The Spinal Cord

Lab 3

January 15, 2024 - Dr. Krebs (claudia.krebs@ubc.ca)

Objectives:

1. Describe the gross anatomy of the spinal cord and its relationship to the vertebral canal and the organization of blood supply to the spinal cord.
2. Identify the locations of the corticospinal tract, the posterior column-medial lemniscus system and the anterolateral system in a cross section of the spinal cord.
3. Identify the location of somatic sensory, visceral sensory, somatic motor and visceral motor neurons in the gray matter of the spinal cord.
4. Sketch the longitudinal course of the corticospinal tract, the posterior column-medial lemniscus system and the anterolateral system throughout the spinal cord and brainstem and demonstrate an understanding of somatotopic arrangement, site of crossing fibres, and modalities carried within these tracts.
5. Identify the meningeal layers around the spinal cord and relate these to the spaces they border with and define. Explain the functional importance of these spaces for clinical practice.
6. Describe how the neuroanatomy of micturition relates to the underlying pathways and their locations in the brainstem and spinal cord. Correlate clinical presentations of bladder dysfunction to lesions of these pathways.
7. Describe the typical symptoms seen in spinal cord injuries as they relate to motor, sensory and autonomic function to the tracts discussed in this lab.

Resources

Below are the e-tutorials, videos and web resources for this lab - click the green buttons to access them.

Spinal Cord (Module) | Spinothalamic Tract (Module) | Corticospinal Tract (Module)

PCML Pathway (Module) | Micturition (Module)

Spinal Cord (Video) | Spinal Nerves (Video) | Web Syllabus & Links

*This icon located throughout the lab manual indicates **checklist items**!*

*Check out our neuroanatomy game **Cerebro**!*

APK Download (Android)
App Store (iOS)

Note: Case discussion videos are posted on Entrada.

Please use these cases to apply your knowledge to the clinical scenario. Try to reason through the cases rather than memorizing an answer. Every patient presents differently and your ability to manipulate and apply your knowledge will lead towards diagnosis.

Remember: neurology is applied neuroanatomy!

** NOTE: Interactive PDFs are best viewed on desktop/laptop computers - functionality is not reliable on mobile devices **

The Spinal Cord

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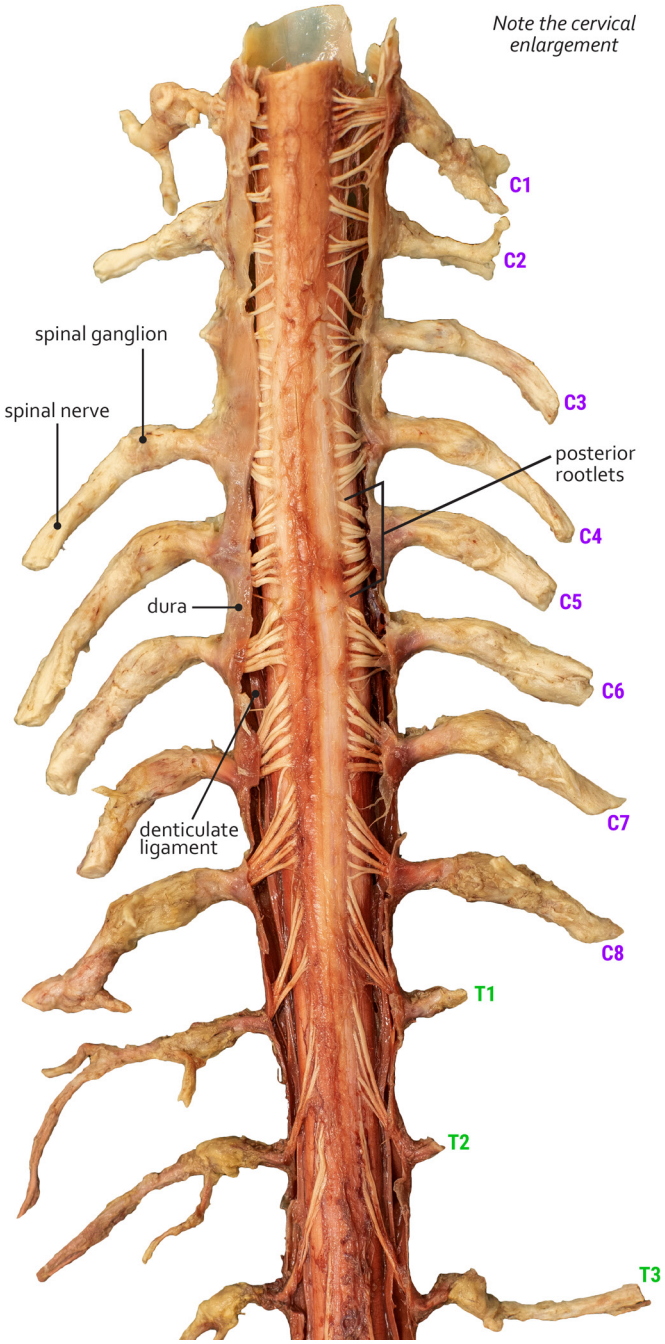
Gross Anatomy

Identify the following structures on a spinal cord specimen:

- enlargements
- conus medullaris
- spinal nerves with anterior & posterior roots
- spinal ganglion
- filum terminale
- denticulate ligament



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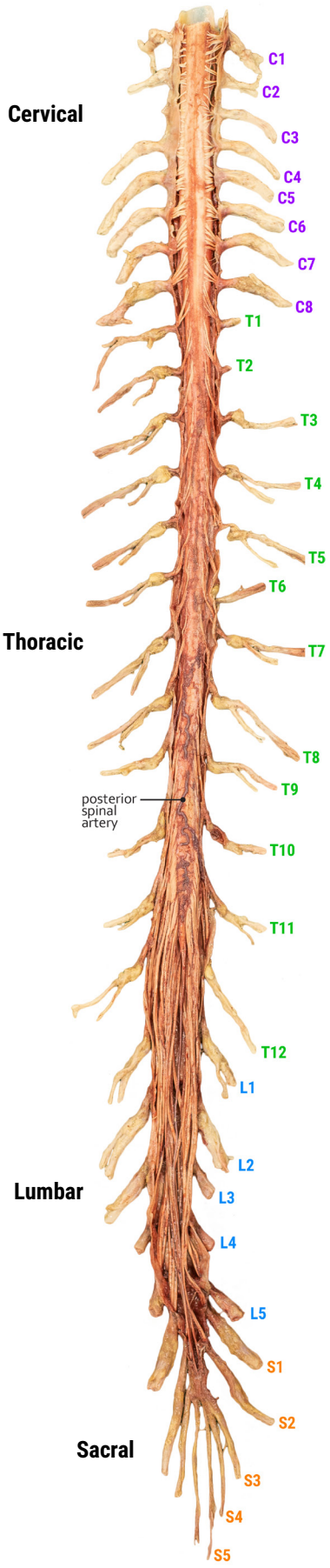
Dissection of Cervical Spinal Cord



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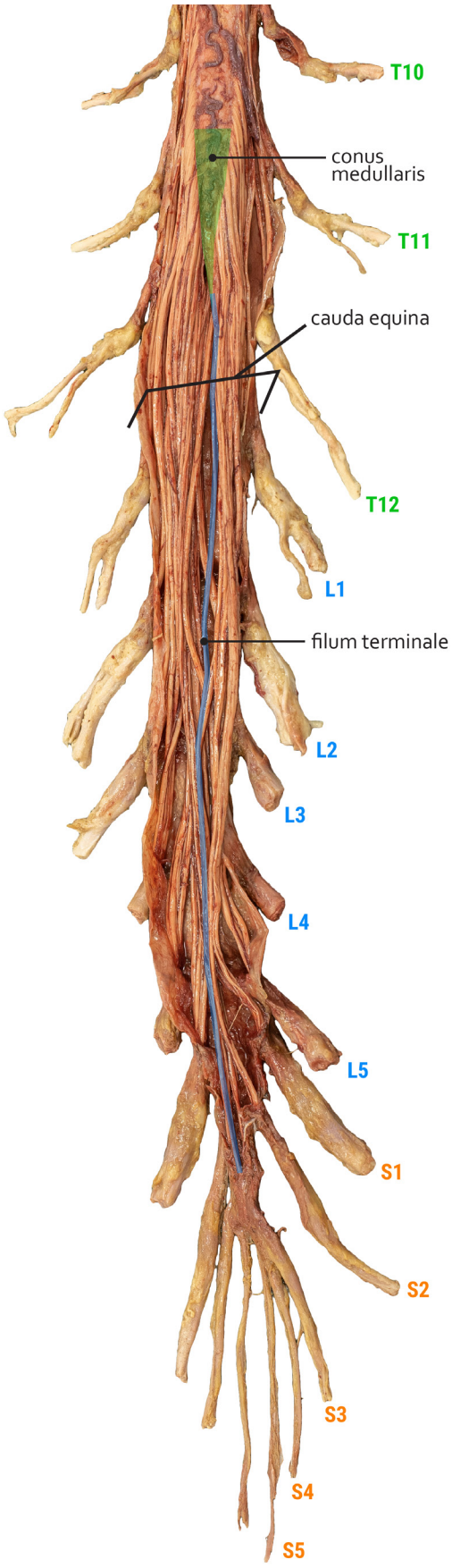

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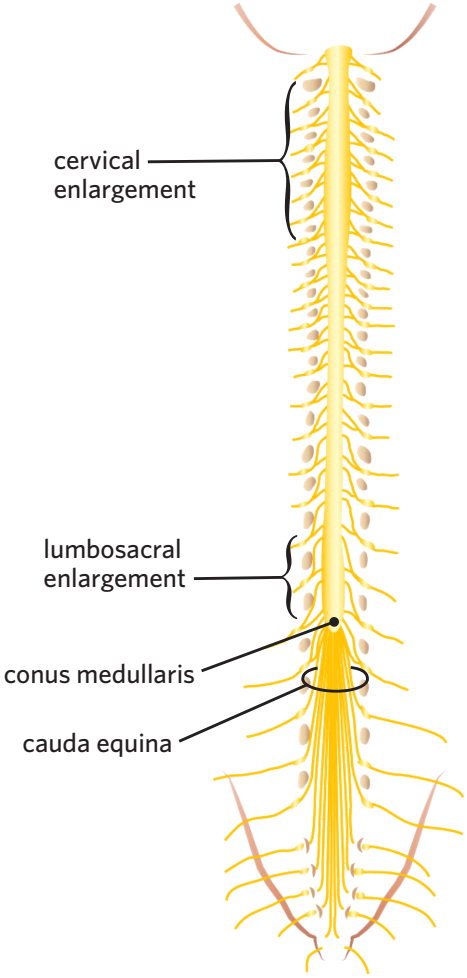
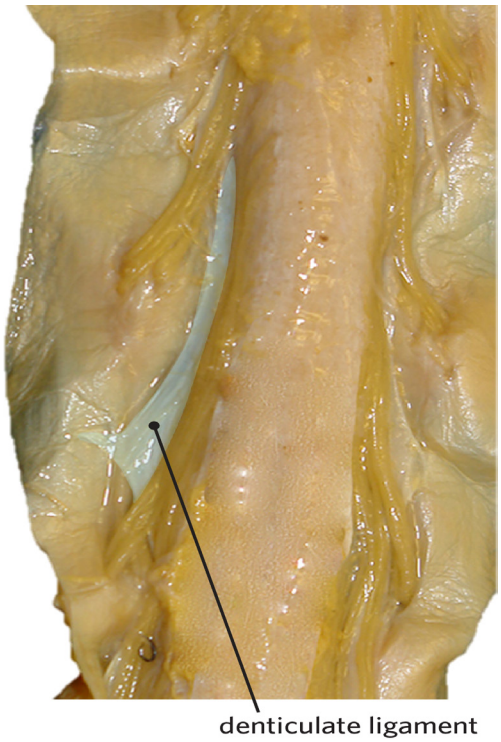
Dissection of Terminal Portion of Spinal Cord





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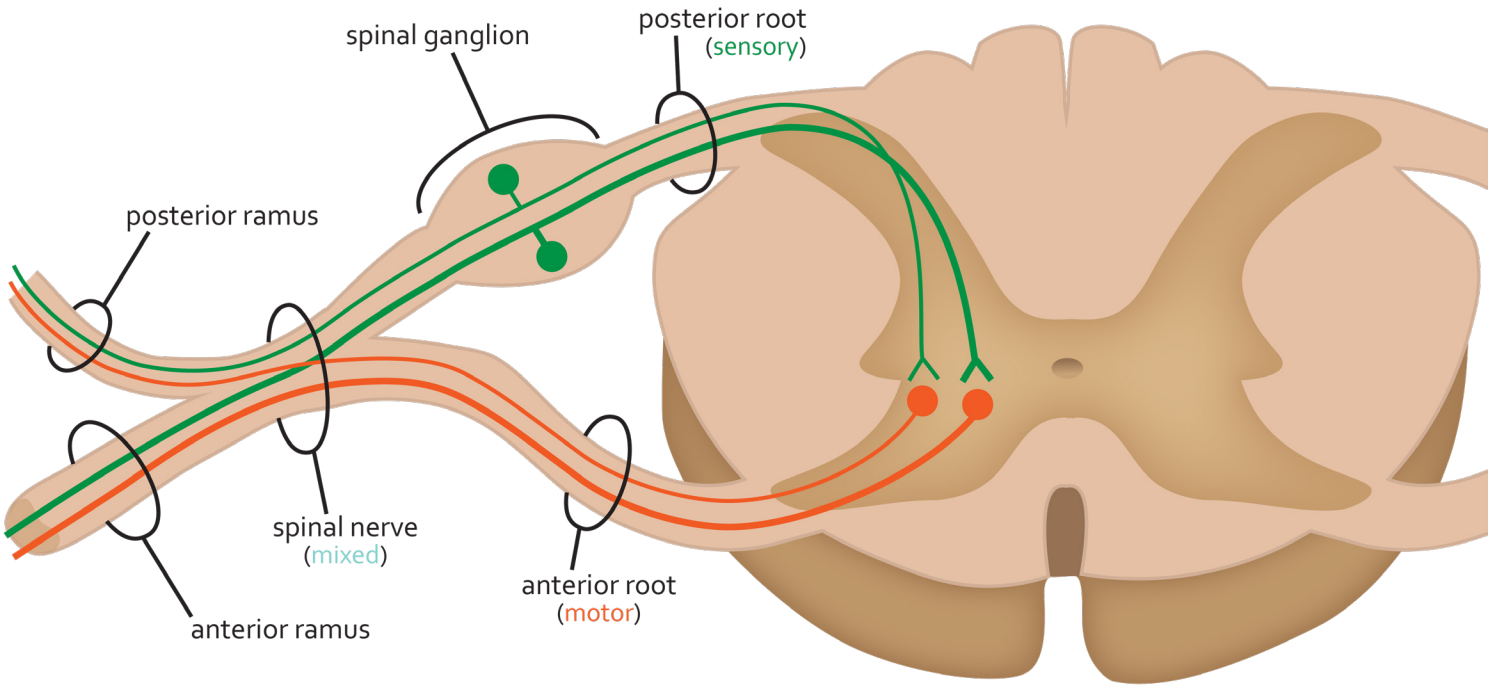

Schematic of Spinal Nerve Components

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Blood Supply

The **spinal cord** and **brainstem** are supplied by the **vertebral-basilar system**.

The **cortex** is supplied by both the **vertebral-basilar system** and **internal carotid system**.

All along the **spinal cord** you can find **one anterior spinal artery** and **two posterior spinal arteries**.

They receive their blood supply from two major sources:

1. vertebral-basilar system
2. segmental arteries

Identify the following arteries:

- ◯ basilar
- ◯ vertebral
- ◯ anterior spinal

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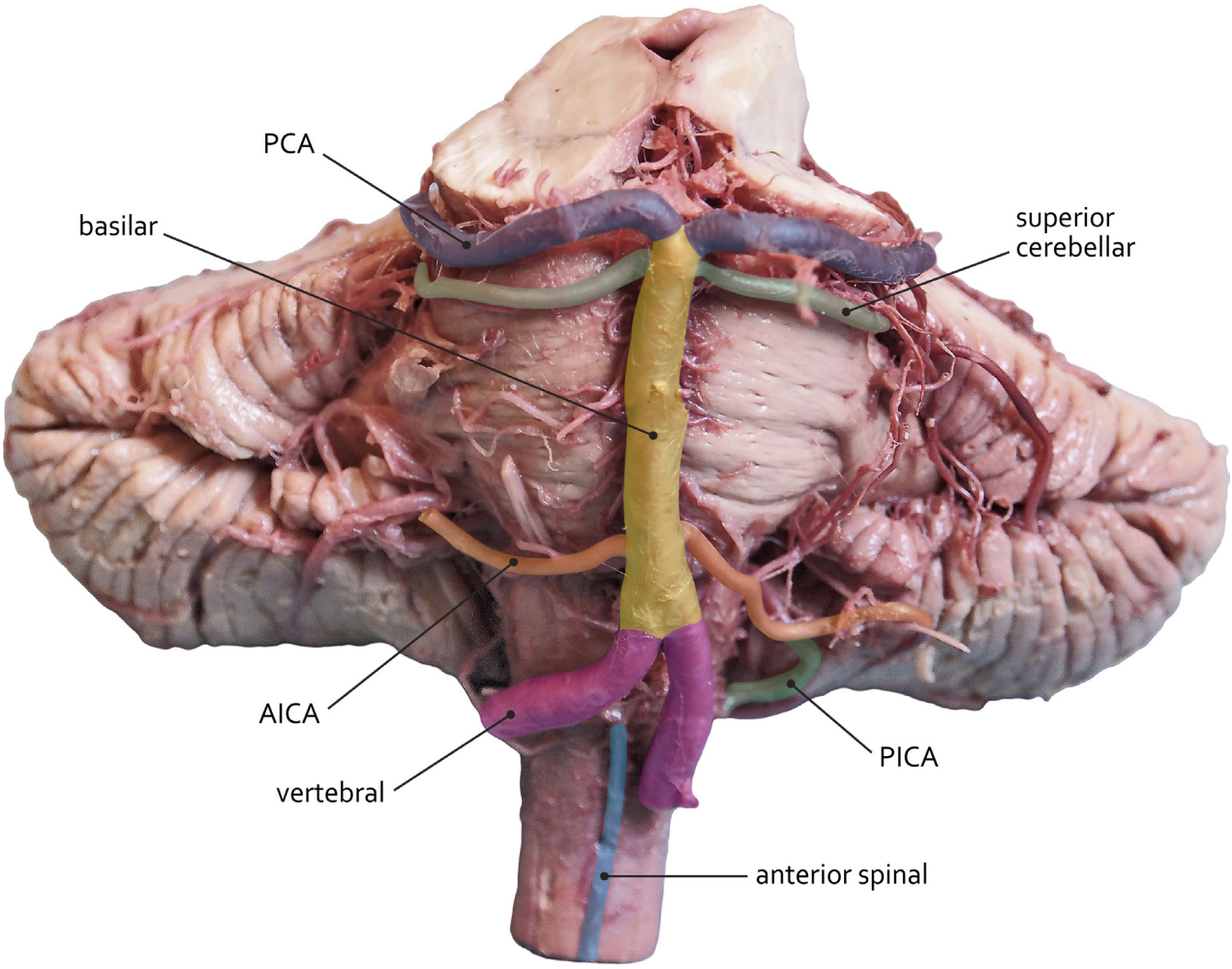
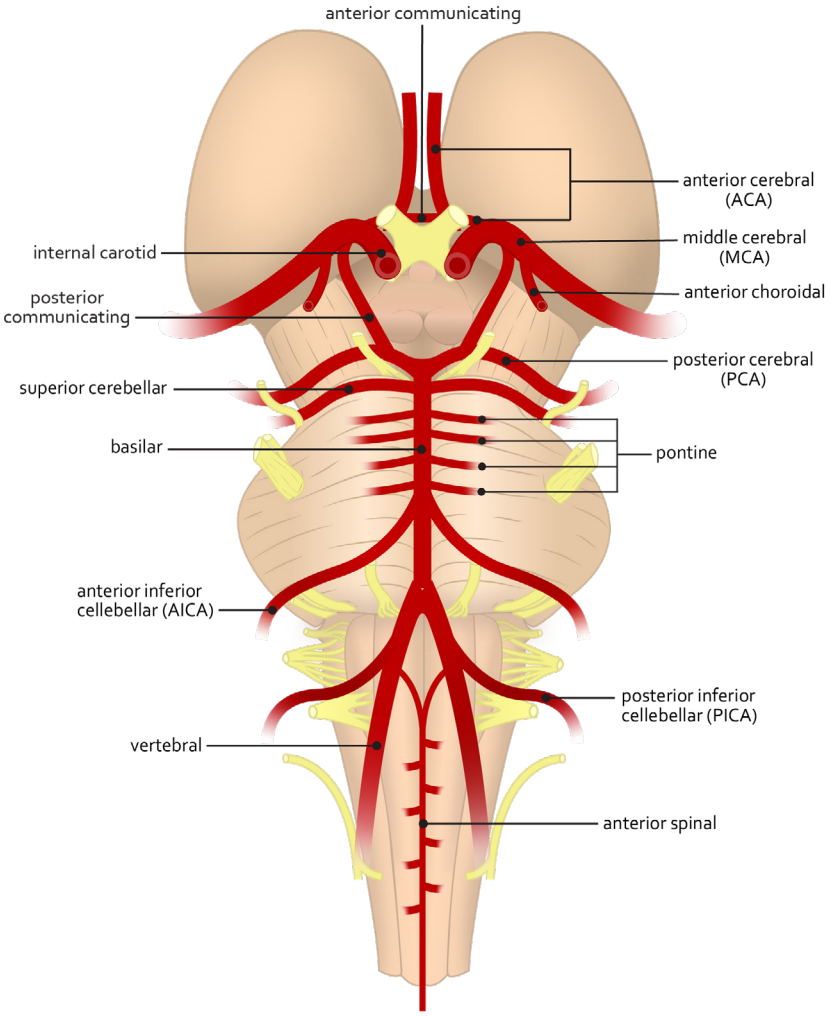


Vertebral-Basilar System on Brainstem



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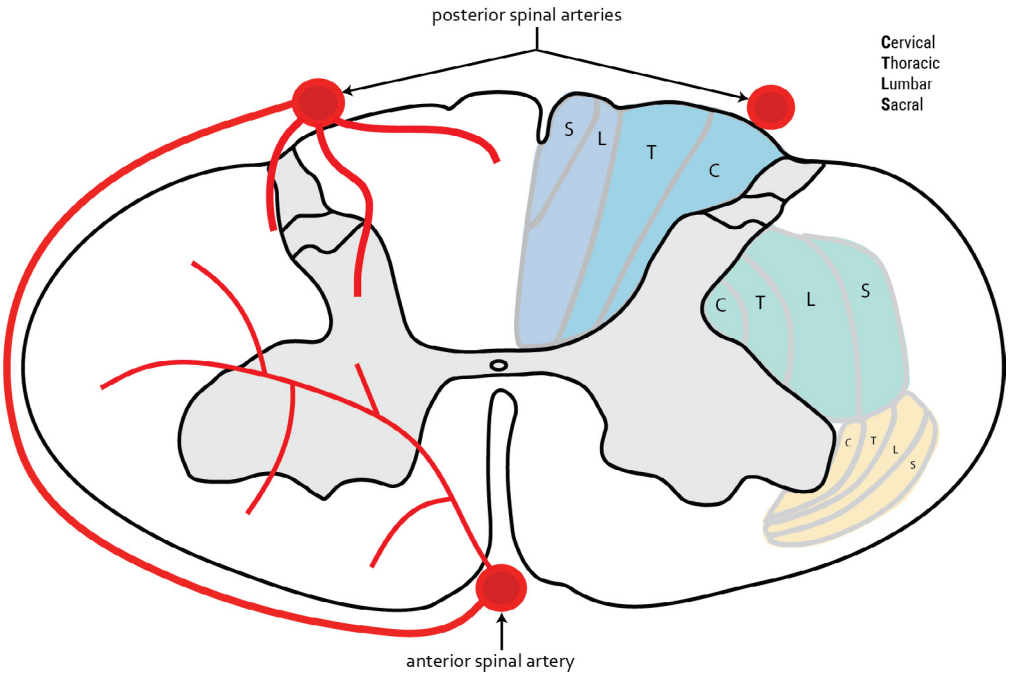
Cerebral Arterial Circle (Circle of Willis) on Anterior Brainstem



Show Perfusion Areas

Spinal Arteries in Spinal Cord Cross-Section

Gray Matter & White Matter

Micrographs (Web)

(interactive atlas for all micrographs)

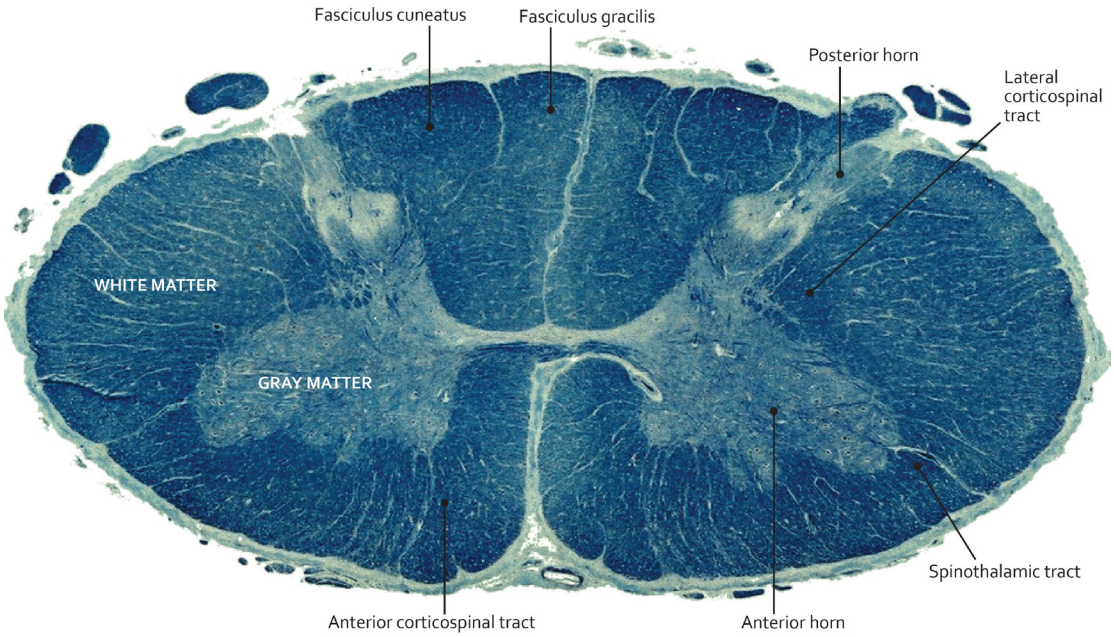
On micrograph #1 identify the following structures:

Gray Matter:

- ◯ anterior horn
- ◯ posterior horn

White Matter:

- ◯ spinothalamic tract
- ◯ posterior columns (fasciculus gracilis & fasciculus cuneatus)
- ◯ lateral and anterior corticospinal tracts



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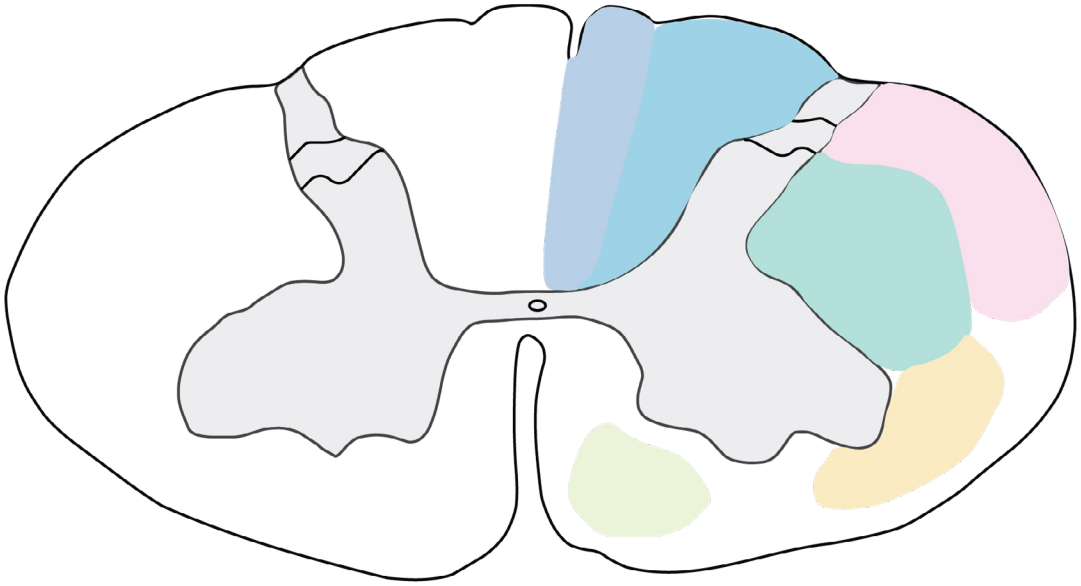
Spinal Cord in Cross-Section



Fasciculus gracilis
sensory (fine touch, proprioception, vibration) from ipsilateral lower limb

Fasciculus cuneatus
sensory (fine touch, proprioception, vibration) from ipsilateral upper limb

Spinocerebellar tract
proprioception from limbs to cerebellum

Lateral corticospinal tract
motor to ipsilateral ventral horn mostly limb musculature

Spinothalamic tract
pain, temperature and non-discriminative/coarse touch from contralateral side of the body

Anterior corticospinal tract
motor to ipsi- and contralateral ventral horn, mostly axial musculature

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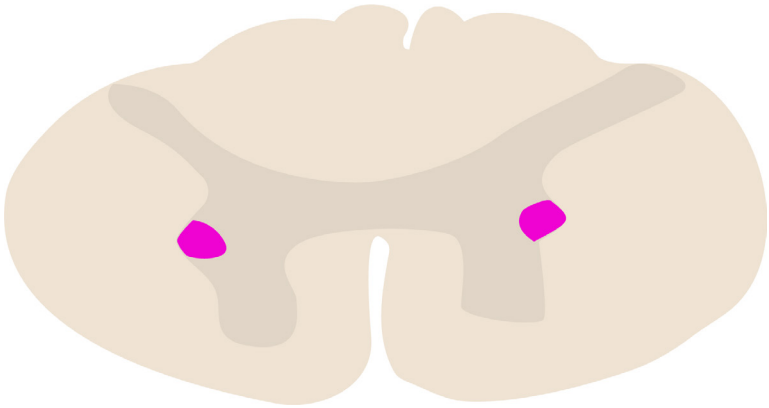
Location of sympathetic *neurons*

- in the lateral horn of the spinal cord at T1-L2



Sympathetic Neurons in Thoracic Cord

Location of parasympathetic *neurons*

- in the brainstem (associated with CN III, VII, IX, X) and in the sacral cord (S2-4, lateral horn)

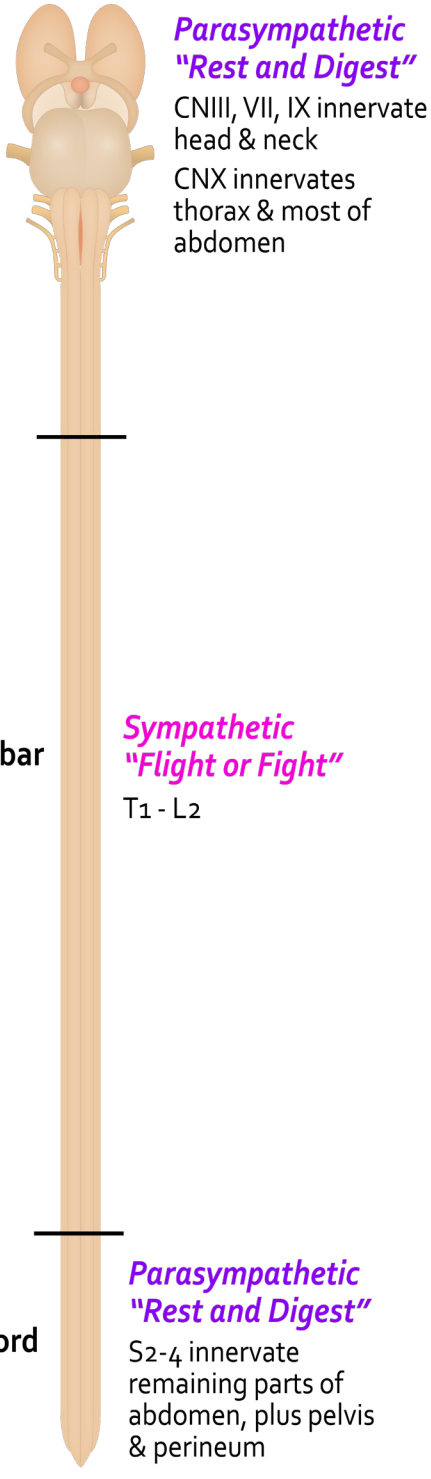
Parasympathetic Neurons in Sacral Cord

Note:
There is a study and some evidence that the sacral outflow may need to be re-defined as sympathetic. This is a matter of great controversy at the moment. Stay tuned to this research!

Spiral from MEDD 411:

Sympathetic NS (Video)

Parasympathetic NS (Video)



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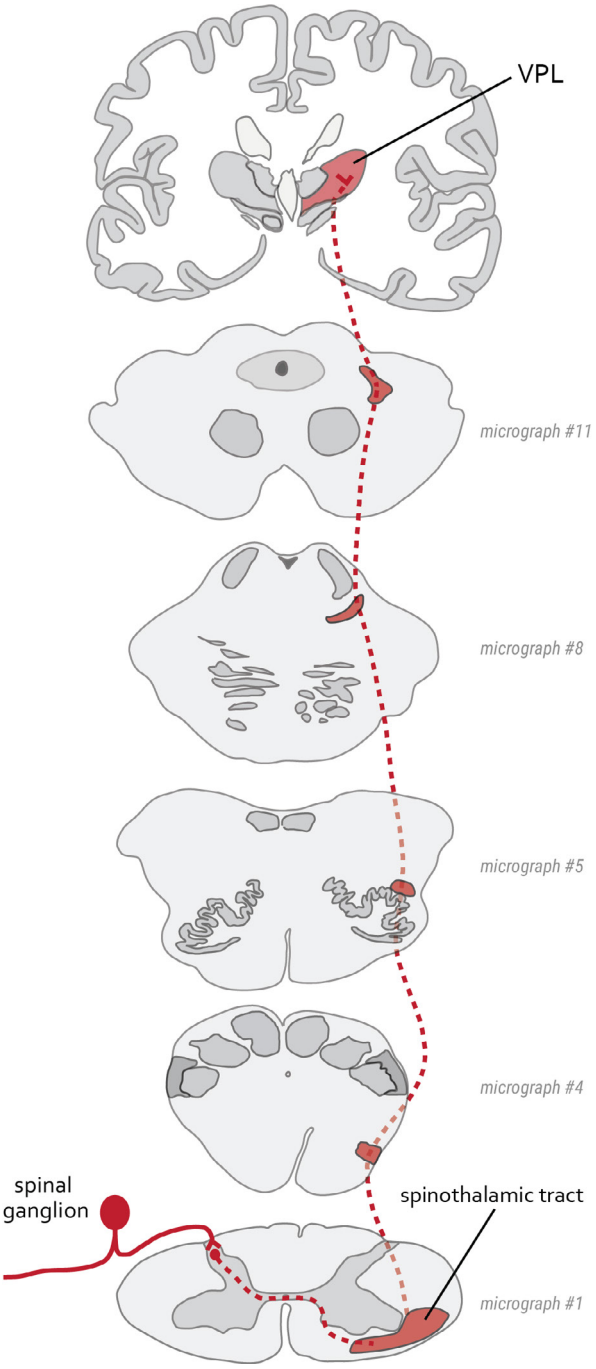
Spinothalamic Tract

Spinothalamic Tract (Module)

- Pain and temperature
- Non-discriminative (coarse) touch



5 The spinothalamic tract terminates in the VPL of the thalamus. From the thalamus fibers project through the internal capsule and corona radiata to terminate in the primary somatosensory cortex (postcentral gyrus).

4 In the pons and midbrain, the spinothalamic tract lies lateral to the medial lemniscus.

3 In the rostral medulla, the spinothalamic tract lies just posterior and lateral to the inferior olivary nucleus.

2 Spinothalamic tract in the caudal medulla.

1 Axons enter the spinal cord via the spinal ganglion, travel up or down 1-2 segments in Lissauer's tract and then synapse in the posterior horn.
Axons of secondary neurons cross the midline in the anterior white commissure and ascend as the spinothalamic tract in the spinal cord.

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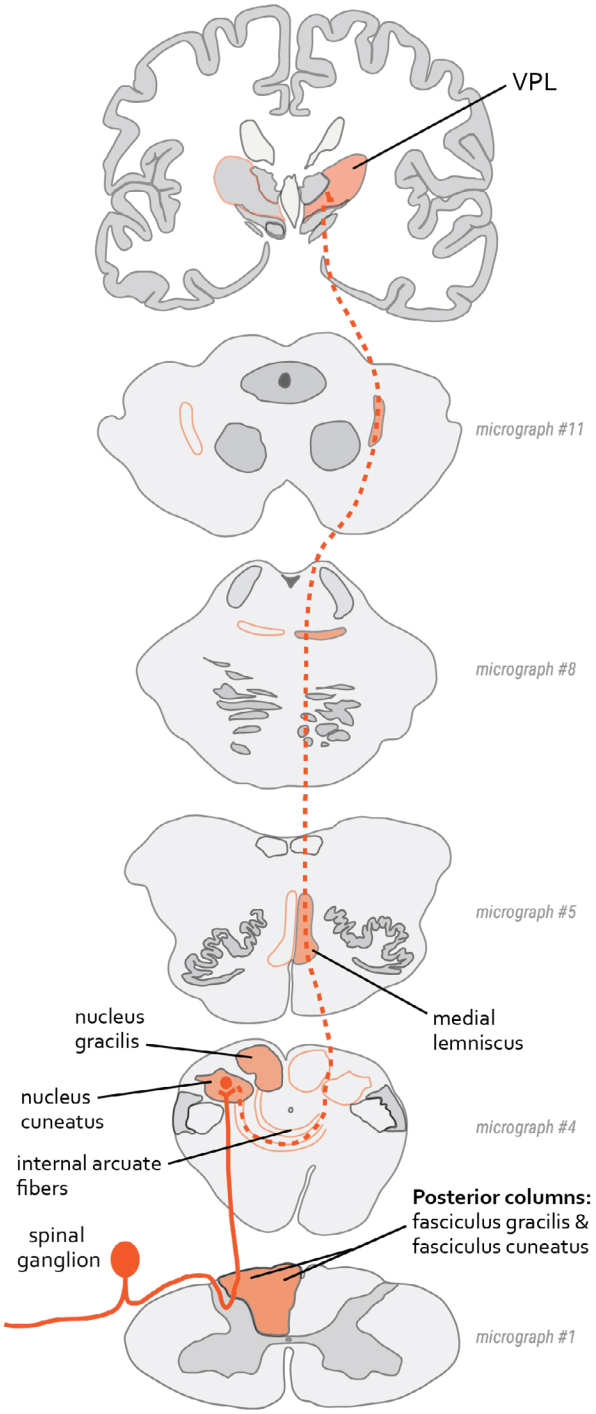
Posterior Column Medial Lemniscus Pathway

- Discriminative (fine) touch, vibration and conscious proprioception

PCML Pathway (Module)



6. The medial lemniscus terminates in the VPL of the thalamus. From the thalamus fibers project through the internal capsule and corona radiata to terminate in the primary somatosensory cortex (postcentral gyrus).

5. As the medial lemniscus continues to ascend through the rostral pons and midbrain, it moves laterally and vertically.

4. In the caudal pons, the medial lemniscus flattens horizontally.

3. In the rostral medulla, the fibers travel as the medial lemniscus adjacent to the midline.

2. They terminate in nucleus gracilis and nucleus cuneatus. From these nuclei, axons of secondary neurons cross the midline as internal arcuate fibers, and form the medial lemniscus.

1. Axons enter the spinal cord from the spinal ganglion and pass directly to the ipsilateral dorsal column.

   Caudal fibers (below T6) enter fasciculus gracilis (medial) and rostral fibers (at & above T6) enter fasciculus cuneatus to ascend.

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Lateral and Anterior Corticospinal Tract

Corticospinal Tract (Module)

- Voluntary motor control (below the head)

1. The corticospinal tract originates in the motor cortex.
   Descending fibers form the corona radiata, and converge to pass through the posterior limb of the internal capsule.

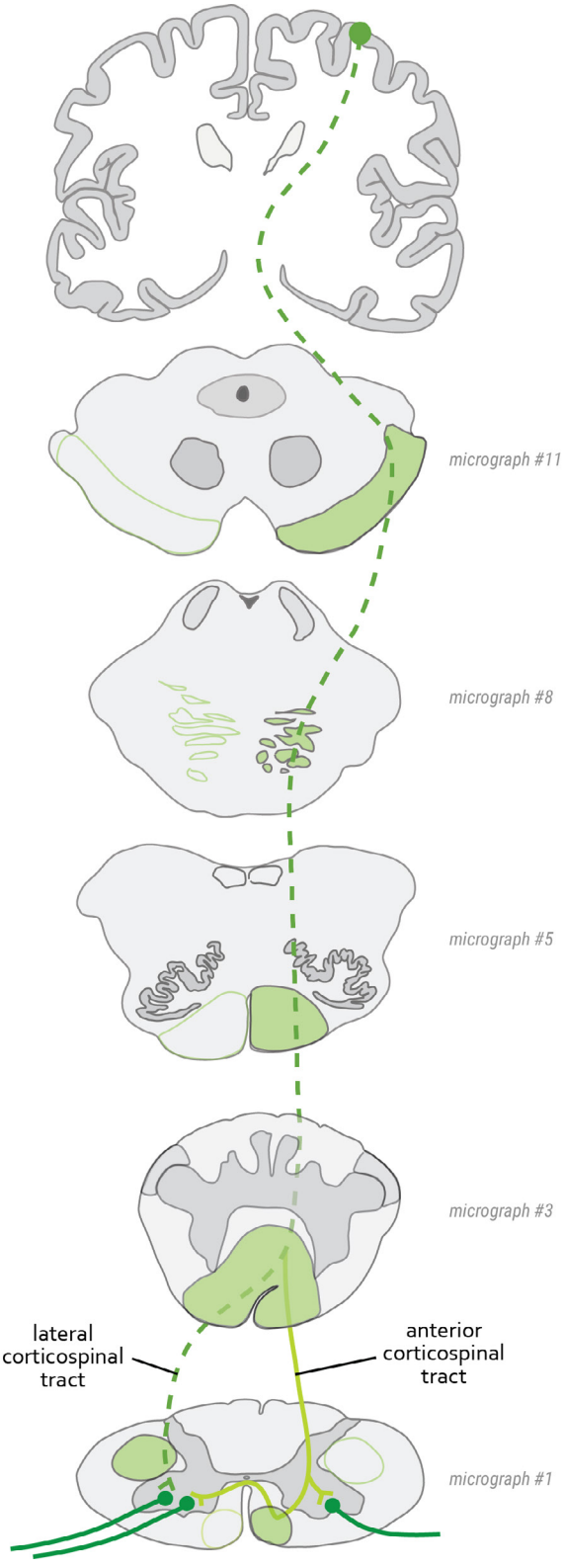
2. Corticospinal fibers descend through the middle of the cerebral peduncles in the anterior part of the midbrain.

3. In the pons, the fibers are broken up into many bundles.

4. The corticospinal tract descends as the pyramids in the anterior part of the medulla.

5. At the junction of the medulla and spinal cord, most (85-90%) fibers cross the midline in the decussation of the pyramids. These crossed fibers go on to form the lateral corticospinal tract.
   Uncrossed fibers (10-15%) descend as the anterior corticospinal tract.

6. The lateral corticospinal tract terminates on the ipsilteral lower motor neurons (LMN) in the anterior horn of the spinal cord.
   The anterior corticospinal tract fibers cross the midline at the level where they terminate on the LMNs.



Identify on micrographs:

Micrographs (Web)

(interactive atlas for all micrographs)

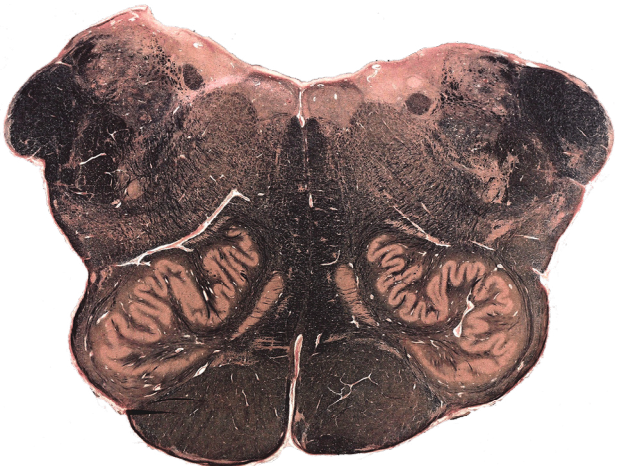
#11 (superior midbrain)

- ◯ medial lemniscus
- ◯ medial longitudinal fasciculus
- ◯ spinothalamic tract

#8 (rostral pons & cerebellum)

- ◯ medial lemniscus
- ◯ medial longitudinal fasciculus
- ◯ corticospinal fibers
- ◯ spinothalamic tract

#5 (superior medulla)



- ◯ medial lemniscus
- ◯ medial longitudinal fasciculus
- ◯ spinothalamic tract
- ◯ spinocerebellar tract
- ◯ pyramid

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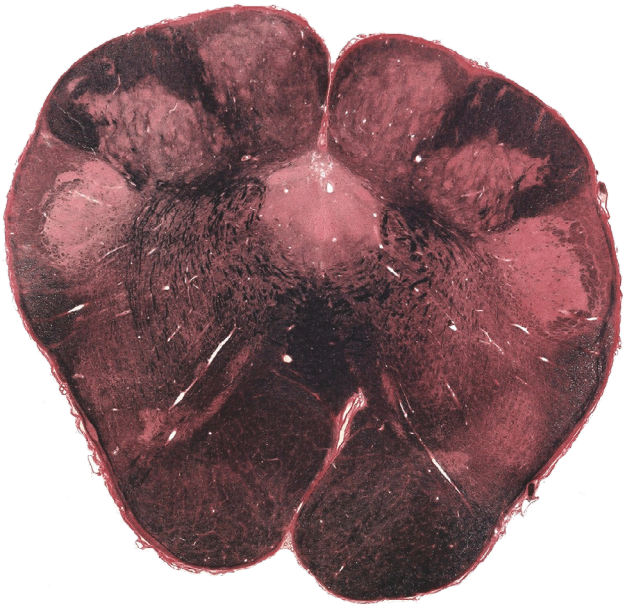
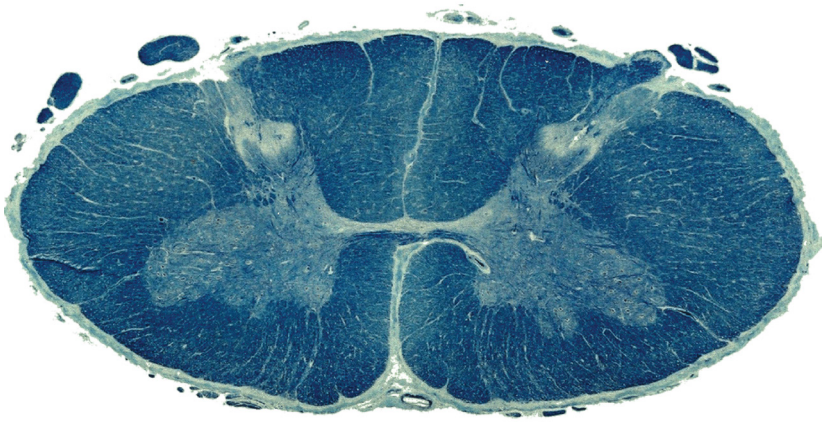
#4 (medulla)



- ◯ fasciculus gracilis, fasciculus cuneatus (posterior columns)
- ◯ nucleus gracilis, nucleus cuneatus
- ◯ internal arcuate fibers
- ◯ spinothalamic tract
- ◯ spinocerebellar tract
- ◯ pyramid

#1 (spinal cord)



- ◯ anterior & lateral corticospinal tracts
- ◯ fasciculus gracilis, fasciculus cuneatus (posterior columns)
- ◯ anterior & posterior horns
- ◯ spinothalamic tract
- ◯ spinocerebellar tract

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Illustration: Milo Applejohn

Case #1

Mr. Grant (he/him) presents with the following neurological symptoms:

1. Spastic paralysis of the left leg, positive Babinski sign (toes upgoing) on the left; both upper limbs have full strength and show no spasticity.
2. Loss of discriminative touch, vibration and joint position sense from approximately the level of the nipples down on the left side only.
3. Loss of pain and temperature sensation from the mid-abdomen downward on the right side.

List the complaints and a possible neuroanatomical location for the complaints.

Where do you think the lesion could be?

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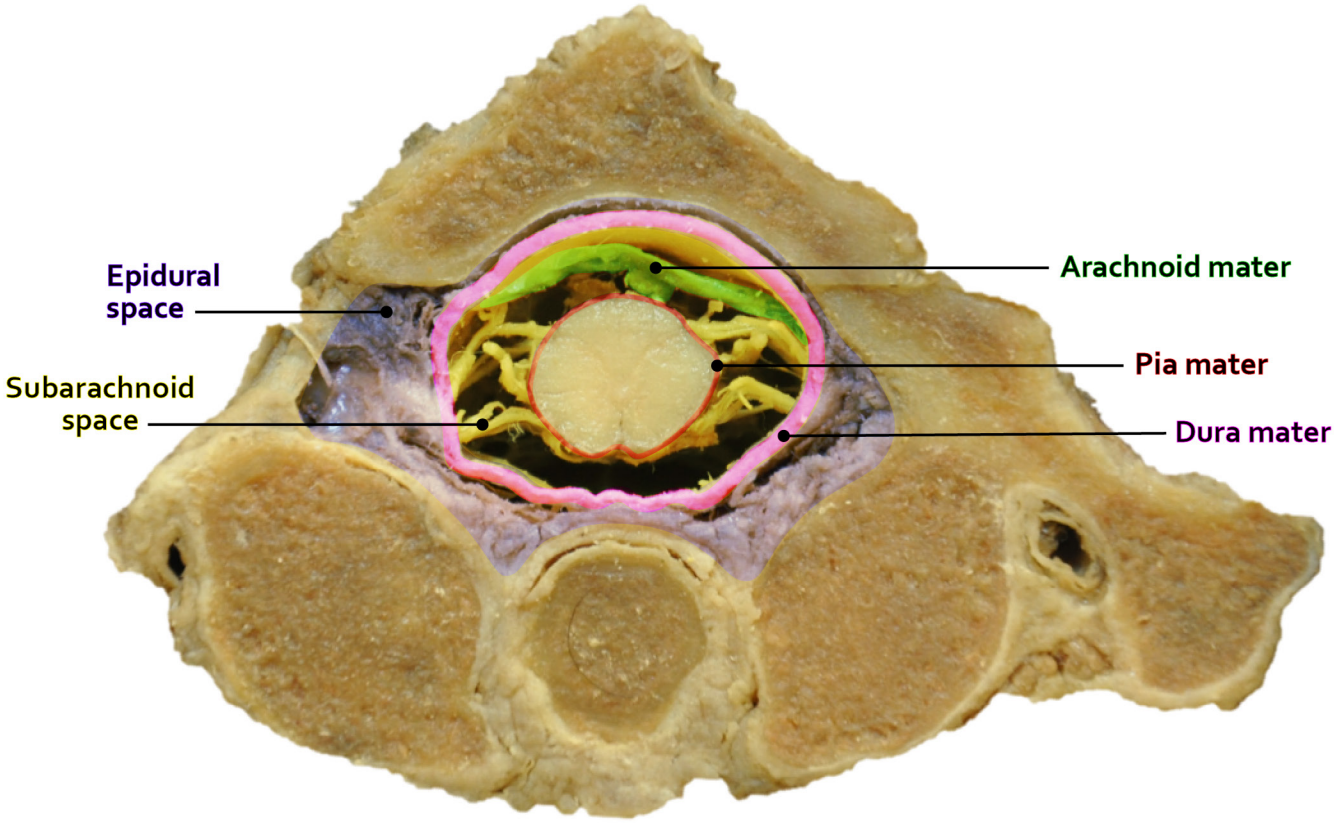
Meninges

Identify the following structures on a spinal cord specimen:

- Spinal meninges
  - Dura mater
  - Arachnoid mater
  - Pia mater
- Epidural space
- Subarachnoid space



Cervical Spinal Cord (cross-section)

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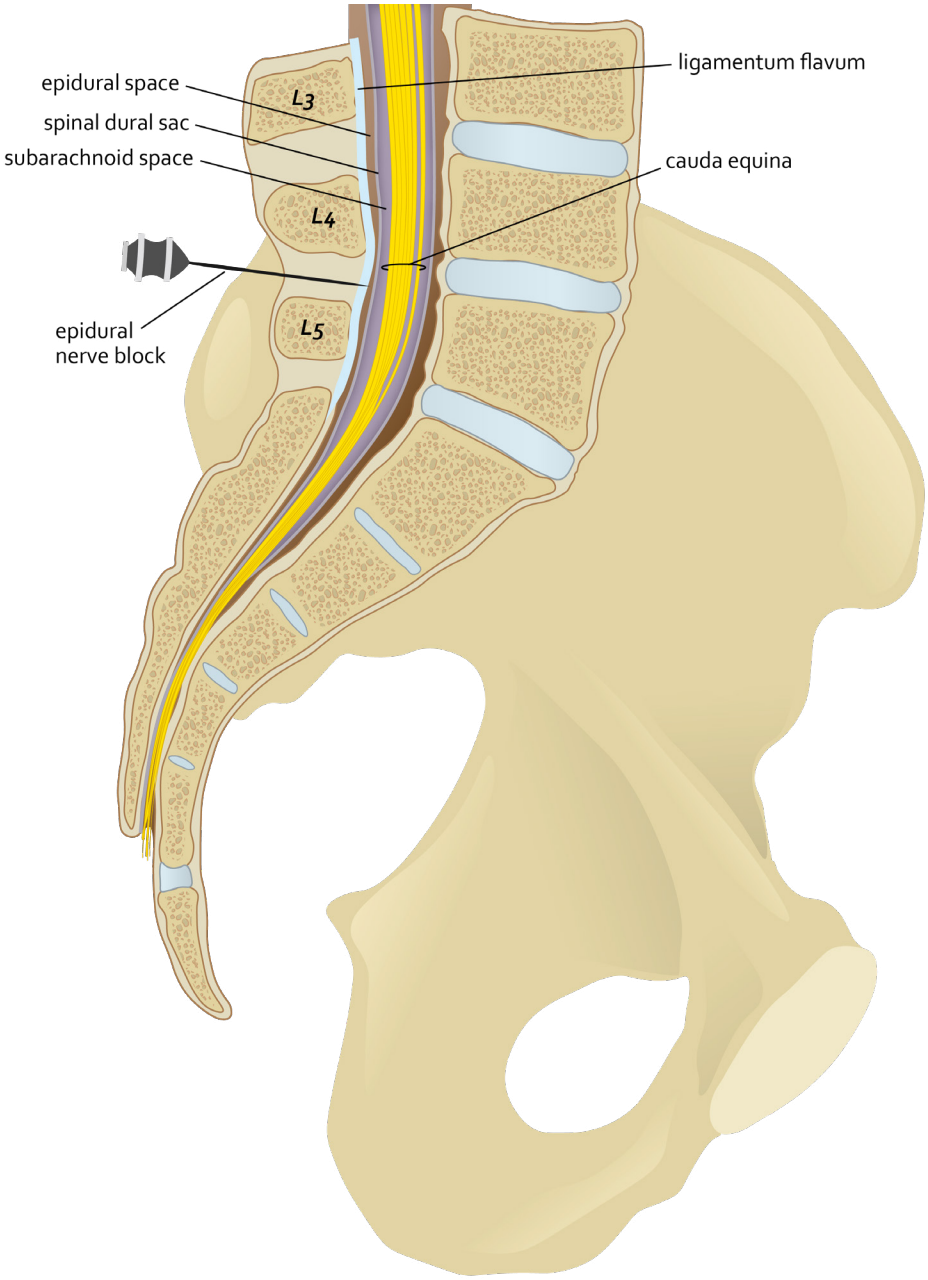
The anatomical layers around the spinal cord are important for clinical practice.

The **epidural space** is used to administer anaesthetic for temporary pain relief.

The **subarachnoid space** is filled with CSF. You can insert a needle into this space to obtain a sample of CSF.

Check out this video for a clinical guide to performing a spinal tap: CSF Sampling (Video)



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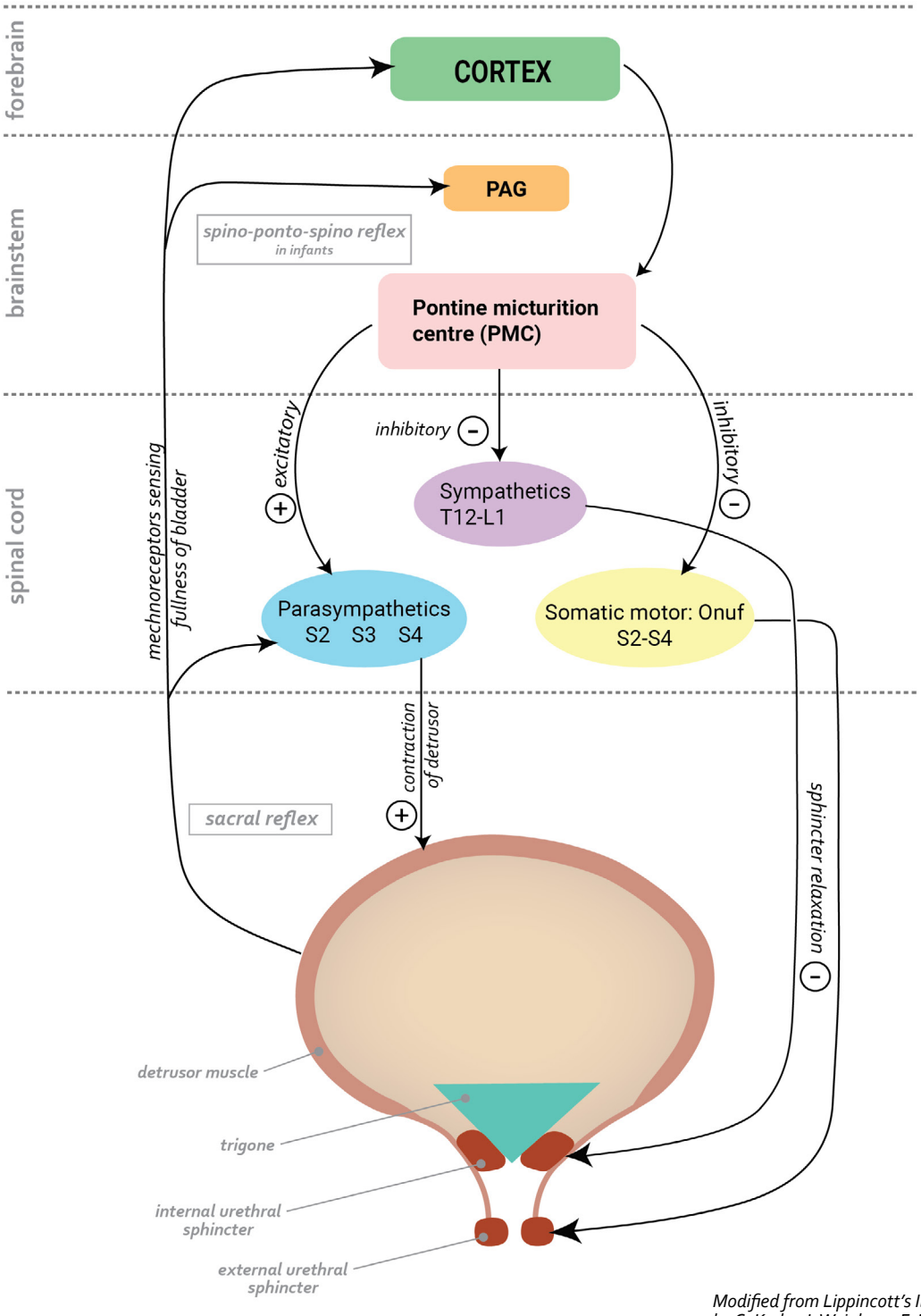
Micturition

The control of micturition is a complex interplay between the visceral and somatic nervous systems, and it involves various levels of the spinal cord, the brainstem and the cortex. Patients with spinal cord injuries will have this system impacted.



Micturition (Module)

E-tutorial with a step-by-step interactive guide to micturition

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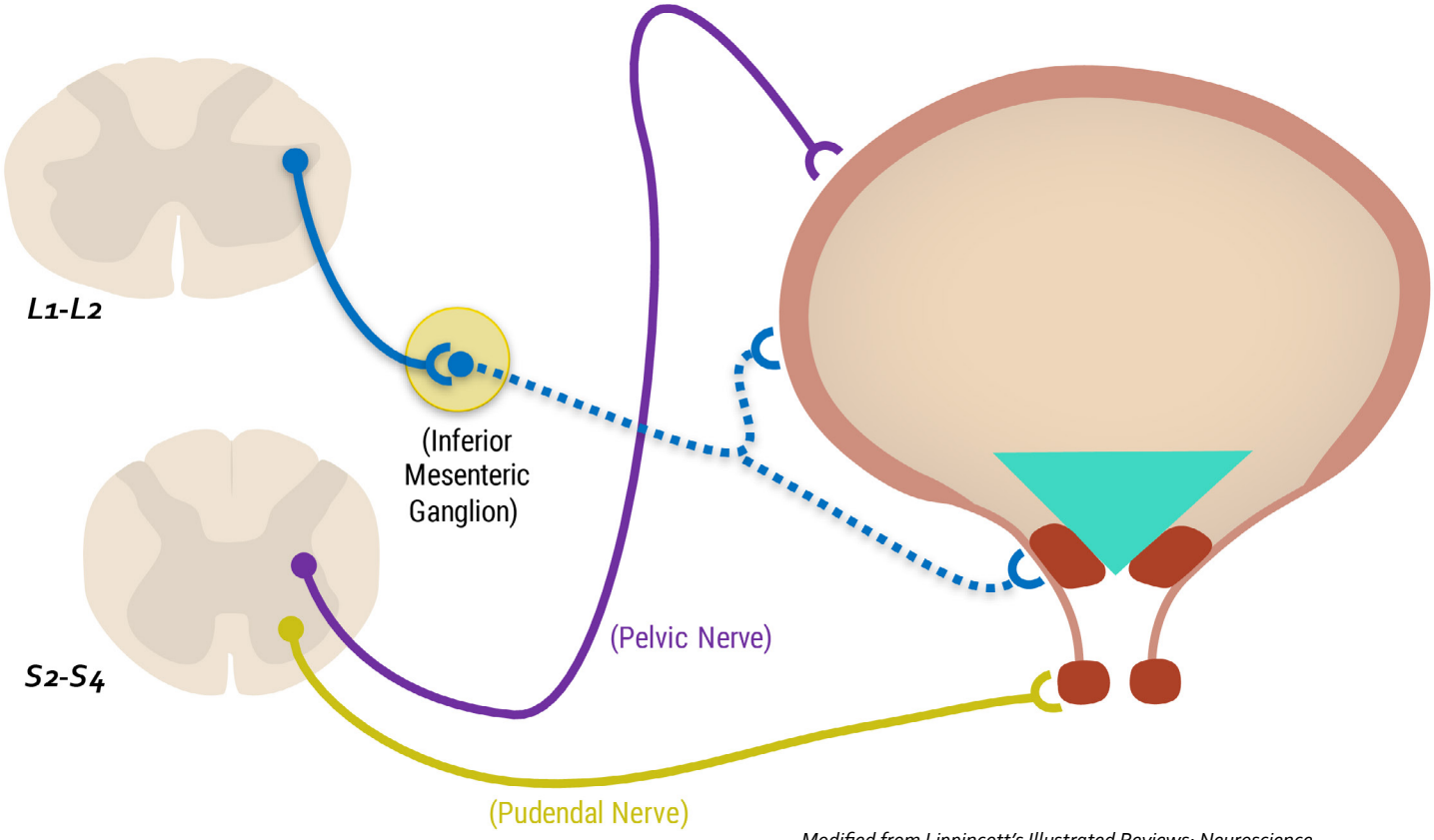
Innervation of the Bladder

1. **Pain and temperature (somatic afferent)**
   - from mucosa of fundus; fibers travel with sympathetics, reach spinal cord at T12/L1; from there via spinothalamic tract to CNS
   - from neck of bladder; travel with sympathetics, reach spinal cord at S2, 3, 4; from there via spinothalamic tract to CNS
2. **Fullness of bladder (visceral afferent)**
   - mechanoreceptors in the bladder wall; project to sacral parasympathetics S2, 3, 4
3. **Voiding (parasympathetic visceromotor)**
   - detrusor muscle innervated by parasympathetics from S2, 3, 4
4. **Innervation of the internal urethral sphincter (sympathetic visceromotor), males only**
   - sympathetic visceromotor neurons (T11-L2)
5. **Innervation of the external urethral sphincter (somatic motor, pudendal nerve)**
   - Onuf nucleus at S2, 3, 4 with pudendal nerve
6. **Micturition centers**
   - Cortical: superior frontal gyrus
   - Pons: pontine micturition center and pontine storage centre, periaqueductal gray



Approach to Innervation of the Bladder

What do you want to do?

Voiding Urine

- Is the bladder full? **sensory fibers: spinal cord to cortex**
- Is it appropriate? **cortical decision**
- Let's coordinate voiding! **Pontine micturition centre (PMC)**: brainstem, pons
- To void, the detrusor needs to contract and the sphincter needs to relax
- **Detrusor** is innervated by **parasympathetic fibres** from S2-4 in the spinal cord (= *like a lower motor neuron*)
  - they get their input from the **PMC**
- **External sphincter** is innervated by **somatic fibres** from S2-4 (= *like a lower motor neuron*)
  - they get their input from the **PMC**
- PMC **stimulates the parasympathetics** (detrusor) and **inhibits the somatics** (sphincter)
- In males there is also an **internal urethral sphincter,** which receives **sympathetic innervation** (T12 / L1)
  - it is also inhibited by the **PMC**

Retaining Urine

- When you want to retain urine in the bladder, the **pontine storage center (PSC) coordinates the reverse**
  - **contraction of sphincter** and **relaxation of detrusor**

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Case #2

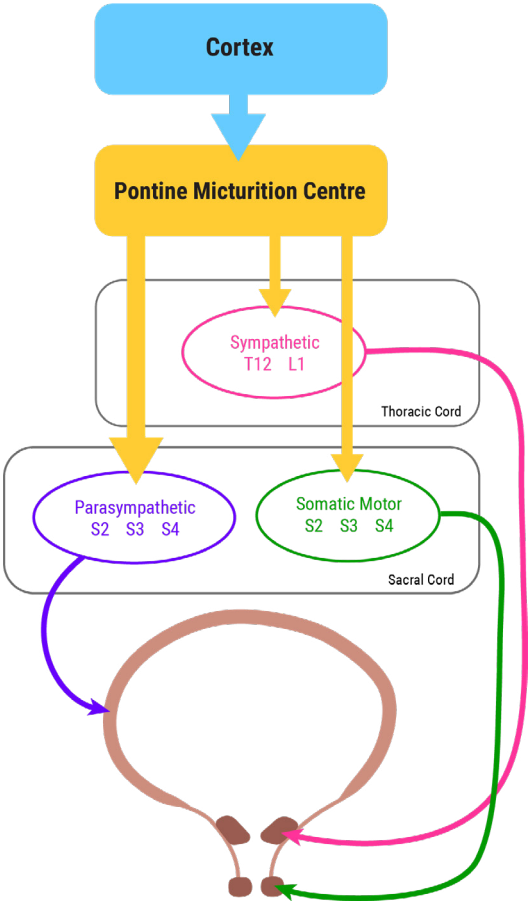
Travis (they/them; 24 years old) comes in severely injured in a mountain biking accident. Although conscious, they report excruciating back pain loss of motor and sensory function in their legs. They are placed in spinal precautions, air-lifted to a trauma centre.

Illustration: Milo Applejohn

What level of the spinal cord would be injured?

Think specifically about bladder function - which tracts are affected?

What are the consequences for bladder function?



Use this diagram to conceptualize the affected tracts and the consequences for function.

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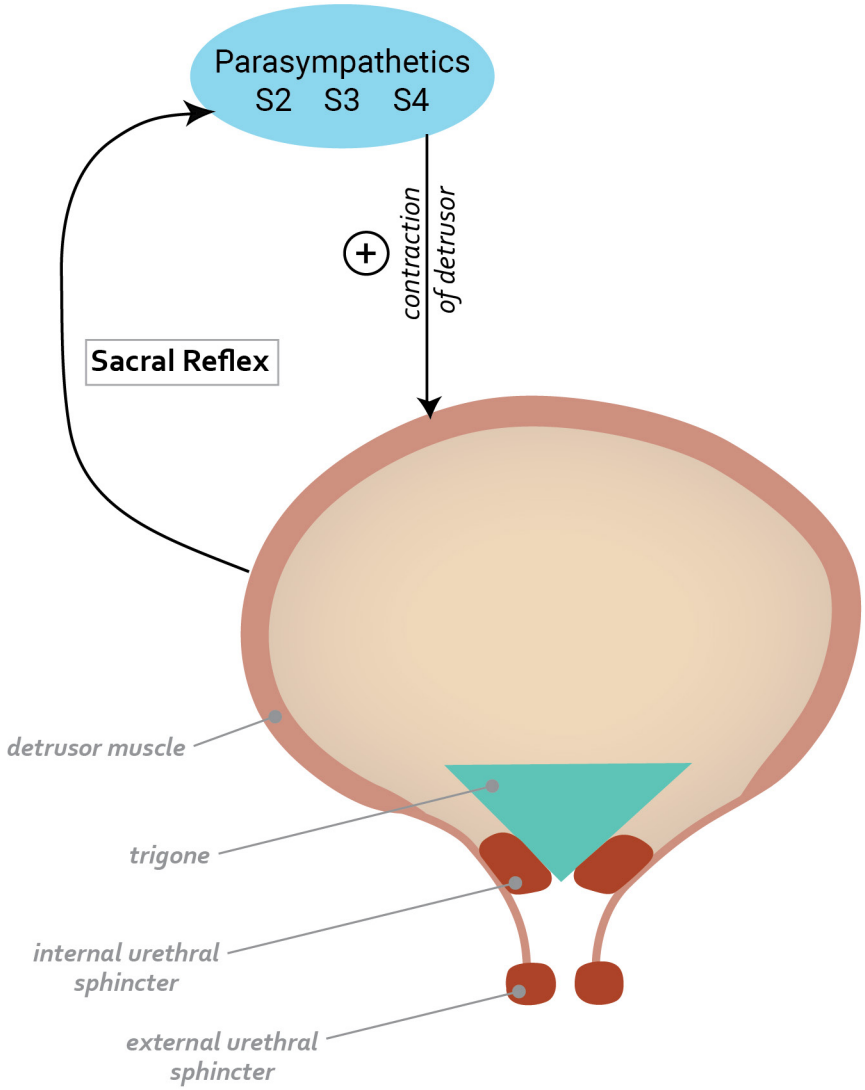
Sacral Reflex Pathway

1. Stretch receptors in bladder wall are activated
2. Stretch receptor output is transmitted via afferent fibers of the pelvic nerve to the sacral cord
3. Parasympathetic nerve cell bodies (S2-4) are activated, detrusor contracts

In infants: there is no control over the external sphincter

In adults: the external sphincter is under somatic control through the pudendal nerve



Modified from Lippincott's Illustrated Reviews: Neuroscience by C. Krebs, J. Weinberg, E.J. Akesson, and E. Dilli. For educational use only.

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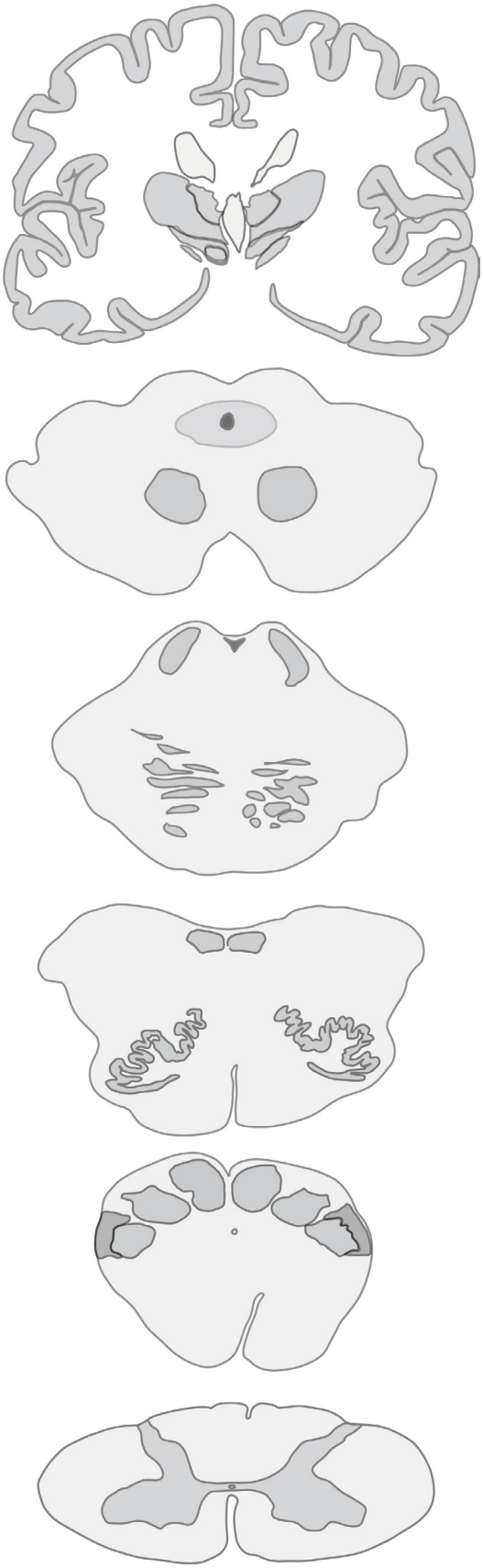
You can use this template to practice drawing the different pathways:



RESOURCES

Websites:

Neuroanatomy | Entrada

Recommended Textbooks:

Lippincott Illustrated Reviews: Neuroscience
By: Claudia Krebs, Joanne Weinberg, Elizabeth J. Akesson, Esma Dilli
Lippincott Williams & Wilkins
ISBN 978-1-4963-6789-1

Neuroanatomy Through Clinical Cases
By: Hal Blumenfeld
Sinauer
ISBN 978-0-8789-3613-7

Neuroanatomy in Clinical Context: An Atlas of Structures, Sections, Systems, and Syndromes
By: Duane E. Haines
Wolters kluwer Health
ISBN 978-1-4511-8625-3

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