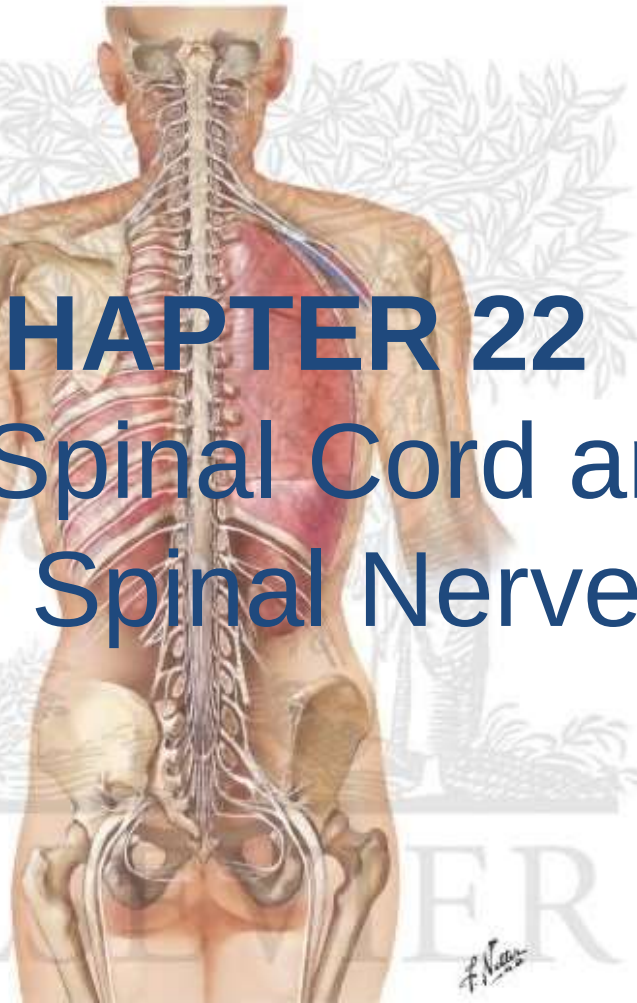




CHAPTER 22

The Spinal Cord and The Spinal Nerves





Introduction

- The spinal cord
 - Contains neural circuits that control some of your quickest reactions to environmental changes
 - Is the site for integration of neuronal stimulation
 - Relays sensory nerve impulses
 - Is continuous with the brain and together they constitute the central nervous system (CNS)

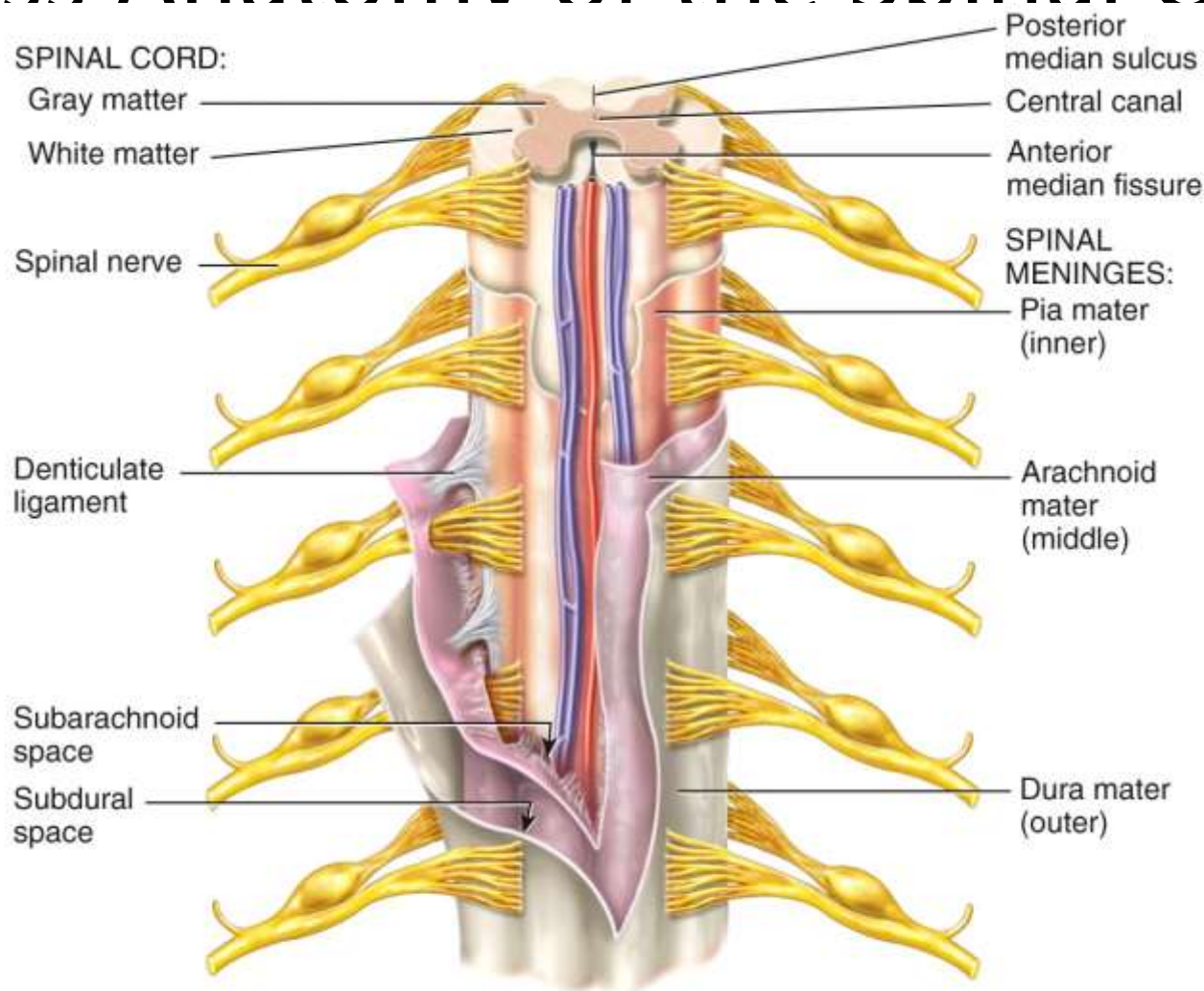


Protective Structures

- **Vertebral column**
- **Meninges:**
 - **Dura mater:** is a thick membrane made of dense irregular connective tissue that surrounds the brain and spinal cord. It is the outermost of the three layers of membrane called the meninges that protect the central nervous system.
 - **Arachnoid mater:** named for its spiderweb-like appearance, is a thin, transparent membrane surrounding the spinal cord like a loosely fitting sac. Continuous with the cerebral arachnoid above, it passes through the foramen magnum and descends caudally to the S2 vertebral level
 - **Pia mater:** is a thin fibrous tissue that is permeable to water and small solutes. The pia mater allows blood vessels to pass through and nourish the brain. The perivascular space between blood vessels and pia mater is proposed to be part of a pseudolymphatic system for the brain (glymphatic system)



Gross Anatomy of the Spinal Cord



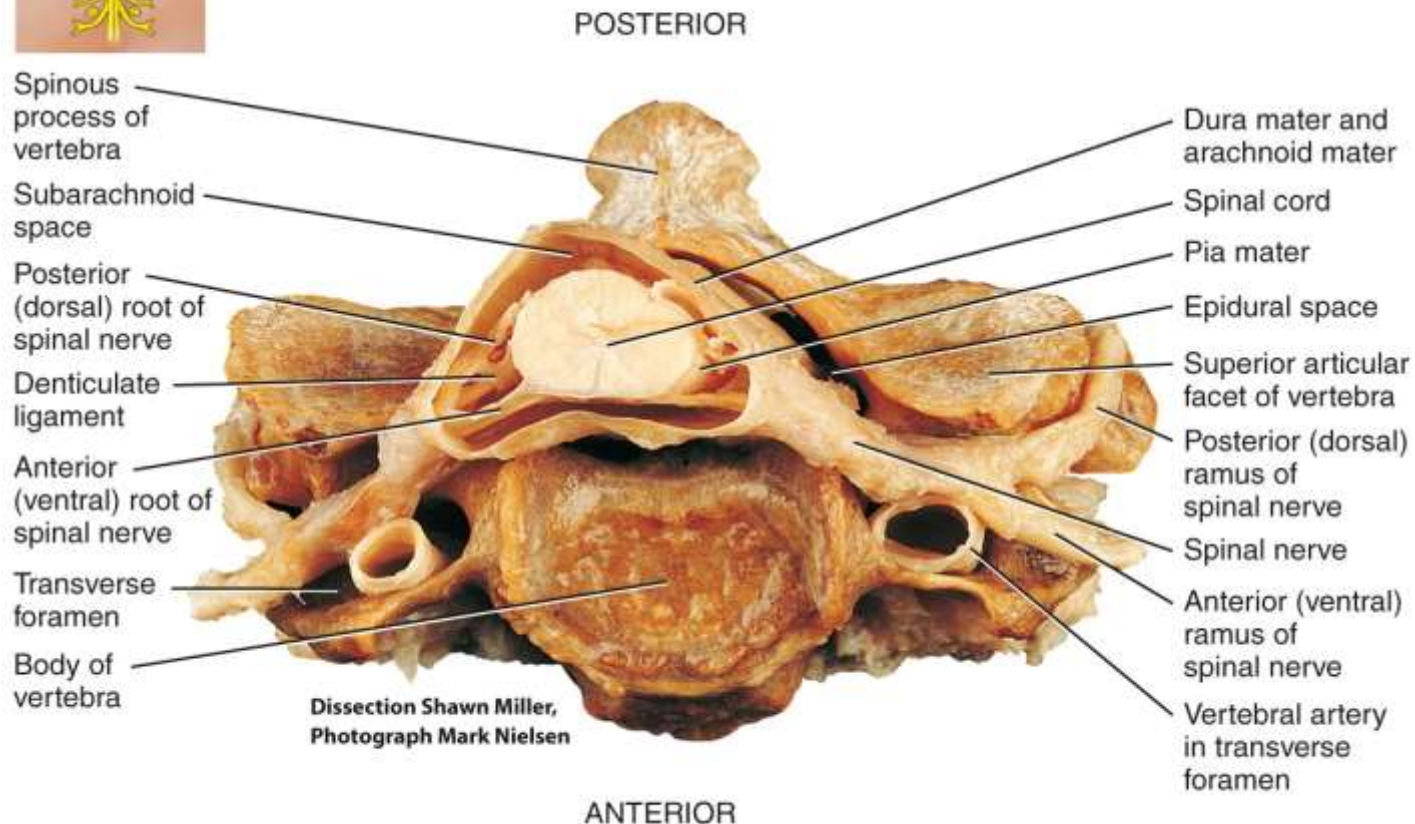
(a) Anterior view and transverse section through spinal cord



Gross Anatomy of the Spinal Cord



View
Transverse plane



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

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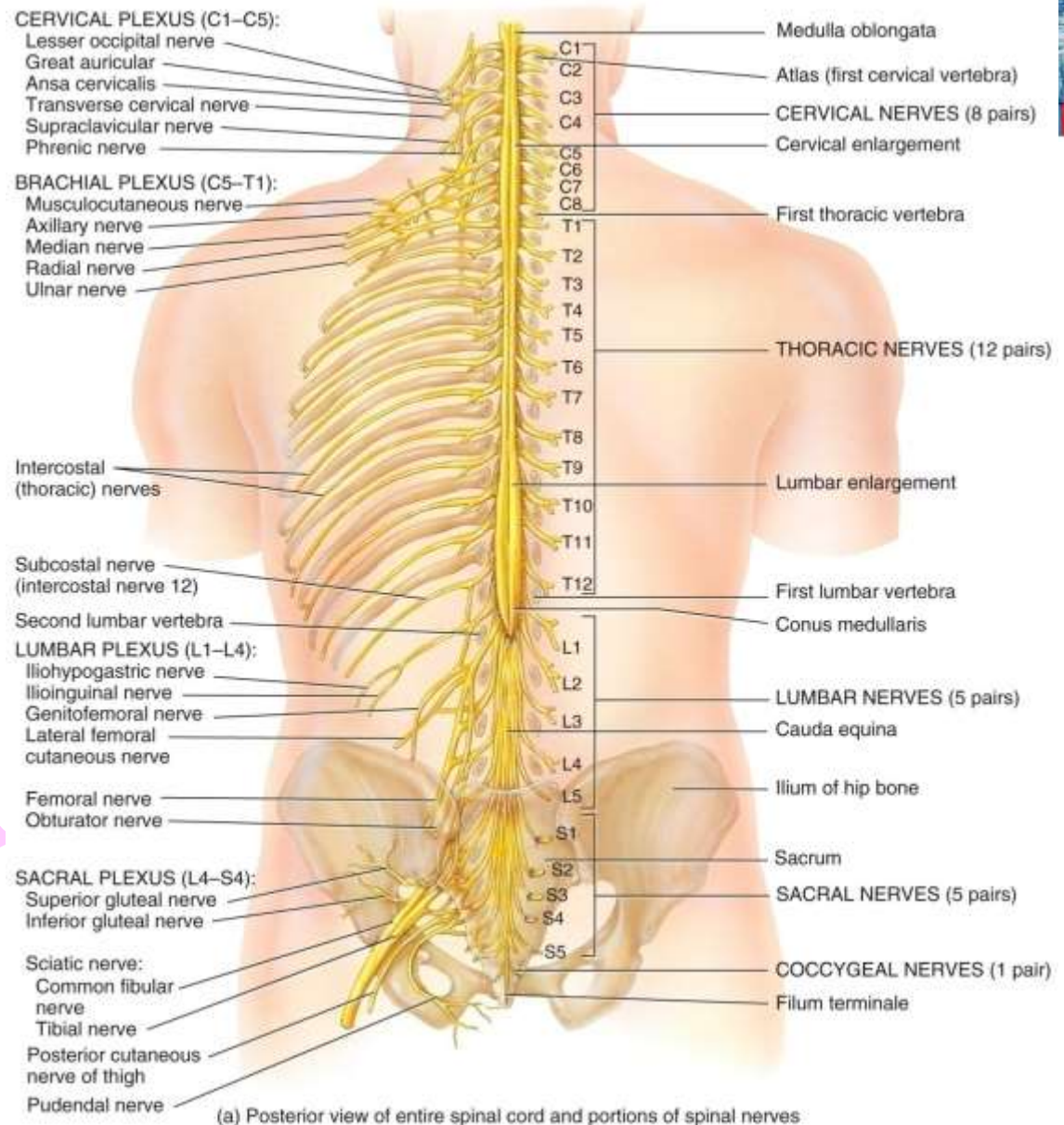
External Anatomy of the Spinal Cord



- The length of the adult spinal cord is 42–45 cm (16–18 in.).
- Its maximum diameter is about 1.5 cm (0.6 in.) in the lower cervical region and smaller in the thoracic region.
- **Cervical enlargement:** corresponds with the attachments of the large nerves which supply the upper limbs. It extends from about the fifth cervical to the first thoracic vertebra, its maximum circumference (about 38 mm.) being on a level with the attachment of the sixth pair of cervical nerves.
- **Lumbar enlargement:** (or lumbosacral enlargement) is a widened area of the spinal cord that gives attachment to the nerves which supply the lower limbs. It commences about the level of T11 and ends at L2, and reaches its maximum circumference, of about 33 mm.
- **Conus medullaris:** or conus terminalis is the tapered, lower end of the spinal cord. It occurs near lumbar vertebral levels 1 (L1) and 2 (L2), occasionally lower
- **Filum terminale:** is an extension of the pia mater that is attached to the coccygeal segments, whose function is to suspend the cord in the CSF (like the denticulate ligaments).

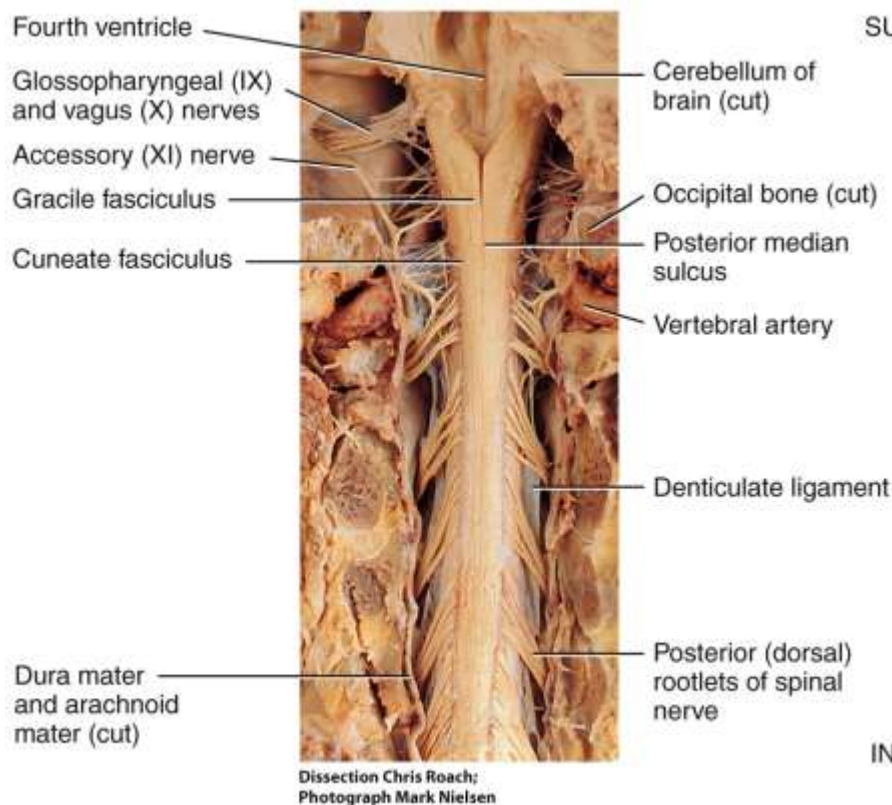
External Anatomy of the Spinal Cord and the Spinal Nerves

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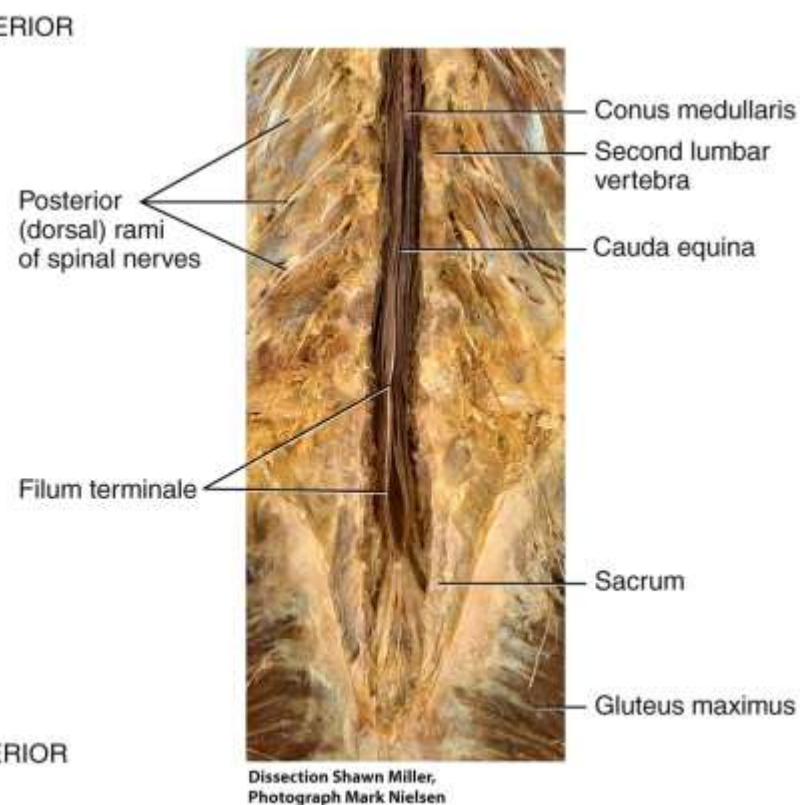




External Anatomy of the Spinal Cord and the Spinal Nerves



(b) Posterior view of cervical region of spinal cord

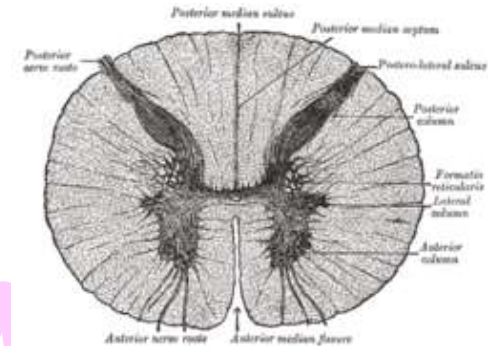
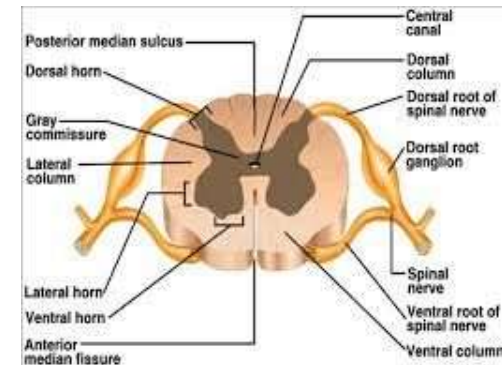


(c) Posterior view of inferior portion of spinal cord



Internal Anatomy of the Spinal Cord

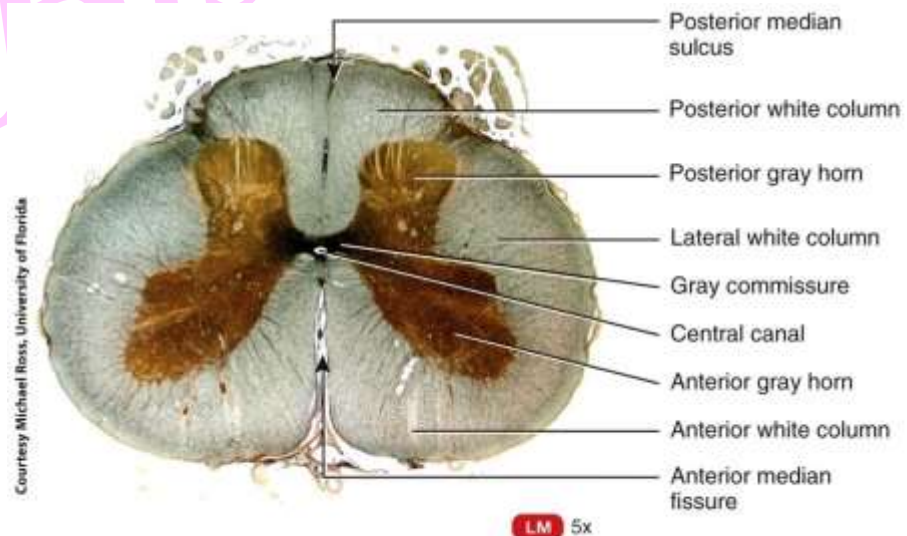
- **Anterior median fissure:** a groove along the anterior midline of the spinal cord that incompletely divides it into symmetrical halves.
- **Posterior median sulcus:** a shallow groove along the midline of the posterior part of the spinal cord that separates the two posterior funiculi and is the external boundary of the posterior median septum
- **Gray commissure:** is a thin strip of grey matter that surrounds the central canal of the spinal cord and, along with the anterior white commissure, connects the two halves of the cord





Internal Anatomy of the Spinal Cord

- **Central canal:** also known as ependymal canal, is the cerebrospinal fluid-filled space that runs through the spinal cord. The central canal below at the ventricular system of the brain, from which it receives cerebrospinal fluid, and shares the same ependymal lining.
- **Anterior (ventral) white commissure:** is a bundle of nerve fibers which cross the midline of the spinal cord just anterior to the gray commissure



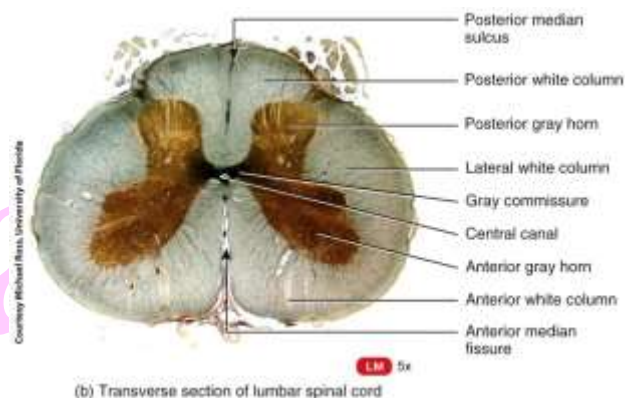
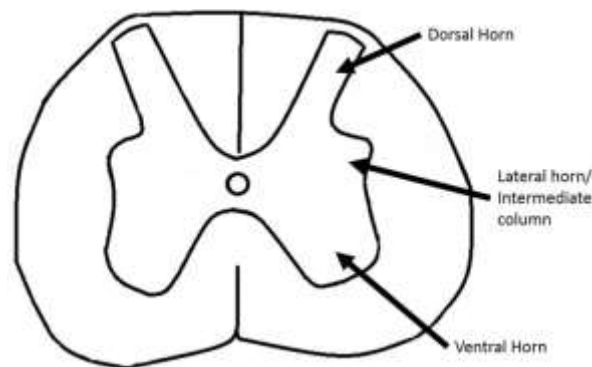
(b) Transverse section of lumbar spinal cord



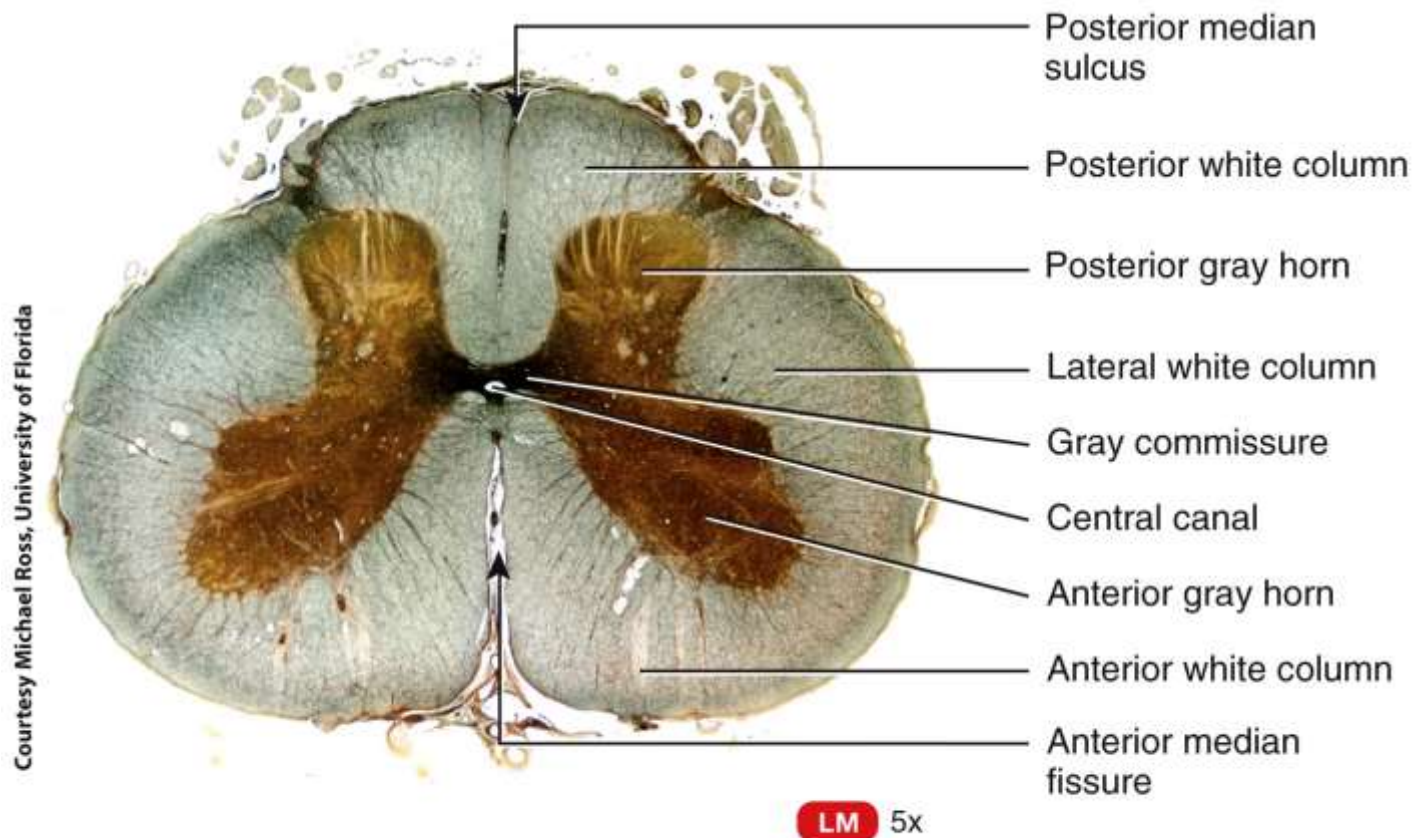
Internal Anatomy of the Spinal Cord

- **Horns:**

- **Anterior (ventral) gray horns:** (also called the anterior cornu, anterior horn of spinal cord or ventral horn) is the front column of grey matter in the spinal cord. It is one of the three grey columns. ... The anterior grey column is the column where the cell bodies of alpha motor neurons are located
- **Posterior (dorsal) gray horns:** (posterior cornu, dorsal horn, spinal dorsal horn posterior horn) of the spinal cord is one of the three grey columns of the spinal cord. It receives several types of sensory information from the body, including fine touch, proprioception, and vibration
- **Lateral gray horns:** present primarily in the thoracic region, and contain the preganglionic visceral motor neurons that project to the sympathetic ganglia (see Figure 1.10C). ... The lateral columns include axons that travel from the cerebral cortex to contact spinal motor neurons



Internal Anatomy of the Spinal Cord: The Organization of Gray Matter and White Matter



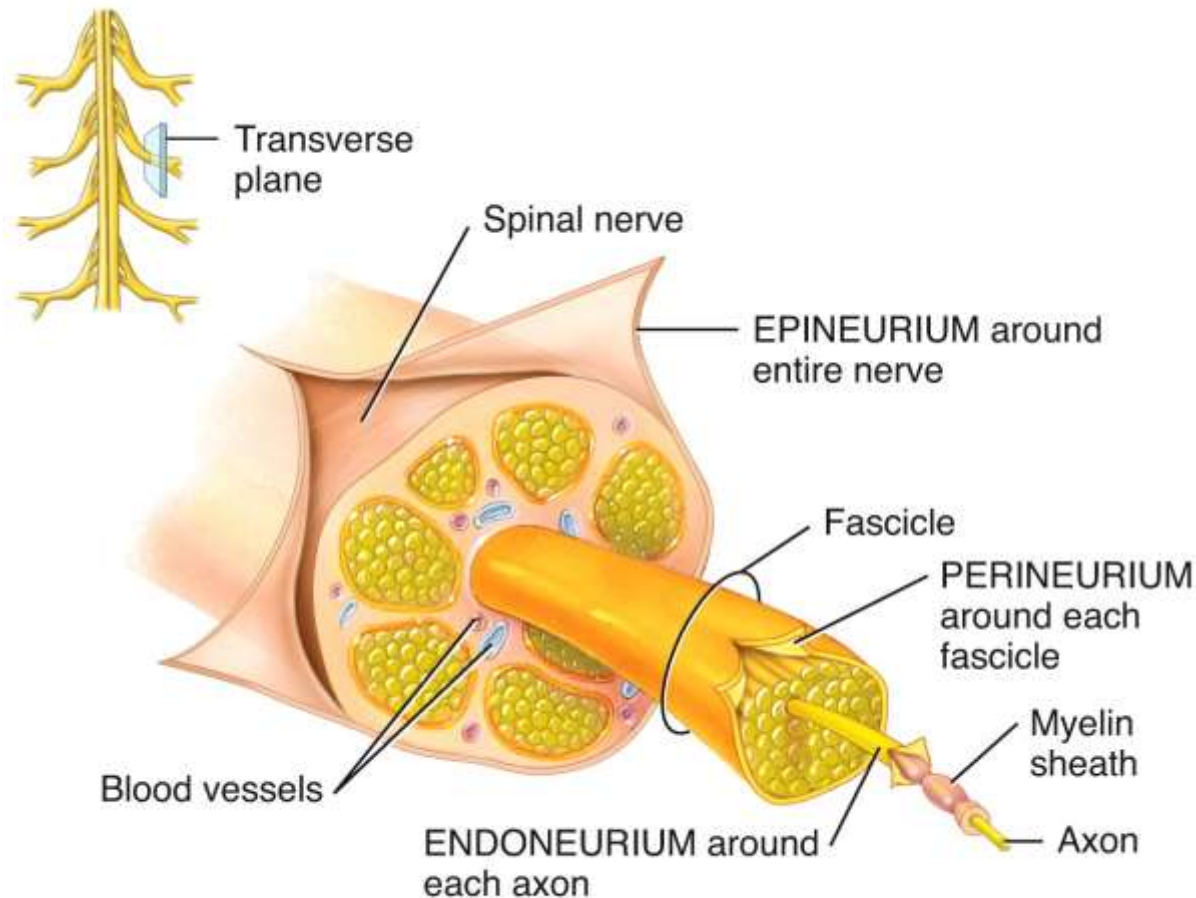
(b) Transverse section of lumbar spinal cord



Spinal Nerves

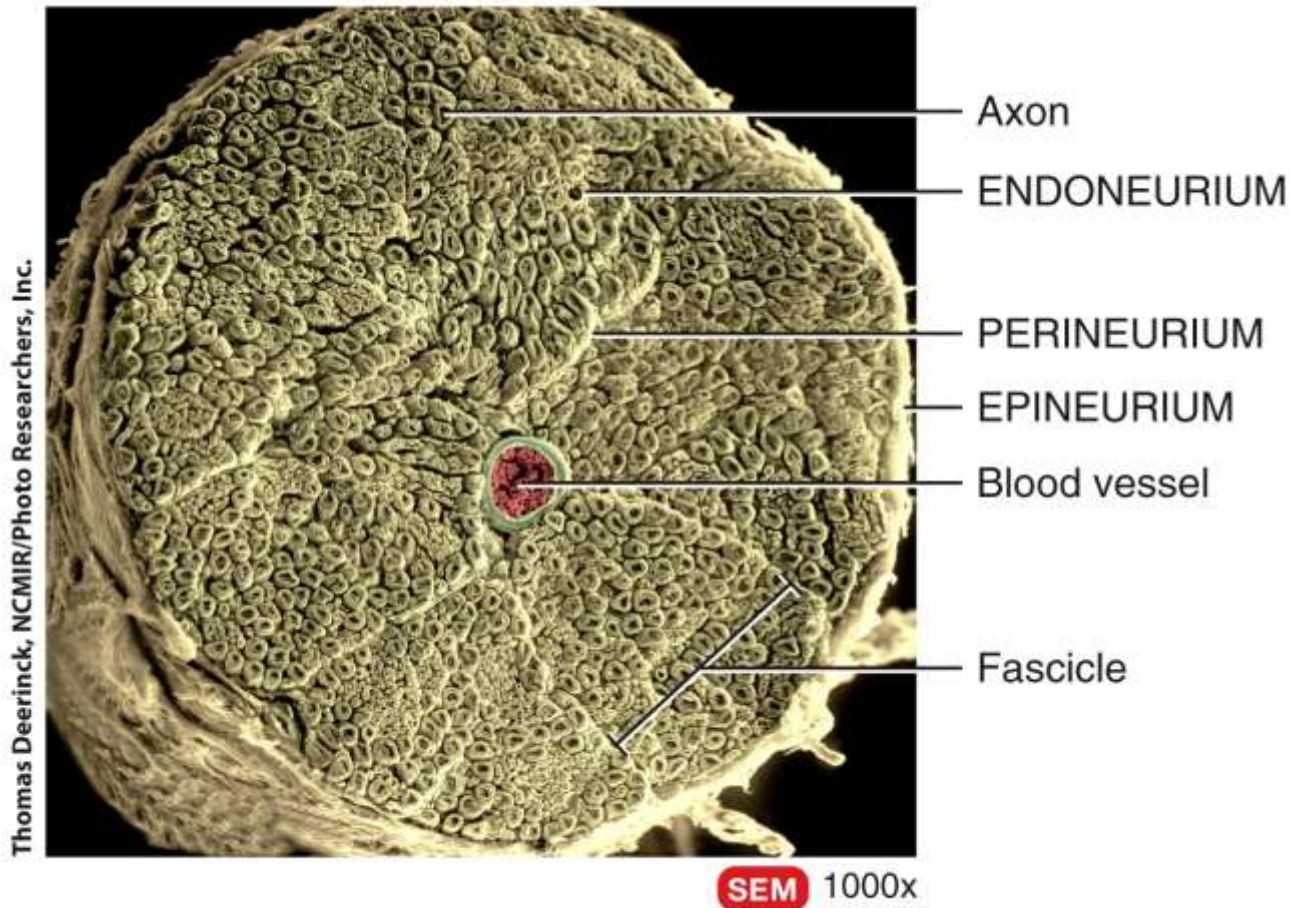
- Spinal nerves and the nerves that branch from them are part of the peripheral nervous system (PNS).
- They connect the CNS to sensory receptors, muscles, and glands in all parts of the body.

Organization and Connective Tissue Coverings of a Spinal Nerve



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

Organization and Connective Tissue Coverings of a Spinal Nerve

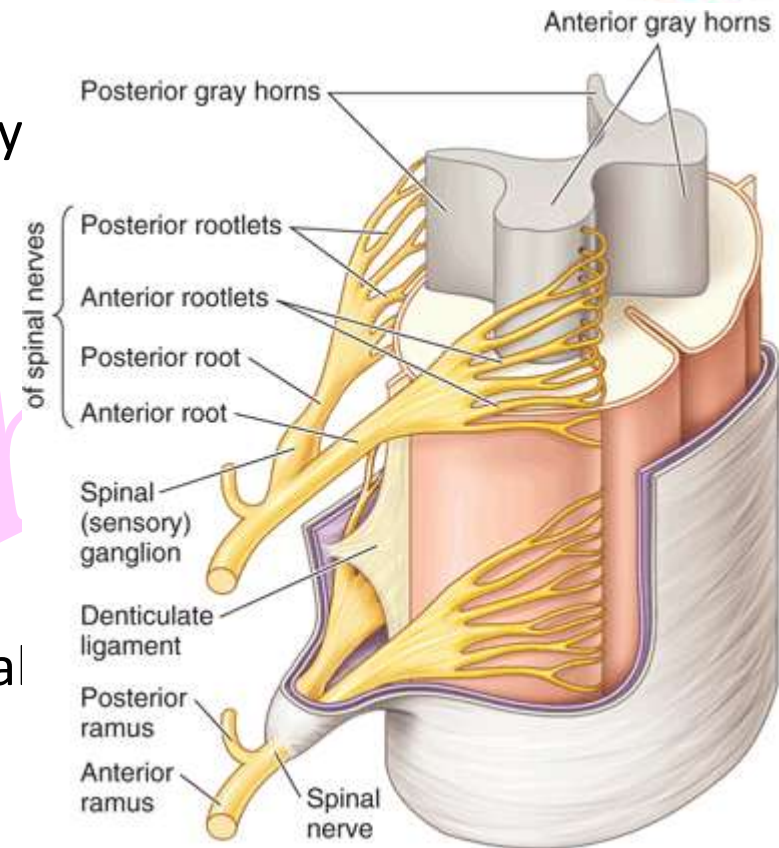


(b) Transverse section of several nerve fascicles

Organization of Spinal Nerves



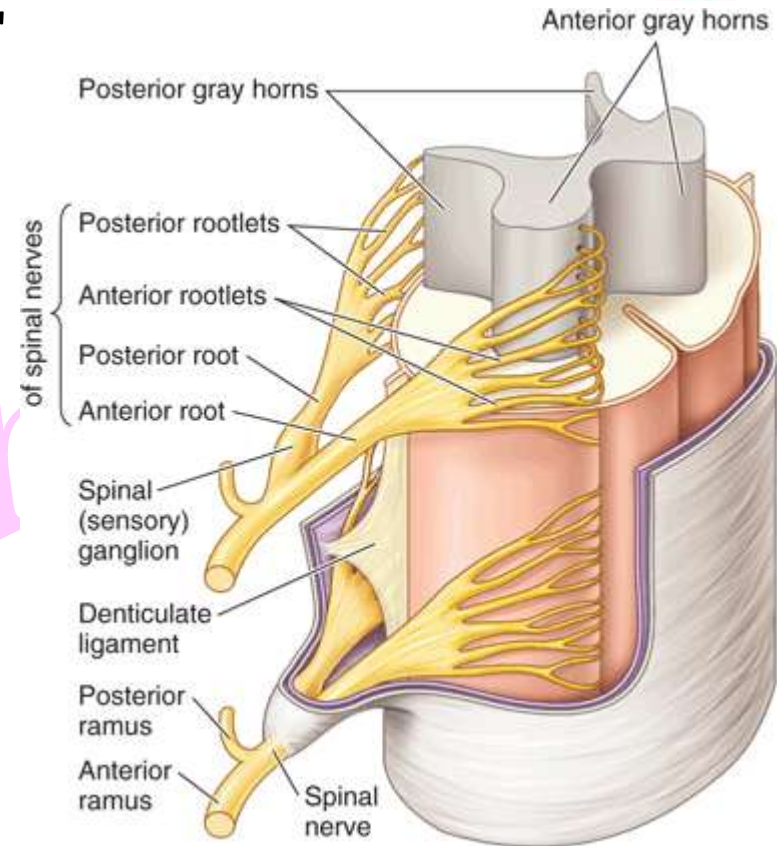
- **Rootlets:** leave the spinal cord at the anterolateral and posterolateral sulci. Anterior rootlets contain predominantly efferent fibers from the anterior horn and carry motor signals to voluntary muscles. At thoracic and upper lumbar regions, they also carry preganglionic sympathetic fibers from the lateral horns.
- **Anterior (ventral) roots:** is the efferent motor root of a spinal nerve. At its distal end, the ventral root joins with the dorsal root to form a mixed spinal nerve



Organization of Spinal Nerves



- **Posterior (dorsal) roots:** is one of two "roots" which emerge from the spinal cord. It emerges directly from the spinal cord, and travels to the dorsal root ganglion. ... The dorsal root transmits sensory information, forming the afferent sensory root of a spinal nerve.
- **Posterior (dorsal) root ganglion:** is a cluster of neurons (a ganglion) in a dorsal root of a spinal nerve. The cell bodies of sensory neurons known as first-order neurons are located in the dorsal root ganglia.
- **Spinal nerve trunk:** Immediately beyond the spinal ganglion, the anterior and posterior nerve roots unite to form the trunk of spinal nerve which emerges through the intervertebral foramen





Branches of the Spinal Nerves

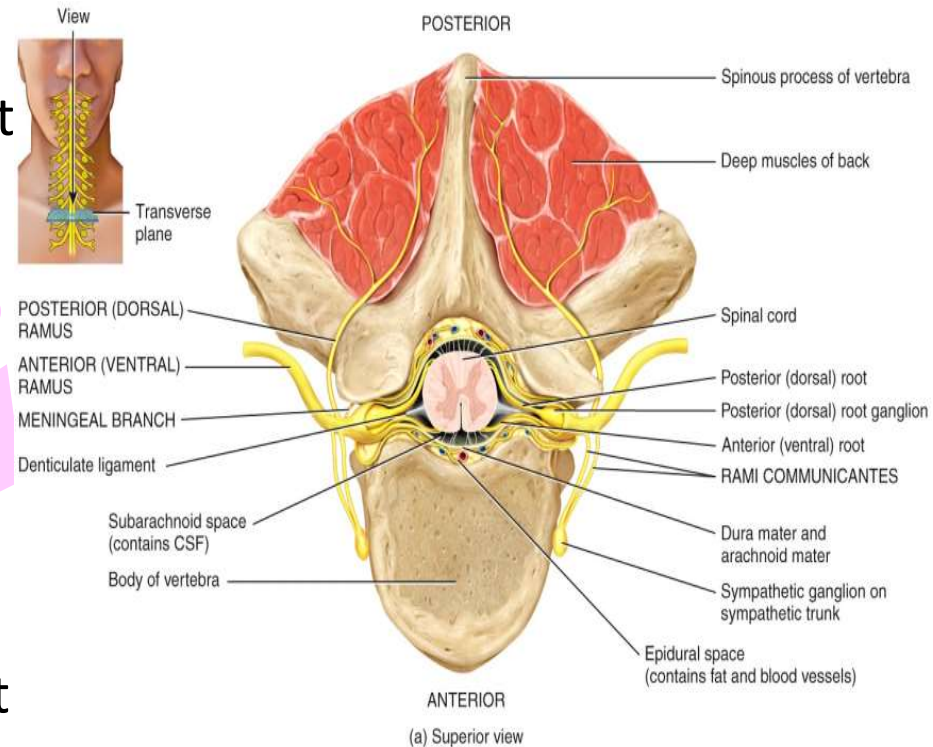
- **Rami (singular = ramus)**
- **Posterior (dorsal) ramus:** is the dorsal branch of a spinal nerve that forms from the dorsal root of the nerve after it emerges from the spinal cord. The dorsal ramus carries information that supplies muscles and sensation to the human back.
- **Anterior (ventral) ramus:** is the anterior division of a spinal nerve. The ventral rami supply the antero-lateral parts of the trunk and the limbs. Shortly after a spinal nerve exits the intervertebral foramen, it branches into the dorsal-ramus; the ventral-ramus; and the ramus-communicans.
- Meningeal branch
- Rami communicantes



Branches of the Spinal Nerves

- **Meningeal branch:** (also known as recurrent meningeal nerves, sinuvertebral nerves, or recurrent nerves of Luschka) are a number of small nerves that branch from the segmental spinal nerve near the origin of the anterior and posterior rami, but before the rami communicantes.

Supply nerve function to the vertebrae themselves, including the ligaments, dura, blood vessels, intervertebral discs, facet joints and periosteum.



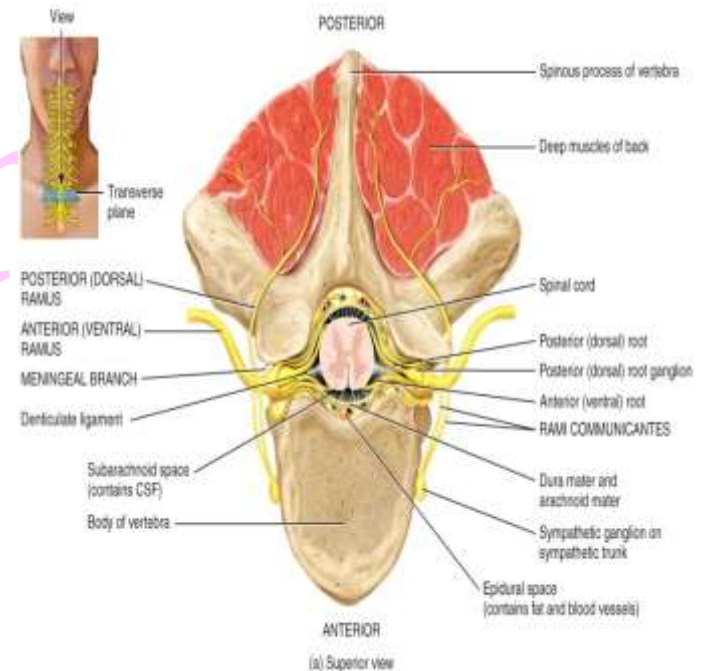


Branches of the Spinal Nerves

Rami communicantes:

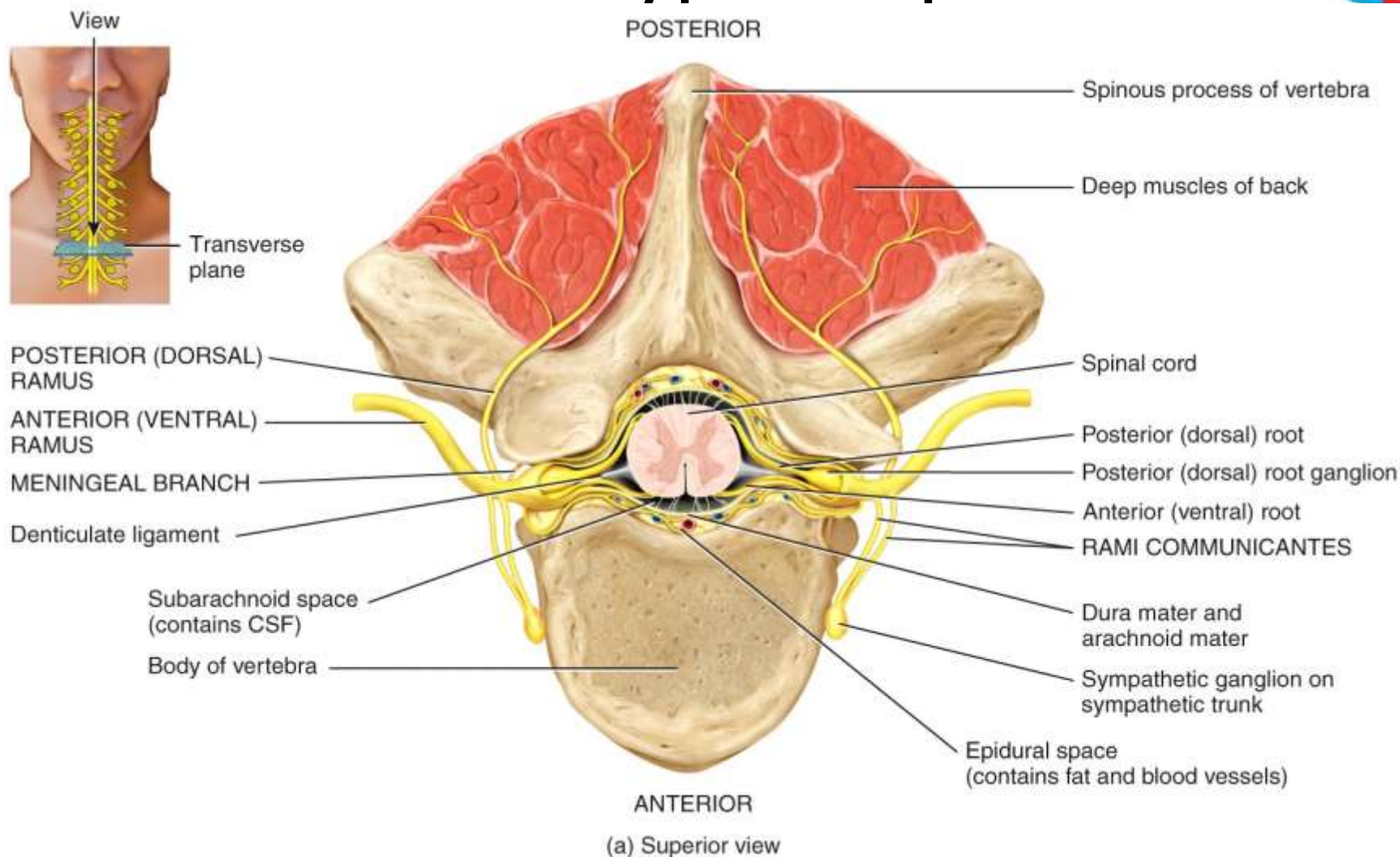
The grey rami communicantes exist at every level of the spinal cord and are responsible for carrying postganglionic nerve fibres from the paravertebral ganglia to their destination, and for carrying those preganglionic nerve fibres which enter the paravertebral ganglia but do not synapse.

The white rami communicantes exist only at the levels of the spinal cord where the intermediolateral cell column is present (T1-L2) and are responsible for carrying preganglionic nerve fibres from the spinal cord to the paravertebral ganglia.



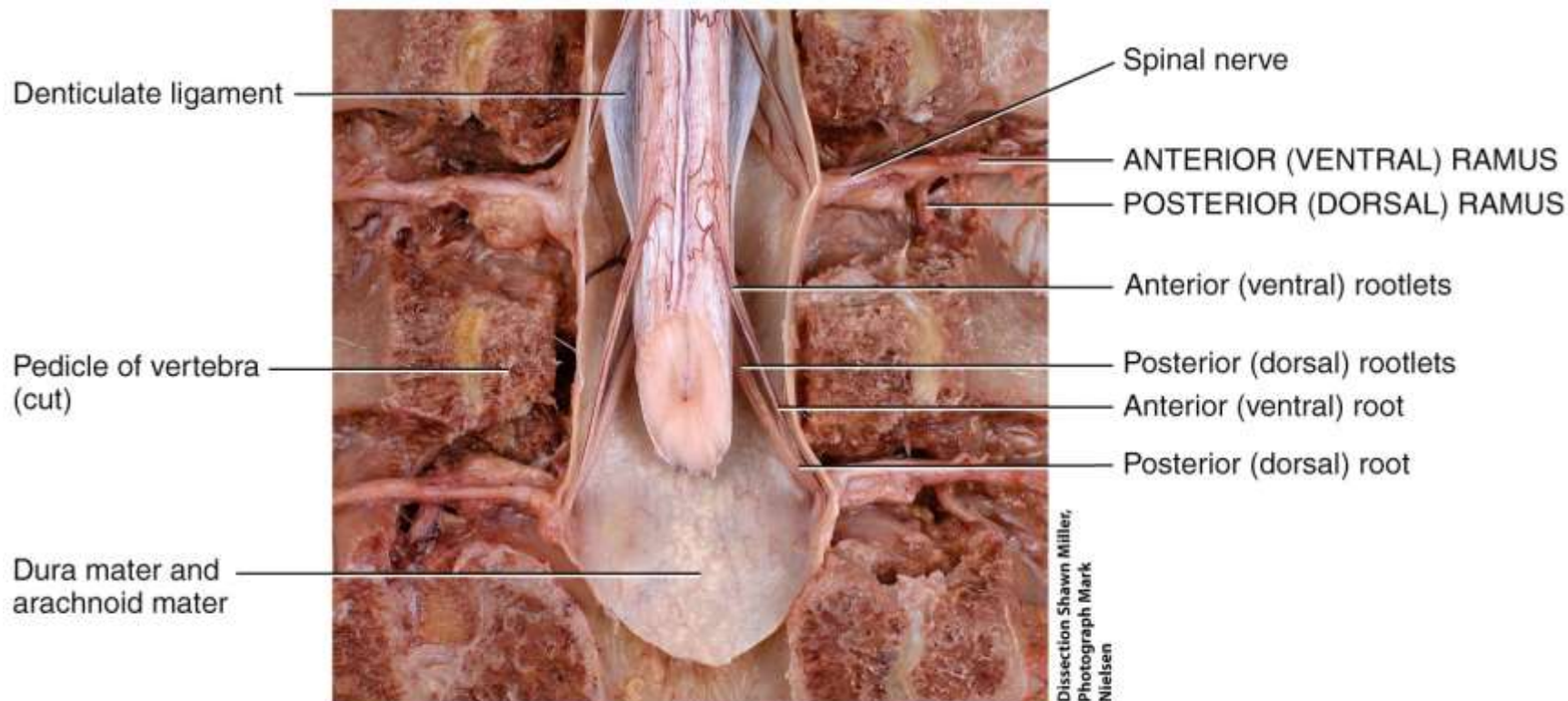


Branches of a Typical Spinal Nerve





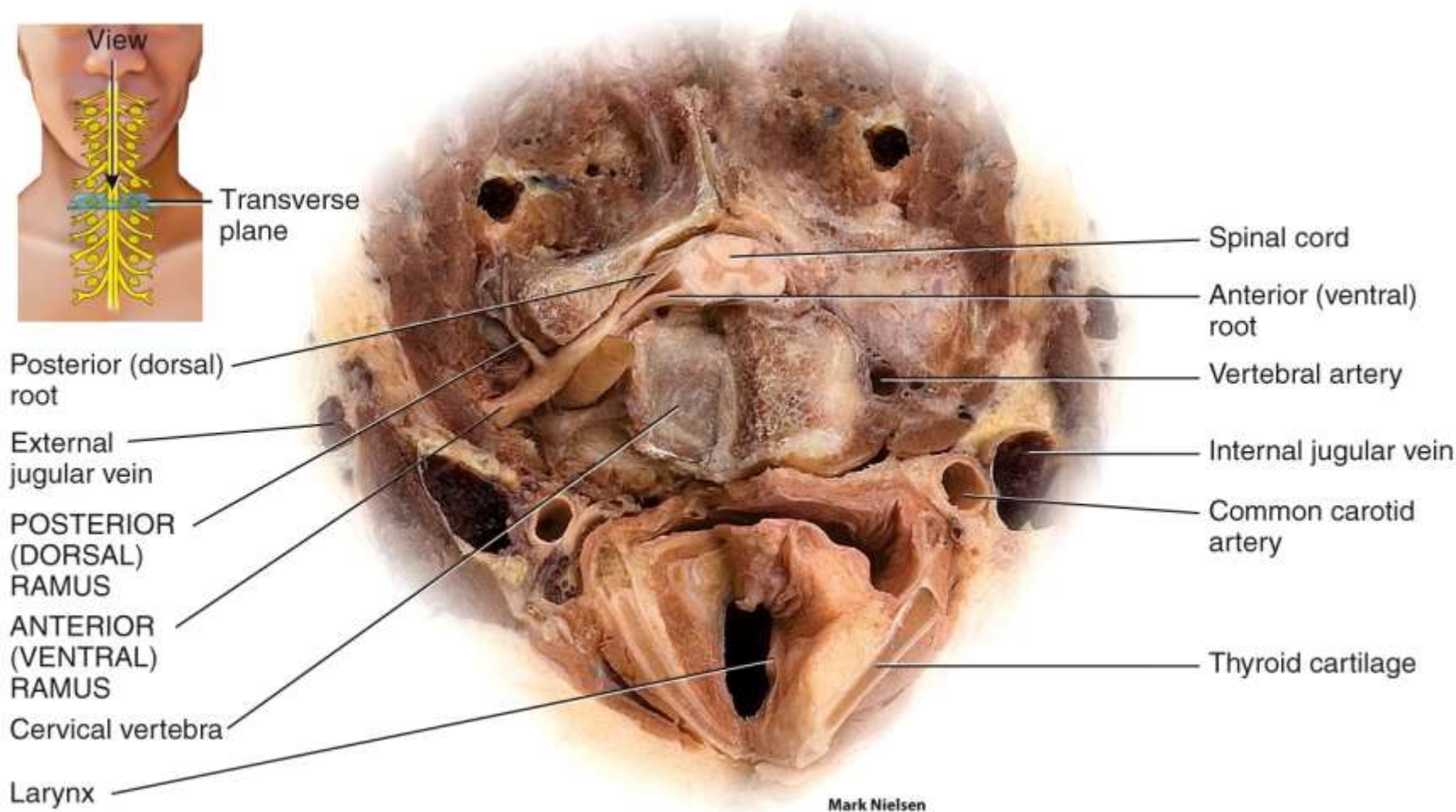
Branches of a Typical Spinal Nerve



(b) Anterior view and oblique section of spinal cord



Branches of a Typical Spinal Nerve



(c) Superolateral view of transverse section of neck

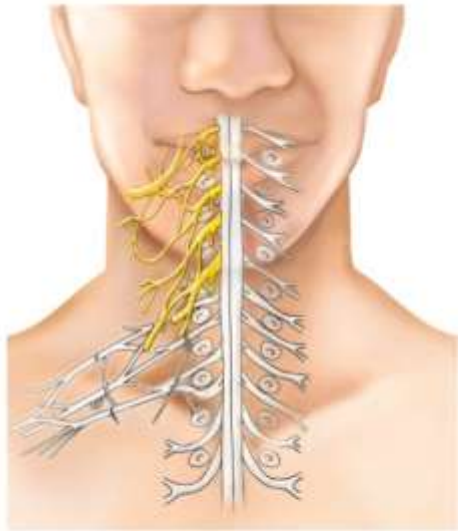


Plexuses

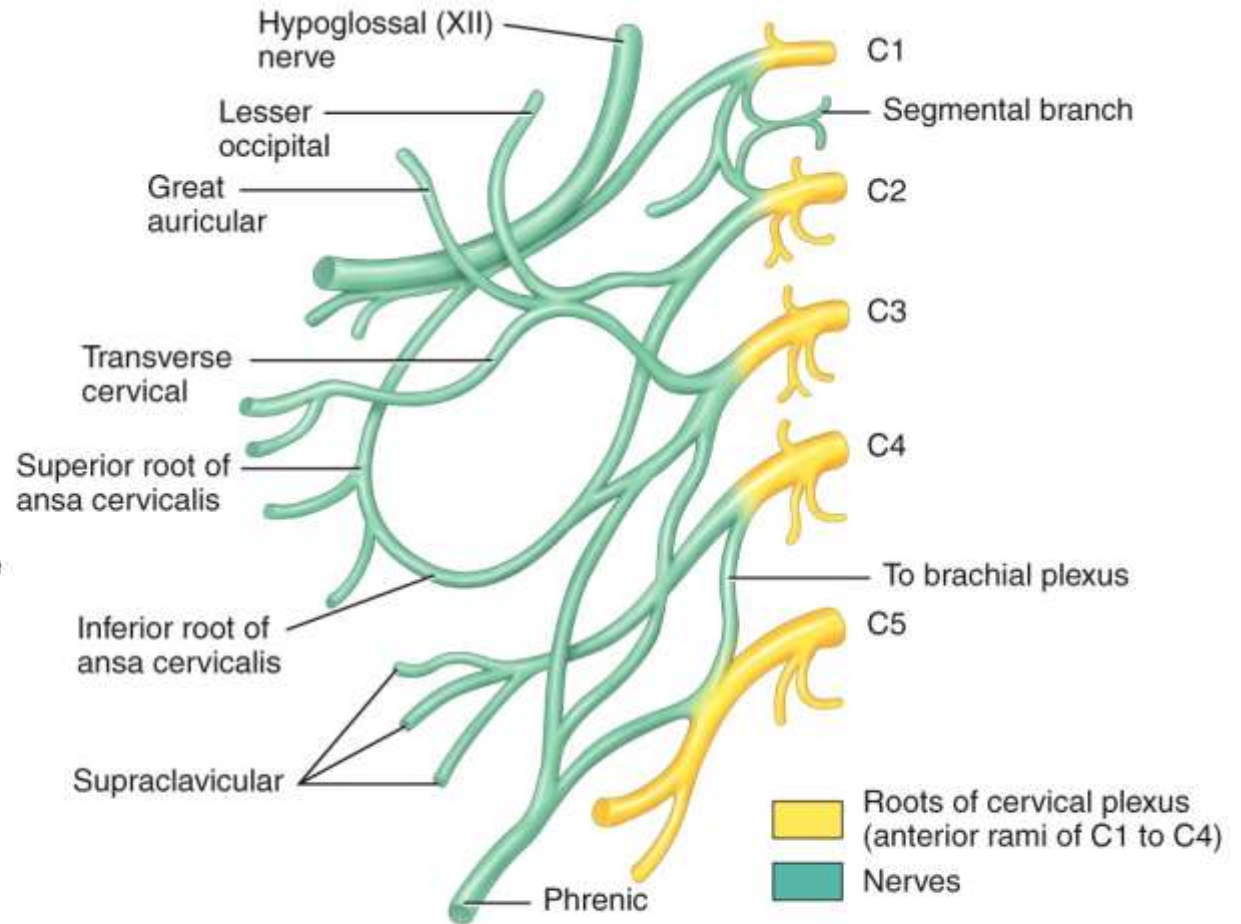
- Axons from the anterior rami of spinal nerves, except for thoracic nerves T2–T12, form networks on both left and right sides of the body. Each network is called a plexus.
- The principal plexuses are the cervical plexus, brachial plexus, lumbar plexus, and sacral plexus.
- A smaller coccygeal plexus is also present.
- Groups of nerves emerge from the plexuses.



Cervical Plexus in Anterior View



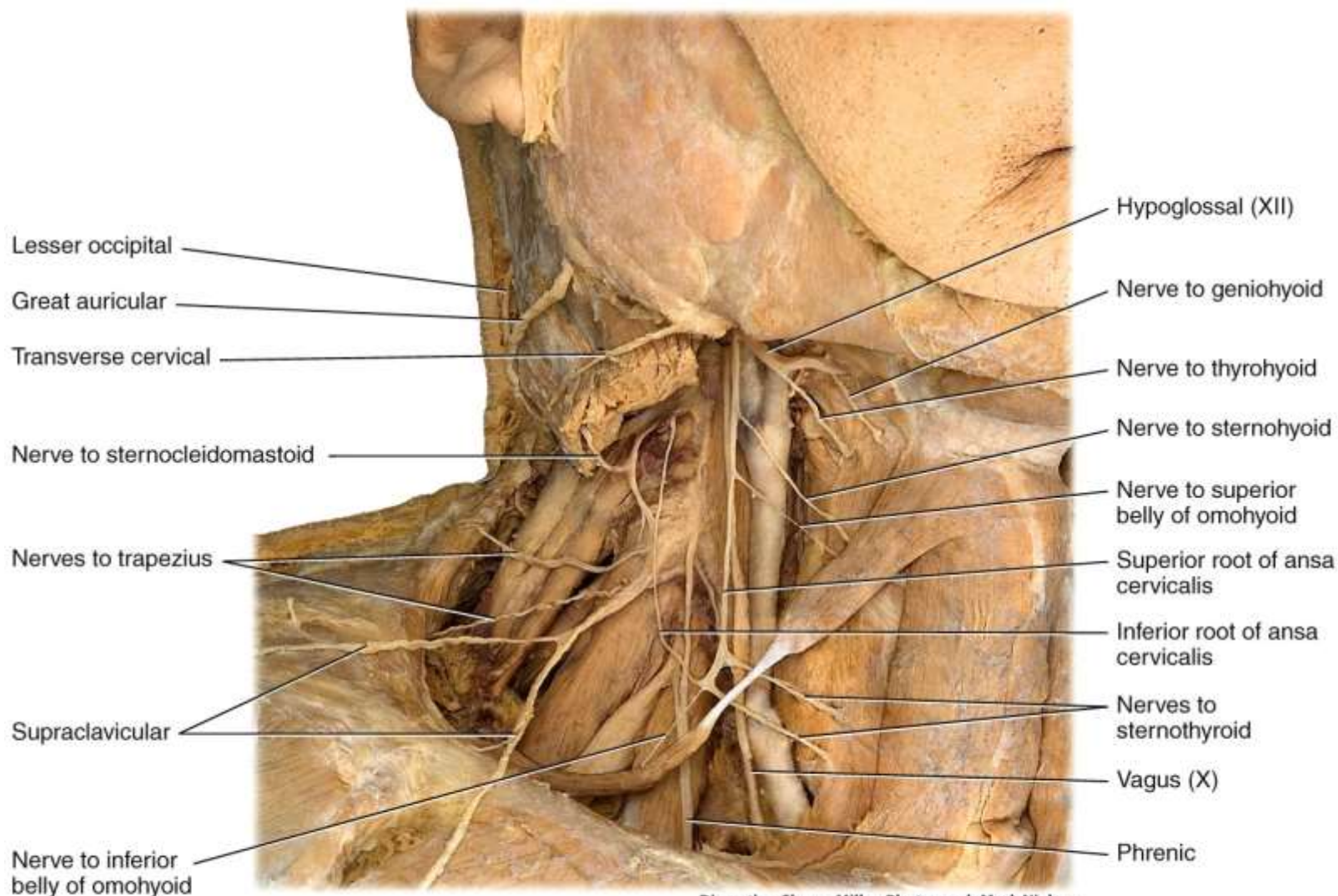
Cervical plexus projected to surface



(a) Origin of cervical plexus



Cervical Plexus in Anterior View

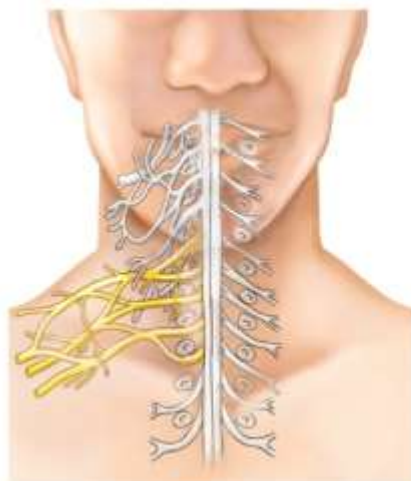


Dissection Shawn Miller, Photograph Mark Nielsen

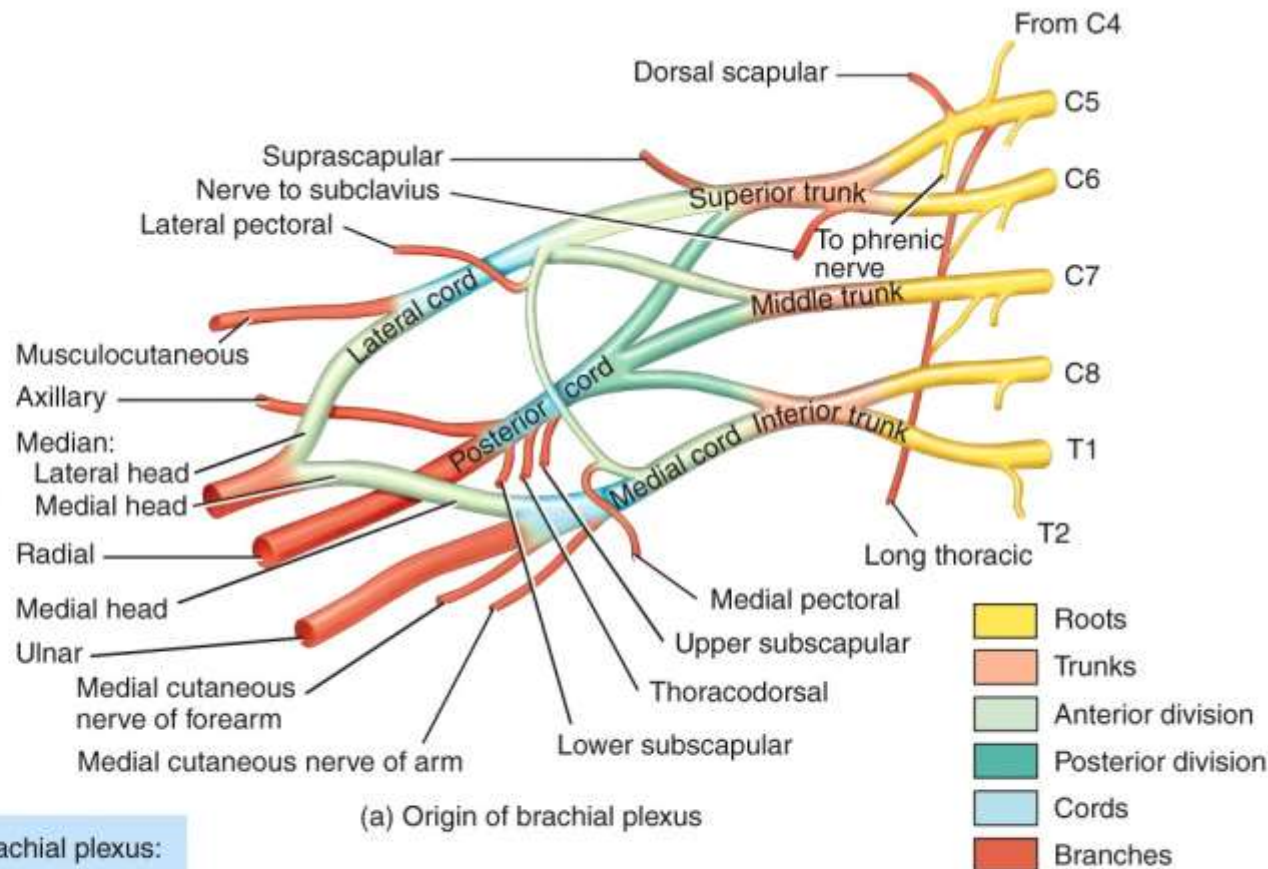
(b) Anterior view of cervical plexus



Brachial Plexus in Anterior View



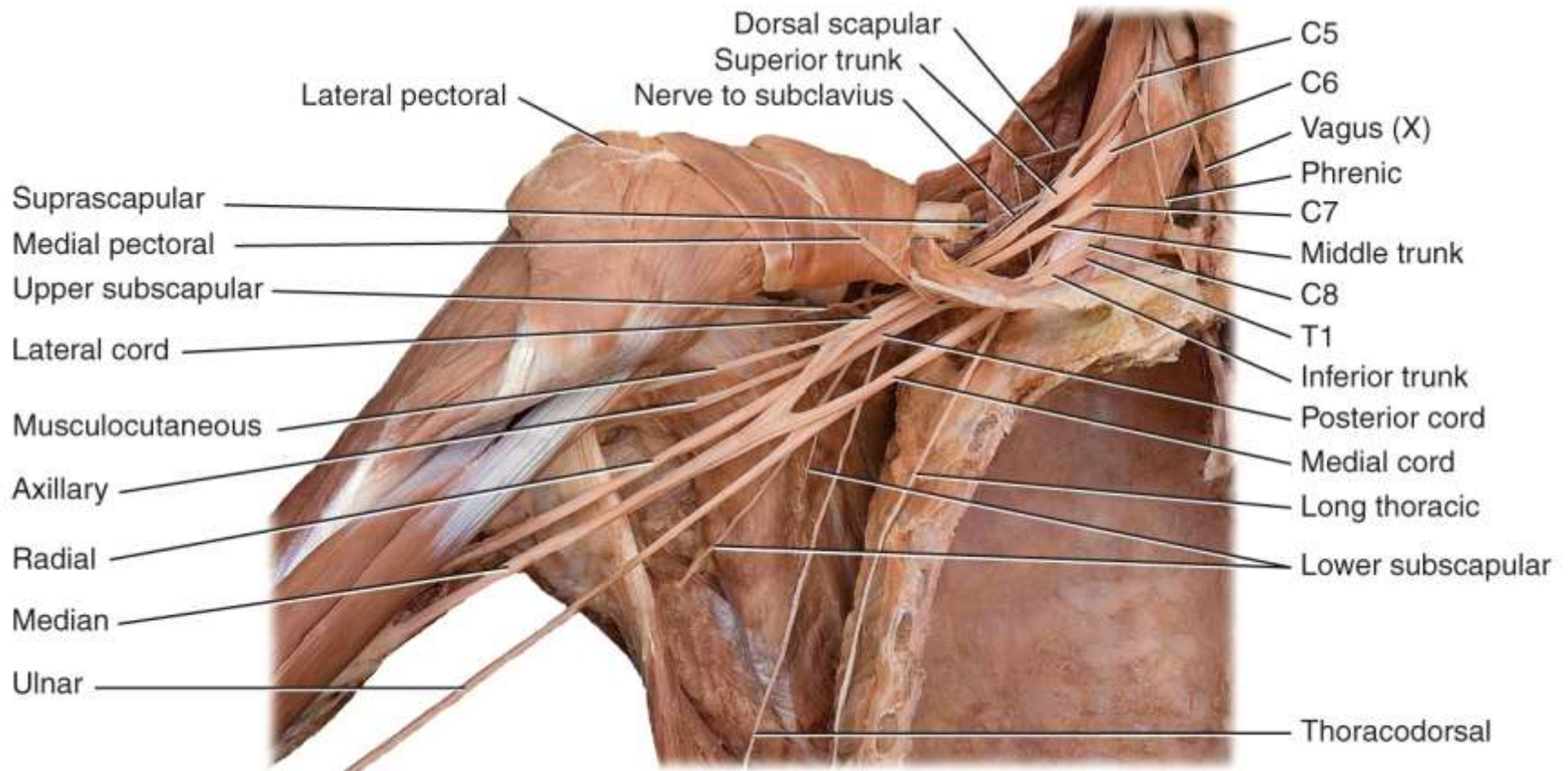
Brachial plexus projected to surface



MNEMONIC for subunits of the brachial plexus:
Risk **T**akers **D**on't **C**autiously **B**ehave.
Roots, **T**runks, **D**ivisions, **C**ords, **B**ranches



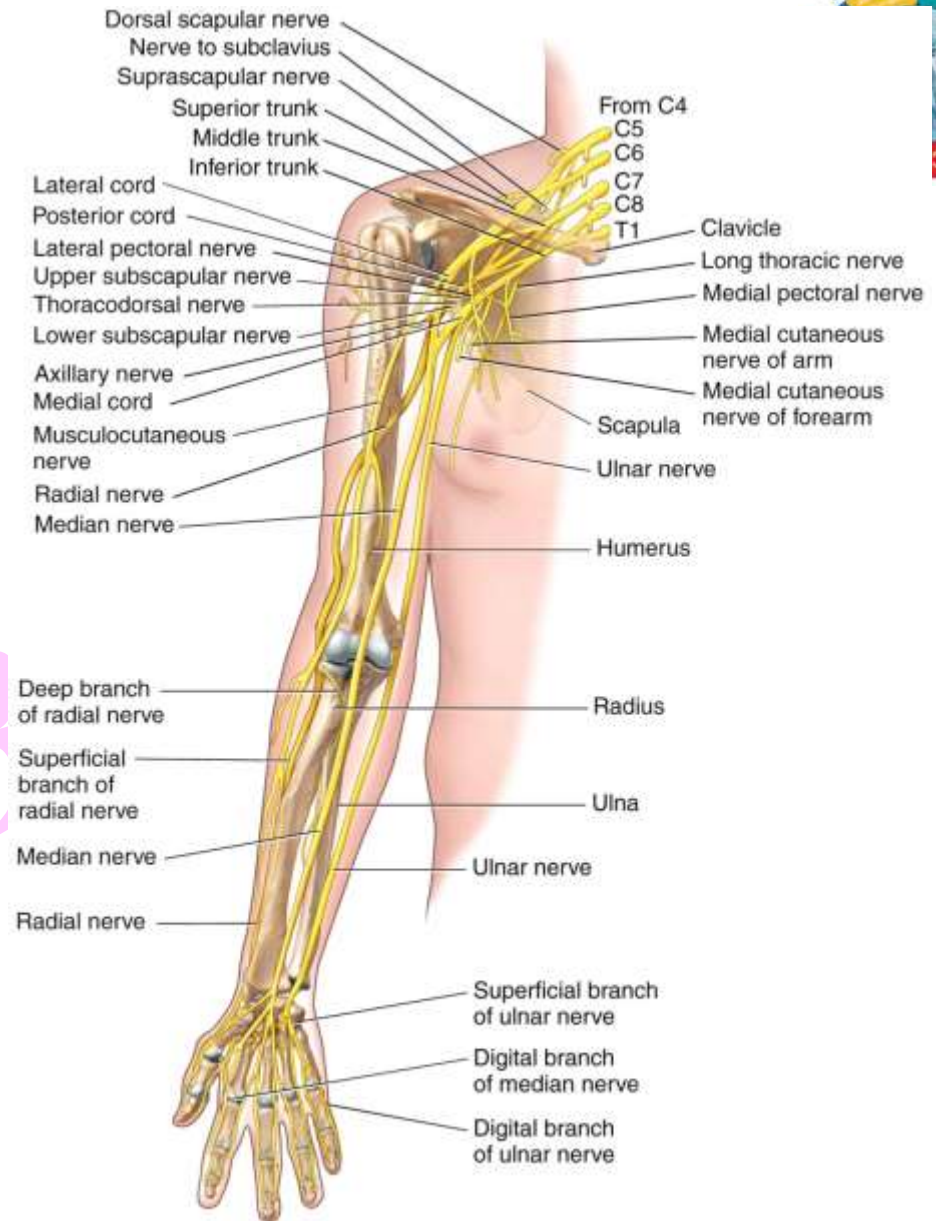
Brachial Plexus in Anterior View



(b) Anterior view of brachial plexus

Dissection Richard Homer;
Photograph Mark Nielsen

Brachial Plexus in Anterior View



(c) Distribution of nerves from brachial plexus

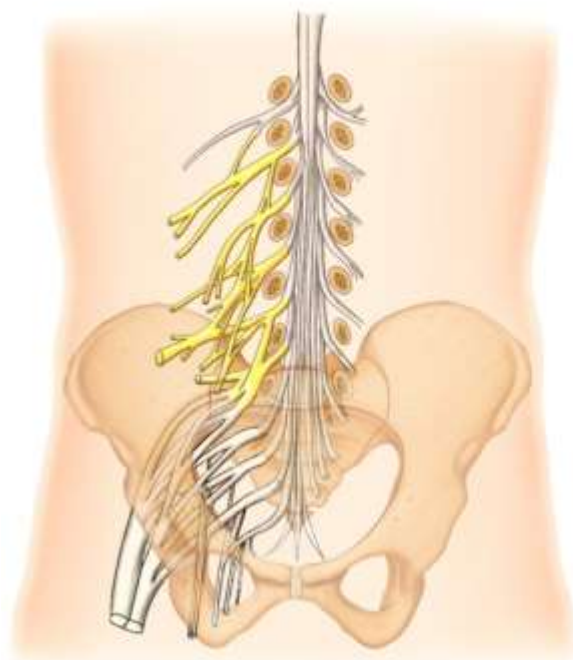
Clinical Connection



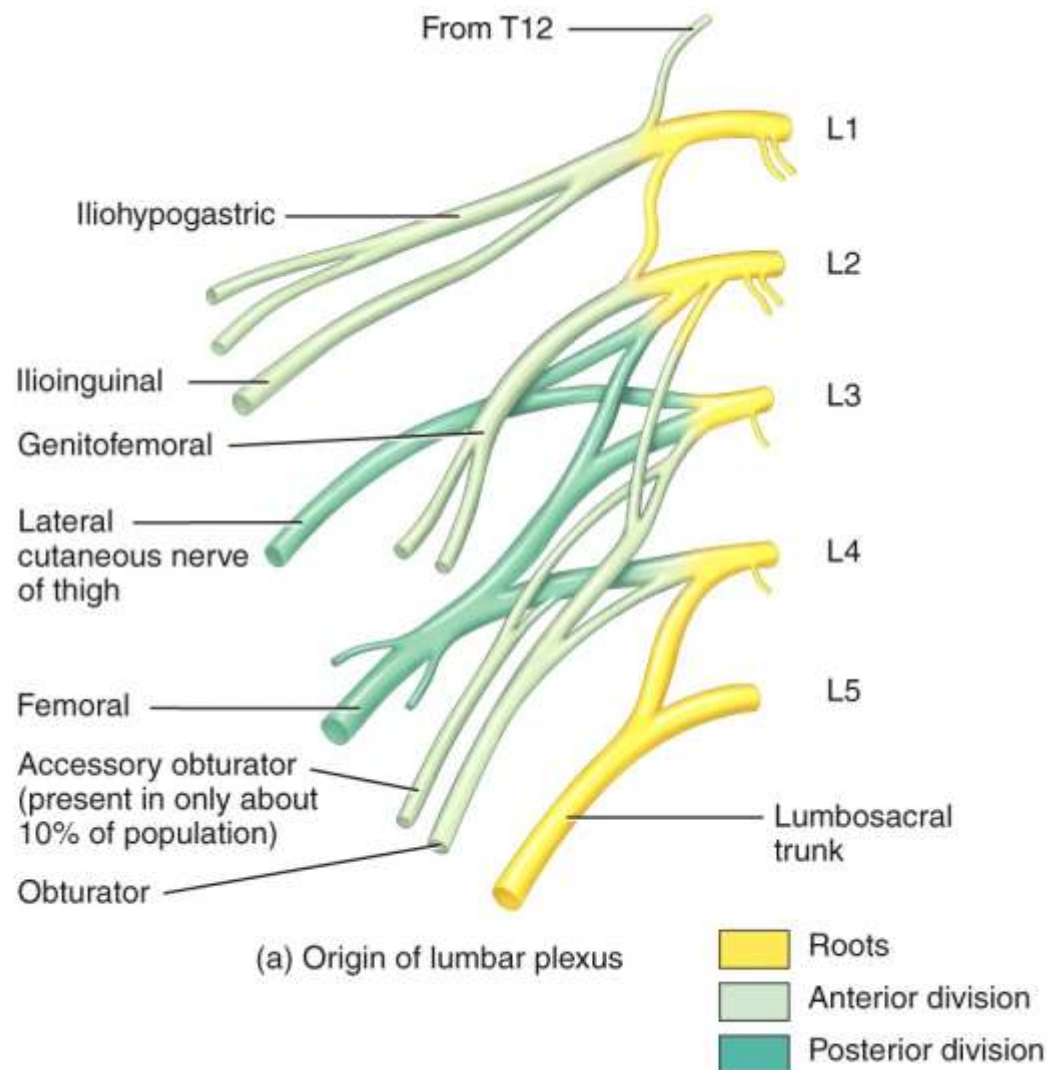
- Injuries to nerves emerging from the brachial plexus:
 - Erb-Duchenne palsy (waiter's tip position)
 - Radial nerve injury (wrist drop)
 - Median nerve palsy (Ape hand)
 - Ulnar nerve palsy (claw hand)
 - Long thoracic nerve injury (winged scapula)
 - Klumpke's paralysis: eighth cervical (C8) and first thoracic (T1)



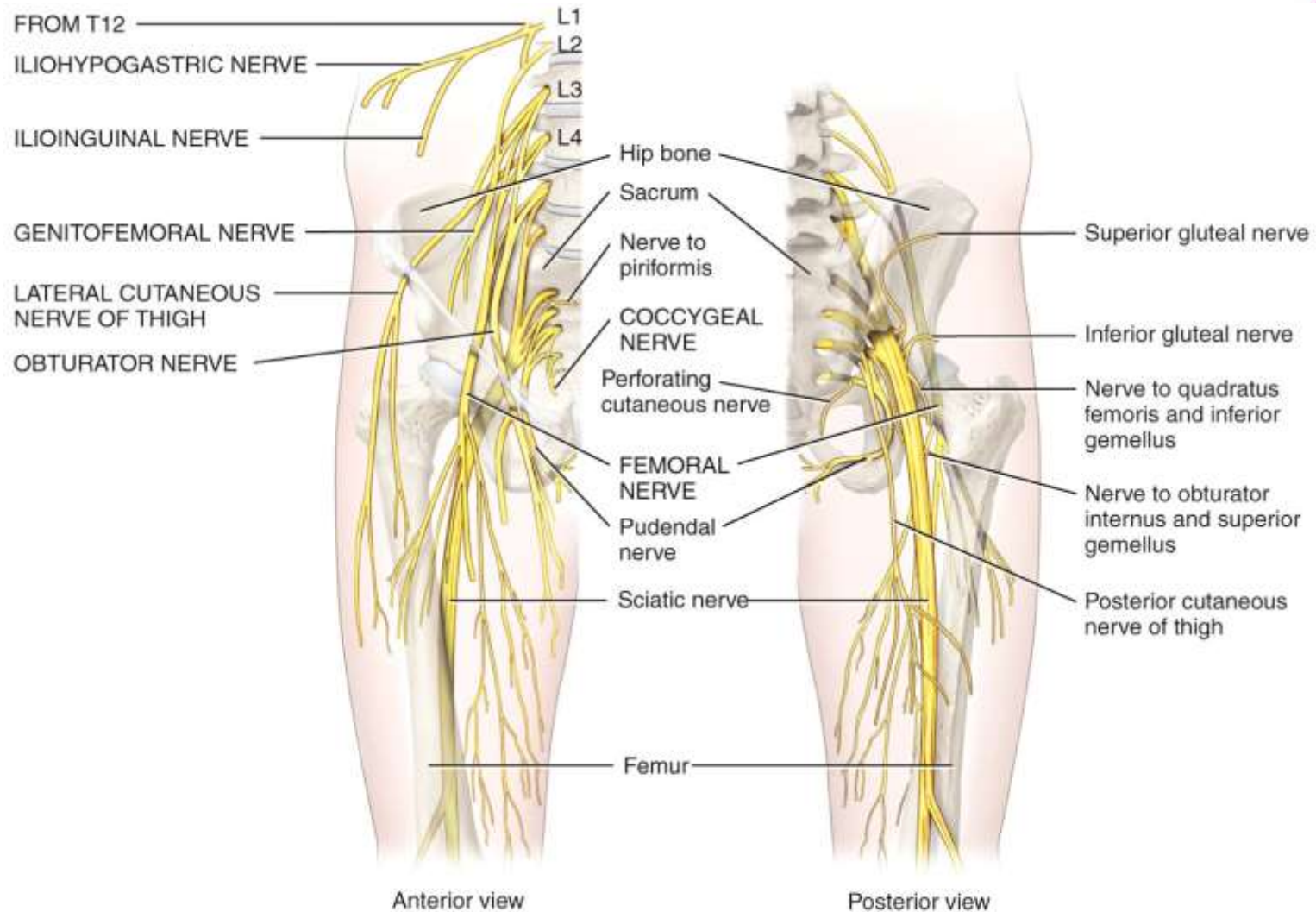
Lumbar Plexus in Anterior View



Lumbar plexus projected to surface



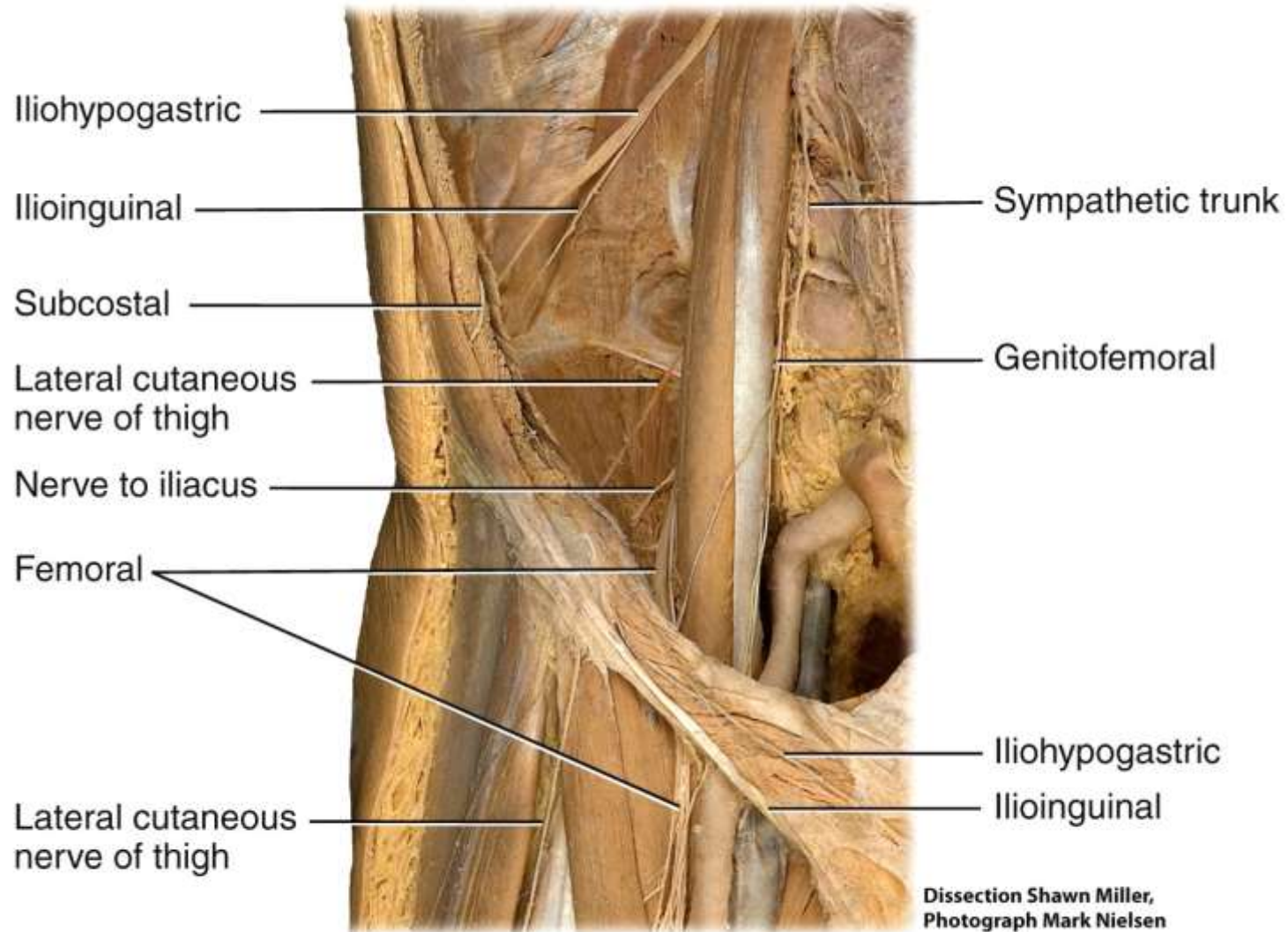
Lumbar Plexus in Anterior View



(b) Distribution of nerves from lumbar plexus

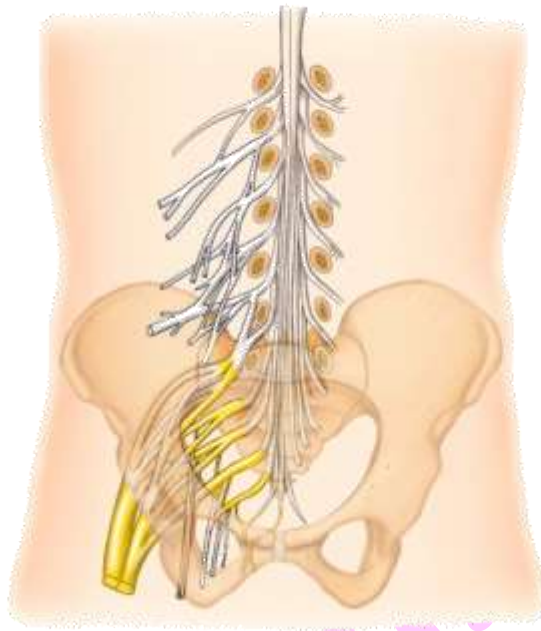


Lumbar Plexus in Anterior View

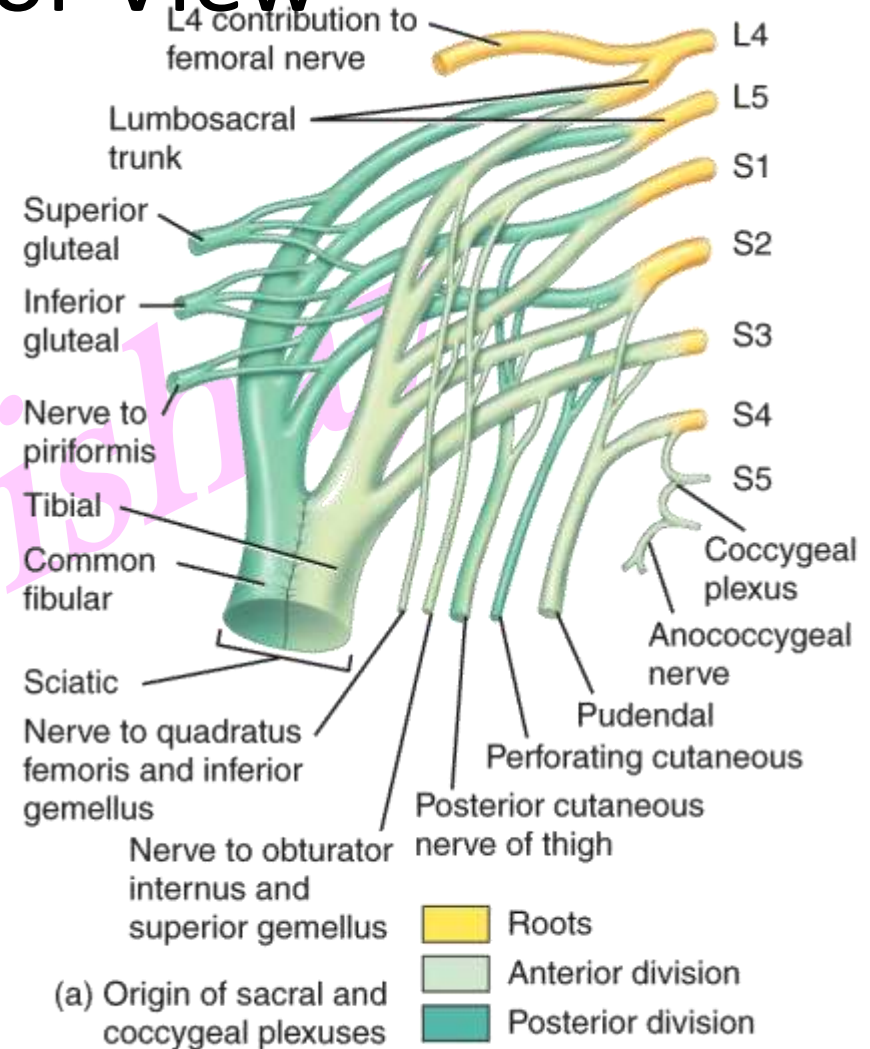


(c) Anterior view of lumbar plexus in right pelvic region

Sacral and Coccygeal Plexuses in Anterior View

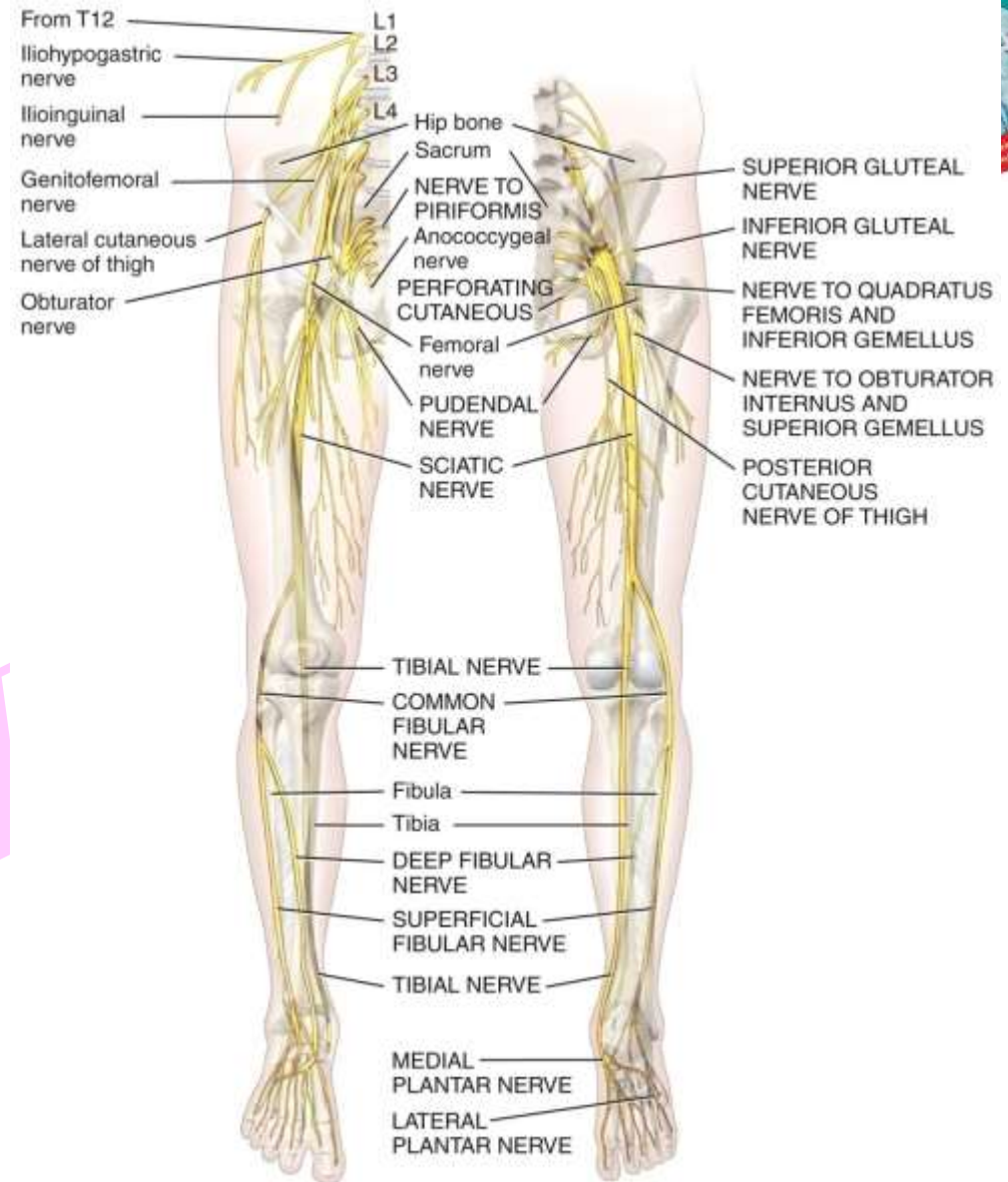


Sacral and coccygeal plexuses projected to surface



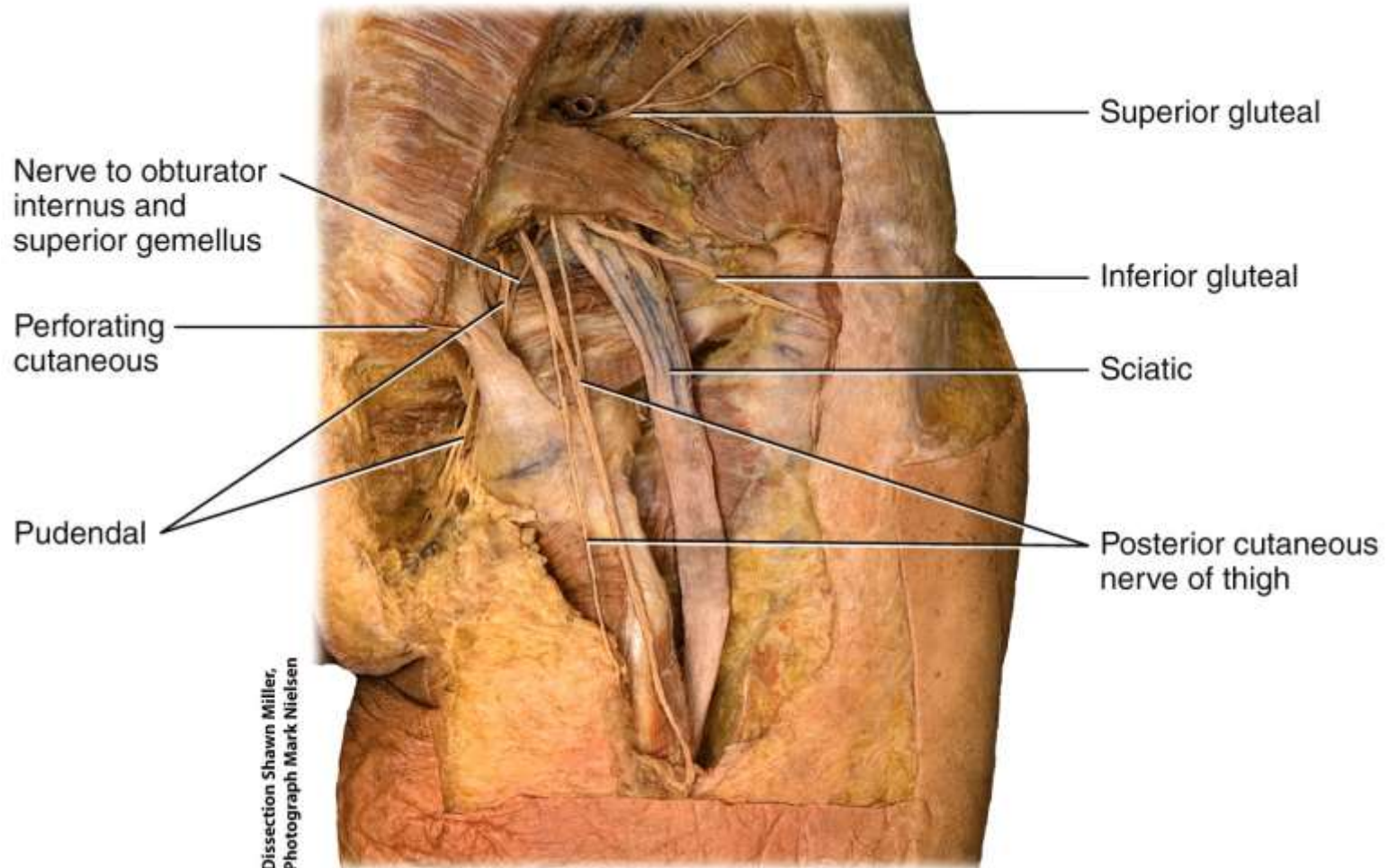
Sacral and Coccygeal Plexuses in Anterior View

R.1



Anterior view Posterior view
(b) Distribution of nerves from the sacral and coccygeal plexuses

Sacral and Coccygeal Plexuses in Anterior View



(c) Posterior view of sacral plexus in right gluteal region

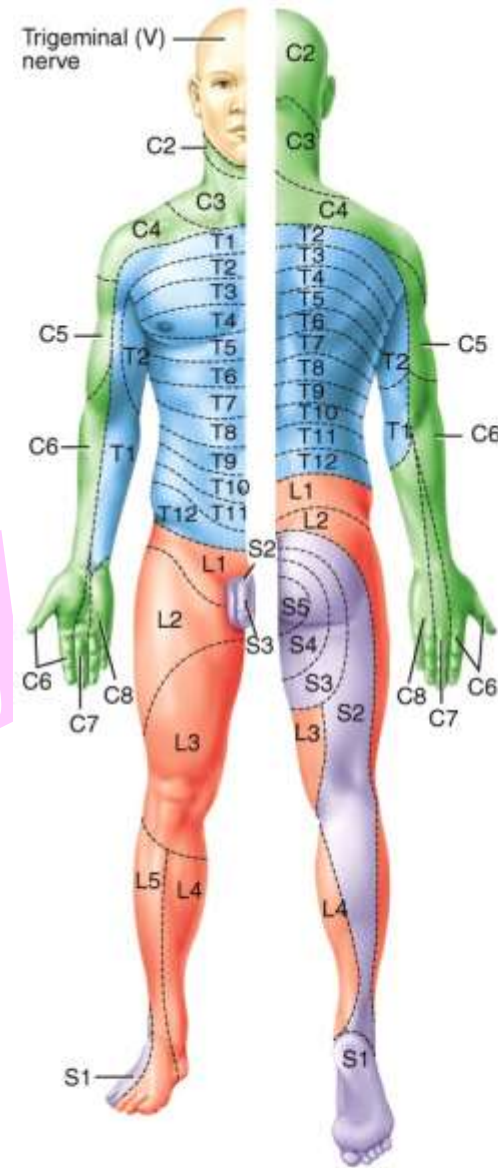
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Dermatomes versus Cutaneous Fields

- Each spinal nerve contains sensory neurons that serve a specific, predictable segment of the body.
- Dermatomes are the areas of the skin that provides sensory input to the CNS via one pair of spinal nerves.
- Knowing which spinal cord segments supply each dermatome makes it possible to locate damaged regions of the spinal cord.
- The nerve supply in adjacent dermatomes overlaps somewhat.

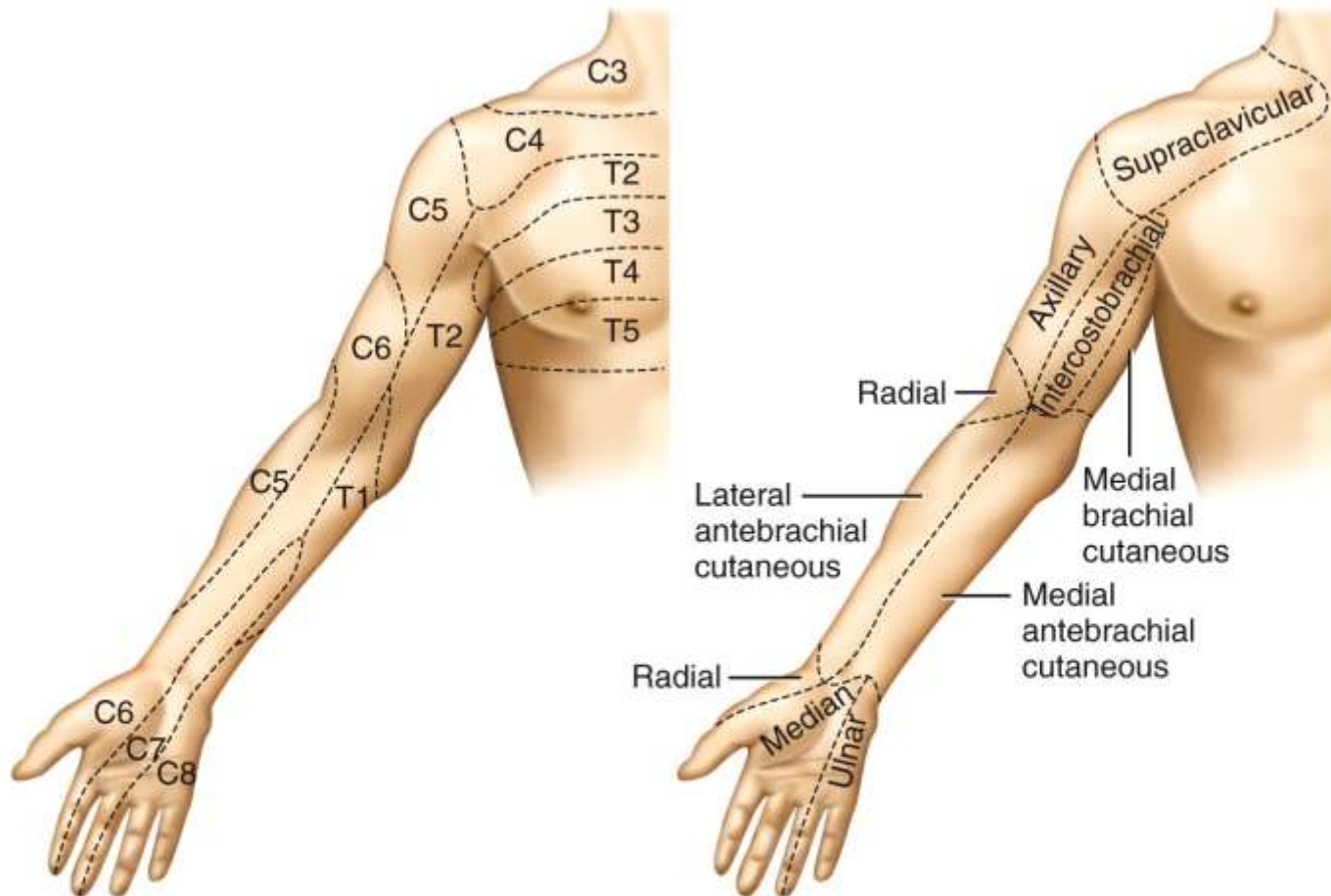
Distribution of Dermatomes and Cutaneous Fields



Anterior view Posterior view
(a) Distribution of dermatomes



Distribution of Dermatomes and Cutaneous Fields



(b) Comparison between distributions of dermatomes (left) and cutaneous fields (right)

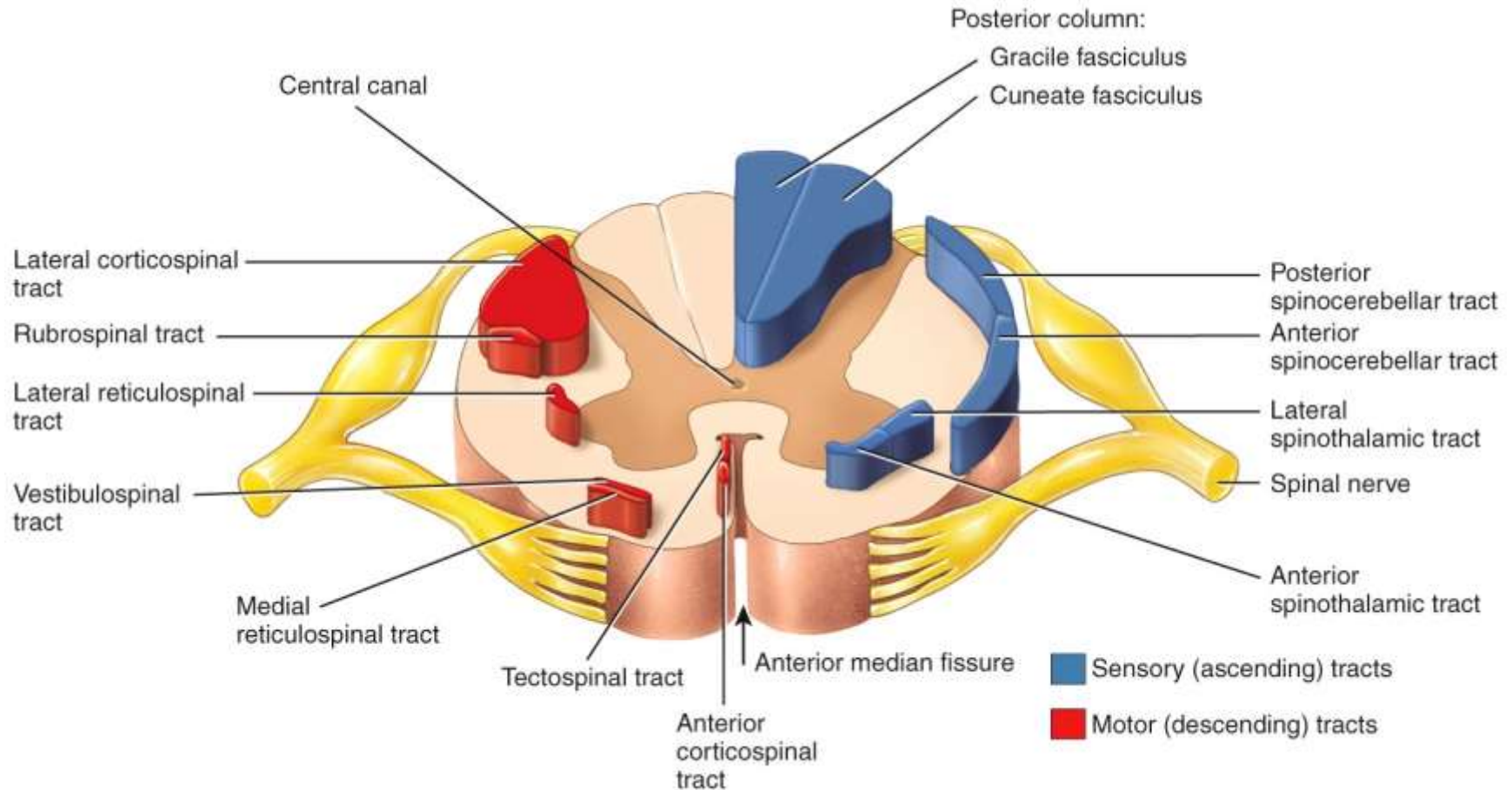


Clinical Connection

- **Shingles:**

Shingles is a viral infection that causes a painful rash. Although **shingles** can occur anywhere on your body, it most often appears as a single stripe of blisters that wraps around either the left or the right side of your torso. **Shingles** is caused by the varicella-zoster virus — the same virus that causes chickenpox

The Locations of Selected Sensory and Motor Tracts





Sensory and Motor Tracts

- **Afferent pathways:**
- Lateral and anterior spinothalamic tracts
- Posterior columns
- **Direct efferent pathways (Pyramidal tracts)**
 - Lateral and anterior corticospinal tract
 - Corticobulbar tract
- **Indirect efferent pathways (Extra Pyramidal tracts)**
 - Rubrospinal tract
 - Tectospinal tract
 - Vestibulospinal tract
 - Lateral and medial reticulospinal tract

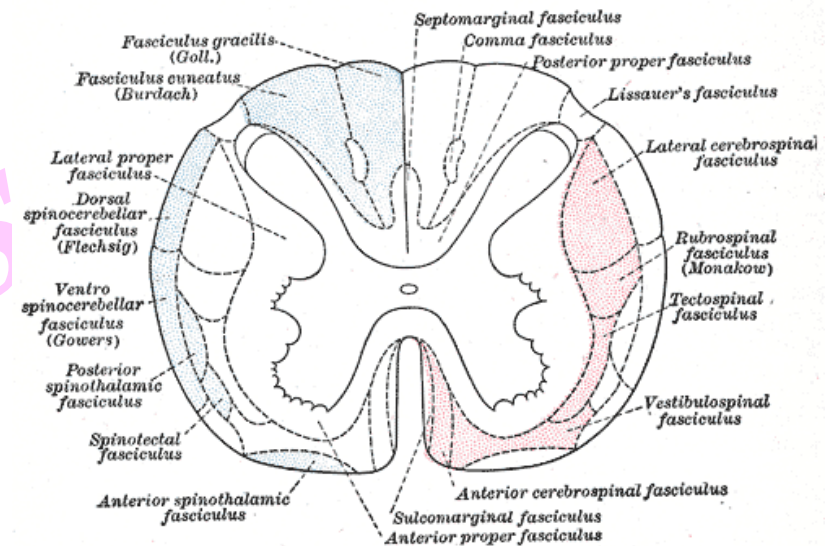


LATERAL AND ANTERIOR SPINOTHALAMIC TRACTS

The **spinothalamic tract** consists of two adjacent pathways:

Anterior and lateral.

- The **anterior spinothalamic tract** carries information about crude touch.
- The **lateral spinothalamic tract** conveys pain and temperature. In the spinal cord, the **spinothalamic tract** has somatotopic organization.





SOMATOTOPIC ORGANIZATION

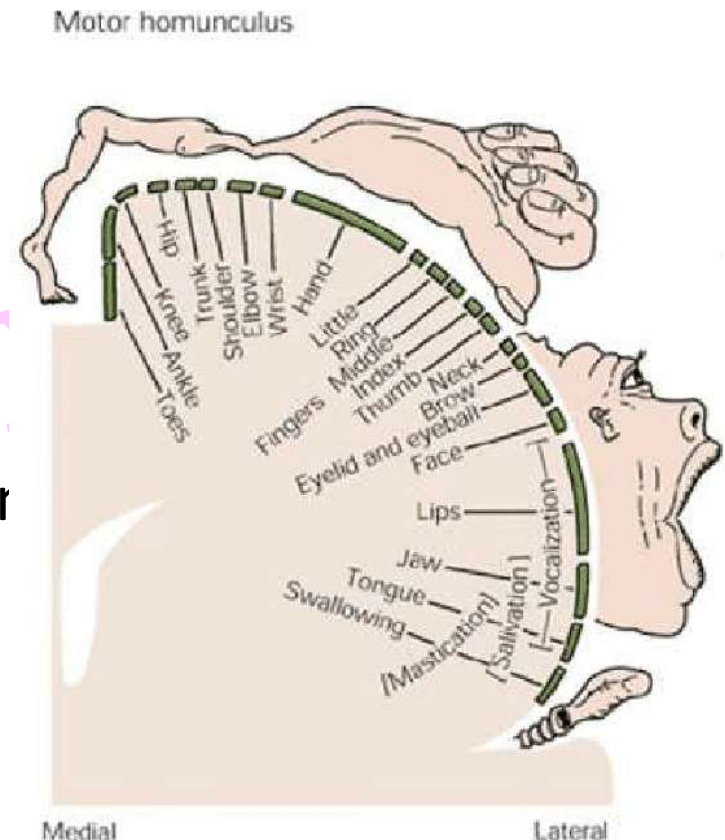
somatotopic organization. the topographic distribution of areas of the motor cortex relating to specific activities of skeletal muscles, as mapped by electrically stimulating a point in the cortex and observing associated movement of a skeletal muscle in the face, the trunk, or a limb. See also motor homunculus



MOTOR HOMUNCULUS

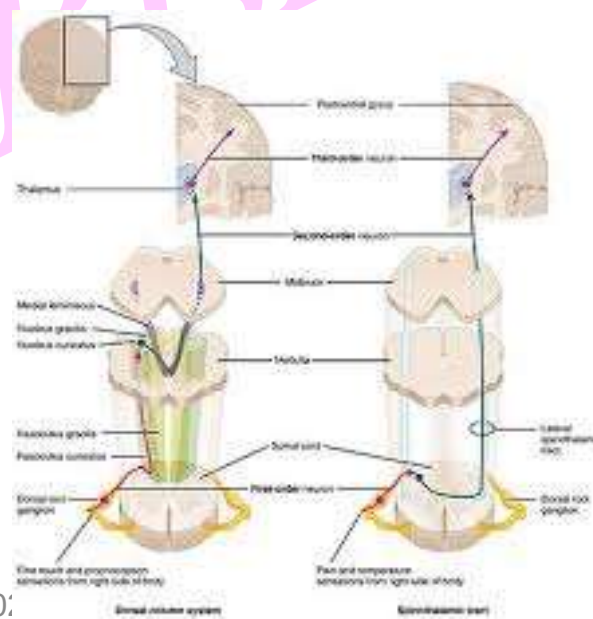
A **motor homunculus** represents a map of brain areas dedicated to **motor** processing for different anatomical divisions of the body.

The primary **motor** cortex is located in the precentral gyrus, and handles signals coming from the premotor area of the frontal lobes.



POSTERIOR COLUMNS

posterior columns, the **dorsal columns** refers to the **posterior** spinal cord, which contains ascending sensory pathways that carry information about tactile sensations and proprioception

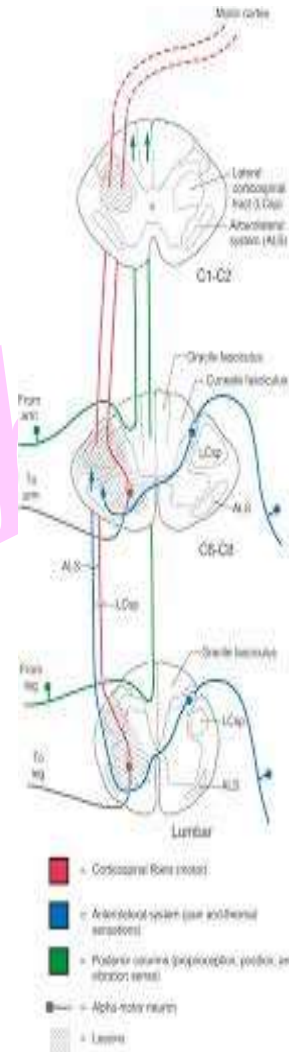
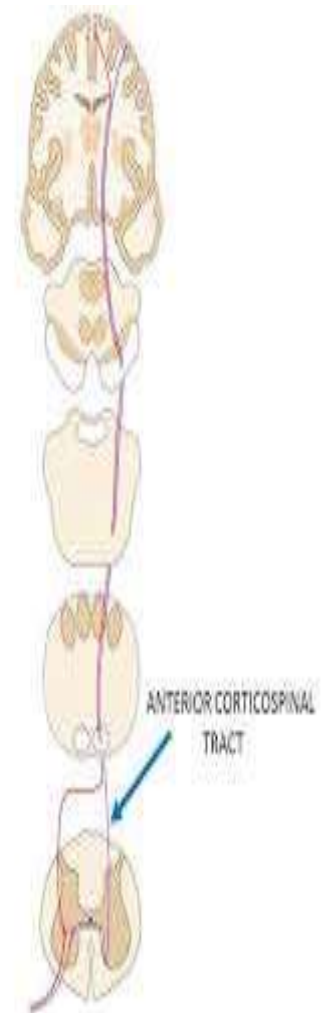




Lateral and anterior corticospinal tract

Pyramidal tracts: refers to upper motor neurons that originate in the cerebral cortex and terminate in the spinal cord (corticospinal) or brainstem (corticobulbar).

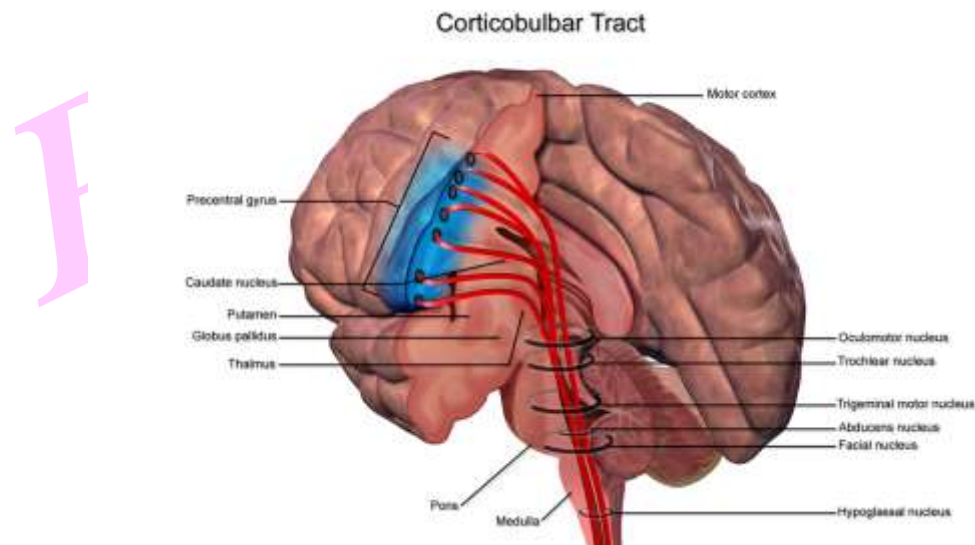
In contrast to the **lateral corticospinal tract** which controls the movement of the limbs, the **anterior corticospinal tract** controls the movements of axial muscles (of the trunk). A few of its fibers pass to the **lateral** column of the same side and to the gray matter at the base of the posterior grey column





Corticobulbar tract

The **corticobulbar** (or **corticonuclear**) **tract** is a two-neuron white matter motor pathway connecting the motor cortex in the cerebral cortex to the medullary pyramids, which are part of the brainstem's medulla oblongata (also called "bulbar") region, and are primarily involved in carrying the motor function of the non-oculomotor cranial nerves.





Corticobulbar tract

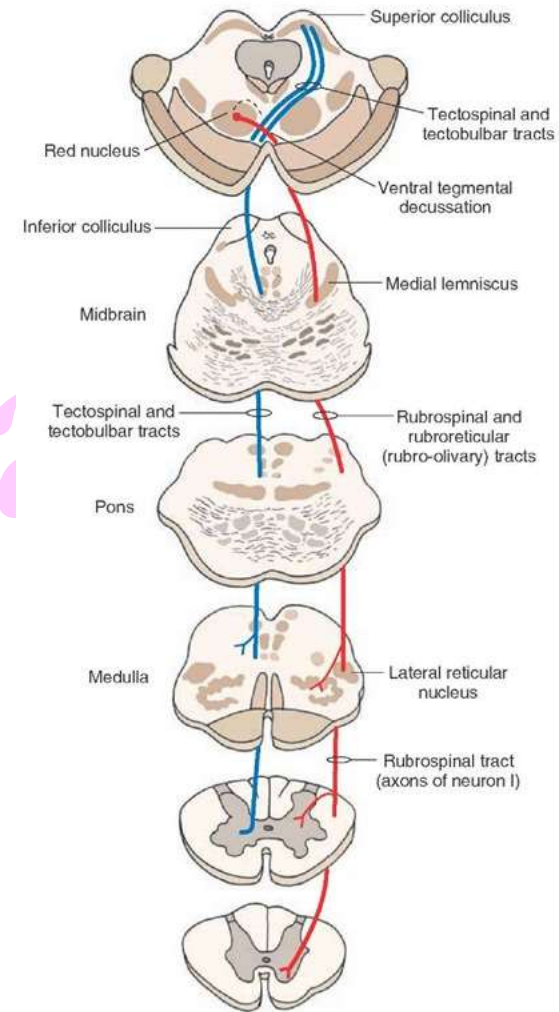
The corticobulbar tract is one of the pyramidal tracts, the other being the corticospinal tract. The corticobulbar tract innervates cranial motor nuclei bilaterally with the exception of the lower facial nuclei which are innervated only unilaterally (below the eyes), by the contralateral cortex. Among those nuclei that are bilaterally innervated a slightly stronger connection contralaterally than ipsilaterally is observed. The corticobulbar tract directly innervates the nuclei for cranial nerves V, VII, IX, and XII. The corticobulbar tract also contributes to the motor regions of cranial nerve X in the nucleus ambiguus.



Rubrospinal tract

The **rubrospinal tract** originates in the red nucleus of the midbrain, decussates, and then descends in the lateral aspect of the spinal cord. Major afferents are from the cerebellar and cerebral cortices, and the **rubrospinal tract** projects to nuclei in the brain stem and cerebellum before reaching the spinal cord

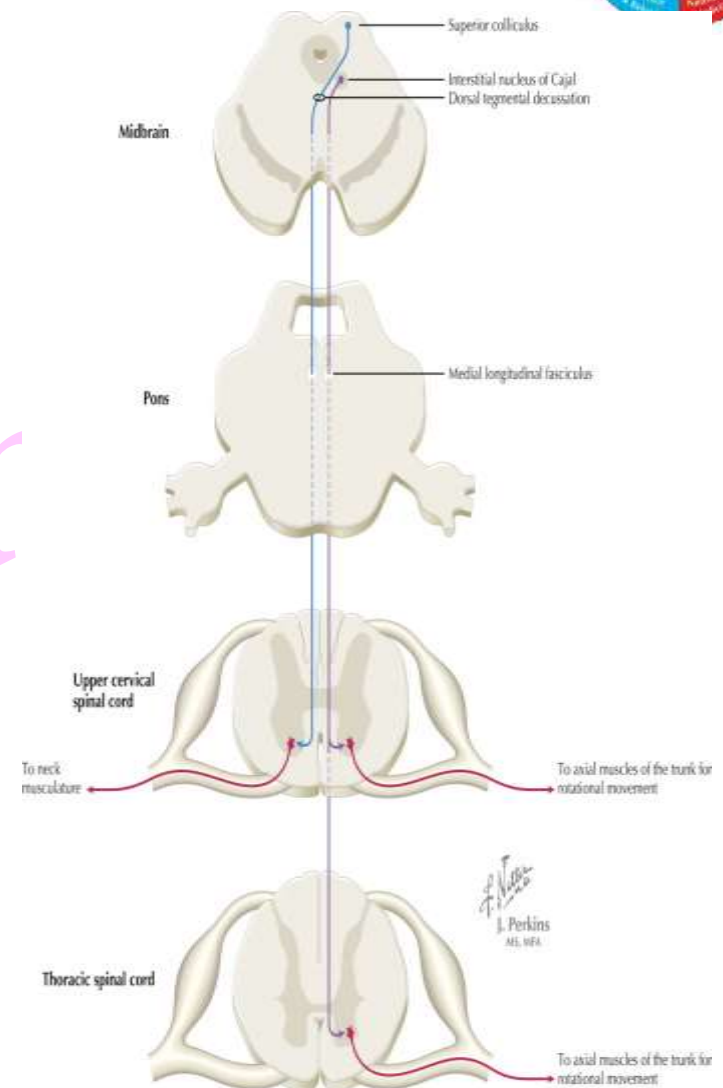
The tract is responsible for large muscle movement regulation flexor and inhibiting extensor tone as well as fine motor control. It terminates primarily in the cervical and thoracic portions of the spinal cord, suggesting that it functions in upper limb but not in lower limb control





Tectospinal tract

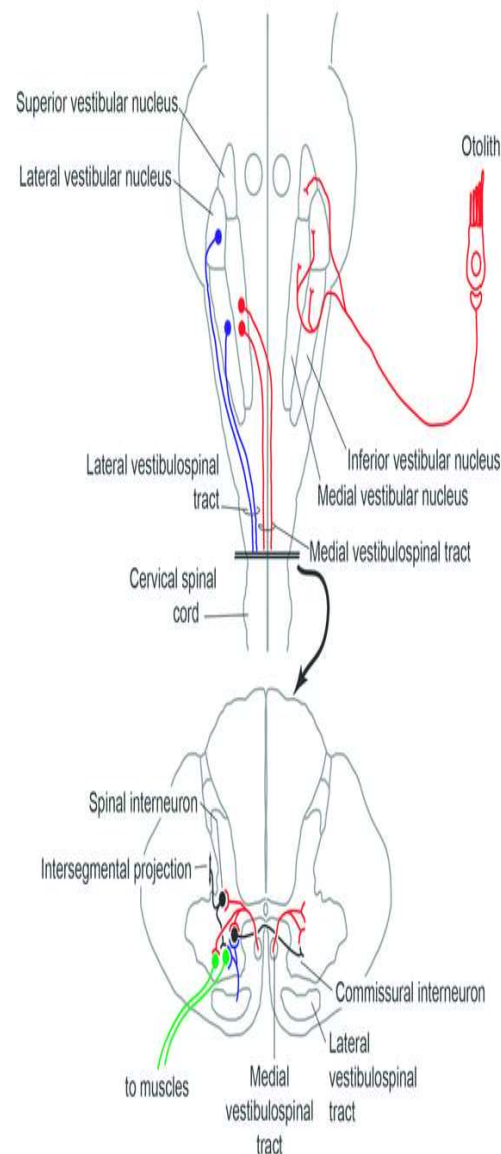
In humans, the **tectospinal** tract (or colliculospinal tract) is a nerve tract that coordinates head and eye movements. This tract is part of the extrapyramidal system and connects the midbrain tectum, and cervical regions of the spinal cord



Vestibulospinal tract

The vestibular nuclei receive information through the vestibulocochlear nerve about changes in the orientation of the head. The nuclei relay motor commands through the vestibulospinal tract.

The function of these motor commands is to alter muscle tone, extend, and change the position of the limbs and head with the goal of supporting posture and maintaining balance of the body and head

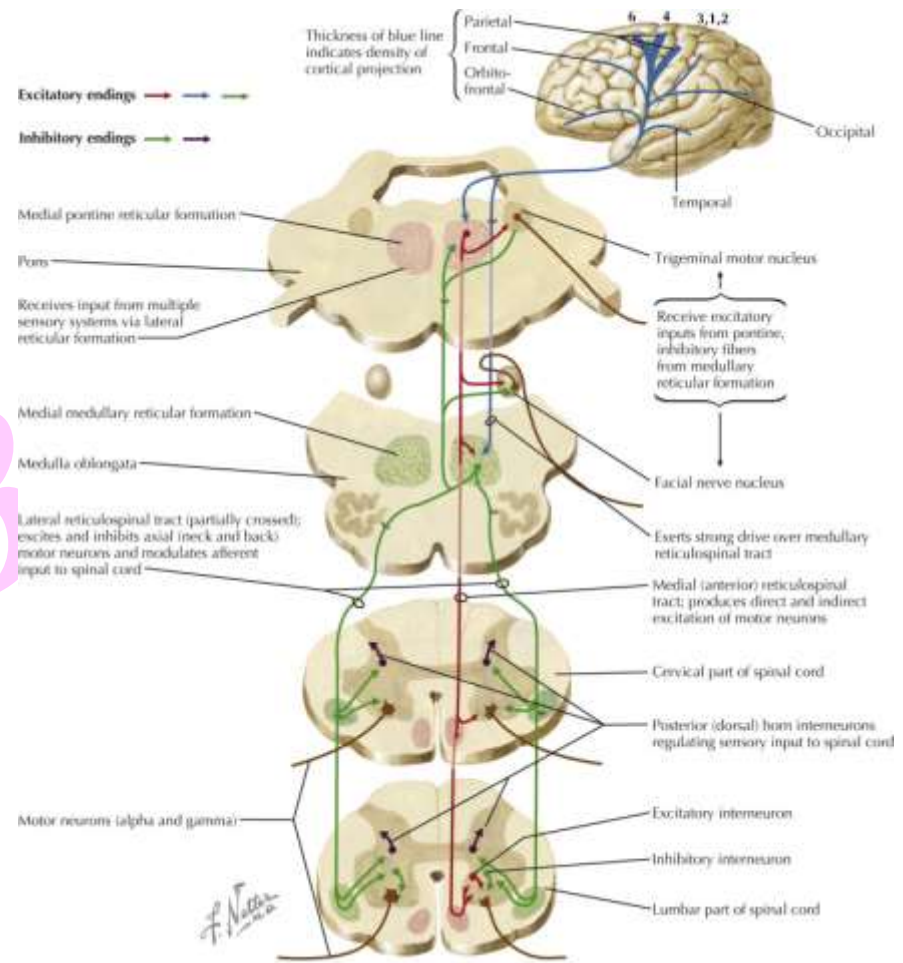




Lateral and medial reticulospinal tract

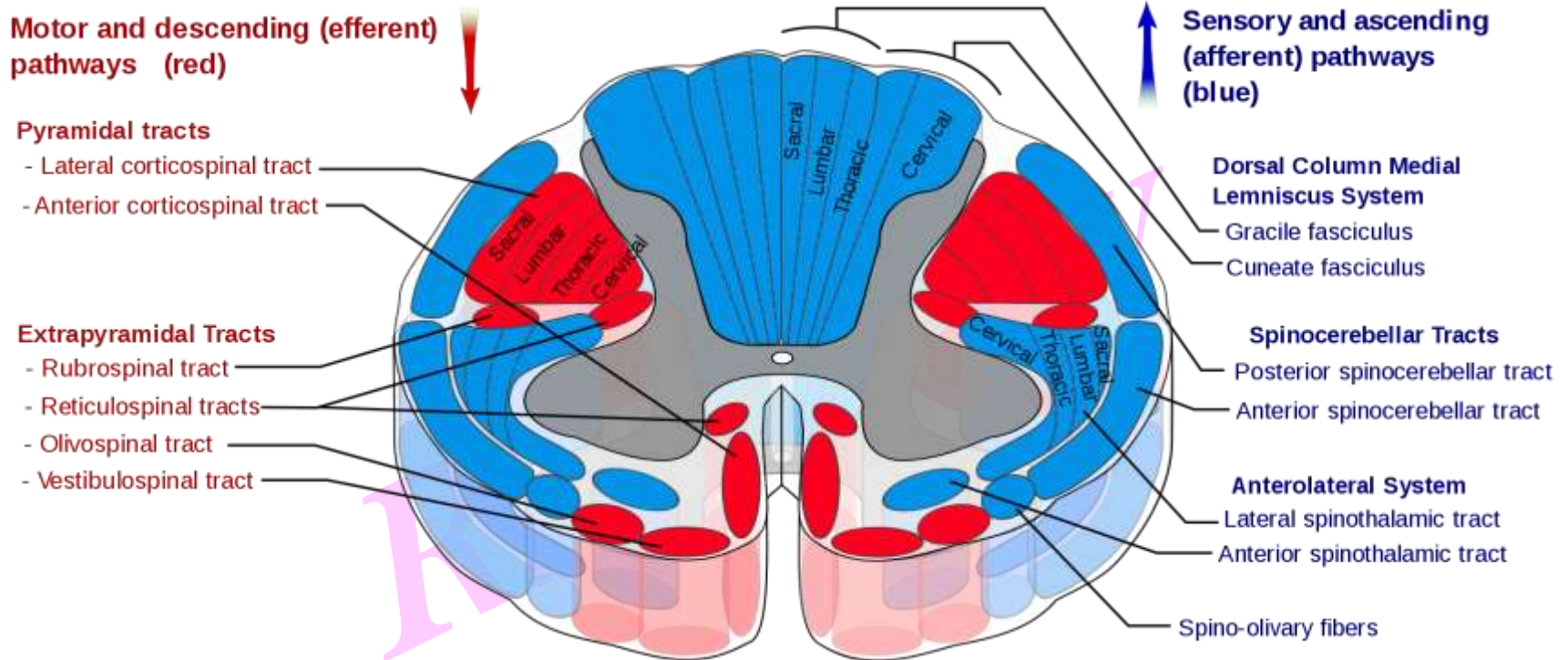
The tract is divided into two parts: the medial (or pontine) and lateral (or medullary) reticulospinal tracts (MRST and LRST).

- The MRST is responsible for exciting anti-gravity, extensor muscles.
- The LRST is responsible for inhibiting excitatory axial extensor muscles of movement





SPINAL TRACTS (AFF & EFF)

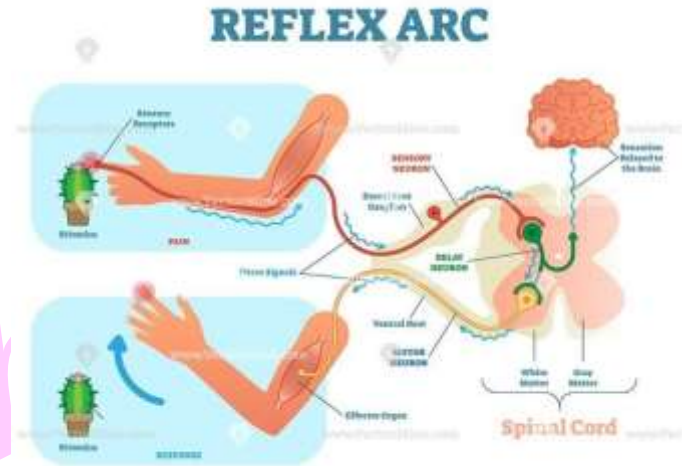




Reflexes and Reflex Arcs

- **Reflexes:**

- **Spinal reflexes:** are those which act through the spinal cord. Receptors in the muscles and tendons are stimulated by stretch, so initiating impulses which travel via the sensory neurones of the peripheral nerve to the posterior horn of the spinal cord
- Cranial reflex: The **reflexes** that involve sensory and motor nerve fibres of **cranial** nerves and control the head region are known as **cranial reflexes**. Since, **cranial reflexes** involve head, eyes, nose, mouth, swallowing and facial expression, they produce the vital and involuntary responses.



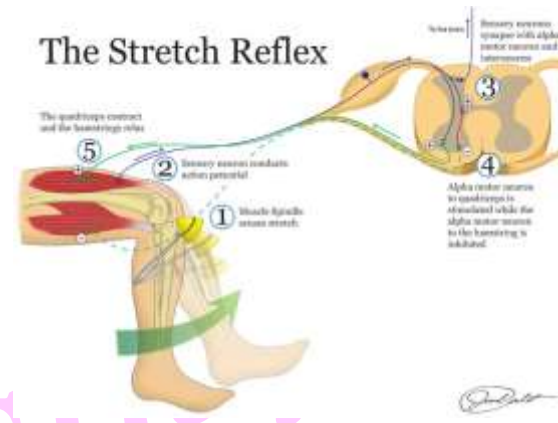
Reflexes involving cranial nerves

Name	Sensory	Motor
Pupillary light reflex	II	III
Accommodation reflex	II	III
Jaw jerk reflex	V	V
Corneal reflex, also known as the blink reflex	V	VII
Vestibulo-ocular reflex	VIII	III, IV, VI +
Gag reflex	IX	X



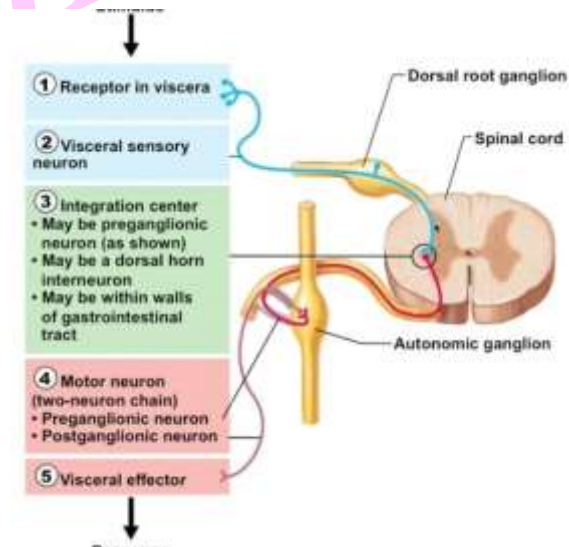
Reflexes and Reflex Arcs

- **Somatic reflexes:** are one of the two types of reflex arcs, and specifically involve the skeletal muscles. They are unlearned muscle reflexes that are mediated by the brainstem and spinal cord.



- **Autonomic (visceral) reflexes:** are unconscious motor **reflexes** relayed from the organs and glands to the CNS through visceral afferent signaling.

This **reflex** is similar to the somatic **reflex**, but the efferent branch is composed of two neurons. ... The role of **visceral reflexes** is to maintain a balance of function in the organ systems of the body.





Reflex and Reflex Arc

- Components of a reflex arc
 - Sensory receptor
 - Sensory neuron
 - Integrating center
 - Motor neuron
 - Effector



Patellar Reflex Showing Components of a Reflex Arc

