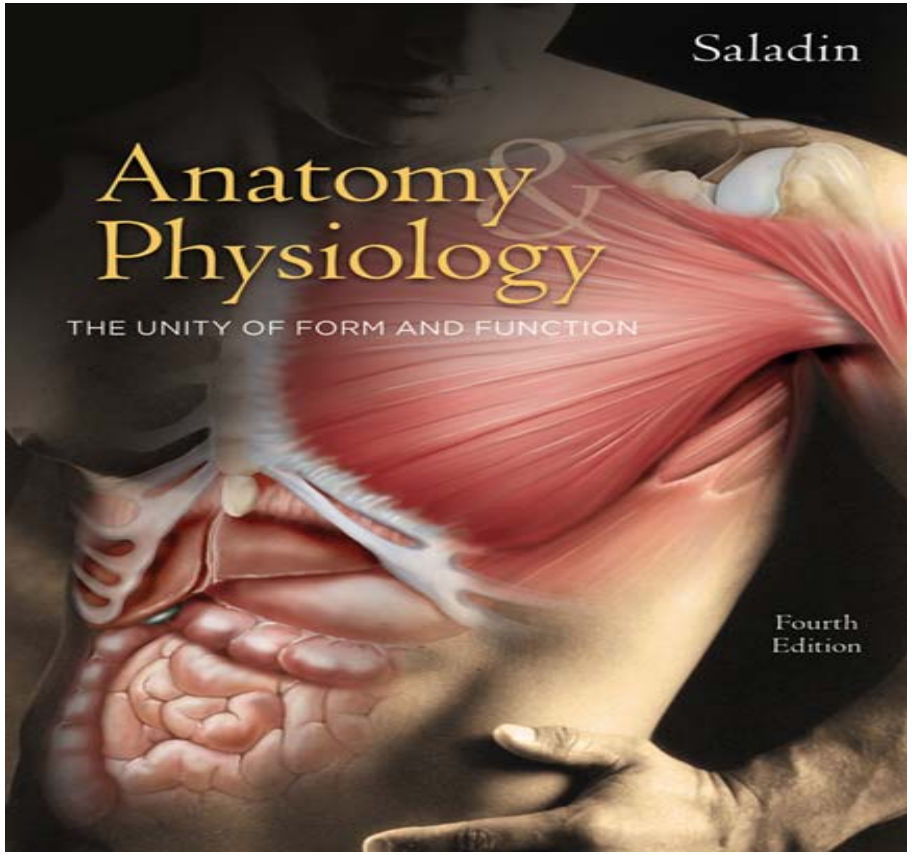
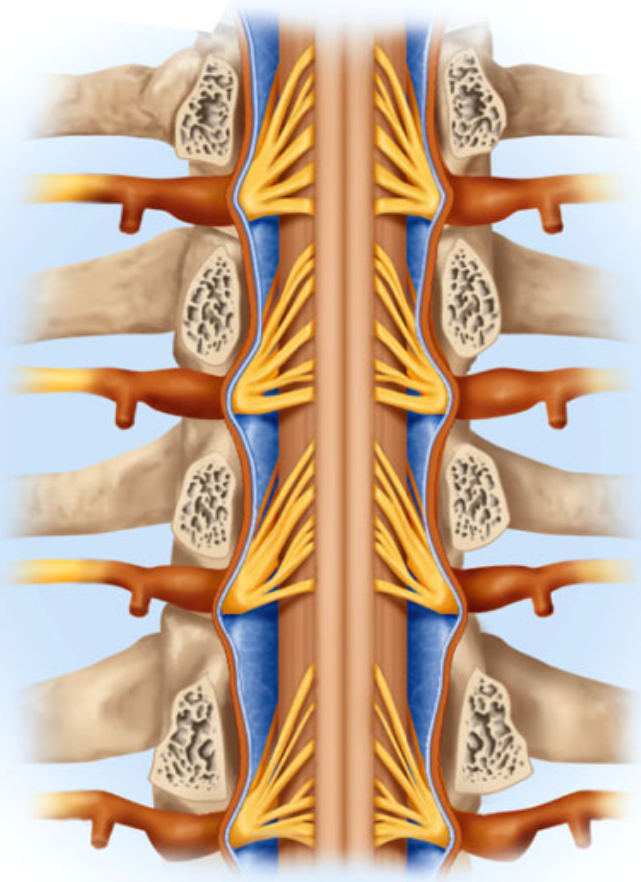
Human Anatomy & Physiology

Spinal Cord, Spinal Nerves and Somatic Reflexes



Spinal Cord, Spinal Nerves and Somatic Reflexes

- Spinal cord
- Spinal nerves
- Somatic reflexes



(b)

Overview of Spinal Cord

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

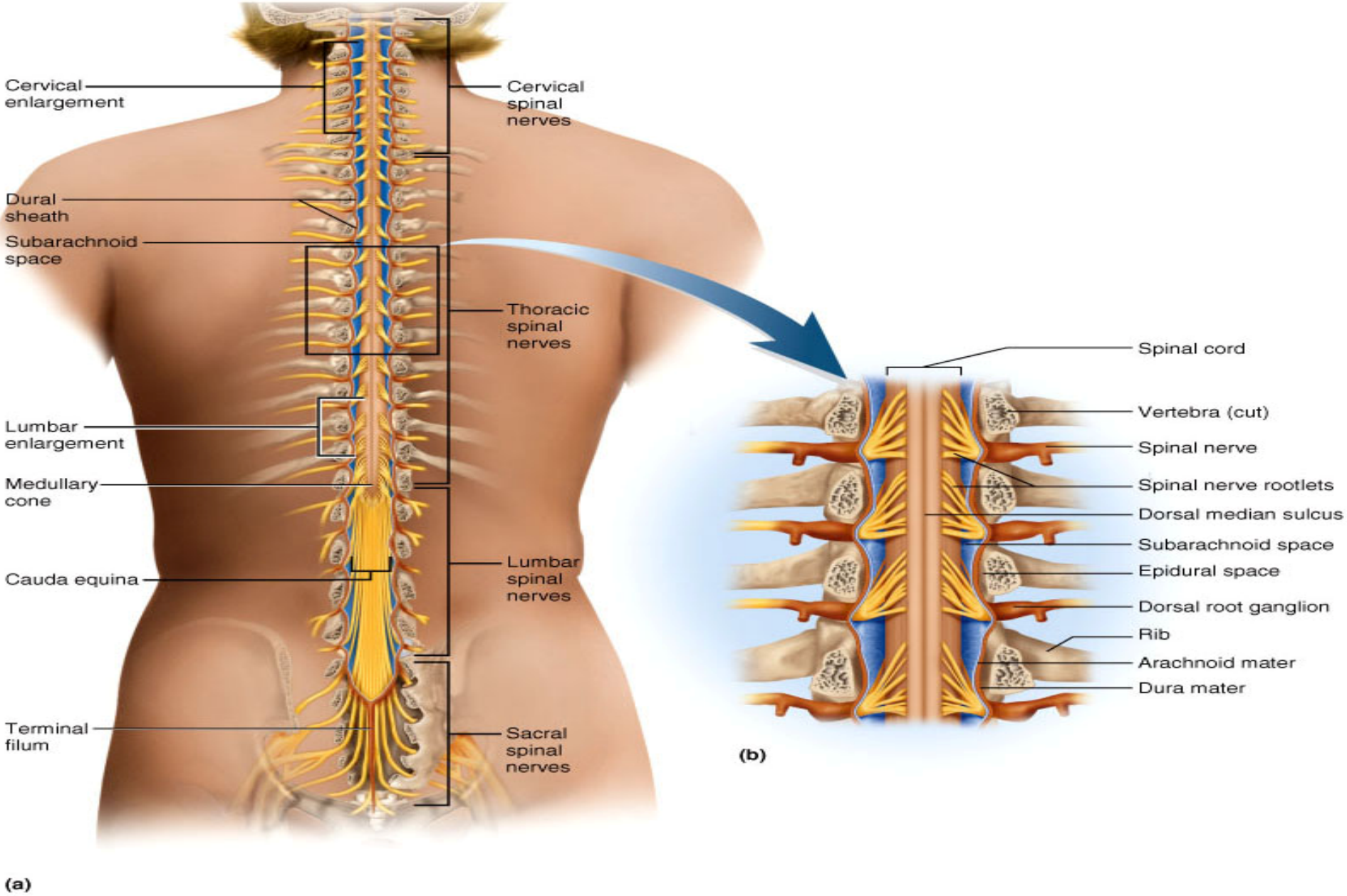
Functions of the Spinal Cord

- **Conduction**
  - bundles of fibers passing information up and down spinal cord
- **Locomotion**
  - repetitive, coordinated actions of several muscle groups
  - central pattern generators are pools of neurons providing control of flexors and extensors (walking)
- **Reflexes**
  - involuntary, stereotyped responses to stimuli (remove hand from hot stove)
  - involves brain, spinal cord and peripheral nerves

Anatomy of the Spinal Cord

- Cylinder of nerve tissue within the vertebral canal (thick as a finger)
  - vertebral column grows faster so in an adult the spinal cord only extends to L1
- 31 pairs of spinal nerves arise from cervical, thoracic, lumbar and sacral regions of the cord
  - each cord segment gives rise to a pair of spinal nerves
- Cervical and lumbar enlargements
- Medullary cone (conus medullaris) = tapered tip of cord
- Cauda equinae is L2 to S5 nerve roots resemble horse's tail

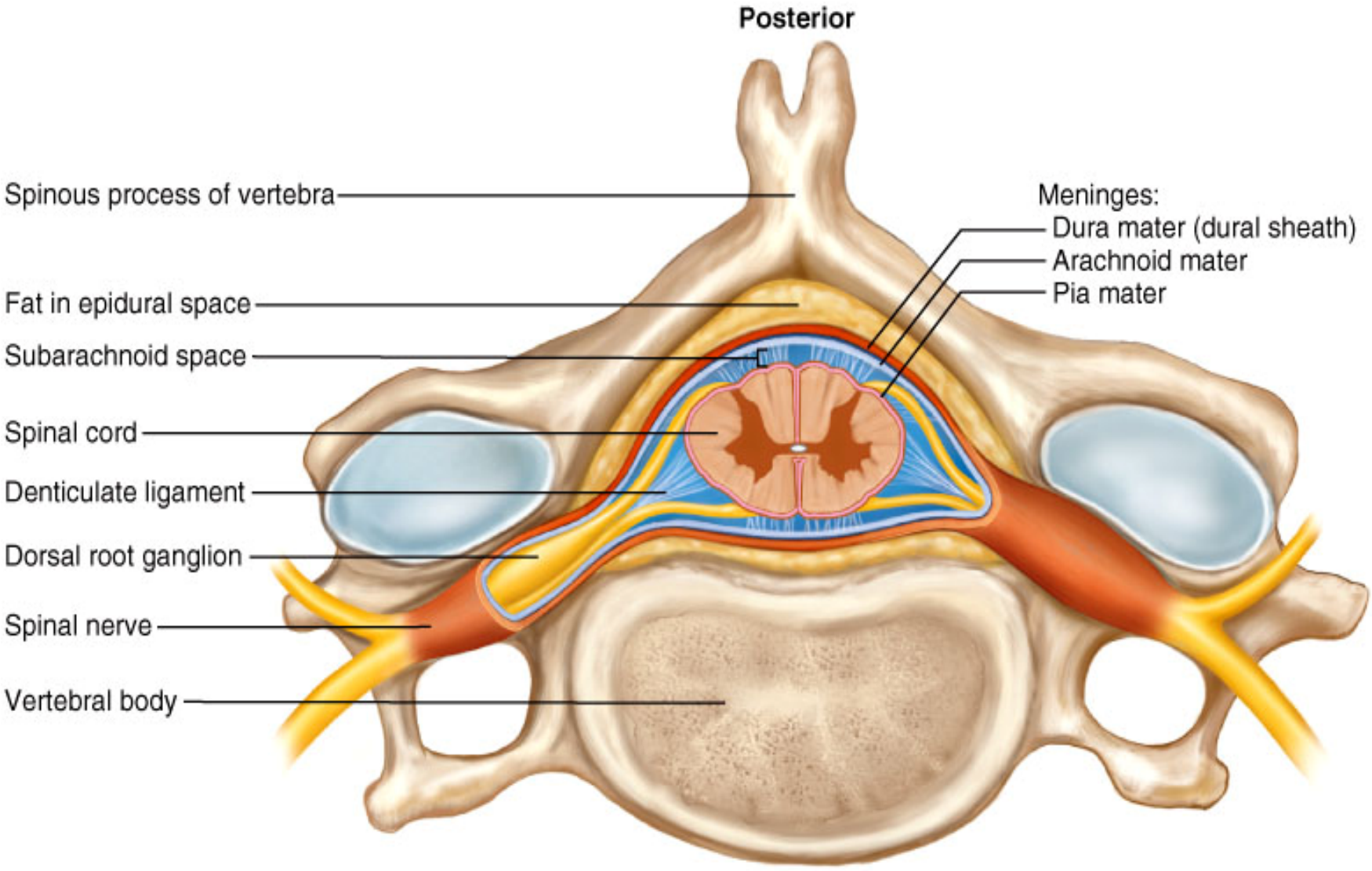
Gross Anatomy of Lower Spinal Cord



Meninges of the Spinal Cord

- 3 Fibrous layers enclosing spinal cord
- Dura mater
  - tough collagenous membrane surrounded by epidural space filled with fat and blood vessels
    - epidural anesthesia utilized during childbirth
- Arachnoid mater
  - layer of simple squamous epithelium lining dura mater and loose mesh of fibers filled with CSF (creates subarachnoid space)
- Pia mater
  - delicate membrane adherent to spinal cord
  - filium terminale and denticulate ligaments anchor the cord

Meninges of Vertebra and Spinal Cord

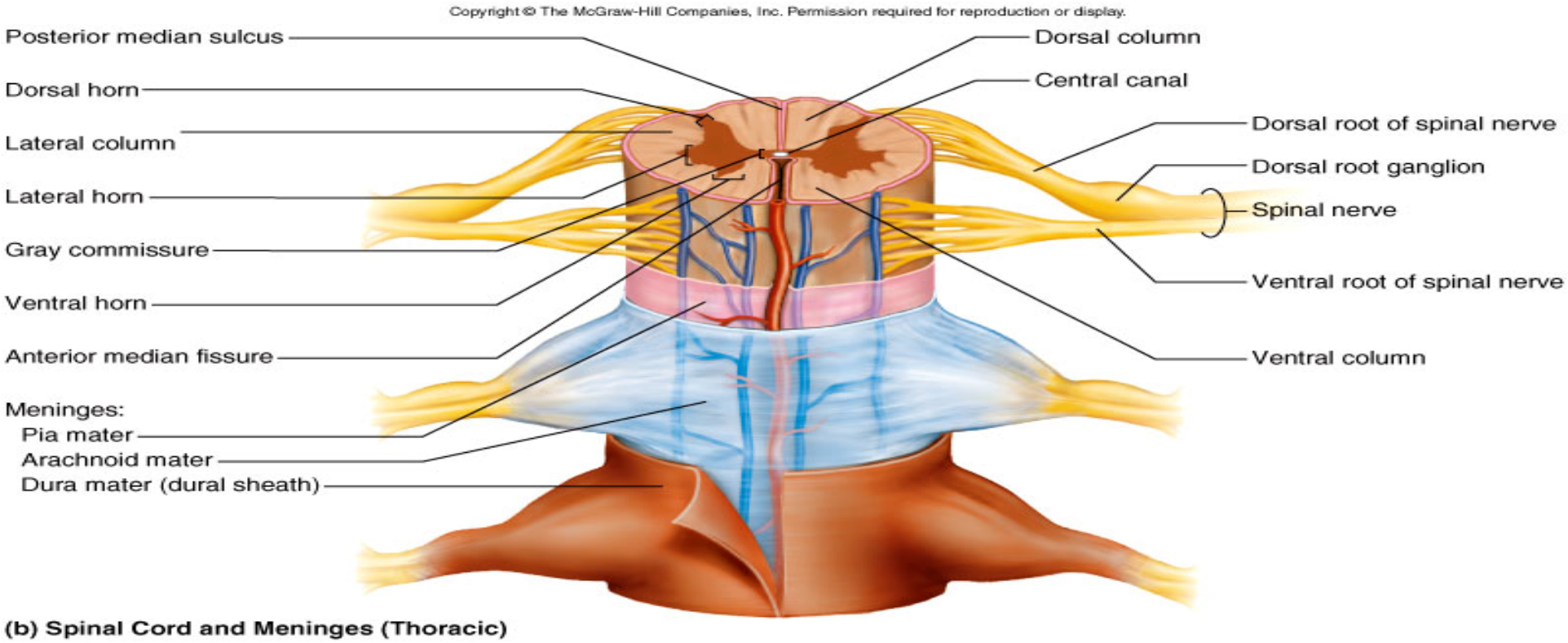


(a) Spinal Cord and Vertebra (Cervical)

Spina Bifida

- Congenital defect in 1 baby out of 1000
- Failure of vertebral arch to close covering spinal cord
- Folic acid (B vitamin) as part of a healthy diet for all women of childbearing age reduces risk

Cross-Sectional Anatomy of the Spinal Cord

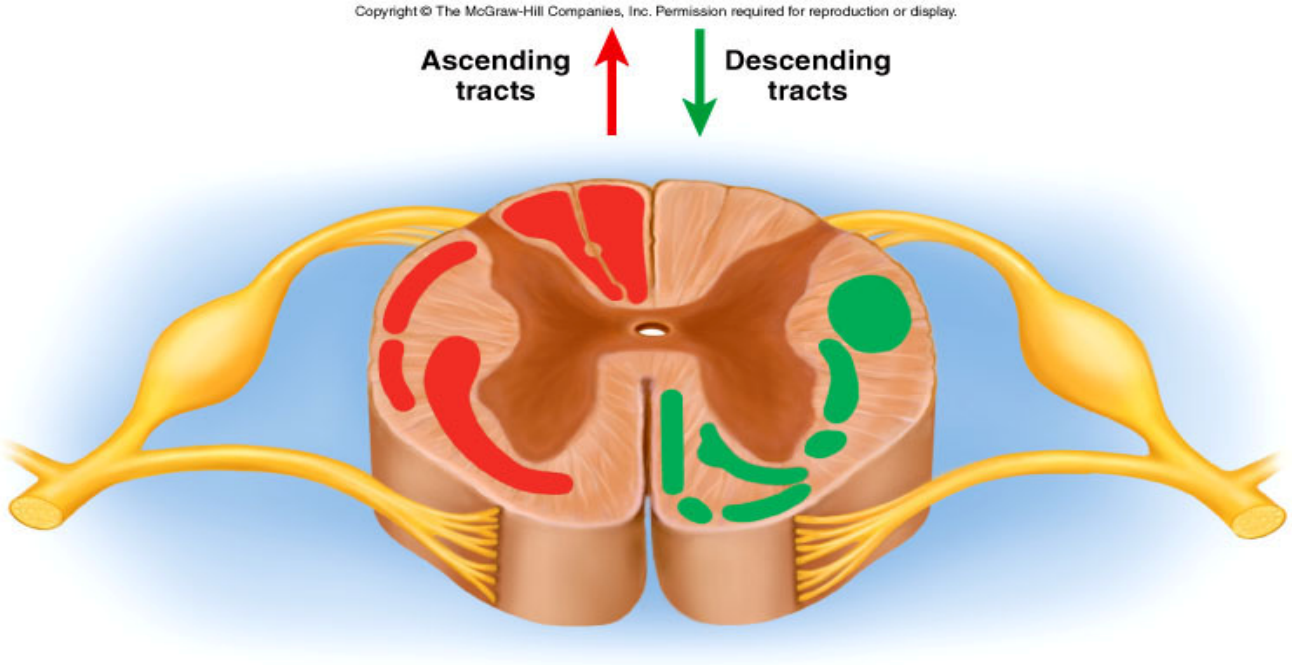


(b) Spinal Cord and Meninges (Thoracic)

- **Central area of gray matter shaped like a butterfly and surrounded by white matter in 3 columns**
- **Gray matter = neuron cell bodies with little myelin**
- **White matter = myelinated axons**

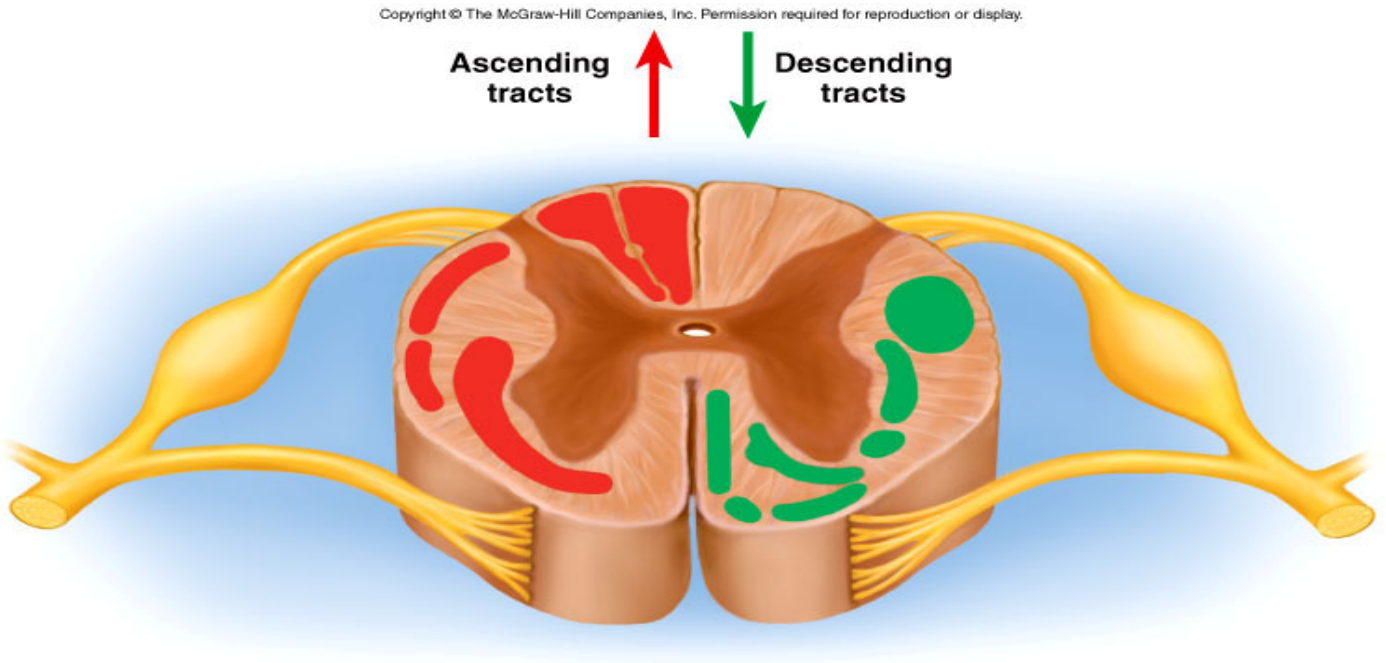
Gray Matter in the Spinal Cord

- Pair of dorsal or posterior horns
  - dorsal root of spinal nerve is totally sensory fibers
- Pair of ventral or anterior horns
  - ventral root of spinal nerve is totally motor fibers
- Connected by gray commissure punctured by a central canal continuous above with 4th ventricle

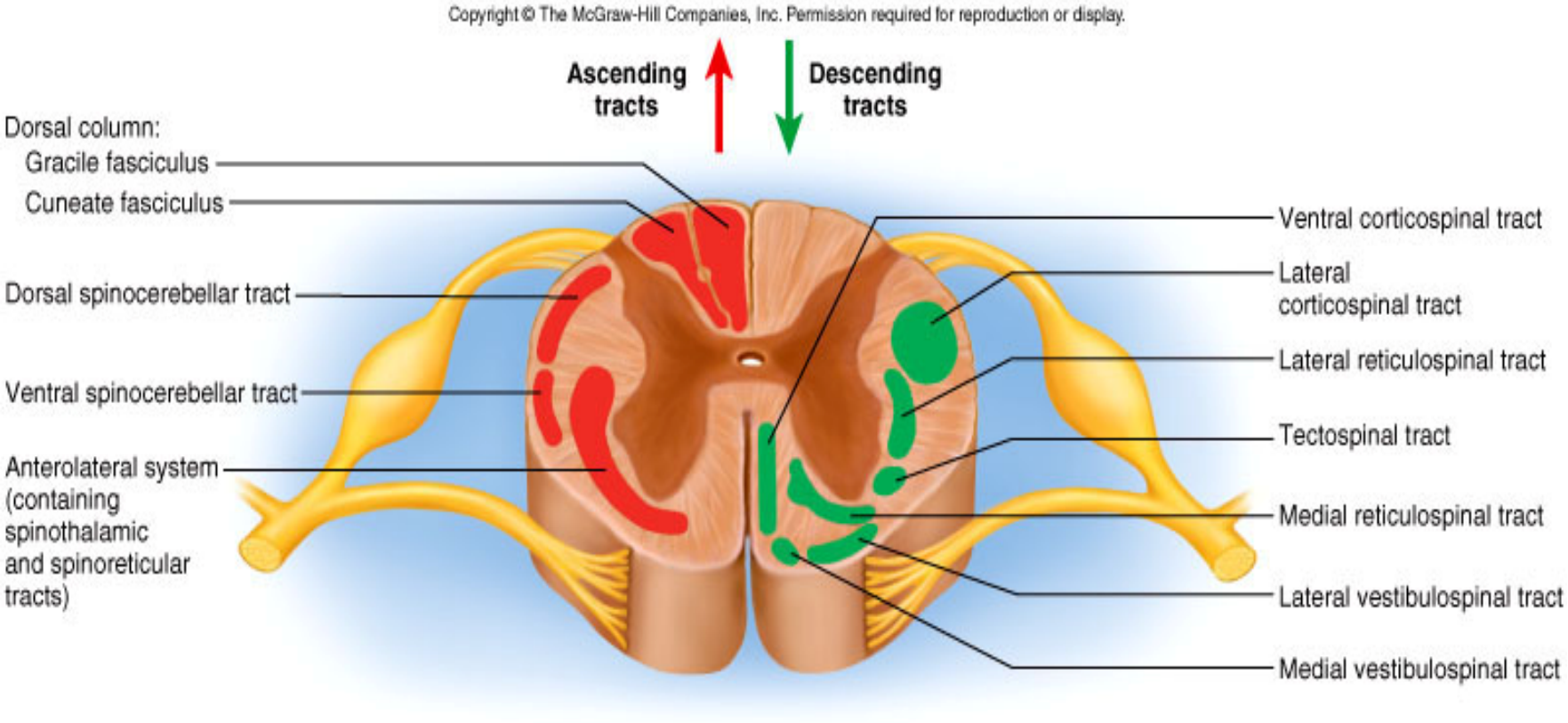


White Matter in the Spinal Cord

- White column = bundles of myelinated axons that carry signals up and down to and from brainstem
- 3 pairs of columns or funiculi
  - dorsal, lateral, and anterior columns
- Each column is filled with named tracts or fasciculi (fibers with a similar origin, destination and function)



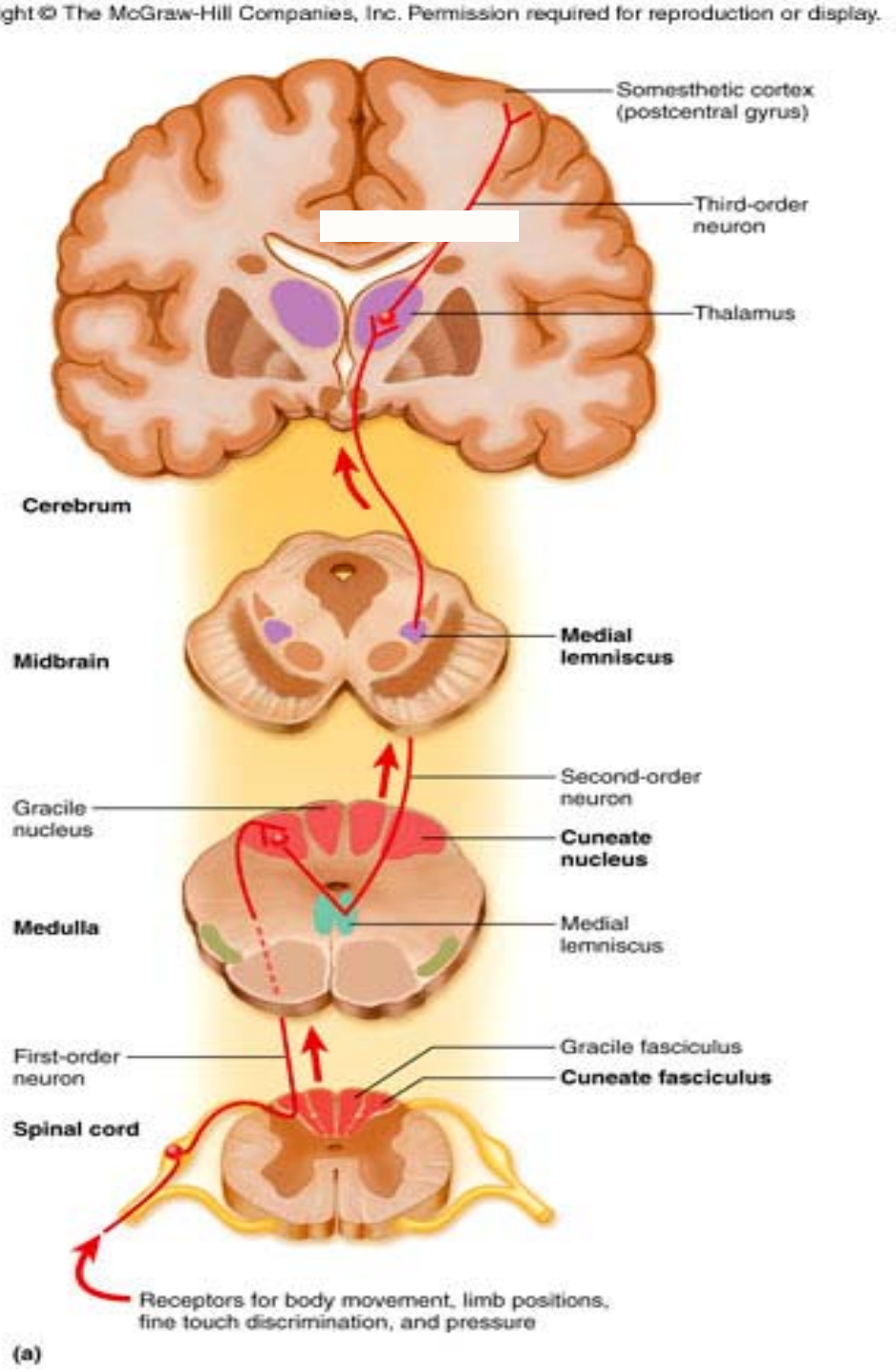
Spinal Tracts



- **Ascending and descending tract head up or down while decussation means that the fibers cross sides**
- **Contralateral means origin and destination are on opposite sides while ipsilateral means on same side**

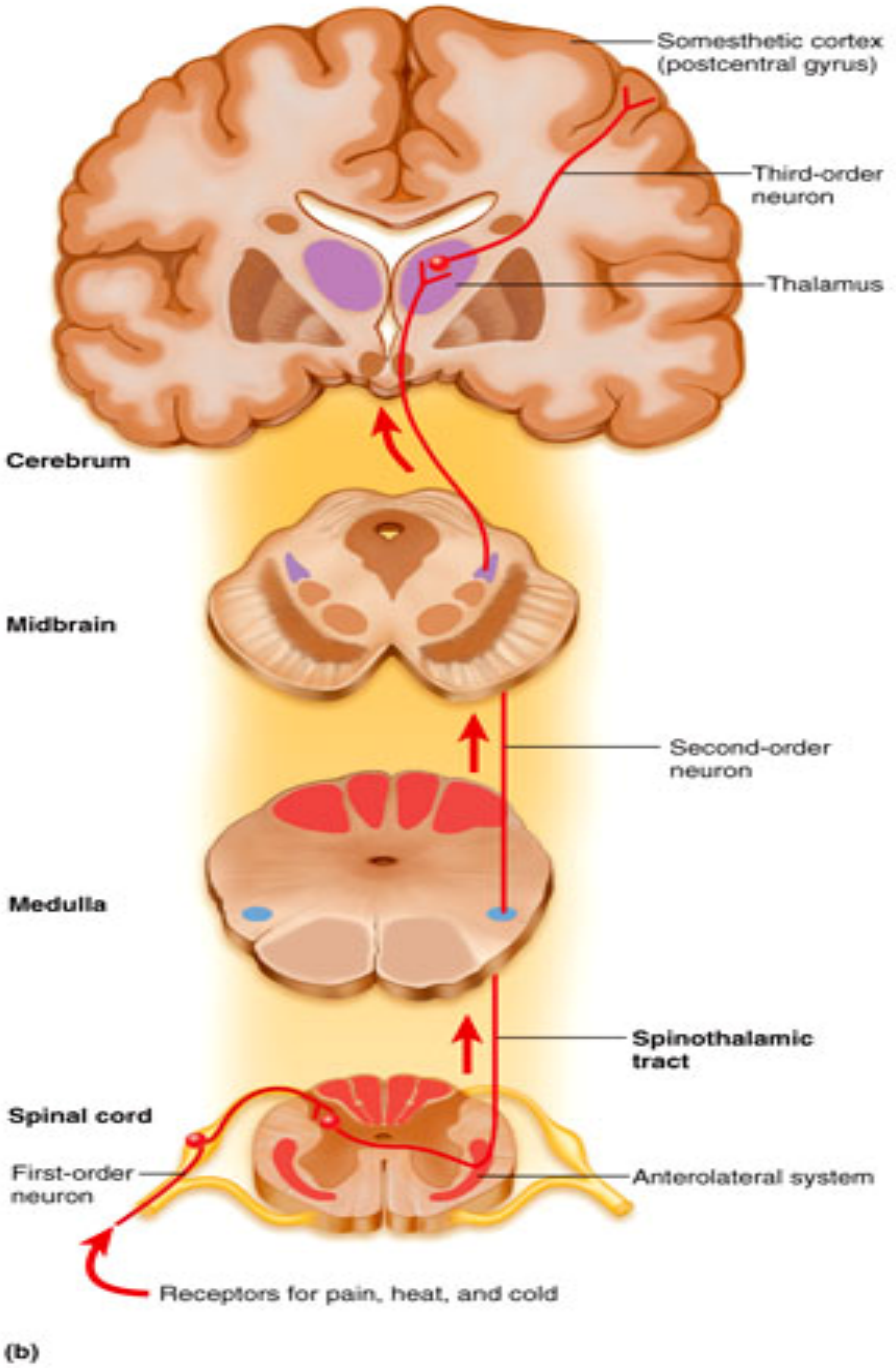
Dorsal Column Ascending Pathway

- Deep touch, visceral pain, vibration, and proprioception
- Fasciculus gracilis and cuneatus carry signals from arm and leg
- Decussation of 2nd order neuron in medulla
- 3rd order neuron in thalamus carries signal to cerebral cortex



Spinothalamic Pathway

- Pain, pressure, temperature, light touch, tickle and itch
- Decussation of the second order neuron occurs in spinal cord
- Third order neurons arise in thalamus and continue to cerebral cortex



Spinoreticular Tract

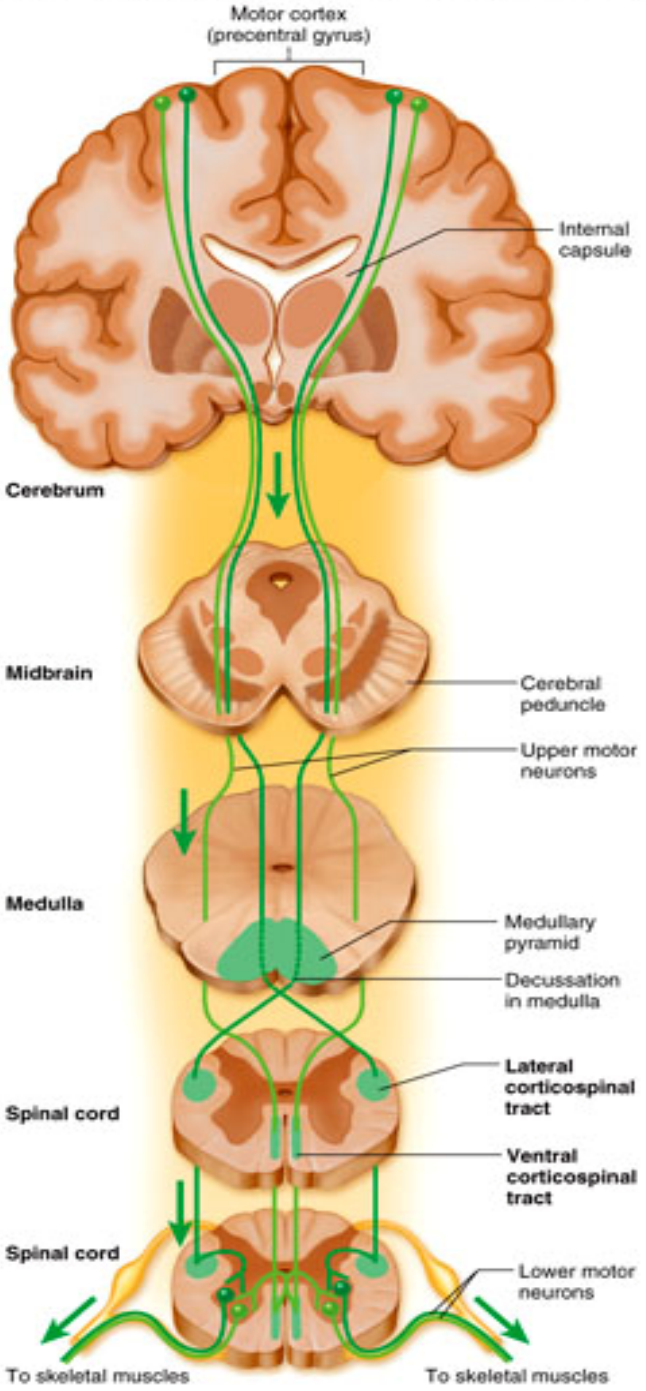
- Pain signals from tissue injury
- Decussate in spinal cord and ascend with spinothalamic fibers
- End in reticular formation (medulla and pons)
- 3rd and 4th order neurons continue to thalamus and cerebral cortex

Spinocerebellar Pathway

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

Corticospinal Tract

- Precise, coordinated limb movements
- Two neuron pathway
  - upper motor neuron in cerebral cortex
  - lower motor neuron in spinal cord
- Decussation in medulla



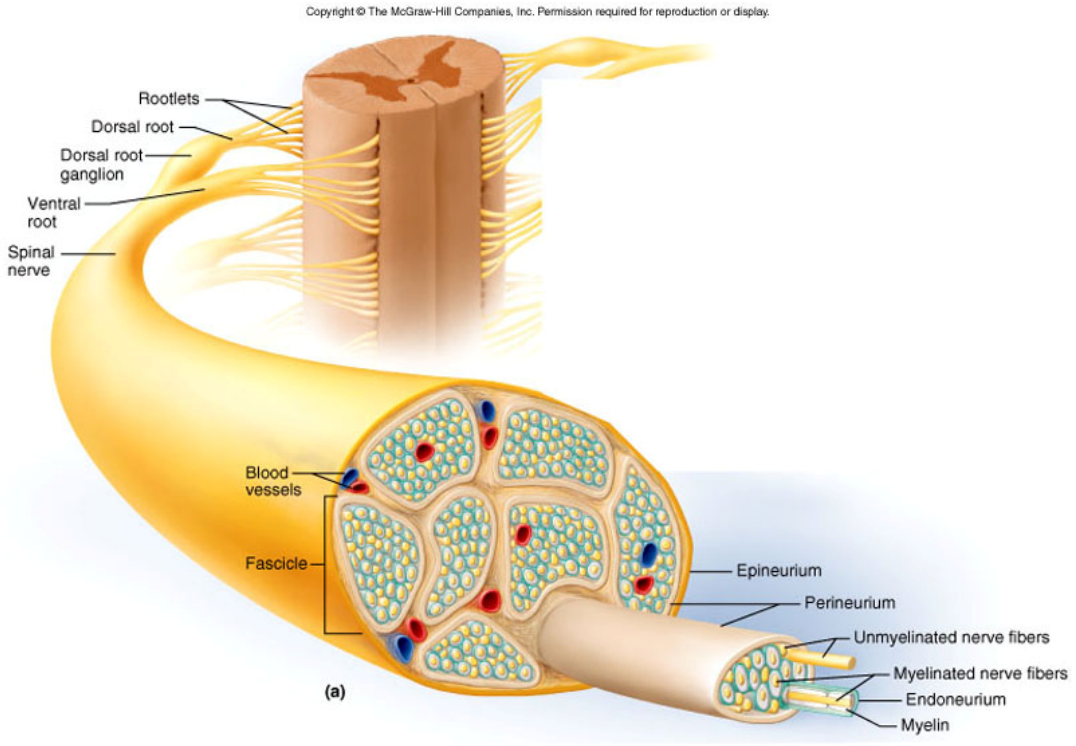
Descending Motor Tracts

- **Tectospinal tract (tectum of midbrain)**
  - reflex turning of head in response to sights and sounds
- **Reticulospinal tract (reticular formation)**
  - controls limb movements important to maintain posture and balance
- **Vestibulospinal tract (brainstem nuclei)**
  - postural muscle activity in response to inner ear signals

Poliomyelitis and ALS

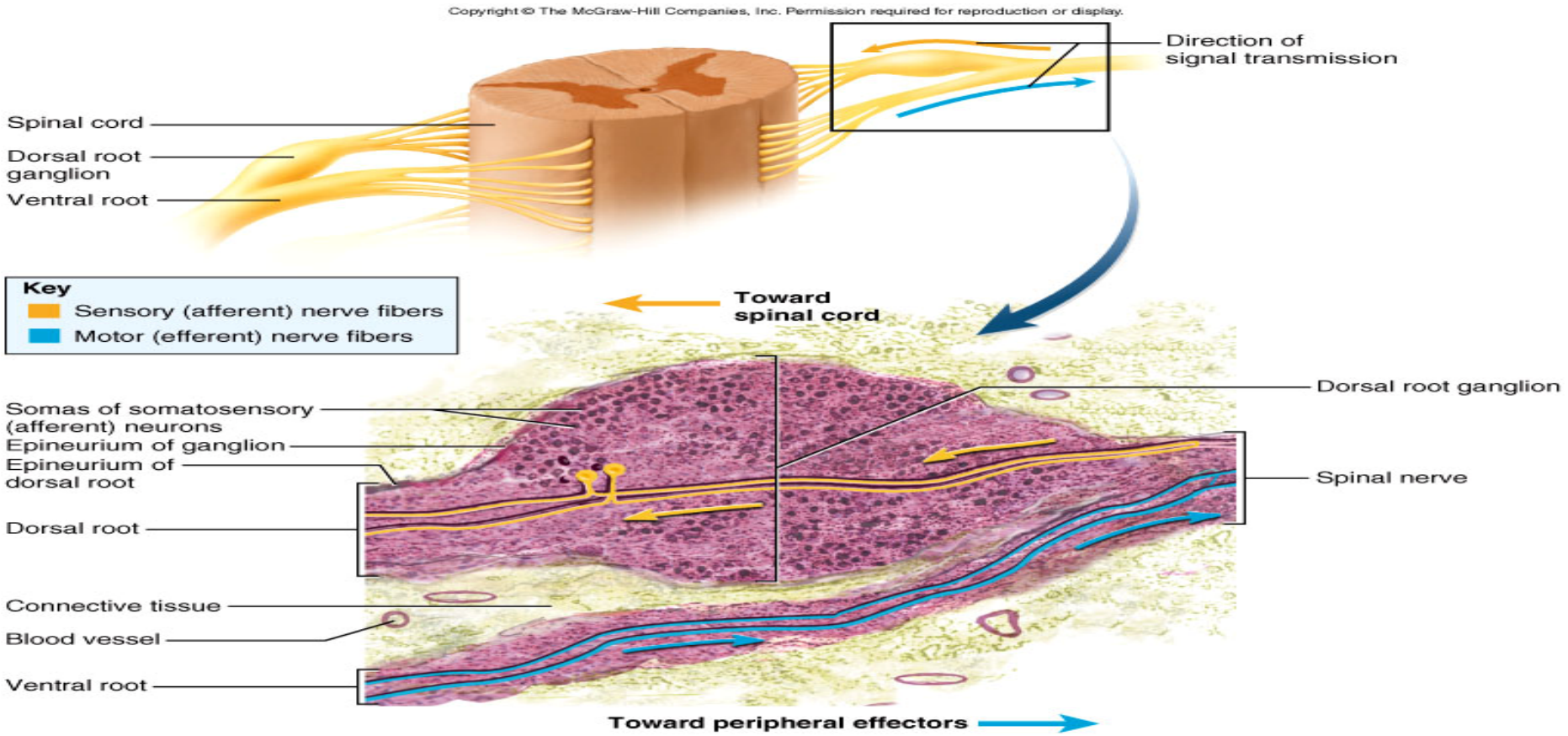
- Diseases causing destruction of motor neurons and skeletal muscle atrophy
- Poliomyelitis caused by poliovirus spread by fecally contaminated water
  - weakness progresses to paralysis and respiratory arrest
- Amyotrophic lateral sclerosis
  - sclerosis of spinal cord due to astrocyte failure to reabsorb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

Anatomy of a Nerve



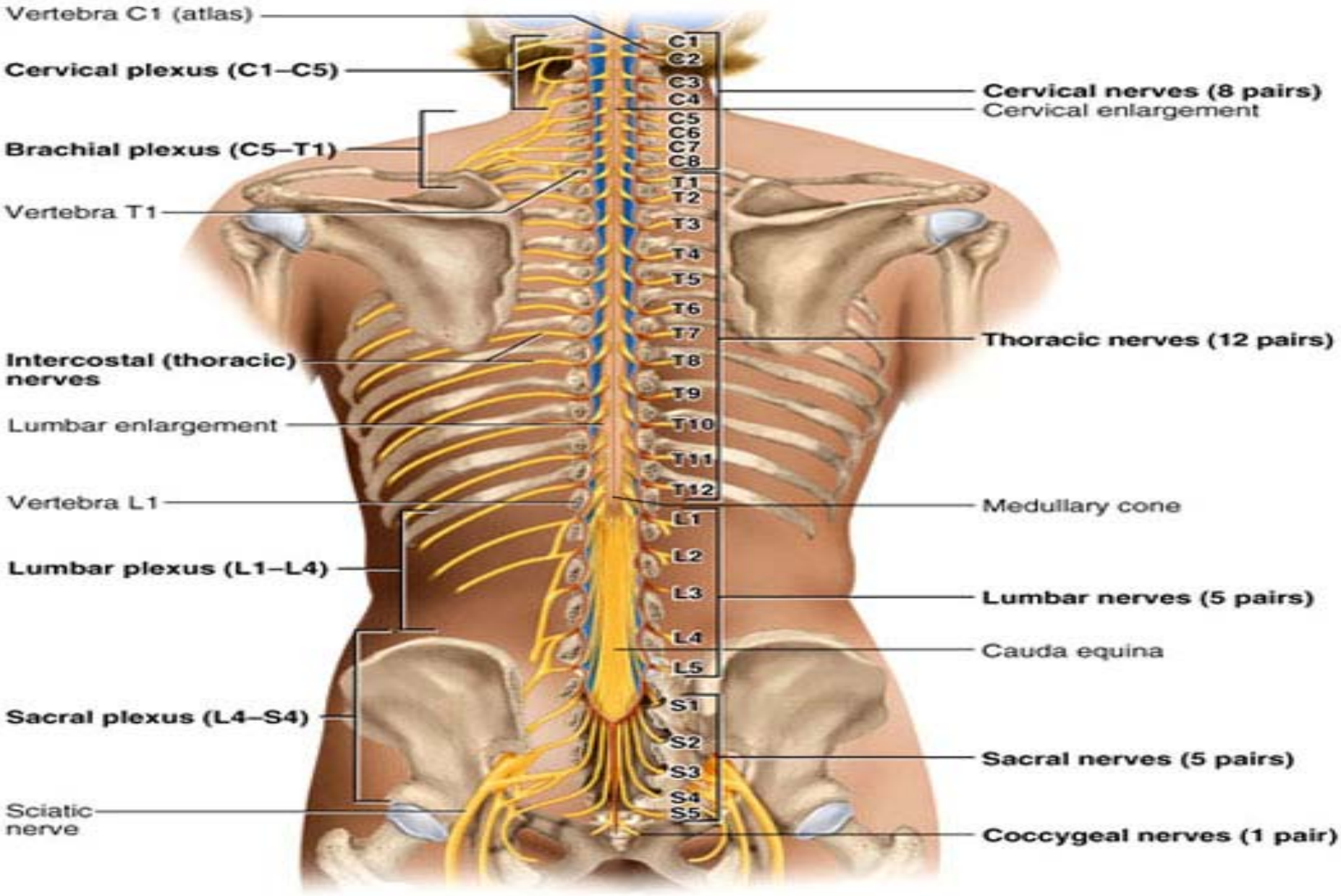
- A nerve is a bundle of nerve fibers (axons)
- Epineurium covers nerves, perineurium surrounds a fascicle and endoneurium separates individual nerve fibers
- Blood vessels penetrate only to the perineurium

Anatomy of Ganglia in the PNS



- Cluster of neuron cell bodies in nerve in PNS
- Dorsal root ganglion is sensory cell bodies
  - fibers pass through without synapsing

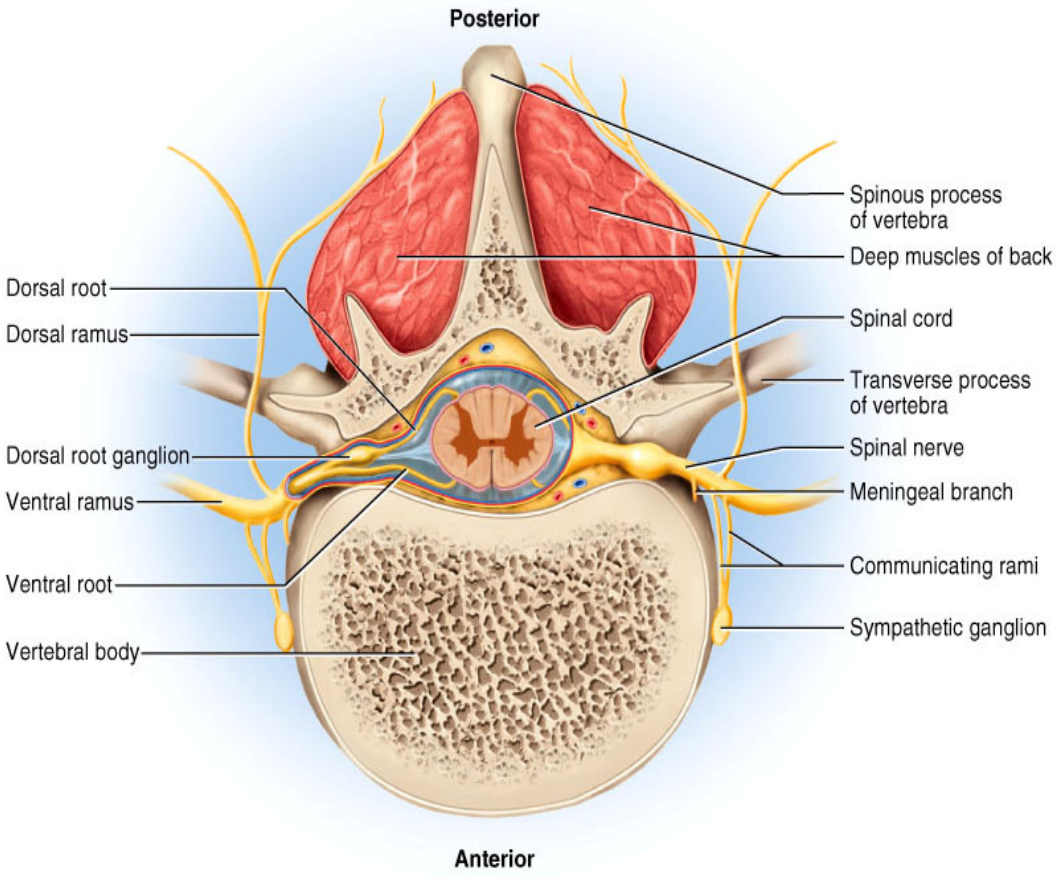
Spinal Nerve Roots and Plexuses



The Spinal Nerves

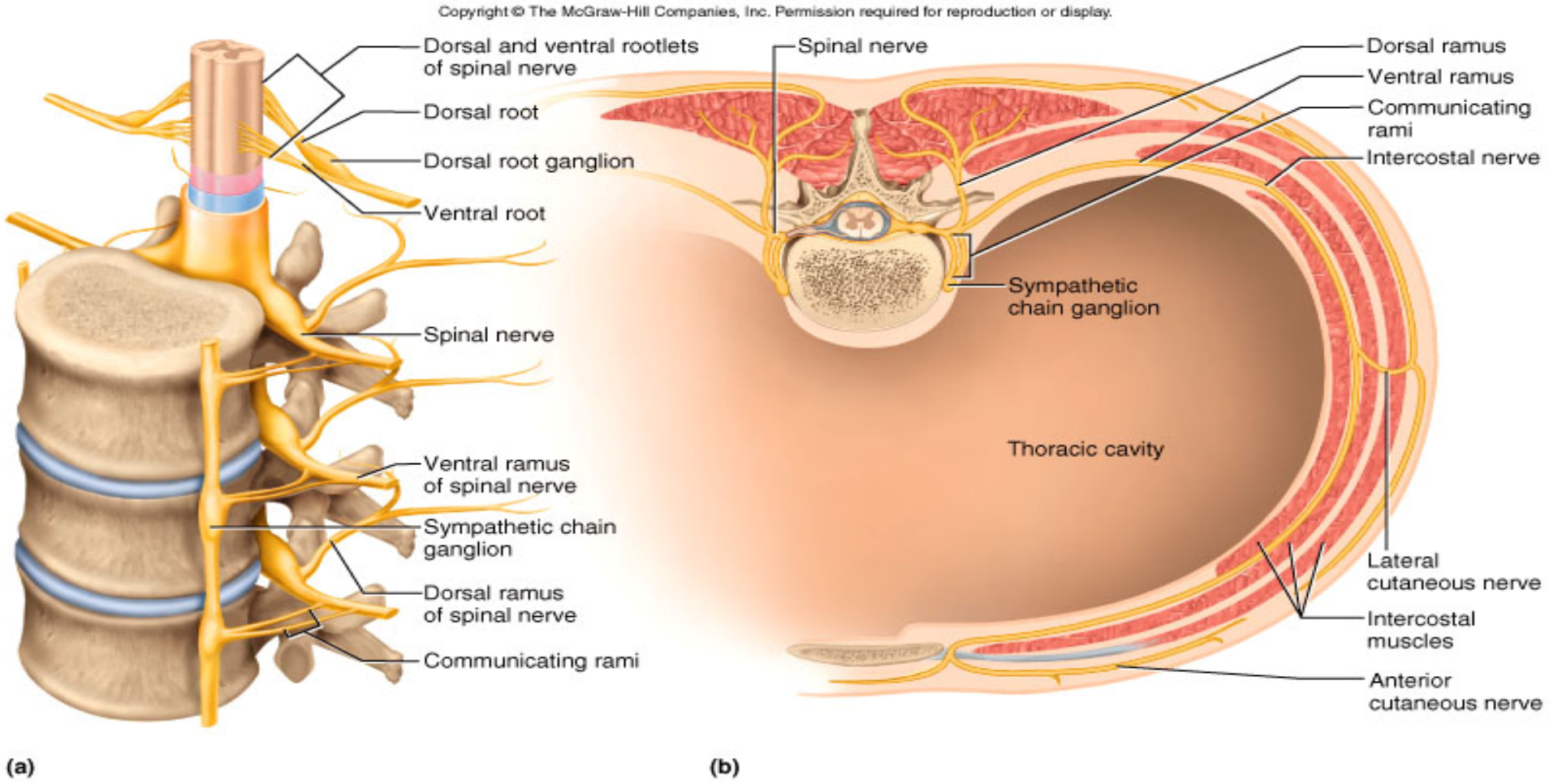
- 31 pairs of spinal nerves (1st cervical above C1)
  - mixed nerves exiting at intervertebral foramen
- Proximal branches
  - dorsal root is sensory input to spinal cord
  - ventral root is motor output of spinal cord
  - cauda equina is roots from L2 to C0 of the cord
- Distal branches
  - dorsal ramus supplies dorsal body muscle and skin
  - ventral ramus to ventral skin and muscles and limbs
  - meningeal branch to meninges, vertebrae and ligaments

Branches of a Spinal Nerve



- **Spinal nerves: 8 cervical, 12 thoracic, 5 lumbar, 5 sacral and 1 coccygeal.**
- **Each has dorsal and ventral ramus.**

Rami of Spinal Nerves



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

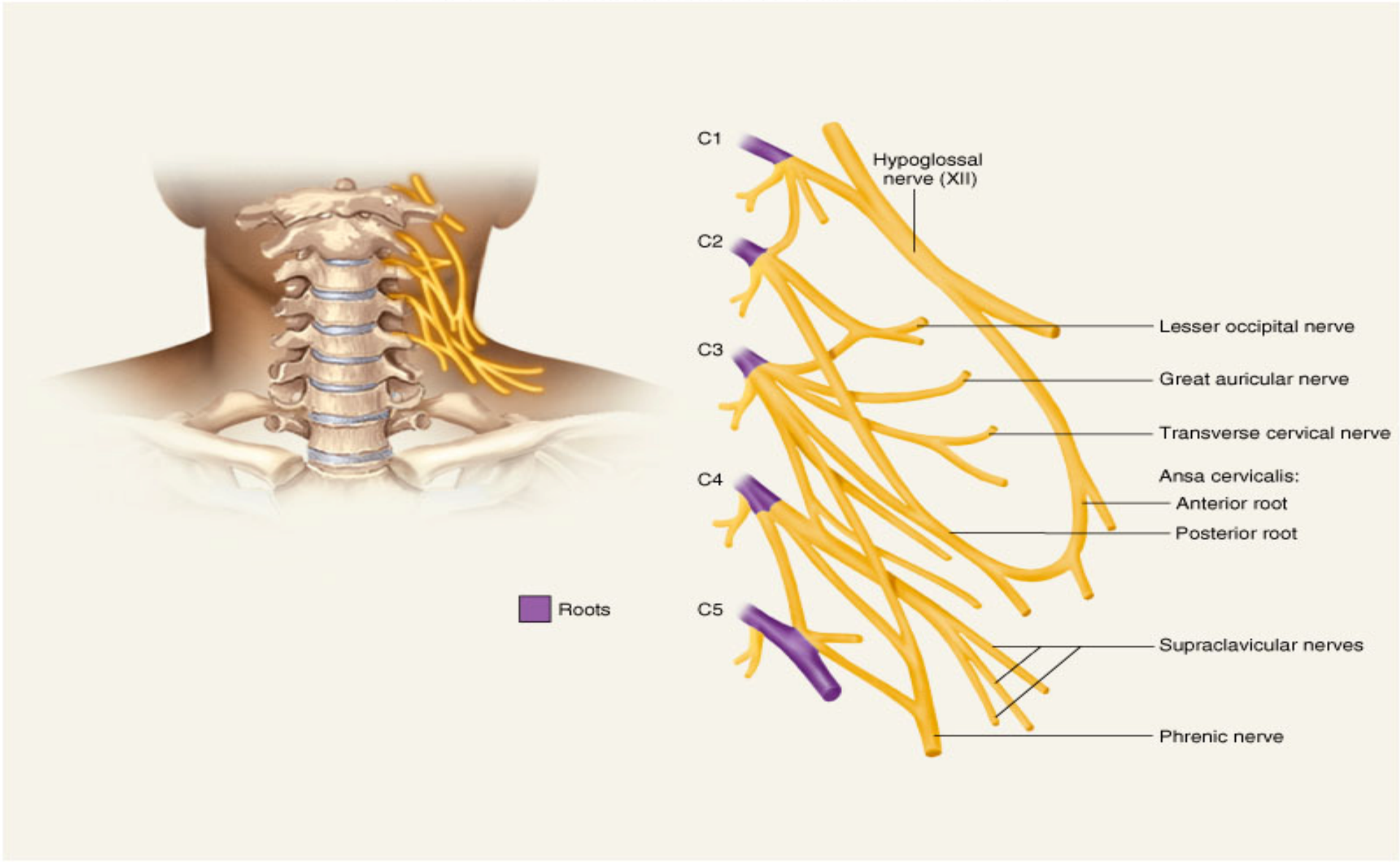
Shingles

- Skin eruptions along path of nerve
- *Varicella-zoster* virus (chicken pox) remains for life in dorsal root ganglia
- Occurs after age 50 if immune system is compromised
- No special treatment

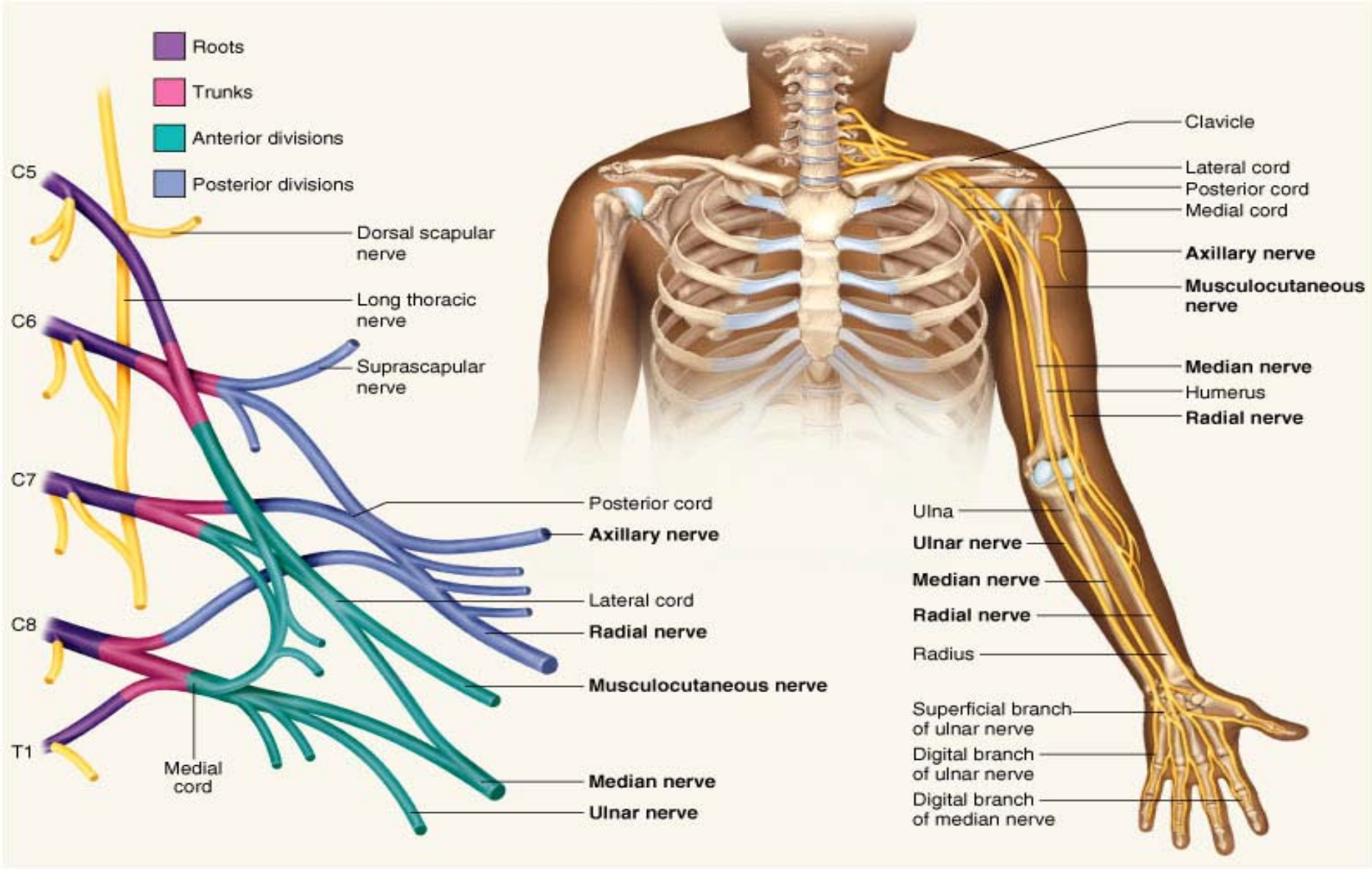
Nerve Plexuses

- **Ventral rami branch and 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 and neck**
  - **lumbar in the low back, L1 to L4**
    - **supplies abdominal wall, anterior thigh and genitalia**
  - **sacral in the pelvis, L4, L5 and S1 to S4**
    - **supplies remainder of lower trunk and lower limb**
  - **coccygeal, S4, S5 and C0**

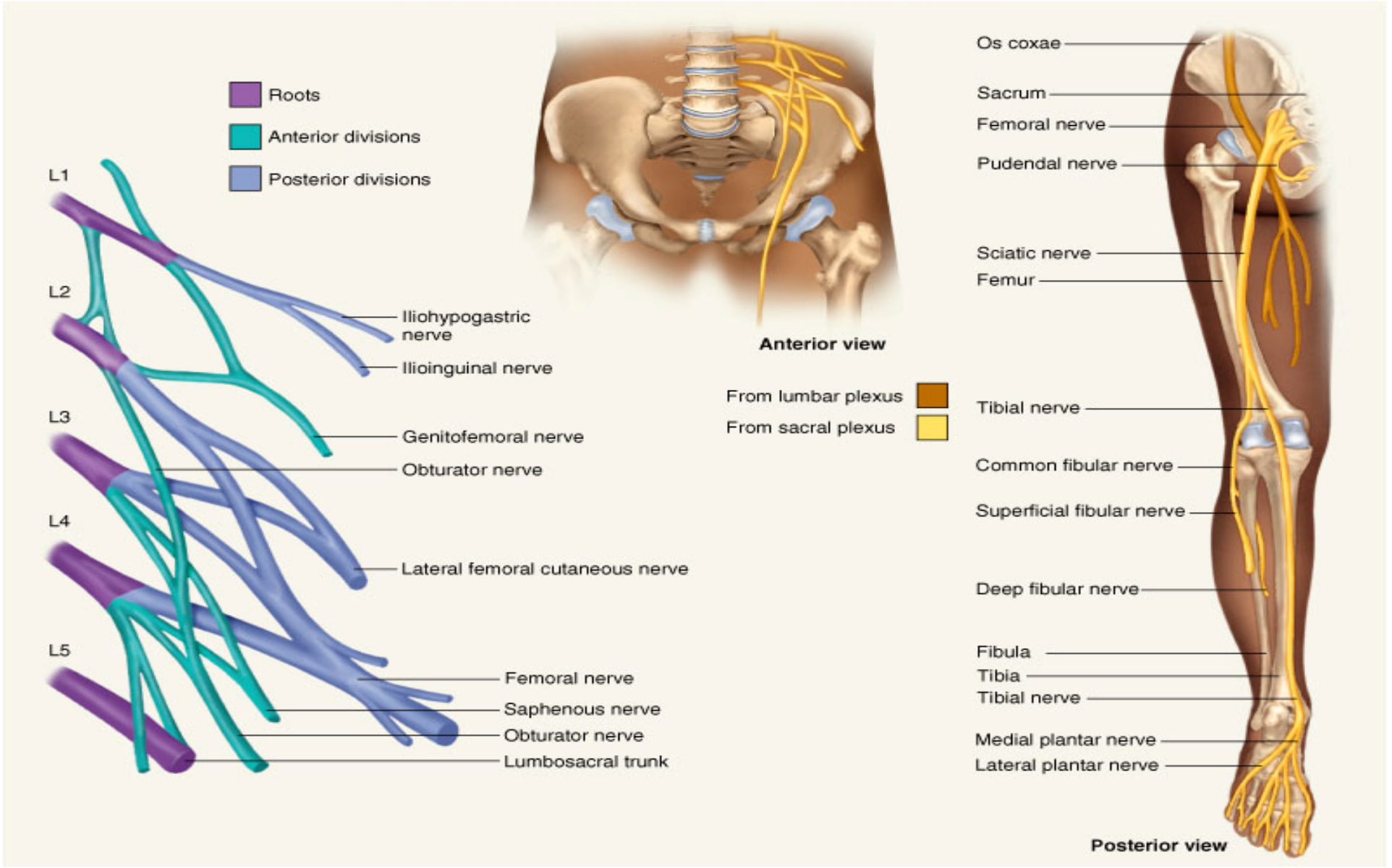
The Cervical Plexus



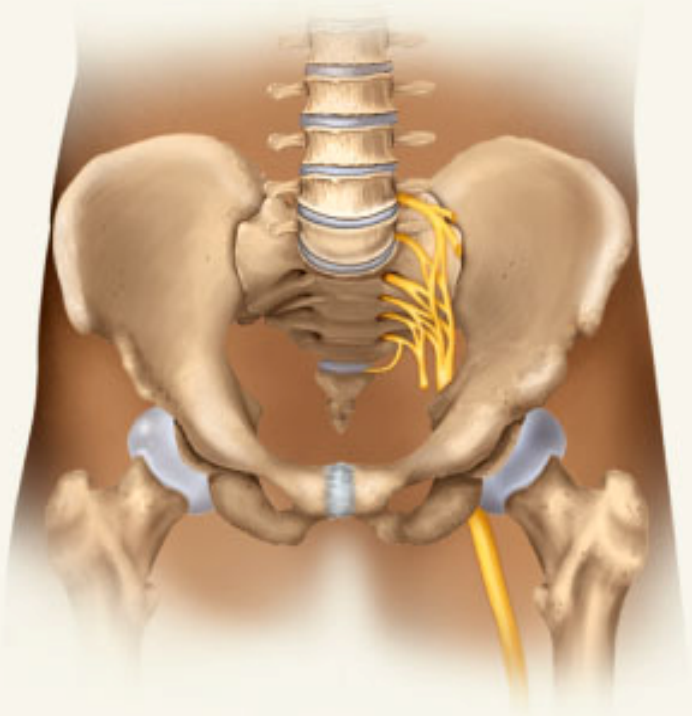
The Brachial Plexus

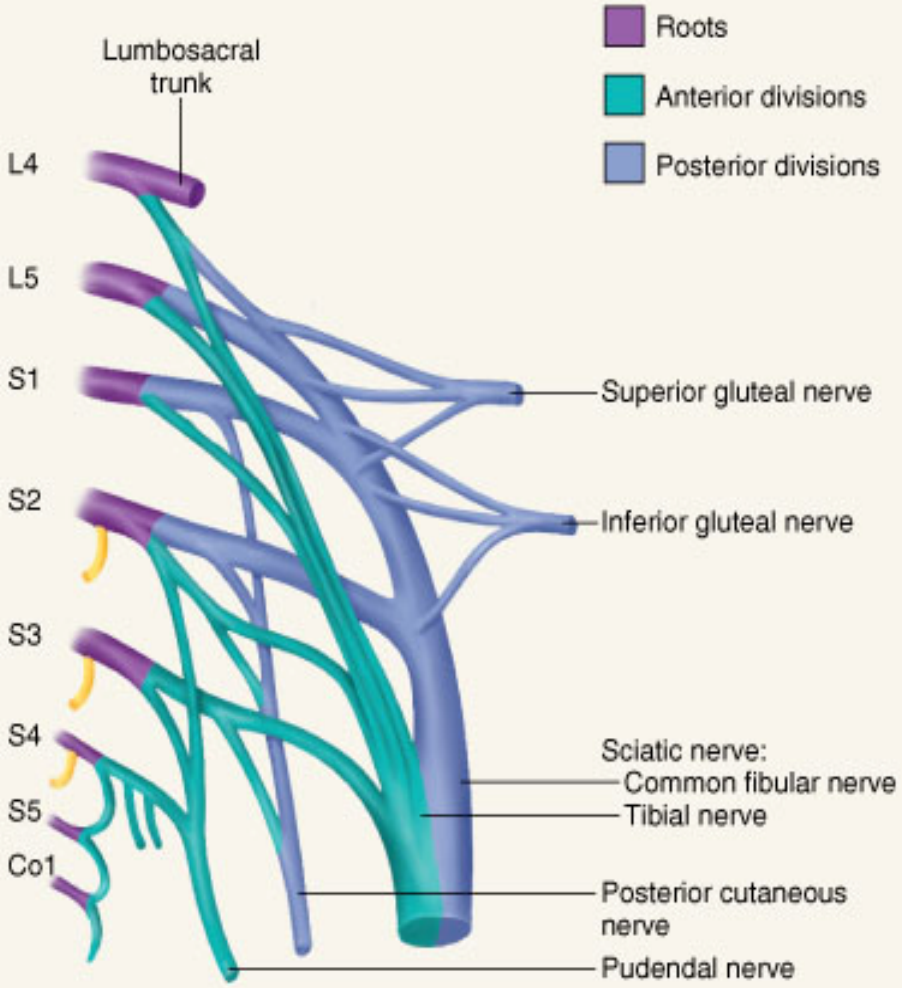


The Lumbar Plexus



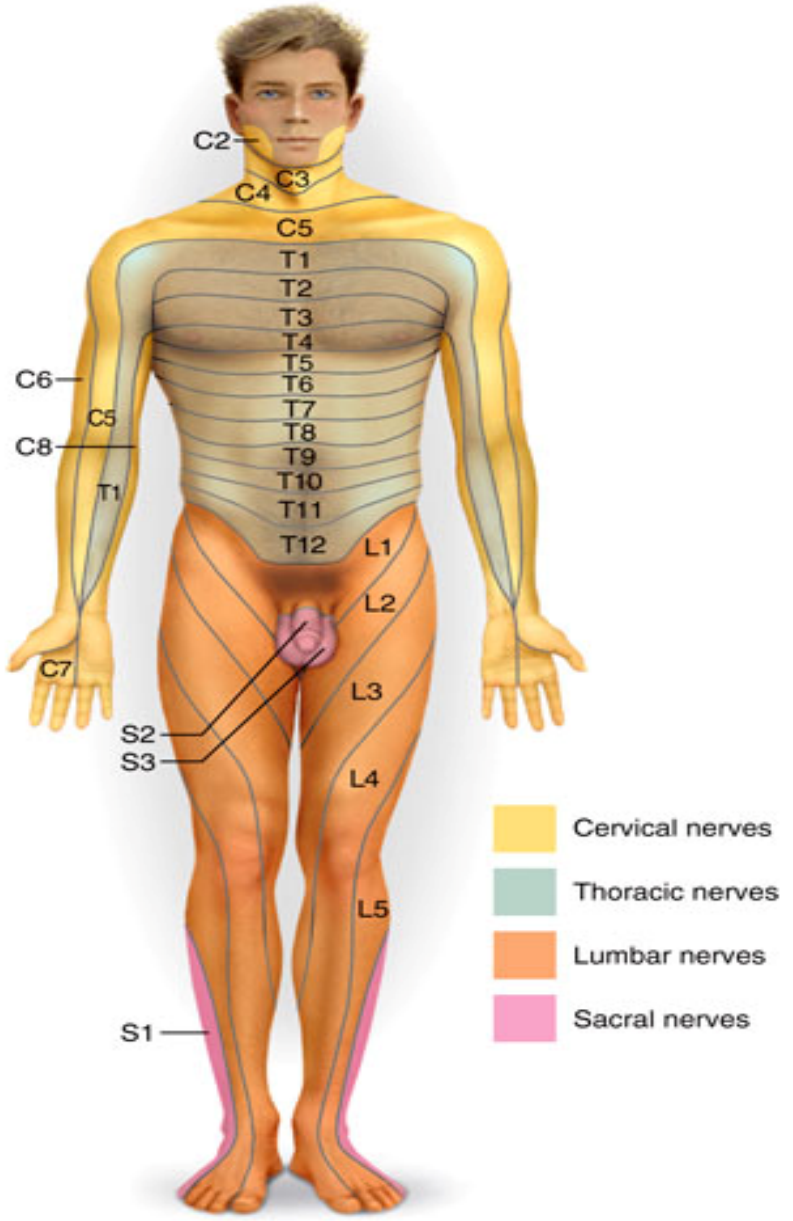
The Sacral and Coccygeal Plexuses





Cutaneous Innervation and Dermatomes

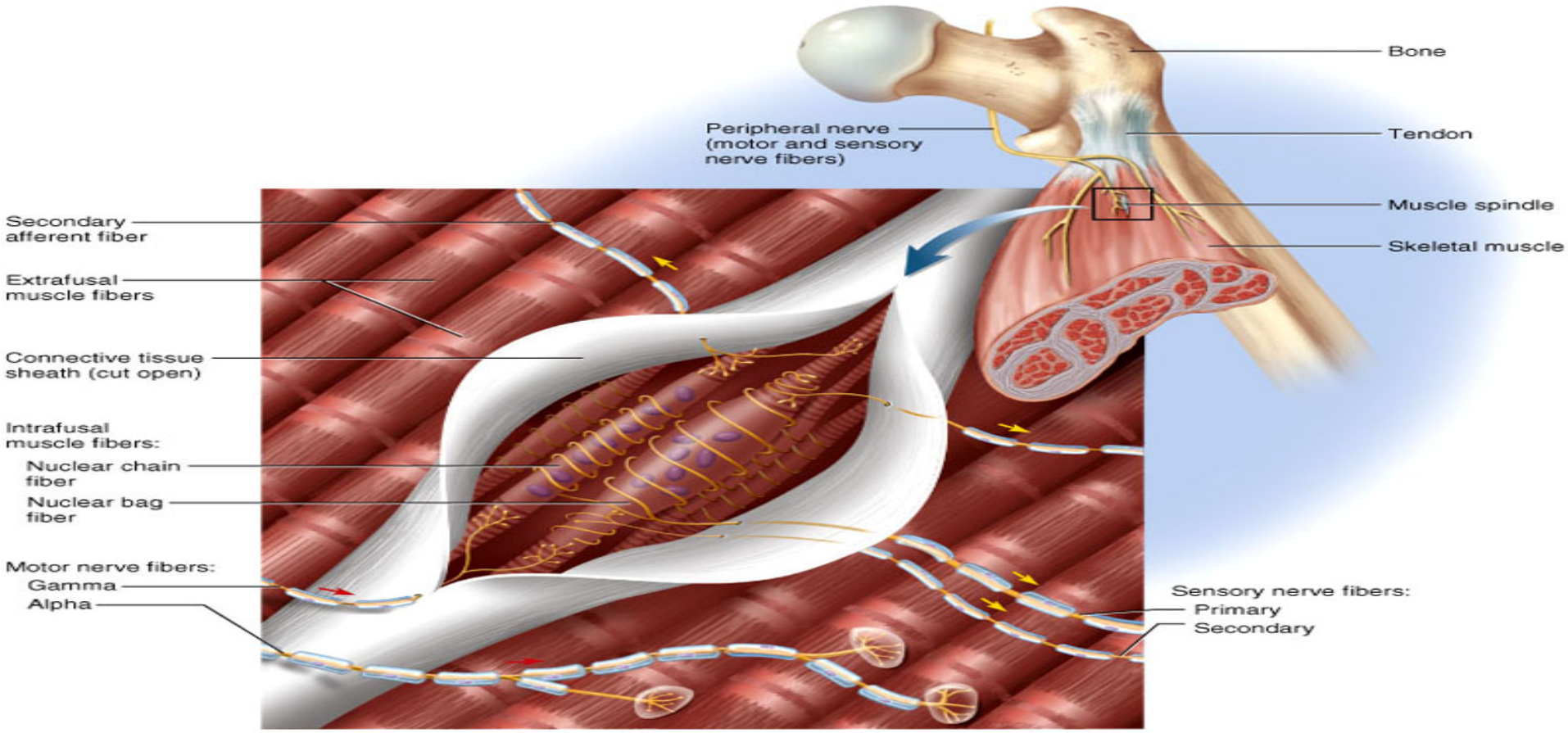
- Each spinal nerve receive sensory input from a specific area of skin called dermatome
- Overlap at edges by 50%
  - a total loss of sensation requires anesthesia of 3 successive spinal nerves



Nature of Somatic Reflexes

- Quick, involuntary, stereotyped reactions of glands or muscle to sensory stimulation
  - automatic responses to sensory input that occur without our intent or often even our awareness
- Functions by means of a somatic reflex arc
  - stimulation of somatic receptors
  - afferent fibers carry signal to dorsal horn of spinal cord
  - one or more interneurons integrate the information
  - efferent fibers carry impulses to skeletal muscles
  - skeletal muscles respond

The Muscle Spindle

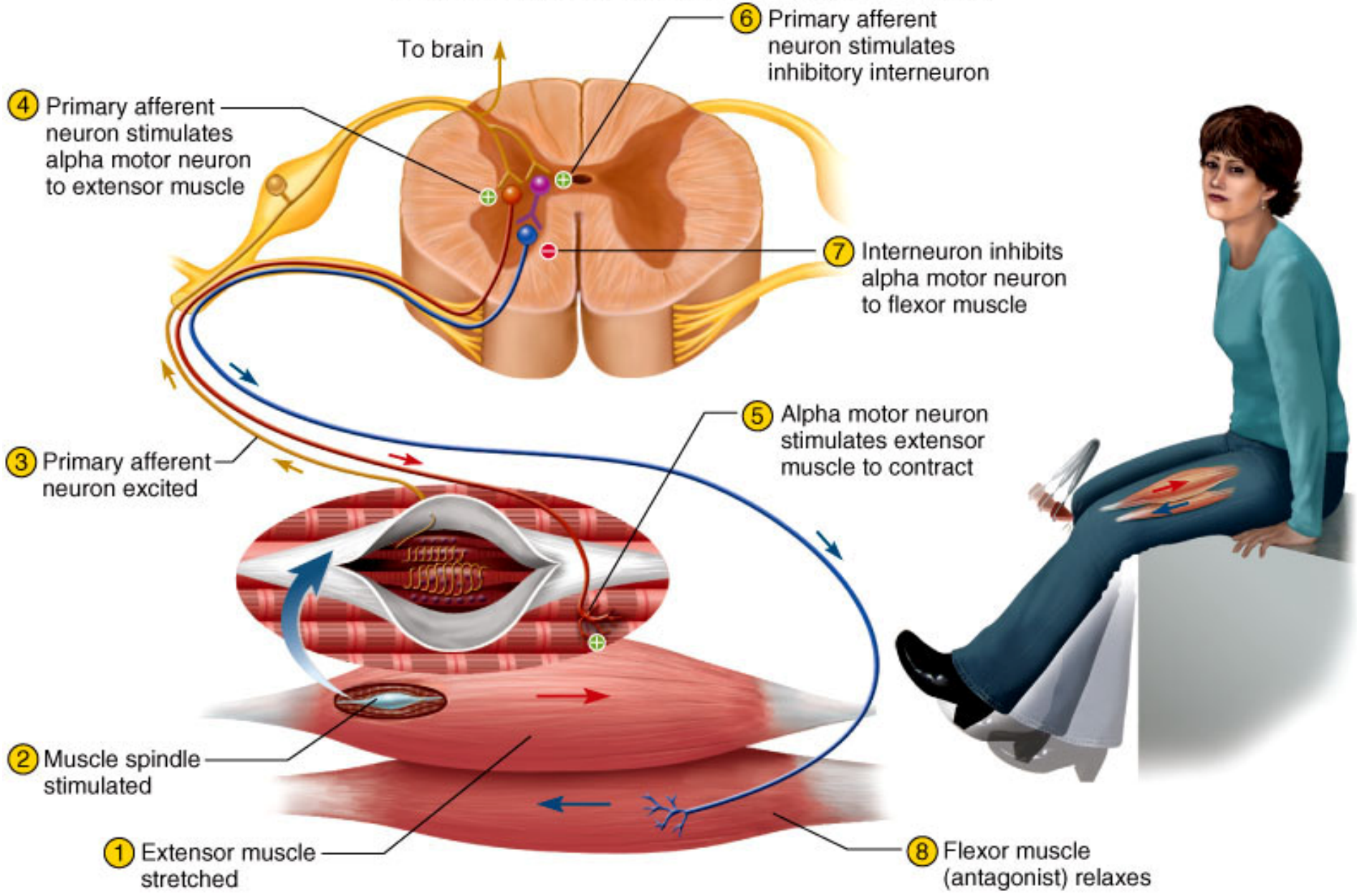


- Sense organ (proprioceptor) that monitors length of muscle and how fast muscles change in length
- Composed of intrafusal muscle fibers, afferent fibers and gamma motorneurons

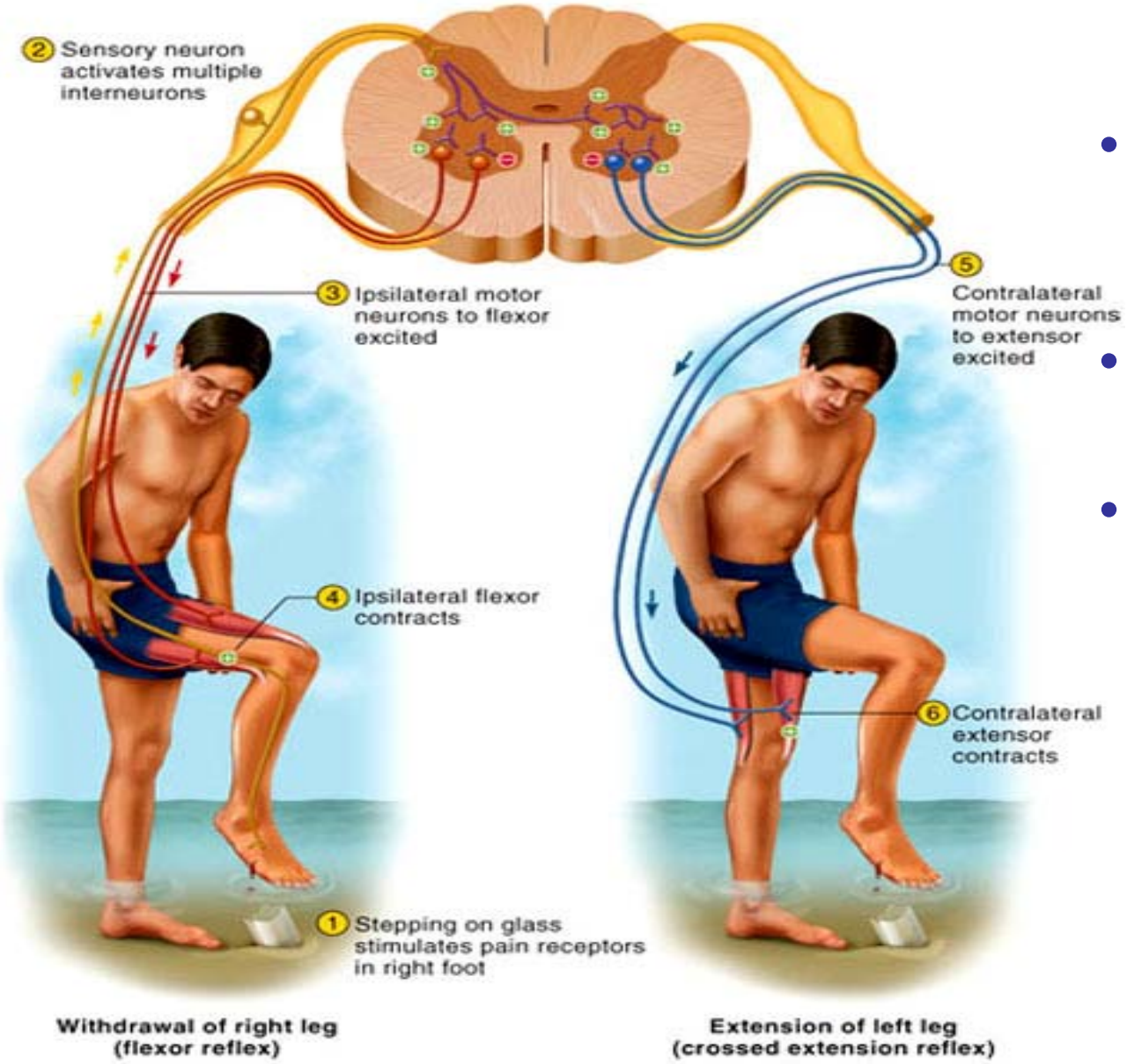
The Stretch (Myotatic) Reflex

- When a muscle is stretched, it contracts and maintains increased tonus (stretch reflex)
  - helps maintain equilibrium and posture
    - head starts to tip forward as you fall asleep
    - muscles contract to raise the head
  - stabilize joints by balancing tension in extensors and flexors smoothing muscle actions
- Very sudden muscle stretch causes tendon reflex
  - knee-jerk (patellar) reflex is monosynaptic reflex
  - testing somatic reflexes helps diagnose many diseases
- Reciprocal inhibition prevents muscles from working against each other

The Patellar Tendon Reflex Arc

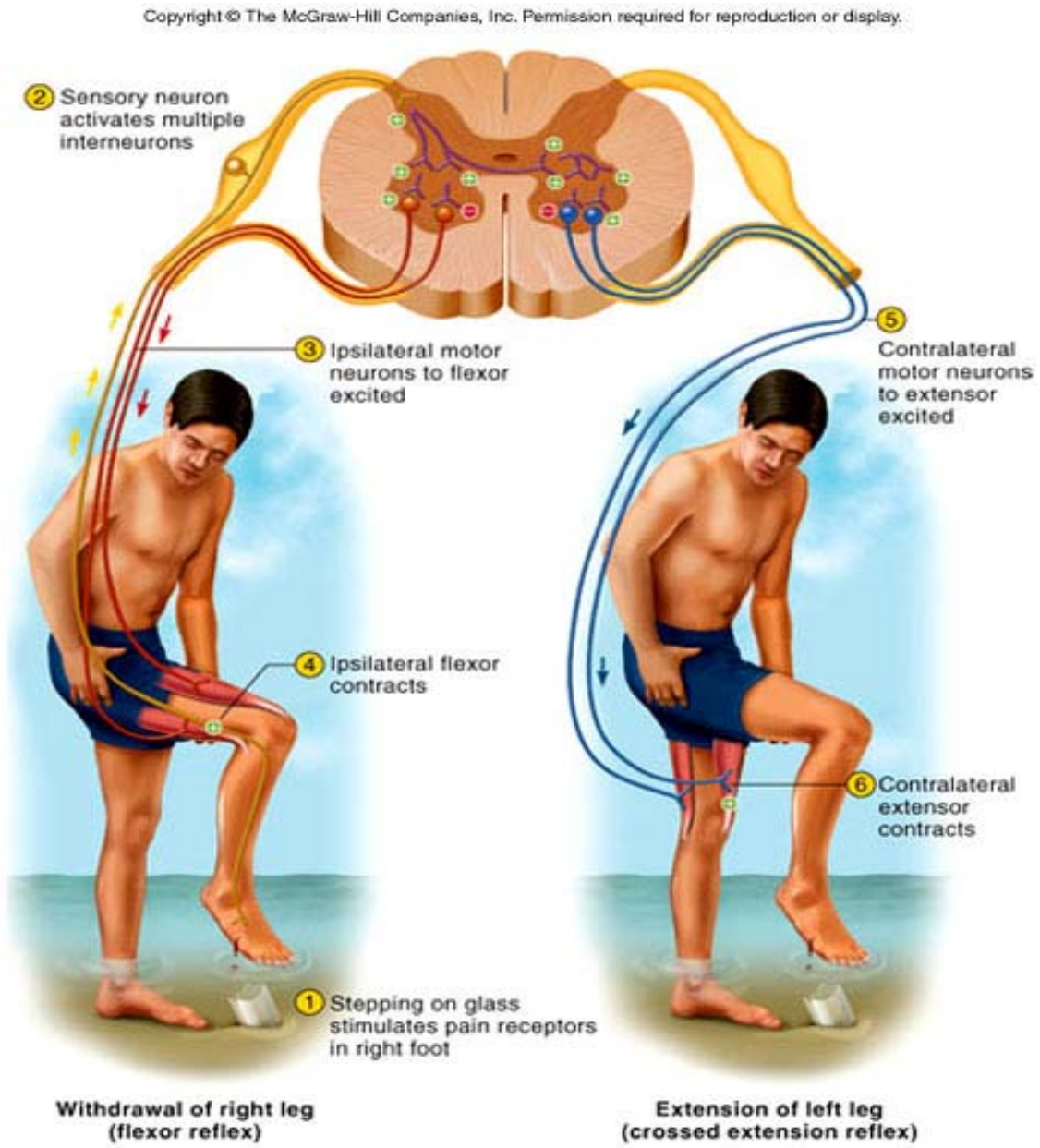


Flexor Withdrawal Reflexes



- Occurs during withdrawal of foot from pain
- Polysynaptic reflex arc
- Neural circuitry in spinal cord controls sequence and duration of muscle contractions

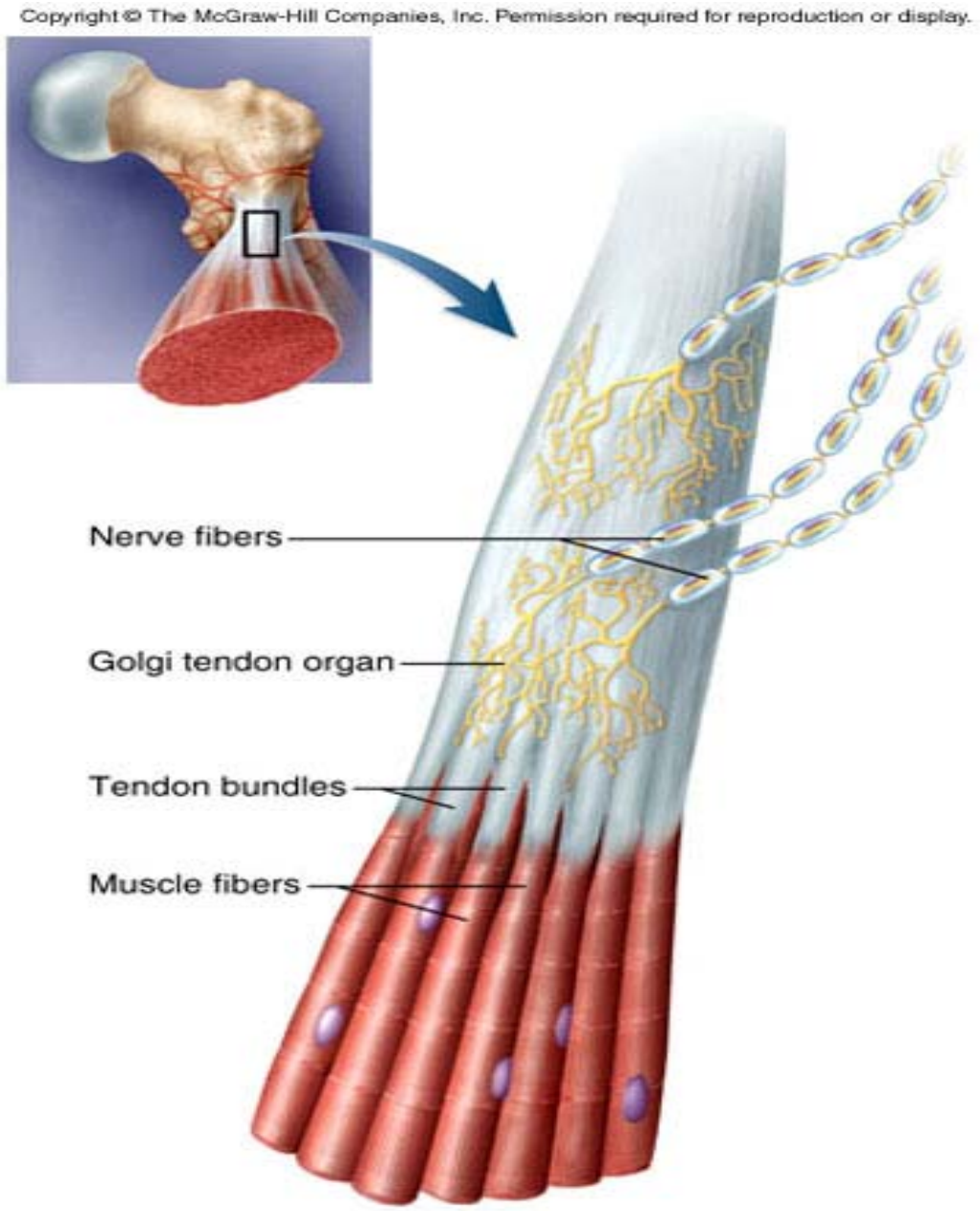
Crossed Extensor Reflexes



- Maintains balance by extending other leg
- Intersegmental reflex extends up and down the spinal cord
- Contralateral reflex arcs explained by pain at one foot causes muscle contraction in other leg

Golgi Tendon Reflex

- Proprioceptors in a tendon near its junction with a muscle -- 1mm long, encapsulated nerve bundle
- Excessive tension on tendon inhibits motor neuron
  - muscle contraction decreased
- Also functions when muscle contracts unevenly



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