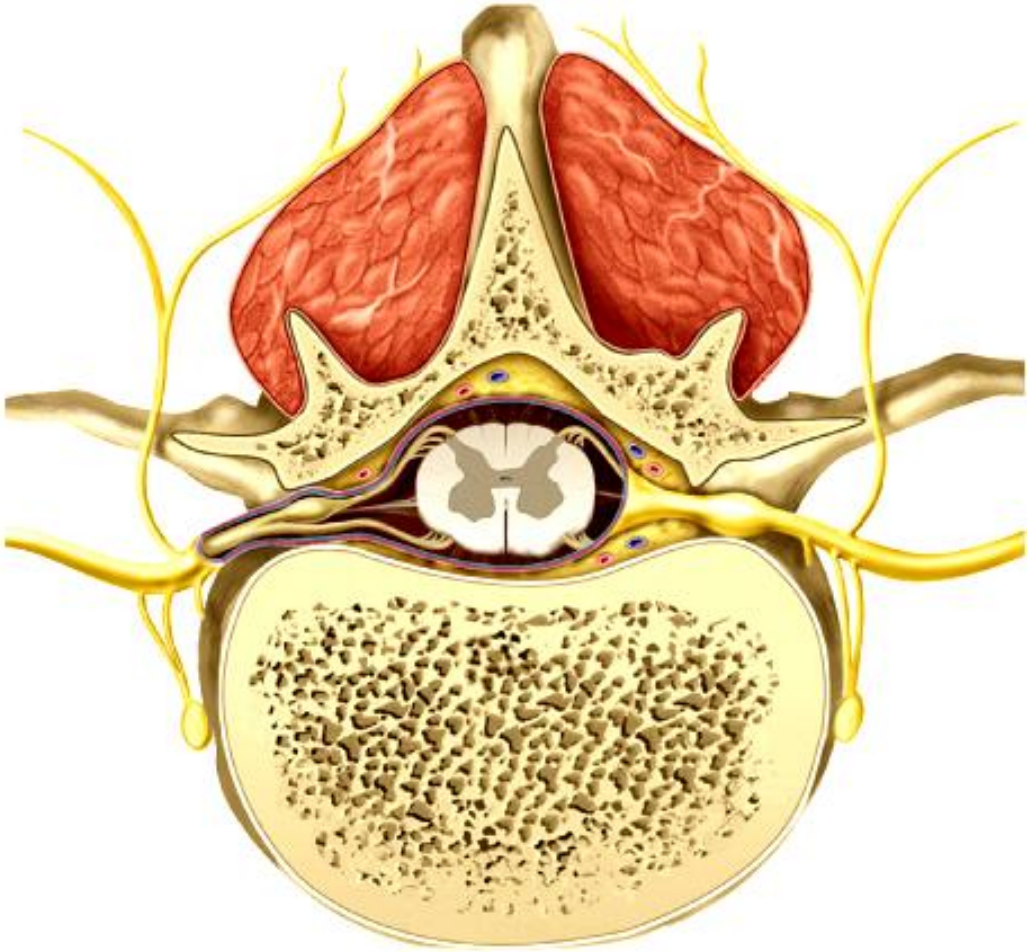
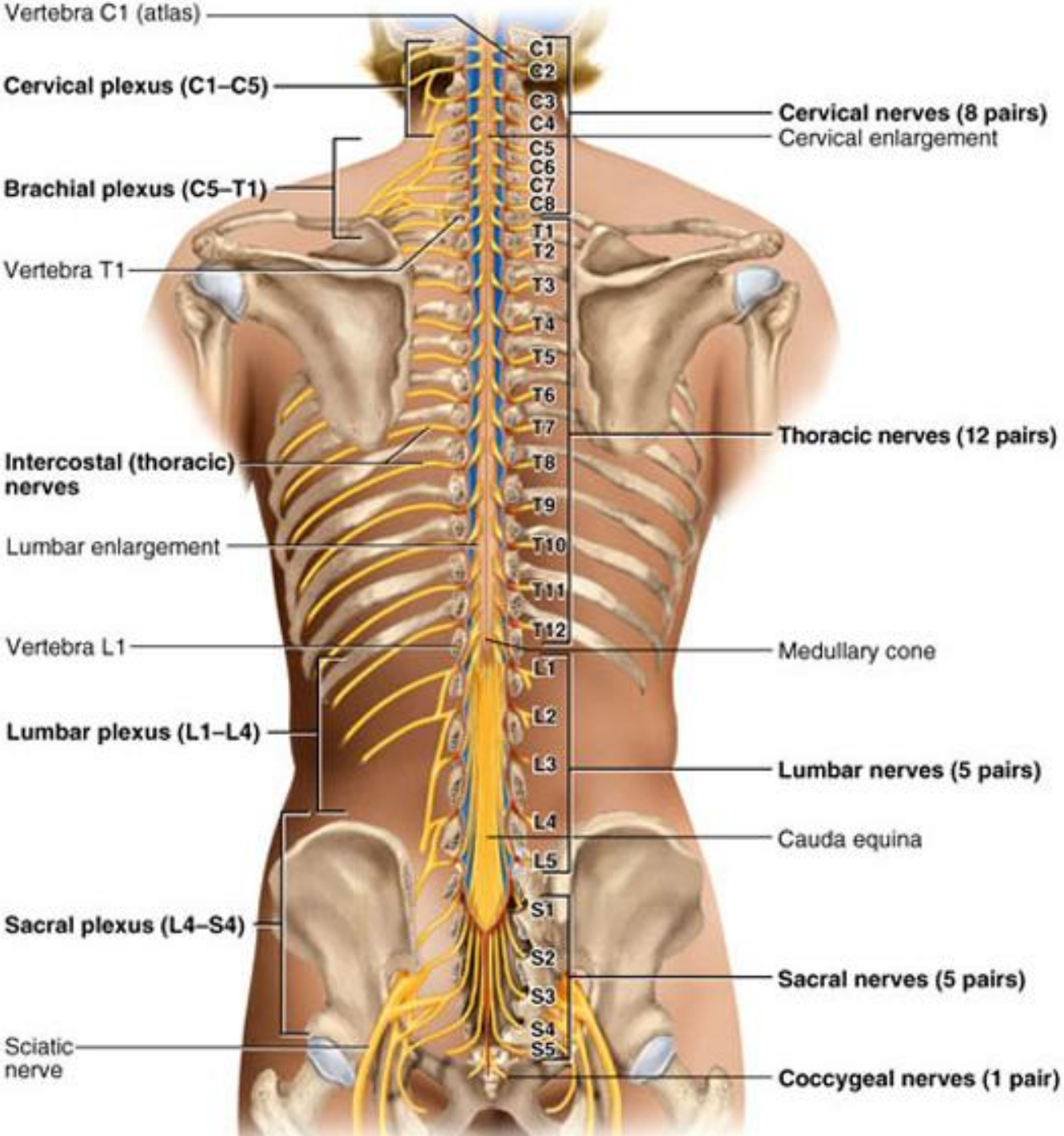
Spinal Cord, Spinal Nerves and Somatic Reflexes

Chapter 13

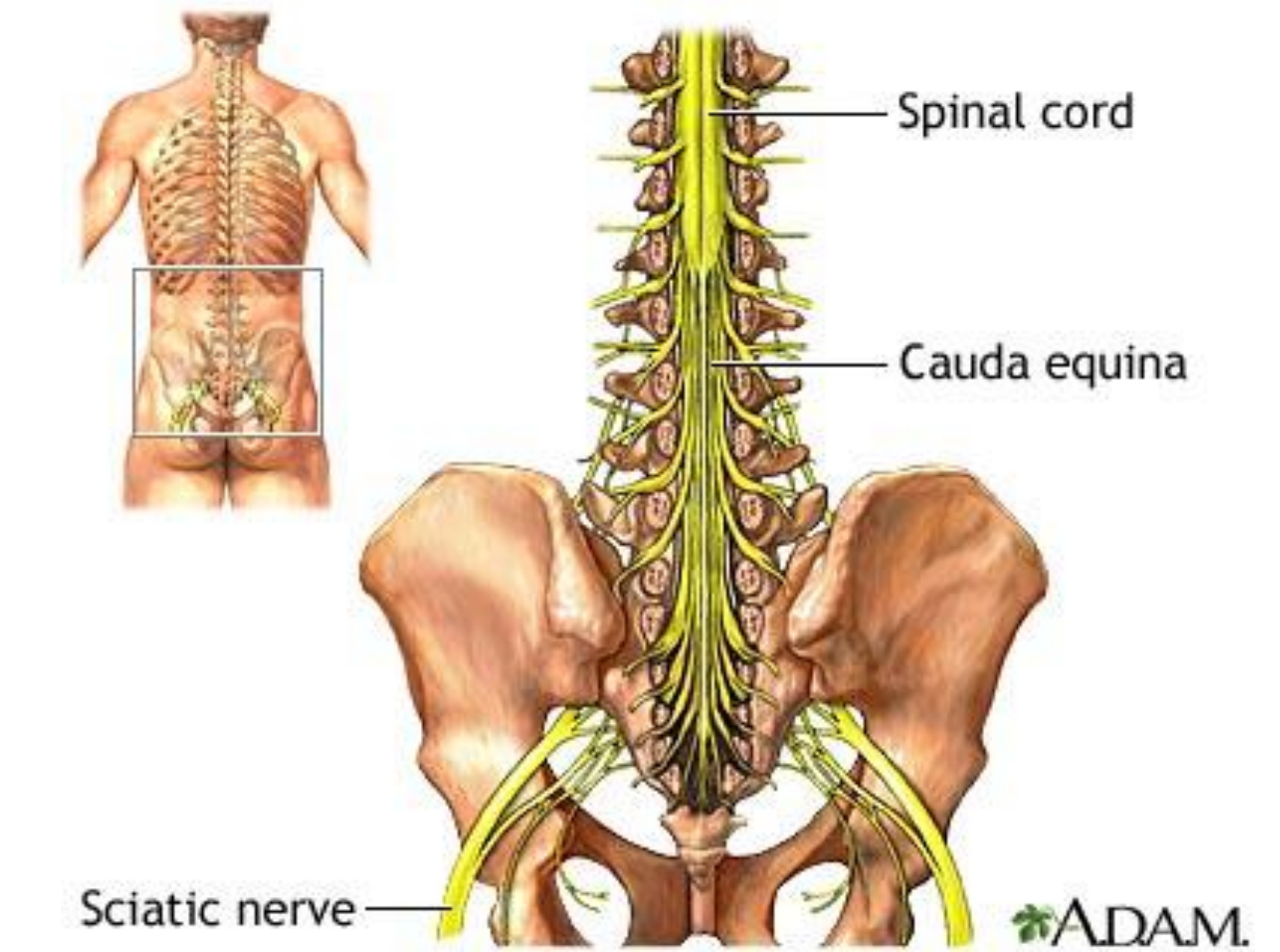


Anatomy of the Spinal Cord

- Cylinder of nerve tissue within the vertebral canal.
  - Vertebral column grows faster than the spinal cord so in an adult the spinal cord only extends to L1.
- 31 pairs of spinal nerves arise from cervical, thoracic, lumbar, sacral and coccygeal regions of the cord.
- Cauda Equina (resemble a horse's tail) is the highly branched part of the spinal cord from L2 to S5 which is composed of nerve roots.

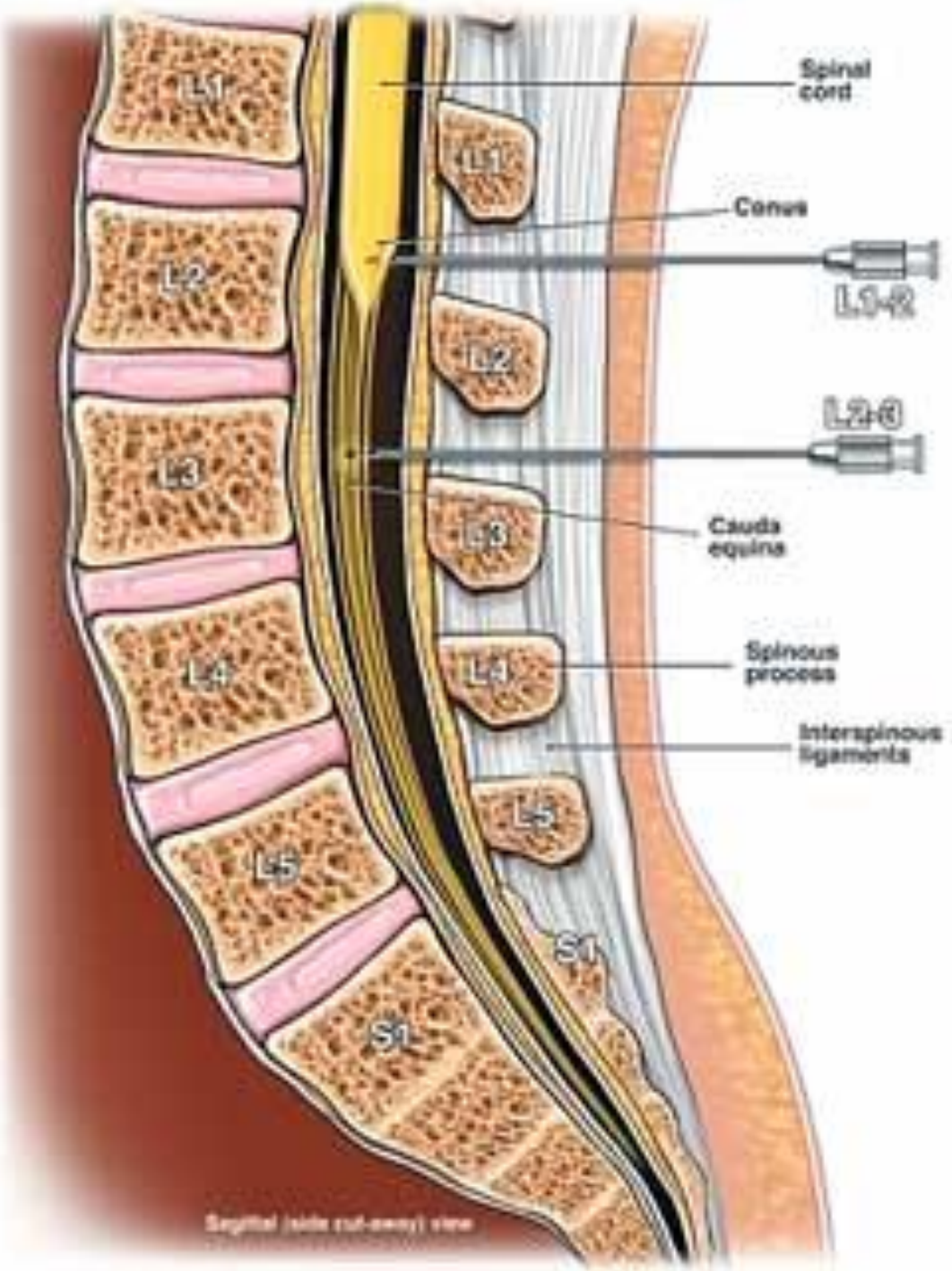

Vertebra C1 (atlas)
Cervical plexus (C1–C5)
Brachial plexus (C5–T1)
Vertebra T1
Intercostal (thoracic) nerves
Lumbar enlargement
Vertebra L1
Lumbar plexus (L1–L4)
Sacral plexus (L4–S4)
Sciatic nerve
C1
C2
C3
C4
C5
C6
C7
C8
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
T12
L1
L2
L3
L4
L5
S1
S2
S3
S4
S5
Cervical nerves (8 pairs)
Cervical enlargement
Thoracic nerves (12 pairs)
Medullary cone
Lumbar nerves (5 pairs)
Cauda equina
Sacral nerves (5 pairs)
Coccygeal nerves (1 pair)

Gross Anatomy of Lower Spinal Cord



Gross Anatomy of the Lower Spinal Cord

1. Spinal Cord
2. Dura Mater reflected open
3. Medulary Cone
4. Cauda Equina


Spinal cord
Conus
L3-4
L2-3
Cauda equina
Spinous process
Interspinous ligaments
L1
L2
L3
L4
L5
S1
Sagittal (side cut-away) view

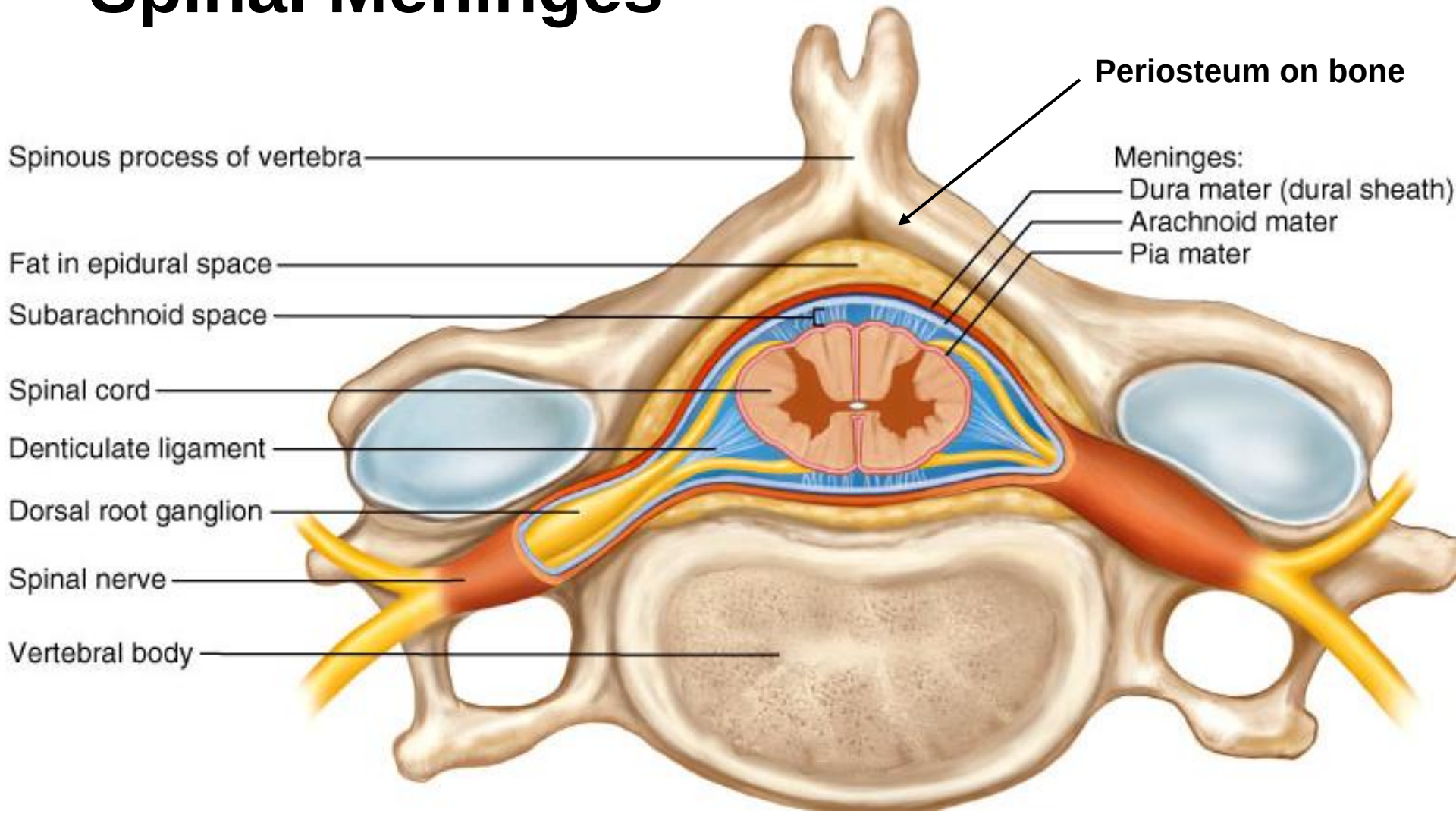
Meninges of the Spinal Cord and Brain are similar

Dura Mater

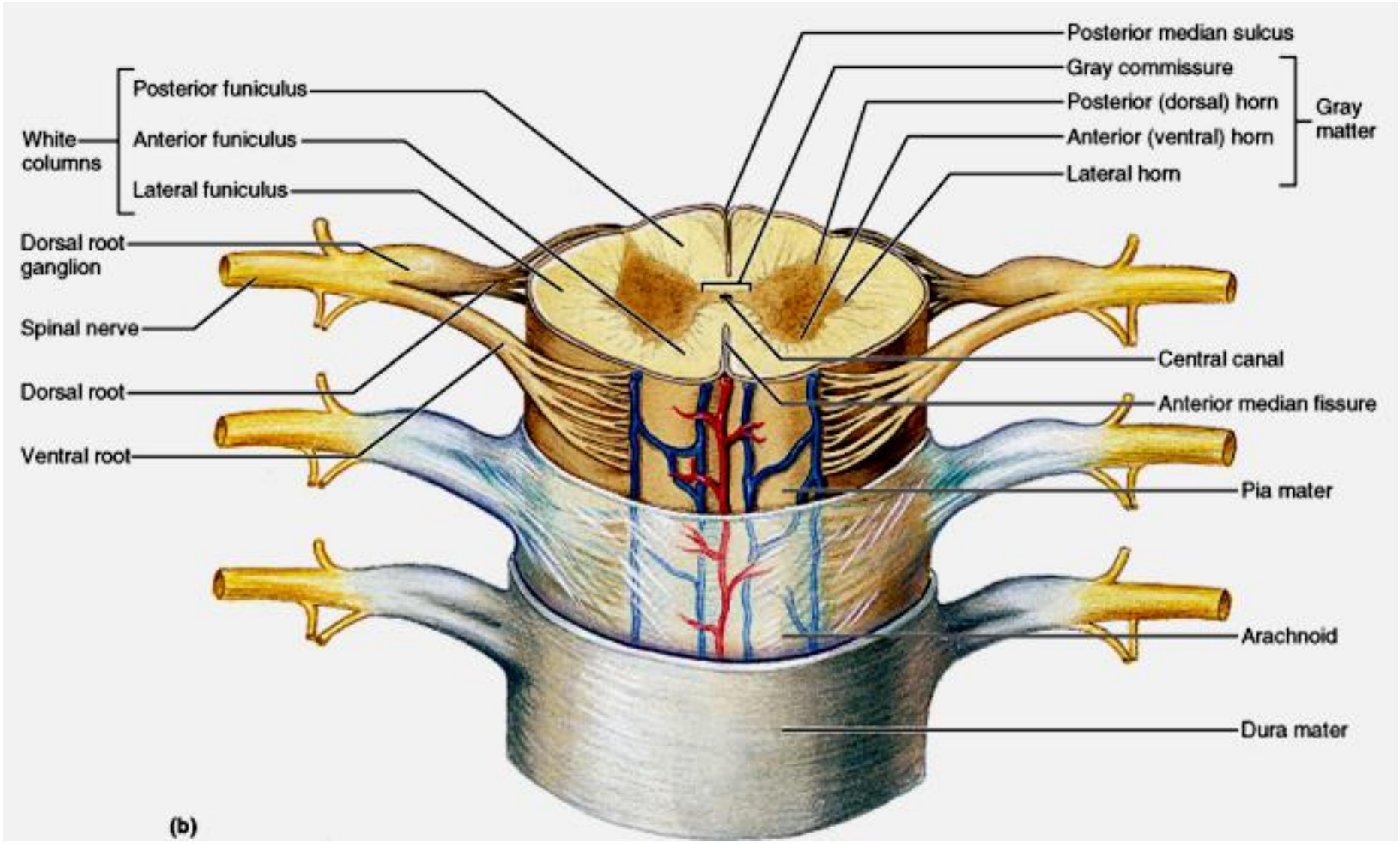
- outermost membrane of tough collagen fibers
- epidural space between the dura mater and the vertebral canal is filled with fat and blood vessels
  - epidural anesthesia is delivered into the epidural space

- **Arachnoid** (Mater)
  - middle layer composed of a simple squamous epithelium and a loose mesh of connective tissue fibers (like a spider web)
  - Subarachnoid space is filled with Cerebrospinal Fluid (CSF)
    - spinal anesthesia is delivered into the subarachnoid space
- **Pia Mater**
  - delicate membrane attached to surface of spinal cord

Spinal Meninges

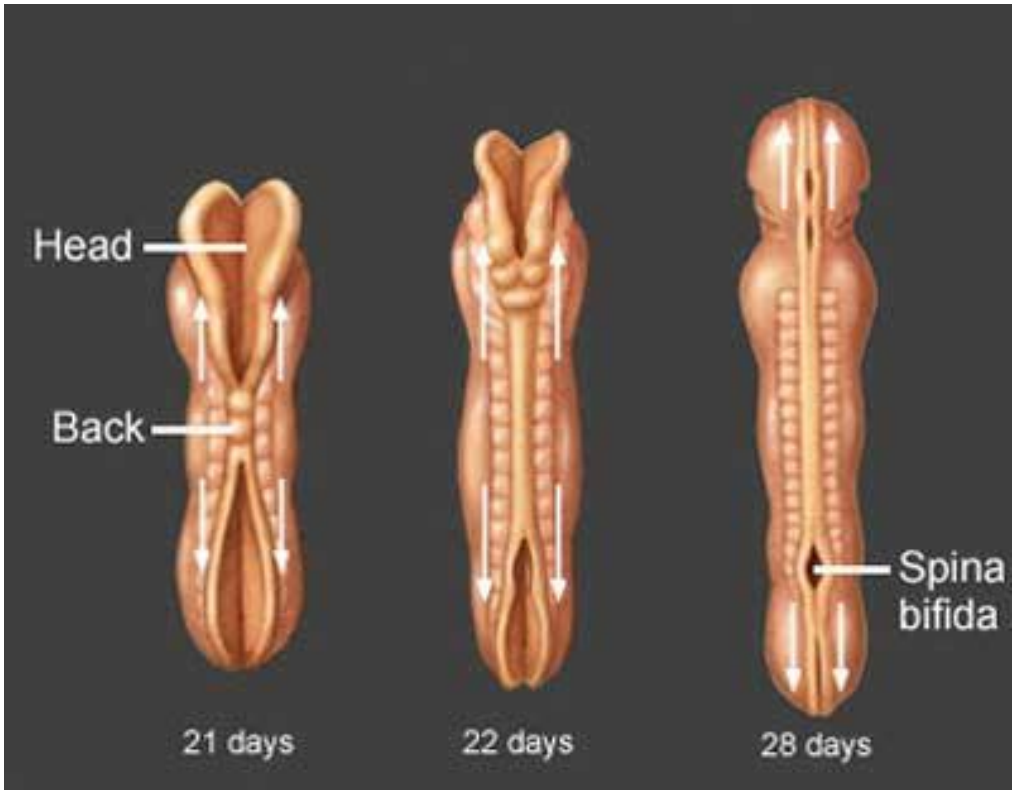


Meninges of the Spinal Cord

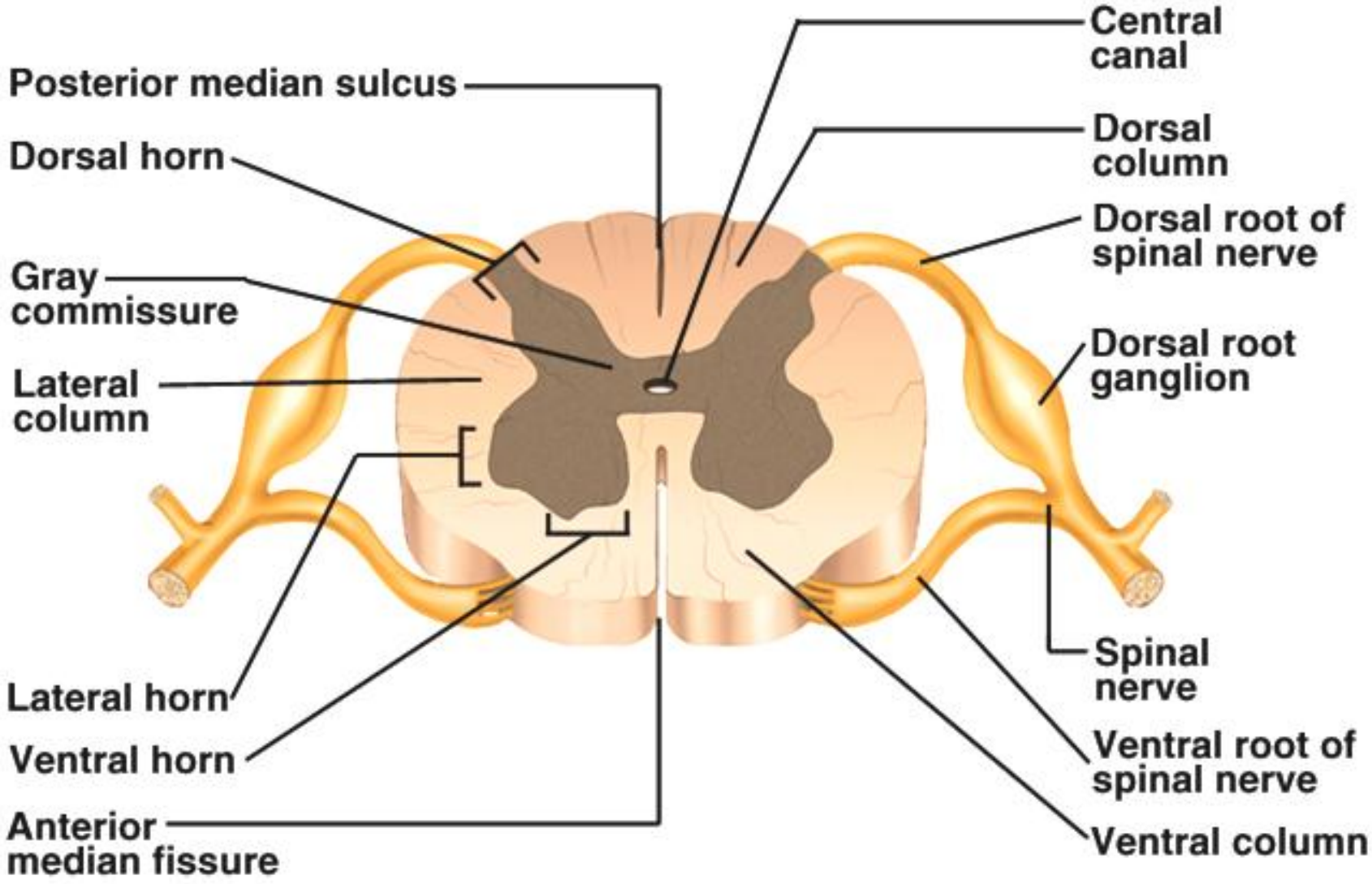


Spina Bifida

- Congenital defect in 1 baby out of 1000
- Failure of vertebral arch to form over spinal cord
- CSF pressure stretches meninges
- Mothers can reduce risk by taking sufficient folic acid during pregnancy

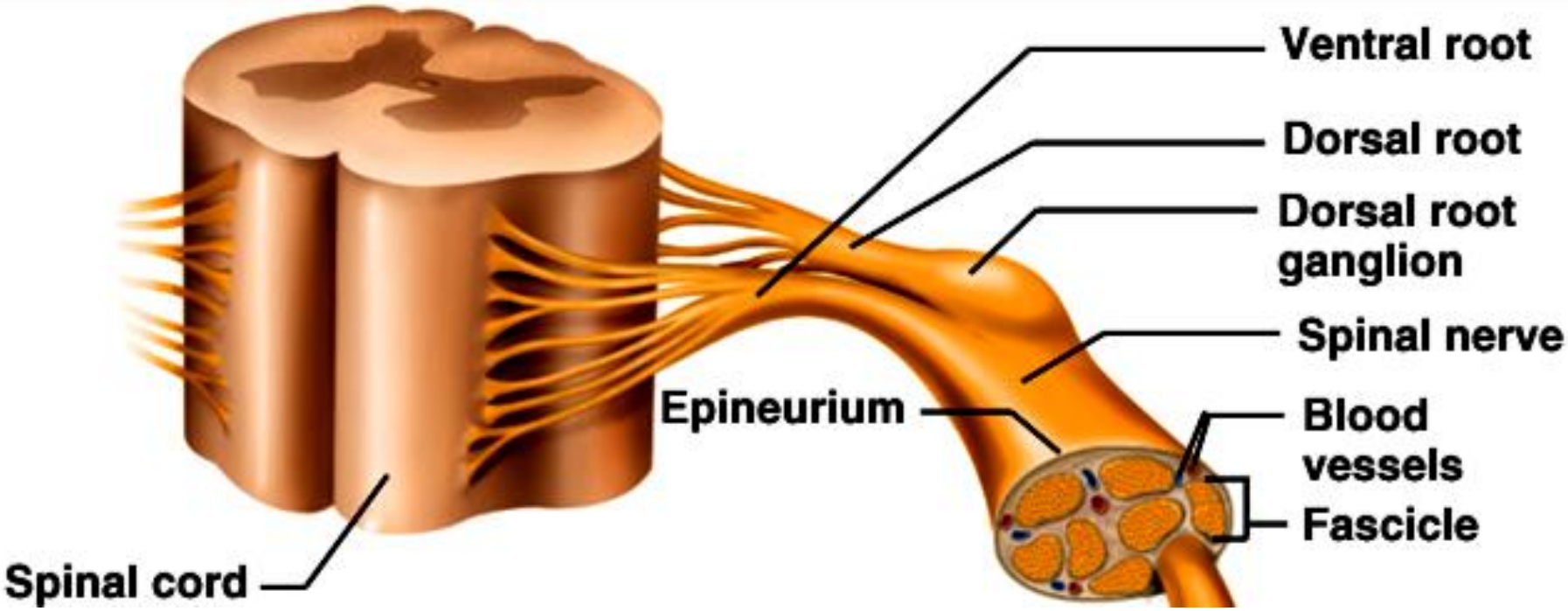


Anatomy of the Spinal Cord



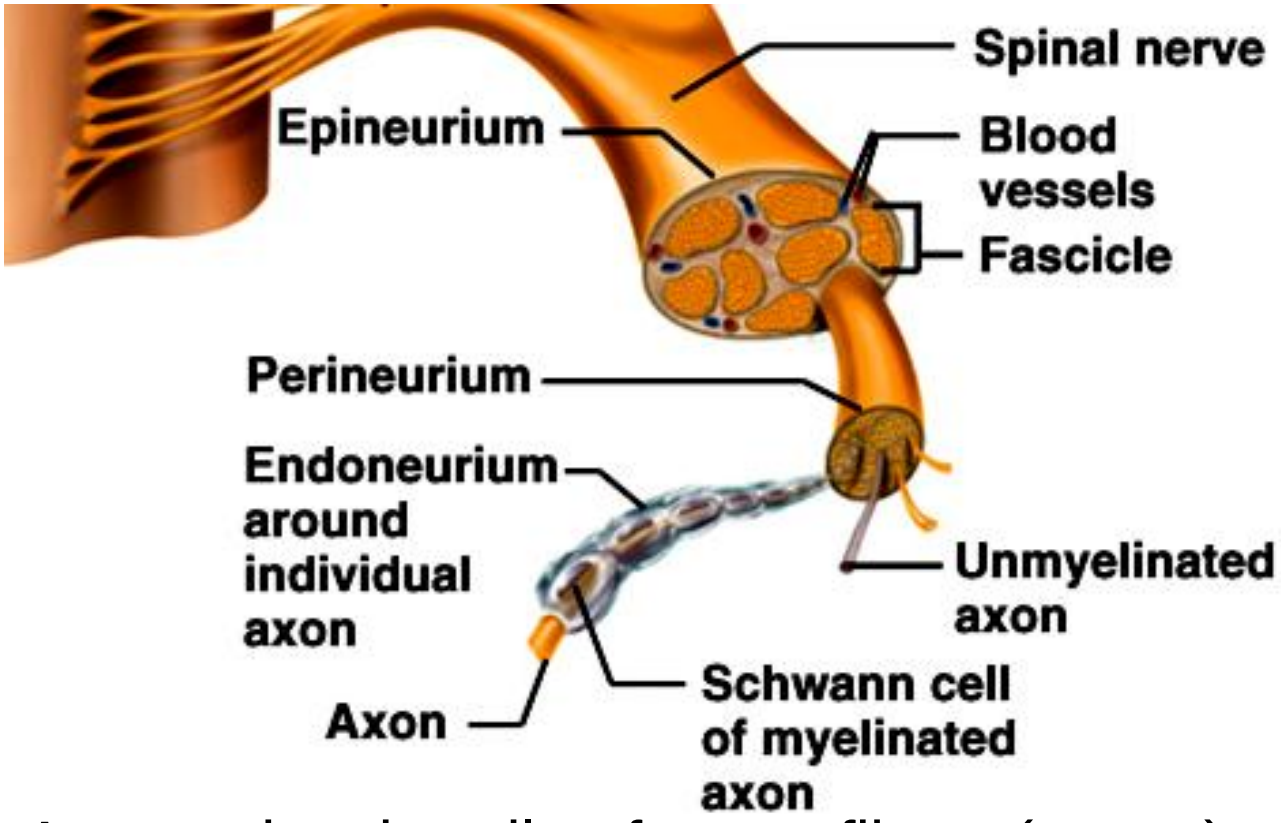
- Gray matter = mostly neuron cell bodies
- White matter = myelinated axons

Anatomy of a Spinal Nerve



- 31 pairs of spinal nerves
  - 8 cervical, 12 thoracic, 5 lumbar, 5 sacral and 1 coccygeal

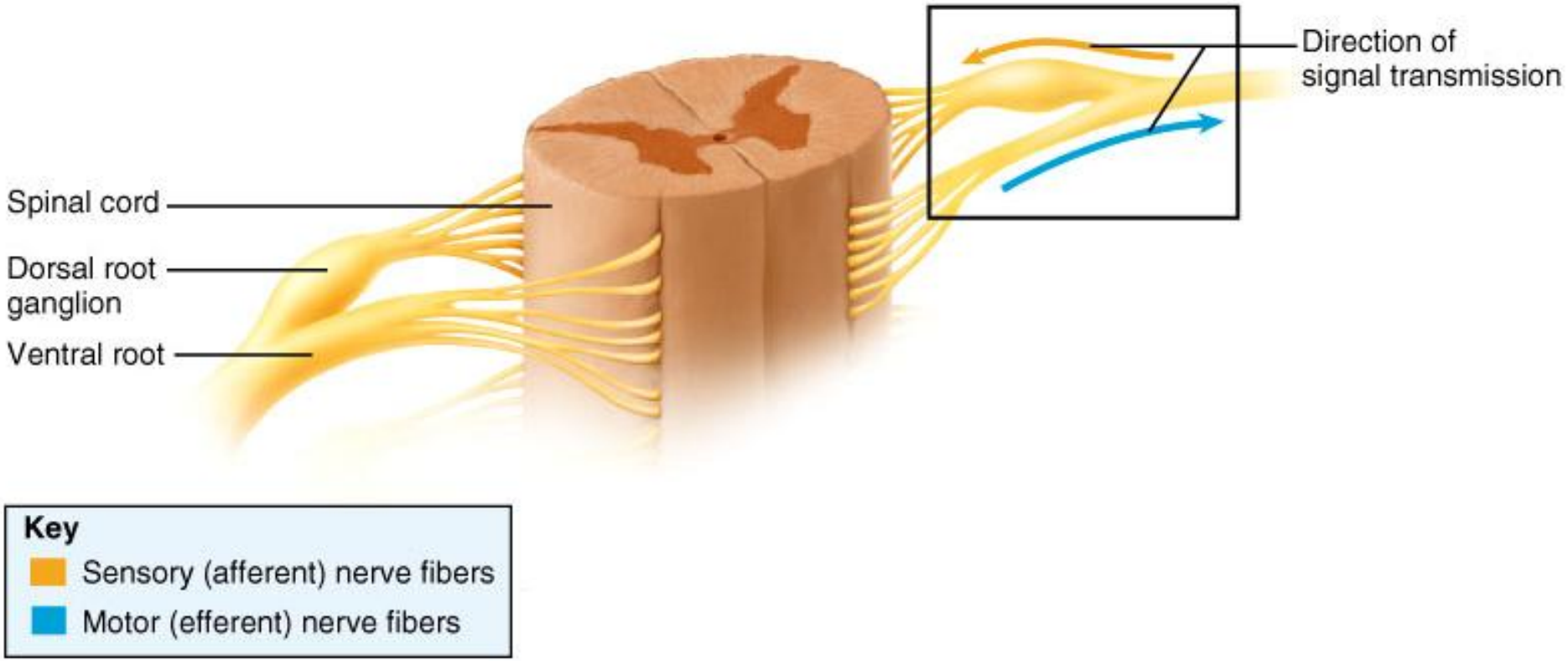
Connective Tissues of a Spinal Nerve



A nerve is a bundle of nerve fibers (axons) covered with 3 layers of Connective Tissue:

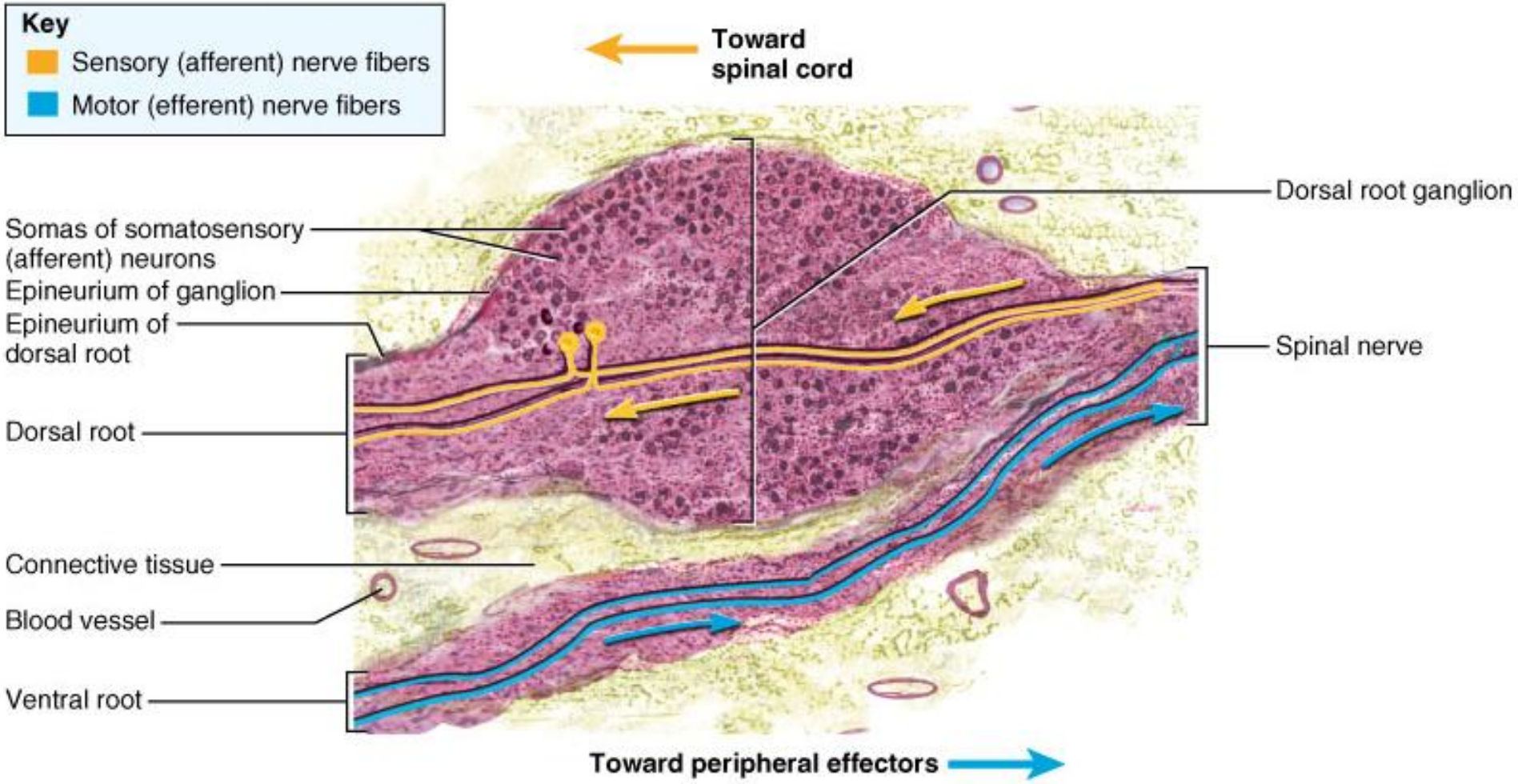
- **Epineurium** covers nerves and conducts blood vessels along nerves.
- **Perineurium** surrounds a fascicle (bundle) of axons and conducts blood vessels into the nerve.
- **Endoneurium** is the basal lamina and loose connective tissue fibers around the Schwann cells. Blood vessels do not penetrate through the endoneurium.

Spinal Nerve Roots




Posterior median sulcus
Gracile fasciculus
Cuneate fasciculus
Lateral column
Segment C5
Cross section
Arachnoid mater
Dura mater
Neural arch of vertebra C3 (cut)
Vertebral artery
Spinal nerve C5:
Rootlets
Dorsal root
Dorsal root ganglion
Ventral root

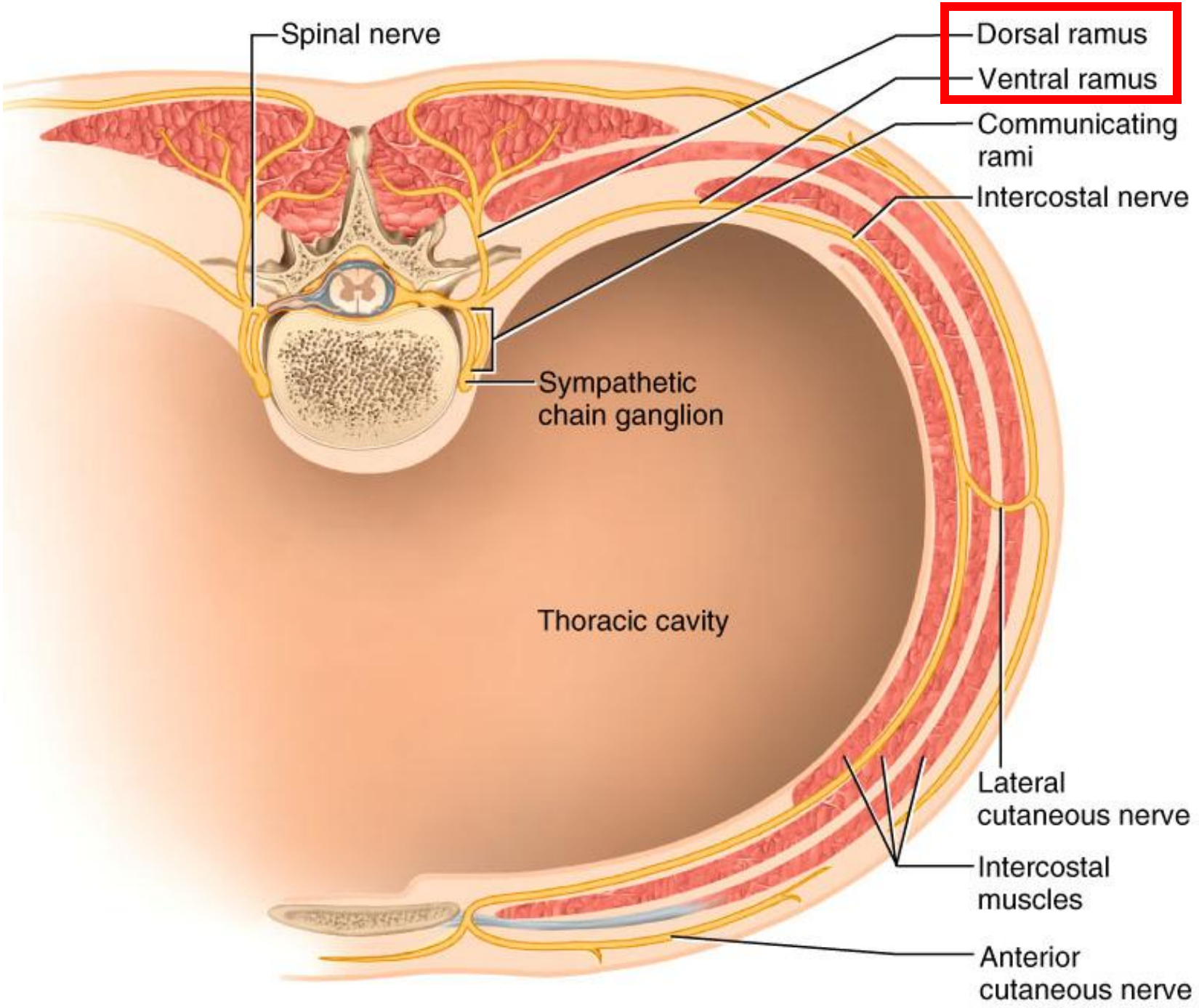
Dorsal Root Ganglion



- Ganglia in the PNS are clusters of neuron somas (cell bodies) in a nerve.
- Example: Dorsal Root Ganglion is the location of the sensory neuron somas.

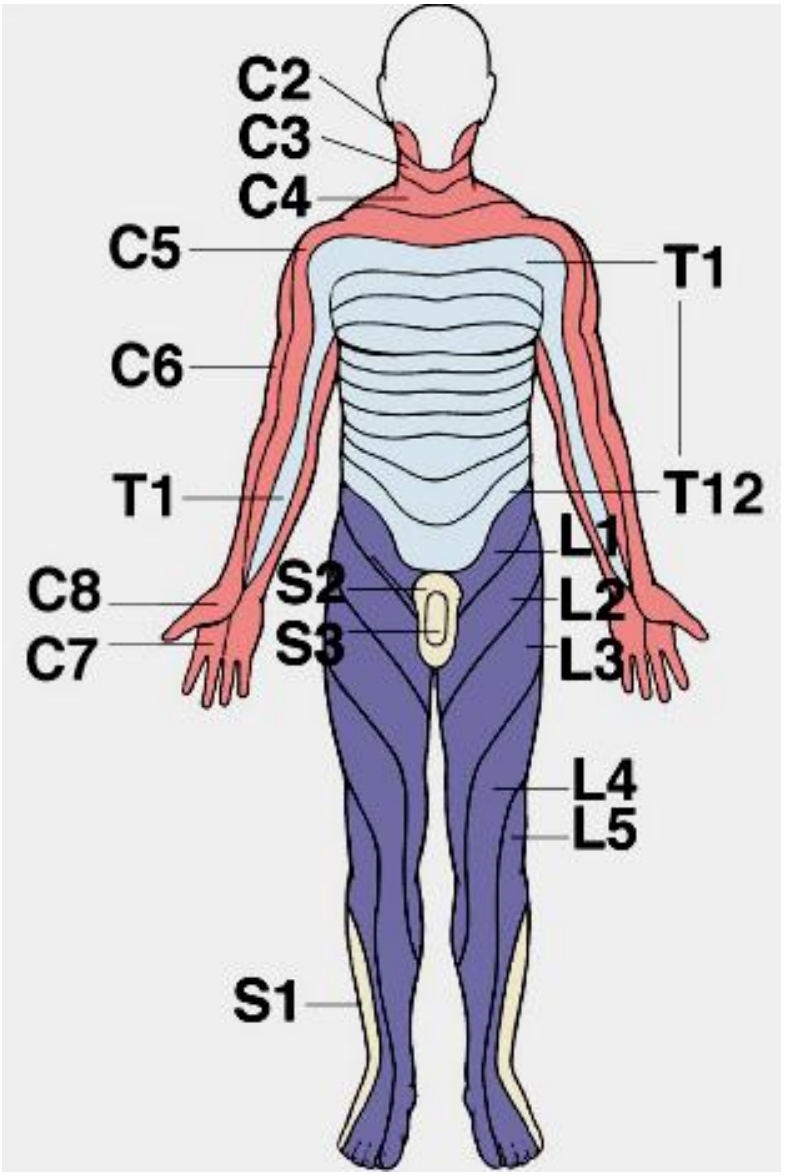
Branches of the Spinal Nerves

- **Proximal Branches**
  - **dorsal root** (sensory input to spinal cord)
  - **ventral root** (motor output of spinal cord)
- **Distal Branches**
  - **dorsal ramus** serves dorsal body muscle and skin
  - **ventral ramus** serves ventral body and limb muscles and skin
  - **meningeal branch** serves meninges, vertebrae and ligaments

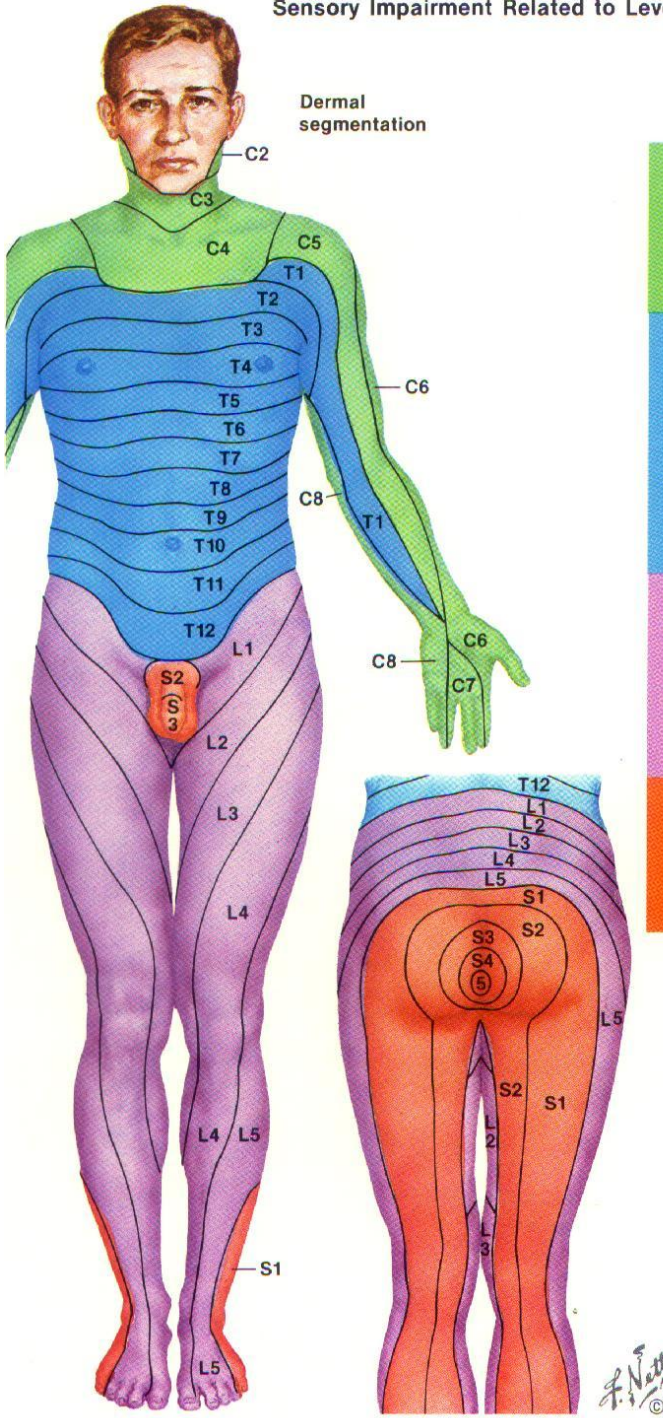

Spinal nerve
Dorsal ramus
Ventral ramus
Communicating rami
Intercostal nerve
Sympathetic chain ganglion
Thoracic cavity
Lateral cutaneous nerve
Intercostal muscles
Anterior cutaneous nerve

Cutaneous Innervation and Dermatomes

- Each spinal nerve receives sensory input from a specific area of skin called a dermatome.



Sensory Impairment Related to Level of Spinal Cord Injury



Key indicators

Cervical segments

- C5–Anterolateral shoulder
- C6–Thumb
- C7–Middle finger
- C8–Little finger

Thoracic segments

- T1–Medial arm
- T3–3rd, 4th interspace
- T4–Nipple line, 4th, 5th interspace
- T6–Xiphoid process
- T10–Navel
- T12–Pubis

Lumbar segments

- L2–Medial thigh
- L3–Medial knee
- L4–Medial ankle Great toe
- L5–Dorsum of foot

Sacral segments

- S1–Lateral foot
- S2–Posteromedial thigh
- S3, 4, 5–Perianal area

F. Netter M.D.

Pain

- Pain is discomfort caused by tissue injury or noxious stimulation.
- Pain is a valuable sense because it helps us learn how to avoid serious injury.
  - Neuropathy is the loss of the sense of pain.
  - Diseases including diabetes mellitus and leprosy can cause neuropathy.

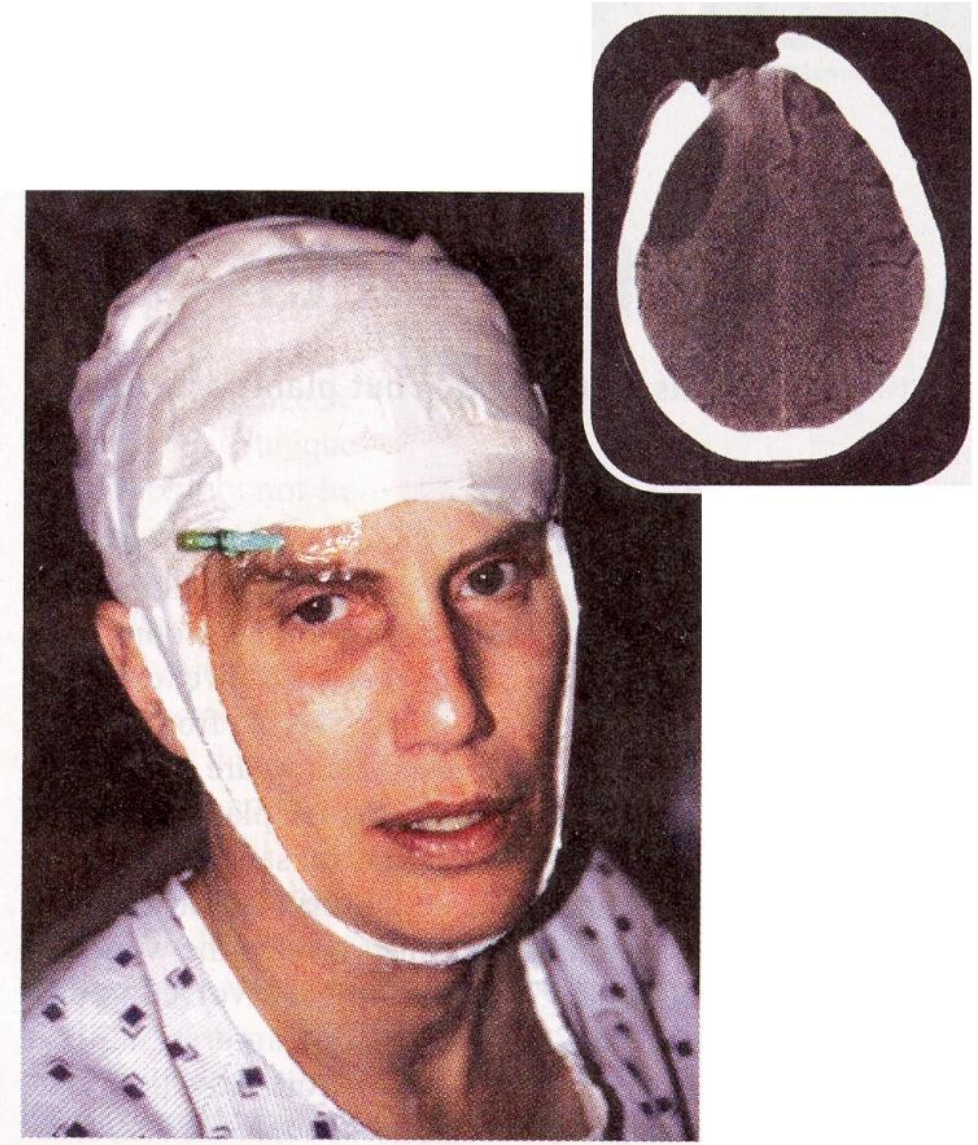
Nociceptors

- Nociceptors are specialized sensory nerve fibers that sense pain.
- Nociceptors are abundant in skin, mucous membranes, organs, meninges, but NOT the brain.
- Fast Pain is transmitted through myelinated fibers and produces instantaneous sharp, localized, stabbing pain.
- Slow Pain follows fast pain and is transmitted through unmyelinated fibers and produces longer-lasting, dull, diffuse feeling of pain.
- Somatic Pain comes from the skin, muscles and joints.
- Visceral Pain comes from internal organs.
- Bradykinin released by injured tissues is the most potent pain stimulus known, and triggers a cascade of reactions that promote healing.
- Seratonin, prostaglandins, histamine, K^+, and ATP also stimulate nociceptors.

Shingles

- Skin eruptions along the path of a spinal nerve (dermatome) caused by the chicken pox virus (*Varicella zoster*) that lives in the dorsal root ganglia for life.
- Periodic flair-ups can occur along the path of an infected nerve.
- Flair-ups are more common after age 50 or if the person's immune system is compromised.
- Treated with aspirin and cortisone creams to relieve pain and inflammation.

In 1998, at age 38, Mary Ellen Nelsen had a shingles outbreak. Antiviral drugs cleared up the painful shingles rash on her face and scalp, but a ferocious itch took its place. “It was relentless,” Nilsen says. Over a 13 month period, Nilsen scratched, despite her best efforts not to, and despite her horror at the growing lesions she saw in the mirror. At the time, Nilsen says, she had no idea that the damage she was doing to herself was more than skin deep, but she ended up in a Boston emergency room with brain tissue protruding through a hole she scratched through her skull which resulted in frontal-lobe brain damage. The virus damaged sensory nerves in a way that induced itch, but left her unable to feel pain from the scratching-induced wounds.

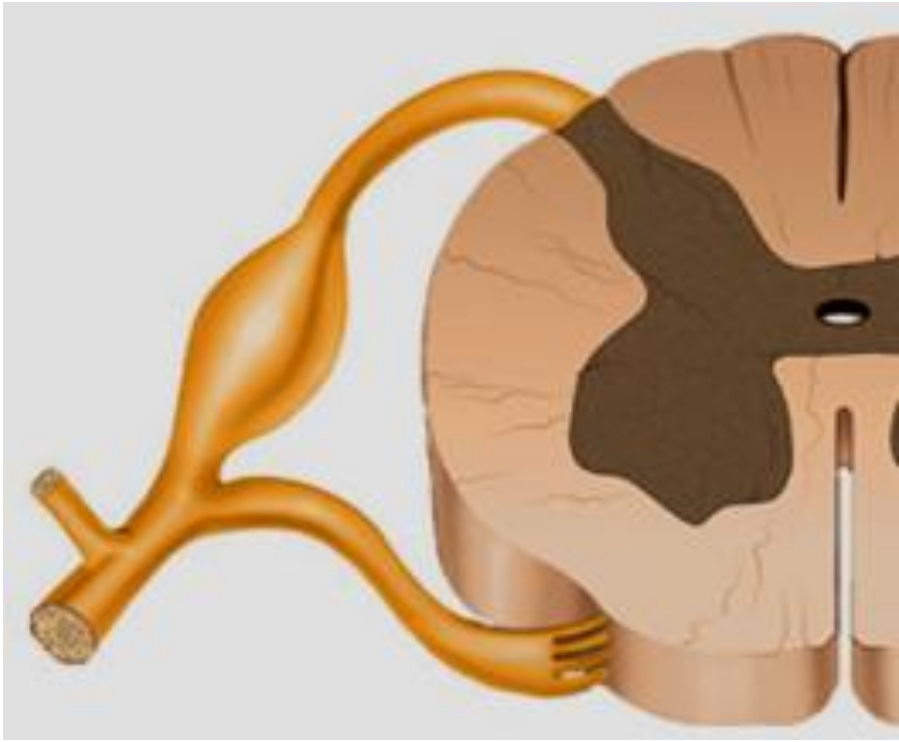


Itchy nightmare. Bandages protect Mary Ellen Nilsen’s head after a chronic itch drove her to scratch through her skull (CT scan, *inset*).

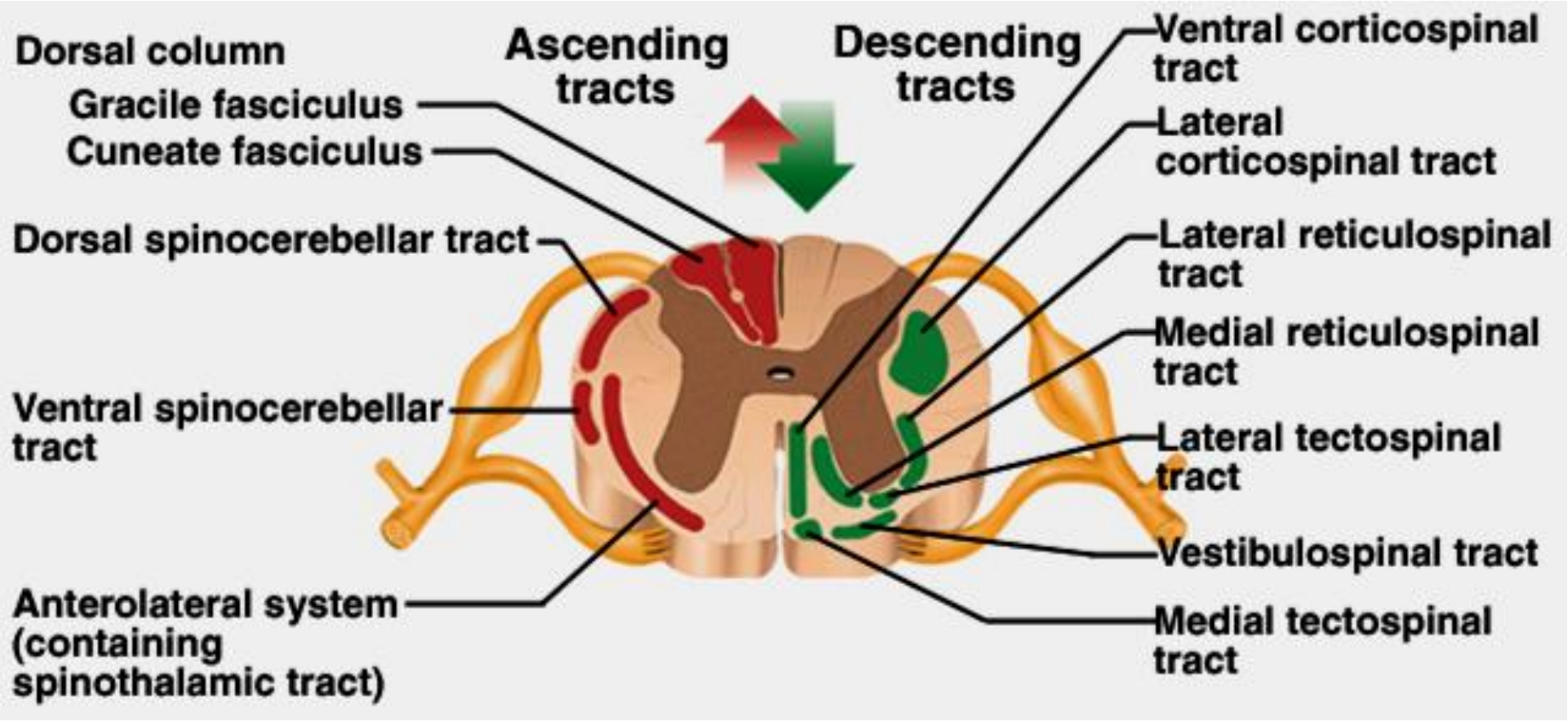
G. Miller (2007) Grasping for Clues to the Biology of Itch. Science 12 October 2007 Vol 318 p. 189.

Gray Matter in the Spinal Cord is divided into Horns

- Dorsal horns lead to the dorsal roots of spinal nerves
  - dorsal root is totally composed of sensory fibers
  - dorsal root ganglion contains the somas of unipolar sensory neurons
- Ventral horns lead to the ventral roots of spinal nerves
  - ventral root is totally composed of motor fibers
- Gray Commissure forms a bridge of gray matter between the horns
- Central canal filled with CSF and is continuous with the 4th ventricle of the brain



White Matter in the Spinal Cord is divided into Tracts

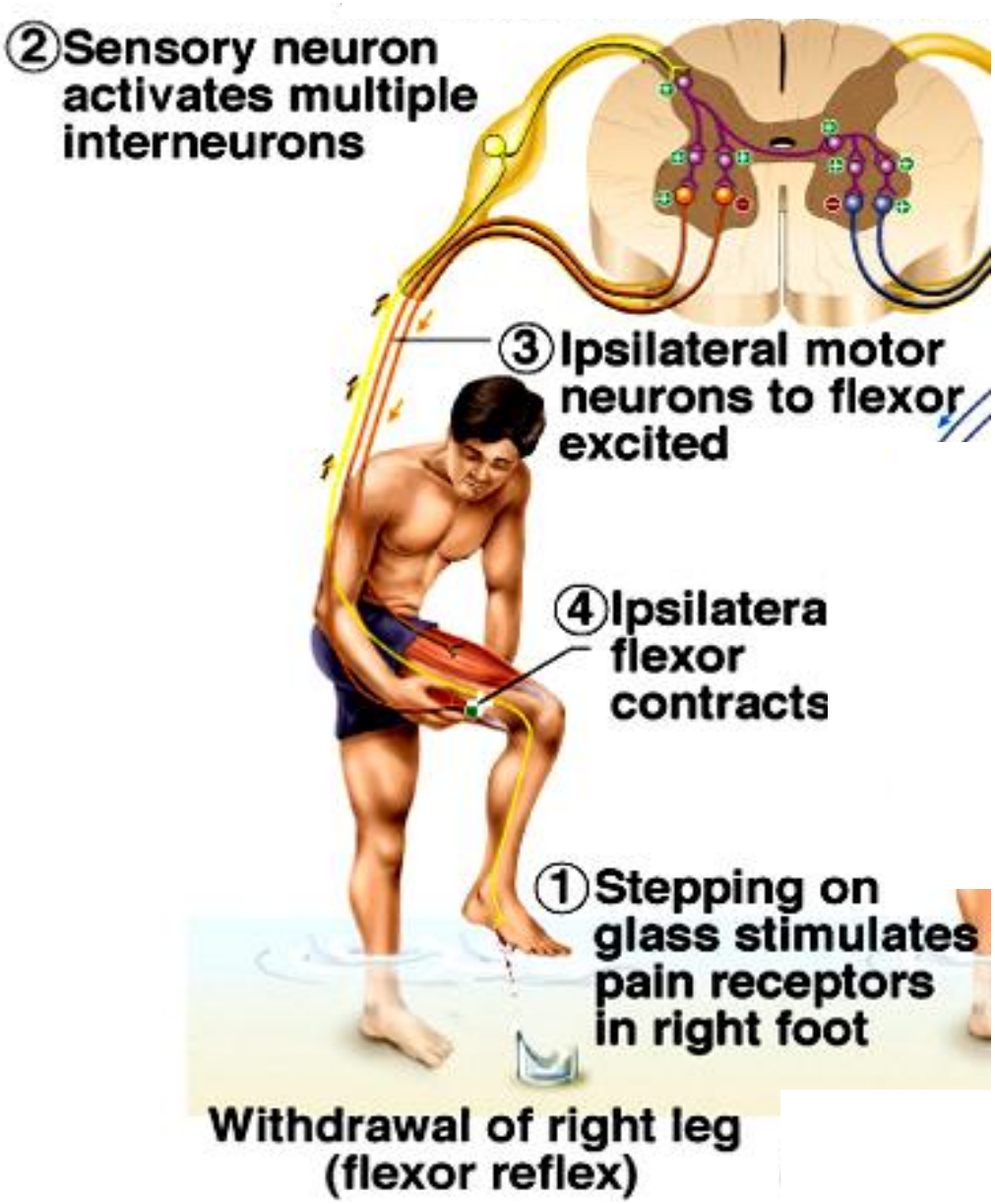


- Ascending Tracts carry signals up to brain.
- Descending tracts carry signals down spinal cord.
- Tracts can be Contralateral (origin and destination are on opposite sides) or Ipsilateral (origin and destination are on the same side).

Somatic Reflexes

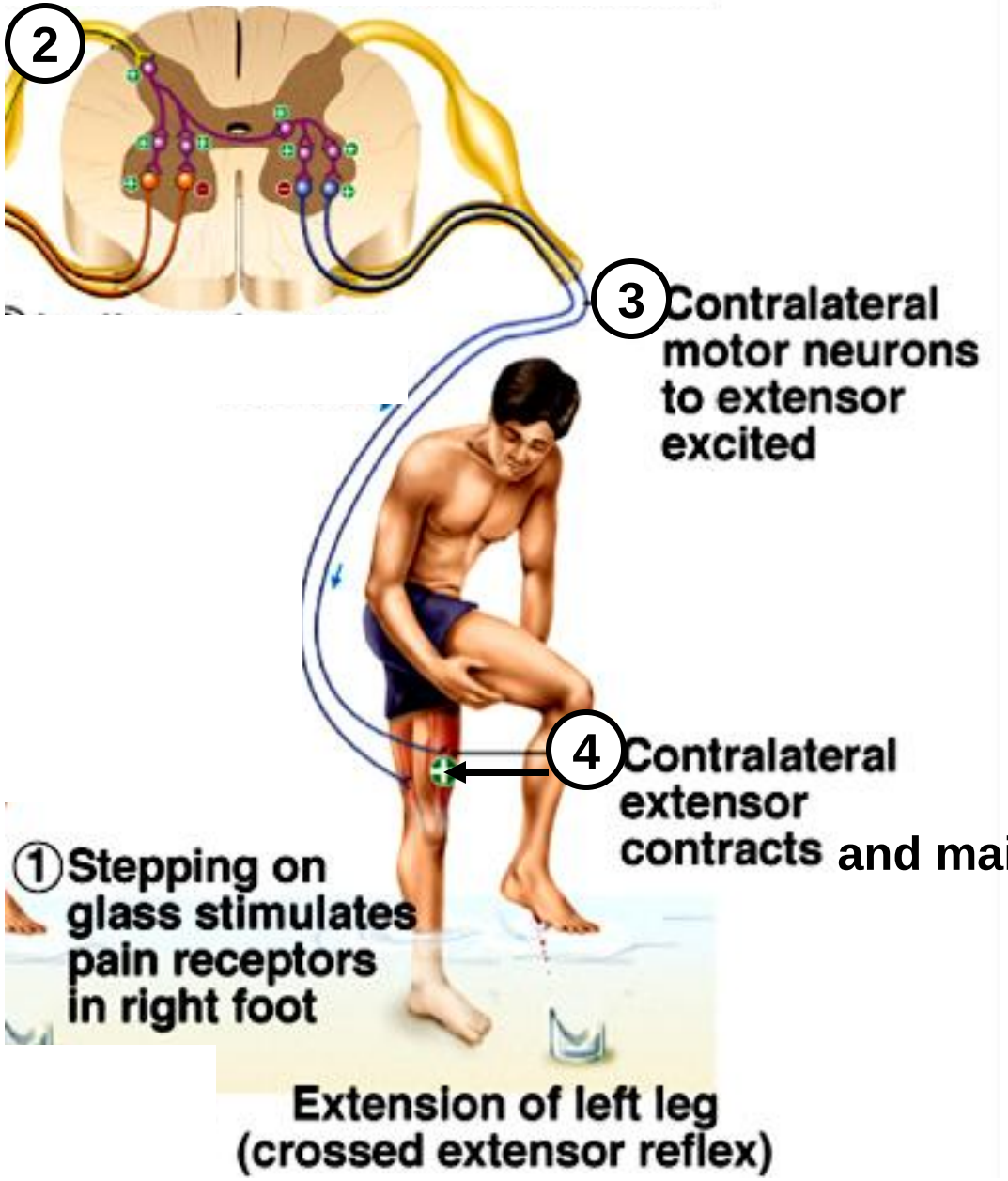
- Somatic Reflexes are quick, involuntary, stereotyped reactions of glands or muscle in response to sensory stimulation
- Automatic responses to sensory input that occur without our intent or often even our awareness occur through a Somatic Reflex Arc:
  1) stimulation of somatic receptors
  2) afferent fibers carry signal to dorsal horn of spinal cord
  3) interneurons integrate the information in spinal cord
  4) efferent fibers carry impulses to skeletal muscles
  5) skeletal muscles respond
- Examples: Flexor Withdrawal Reflex and Crossed Extensor Reflex

Flexor Withdrawal Reflex



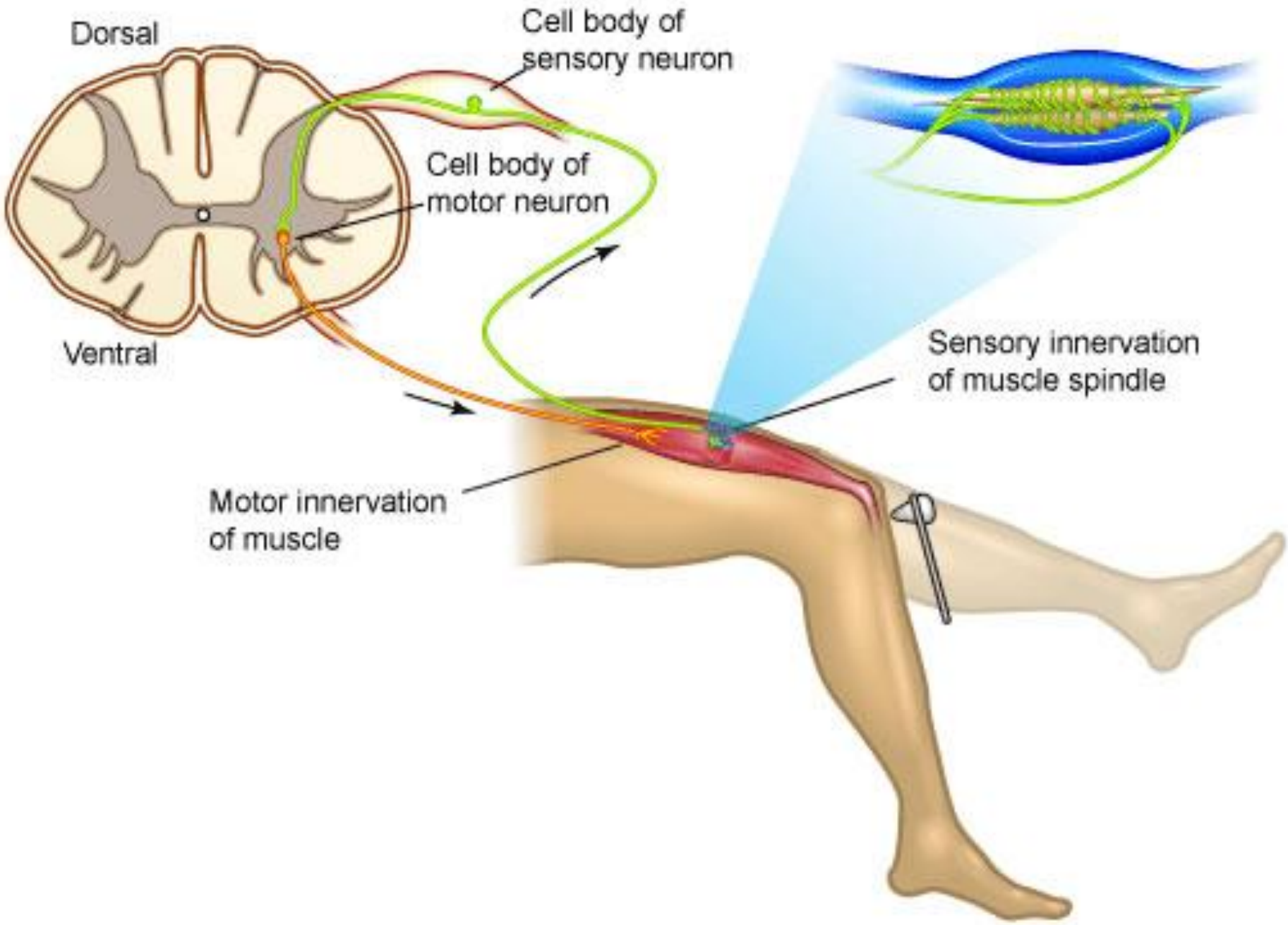
- Flexor Withdrawal Reflex quickly withdraws foot from pain.
- Neural circuitry in spinal cord controls sequence and duration of muscle contractions without the brain.

Crossed Extensor Reflex



The Stretch (Myotatic) Reflex

- When a muscle is stretched quickly, it contracts to help maintain equilibrium and posture.
  - example: when your head starts to tip forward as you fall asleep, the muscles are stretched and respond by quickly contracting to raise the head and correct the posture.
  - the reflex maintains posture by balancing tension in extensors and flexors at particular joints (neck, knees, hips, spine, etc.).
- Stretch is sensed by modified muscle cells called Muscle Spindles that are innervated by special sensory neurons called primary afferent neurons.
- Special motor neurons called alpha-motor neurons quickly respond to contract the stretched muscle.
- Reciprocal inhibition prevents flexors and extensors from working against each other.


Dorsal
Cell body of sensory neuron
Cell body of motor neuron
Ventral
Sensory innervation of muscle spindle
Motor innervation of muscle

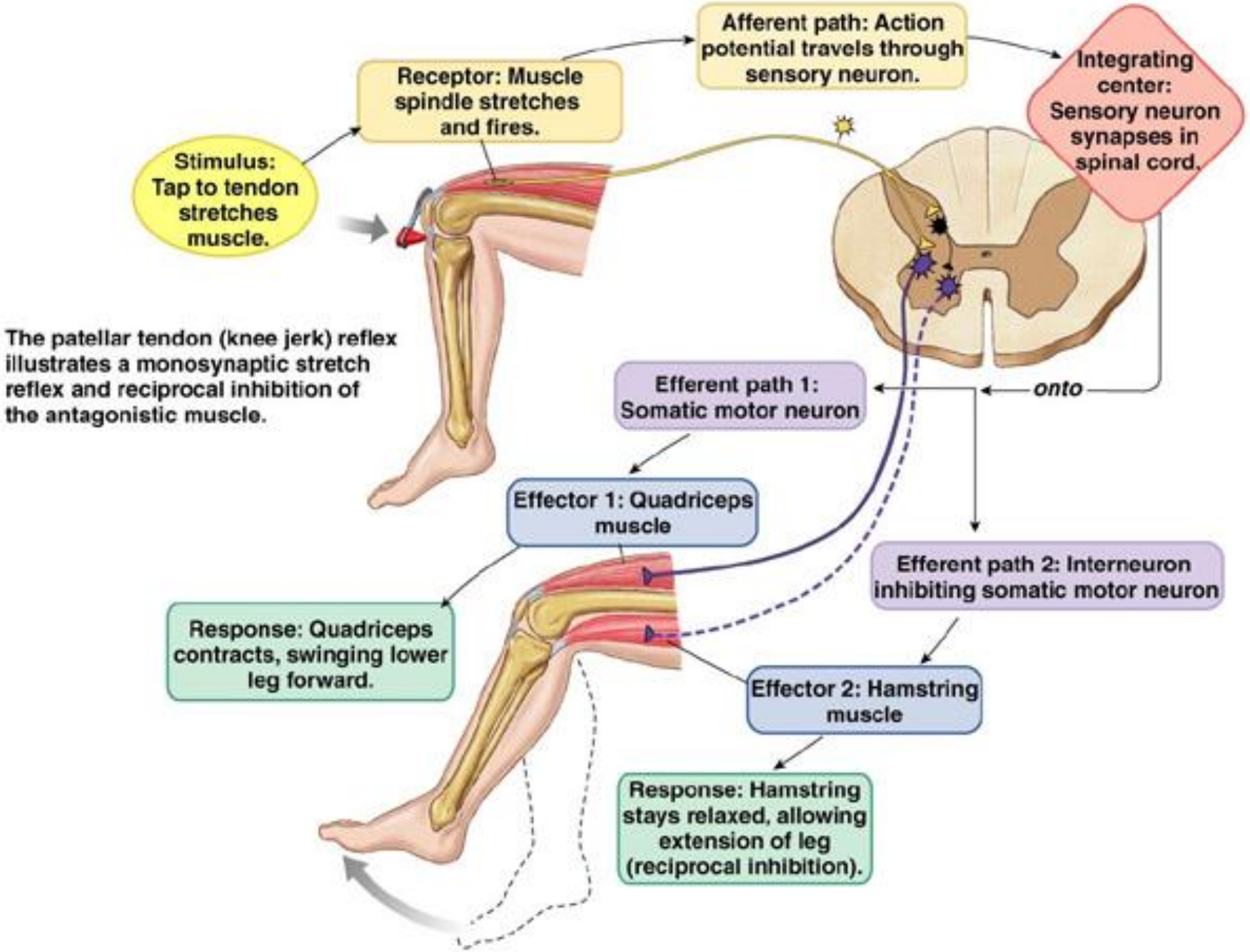
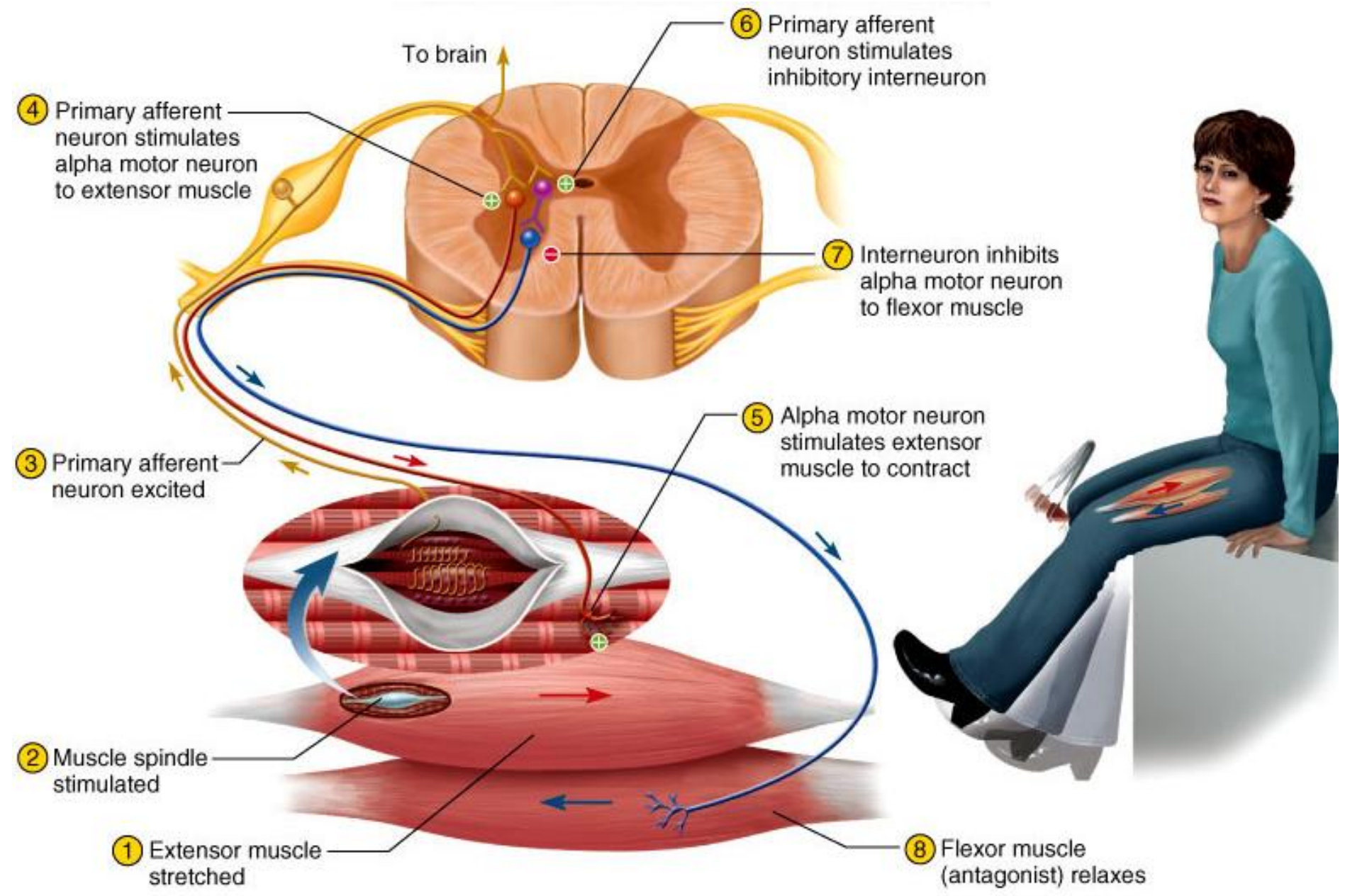


Fig. 13-7

END

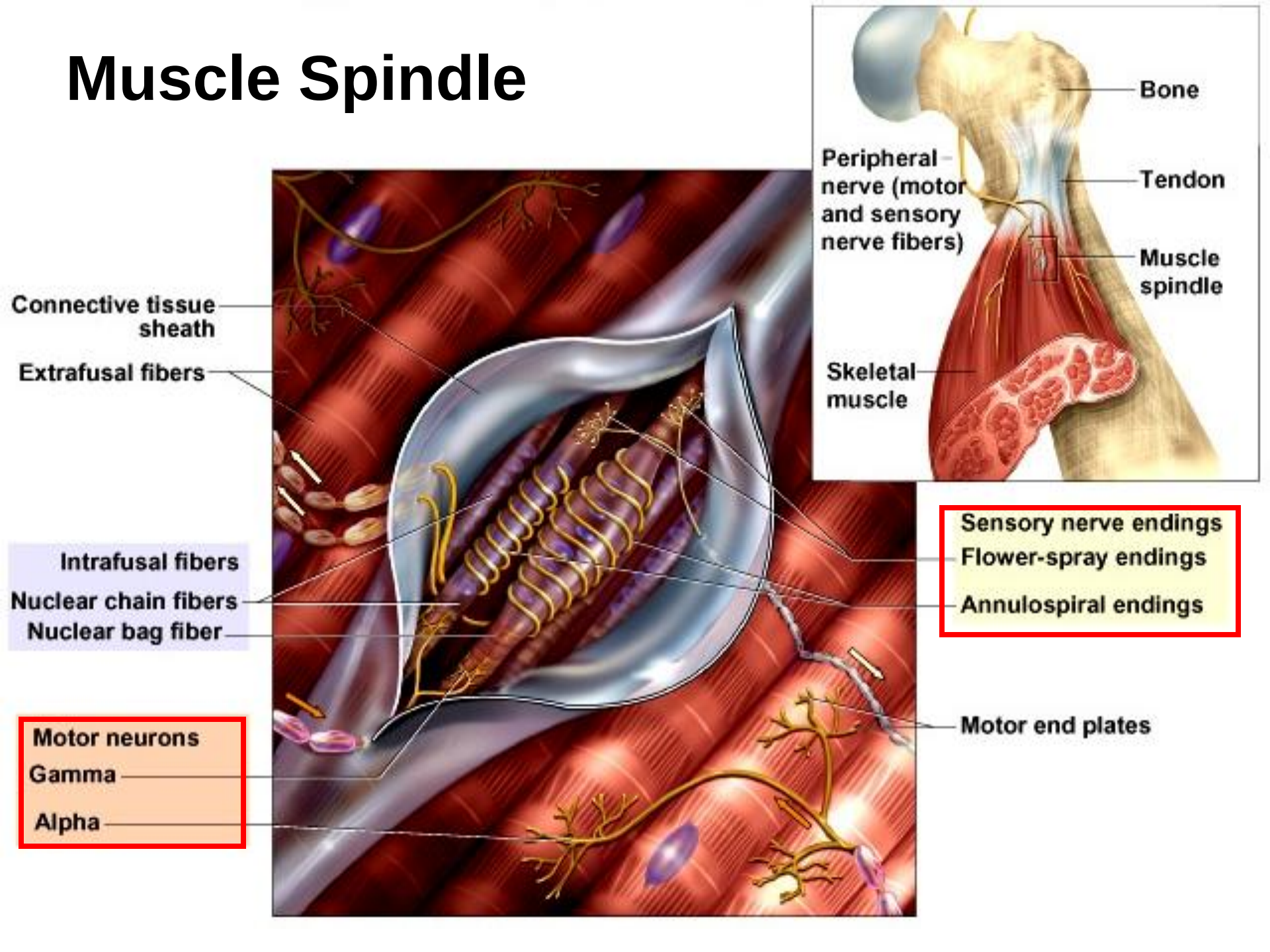
The Patellar Ligament Reflex Arc



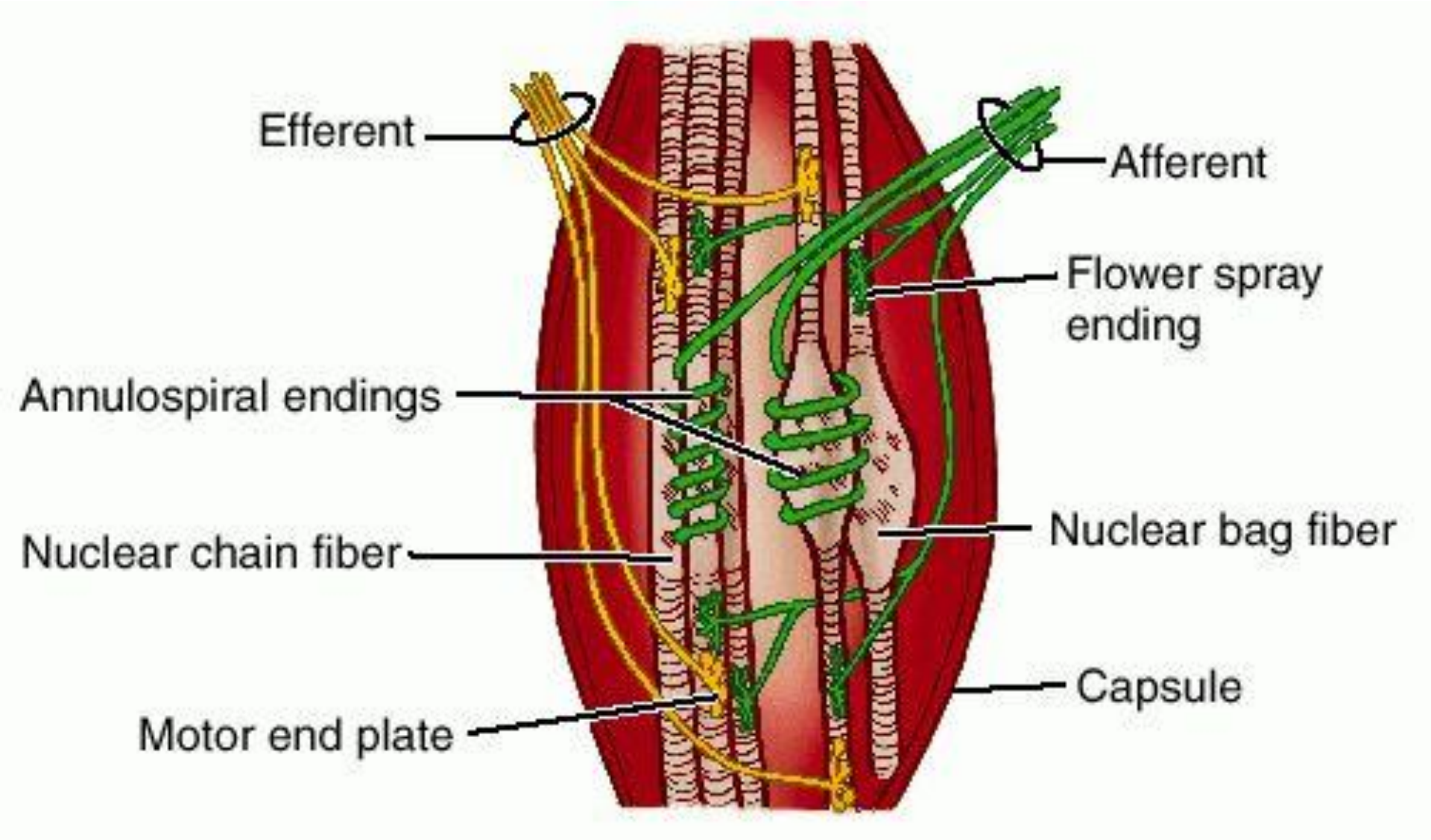
Muscle Spindle

- Muscle spindle senses the length of skeletal muscles.
- The spindles are modified skeletal muscle cells that are wrapped with special sensory fibers that synapse with interneurons in the spinal cord that quickly activate motor neurons to compensate for the stretch and inhibit antagonistic muscles.

Muscle Spindle

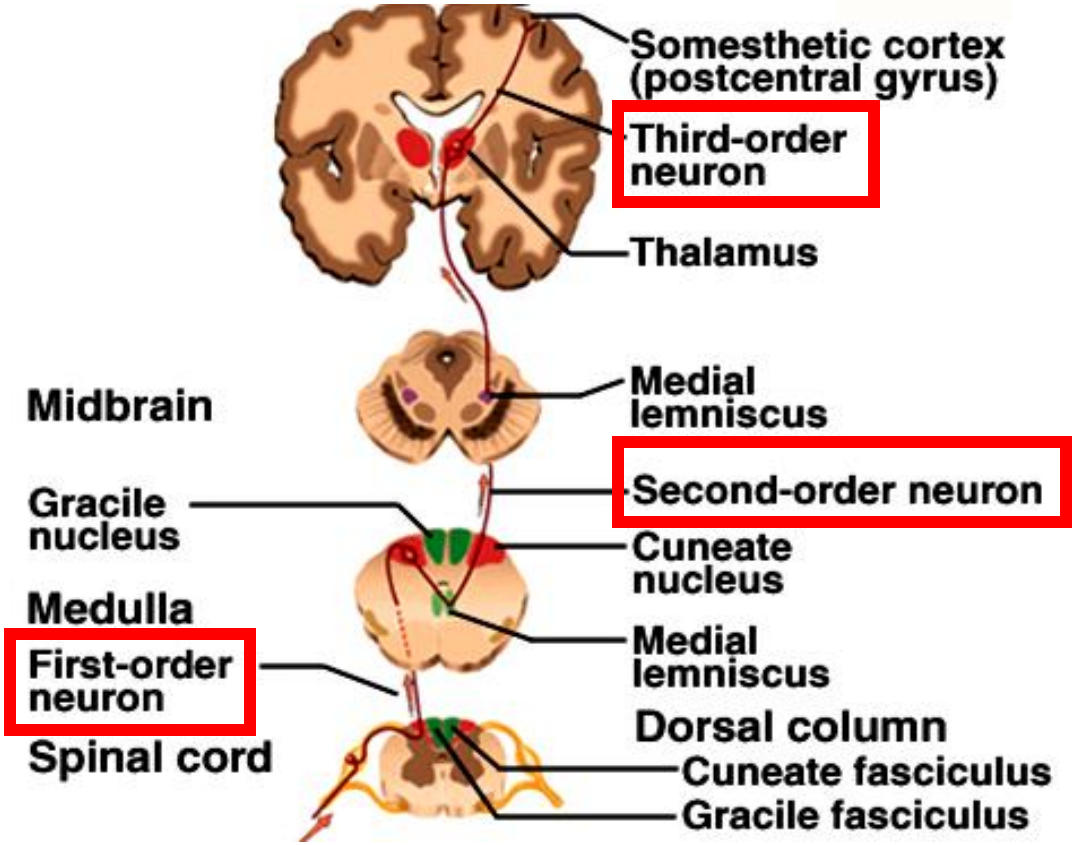


Muscle Spindle



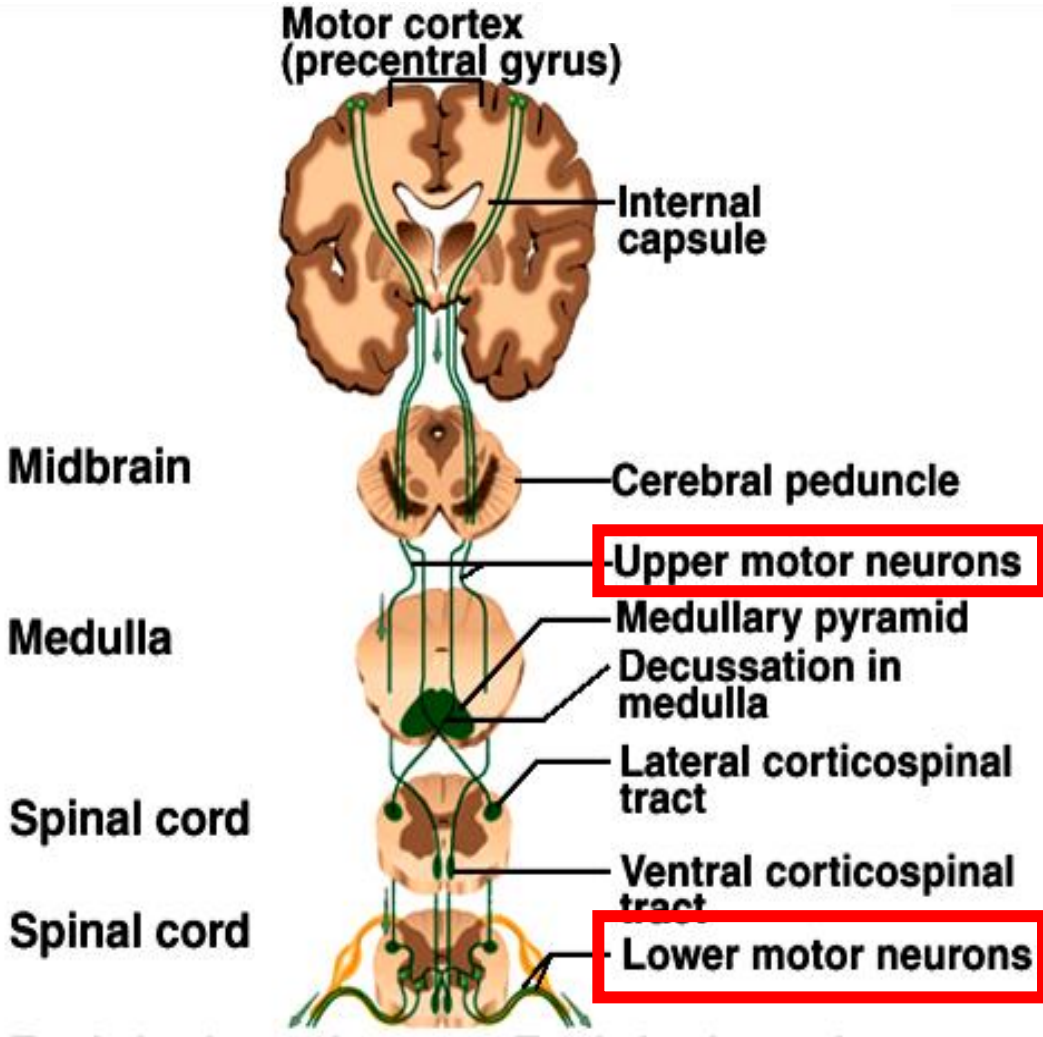
Ascending Pathway Example: The Dorsal Column

- Sensations of deep touch, visceral pain, vibration are relayed from First Order to Second Order to Third Order Neurons.
- Third Order Neurons in thalamus carry signal to cerebral cortex where it is perceived.

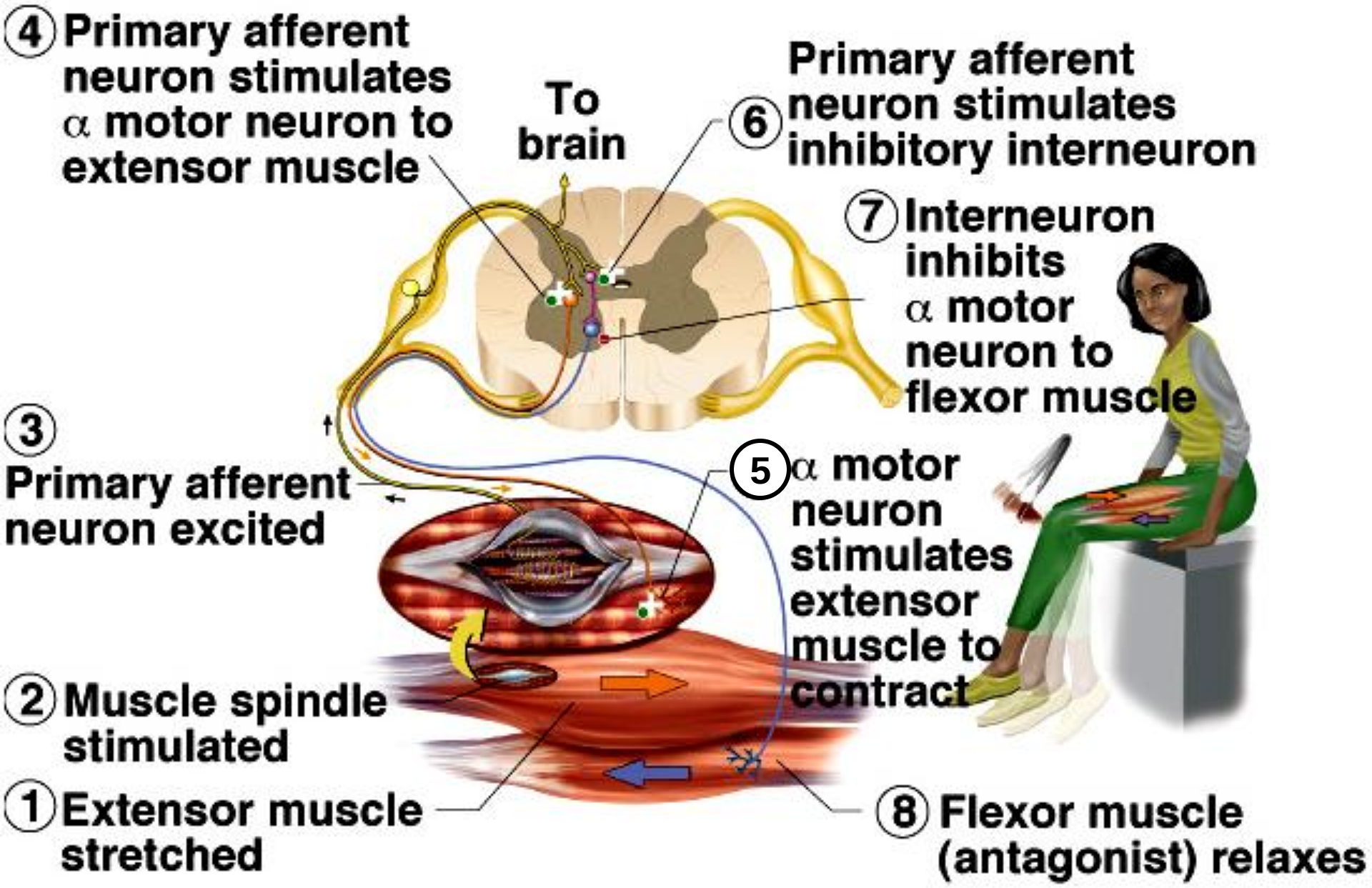


Descending Pathway Example: The Corticospinal Tract

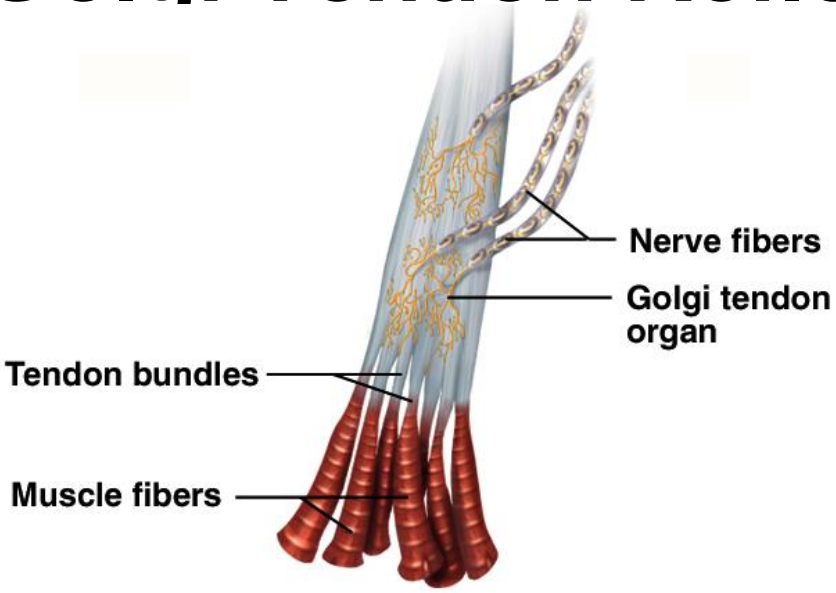
- Precise, coordinated limb movements are initiated in the motor cortex of the brain and relayed to the spinal cord.
- Two neuron pathway starts with an upper motor neuron in cerebral cortex that makes a synapse with a lower motor neuron in the spinal cord that carries the signal to a muscle



The Patellar Tendon Reflex Arc



Golgi Tendon Reflex



- Golgi Tendon Organs are Proprioceptors in tendons.
- Excessive tension on the tendon inhibits the motor neuron to that muscle and muscle contraction is decreased.

The Spinal Cord

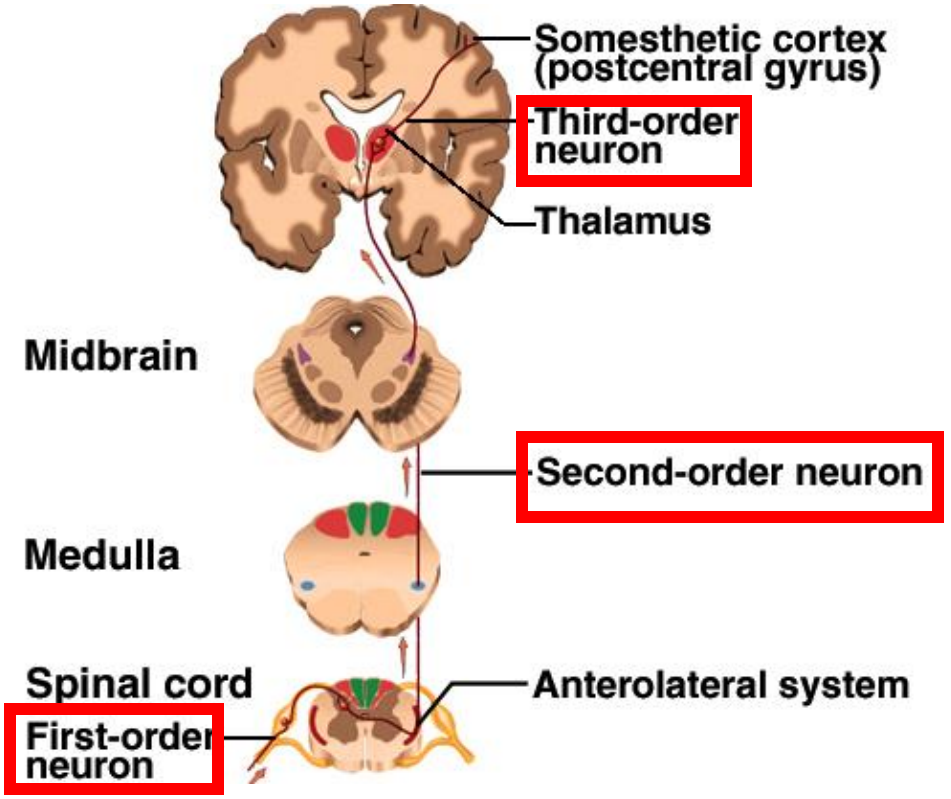
- Conducts information between brain and body.
- Extends through vertebral canal from foramen magnum to L1.
- Each pair of spinal nerves receives sensory information and sends out motor signals to muscles and glands.
- Spinal cord is part of the Central Nervous System while the spinal nerves are part of the Peripheral Nervous System

Functions of the Spinal Cord

- Conduction
  - bundles of nerve fibers pass information up and down spinal cord.
- Locomotion
  - coordinates actions of several muscle groups
  - central pattern generators are pools of neurons that provide control of flexors and extensors as in walking.
- Reflexes
  - involuntary, stereotyped responses to stimuli (remove hand from hot stove) involves brain, spinal cord and peripheral nerves.

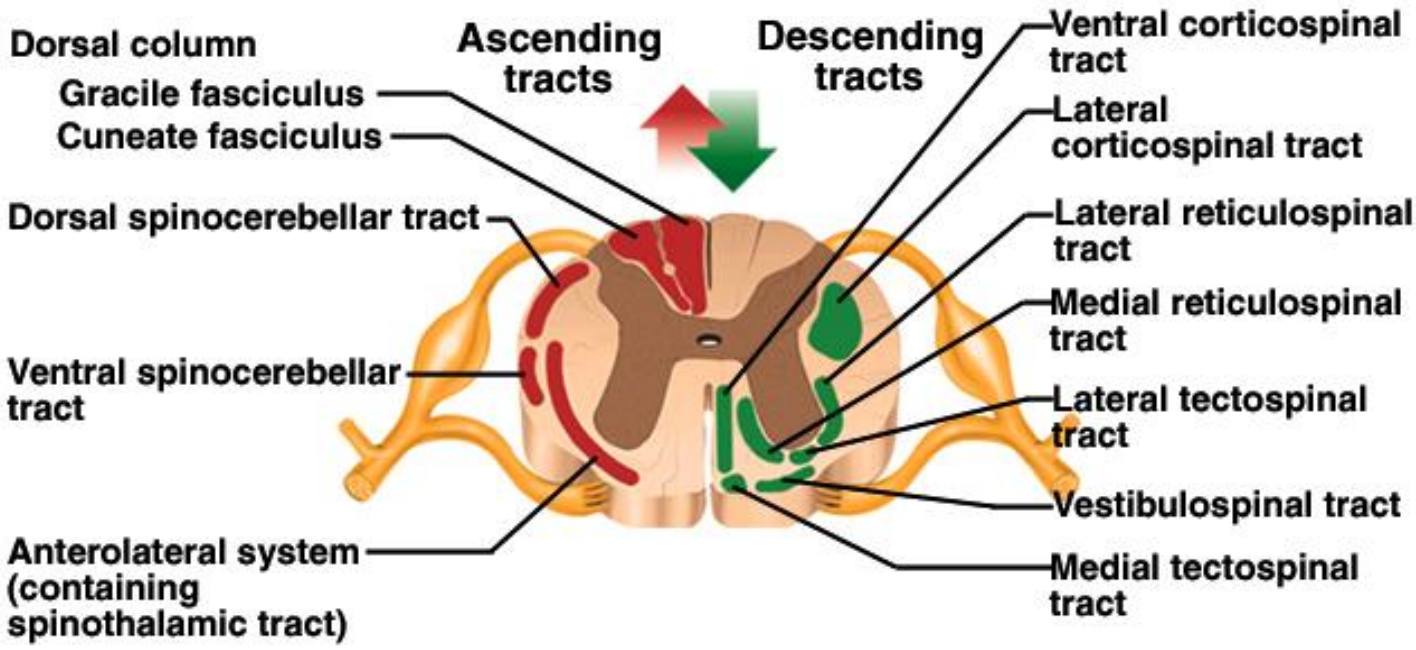
Spinothalamic Pathway

- Pain, pressure, temperature, light touch, tickle & itch
- Decussation of the second order neuron occurs in spinal cord



Spinocerebellar Pathway

- Proprioceptive signals in limbs and trunk travel up to the cerebellum
- Second order nerves ascend in lateral column



Descending Motor Tracts

- Tectospinal tract
  - reflex movements of head
- Reticulospinal tract
  - controls limb movements important to maintain posture
- Vestibulospinal tract
  - postural muscle activity in response to inner ear signals

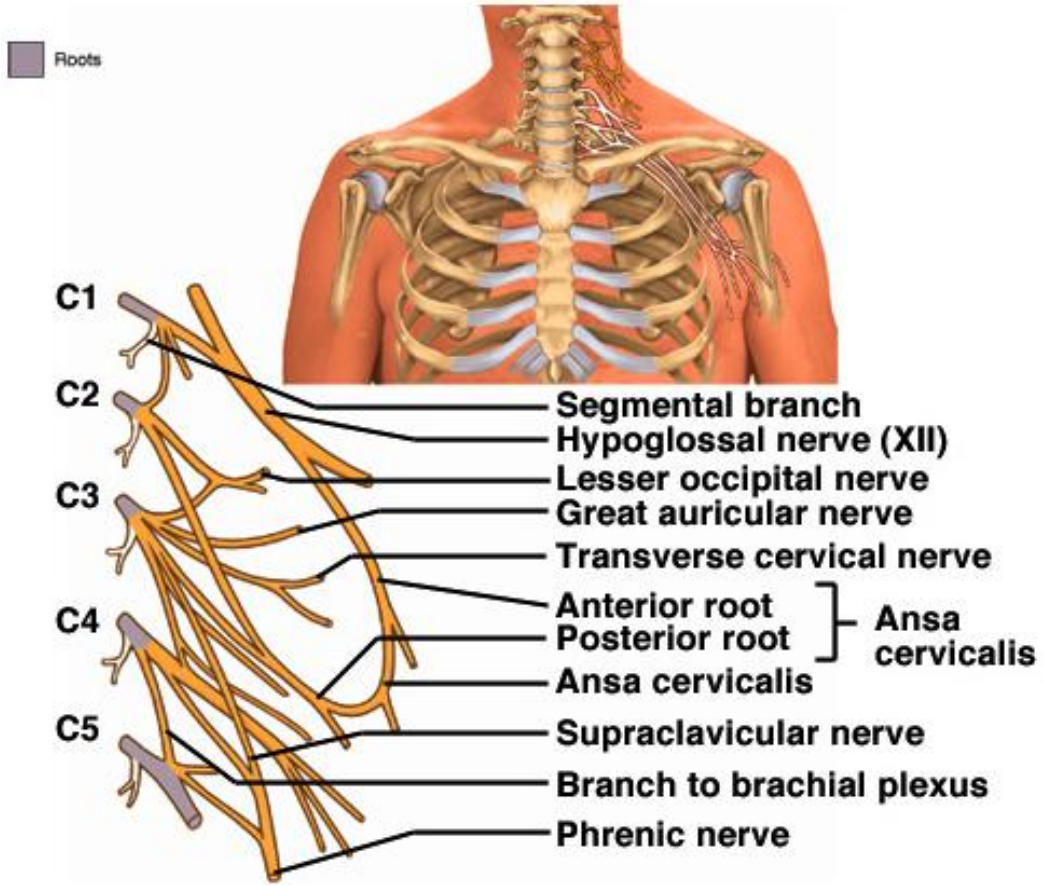
Spinal Cord Trauma

- 10-12,000 people/ year are paralyzed
- 55% occur in traffic accidents
- This damage poses risk of respiratory failure
- Early symptoms are called spinal shock
- Tissue damage at time of injury is followed by post-traumatic infarction

Nerve Plexuses

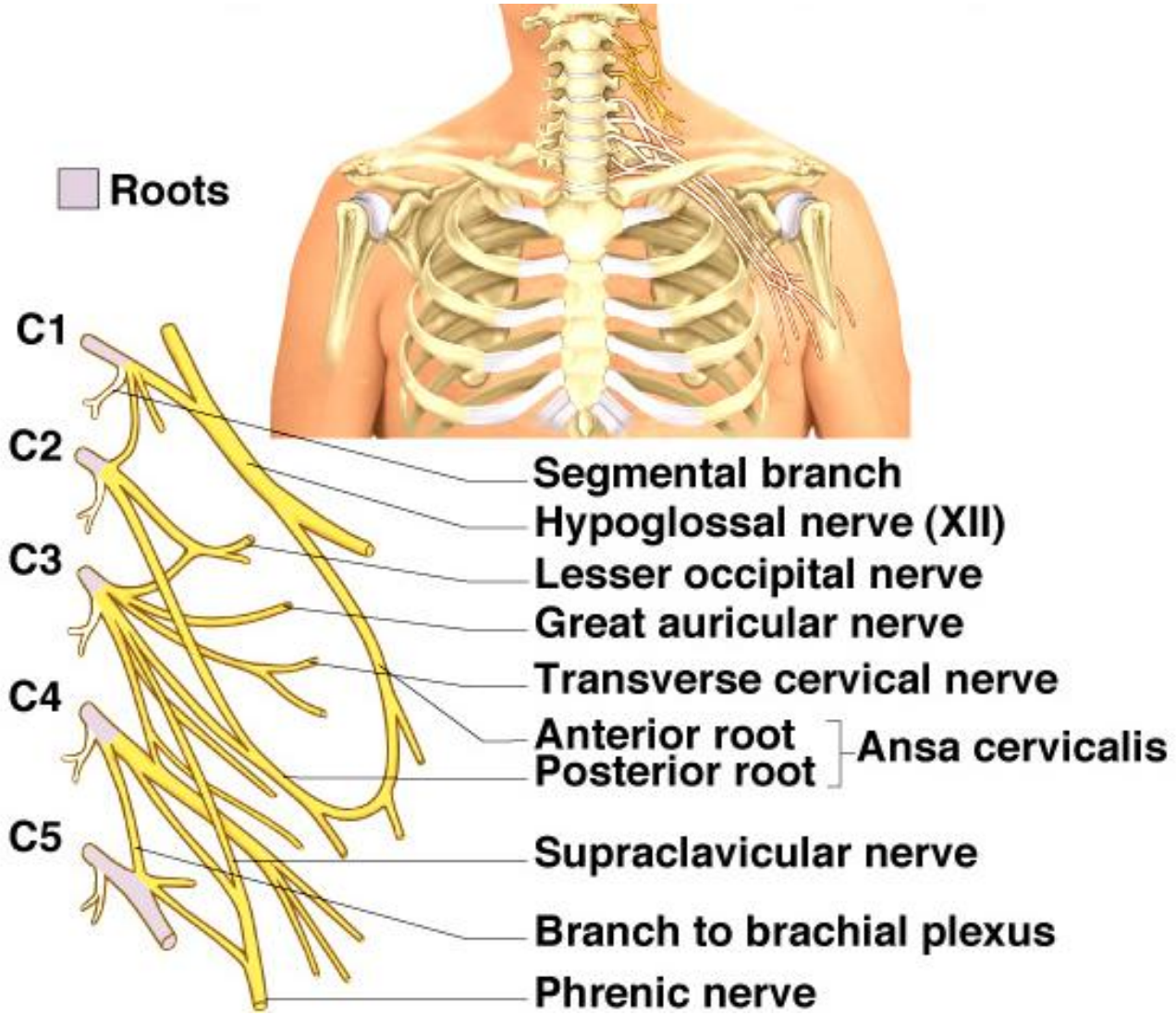
- Ventral rami branch & anastomose repeatedly to form 5 nerve plexuses
  - cervical in the neck, C1 to C5
    - supplies neck and phrenic nerve to the diaphragm
  - brachial in the armpit, C5 to T1
    - supplies upper limb and some of shoulder & neck
  - lumbar in the low back, L1 to L4
    - supplies abdominal wall, anterior thigh & genitalia
  - sacral in the pelvis, L4, L5 & S1 to S4
    - supplies remainder of butt & lower limb
  - coccygeal, S4, S5 and C0

Structure of a Nerve Plexus

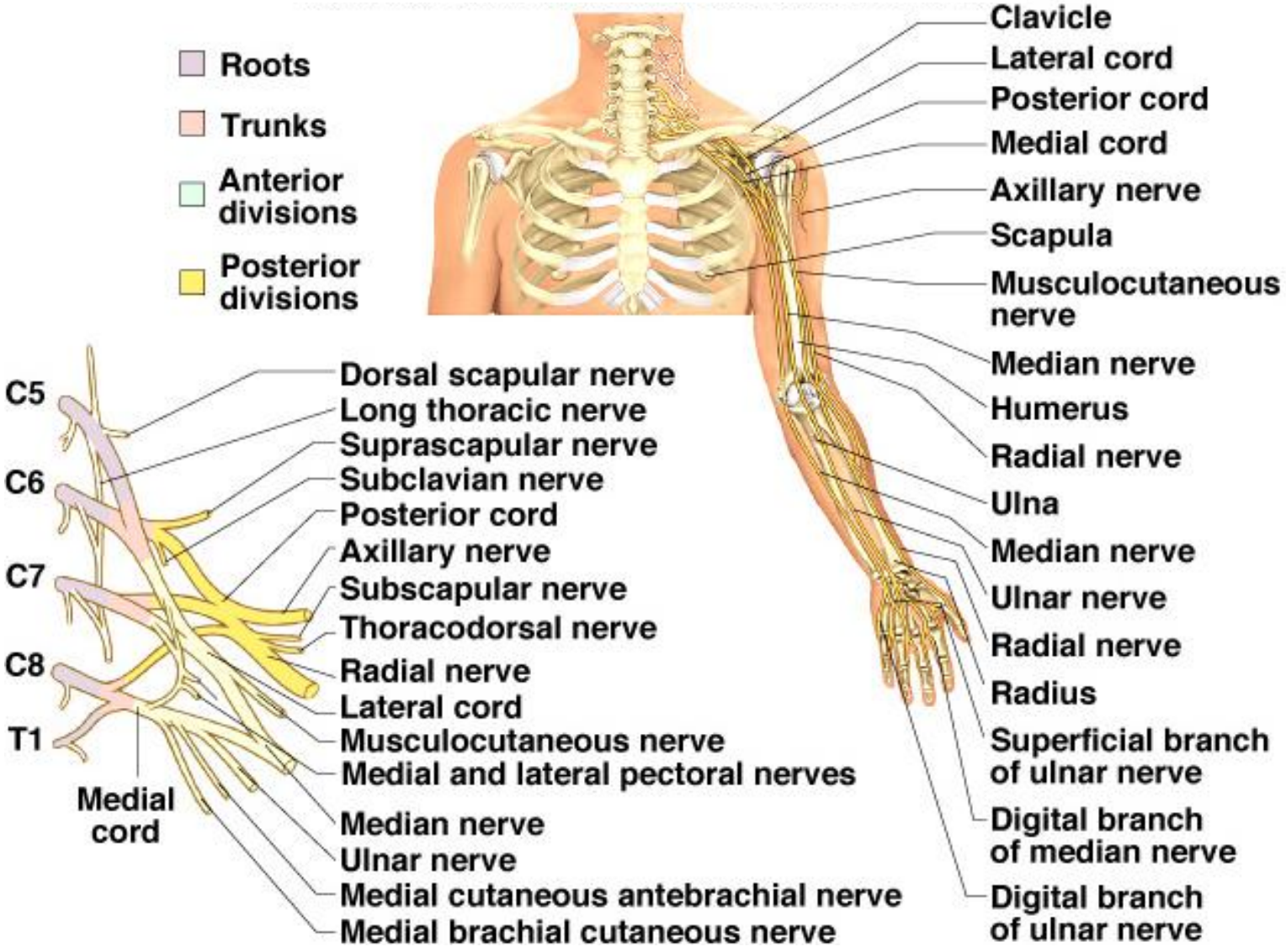


- Notice the branching and merging of nerves in this example of a plexus

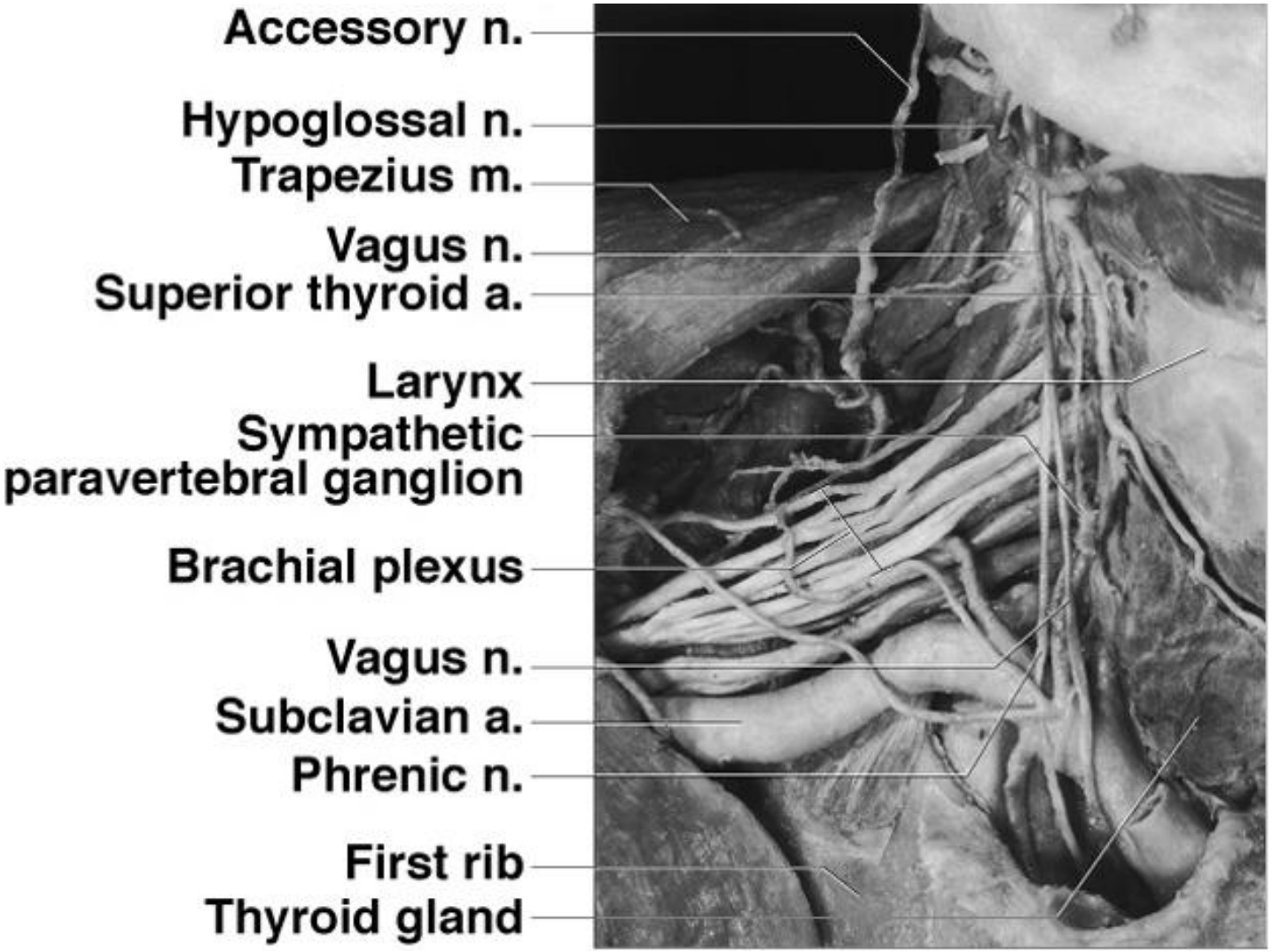
The Cervical Plexus



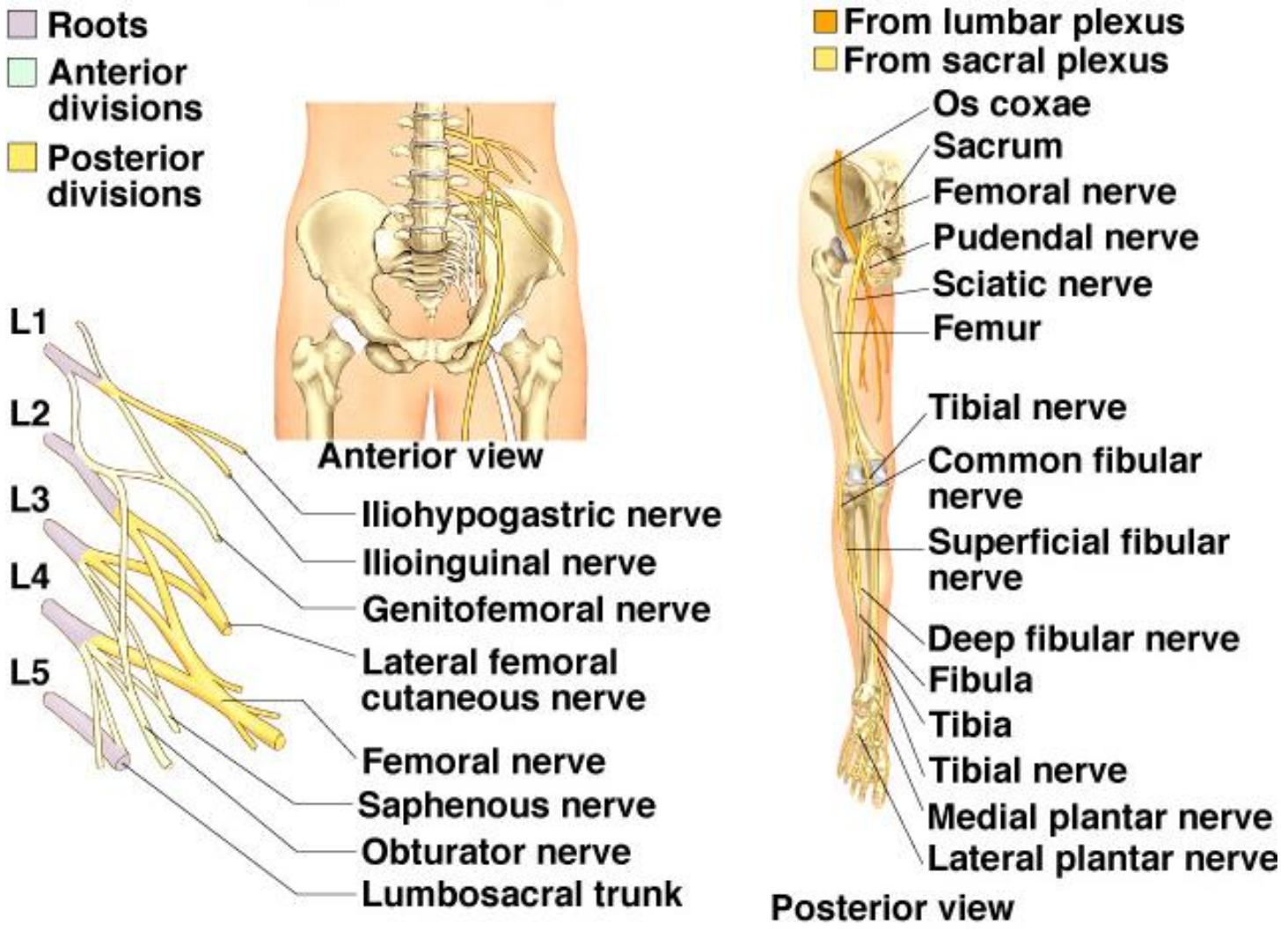
The Brachial Plexus



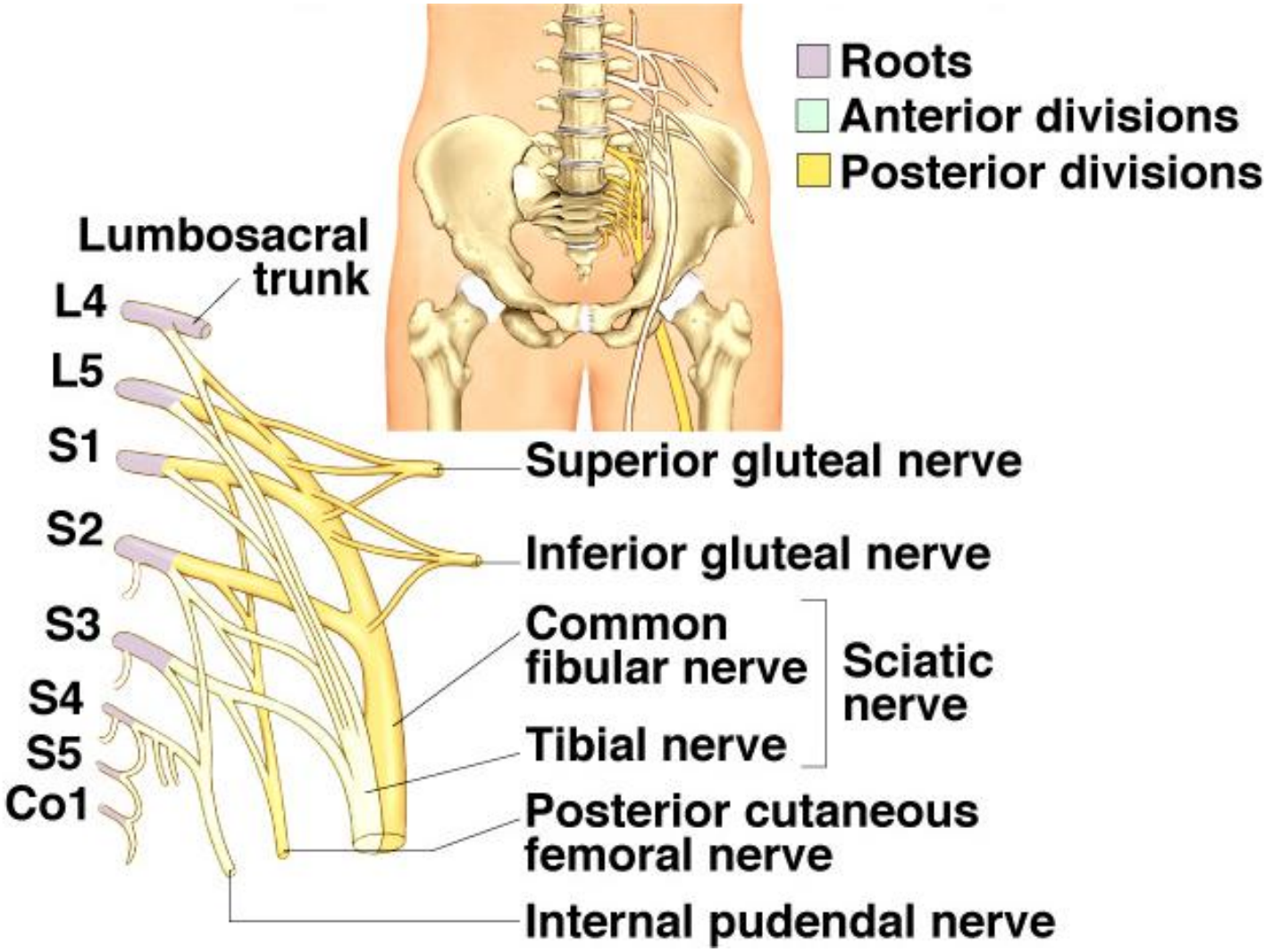
Dissection of the Brachial Plexus



The Lumbar Plexus



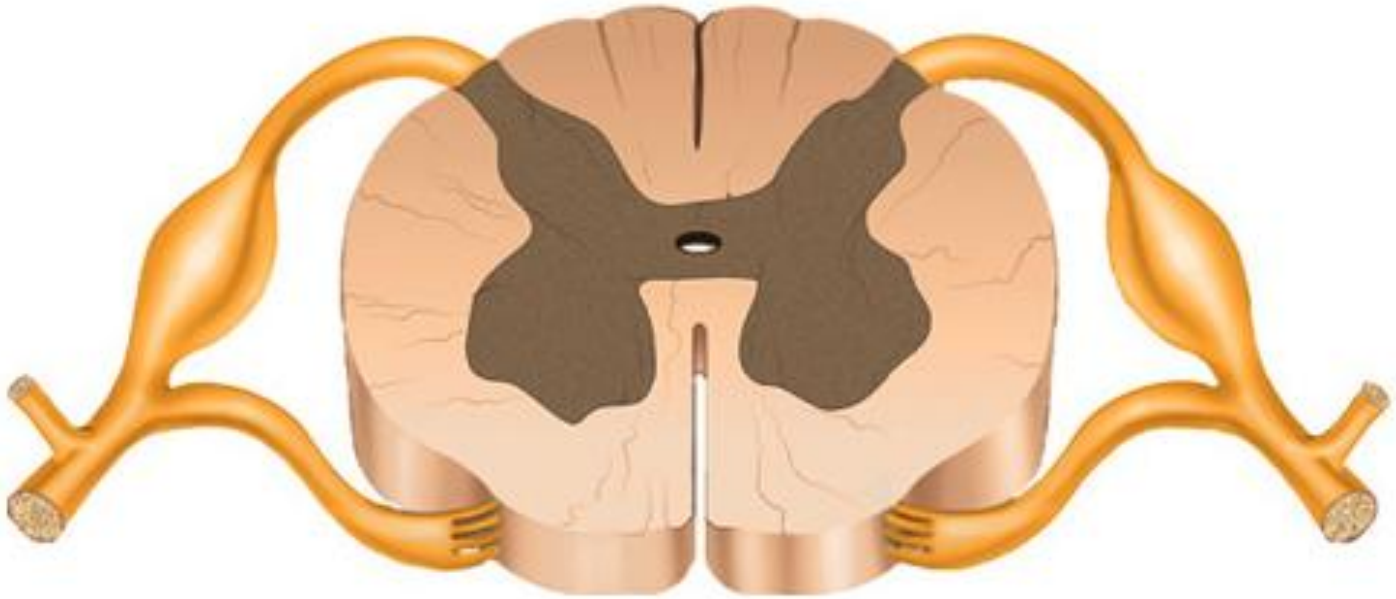
The Sacral and Coccygeal Plexuses



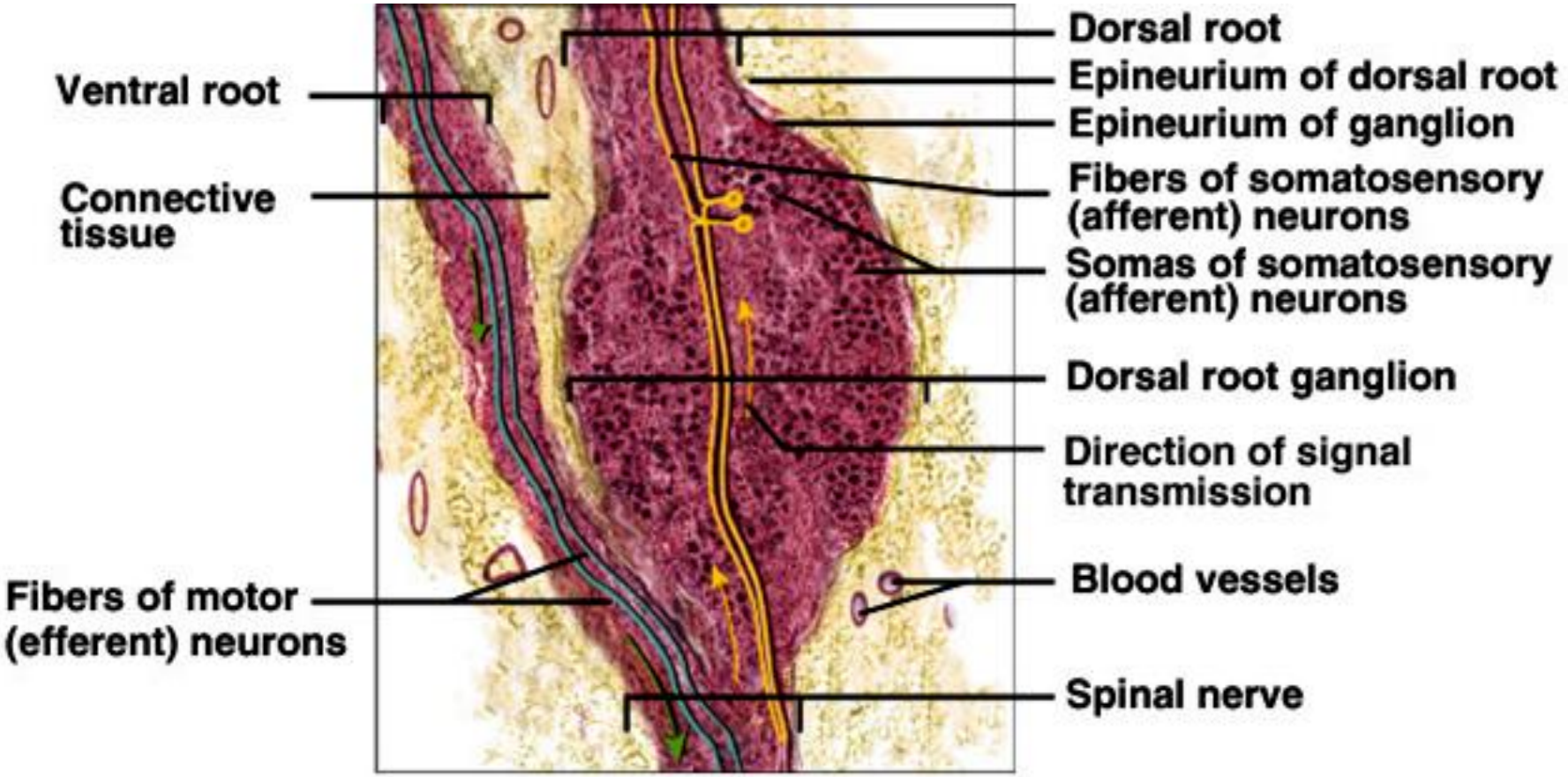
Poliomyelitis and ALS

- Diseases causing destruction of motor neurons and skeletal muscle atrophy
- Poliomyelitis caused by poliovirus spread by fecally contaminated water
  - weakness progresses to paralysis and respiratory arrest
- Amyotrophic lateral sclerosis
  - sclerosis of spinal cord due to astrocyte failure to reabsorb glutamate neurotransmitter
  - paralysis and muscle atrophy

- White matter is divided into columns which are bundles of myelinated axons that carry signals up and down the spinal cord.
- Each column is filled with tracts named for fibers with a similar origin, destination and function.



Anatomy of Ganglia in the PNS



- Ganglia in the PNS are clusters of neuron somas (cell bodies) in a nerve.
- Example: Dorsal Root Ganglion is the location of the sensory neuron somas.