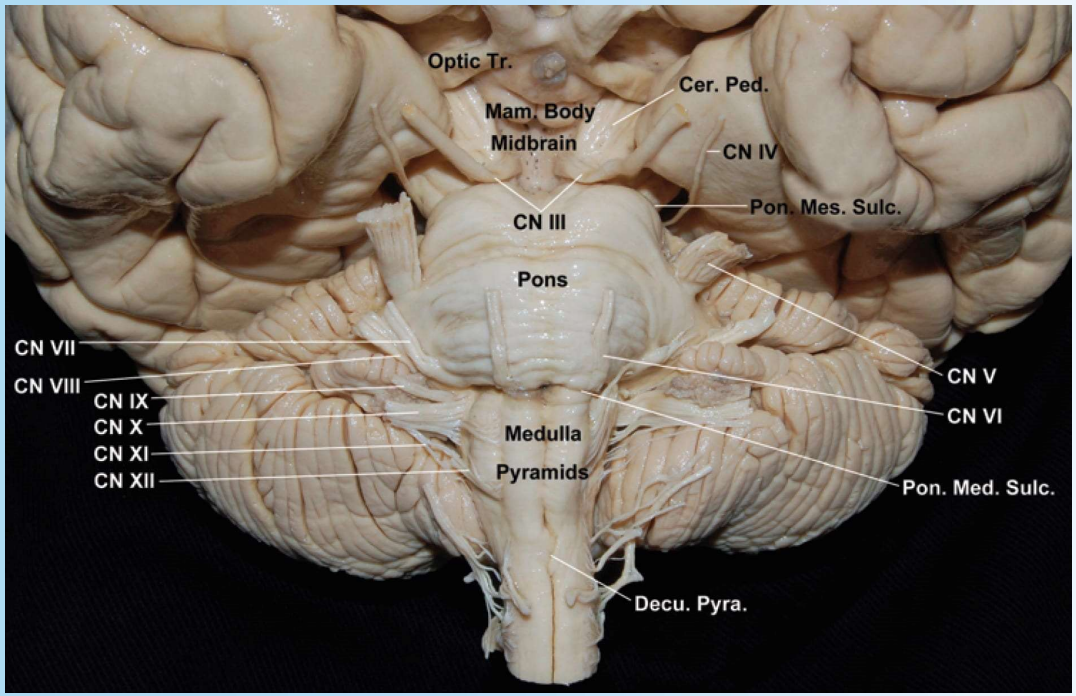
The Brainstem: Structure & Function

Sebastian Wolinski

Objectives

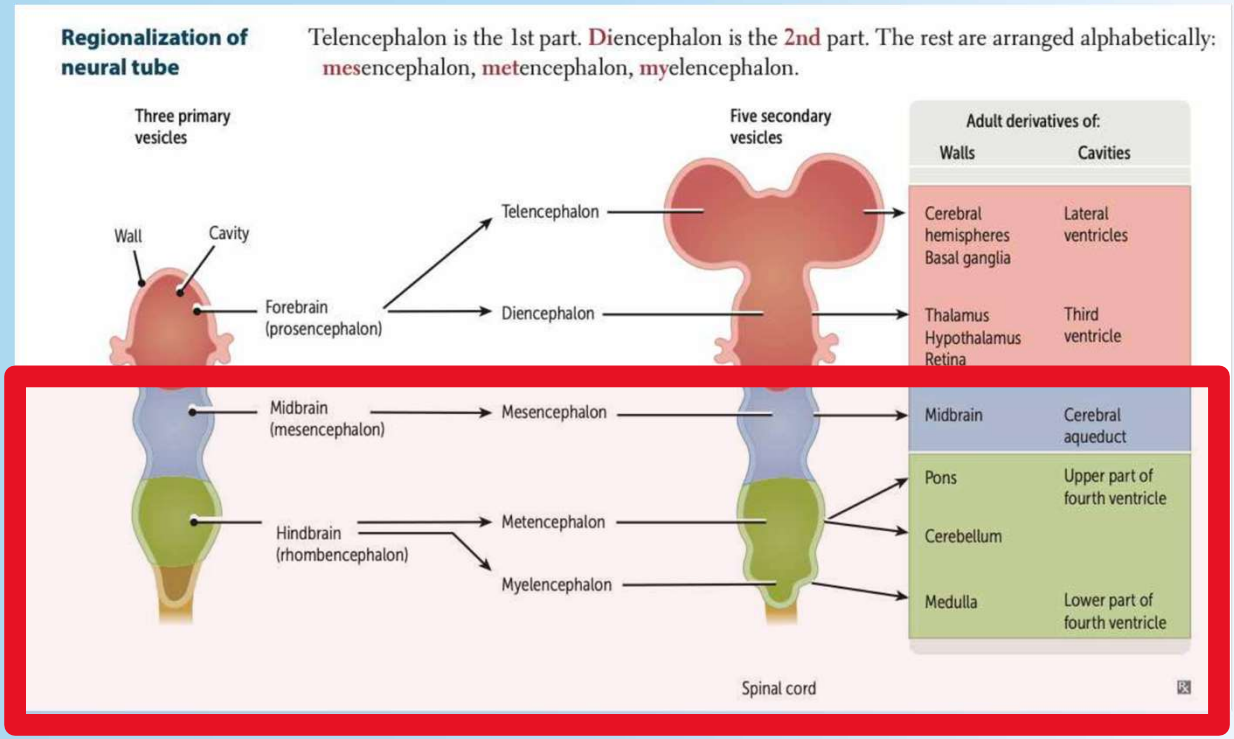
- Quick Embryology recap
- Cranial Nerves (rule of 4's)
- Basics of Brainstem
- Midbrain
- Pons
- Medulla
- Blood Supply & Strokes



studyaid

Quick Embryology

"Tie, Di, Mes Met My"



studyaid

The Rule of 4's

- The simplest way to remember which Cranial Nerves go where:
- I + II = above brainstem
- III + IV = Midbrain

= 4

- V, VI, VII, VIII = Pons (4)
- IX, X, XI, XII = Medulla (4)

Basics of the Brainstem

With Cranial Nerves and nuclei, you can easily divide their location in the brainstem via their NUMBER and FUNCTION

MOTOR nuclei are MEDIAL, Sensory are found Lateral.

I, II → above brainstem, uninvolved

III, IV (midbrain)

- **III** is predominantly motor = medial (E-W too)
- **IV** is pure motor = medial

V, VI, VII, VIII (pons)

- **V** mostly sensory, and HUGE, and found laterally.
  → even stretches into medulla
- **VI** is pure motor = medial
- **VII** is a strong mix of motor (facial expression) and sensory (taste)
  → sits on border of medial/lateral division
- **VIII** pure sensory = lateral, and sits at pontomedullary angle aka cerebellopontine angle

IX, X, XI, XII (medulla)

- **IX** largely sensory so → lateral
- **X** lots of nuclei, but found dominantly lateral
- **XI** is outside brainstem
- **XII** – pure motor = medial

Basics of the Brainstem

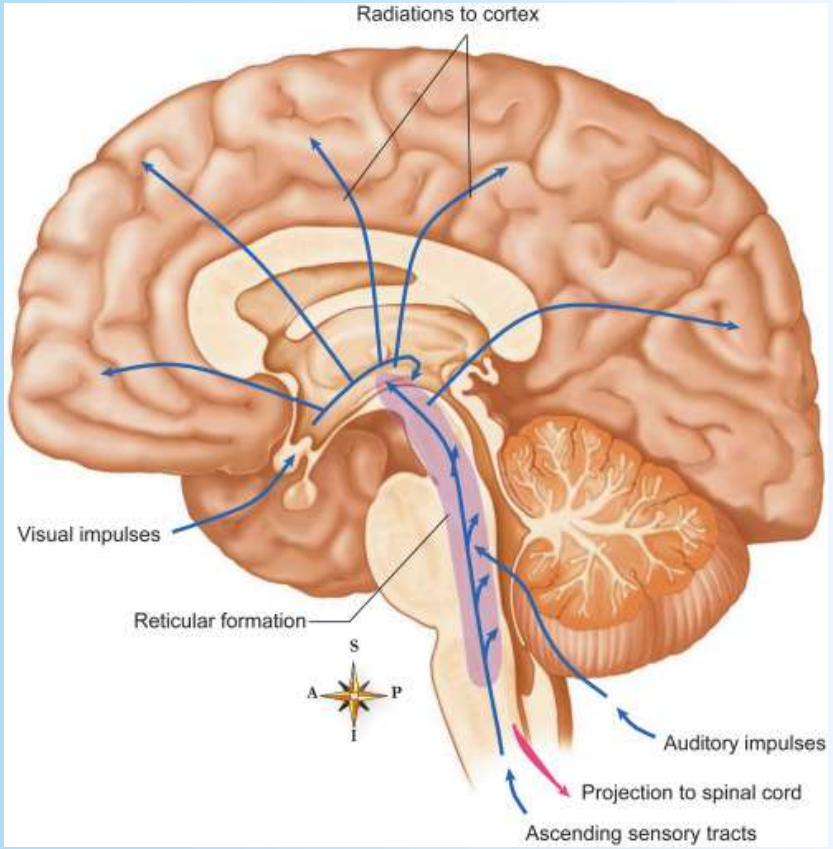
- **Spinal Tracts**
  - To get to the spinal cord, or cerebellum, all spinal tracts must travel through the brainstem!

  - You can easily identify starting destination & final destination
    - E.g. Corticospinal → Cortico = Start in cortex & spinal = end in spinal cord (UMN)
    - E.g. Corticobulbar → Cortico = Cortex, bulbar = brainstem

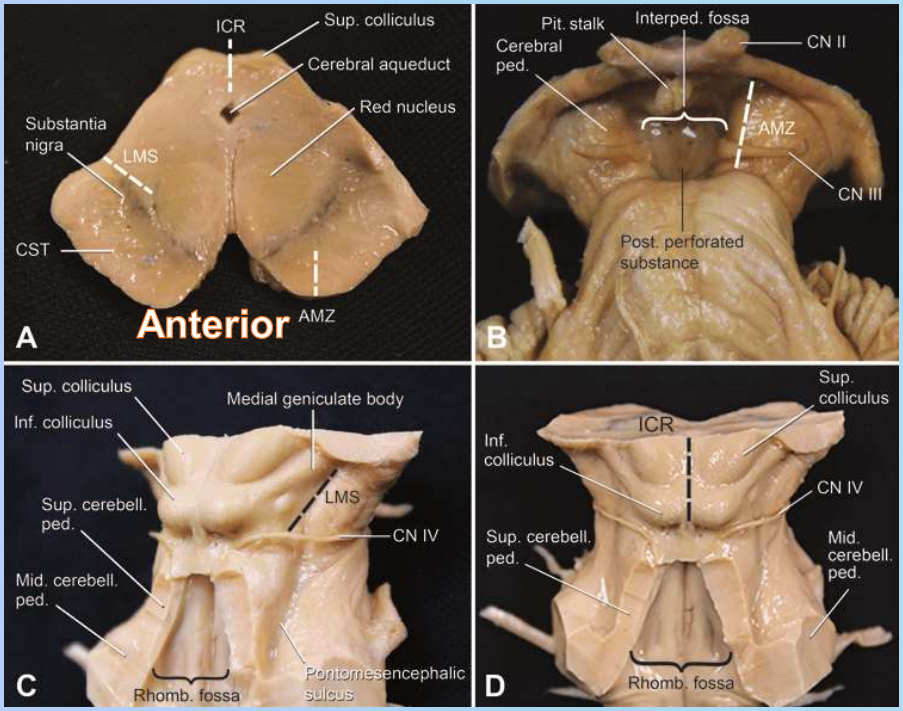
  - Most importantly, the:
    - Corticospinal tract,
    - Dorsal Column ML,
    - Spinothalamic tract,
    - Sympathetic (hypothalamospinal) tract
  - travel the FULL course of the brain stem

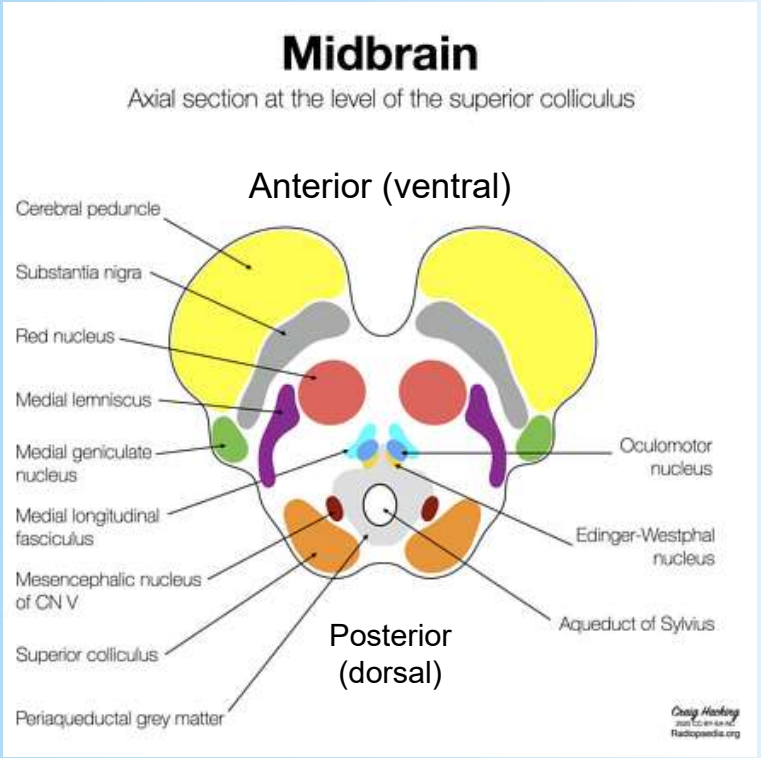
Basics of the Brainstem

- **Reticular Formation**
  - Extends through entire brainstem
  - Involved in Consciousness
    - Arousal/wakefulness (reticular activating system)
    - Autonomic regulation (breathing, hear rate)
    - Reflexes like swallowing, sneezing, respiration



Midbrain


ICR
Sup. colliculus
Cerebral aqueduct
Red nucleus
Substantia nigra
LMS
CST
Anterior
AMZ
A
Pit. stalk
Interped. fossa
Cerebral ped.
CN II
AMZ
CN III
Post. perforated substance
B
Sup. colliculus
Medial geniculate body
Inf. colliculus
LMS
Sup. cerebell. ped.
CN IV
Mid. cerebell. ped.
Rhomb. fossa
Pontomesencephalic sulcus
C
Sup. colliculus
ICR
Inf. colliculus
CN IV
Sup. cerebell. ped.
Mid. cerebell. ped.
Rhomb. fossa
D


Midbrain
Axial section at the level of the superior colliculus
Anterior (ventral)
Cerebral peduncle
Substantia nigra
Red nucleus
Medial lemniscus
Medial geniculate nucleus
Medial longitudinal fasciculus
Mesencephalic nucleus of CN V
Superior colliculus
Periaqueductal grey matter
Oculomotor nucleus
Edinger-Westphal nucleus
Aqueduct of Sylvius
Posterior (dorsal)

Intro to Midbrain

AKA the Mesencephalon

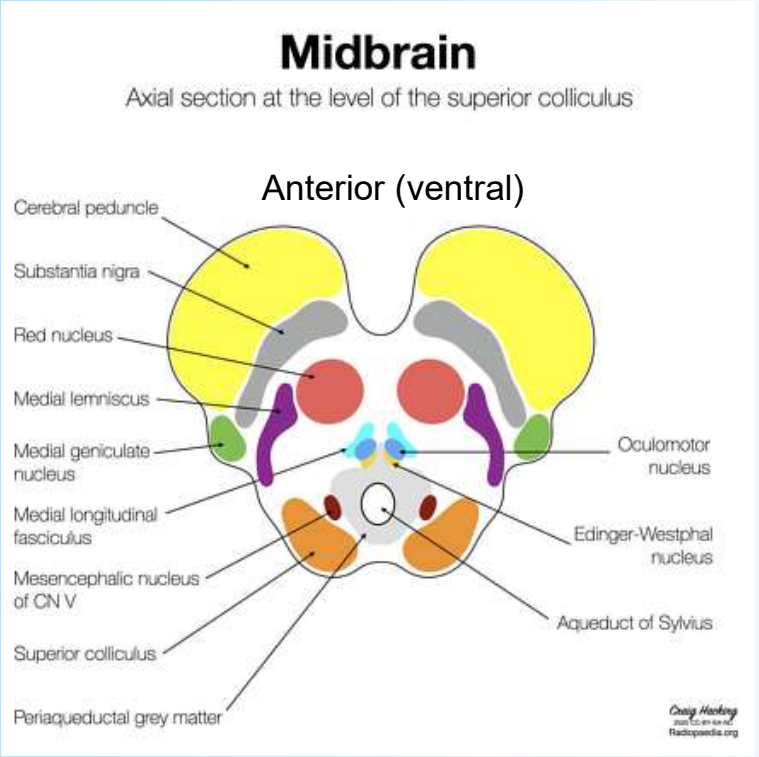
pons is below and the **diencephalon** is above (thalamus & hypothalamus).

Shortest part of brainstem (1.5cm)

The **midbrain** acts as a **superhighway and command center**:

→ **Pathway for ascending sensory and descending motor tracts**

→Contains **nuclei** essential for **vision**, **hearing**, **motor control**, **alertness**, and **temperature regulation**



📐 **DIVISIONS (From dorsal to ventral)**

Region	Also Known As	Key Structures
Tectum	"Roof"	Superior & inferior colliculi
Tegmentum	"Core"	Cranial nerve nuclei, red nucleus, reticular formation
Basis pedunculi	"Floor" (a.k.a. cerebral peduncles)	Corticospinal/corticobulbar tracts

studyaid

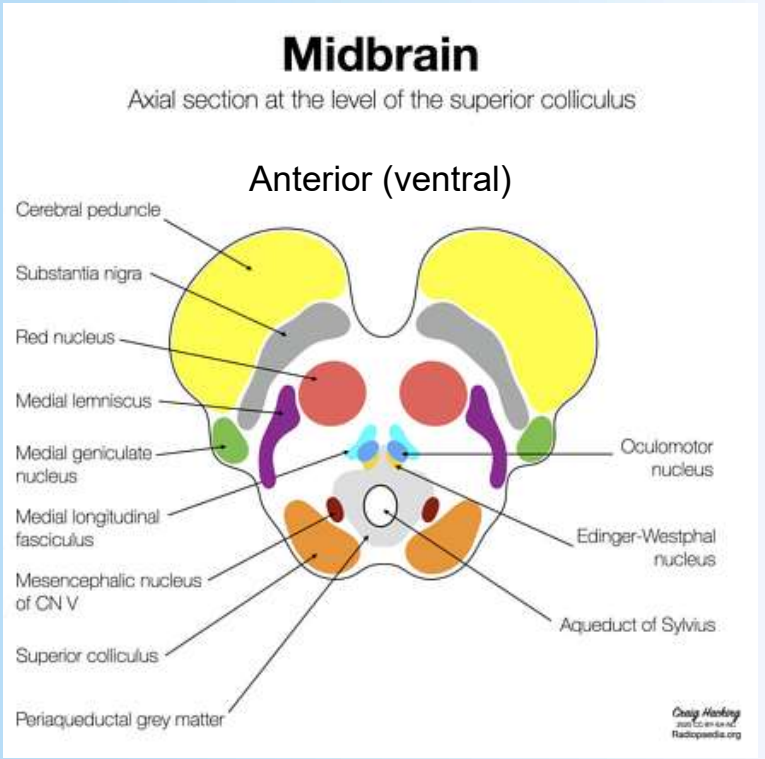
Midbrain - Tectum (roof)

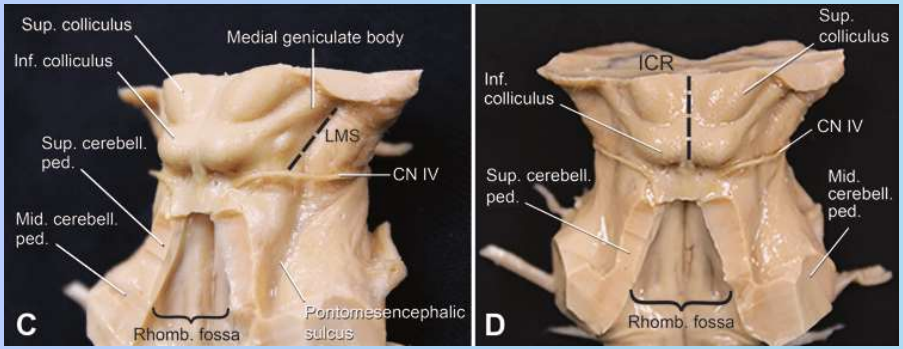
Tectum (Roof)

👀 **Superior colliculi**: Visual reflexes (e.g., tracking a moving object)

👂 **Inferior colliculi**: Auditory reflexes (e.g., turning your head to a loud bang)

Mnemonic: "**S**uperior = **S**ight, **I**nferior = **I**pod (sound)"





📐 **DIVISIONS (From dorsal to ventral)**

Region	Also Known As	Key Structures
Tectum	"Roof"	Superior & inferior colliculi
Tegmentum	"Core"	Cranial nerve nuclei, red nucleus, reticular formation
Basis pedunculi	"Floor" (a.k.a. cerebral peduncles)	Corticospinal/corticobulbar tracts

Midbrain - Tegmentum

AKA Middle area (the core)

•**Red nucleus**: Relay for **motor coordination** (especially limb flexors)

•**Substantia nigra**: Dopamine-producing neurons; **degenerates in Parkinson's** 🧠

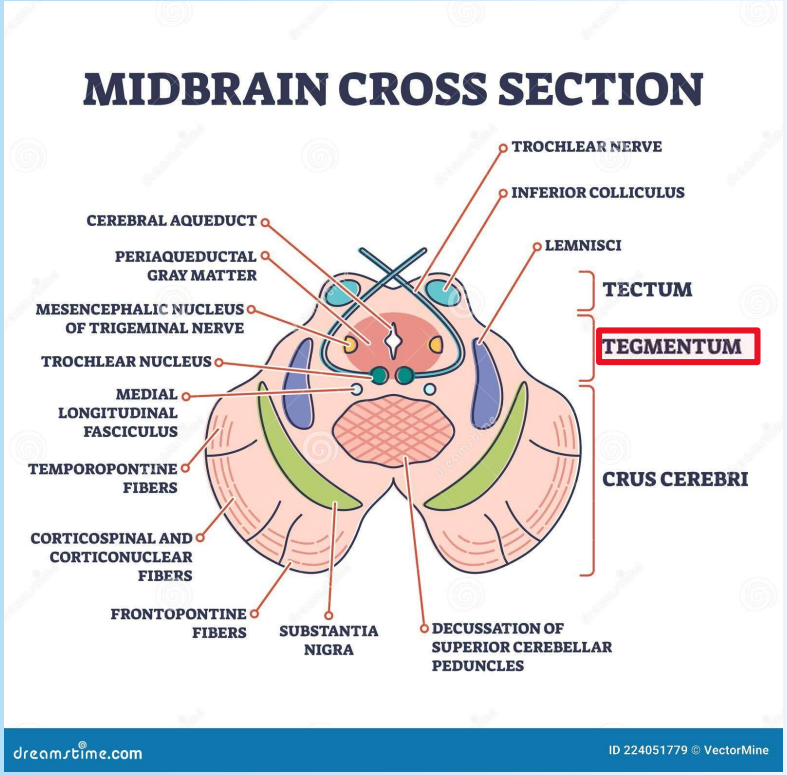
•**Periaqueductal gray matter**: Pain modulation, around the **cerebral aqueduct**

•**<u>CN nuclei</u>**:

•**Oculomotor nerve (CN III)** nucleus (at level of the **superior colliculus**)

•**Trochlear nerve (CN IV)** nucleus (at level of the **inferior colliculus**)

•**Edinger-Westphal nucleus**: Parasympathetic nucleus of CN III (just posterior to CN III)



What are the main functions of the E-W nucleus of CN III?

- **Pupillary constriction & Lens accommodation**
- (synapses at ciliary ganglion before reaching the eye)

studyaid

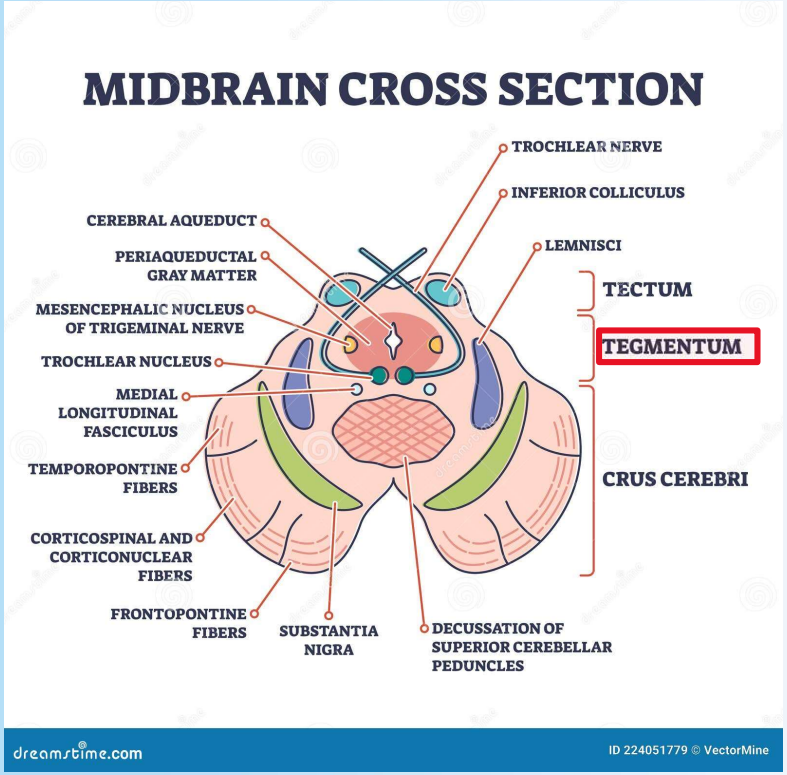
Midbrain -
Basis Pedunculi / Crus Cerebri

AKA the Floor

- Contains **cerebral peduncles**:
- **Corticospinal**, **corticobulbar**, and **corticopontine** tracts

🔍 FUNCTIONAL HIGHLIGHTS of MIDBRAIN

- **Eye movement control** (CN III, IV)
- **Auditory and visual reflexes** (colliculi)
- **Pain inhibition** (via periaqueductal gray)
- **Motor pathway relay** (via red nucleus & substantia nigra)
- **Dopaminergic modulation** (key for initiating movement)



What eye movement are we missing?

Abduction of eye via Lateral rectus m. from CN VI

studyaid

Pons

📍 **Location:**

Above: Medulla
Below: Midbrain

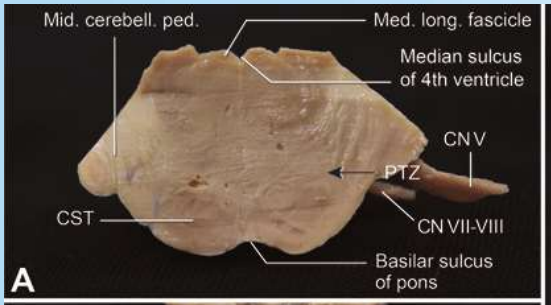
•**Posteriorly**: Forms the **floor of the 4th ventricle**

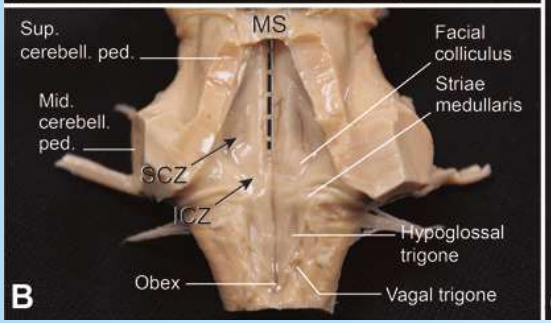
•Looks like a **bulging belly** on the anterior brainstem

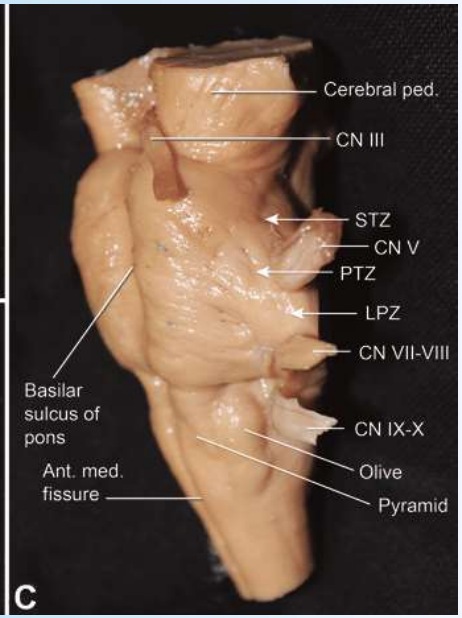
🧠 Latin “pons” = **bridge**, because it connects the **cerebrum to the cerebellum** via the **middle cerebellar peduncles**

•Contains the **Locus Coeruleus**:
→ Produces NOREPINEPHRINE for the CNS (90%)

→ Involved in arousal, attention, stress response
→ Degenerates in Parkinson’s, Alzheimer’s







🍱 DIVISIONS

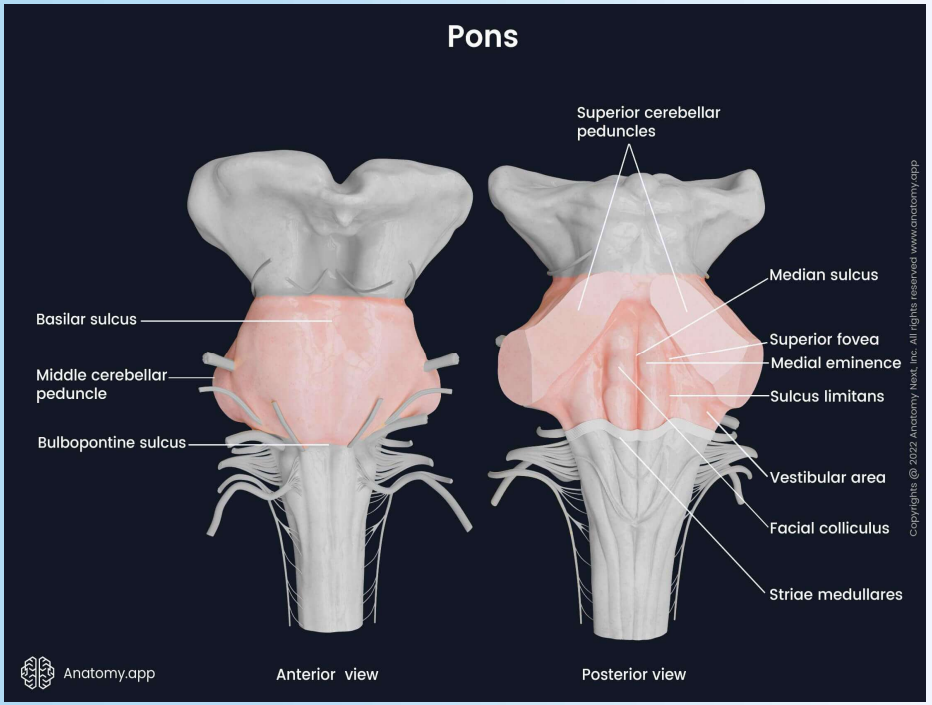
Region	Description	Main Contents
Basilar (ventral) pons	Motor tract-heavy front	Corticospinal & corticobulbar tracts, pontine nuclei
Tegmental (dorsal) pons	Nuclei & cranial nerve goodness	CN nuclei, reticular formation, sensory tracts

Pons

Basilar Pons:
(the anterior side)

- **Corticospinal tract**: Descending motor pathway
- **Corticobulbar tract**: From cortex to CN nuclei
- **Pontine nuclei**: Relay motor signals to the cerebellum
- **Transverse pontine fibers** → enter **middle cerebellar peduncle**

- The pontine nuclei relaying info → cerebellum allows us to have fine motor movement



DIVISIONS

Region	Description	Main Contents
Basilar (ventral) pons	Motor tract-heavy front	Corticospinal & corticobulbar tracts, pontine nuclei
Tegmental (dorsal) pons	Nuclei & cranial nerve goodness	CN nuclei, reticular formation, sensory tracts

Pons

Tegmentum of Pons:
(the posterior side)

•**Ascending sensory tracts**:

•**Medial lemniscus** (fine touch, vibration)

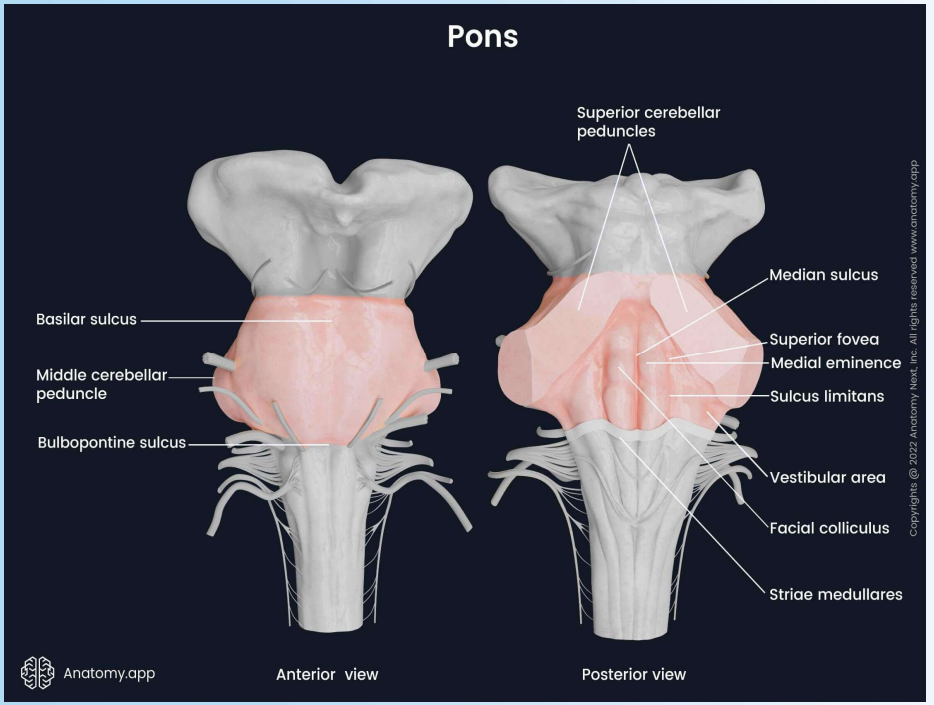
•**Spinothalamic tract** (pain/temp)

•**Reticular formation**: Keeps you awake and breathing

•Cerebellar Peduncles

•**Middle cerebellar peduncle**: Biggest one—motor input from pons → cerebellum

•**Superior cerebellar peduncle** (upper pons): Output from cerebellum → midbrain/thalamus



•**CN nuclei**:
•**CN V** – trigeminal: motor & sensory (mid-pons)
•**CN VI** – abducens (lower pons, medial)
•**CN VII** – facial (lower pons, lateral)
•**CN VIII** – vestibulocochlear (at pontomedullary junction)

studyaid

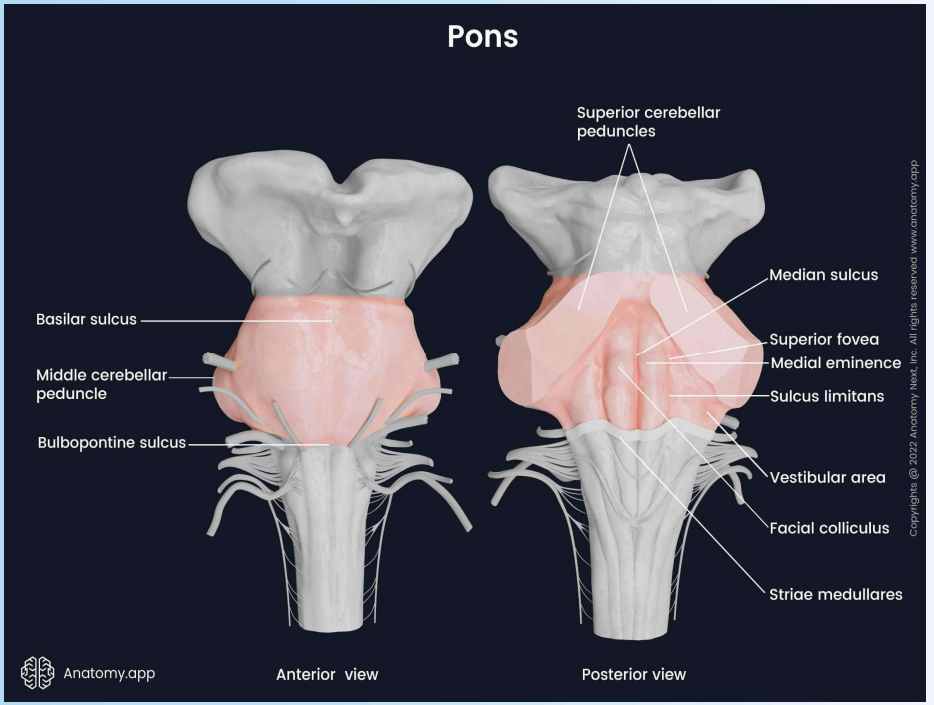
Pons

🎯 FUNCTIONAL HIGHLIGHTS

•**Relay station**: Cortex ↔ Cerebellum communication

•**Motor control**: Pontine nuclei are for fine-tuning movement

•**Cranial nerve functions**:
- CN V – facial sensation, mastication
- CN VI – lateral eye movement
- CN VII – facial expression, taste (ant. 2/3), lacrimation, salivation
- CN VIII – balance and hearing



CADAVER TIPS

Basilar pons = Large round ventral (anterior) part packed with vertical **motor tracts** and horizontal transverse fibers

Cranial nerves:

→ CN VI exits medially at pontomedullary junction AKA Cerebellopontine angle

→ CN VII & VIII exit more laterally

🧠 the facial nerve takes a looping path:

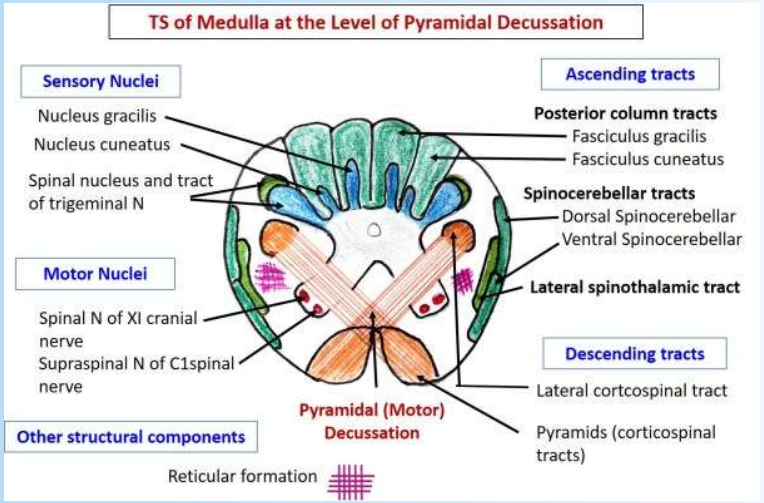
"Facial nerve takes the scenic route"

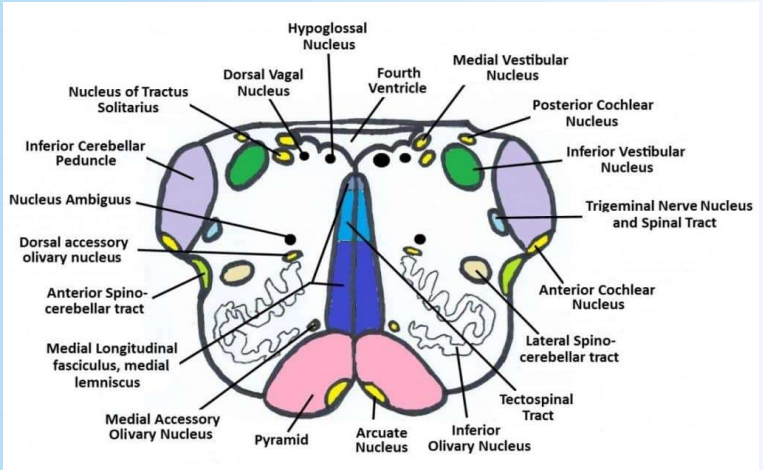
→ **CN VII loops around the abducens nucleus** inside the pons!

studyaid

Medulla

- **<u>Cranial Nerve Nuclei</u>**
- CN **IX** – glossopharyngeal
- CN **X** – vagus
- CN **XI** – accessory (cranial root)
- CN **XII** – hypoglossal



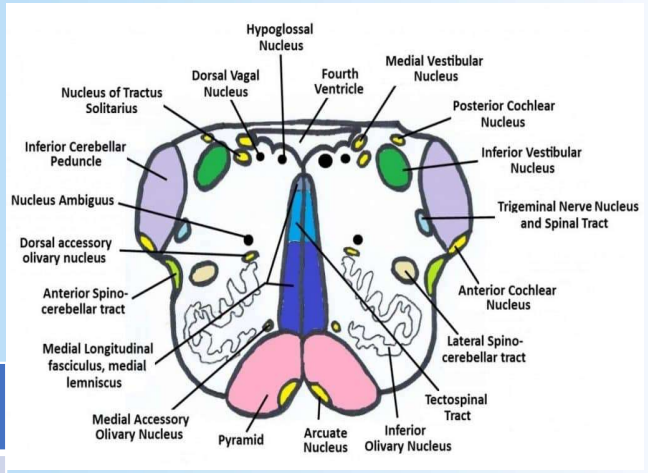


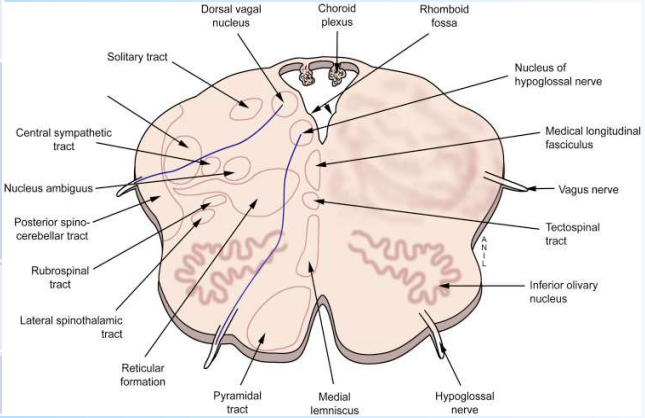
studyaid

Medulla

- Combo Nuclei of the Medulla

Nucleus	Cranial Nerve(s)	Function	Location
Nucleus Ambiguus	CN IX, X, XI	Motor to pharynx, larynx, soft palate (**Swallowing & speaking**)	Lateral Medulla
Dorsal motor nuc. of Vagus	CN X	**PARASYMPATHETIC** to heart, lungs, GI	Posterior medulla (beneath 4th ventrical)
Nucleus tractus Solitarius	CN VII, IX, X	**TASTE** (VII → ant. 2/3 of tongue, IX + X → post 1/3) epiglottis & visceral afferents (**baroreceptors**)	Dorsal medulla
Spinal trigeminal nucleus	CN V, VII, IX, X	Pain & temp. from the face	Lateral medulla, extending from pons
Hypoglossal nucleus	CN XII	Motor to tongue	Medial Medulla





studyaid

Nucleus Ambiguus

- Medulla
- CN IX, X, XI
- IX (glossopharyngeal)
- X (vagus)
- Work together for swallowing. N. Ambiguus essentially coordinates the movement of swallowing

S – Swallowing

> Controls the muscles of the **pharynx and larynx** (via CN IX & X)

W – Words

> Speech production through **laryngeal muscles** (think **hoarseness** when it's damaged)

A – Autonomic control of the heart

> Parasympathetic innervation to the **heart** via **CN X** (minor role, slows heart rate)

G – Gag reflex motor (efferent limb via CN X)

Dorsal Motor nucleus of vagus (CN X)

- Medulla
- CN X

S – Swallowing

> Controls the muscles of the **pharynx and larynx** (via CN IX & X)

W – Words

> Speech production through **laryngeal muscles** (think **hoarseness** when it's damaged)

A – Autonomic control of the heart

> Parasympathetic innervation to the **heart** via **CN X** (minor role, slows heart rate)

G – Gag reflex motor (efferent limb via CN X)

- Is the epicenter of parasympathetic release from the vagus nerve.
  - E.g.
    - Heart
    - Lungs
    - GI tract (pancreas, gallbladder, secretions
    - Kidney

Nucleus Tractus Solitarius

S – Swallowing

> Controls the muscles of the **pharynx and larynx** (via CN IX & X)

W – Words

> Speech production through **laryngeal muscles** (think **hoarseness** when it's damaged)

A – Autonomic control of the heart

> Parasympathetic innervation to the **heart** via **CN X** (minor role, slows heart rate)

G – Gag reflex motor (efferent limb via CN X)

- Medulla
- CN VII, IX, X
- It's called "solitary" because it carries visceral (internal organ) sensory fibers, which are distinct from somatic sensory fibers — they run alone, hence: “solitary”.

- 🧠 Mnemonic:
  - “NTS = Nice Taste Station”…
  - and also “Nervous Traffic Sensor” — because it’s always monitoring autonomic input.

Baroreceptors & Chemoreceptors (GVA)	CN IX, X	Carotid sinus, aortic arch
Taste (SVA)	CN VII, IX, X	Tongue, epiglottis

Spinal Trigeminal Nucleus

Afferent Inputs (1st-order neurons):

Nerve	Sensory Info
CN V (Trigeminal)	Face (main source)
CN VII (Facial)	Part of the external ear
CN IX (Glossopharyngeal)	Posterior tongue, pharynx
CN X (Vagus)	External auditory canal, larynx

- Medulla
- CN V, VII, IX, X
- Spinal because it stretches from Midbrain to spinal cord

- Pure sensory (afferent) from the face and the oropharynx

- All sensory from the CN's above come to the STN, synapse and then move up to the Ventral Posteromedial Nucleus (VPM) → Primary Sensory Cortex

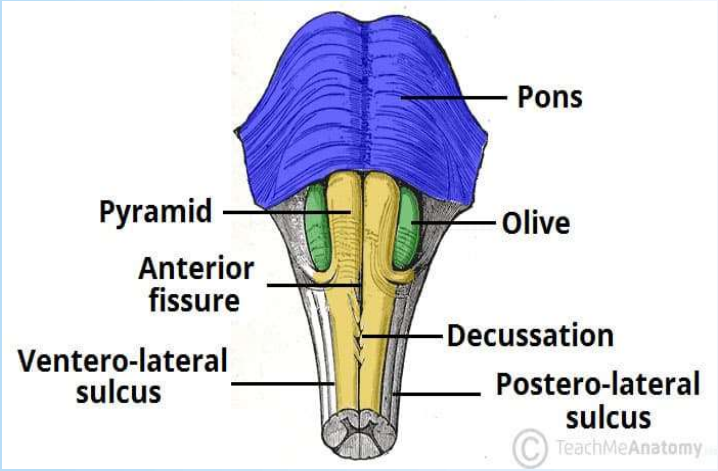
Hypoglossal nucleus

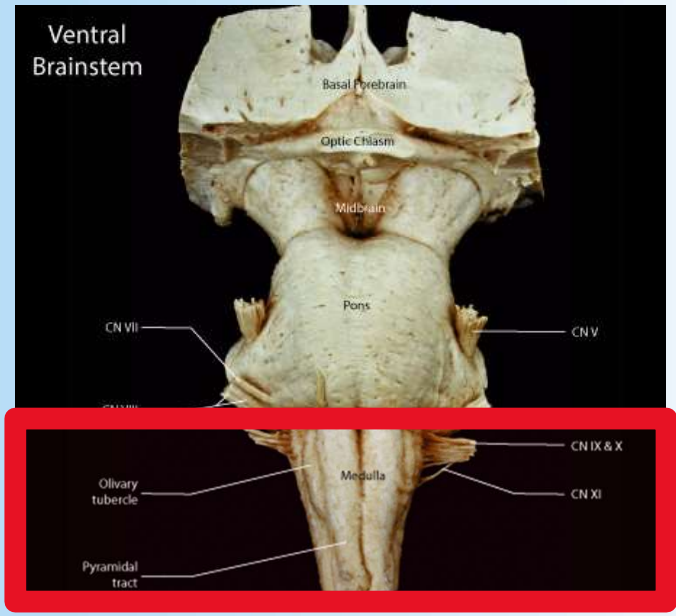
- CN XII, pure motor to tongue ☺

Medulla

- <u>Anatomical Structures</u>
- **Pyramids** (anterior)
  - Contain **corticospinal tracts**
  - Site of pyramidal **decussation** (crossing over of motor fibers)

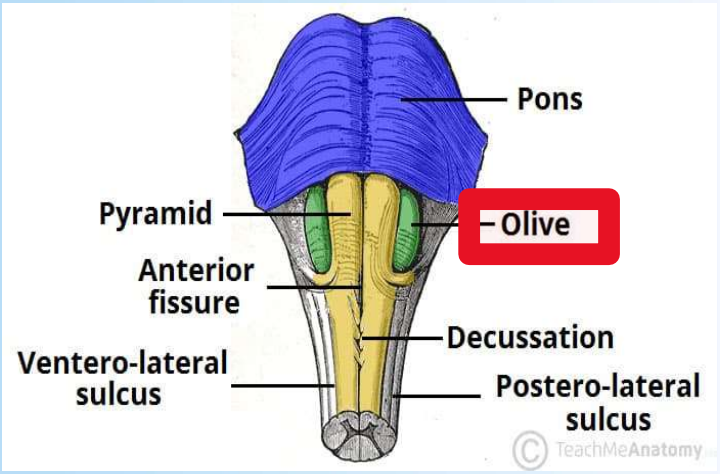
- ❗ Lesion above = contralateral symptoms; below = ipsilateral
  - E.g. Stroke above medullary pyramids in **medial part of the right Motor cortex**
    - **Contralateral loss of movement in <u>Left Leg</u>**
  - E.g. Lesion below at level of C7, in the left half of spinal cord
    - **Ipsilateral** loss of movement in Left Leg, (and triceps & fingers)

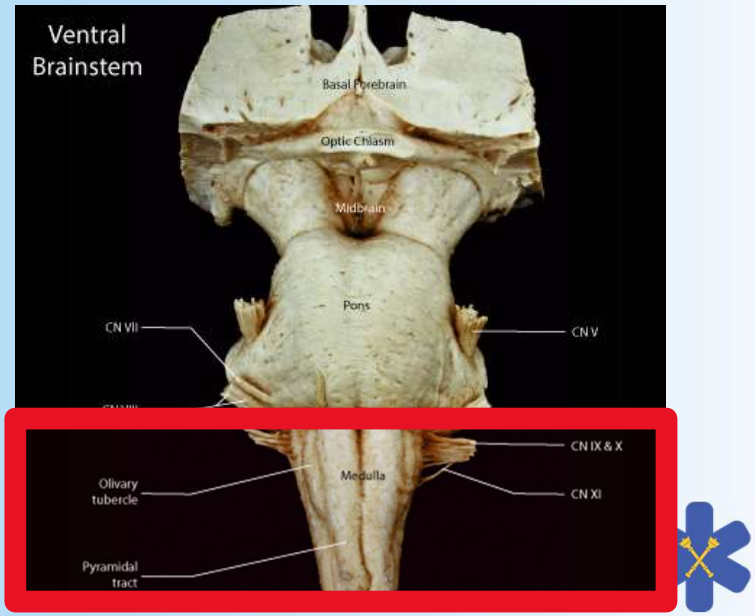




Medulla

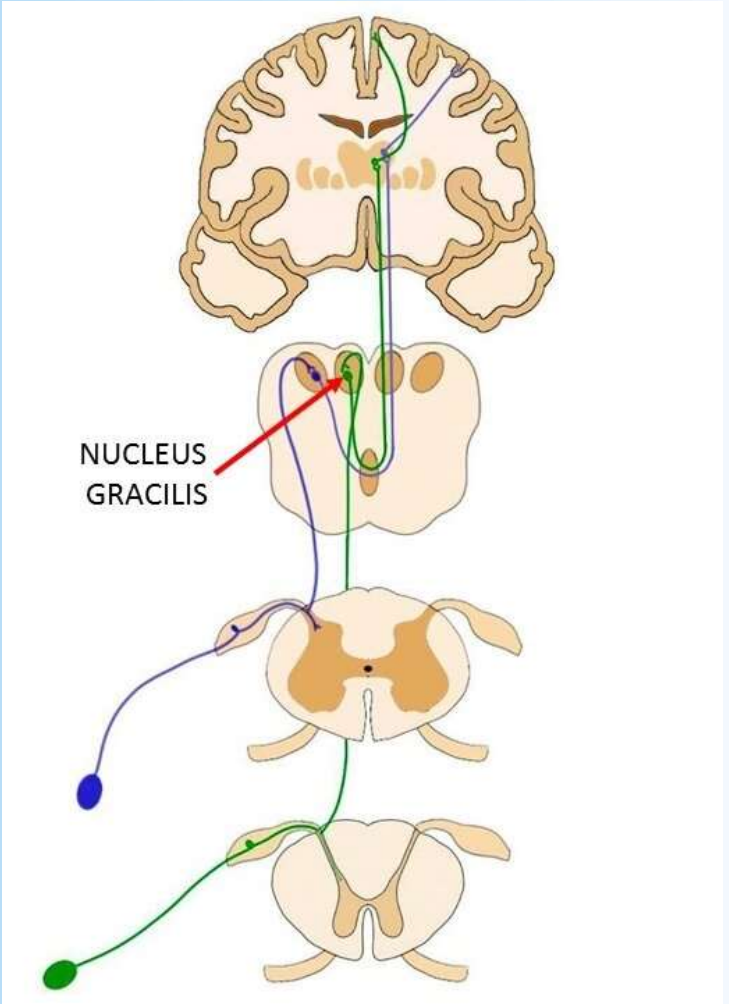
- Olives (lateral bulges)
- Contain the **inferior olivary nucleus: motor learning** & cerebellar relay





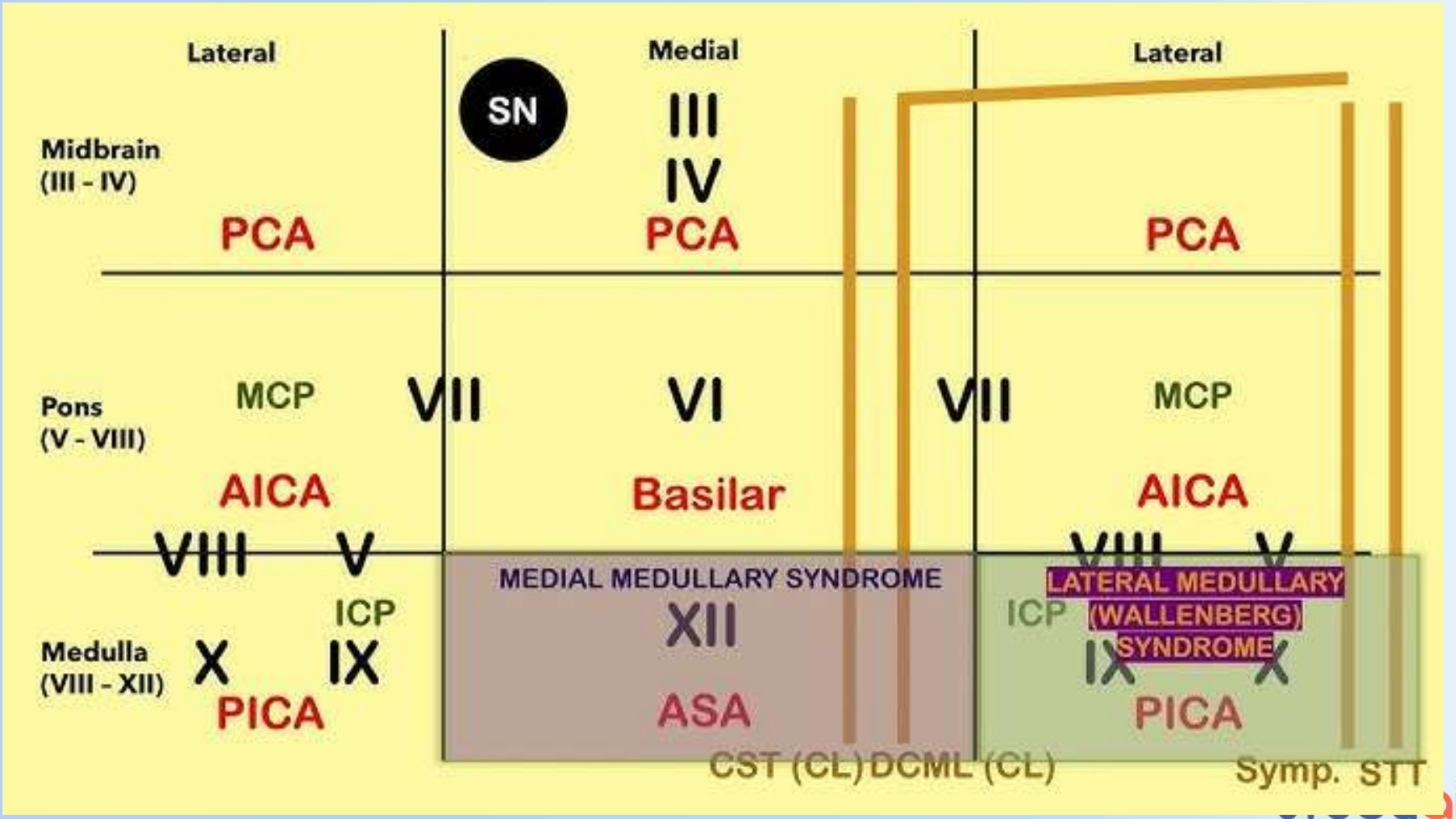
Medulla

- **Anatomical Structures**
- **Posterior Column Nuclei**
- Nucleus gracilis (legs)
- nucleus cuneatus (arms)
- Receive **sensory info** (fine touch, vibration, proprioception) from the spinal cord
- Fibers **decussate** as internal arcuate fibers and form the **medial lemniscus**

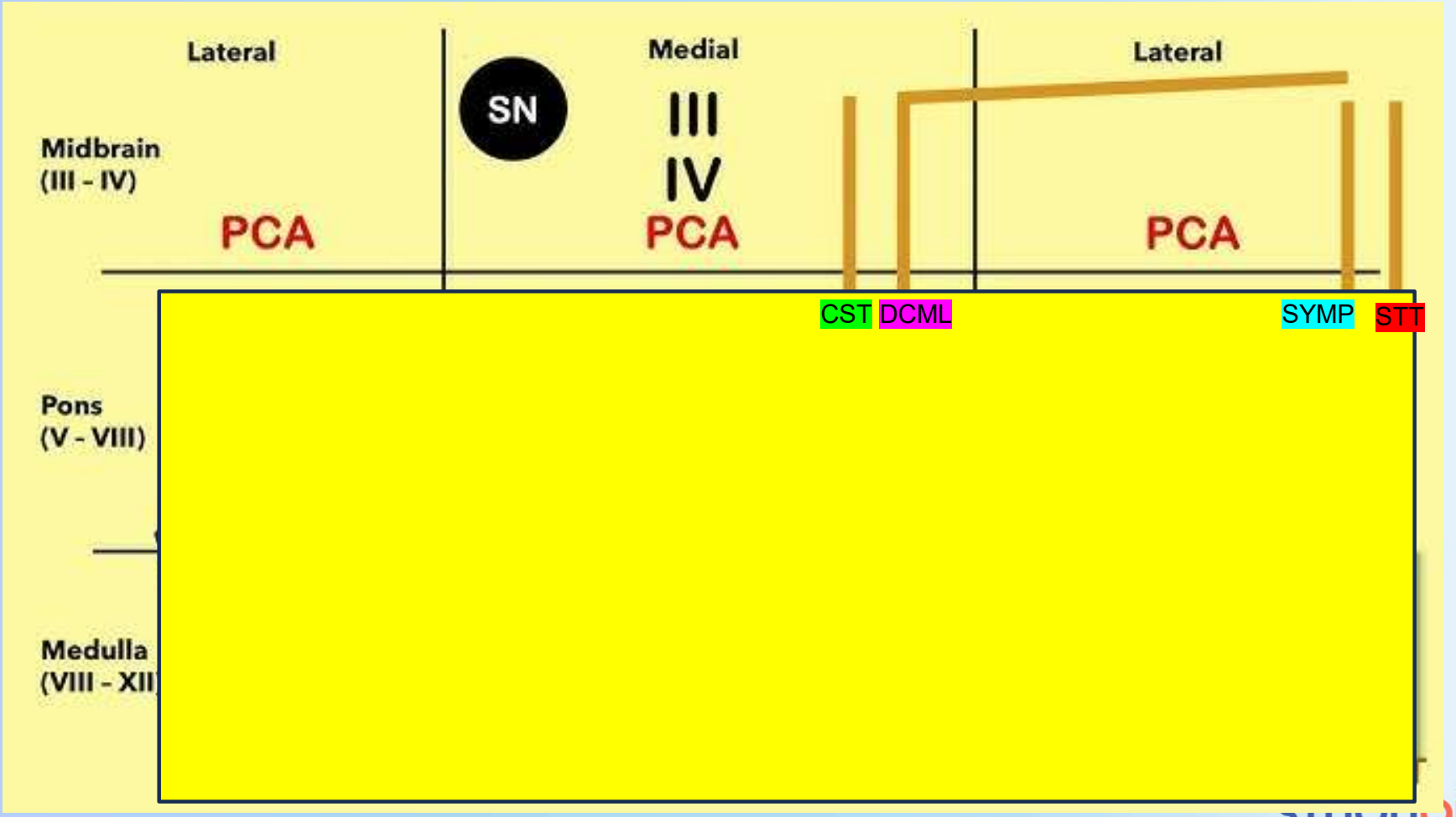


studyaid

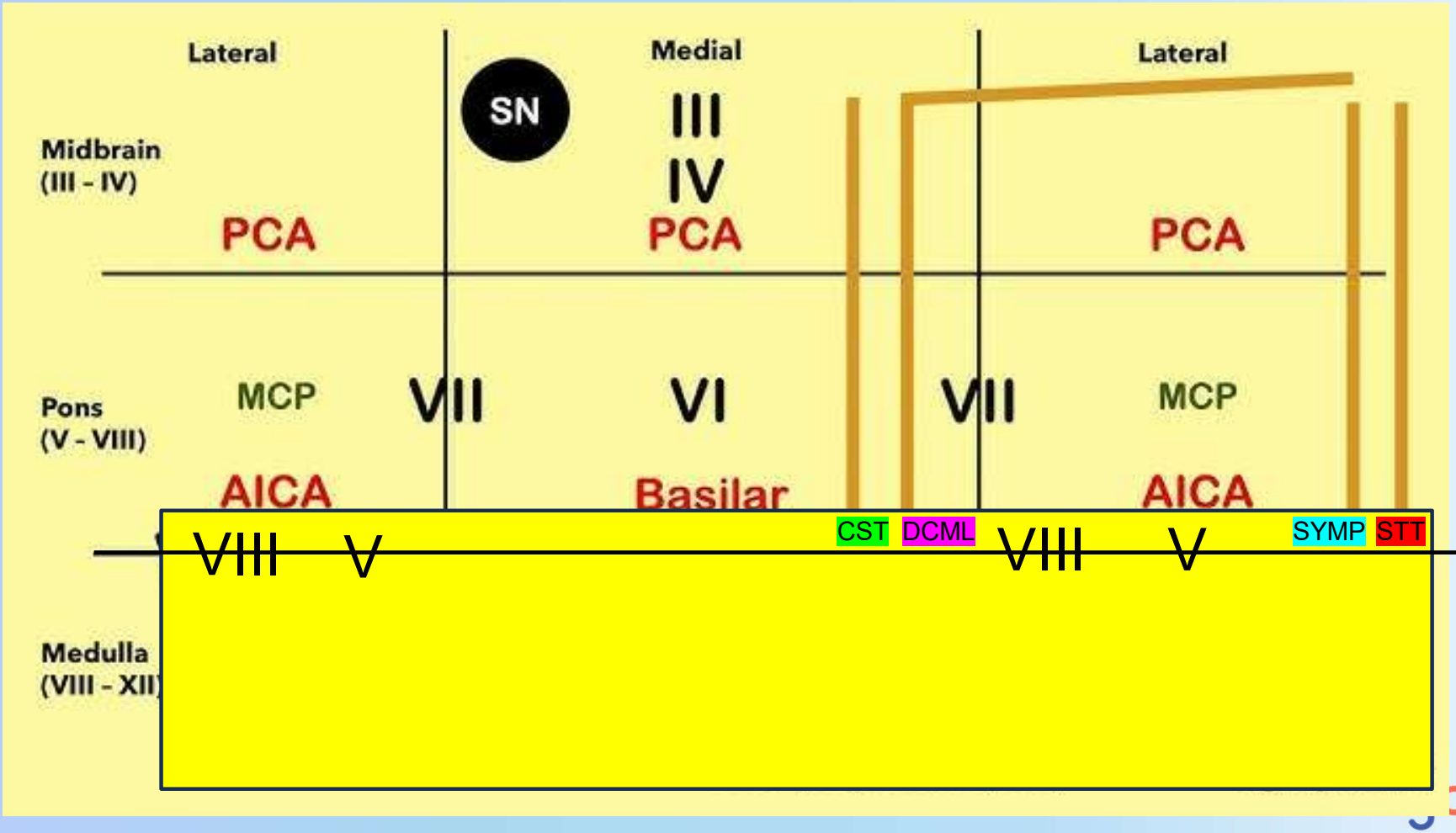
Blood Supply to Brain Stem



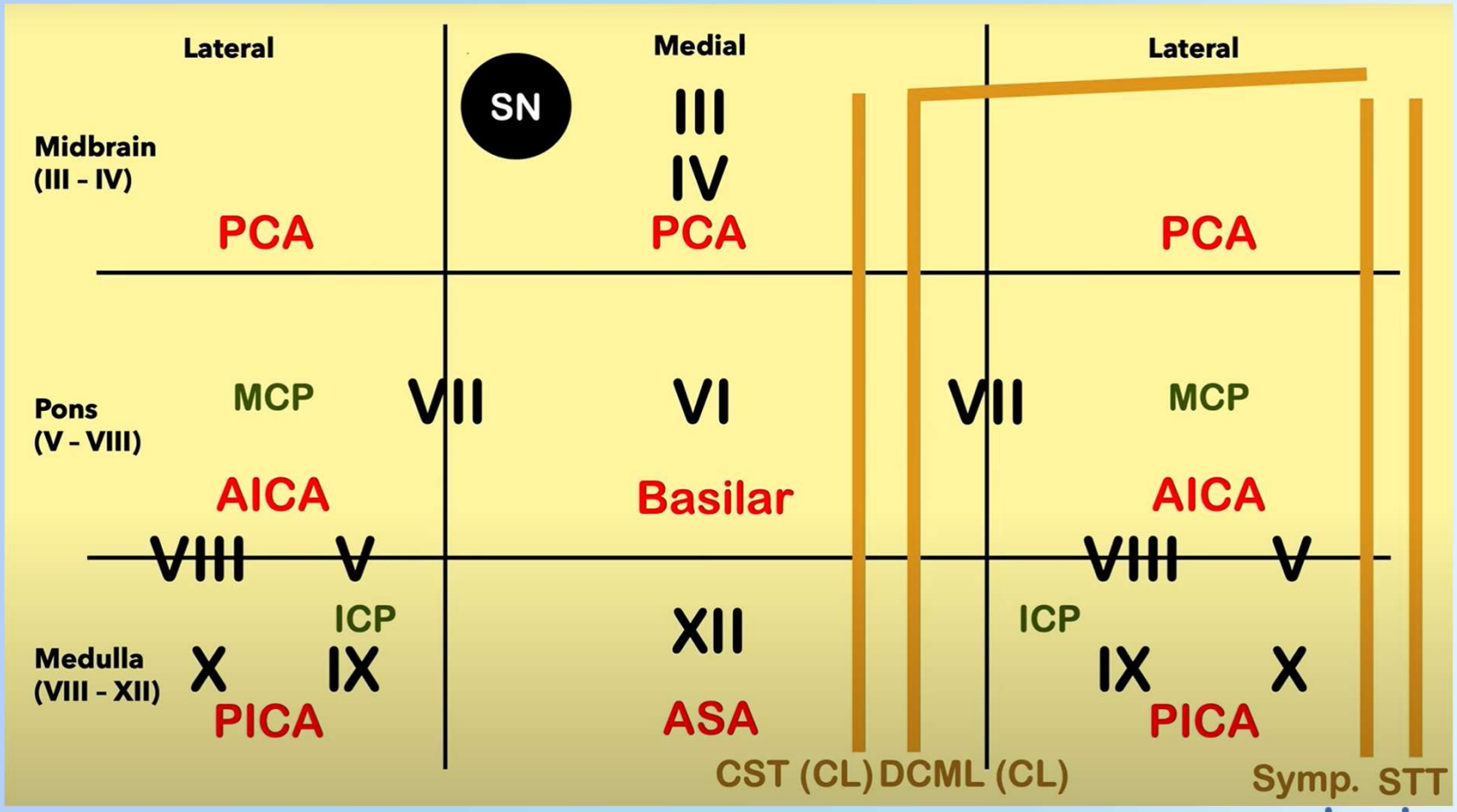
Blood Supply to Brain Stem



Blood Supply to Brain Stem



Blood Supply to Brain Stem

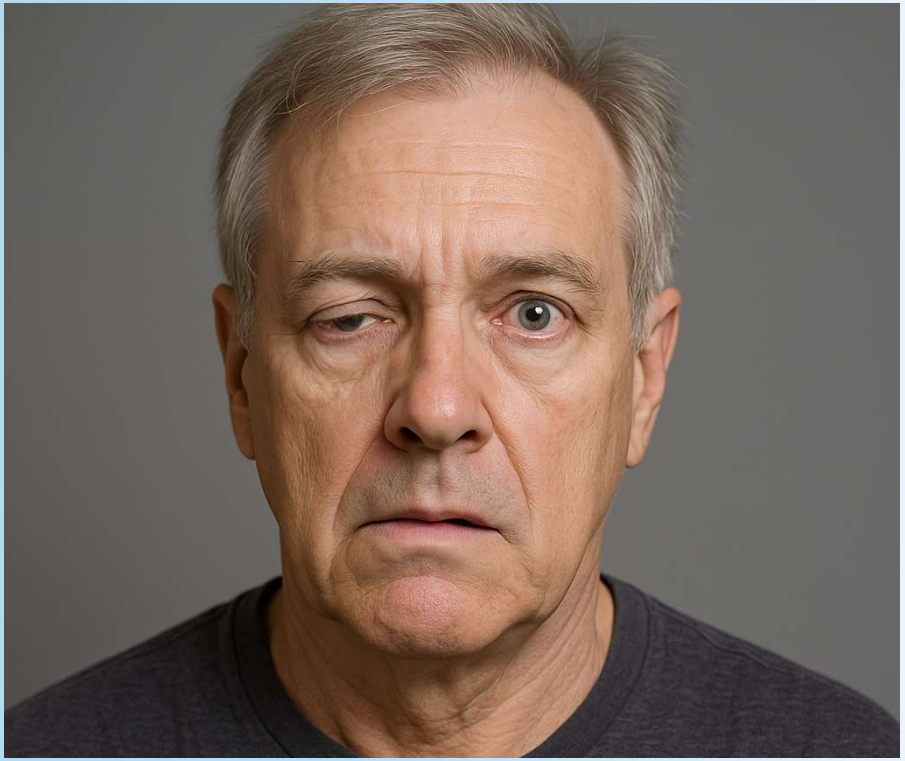


studyaid

Case Studies to Solidify your Knowledge #1

A 71-year-old man presents with sudden **dizziness, nausea, hoarseness**, and **numbness**. On exam:

- He has **loss of pain and temp on the left side of his body** and **right side of his face.**
- His voice is **hoarse**, with **dysphagia.**
- He is **ataxic on the right side**, with **vertigo and nystagmus.**
- He has **ptosis and miosis on the right side.**



studyaid

Case Studies to Solidify your Knowledge #1

A 71-year-old man presents with sudden **dizziness, nausea, hoarseness**, and **numbness**. On exam:

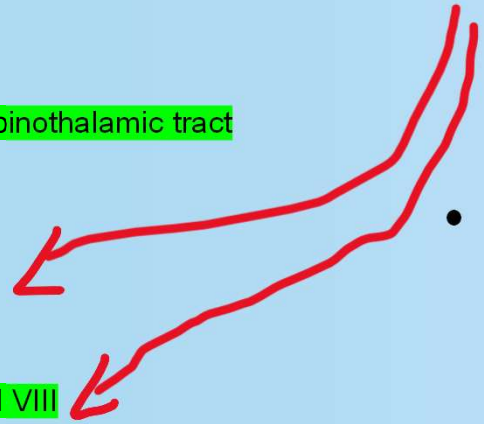
- He has **loss of pain and temp on the right side of his body** and **left side of his face.**
- His voice is **hoarse**, with **dysphagia**.
- He is **ataxic on the left side**, with **vertigo and nystagmus**.
- He has **ptosis and miosis on the left side.**

- What Cranial Nerves are involved, and what part of the brainstem would that point us to?
- Are the CN's located laterally or medially?
- What artery is infarcted?

#1 = Lateral Medullary (Wallenberg) Syndome

A 71-year-old man presents with sudden **dizziness, nausea, hoarseness**, and **numbness**. On exam:

- He has **loss of pain and temp on the right side of his body** and **left side of his face.** Spinothalamic tract
- His voice is **hoarse**, with **dysphagia**. CN IX, X
- He is **ataxic on the left side**, with **vertigo and nystagmus**. CN VIII
- He has **ptosis and miosis** on **the left side.** Horner Syndrome: Symp tract



- What Cranial Nerves are involved, and what part of the brainstem would that point us to?
- Are the CN's located laterally or medially?

  Lateral & Lateral, Symp and ST tract are also lateral
- What artery is infarcted?

  PICA

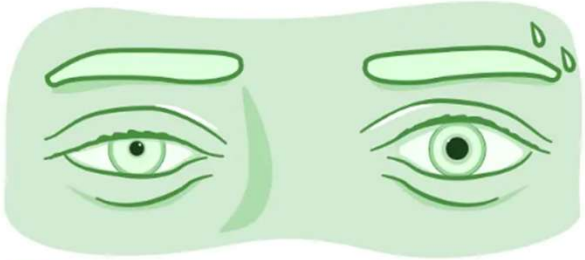
studyaid

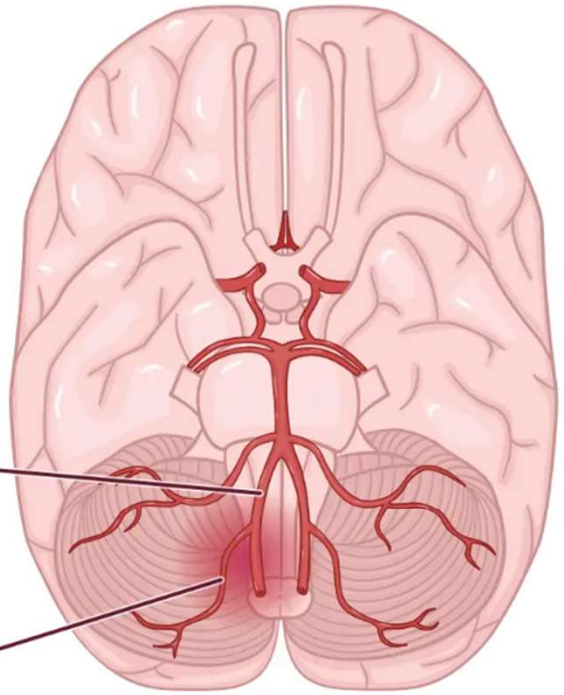
WALLENBERG SYNDROME

"LATERAL MEDULLARY SYNDROME" OR
"POSTERIOR INFERIOR CEREBELLAR ARTERY (PICA) SYNDROME"

SYMPTOMS:

- HORNER SYNDROME (DECREASED PUPIL SIZE, DROOPING EYELID, DECREASED SWEATING)
- DOUBLE VISION
- SLURRED SPEECH
- DIZZINESS





Case Studies to Solidify your Knowledge #2

🧑‍⚕️ **Patient:** A 58-year-old man presents with sudden vertigo, nausea, left-sided facial weakness, and difficulty hearing in his left ear.

He also reports loss of balance and a sensation of falling to the left.

🔍 **Exam Findings:**

Left LMN facial palsy: Weakness of both upper and lower face

Left hearing loss: Sensorineural

Left-sided ataxia: Uncoordinated limb movement, wide-based gait

Left-sided facial numbness (pain/temp): Feels like "a dentist shot gone wrong“

Right-sided body numbness (pain/temp): In arm and leg

Left Horner’s syndrome: Ptosis, miosis, anhidrosis

Nystagmus and vertigo when asked to fix gaze

Case Studies to Solidify your Knowledge #2

🔍 **Exam Findings:**

Left LMN facial palsy: Weakness of both upper and lower face

- **Left hearing loss**
- **Left-sided ataxia**: Uncoordinated limb movement, wide-based gait
- **Left-sided facial numbness** (pain/temp): Feels like "a dentist shot gone wrong"
- **Right-sided body numbness** (pain/temp): In arm and leg
- **Left Horner's syndrome**: Ptosis, miosis, anhidrosis
- **Nystagmus and vertigo** when asked to fix gaze (look straight at object)

- What Cranial Nerves are involved, and what part of the brainstem would that point us to?
- Are the CN's located laterally or medially?
- What artery is infarcted?

studyaid

Case Studies to Solidify your Knowledge #2

🔍 **Exam Findings:**

Left LMN facial palsy: Weakness of both upper and lower face

- **Left hearing loss** CN VIII
- **Left-sided ataxia**: Uncoordinated limb movement, wide-based gait CN VIII
- **Left-sided facial numbness** (pain/temp): Feels like "a dentist shot gone wrong" CN V
- **Right-sided body numbness** (pain/temp): In arm and leg Spinothalamic tract
- **Left Horner's syndrome**: Ptosis, miosis, anhidrosis Sympathetic tract
- **Nystagmus and vertigo** when asked to fix gaze (look straight at object) CN VIII

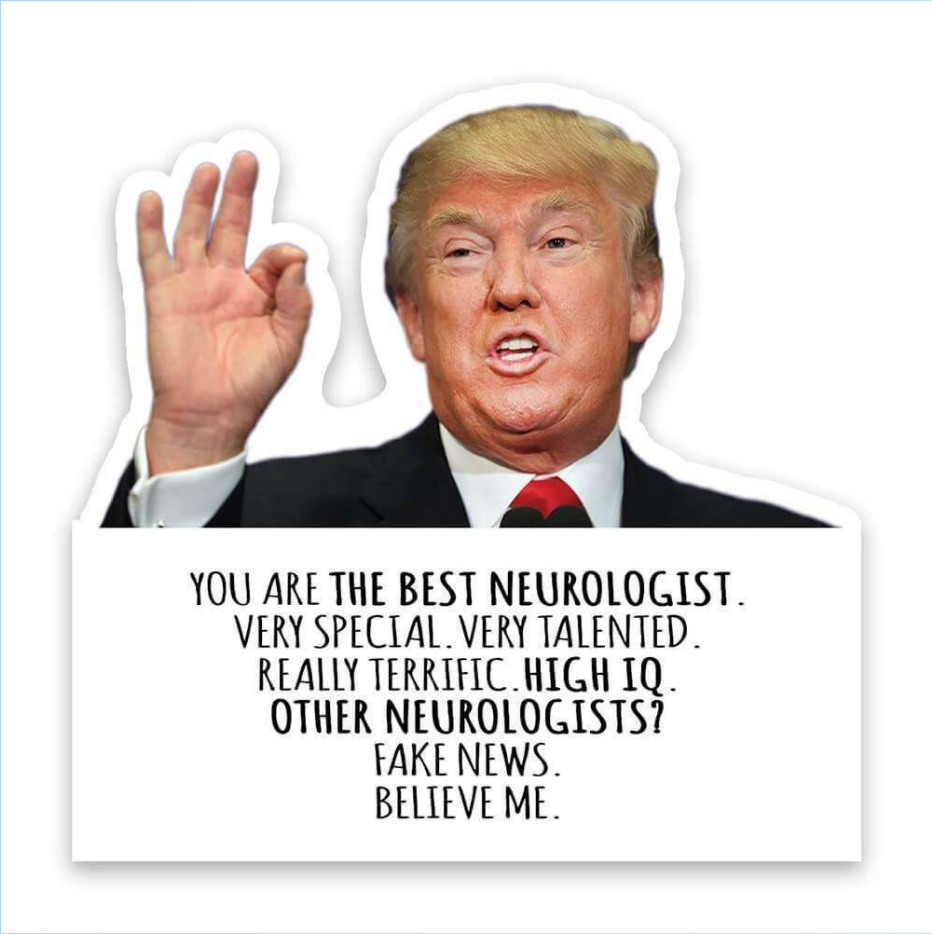
- What Cranial Nerves are involved, and what part of the brainstem would that point us to?
- Are the CN's located laterally or medially?

  CN V is lateral, VII is on the border, CN VIII lateral
  STT and Sympathetic tract are both lateral
- What artery is infarcted?

AICA

studyaid

Some (not) Fake news for you!



Good Luck on Exam Day!

studyaid