The Brain Stem

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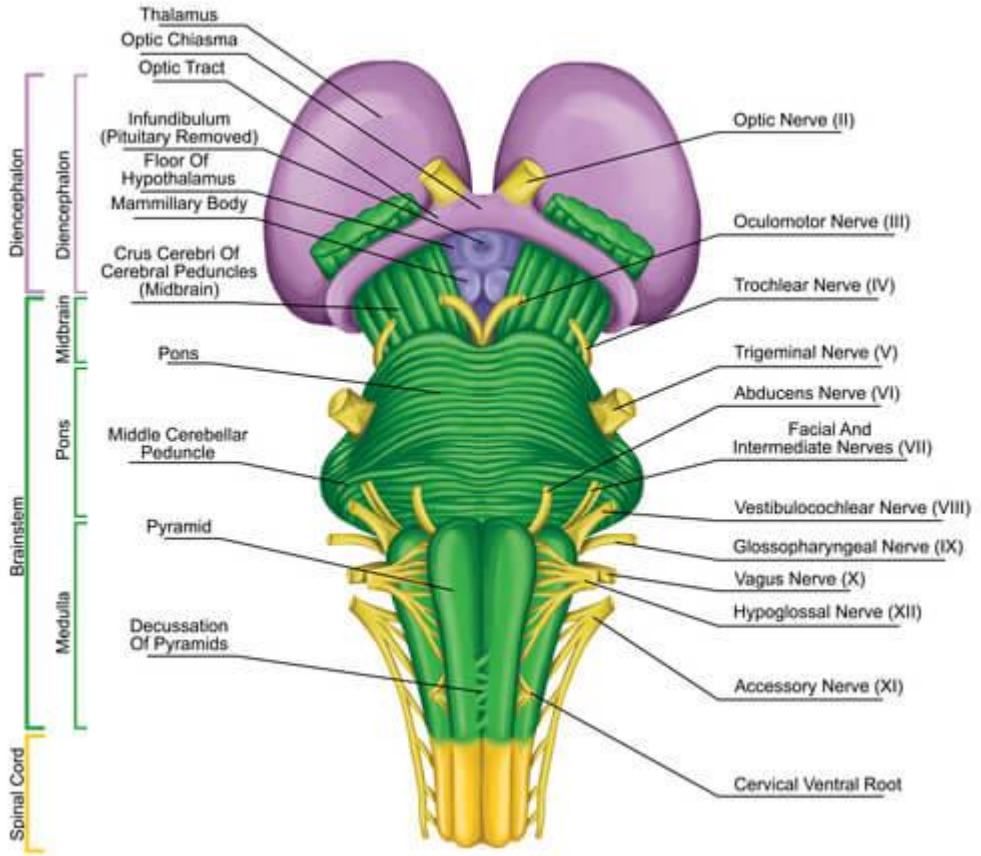
The Brain Stem

- Contains
  - Nuclear groups & nerve fibers of the Cranial Nerves
  - Ascending Sensory tracts from spinal cord to thalamus to cortex
  - Descending Motor pathways from cortex, subcortical nuclei to brain stem to spinal cord
  - Reticular Formation
  - Passage for Aqueduct of Sylvius - circulation of cerebrospinal fluid



Cranial Nerve Classes

- Motor Nerves
  - General Somatic motor neurons
    - extraocular muscles & tongue
  - Special Somatic motor neurons
    - control chewing, Facial expression, larynx, pharynx
  - General Visceral (Autonomic) motor neurons
    - blood vessels, glands, smooth muscle

Cranial Nerve Classes

- Sensory Nerves
  - General Somatic afferent neurons
    - Face skin & mucus membranes in mouth
    - Touch, pain, temperature, proprioception
  - Specific Somatic afferent neurons
    - Cochlea, vestibular apparatus, inner ear
    - Hearing, vision, balance
  - General Visceral (Autonomic) afferent neurons
    - Sensory of internal organs, larynx, pharynx
    - Mechanical, pain, temperature, proprioception
  - Special Visceral (Autonomic) afferent neurons
    - Taste buds
    - Olfaction, taste

Cranial Nerves

#	Name	Type	Function	Test
I	Olfactory	Sensory	Smell	Identify smells
II	Optic	Sensory	Sight	Read with both eyes and each eye separately
III	Oculomotor	Motor	Eye Movements	• Pupils should contract together when light is shown to one. • Pupils should constrict when looking at near object, dilate when looking at far object. • Eyes should converge when looking at near object and diverge when looking at far object.
IV	Trochlear	Motor	Eye Movements	Follow moving penlight
V	Trigeminal	Mixed	**Sensory:** Cutaneous & proprioceptive sensations from skin, muscles, & joints in the face & mouth. Sensory innervation of the teeth **Motor:** Muscles for mastication	• Should blink when cornea is touched • Face should be sensitive to pain and differentiate b/t hot and cold stimuli
VI	Abducens	Motor	Eye Movements	Both eyes should move in unison
VII	Facial & Intermediate	Mixed	**Sensory:** Taste sensation from anterior 2/3 of tongue. Skin sensation from external ear **Motor:** Muscles of facial expression, lacrimal glands, & salivary glands	Should be able to smile, raise eyebrows, puff out checks, and distinguish tastes

Cranial Nerves

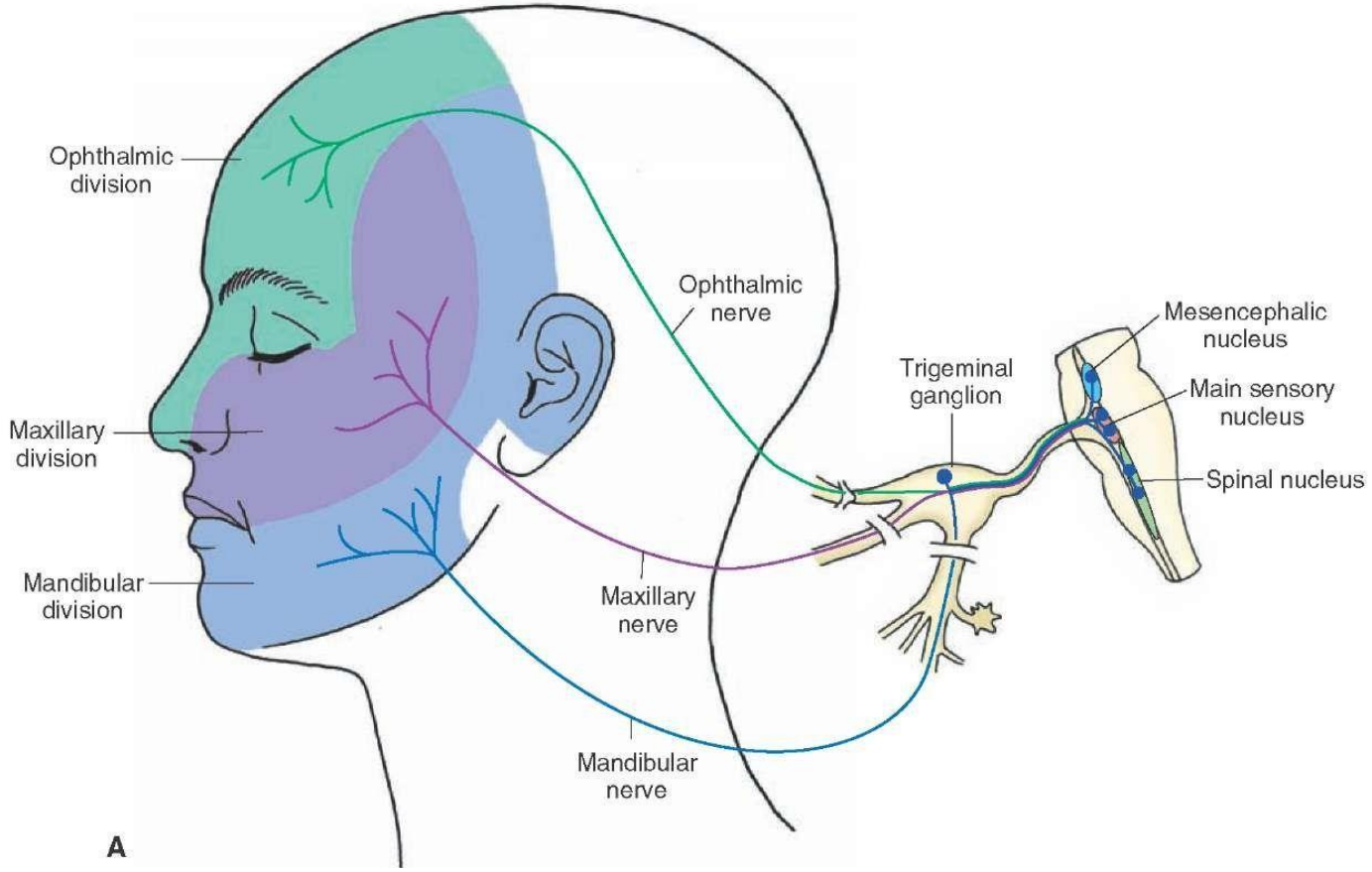
#	Name	Type	Function	Tests
VIII	Vestibulocochlear	Sensory	Hearing, balance, postural reflexes, head orientation	• Should be able to hear a wrist waste ticking • Have upright posture & maintain balance
IX	Glossopharyngeal	Mixed	Autonomic fibers innervate parotid gland (salivary gland) **Sensory:** Taste sensation from posterior 1/3 of tongue. **Motor:** Face and speaking muscles	• Appropriate gag reflex • Swallow easily
X	Vagus	Mixed	**Autonomic:** Heart, blood vessels, trachea, bronchi, esophagus, stomach, intestine **Sensory:** Visceral sensation pharynx, larynx, thorax, abdomen. Taste buds in the epiglottis **Motor:** Muscles of larynx, pharynx, speech	• Swallow easily • Speak audibly
XI	Spinal Accessory	Motor	Trapezius (Back of neck, upper back) & Sternocleidomastoid (side of neck) muscles	• Shrug shoulders • Turn head left to right
XII	Hypoglossal	Motor	Tongue muscles	• Move tongue without difficulty

The Trigeminal System

Cranial nerve V

- Tri – 3 branches
  - Ophthalmic (receives sensation)
  - Maxillary (receives sensation)
  - Mandibular (sensory & motor)

- Sensory cells project to Mesencephalic Trigeminal Nucleus (ventral pons)
- Motor cells from Trigeminal Motor Nucleus (pons)



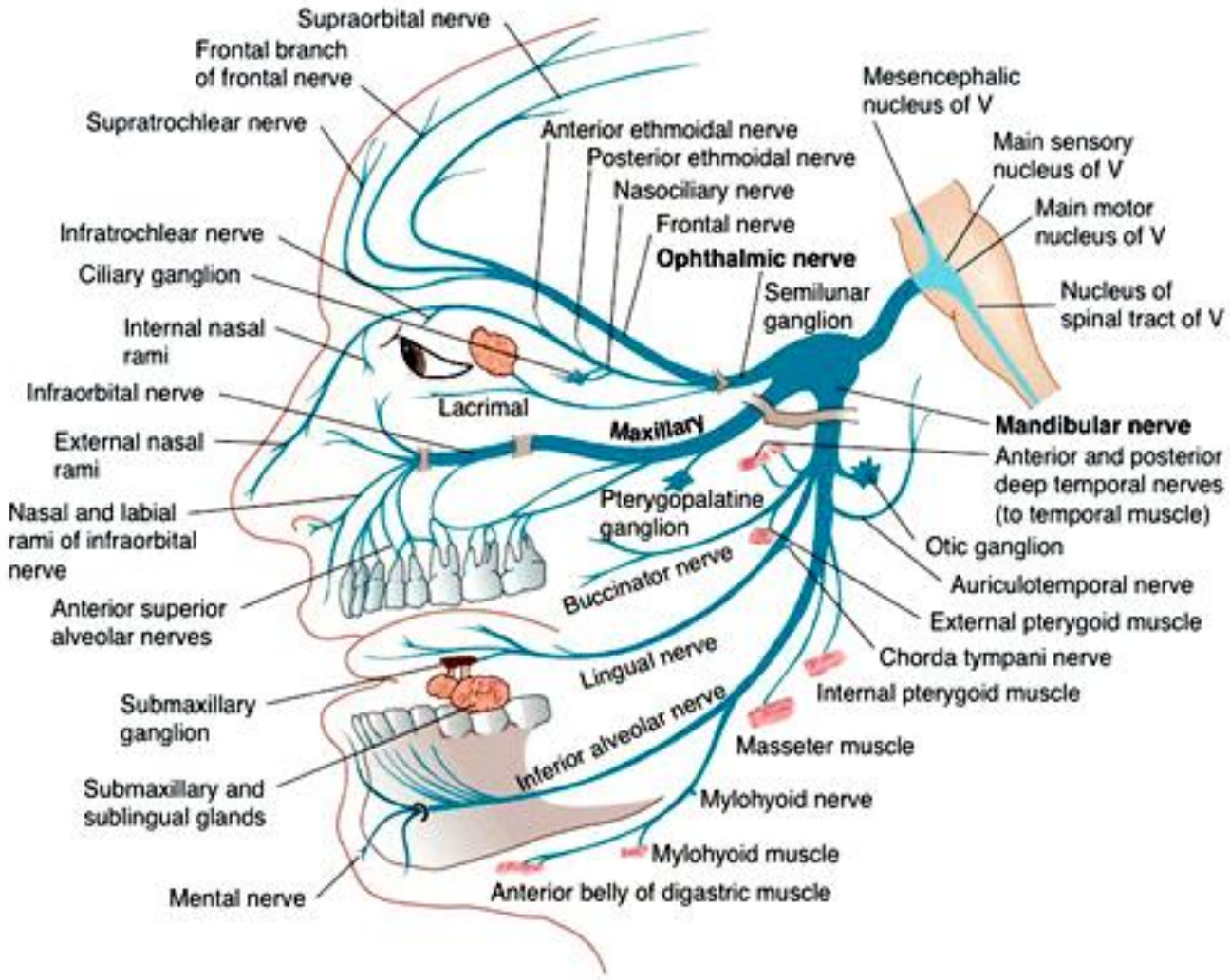
The Trigeminal System

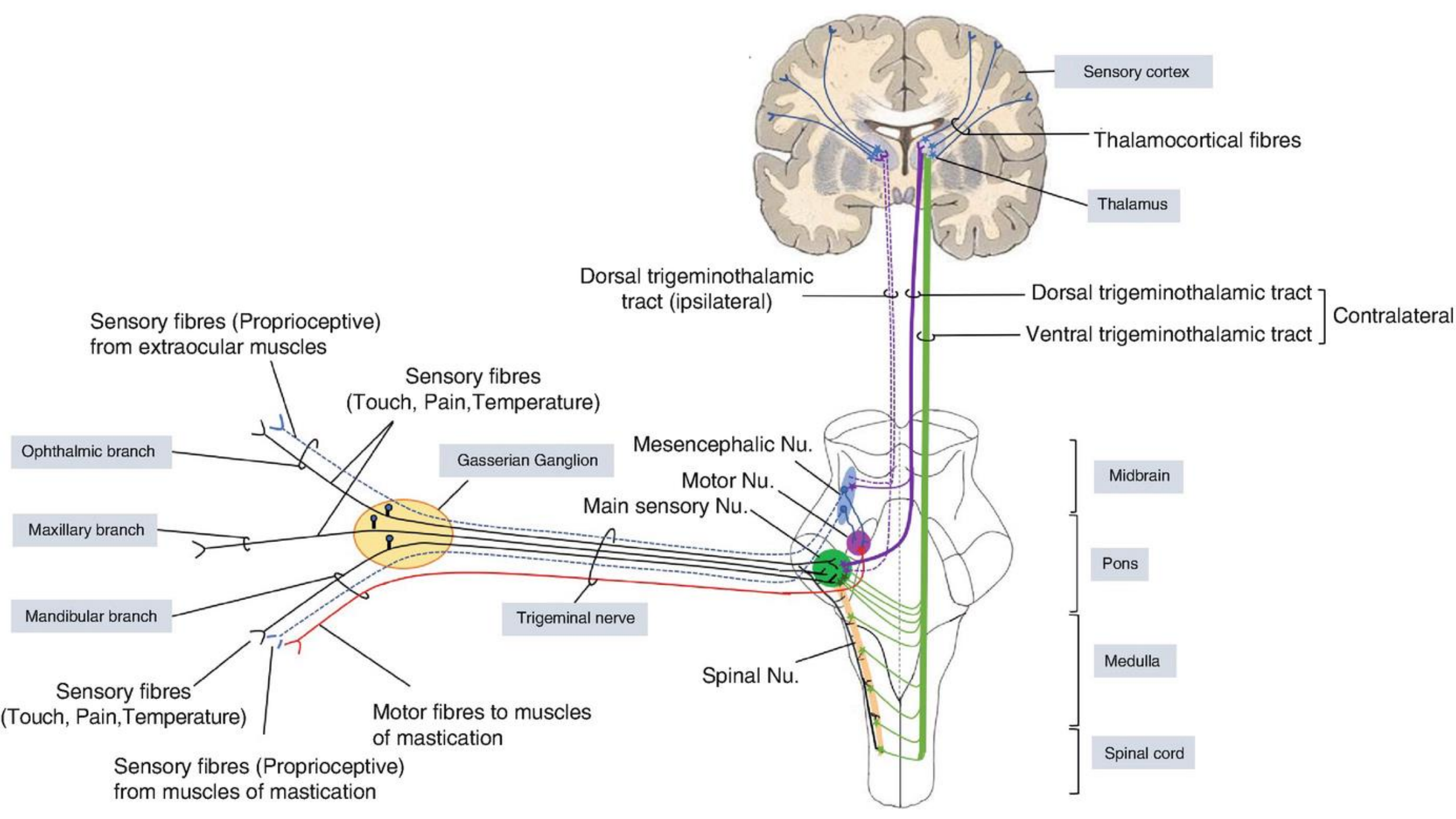
Cranial nerve V

- Sensory information from face, conjunctiva, oral cavity (anterior 2/3 of tongue, tooth pulp, gums), and dura mater
  - (Tactile) Mechanoreceptors
    - mediated by principal sensory nucleus
  - Proprioception of jaw muscles
    - mediated by mesencephalic nucleus
  - Thermoreceptors & Nociceptors
    - mediated by spinal nucleus

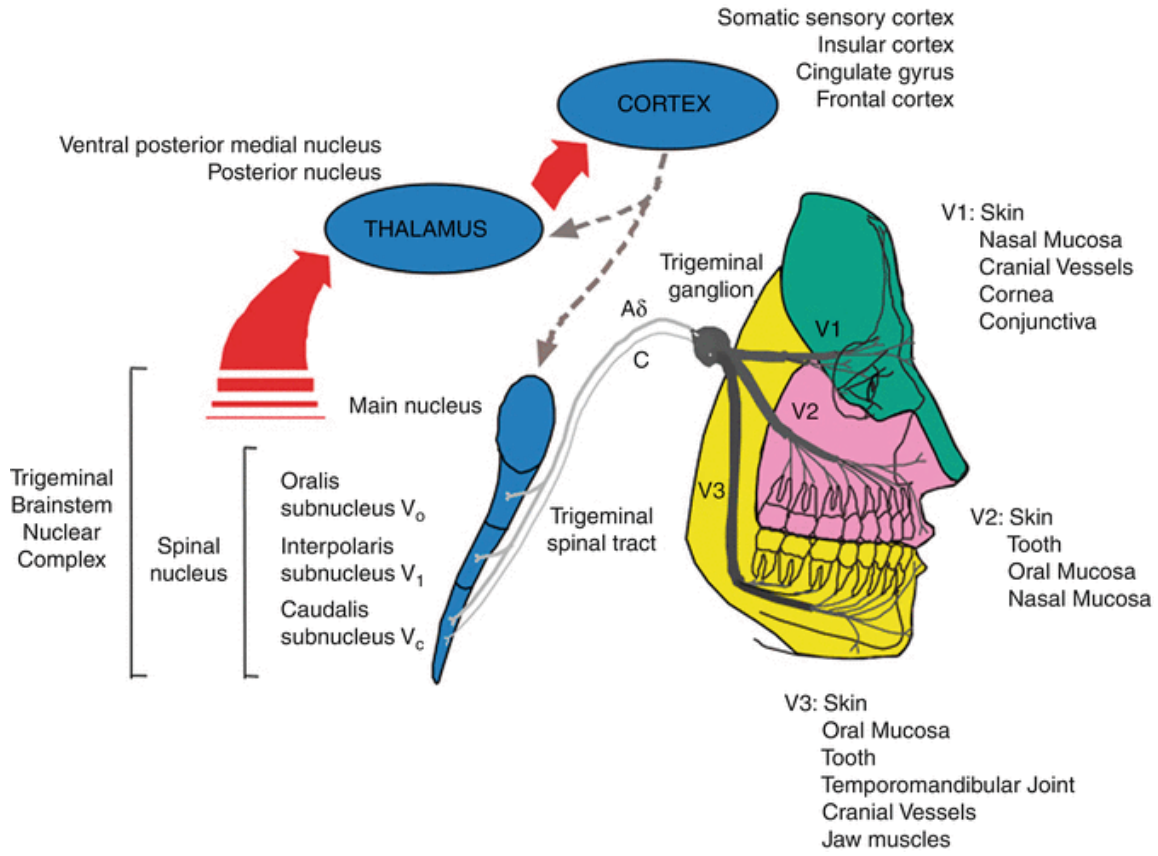
- Motor information for mastication

- Mystacial Vibrissae (whiskers in mammals and rodents)
  - fibers called barrels have 2,500 neurons




Sensory cortex
Thalamocortical fibres
Thalamus
Dorsal trigeminothalamic tract (ipsilateral)
Dorsal trigeminothalamic tract
Ventral trigeminothalamic tract
Contralateral
Sensory fibres (Proprioceptive) from extraocular muscles
Sensory fibres (Touch, Pain,Temperature)
Ophthalmic branch
Gasserian Ganglion
Maxillary branch
Mandibular branch
Mesencephalic Nu.
Motor Nu.
Main sensory Nu.
Trigeminal nerve
Spinal Nu.
Sensory fibres (Touch, Pain,Temperature)
Motor fibres to muscles of mastication
Sensory fibres (Proprioceptive) from muscles of mastication
Midbrain
Pons
Medulla
Spinal cord

- Trigeminal Neuralgia
  - Severe face pain
  - Sever 5th nerve root relieves pain but also removes blinking reflex
  - If you cut before it enters nucleus caudalis then it just affects the pain fibers selectively

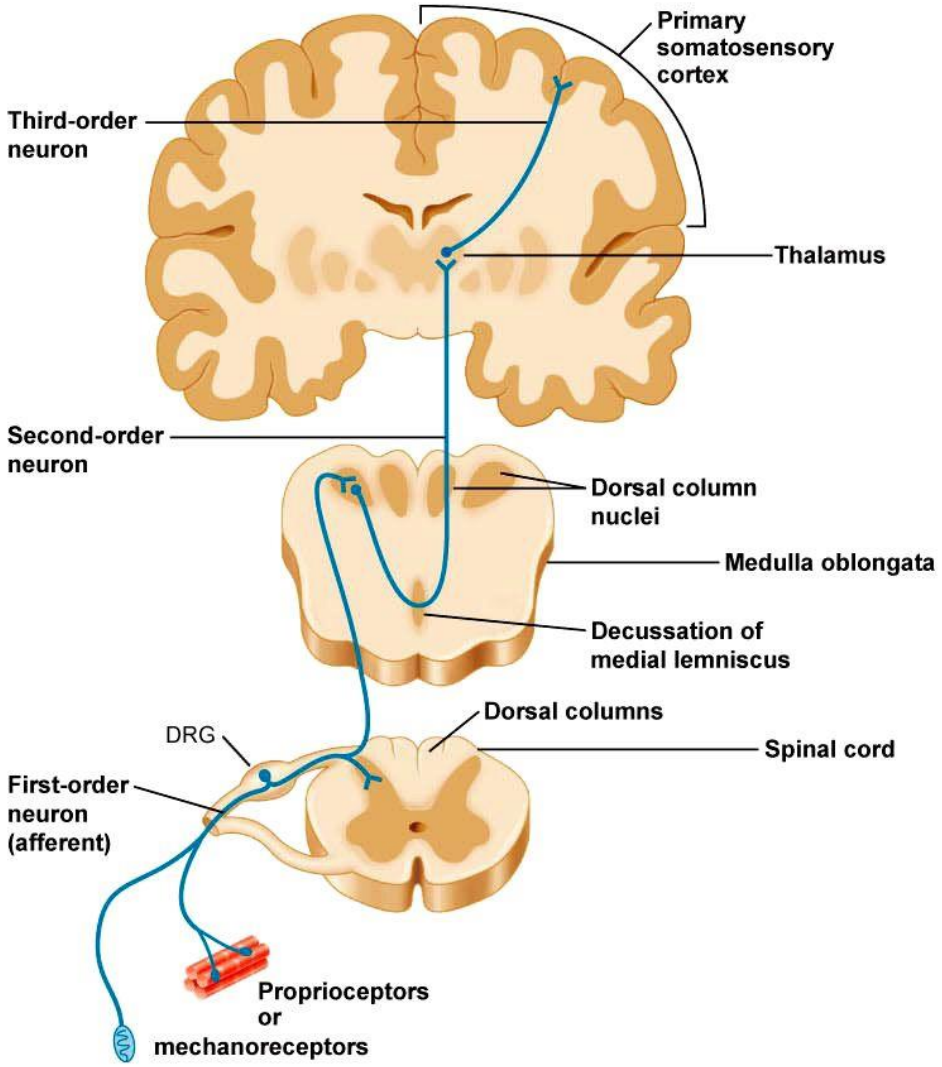


Ascending Tracts

- Dorsal column-medial lemniscal system
  - Sensations of discriminative touch, vibration, & joint position

- Lateral spinothalamic tract
  - Sensation of pain, temperature, crude touch from contralateral side of body

- Spinocerebellar tract
  - Information about the position of body in space and body segments relative to each other



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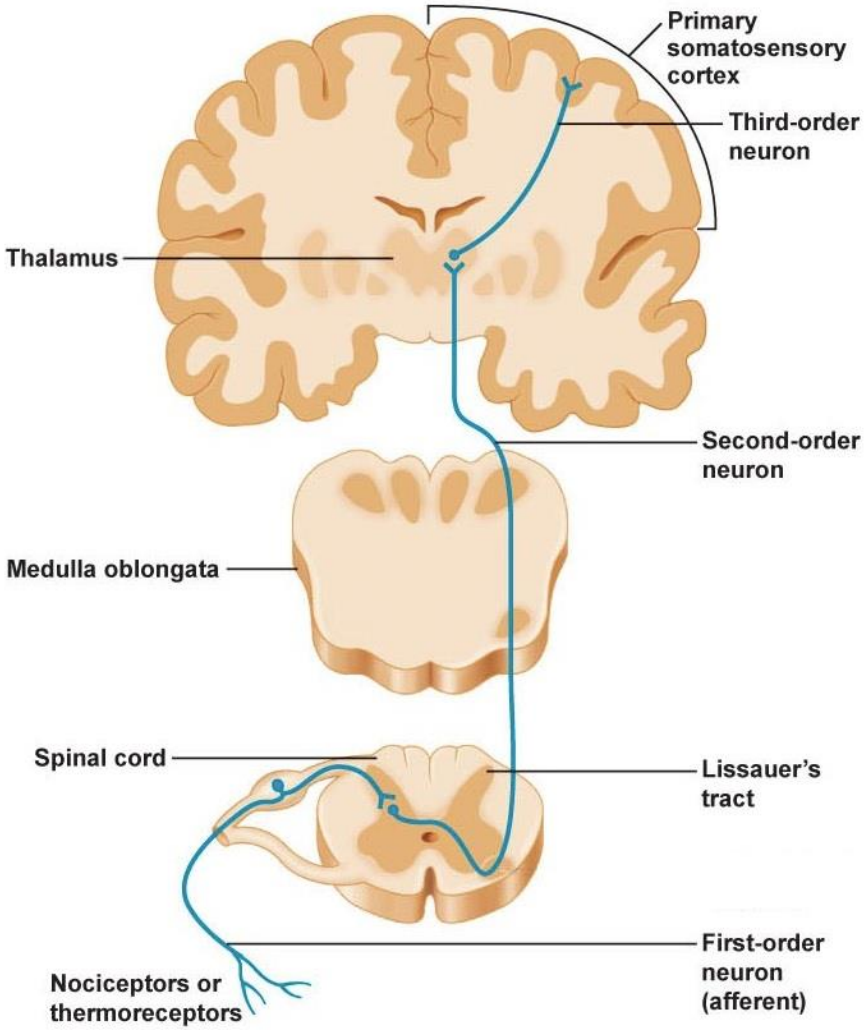

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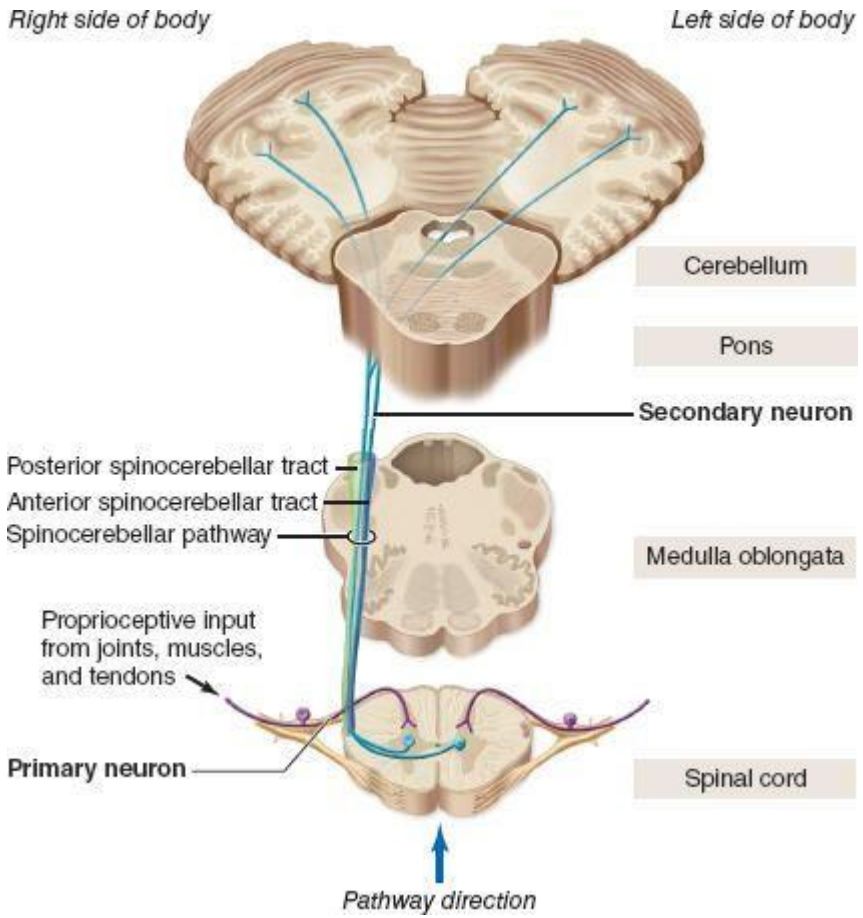
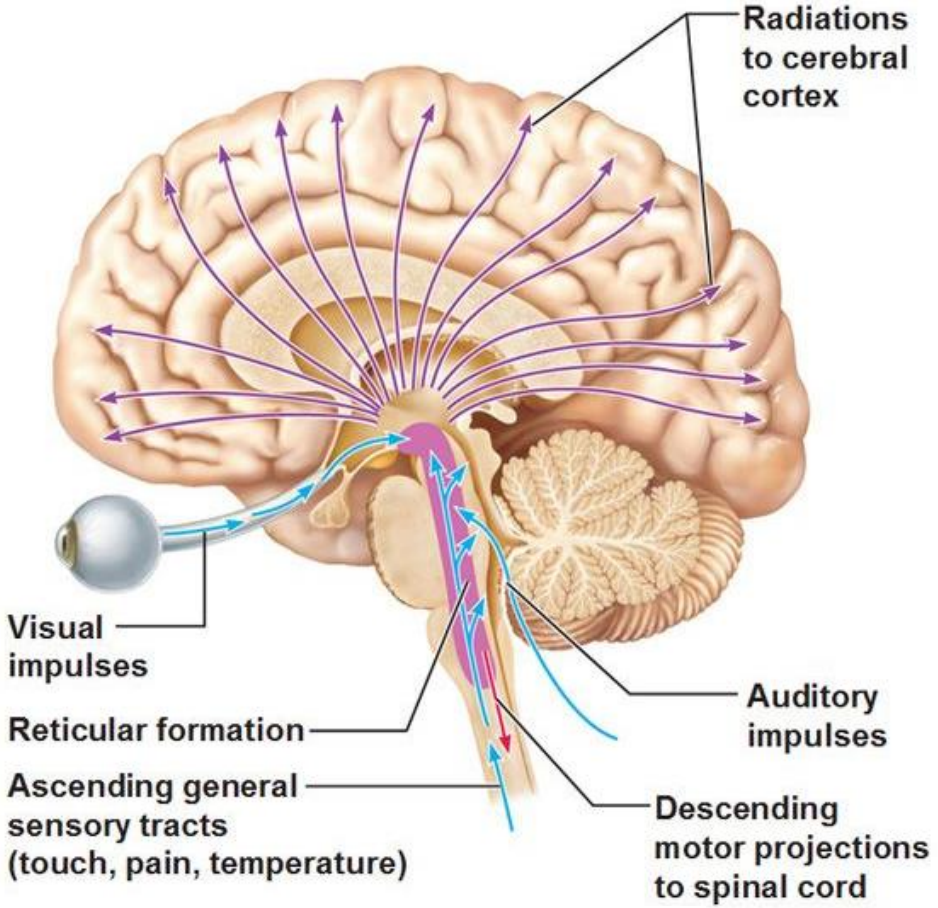
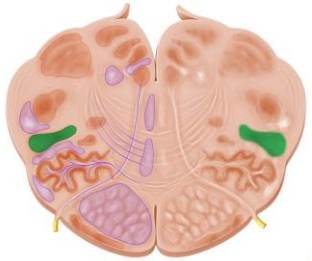


The Reticular Formation

- Distributed throughout the Medulla, Pons, and Midbrain
- 4 Functions
  - Alertness
    - Giuseppe Moruzzi (1940s)
      - Stimulated reticular formation of deeply anesthetized animals
      - EEG pattern changed overall brain activity from a state resembling sleep to one resembling awake state

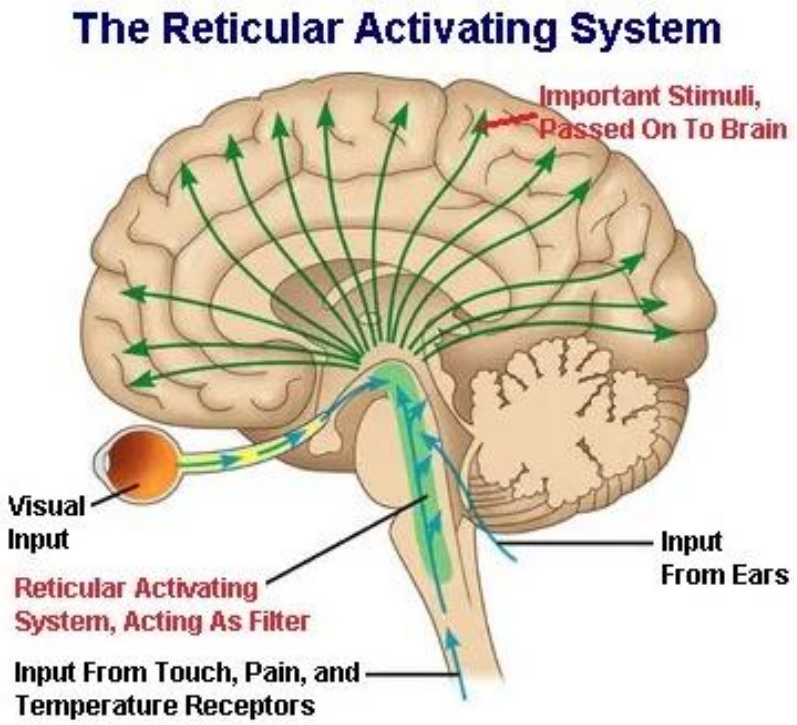




The Reticular Activating System

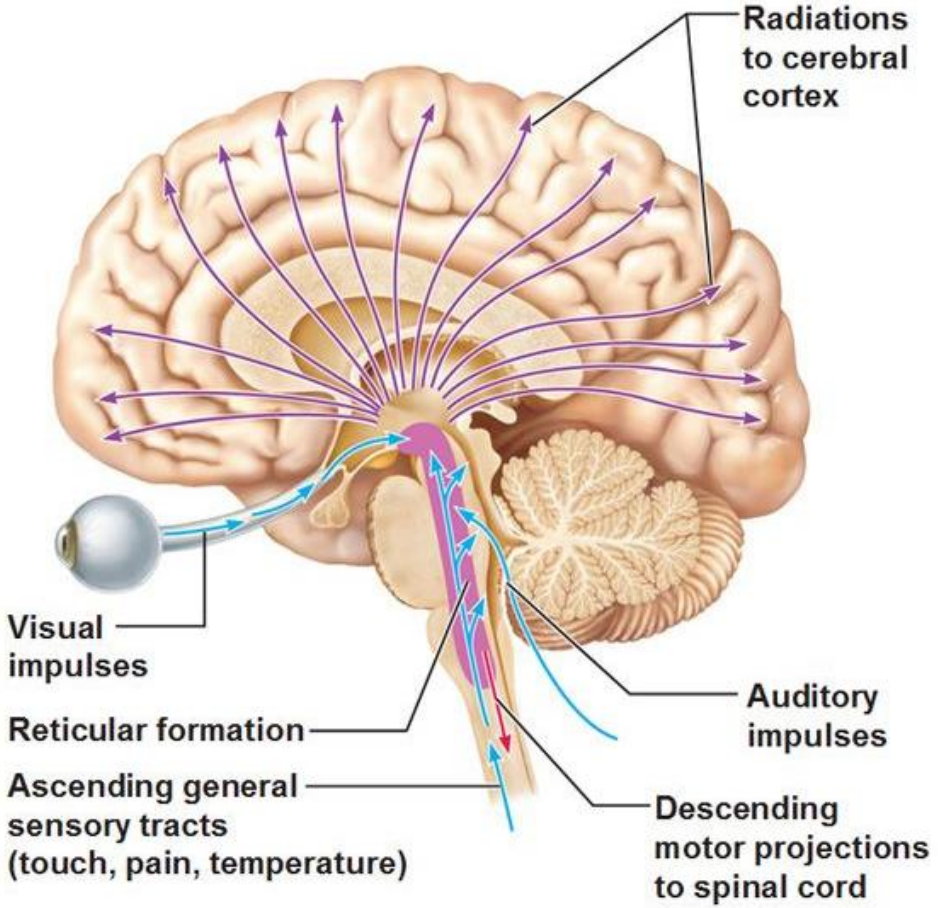
- Regulates arousal/Attentional Filter
  - Ascends to the cortex to enhance attentive state and facilitate conscious perception od sensory stimuli
  - Inhibitory – if weak then pt will have symptoms of ADHD
  - Excitatory - if weak pt will appear passive and fatigued

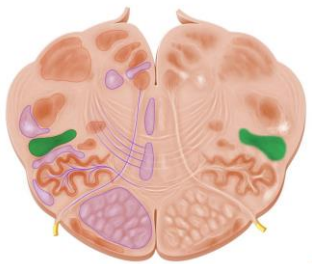
- Participates in fight or flight responses
  - Over-reactive in PTSD
    - Exaggerated startle reflex
    - Decrease in habituation to repeated sensory stimuli
    - Dysregulated sleep – insomnia, nightmares, frequent awakenings



The Reticular Formation

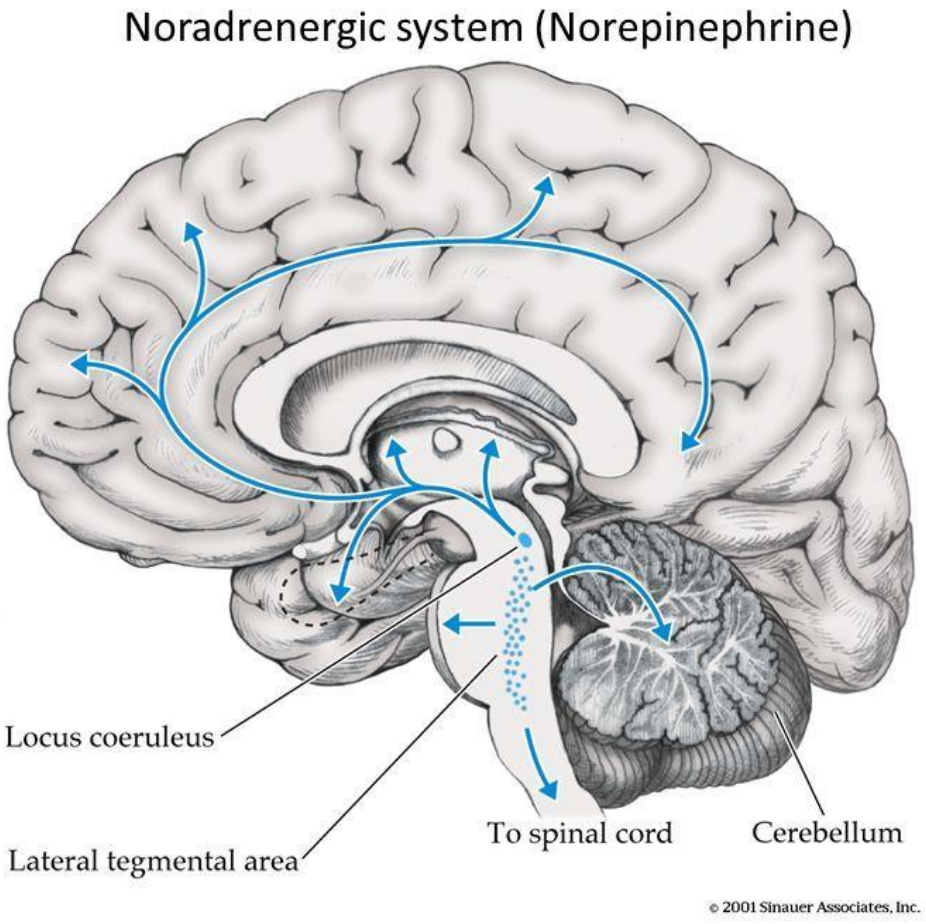
- Distributed throughout the Medulla, Pons, and Midbrain
- 4 Functions
  - Muscle tone
    - Pontine reticulospinal tract & medullary reticulospinal tract
    - Important for control of motor function
  - Breathing & Cardiac functions
    - Control diaphragm
    - Accelerate or depress heart rate in response to appropriate stimuli
  - Modulate Pain Sense
    - Influence information flow through the dorsal horn of spinal cord





The Reticular Formation

- Major nuclear groups for neurotransmitters
  - Noradrenaline (also called Norepinephrine) – plays role in fight or flight response to perceived danger
    - **Locus Coeruleus**
      - Axons project to spinal cord, brain stem, thalamus and cerebellar and cerebral cortices
      - Activated by novel stimuli – role in orienting & attending to sudden contrasting or aversive sensory input
    - **Lateral tegmental neurons of the medullary lateral pontine tegmentum**
      - Activation decreases arterial pressure, heart rate, and blood pressure



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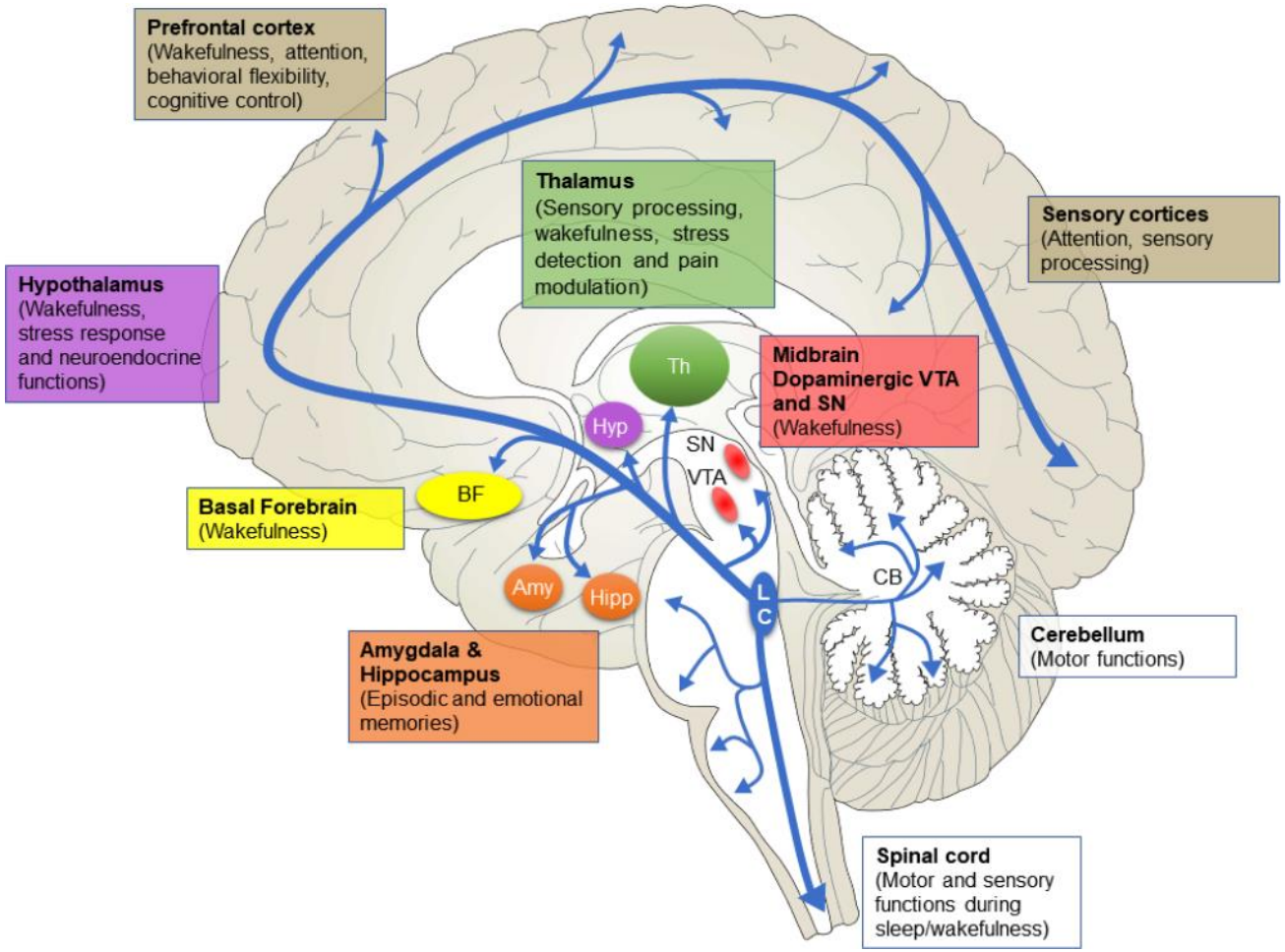
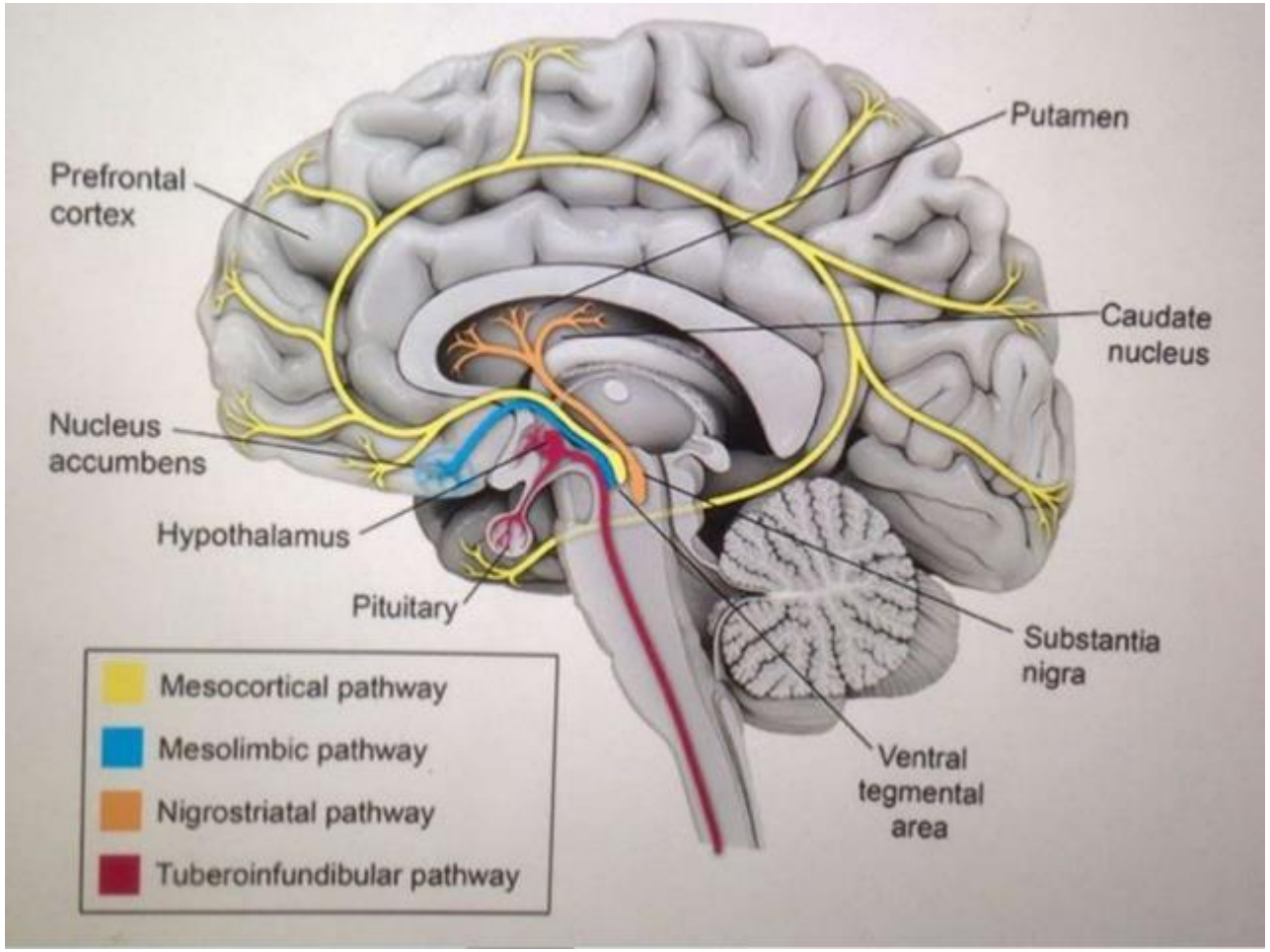


The Reticular Formation

- Major nuclear groups for neurotransmitters
  - Dopamine – “Pleasure”/ Motivational salience relevant for executive function and motor control
    - Midbrain -> striatum, limbic system, and neocortex
    - Mesostriatal system
      - Substantia nigra -> ventral tegmentum -> striatal areas
      - Important role of voluntary movement
      - Damage results in motor disorders of Parkinson's
    - Mesolimbic & mesocortical systems
      - Ventral tegmentum -> limbic & cortical areas
      - Unknown function but may play a role in cognition



Midbrain – Trauma - Psychosis

- Borderline personality disorder - border between psychosis & neurosis
- Many have childhood trauma – physical or sexual abuse or emotional neglect
- Emotional stress -> psychotic episodes
- Theory: Early-life trauma modifies function of midbrain dopaminergic system -> triggers psychotic episodes in BPD & Schizophrenia
- Relative to controls increased activation of midbrain, medial frontal gyrus, pulvinar, and cerebellum in repress to emotional stimuli
    - Midbrain activation additionally correlated with severity of psychotic symptoms, especially persecutory beliefs
    - Cuneus increased activation when viewing neutral & fearful faces
        - role in visual processing
        - perceive neutral faces as negative
        - Role in theory of mind

Figure 2. Regions of activation in medial frontal gyrus and cerebellum which correlated significantly with childhood physical abuse, as assessed by the CTQ, in those with borderline personality disorder. Red areas show activation meeting threshold $P < 0.005$ across whole brain, superimposed on the mean T1 image. CTQ, childhood trauma questionnaire.

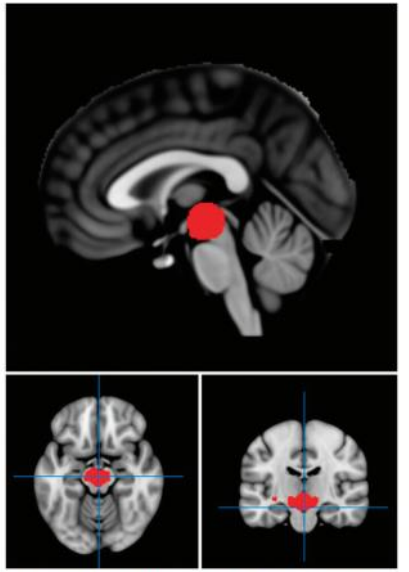
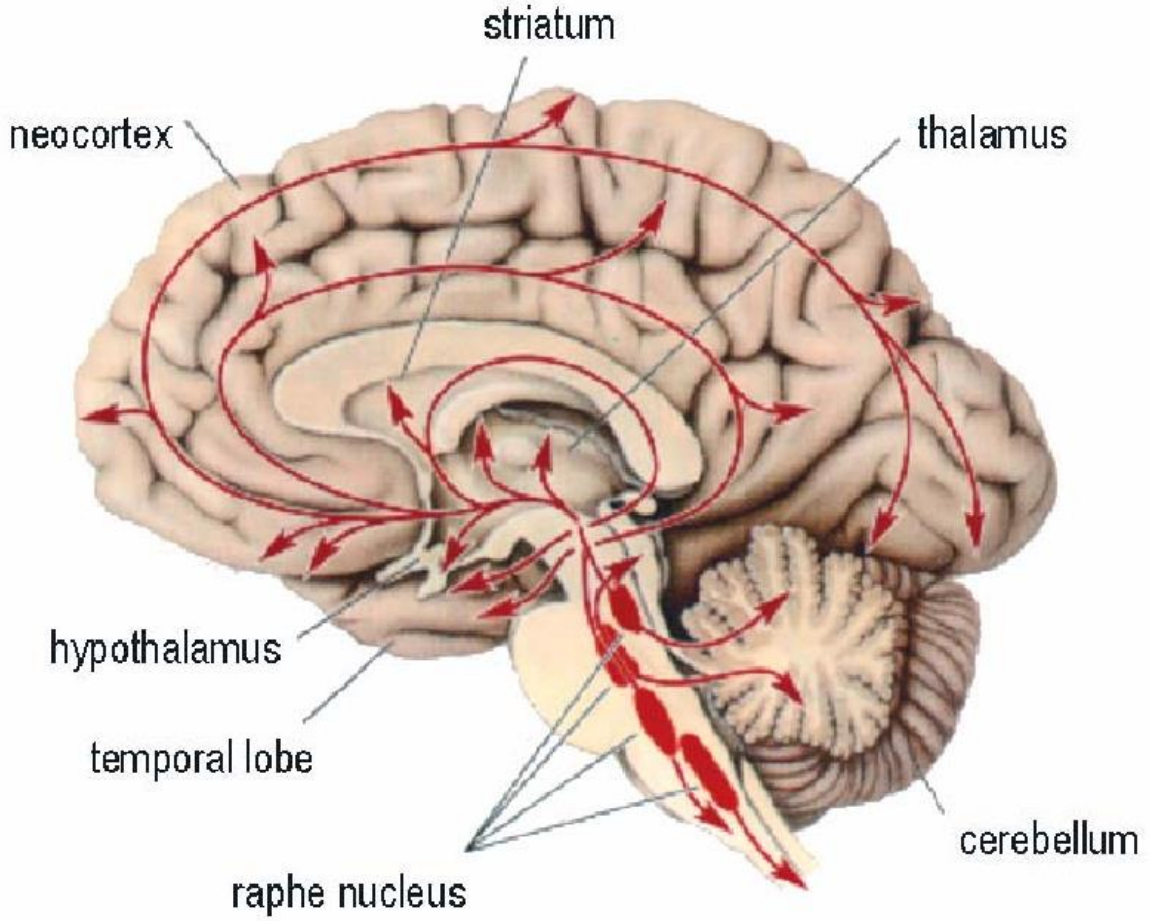


Figure 3. Region of activation in midbrain, which correlated significantly with childhood physical abuse, as assessed by the CTQ, in those with borderline personality disorder. Red areas show activation meeting threshold $P < 0.005$ within a midbrain/ventral striatum mask, superimposed on the mean T1 image. CTQ, childhood trauma questionnaire.

Nicoli, K., Romaniuk, L., & Hall, J. (2015). Childhood trauma, midbrain activation and psychotic symptoms in borderline personality disorder. *Translational Psychiatry, 5,*

The Reticular Formation

- Major nuclear groups for neurotransmitters
    - Serotonin –
        - Stabilizes mood, feelings of well-being, and happiness
        - Facilitates synaptic transmission of action potentials
        - Plays a role in sleeping, eating, and digestion
        - Too little serotonin -> depression
        - Too much serotonin -> excessive nerve cell activity
    - Raphe nuclei



Medulla & Depression

- Major Depressive Disorder (MDD) – sustained negative affect & diminished positive affect
- May be due to aberrant interactions of brain networks
- Brain stem is connected to hierarchical system that is critical for emotion regulation as well as cognition
    - Medulla -> limbic system including amygdala, hippocampus, hypothalamus, & insula
- Relative to healthy controls, MDD increased connectivity between left medulla & right inferior parietal cortex (higher anxiety)
    - IPC – interoception (perception of sensations from inside the body), execution, attention, action inhibition, social & spatial cognition, visuospatial attentional processing
    - Connection may be related to deficits seen in MDD pts in motor learning, execution, inhibition, and cognition -> working memory & attention.

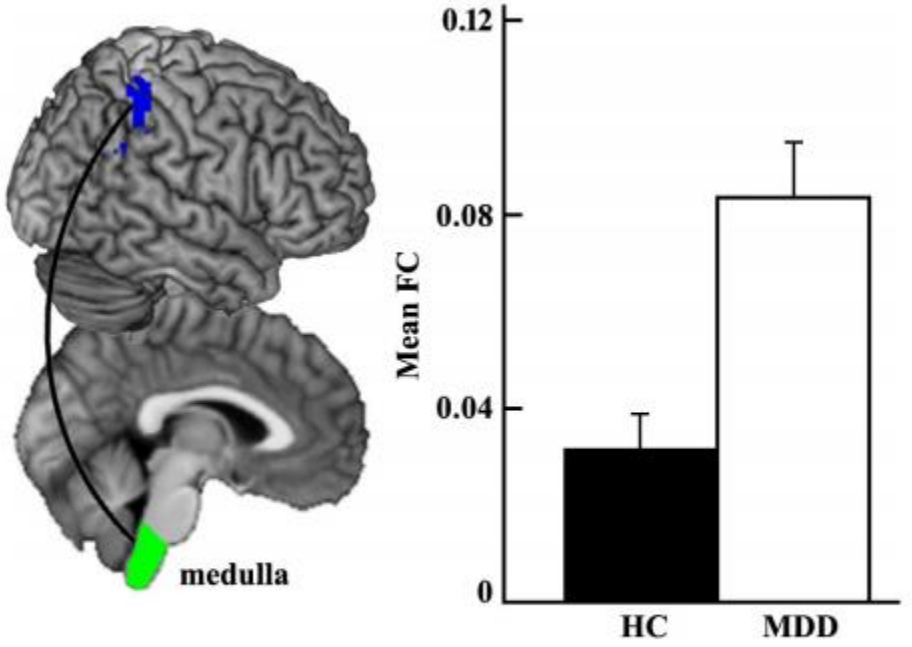
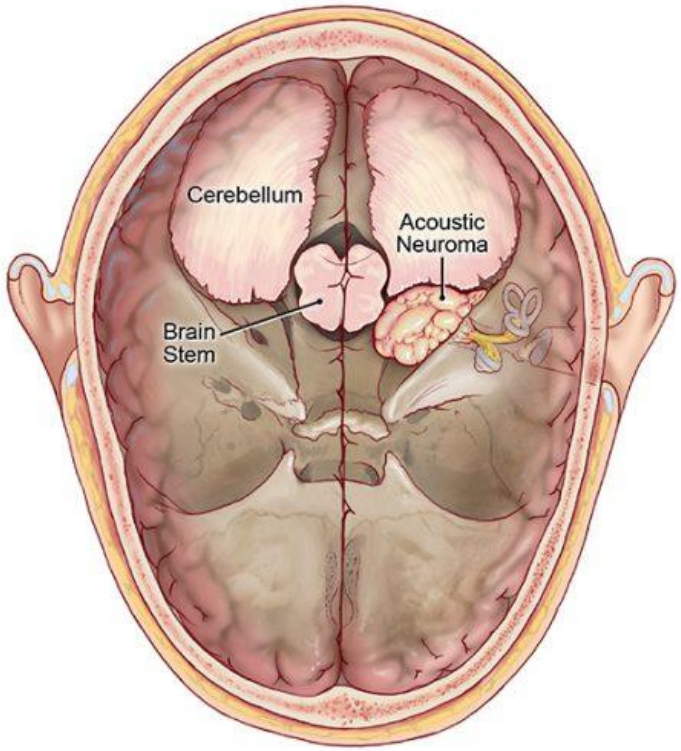


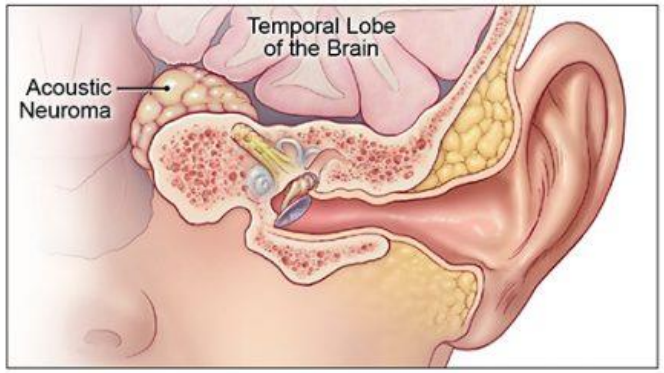
FIGURE 2 | Increased functional connectivity between left medulla and right inferior parietal cortex (IPC) in MDD patients compared to healthy controls using two-sample *t*-test.

Luo, L., Wu, K., Gao, S., Kong, X., Lu, F., Wu, F., Wu, H., & Wang, J. (2018). Increased functional connectivity between the medulla and inferior parietal cortex in medication-free major depressive disorder. *Frontiers in Neuroscience, 12,*

Clinical Syndromes of the Brain Stem

- Extra-axial Lesion
- Acoustic Neuroma
  - Tumor of the Schwann cells of the sheath of the acoustic nerve (VIII) grows in the angler between the Cerebellum & Pons
  - First compresses the cochlear nerve -> ringing in the ears, loss of hearing, deafness
  - Grows to compress on afferent fibers of the trigeminal nerve (V) -> loss of corneal blink reflex
  - Eventually compresses facial nerve (VII) and cerebellum -> facial paralysis
  - Compress the corticospinal CSF aqueduct causes hydrocephalus
  - Tumors are benign and are accessible for surgical removal





Clinical Syndromes of the Brain Stem

- Medial Syndrome of the Medulla
  - Fibers of the Hypoglossal nerve (XII)
  - Ipsilateral weakness and wasting of that half of the tongue

- Medial Syndrome of the Pons
  - If Abducens nerve (VI) is affected -> Lateral rectus muscle may be paralyzed
  - Paramedian Pontine Reticular formation -> Ipsilateral gaze palsey (paralysis & involuntary tremors)
  - Vestibular or cerebellar connections or medial longitudinal fasciculus -> Nystagmus (repetitive, uncontrolled movements)

Clinical Syndromes of the Brain Stem

- Lateral Lesions of Medulla & Pons
- 6 common manifestations

Region Affected	Manifestation
Spinothalamic tract	Contralateral loss of pain & temperature sensations of limb and trunk
Descending autonomic fibers	Ipsilateral Horner's syndrome (small pupil with normal reaction to light), drooping eyelid, decreased sweating on the ipsilateral side of the face
Sensory trigeminal nucleus or descending tract	Ipsilateral loss of cutaneous sensation on the face
Vestibular Connections	Nystagmus & nausea
Cerebellar connections	Ataxia of ipsilateral limbs
?	Hiccups

Clinical Syndromes of the Brain Stem

- Lateral Lesions of Medulla
  - 6 common manifestations
  - Also, glossopharyngeal (IX) and vagal (X) nerve may be involved
    - Difficulty swallowing
    - Hoarse voice because paralysis of ipsilateral vocal cord & loss of pharyngeal reflex
  - If solitary nucleus is involved -> loss of taste on ipsilateral side of tongue

Clinical Syndromes of the Brain Stem

- Lateral Lesions of Lower Pons
  - 6 common manifestations
  - Also, 3 additional signs arise from damage of the facial (VII) and auditory (VIII) nuclei
    - Ipsilateral facial paralysis
    - Deafness and tinnitus
    - Ipsilateral gaze paralysis if extends to pontine gaze center

- Lateral Lesions of Mid Pons
  - 6 common manifestations
  - Trigeminal motor functions are implicated
    - Bilateral lesions cause difficulty in chewing
    - Unilateral lesions cause deviations of the jaw toward the side of the lesion when the mouth is opened

Clinical Syndromes of the Brain Stem

- Bilateral lesion of ventral pons
    - Interrupt corticobulbar and corticospinal tracts on both sides
        - Quadriplegic
        - Unable to speak
        - Incapable of facial movement
        - Resembles comma but eyes are open and move, pt is fully conscious and able to communicate by eye or eyelid movement (Locked-in)

Thank You