LEARNING OBJECTIVES

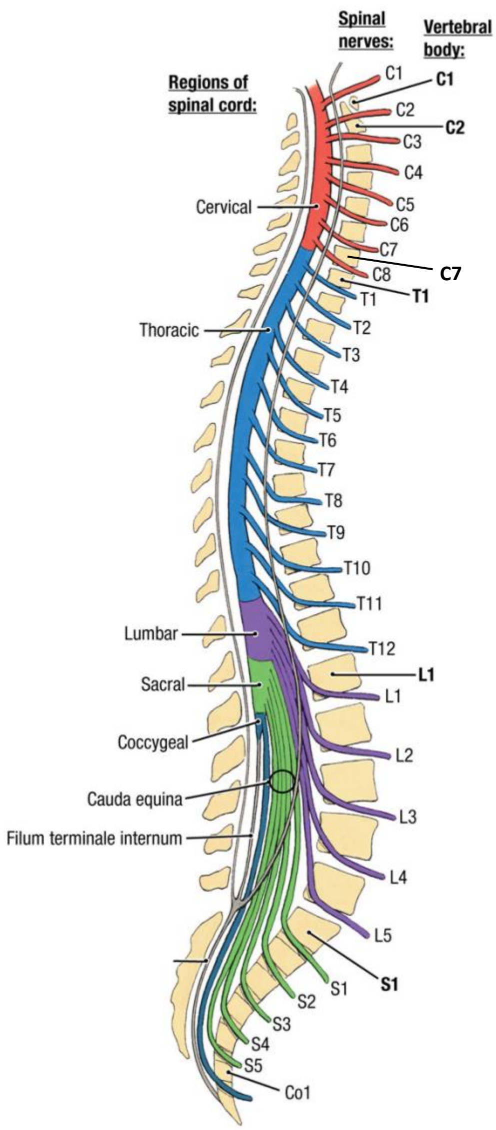
By the end of this lab you should be able to:

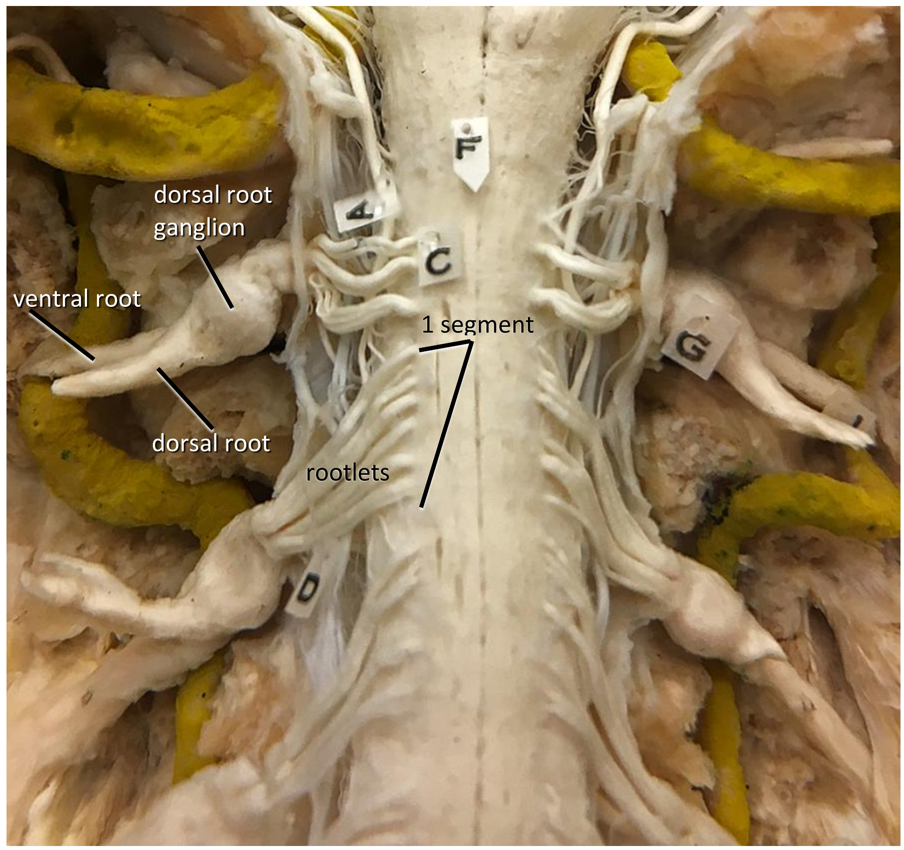
1. name the segments of the spinal cord along with their number
2. describe the relationship between spinal roots, dorsal root ganglia, and spinal rootlets
3. locate on slides: anterior median fissure, posterior median sulcus, posterolateral sulcus, central canal, white and gray matter, cervical and lumbosacral enlargements
4. identify the 3 meningeal layers, the spaces they create, and the items they contain on gross specimens and slides of spinal cord
5. describe how the spinal cord terminates in the vertebral column and associated structures including cauda equina, filum terminale, and lumbar cistern
6. explain the use of anesthetics for spinal anesthesia
7. evaluate clinical disorders involving the conus medullaris and cauda equina
8. describe the concept of cell columns/horns in gray matter
9. identify the 4 levels of the spinal cord in cross sections
10. describe the blood supply to the spinal cord.

Overall Organization and External Structure

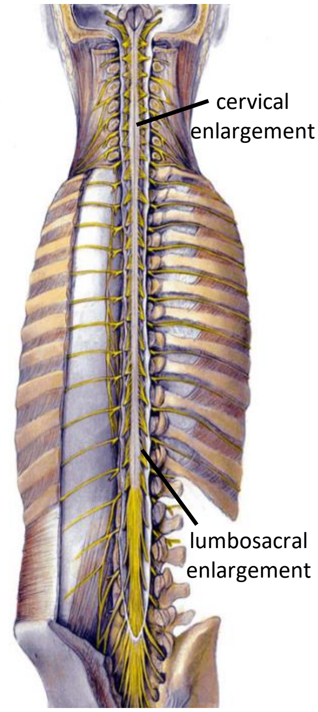
The spinal cord is divided into 31 anatomical segments: 8 cervical, 12 thoracic, 5 lumbar, 5 sacral, 1 coccygeal. Each segment is associated with a spinal nerve that transmits sensory and motor information to specific areas of the body (dermatomes). As each spinal nerve approaches the spinal cord, it divides into a dorsal and ventral root at the intervertebral foramen. As each dorsal and ventral root approaches the cord, it divides into multiple small branches called rootlets. Each spinal cord segment is about a 1 inch length of spinal cord, but these decrease in length at more caudal levels.

Spinal nerves from C1 to C8 exit ***above*** their respective vertebrae. However, since there are 8 cervical segments to the spinal cord but only 7 cervical vertebral bodies, all remaining spinal nerves exit ***below*** their respective vertebrae.





The ventral roots carry motor information to muscles of the body. The dorsal roots carry sensory information from the body. Each dorsal root has a dorsal root ganglion located in the intervertebral foramen.

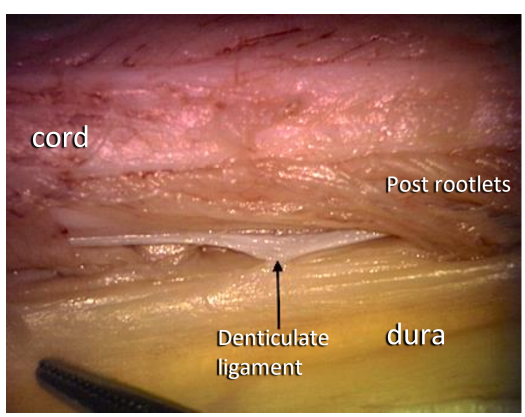


Along its length, the spinal has longitudinal grooves (slide 108) that separate it into regions: anterior median fissure, posterior median sulcus, and posterolateral and anterolateral sulci (location of dorsal and ventral rootlets, respectively). The spinal cord is expanded in diameter at 2 locations along its length, the cervical and lumbosacral enlargements. These correspond to the increased number of nerve cell bodies and fibers that are necessary for supplying the upper and lower limbs compared to thoracic areas.

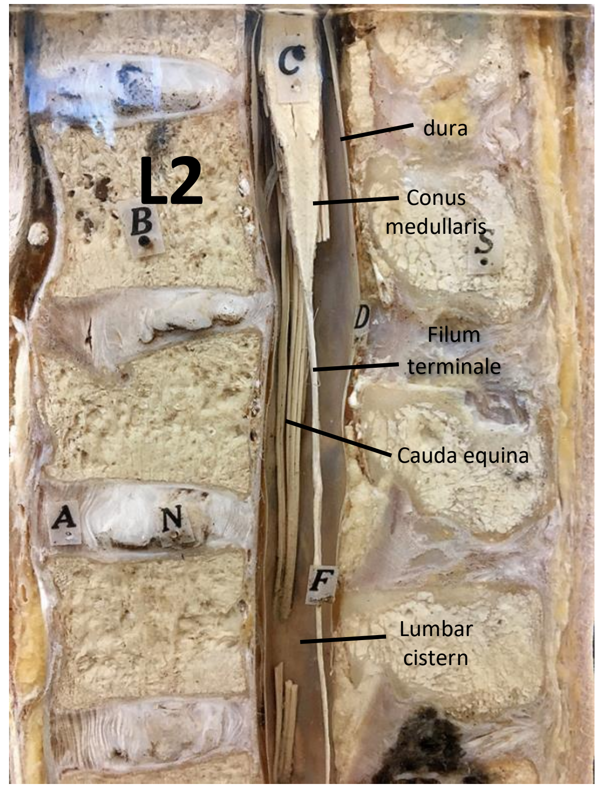
> *Clinical applications*: Degenerative or traumatic changes in intervertebral discs and vertebral bodies can cause narrowing of the intervertebral foramina resulting in increased pressure on dorsal and ventral nerve roots. This often causes a *radicular* (root) localization of sensory (pain) and motor (weakness) deficits that involve specific body dermatomes related to the involved spinal segment. *Protrusion of a particular disc affects the next lower spinal nerve (eg disc L2-L3 affects spinal nerve L3)*.

Meninges

The spinal cord is covered by the 3 meningeal layers similar to the brain: dura, arachnoid, and pia, which also create their respective spaces: epidural and subarachnoid (slide 104). However, in the spinal cord, a real space exits between the dura and the vertebral bone (epidural space) that contains fat and blood vessels (slide 103). The subarachnoid space contains spinal nerve rootlets and blood vessels (slide 105). An outgrowth of the pia along the lateral edge of the spinal cord creates a series of about 20 pairs of attachments known as denticulate ligaments that insert into the dura to anchor the cord in the vertebral column. The dura covers the dorsal and ventral roots and dorsal root ganglion within the intervertebral foramina, but as they exit to form spinal nerves, the dura becomes epineurium that covers all peripheral nerves.

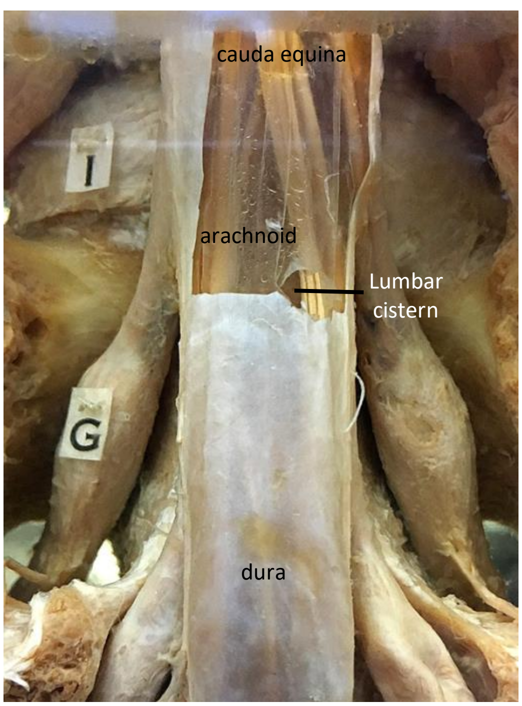


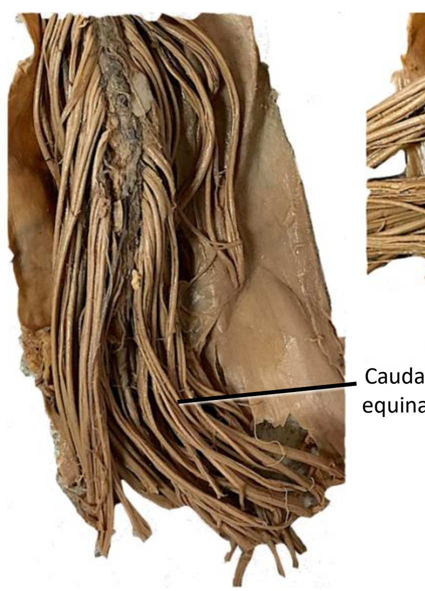
Clinical applications: 1) Denticulate ligaments are surgical landmarks between dorsal and ventral roots of the spinal cord. They divide the spinal cord into anterior and posterior compartments and help localize midline points. 2) The epidural space is a convenient location for injection of anesthetics. Needles or catheters can be used to infuse anesthetics over long periods of time at any vertebral level. Blockade of spinal nerve activity occurs over restricted regions of the body due to limited diffusion in the epidural space.

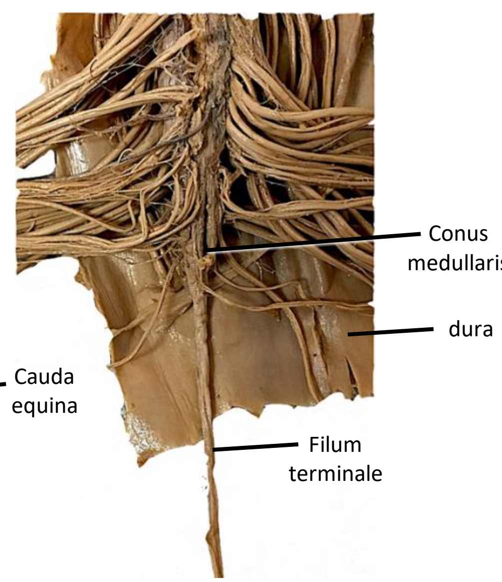


Spinal Cord Length

During embryogenesis the spinal cord and vertebral canal are equal in length. However, the spinal cord grows slower than the vertebral canal so that in adults the end of the spinal cord is located at about vertebral level L2. The spinal cord has a cone shaped ending called the conus medullaris. The pia continues past the conus medullaris and tapers to form a long fibrous extension called the filum terminale that is attached to the coccygeal vertebrae. The subarachnoid space from L2 to the end of the vertebral canal is the *lumbar cistern*, which is filled with the dorsal and ventral roots of spinal segments L2 to Coc1 that must descend to exit through their respective intervertebral foramina. This collection of nerve roots is known as the cauda equina.



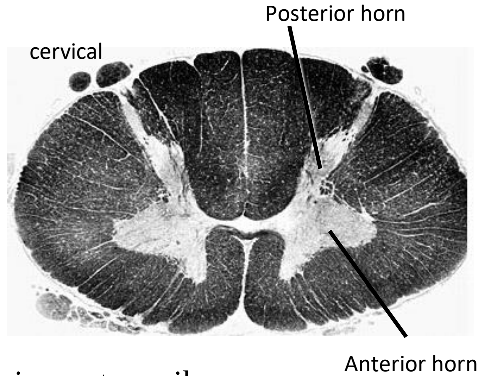




Clinical applications: The lumbar cistern is where CSF is removed during a lumbar puncture, a location where the spinal cord cannot be punctured. Anesthetics can be infused into this region for spinal anesthesia, which produces a faster and more complete block compared to epidural anesthesia. However, anesthesia is more limited in duration and must be confined to these lower spinal levels - the procedure must ensure that the anesthetic does not travel to higher levels where it can affect cardiac and respiratory function.

Cauda equina syndrome*:* Problems at *vertebral* levels below L2 will affect the nerve roots within the cauda equina. This can result from disk herniation, tumor, infection, and other causes. Symptoms will relate to the particular nerve roots affected and can include sensory, motor, and autonomic (bladder) dysfunction in the lower part of the body.

Tethered Cord Syndrome*:* During development, the conus medullaris may become abnormally attached (tethered) to subcutaneous tissue. The cord becomes anchored in a lower position in the vertebral canal with a shortened filum terminale and dural adhesions preventing upward mobility. Symptoms include sensory, motor, and bladder deficits for the lower body, back pain, and scoliosis.



Internal Structure

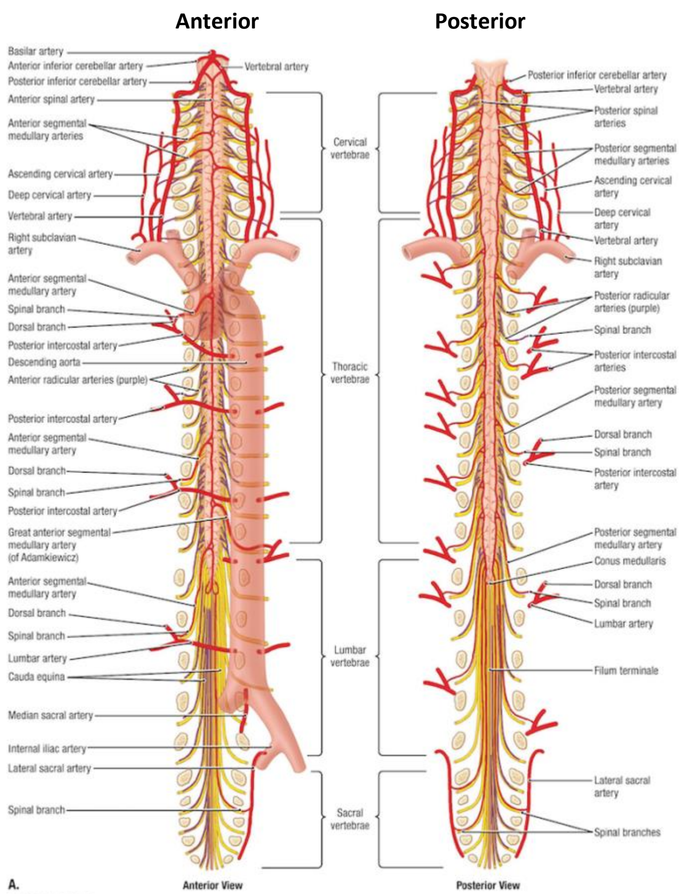
A cross section of the spinal cord reveals its internal structure, which is consistent throughout all segments (slide 107). An inner H-shaped area is composed of gray matter containing nerve cell bodies. That is surrounded by white matter that extends to the surface containing myelinated nerve fibers. A central canal, an extension of the ventricular system, is located in the center of the spinal cord. In our sections, white matter appears black due to histological stains that bind to myelin compared to the lighter, unmyelinated gray matter, allowing us to easily differentiate these 2 areas. In white matter, nerve fibers of each functional system are bundled together into fasciculi or tracts that travel longitudinally for long distances up or down the spinal cord. These fasciculi lie adjacent in white matter and cannot be obviously distinguished. The deeper gray matter is divided into anterior and posterior "horns" that correspond to motor and sensory neurons, respectively. A lateral horn exits at thoracic levels of the spinal cord (slide 109). The nerve cell bodies in these horns that are associated with specific functions often extend over several segments longitudinally and are therefore referred to as columns. The length of cell columns varies, but some columns extend the entire length of the spinal cord. Examine the following slides:

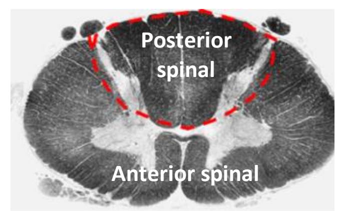
- Slide 107 – **Compare** how the white and gray matter changes at each level of the cord. Gray matter is greatest at the cervical and lumbosacral levels, which contain nerve cell bodies for the limbs. White matter decreases from cervical to sacral levels (descending fibers terminate sequentially as they travel caudally; ascending fibers headed to the brain accumulate rostrally).

Blood Supply

The spinal cord receives its blood supply from *1 anterior* and *2 posterior spinal arteries*. These begin as branches of the vertebral artery in the medulla. The anterior spinal artery descends in the anterior median fissure to supply the anterior 2/3s of the cord. The 2 posterior spinal arteries are positioned between the posterior median sulcus and posterolateral sulcus on each side and form an anastomotic network with each other as they descend. Both arterial systems receive frequent contributions from segmental arteries at thoracic and abdominal levels to reinforce the blood supply, but the posterior spinal artery receives the largest contribution. The especially large segmental artery of Adamkiewicz, which contributes to the anterior spinal circulation, is a major source of blood to lower thoracic and upper lumbar cord levels.

> *Clinical applications:* The effect of occlusion of the anterior spinal artery often is limited to several cord segments due to segmental arteries that feed it at other levels. However, consequences can still be severe due to long tracts that travel through the ischemic region. Occlusion of the posterior spinal artery rarely causes deficits due to its anastomotic network and many segmental contributions.

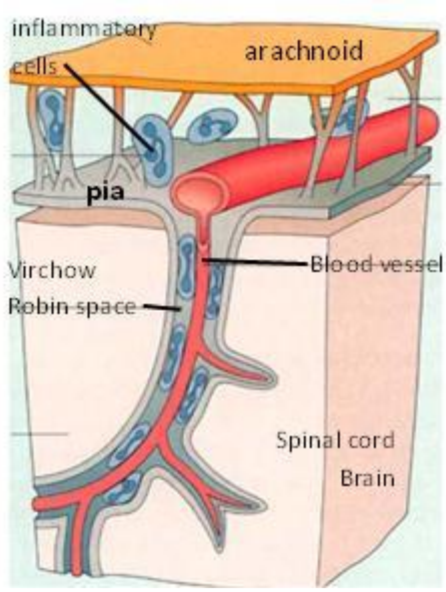


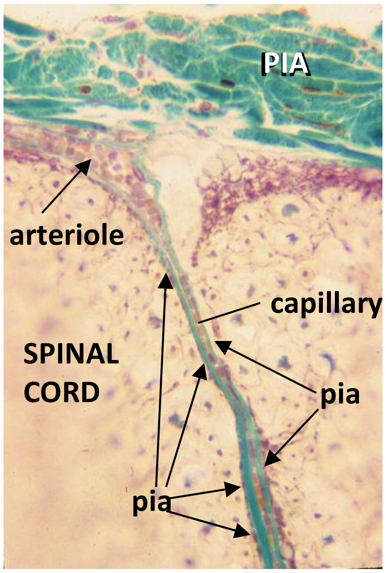


Territories of the anterior and posterior spinal arteries

Virchow-Robin Space – **slide 106**

Blood vessels in the subarachnoid space entering the spinal cord and brain do not penetrate the pia. Rather they remain surrounded by it, creating a perivascular space between pia and blood vessel known as the Virchow-Robin space that extends to the level of capillaries. It is continuous with the subarachnoid space and with CSF. It may serve as a route for extracellular fluid exchange with the CSF, but it may also be a route for transmission of infection from the subarachnoid space.





If you need more information on spinal cord anatomy, see this reference: https://accessmedicine.mhmedical.com/content.aspx?bookid=2478&sectionid=202020055#1158276585