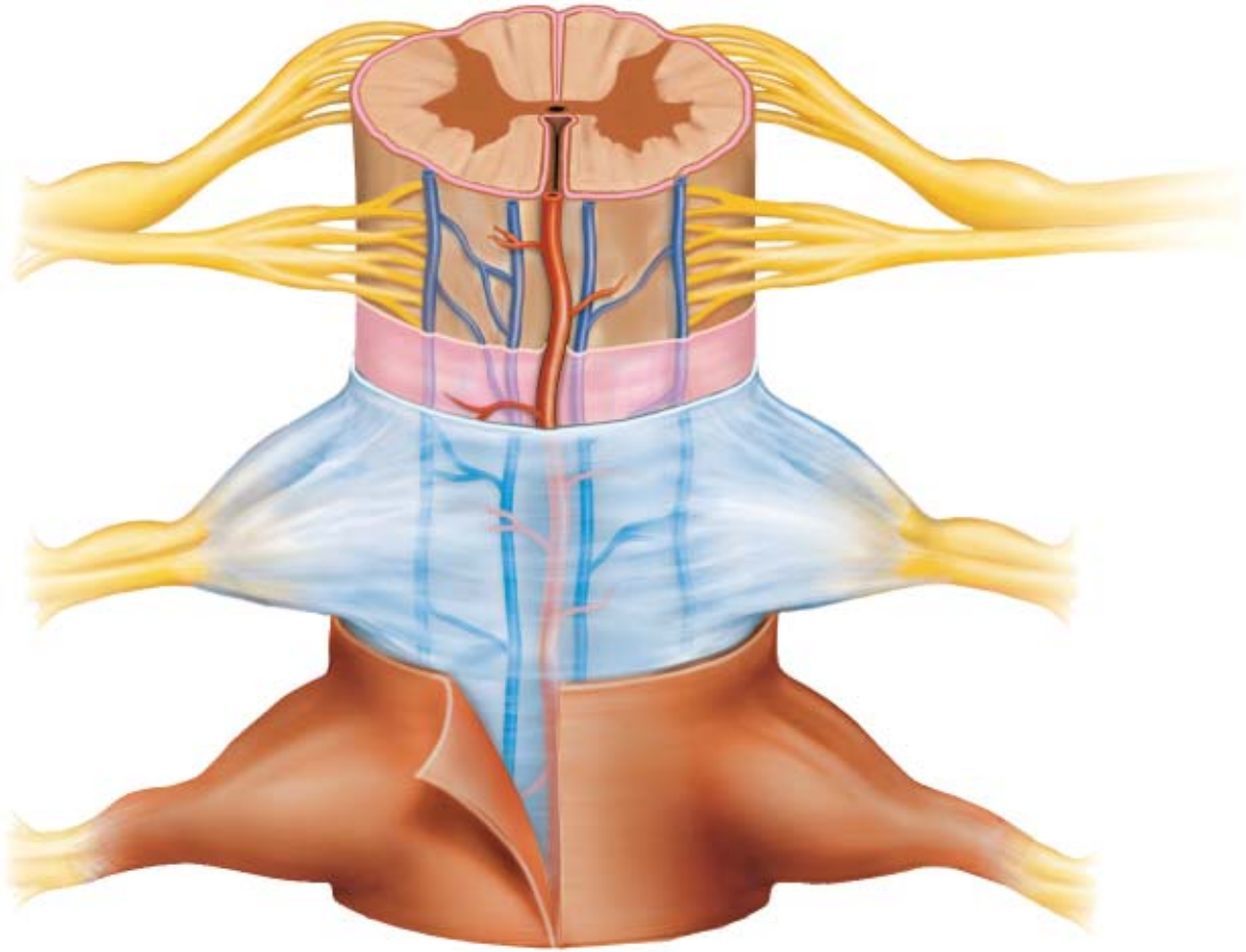
Chapter 13

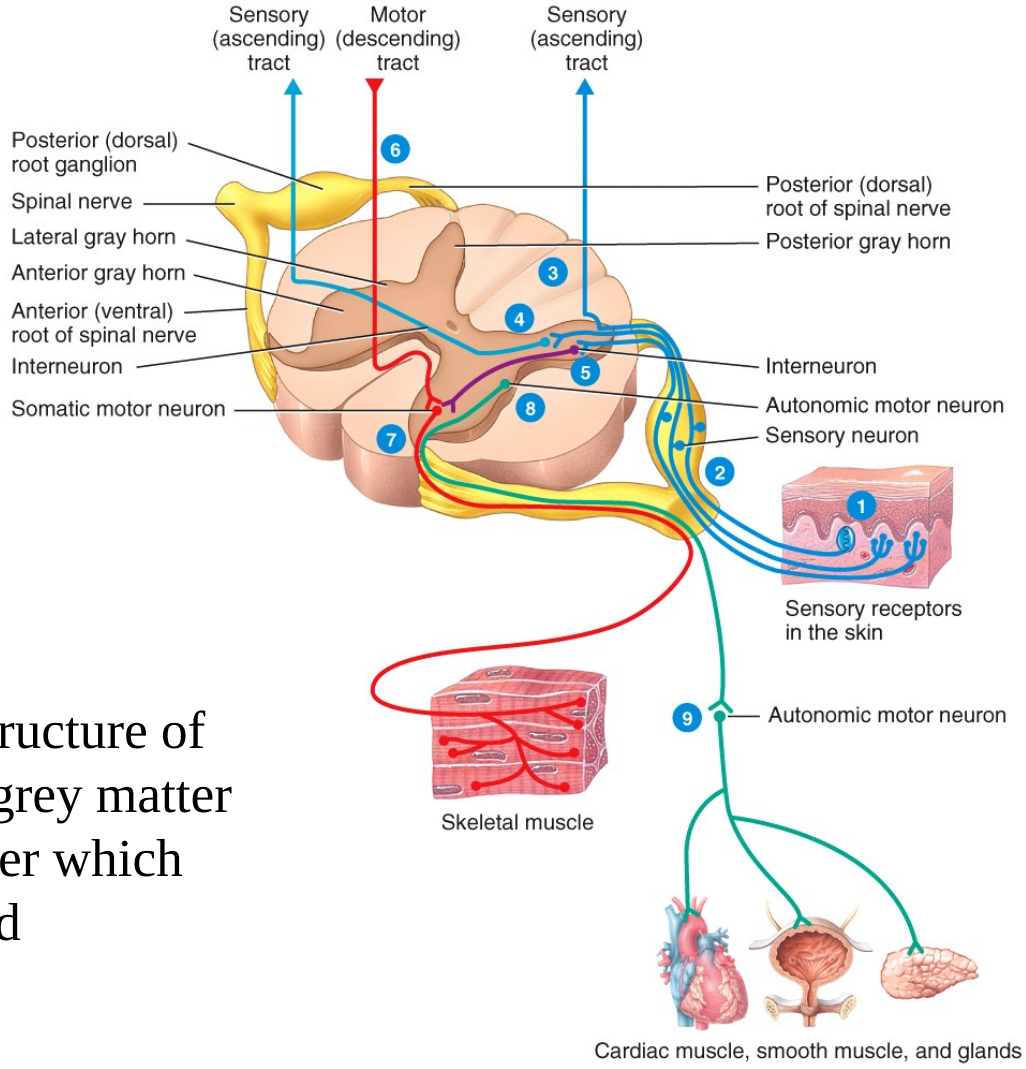
The Spinal Cord



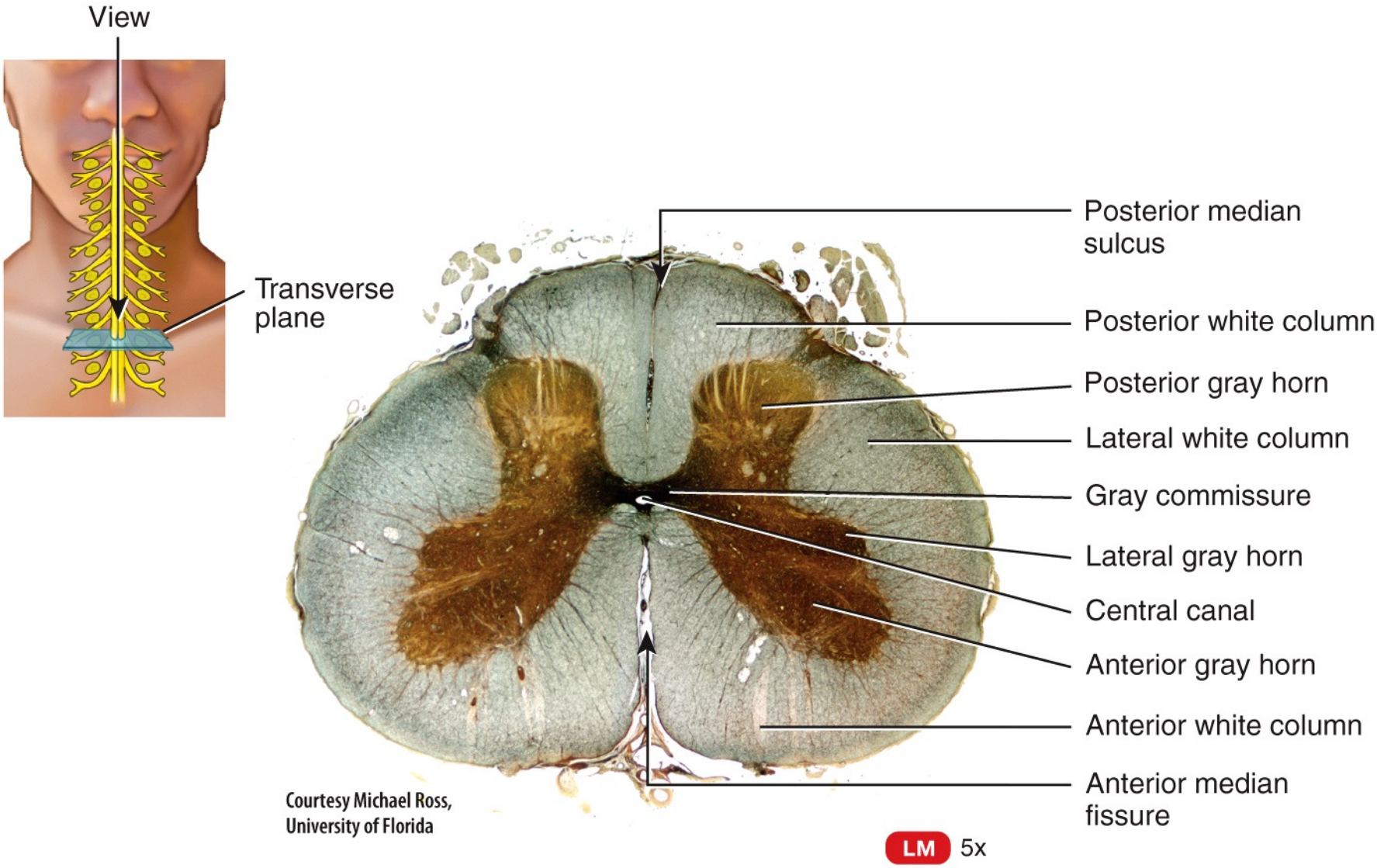
Functions of the Spinal Cord

- Conduction
  - bundles of fibers passing information up and down spinal cord, connecting different levels of the trunk with each other and with the brain
- Locomotion
  - walking involves repetitive, coordinated actions of several muscle groups
  - local neural circuits (central pattern generators) are pools of neurons providing control of flexors and extensors that cause alternating movements of the lower limbs
- Reflexes
  - involuntary, stereotyped responses to stimuli // e.g. withdrawal of hand from pain
  - involves brain, spinal cord and peripheral nerves

How Action Potentials Travel Between the PNS, Spinal Cord, and Brain



Note: image misrepresents structure of posterior and anterior horn's grey matter // it is the posterior grey matter which extends to the edge of the cord



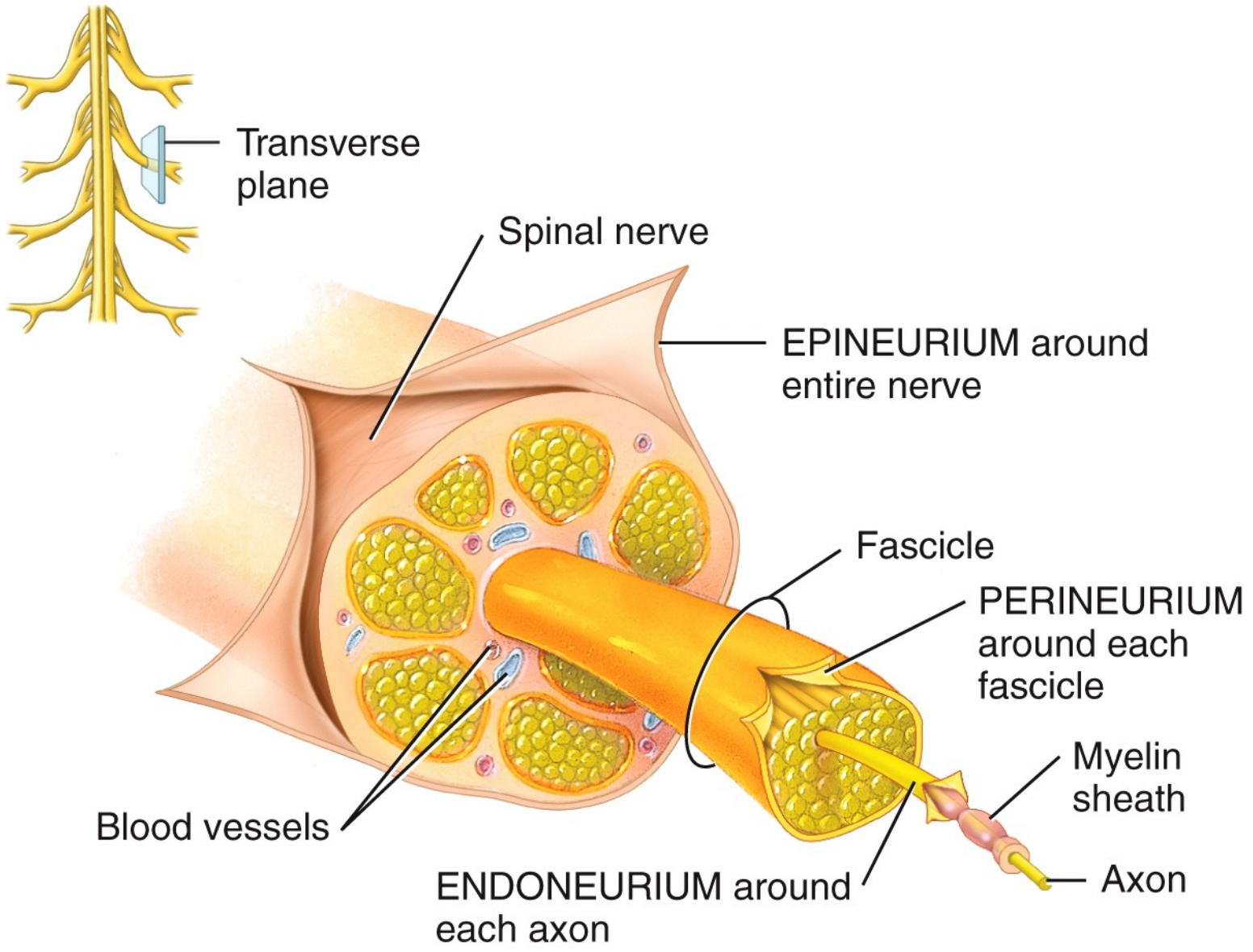
(b) Transverse section of lumbar spinal cord

Surface Anatomy

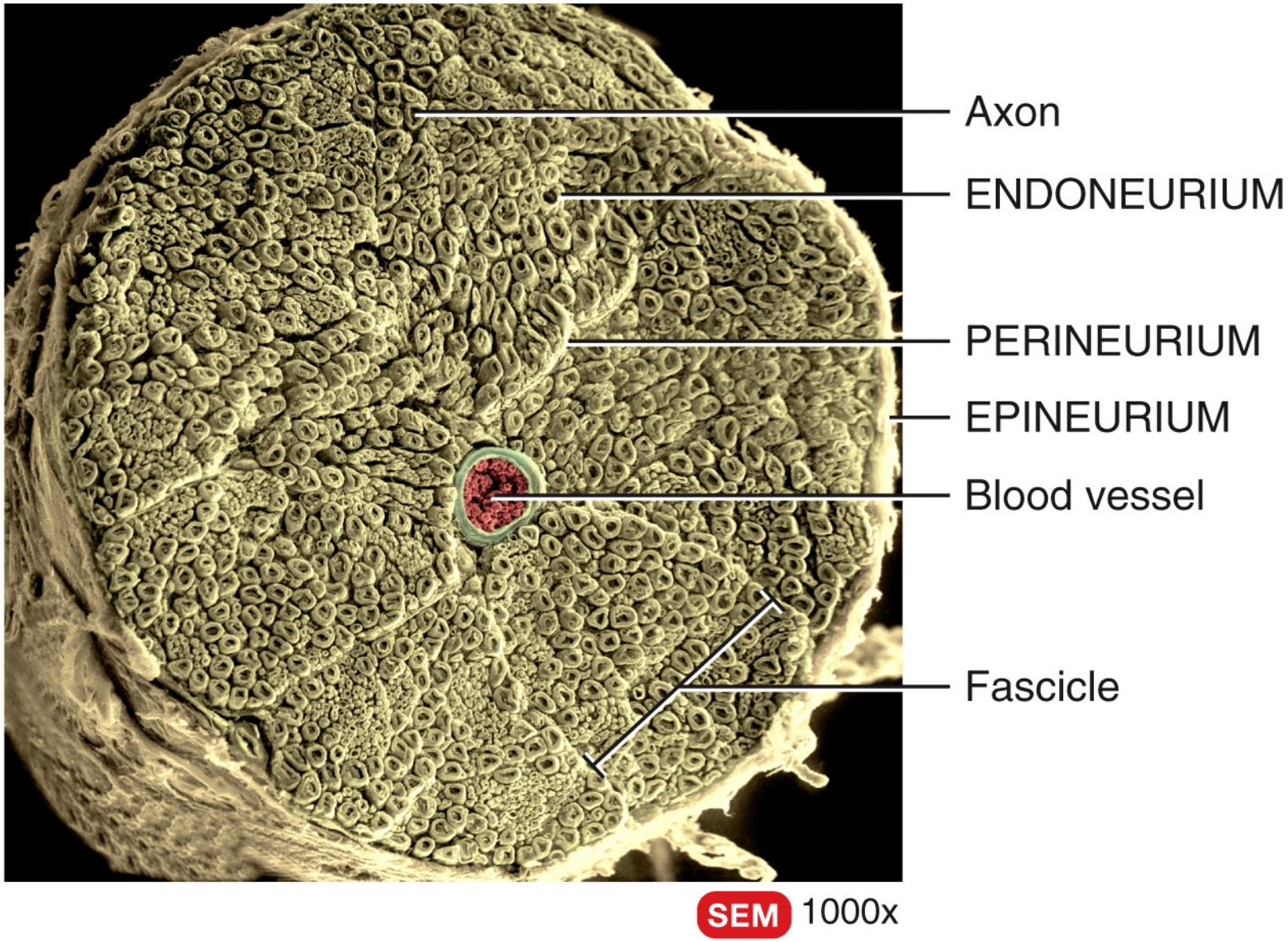
- **spinal cord** – cylinder of nervous tissue that arises from the brainstem at the foramen magnum of the skull
  - passes through the **vertebral canal**
  - inferior margin **ends at L1** or a little beyond
  - averages 1.8 cm thick and 45 cm long
  - occupies the **upper two-thirds of the vertebral canal**

Surface Anatomy

- spinal cord gives rise to 31 pair of spinal nerves
  - first pair passes between the skull and C1
  - all other pass through intervertebral foramina
- a segment of the spinal cord refers to part of the spinal cord supplied by each pair of spinal nerves

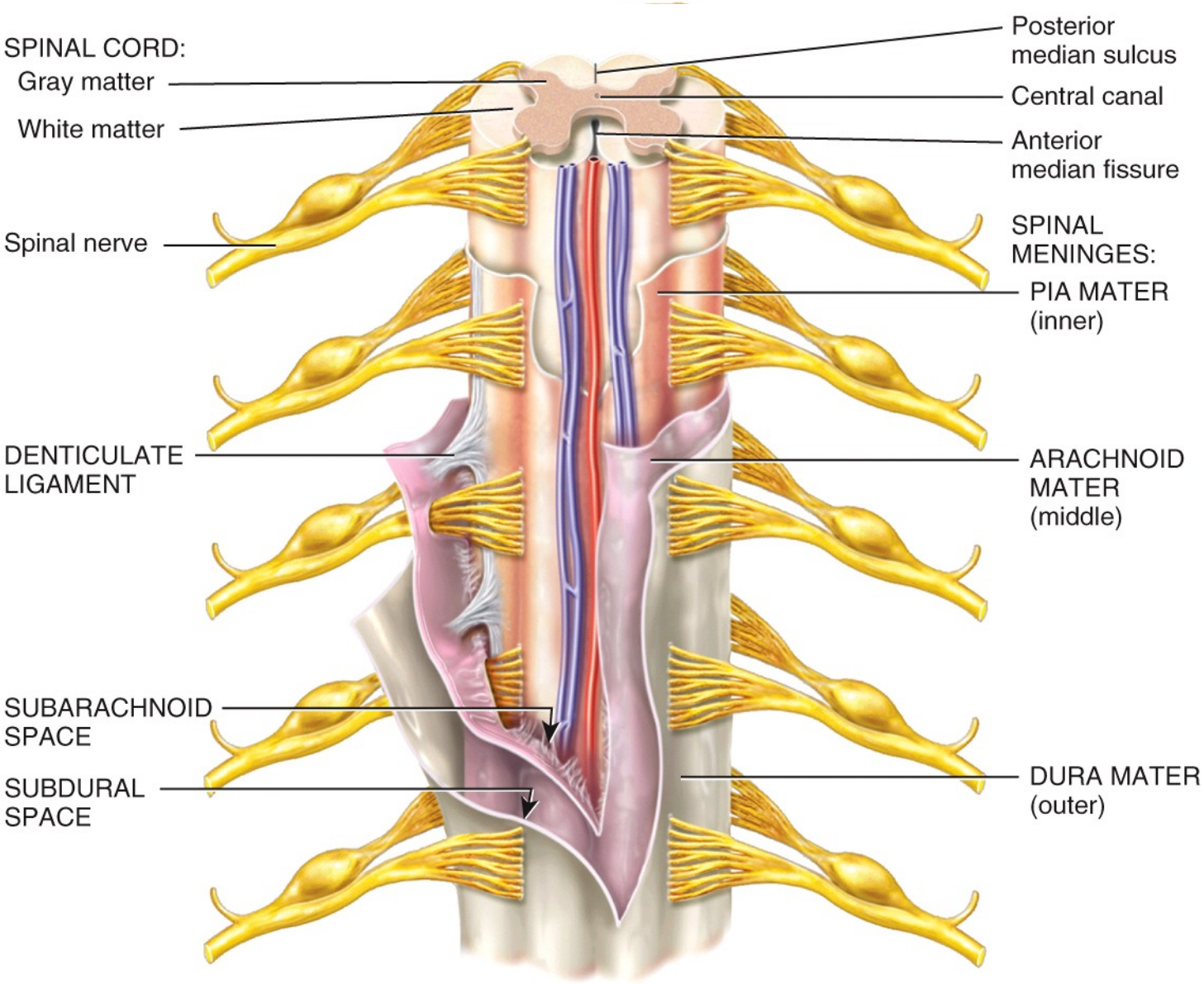


(a) Transverse section showing the coverings of a spinal nerve



Thomas Deerinck, NCMIR/Photo Researchers, Inc.

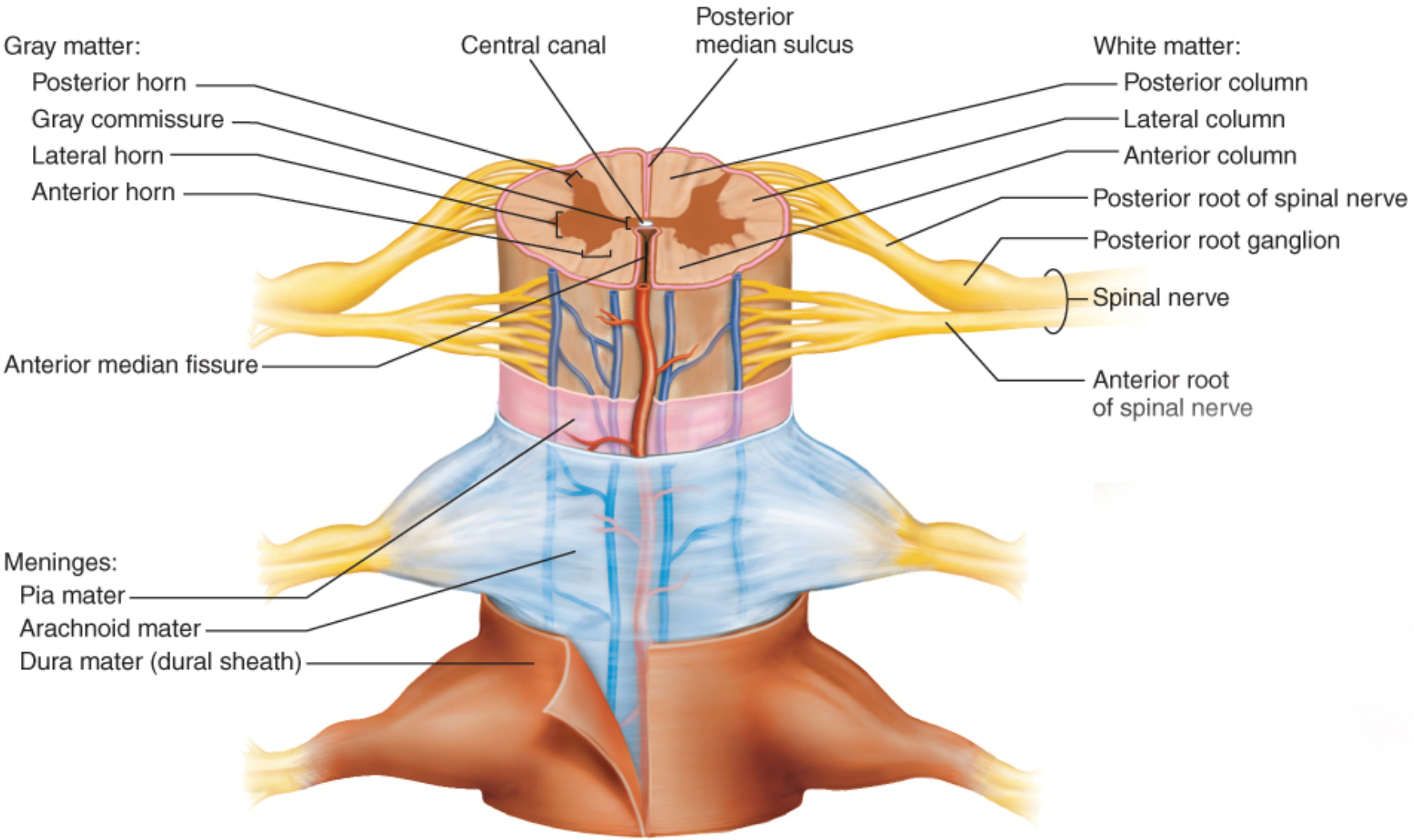
(b) Transverse section of several nerve fascicles



(a) Anterior view and transverse section through spinal cord

Surface Anatomy

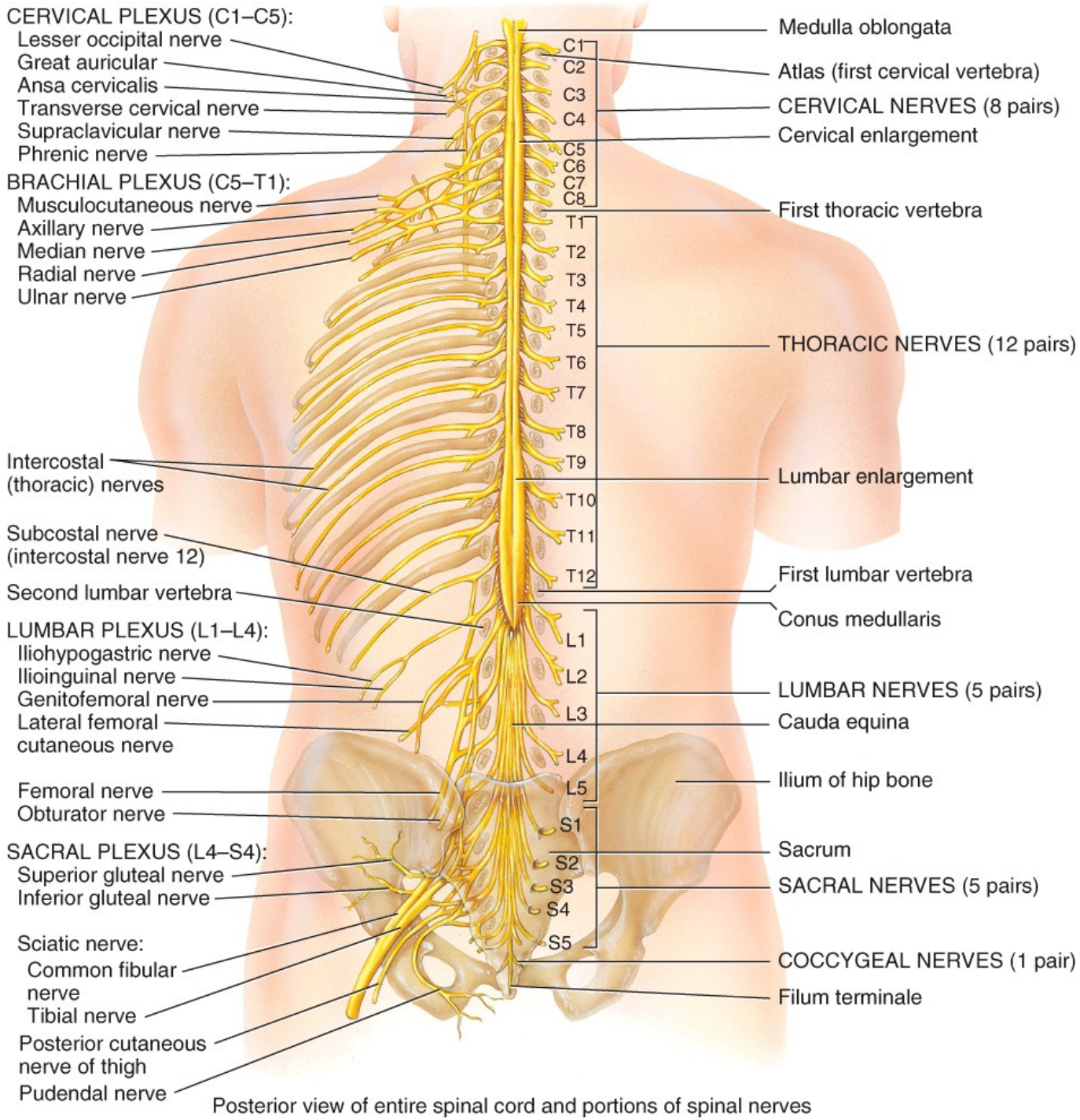
- longitudinal grooves on anterior and posterior surface of spinal cord
  - anterior median fissure
  - posterior median sulcus
- spinal cord divided into the cervical, thoracic, lumbar, and sacral regions
- two areas of the cord are thicker than elsewhere
  - cervical enlargement – nerves to upper limb
  - lumbar enlargement – nerves to pelvic region and lower limbs



(b) Spinal cord and meninges (thoracic)

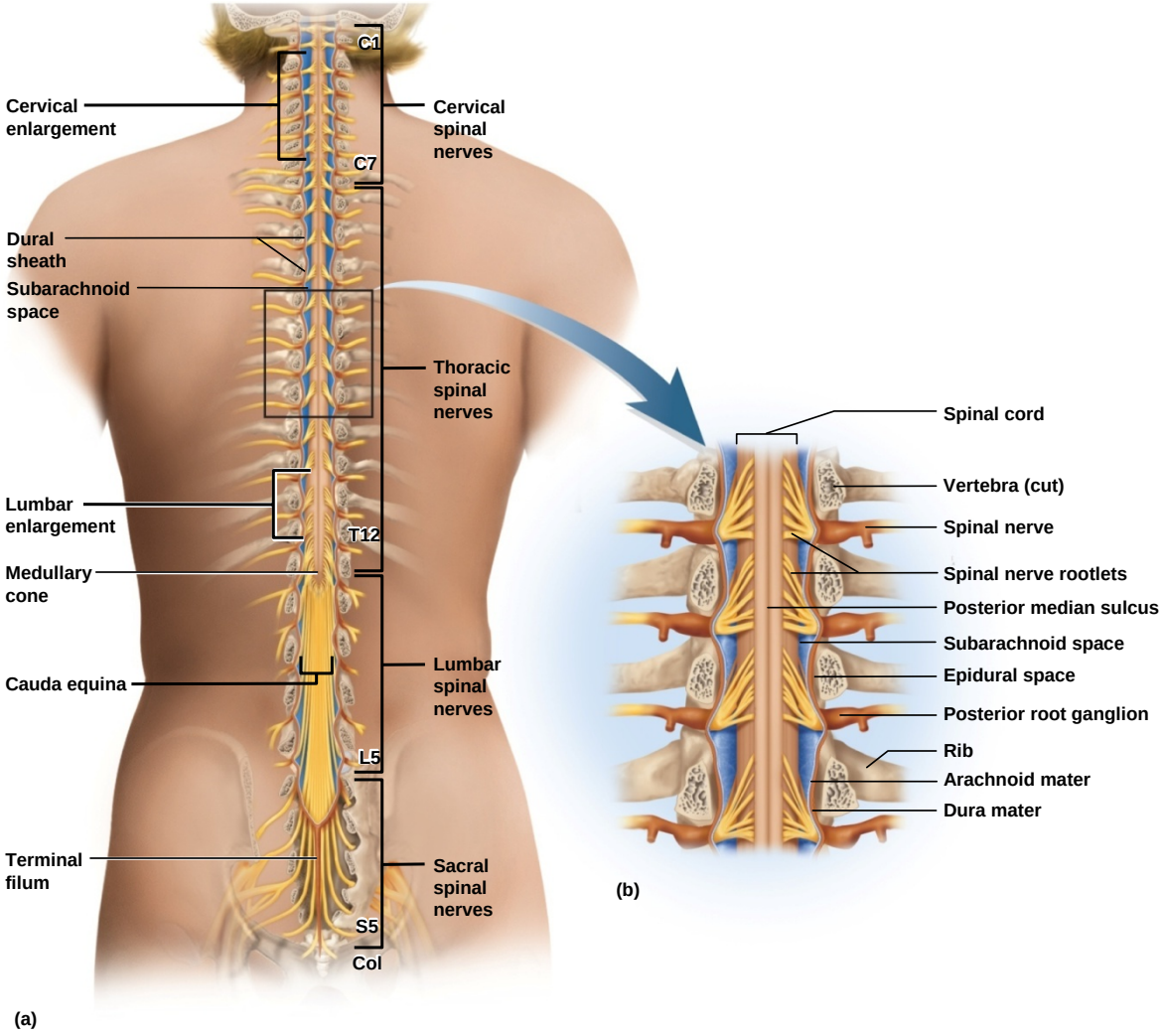
Surface Anatomy

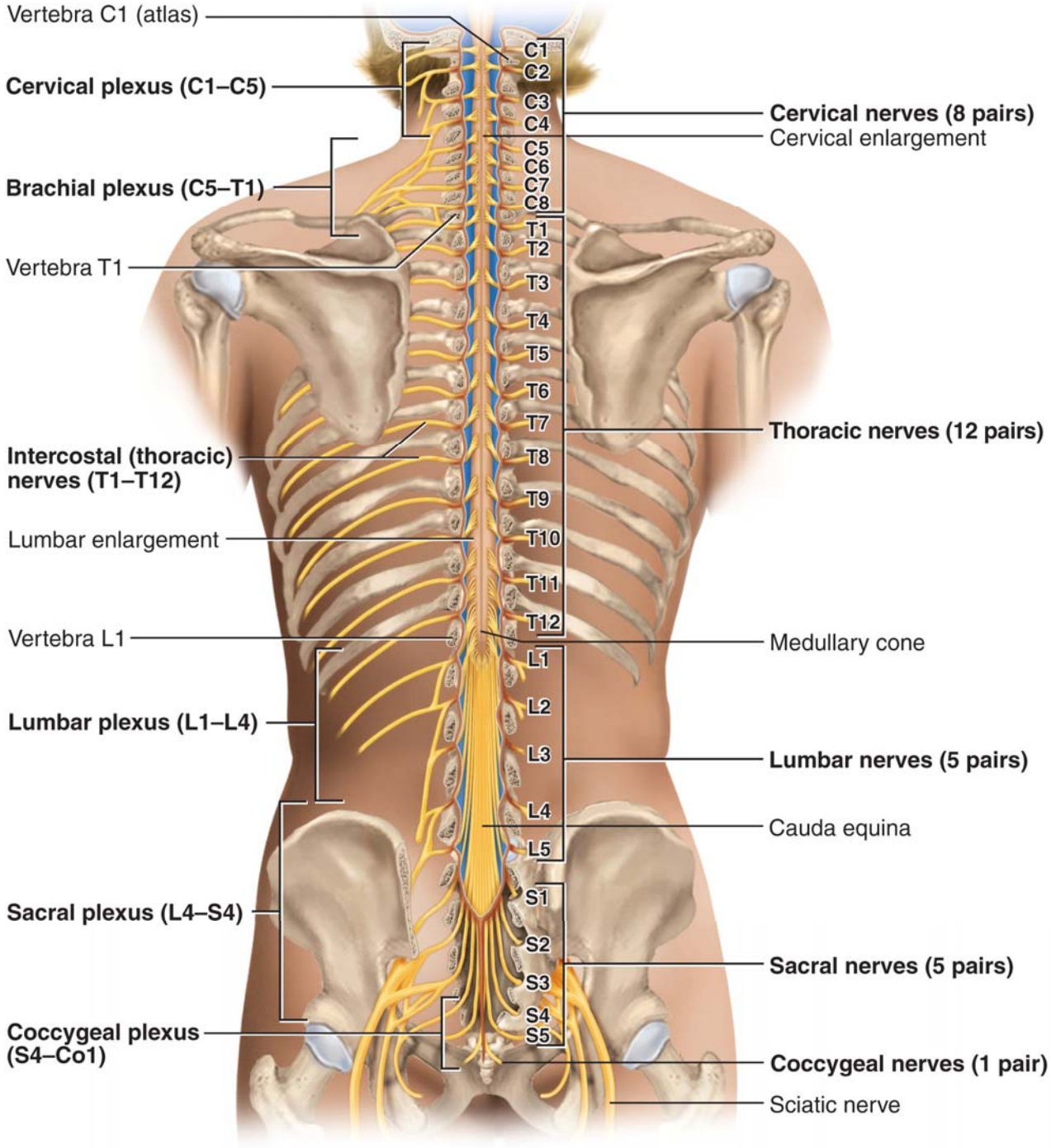
- medullary cone (conus medullaris) – cord tapers to a point inferior to lumbar enlargement
- cauda equina – bundle of nerve roots that occupy the vertebral canal from L2 to S5
- terminal filum – extension of pia matter from medullary cone which anchors spinal cord to inferiorly to coccyx



Posterior view of entire spinal cord and portions of spinal nerves

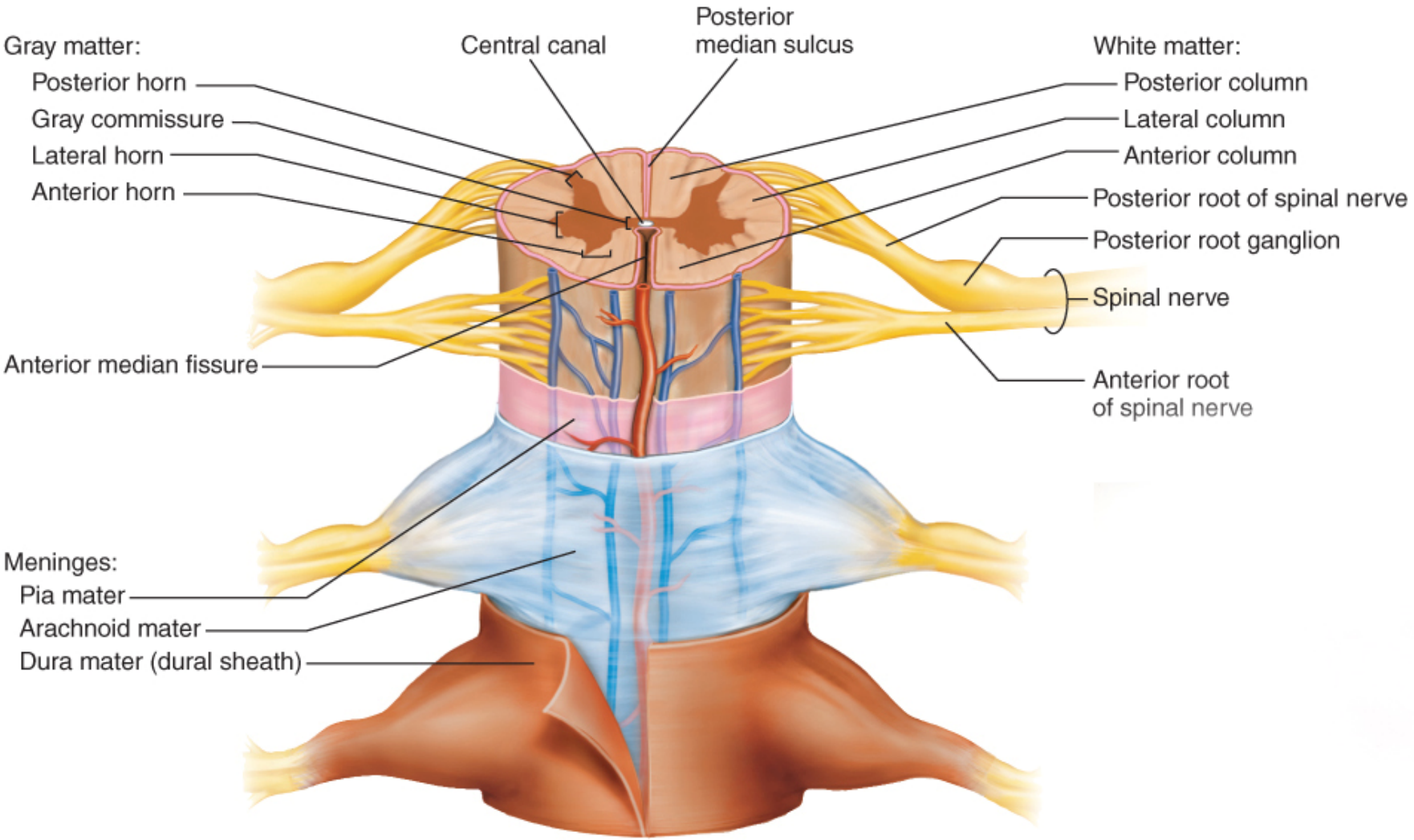
Anatomy of Lower Spinal Cord



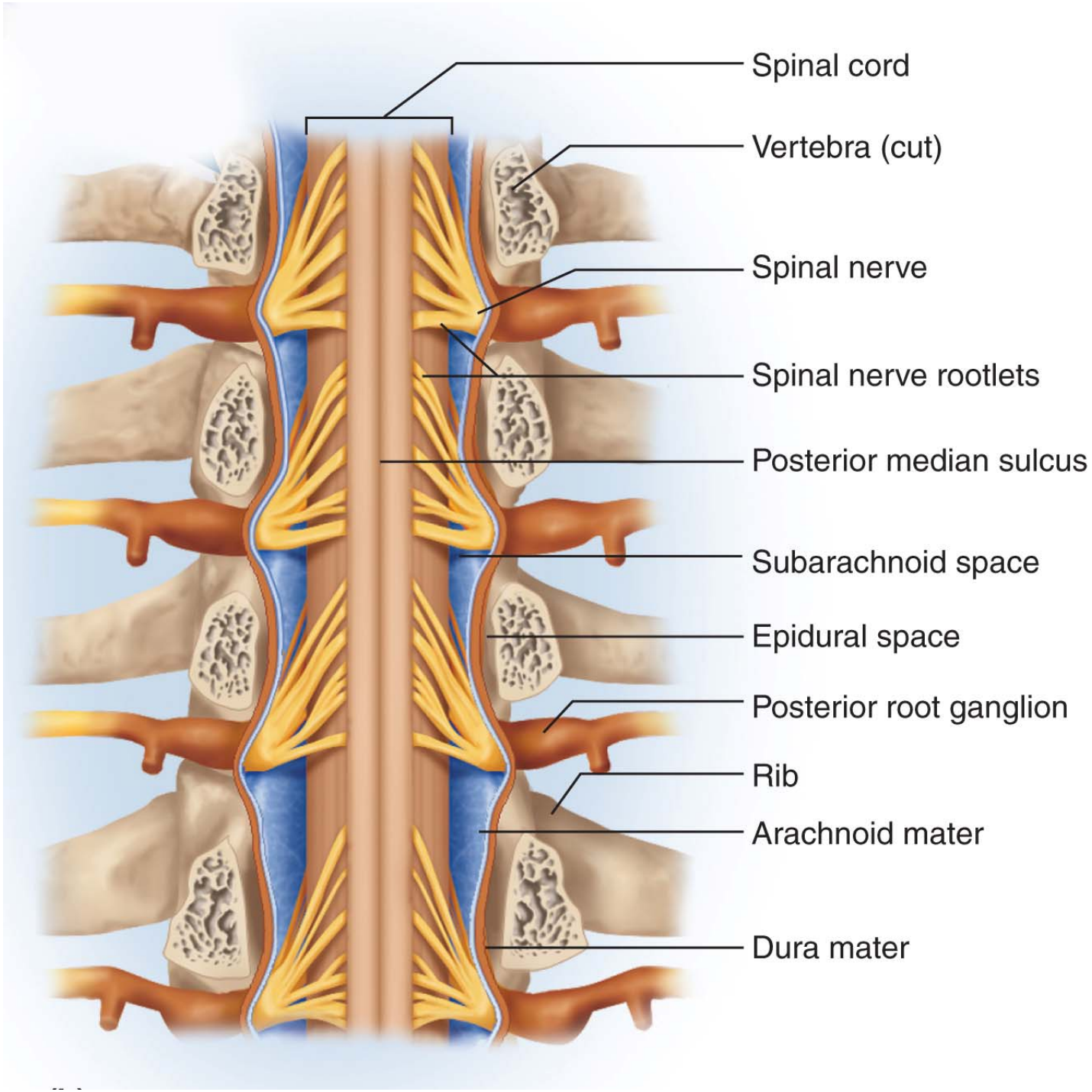


Meninges of the Spinal Cord

- three fibrous connective tissue membranes that enclose the brain and spinal cord
  - separate soft tissue of central nervous system from bones of cranium and vertebral canal
  - from superficial to deep
    - dura mater
    - arachnoid mater
    - pia mater



(b) Spinal cord and meninges (thoracic)


Spinal cord
Vertebra (cut)
Spinal nerve
Spinal nerve rootlets
Posterior median sulcus
Subarachnoid space
Epidural space
Posterior root ganglion
Rib
Arachnoid mater
Dura mater

Meninges of the Spinal Cord – Dura Mater

- forms loose-fitting sleeve around spinal cord – dural sheath
- tough, collagenous membrane surrounded by epidural space filled with fat, blood vessels, and loose connective tissue
  - epidural anesthesia utilized during childbirth

Meninges of the Spinal Cord - Arachnoid Mater

- arachnoid membrane - layer of simple squamous epithelium lining dura mater and a loose mesh of collagenous and elastic fibers spanning the gap between the arachnoid membrane and the pia mater

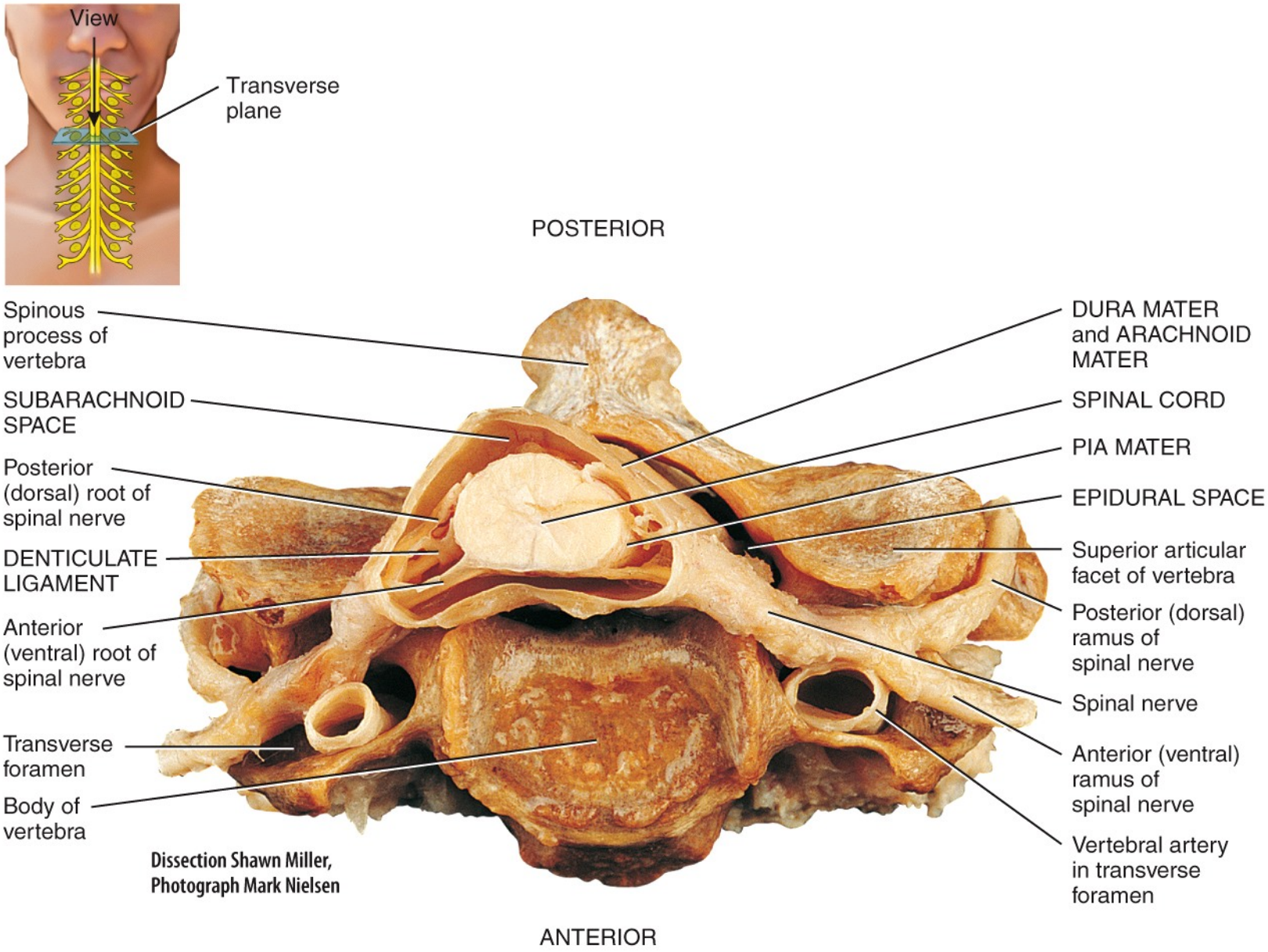
- subarachnoid space – gap between arachnoid membrane and the pia mater

  - filled with cerebrospinal fluid (CSF)

  - lumbar cistern – subarachnoid space inferior to medullary cone that contains cauda equina and CSF

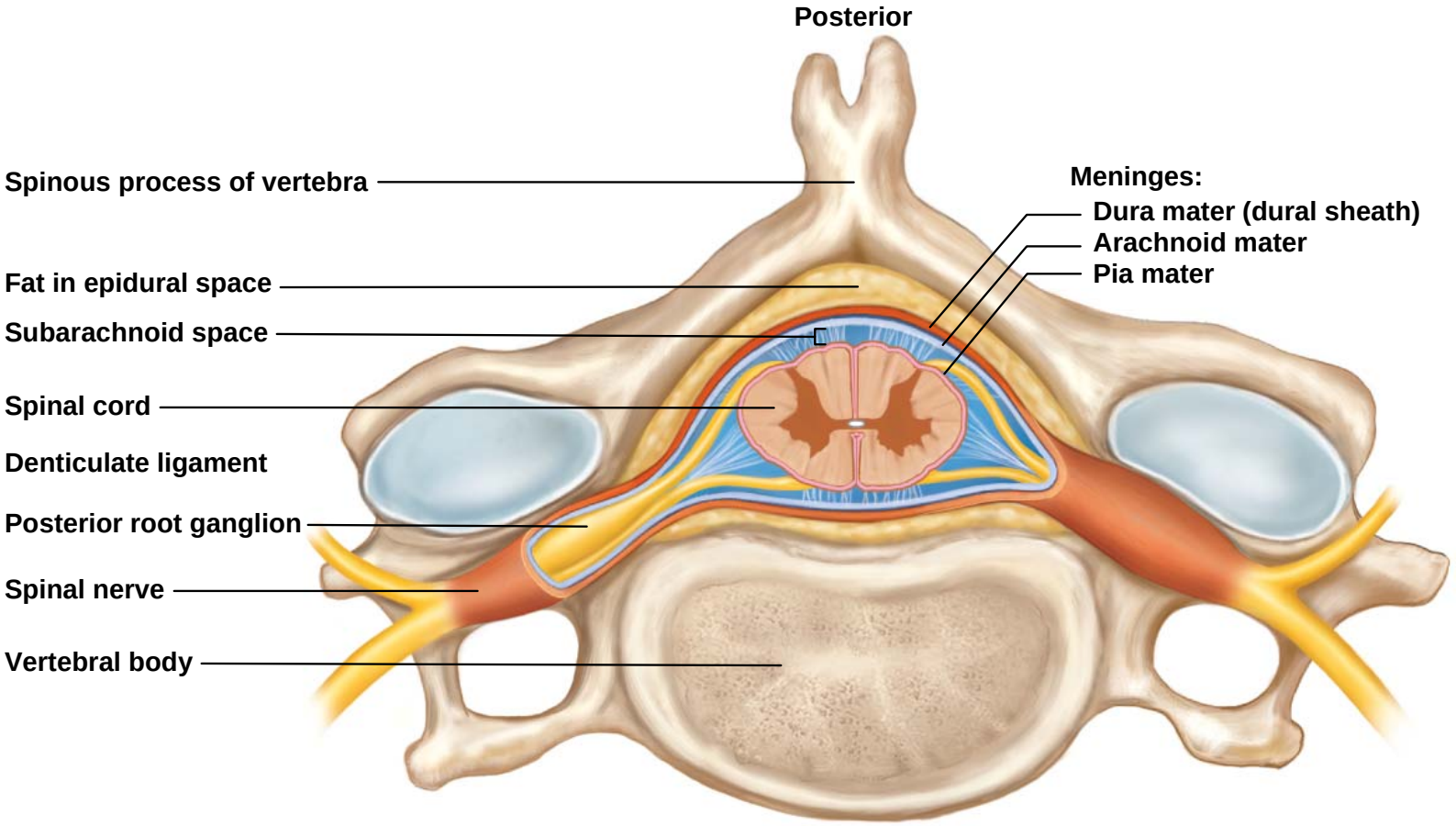
Meninges of the Spinal Cord – Pia Mater

- delicate, translucent membrane that follows the contours of the spinal cord
- terminal filum – fibrous strand of pia mater that extends beyond the medullary cone within the lumbar cistern
- coccygeal ligament – formed from fusion of terminal filum and dura mater // anchors the cord and meninges to vertebra Co1
- denticulate ligaments – extend through the arachnoid to the dura // anchors spinal cord to limit side to side movement



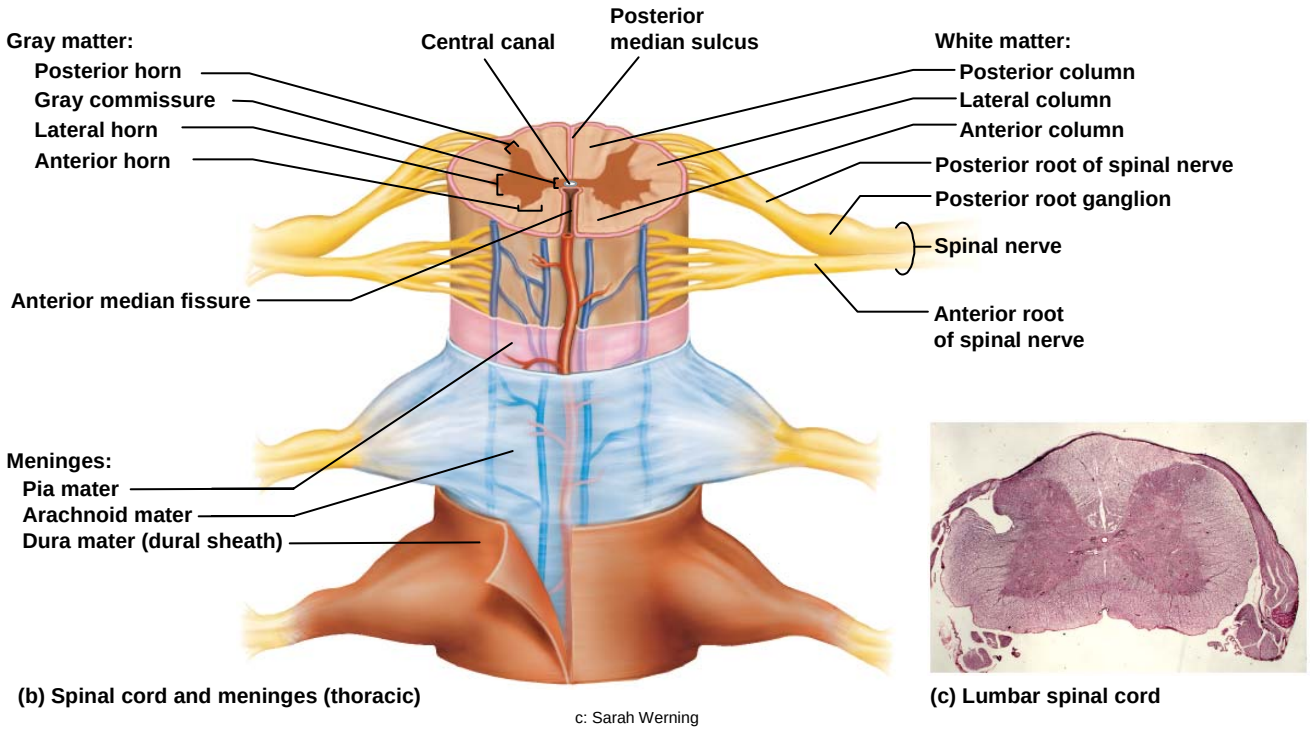
(b) Transverse section of the spinal cord within a cervical vertebra

Meninges of Vertebra and Spinal Cord



(a) Spinal cord and vertebra (cervical)

Cross-Sectional Structure of the Spinal Cord

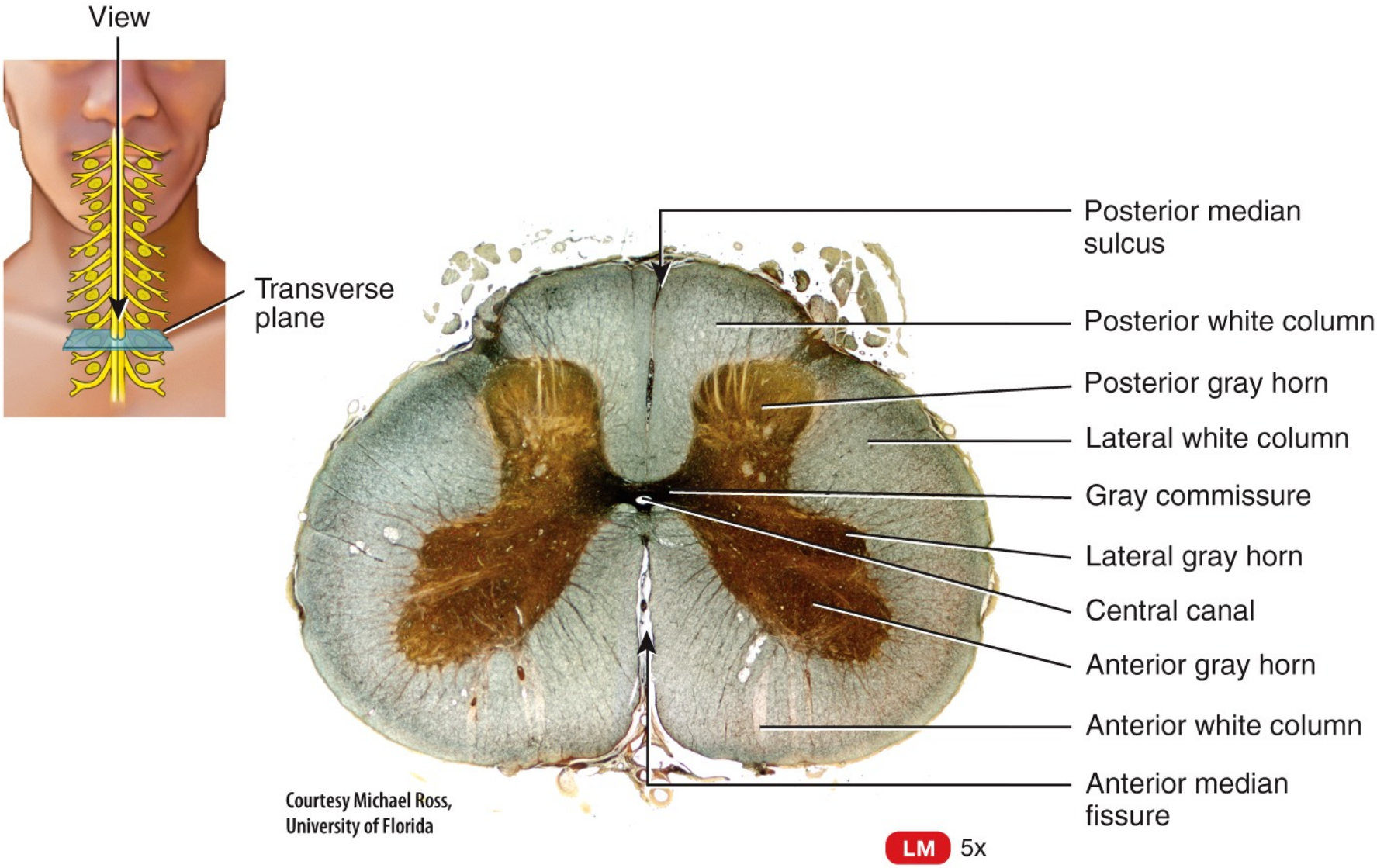


(b) Spinal cord and meninges (thoracic)

c: Sarah Werning

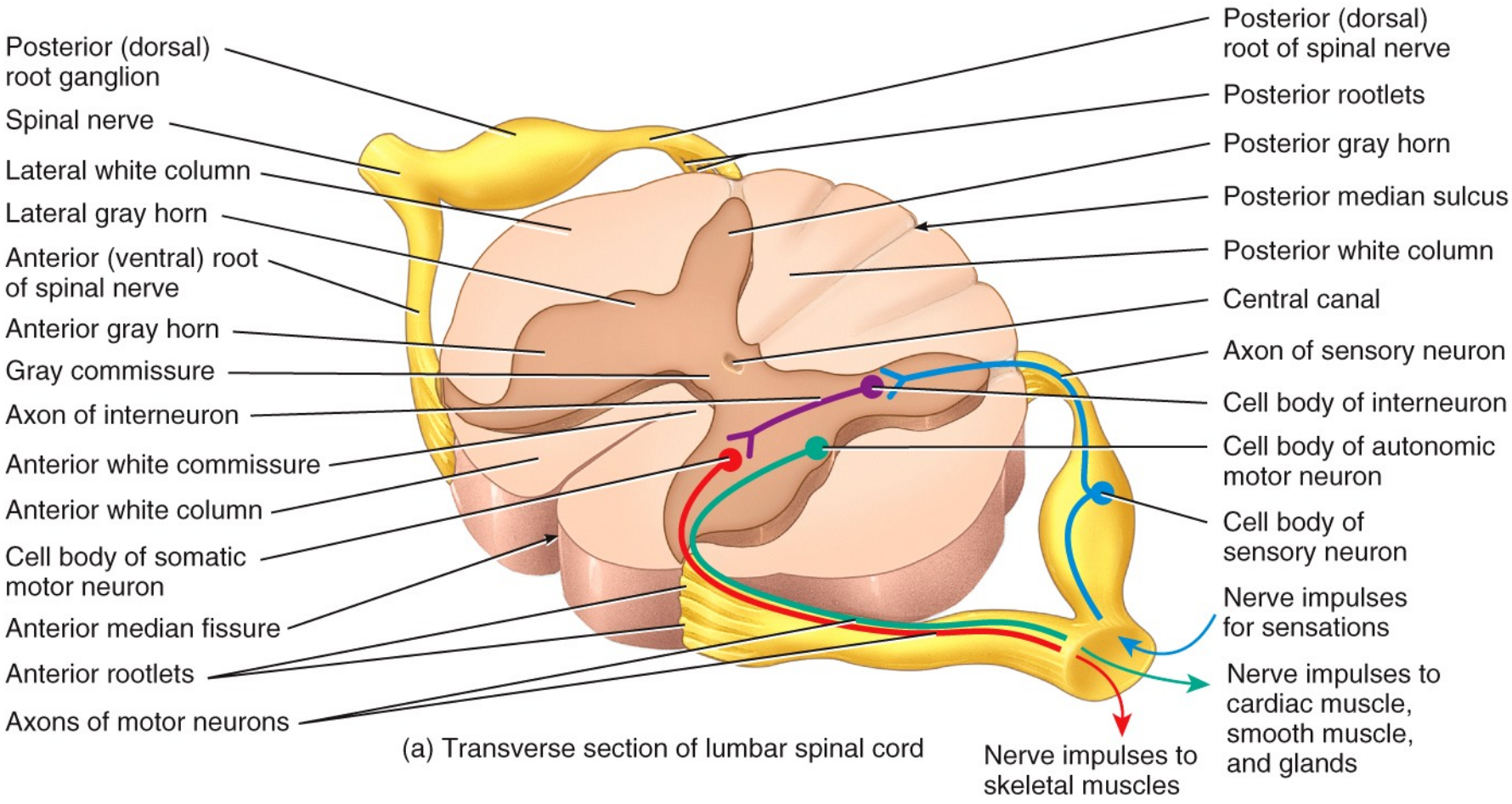
(c) Lumbar spinal cord

- central area of gray matter shaped like a butterfly and surrounded by white matter in 3 columns // white areas = tracts
- gray matter - neuron cell bodies with little myelin // site of information processing – synaptic integration // grey matter = horns
- white matter – abundantly myelinated axons // carry signals from one part of the CNS to another



(b) Transverse section of lumbar spinal cord

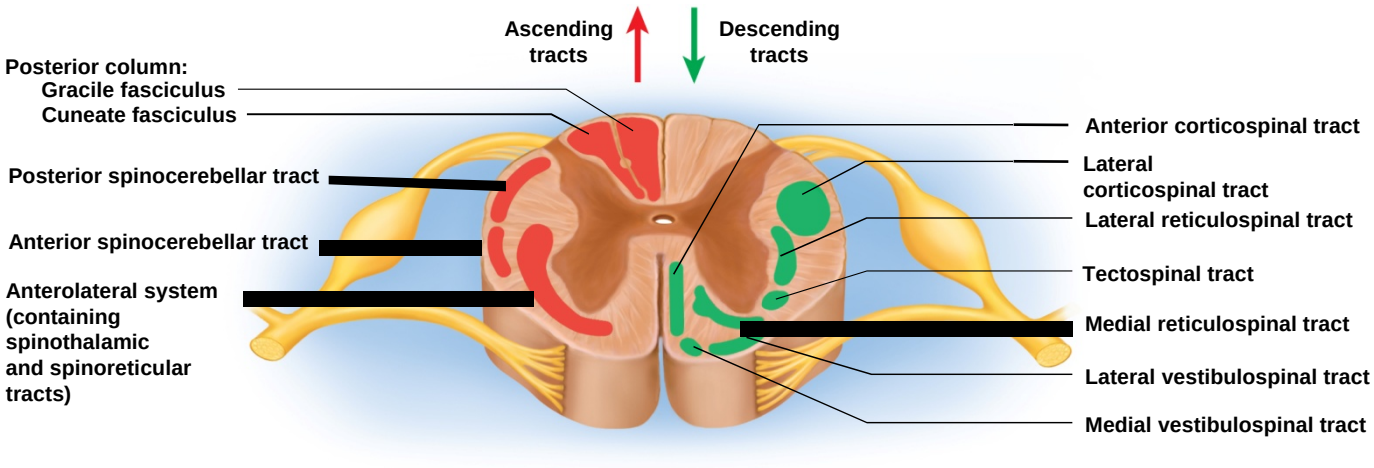
Posterior, Anterior, and Lateral Horns of the Spinal Cord



Gray Matter in the Spinal Cord

- pair of posterior (dorsal) horns // posterior (dorsal) root of spinal nerve carries only sensory fibers

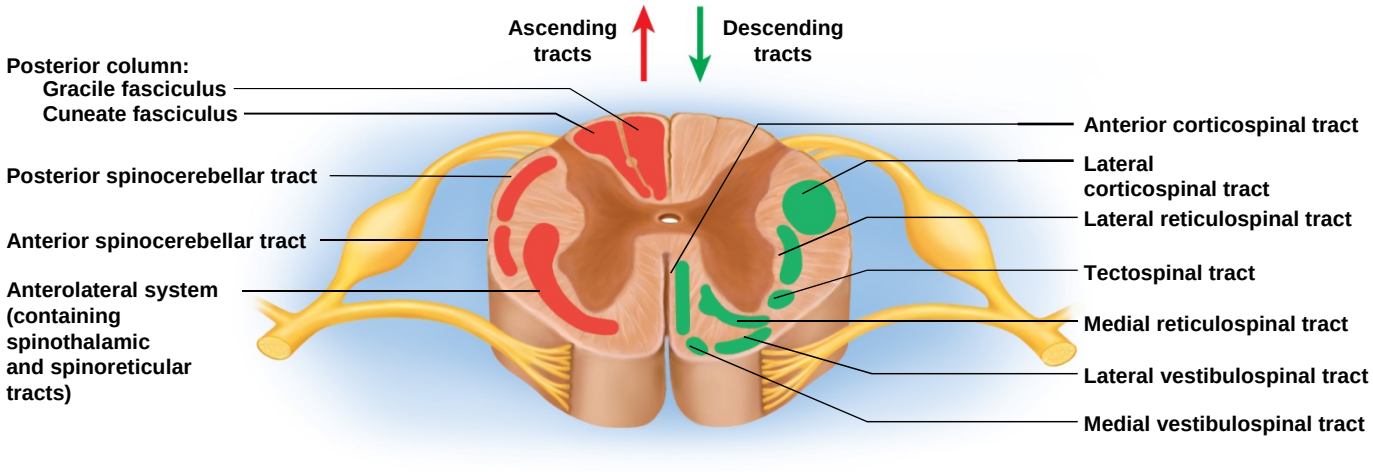
- pair of thicker anterior (ventral) horns // anterior (ventral) root of spinal nerve carries only motor fibers



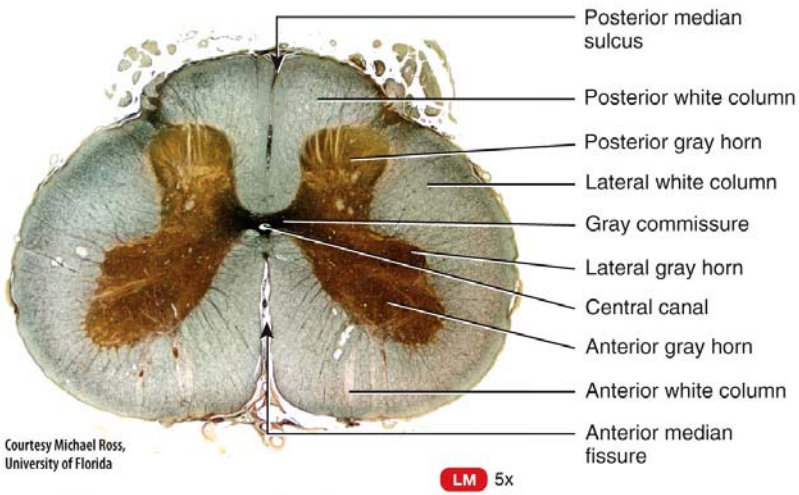
Gray Matter in the Spinal Cord

- gray commissure connects right and left sides // punctured by a central canal lined with ependymal cells and filled with CSF

- lateral horn = visible from T2 through L1 // contains neurons of sympathetic nervous system



Functions of the Spinal Cord Horns

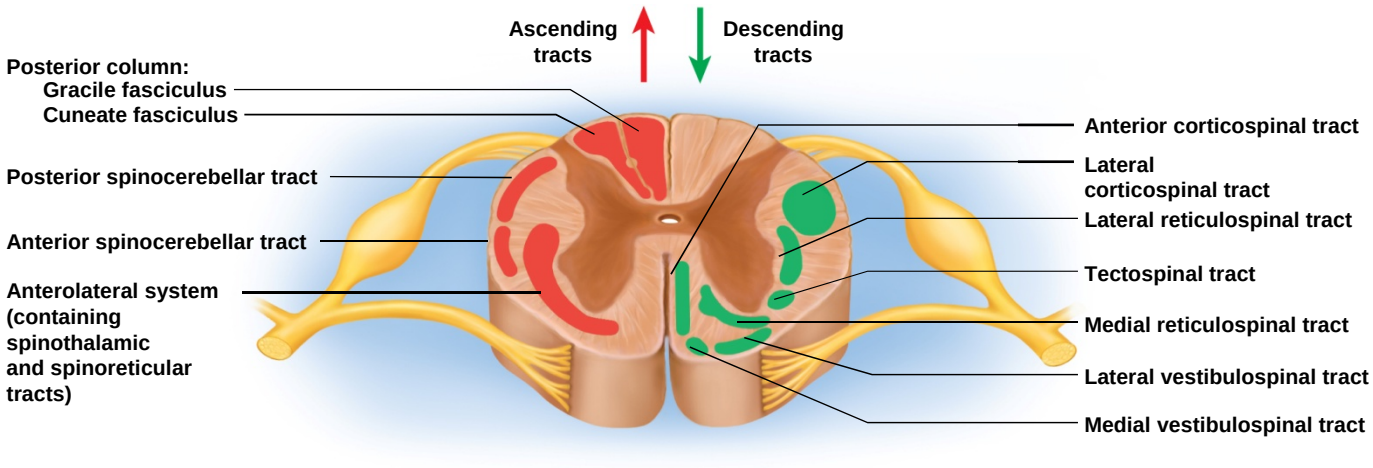


(b) Transverse section of lumbar spinal cord

- **Posterior grey horns / cell bodies and axons of interneurons + incoming sensory neurons form dorsal root ganglion**
- **Anterior grey horns / somatic motor nuclei to skeletal muscles**
- **Lateral grey horns / only in thoracic and upper lumbar / contain autonomic motor nuclei / regulate smooth muscle – cardiac muscle - glands**

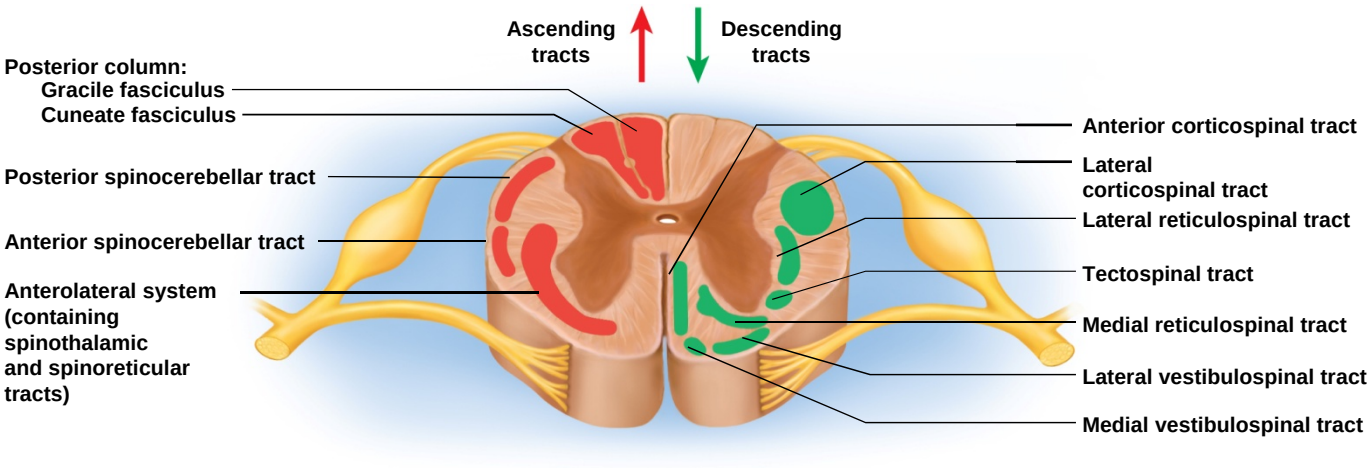
White Matter in the Spinal Cord

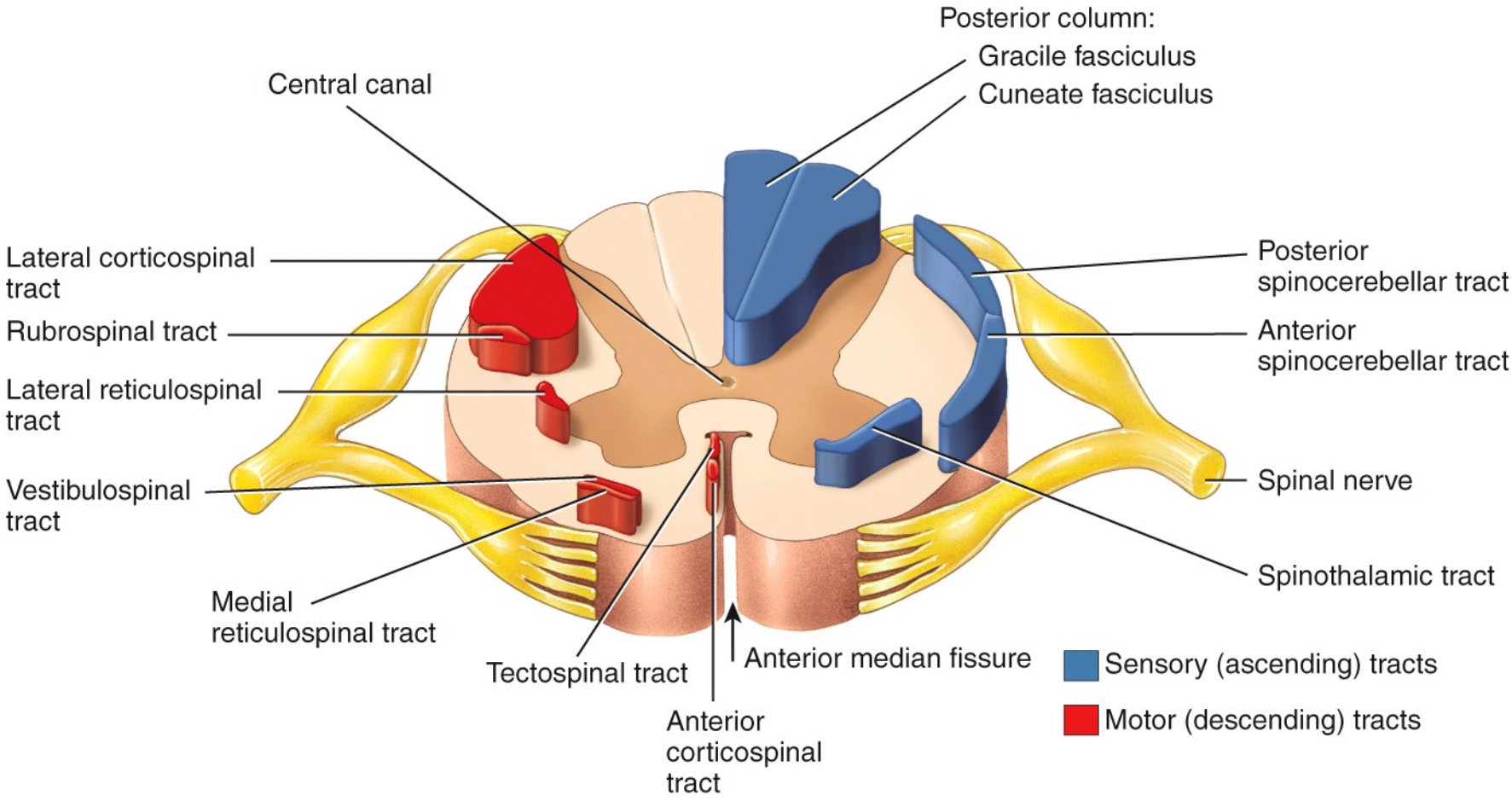
- white matter of the spinal cord surrounds the gray matter
- consists of bundles of axons that course up and down the cord that provide avenues of communication between different levels of the CNS



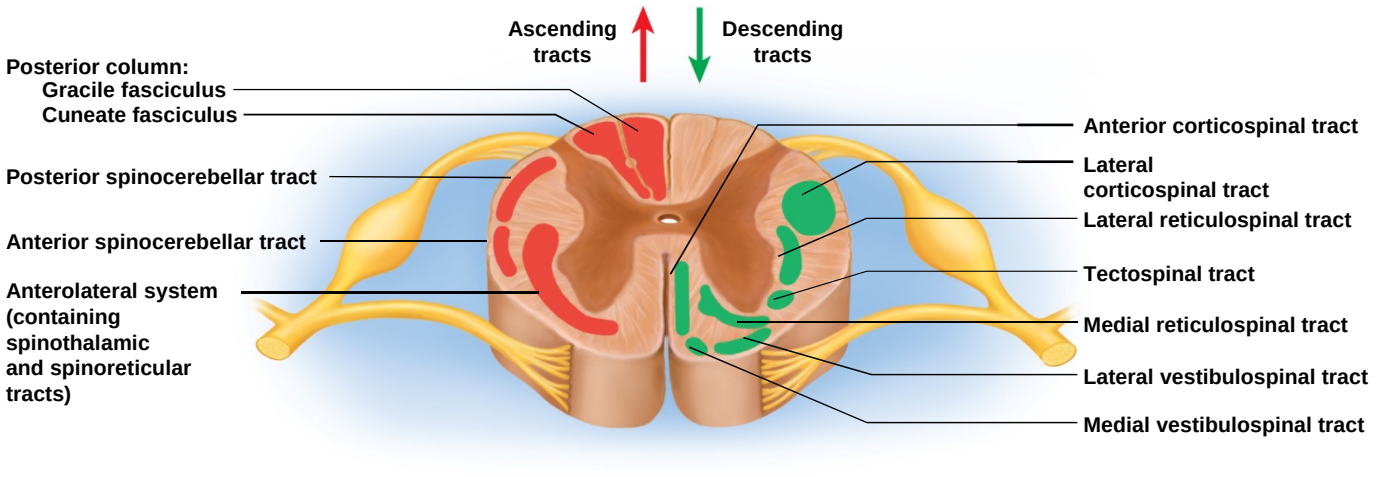
White Matter in the Spinal Cord

- columns or funiculi – three pair of these white matter bundles
    - Posterior columns (dorsal)
    - Lateral columnsl
    - Anterior columns (ventral)
- tracts or fasciculi – subdivisions of each column



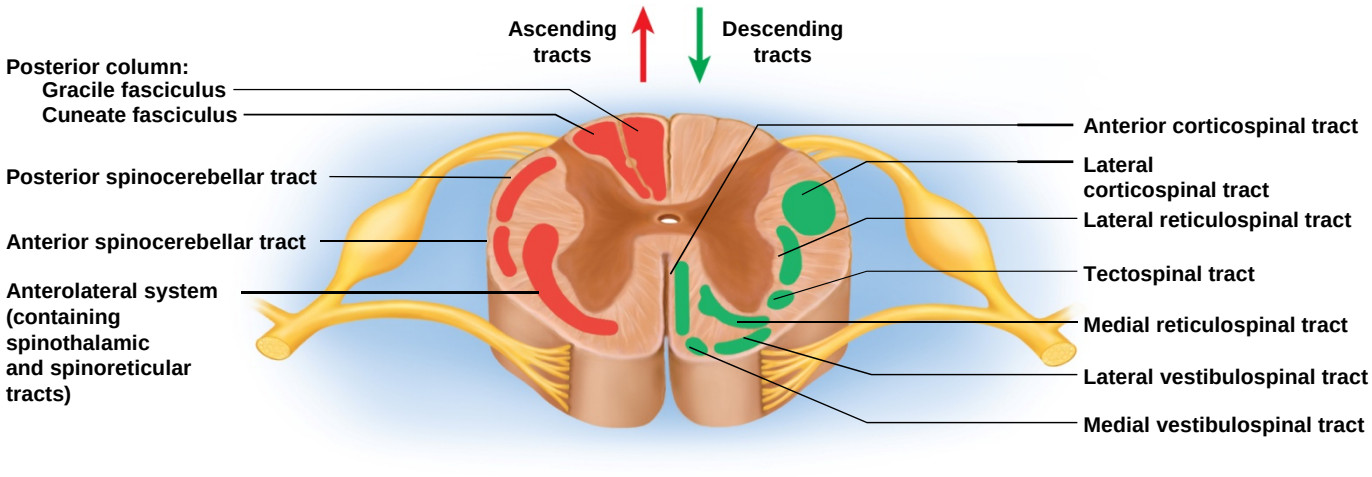

Posterior column:
Gracile fasciculus
Cuneate fasciculus
Central canal
Lateral corticospinal tract
Rubrospinal tract
Lateral reticulospinal tract
Vestibulospinal tract
Medial reticulospinal tract
Tectospinal tract
Anterior corticospinal tract
Anterior median fissure
Posterior spinocerebellar tract
Anterior spinocerebellar tract
Spinal nerve
Spinothalamic tract
Sensory (ascending) tracts
Motor (descending) tracts

Spinal Tracts



- ascending tracts – carry sensory information up the spinal cord
- descending tracts – carry motor information down the spinal cord // all nerve fibers in a given tract have a similar origin, destination, and function
- decussation – as the fibers pass up or down the brainstem and spinal cord they cross over from the left to the right side and vise versa

Spinal Tracts



- contralateral – when the origin and destination of a tract are on opposite sides of the body

- ipsilateral – when the origin and destination of a tract are on the same side of the body // does not decussate

Ascending Tracts

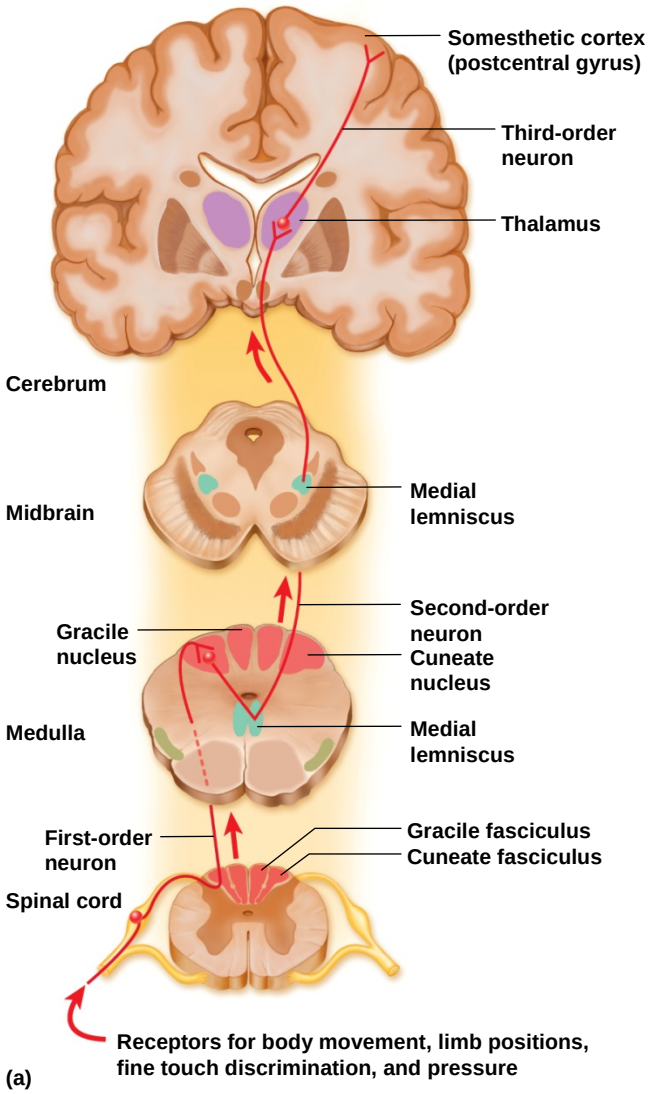
- ascending tracts carry sensory signals **up the spinal cord**
- sensory signals **travel across three neurons** from origin in receptors to the destination in the sensory areas of the brain
  - **first order neurons** – detect stimulus and transmit signal to spinal cord or brainstem
  - **second order neurons** – continues to the thalamus at the upper end of the brainstem
  - **third order neurons** – carries the signal the rest of the way to the sensory region of the cerebral cortex

Major Ascending Tracts

- **gracile fasciculus**
- **cuneate fasciculus**
- **spinothalamic tract**
- **spinoreticular tract**
- **posterior (dorsal) and anterior (ventral) spinocerebellar tracts**

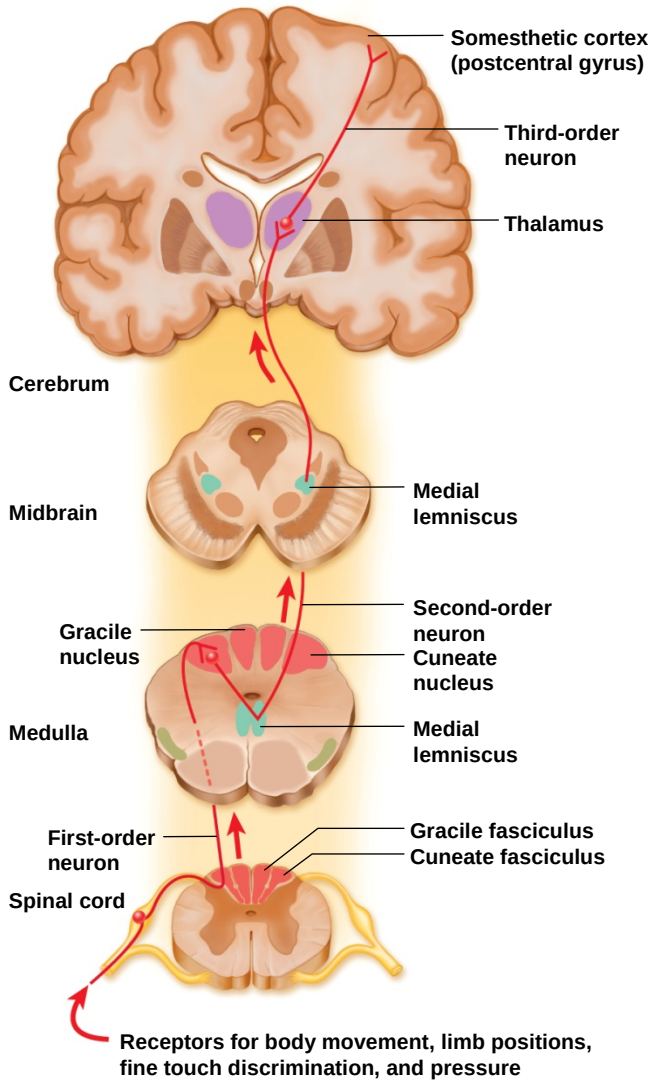
Gracile Fasciculus

- carries signals from midthoracic and lower parts of the body
- below T6, it composes the entire posterior column // at T6 joins cuneate fasciculus
- consists of first-order nerve fibers that travel up the ipsilateral side of the spinal cord
- terminates at the gracile nucleus of the medulla oblongata
- carries signals for vibration, visceral pain, deep and discriminative touch, and proprioception from lower limbs and lower trunk
- proprioception – non-visual sense of the position and movements of the body / conscious



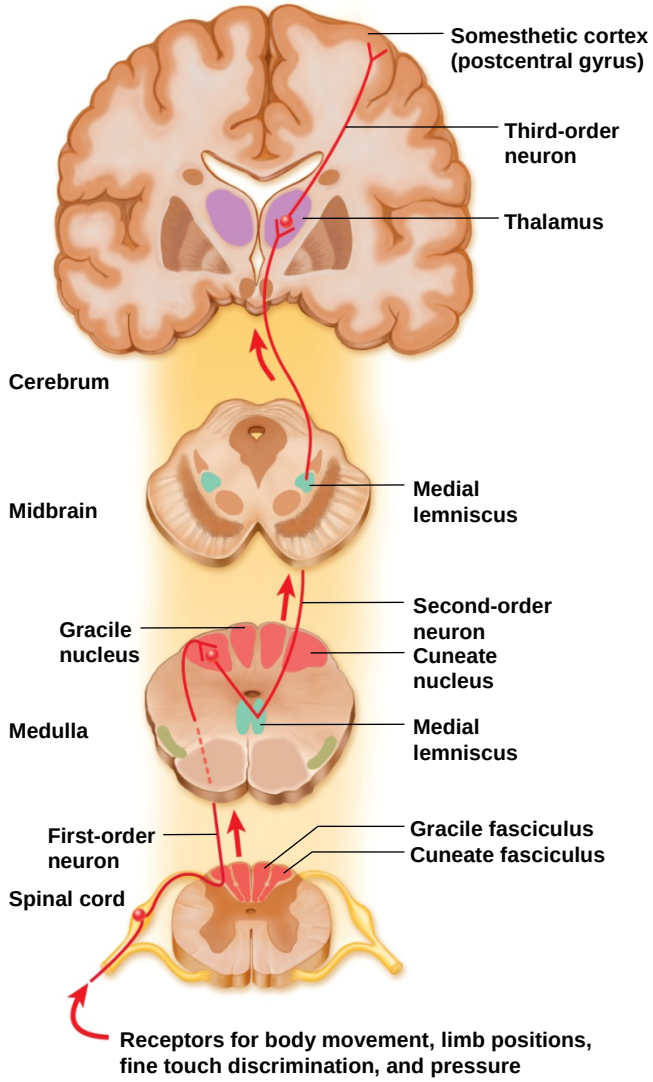
Cuneate Fasciculus

- originate from the level of T6 and up // upper limb and chest
- joins gracile fasciculus at T6
- occupies lateral portion of the posterior column // forces gracile



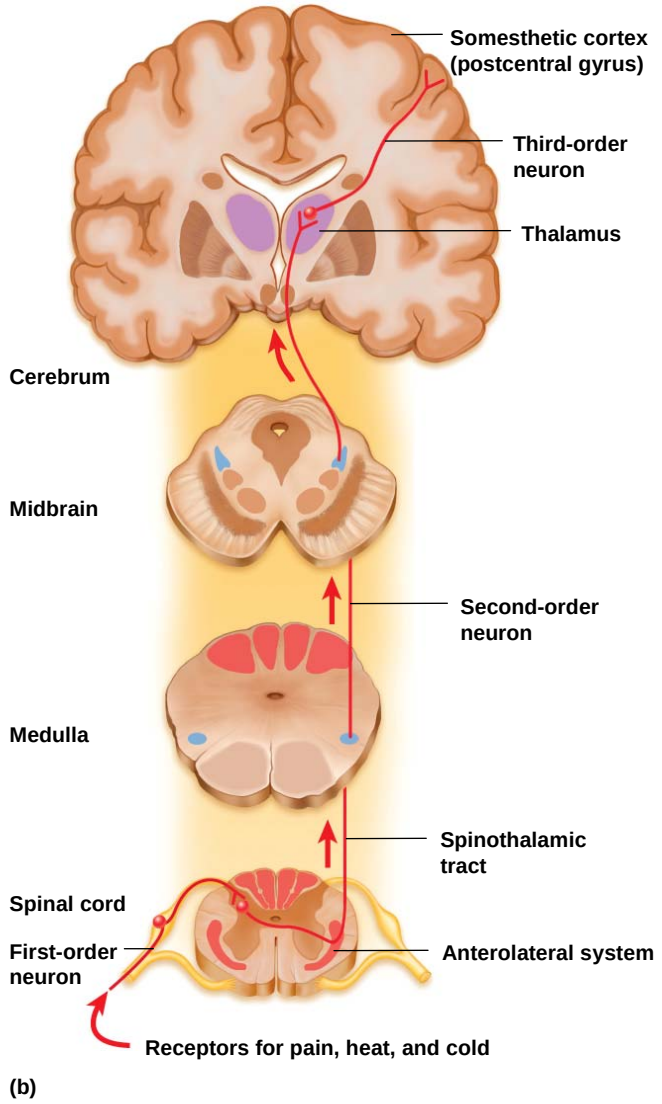
Cuneate Fasciculus

- medial lemniscus // formed from the second-order neurons of gracile and cuneate systems that decussate in the medulla
  - tracts of these nerve fibers lead the rest of the way to the thalamus
  - third-order neurons go from thalamus to cerebral cortex
  - carry signals to contralateral cerebral hemisphere



Spinothalamic Pathway

- one of the smaller tracts of the anterolateral system
  - passes up the anterior and lateral columns of the spinal cord
- carry signals for pain, pressure, temperature, light touch, tickle, and itch
- first-order neurons end in posterior horn of spinal cord
- synapse with second-order neurons which decussate to other side of spinal cord and form the ascending spinothalamic tract that goes to the thalamus
- third-order neurons continue from there to cerebral cortex
- sends signals to the contralateral cerebral hemisphere



Spinoreticular Tract

- travel up the anterolateral system
- carries pain signals resulting from tissue injury
- first-order neurons enter posterior horn and immediately synapse with second-order neurons
- decussate to opposite anterolateral system
  - ascend the cord // end in reticular formation – loosely organized core of gray matter in the medulla and pons
- *third-order neurons* continue from the pons to the thalamus
- *fourth-order neurons* complete the path to the cerebral cortex (Note: exception to the rule!)

Spinocerebellar Tracts

- travel through lateral column
- carry proprioceptive signals from limbs and trunk up to the cerebellum
- first-order neurons originate in the muscles and tendons // end in posterior horn of the spinal cord
- second-order nerves ascend spinocerebellar tracts and end in cerebellum
  - fibers of the posterior tract travel up the ipsilateral side of the spinal cord
  - fibers of the anterior tract cross over and travel up the contralateral side // cross back in the brainstem to enter the ipsilateral side of the cerebellum
- provide cerebellum with feedback needed to coordinate muscle actions

Descending Tracts

- Carry motor signals down the brainstem and spinal cord // direct and indirect motor pathways (pyramidal and extrapyramidal)

- Involves two neurons

  – upper motor neuron // originate in cerebral cortex or brainstem // terminates on a lower motor neuron

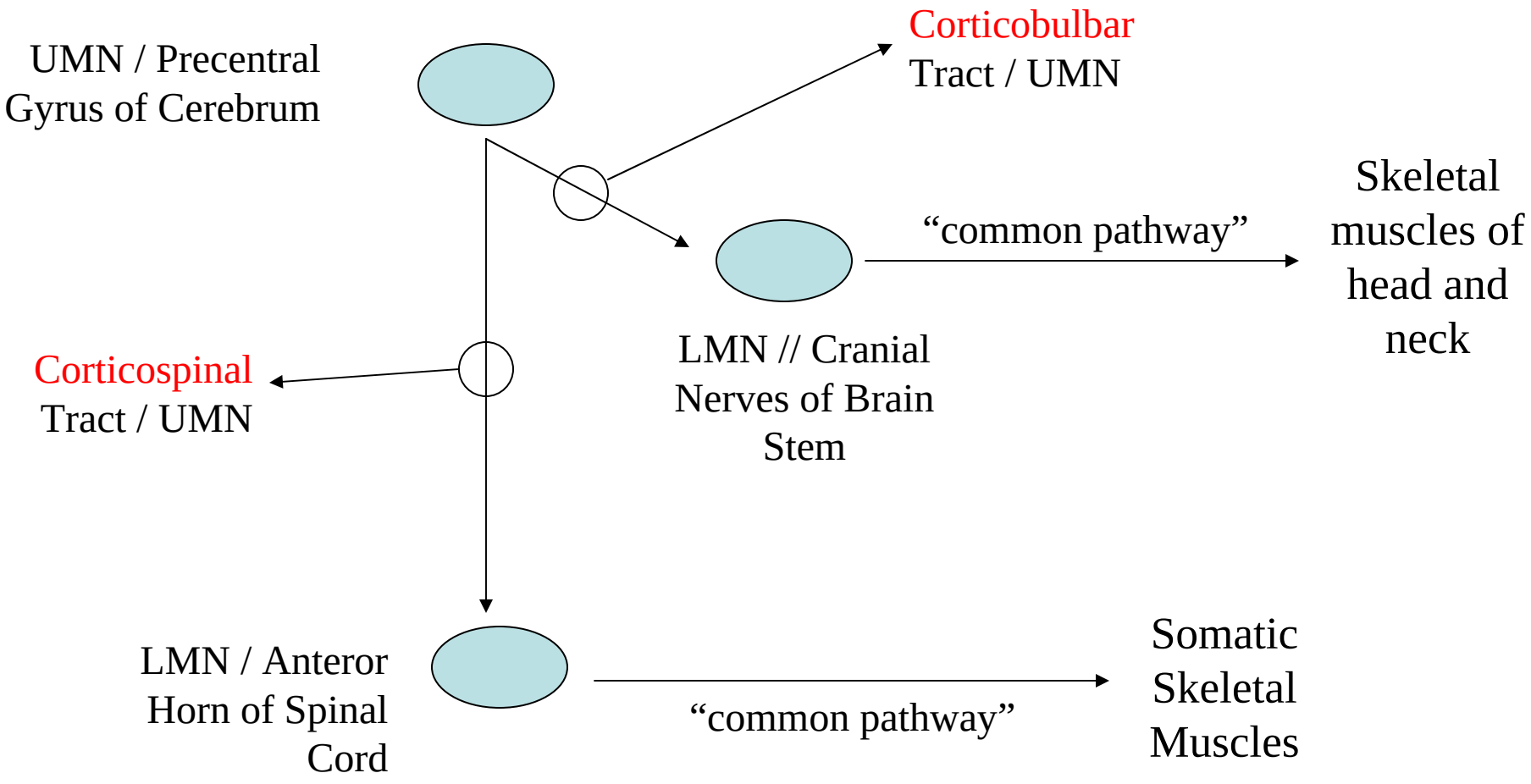
  – lower motor neuron // originate in brainstem or spinal cord // the upper motor neuron synapse on LMN that leads the rest of the way to the muscle or other target organ

Descending Tracts

- Carry motor signals down the brainstem and spinal cord // direct and indirect motor pathways (pyramidal and extrapyramidal)
- Direct pathways
  - Corticospinal = upper motor neuron / synapse with anterior horn neurons = lower motor neuron
  - Corticobulbar = upper motor neuron / synapse with cranial nerves = lower motor neuron / innervate skeletal muscles in head and neck
- Indirect pathways
  - Involved in involuntary responses to skeletal muscles / visual, equilibrium, posture
  - Tectospinal / vestibulospinal / rubriospinal / reticularspinal tracts

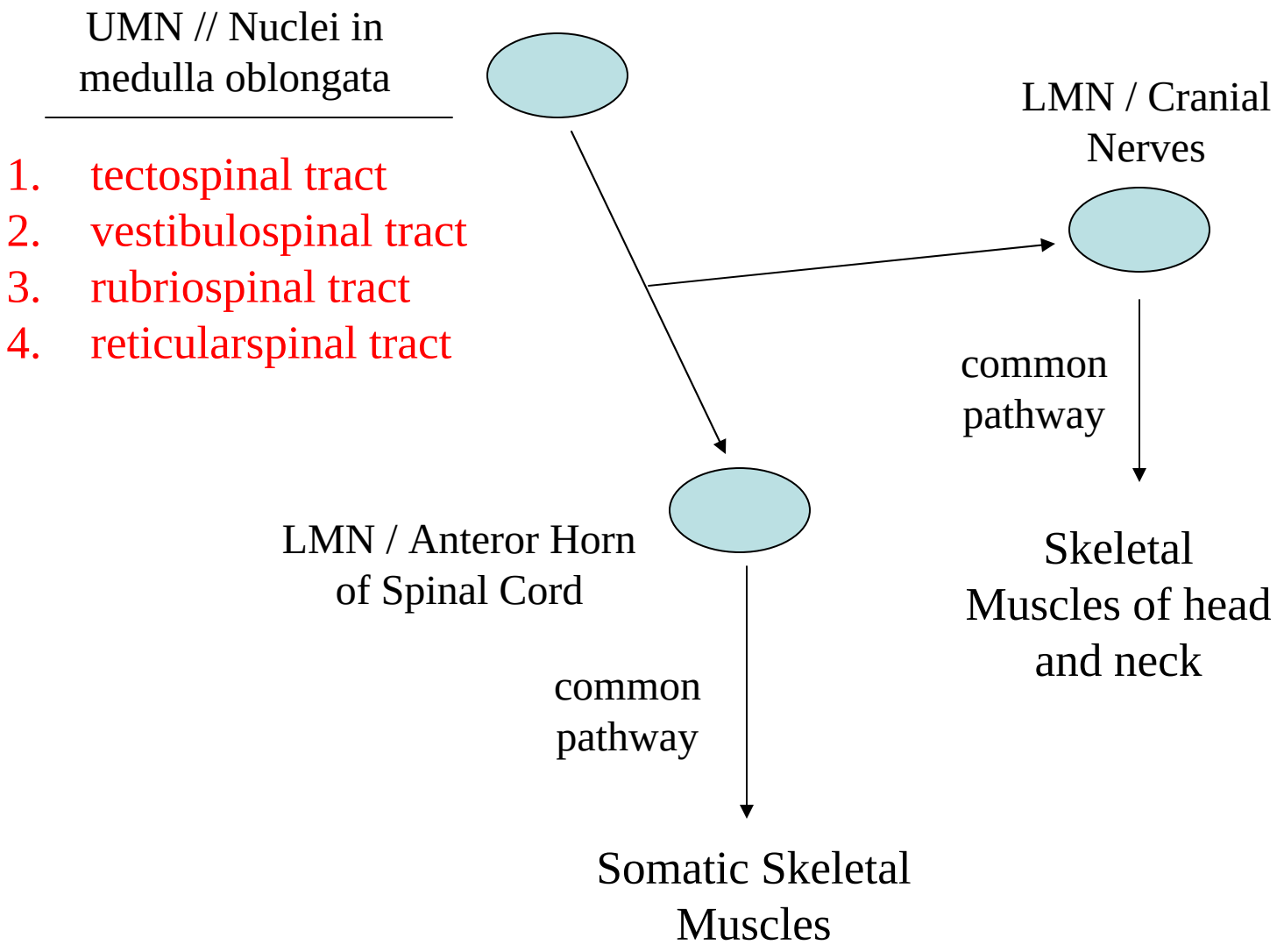
Descending Tracts

These pathways are known as the “direct pathways”.



Descending Tracts

This pathway is known as the “indirect pathways”.



Descending Motor Tracts

- tectospinal tract – begins in midbrain region (tectum)
  - crosses to contralateral side of midbrain
  - reflex turning of head in response to sights and sounds

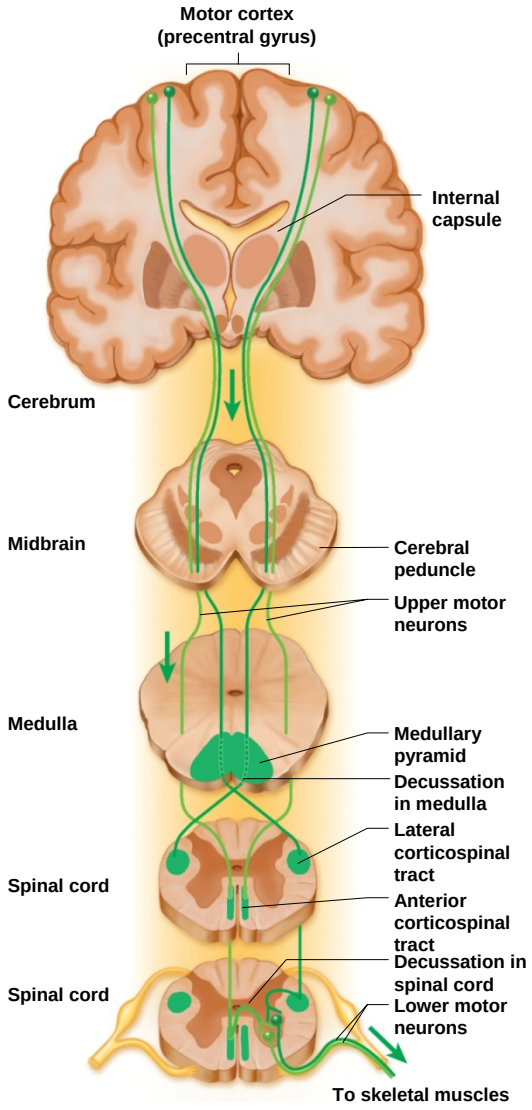
- lateral and medial reticulospinal tract
  - originate in the reticular formation of brainstem
  - controls muscles of upper and lower limbs // especially those for posture and balance
  - contain descending analgesic pathways // reduce the transmission of pain signals to brain

Descending Motor Tracts

- **lateral** and **medial** **vestibulospinal tract**
  - begins in brainstem **vestibular nuclei**
  - receives impulses for balance from inner ear
  - controls extensor muscles of limbs for balance control

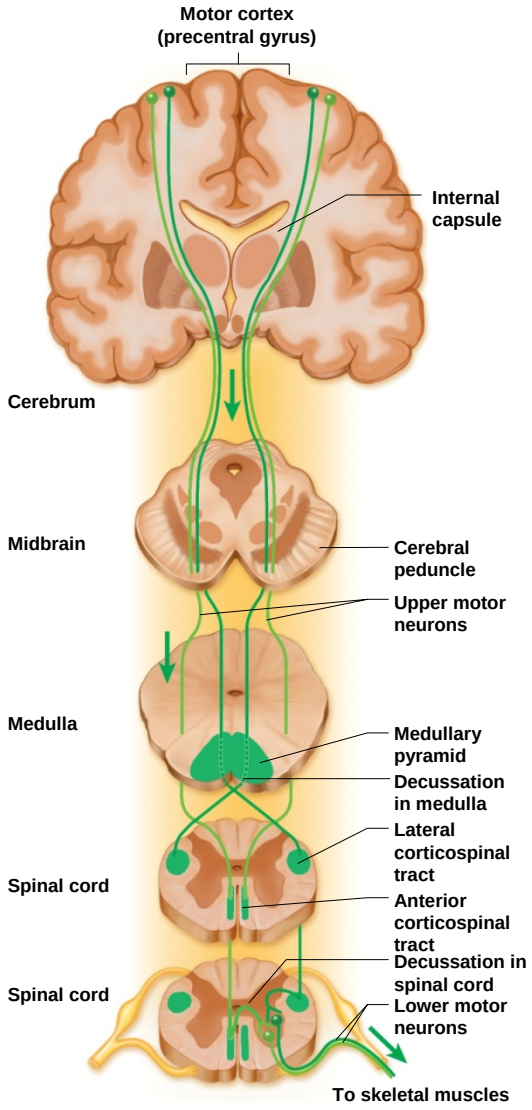
Corticospinal Tracts

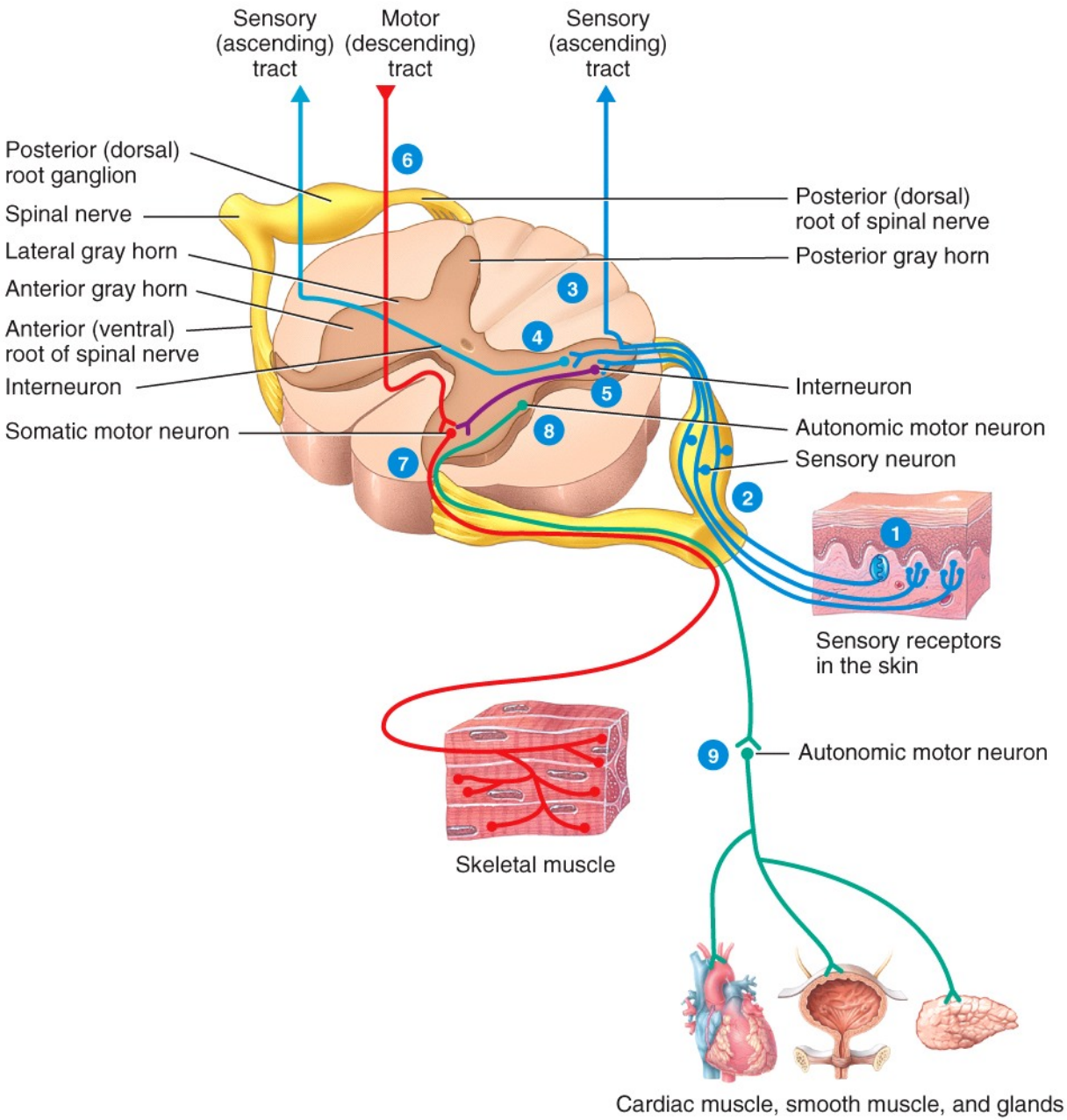
- from cerebral cortex for precise, finely coordinated limb movements
- pyramids – ridges on anterior surface of the medulla oblongata formed from fibers of this system
- decussate in lower medulla



Corticospinal Tracts

- lateral corticospinal tract on contralateral side of spinal cord
- anterior (ventral) corticospinal tract on ipsilateral side of spinal cord
- two neuron pathway
  - upper motor neuron in cerebral cortex
  - lower motor neuron in spinal cord




Sensory (ascending) tract
Motor (descending) tract
Sensory (ascending) tract
Posterior (dorsal) root ganglion
Spinal nerve
Lateral gray horn
Anterior gray horn
Anterior (ventral) root of spinal nerve
Interneuron
Somatic motor neuron
Posterior (dorsal) root of spinal nerve
Posterior gray horn
Interneuron
Autonomic motor neuron
Sensory neuron
Sensory receptors in the skin
Skeletal muscle
Autonomic motor neuron
Cardiac muscle, smooth muscle, and glands
1
2
3
4
5
6
7
8
9

Damage to Spinal Cord

- accidents damage the spinal cord of thousands of people every year
  - paraplegia - paralysis of lower limbs
  - quadriplegia – paralysis of all four limbs
  - hemiplegia – paralysis of one side of the body only
  - respiratory paralysis - loss of sensation or motor control
  - disorders of bladder, bowel and sexual function
- damage to spinal cord also occur from strokes or other brain injuries

Spina Bifida

- spina bifida – congenital defect in which one or more vertebrae fail to form a complete vertebral arch for enclosure of the spinal cord

  - in 1 baby out of 1000
  - common in lumbosacral region
  - spina bifida occulta and spina bifida cystica

- folic acid (a B vitamin) as part of a healthy diet for all women of childbearing age reduces risk

  - defect occurs during the first four weeks of development, so folic acid supplementation must begin 3 months before conception