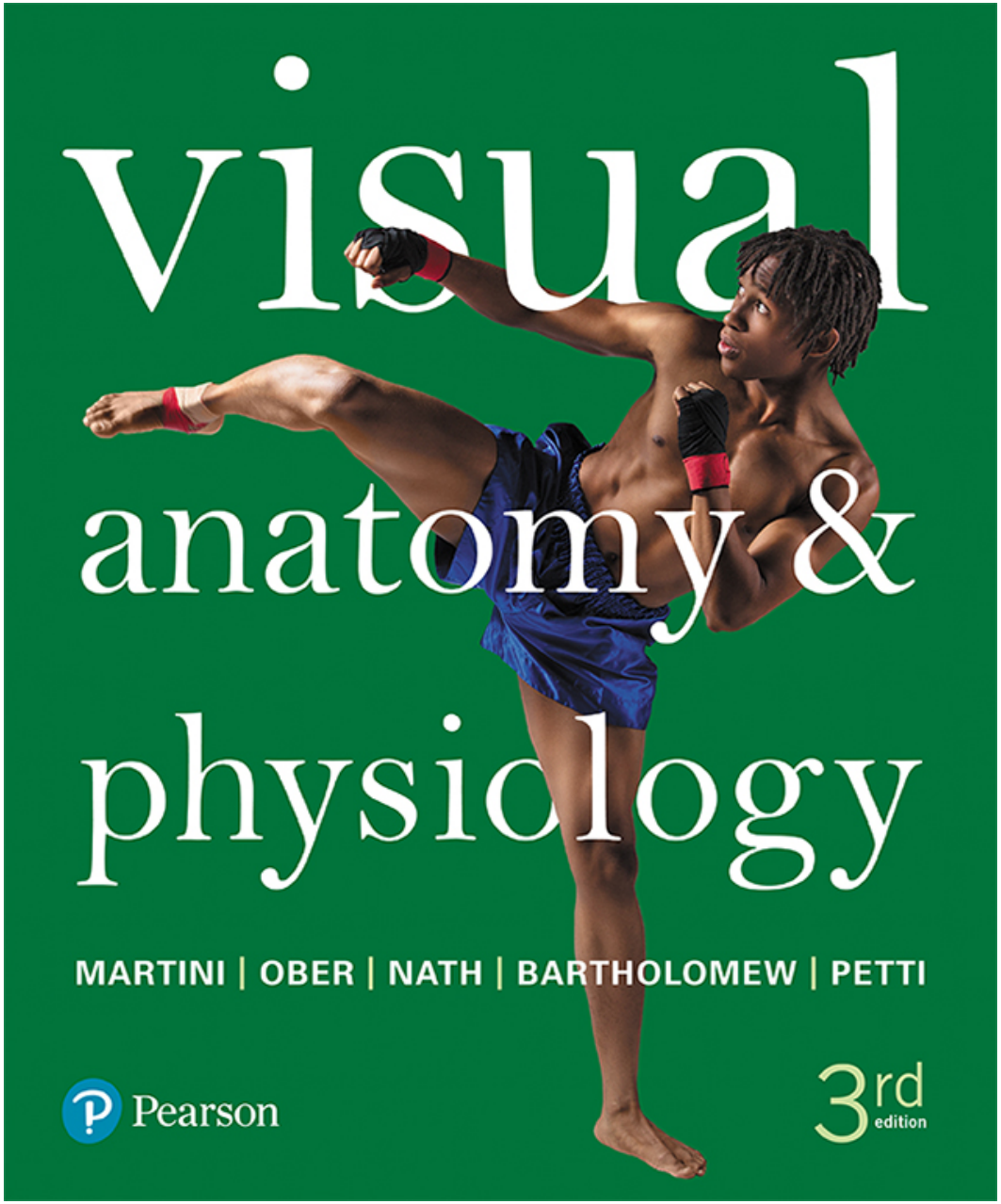


12

The Spinal Cord, Spinal Nerves, and Spinal Reflexes

Lecture Presentation by
Lori Garrett

Section 1: Functional Organization of the Spinal Cord

Learning Outcomes

12.1 Describe how the spinal cord can function without input from the brain.

12.2 Discuss the anatomical features of the spinal cord.

12.3 Describe the three meningeal layers that surround the spinal cord.

12.4 Explain the roles of gray matter and white matter in processing and relaying sensory information and motor commands.

Section 1: Functional Organization of the Spinal Cord

Learning Outcomes (continued)

12.5 Describe the major components of a spinal nerve.

12.6 Describe the rami associated with spinal nerves.

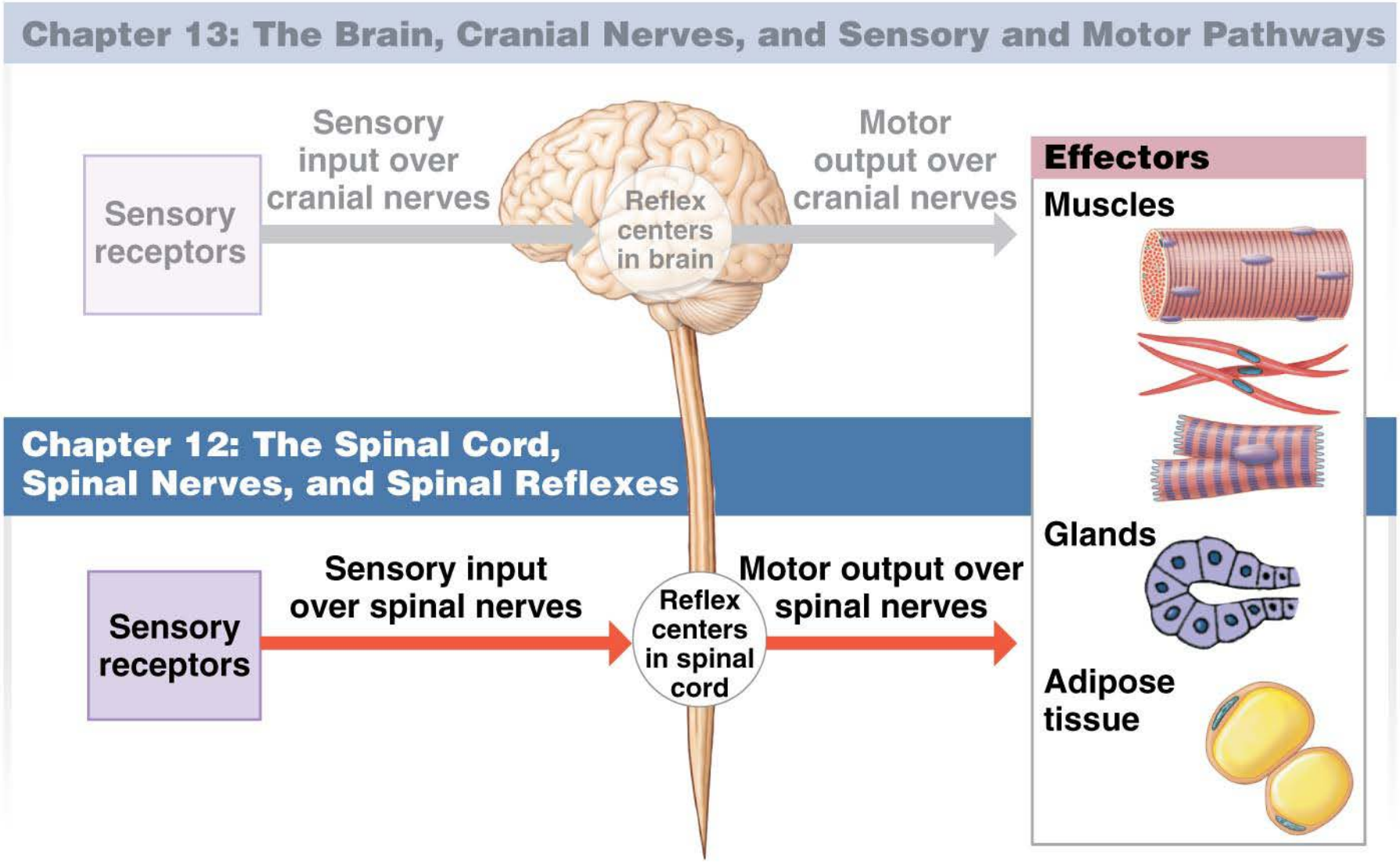
12.7 Relate the distribution pattern of spinal nerves to the region they innervate.

12.8 Describe the cervical plexus.

12.9 Relate the distribution pattern of the brachial plexus to its function.

12.10 Relate the distribution patterns of the lumbar plexus and sacral plexus to their functions.

Module 12.1: The spinal cord can function independently from the brain



Module 12.1: The brain and spinal cord

Both the brain and the spinal cord:

- Receive sensory input from receptors
- Contain reflex centers
- Send motor output to effectors

Reflex

- Rapid, automatic response triggered by specific stimuli

Spinal reflexes

- Controlled in the **spinal cord**
- Function without input from the brain

Module 12.1: Review

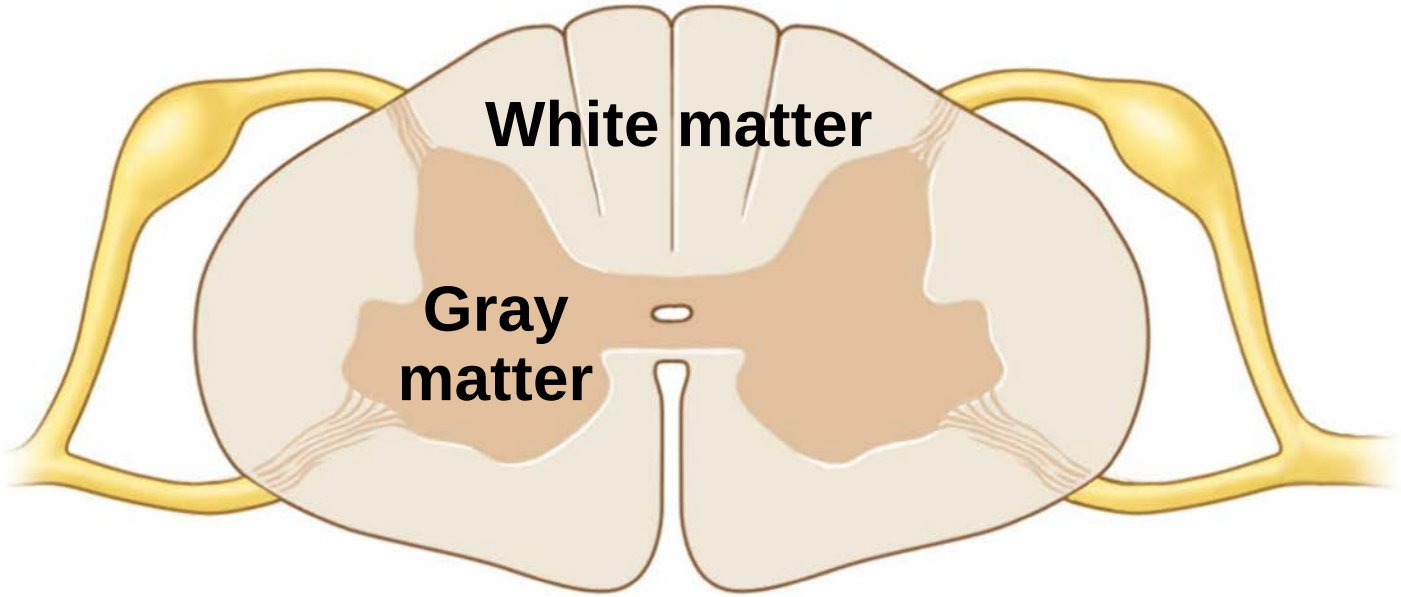
A. Describe the direction of sensory input and motor commands relative to the spinal cord.
B. What is a reflex?
C. Define spinal reflex.

Learning Outcome: Describe how the spinal cord can function without input from the brain.

Module 12.2: The spinal cord has 31 segments with 31 pairs of nerves

Spinal cord structure: cross section

- Outer white matter
- Inner gray matter with central canal



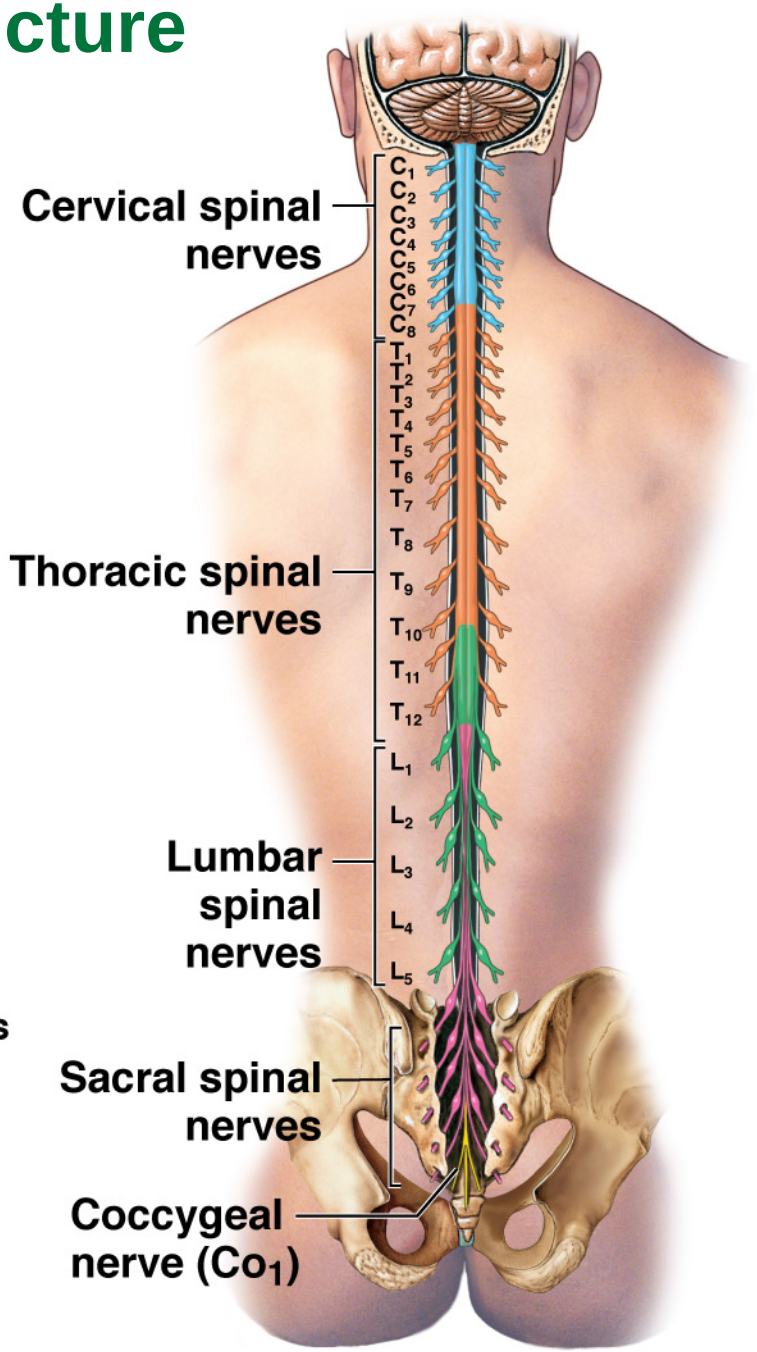
Module 12.2: Spinal cord structure

Spinal cord structure

- Adult length ~ 45 cm (18 in.)
  - Max. width ~ 14 mm (0.55 in.)
  - Ends at L_1–L_2

Spinal cord has 31 segments:

- 8 cervical
- 12 thoracic
- 5 lumbar
- 5 sacral
- 1 coccygeal

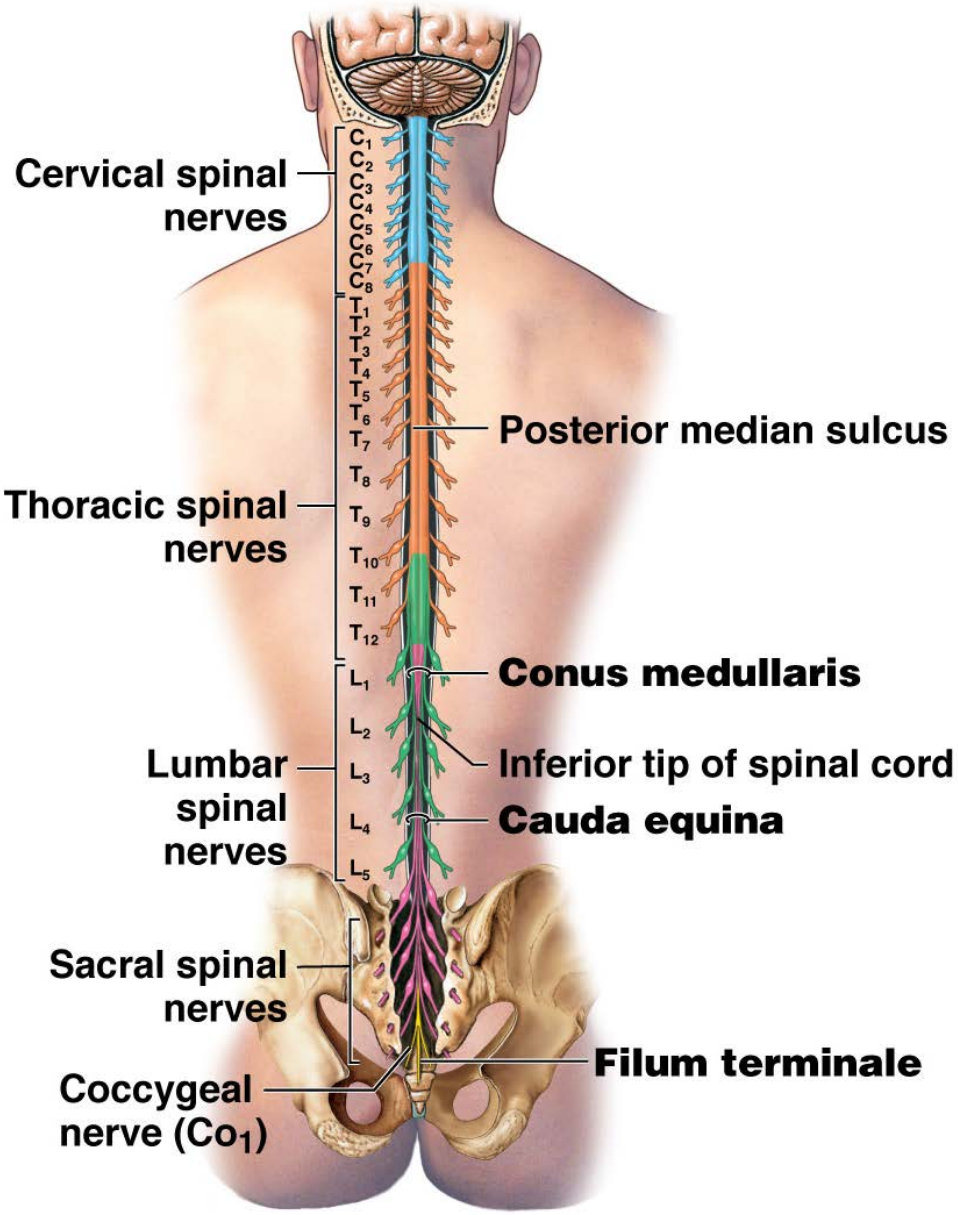


Module 12.2: Spinal cord structure

Conus medullaris: cone-shaped end of spinal cord at L_1–L_2

Filum terminale ("terminal thread")

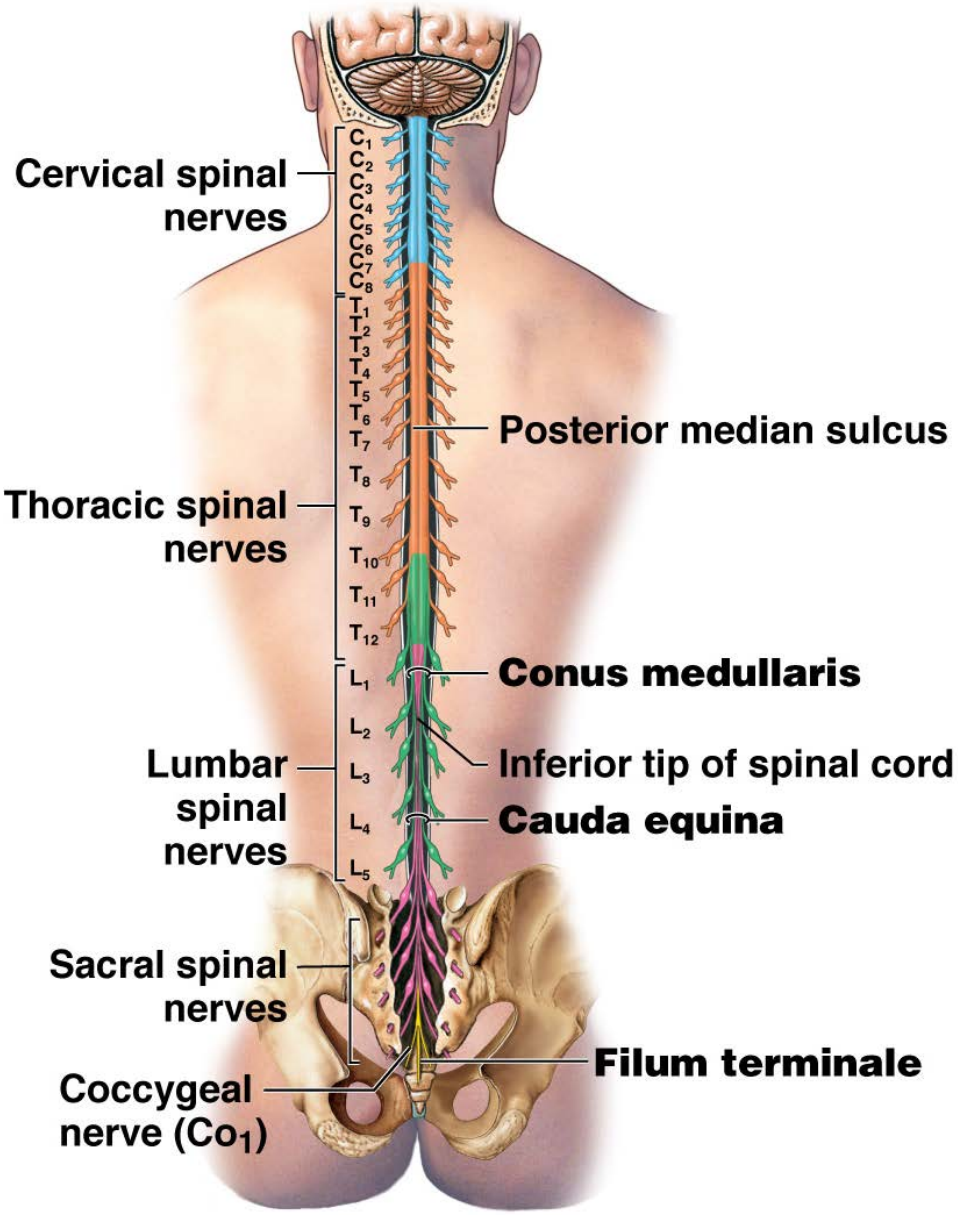
- Strand of fibrous tissue from tip of conus medullaris to S_2
- Provides longitudinal support to spinal cord



Module 12.2: Spinal cord structure

Cauda equina (*cauda*, tail + *equinus*, horse)

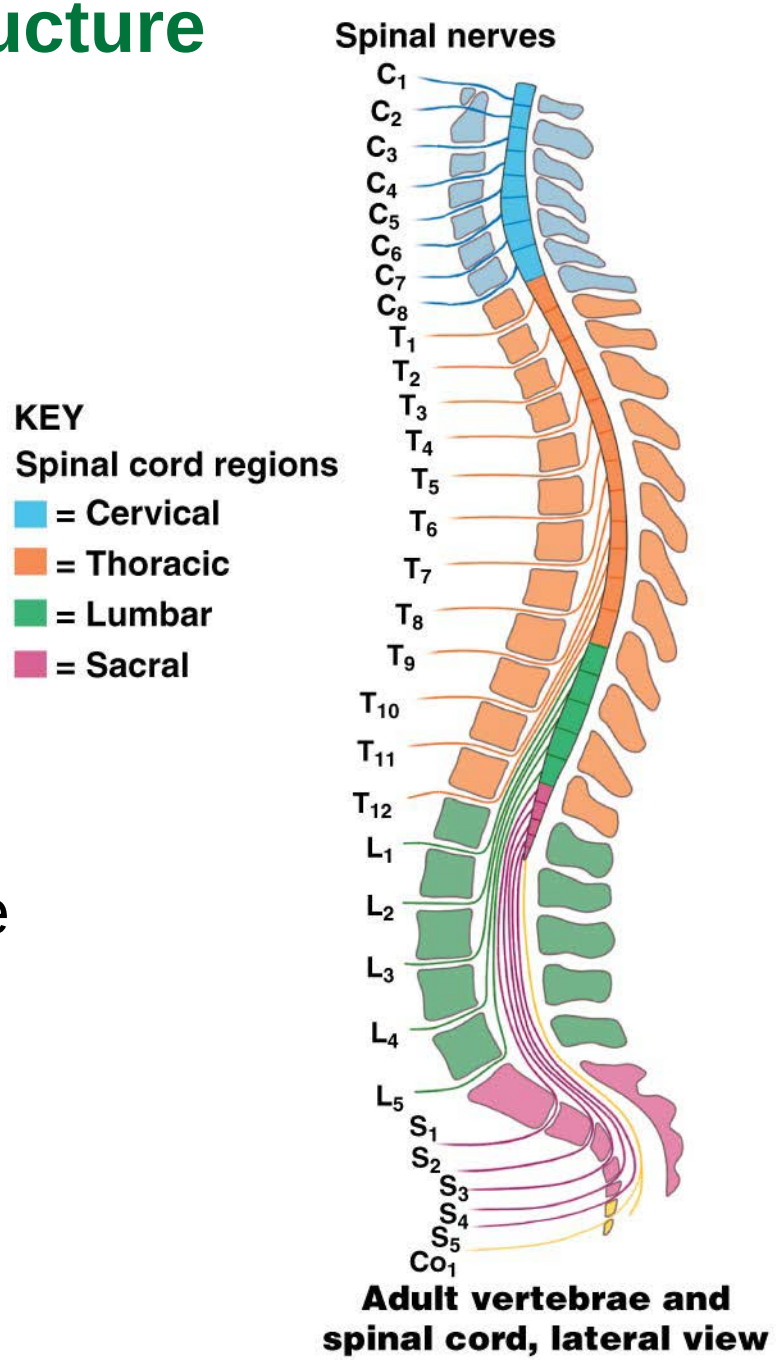
- Extended anterior and posterior roots of spinal segments L_2 to S_5 and filum terminale
- Name comes from resemblance to a horse's tail



Module 12.2: Spinal cord structure

Naming spinal nerves

- 31 pairs of spinal nerves arise from 31 spinal cord segments
- Designated by the region and number:
  - C_1 runs above 1st cervical vertebra
  - C_8 below 7th cervical vertebra
  - All others named for vertebrae above
- *Example:* T_1 is below 1st thoracic vertebra

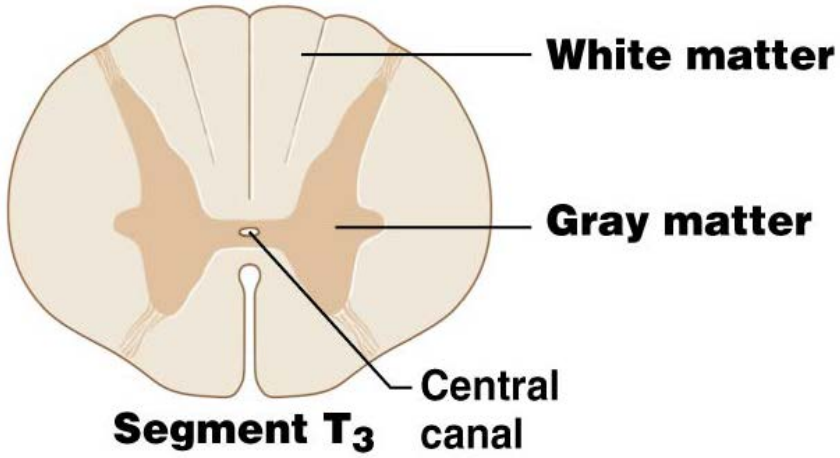


Adult vertebrae and spinal cord, lateral view

Module 12.2: Spinal cord structure

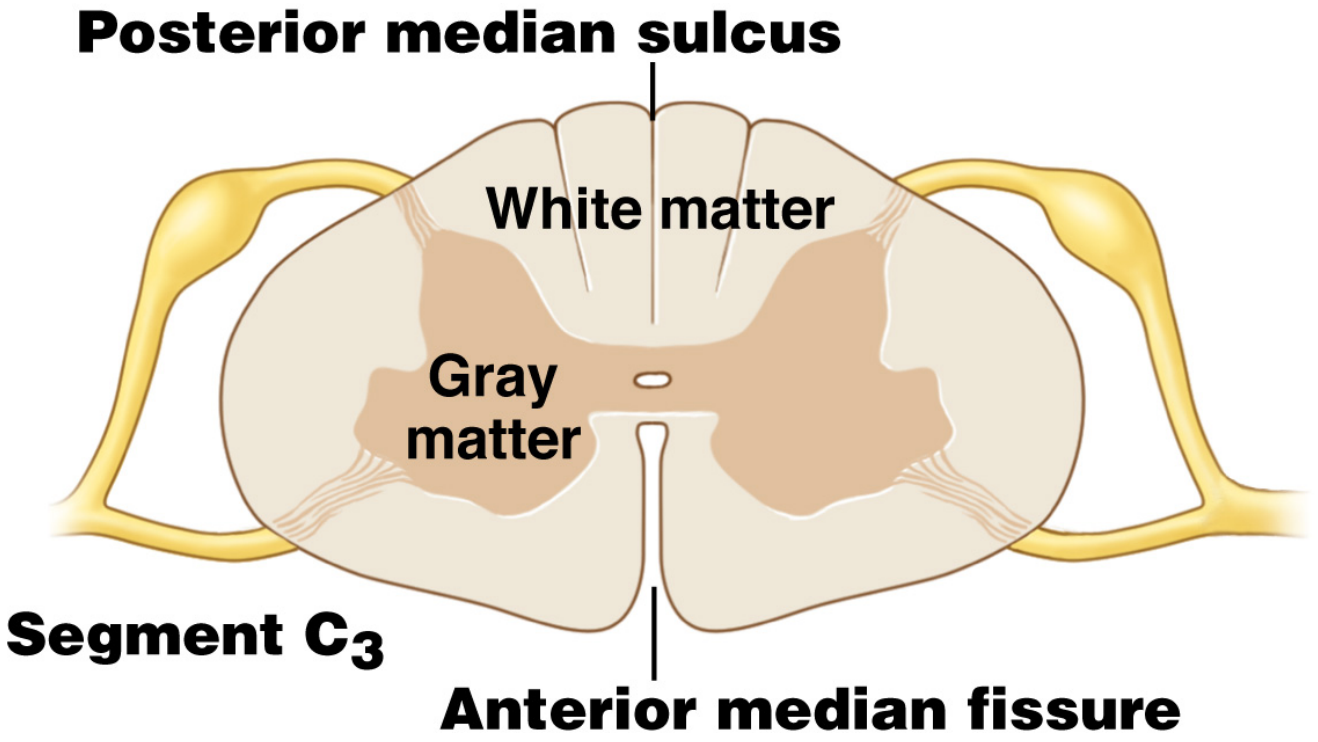
Cross-sectional spinal cord anatomy

- **White matter**—superficial; myelinated & unmyelinated axons
- **Gray matter**—deep; forms an H, or butterfly shape
  - Mostly neuron cell bodies, neuroglia, unmyelinated axons
  - Central canal—contains cerebrospinal fluid



Module 12.2: Spinal cord structure

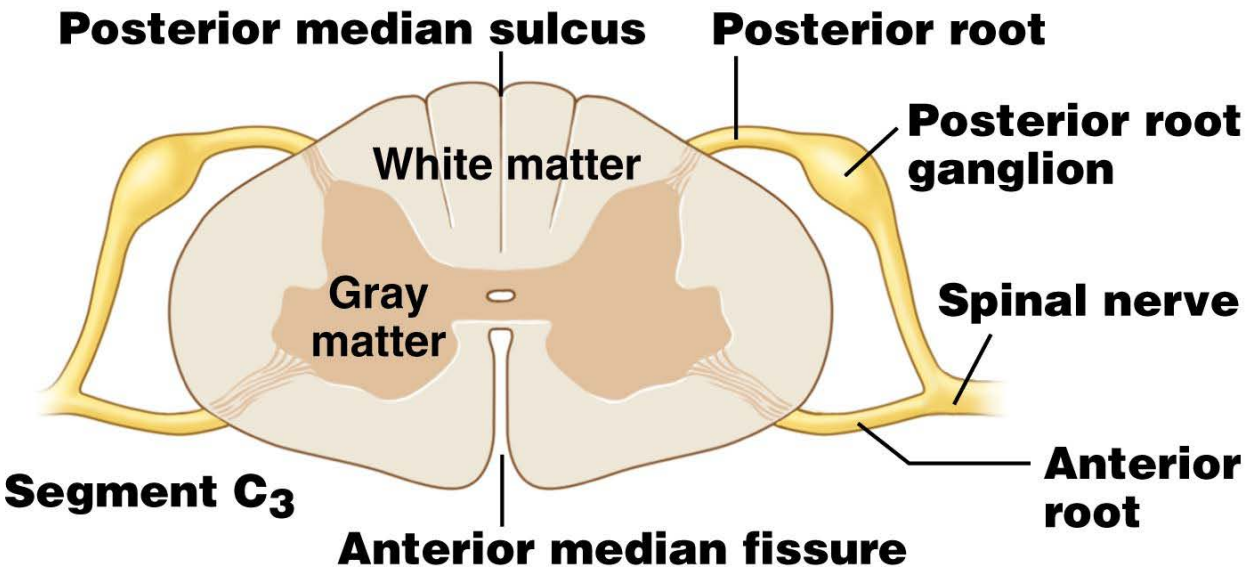
- **Posterior median sulcus**
  - Shallow, longitudinal groove on posterior surface
- **Anterior median fissur**e—deep groove on anterior surface



Module 12.2: Spinal cord structure

Spinal nerve—axons of sensory and motor neurons

- **Anterior root** contains axons of motor neurons
- **Posterior root** contains axons of sensory neurons
- **Posterior root ganglion** (spinal ganglion) contains cell bodies of sensory neurons in posterior root



Module 12.2: Review

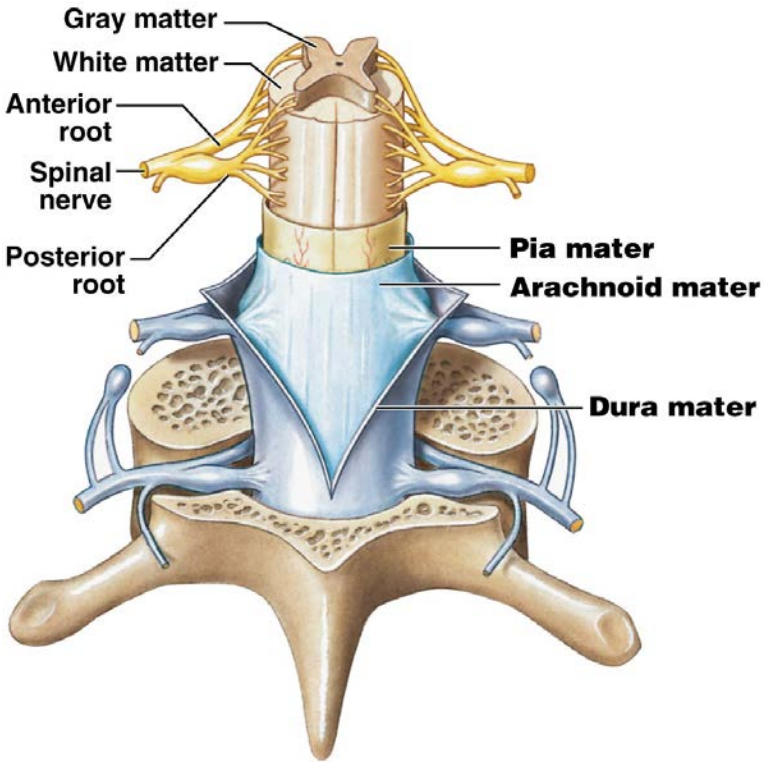
A. A typical spinal cord has how many pairs of spinal nerves, and where does the spinal cord end?
B. Name the pair of spinal nerves that emerges between vertebrae C7 and T1.
C. Describe the gross anatomical features of a cross section of the spinal cord.
D. Describe the composition of gray matter of the spinal cord.
E. What is the significance of the cauda equina?

Learning Outcome: Discuss the anatomical features of the spinal cord.

Module 12.3: Describe the three meningeal layers that surround the spinal cord

Spinal meninges

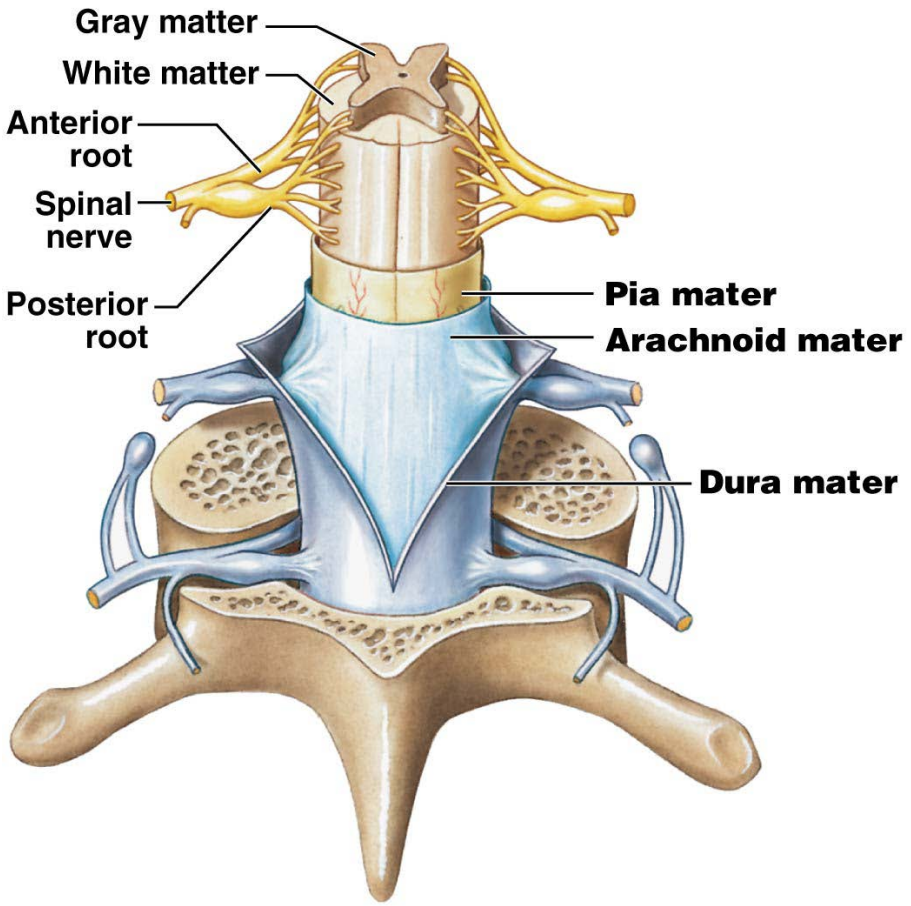
- 3 specialized membranes surrounding spinal cord and continuous with the cranial meninges
  1. Dura mater—outermost layer
  2. Arachnoid mater—middle layer
  3. Pia mater—innermost layer
- Functions
  - Physical stability
  - Shock absorption
  - Carry blood supply (oxygen and nutrients)



Module 12.3: Meninges

Dura mater (*dura*, hard + *mater*, mother)

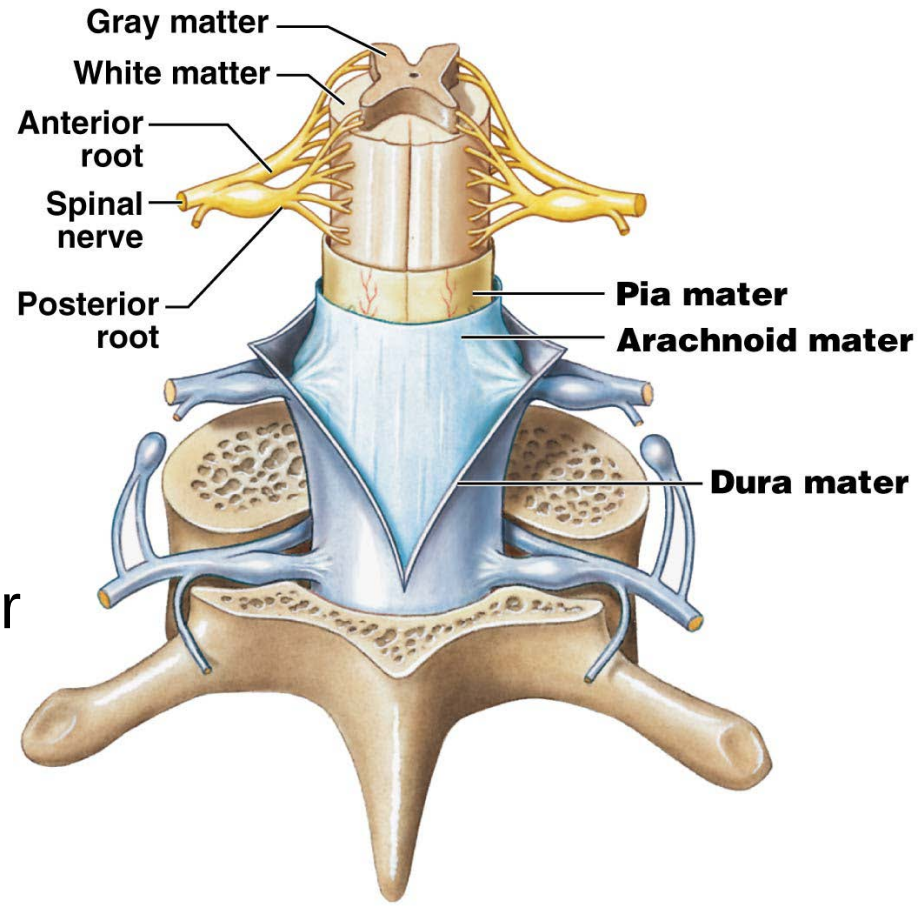
- Outermost covering
- Tough, fibrous
- Dense collagen fibers oriented along the longitudinal axis of the spinal cord



Module 12.3: Meninges

Arachnoid mater (*arachne*, spider + *mater*, mother)

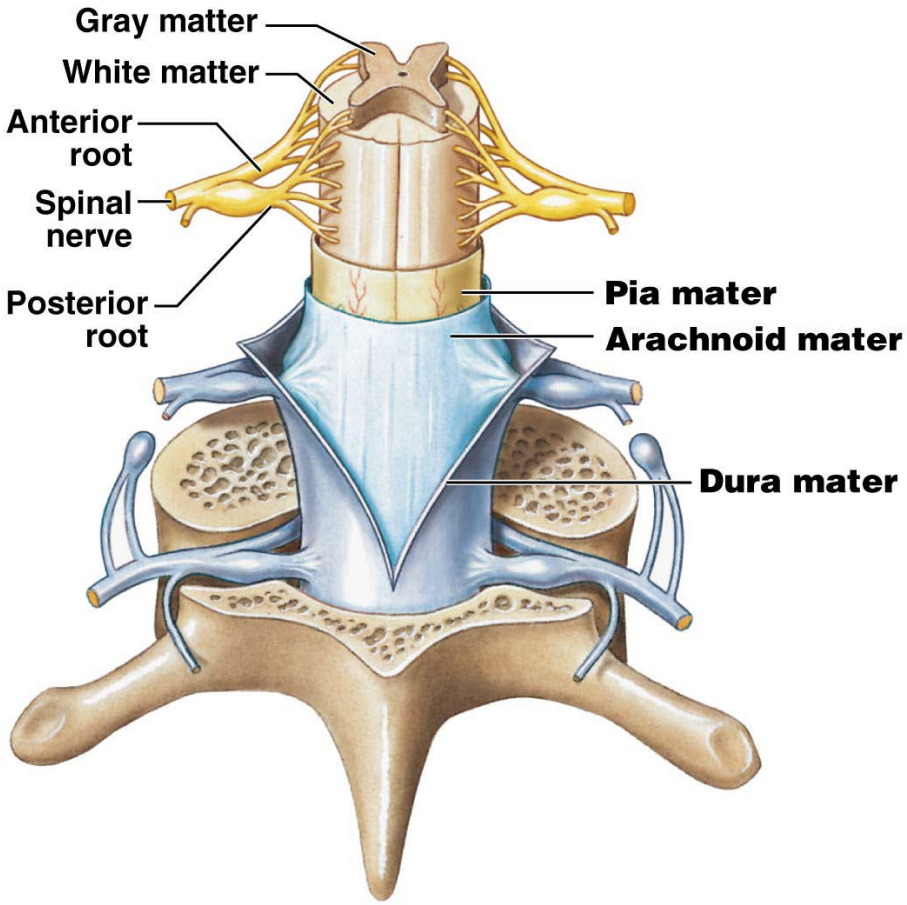
- Middle meningeal layer
  - Includes **arachnoid membrane**—layer of simple squamous epithelium
  - **Subarachnoid space**—between arachnoid membrane and pia mater



Module 12.3: Meninges

Pia mater (*pia*, delicate + *mater*, mother)

- Innermost meningeal layer
- Meshwork of elastic and collagen fibers
- Anchored to neural tissue

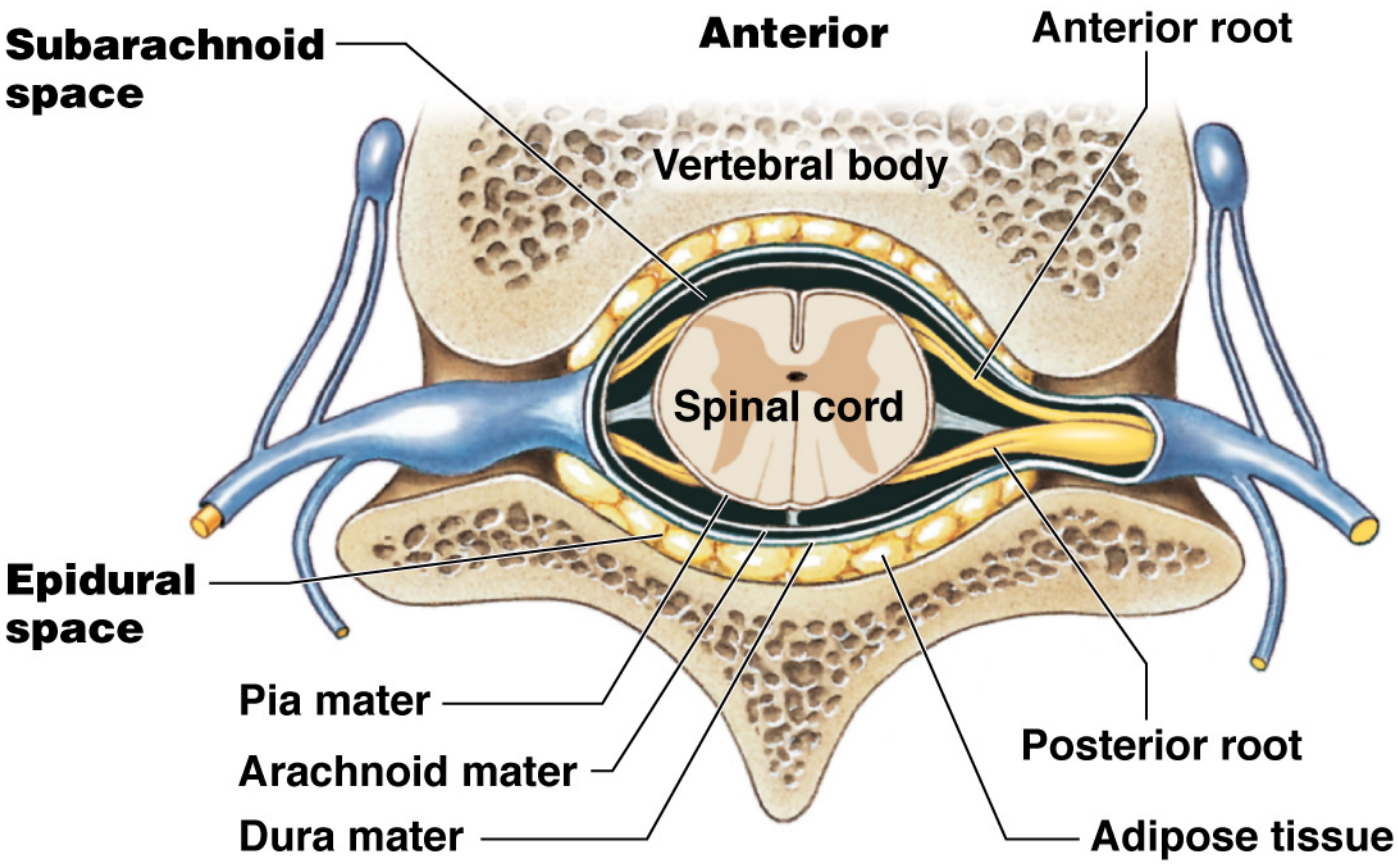


Module 12.3: Meninges

Spaces associated with meninges

- **Subarachnoid space**
  - Contains arachnoid trabeculae—collagen and elastic fibers; anchor arachnoid mater to pia mater
  - Contains **cerebrospinal fluid** (**CSF**)—shock absorber; diffusion of gases, nutrients, etc.
  - Blood vessels for spinal cord are located here
- **Epidural space**
  - Between dura mater and vertebrae
  - Areolar tissue, blood vessels, and adipose tissue

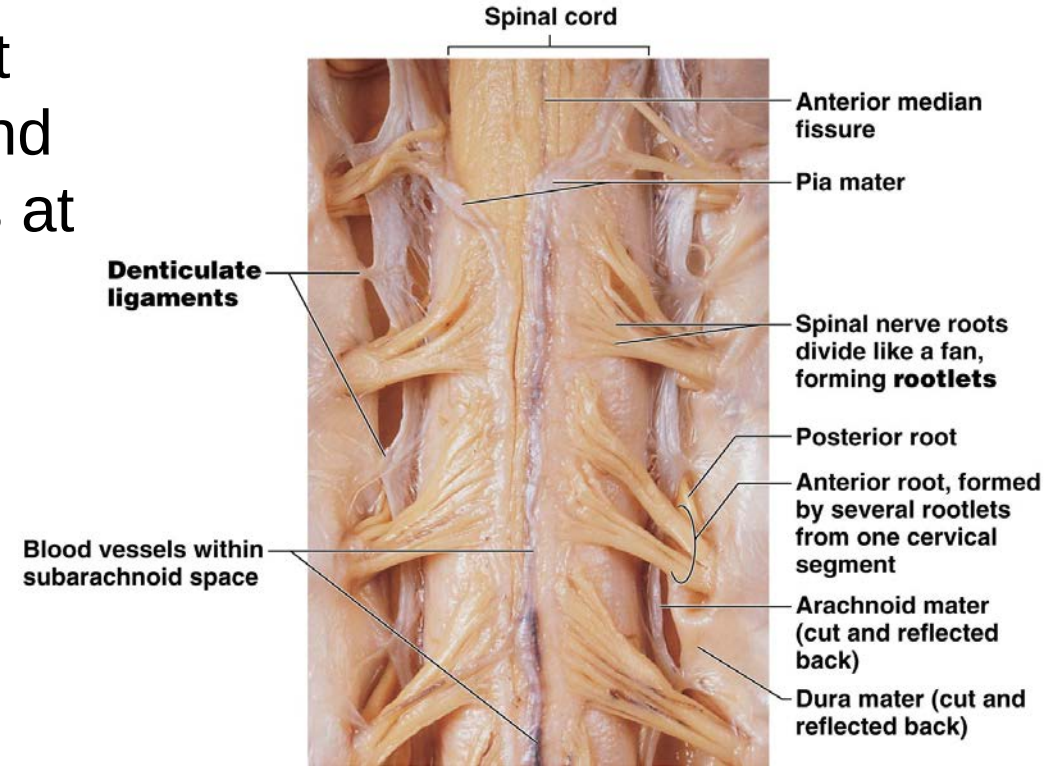
Cross-sectional view of the spinal cord, showing the meninges and associated spaces



Module 12.3: Meninges

Supporting ligaments maintain position of spinal cord

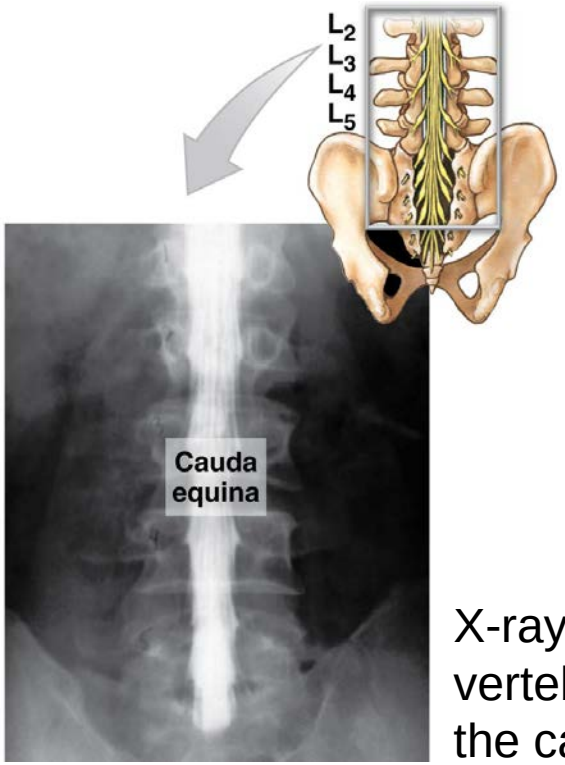
- **Denticulate ligaments** extend from pia mater through arachnoid mater to dura mater; prevent lateral movement
  - Dural connections at foramen magnum and coccygeal ligaments at sacrum prevent superior–inferior movements



Module 12.3: Meninges

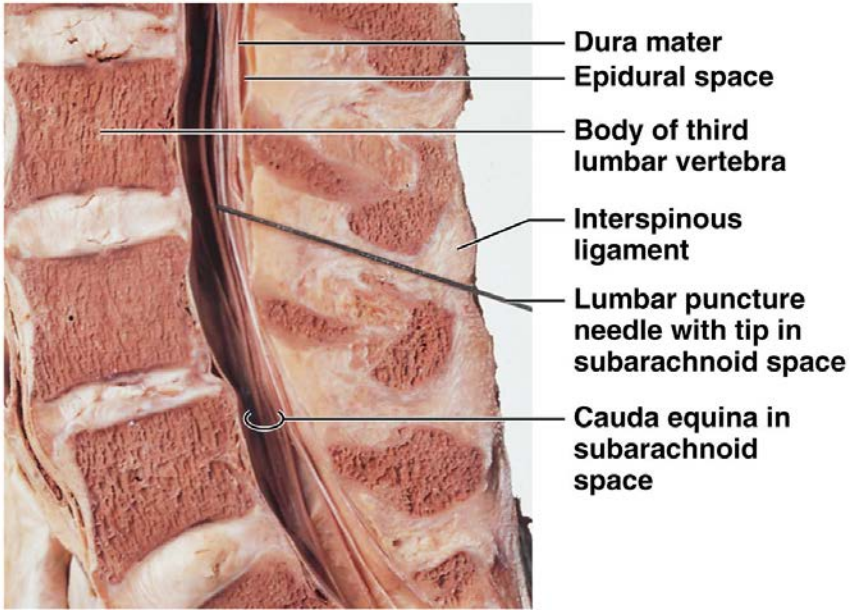
Lumbar puncture, or spinal tap

- Withdraw sample of cerebrospinal fluid
- Needle inserted into subarachnoid space, lumbar region, below conus medullaris to avoid spinal cord



X-ray of the lumbar vertebrae, showing the cauda equina

Sagittal view of the lumbar spine, showing proper placement of a lumbar puncture needle.



Module 12.3: Review

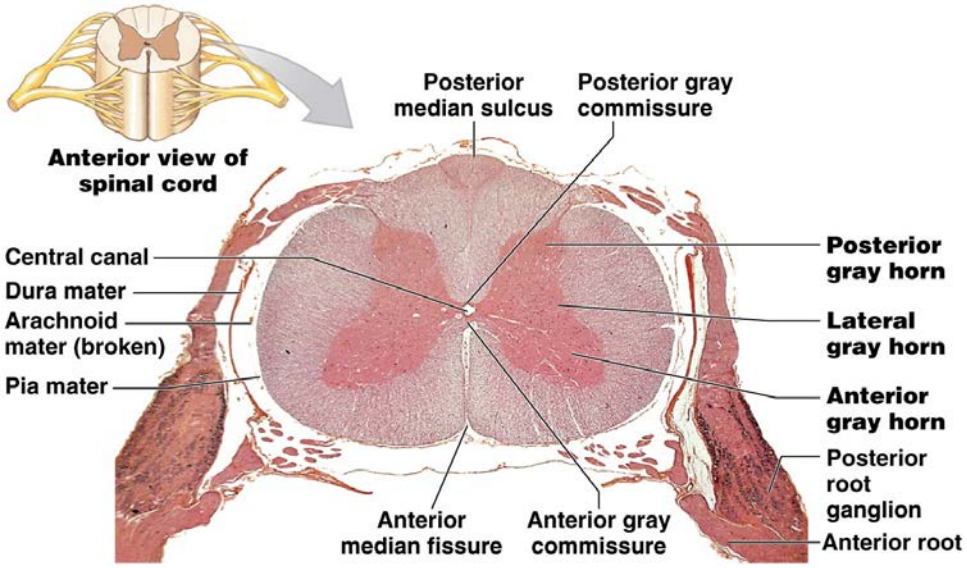
A. Where is spinal CSF located?
B. Name the structures and spinal coverings that are penetrated during a lumbar puncture procedure.

Learning Outcome: Describe the three meningeal layers that surround the spinal cord.

Module 12.4: Gray matter integrates sensory and motor functions, and white matter carries information

Structural organization of gray matter

- **Posterior gray horn**—somatic and visceral sensory nuclei
- **Lateral gray horn**—only in thoracic and lumbar segments; contains visceral motor nuclei
- **Anterior gray horn**—somatic motor nuclei

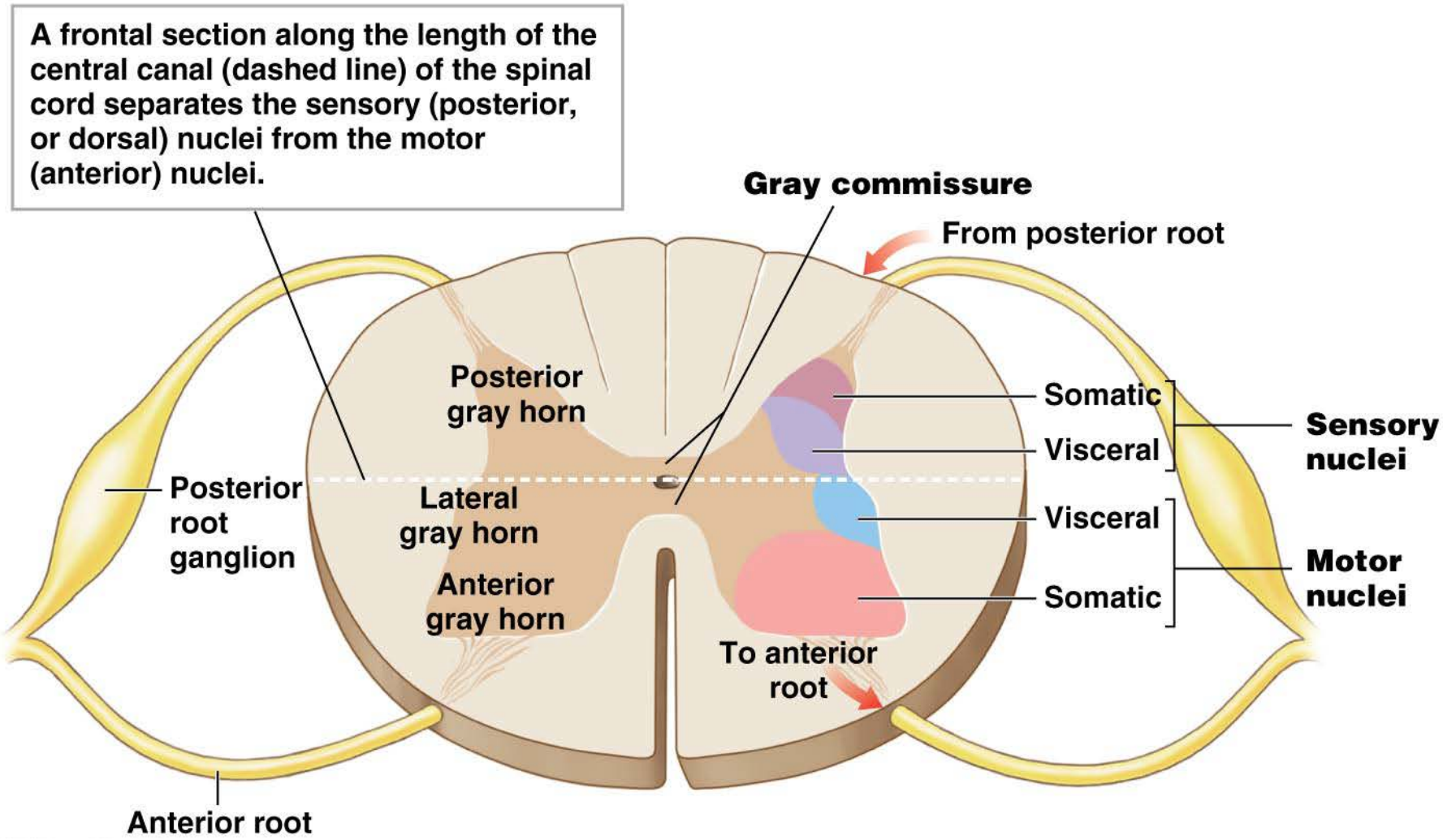


Module 12.4: White and gray matter

Functional organization of gray matter

- **Nuclei**
  - Functional groups of neuron cell bodies in gray matter of spinal cord
  - **Sensory nuclei** receive and relay sensory information
  - **Motor nuclei** issue motor commands to effectors
- **Gray commissures** (*commissura*, a joining)
  - Contain axons that cross from side to side in spinal cord
  - Located posterior and anterior to the central canal; named by this position

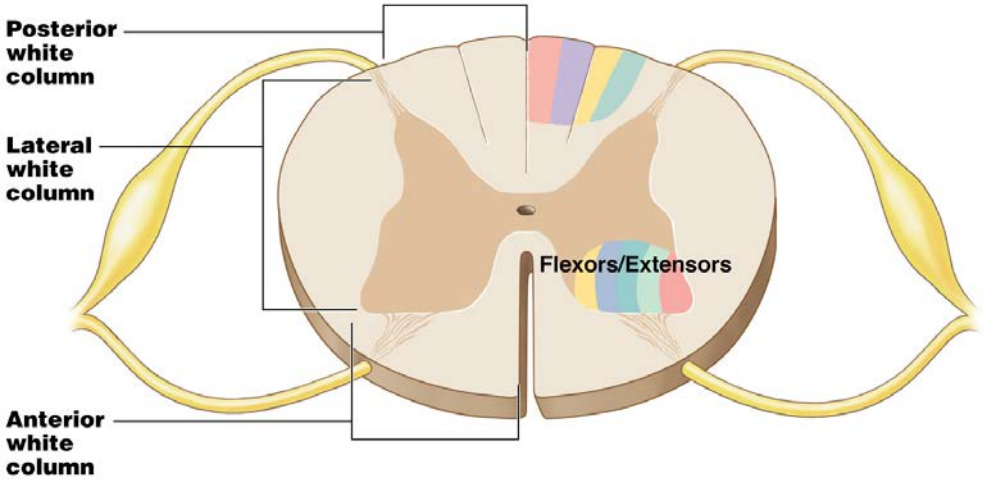
A cross-sectional view of the spinal cord



Module 12.4: White and gray matter

Structural organization of white matter

- Three **columns** on each side of spinal cord
  - **Posterior white column** between posterior gray horns and posterior median sulcus
  - **Lateral white column** between anterior and posterior columns
  - **Anterior white column** between anterior gray horns
- **Anterior white commissure**
  - Interconnects anterior white columns; axons cross side to side

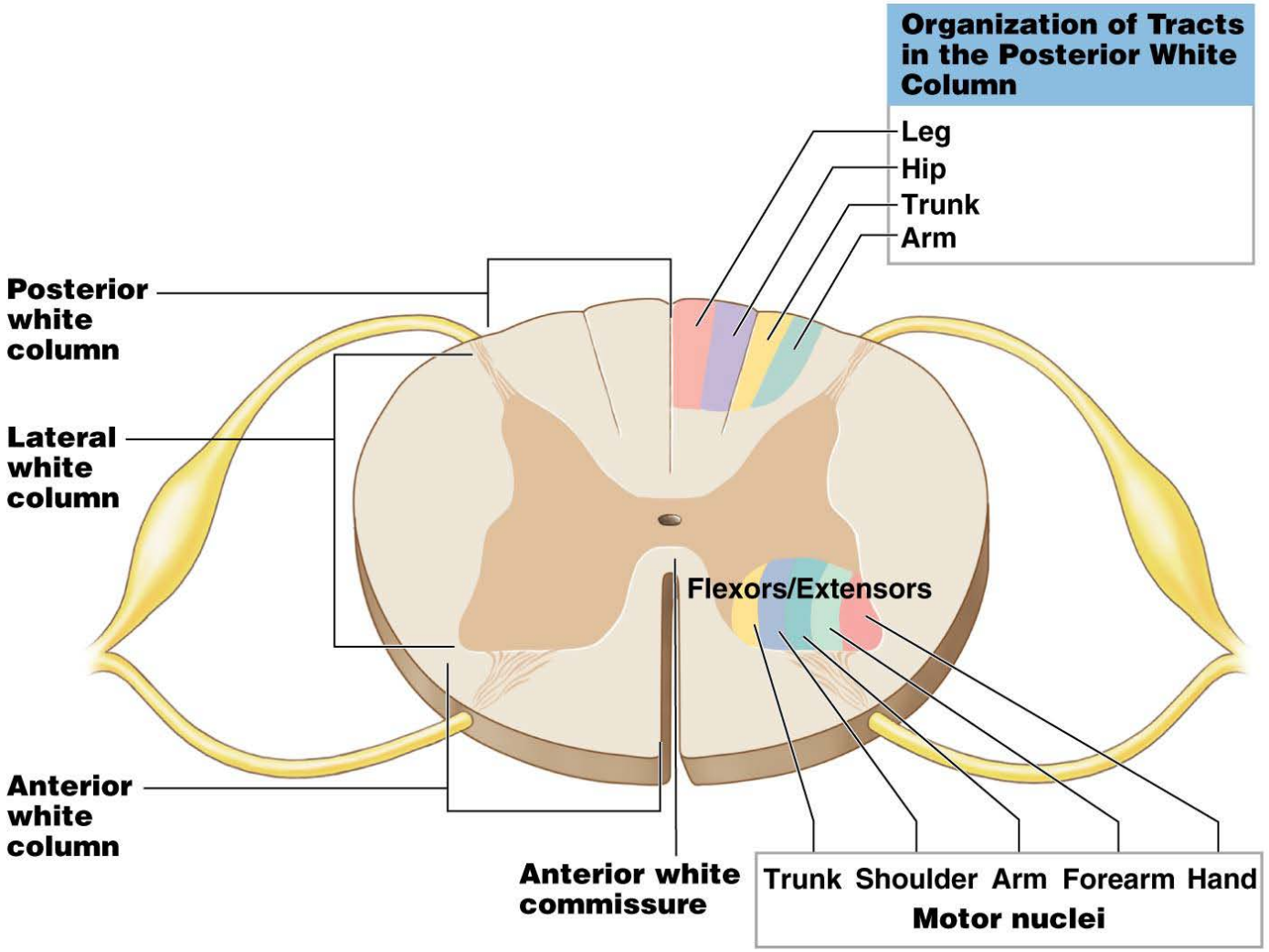


Module 12.4: White and gray matter

White matter is organized in tracts

- Bundles of axons in CNS (similar to a nerve in PNS)
- **Ascending tracts** carry sensory information
  - In posterior columns
- **Descending tracts** carry motor commands
  - In anterior columns

Structural and functional organization of the white matter in the spinal cord



Module 12.4: Review

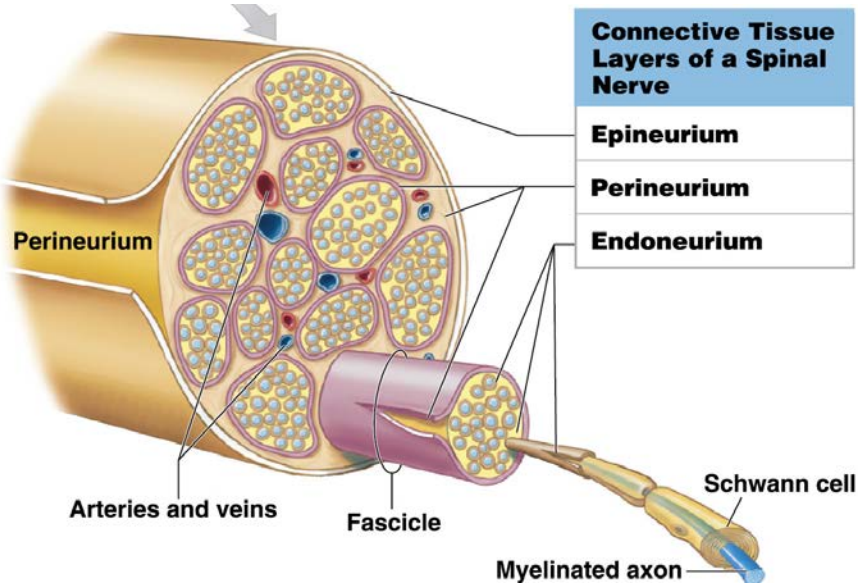
A. Differentiate between sensory nuclei and motor nuclei.
B. A person with polio has lost the use of his leg muscles. In which area of his spinal cord would you expect the virus-infected motor neurons to be?
C. A disease that damages myelin sheaths would affect which portion of the spinal cord?

Learning Outcome: Explain the roles of gray matter and white matter in processing and relaying sensory information and motor commands.

Module 12.5: Spinal nerves have a similar anatomical structure and distribution pattern

3 connective tissue layers surround spinal nerves

1. **Epineurium**—Outermost; dense network of collagen fibers
2. **Perineurium**—Middle layer; separates nerve into fascicles (bundles of axons).
3. **Endoneurium**—Innermost; surrounds individual axons



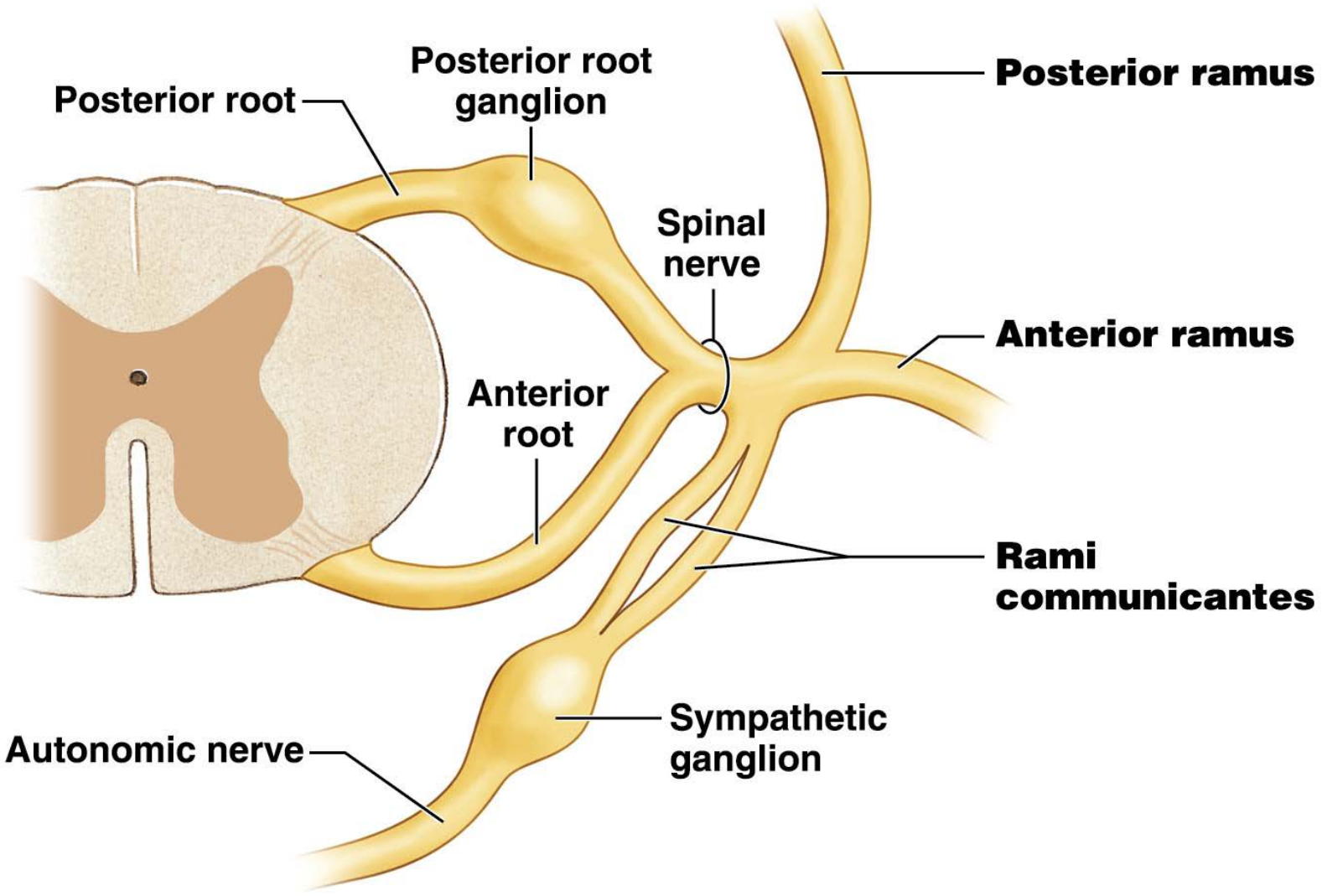
Module 12.5: Spinal nerve organization

Blood supply—arteries/veins go through epineurium, branch in perineurium; capillaries enter endoneurium.

Spinal nerve rami

- Each spinal neve divides to form two rami
  - **Posterior ramus**—muscles, joints, skin of back
  - **Anterior ramus**—lateral and anterior trunk; limbs
  - Rami communicantes—in spinal nerves T_1–L_2, carry motor output of **sympathetic division** of ANS (responsible for “fight-or-flight” response)

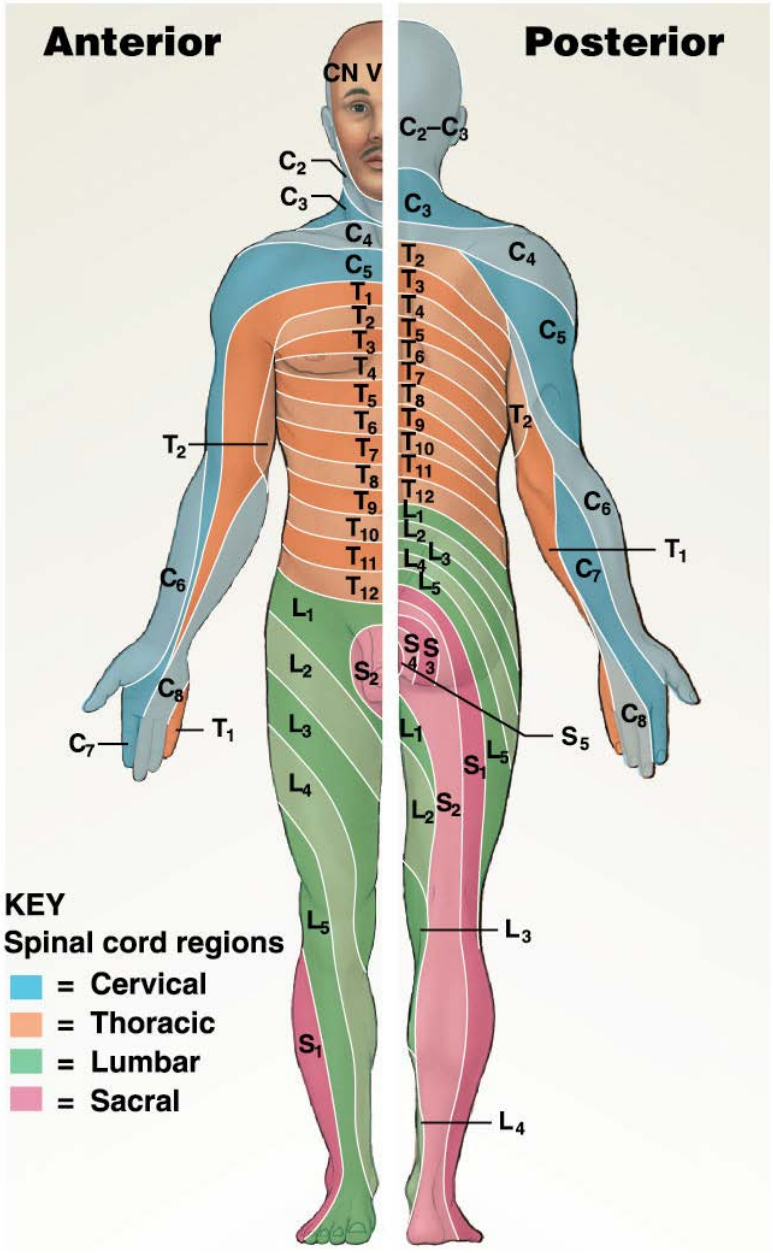
The posterior and anterior rami and rami communicantes of a spinal nerve



Module 12.5: Spinal nerve organization

Dermatome

- A specific bilateral area of skin supplied by pair of spinal nerves
- C1 usually lacks a sensory branch; when present it supplies scalp with C_2/C_3
- Face monitored by CN V
- Dermatome boundaries overlap



Module 12.5: Spinal nerve organization

Shingles

- Varicella-zoster virus (VZV)—herpes virus; causes chickenpox and shingles
- Attacks neurons in posterior roots and sensory ganglia
- Painful rash/blisters along dermatome of affected nerve
- History of chickenpox increases risk of shingles—virus lies dormant; unknown trigger reactivates
- Single bout or recurrent
- Shingles vaccine now available

Module 12.5: Review

A. Identify the three layers of connective tissue of a spinal nerve, and identify the major peripheral branches of a spinal nerve.
B. Describe a dermatome.
C. Explain the cause of shingles.

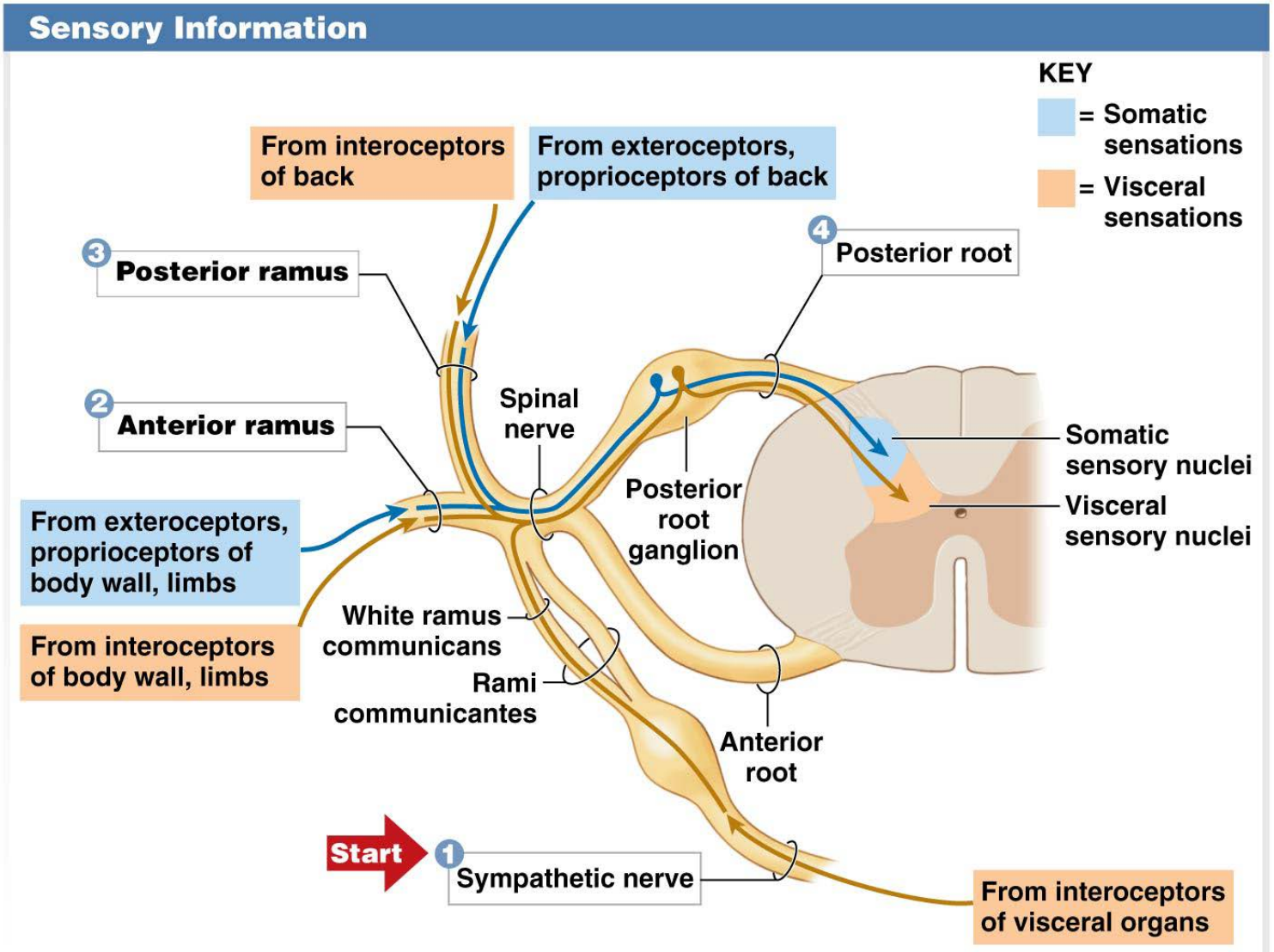
Learning Outcome: Describe the major components of a spinal nerve.

Module 12.6: Each ramus of a spinal nerve provides sensory and motor innervation to a specific region

Sensory information—collected from periphery; delivered to sensory nuclei in spinal cord

1. **Sympathetic nerve**—sensory information from visceral organs
2. **Anterior ramus**—from ventrolateral body surface, body wall, and limbs
3. **Posterior ramus**—from skin/skeletal muscles of back
4. **Posterior root** of spinal nerves carry sensory information to spinal cord

The path of sensory information in spinal nerves and the spinal cord



Module 12.6: Sensory and motor distribution

Motor commands—originate in motor nuclei

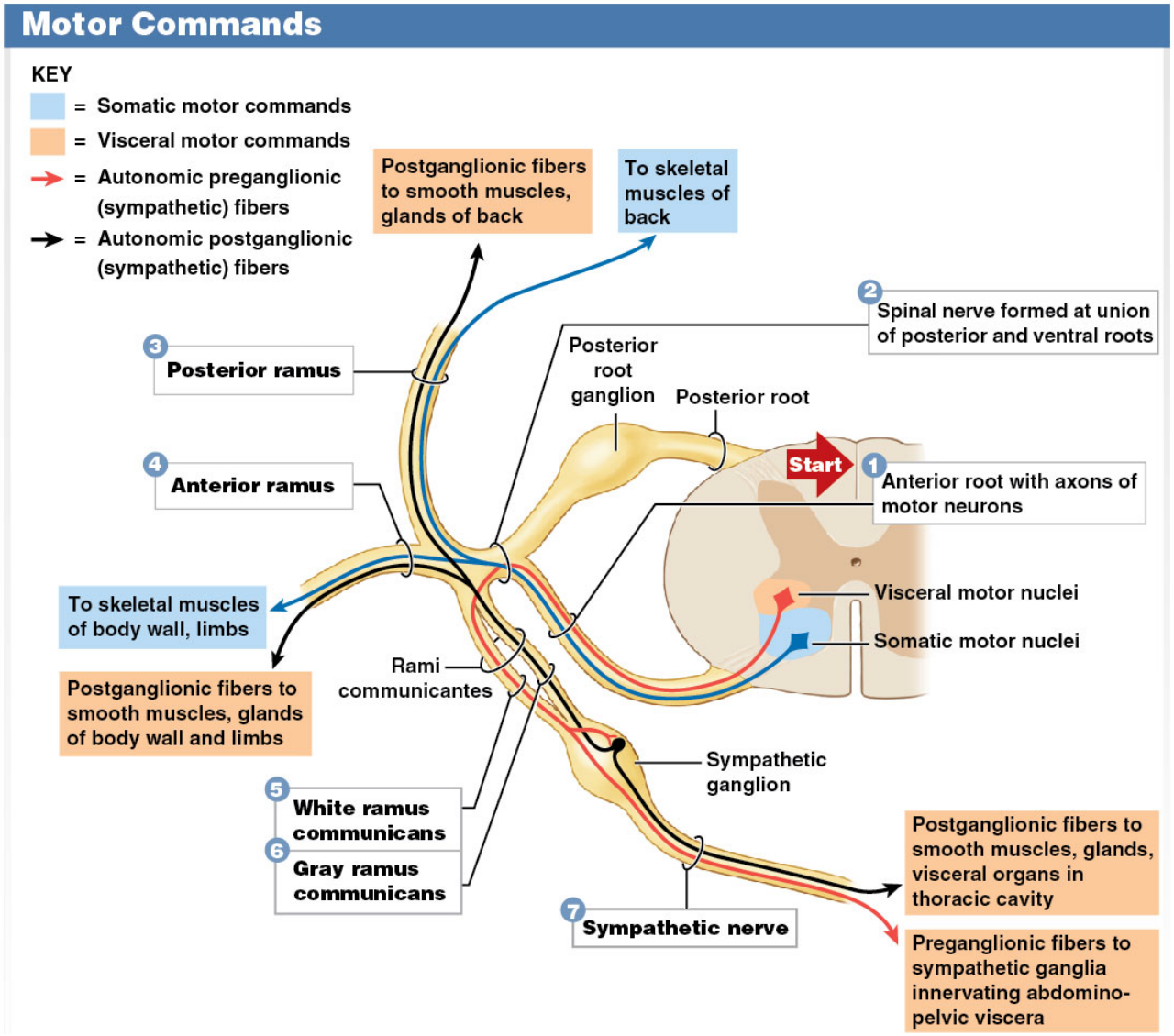
1. **Anterior root**—axons of somatic and visceral motor neurons
2. **Spinal nerve** forms at junction of anterior and poster roots
3. **Posterior ramus**—somatic/visceral motor fibers to skin/skeletal muscles of back
4. **Anterior ramus**—ventrolateral body surface, body wall, limbs

Module 12.6: Sensory and motor distribution

Motor commands—originate in motor nuclei (continued)

5. **White ramus communicans**—short branch with preganglionic visceral motor fibers to sympathetic ganglia (white—myelinated)
6. **Gray ramus communicans**—postganglionic fibers to glands/smooth muscle (gray—unmyelinated)
7. **Sympathetic nerve**—pre-/postganglionic fibers to thoracic cavity

The path of motor information in spinal nerves and the spinal cord



Module 12.6: Review

A. Which ramus carries sensory information from the limbs?
B. Through which root of a spinal nerve does visceral sensory information arrive?
C. Which ramus provides sensory and motor innervation to the skin and skeletal muscles of the back?
D. Describe the white and gray rami communicantes.

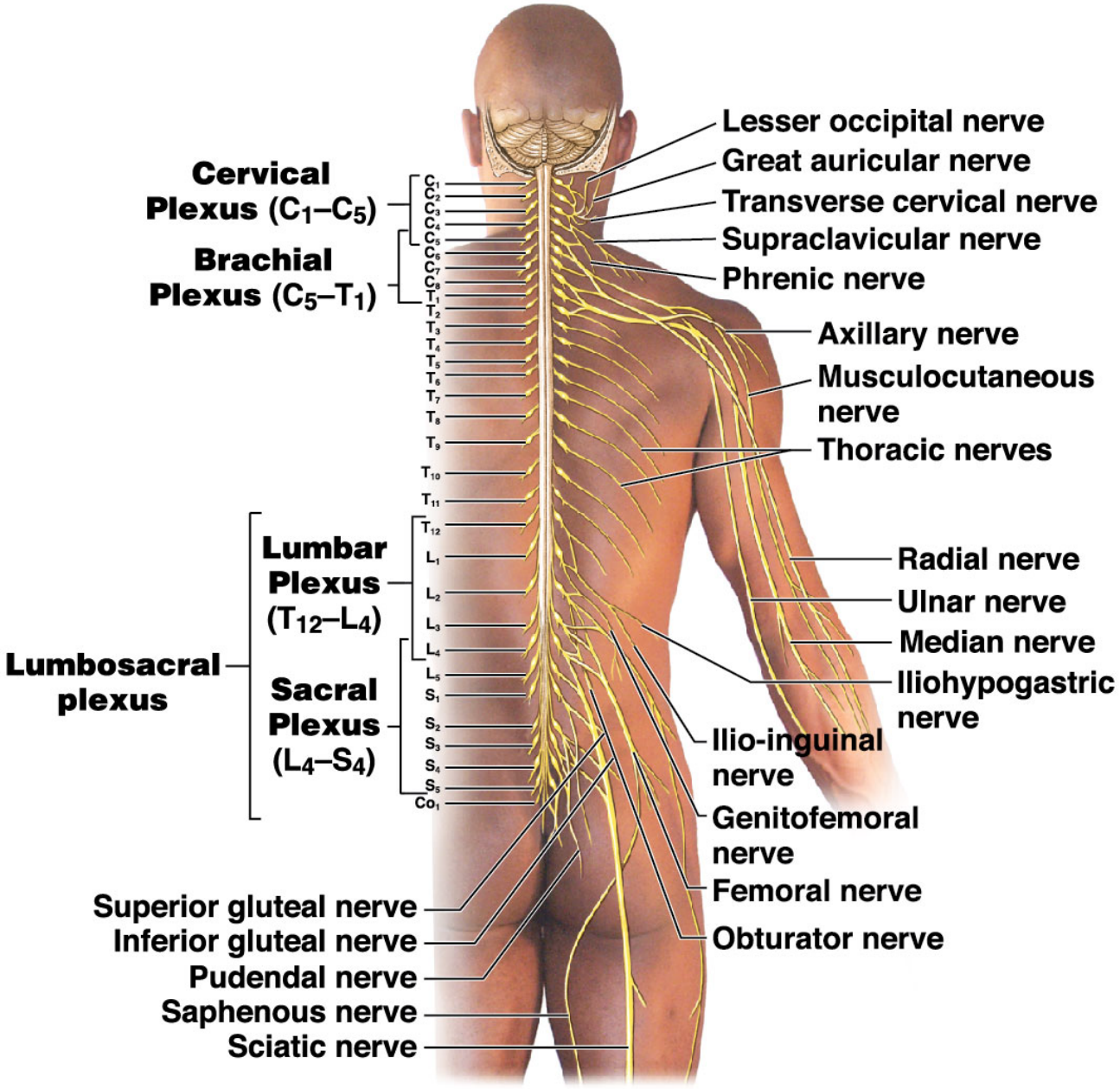
Learning Outcome: Describe the rami associated with spinal nerves.

Module 12.7: Spinal nerves form nerve plexuses that innervate the skin and skeletal muscles

Nerve plexus (*plexus*, braid)

- Complex, interwoven nerve network
- Formed during development
- Anterior rami of adjacent spinal nerves blend fibers to form plexuses
- 4 major nerve plexuses
  1. **Cervical plexus—**neck and diaphragm
  2. **Brachial plexus—**pectoral girdle, upper limb
  3. **Lumbar plexus—**pelvic girdle, lower limb
  4. **Sacral plexus—**pelvic girdle, lower limb

The major nerve plexuses



Module 12.7: Review

A. Define nerve plexus, and list the major nerve plexuses.
B. Which spinal nerves are *not* part of a nerve plexus?

Learning Outcome: Relate the distribution pattern of spinal nerves to the region they innervate.

Module 12.8: The cervical plexus innervates the muscles of the neck and diaphragm

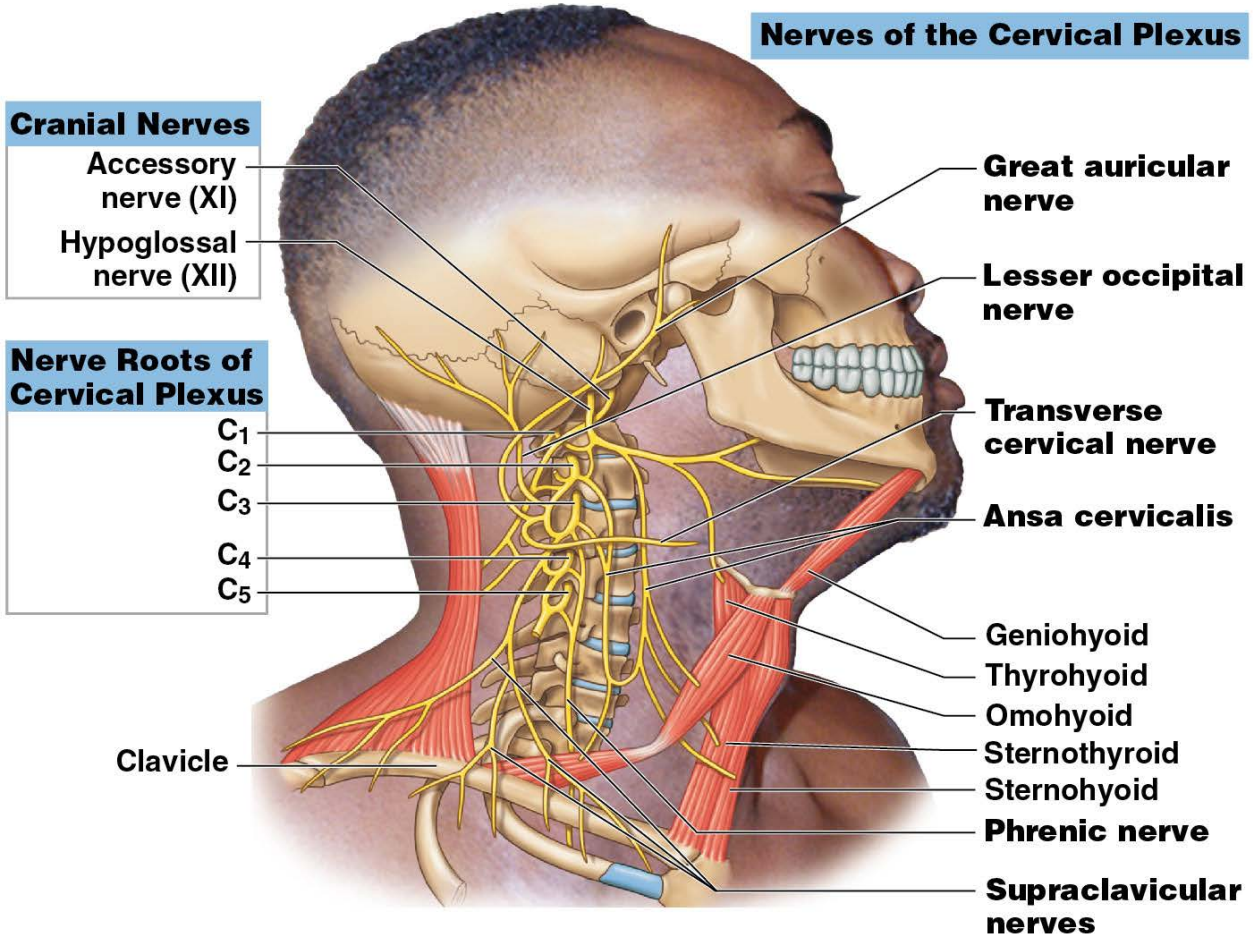
The cervical plexus

- From anterior rami of spinal nerves C_1–C_5
- Branches innervate skin/muscles of neck
- Extends into thoracic cavity

Phrenic nerve

- Formed by C_3–C_5
- Provides entire nerve supply to the diaphragm (breathing)

Module 12.8: The cervical plexus



Nerves of the Cervical Plexus

Nerve and Distribution	Spinal Segments
Great auricular	
Skin over the posterior aspect of the ear and the neck	C_2–C_3
Lesser occipital	
Skin of the neck and the scalp posterior and superior to the ear	C_2
Transverse cervical	
Skin of the anterior triangle of the neck	C_3–C_4
Ansa cervicalis	
Five of the extrinsic laryngeal muscles by way of the hypoglossal nerve (XII) Geniohyoid Thyrohyoid Omohyoid Sternothyroid Sternohyoid	C_1–C_4
Phrenic	
Diaphragm	C_3–C_5
Supraclaviculars	
Skin of the neck and shoulder	C_3–C_4

Module 12.8: Review

A. Damage to which nerve of the cervical plexus would interfere with the ability to breathe?

B. When an anesthetic blocks the function of the anterior rami of the cervical spinal nerves, which areas of the body will be affected?

Learning Outcome: Describe the cervical plexus.

Module 12.9: The brachial plexus innervates the pectoral girdle and upper limbs

The brachial plexus

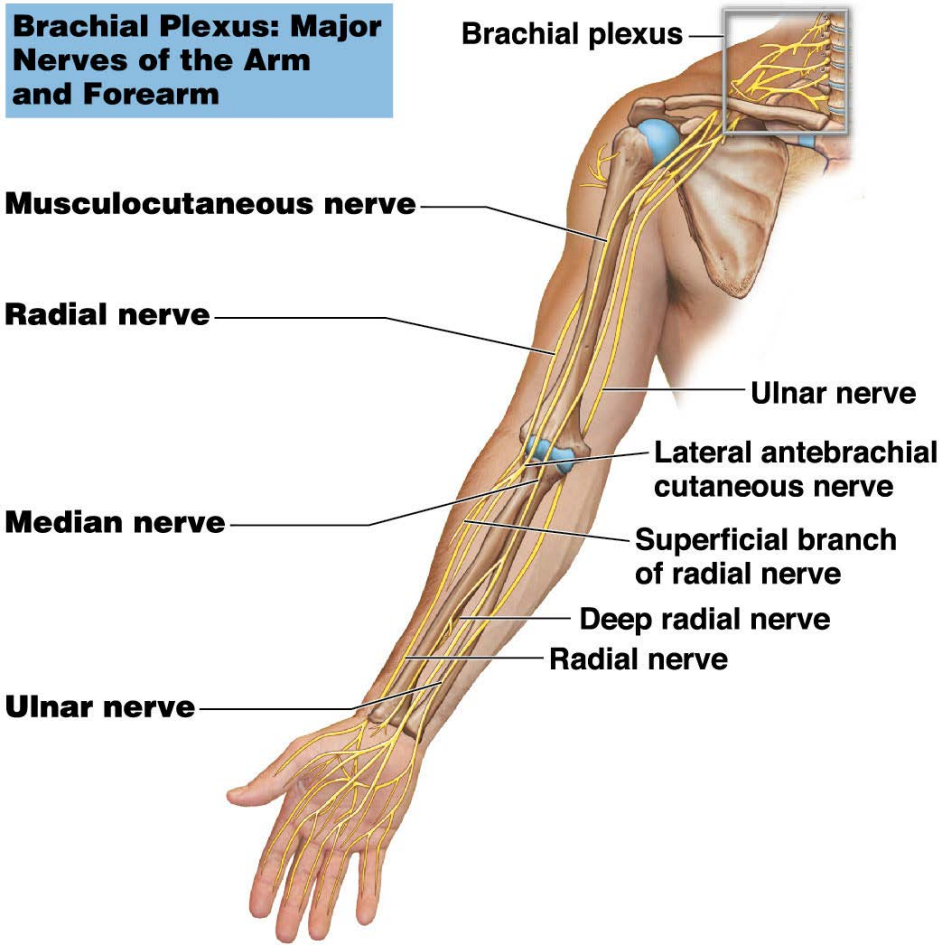
- Innervates pectoral girdle, upper back, upper limbs
- Anterior rami of C_5–T_1, form **trunks**; trunks split into **divisions**; divisions combine to form **cords**
- Most nerves of brachial plexus come off cords; a few originate at the trunks

Module 12.9: The brachial plexus innervates the pectoral girdle and upper limbs

Major brachial plexus nerves

- Musculocutaneous nerve
- Median nerve
- Ulnar nerve
- Axillary nerve
- Radial nerve

Module 12.9: The brachial plexus

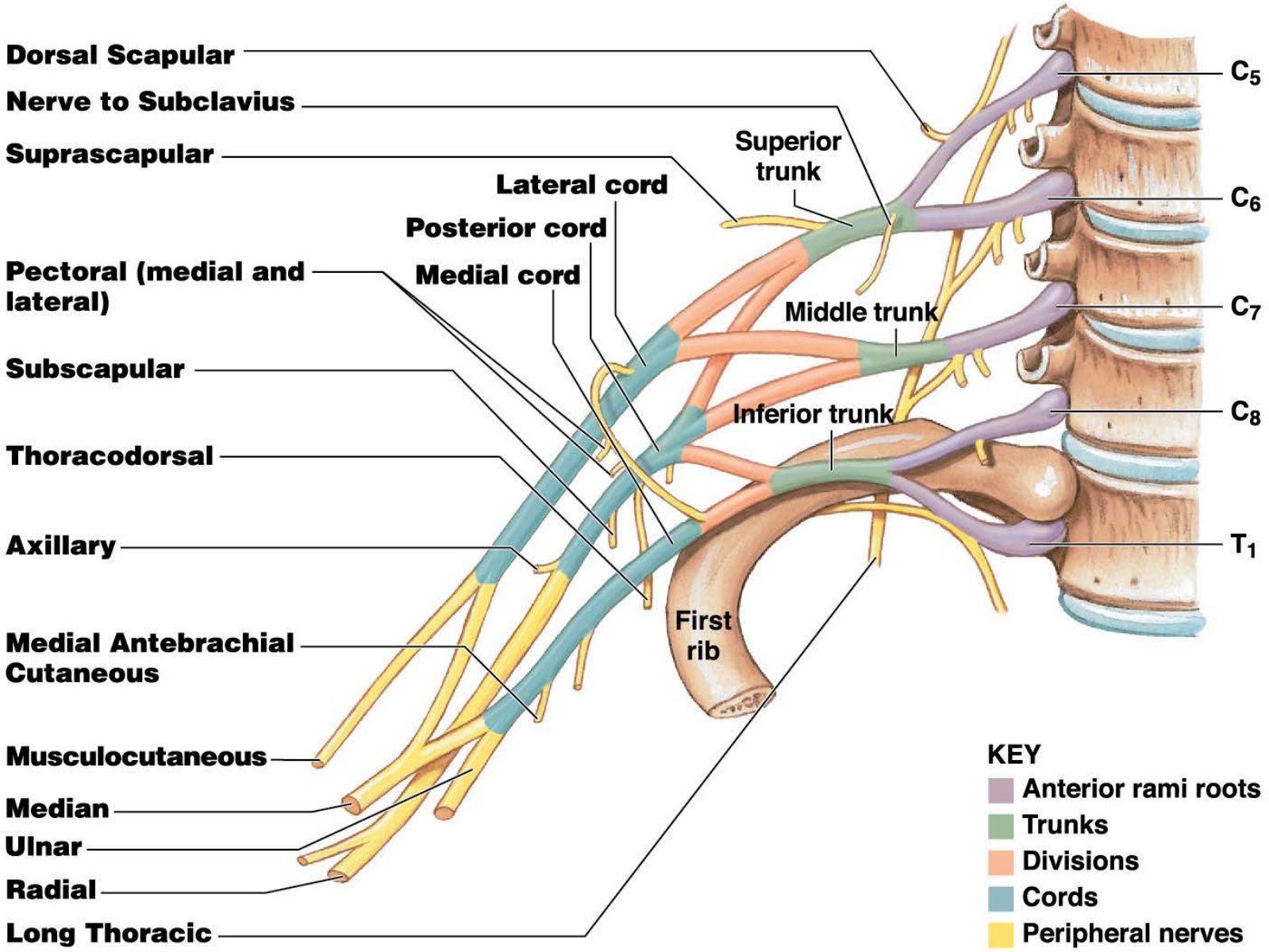


Brachial Plexus: Major Nerves of the Arm and Forearm

Spinal Segments*	Nerve and Distribution
	Musculocutaneous
C_5–T_1	Flexor muscles on the arm (biceps brachii, brachialis, and coracobrachialis); sensory from skin over the lateral surface of the forearm through the lateral antebrachial cutaneous nerve
	Radial
C_5–T_1	Many extensor muscles on the arm and forearm (triceps brachii, anconeus, extensor carpi radialis, extensor carpi ulnaris, and brachioradialis); and abductor pollicis muscle by the deep branch; sensory from skin over the postero-lateral surface of the limb through the posterior brachial cutaneus nerve, posterior antebrachial cutaneous nerve, and the superficial branch (radial half of the hand)
	Median
C_6–T_1	Flexor muscles on the forearm (flexor carpi radialis and palmaris longus muscles); pronator quadratus and pronator teres; digital flexors (through the anterior interosseous nerve); sensory from skin over the anterolateral surface of the hand
	Ulnar
C_8–T_1	Flexor carpi ulnaris, flexor digitorum profundus, adductor pollicis, and small digital muscles by the deep branch; sensory from skin over medial surface of the hand through the superficial branch

* The brachial plexus can also have fibers from C_4, T_2, or both.

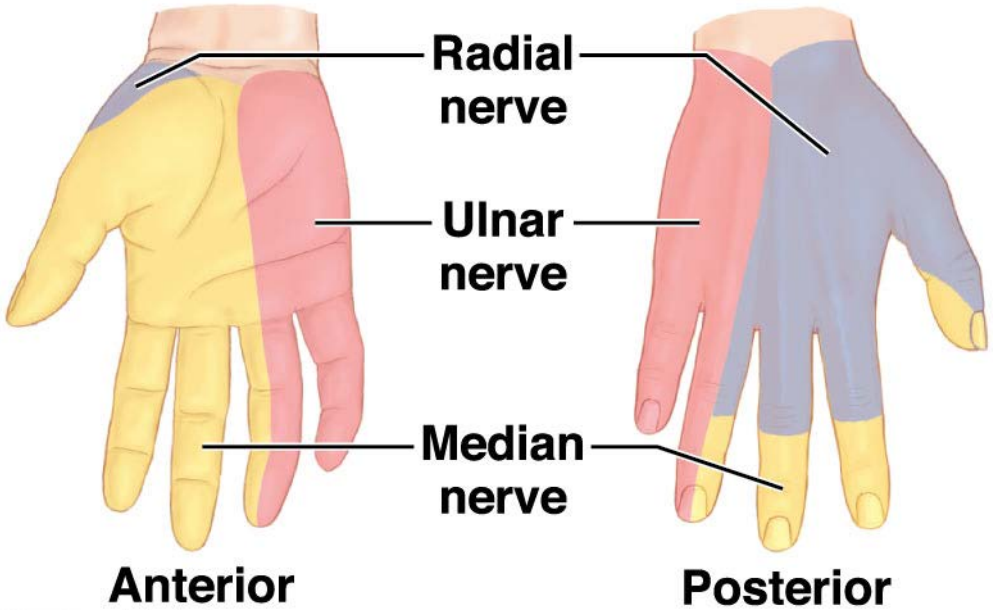
Nerves of the brachial plexus



Module 12.9: The brachial plexus

The brachial plexus (continued)

- Cutaneous nerve distribution to wrist/hand is clinically important
- Nerve damage can be precisely localized by testing sensory function of the hand



Module 12.9: Review

A. Describe the brachial plexus.
B. Define a nerve plexus trunk and cord.
C. Name the major nerves associated with the brachial plexus.

Learning Outcome: Relate the distribution pattern of the brachial plexus to its function.

Module 12.10: The lumbar and sacral plexuses innervate the skin and skeletal muscles of the trunk and lower limbs

Lumbar and sacral plexuses

- From lumbar and sacral segments of spinal cord
- Innervate lower trunk, pelvic girdle, lower limbs

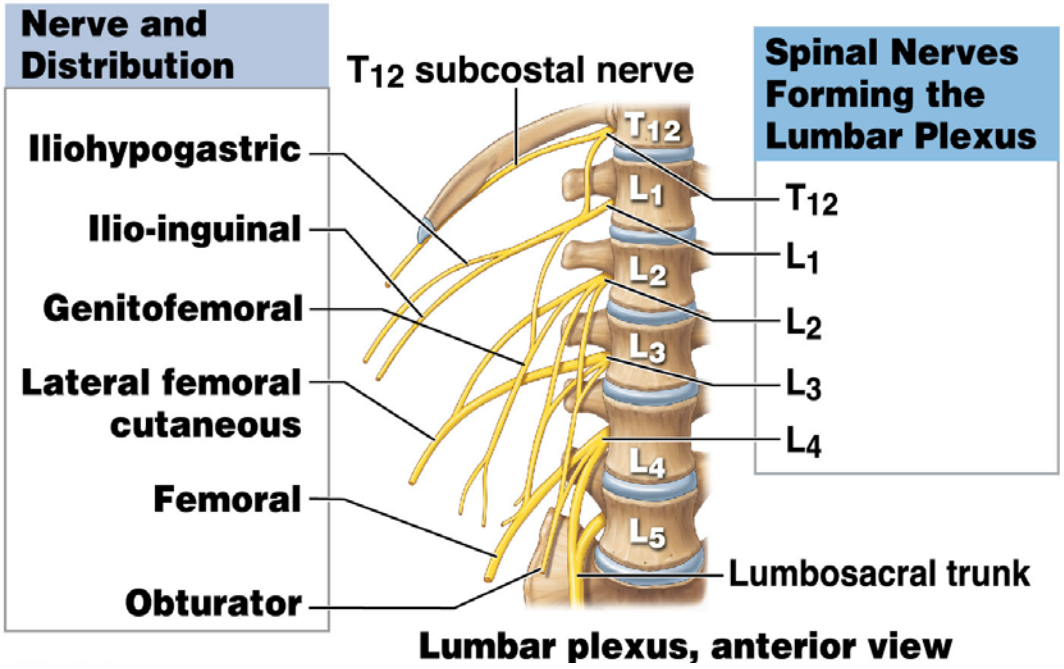
The lumbar plexus

- Formed from spinal nerves T_{12}–L_4
- Lumbosacral trunk—L_4 branches contribute to sacral plexus

The sacral plexus

- Formed from spinal nerves L_4–S_4
- Contains the **sciatic nerve**—largest/longest nerve in body

The lumbar plexus

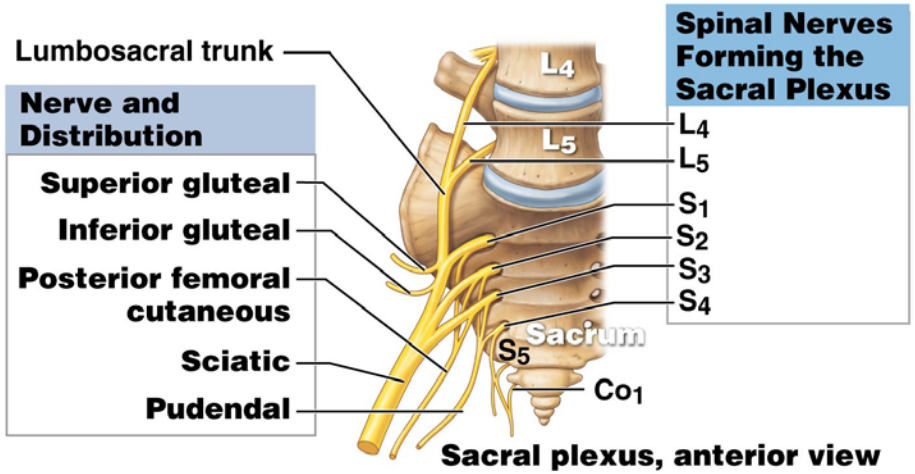


Lumbar plexus, anterior view

Lumbar Plexus

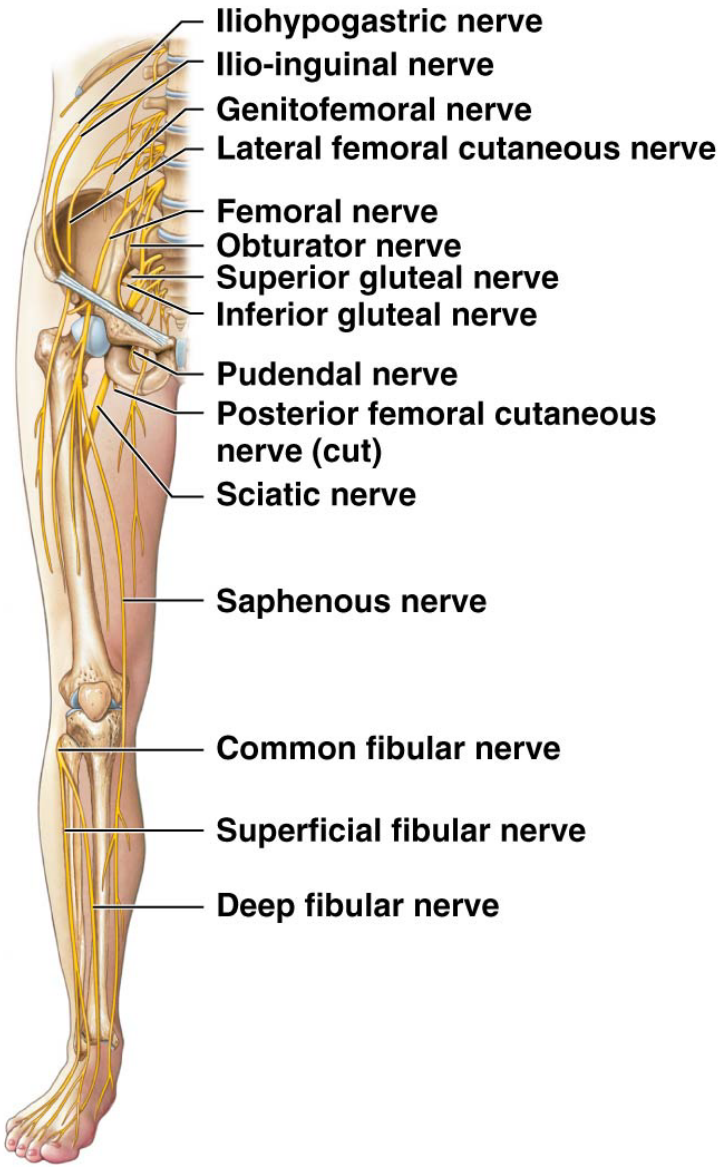
Spinal Segments	Nerve and Distribution
	Iliohypogastric
T_{12}–L_1	External and internal oblique and transverse abdominis; skin over the inferior abdomen and buttocks
	Ilio-inguinal
L_1	Abdominal muscles (with iliohypogastric nerve); skin over superior, medial thigh and portions of external genitalia
	Genitofemoral
L_1–L_2	Skin over anteromedial thigh and portions of external genitalia
	Lateral femoral cutaneous
L_2–L_3	Skin over anterior, lateral, and posterior thigh
	Femoral
L_2–L_4	Quadriceps, sartorius, pectineus, and iliopsoas; skin of the anteromedial thigh and medial surface of the leg and foot
	Obturator
L_2–L_4	Gracilis and adductor magnus, brevis, and longus; skin from the medial surface of the thigh

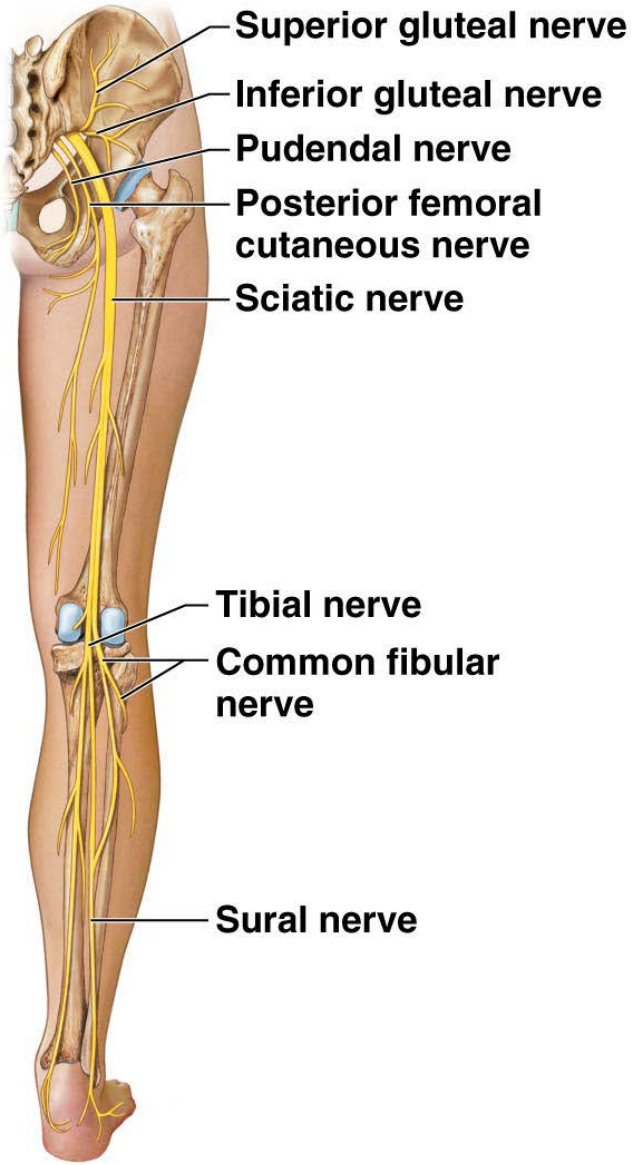
The sacral plexus



Sacral Plexus	
Spinal Segments	**Nerve and Distribution**
	Superior gluteal
L_4–S_2	Gluteus minimus, gluteus medius, and tensor fasciae latae
	Inferior gluteal
L_5–S_2	Gluteus maximus
	Posterior femoral cutaneous
S_1–S_3	Skin over perineum and posterior thigh and leg
	Sciatic
L_4–S_3	Semimembranosus, semitendinosus, and adductor magnus; branches into tibial and common fibular nerves
	Pudendal
S_2–S_4	Muscles of the perineum; skin of external genitalia; bulbospongiosus and ischiocavernosus

Nerves of the lumbar and sacral plexuses

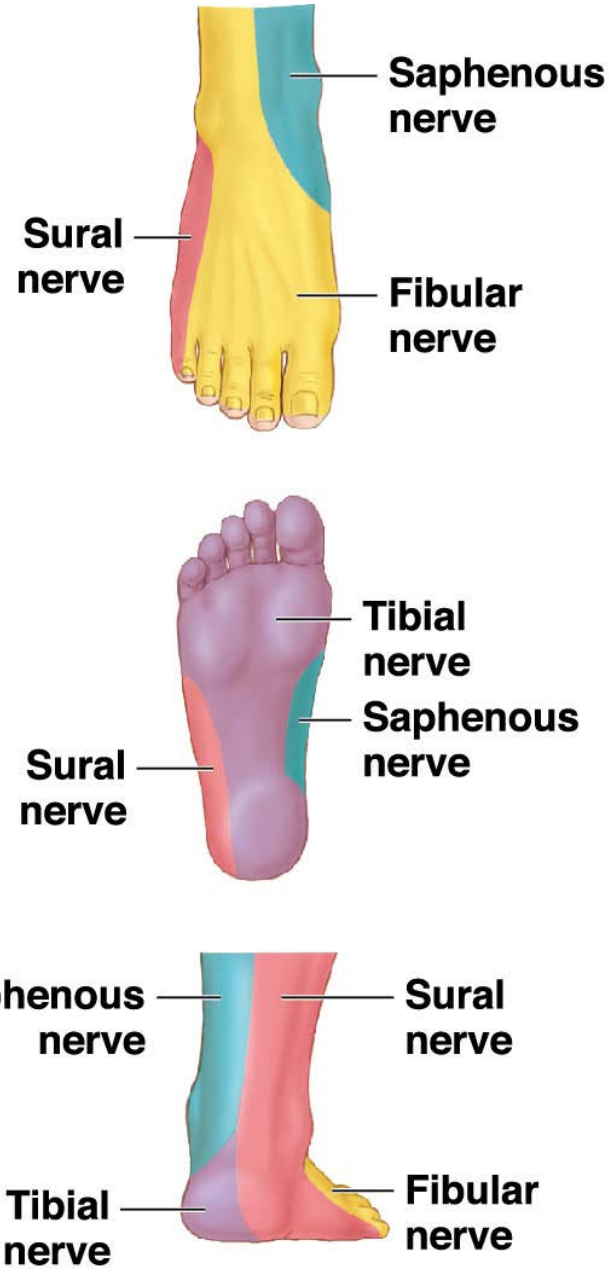




Module 12.10: Lumbar and sacral plexus

Sensory innervation of foot

- Nerves supplying foot and ankle:
  - Saphenous nerve
  - Sural nerve
  - Common fibular nerve
  - Tibial nerve
- As in hand, mapping sensory perception can determine damage to specific peripheral nerves.



Module 12.10: Review

A. Describe the lumbar plexus and sacral plexus.
B. List the major nerves of the sacral plexus.
C. Which nerve divides into the tibial nerve and common fibular nerve?

Learning Outcome: Relate the distribution patterns of the lumbar plexus and sacral plexus to their functions.

Section 2: Introduction to Reflexes

Learning Outcomes

12.11 Discuss the significance of neuronal pools, and describe their major patterns of neuron interaction.

12.12 Describe the steps in a reflex.

12.13 Describe the steps in the stretch reflex.

12.14 Explain withdrawal reflexes and crossed extensor reflexes and the responses produced by each.

12.15 CLINICAL MODULE Explain the value of reflex testing and how the brain may control and modify reflex responses.

Module 12.11: CNS neurons are grouped into neuronal pools, which form neural circuits

Neuronal pools

- Functional groups of interconnected neurons
  - May involve neurons in several regions of the brain
  - May involve neurons in one specific CNS location
- Number of pools estimated between a few hundred and a few thousand
- Pattern of interaction reflects function of the pool
- Most complex processing occurs in brain
- Simplest circuits are in PNS and spinal cord; control automatic responses of reflexes

Module 12.11: Neural circuits

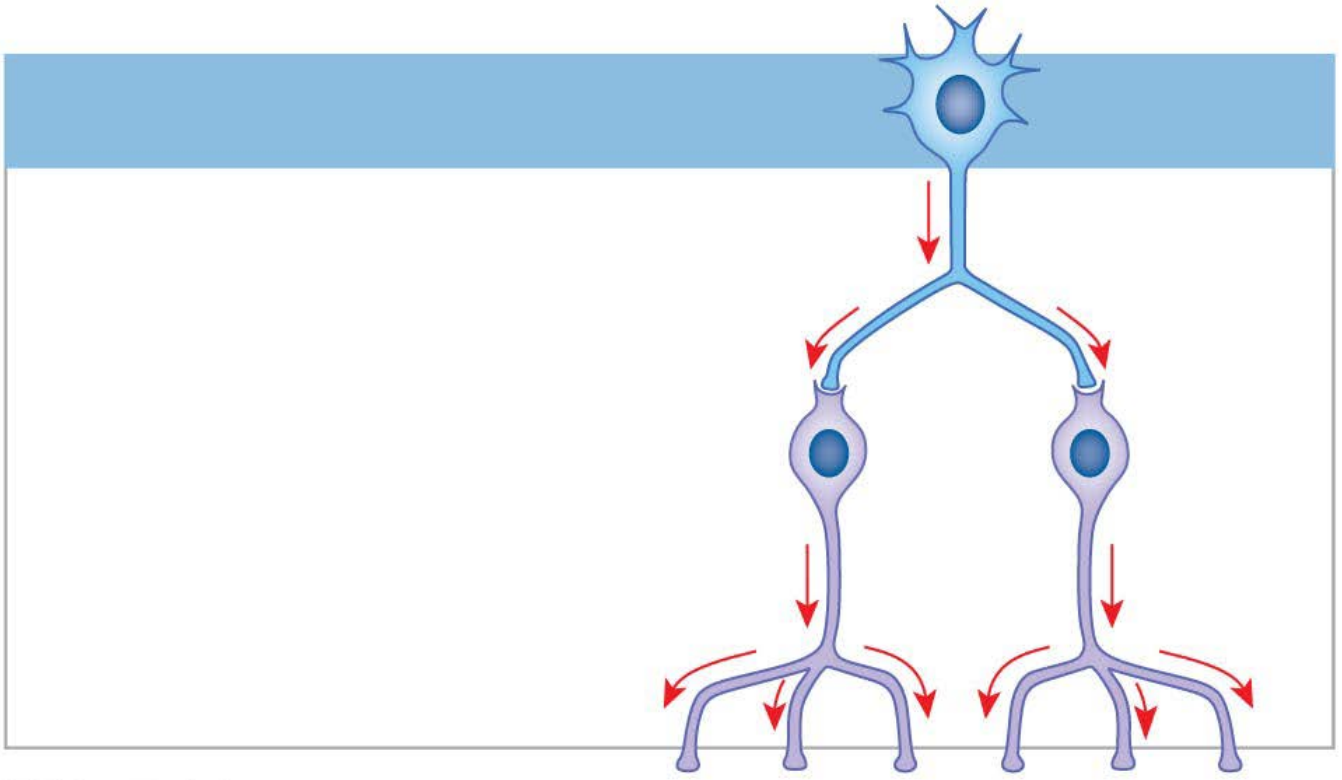
Neural circuit

- “Wiring diagram” of neuron interaction
- Common patterns include:
  - Divergence
  - Parallel processing
  - Serial processing
  - Convergence
  - Reverberation

Module 12.11: Neural circuits

Divergence

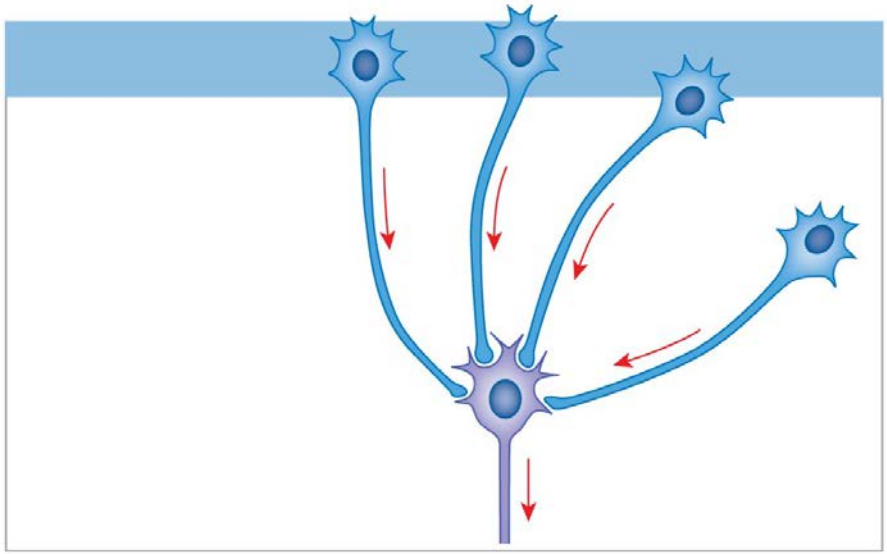
- Spreads information from one neuron to several, or from one pool to several pools
- Allows broad distribution of specific input



Module 12.11: Neural circuits

Convergence

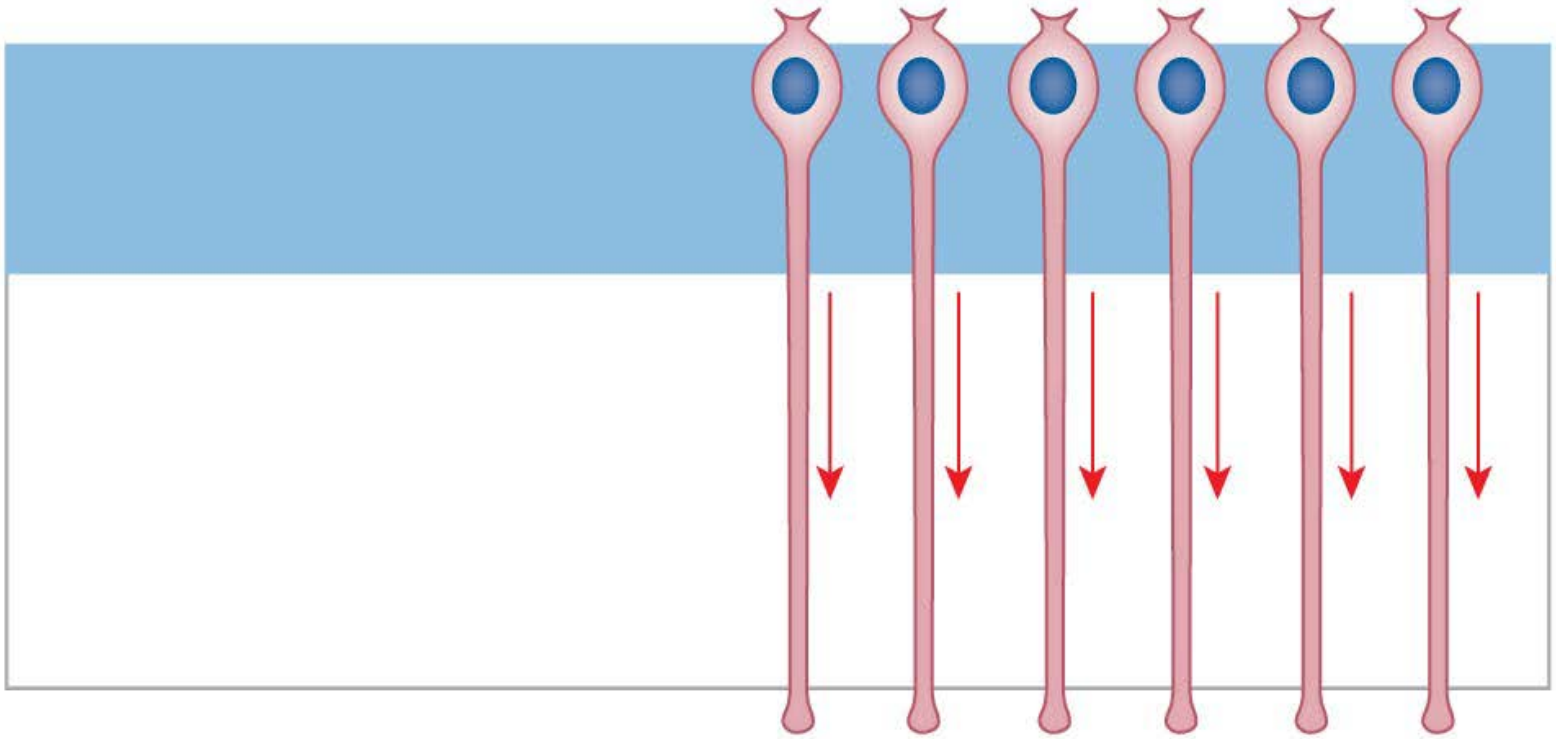
- Several neurons synapse on a single postsynaptic neuron
- Motor neurons—can experience both conscious and unconscious control
- *Example*: voluntary adjustment to normal (automatic) breathing depth and rate



Module 12.11: Neural circuits

Parallel processing

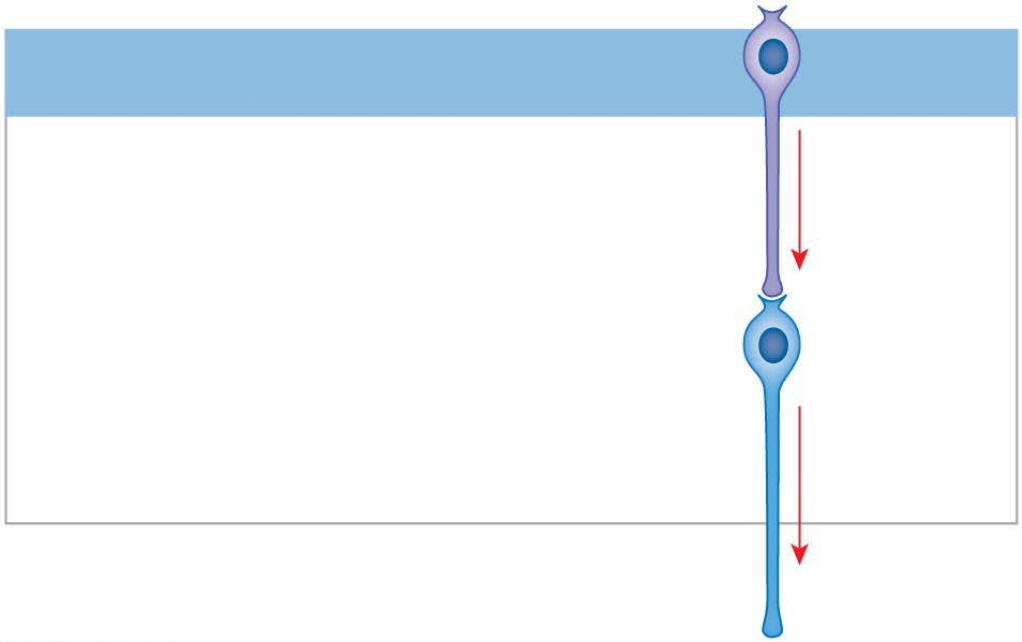
- Several neurons or neuronal pools process the same information simultaneously
- Requires divergence prior to this process



Module 12.11: Neural circuits

Serial processing

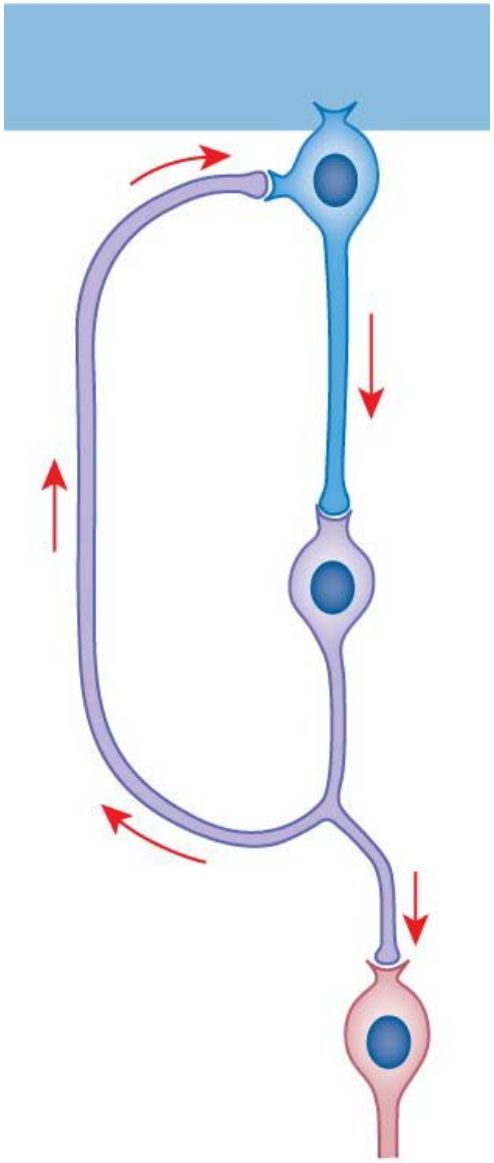
- Information relayed in stepwise fashion from one neuron to the next, or from one neuronal pool to another neuronal pool
- *Example*: sensory information relayed from one part of brain to another part



Module 12.11: Neural circuits

Reverberation

- Collateral branches of axons along circuit; extend back toward the source of impulse and keep stimulating presynaptic neurons
- Positive feedback loop
- Continues until synaptic fatigue or inhibitory stimuli end cycle



Module 12.11: Review

A. Differentiate between divergent and convergent neural circuits.
B. Which kind of neural circuit processes information in a stepwise fashion, one neuron to another?
C. Where does the simplest processing occur?

Learning Outcome: Discuss the significance of neuronal pools, and describe their major patterns of neuron interaction.

Module 12.12: Reflexes are vital to homeostasis

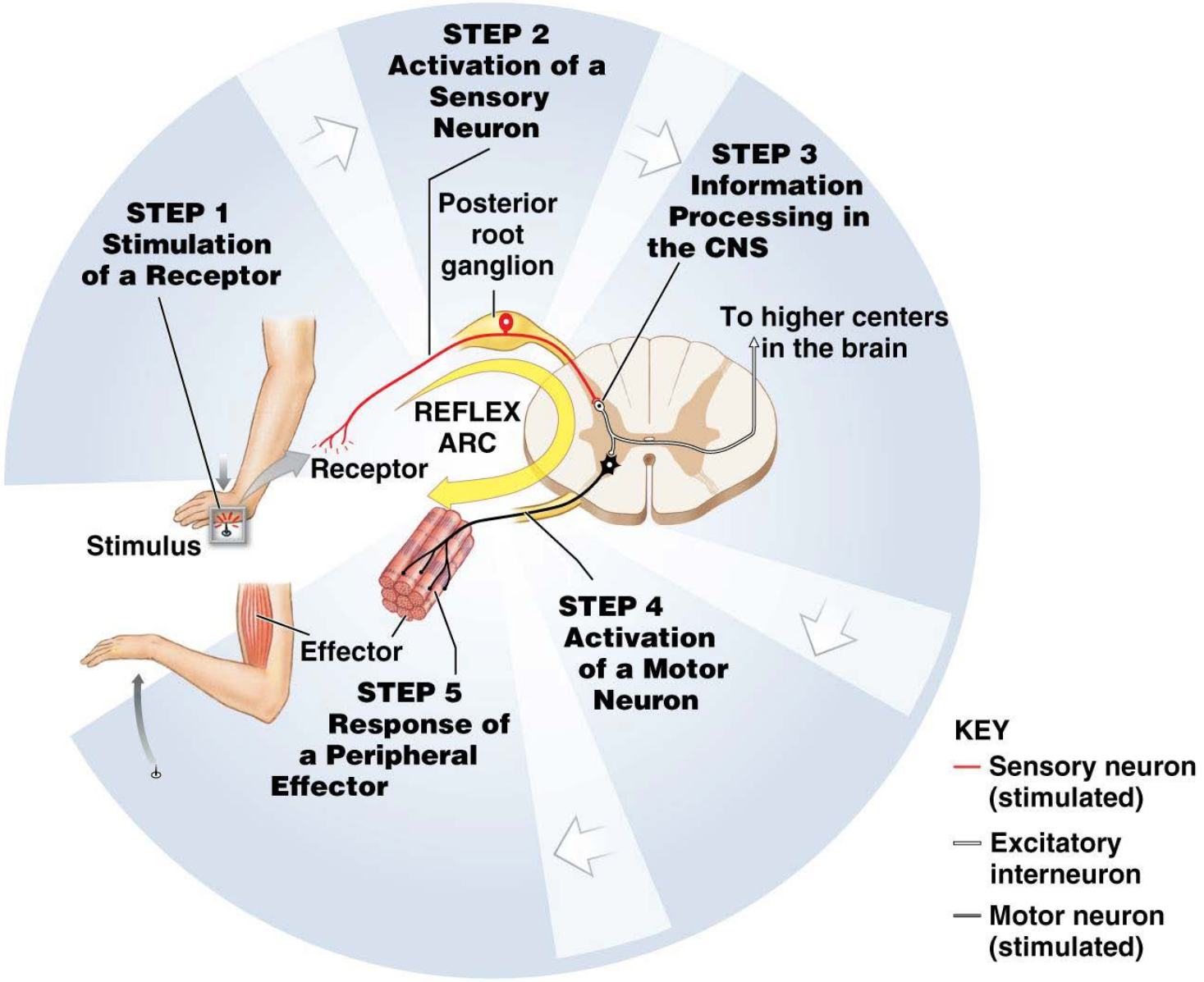
Reflexes

- Rapid, automatic responses to specific stimuli
- Preserve homeostasis through rapid adjustments in organ/organ system function
- Little variability in response

5 components of a reflex arc

1. *Stimulation* of a receptor
2. *Activation* of a sensory neuron
3. Information *processing* in the CNS
4. *Activation* of a motor neuron
5. *Response* of a peripheral effector

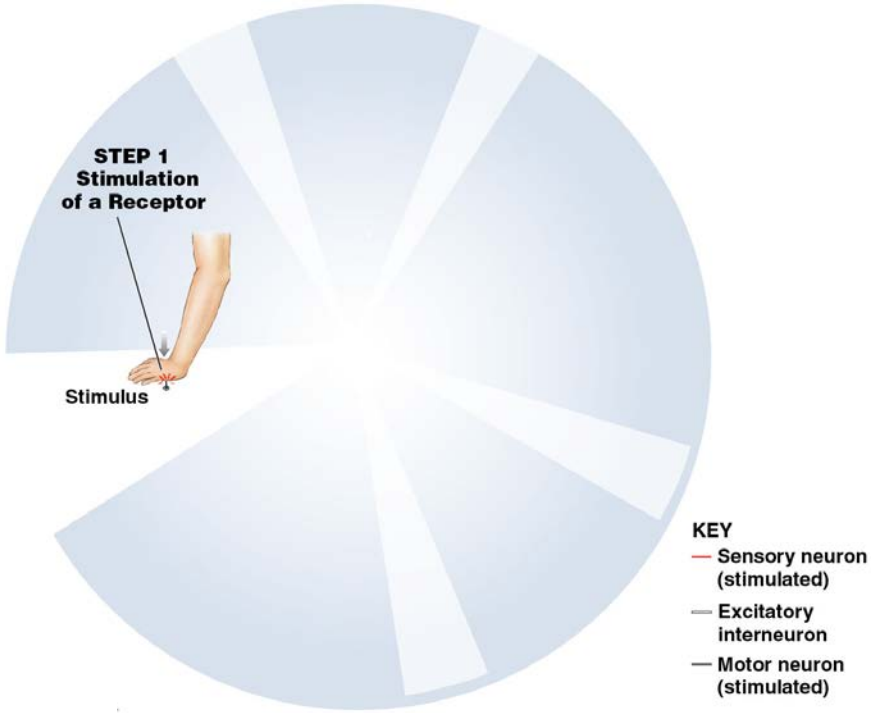
The steps of a simple reflex arc



Module 12.12: Reflexes

Steps in a simple reflex arc

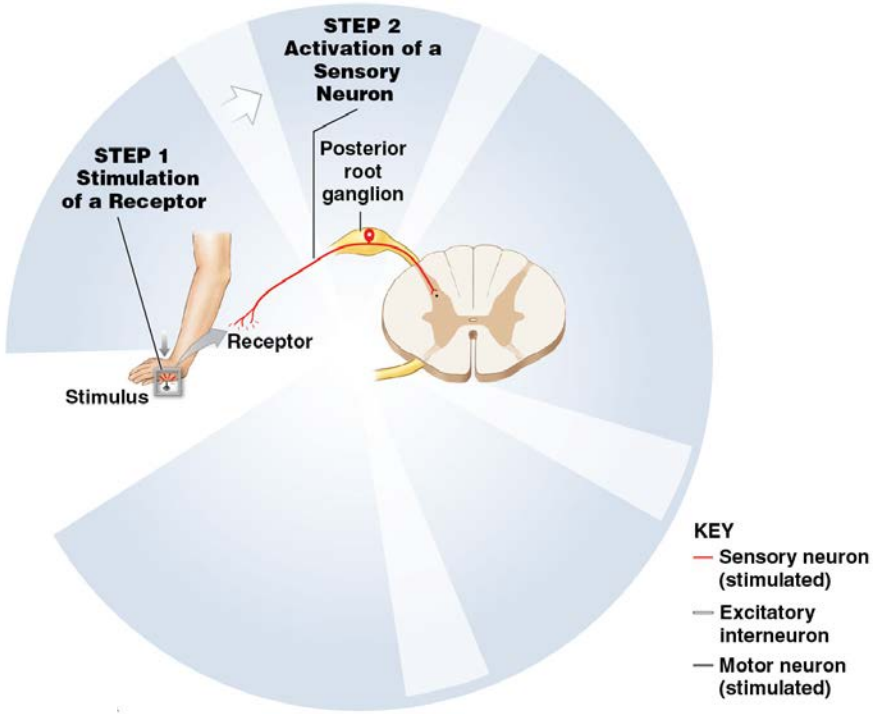
1. **Activation of a receptor by a stimulus**
   - Receptor can be specialized cell or dendrites of a sensory neuron; detect physical or chemical changes
     - *Example*: Lean on tack, stimulates pain receptors



Module 12.12: Reflexes

2. Activation of a sensory neuron

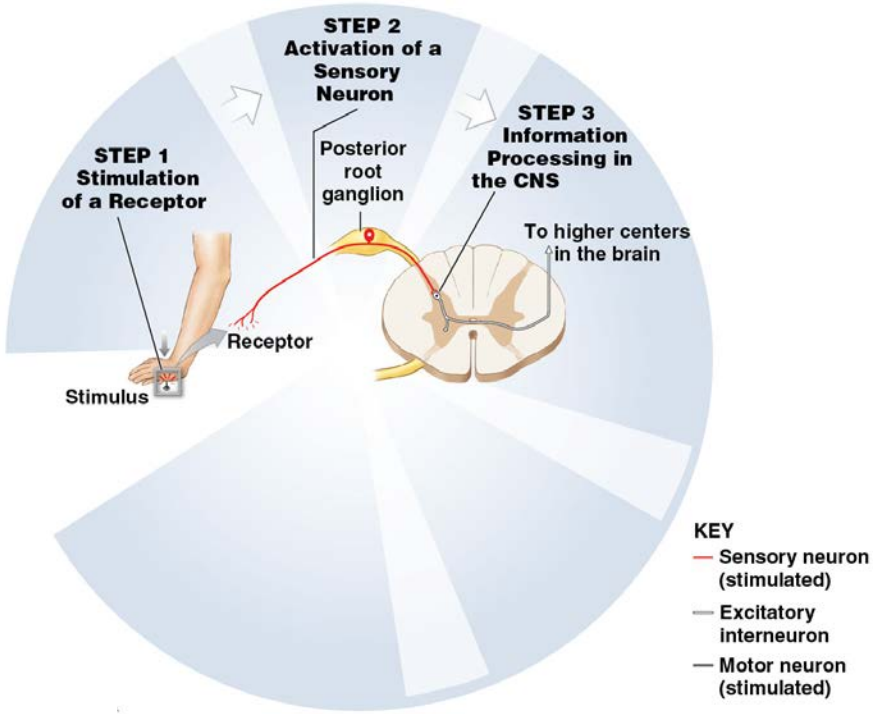
- Stimulation of dendrites produces graded polarization
- Generates action potentials in sensory neurons; signal enters spinal cord through posterior root



Module 12.12: Reflexes

3. Information processing in the CNS

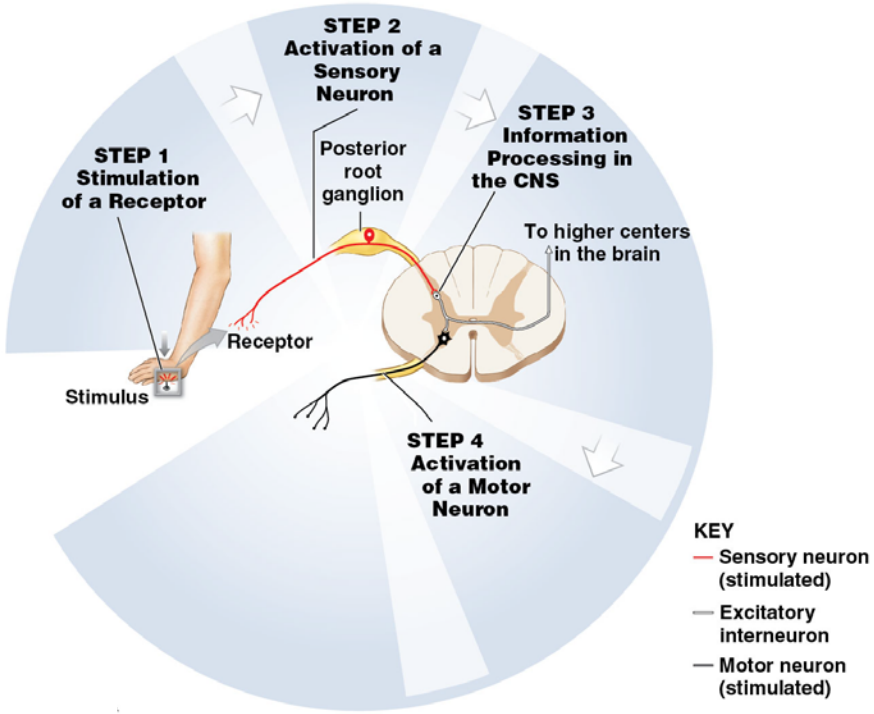
- Sensory neuron releases neurotransmitter, causes excitatory postsynaptic potentials (EPSPs) at interneuron
- Signals integrated with others arriving at same time.



Module 12.12: Reflexes

4. Activation of a motor neuron

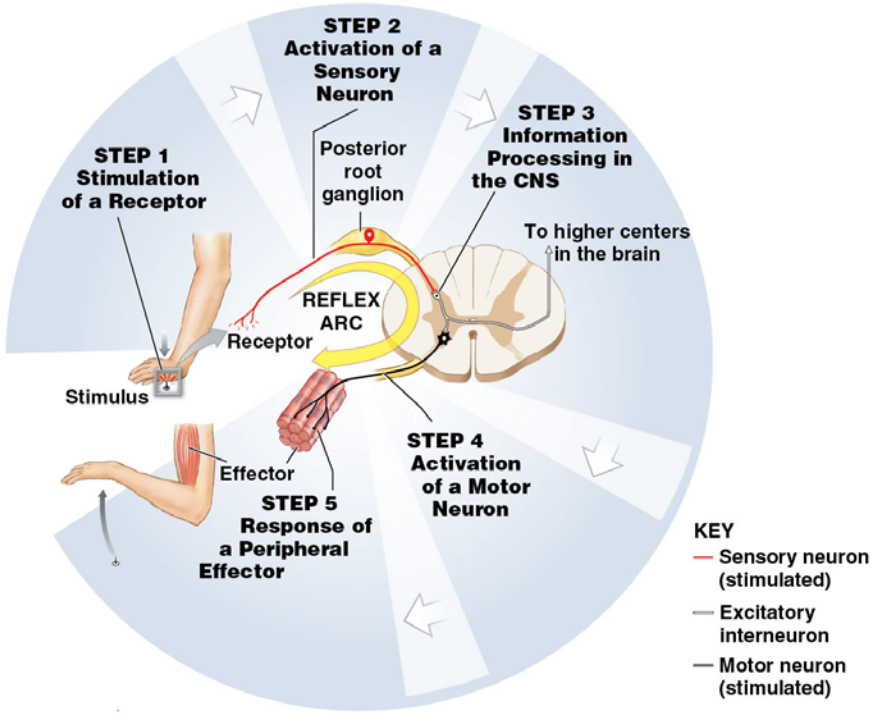
- Interneuron stimulates motor neurons that carry action potentials to periphery
- Simultaneously, collaterals from interneuron may send pain sensations to other areas in CNS



Module 12.12: Reflexes

5. Response of a peripheral effector

- Motor neuron(s) release neurotransmitters at axon terminals; stimulates effector to respond
- *Example*: skeletal muscle contraction to pull away from tack



Module 12.12: Reflexes

Classification of reflexes

- **4 Classes:**
  1. **Development**—innate or acquired
  2. **Nature of response—**somatic or visceral
  3. **Complexity of circuit—**monosynaptic or polysynaptic
  4. **Processing site—**spinal or cranial

Module 12.12: Reflexes

Development of reflexes—*innate* or *acquired*

- **Innate reflexes**
  - Basic neural reflexes formed before birth
  - Appear in predictable developmental sequence from simplest to more complex
- **Acquired reflexes** (*conditioned reflexes*)
  - Rapid, automatic learned motor patterns
  - Repetition enhances them

Module 12.12: Reflexes

Nature of response—*somatic* or *visceral*

- **Somatic reflexes**
  - Involuntary control of skeletal muscles
  - Immediate—important in emergencies
  - Example—withdrawal reflex
- **Visceral reflexes** (*autonomic reflexes*)
  - Control involuntary effectors
    - Smooth muscle
    - Cardiac muscle
    - Glands
    - Adipose tissue

Module 12.12: Reflexes

Complexity of circuit—*monosynaptic* or *polysynaptic*

- **Monosynaptic reflexes**
  - Single synapse—simplest reflex arcs
  - Sensory neuron synapses directly with motor neuron (no interneuron)
  - Fast response
- **Polysynaptic reflexes**
  - At least one interneuron between sensory neuron and motor neuron
  - Slower response; delay increases with number of synapses involved (longer path = longer delay)

Module 12.12: Reflexes

Processing site—*spinal* or *cranial*

- Spinal reflexes
  - Processing occurs in spinal cord
  - **Intersegmental reflexes**—involve multiple segments of spinal cord
- Cranial reflexes
  - Processing occurs in brain

Classification of reflexes

Development	
Innate reflexes	Acquired reflexes

Nature of the Response	
Somatic reflexes	Visceral reflexes

Complexity of the Circuit	
Monosynaptic reflex	Polysynaptic reflexes

Processing Site	
Spinal reflexes	Cranial reflexes

Module 12.12: Review

A. What are common characteristics of reflexes?
B. List the components of a reflex arc.
C. Describe the various classifications of neural reflexes.

Learning Outcome: Describe the steps in a reflex.

Module 12.13: The stretch reflex is a monosynaptic reflex involving muscle spindles

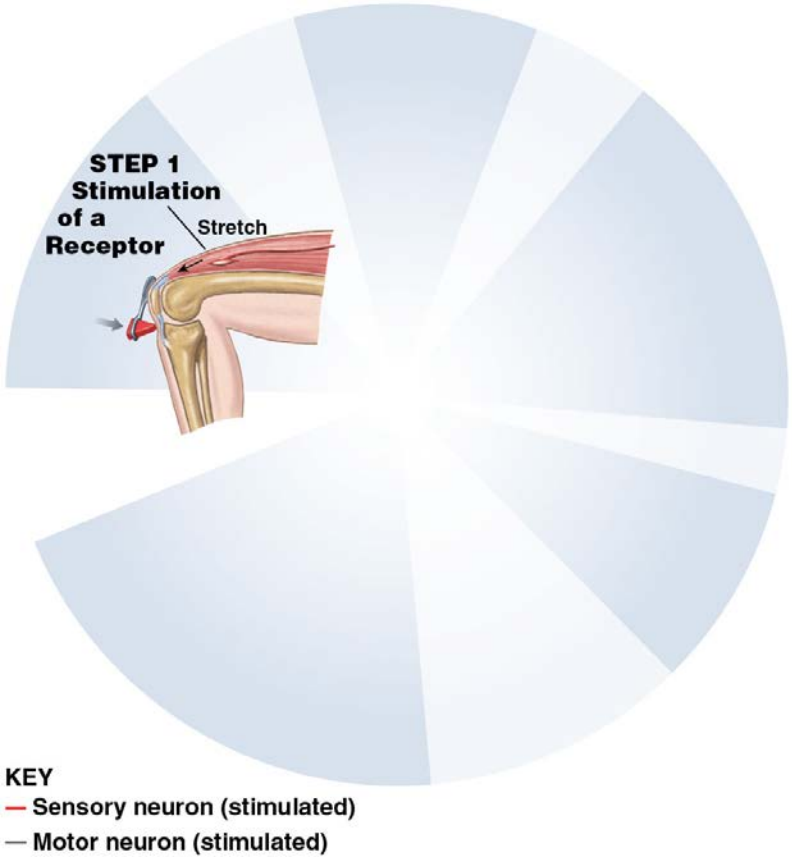
Stretch reflex

- Best known monosynaptic reflex
- Automatically regulates skeletal muscle length
  - Stimulus: increasing muscle length
  - Sensory neuron triggers immediate motor response (contraction of stretched muscle)
  - *Example*: **Patellar (knee-jerk) reflex**

Module 12.13: The stretch reflex

Steps in the patellar reflex

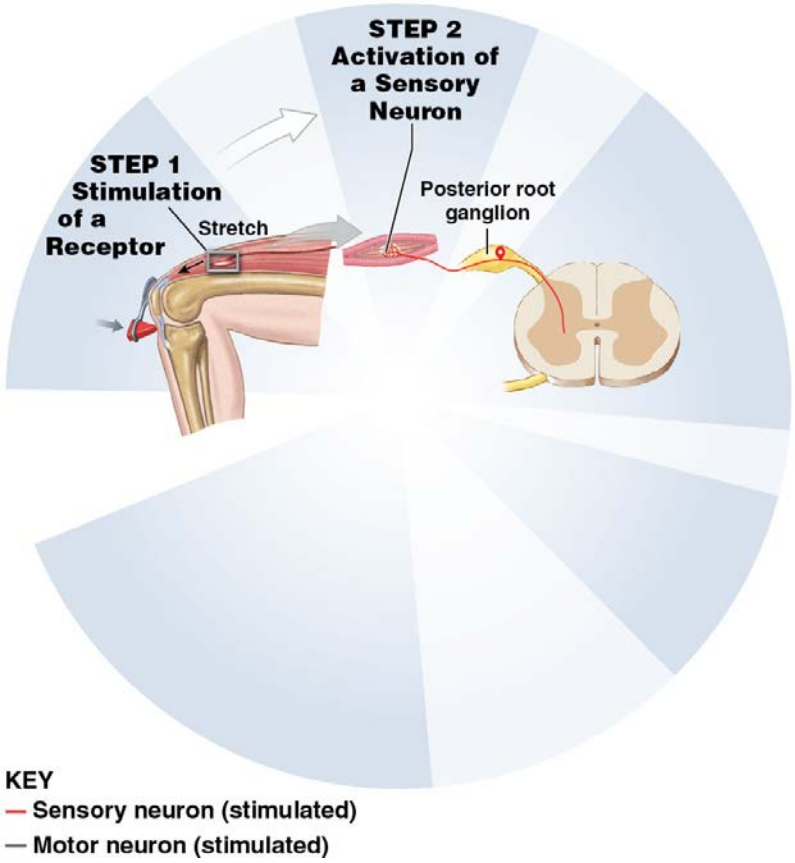
1. **Stimulation of a receptor**
   - Tapping patellar ligament stretches fibers in quadriceps femoris muscle



Module 12.13: The stretch reflex

2. Activation of a sensory neuron

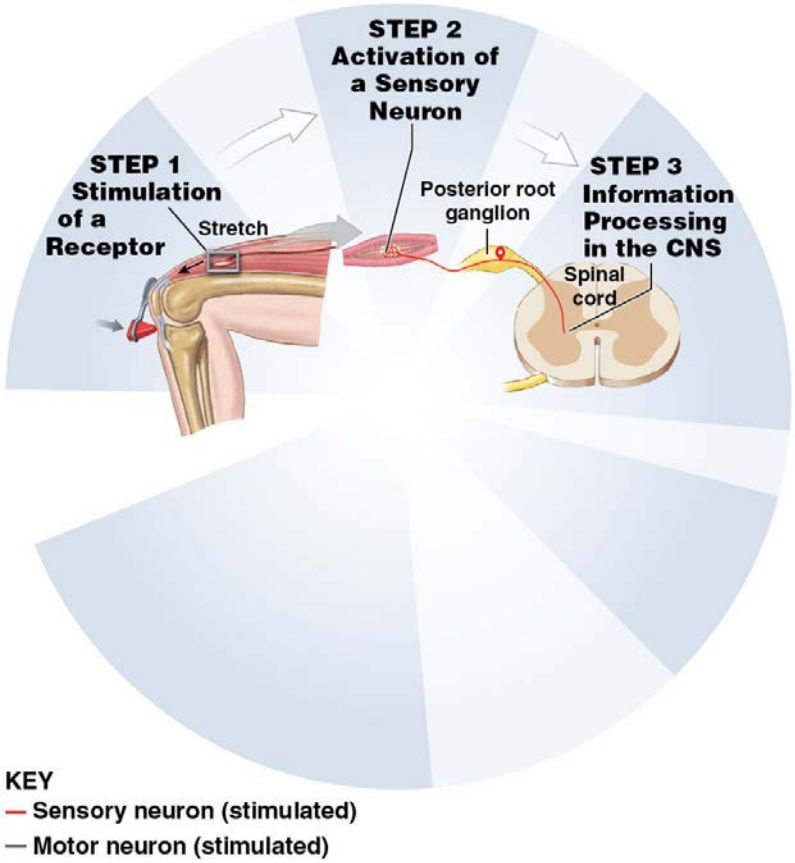
- Distortion of stretch receptors stimulates sensory neurons
- Sensory neurons enter spinal cord; synapse directly with motor neurons of the motor units in stretched muscle



Module 12.13: The stretch reflex

3. Information processing in CNS

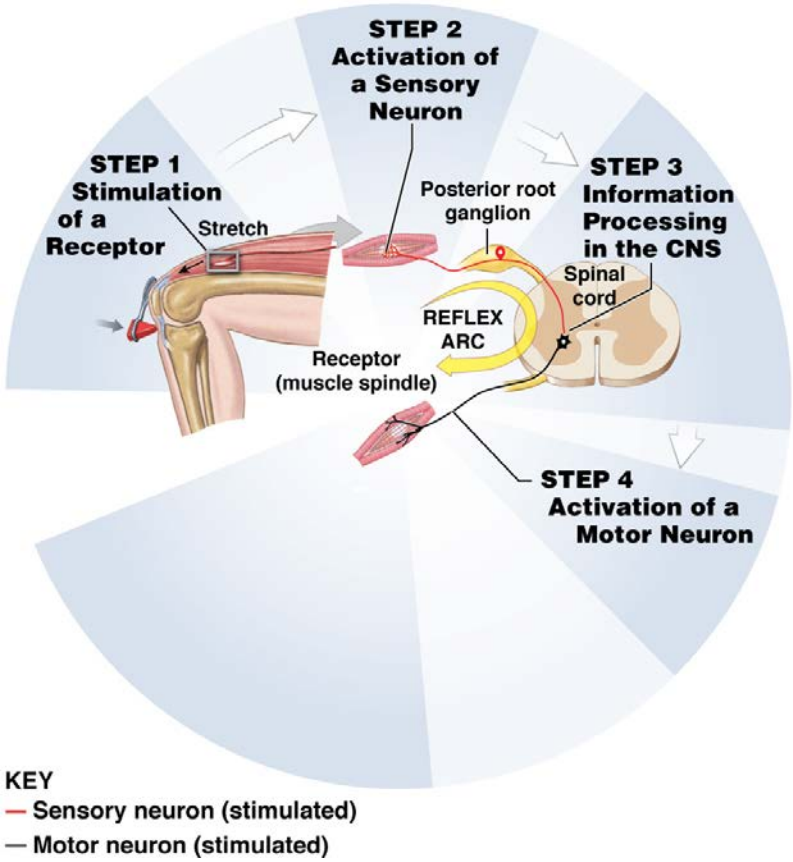
- Occurs at cell body of the motor neuron—no interneuron
- Sufficient stimulation activates the motor neuron



Module 12.13: The stretch reflex

4. Activation of a motor neuron

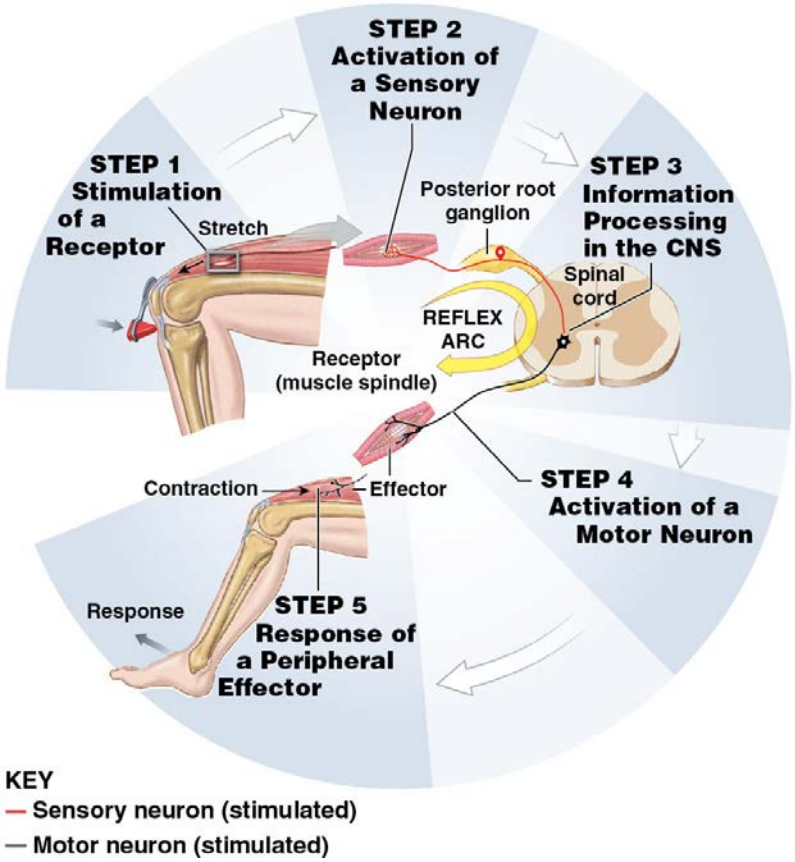
- Once activated, motor neuron sends action potential to the effector—quadriceps femoris



Module 12.13: The stretch reflex

5. Response of peripheral effector

- Skeletal muscle fibers of stretched muscle are stimulated to contract
- Quadriceps femoris extends knee in a brief kick

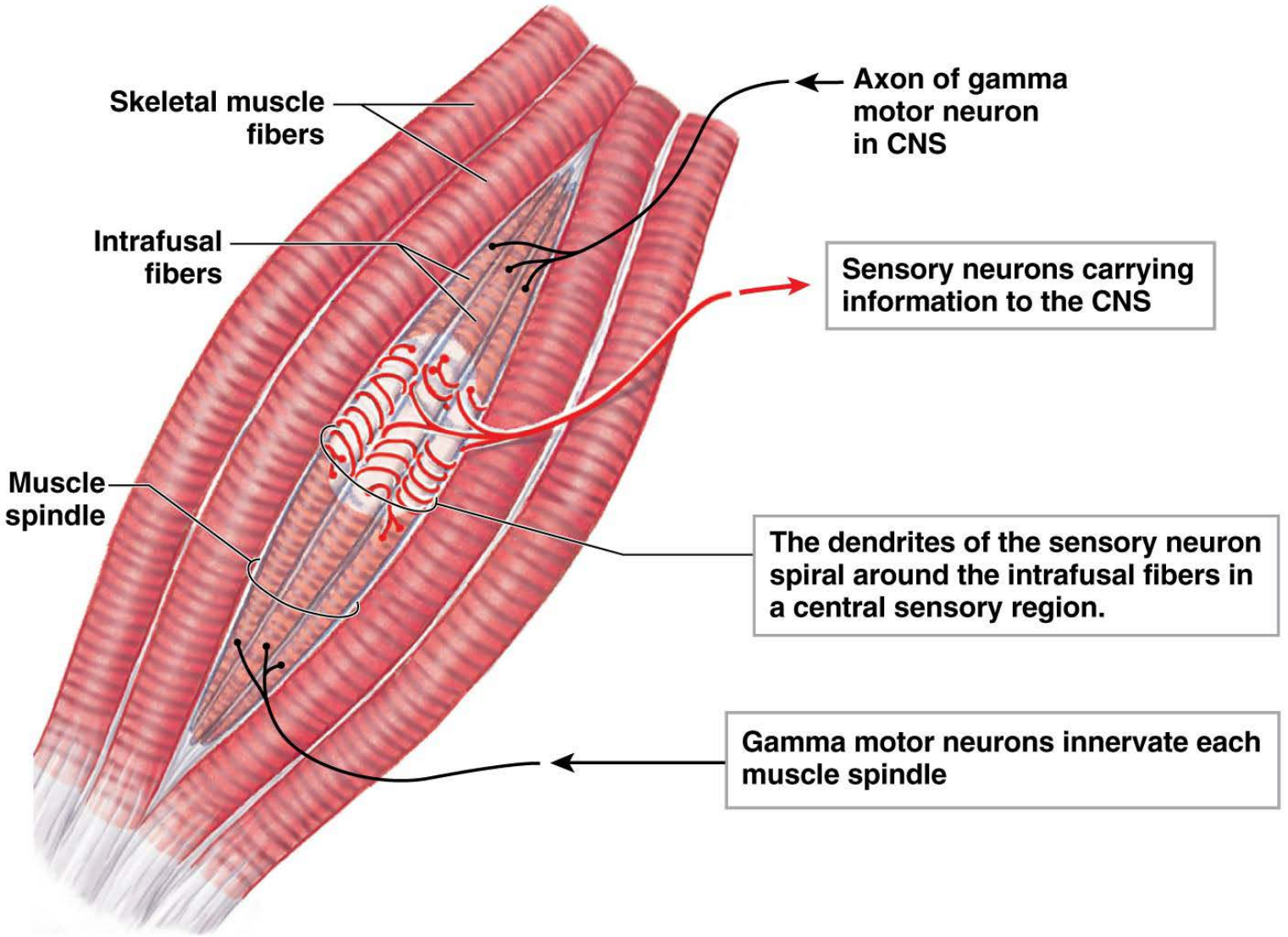


Module 12.13: The stretch reflex

Muscle spindles = Sensory receptors for stretch reflex

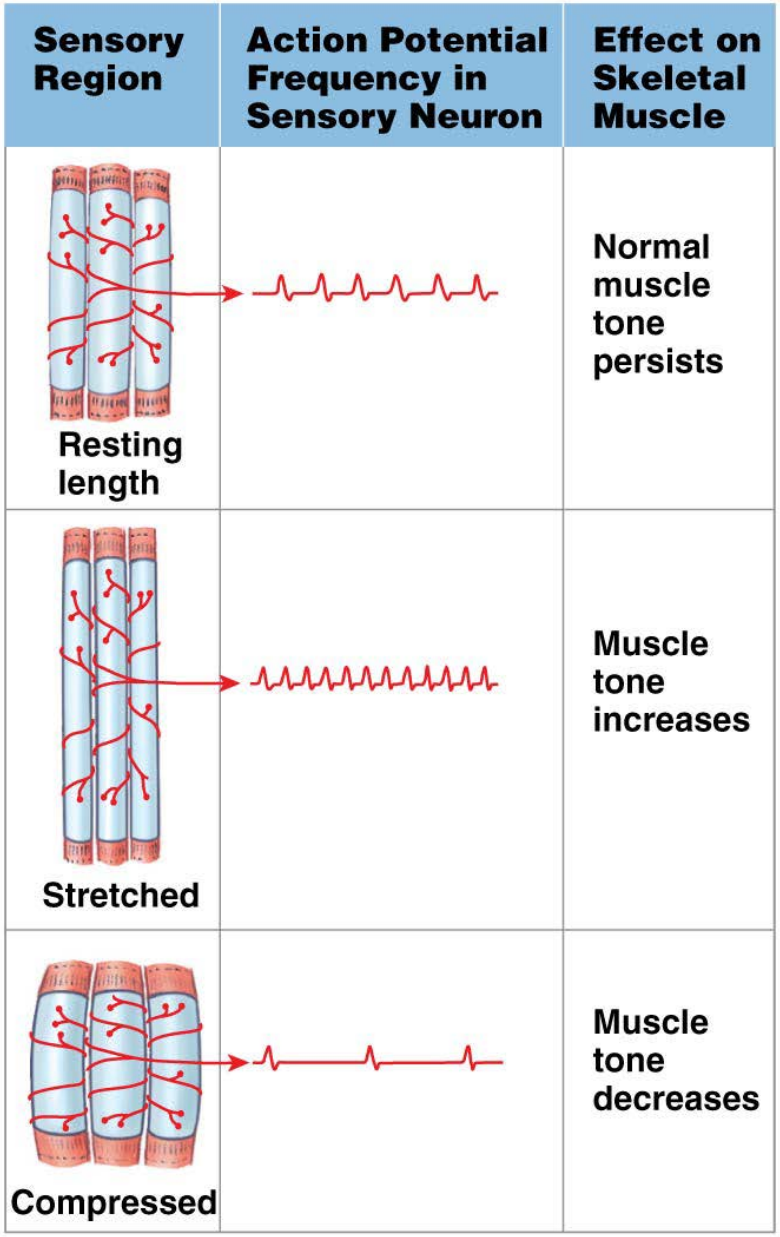
- Made of intrafusal muscle fibers—bundles of small, specialized skeletal muscle fibers; supplied by both sensory and motor neurons
- Surrounded by muscle fibers that maintain resting muscle tone and can contract whole muscle
- **Gamma motor neuron** innervates each muscle spindle
  - Alters tension in intrafusal fibers; allows CNS to increase/decrease muscle tone

Structure of a muscle spindle



Module 12.13: The stretch reflex

- Stretched length stimulates more frequent action potentials from sensory neuron
  - Stimulates motor neurons
  - Increases muscle tone
- Compressed length inhibits sensory neuron
  - Reduces stimulation of motor neuron
  - Decreases muscle tone



Module 12.13: The stretch reflex

Postural reflexes

- Category of stretch reflexes
- Help maintain a normal, upright position
- *Example*: Standing
  - Many muscle groups work in opposition to one another to maintain balance
  - Leaning forward stimulates stretch receptors in calf muscles
  - They respond by contracting to pull you back upright
  - Postural muscle adjustments are usually unconscious

Module 12.13: Review

A. Define stretch reflex.
B. In the patellar reflex, identify the response observed and the effectors involved.
C. In the patellar reflex, how does stimulation of the muscle spindle by gamma motor neurons affect sensitivity and reaction time?

Learning Outcome: Describe the steps in the stretch reflex.

Module 12.14: Withdrawal reflexes and crossed extensor reflexes are polysynaptic reflexes

Withdrawal reflexes

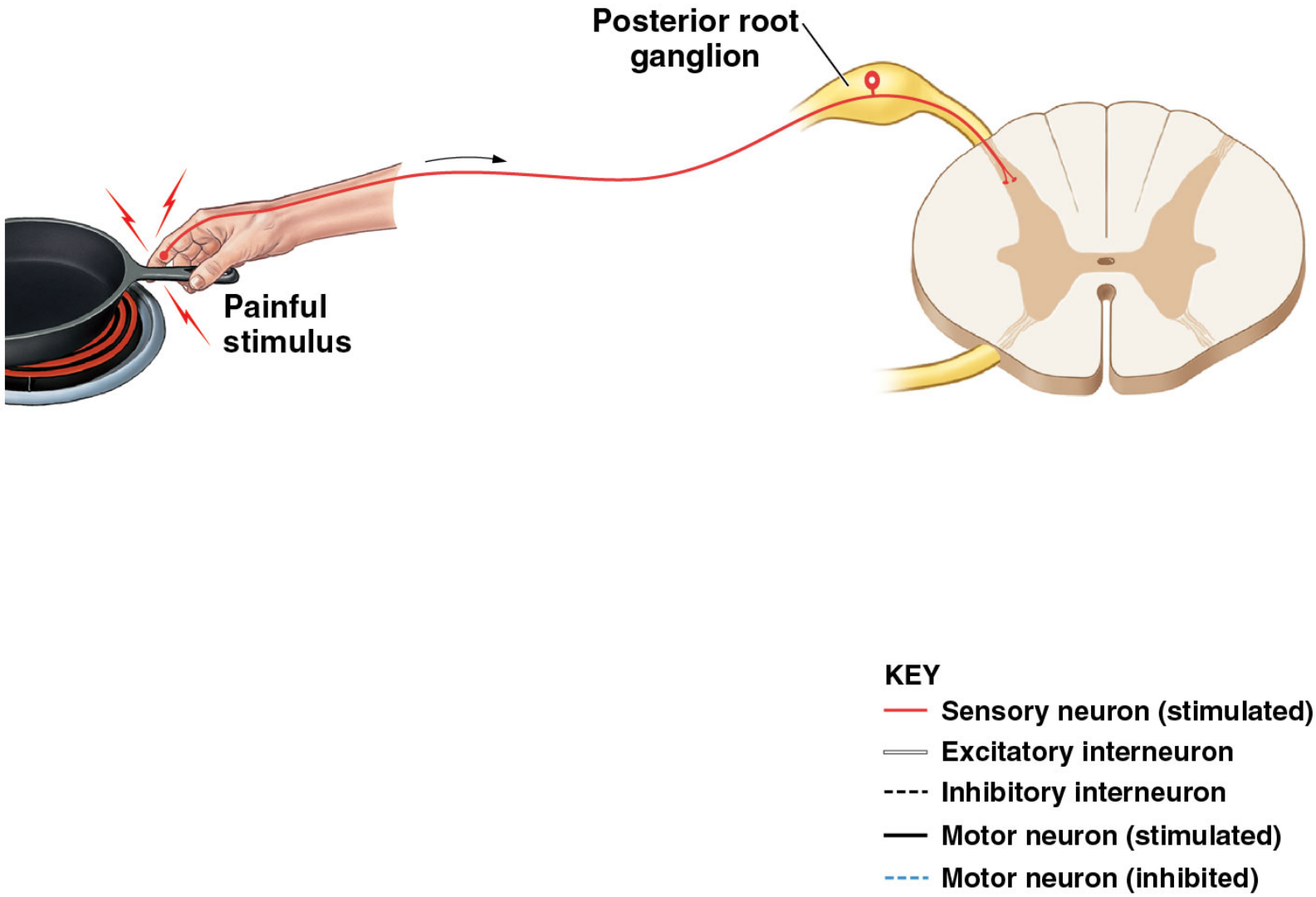
- Move away from stimulus
  - Strongest triggered by painful stimuli
  - Sometimes initiated by stimulus from touch or pressure receptors
- Versatile because sensory neurons activate many pools of interneurons
  - Distribution and strength of response depend on intensity and location of stimulus

Module 12.14: Polysynaptic reflexes

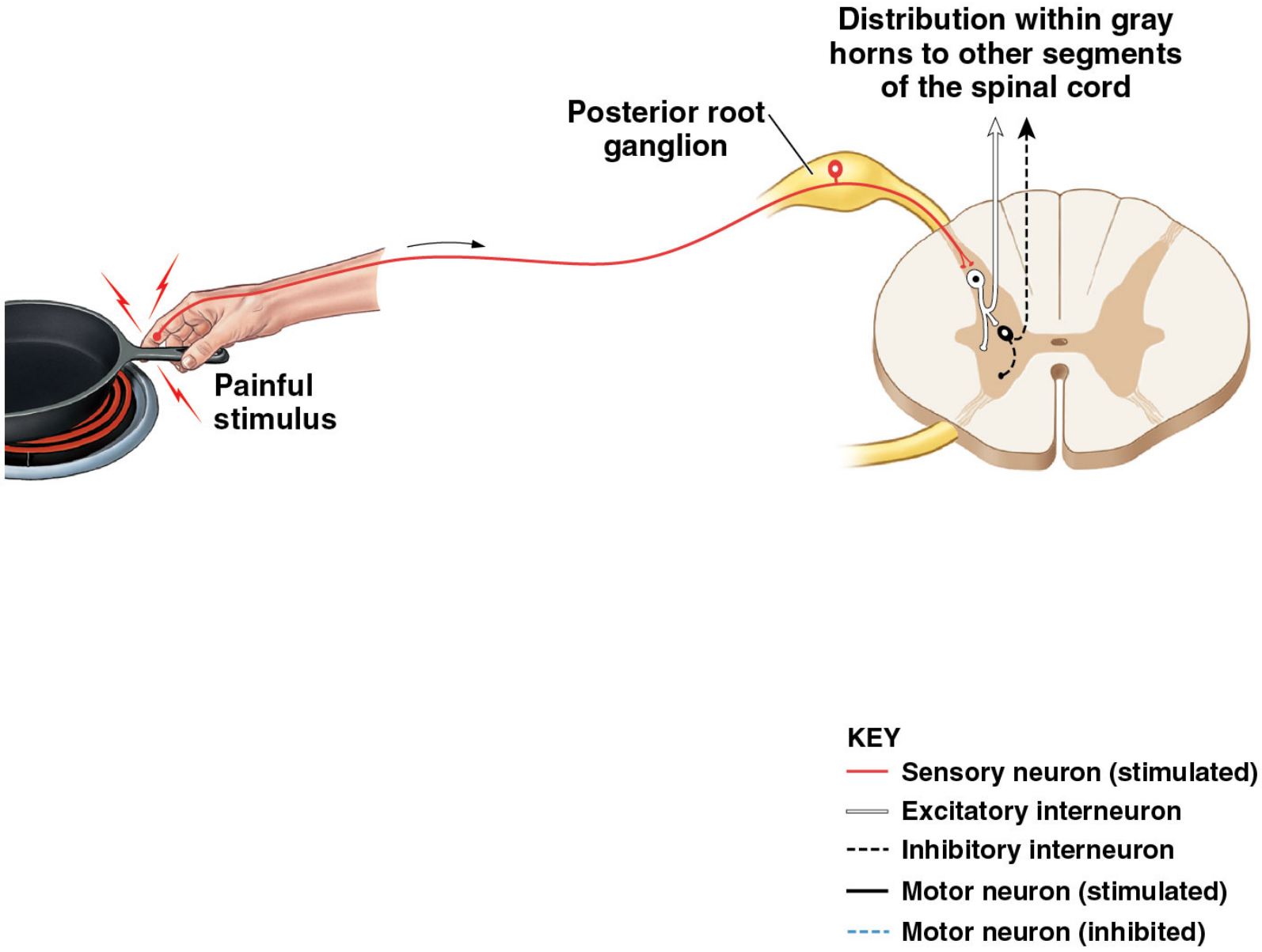
Flexor reflex

- Type of withdrawal reflex
- Affects muscles of a limb
- *Example*: Pain stimulus of grabbing a hot pan
  1. Pain receptors stimulated
  2. Sensory neurons activate interneurons in spinal cord
  3. Interneurons stimulate motor neurons in anterior gray horns resulting in:
     - Contraction of flexor muscles—withdraws hand from stimulus
     - **Reciprocal inhibition**—keeps extensors relaxed (blocks opposition)

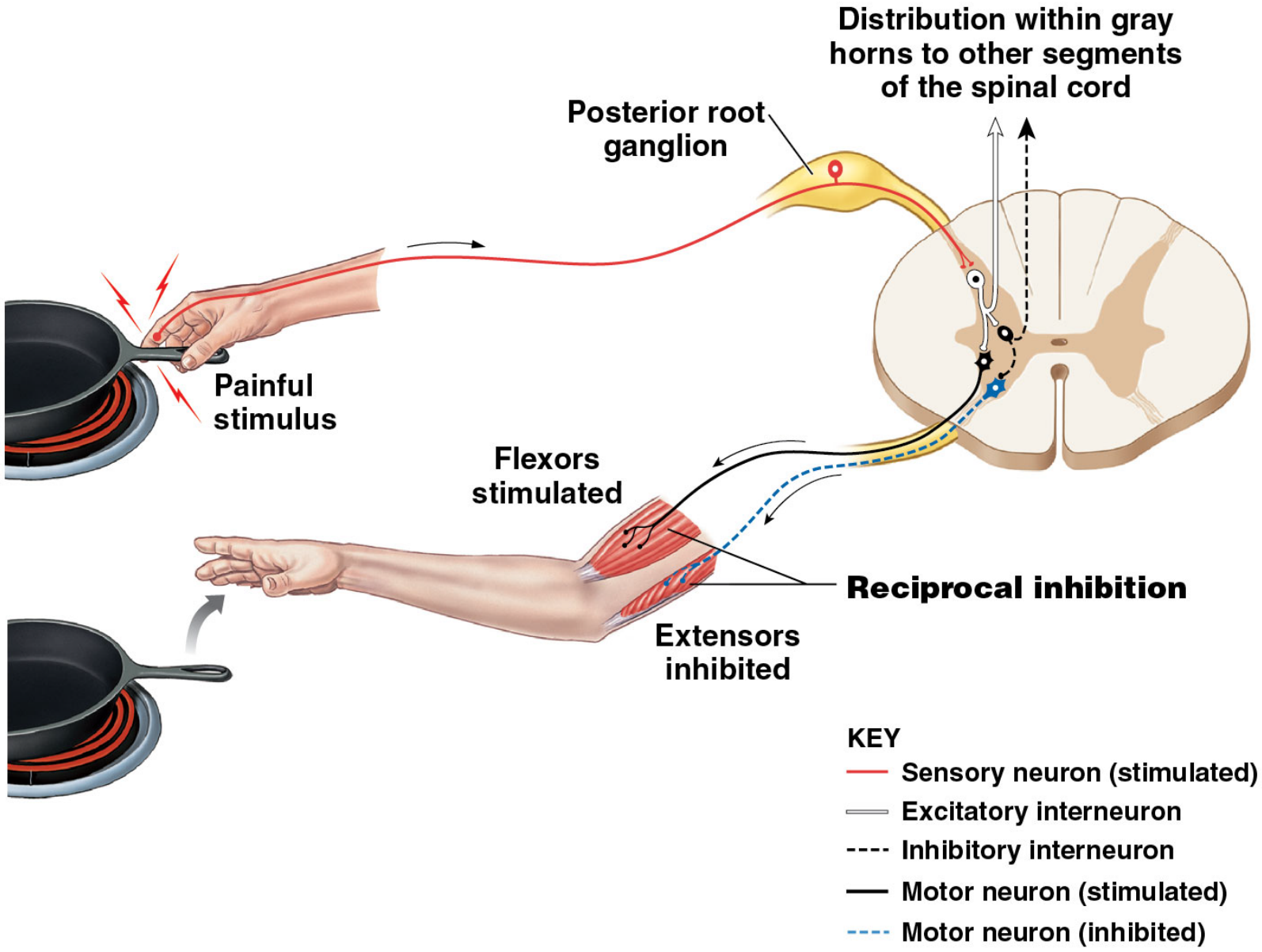
Steps in a flexor reflex



Steps in a flexor reflex



Steps in a flexor reflex



Module 12.14: Polysynaptic reflexes

Crossed extensor reflexes

- Stretch reflexes and withdrawal reflexes use ipsilateral reflex arcs (*ipsi*, same)
  - Sensory stimulus and motor responses are on the same side of the body
- Crossed extensor reflexes involve contralateral reflex arcs (*contra*, opposite)
  - An additional motor response occurs on side *opposite* the stimulus

Module 12.14: Polysynaptic reflexes

Crossed extensor reflexes (continued)

- Coordinated with flexor reflex
- Flexion of affected side accompanied by extension of opposite side
- *Example*:
  1. Step on something sharp
  2. Before flexor reflex lifts injured foot, crossed extensor reflex straightens opposite limb to receive body weight
  3. Then flexor reflex can lift foot

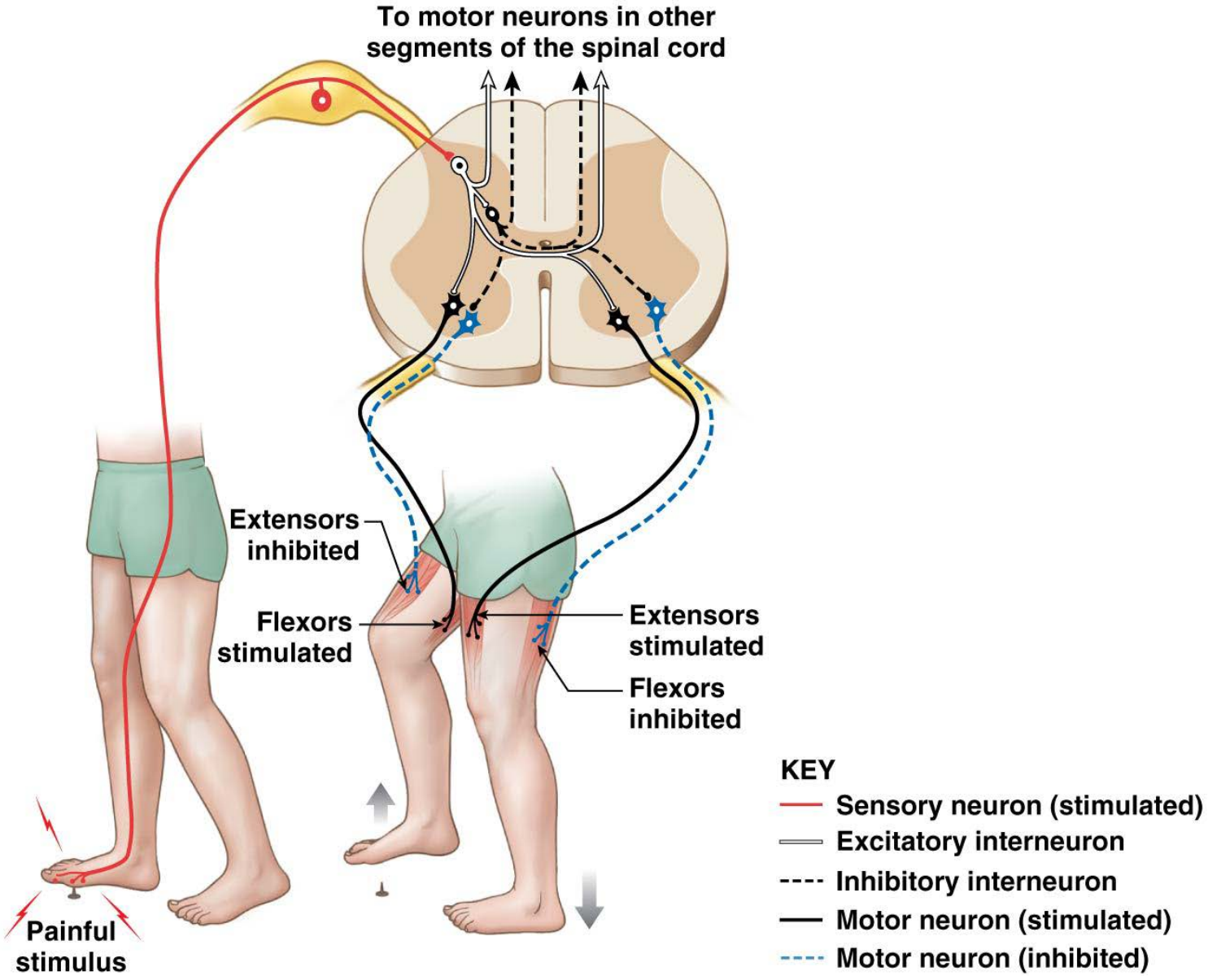
Module 12.14: Polysynaptic reflexes

Crossed extensor reflexes (continued)

1. Stimulus elicits flexor reflex to pull affected foot away
   - Interneurons stimulate flexors/inhibit extensors
2. Crossed extensor reflex occurs simultaneously
   - Collaterals of excitatory and inhibitory interneurons cross spinal cord to motor neurons in unaffected leg
     - Excitatory interneurons stimulate extensors
     - Inhibitory interneurons relax the flexor muscles
   - Opposite leg straightens (crossed extension) to support shift in weight

- These are maintained by reverberating circuits

The crossed-extensor reflex



Module 12.14: Polysynaptic reflexes

Polysynaptic reflexes

- Responsible for automatic actions involved in complex movements (examples—walking and running)

Module 12.14: Polysynaptic reflexes

Five properties

1. Involve pools of interneurons—may be excitatory or inhibitory
2. Involve multiple spinal segments—may activate muscle groups in many areas
3. Involve reciprocal inhibition—coordinates movement and reduces resistance
4. Have reverberating circuits that prolong motor response
5. Several reflexes may cooperate to produce coordinated, controlled response

Module 12.14: Review

A. Describe the flexor reflex.
B. During a withdrawal reflex of the foot, what happens to the limb on the side opposite the stimulus? What is this response called?
C. Identify the basic characteristics of polysynaptic reflexes.

Learning Outcome: Explain withdrawal reflexes and crossed extensor reflexes and the responses produced by each.

Module 12.15: The brain can inhibit or facilitate spinal reflexes, and reflexes can be used to determine the location and severity of damage to the CNS

The brain can influence reflexes

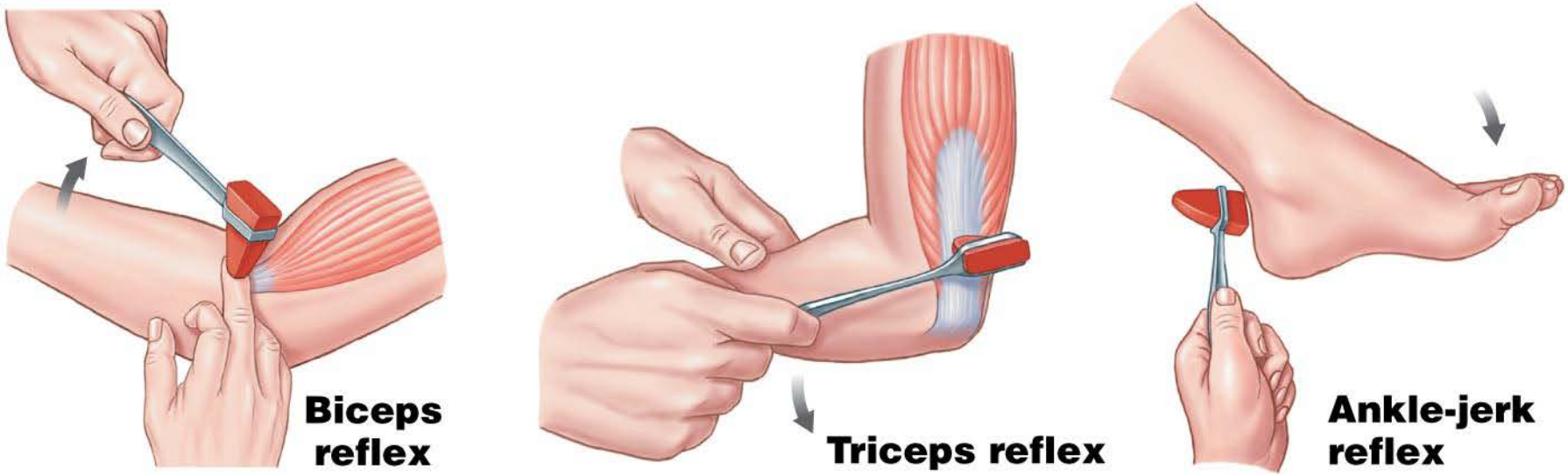
- Can facilitate or inhibit motor neurons or interneurons involved in a reflex
- Facilitation is called **reinforcement**
- *Example*: Jendrassik maneuver facilitates patellar reflex
  - Trying to pull apart interlocked hands produces bigger kick when patellar tendon is tapped
  - Occurs even if person is aware of the technique

Module 12.15: Reflex assessment

Reflexes assessed during physical exams

Biceps reflex, triceps reflex, ankle-jerk reflex

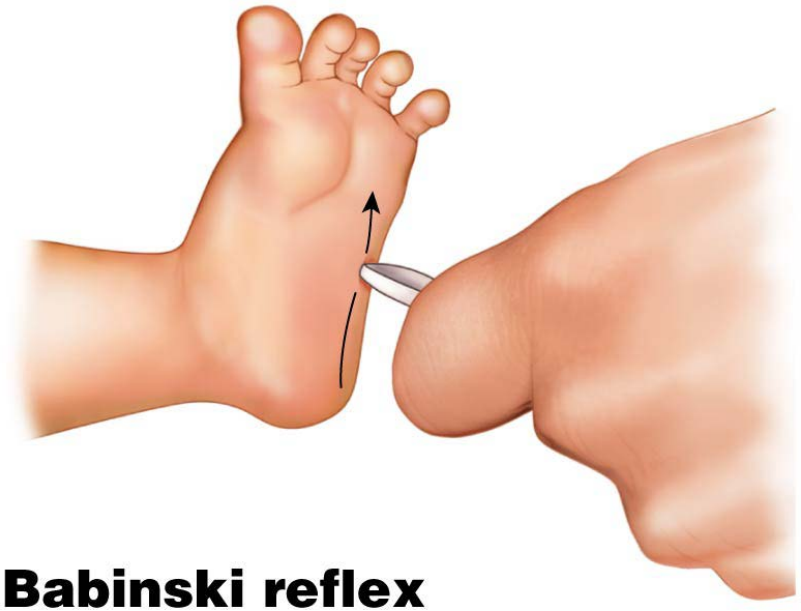
- Stretch reflexes
- Each controlled by specific segments of spinal cord
- Reflex responses provide information about status of the corresponding spinal segments



Module 12.15: Reflex assessment

Babinski reflex

- Stroking foot on lateral side of sole triggers extension of hallux (big toe) and spreading of other toes
- Normal in infant—occurs due to lack of inhibition by descending motor fibers
- Response disappears as descending pathways develop

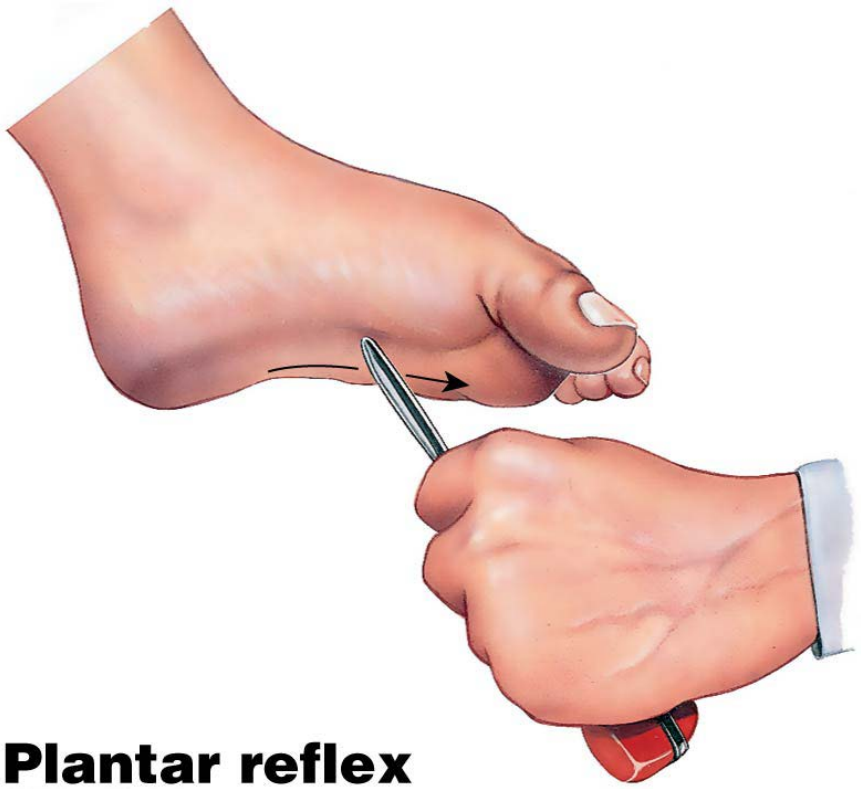


Babinski reflex

Module 12.15: Reflex assessment

Plantar reflex

- Same stimulus causes toe curling (plantar flexion) once inhibitory descending pathways develop
- Normal in adults

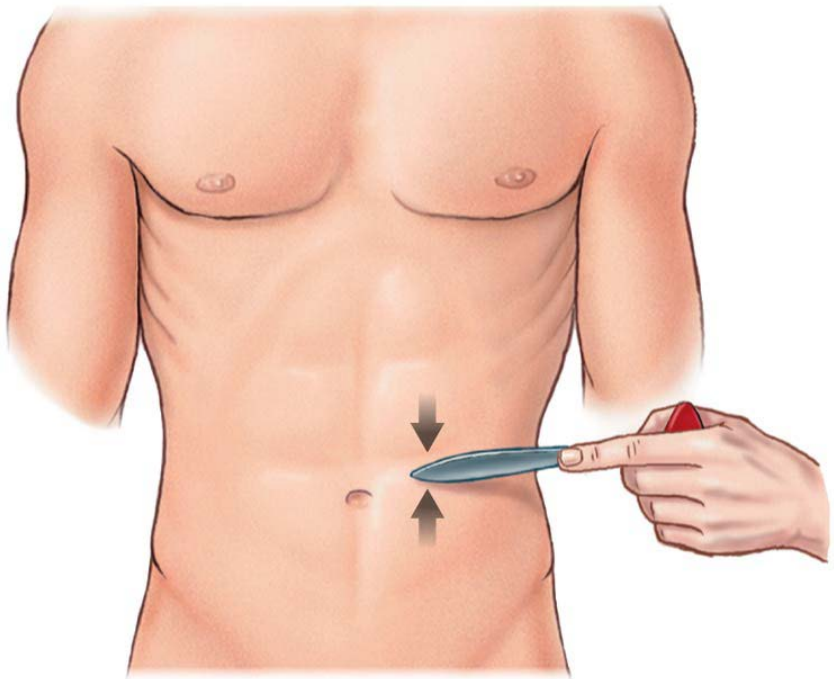


Plantar reflex

Module 12.15: Reflex assessment

Abdominal reflex

- Light stroking of skin produces reflexive twitch in abdominal muscles; moves navel toward stimulus
- Depends on facilitation of descending tracts
- Absence may indicate damage to descending tracts



Abdominal reflex

Module 12.15: Reflex assessment

Reflexes Used in Diagnostic Testing

Reflex	Stimulus	Afferent Nerve(s)	Spinal Segment	Efferent Nerve(s)	Normal Response
Superficial Reflexes					
Abdominal reflex	Light stroking of skin of abdomen	T_7–T_{12} depending on region stroked	T_7–T_{12} at level of arrival	Same as afferent	Contractions of abdominal muscles that pull navel toward the stimulus
Cremasteric reflex	Stroking of skin of upper thigh	Femoral nerve	L_1	Genitofemoral nerve	Contraction of cremaster, elevation of scrotum
Plantar reflex	Longitudinal stroking of lateral side of sole of foot	Tibial nerve	S_1, S_2	Tibial nerve	Flexion at toe joints
Anal reflex	Stroking of region around the anus	Pudendal nerve	S_4, S_5	Pudendal nerve	Constriction of external anal sphincter
Stretch Reflexes					
Biceps reflex	Tap to tendon of biceps brachii near its insertion	Musculocutaneous nerve	C_5, C_6	Musculocutaneous nerve	Flexion at elbow
Triceps reflex	Tap to tendon of triceps brachii near its insertion	Radial nerve	C_6, C_7	Radial nerve	Extension at elbow
Brachioradialis reflex	Tap to forearm near styloid process of the radius	Radial nerve	C_5, C_6	Radial nerve	Flexion at elbow, supination, and flexion at finger joints
Patellar reflex	Tap to patellar ligament	Femoral nerve	L_2–L_4	Femoral nerve	Extension at knee
Ankle-jerk reflex	Tap to calcaneal tendon	Tibial nerve	S_1, S_2	Tibial nerve	Extension (plantar flexion) at ankle

Module 12.15: Review

A. Define *reinforcement* as it pertains to spinal reflexes.
B. What purpose does reflex testing serve?
C. After injuring her back, 22-year-old Tina exhibits a positive Babinski reflex. What does this imply about her injury?

Learning Outcome: Explain the value of reflex testing and how the brain may control and modify reflex responses.