensory from skin over anterior, medial surface of arm and forearm
Radial nerve	C_5–T_1	Many extensor muscles on the arm and forearm (triceps brachii, anconeus, extensor carpi radialis, extensor carpi ulnaris, and brachioradialis muscles); supinator muscle, digital extensor muscles, and abductor pollicis muscle via the *deep branch*; sensory from skin over the posterolateral surface of the limb through the *posterior brachial cutaneous nerve* (arm), *posterior antebrachial cutaneous nerve* (forearm), and the *superficial branch* (radial half of hand)
Musculocutaneous nerve	C_5–T_1	Flexor muscles on the arm (biceps brachii, brachialis, and coracobrachialis muscles); sensory from skin over lateral surface of the forearm through the *lateral antebrachial cutaneous nerve*
Median nerve	C_6–T_1	Flexor muscles on the forearm (flexor carpi radialis and palmaris longus muscles); pronator quadratus and pronator teres muscles; digital flexors (through the *anterior interosseous nerve*); sensory from skin over anterolateral surface of the hand
Ulnar nerve	C_8, T_1	Flexor carpi ulnaris muscle, flexor digitorum profundus muscle, adductor pollicis muscle, and small digital muscles via the *deep branch*; sensory from skin over medial surface of the hand through the *superficial branch*

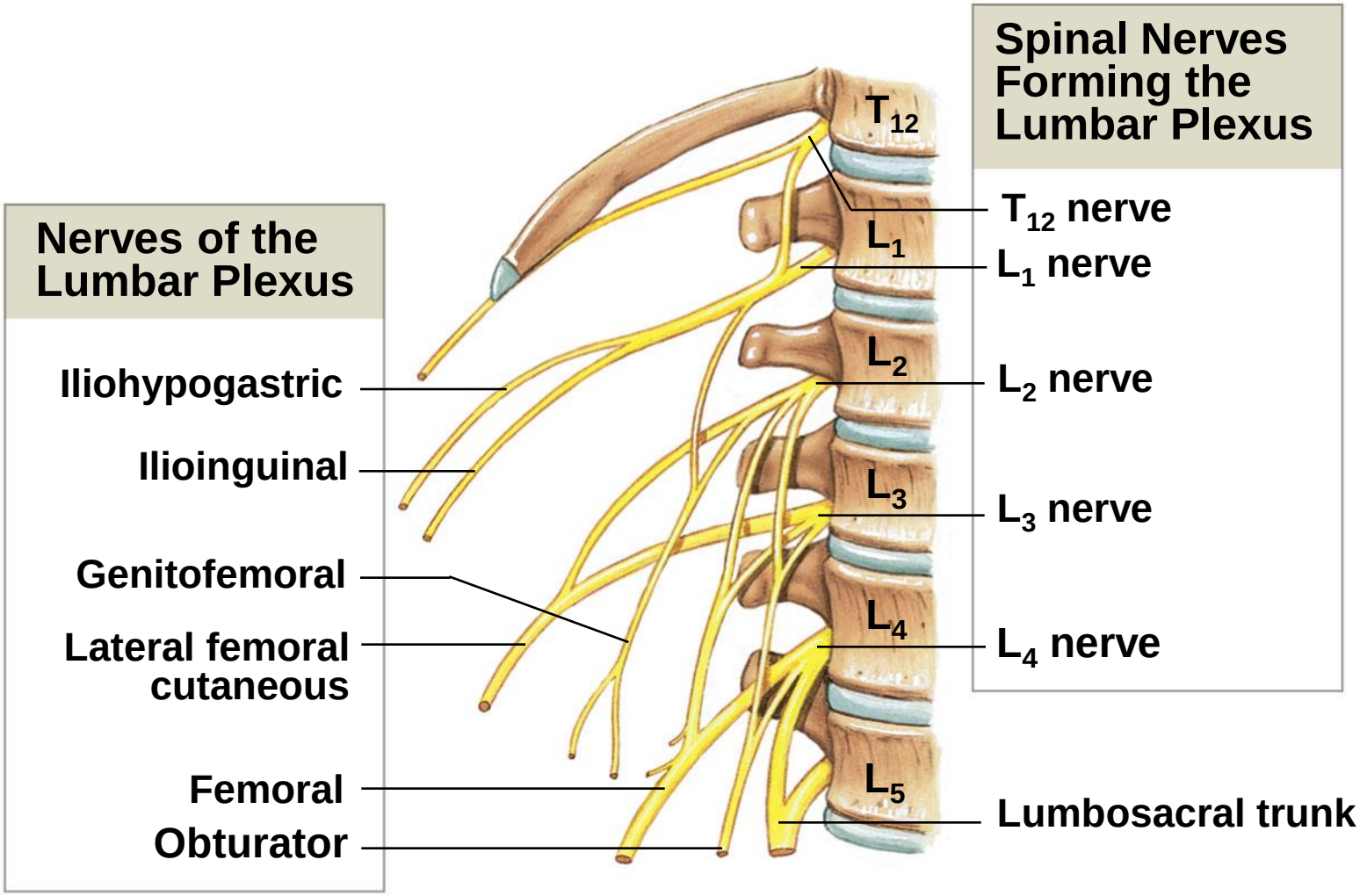
13-4 Spinal Nerves and Plexuses

- The **Lumbar Plexus**
  - Includes ventral rami of spinal nerves T_{12}–L_4
  - Major nerves
    - **Genitofemoral nerve**
    - **Lateral femoral cutaneous nerve**
    - **Femoral nerve**

13-4 Spinal Nerves and Plexuses

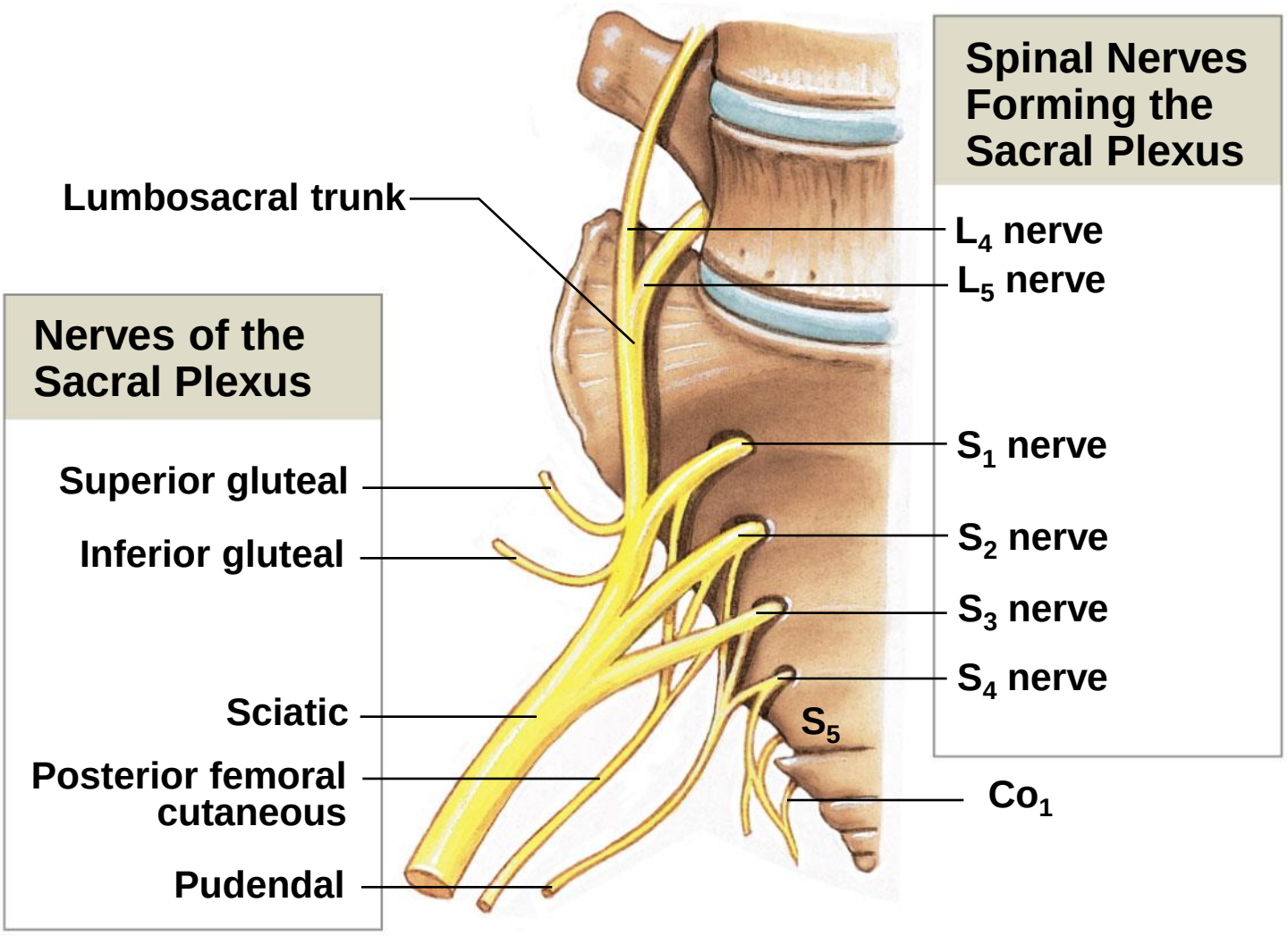
- The **Sacral Plexus**
  - Includes ventral rami of spinal nerves L_4–S_4
  - Major nerves
    - **Pudendal nerve**
    - **Sciatic nerve**
  - Two branches of the sciatic nerve
    1. **Fibular nerve**
    2. **Tibial nerve**

Figure 13-13a The Lumbar and Sacral Plexuses



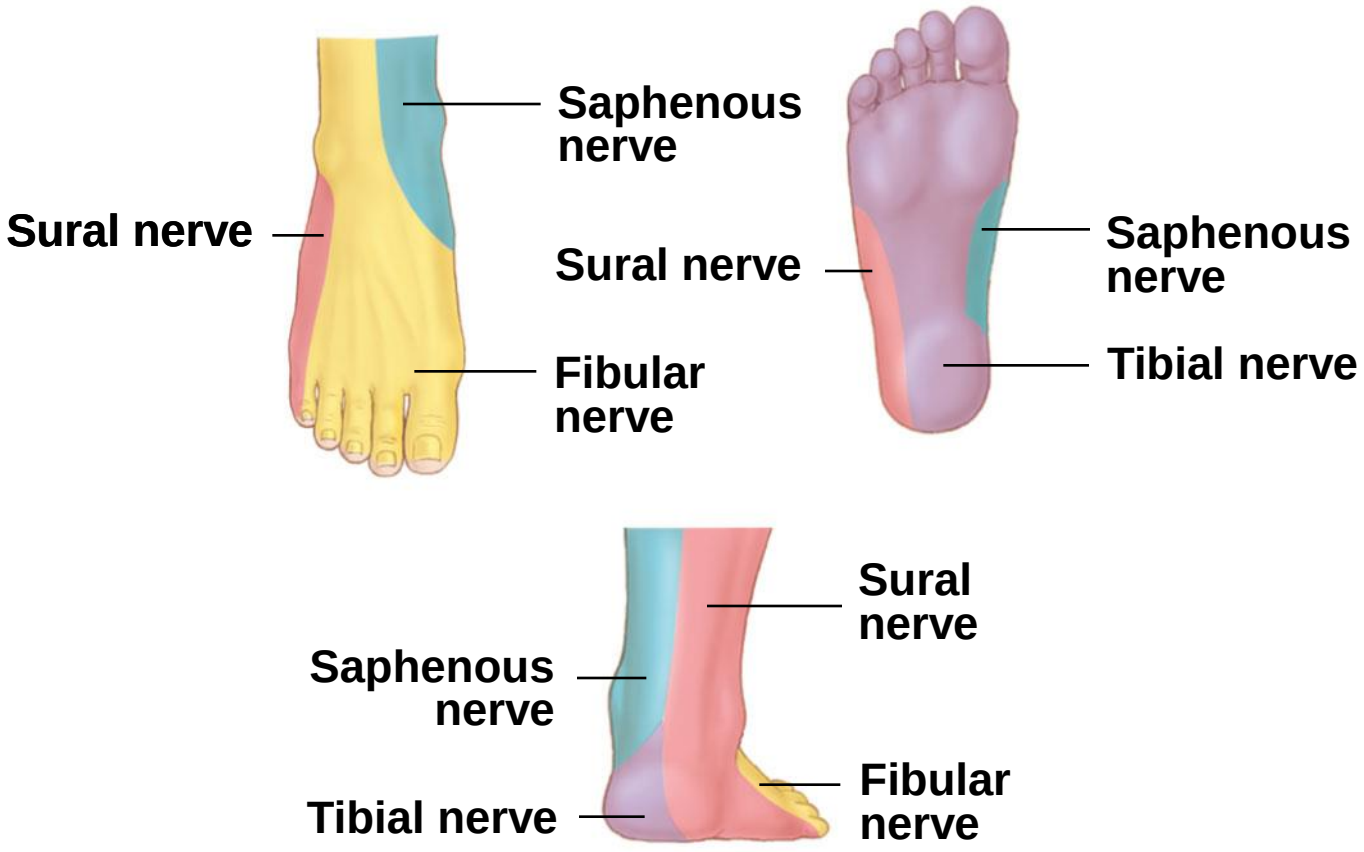
a Lumbar plexus, anterior view

Figure 13-13b The Lumbar and Sacral Plexuses



b Sacral plexus, anterior view

Figure 13-13d The Lumbar and Sacral Plexuses



d Cutaneous distribution of the nerves in the foot and ankle

13-5 Neuronal Pools

- Functional Organization of Neurons
  - Sensory neurons
    - About 10 million
    - Deliver information to CNS
  - Motor neurons
    - About 1/2 million
    - Deliver commands to peripheral effectors
  - Interneurons
    - About 20 billion
    - Interpret, plan, and coordinate signals in and out

Reflexes Summary

- A reflex is a quick, involuntary motor response to a stimulus.
- It is often the body's attempt to avoid danger or painful stimuli or as a way to maintain homeostasis.
- Some examples are lifting the foot when stepping on something painful, turning the head towards a sound, or the changes in pupil diamter in response to light intensity.
- Every time the body performs a particular reflex, it is repeated without variation and is said to be stereotyped.

13-6 Reflexes

- **Reflexes**
  - Automatic responses coordinated within spinal cord
  - Through interconnected sensory neurons, motor neurons, and interneurons
  - Produce simple and complex reflexes

13-6 Reflexes

- *Neural Reflexes*
  - Rapid, automatic responses to specific stimuli
  - Basic building blocks of neural function
  - One neural reflex produces one motor response
  - **Reflex arc**
    - The wiring of a single reflex
    - Beginning at *receptor*
    - Ending at peripheral *effector*
    - Generally opposes original stimulus (negative feedback)

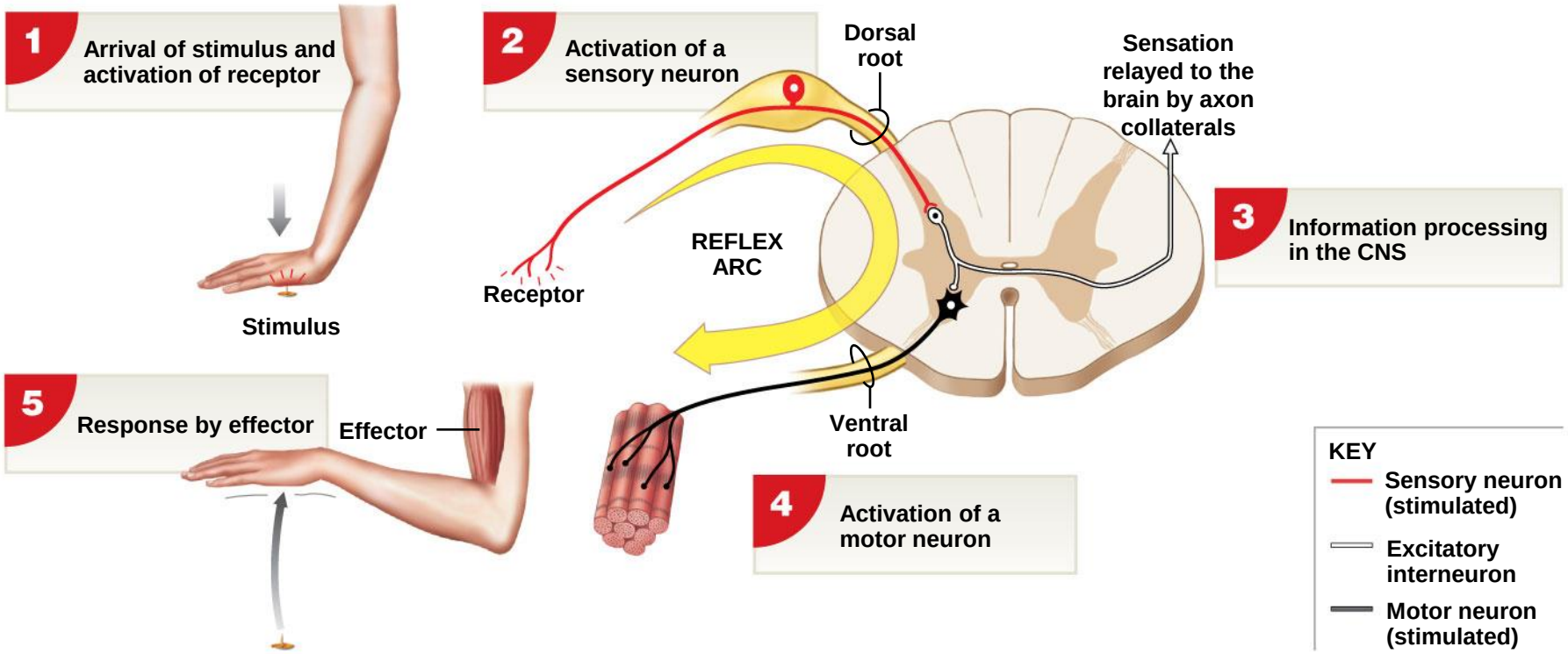
Reflex Arc

- The pathway mediating a reflex, has 5 components:
  - 1. receptor
  - 2. the sensory neuron which carries information about the stimulus to the central nervous system
  - 3. the integration center with interneurons/association neurons usually the brain or spinal cord.
  - 4. a motor neuron which carries information to the effector,
  - 5. effector, which would be a muscle or a gland.

13-6 Reflexes

- Five Steps in a Neural Reflex
  - ***Step 1: Arrival of stimulus, activation of receptor***
    - Physical or chemical changes
  - ***Step 2: Activation of sensory neuron***
    - Graded depolarization
  - ***Step 3: Information processing by postsynaptic cell***
    - Triggered by neurotransmitters
  - ***Step 4: Activation of motor neuron***
    - Action potential
  - ***Step 5: Response of peripheral effector***
    - Triggered by neurotransmitters

Figure 13-15 Events in a Neural Reflex



13-6 Reflexes

- Four Classifications of Reflexes
  1. By early development
  2. By type of motor response
  3. By complexity of neural circuit
  4. By site of information processing

13-6 Reflexes

- Development of Reflexes
  - **Innate reflexes**
    - Basic neural reflexes
    - Formed before birth
  - **Acquired reflexes**
    - Rapid, automatic
    - Learned motor patterns

13-6 Reflexes

- Motor Response
  - Nature of resulting motor response
    - **Somatic reflexes**
      - Involuntary control of nervous system
        - Superficial reflexes of skin, mucous membranes
        - Stretch or deep tendon reflexes (e.g., *patellar*, or *"knee-jerk," reflex*)
    - **Visceral reflexes** *(autonomic reflexes)*
      - Control systems other than muscular system

Somatic vs. Visceral

- Somatic reflexes involve the somatic nervous system and result in the contraction of muscle.
- Visceral reflexes involved the autonomic nervous system and are the result of internal stimuli.
- An example would be the basoreflex in which the brain receives information about blood pressure and heart rate and blood vessel tone are adjusted accordingly.

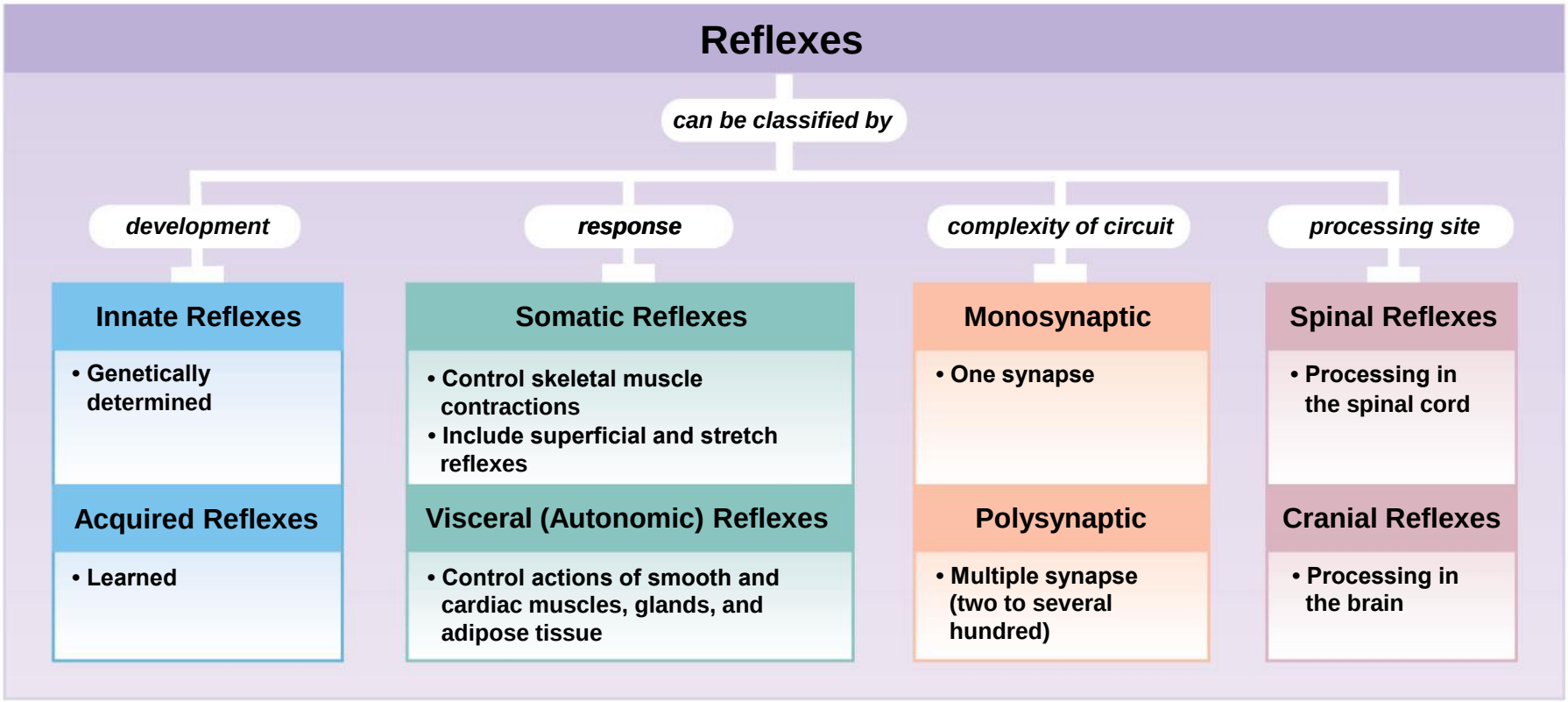
13-6 Reflexes

- Complexity of Neural Circuit
  - **Monosynaptic reflex**
    - Sensory neuron synapses directly onto motor neuron
  - **Polysynaptic reflex**
    - At least one interneuron between sensory neuron and motor neuron

13-6 Reflexes

- Site of Information Processing
  - **Spinal reflexes**
    - Occur in spinal cord
  - **Cranial reflexes**
    - Occur in brain

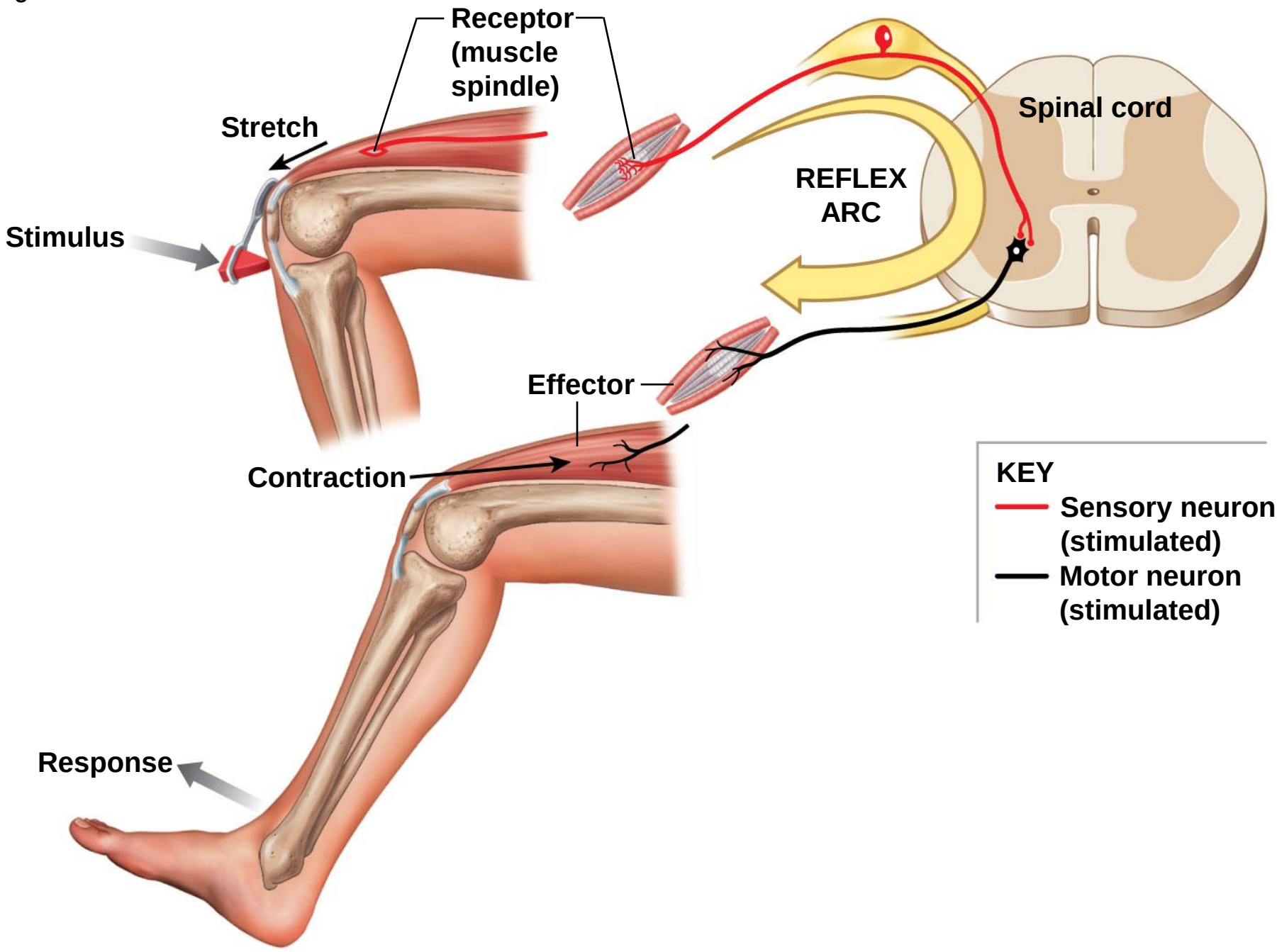
Figure 13-16 The Classification of Reflexes



13-7 Spinal Reflexes

- Spinal Reflexes
  - Range in increasing order of complexity
    - Monosynaptic reflexes
    - Polysynaptic reflexes
    - **Intersegmental reflex arcs**
      - Many segments interact
      - Produce highly variable motor response

Figure 13-17 A Stretch Reflex



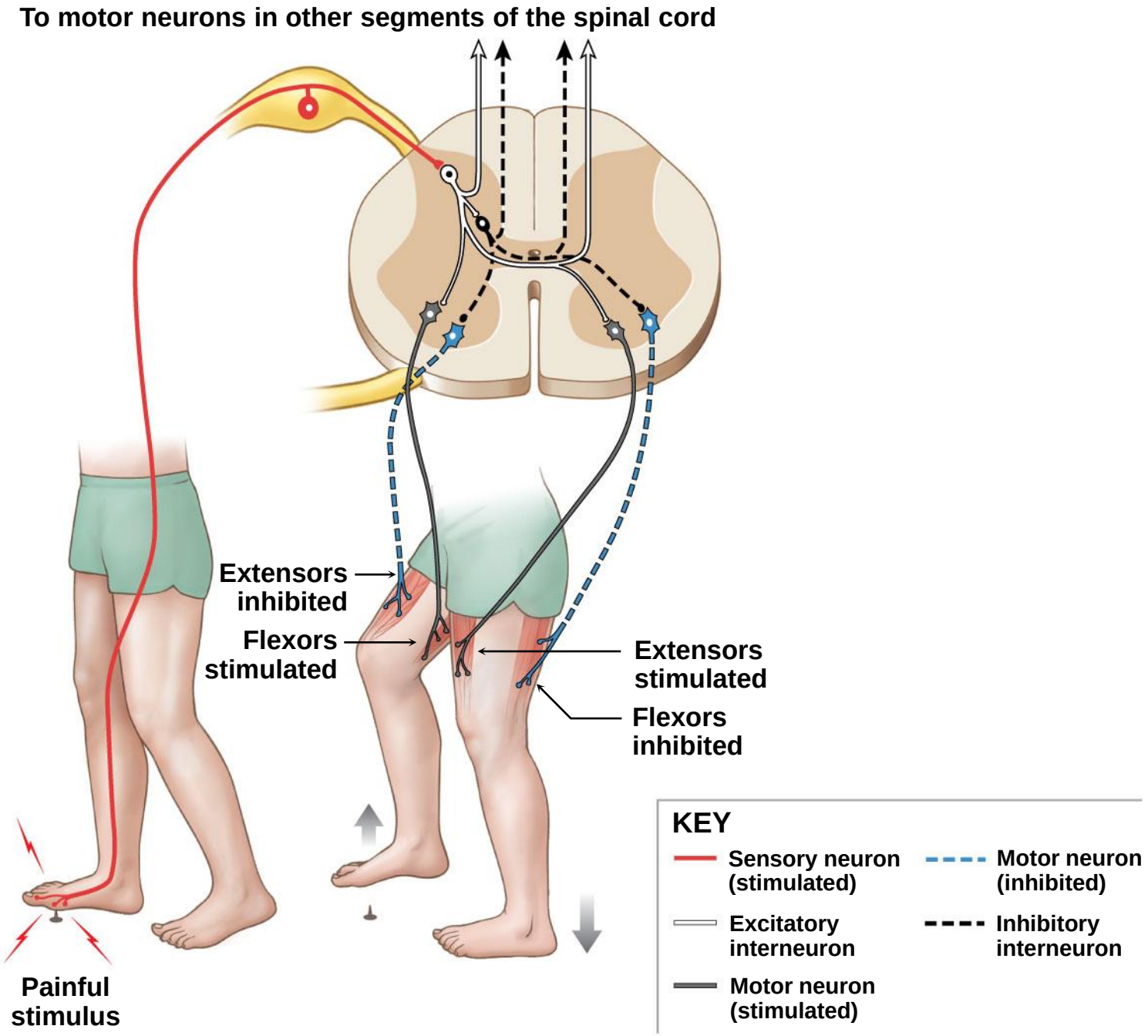
13-7 Spinal Reflexes

- Reflex Arcs
  - *Ipsilateral reflex arcs*
    - Occur on same side of body as stimulus
    - Stretch, tendon, and withdrawal reflexes
  - **Crossed extensor reflexes**
    - Involve a *contralateral reflex arc*
    - Occur on side opposite stimulus

13-7 Spinal Reflexes

- Crossed Extensor Reflexes
  - Occur simultaneously, coordinated with flexor reflex
  - For example, flexor reflex causes leg to pull up
    - Crossed extensor reflex straightens other leg
    - To receive body weight
    - Maintained by reverberating circuits

Figure 13-20 The Crossed Extensor Reflex



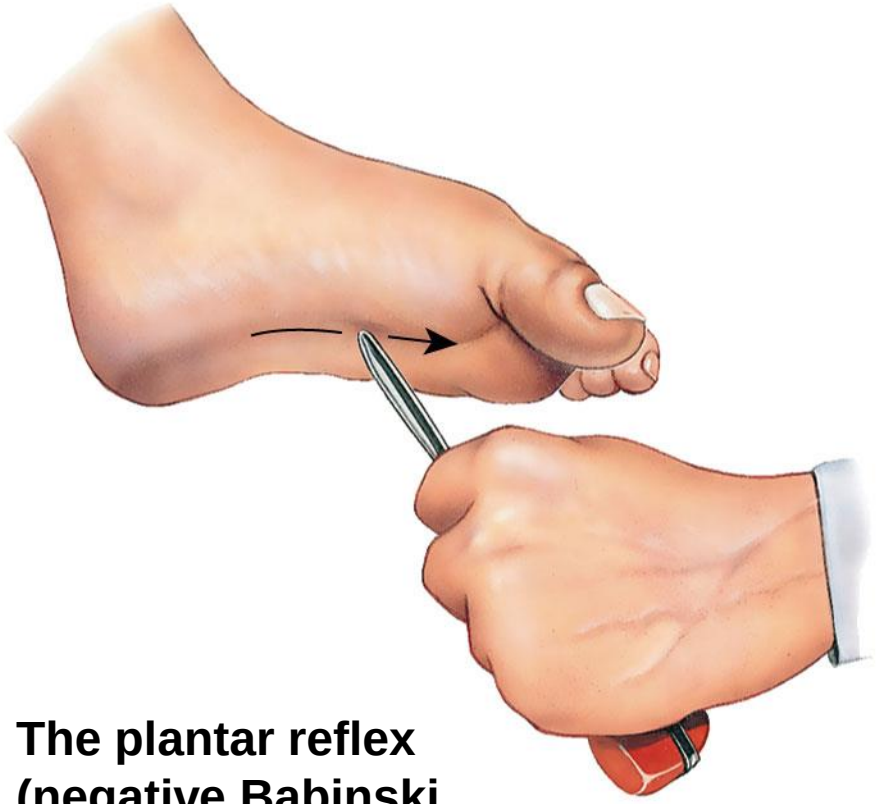
Spinal Reflexes Summary

- Most reflexes are polysynaptic, meaning they have more than one synapse, and thus involve more than 2 neurons.
- If only 2 neurons are involved, then the reflex is said to be monosynaptic.
- If the effect of the reflex occurs on the same side of the body as the signal from the receptor, then the reflex is considered ipsilateral.
- If the effect occurs on the opposite side of the body, then the reflex is said to be contralateral.
- If you step on a tack with a right food, you will raise the right foot off the ground (ipsilateral; withdrawal reflex), but you will firmly plant the left foot on the ground (contralateral; crossed extensor reflex) to prevent yourself from falling over.

13-8 Example of Spinal Reflexes

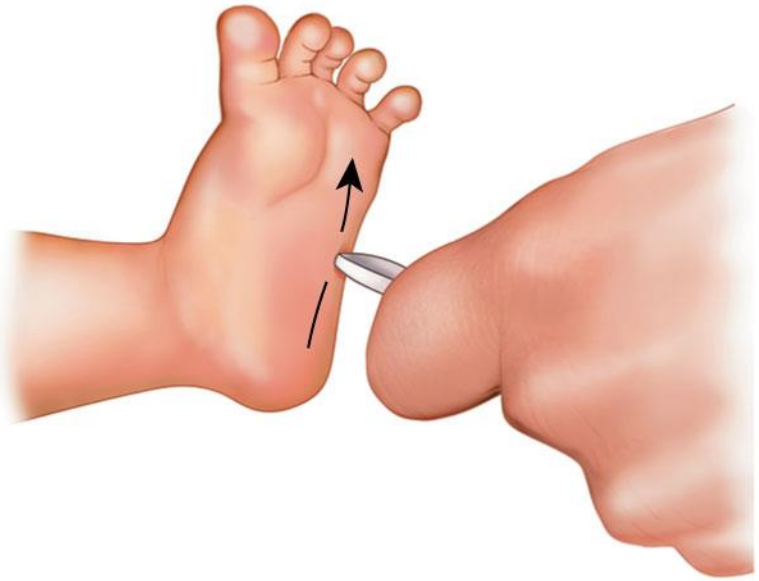
- Patellar reflex (knee jerk)-assesses the reflex arc involving spinal cord segments L2-L4
- Achilles reflex (ankle jerk)-Assesses the reflex arc involving spinal cord segments S1 to S2
- Biceps reflex-Demonstrates the reflex arc involving spinal cord segments C5-C6
- Plantar reflex (The *Babinski Reflex)*-This test is performed to assess damage to the corticospinal tract that may be caused by demyelination or damage to the tract itself.
  - Normal in infants
  - May indicate CNS damage in adults

Figure 13-21a The Babinski Reflexes



a **The plantar reflex (negative Babinski reflex), a curling of the toes, is seen in healthy adults.**

Figure 13-21b The Babinski Reflexes



b **The Babinski sign (positive Babinski reflex) occurs in the absence of descending inhibition. It is normal in infants, but pathological in adults.**