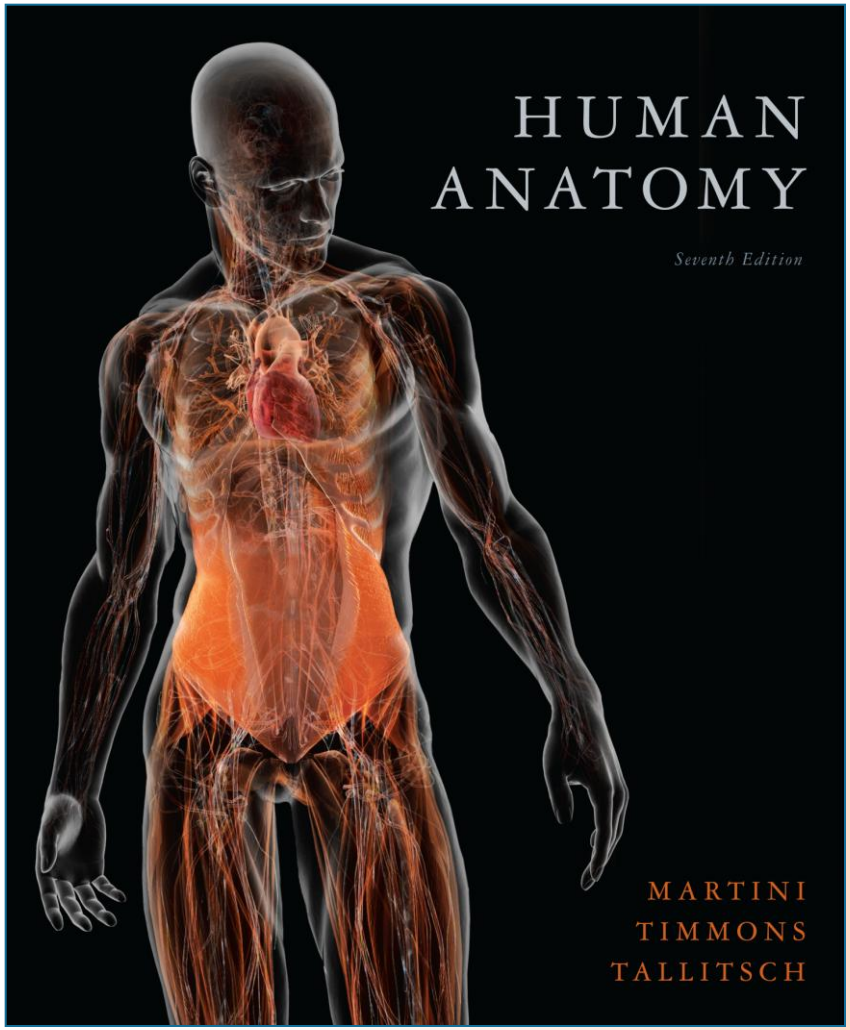


14

The Nervous System: The Spinal Cord and Spinal Nerves

PowerPoint® Lecture Presentations prepared by
Steven Bassett
Southeast Community College
Lincoln, Nebraska

Introduction

- The Central Nervous System (CNS) consists of:
  - The **spinal cord**
    - Integrates and processes information
    - Can function with the brain
    - Can function independently of the brain
  - The **brain**
    - Integrates and processes information
    - Can function with the spinal cord
    - Can function independently of the spinal cord

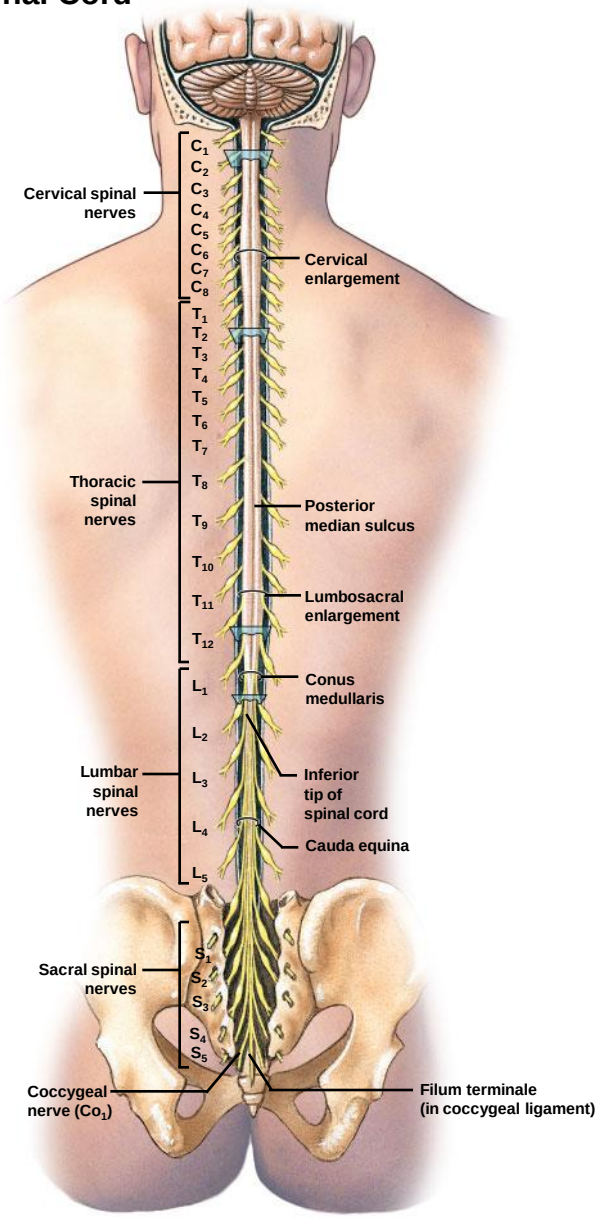
Gross Anatomy of the Spinal Cord

- Features of the Spinal Cord
  - 45 cm in length
  - Passes through the foramen magnum
  - Extends from the brain to L_1
  - Consists of:
    - **Cervical region**
    - **Thoracic region**
    - **Lumbar region**
    - **Sacral region**
    - **Coccygeal region**

Gross Anatomy of the Spinal Cord

- Features of the Spinal Cord
  - Consists of (continued):
    - **Cervical enlargement**
    - **Lumbosacral enlargement**
    - **Conus medullaris**
    - **Cauda equina**
    - **Filum terminale**: becomes a component of the coccygeal ligament
    - Posterior and anterior **median sulci**

Figure 14.1a Gross Anatomy of the Spinal Cord

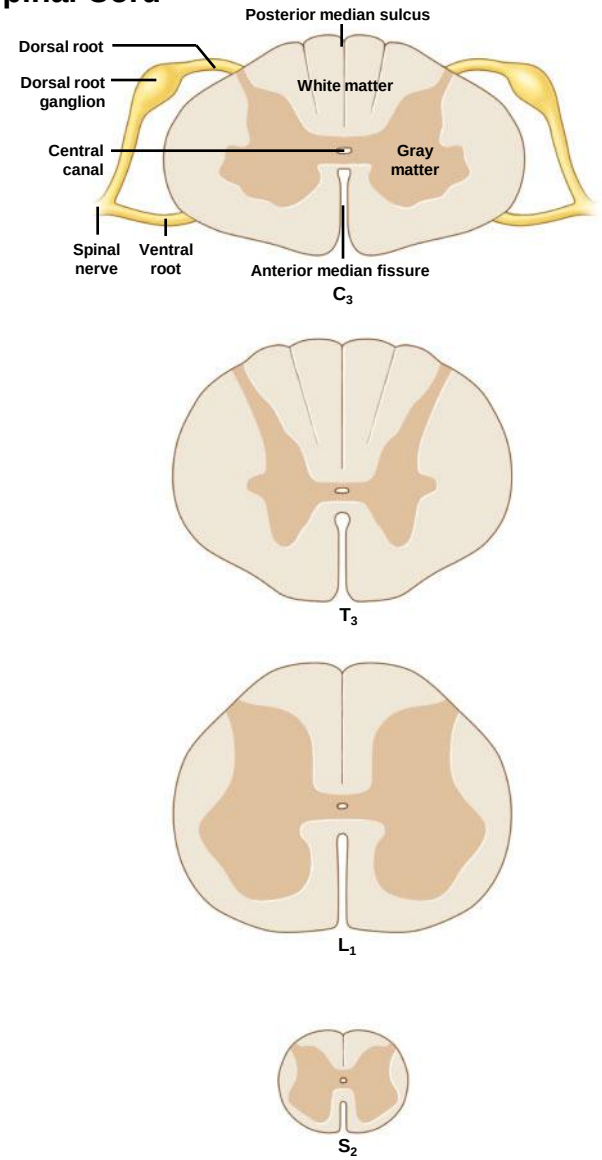


a Superficial anatomy and orientation of the adult spinal cord. The numbers to the left identify the spinal nerves and indicate where the nerve roots leave the vertebral canal. The spinal cord, however, extends from the brain only to the level of vertebrae L_1–L_2.

Gross Anatomy of the Spinal Cord

- Features of the Spinal Cord
  - Transverse view
    - **White matter**
    - **Gray matter**
    - **Central canal**
    - Dorsal root and ventral root: merge to form a **spinal nerve**
    - **Dorsal root** is sensory: axons extend from the soma within the **dorsal root ganglion**
    - **Ventral root** is motor

Figure 14.1d Gross Anatomy of the Spinal Cord

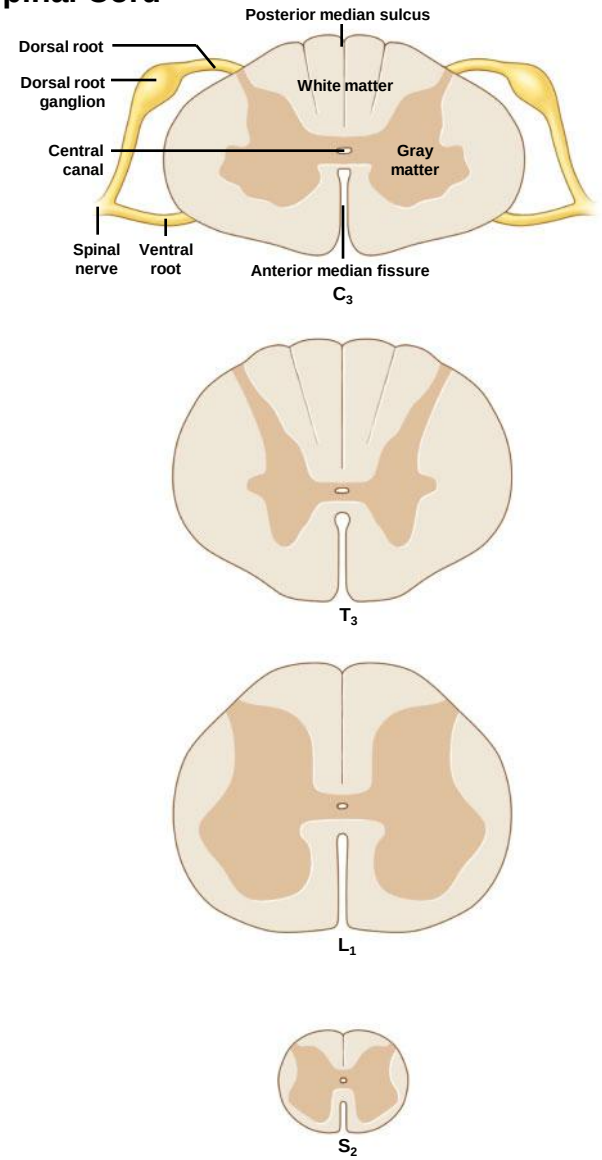


d Inferior views of cross sections through representative segments of the spinal cord showing the arrangement of gray and white matter

Gross Anatomy of the Spinal Cord

- Features of the Spinal Nerves
  - Consist of:
    - **Sensory nerves** (afferent nerves): transmit impulses toward the spinal cord
    - **Motor nerves** (efferent nerves): transmit impulses away from the spinal cord

Figure 14.1d Gross Anatomy of the Spinal Cord

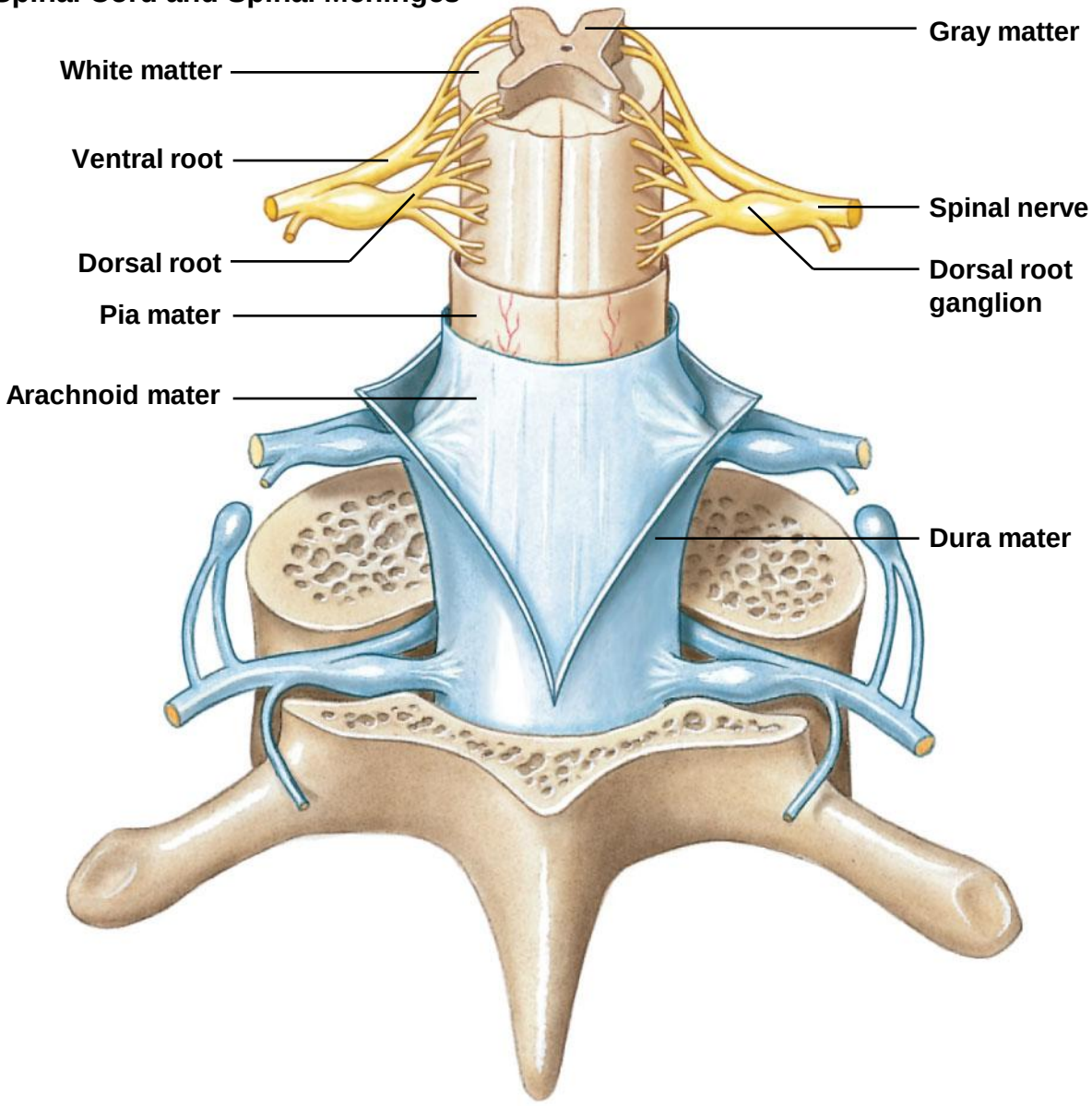


d Inferior views of cross sections through representative segments of the spinal cord showing the arrangement of gray and white matter

Spinal Meninges

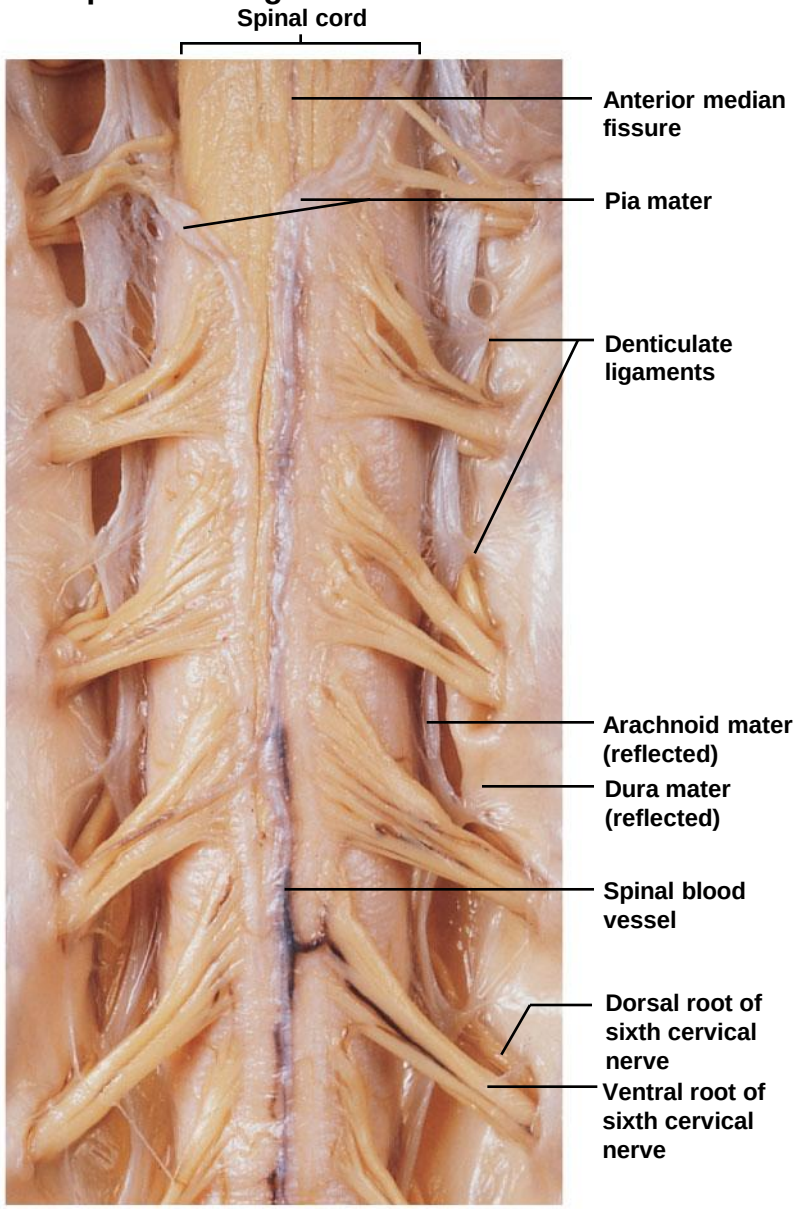
- Features of spinal meninges:
  - Specialized membranes that provide protection, physical stability, and shock absorption
  - Continuous with the cranial (cerebral) meninges
  - **Denticulate ligaments** help anchor the spinal cord in position
  - Made of three layers
    - **Dura mater**: tough, fibrous outermost layer
    - **Arachnoid mater**: middle layer
    - **Pia mater**: innermost layer

Figure 14.2c The Spinal Cord and Spinal Meninges



C **Posterior view of the spinal cord showing the meningeal layers, superficial landmarks, and distribution of gray and white matter**

Figure 14.2a The Spinal Cord and Spinal Meninges



a Anterior view of spinal cord showing meninges and spinal nerves. For this view, the dura and arachnoid membranes have been cut longitudinally and retracted (pulled aside); notice the blood vessels that run in the subarachnoid space, bound to the outer surface of the delicate pia mater.

Sectional Anatomy of the Spinal Cord

- **Gray matter**
  - Central canal
  - Consists of somas (cell bodies) surrounding the central canal
- **White matter**
  - Consists of axons
  - Nerves are organized into tracts or columns
  - Located outside the gray matter area

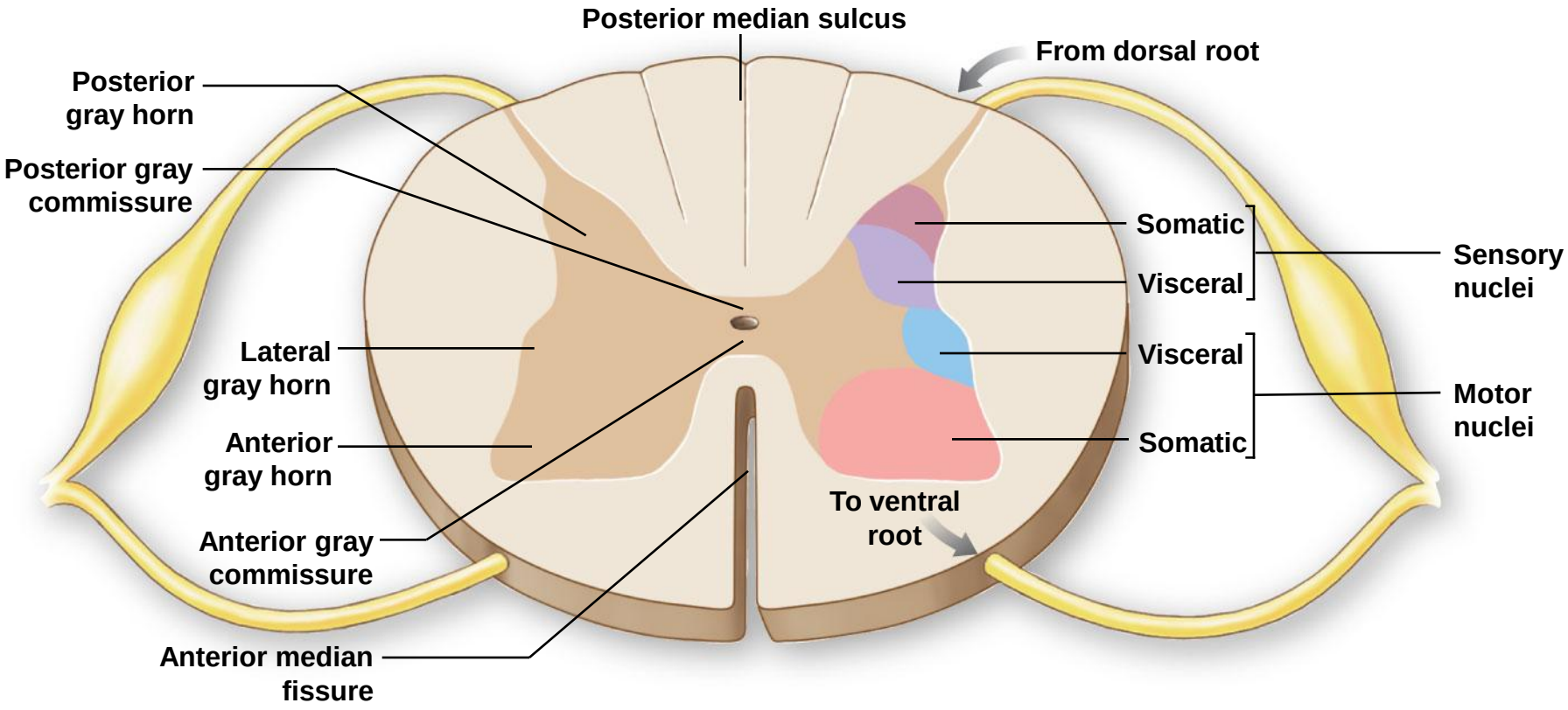
Sectional Anatomy of the Spinal Cord

- Organization of Gray Matter
  - Somas are organized into groups called nuclei
    - Sensory nuclei
    - Motor nuclei
  - Transverse view shows:
    - **Posterior gray horns**
    - **Lateral gray horns**
    - **Anterior gray horns**
    - **Gray commissure**

Sectional Anatomy of the Spinal Cord

- Organization of gray matter
  - **Posterior gray horns**: somatic sensory and visceral nuclei
  - **Lateral gray horns**: visceral motor nuclei
  - **Anterior gray horns**: somatic motor nuclei
  - **Gray commissure**
    - Consists of axons crossing from one side to the other

Figure 14.4b Sectional Organization of the Spinal Cord

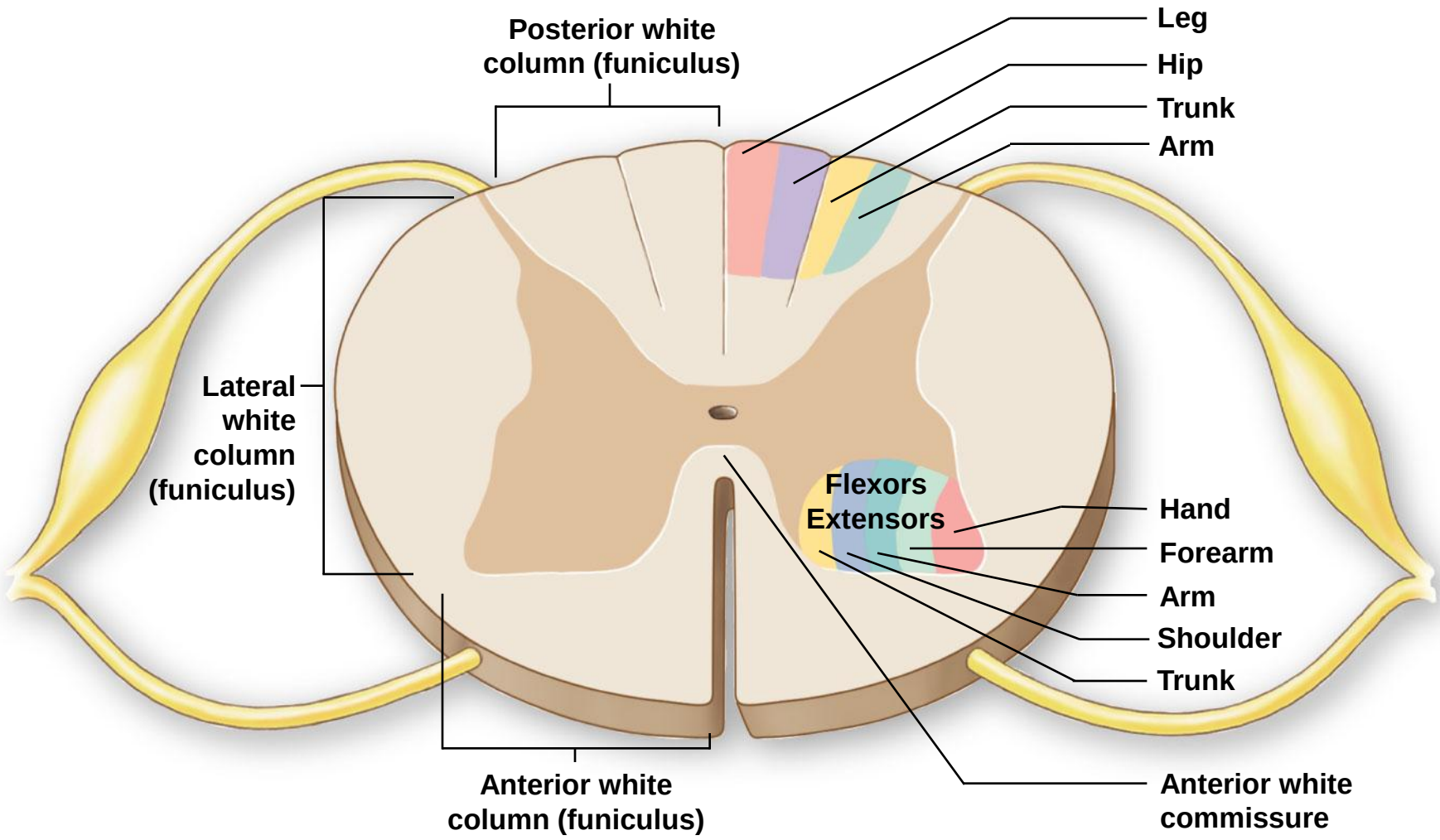


b The left half of this sectional view shows important anatomical landmarks; the right half indicates the functional organization of the gray matter in the anterior, lateral, and posterior gray horns.

Sectional Anatomy of the Spinal Cord

- Organization of white matter
  - Consists of columns of nerves (**fascicles**)
  - Columns convey either:
    - Sensory tracts (ascending tracts)
    - Motor tracts (descending tracts)

Figure 14.4c Sectional Organization of the Spinal Cord

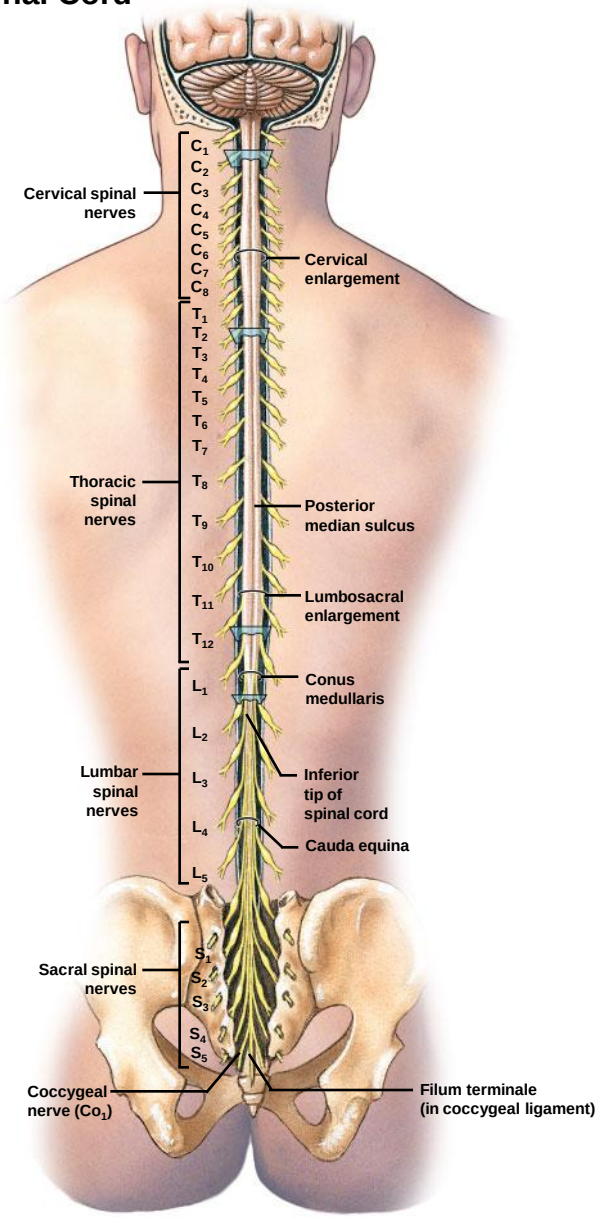


c The left half of this sectional view shows the major columns of white matter. The right half indicates the anatomical organization of sensory tracts in the posterior white column for comparison with the organization of motor nuclei in the anterior gray horn. Note that both sensory and motor components of the spinal cord have a definite regional organization.

Spinal Nerves

- There are 31 pairs of spinal nerves
  - 8 cervical nerves
  - 12 thoracic nerves
  - 5 lumbar nerves
  - 5 sacral nerves
  - 1 coccygeal nerve

Figure 14.1a Gross Anatomy of the Spinal Cord

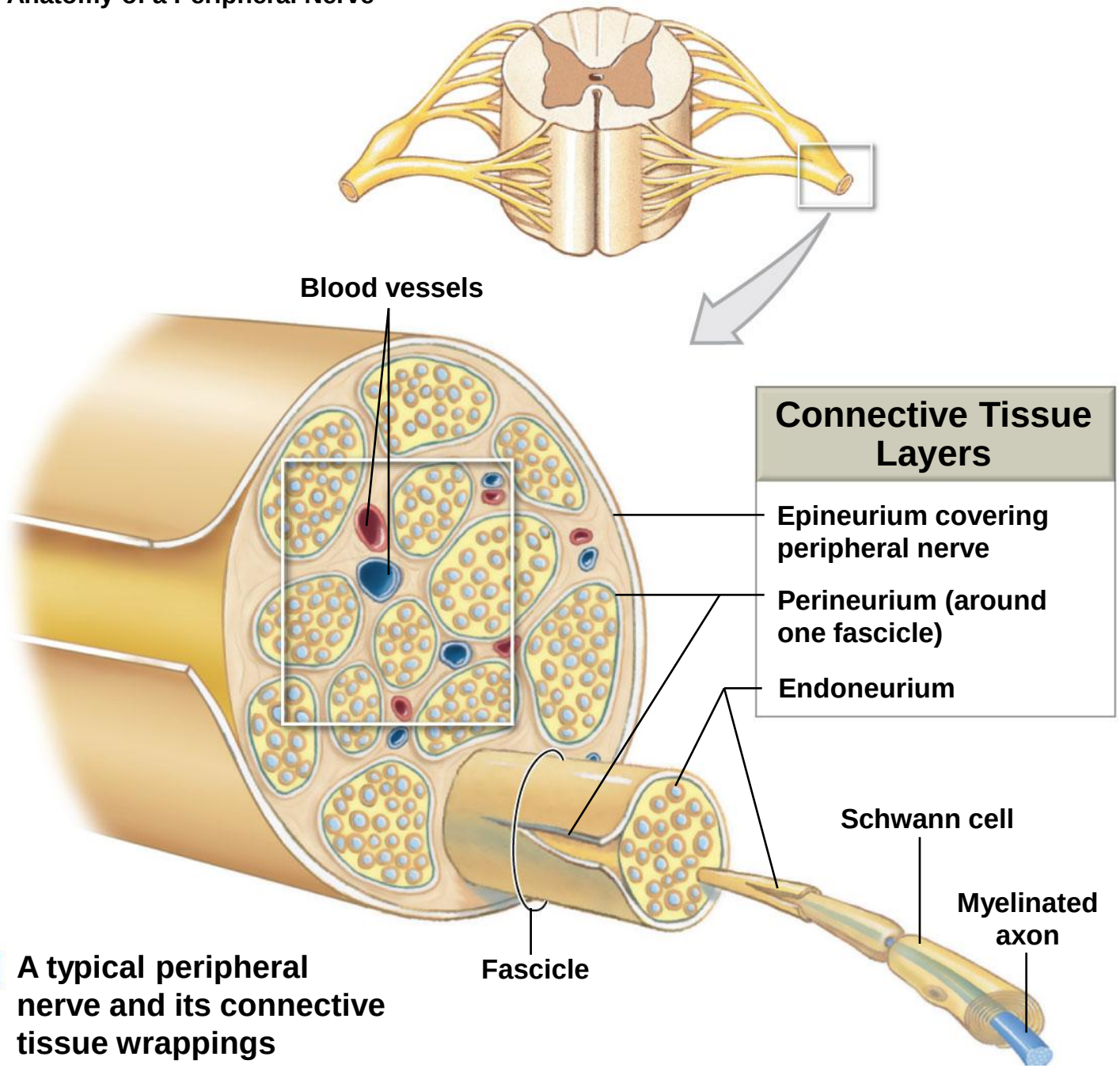


a Superficial anatomy and orientation of the adult spinal cord. The numbers to the left identify the spinal nerves and indicate where the nerve roots leave the vertebral canal. The spinal cord, however, extends from the brain only to the level of vertebrae L_1–L_2.

Spinal Nerves

- Spinal nerves
  - Each peripheral nerve consists of:
    - **Epineurium**: outer layer – becomes continuous with the dura mater
    - **Perineurium**: layer surrounding a fascicle – a **fascicle** is a bundle of axons
    - **Endoneurium**: layer surrounding a single axon

Figure 14.5a Anatomy of a Peripheral Nerve



a A typical peripheral nerve and its connective tissue wrappings

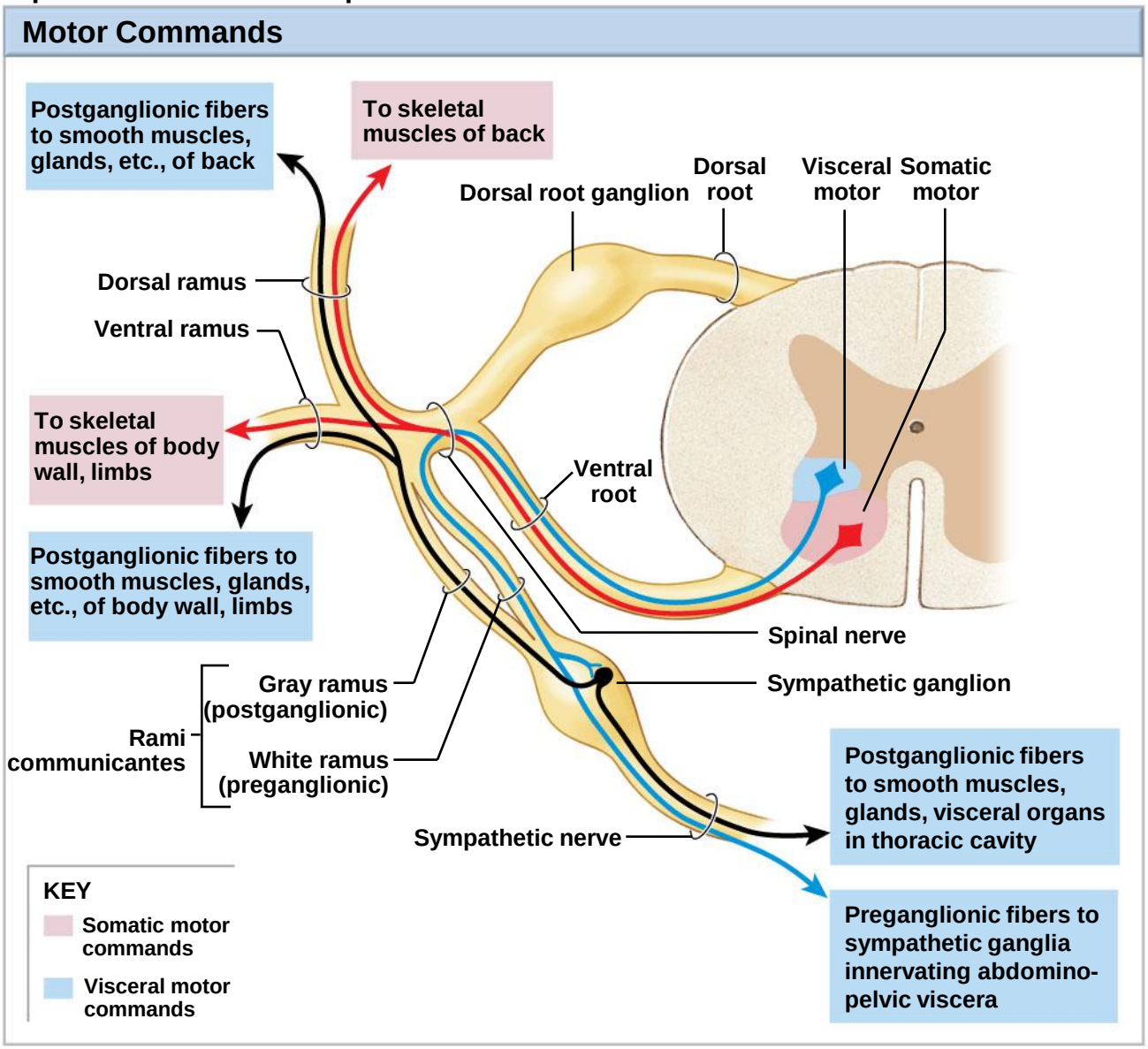
Spinal Nerves

- Peripheral Distribution of Spinal Nerves
  - Four branches of the spinal nerves:
    - **White ramus**
    - **Gray ramus**
      - White and gray ramus are collectively called **rami communicantes**
    - **Dorsal ramus**
    - **Ventral ramus**

Spinal Nerves

- Branches of the spinal nerves (details)
  - **Rami communicantes (white and gray ramus)**
    - Innervates smooth muscles, glands, and organs
    - Motor impulses leave the spinal cord through the ventral root to the spinal nerves
  - **Dorsal ramus**
    - Innervates skeletal muscles of the neck and back
  - **Ventral ramus**
    - Innervates skeletal muscles of the limbs

Figure 14.6a Peripheral Distribution of Spinal Nerves

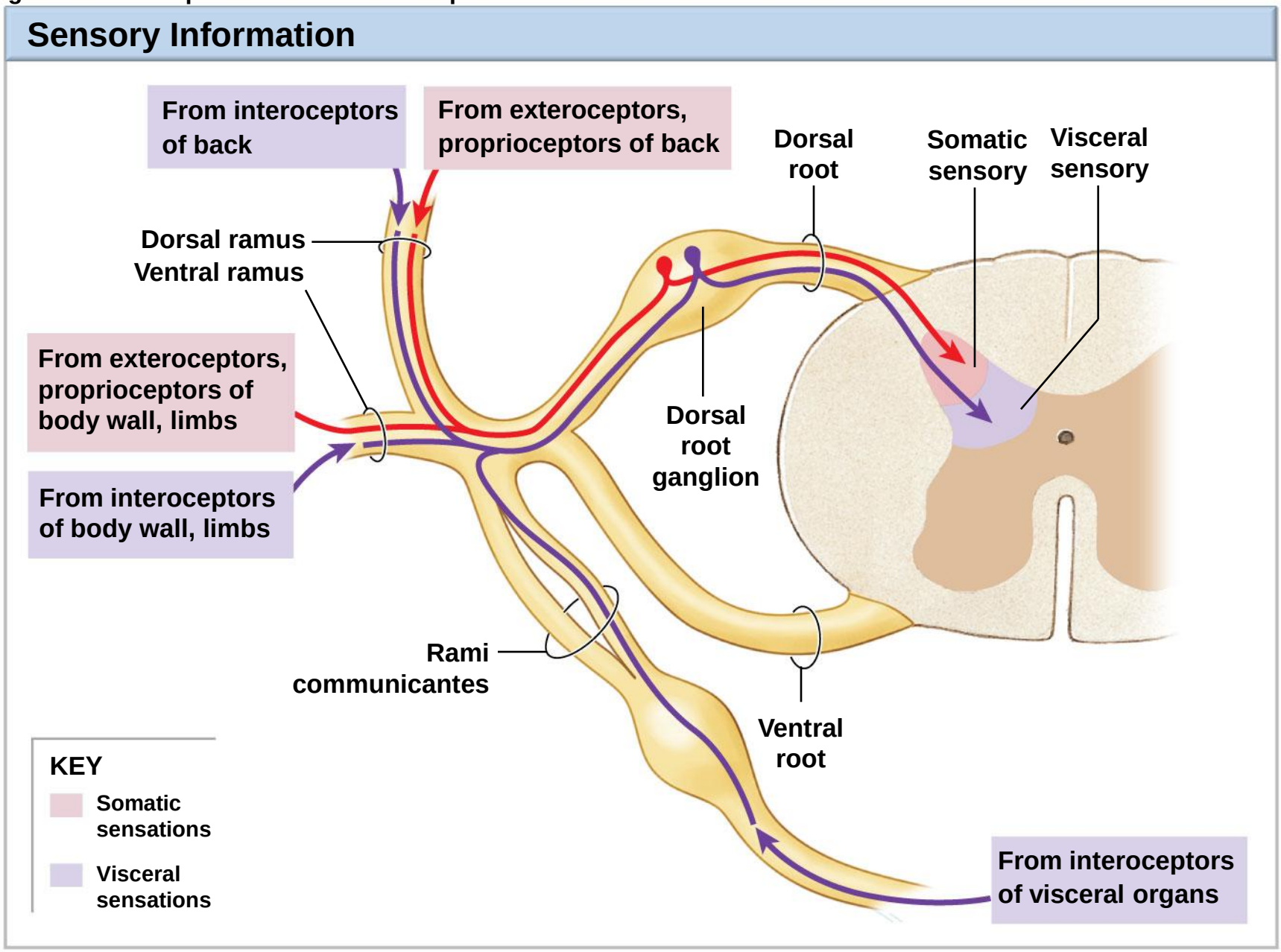


a The distribution of motor neurons in the spinal cord and motor fibers within the spinal nerve and its branches. Although the gray ramus is typically proximal to the white ramus, this simplified diagrammatic view makes it easier to follow the relationships between preganglionic and postganglionic fibers.

Spinal Nerves

- Sensory impulses associated with the spinal nerves
  - Sensory impulses travel in the spinal nerve through the dorsal root to the spinal cord

Figure 14.6b Peripheral Distribution of Spinal Nerves

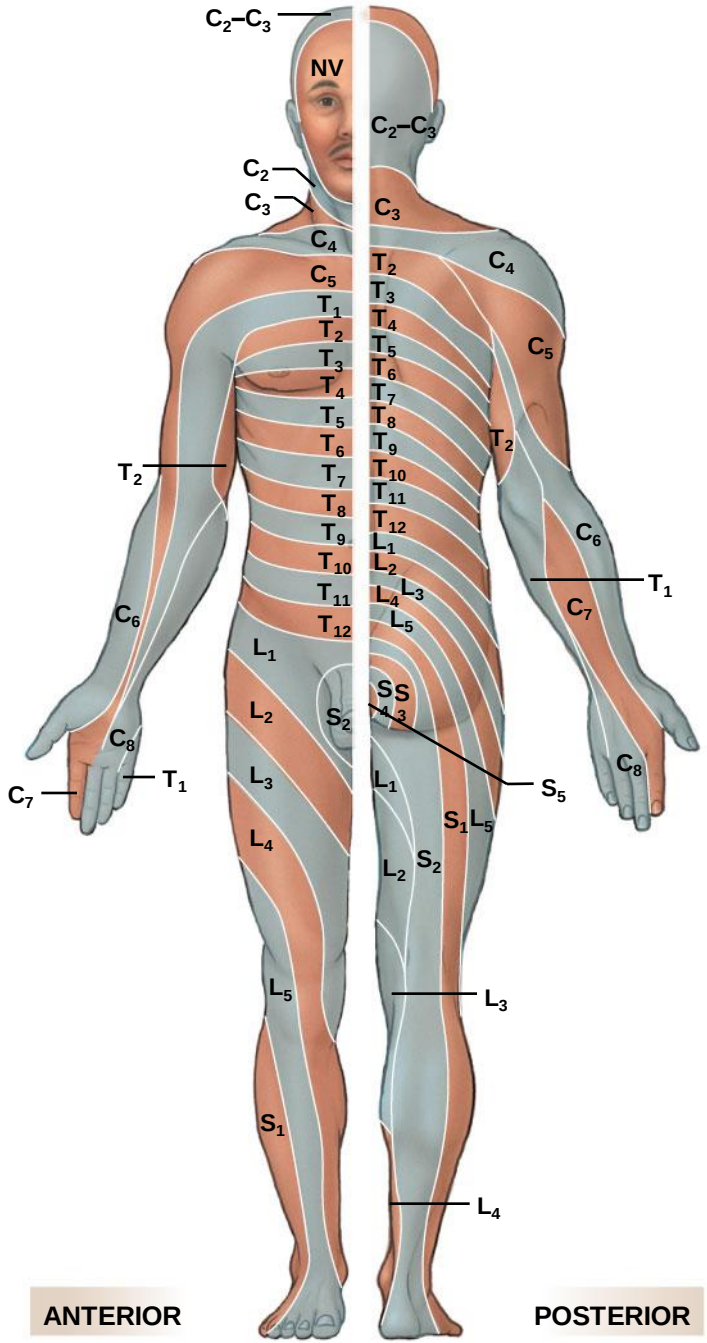


b A comparable view detailing the distribution of sensory neurons and sensory fibers

Spinal Nerves

- Dermatomes
  - Each pair of spinal nerves monitors specific surface areas
  - These are clinically important areas regarding surgery

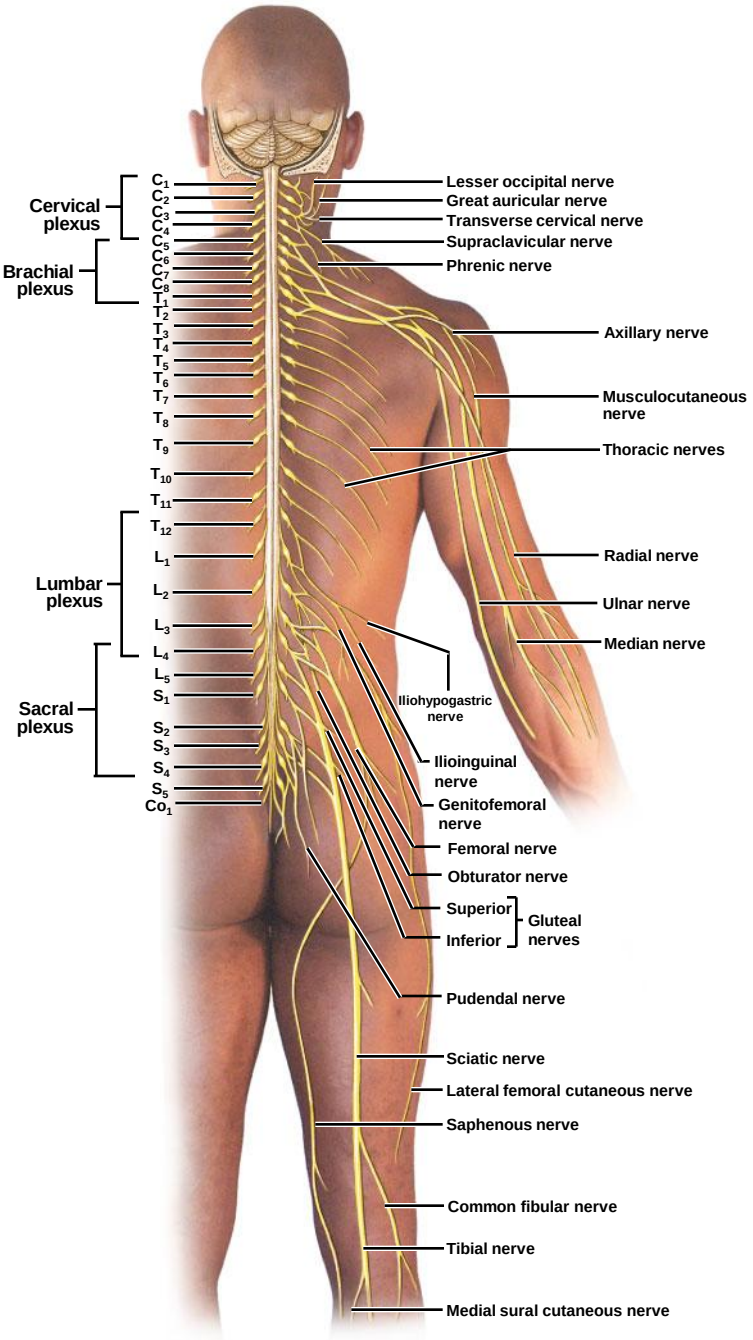
Figure 14.7 Dermatomes



Nerve Plexuses

- There are four nerve plexuses
  - **Cervical plexus**
  - **Brachial plexus**
  - **Lumbar plexus**
  - **Sacral plexus**
    - Sometimes the lumbar and sacral are combined to form the **lumbosacral plexus**

Figure 14.8 Peripheral Nerves and Nerve Plexuses



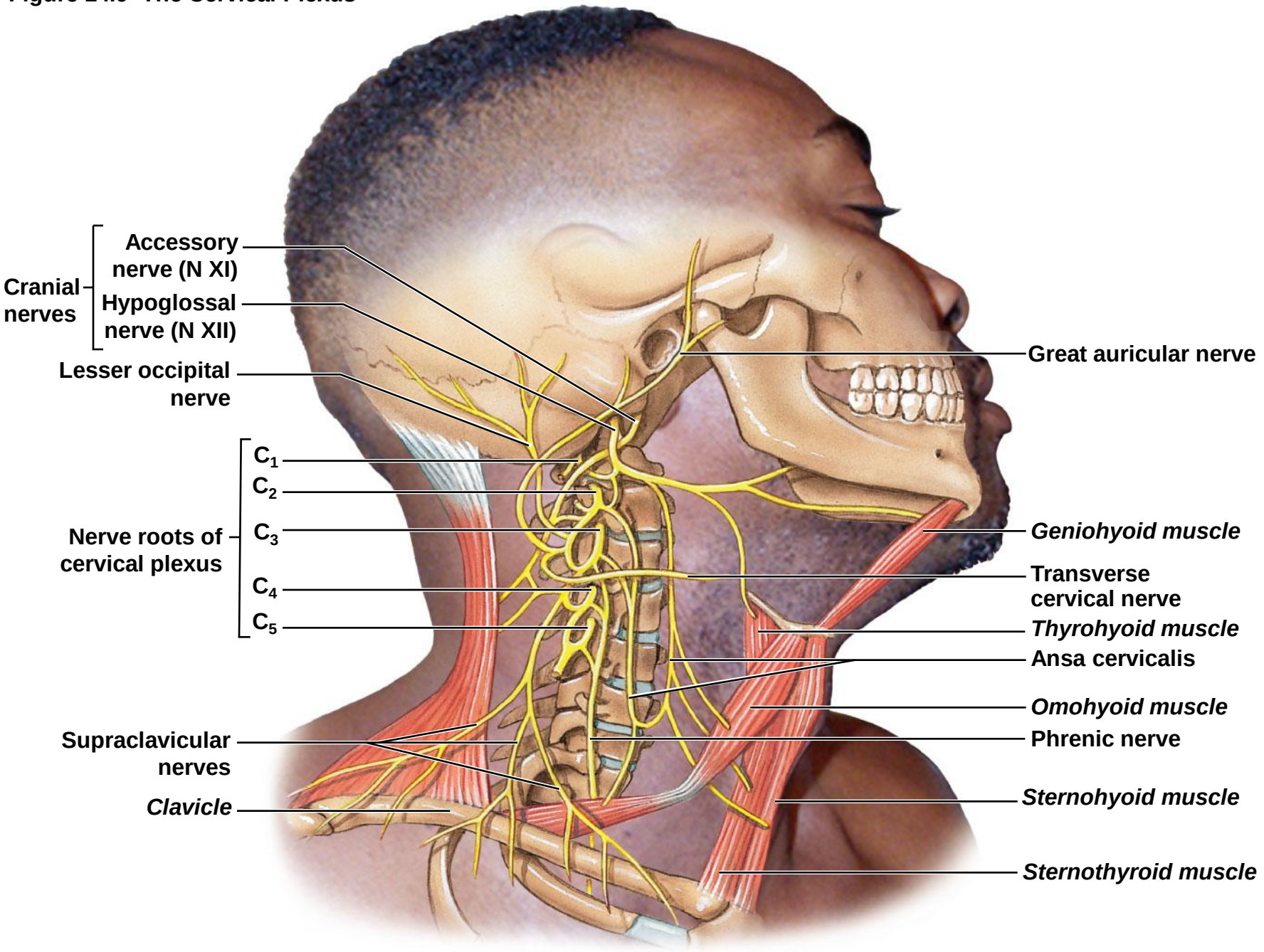
Nerve Plexuses

- The Cervical Plexus (C_1–C_5)
  - Consists of **cutaneous** and **muscular** branches
  - Cutaneous branch innervates:
    - Head
    - Neck
    - Chest

Nerve Plexus

- The Cervical Plexus
  - Consists of **cutaneous** and **muscular** branches
  - Muscular branch innervates:
    - **Omohyoid, sternohyoid, geniohyoid, thyrohyoid**
    - **Sternothyroid**
    - **Scalenes**
    - **Sternocleidomastoid**
    - **Levator scapulae**
    - **Trapezius**
    - **Diaphragm** (controlled by the **phrenic nerve** of the cervical plexus)

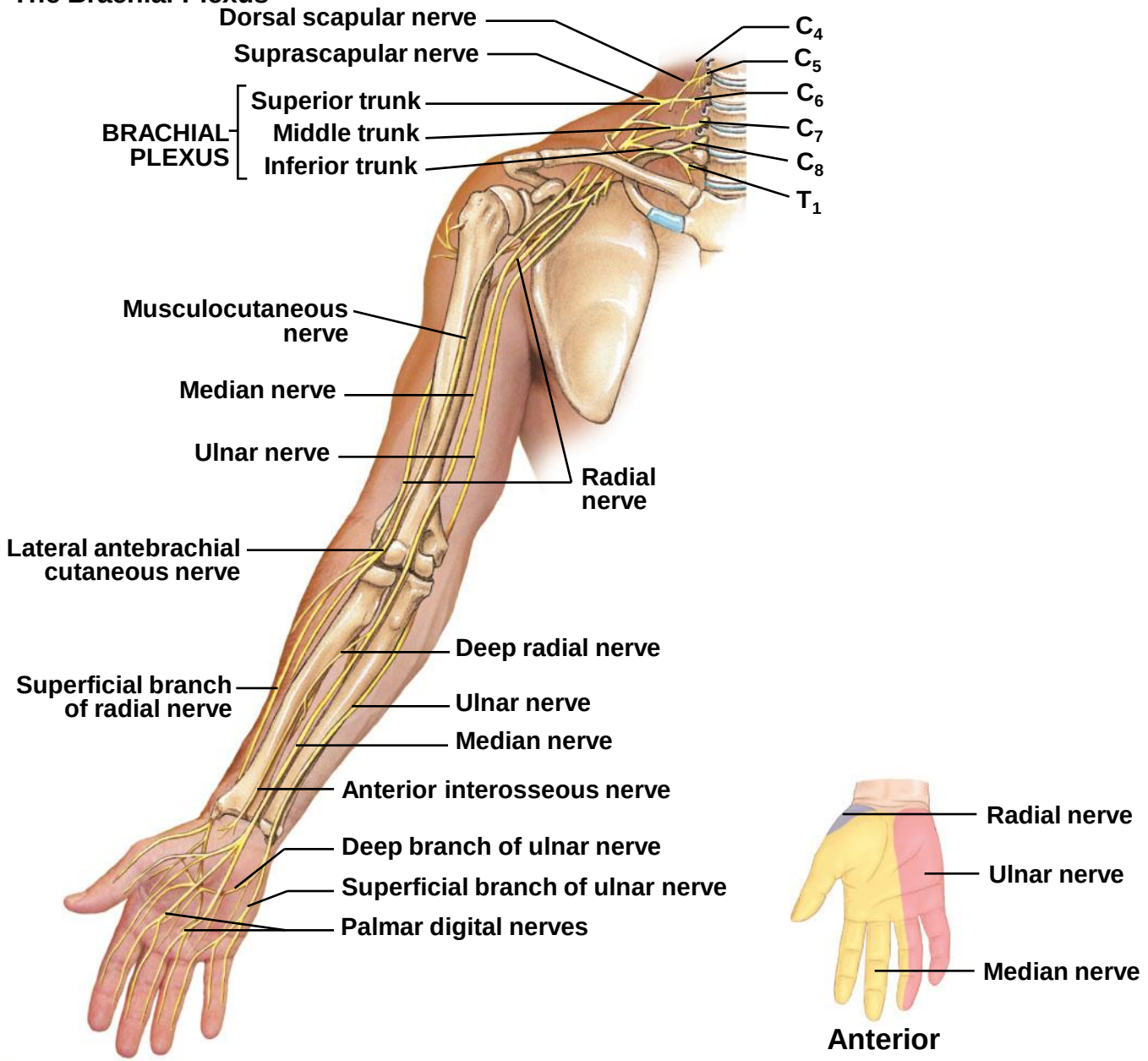
Figure 14.9 The Cervical Plexus



Nerve Plexus

- The Brachial Plexus (C_4–T_1)
  - The immediate nerves emerging from C_5 to T_1 are the:
    - **Superior trunk**
    - **Middle trunk**
    - **Inferior trunk**
  - These trunks all merge to form the lateral cord

Figure 14.10b The Brachial Plexus

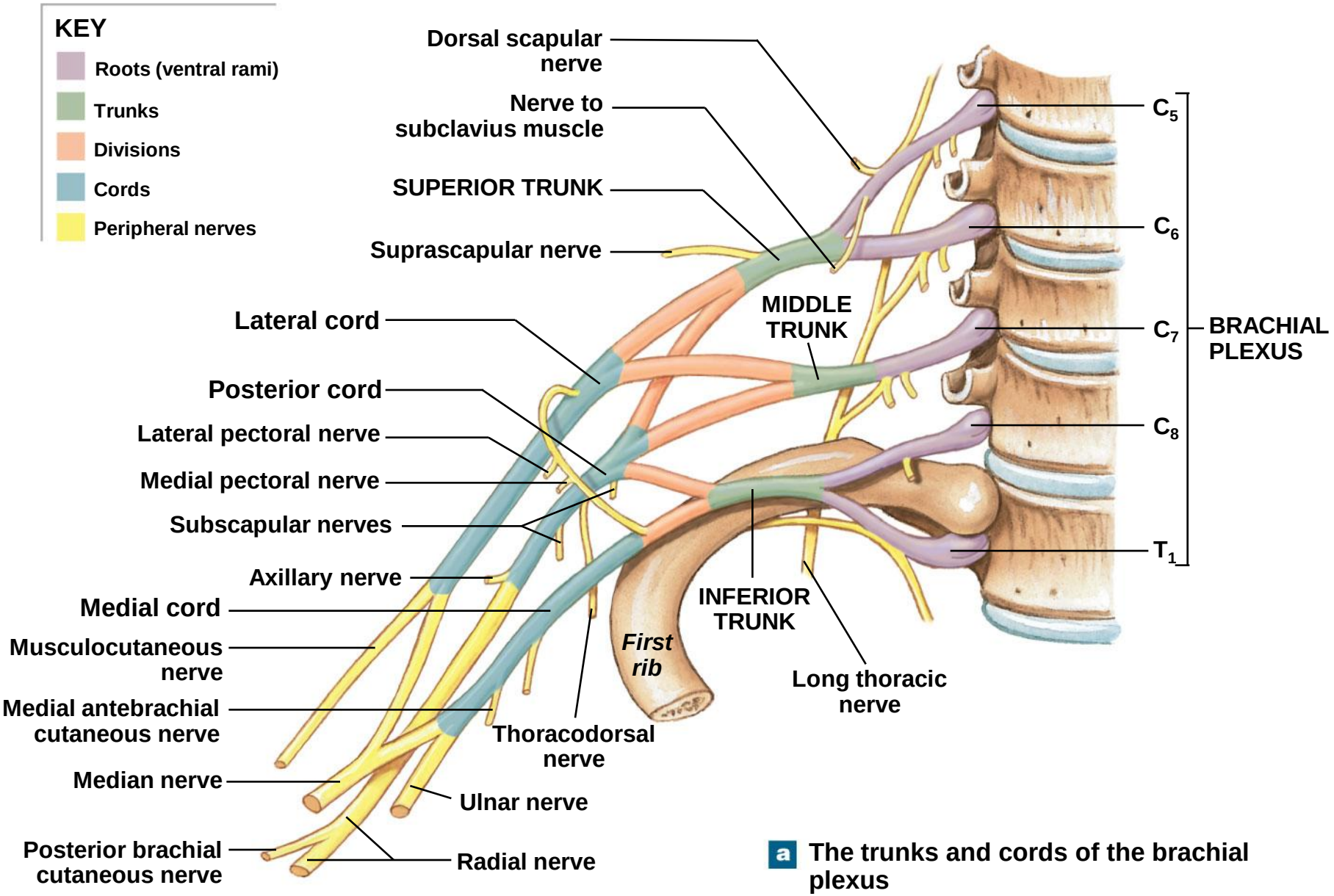


b Anterior view of the brachial plexus and upper limb showing the peripheral distribution of major nerves

Nerve Plexus

- The cords of the brachial plexus
  - **Lateral cord**: merging of the trunks
  - **Medial cord**: an extension of the inferior trunk
  - **Posterior cord**: an extension of the middle trunk

Figure 14.10a The Brachial Plexus

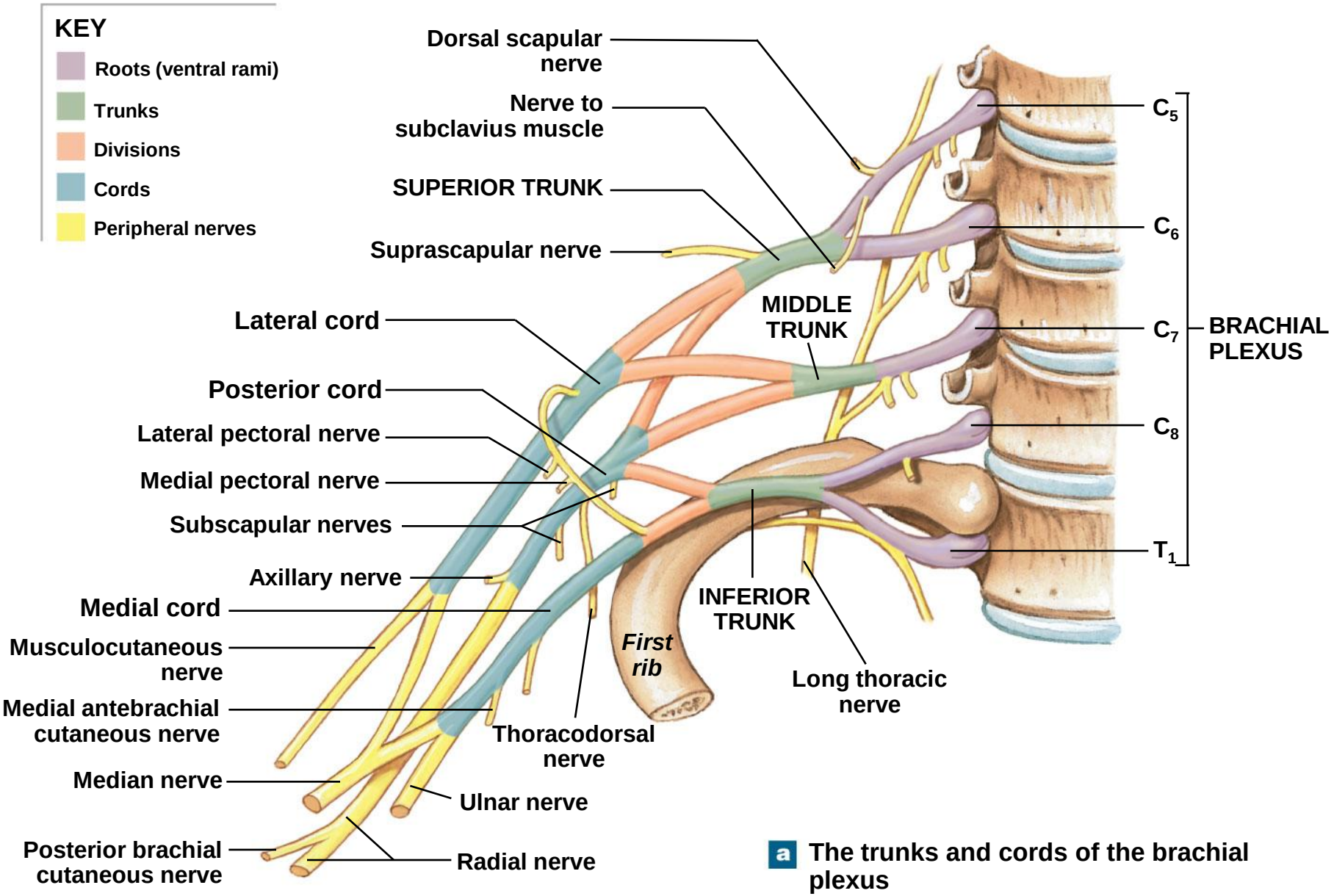


a The trunks and cords of the brachial plexus

Nerve Plexus

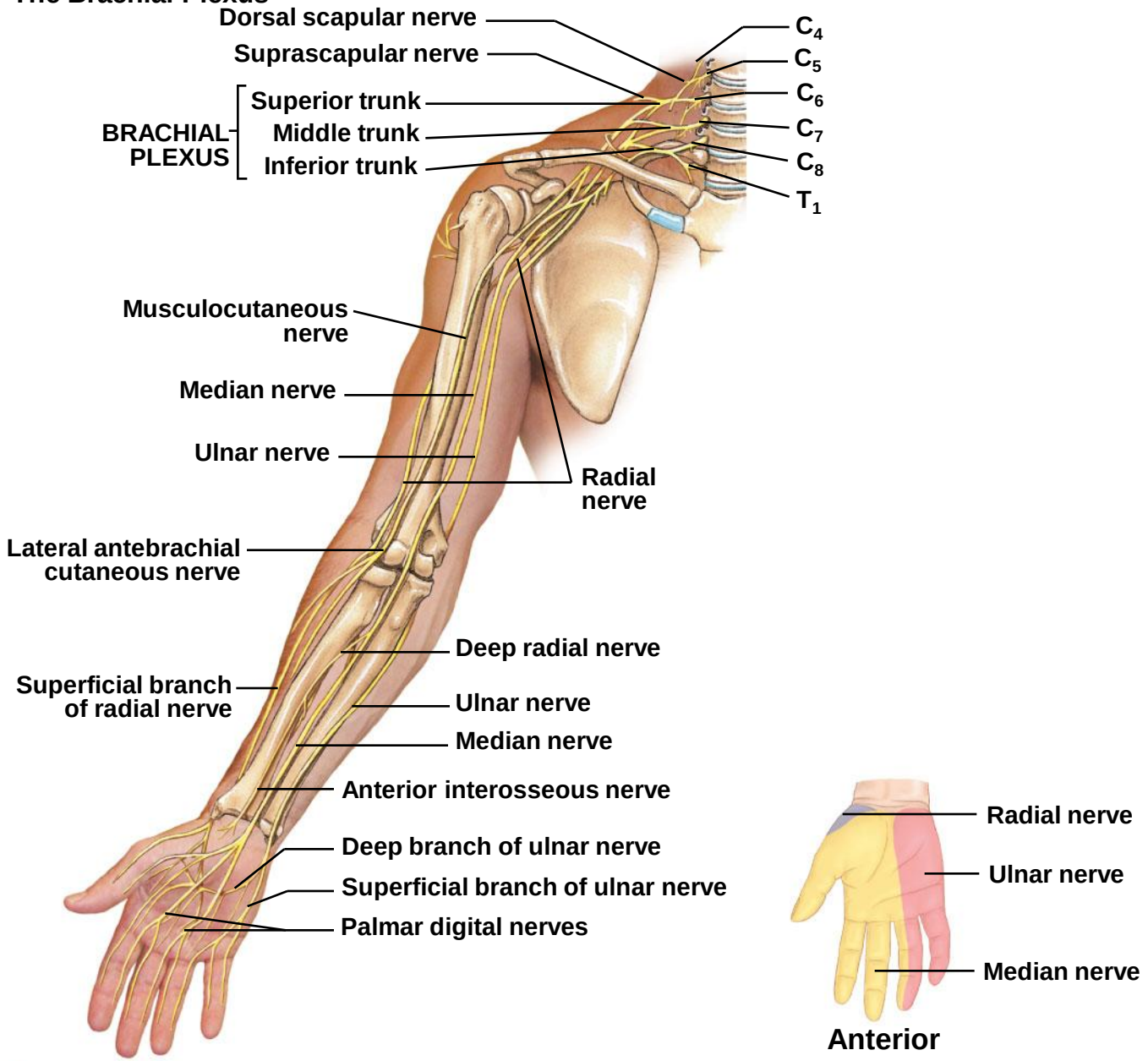
- The cords of the brachial plexus (details)
  - **Lateral cord**: extends to form the **musculocutaneous nerve**
  - The lateral cord and medial cord extend to form the **median nerve**
  - **Medial cord** extends to form the **ulnar nerve**
  - **Posterior cord**: branches to form the **radial nerve** and **axillary nerve**

Figure 14.10a The Brachial Plexus



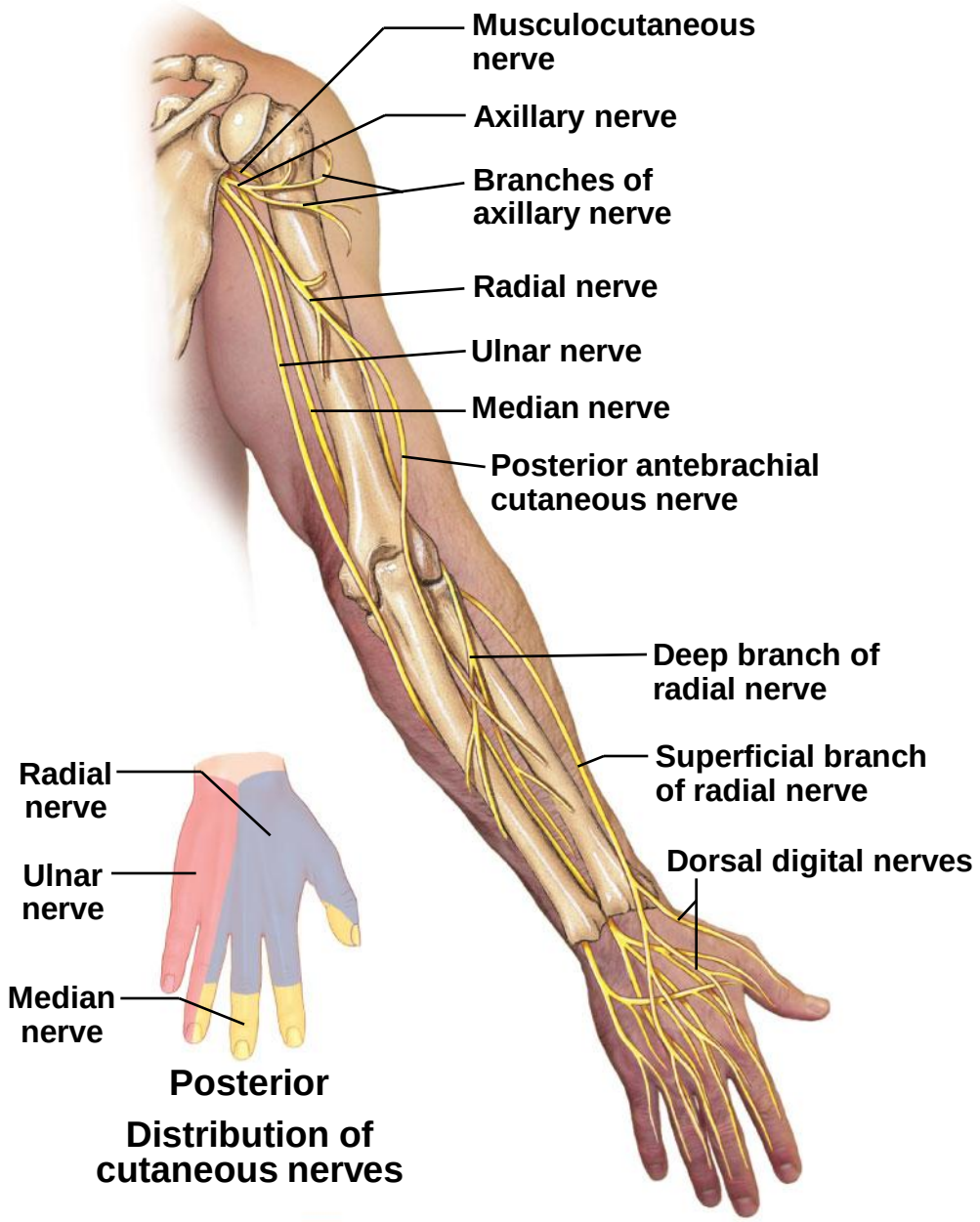
a The trunks and cords of the brachial plexus

Figure 14.10b The Brachial Plexus



b Anterior view of the brachial plexus and upper limb showing the peripheral distribution of major nerves

Figure 14.10c The Brachial Plexus



C Posterior view of the brachial plexus and the innervation of the upper limb

Figure 14.11 The Cervical and Brachial Plexuses

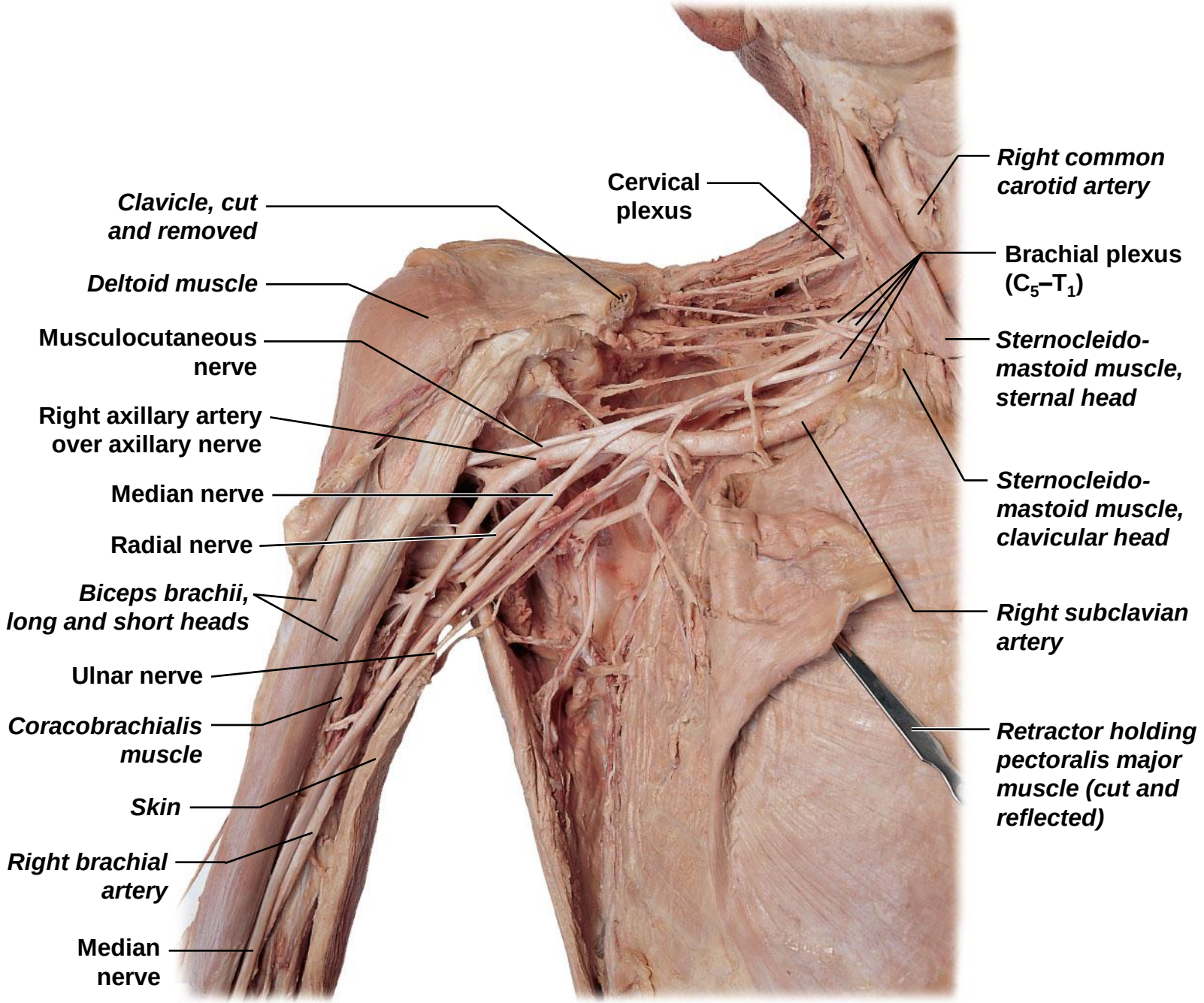


Table 14.2 The Brachial Plexus

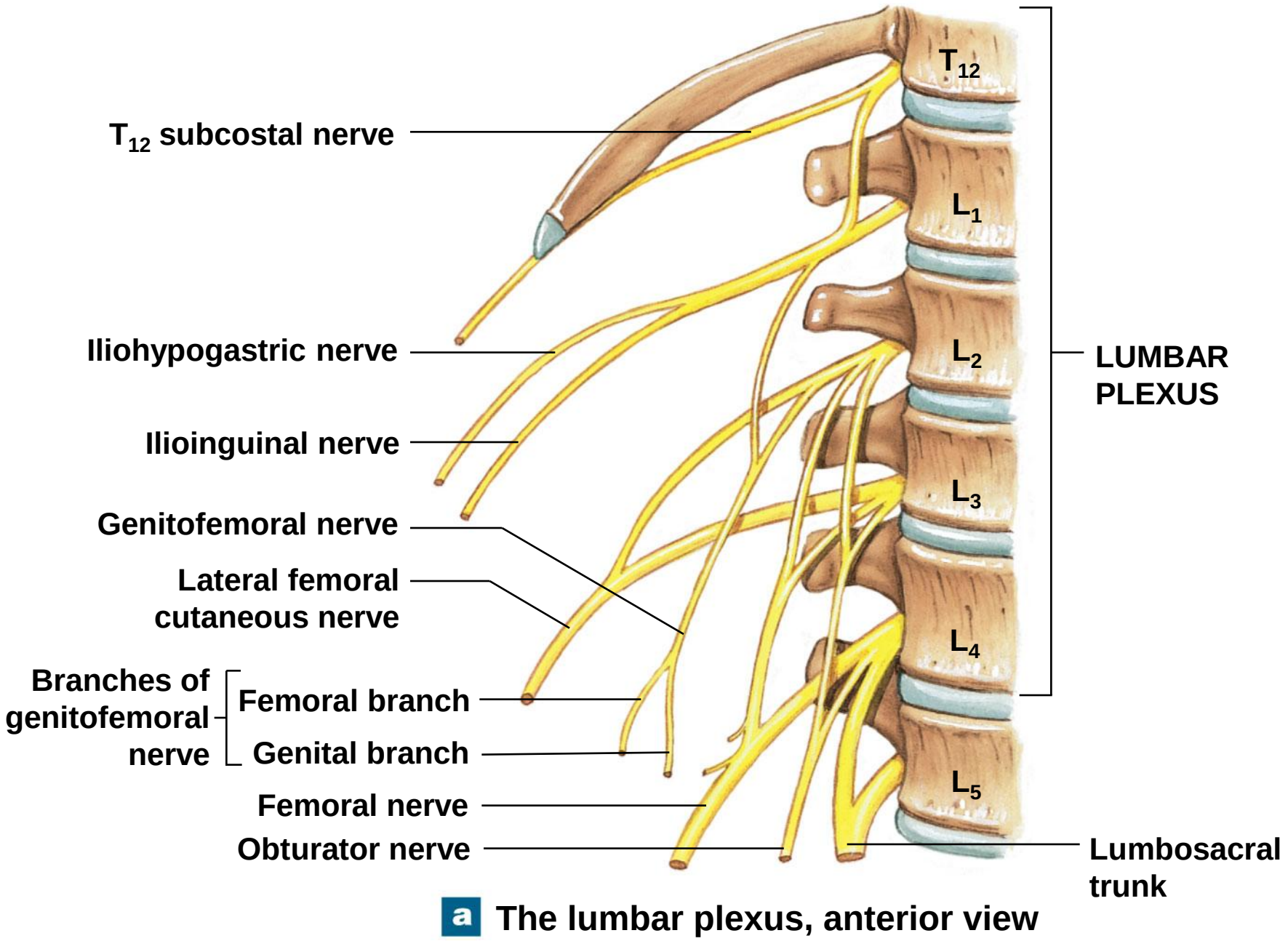
Table 14.2 The Brachial Plexus

Spinal Segments	Nerve(s)	Distribution
C_4–C_6	Nerve to subclavius	Subclavius muscle
C_5	Dorsal scapular nerve	Rhomboid and levator scapulae muscles
C_5–C_7	Long thoracic nerve	Serratus anterior muscle
C_5, C_6	Suprascapular nerve	Supraspinatus and infraspinatus muscles; sensory from shoulder joint and scapula
C_5–T_1	Pectoral nerves (medial and lateral)	Pectoralis muscles
C_5, C_6	Subscapular nerves	Subscapularis and teres major muscles
C_6–C_8	Thoracodorsal nerve	Latissimus dorsi muscle
C_5, C_6	Axillary nerve	Deltoid and teres minor muscles; sensory from skin of shoulder
C_8, T_1	Medial antebrachial cutaneous nerve	Sensory from skin over anterior, medial surface of arm and forearm
C_5–T_1	Radial nerve	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 portion of hand)
C_5–C_7	Musculocutaneous nerve	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*
C_6–T_1	Median nerve	Flexor muscles on the forearm (flexor carpi radialis and palmaris longus muscles); pronator quadratus and pronator teres muscles; radial half of flexor digitorum profundus muscle, digital flexors (through the *anterior interosseous nerve*); sensory from skin over anterolateral surface of the hand
C_8, T_1	Ulnar nerve	Flexor carpi ulnaris muscle, ulnar half of flexor digitorum profundus muscle, adductor pollicis muscle, and small digital muscles through the *deep branch*; sensory from skin over medial surface of the hand through the *superficial branch*

Nerve Plexus

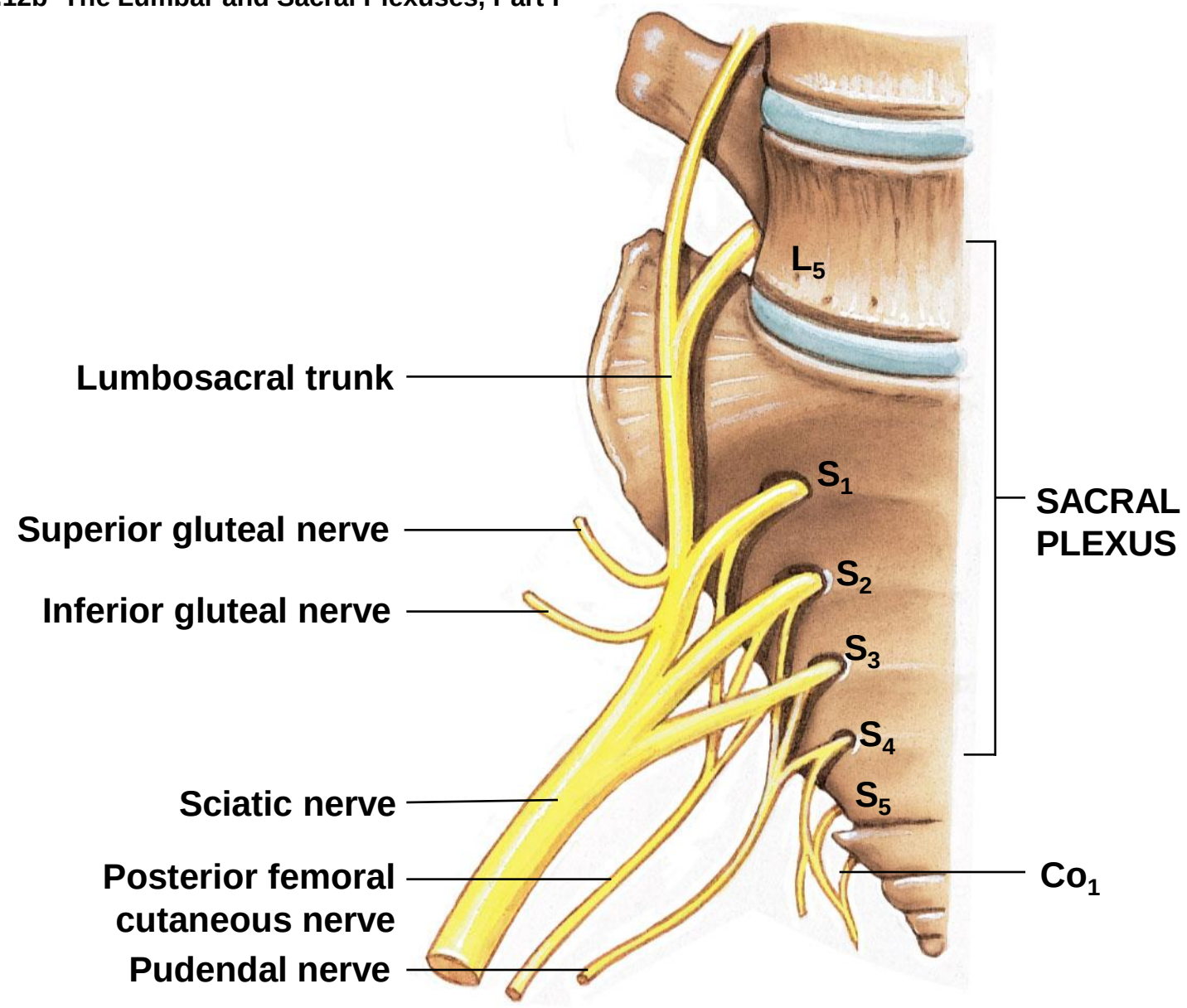
- The Lumbar and Sacral Plexuses (T_{12}–S_4)
  - Also called the **lumbosacral plexus**
  - Lumbar plexus nerves
    - **Genitofemoral nerve**
    - **Lateral femoral cutaneous nerve**
    - **Femoral nerve**
  - Sacral plexus nerves
    - **Sciatic nerve** (branches to form the **common fibular** nerve and the **tibial nerve**)
    - **Pudendal nerve**

Figure 14.12a The Lumbar and Sacral Plexuses, Part I



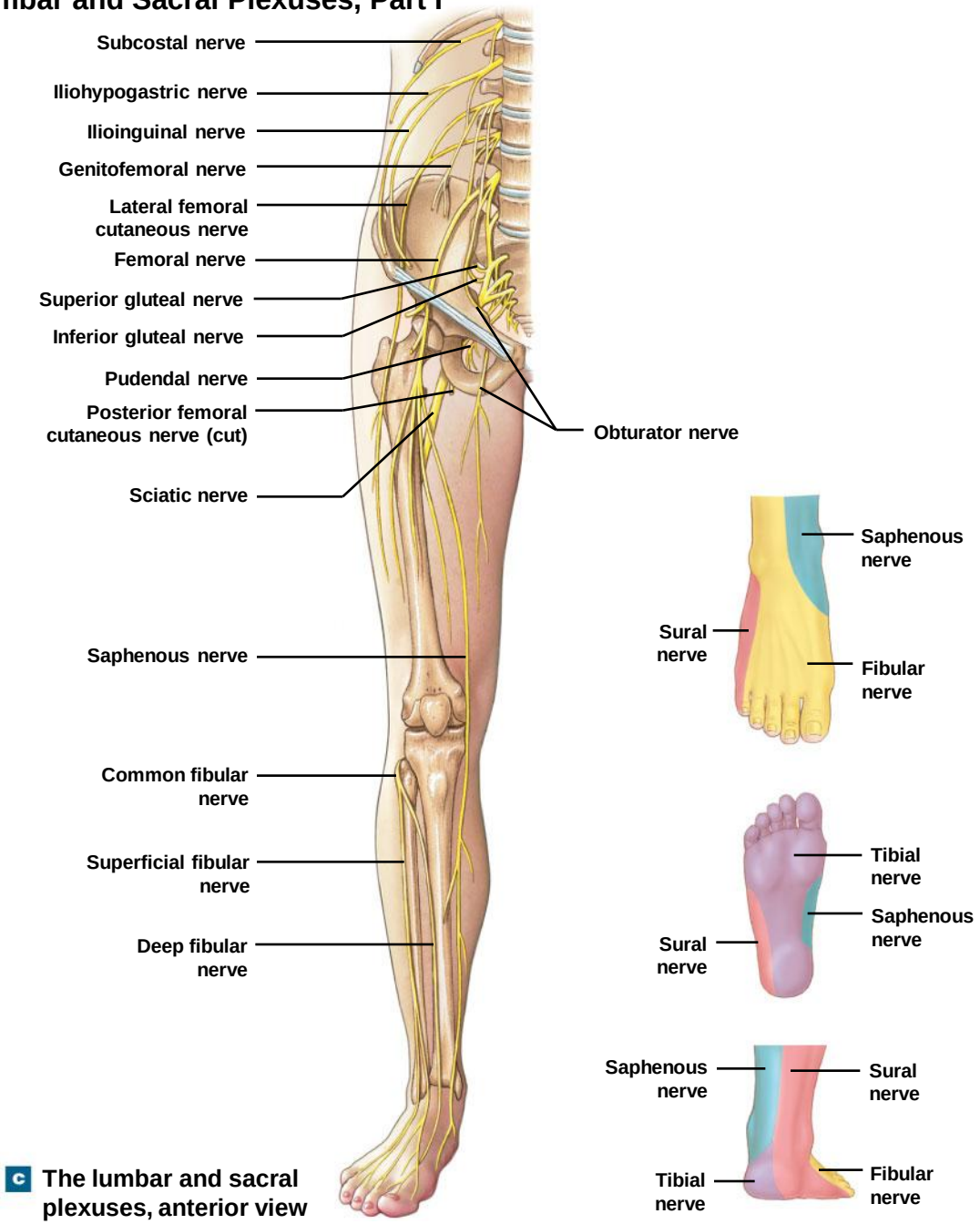
a The lumbar plexus, anterior view

Figure 14.12b The Lumbar and Sacral Plexuses, Part I



b The sacral plexus, anterior view

Figure 14.12c The Lumbar and Sacral Plexuses, Part I



c The lumbar and sacral plexuses, anterior view

Table 14.3 The Lumbar and Sacral Plexuses

Table 14.3 The Lumbar and Sacral Plexuses

Spinal Segment(s)	Nerve(s)	Distribution
LUMBAR PLEXUS		
T_{12}–L_1	Iliohypogastric nerve	Abdominal muscles (external and internal oblique muscles, transverse abdominis muscles); skin over inferior abdomen and buttocks
L_1	Ilioinguinal nerve	Abdominal muscles (with *iliohypogastric nerve*); skin over superior, medial thigh and portions of external genitalia
L_1, L_2	Genitofemoral nerve	Skin over anteromedial surface of thigh and portions of external genitalia
L_2, L_3	Lateral femoral cutaneous nerve	Skin over anterior, lateral, and posterior surfaces of thigh
L_2–L_4	Femoral nerve	Anterior muscles of thigh (sartorius muscle and quadriceps group); adductors of hip (pectineus and iliopsoas muscles); skin over anteromedial surface of thigh, medial surface of leg and foot
L_2–L_4	Obturator nerve	Adductors of hip (adductors magnus, brevis, and longus); gracilis muscle; skin over medial surface of thigh
L_2–L_4	Saphenous nerve	Skin over medial surface of leg
SACRAL PLEXUS		
L_4–S_2	Gluteal nerves:	
	Superior	Abductors of hip (gluteus minimus, gluteus medius, and tensor fasciae latae)
	Inferior	Extensor of hip (gluteus maximus)
S_1–S_3	Posterior femoral cutaneous nerve	Skin of perineum and posterior surface of thigh and leg
L_4–S_3	Sciatic nerve:	Two of the hamstrings (semimembranosus and semitendinosus); adductor magnus (with *obturator nerve*)
	Tibial nerve	Flexors of knee and extensors (plantar flexors) of ankle (popliteus, gastrocnemius, soleus, and tibialis posterior muscles and long head of the biceps femoris muscle); flexors of toes; skin over posterior surface of leg; plantar surface of foot
	Fibular nerve	Short head of biceps femoris muscle; fibularis (brevis and longus) and tibialis anterior muscles; extensors of toes; skin over anterior surface of leg and dorsal surface of foot; skin over lateral portion of foot (through the *sural nerve*)
S_2–S_4	Pudendal nerve	Muscles of perineum, including urogenital diaphragm and external anal and urethral sphincter muscles; skin of external genitalia and related skeletal muscles (bulbospongiosus and ischiocavernosus muscles)

Figure 14.12d The Lumbar and Sacral Plexuses, Part I

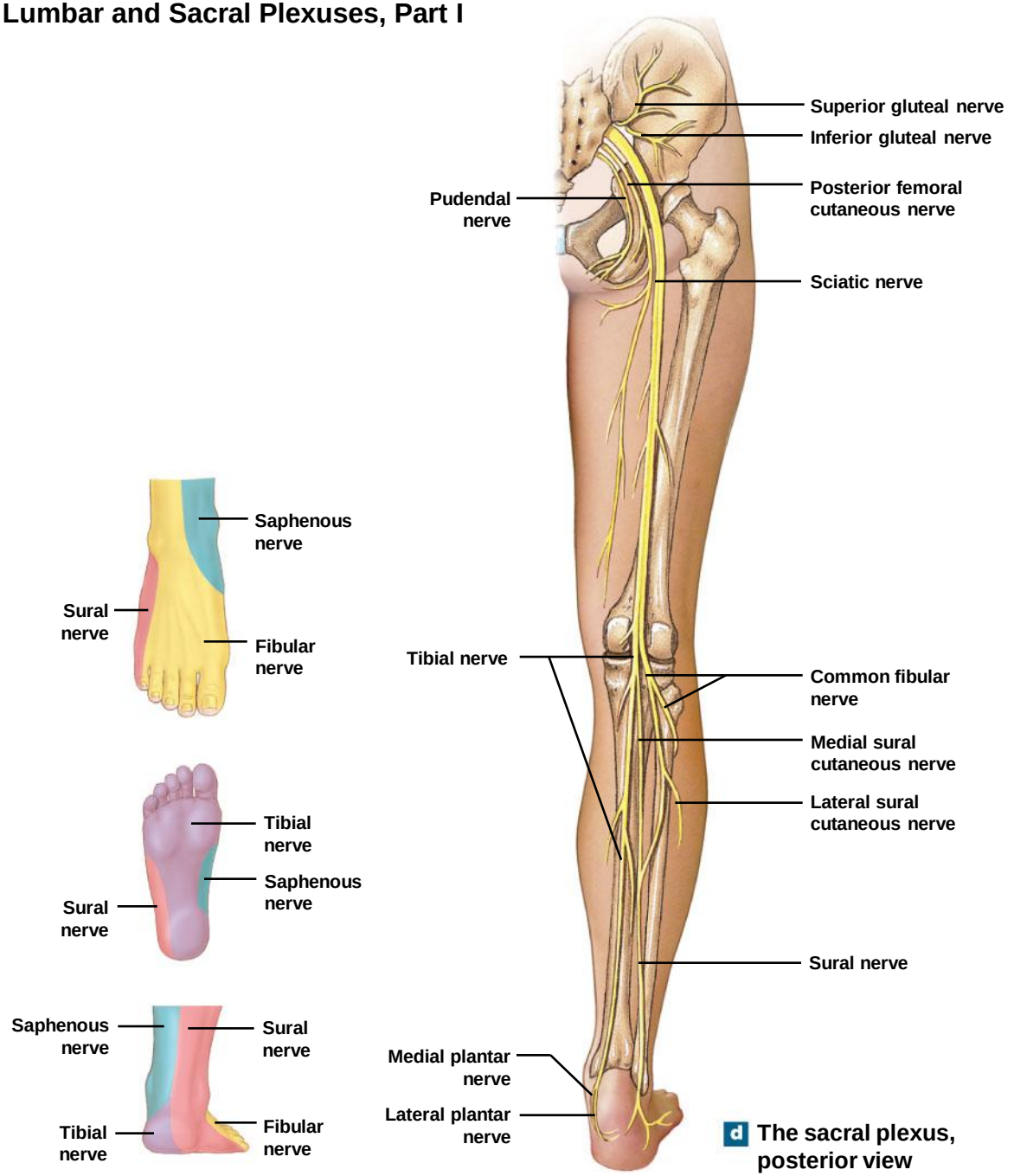
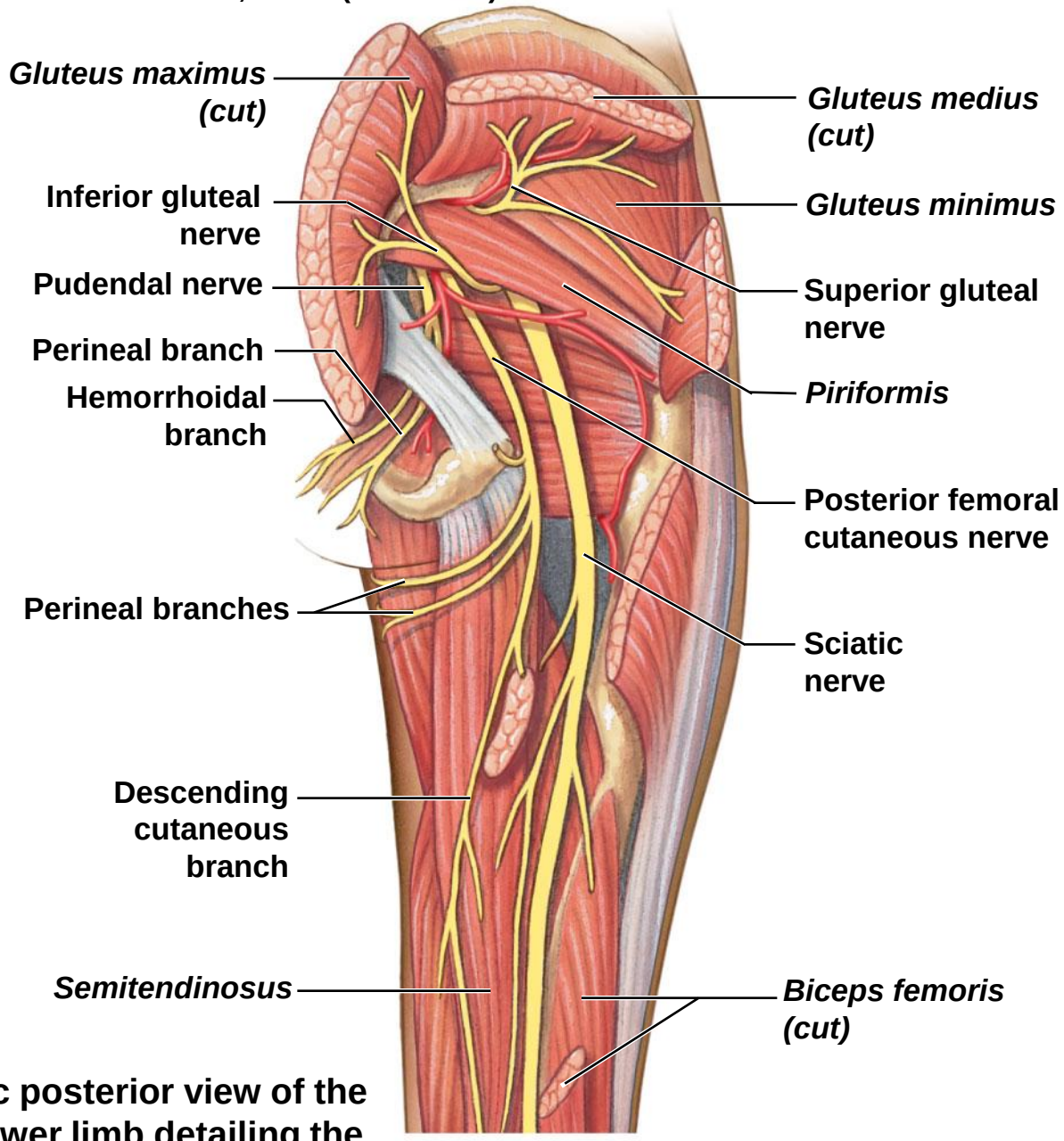
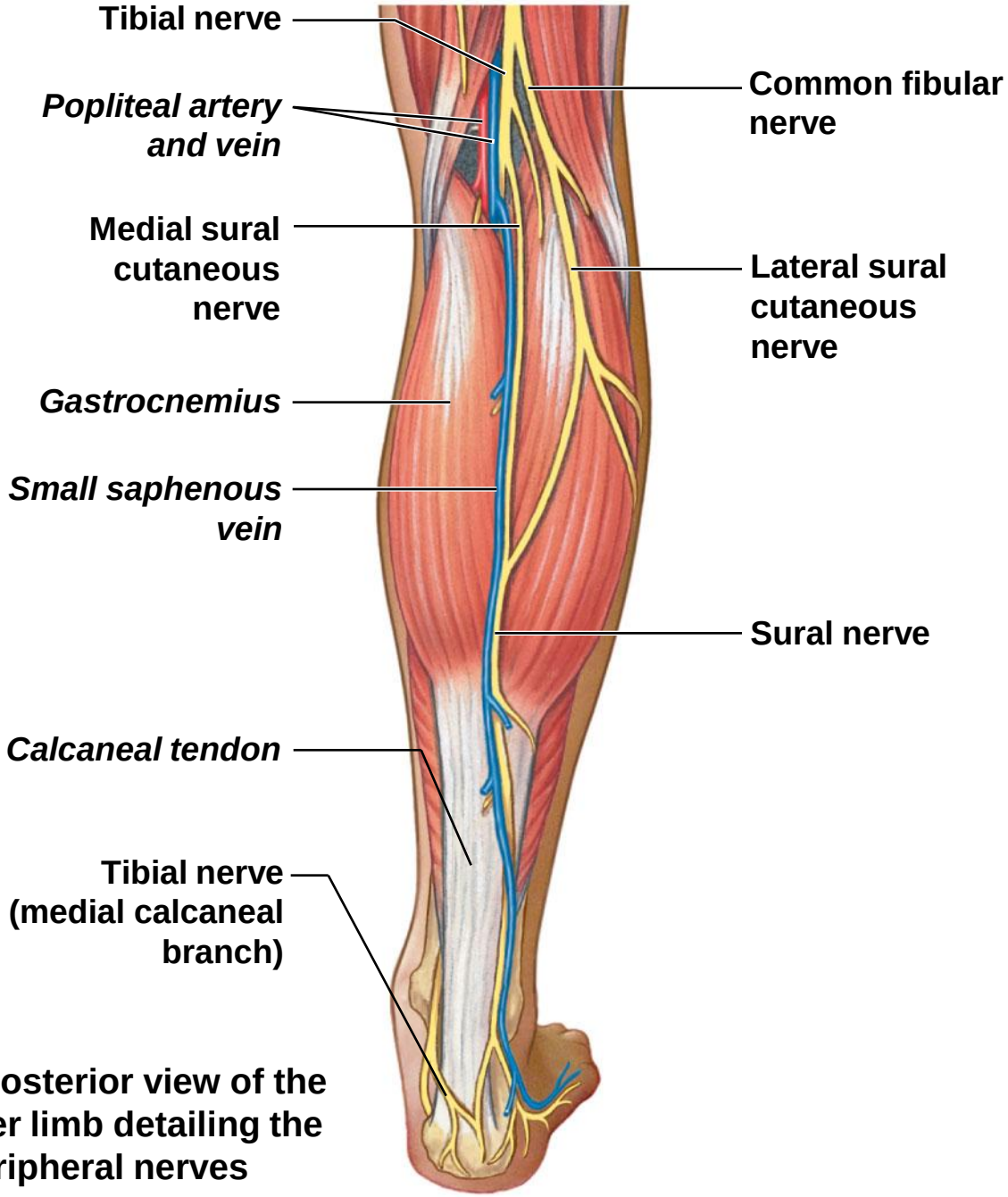


Figure 14.13c The Lumbar and Sacral Plexuses, Part II (Part 1 of 2)



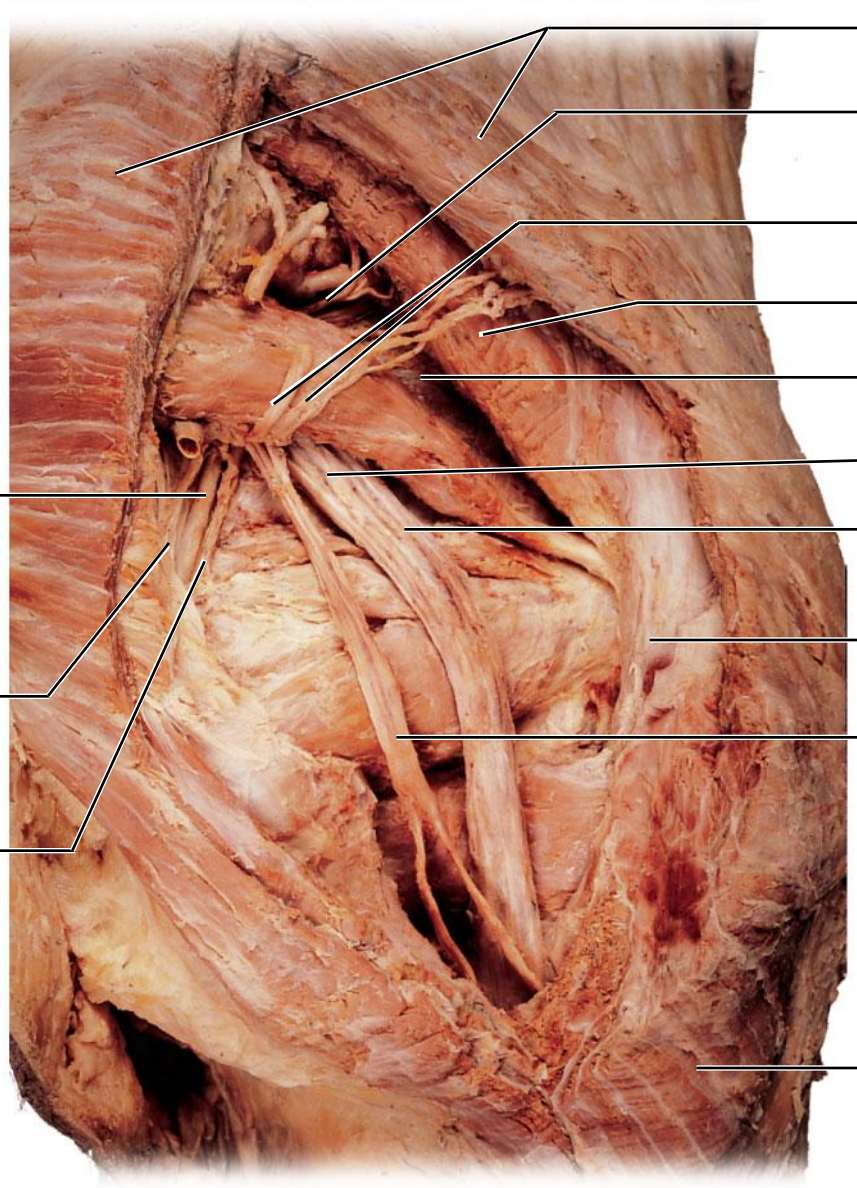
c **A diagrammatic posterior view of the right hip and lower limb detailing the distribution of peripheral nerves**

Figure 14.13c The Lumbar and Sacral Plexuses, Part II (Part 2 of 2)



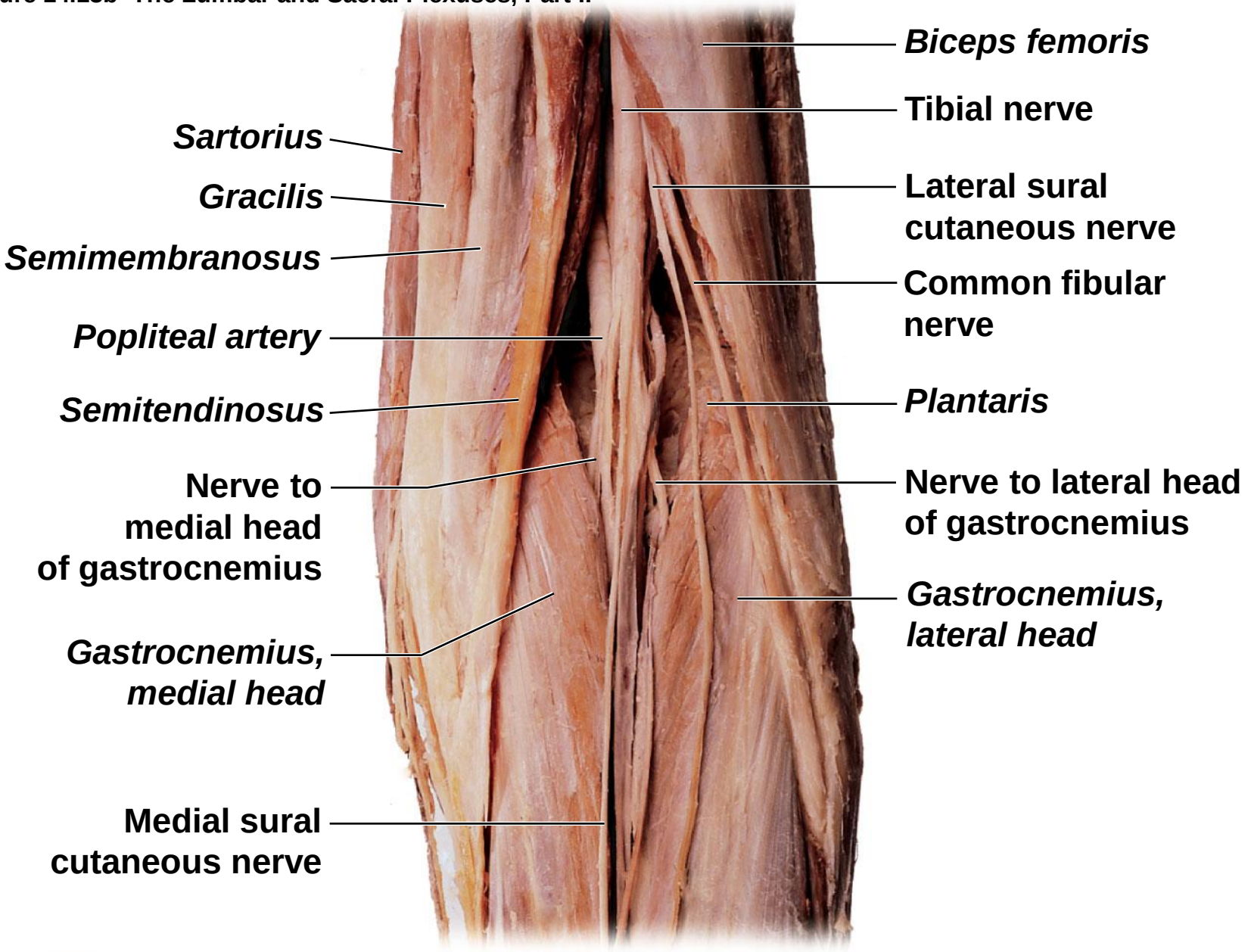
C A diagrammatic posterior view of the right hip and lower limb detailing the distribution of peripheral nerves

Figure 14.13a The Lumbar and Sacral Plexuses, Part II



a A dissection of the right gluteal region

Figure 14.13b The Lumbar and Sacral Plexuses, Part II



b A dissection of the popliteal fossa

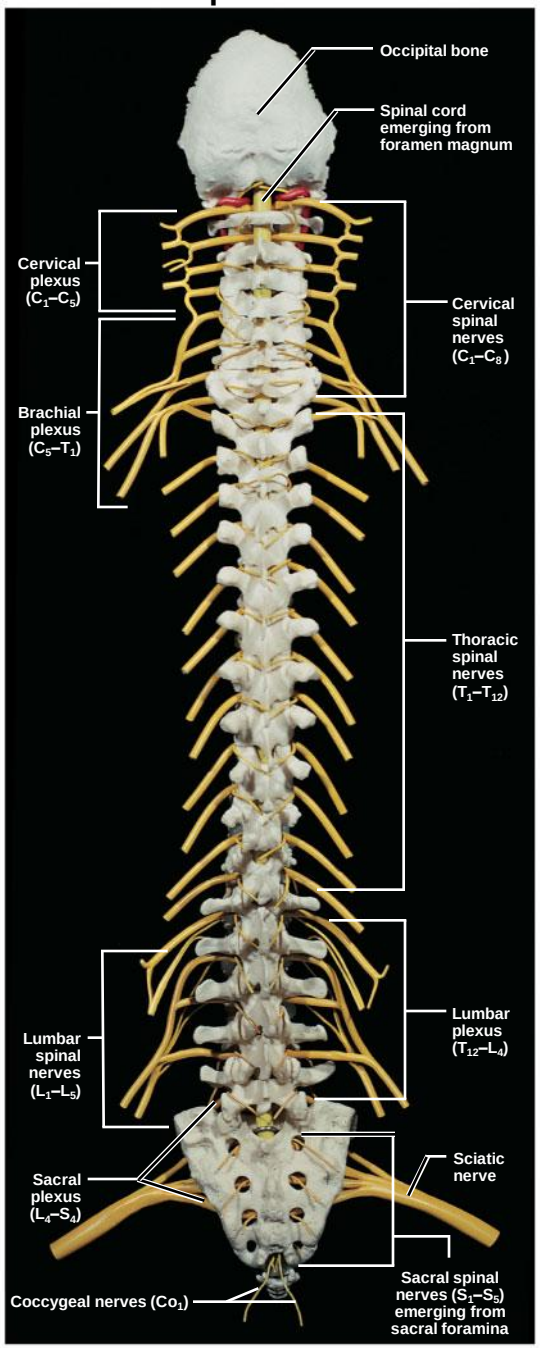
Nerve Plexus

- Summary of the spinal nerves
  - **Cervical spinal nerves** emerge from C_1–C_8
  - **Thoracic spinal nerves** emerge from T_1–T_{12}
  - **Lumbar spinal nerves** emerge from L_1–L_5
  - **Sacral spinal nerves** emerge from S_1–S_5
  - **Coccygeal spinal nerves** emerge from Co_1

Nerve Plexus

- Summary of the nerve plexuses
  - **Cervical plexus** nerves emerge from C_1–C_5
  - **Brachial plexus** nerves emerge from C_5–T_1
  - There is not a thoracic plexus
  - **Lumbar plexus** nerves emerge from T_{12}–L_4
  - **Sacral plexus** nerves emerge from L_4–S_4
  - There is not a coccygeal plexus

Figure 14.3 Posterior View of Vertebral Column and Spinal Nerves



Reflexes

- Reflex
  - An immediate involuntary response
- Reflex arc
  - The neural “wiring” of a single reflex
  - Begins at a sensory receptor and ends at a peripheral receptor

Reflexes

- Reflexes are classified according to:
  - Their development
    - Innate or acquired
  - The site where information is processed
    - Spinal or cranial (cerebral)
  - The nature of the resulting motor response
    - Somatic, visceral, or autonomic
  - The complexity of the neural circuit
    - Monosynaptic or polysynaptic

Reflexes

- Pathway of a reflex arc
  - 1. Activation of a sensory receptor
  - 2. Relay of information to the CNS
  - 3. Information processing
  - 4. Activation of a motor neuron
  - 5. Response by the effector

PLAY ANIMATION Components of a Reflex Arc

Figure 14.14 A Reflex Arc

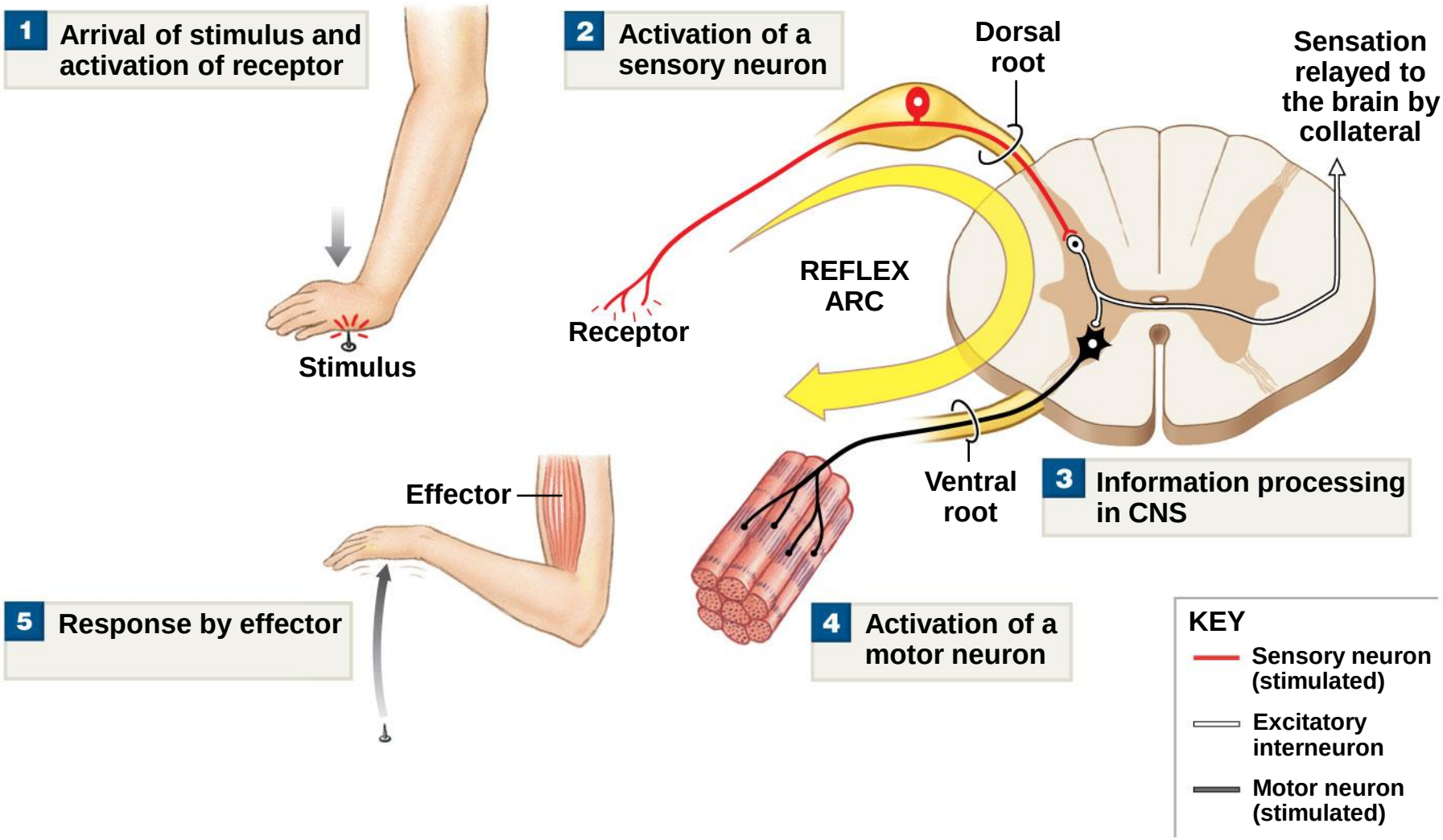
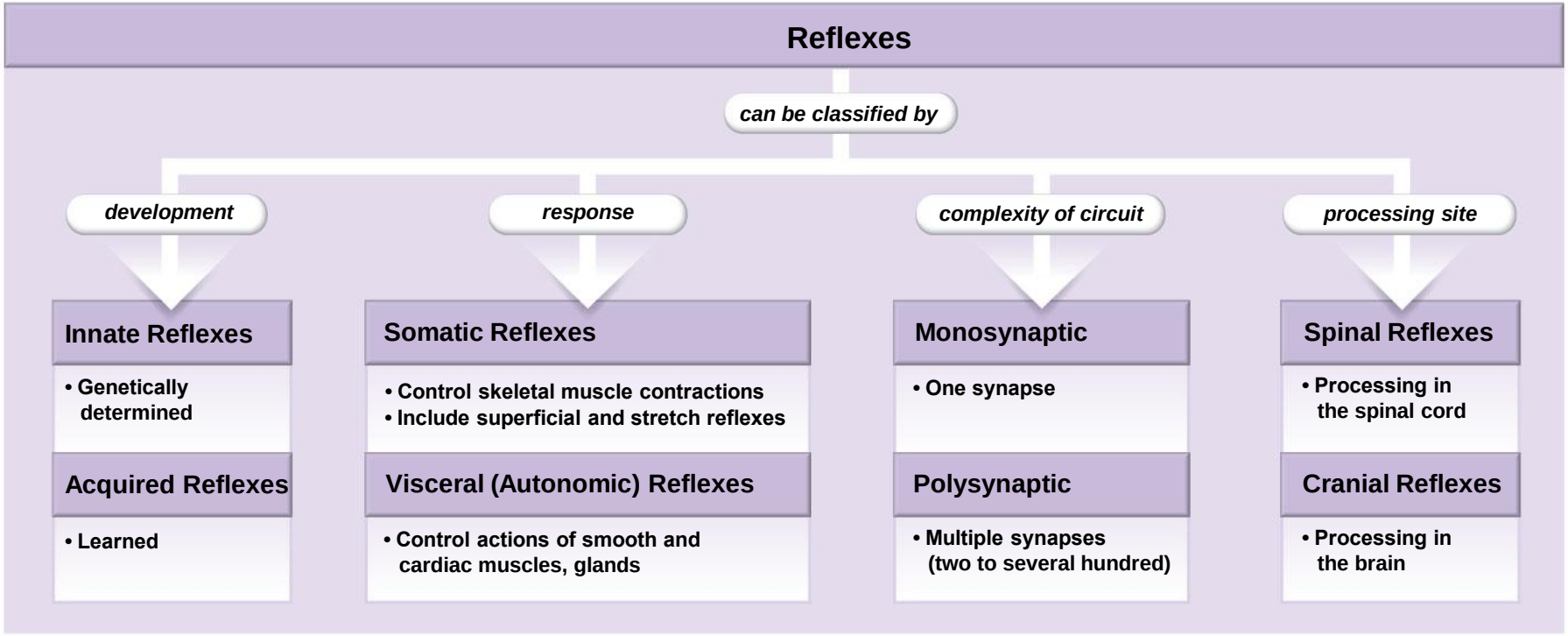


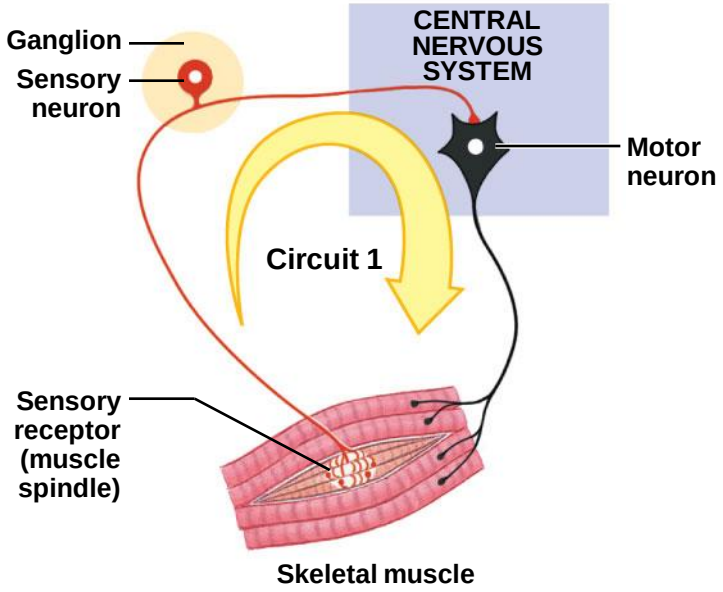
Figure 14.15 The Classification of Reflexes



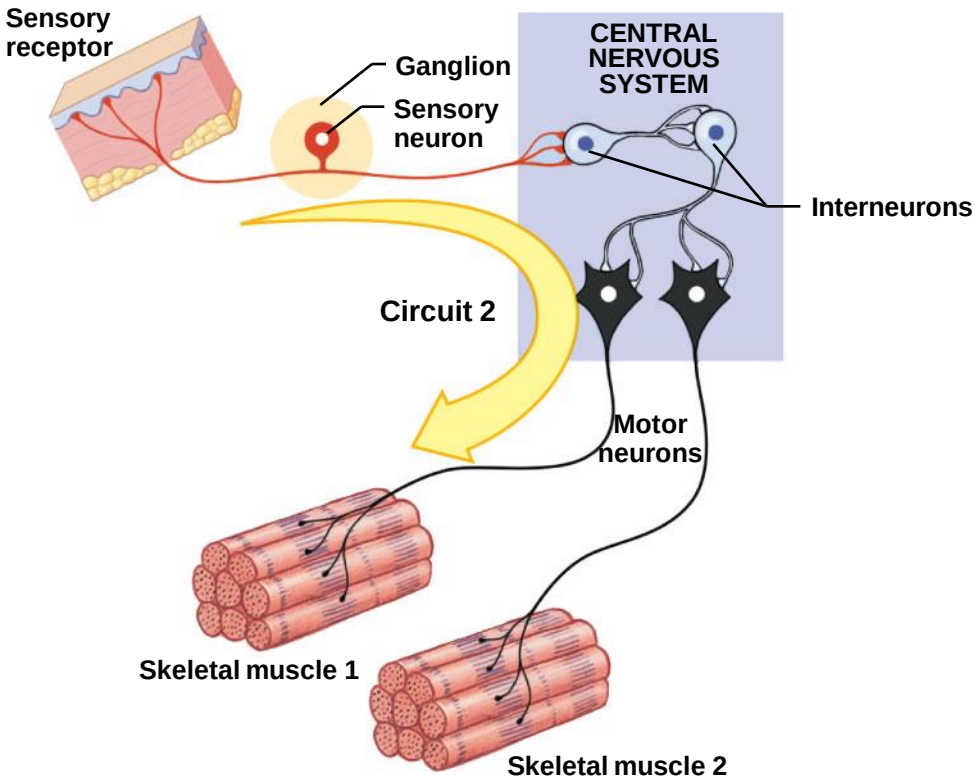
Reflexes

- Spinal reflexes can be:
  - **Monosynaptic**
    - Involves a single segment of the spinal cord
  - **Polysynaptic**
    - Integrates motor output from several spinal segments

Figure 14.16 Neural Organization and Simple Reflexes



a A monosynaptic reflex circuit involves a peripheral sensory neuron and a central motor neuron. In this example, stimulation of the receptor will lead to a reflexive contraction in a skeletal muscle.

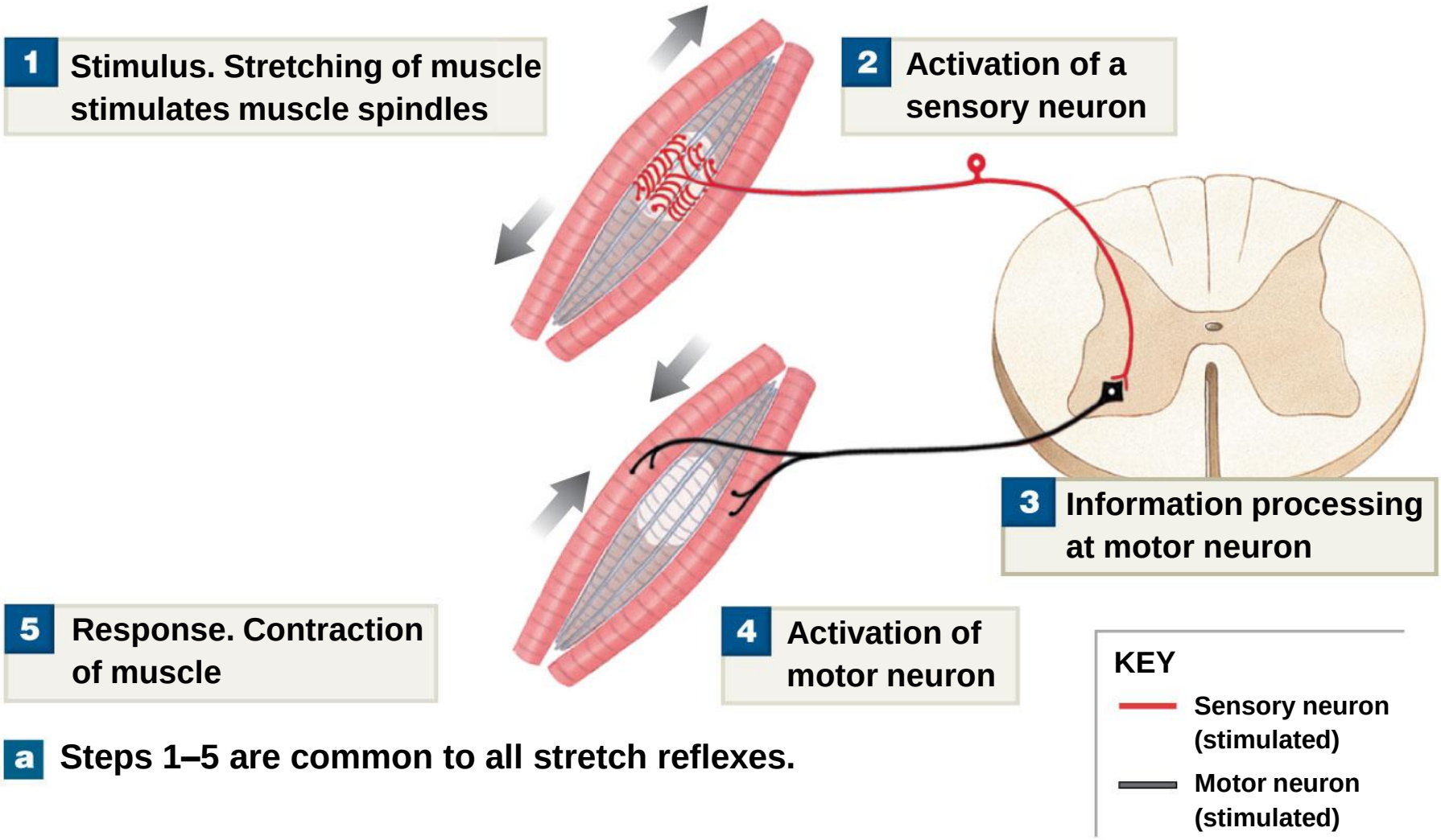


b A polysynaptic reflex circuit involves a sensory neuron, interneurons, and motor neurons. In this example, the stimulation of the receptor leads to the coordinated contractions of two different skeletal muscles.

Reflexes

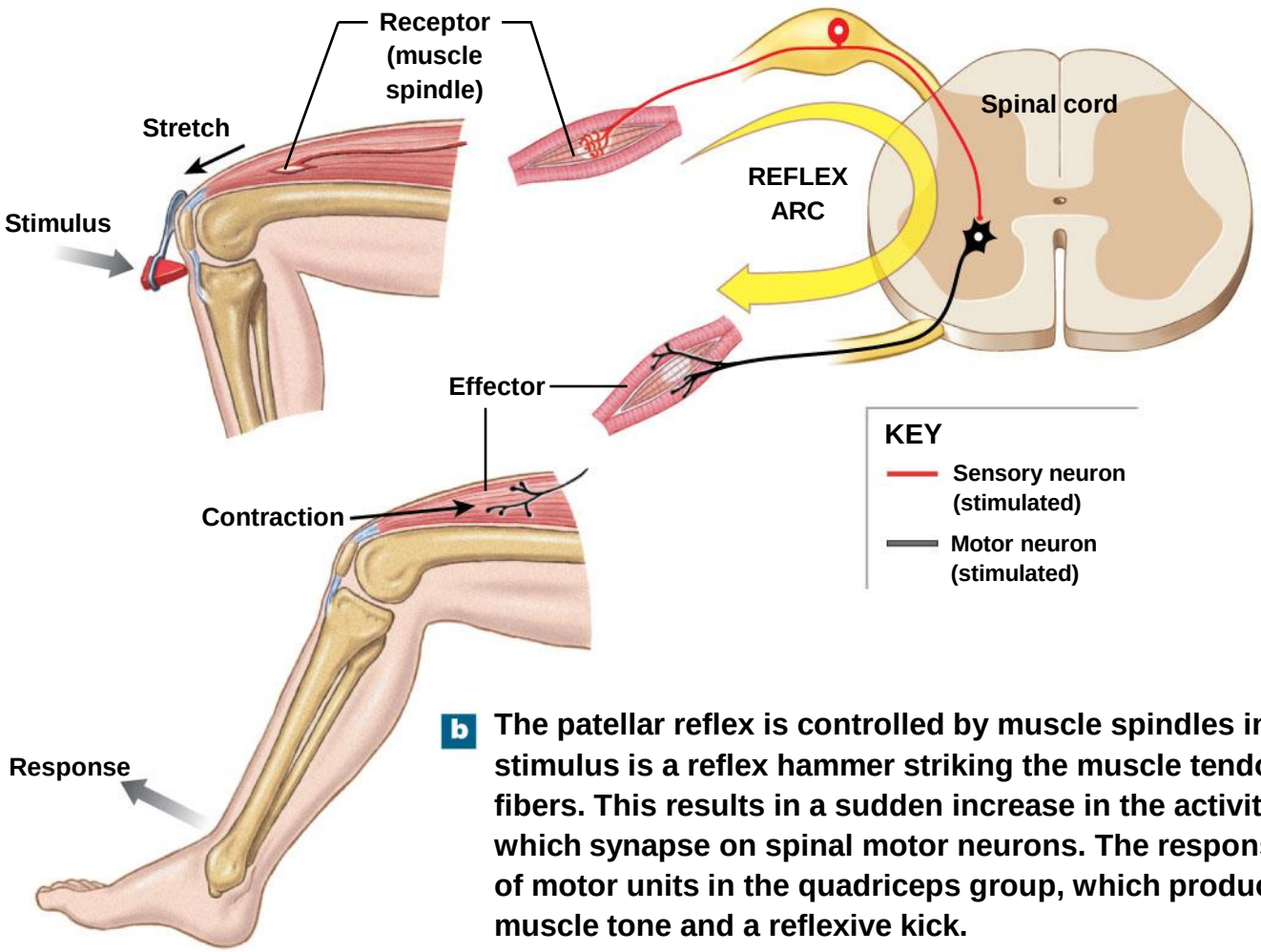
- Stretch reflex
  - 1. Stimulus stretches a muscle
  - 2. Activates a sensory neuron
  - 3. Information is processed in the spinal cord
  - 4. Motor neurons are activated
  - 5. Muscle (effector) contracts

Figure 14.17a Stretch Reflexes



a Steps 1–5 are common to all stretch reflexes.

Figure 14.17b Stretch Reflexes



b The patellar reflex is controlled by muscle spindles in the quadriceps group. The stimulus is a reflex hammer striking the muscle tendon, stretching the spindle fibers. This results in a sudden increase in the activity of the sensory neurons, which synapse on spinal motor neurons. The response occurs upon the activation of motor units in the quadriceps group, which produces an immediate increase in muscle tone and a reflexive kick.