The Brainstem
Objectives:
After completion of this session you should be able to complete the following objectives:

1. State the 3 major divisions of the brainstem.

2. Describe and identify the boundaries/landmarks that distinguish the medulla, the pons, and the midbrain from one another.

3. Be able to identify the gross anatomical landmarks/structures of the medulla, pons, midbrain on pictures, diagrams, or images.

4. Identify the 4 major transverse sections (levels) of the medulla and the nuclei and tracts that are associated with each of the 4 medullary levels.

5. Identify the 3 major levels of the pons and the nuclei and tracts that are associated with each level.

6. Identify the 2 major levels of the midbrain and the nuclei and tracts that are associated with both levels.

7. Describe the relationship between the ventricular system and the brainstem, i.e. which part of the ventricular system is associated with the midbrain, pons, and medulla?

8. Briefly describe and identify the major arteries that supply the medulla, pons, midbrain.

9. If given an a brainstem image of a lesion, be able to describe the signs/symptoms that you will see in patients with lesions to the the 3 major long tracts of the body: ALS, PC/ML, and voluntary motor pathway, or to cranial nerve nuclei. Or if given the deficits, be able to place the lesion in the proper brainstem location.

Brainstem featuring the Medulla Outline

I. The Brainstem
    A. General information
    B. Three major parts of the brainstem
    C. Gross anatomy of the brainstem
II. The Medulla Oblongata
    A. General information
    B. Gross anatomy of the medulla
    C. Intrinsic anatomy of the medulla - 4 major sections
        1. Caudal medulla
        2. Caudal to mid-medulla
        3. Mid-medulla
        4. Rostral medulla
III. The Pons
    A. General information
    B. Gross anatomy of the pons
    C. Intrinsic anatomy of the pons - 3 major sections
        1. Caudal pons
        2. Mid pons
        3. Rostral pons
IV. The Midbrain
    A. General information
    B. Gross anatomy of the midbrain
    C. Intrinsic anatomy of the midbrain - 2 major sections
        1. Caudal midbrain
        2. Rostral midbrain
    D. Reticular formation
    E. Blood Supply

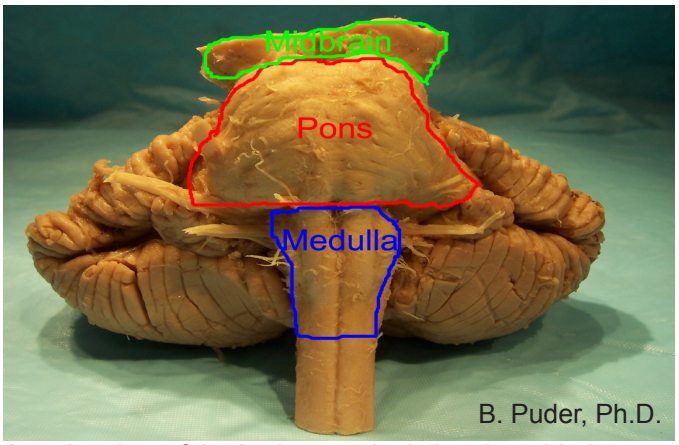
The Brainstem

The Brainstem is part of the CNS, its neighboring structures are the spinal cord caudally and the diencephalon rostrally.

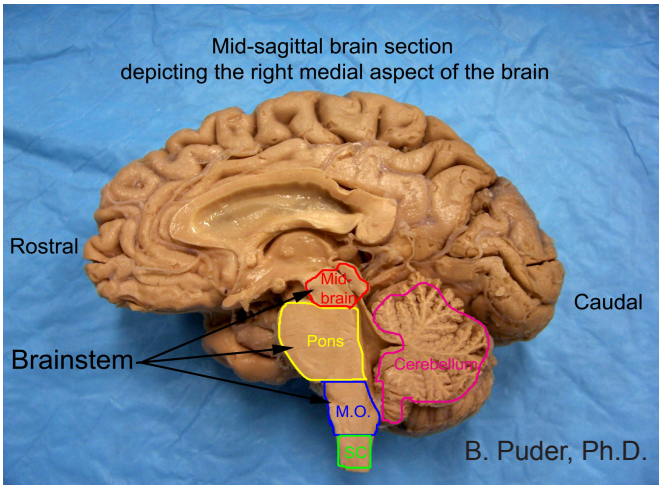
There are **3 major areas that comprise the brainstem:**

1. The **Medulla oblongata** (the most caudal portion)
2. The **Pons**
3. The **Midbrain** (the most rostral portion)

Each of the 3 major areas has some gross structures associated with it on the external surface and when the 3 major areas are sectioned transversely, there are some intrinsic structures - both nuclei and tracts that are identifiable as well.



Anterior view of the brainstem depicting the midrain, pons and medulla oblongata



Embryologically the brainstem developed from 2 of the 3 enlargements after the superior neuropore closed. Those 2 enlargements are the **midbrain (mesencephalon)** and the hindbrain (rhombencephalon). The hindbrain then divided further into the **metencephalon (pons and cerebellum)** and the **myelencephalon (medulla)** .

Please note that the cerebellum is part of the metencephalon, but not part of the brainstem.

There also exists “zones” or regions within the brainstem.

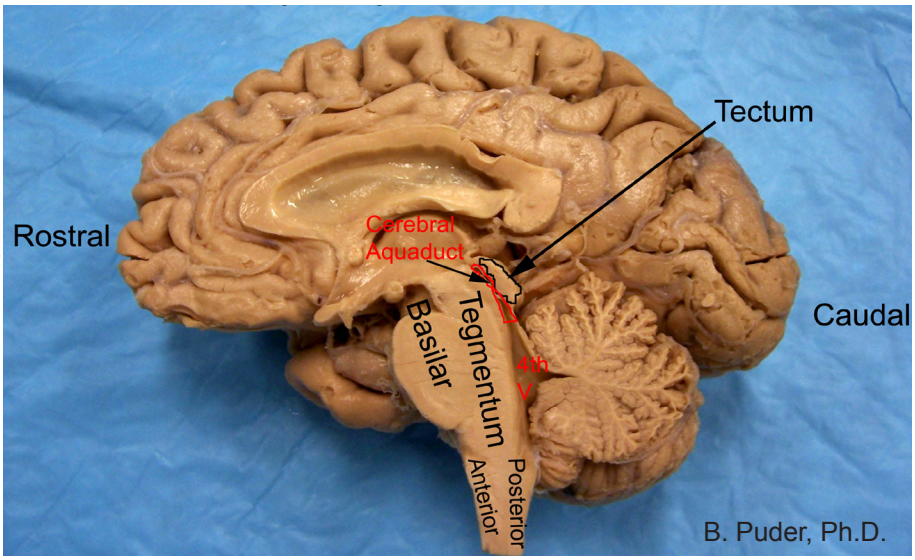
In the **Midbrain and Pons, the most anterior portion is referred to as the basilar part**, and the next part posteriorly to the basilar zone is called the **tegmentum**.

The **Midbrain has an additional zone called the tectum (it means roof)**.

The **zones in the Medulla are referred to as anterior or posterior,** just as we saw in the spinal cord.

The cerebral aquaduct and the 4th ventricle are the part of the ventricular system that is associated with the brainstem.

The cerebral aquaduct runs through the midbrain and divides the tectum from the tegmentum, and the 4th ventricle sits between the cerebellum and the pons and rostral medulla.

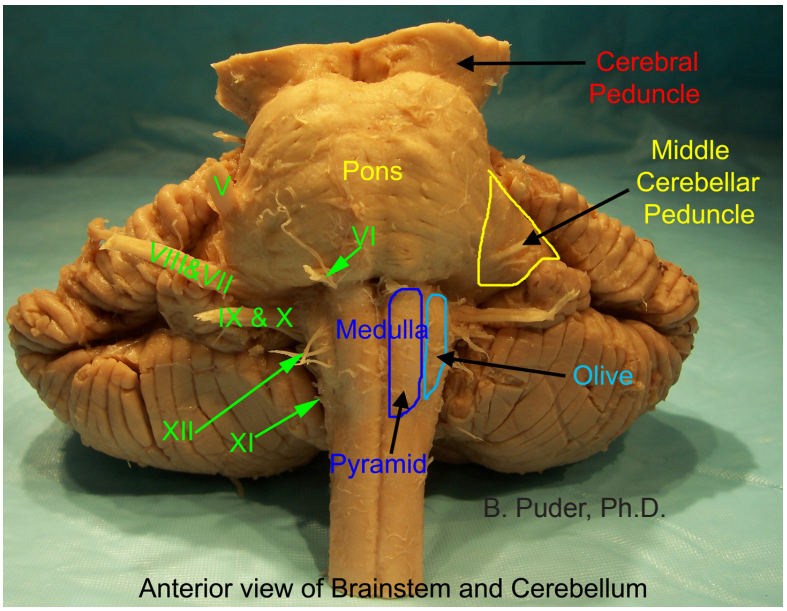


The Medulla
Boundaries: Spinal cord (caudally) and Pons (rostrally).
The Foramen Magnum is at the caudal most portion of the medulla.
Cranial nerves and/or their nuclei associated with the Medulla: XII, XI, X, IX, VIII, and part of V.
The 4th ventricle is located posterior to the rostral medulla, while the central canal runs through the caudal medulla.
Many of the ascending and descending tracts that were seen in the spinal cord are traveling through the medulla as well.

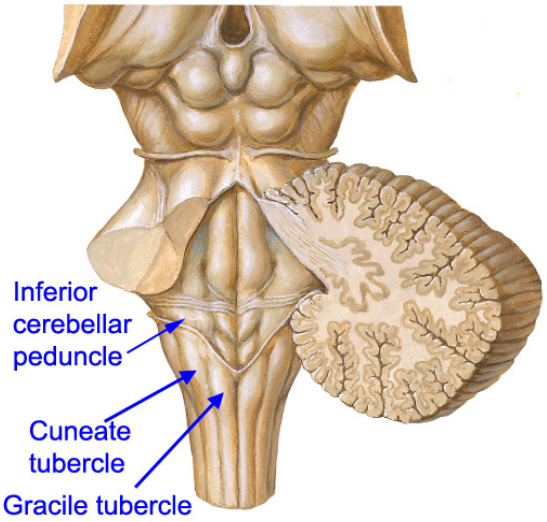
Gross anatomy of the Medulla
Anterior area:
Pyramids
Olives
Cranial nerves IX, X, XI, XII

Posterior area:
Gracile tubercles - medial bumps that contain cell bodies that are part of a somatosensory pathway called the posterior columns/medial lemniscus
Cuneate tubercles - lateral bumps that contain cell bodies of the posterior columns/medial lemniscus pathway

Lateral area:
Inferior cerebellar peduncle
Cerebellopontine angle
Cranial nerves VII & VIII



Anterior view of Brainstem and Cerebellum

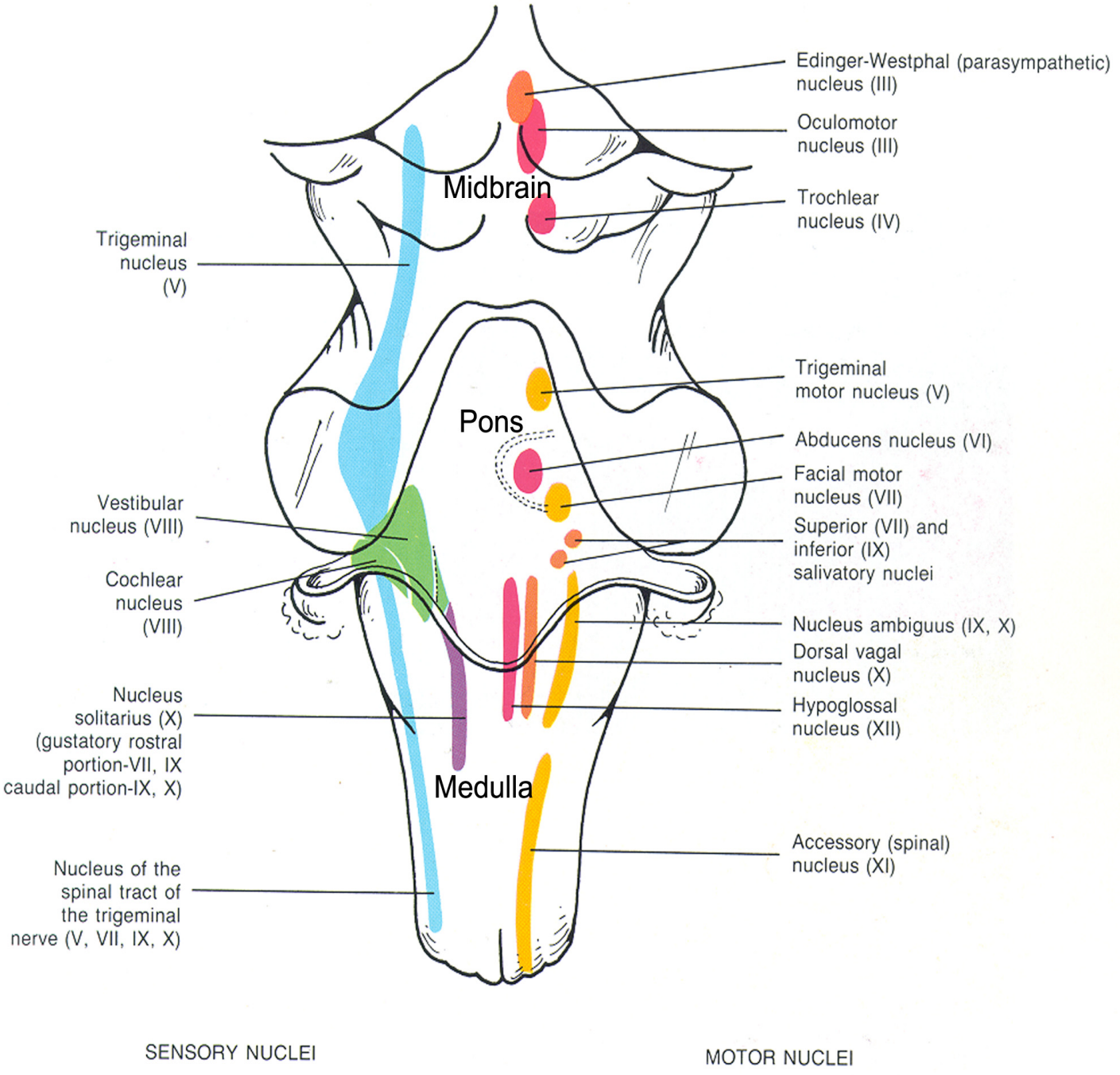


Posterior view of brainstem with part of cerebellum removed

Clinical Aspect:
The **cerebellopontine angle** is of clinical importance because **tumors** called acoustic neuromas (actually they are vestibular schwannomas) can grow here and **affect cranial nerve VIII and eventually CN VII.**

Understanding the long tracts and nuclei of the brainstem

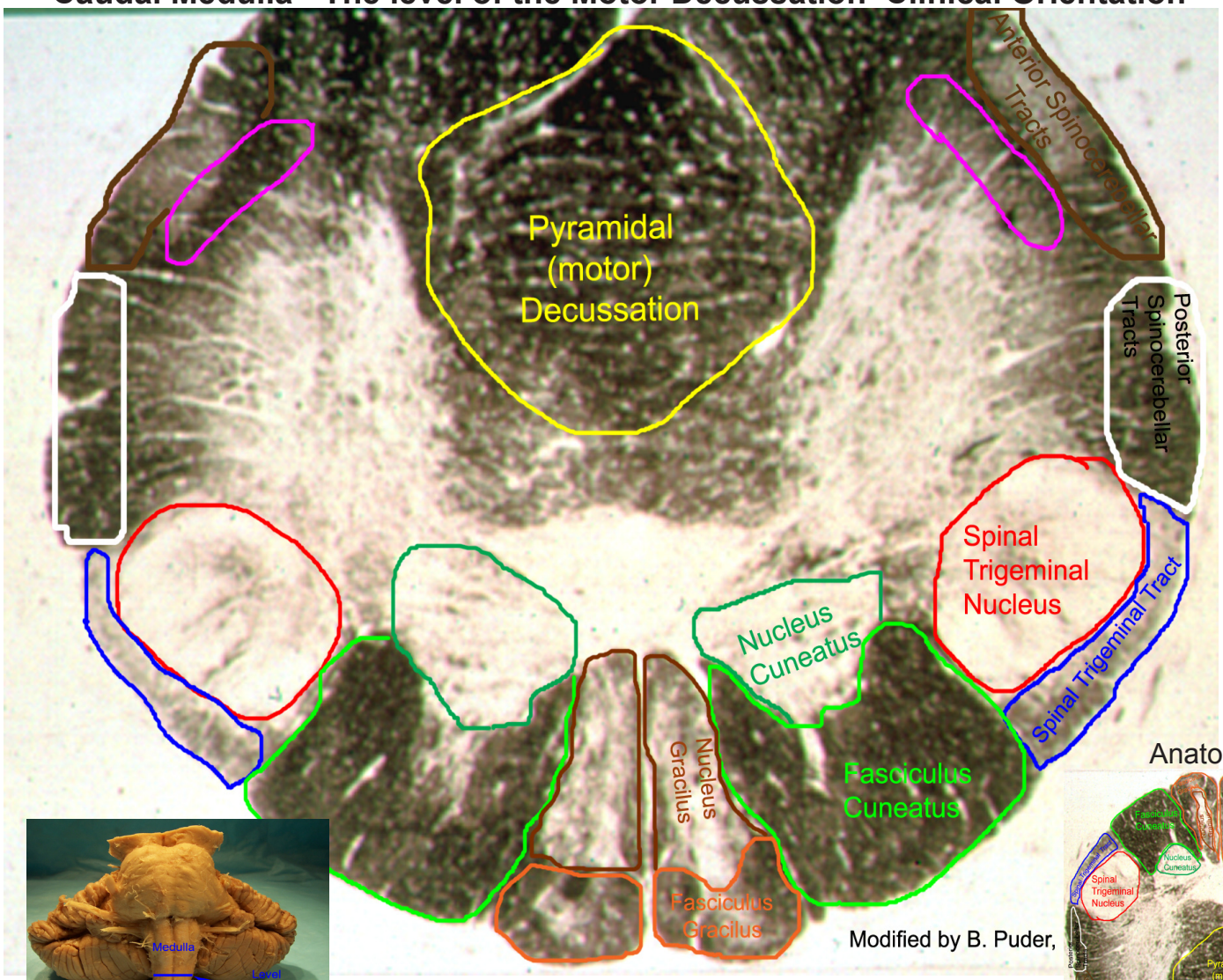
This diagram was taken from the *Cranial Nerves* textbook by Wilson-Paulwels and depicts the posterior view of the brainstem highlighting the cranial nerve nuclei and tracts. Because some of these nuclei and tracts are very long, we will see several of the same nuclei and tracts over several sections as we section through the brainstem i.e. the spinal trigeminal nucleus and tract.



The intrinsic morphology of the Medulla

There are **4 classic transverse sections** through the medulla which highlight various sensory, motor, and autonomic nuclei and tracts.

Caudal Medulla - The level of the Motor Decussation Clinical Orientation



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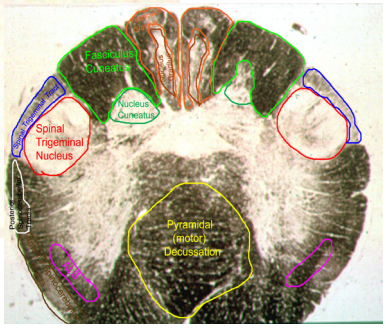


New structures

Motor (pyramidal) decussation - axons of descending upper motor neurons in the corticospinal tract have decided to leave the pyramids, cross over to the contralateral side and change their name and become the lateral corticospinal tracts that we saw in the lateral funiculus of the spinal cord

Spinal trigeminal tract - axons relaying sensory information (pain and temperature)from the face

Spinal trigeminal nucleus - cell bodies: The spinal trigeminal tract axons will synapse upon the spinal trigeminal nucleus and pain and temp info from the face will be relayed to cortical areas.

Previous structure that we saw in the spinal cord:

Fasciculus cuneatus - sensory axons relaying tactile,vibratory sense from the upper half or the body

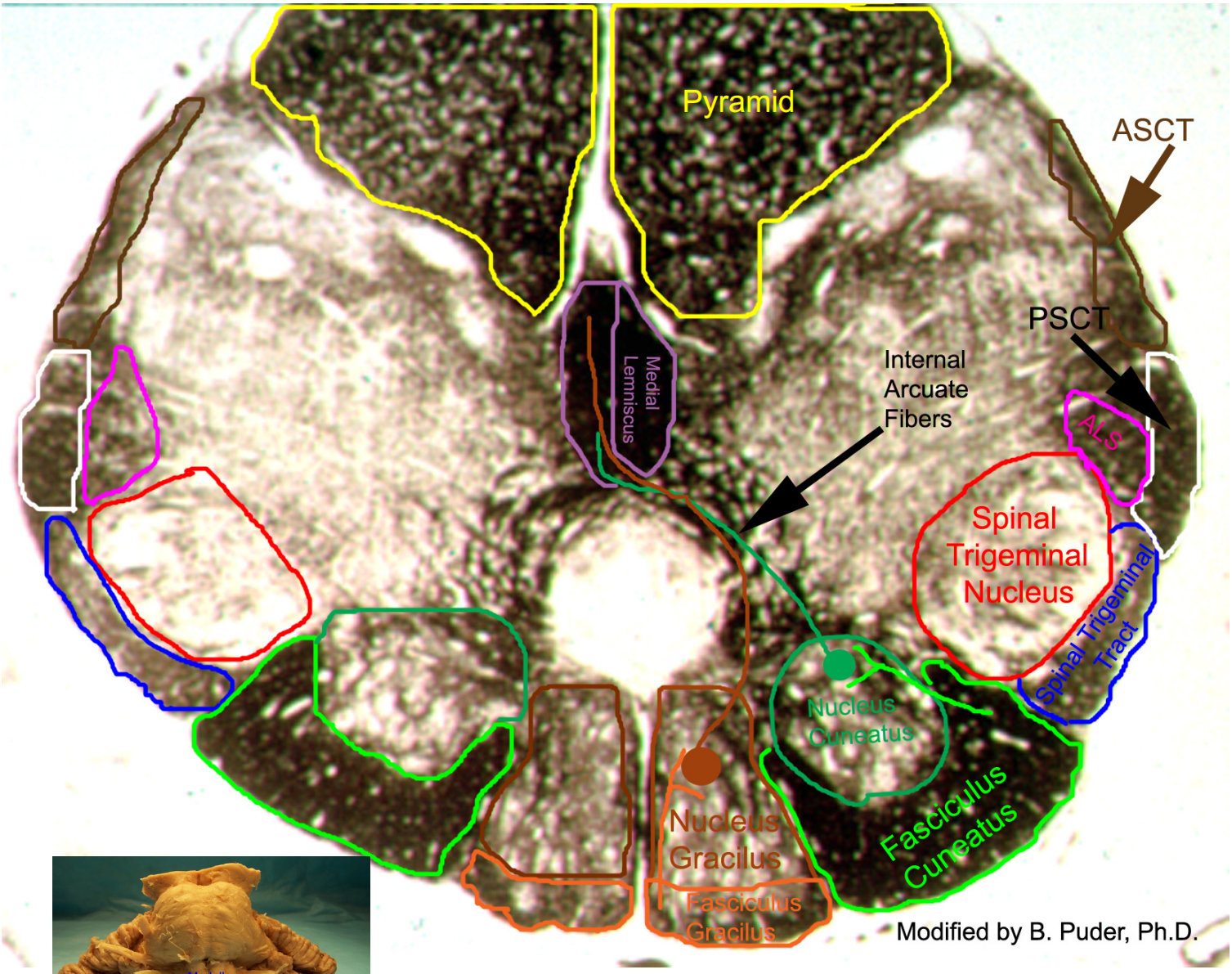
Fasciculus gracilus - Sensory axons relaying tactile, vibratory sense from the lower half of the body

Nucleus cuneatus and nucleus gracilus are starting to show up in this section, but we will see them more prominently in the next section.

ALS - Anterolateral system - contains the spinothalamic axons that are relaying pain and temp info from the contralateral body to the thalamus

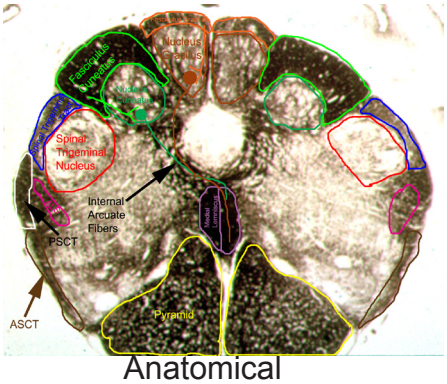
Anterior & Posterior spinocerebellar tracts - relay muscle proprioceptive information to cerebellum

Caudal Medulla - Level of the Sensory Decussation Clinical Orientation



New Structures at this level:
Nucleus Cuneatus and Nucleus Gracilus - cell bodies whose axons will travel through as the **Internal Arcuate Fibers** and cross to the contralateral side and then the axons change their name to **medial lemniscus.** This is an ascending tract carrying tactile, vibratory sensation from the body to the cortex
Pyramids - corticospinal axons are descending through here

Previous Structures:
Spinal Trigeminal Tract and Nucleus
Anterior and Posterior Spinocerebellar tracts
ALS - anterolateral system



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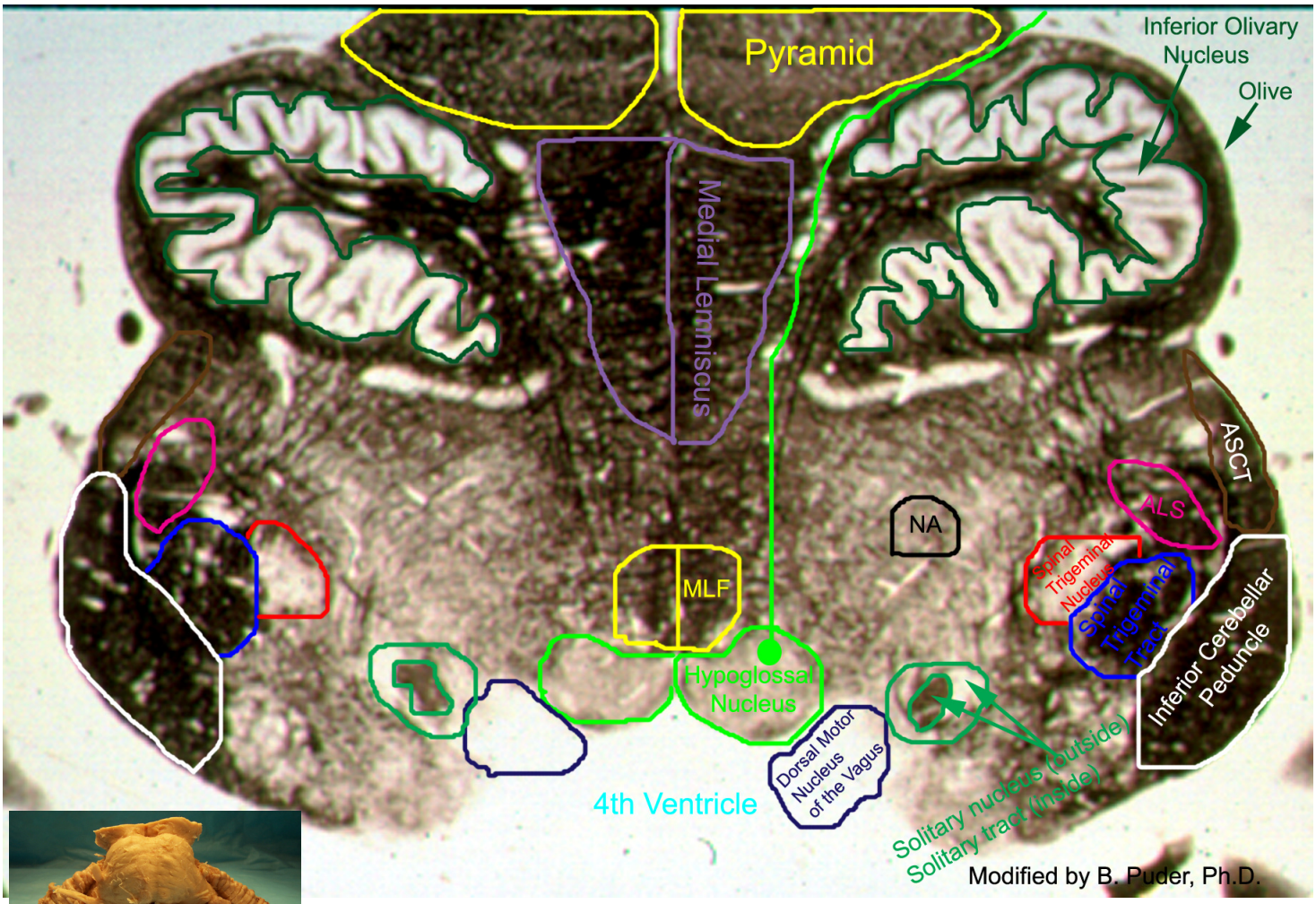
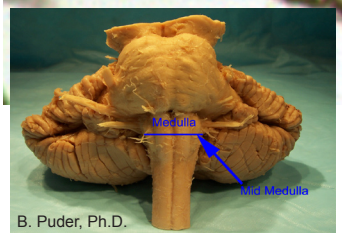
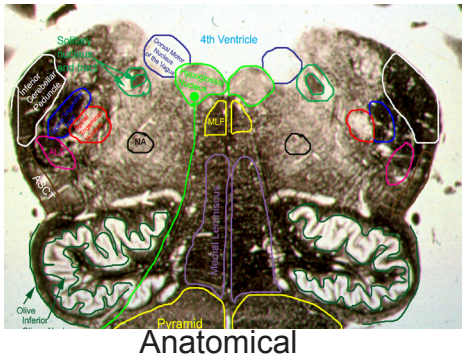




New Structures at this level:
Hypoglossal nucleus - cell bodies of CN XII that innervate the ipsilateral tongue muscles
Hypoglossal nerves - Notice how the hypoglossal nerve exits between the pyramid and olive.
Dorsal Motor nucleus of the Vagus - Preganglionic parasympathetic cell bodies for CN X
Solitary nucleus and solitary tract - receives sensory input from CN VII, IX & X
MLF - medial longitudinal fasciculus - long axonal tract that coordinates left and right eye movements
NA - nucleus ambiguus - Cell bodies of the part of CN IX & X whose axons innervate larynx and pharynx muscles
Inferior cerebellar peduncle - the axons that were in the posterior spinocerebellar tract are now in the inferior cerebellar peduncle and will enter the cerebellum
Inferior Olivary nucleus - cell bodies here receive information from several sources and its axons project to the cerebellum

Previous structures :
Spinal trigeminal nucleus and tract
Anterolateral system
Anterior spinocerebellar tract
Medial Lemniscus
Pyramids



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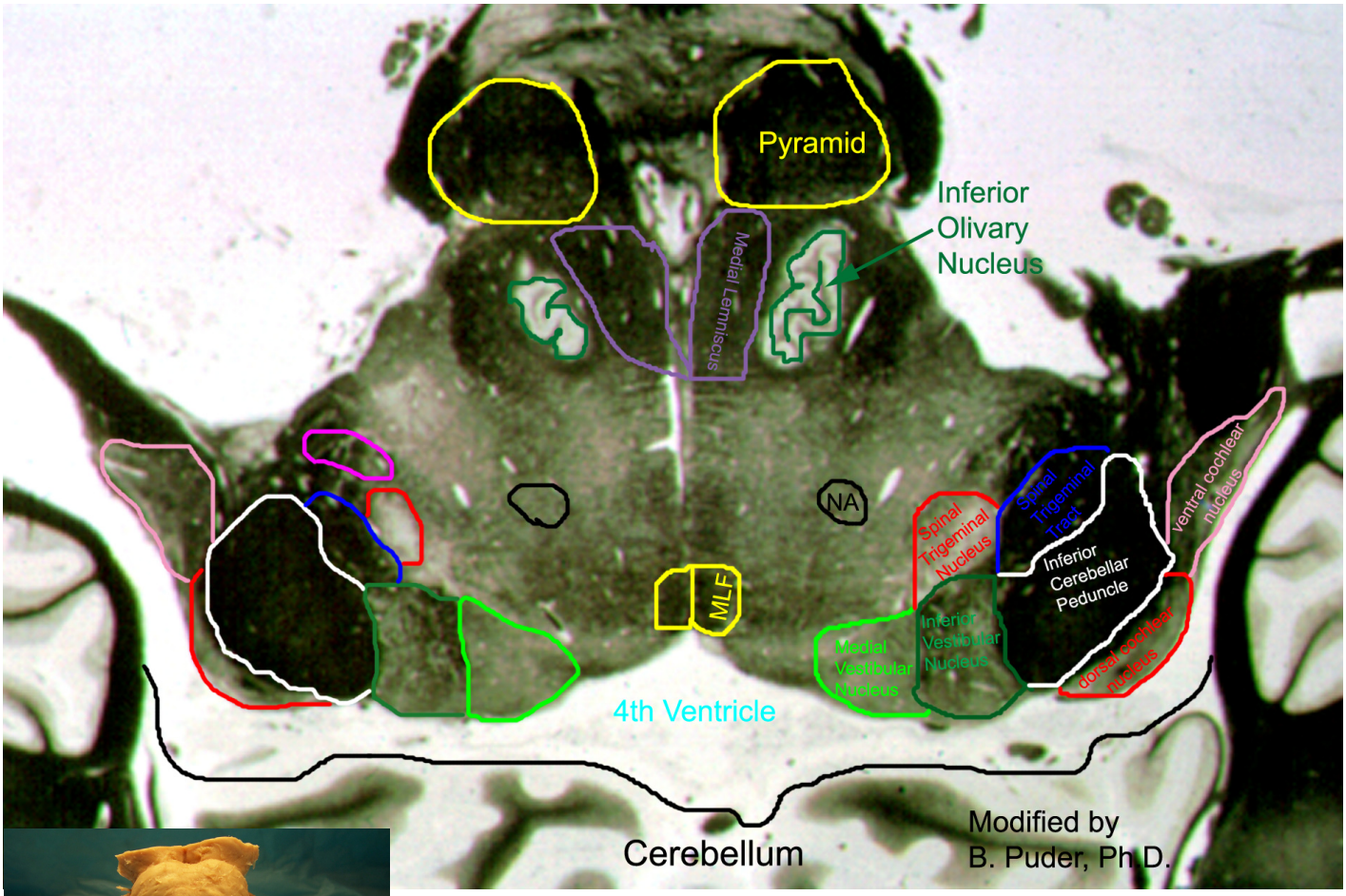
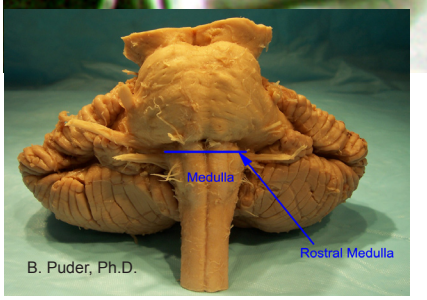
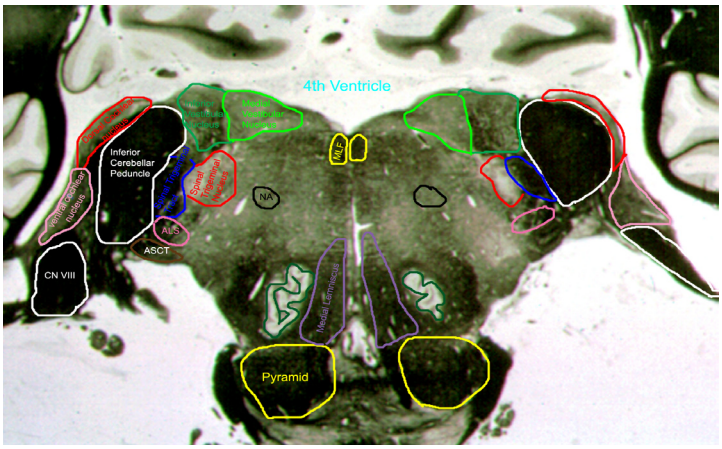
Rostral Medulla, Level of Cranial nuclei VIII Clinical Orientation





New Structures on this section:
Inferior and Medial Vestibular nuclei - cell bodies that are part of CN VIII vestibular portion
Dorsal and ventral cochlear nuclei - cell bodies that are part of CN VIII auditory portion

Old Structures from previous sections:
MLF, medial longitudinal fasciculus
Spinal trigeminal nucleus and tract
NA, Nucleus ambiguus
ALS, anterolateral system
Inferior cerebellar peduncle
Anterior spinocerebellar tract
Inferior Olivary nucleus
Pyramids



Reticular Formation

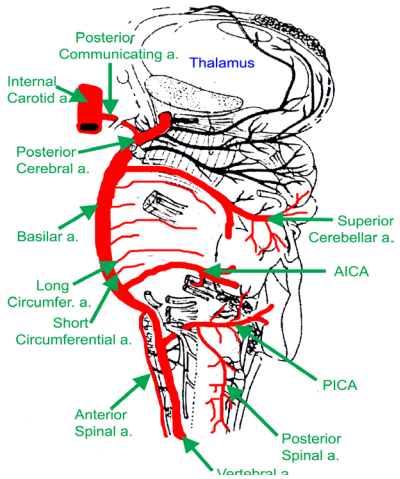
You may have noticed in the medial part of the tegmentum there was a large area that was not labeled. This is the **Reticular formation and it is present throughout the entire brainstem. Reticulum means little net or meshwork**, so this area contains nuclei that are diffuse, with little organization.

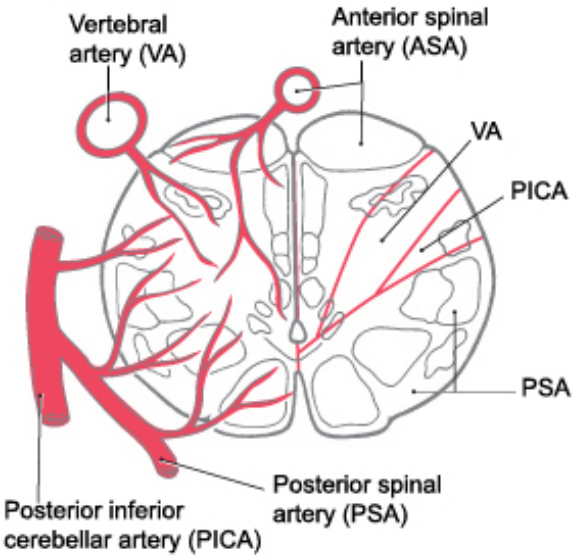
Within the reticular formation is the Raphe nuclei.
Raphe means suture or seam and this set of cell bodies is placed bilaterally adjacent to the midline.
The **Raphe nuclei contain serotonin (5 HT), enkephalin, and CCK** which **help block the transmission of pain information that is traveling to the cortex.**

In the **ventral lateral reticular areas (which would be in the medulla), the cell bodies here help to control heart rate anad respiration.**

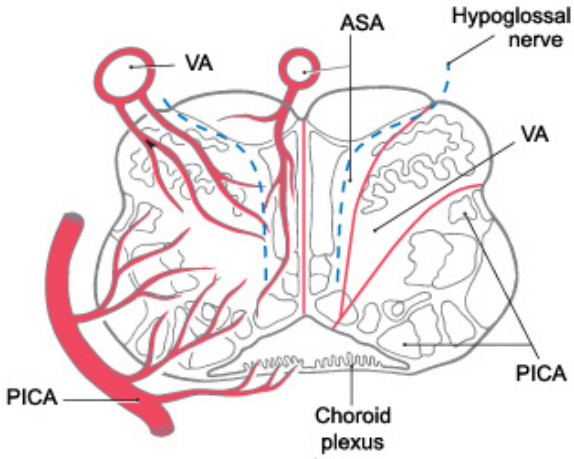
Clinical Aspect:
Compression of the medulla due to injury, increased intracranial pressure due to tumors or hemorrhage can result in central apnea (**damage to the respiratory centers**) and possibly death.

Blood Supply to the Medulla

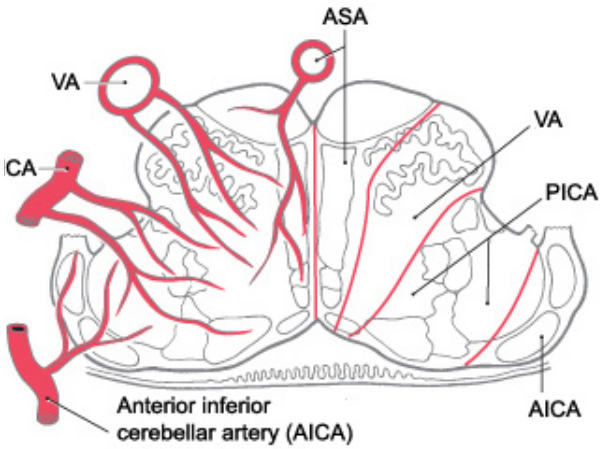




Caudal Medulla -Level of Sensory Decussation



Mid Medulla - Level of CN nuclei XII



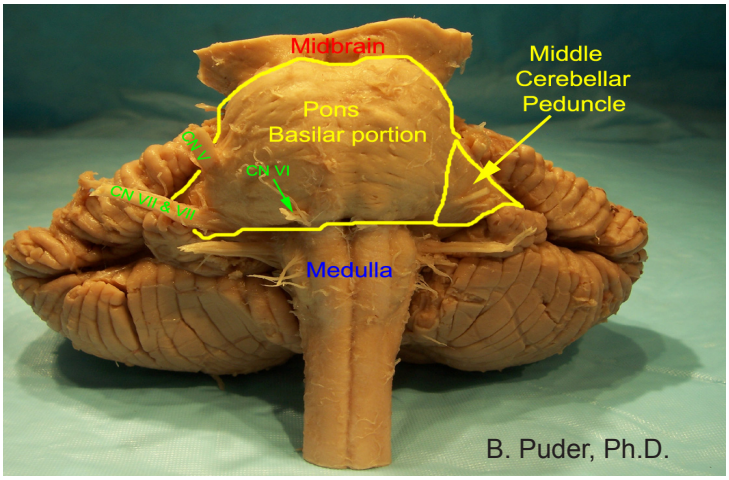
Rostral Medulla

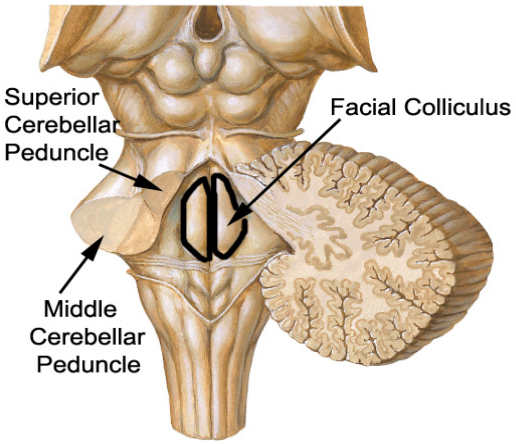
The Pons
The middle portion of the brainstem
Boundaries:
Rostral - Midbrain, Caudal - Medulla, Posterior - 4th ventricle and cerebellum
Pons means “bridge”, early anatomistss thought the Pons looked like a bridge connecting to the cerebellum.
The pons and cerebellum together are called the metencephalon.

The basilar part of the pons contains descending cortical fibers and transverse fibers that are entering the cerebellum.

The tegmental portion of the pons contains sensory and motor nuclei from CN V,VI,VII & VIII.

Gross Anatomy of the Pons



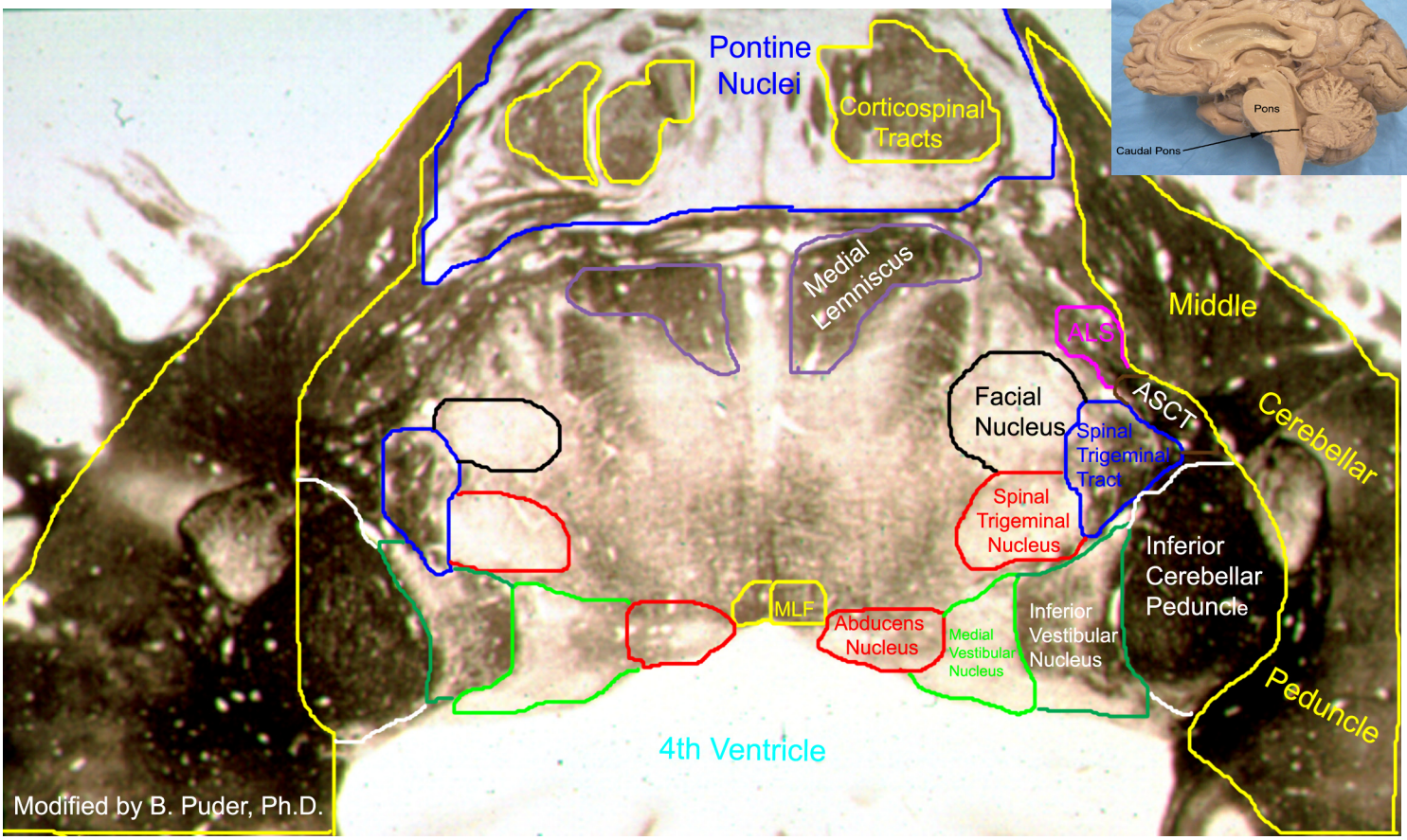


Anterior view - basilar pons CN VI
Lateral view - Middle cerebellar peduncle, CN V, VII & VII
Posterior view (with cerebellum removed) - Middle cerebellar peduncle, Superior cerebellar peduncle, Facial colliculus

Intrinsic anatomy of the Pons
There are **3 major sections of the Pons** which depict various nuclei and tracts.
We will look at the **caudal pons**, followed by the **mid pons** and finally the **rostral pons.**

Clinical Aspect:
The **cerebellopontine angle** is of clinical importance because **tumors** called acoustic neuromas (actually they are vestibular schwannomas) can grow here and **affect cranial nerve VIII and eventually CN VII.**

Caudal Pons - Intrinsic anatomy Clinical Orientation



New Structures in this section:

Abducens nucleus - cell bodies of CN VI whose axons will innervate the lateral rectus extraocular muscle

Facial nucleus - cell bodies of CN VII whose axons will innervate the ipsilateral facial expression muscles

Middle Cerebellar peduncle - axons from various locations entering the cerebellum

SO - (superior olivary nucleus) part of the auditory pathway

Lateral Lemniscus - part of the auditory pathway

Trapezoid body - part of the auditory pathway

Pontine nuclei - cell bodies, some of the axons will project into the cerebellum via the middle cerebellar peduncle

Corticospinal tracts - axons of upper motor cortical neurons that will descend into the medullary pyramids

Old structures:

Medial Lemniscus - this tract is starting to bend laterally

ALS

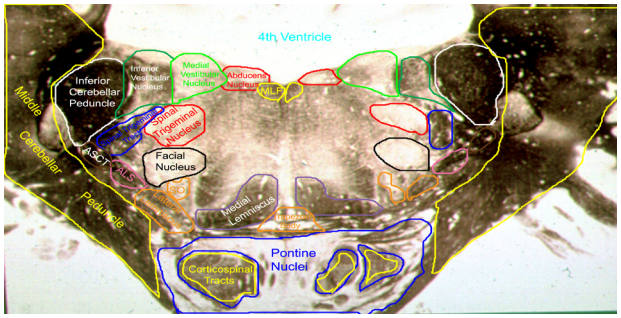
ASCT

Inferior cerebellar peduncle

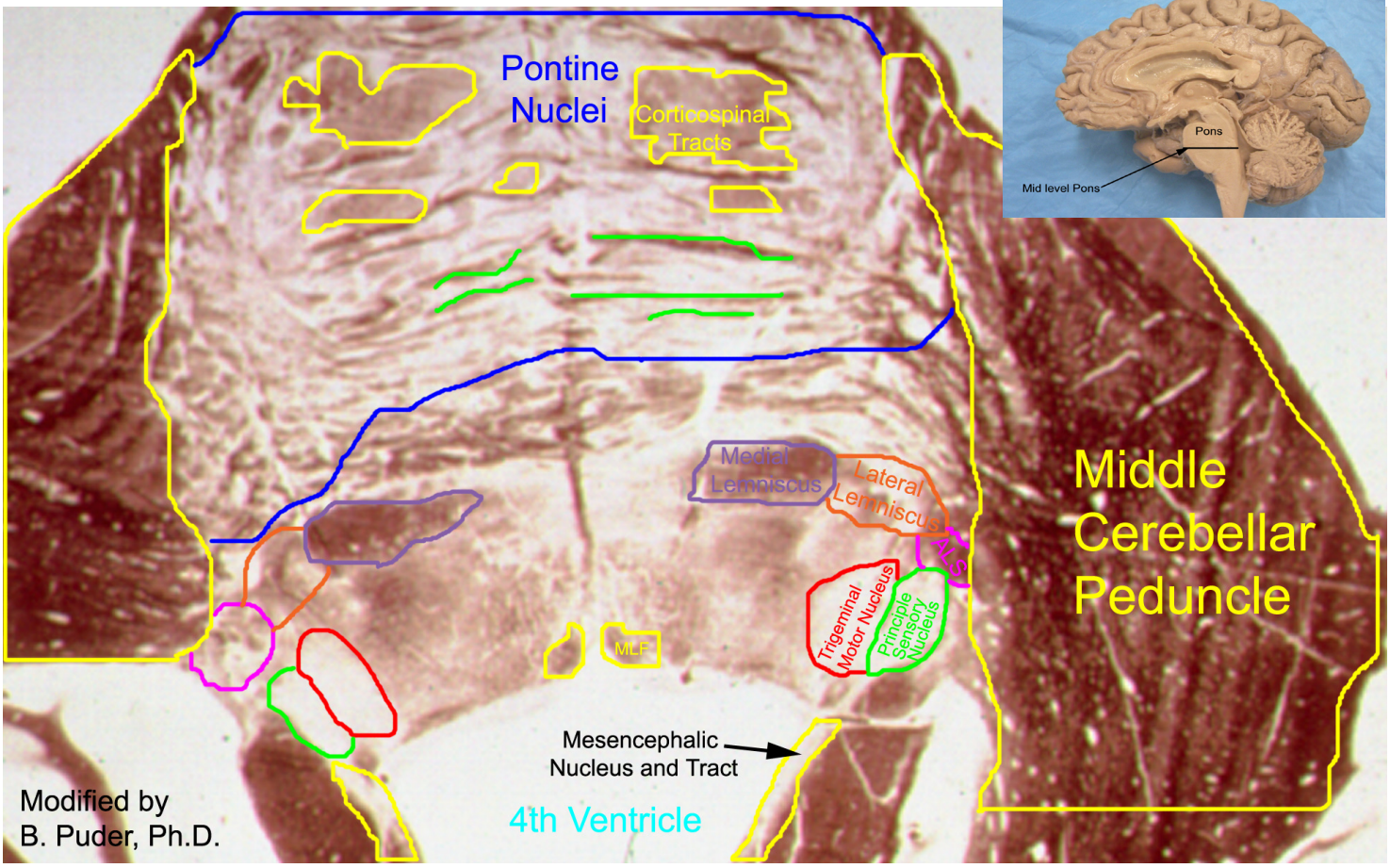
Spinal trigeminal nucleus and tract

MLF

Medial and Inferior Vestibular nuclei

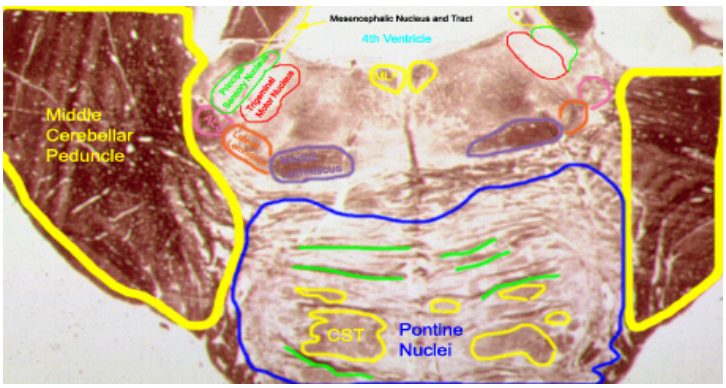


Mid-level Pons Clinical Orientation



New Structures in this section:
Trigeminal motor nucleus - Cell bodies whose axons will innervate the muscles of mastication
Principal sensory nucleus - Cell bodies receiving tactile, vibratory sense from the face
Mesencephalic nucleus and tract - pseudounipolar neurons relaying proprioceptive information from the mastication muscles
Transverse fibers in the pontine nuclei represent pontocerebellar fibers

Previous Structures:
MLF
Middle Cerebellar peduncle
Medial Lemniscus
Lateral Lemniscus
ALS (anterolateral system)
Pontine nuclei
CST (corticospinal tract)



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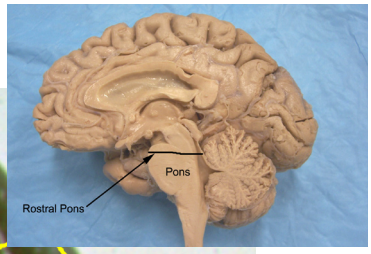
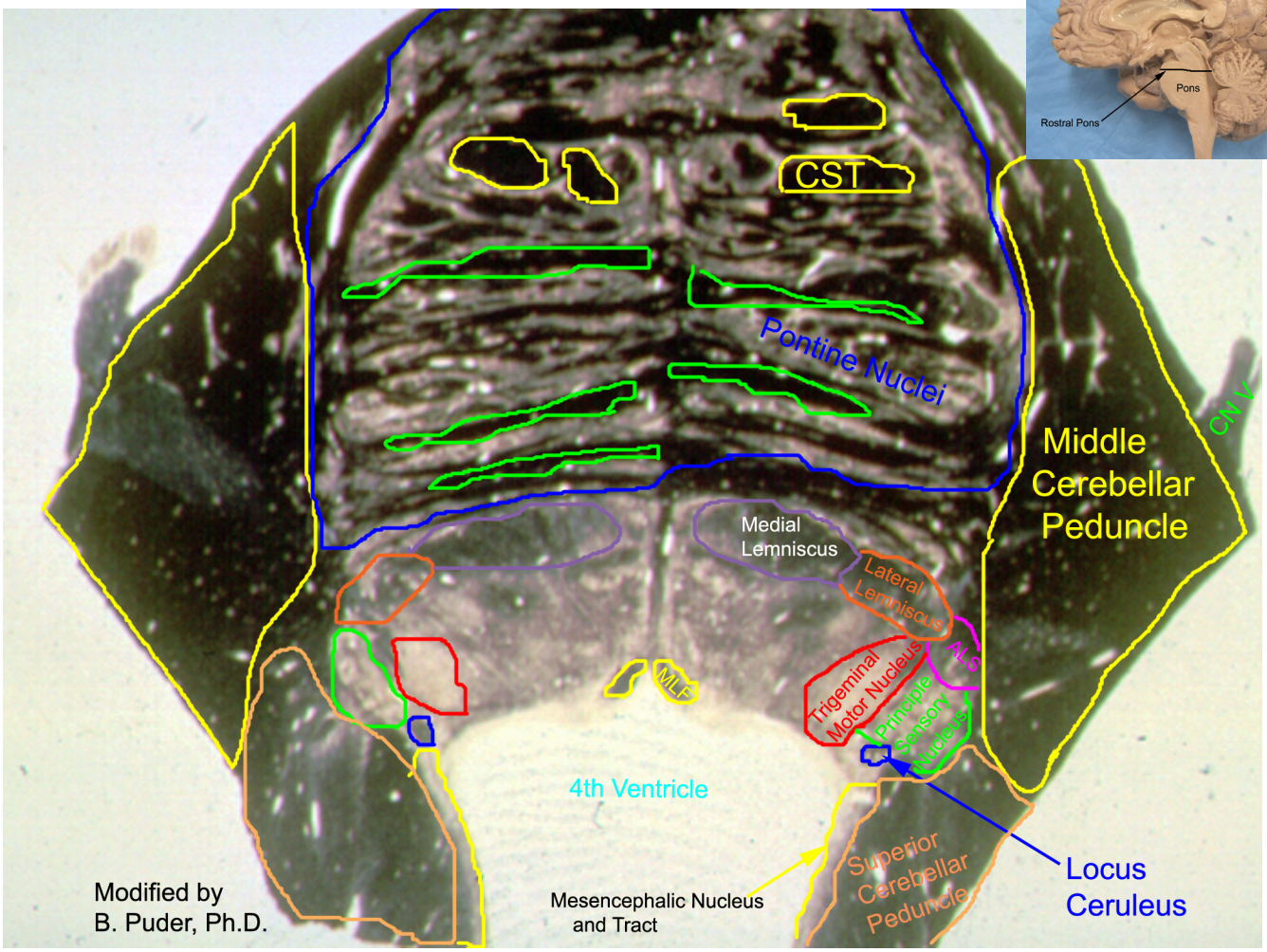
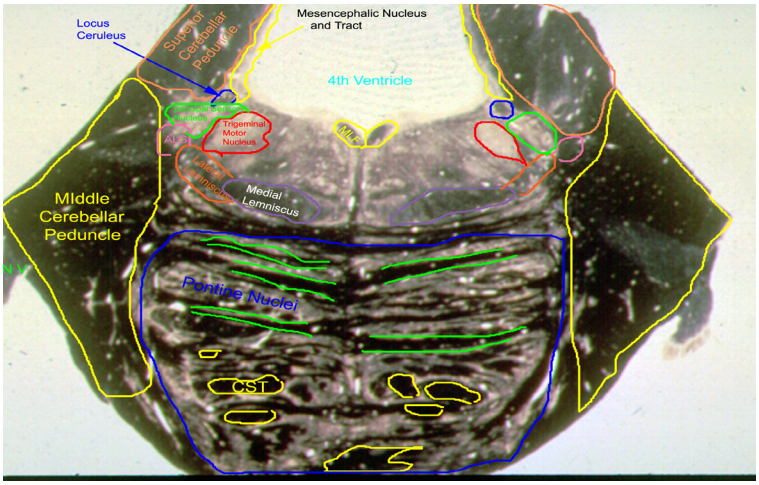
Rostral Pons Clinical Orientation





New Structures in this section:
Superior Cerebellar Peduncle - axons entering and leaving the cerebellum
Locus Ceruleus - cell bodies here have smokey blue appearance. They contain **Noradrenaline/Norepinephrine** and their axons project throughout the CNS including the cortex, diencephalon, limbic system, brainstem, cerebellum and spinal cord. These cell bodies have l**ow discharge rates during sleep and high discharge rates during stress.**

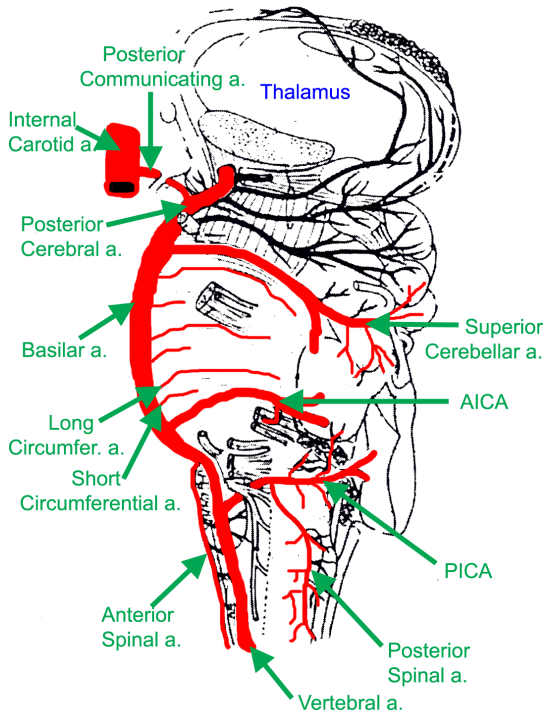
Structures from Previous sections:
Mesencephalic nucleus and tract
MLF
Trigeminal Motor nucleus
Principal Sensory nucleus
ALS
Medial Lemniscus
Lateral Lemniscus
Pontine nuclei
CST corticospinal tract
Middle cerebellar peduncle

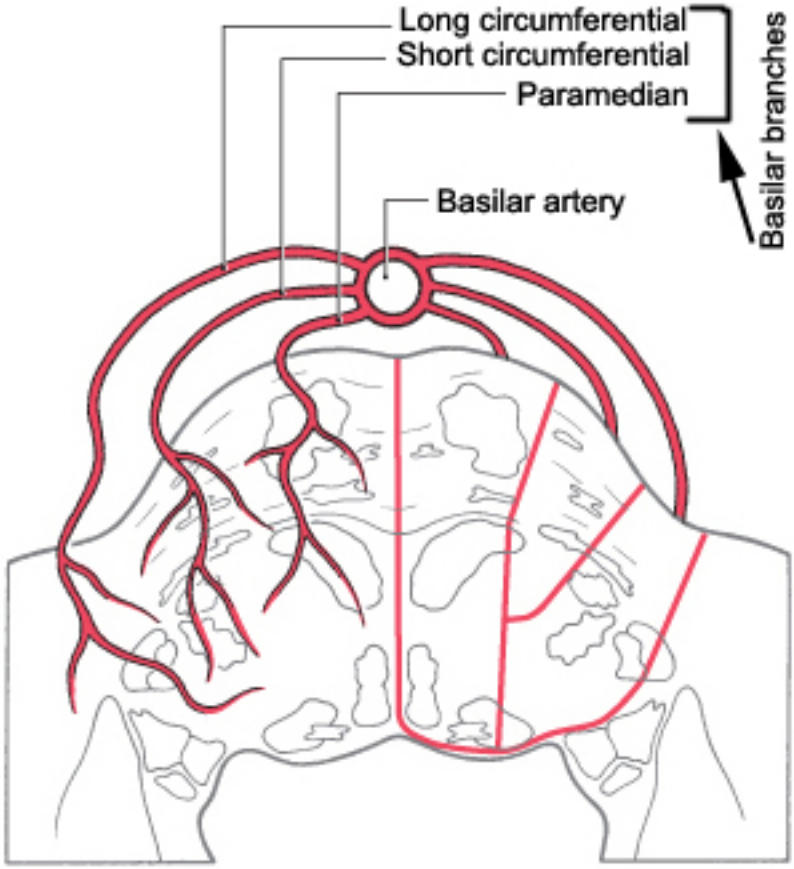


Reticular Formation

Remember the reticular formation is running through the pontine sections just as we saw in the medullary sections.

Blood Supply to the Pons

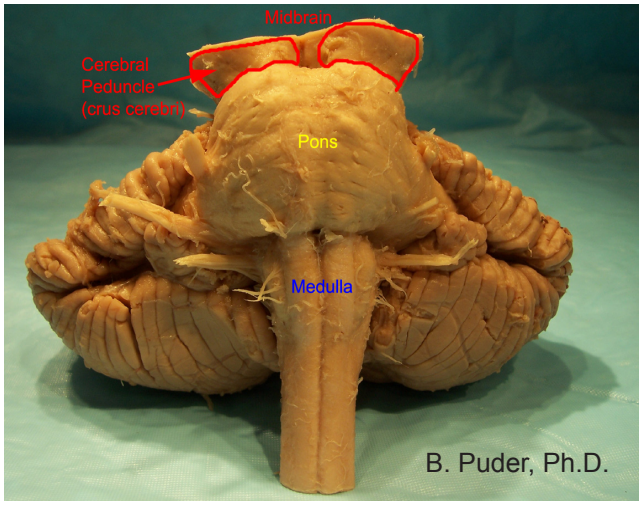




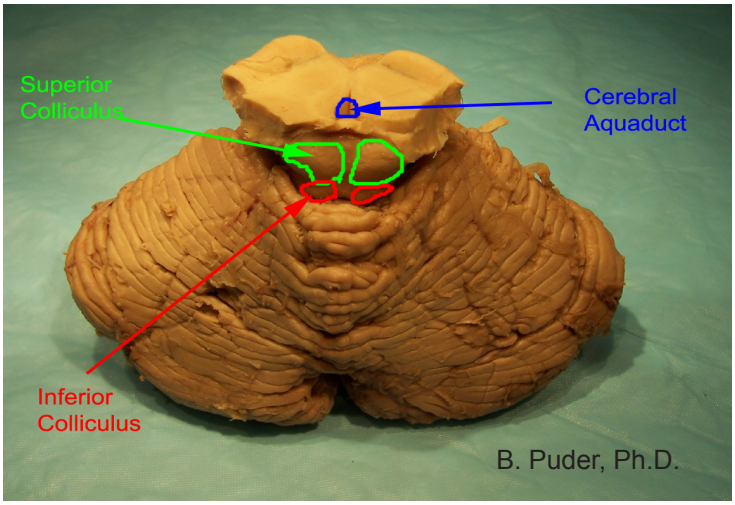
Blood Supply to the pons is from the basilar artery and its branches.

The Midbrain (Mesencephalon)
Boundaries: Rostral - Diencephalon, Caudal - Pons
The cerebral aquaduct runs through the midbrain
Cranial nerve nuclei III & IV are located here
The Midbrain has a basis pedunculi anteriorly, a tegmentum in the middle, and a tectum posteriorly

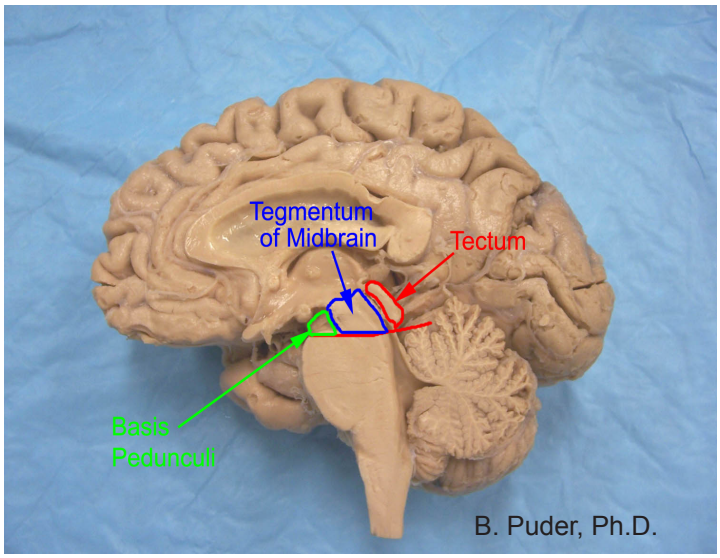
Gross anatomy of the midbrain



Anterior view of the brainstem featuring the cerebral peduncles of the midbrain

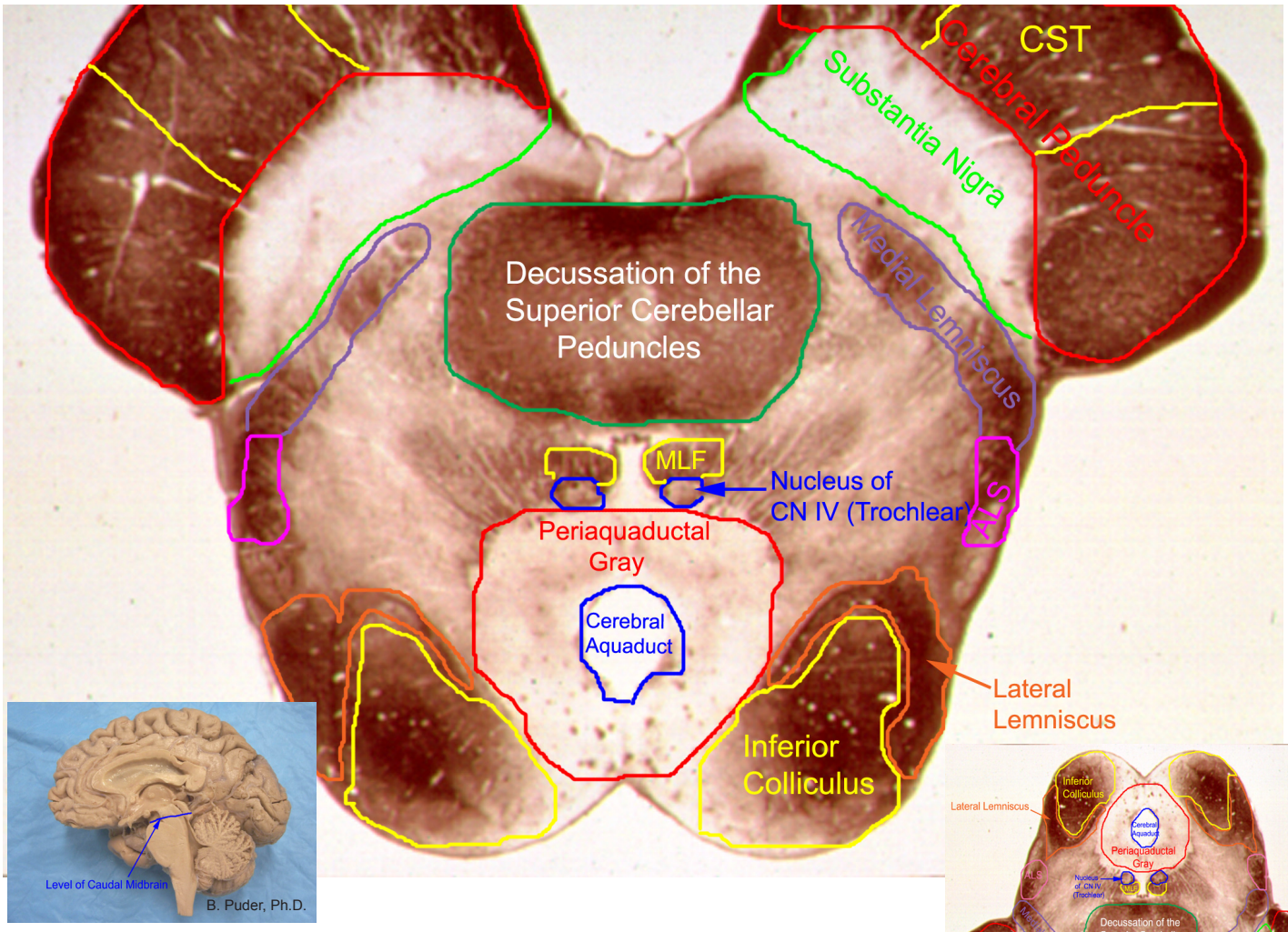


Posterior view of the brainstem featuring the superior and inferior colliculi of the midbrain



Mid-sagittal section depicting the Tectum (roof), Tegmentum, and Basis Pedunculi of the Midbrain

Intrinsic Anatomy of the Midbrain
There are only **2 major transverse sections of the midbrain**: caudal and rostral midbrain
Clinical Orientation

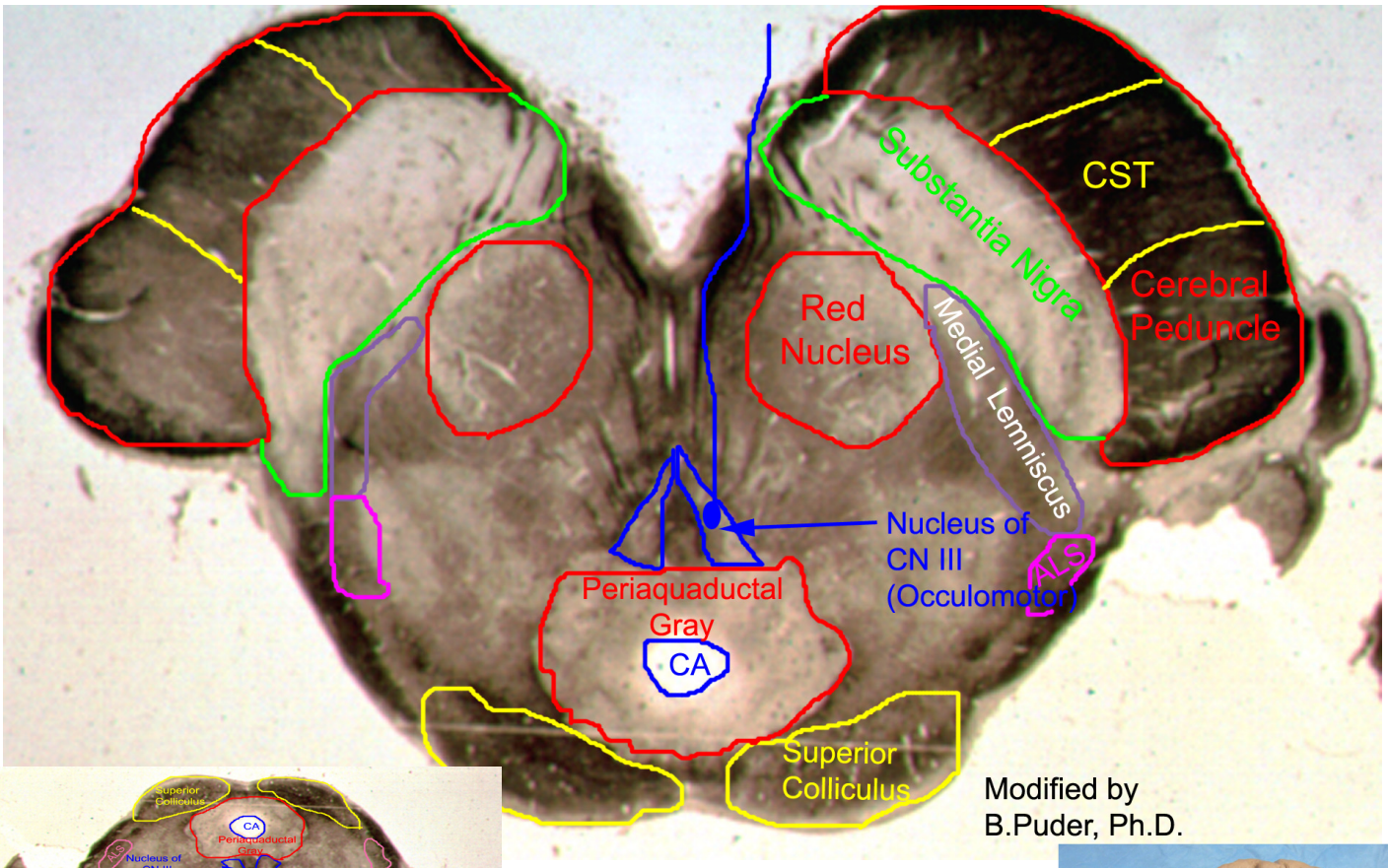


Anatomical

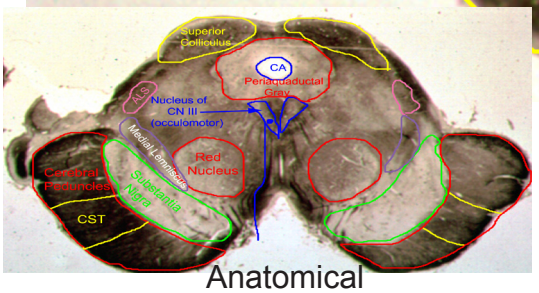
New Structures:
Inferior colliculus - part of the auditory pathway
Cerebral aquaduct - part of the ventricular system
Periaquaductal gray - cell bodies here contain enkephalins that block pain transmission
Trochlear nucleus (nucleus of CN IV)- cell bodies of CN IV that innervate the superior oblique m.
Decussation of the Superior cerebellar peduncles - axons exiting the cerebellum via the superior cerebellar peduncles will cross here and ascend to the cortex, or synapse in the red nucleus
Substantia nigra - part of the basal nuclei (ganglia), cell bodies here contain dopamine and when these cell die, the disease is called **Parkinson's disease**
Cerebral Peduncles - carries axons from many sources, however the **middle 3/5 of each peduncle contain the corticospinal tracts** which are the axons of the upper motor neurons of the cortex which are descending to the spinal cord

Previous structures:
Lateral lemniscus - these axons are now synapsing on the inferior colliculus (part of the auditory pathway)
MLF
ALS
Medial Lemniscus

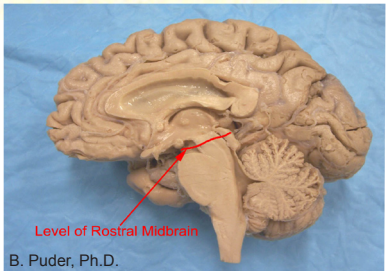
Rostral Midbrain Clinical Orientation



Modified by B.Puder, Ph.D.



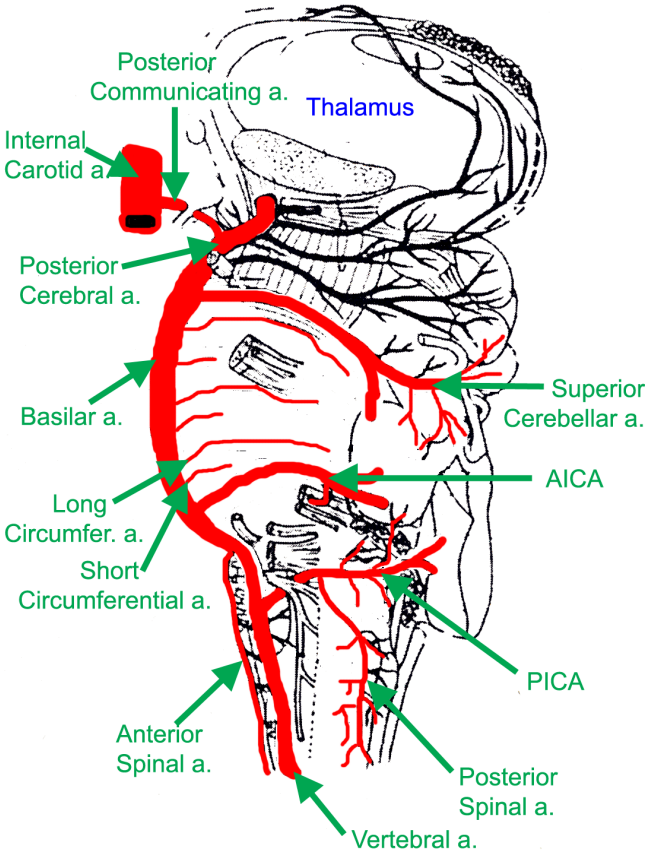
Anatomical

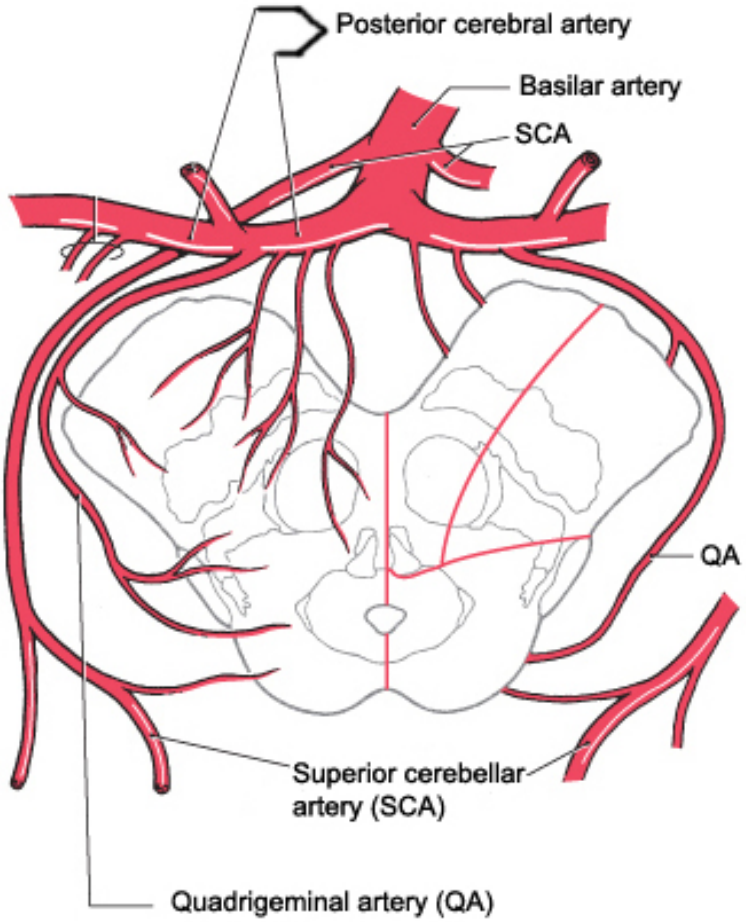


New Structures:
Superior colliculus - part of the visual system
Occulomotor nucleus (CN III nucleus) - cell bodies here project their axons to innervate 4 extraocular muscles
(There's also a parasympathetic nucleus to CN III called the Edinger-Westphal nucleus - it would be just some tiny specks near the top and middle of the occulomotor nucleus. The Edinger-Westphal nucleus contains preganglionic parasympathetic cell bodies whose axons will synapse on the ciliary ganglion and will cause pupillary constriction.
Also note that the **axons of the occulomotor nuclei exit between the 2 cerebral peduncles (in the interpeduncular fossa). This will be of importance when we discuss lesions.**
Red Nucleus - cell bodies here project their axons as the rubrospinal tract wihich will influence lower motor neurons in the spinal cord.

Previous structures:
Cerebral aquaduct
Periaquaductal gray
ALS
Medial Lemniscus
Substantia nigra
Cerebral peduncles
There's also the **reticular formation** in the tegmental area of the midbrrain

Blood Supply to the Midbrain





Branches of the **Superior cerebellar a.** and **Posterior cerebral a**. are the blood supply source for the midbrain.