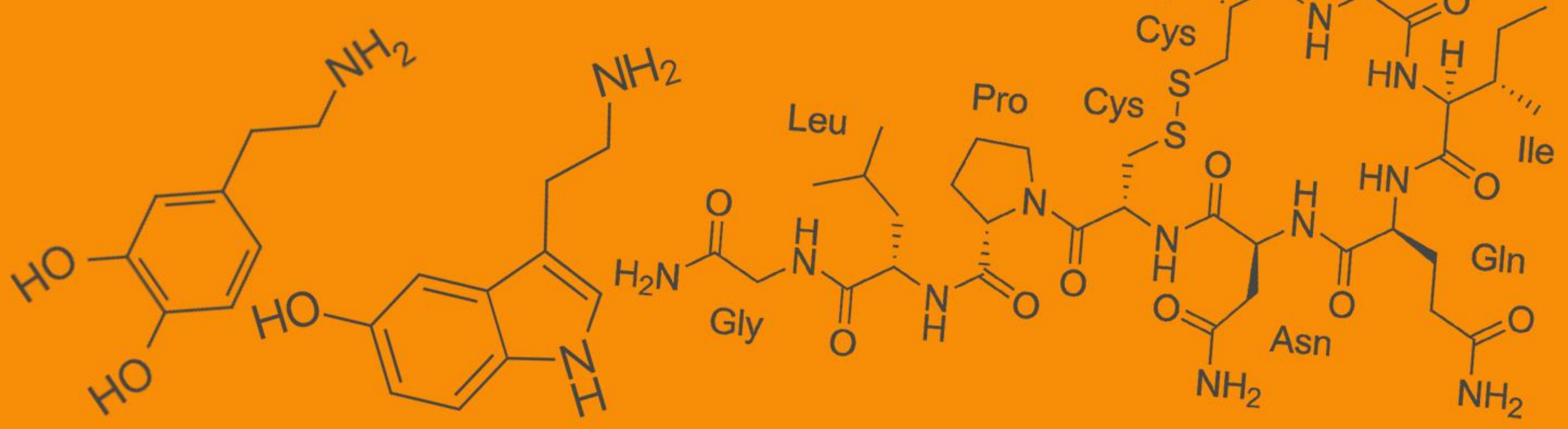
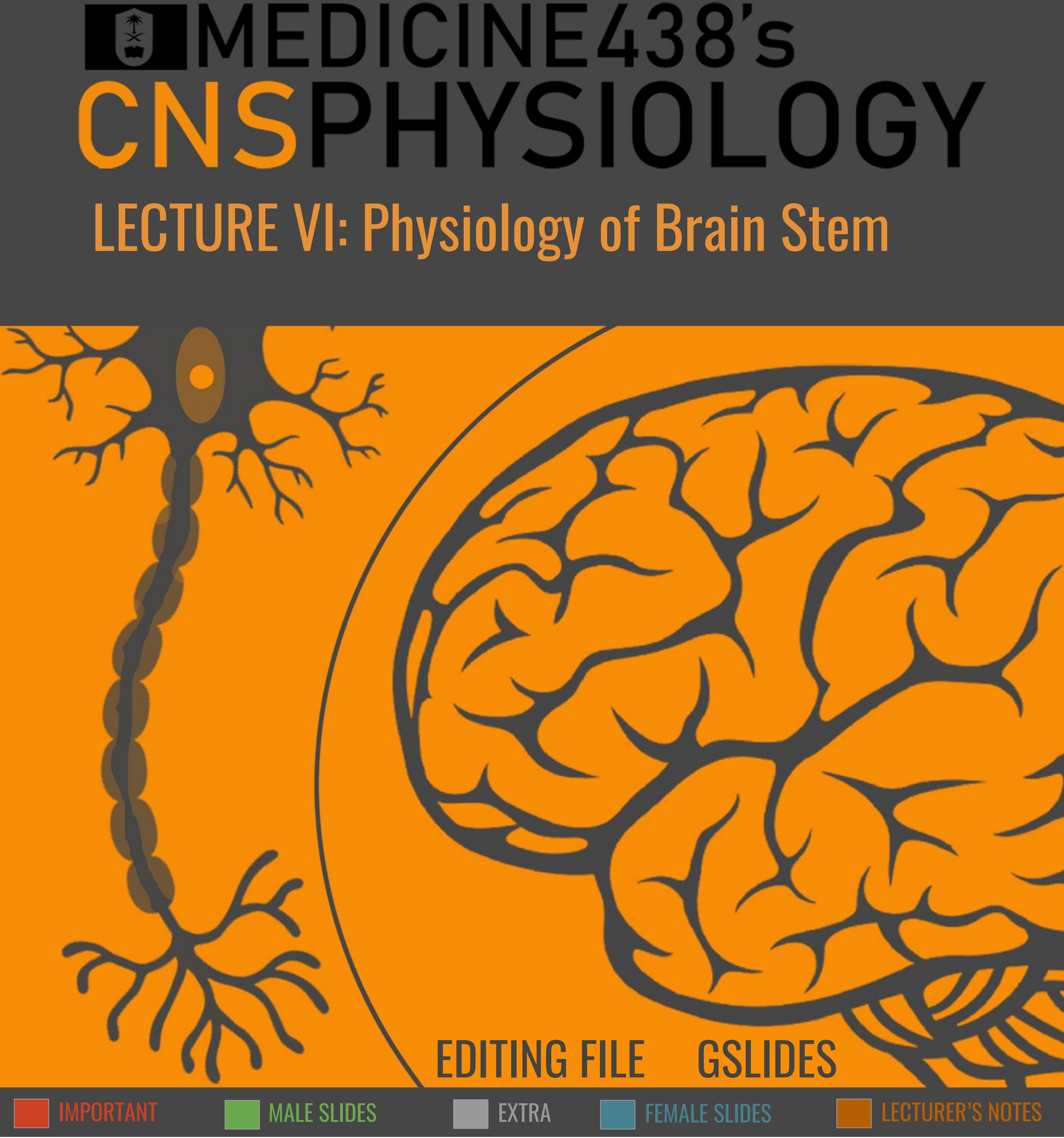


MEDICINE 438's CNS PHYSIOLOGY

LECTURE VI: Physiology of Brain Stem



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IMPORTANT | MALE SLIDES | EXTRA | FEMALE SLIDES | LECTURER'S NOTES

1 Physiology of Brain Stem

Lecture Six

OBJECTIVES

- **Enumerate components of brainstem**
- **List important structures in brainstem**
- **Describe functions of the brainstem**
- **Describe signs & symptoms of brainstem lesion**
- **Understand brainstem function tests**

The Brainstem

PRESENT ONLY IN FEMALE SLIDES

- The brainstem is the lower part of the brain.
- It is adjoining and structurally continuous with the spinal cord

Components of the Brainstem

1. Midbrain
2. Pons
3. Medulla Oblongata

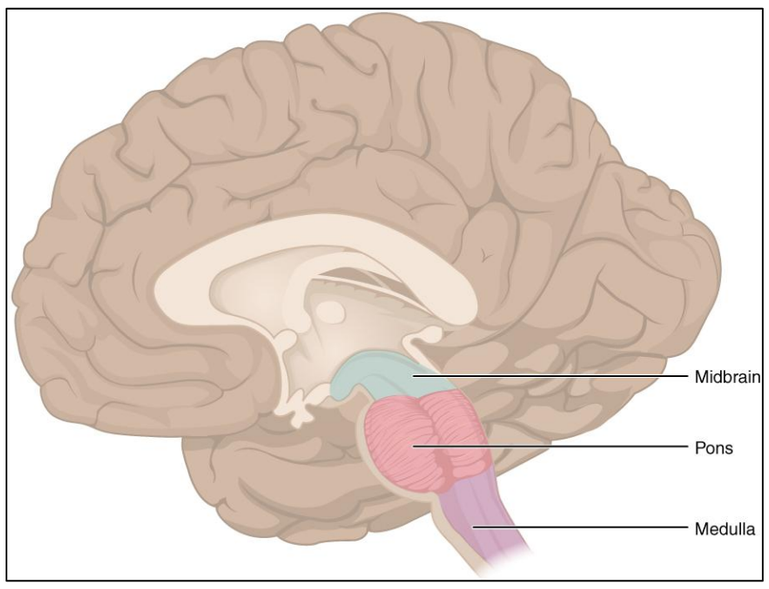


Figure 7-1 Showing components of the brainstem.

- The midbrain, pons and medulla connect to the **cerebellum** via the **<u>superior</u>**, **<u>middle</u>** and **<u>inferior</u> peduncles** respectively.

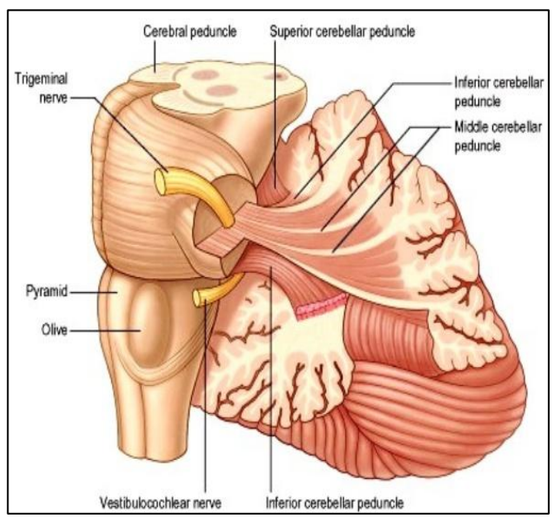


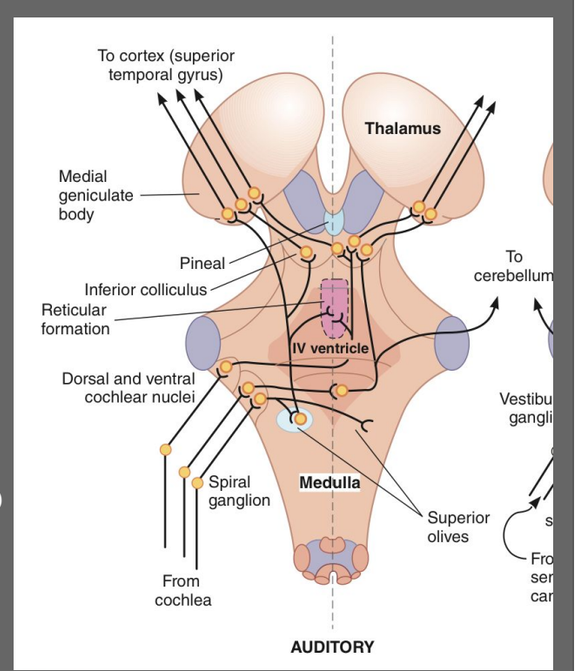
Figure 7-2 Showing cerebellar peduncles.

BOX 6-1: GANONG'S REVIEW OF MEDICAL PHYSIOLOGY & GUYTON AND HALL

AUDITORY PATHWAYS

The ear converts sound waves in the external environment into action potentials that are transmitted through the auditory branch of the 8th cranial nerve (which divides into vestibular and cochlear branches) by multiple routes that converge on the medial geniculate body, a part of the auditory thalamus, which functions to gather all the auditory impulses of the auditory pathway and serves as link between the auditory pathway and the auditory cortex.

- Impulses from the auditory nerve terminate in cochlear nuclei, from there auditory impulses pass through various pathways, some cochlear collaterals from cochlear fibers terminate in superior olivary nucleus, a group of nuclei in the brain stem, which function to determine the direction of sound. Fibers from the superior olivary nucleus can extend and send collaterals to the reticular activating system, which in turns activates all of the nervous system in response to loud sounds.
- Fibers from cochlear nuclei can also terminate in the inferior colliculi, which functions as a center for auditory reflexes, then through its superior brachium (a connecting arm between the colliculi and the geniculate bodies) transmit the auditory impulses to the medial geniculate body.



The Midbrain Is divided into 3 parts:

The Tectum		The Tegmentum	Cerebral Peduncles
A) The superior colliculus: - It constitutes center for **visual reflexes**. - It sends its **superior brachium** to the lateral geniculate body[1] of the thalamus.	**B) The inferior colliculus:** - It is associated with **auditory pathway**. - It sends its **inferior brachium** to the medial geniculate body (refer to BOX 6-1) of the thalamus. - The cerebral aqueduct runs through the midbrain, beneath the colliculi.	- **Ventral** to the cerebral aqueduct. - Several nuclei, tracts and the reticular formation is contained here.	- The ventral side of the midbrain is comprised of paired Cerebral Peduncles - These transmit axons of UMNs.

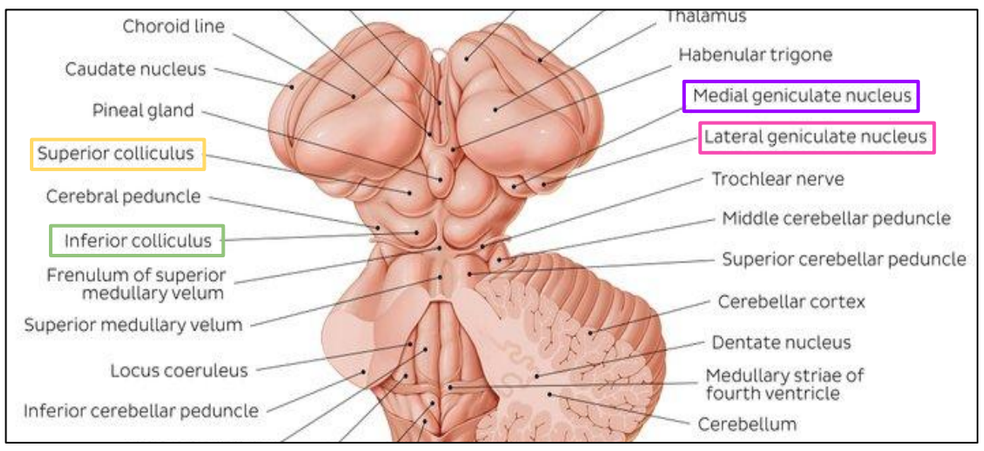


Figure 7-3 Midbrain

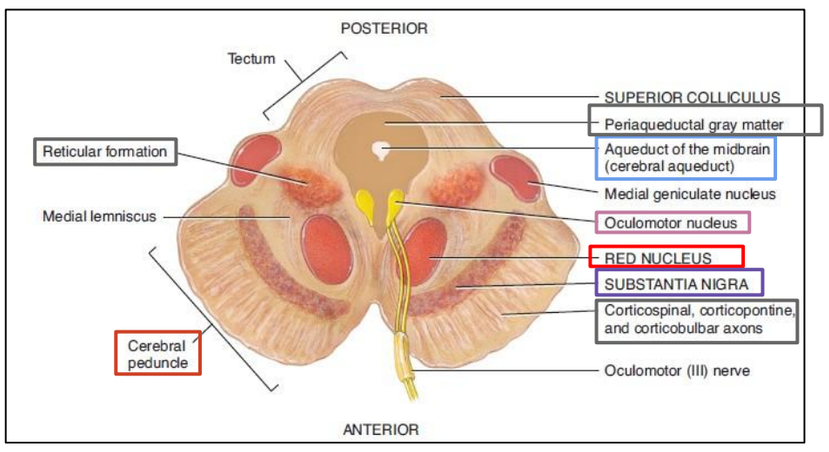


Figure 7-4 Internal structures of the brainstem.

The Midbrain Internal Structures

Reticular Formation	Nerves		Central Tegmental Tract:
A large area that is involved in various important functions of the midbrain: - It contains LMN. - It is involved in the pain desensitization pathway. - It is involved in the arousal and consciousness systems. - It contains the locus coeruleus, which is involved in intensive alertness modulation and in autonomic reflexes.	Oculomotor Nerve (CN III) nucleus	Trochlear Nerve (CN IV) nucleus	- Directly anterior to the floor of the 4th ventricle. - It is a pathway by which many tracts project up to the cortex and down to the spinal cord.

Red Nucleus	Substantia Nigra	Periaqueductal Grey matter
This is a **motor nucleus** that sends a descending tract "Rubrospinal tract" to the lower motor neurons.	- A concentration of neurons in the ventral portion of midbrain. - It is involved in **motor function.**	Around the cerebral aqueduct, contains neurons involved in the pain desensitization pathway

PRESENT ONLY IN FEMALE SLIDES

FOOTNOTES

1. **Brachium:** a connecting arm between the colliculi and the geniculate bodies. **The lateral geniculate nuclei** act much like the medial geniculate body (BOX 6-1) as a relay station, from which signals from the optic pathway can be collected connected to the visual cortex.

The Pons

- At the Level of the mid pons
  - Trigeminal nerve (CN V) emerges
- Between the basal pons
  - Abducens nerve (CN VI) emerges
  - Facial nerve (CN VII) emerges
  - Vestibulocochlear nerve (CN VIII) emerges

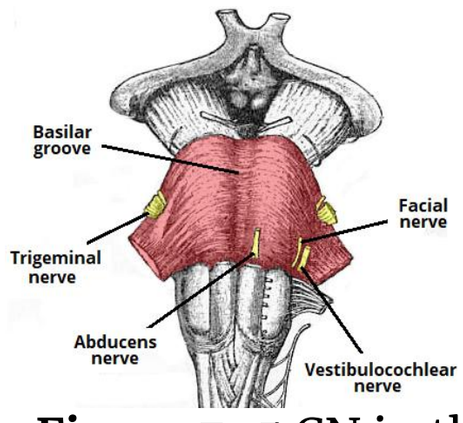


Figure 7-5 CN in the pons

The Medulla

Ventral View

- The most medial part of the medulla is the anterior median fissure.
- Moving laterally on each side are the pyramids, They contain the fibers of the corticospinal (pyramidal) tract as they head inferiorly to synapse on lower motor neuronal cell bodies within the ventral horn of the spinal cord.

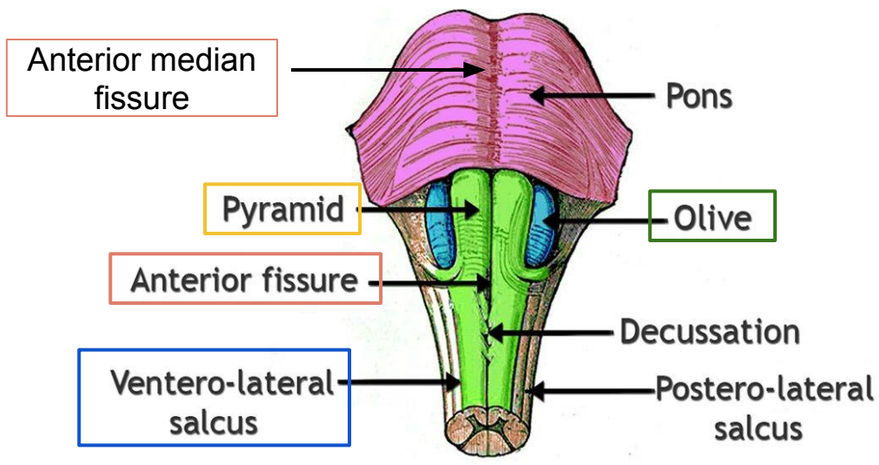


Figure 7-6 Ventral view of the medulla

- The anterolateral sulcus is lateral to the pyramids.
- Emerging from the anterolateral sulci are the **hypoglossal nerve** (CN XII) rootlets.
- Lateral to the anterolateral sulci are the olives containing underlying **inferior olivary nuclei** and afferent fibers.
- Lateral (and dorsal) to the olives are the rootlets for glossopharyngeal (IX) & vagus(X) cranial nerves.

Dorsal View

- The most medial part of the medulla is the posterior median fissure.
- Moving laterally on each side is the fasciculus gracilis.
- Lateral to that is the fasciculus cuneatus
- Superior to each of these, are the **gracile and cuneate tubercles**, respectively
- Underlying these are their respective nuclei.

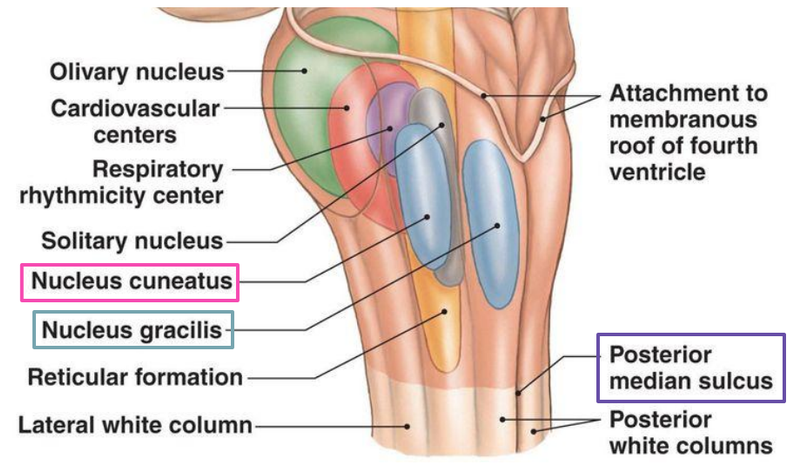


Figure 7-7 Dorsal view of the medulla

- In the midline is the vagal trigone and superior to that is the hypoglossal trigone.
- Underlying each of these are motor nuclei for the respective cranial nerves.

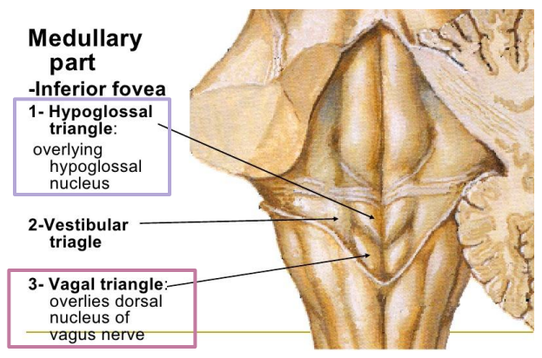


Figure 7-8 Vagal & Hypoglossal trigones

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Brainstem Functions

Though it is small, brain stem is an extremely important part of the brain:

01 Conduct functions

02 Provides the origin of the cranial nerves (CN III-XII)

03 Conjugate eye movement

04 Integrative functions

05 Control of respiration

06 Control of CVS

07 Control of many Stereotyped movement of the body

08 Partial control of gastrointestinal function

09 Control of equilibrium

Other Brainstem Functions

The **autonomic nervous system** is activated mainly by centers located in the spinal cord, brain stem, and hypothalamus
(Cardiovascular Gastrointestinal Autonomic Reflexes)

Functions of Brain Stem Nuclei in **Controlling Subconscious, Stereotyped Movements** [crying, yawn, suckling, stretch] (anencephaly)[1]

Brain stem **Neurohormonal Systems** in the human brain for activating four neurohormonal systems.[2]

Control of Cerebral Activity by Continuous Excitatory Signals from the Brain Stem (**Reticular Excitatory Area of the Brainstem**) → bulboreticular facilitatory area → it is the same brain stem reticular area that transmits facilitatory signals to maintain tone in the antigravity muscles and spinal cord reflexes.

Motor branch of the fifth cranial nerve, and the **chewing** process is controlled by nuclei in the brain stem and also **swallowing, salivary secretion, vomiting** (chemoreceptor trigger zone). The actual mechanics of feeding are controlled by centers in the brain stem.

Vasomotor center for CV control (Baroreceptors) in medulla and **Respiratory Nuclei**

Many of the **behavioral functions** elicited from the hypothalamus and other limbic structures are also mediated through the reticular nuclei in the brainstem and their associated nuclei.

PRESENT ONLY IN MALE SLIDES

FOOTNOTES

1. Guyton and Hall: Rarely, a baby can be born without CNS regions above the midbrain and can survive for a few days, this condition is called **anencephaly,** some of these kids are kept alive for a few months and exhibited the responses mentioned above which suggests that the brain stem integrates these responses since it is the only part of the brain that they possessed.
2. Guyton and Hall: The four neurohormonal systems are (1) norepinephrine system, (2) dopamine system, (3) serotonin, (4) acetylcholine.

Other Brainstem Functions

Neural Pathways for **Control of Eye Movements.** also shows brainstem nuclei for the third, fourth, and sixth cranial nerves by medial longitudinal fasciculus

Nucleus of tractus solitarious → **Taste pathway** → Superior & Inferior salivatory Nuclei[1]

Auditory Nervous Pathways → superior olivary nucleus (BOX 6–1)

Although the **micturition reflex** is an autonomic spinal cord reflex,it can also be inhibited or facilitated by centers in the cerebral cortex or brain stem in pons

Accommodation Is Controlled by Parasympathetic Nerves by 3rd CN

Bulboreticular facilitatory area of brainstem for **gamma efferent system** (stabilizes joints)

PRESENT ONLY IN MALE SLIDES

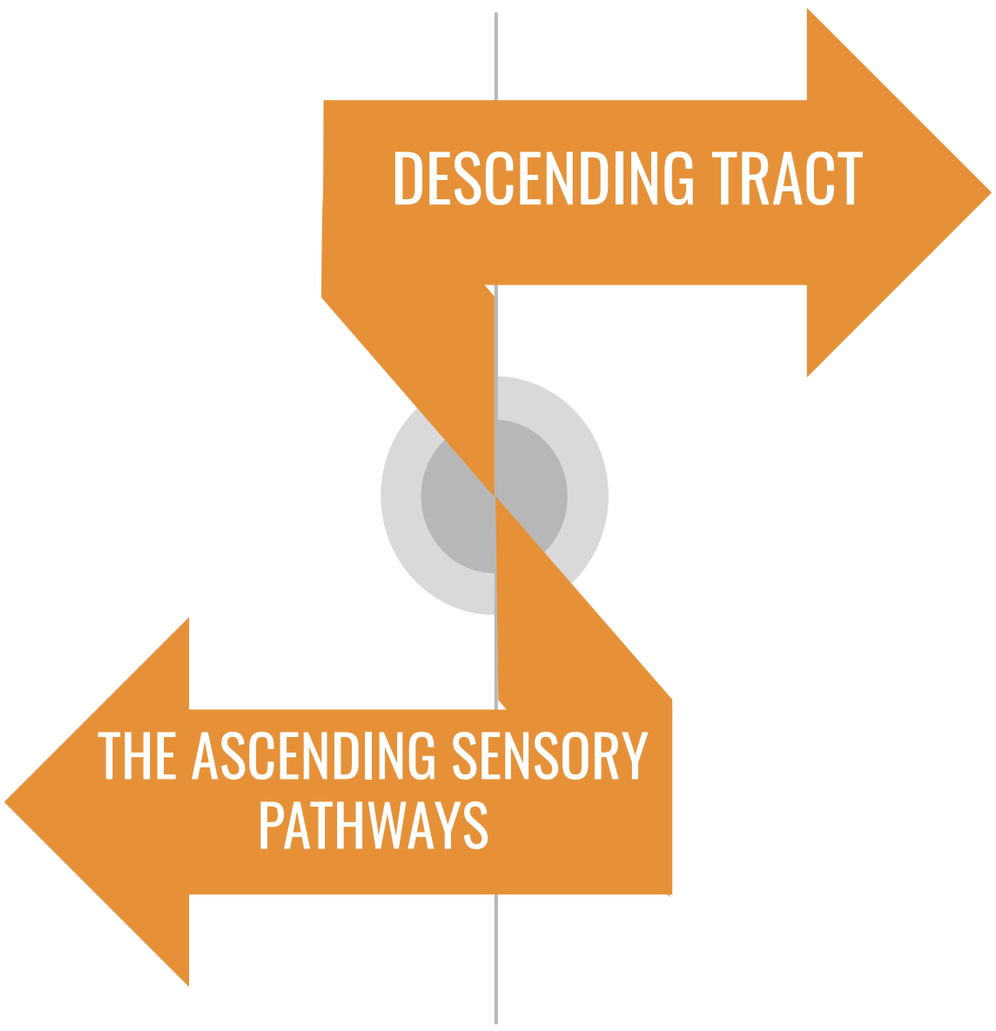
1) Conduct Functions

All information related from the body to the cerebrum and cerebellum and vice versa, **must** traverse the brain stem.

Ascending sensory pathway coming from the body to the brain includes:

a) **The spinothalamic** tract for pain and temperature sensation

b) **The dorsal column,** fasciculus gracilis, and cuneatus for touch, proprioceptive and pressure sensation.



a) **Corticospinal tract (UMN)**
runs through crus cerebri (the anterior portion of the cerebral peduncle), basal part of pons and medullary pyramids; 70-90 % of fibers cross in pyramidal decussation to form the lateral corticospinal tract, synapse on LMN in ventral horn of spinal cord.

b) **Upper motor neurons** originate in brain stem's vestibular, red, and reticular nuclei, which also descend and synapse in the spinal cord.

FOOTNOTES

1. Nucleus of tractus solitarius (NTS) receives taste sensations from vagus nerve (root of the tongue), glossopharyngeal nerve (posterior one third) and facial nerve (anterior two thirds), after receiving taste sensation, NTS can trigger superior and inferior salivary nucleus through efferent connections that it has to secrete digestive juices.

2) Provides the origin of the cranial nerves (CN-III-XII)

- The brain stem provides the main motor and sensory innervation to the face and neck via the cranial nerves (CN III–XII).
- The fibers of cranial nerve nuclei except for olfactory & optic nerve either originating from, or terminating in the cranial nerve nuclei in brainstem.

The Cranial Nerve Origin And Function Of The

Midbrain

- CN III (oculomotor) — Both moves the eyes - CN III constricts the pupils, accommodates.
- CN IV(trochlear) — - CN IV act on *superior oblique muscle* of the eye which rotates the eye down and out.

Pons

- CN V (trigeminal) — - Chews and feels front of the head. - Act on *muscle of mastication*.
- CN VI (abducens) — Moves eyes -Act on *Lateral rectus muscle* of the eye which moves eye laterally.
- CN VII (facial) — -Moves the face, tastes, salivates, cries. - Act on *muscles of facial expression*
- CN VIII (acoustic) — Hears, regulates balance.

Medulla

- CN IX (glossopharyngeal) — -Tastes, salivates, swallows, monitors carotid body and sinus. - Act on *Muscles & mucous membranes of pharynx, the constricted openings from the mouth & the oral pharynx and the posterior third of tongue*
- CN X (vagus) — -Tastes, swallows, lifts palate, talks, communication to and from thoraco-abdominal viscera. - Acts on *Pharynx, larynx, heart, lung and stomach*
- CN XI (accessory) — Turns head, lifts shoulder.
- CN XII (hypoglossal) — -Moves tongue. - Acts on *Intrinsic muscles of the tongue.*

Classification Of The Cranial Nerve According To Function[1]

Functions	Sensory	Motor	Both (Mixed)
Cranial nerve	CN I (Olfactory) CN II (Optic) CN VIII (acoustic)	CN III (oculomotor) CN IV (trochlear) CN VI (abducens) CN XI (accessory) CN XII (hypoglossal)	CN V (trigeminal) CN VII (facial) CN IX (glossopharyngeal) CN X (vagus)

3) Conjugate Eye Movement

It refers to motor coordination of the eyes that allows for bilateral fixation on a single object.

The frontal eye field (FEF) projects to the opposite side at the midbrain-pontine junction, and then innervates **the paramedian pontine reticular formation (PPRF).**
From there, projections directly innervate **the lateral rectus** (contralateral to FEF) and the **medial rectus** muscle (ipsilateral to FEF).
The left FEF command to trigger conjugate eye movements to the right.

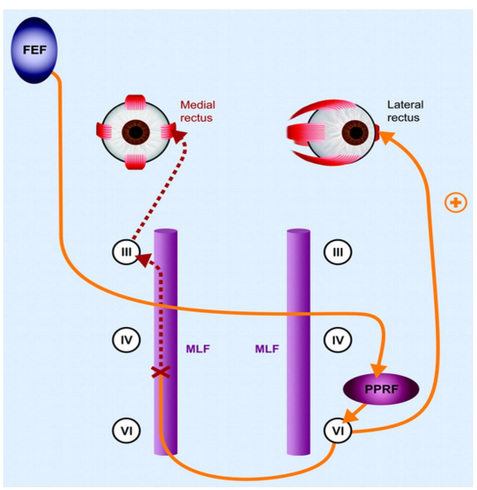


Figure 7-8

PRESENT ONLY IN FEMALE SLIDES

4) Integrative functions

1. It controls consciousness & sleep cycle (alertness and arousal) through reticular formation.
2. It has got center for cardiovascular, respiratory & autonomic nervous system.
3. It has centers for cough, gag, swallow, and vomit.
4. Sense of body balance (Vestibular functions)[2]
5. Plays role in motor control:
   A. **Substantia Nigra** (which is a part of the basal ganglia) is involved in control of movement.
   B. **Red Nucleus** in Midbrain which regulate the motor activity through cerebellum.
6. Pain sensitivity control: **Periaqueductal grey matter** of mesencephalon is an area which is rich in endogenous opioid and is important in modulation of painful stimuli.
7. Auditory & visual processing required for head movements, in the Inferior and superior colliculi which are situated on the dorsal surface of the midbrain.

Functional organization of the Brain stem

1. **Ventral:** **Motor** in function

2. **Middle:** **Sensory** in function
   - Contains medial lemniscus which conveys sensory information from dorsal column.

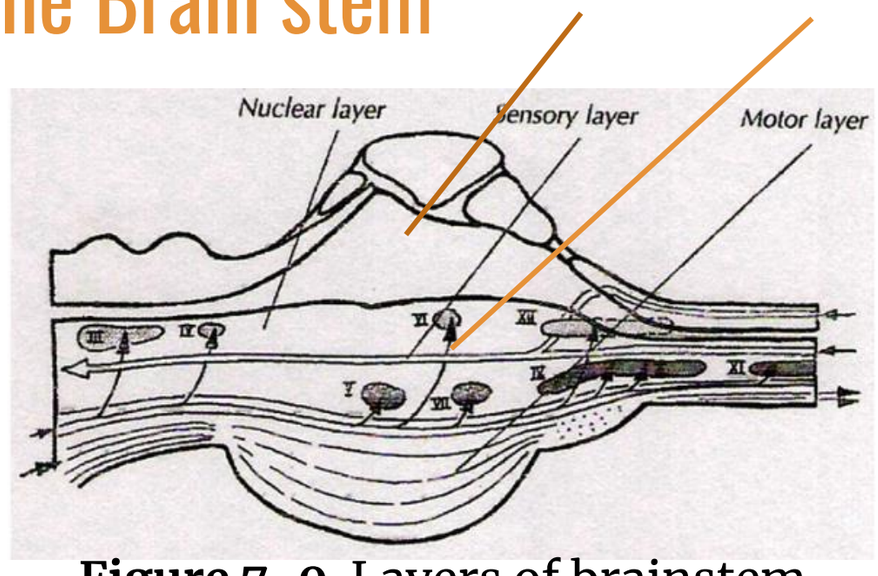


Figure 7-9 Layers of brainstem

FOOTNOTES

1. Mnemonic: Some Say Marry Money But My Brother Says Big Brains Matter More. S: sensory. M: motor. B:both.
2. Check BOX 6-2 in the next page for the mechanism.

8 Physiology of Brain Stem

Lecture Six

Part	Midbrain	Pons	Medulla oblongata
Function	1- Nerve pathway to cerebral hemispheres. 2- Auditory and Visual reflex centers	•Respiratory Center	1. Crossing of motor tracts. 2. Cardiac Center. 3. Respiratory Center. 4. Vasomotor Center (nerves having muscular control of the blood vessel walls) 5. Centers for cough, gag, swallow, and vomit.
Signs and symptoms of lesion	•**Cranial Nerve (CN) deficits:** Ipsilateral CN III, CN IV palsy and ptosis (drooping). •**Pupils:** - Size: Midposition to dilated. - Reactivity: Sluggish to fixed. •**Movement:** Abnormal extensor. •**Respiratory:** Hyperventilating. •**Loss of consciousness LOC:** Varies	**CN Deficits:** CN V, CN VI, CN VII, CN VIII. •**Pupils size:** Pinpoint •**Movement:** Abnormal extensor. •**Respiratory:** -Apneustic (Abnormal respiration marked by sustained inhalation). -Hyperventilation. •**LOC:** Semi-coma	•**Movement:** Ipsilateral paralysis. •**Pupils:** - Size: Dilated. - Reactivity: Fixed. •**Respiratory:** Abnormal breathing patterns •**CN Palsies:** Inability to control movement. Absent cough, gag. •**LOC:** Comatose.

Brainstem Function Tests

To test brainstem reflexes	**To test respiratory centre**	**To test Cardiovascular center**	**Corticospinal tract**	**To test reticular formation**	**Pain response**
-Pupillary and corneal reflexes. **-Vestibulo-ocular reflex:** Injection of iced water into the ear will produce eyes movement. **-Oculocephalic reflex:** Eyes will be fixed when head is moved in one or another directions. -Gag reflex. -Cough reflex.	Look for the normal pattern of respiration	Look for normal circulatory function.	by Motor power, reflexes.	Alertness, Consciousness & Sleep.	Facial grimacing on firm pressure over the supraorbital ridge

BOX 6-2: LANGE'S CLINICAL NEUROLOGY AND NEUROANATOMY & GUYTON and HALL

There is a specialized sensory organ in the inner ear called the vestibular apparatus which detects head movement and hence, help in equilibrium through precise mechanisms discussed later.

- The information for head position is passed on to the vestibular nuclei from the vestibular apparatus, the medial vestibular nuclei for example is connected to the cranial nerves controlling eye muscles, therefore senses of change in position sensed within the vestibular apparatus can pass through the vestibular nuclei and through the medial longitudinal fasciculus to the extraocular muscles for the eyes to move with head movement.
- Furthermore, information from the vestibular apparatus can reach the lateral vestibular nucleus to adjust control of antigravity muscles.
- This is a mechanism on how the vestibular system maintains equilibrium, for example if a person is running and is faced with a sharp turn, the vestibular apparatus begins to detect the rate at which the head begins to turn, using this information, the person can predict how much they will turn within the next 2 seconds and can adjust their legs ahead of time. The cold water on the ear test turns off the vestibular apparatus, if one side is turned off the other side becomes active and the brain will think that the head is turning towards the not-cold side, even though the head hasn't moved, the eyes will move in response to this thought process initiated by mere cold water.

	Structure	Deficit
Midline Structures	**Motor pathway (Corticospinal Tract)**	Contralateral weakness
	Medial lemniscus	Contralateral proprioception/ vibration loss
	Medial longitudinal fasciculus	Ipsilateral internuclear ophthalmoplegia
	Motor nucleus and nerve	Ipsilateral CN function loss
Lateral Structures	Spinocerebellar pathway	Ipsilateral ataxia
	Spinothalamic	Contralateral pain/ temp sensory loss
	Sensory nucleus of CN5	Ipsilateral pain/ temp loss in face
	Sympathetic pathway	Ipsilateral Horner's syndrome
4 Cranial Nerves In Medulla	**Glossopharyngeal CN9**	Ipsilateral pharyngeal sensory loss
	Vagus CN10	Ipsilateral palatal weakness
	Spinal accessory CN11	Ipsilateral shoulder weakness
	Hypoglossal CN12	Ipsilateral weakness of tongue
4 Cranial Nerves In Pons	**Trigeminal CN5**	Ipsilateral facial sensory loss
	Abducens CN6	Ipsilateral eye abduction weakness
	Facial CN7	Ipsilateral facial weakness
	Auditory CN8	Ipsilateral deafness
4 Cranial Nerves Above Pons	**Olfactory CN1**	Not in midbrain
	Optic CN2	Not in midbrain
	Oculomotor CN3	Eye turned out and down
	Trochlear CN4	Eye unable to look down when looking towards nose

The Rule of 4 of Brainstem

1. **structures in 'midline' and begin with 'M'**
   1. Motor pathway (Contralateral weakness)
   2. Medial lemniscus (Contralateral proprioception/vibration loss)
   3. Medial longitudinal fasciculus (Ipsilateral internuclear ophthalmoplegia)
   4. Motor nucleus and nerve (Ipsilateral CN function loss).
2. **4 motor nuclei in midline and are those that are divisors of 12 (3,4,6,12)**
   - Nuclei of CN 3, 4, 6, 12 are midline
   - Nuclei of CN 5, 7, 9, 11 are lateral
3. **4 structures to the 'side' (lateral) and begin with 'S'**
   - Spinocerebellar pathway (Ipsilateral ataxia)
   - Spinothalamic pathway (Contralateral pain/temp sensory loss)
   - Sensory nucleus of CN5 (Ipsilateral pain/temp loss in face)
   - Sympathetic pathway (Ipsilateral Horner's Syndrome)
4. **4 CN in medulla (9,10,11,12), 4 in pons (5,6,7,8) and 4 above pons (1,2,3,4)**

Sample Cases

Sample case 1: A 58 y/o female patient was referred to you because of recent onset of left hemiparesis, left-sided loss of proprioception and right-sided tongue Deviation.

History	Fiber	Location
58 year old woman	Motor (corticospinal tract), right	Medial
Left hemiparesis	Medial lemniscus, right	Medial
Left-sided loss of proprioception	CN12, right	Medulla
Right-sided tongue deviation		Medial

Answers:
- **Medial medullary syndrome (R)** - Vertebral artery, medullary branch (R)

Sample case 2: A 58 y/o female patient was referred to you because of recent onset of Left sided miosis, anhidrosis, ptosis, left-sided ataxia, Uvula deviated to right.

History	Fiber	Location
58 year old woman	Sympathetic tract, Left	Side, left
Left-sided meiosis, anhidrosis, ptosis Left-sided ataxia.	Spinocerebellar	Side, left
Uvula deviated to right.	CN10, Left	Medulla

Answers:
- **Lateral medullary syndrome (L)** - Posterior inferior cerebellar artery (L)

QUIZ

MEDICINE438's
CNSPHYSIOLOGY

1. Which CN originates at the level of mid pons?

A) CN V
B) CN VI
C) CN VII
D) CN VIII

2. Which CN originates from midbrain?

A) CN X
B) CN VII
C) CN VI
D) CN III

3. If there is a lesion in the trochlear cranial nerve what will is cause?

A) Eye turned out and down
B) Eye unable to look down when looking towards nose
C) Ipsilateral eye abduction weakness
D) Ipsilateral eye abduction weakness

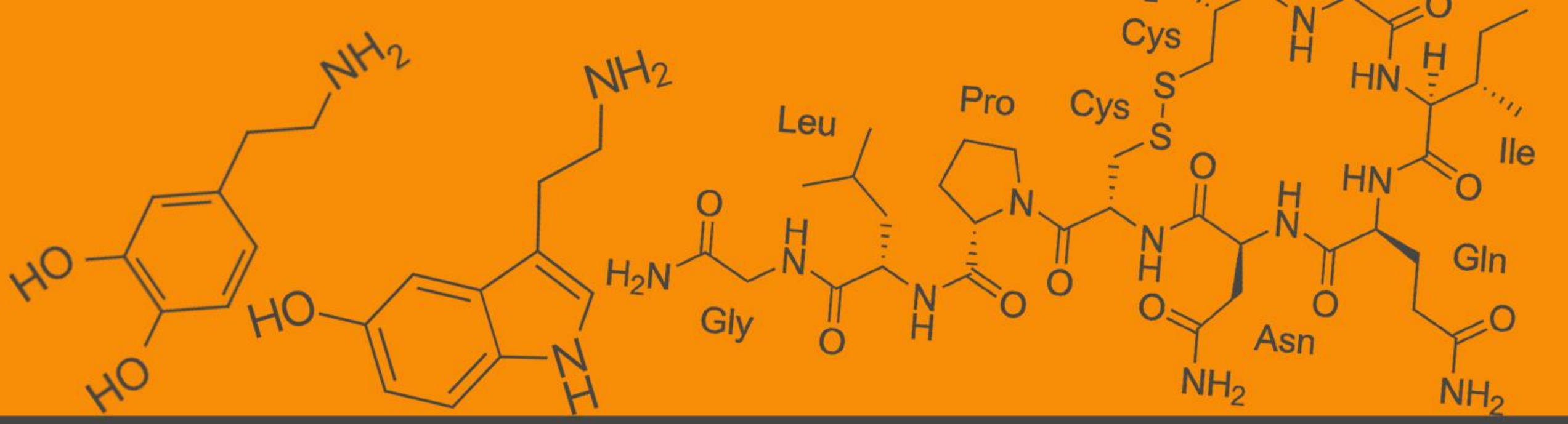
4. A patient came to the emergency department with hyperventilation, drooping of the upper eyelid and dilated pupils. What is the most likely injured area?

A) Midbrain
B) Pons
C) Medulla oblongata
D) Spinal accessory CN11

5. Which of the following is purely motor?

A) Glossopharyngeal
B) Hypoglossal
C) Vagus
D) Facial

ANSWER KEY: A, D, B, A, B



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MEDICINE438's CNSPHYSIOLOGY

REFERENCES

- Guyton and Hall Textbook of Medical Physiology
- Ganong's Review of Medical Physiology