UNIVERSITÀ DEGLI STUDI DI TRIESTE

DEPARTMENT OF MEDICINE, SURGERY AND HEALTH SCIENCES

NEUROLOGY UNIT

Course of
Human Neuroanatomy

Master of Neuroscience, University of Trieste
2026-27

Dr. Federica Palacino

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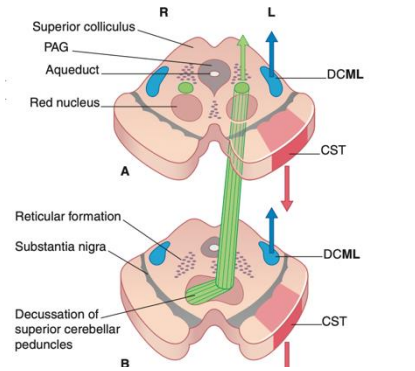
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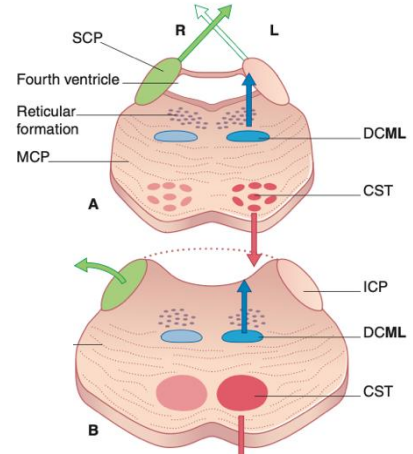
Dr. Federica Palacino

Brainstem:



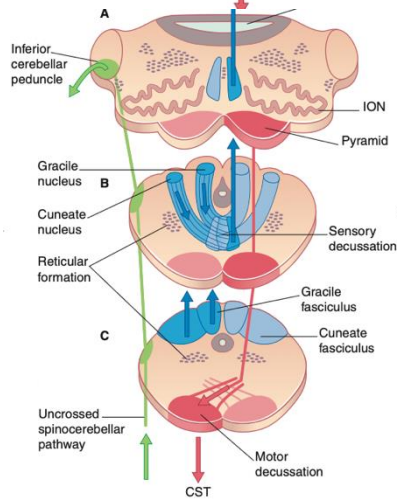
Midbrain

FIGURE 3.4 Transverse sections of midbrain. **(A)** At the level of superior colliculi. **(B)** At the level of inferior colliculi. In this and following diagrams, the corticospinal tract (CST) and dorsal column–medial lemniscal (DC**ML**) pathway connected to the *left* cerebral hemisphere are highlighted. PAG, periaqueductal grey matter.



Pons

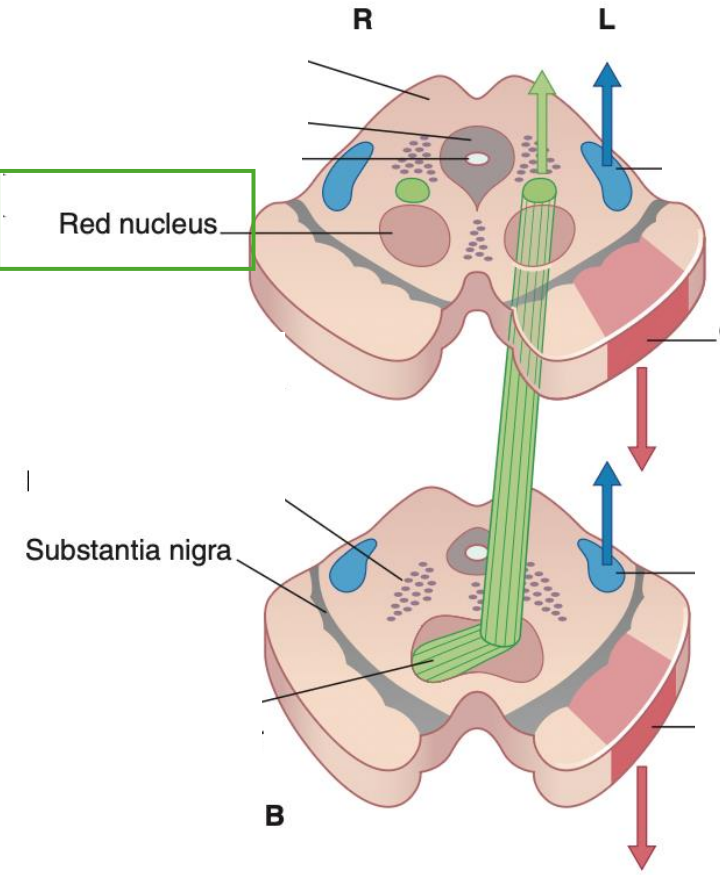
FIGURE 3.5 Transverse sections of pons. **(A)** Upper pons. **(B)** Lower pons. SCP, MCP, ICP, superior, middle, inferior cerebellar peduncles, respectively; CST, corticospinal tract; DC**ML**, dorsal column–medial lemniscal pathway.

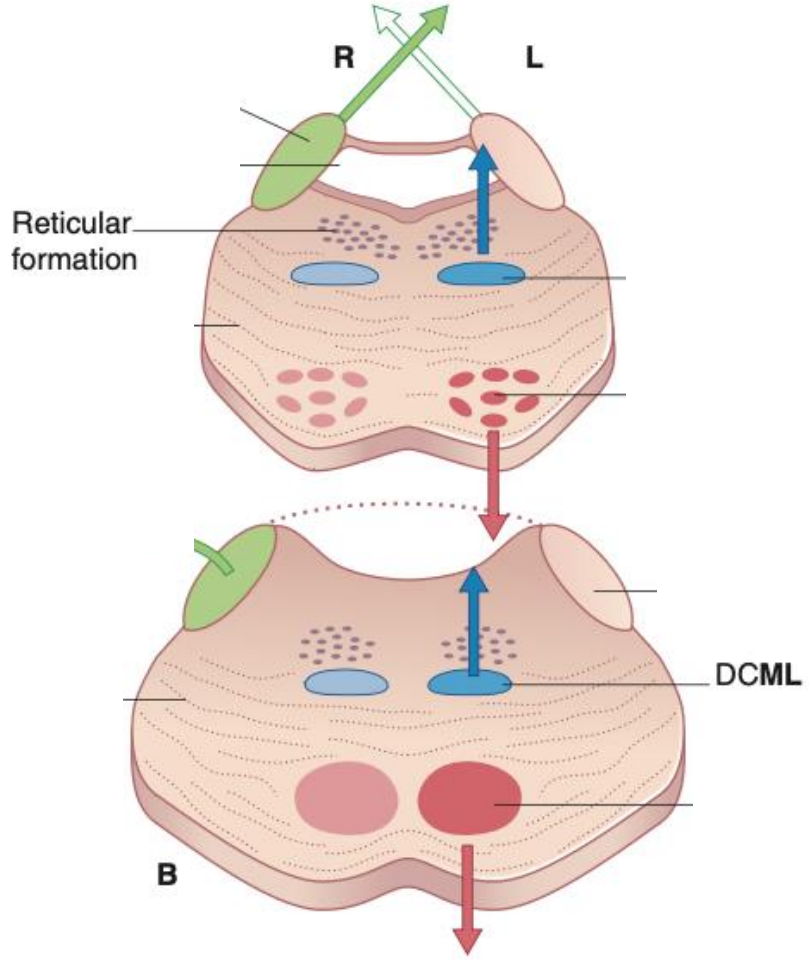


Medulla oblongata

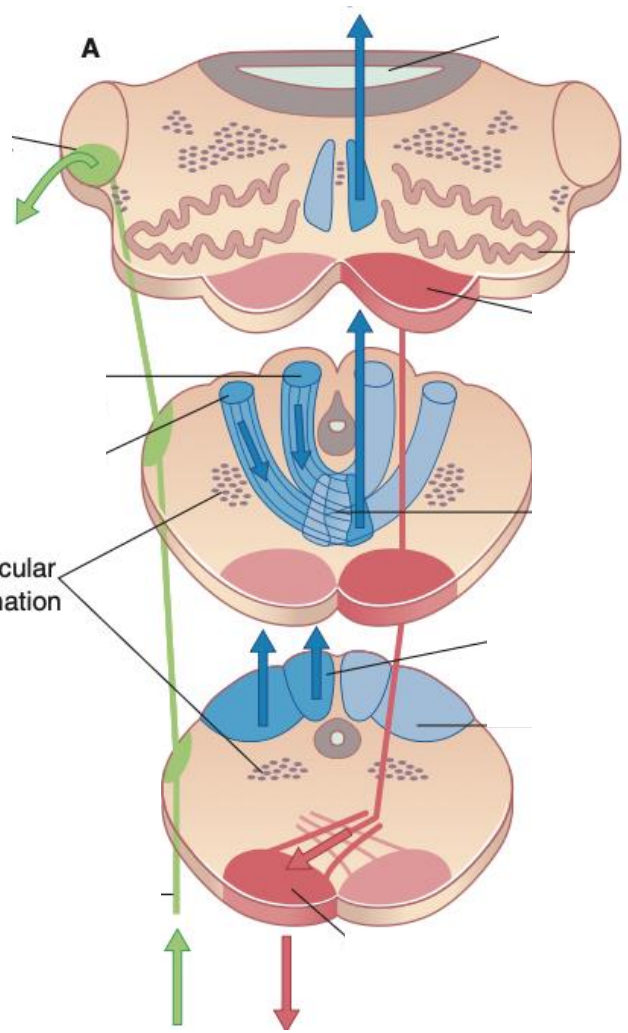
FIGURE 3.6 Transverse sections of medulla oblongata. **(A)** Level of inferior olivary nucleus (ION). **(B)** Level of sensory decussation. **(C)** Level of motor decussation. CST, corticospinal tract; ICP, inferior cerebellar peduncle; DC**ML**, dorsal column–medial lemniscal pathway.

Other important structures

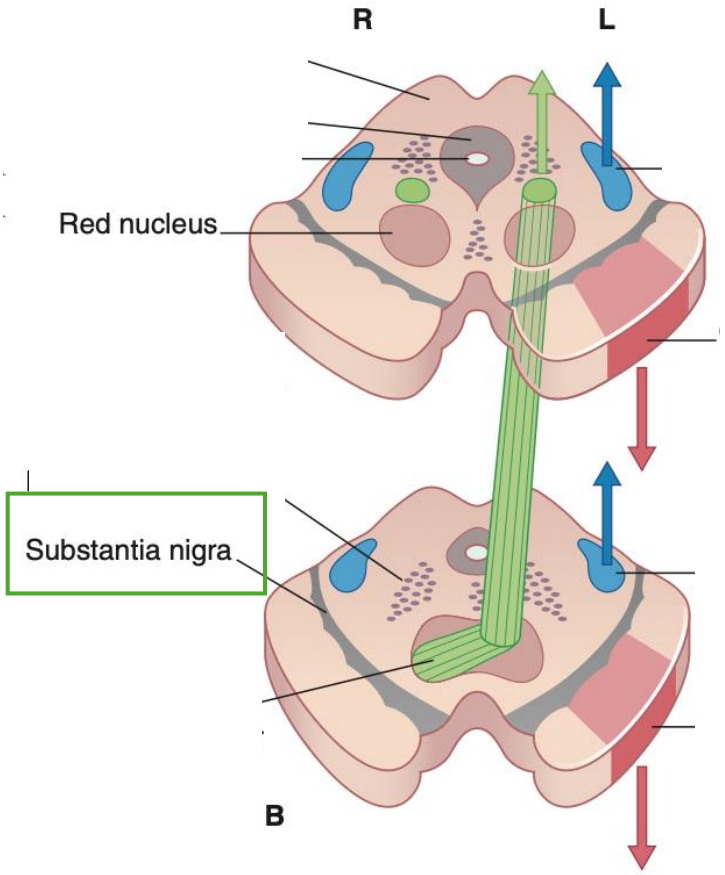


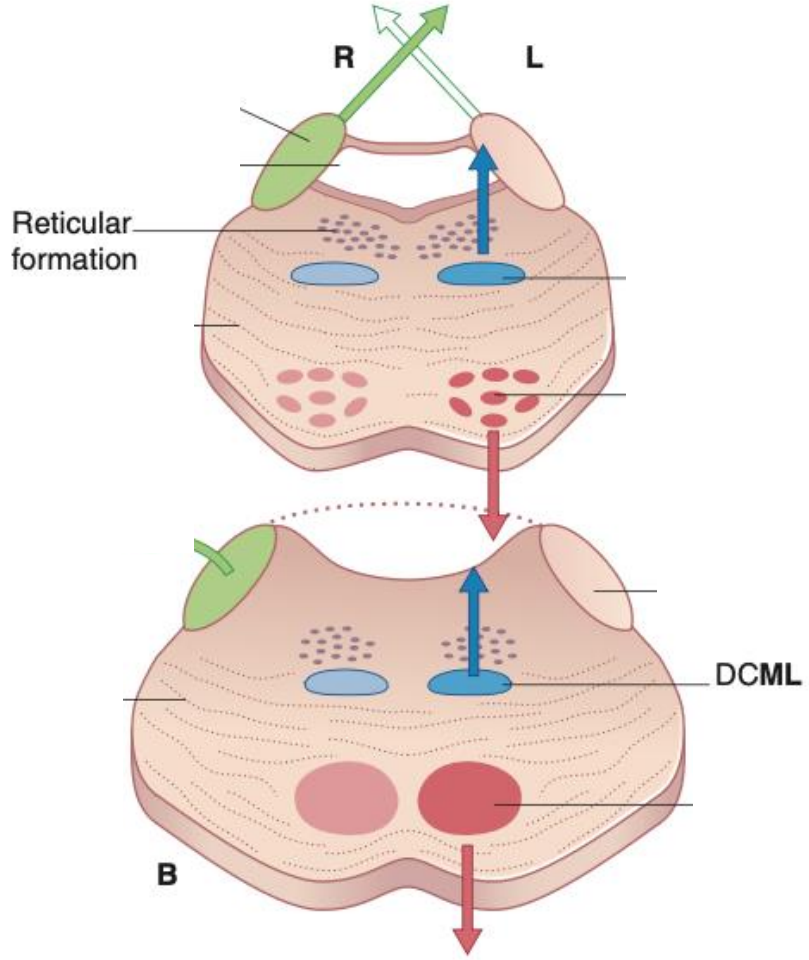


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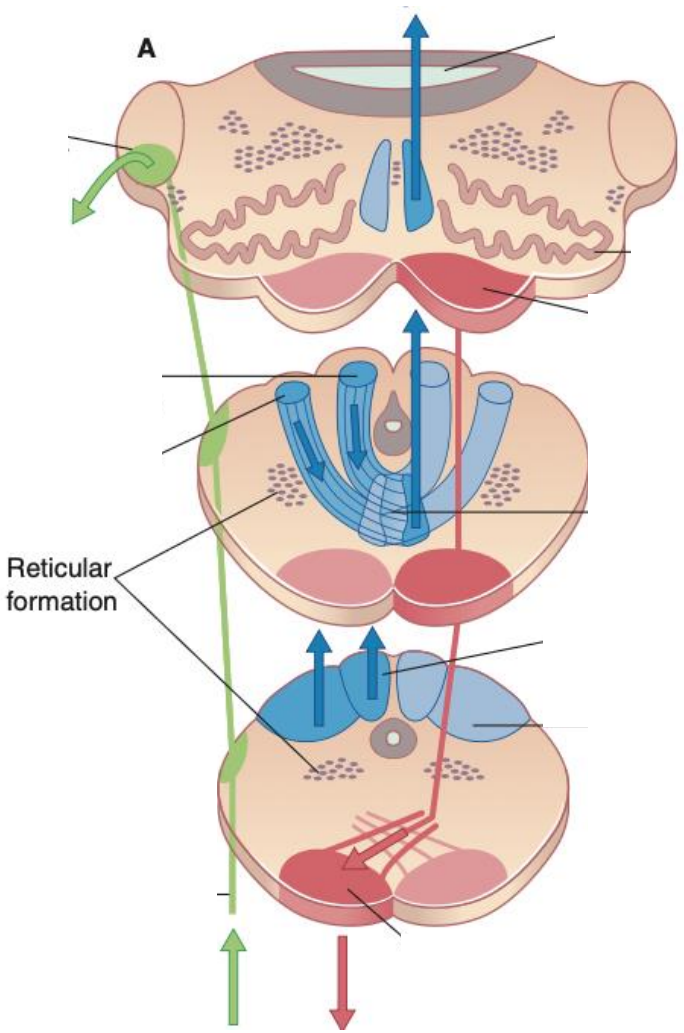


Other important structures

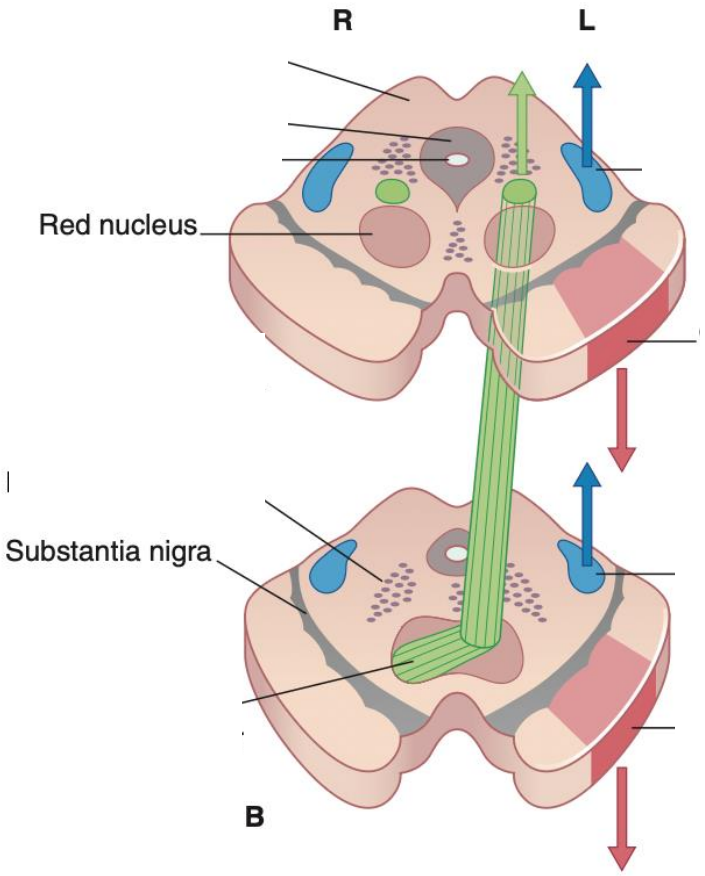


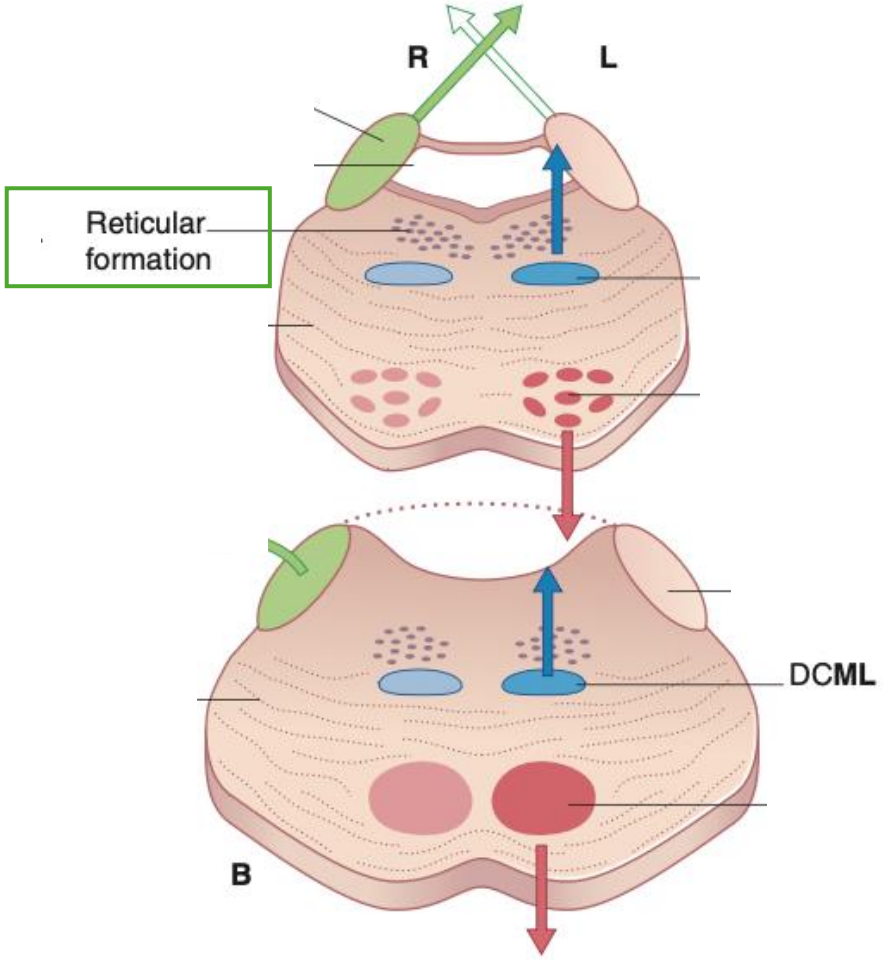


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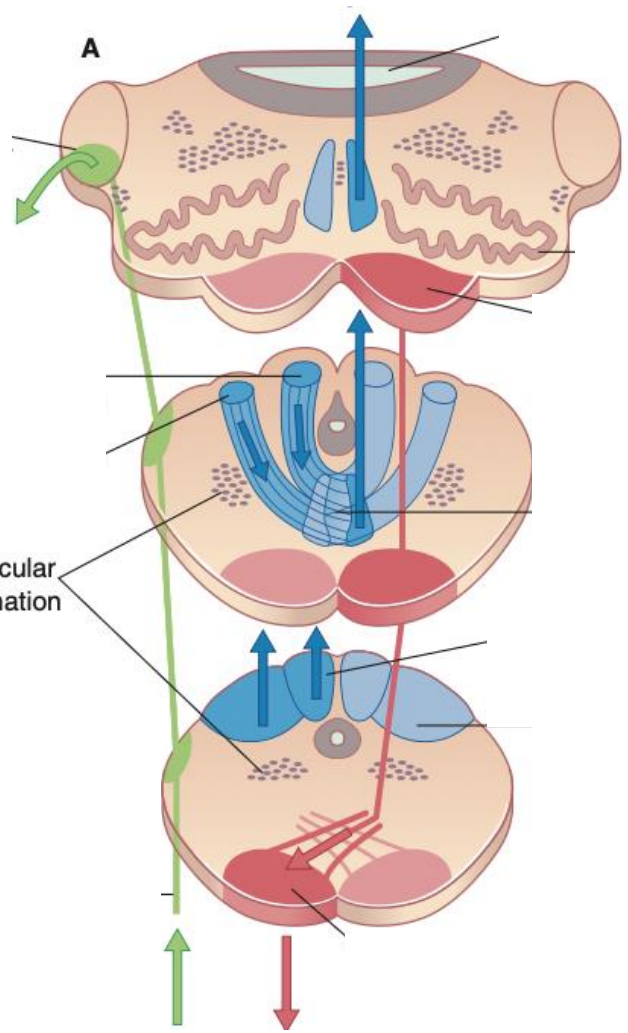


Other important structures





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Reticular formation

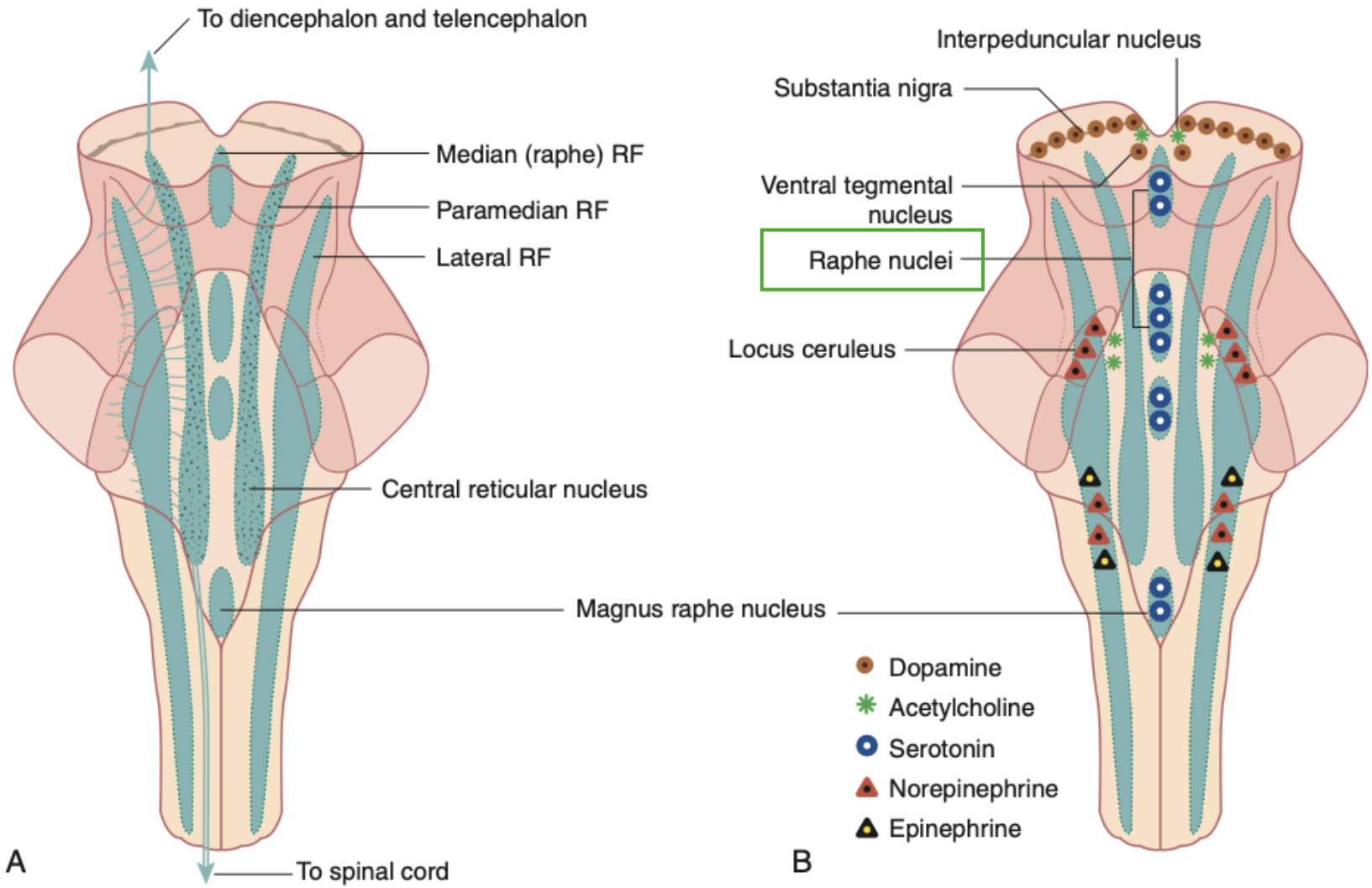


FIGURE 24.1 Reticular formation (RF). **(A)** Subdivisions. **(B)** Aminergic and cholinergic cell groups.

Reticular formation

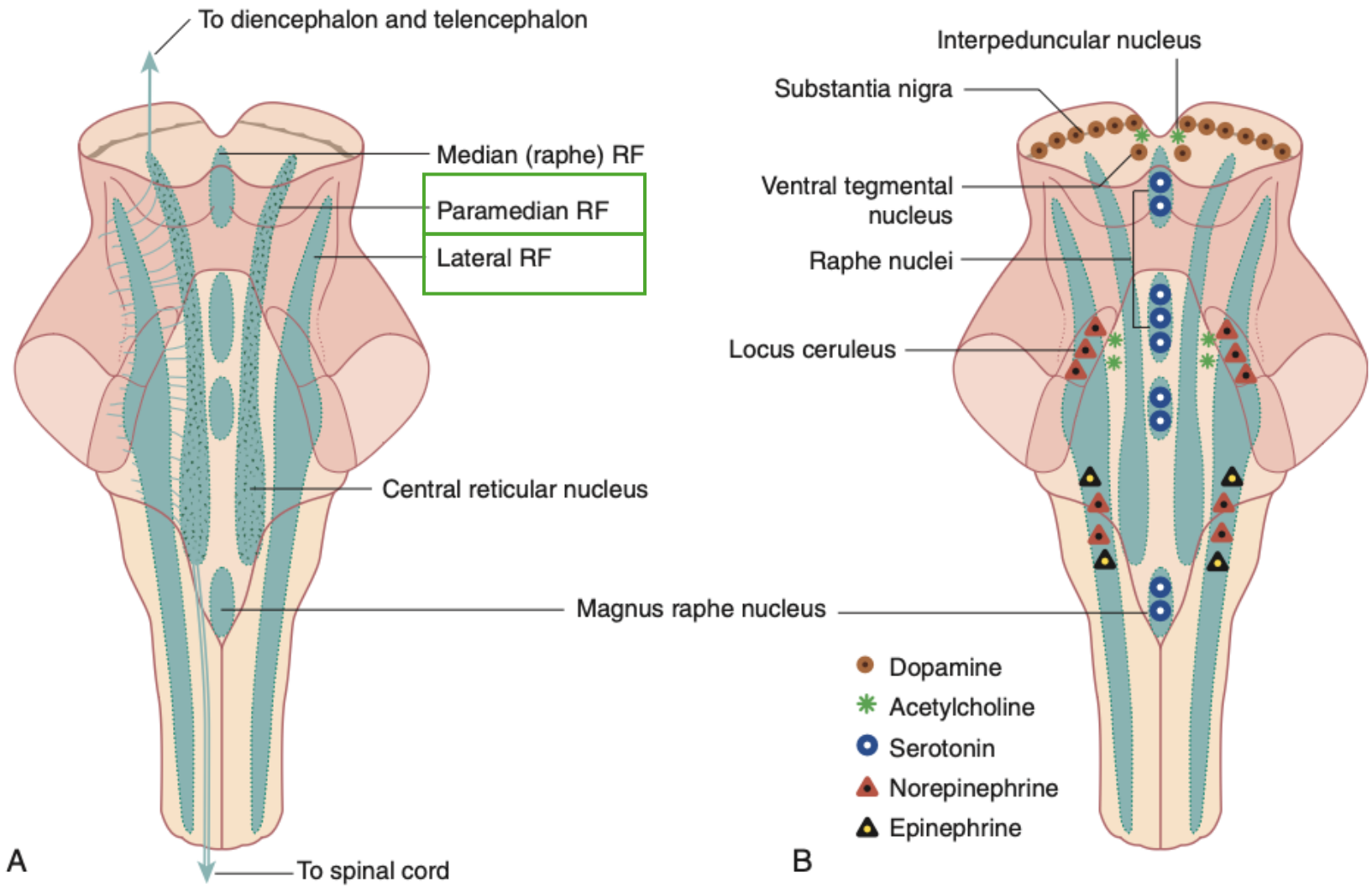


FIGURE 24.1 Reticular formation (RF). **(A)** Subdivisions. **(B)** Aminergic and cholinergic cell groups.

Reticular formation

TABLE 24.1 Aminergic neurons of the reticular formation

Transmitter	Location
Dopamine	Tegmentum of midbrain (substantia nigra, ventral tegmentum)
Epinephrine	Medulla
Histamine	Diencephalon
Norepinephrine	Midbrain, pons, medulla (locus ceruleus)
Serotonin	Raphe nuclei of midbrain, pons, medulla

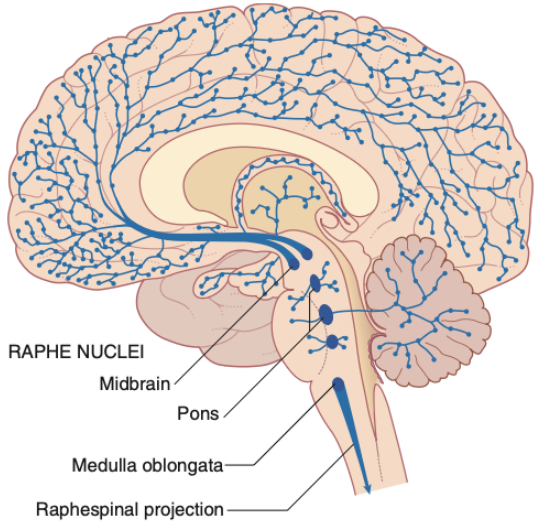


FIGURE 24.2 Serotonergic projections from the brainstem midline (raphe).

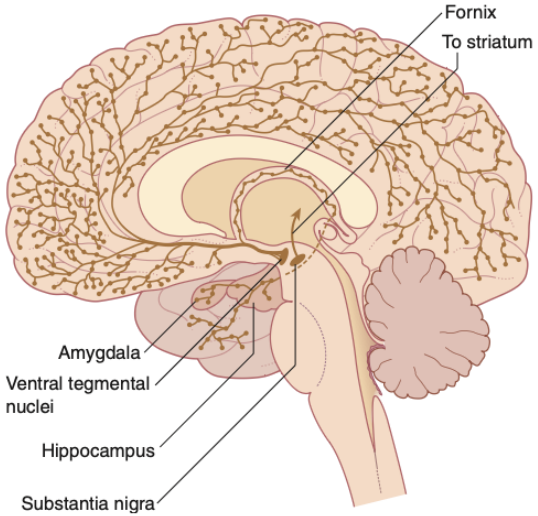


FIGURE 24.3 Dopaminergic projections from the midbrain.

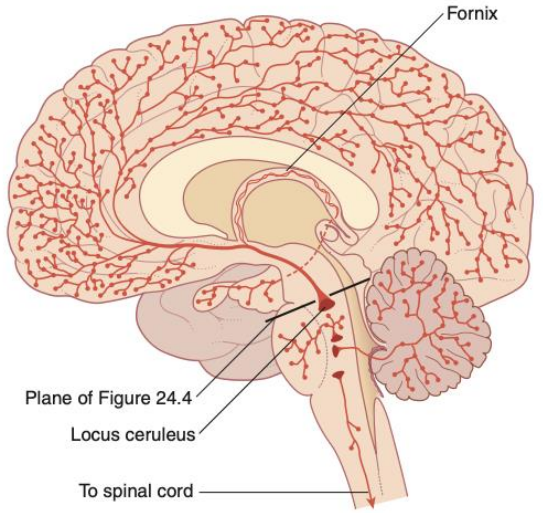


FIGURE 24.5 Noradrenergic projections from the pons and medulla oblongata.

Reticular formation

TABLE 24.2 Elements of the reticular formation and their perceived functions

Element	Function
Aminergic neurons	Sleeping and waking, attention and mood, sensory modulation, blood pressure control
Ascending arousal system (AAS)	Arousal
Central reticular nucleus of medulla oblongata	Vital centres (circulation, respiration)
Lateral medullary nucleus	Conveys somatic and visceral information to the cerebellum
Magnocellular nuclei	Posture, locomotion
Medial parabrachial nucleus	Patterns of respiration during the waking state
Pontine locomotor centre	Pattern generation
Pontine micturition centre	Bladder control
Premotor cranial nerve nuclei	Patterned cranial nerve activities
Salivatory nuclei	Salivary secretion, lacrimation

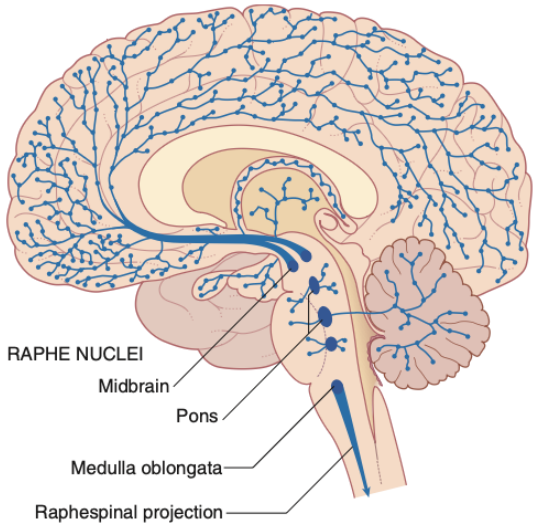


FIGURE 24.2 Serotonergic projections from the brainstem midline (raphe).

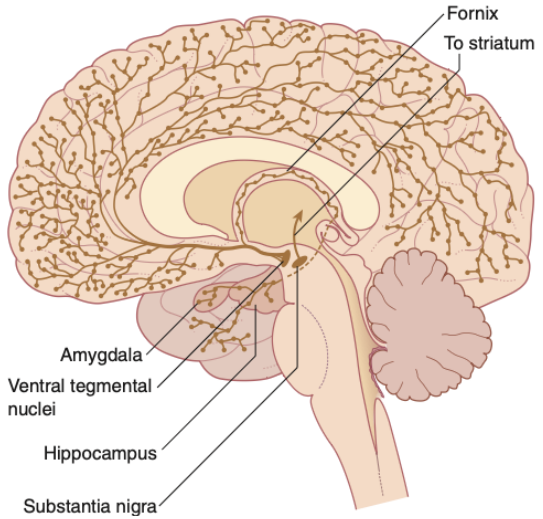


FIGURE 24.3 Dopaminergic projections from the midbrain.

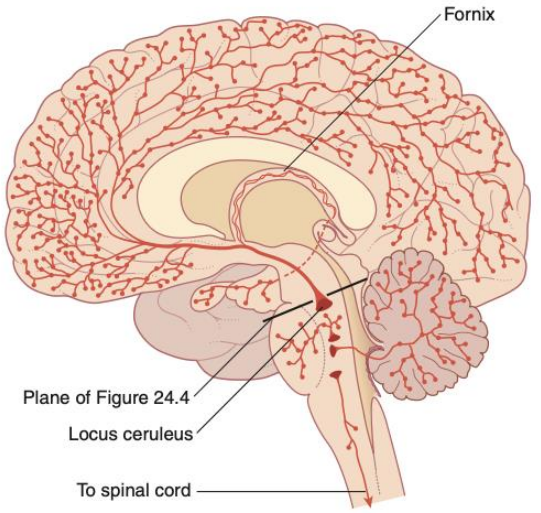
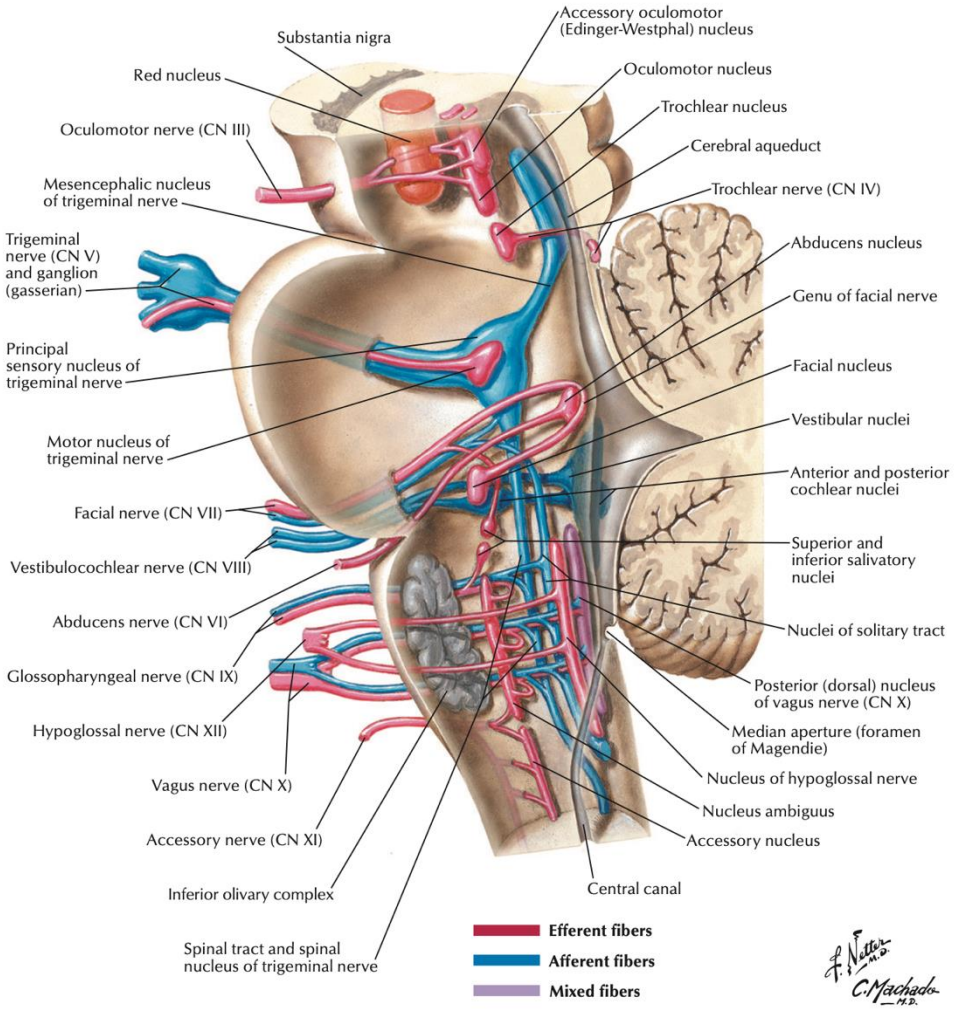
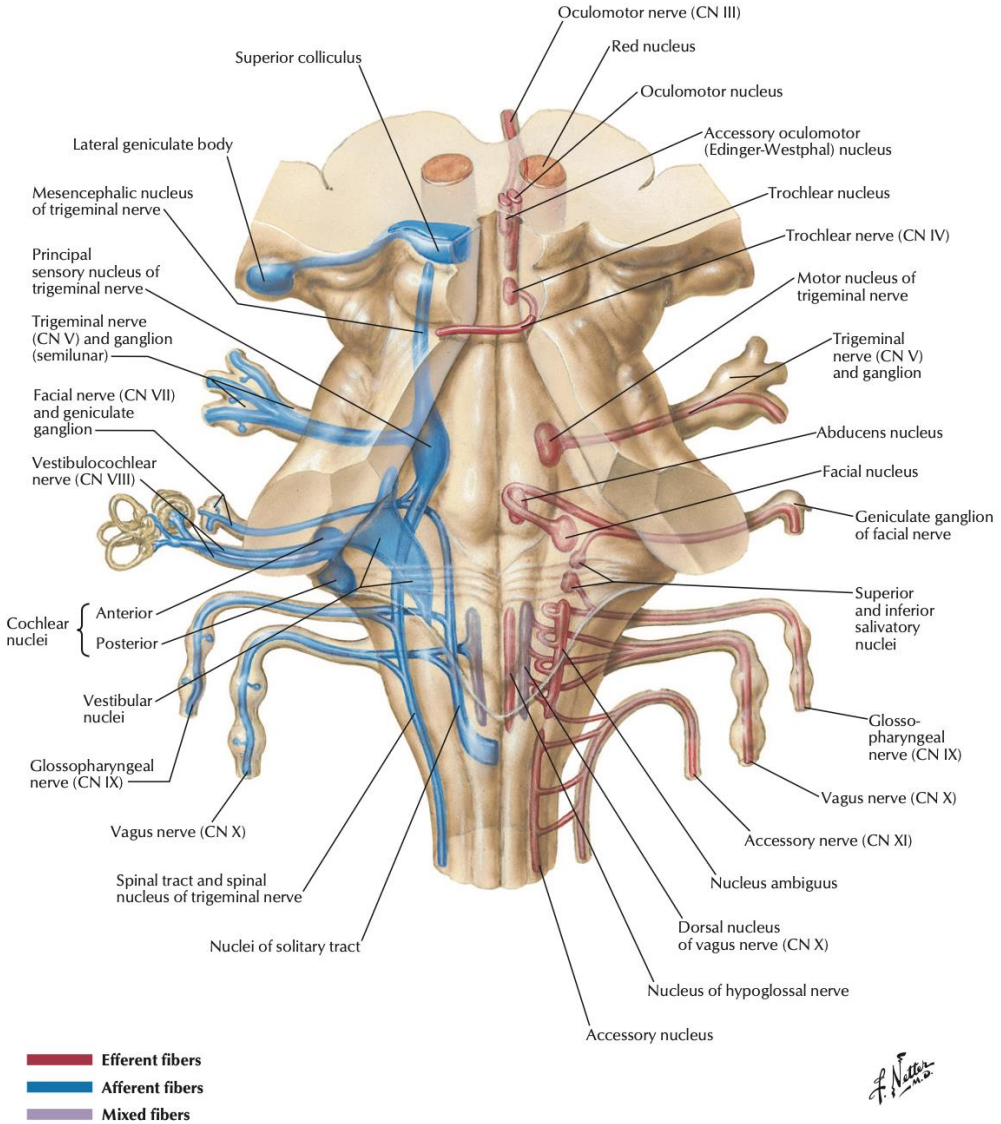


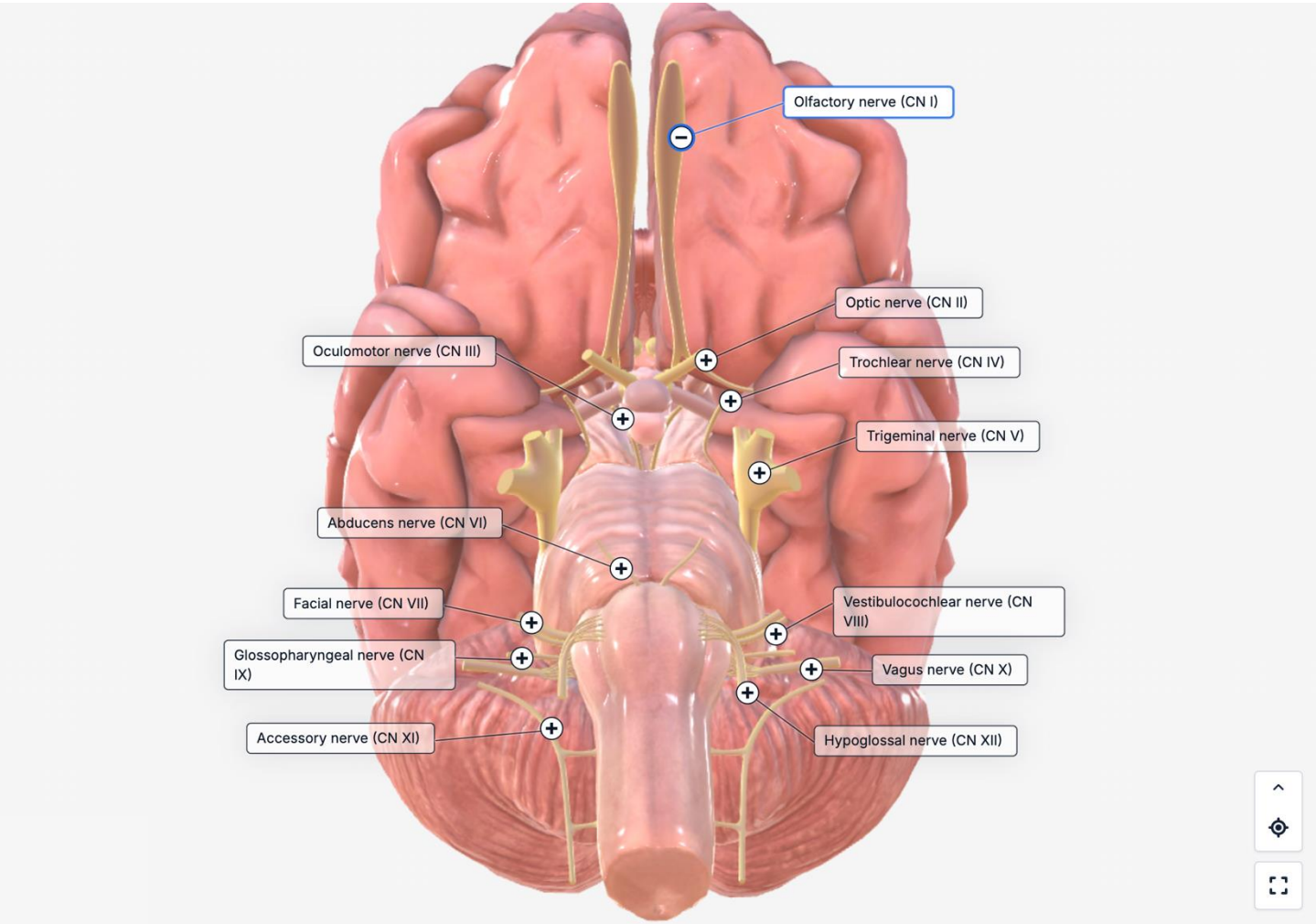
FIGURE 24.5 Noradrenergic projections from the pons and medulla oblongata.

Nuclei of cranial nerves

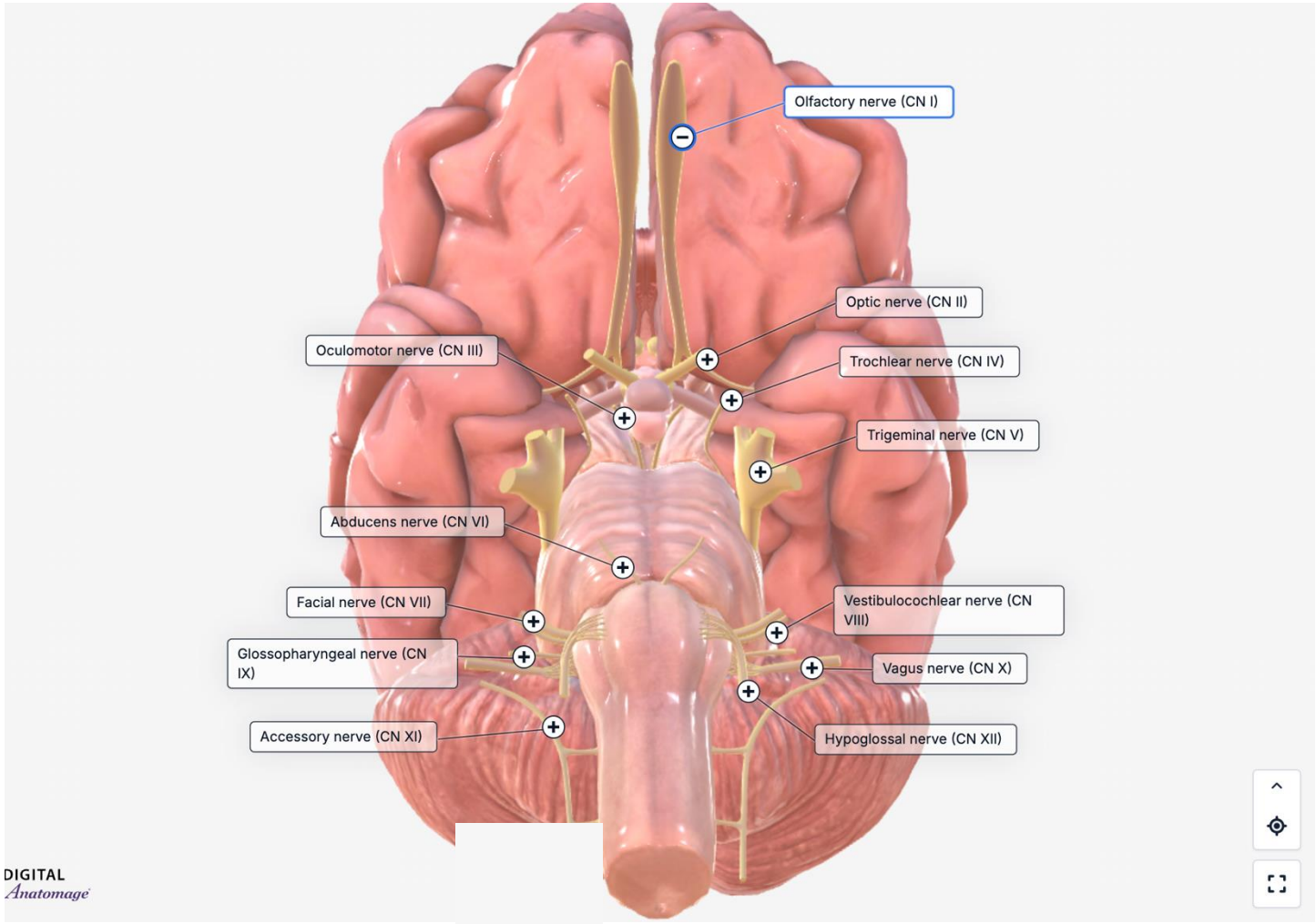




Cranial nerves

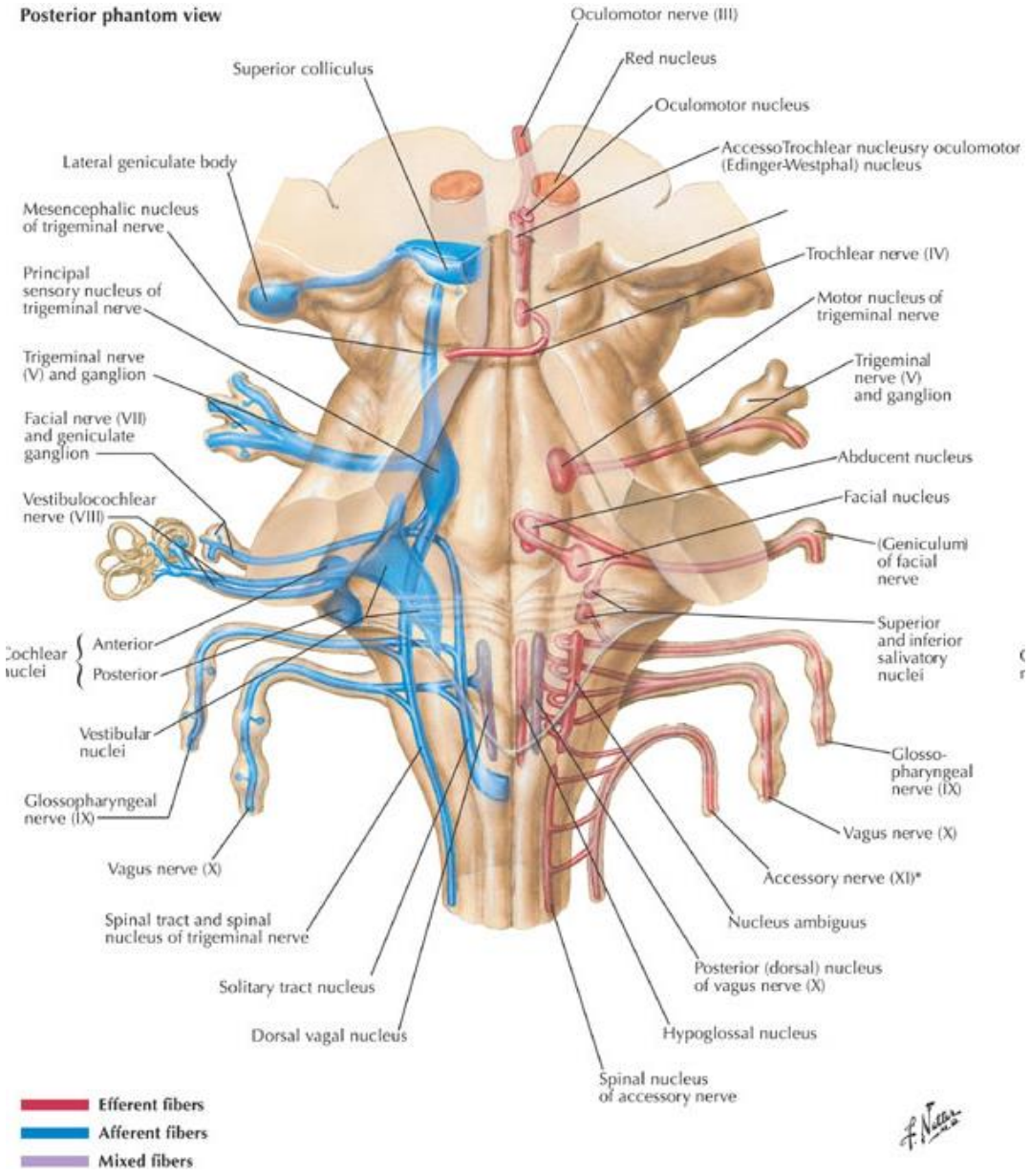


Cranial nerves



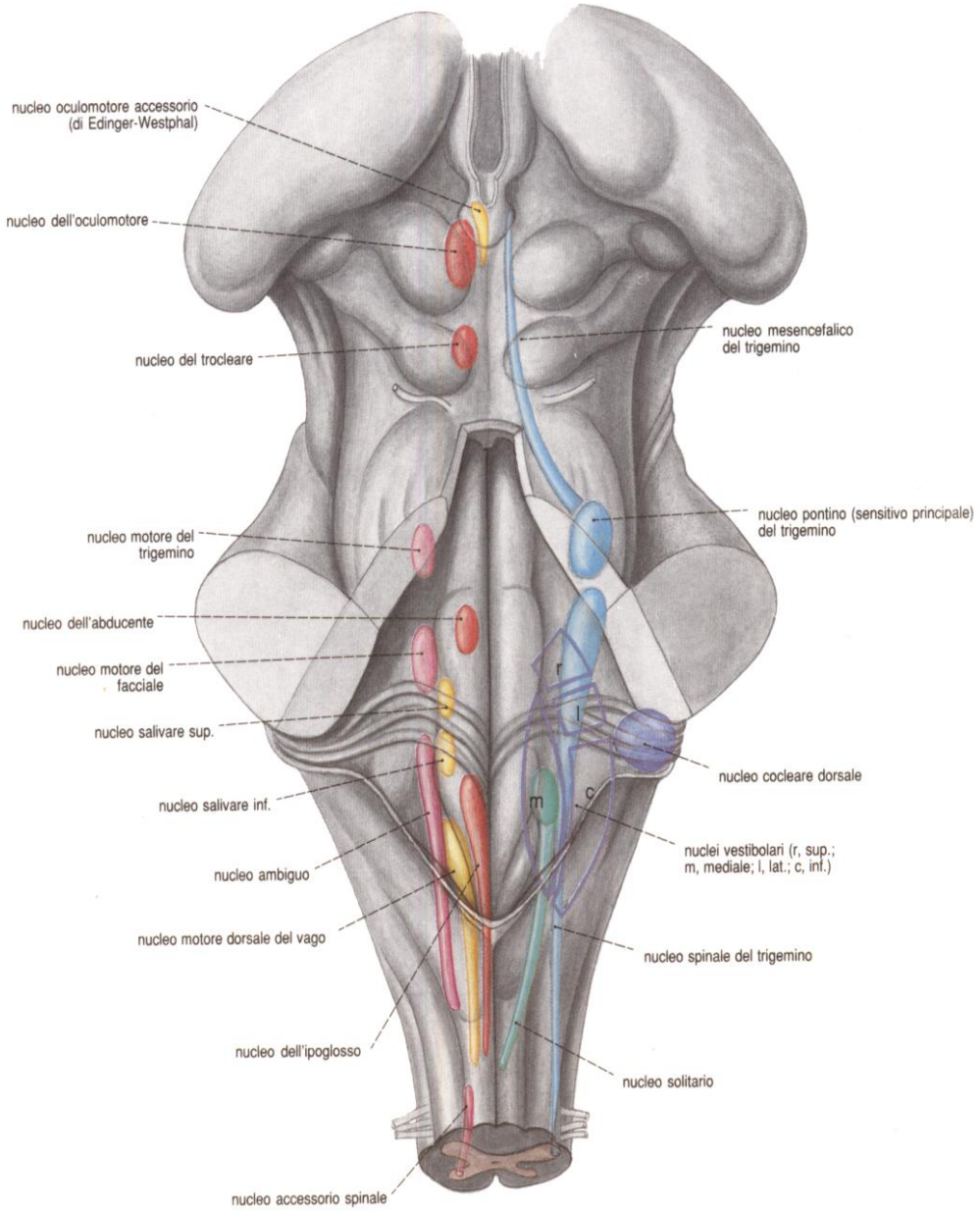
- I - Olfactory nerve
- II - Optic nerve
- III - Oculomotor nerve
- IV - Trochlear nerve
- V - Trigeminal nerve
- VI - Abducens nerve
- VII - Facial nerve
- VIII - Vestibulocochlear nerve
- IX - Glossopharyngeal nerve
- X - Vagus nerve
- XI - Accessory nerve
- XII - Hypoglossal nerve

Cranial nerve



Purely sensory nerves: I, II, and VIII
Purely motor nerves: III, IV, VI, XI, and XII
Mixed nerves: V, VII, IX, and X

Cranial nerve nuclei

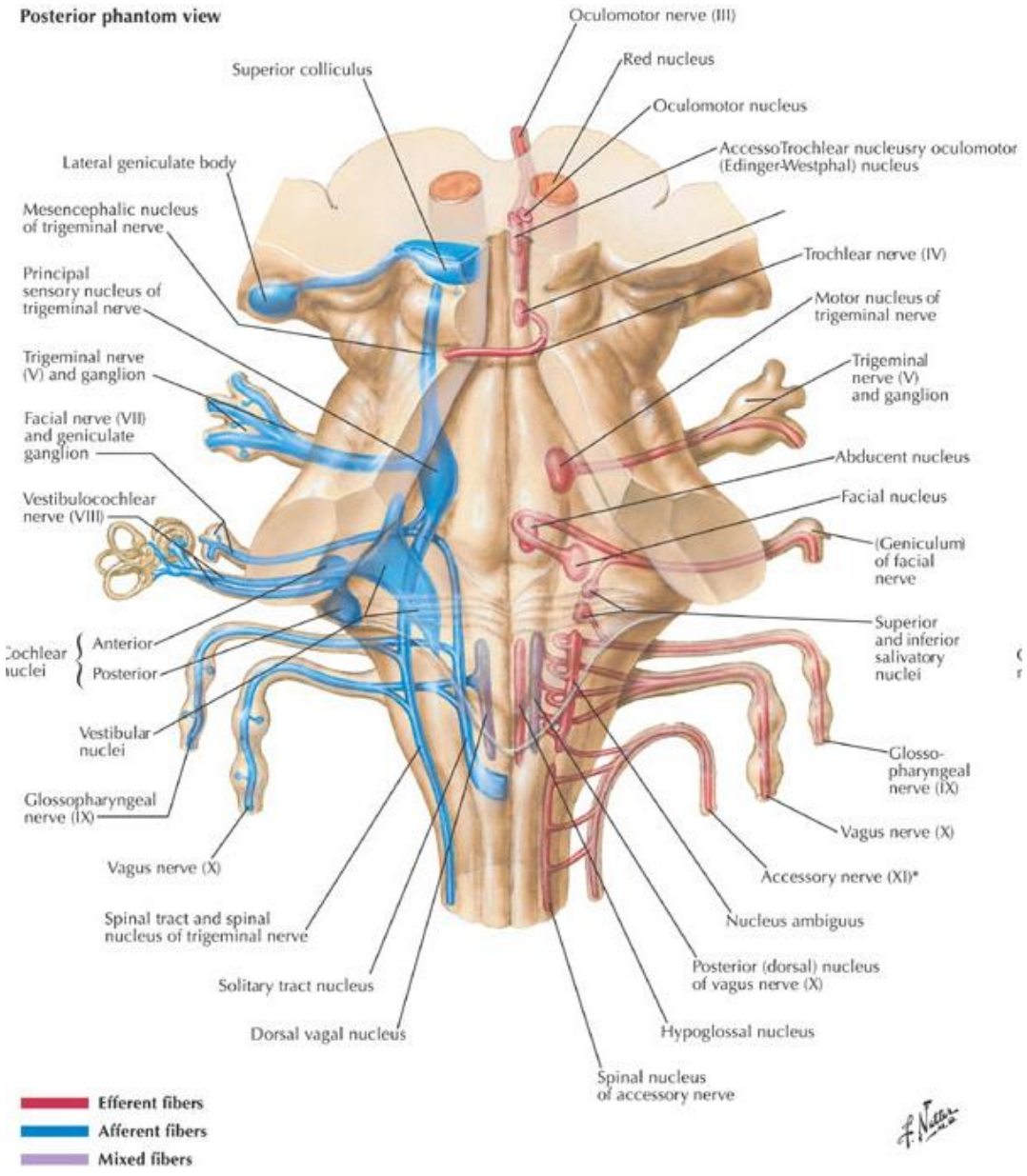


III, IV – mesencephalon

V, VI, VII – pons

VIII, IX, X, XI, XII – medulla oblongata

Cranial nerve



- Motor nuclei:

-- Medial column (CN motor nuclei for III; IV; VI; and XII)

-- Lateral column (CN motor nuclei for V, VII, IX, X, XI)

- Preganglionic parasympathetic nuclei:

--Edinger-Westphal nucleus (CN III)

-- The dorsal (motor) vagal nucleus (CN X)

-- The superior (CN VII) salivatory nucleus

-- The inferior (CN IX) salivatory nucleus

- Secondary sensory nuclei

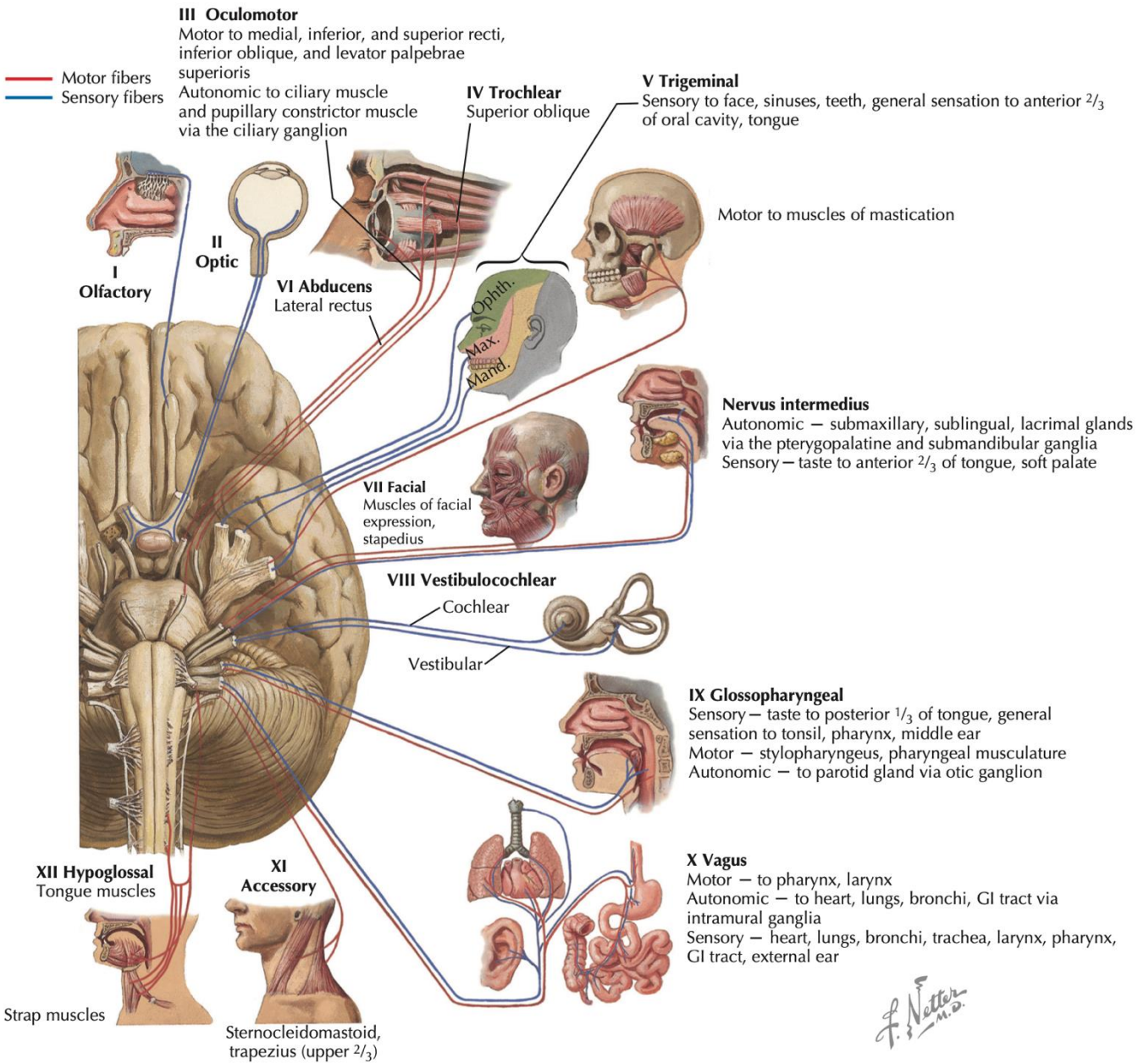
-- the main sensory and descending nuclei of CN V,

-- the vestibular nuclei and cochlear nuclei (CN VIII),

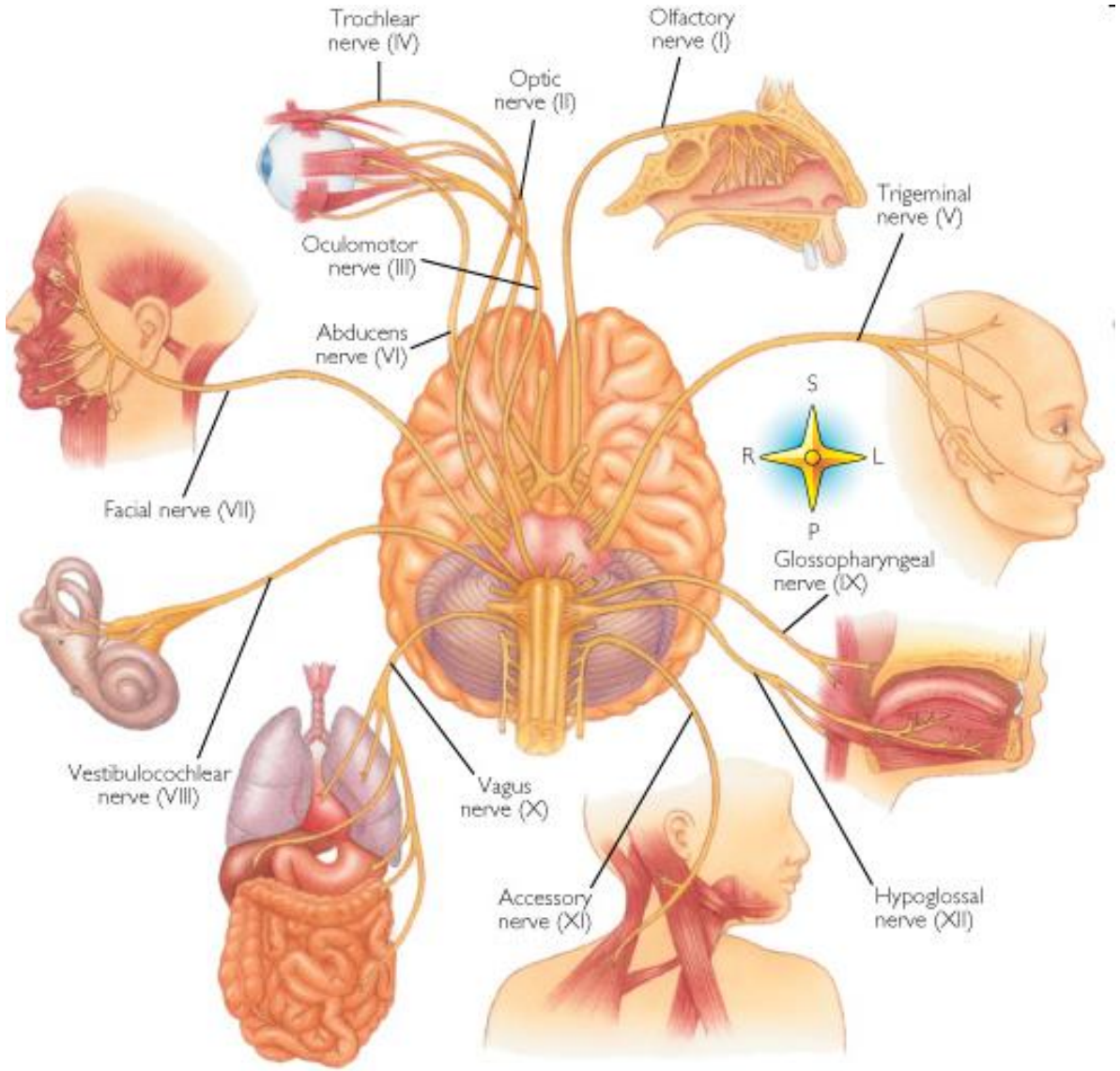
-- the nucleus solitarius (CNs VII, IX, and X)

- The superior colliculus and the lateral geniculate body receive secondary sensory axonal projections from the optic tract;
- The inferior colliculus receives input from the cochlear nuclei and other accessory auditory

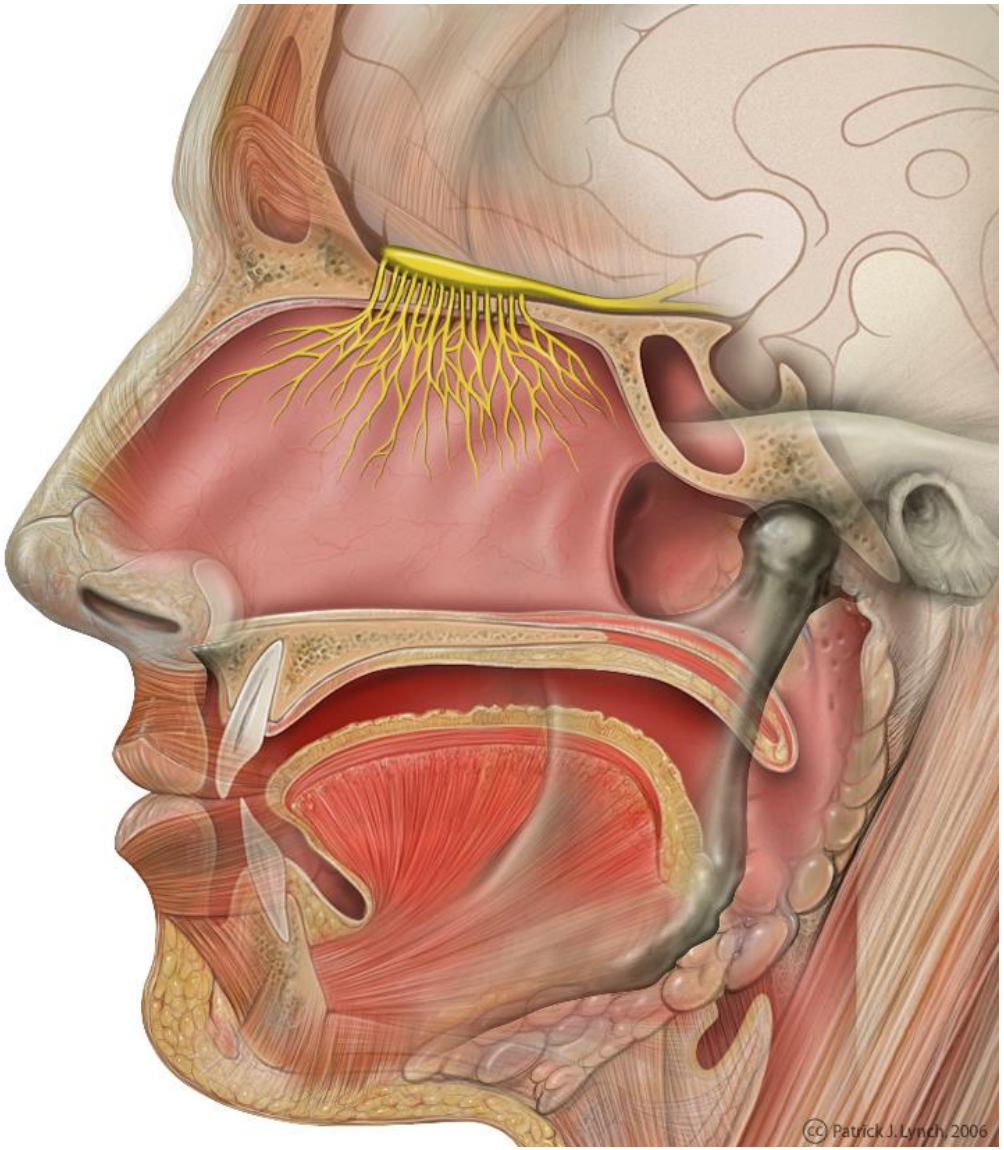
Cranial nerves: schematic distribution



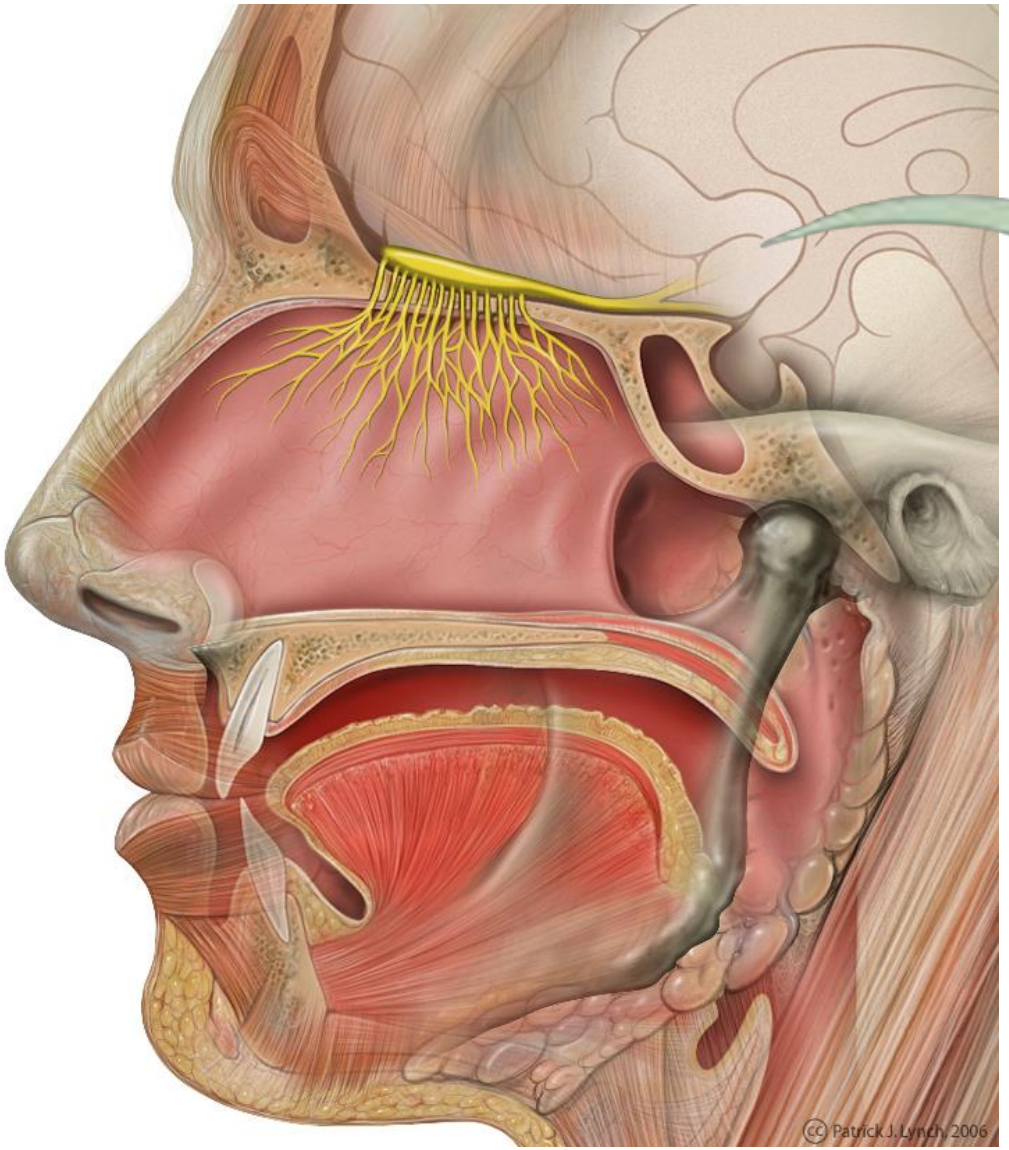
Cranial nerves

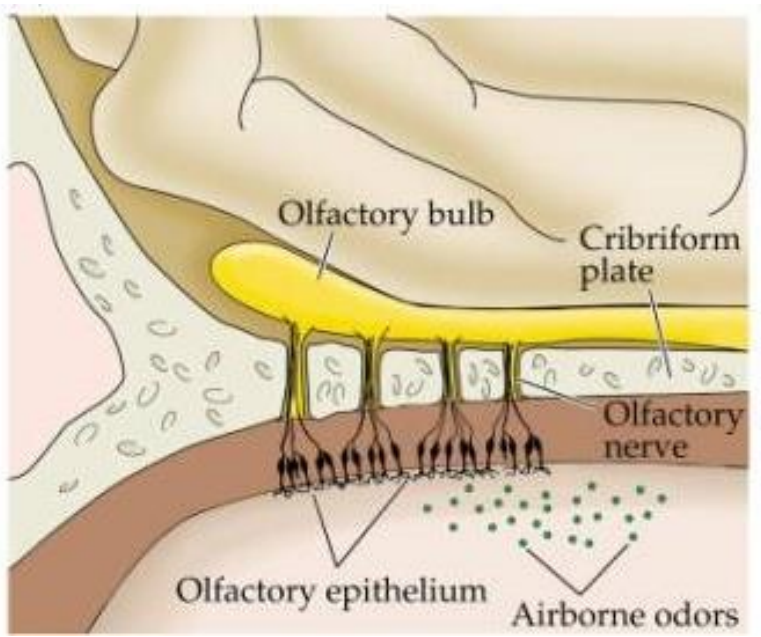


Olfactory nerve (I)



Olfactory nerve (I)





Olfactory epithelium -> Olfactory nerve -> Olfactory bulb -> Olfactory tract->
Olfactory cortex, parahippocampal gyrus; cingulate gyrus; olfactory trigone

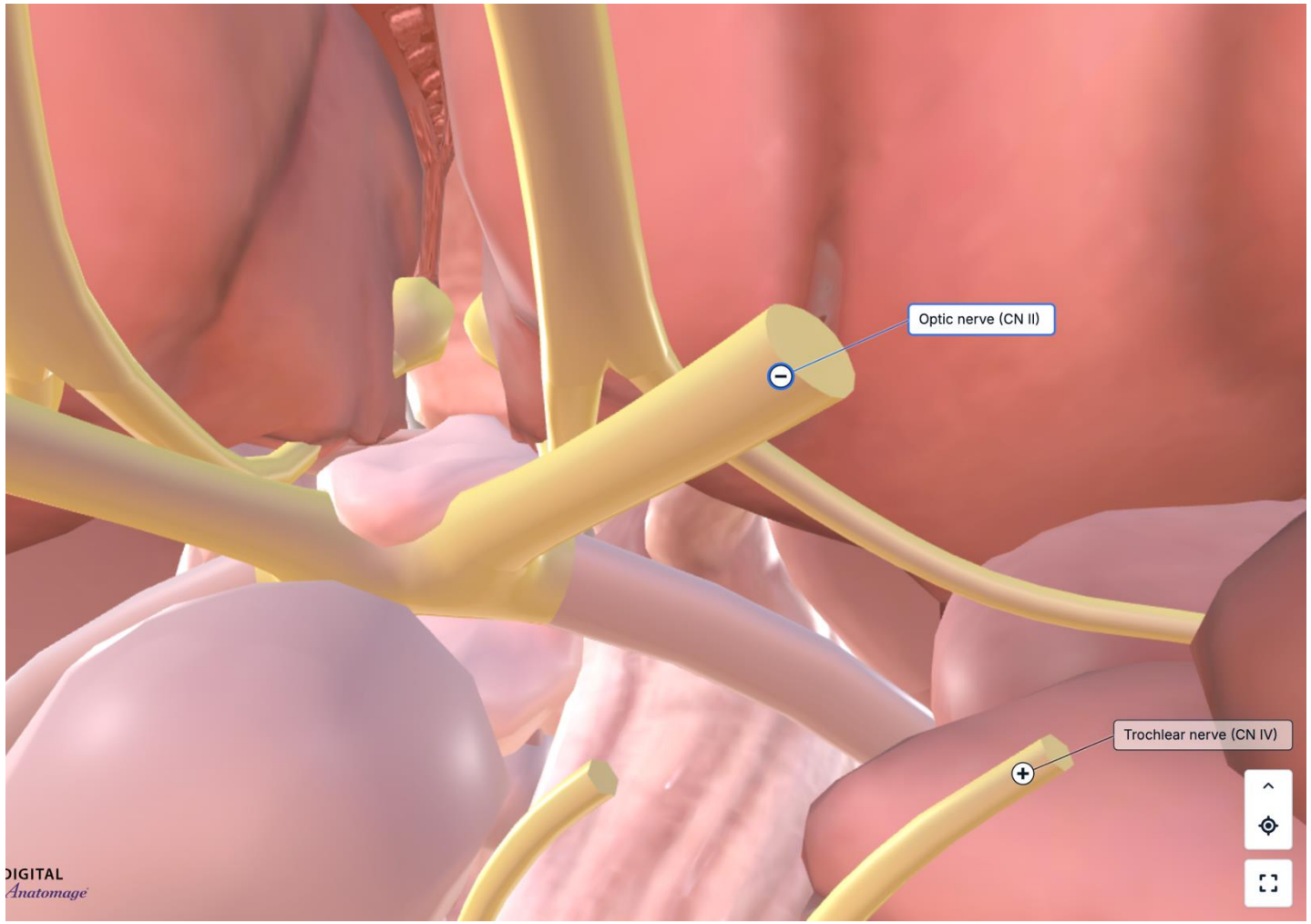
Olfactory nerve (I) disorders

Olfactory disorders are classified into:

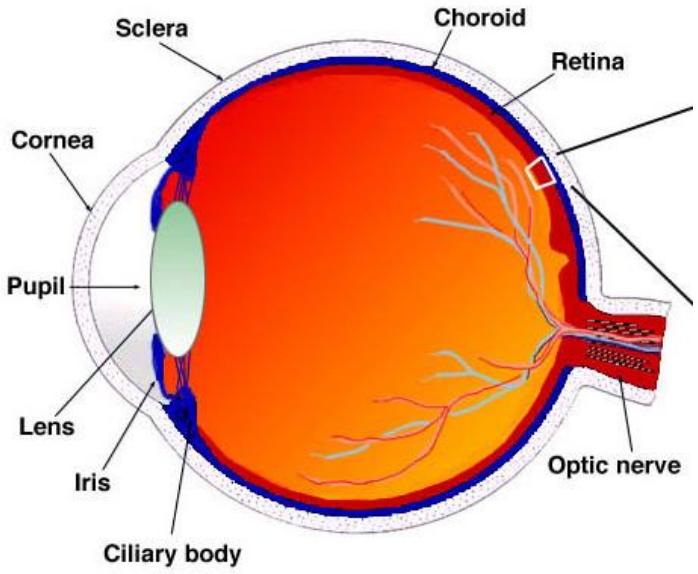
QUALITATIVE:
•Parosmia: distortion of olfactory perception.
•Cacosmia: perception of unpleasant odors.

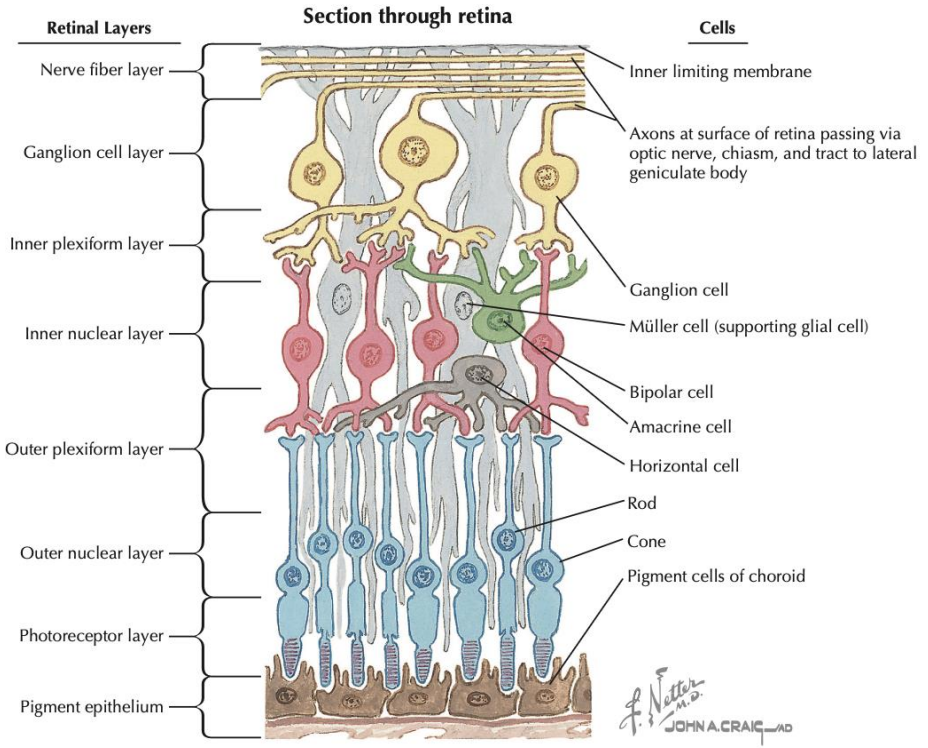
QUANTITATIVE:
•Hyposmia / Anosmia: reduced or absent perception of odors.
•Hyperosmia: increased perception of odors.

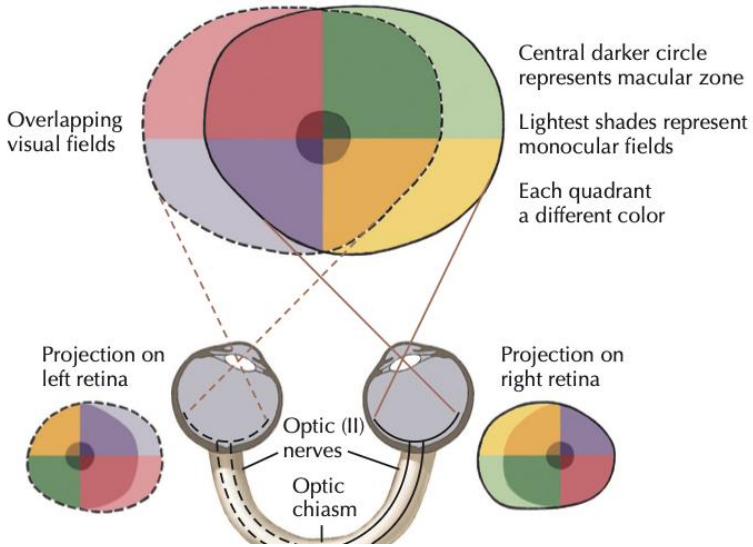
Optic nerve (II)



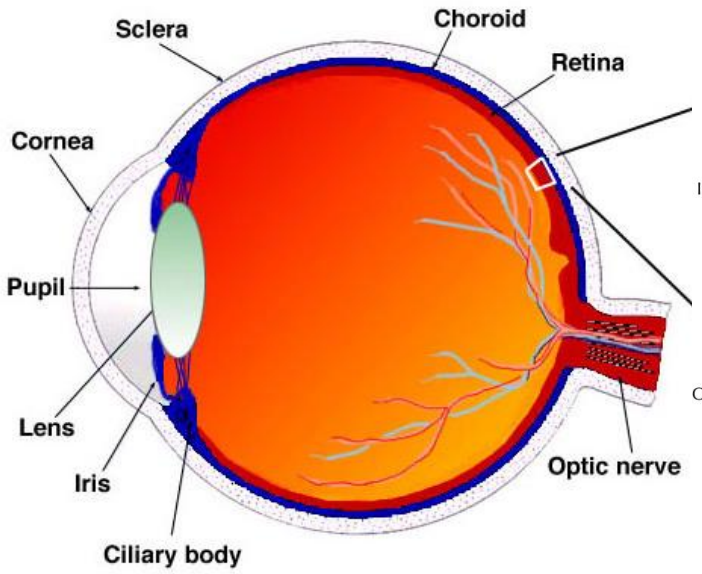
Optic nerve (II)

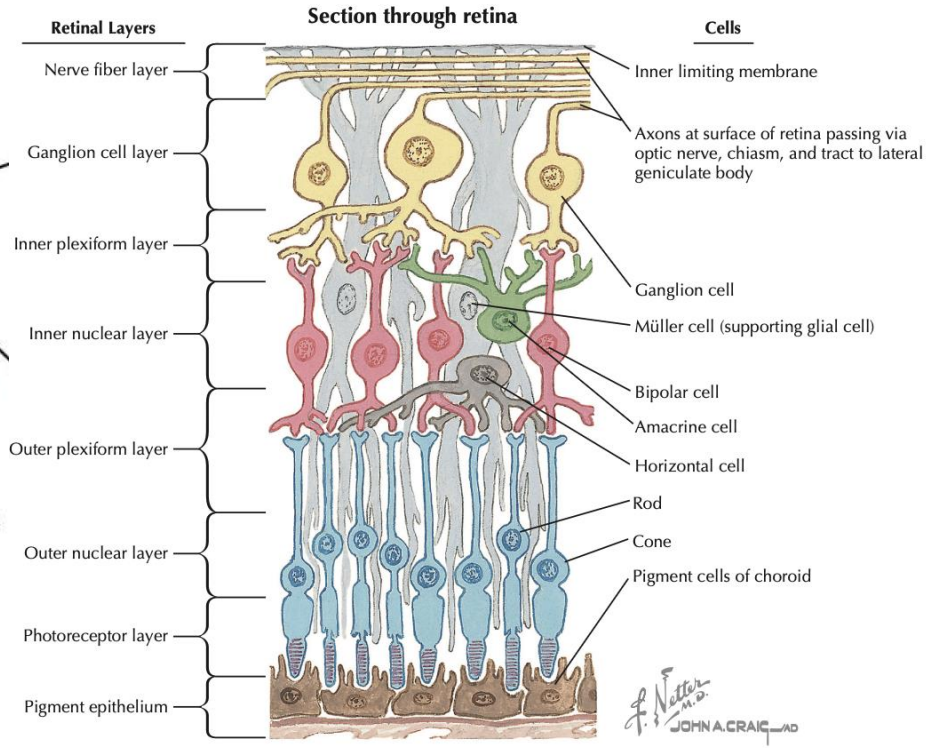


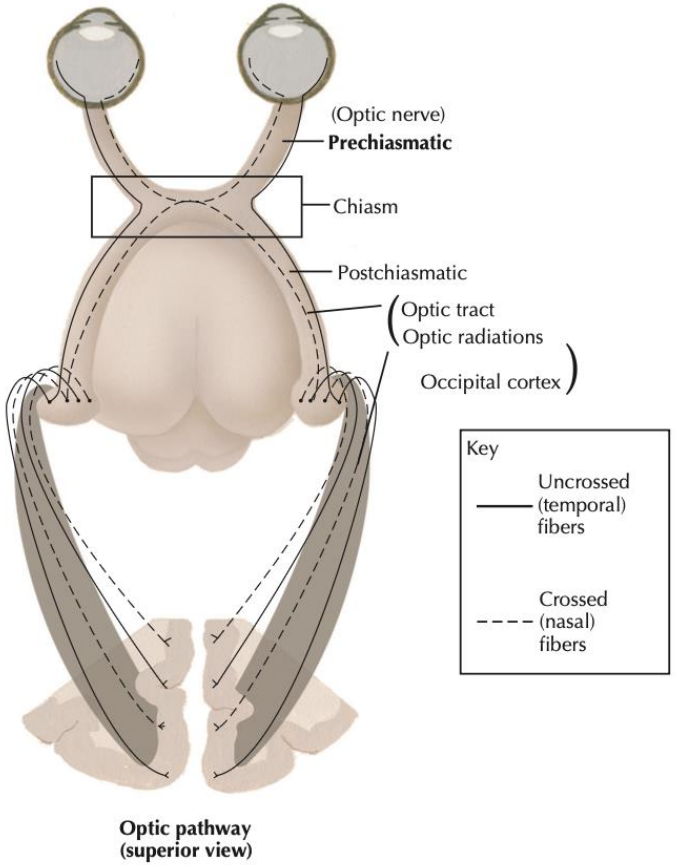




Optic nerve (II)

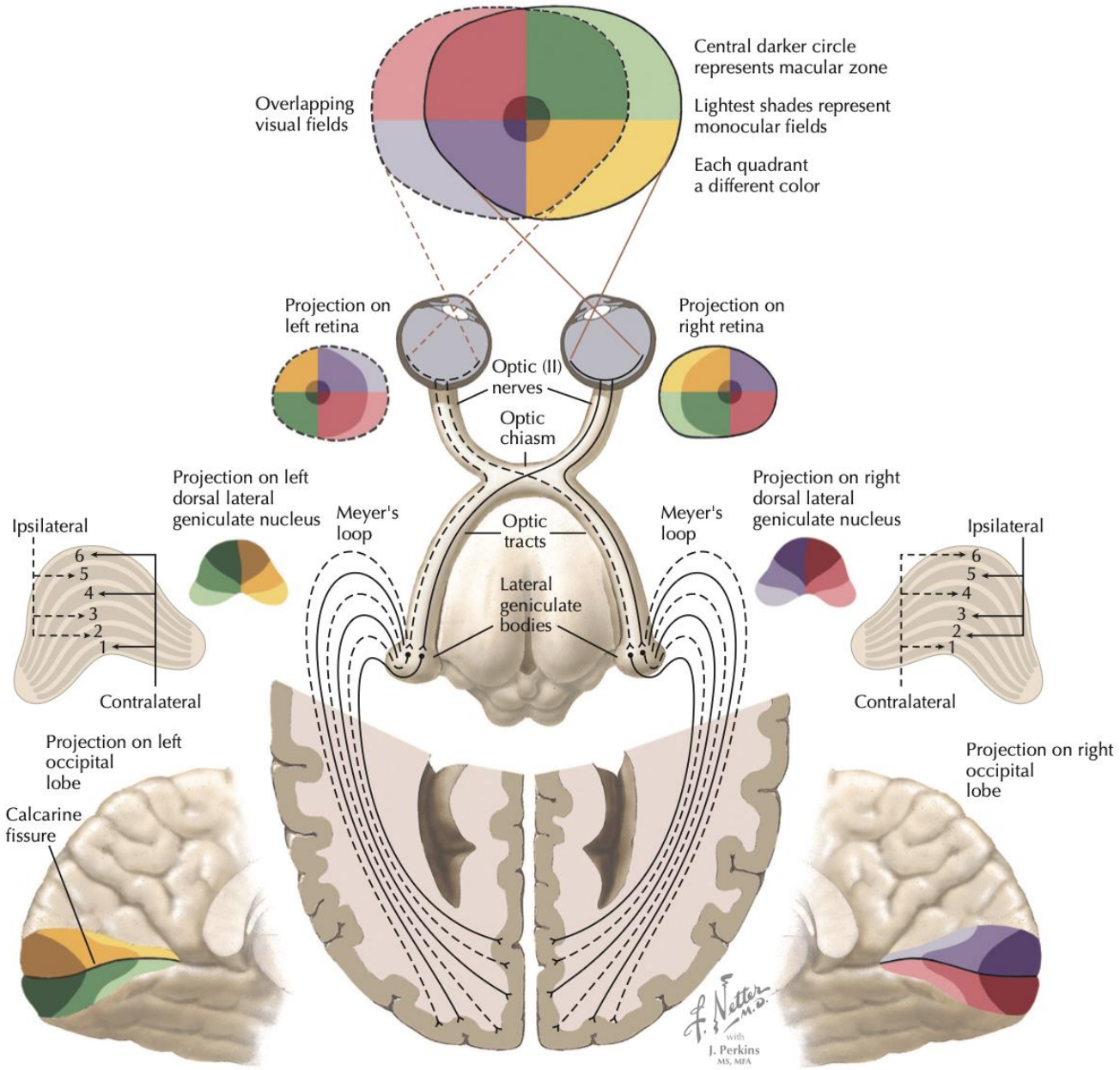




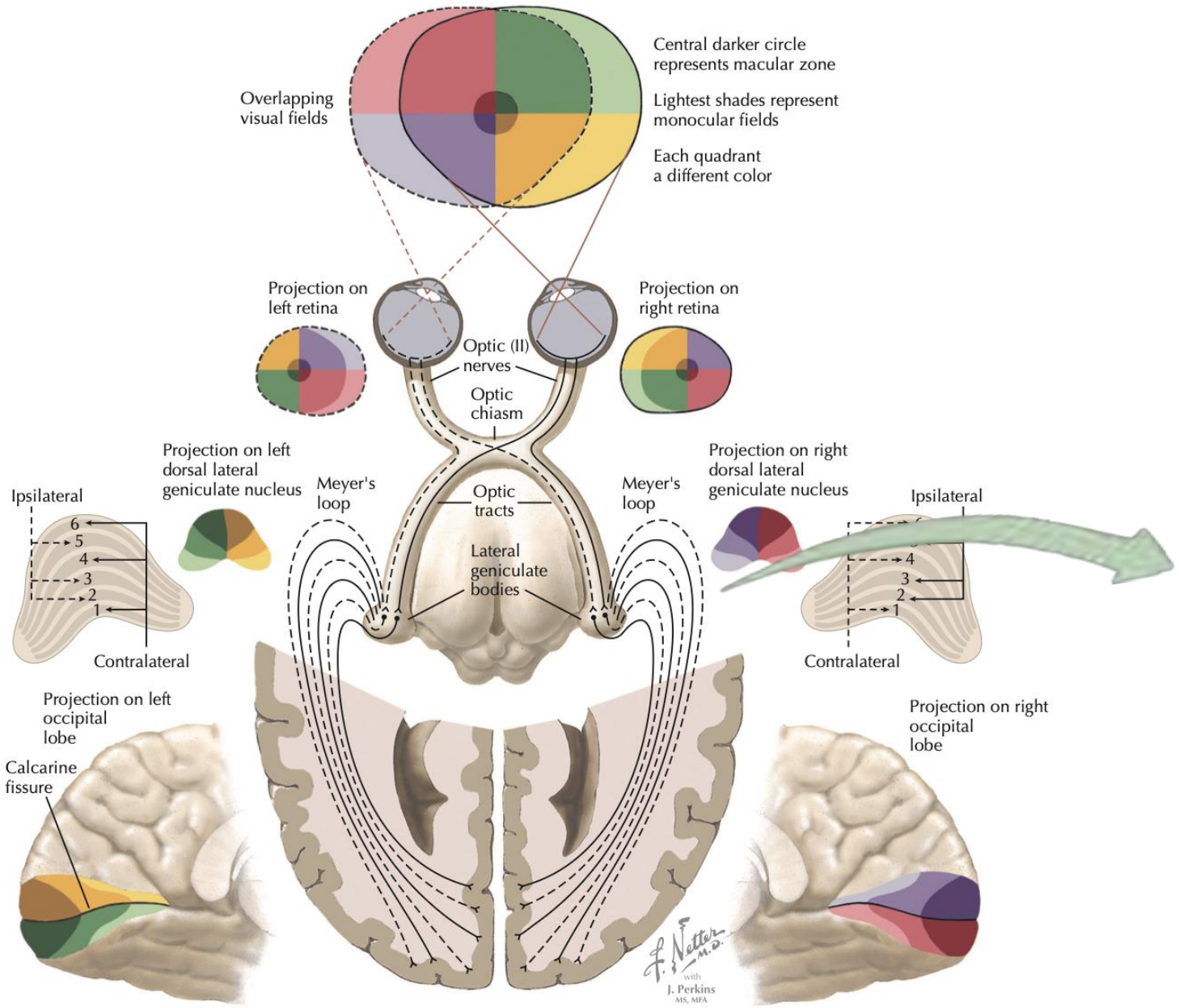


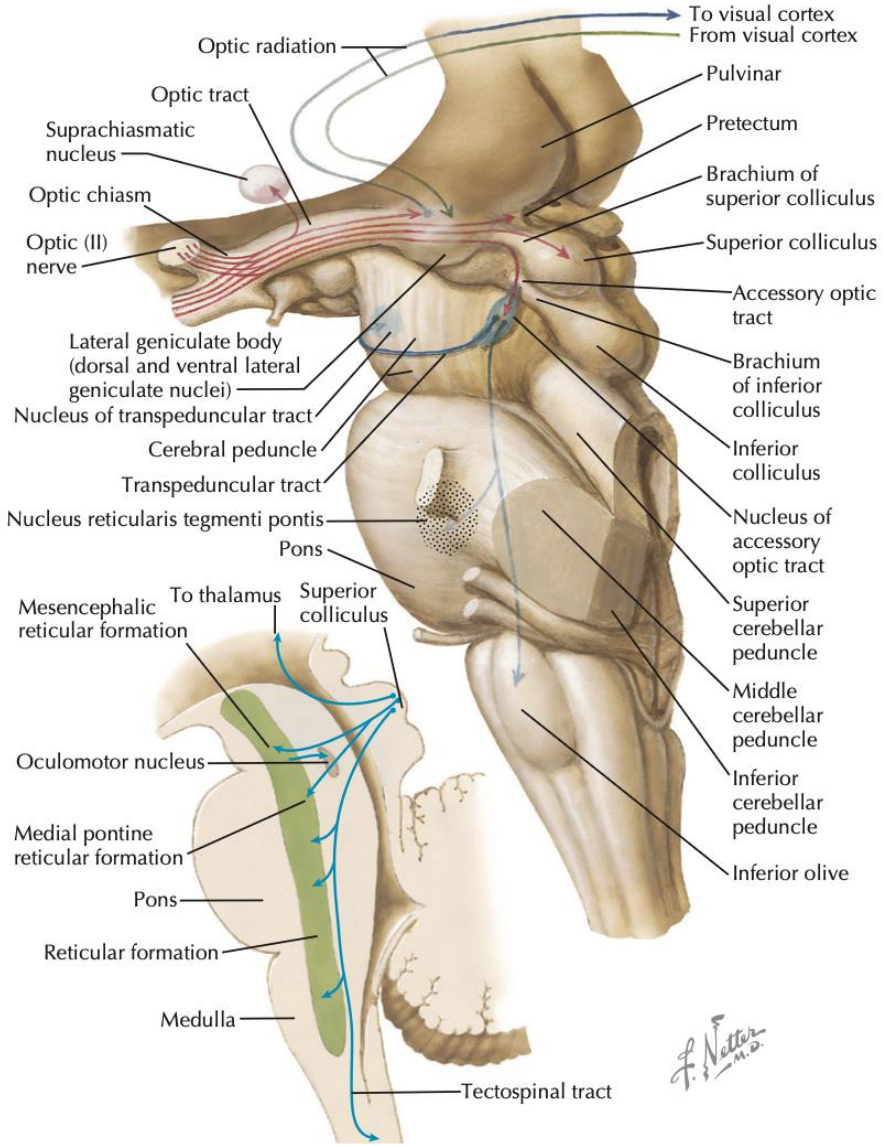
Optic pathway (superior view)

Visual pathway

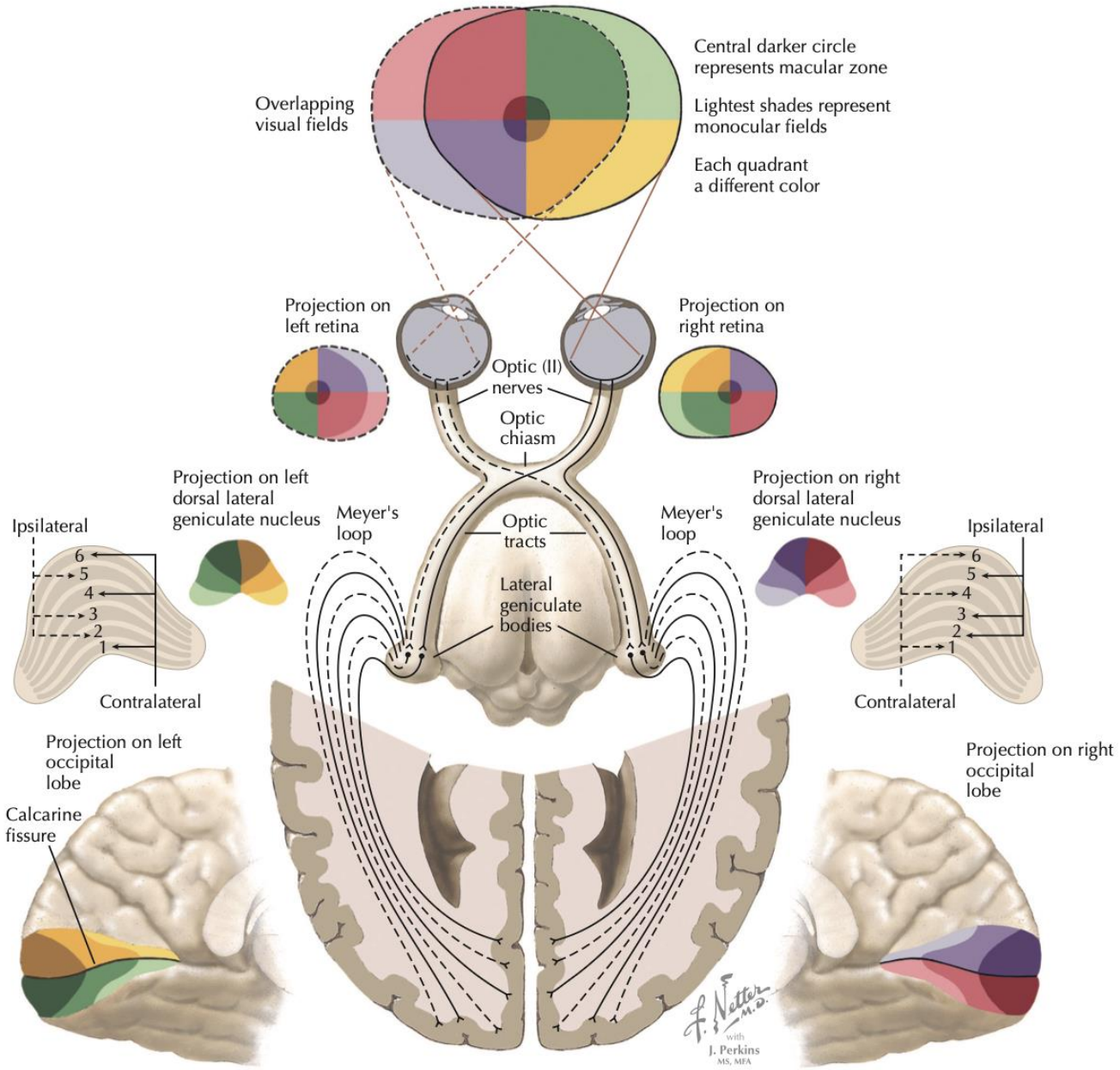


Visual pathway

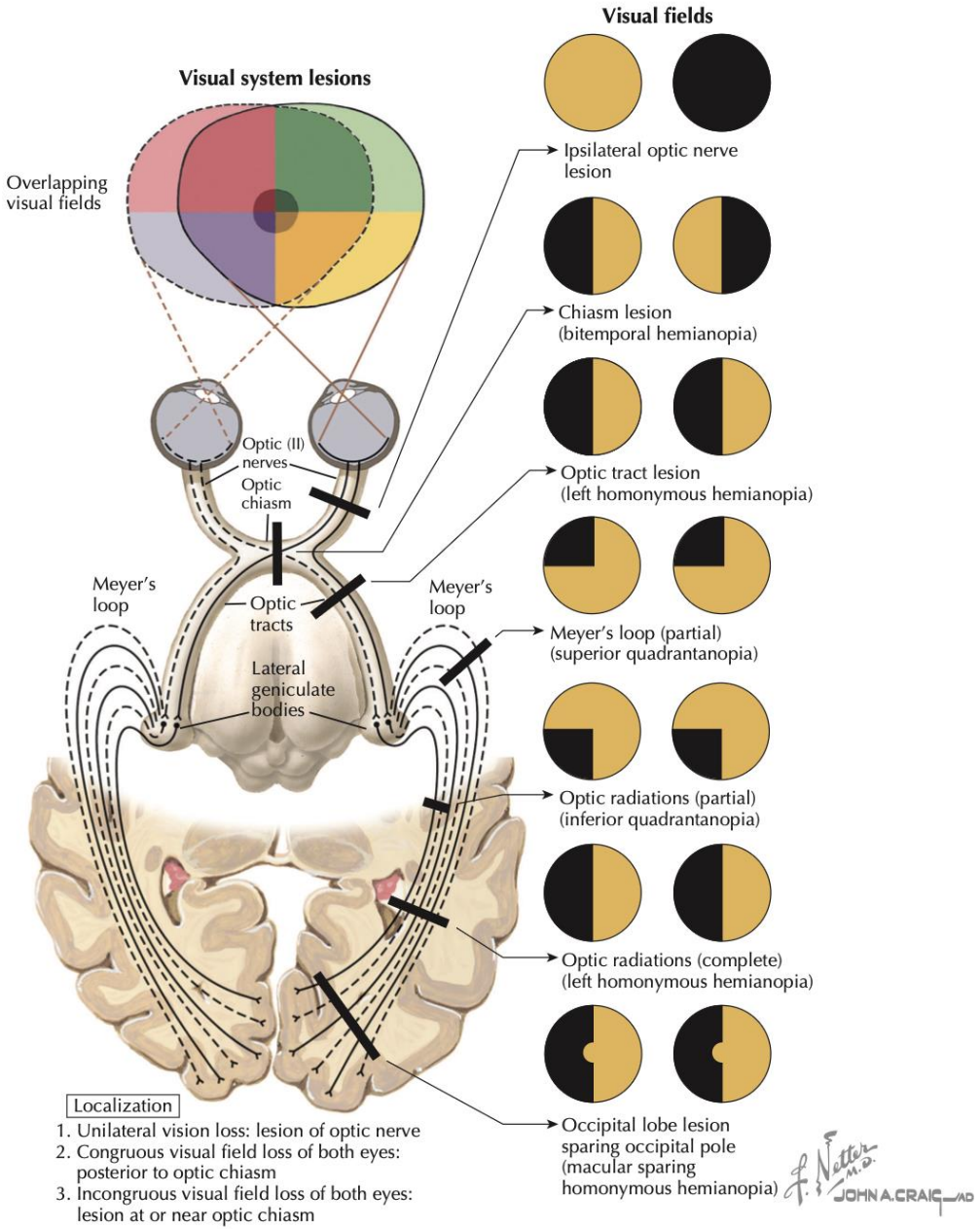




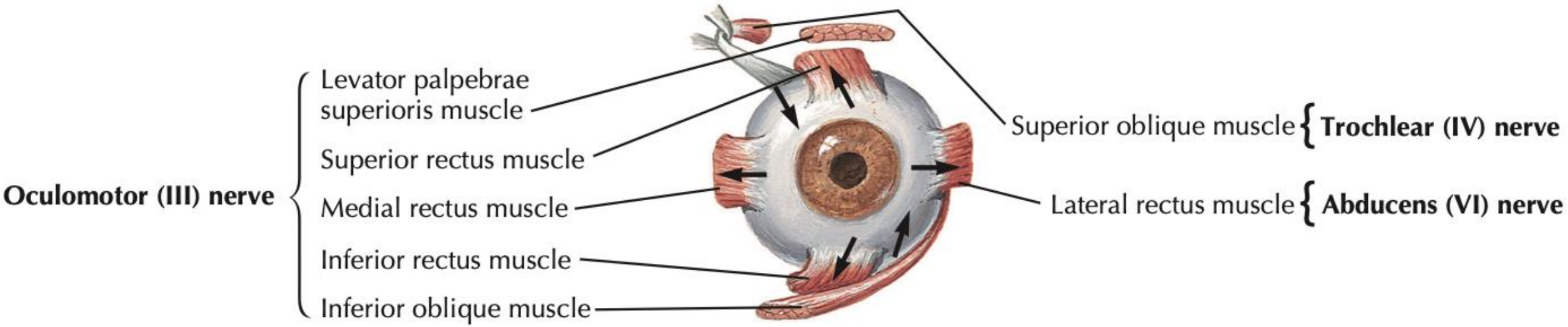
Visual pathway



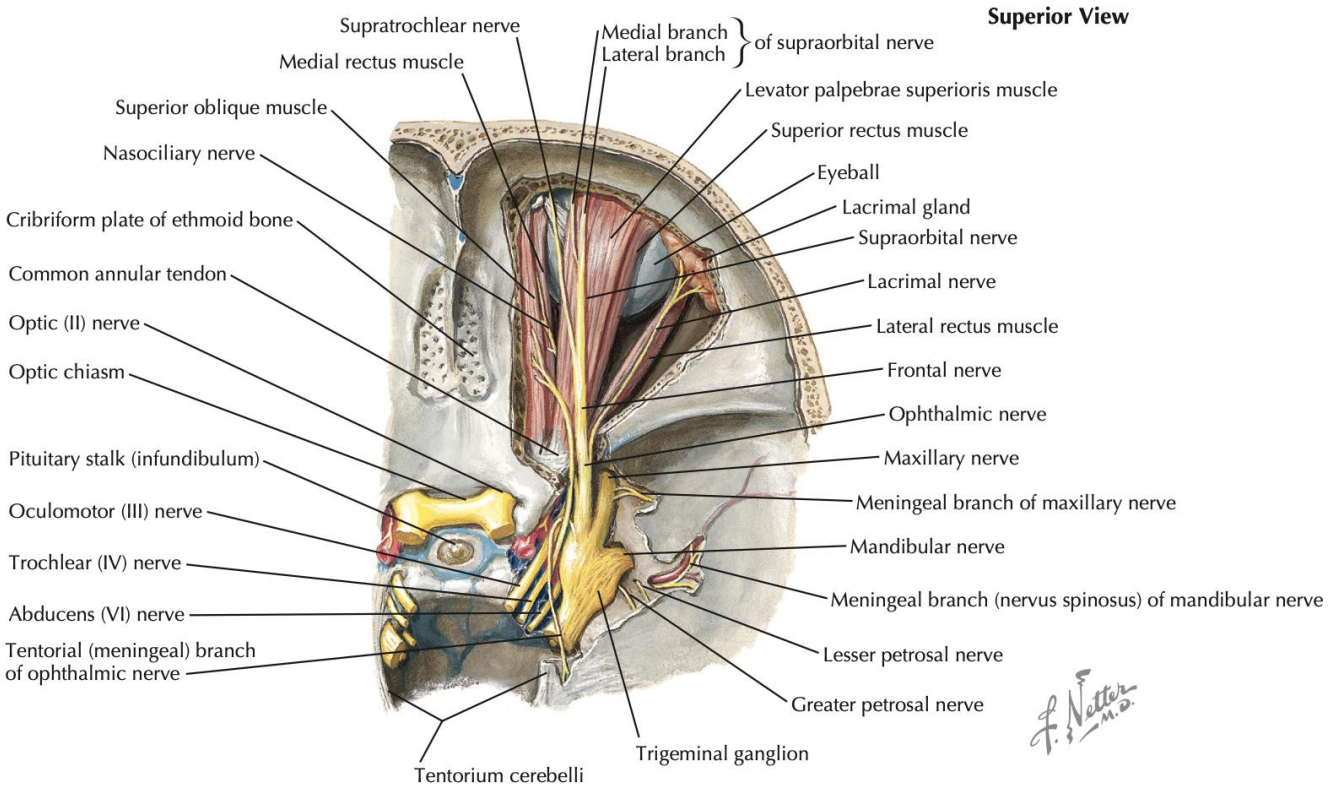
Visual system lesions

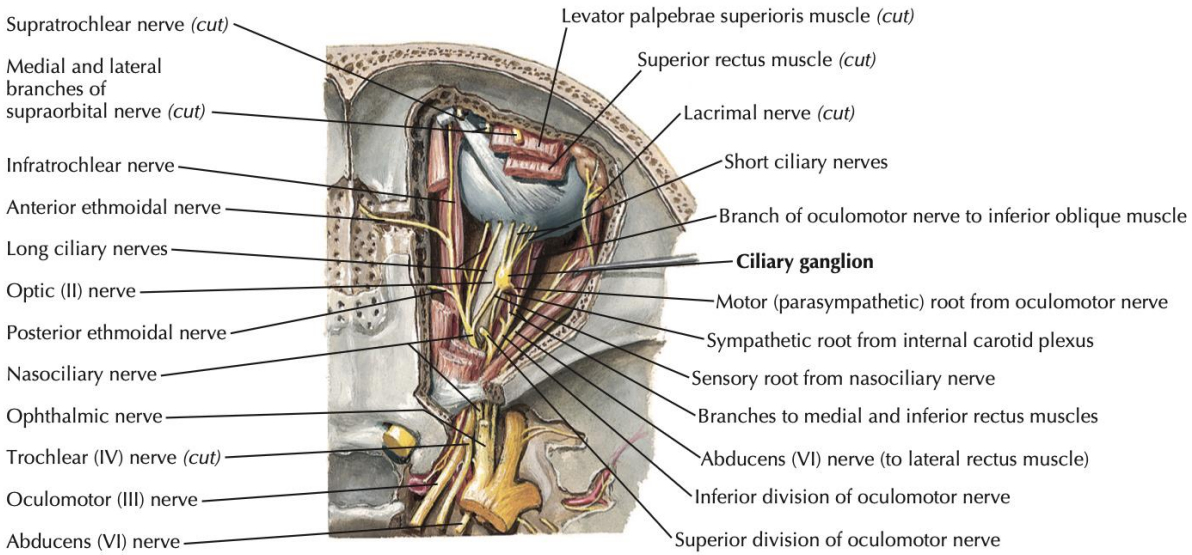


Extraocular Nerves (III, IV, and VI)

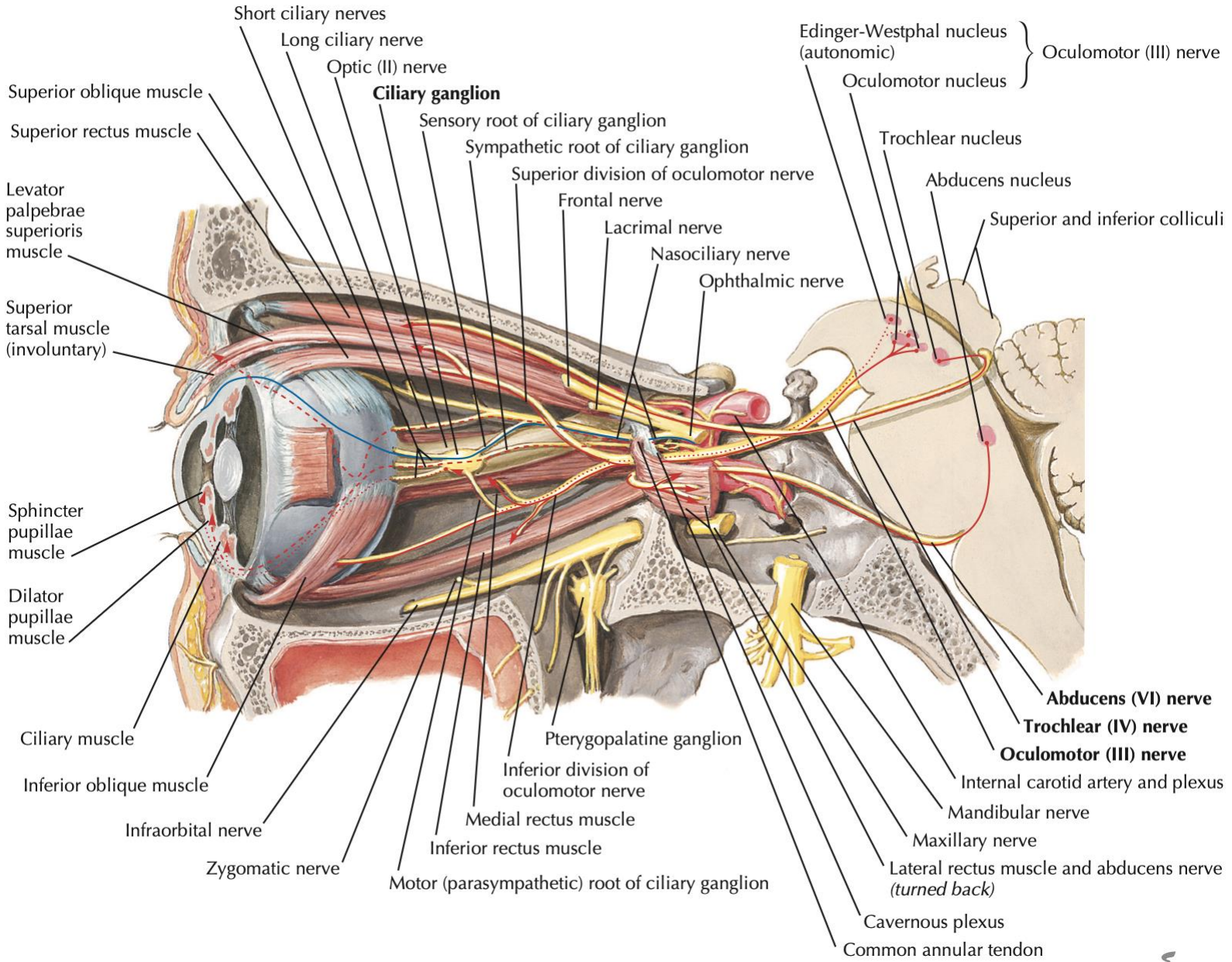


Extraocular Nerves (III, IV, and VI)

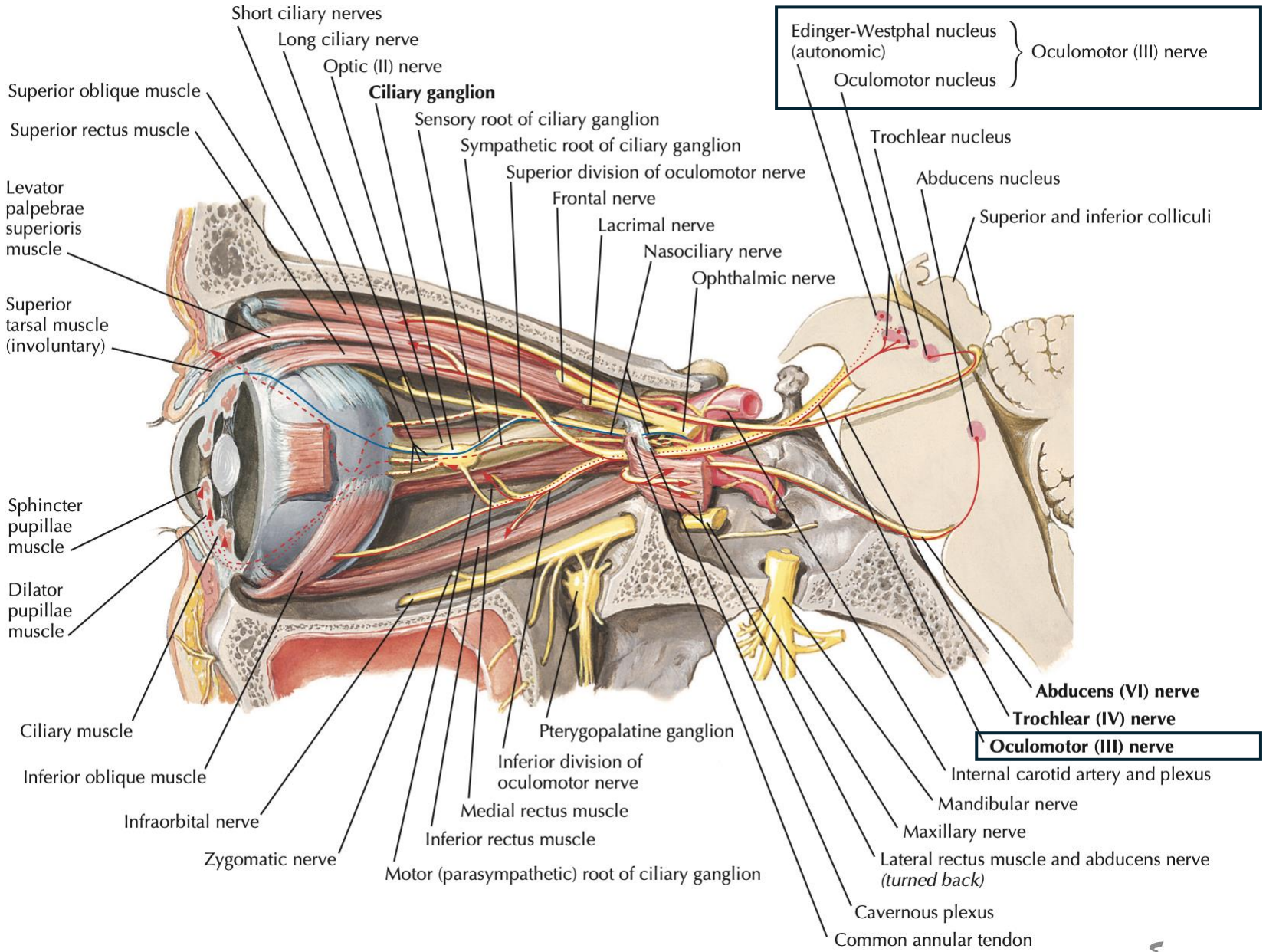




Extraocular Nerves (III, IV, and VI)



Oculomotor nerve (III)



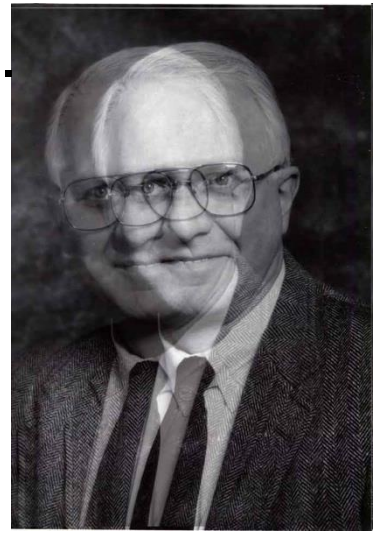
Oculomotor nerve (III) disorders

A. External strabismus (exotropia)
B. Mydriasis
C. Eyelid ptosis
D. Limitation of upward gaze, elevation, depression, and adduction of the eye (diplopia)
E. Pupillary paralysis

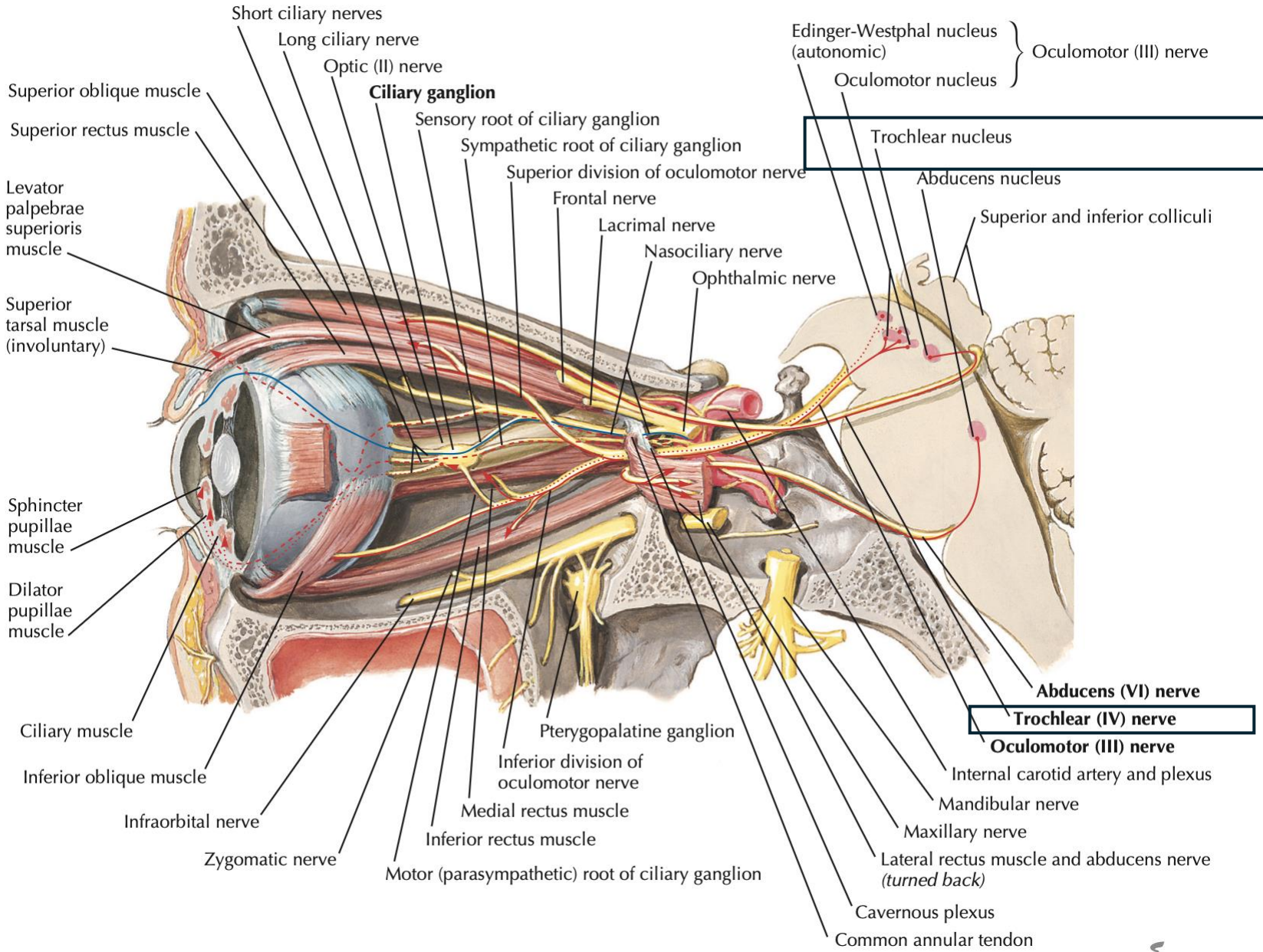
A. 

B. 

C. 

D. 

Trochlear nerve (IV)



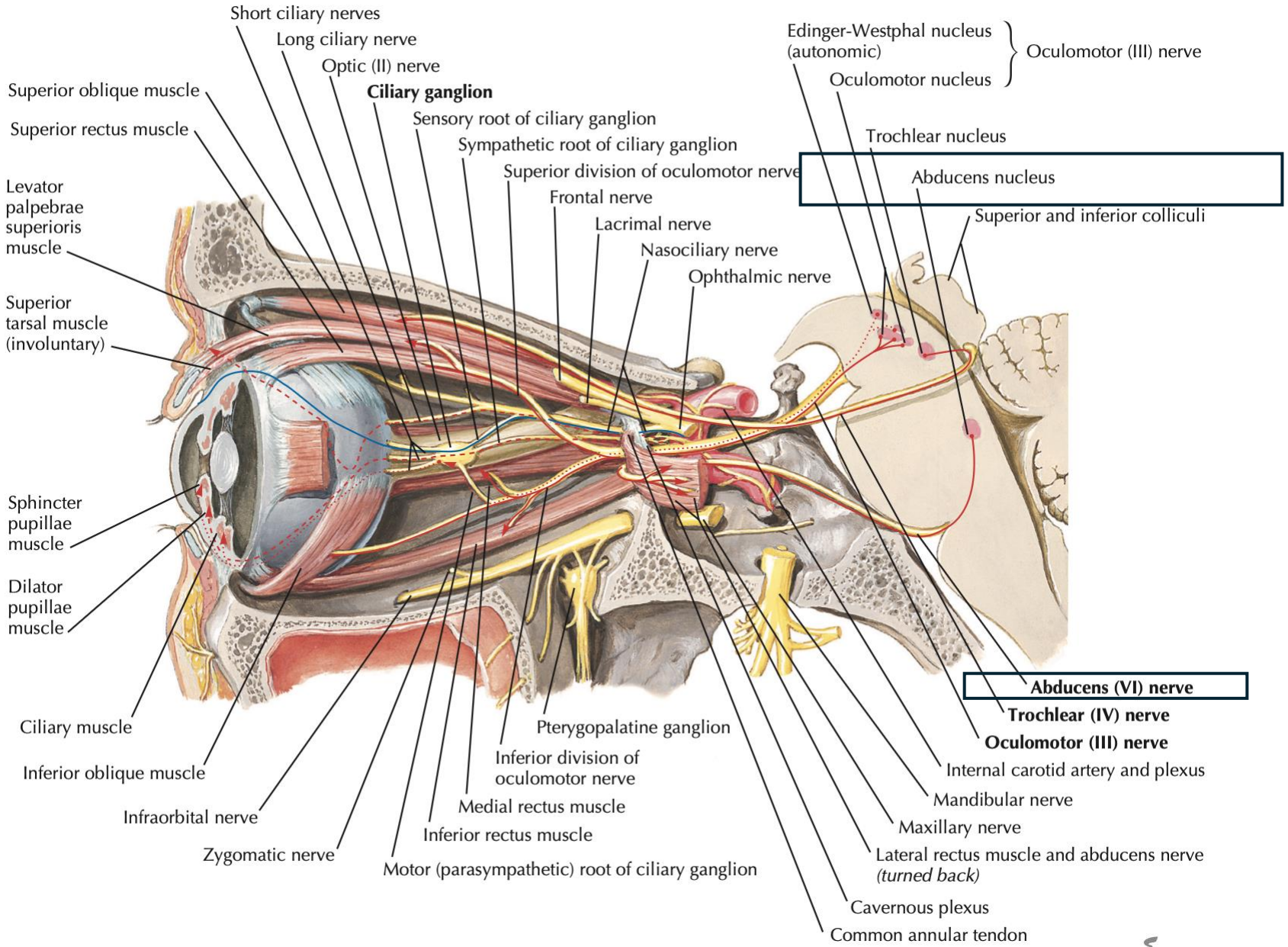
Trochlear nerve (IV) disorder

A. Vertical diplopia

A.



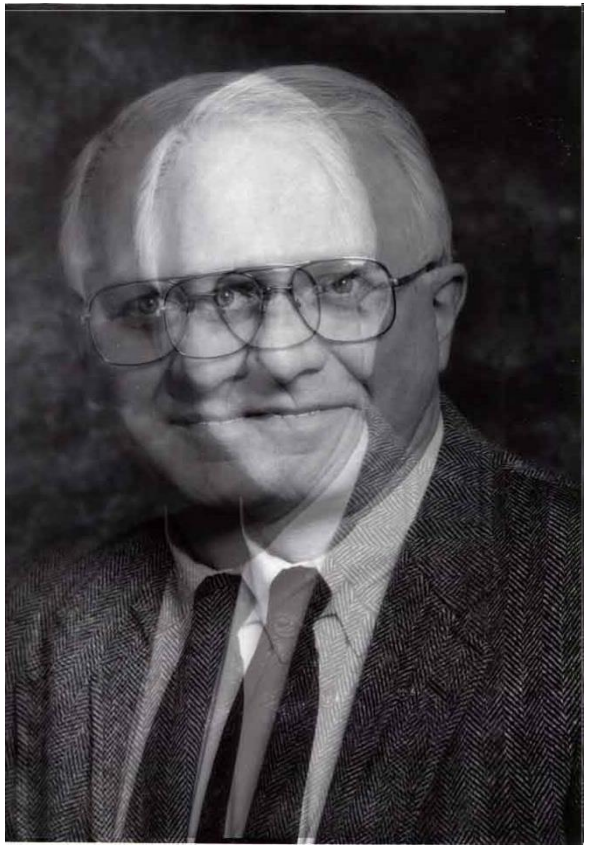
Abducens nerve (VI)



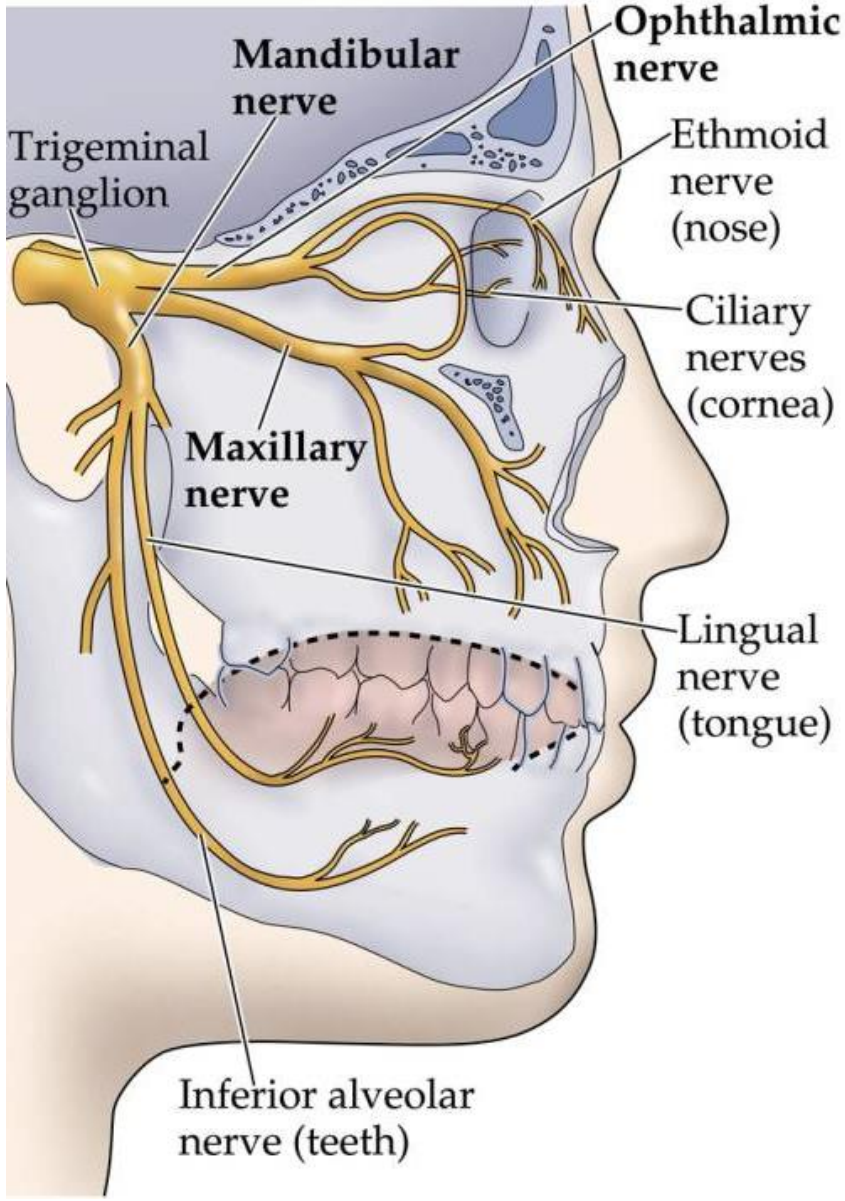
Abducens nerve (VI) disorder

A. Limitation of abduction of the eye (horizontal diplopia)

A.

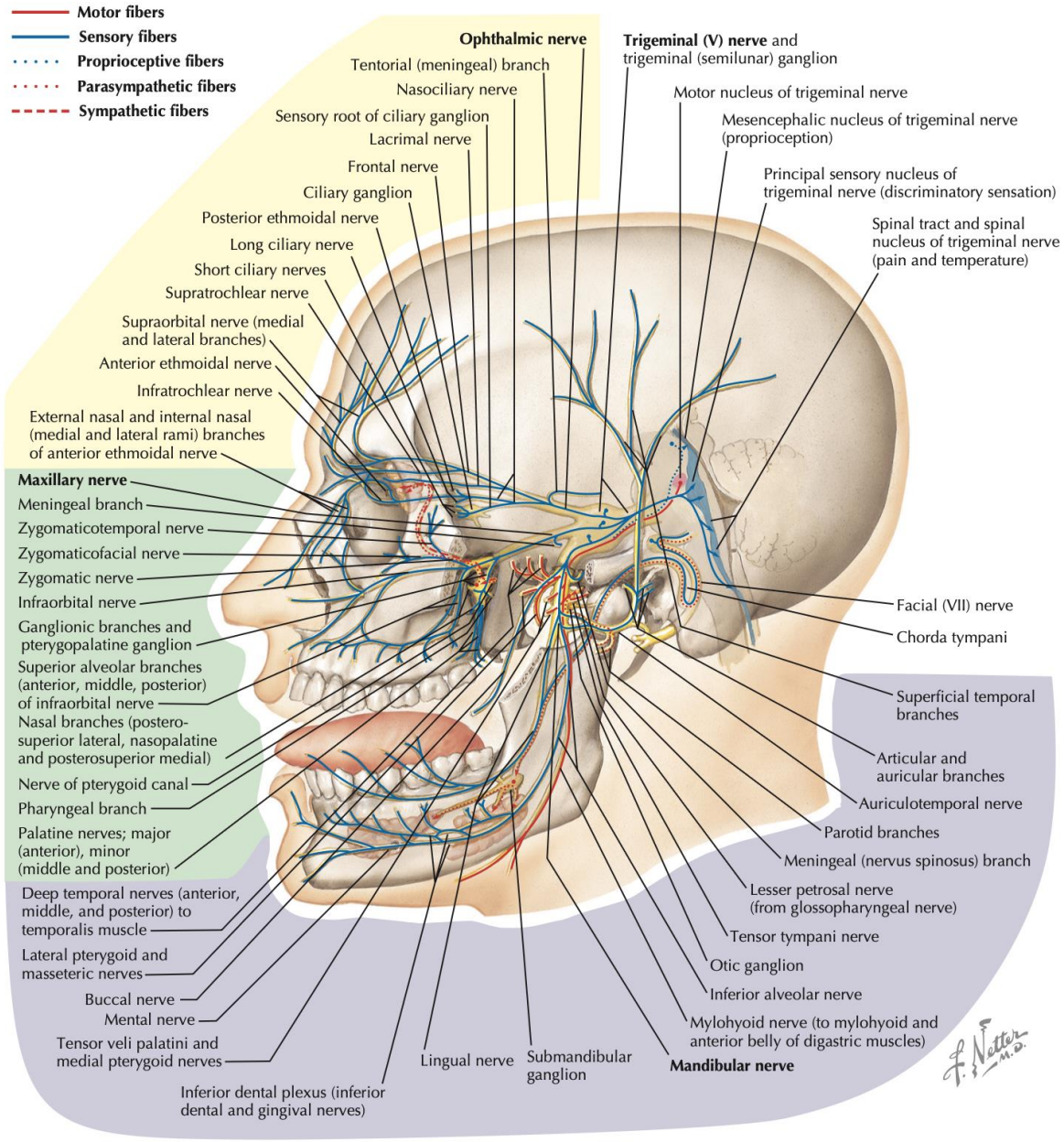


Trigeminal nerve (V)



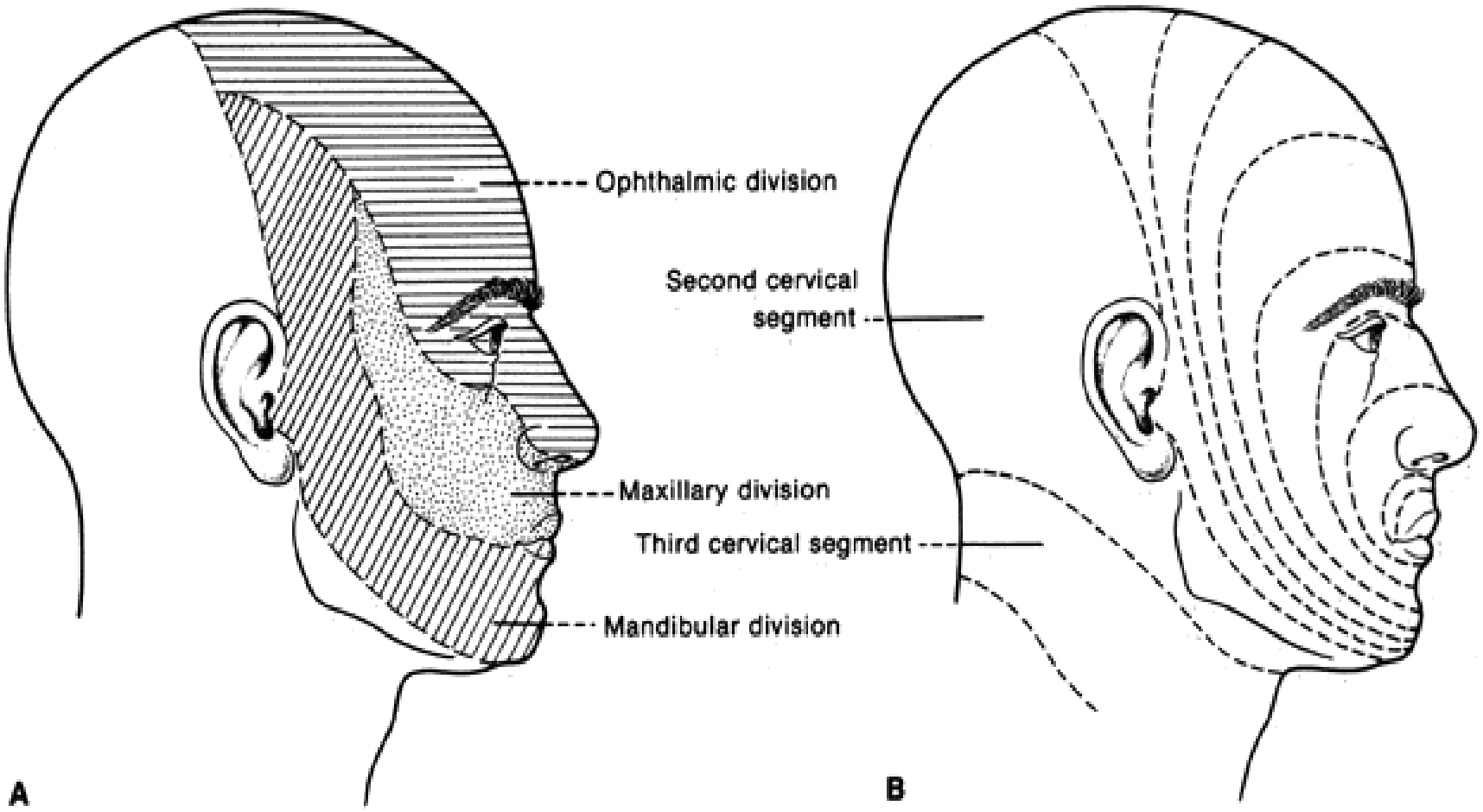
Mixed nerve:
- Motor component (masticatory muscles)
- Sensory component (facial skin, conjunctiva, buccal and nasal mucosa)

Trigeminal nerve (V)



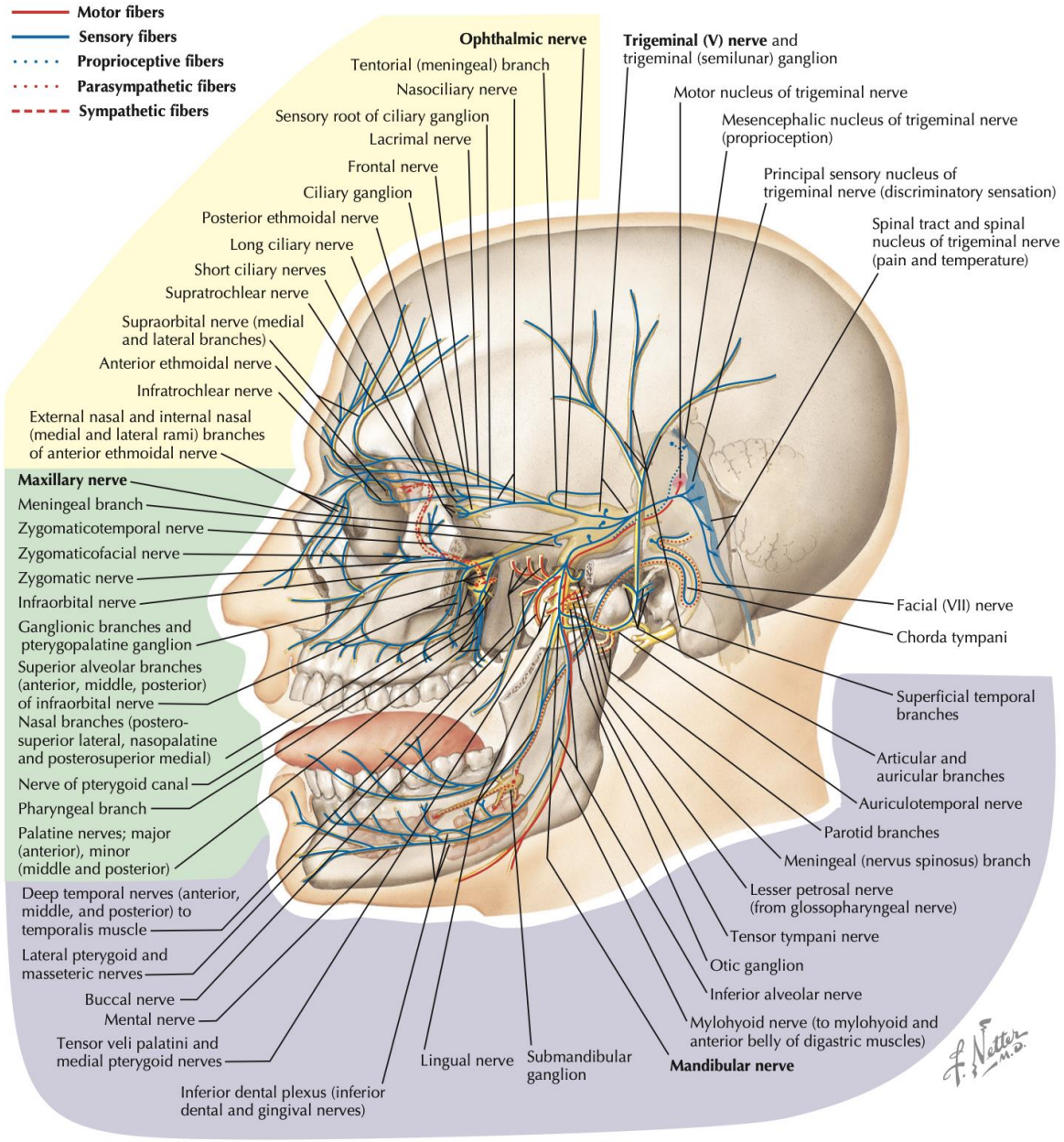
- V1: ophthalmic—sensory innervation;
- V2: maxillary—sensory innervation;
- V3: mandibular—sensory innervation and motor innervation of the masticatory muscles and tensor tympani muscles.

Trigeminal nerve (V)



A. Peripheral distribution
B. Central distribution

Trigeminal nerve (V)



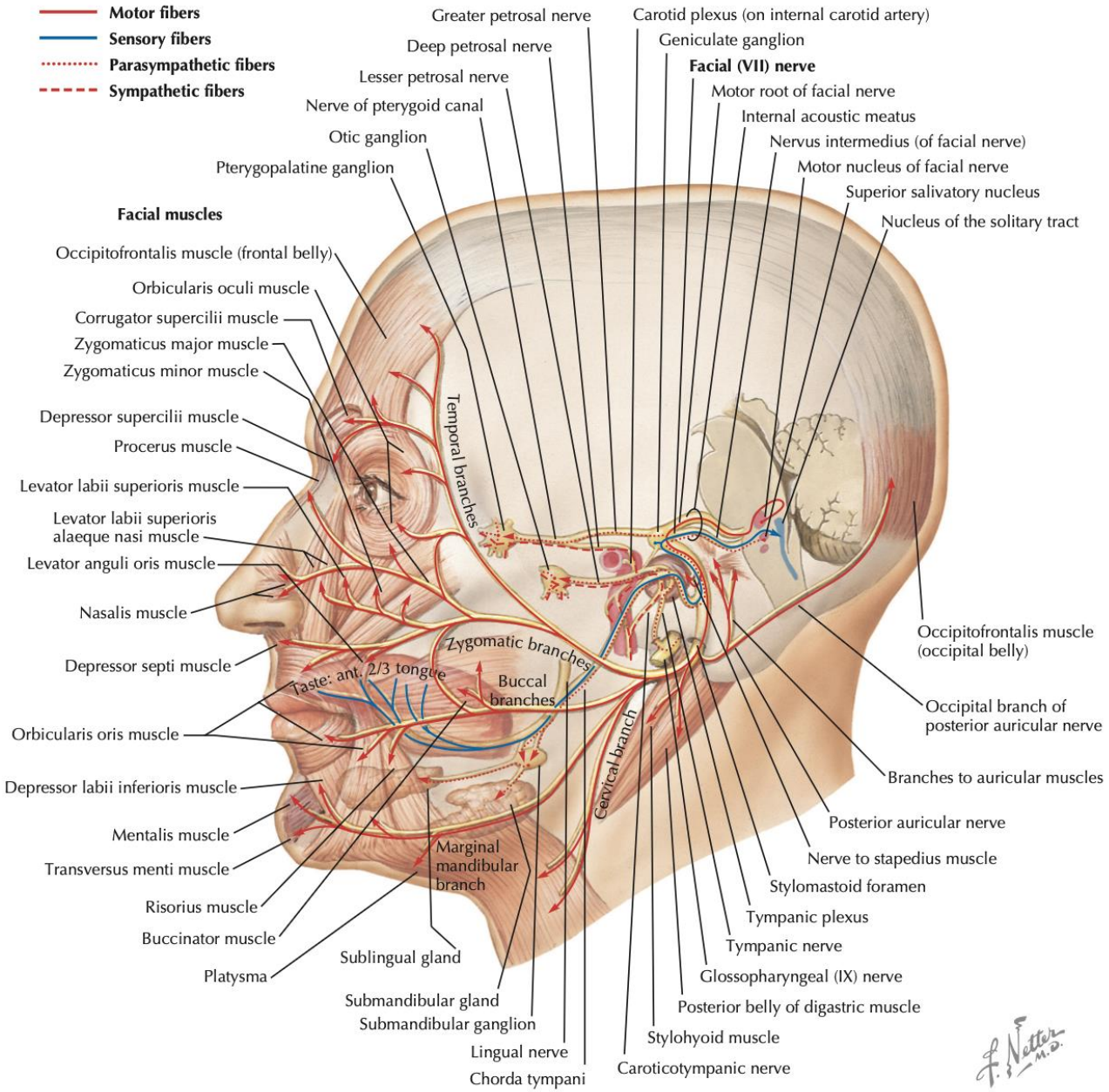
- V1: ophthalmic—sensory innervation;
- V2: maxillary—sensory innervation;
- V3: mandibular—sensory innervation and motor innervation of the masticatory muscles and tensor tympani muscles.

Trigeminal nerve (V) disorder

Trigeminal disorders are classified into:

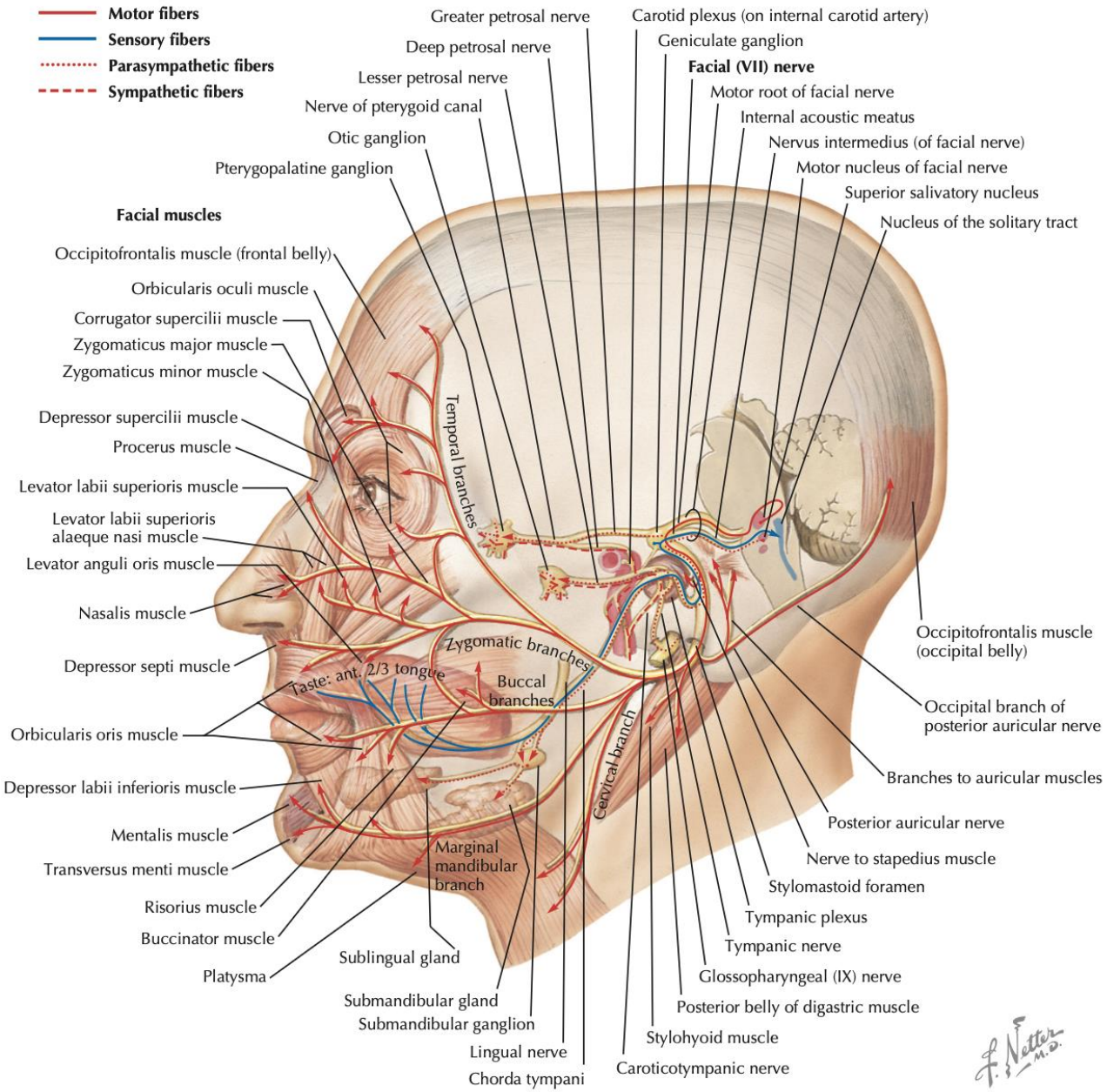
- Hypofunction:
loss of facial sensation or weakness in chewing
- Hyperfunction:
severe facial pain (i.e. trigeminal neuralgia)

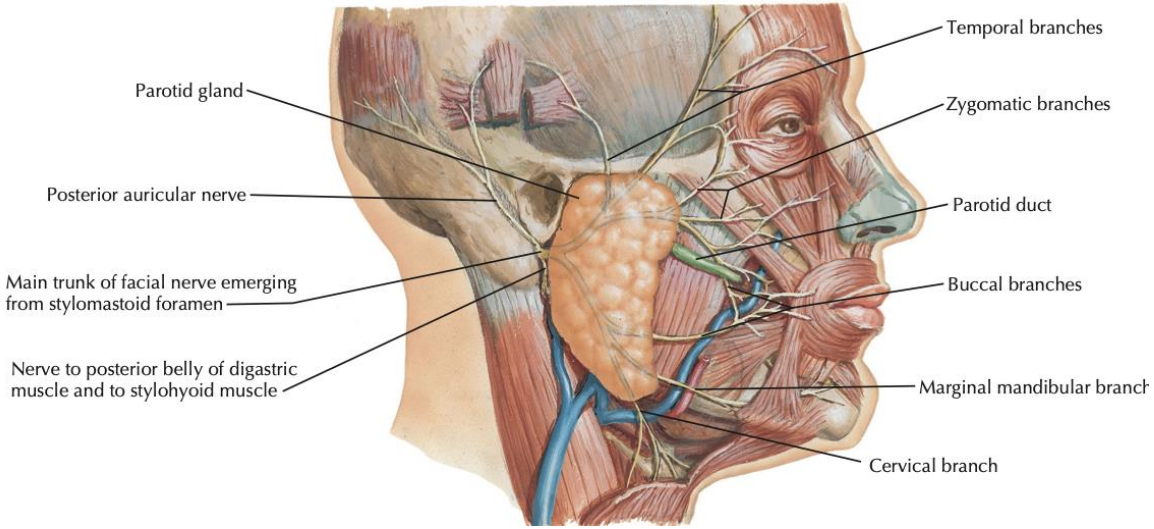
Facial nerve (VII)



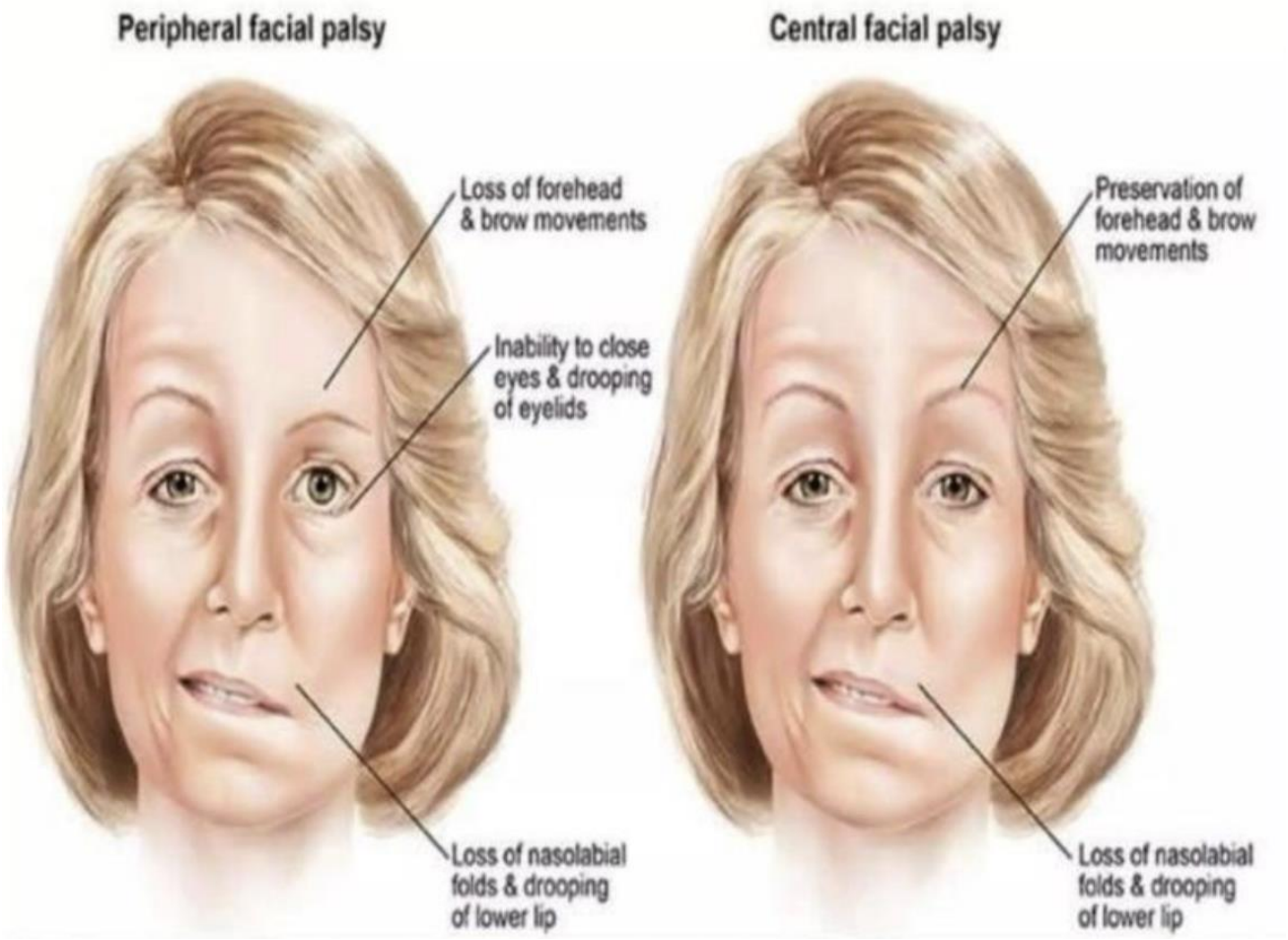
- Motor component, for facial expression
- Sensory component, for taste from anterior two-thirds of the tongue
- Parasympathetic component, for lacrimal and salivary glands

Facial nerve (VII)

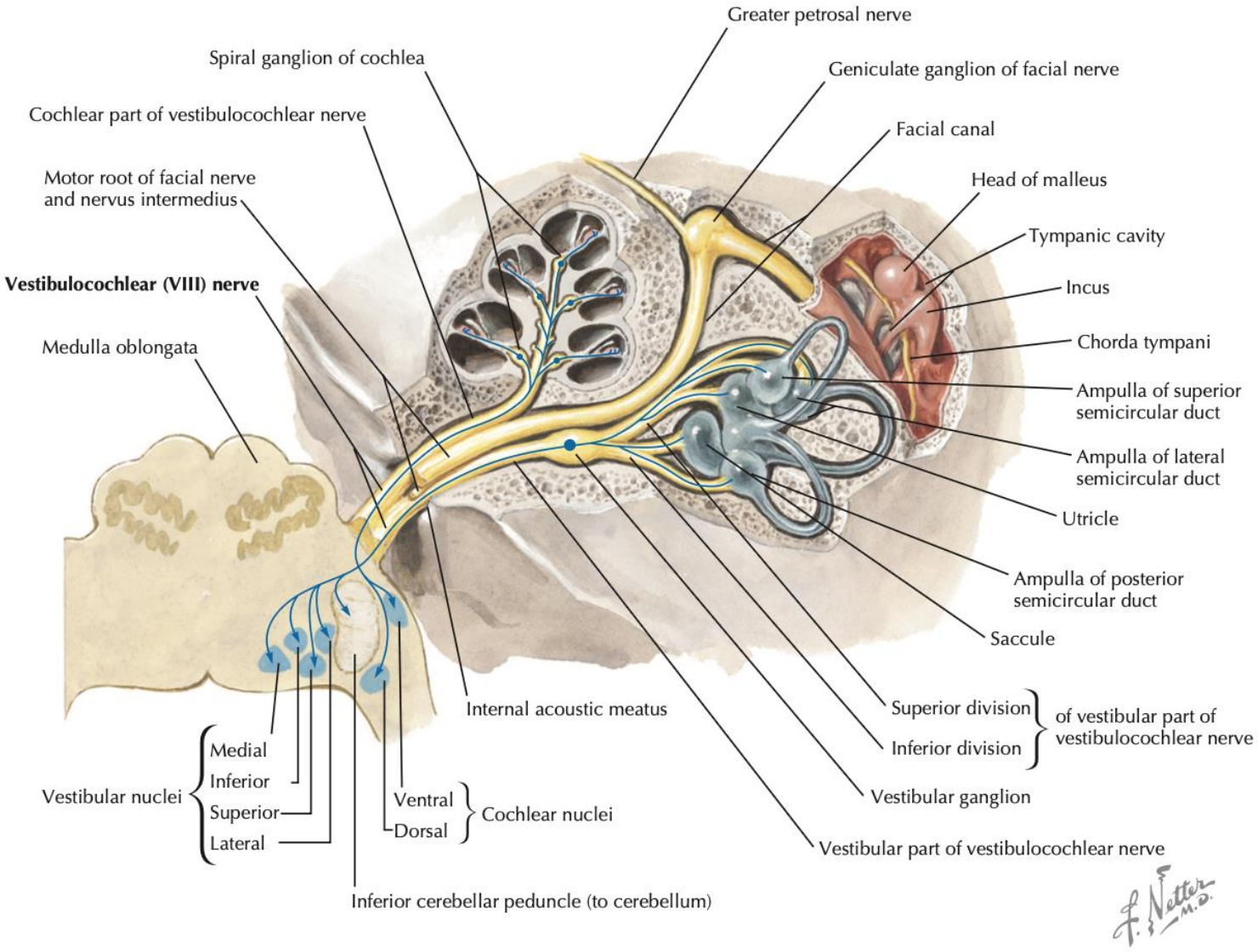




Facial nerve (VII) disorders



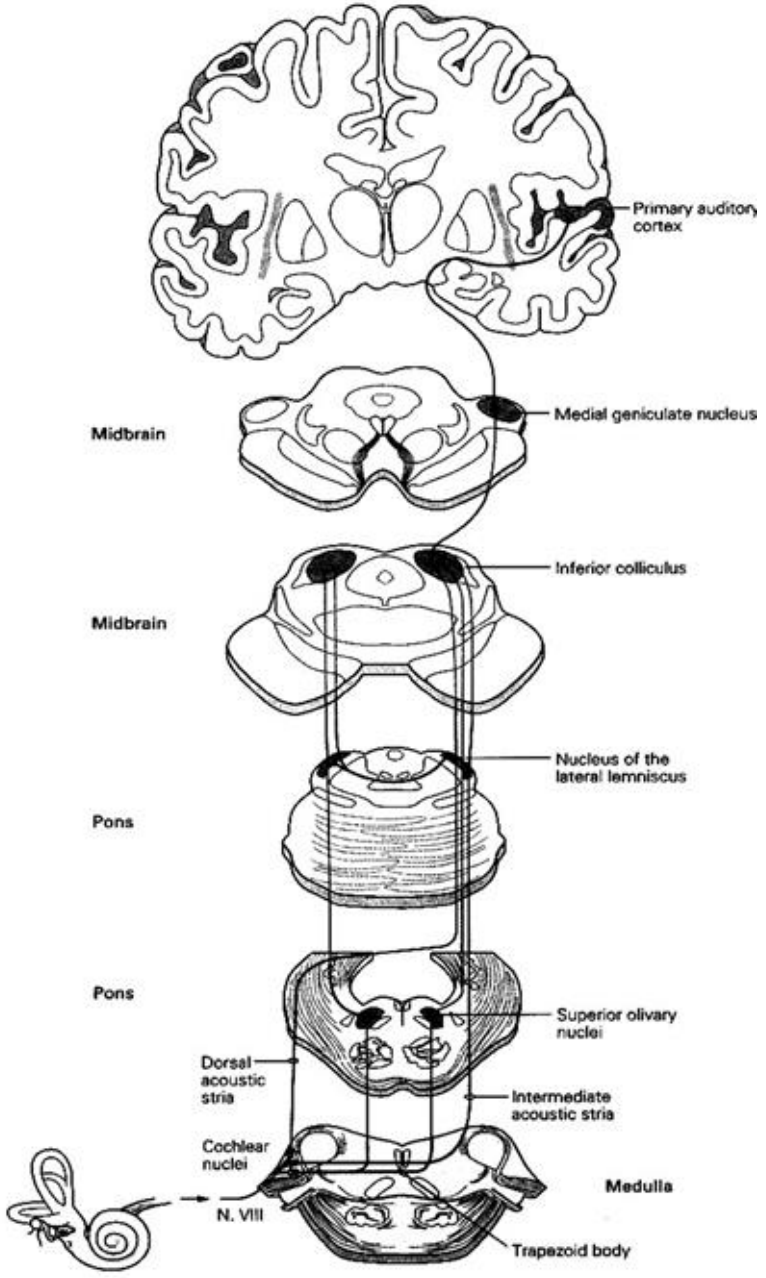
Vestibulocochlear nerve (VIII)



Auditory pathways

1. Ipsilateral auditory (cochlear) nerve: traverses the subarachnoid space together with the vestibular nerve and close to facial nerve, and it enters the brainstem at the pontomedullary junction. Its neuronal bodies are in the spiral ganglion.
2. Ipsilateral cochlear nucleus
3. Superior olivary complex (the majority of fibers decussate to the contralateral superior olivary complex)
4. Contralateral and ipsilateral lateral lemniscus nuclei
5. Contralateral and ipsilateral inferior colliculus
6. Contralateral and ipsilateral medial geniculate nuclei
7. Contralateral and ipsilateral transverse temporal gyrus (auditory region)

Some neurons ascend directly from the cochlear nucleus to the contralateral medial geniculate body.



Vestibulocochlear nerve (VIII) disorders

Disorders of the vestibulocochlear nerve can be divided into:

1) Hearing alterations

•Hearing loss (hypoacusis):

- Conductive hearing loss
- Sensorineural hearing loss
- Neural (retrocochlear) hearing loss

•Hyperacusis / increased auditory phenomena:

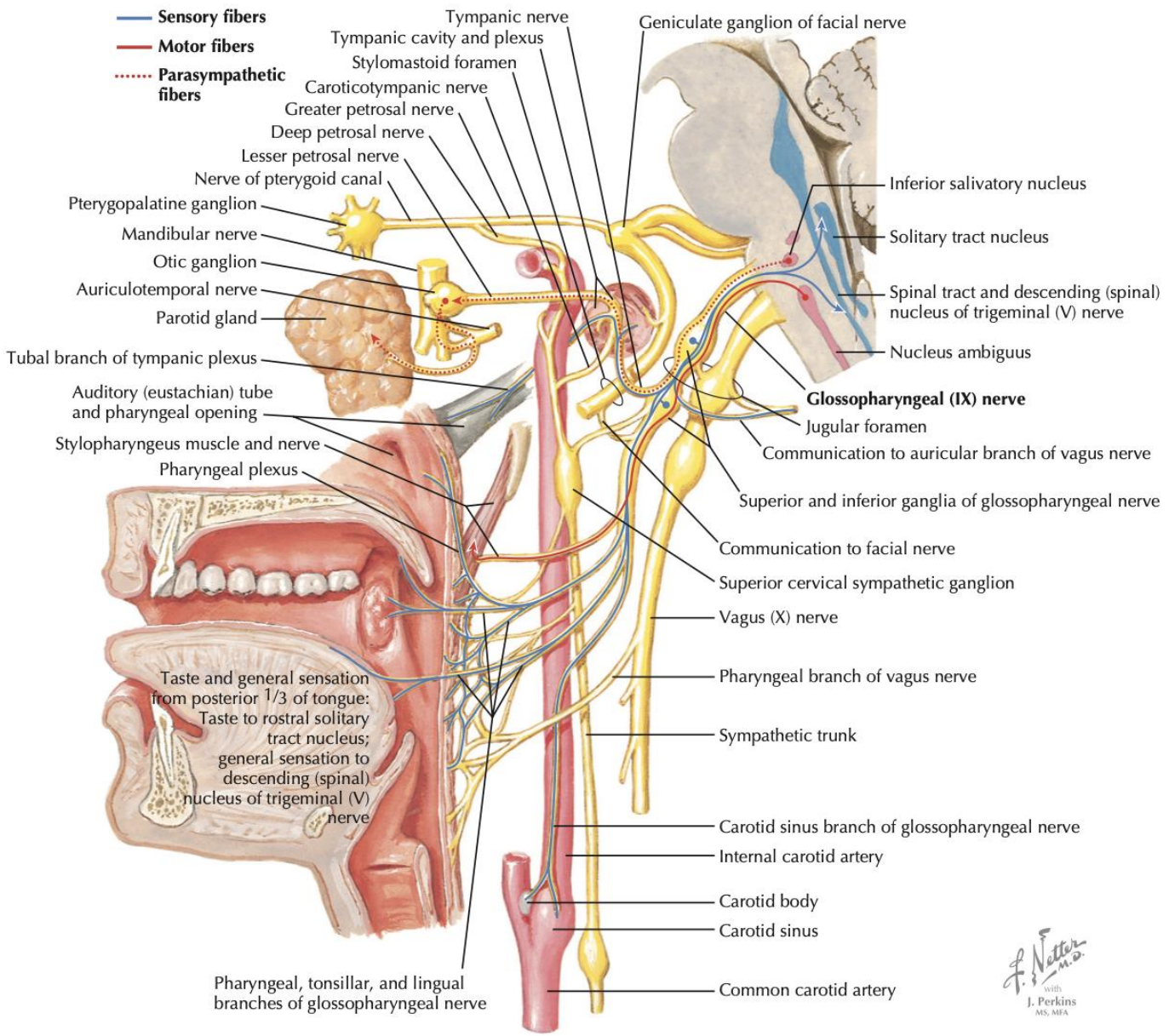
- Auditory hallucinations
- Tinnitus (ringing in the ears), etc.

2) Vestibular component alterations

•Vertigo: a true vertigo consists of an illusion of movement of one's body or head in space (subjective vertigo), or of movement of the surrounding environment relative to the body (objective vertigo)

•Nystagmus: involuntary, rhythmic, conjugate eye movements consisting of a slow phase (deviation of the eyeball away from the central position) and a fast phase (return of the eyeball to the primary gaze position). By convention, nystagmus is named according to the direction of the fast phase.

Glossopharyngeal nerve (IX)



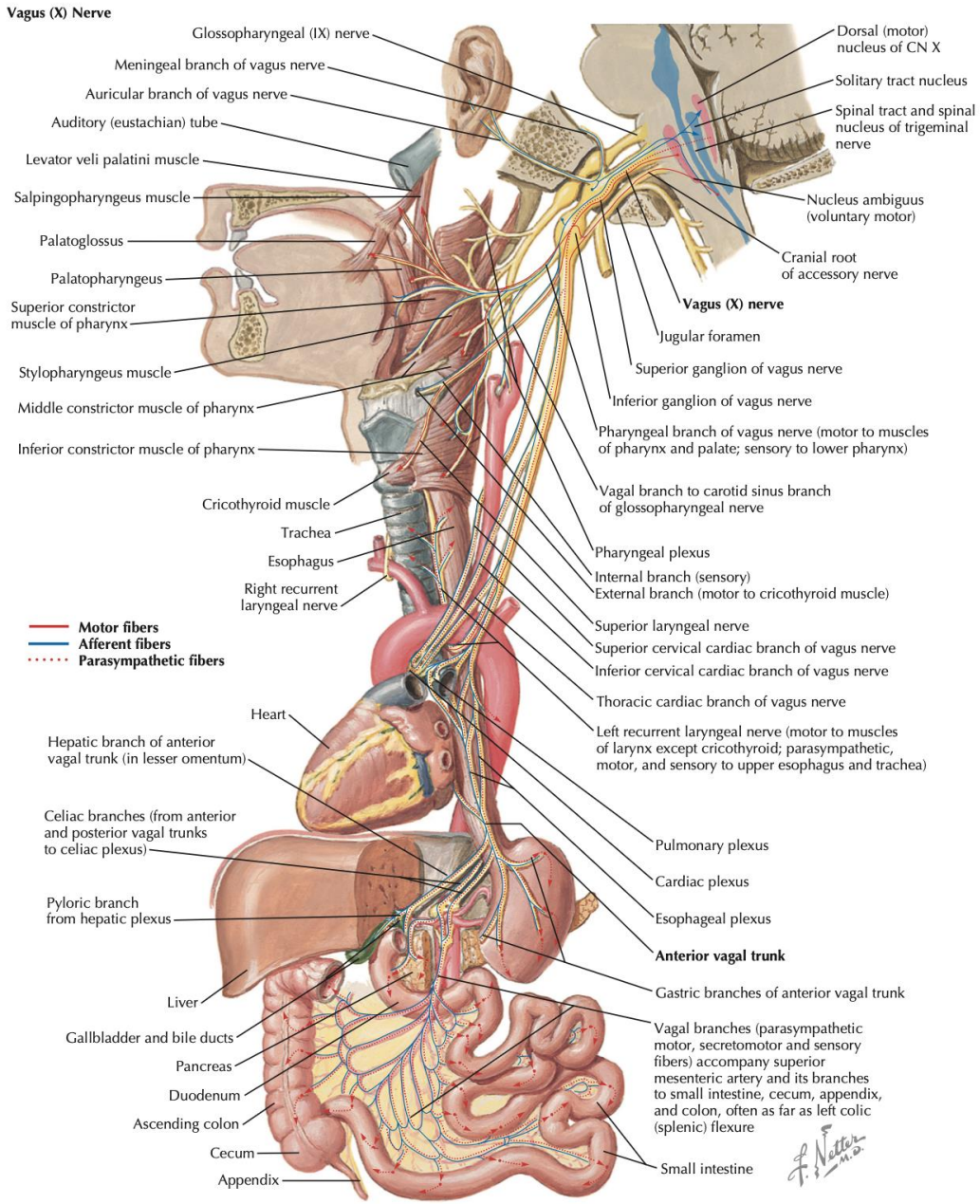
Glossopharyngeal nerve (IX) disorder

Disorders of the glossopharyngeal nerve:

- Difficulty in swallowing
- Hemi-anesthesia of the posterior one-third of the tongue, pharynx, and palate
- Ageusia (loss of taste) of the posterior one-third of the tongue (in lesions of the nerve trunk)
- Absence of the pharyngeal reflex

- Curtain sign: the patient is asked to produce the vowel sound “a”; the pharyngeal constrictor moves toward the healthy side

Vagus nerve (X)



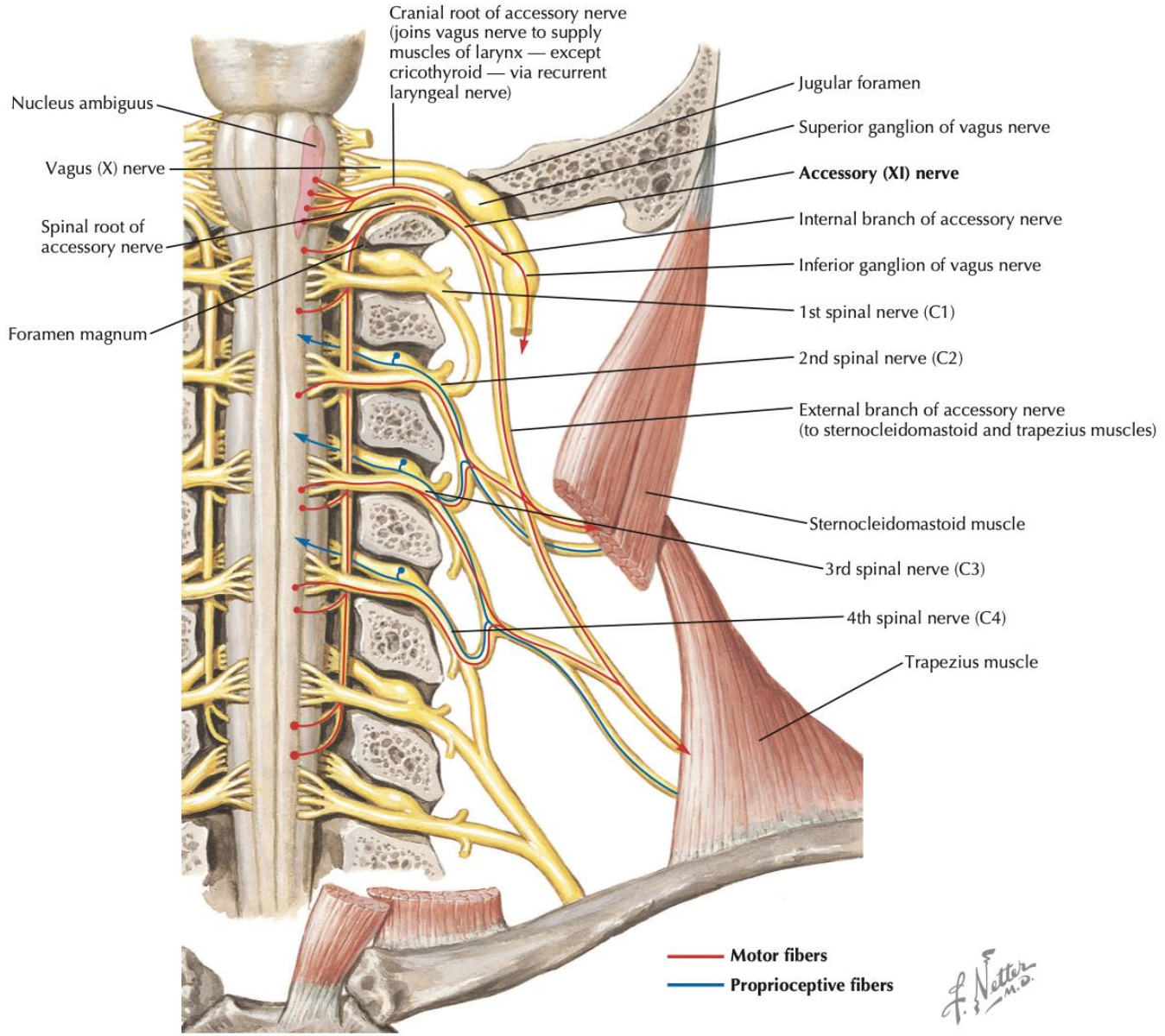
Vagus nerve (X) disorders

Disorders of the vagus nerve :

- If bilateral, incompatible with life.
- If unilateral:

•Pharyngo-laryngo-palatal hemiplegia
•Dysphagia
•Dysphonia
•Dysarthria
•Absence of the pharyngeal reflex
•Alterations in autonomic function

Accessory nerve (XI)

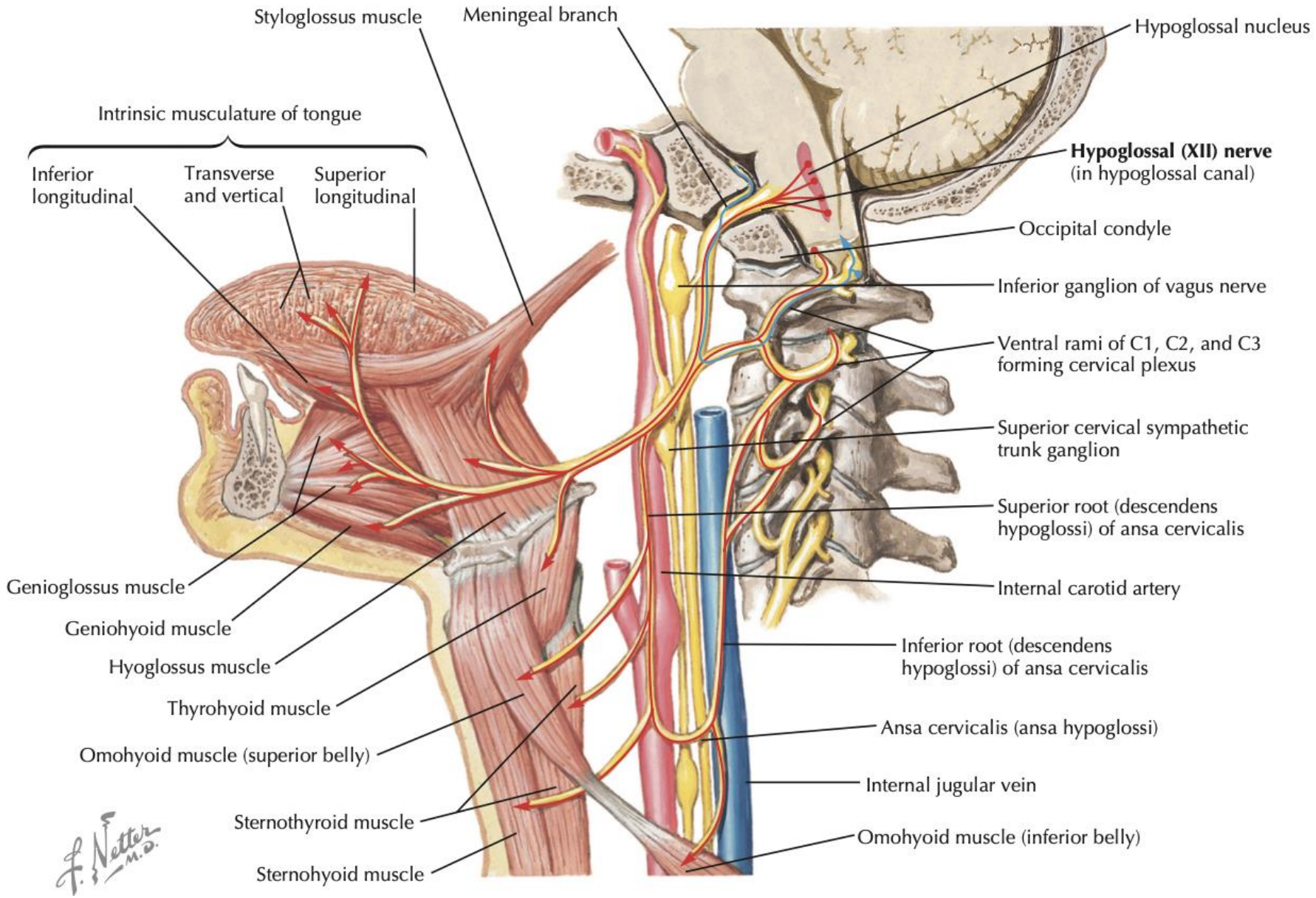


Accessory nerve (XI) disorders

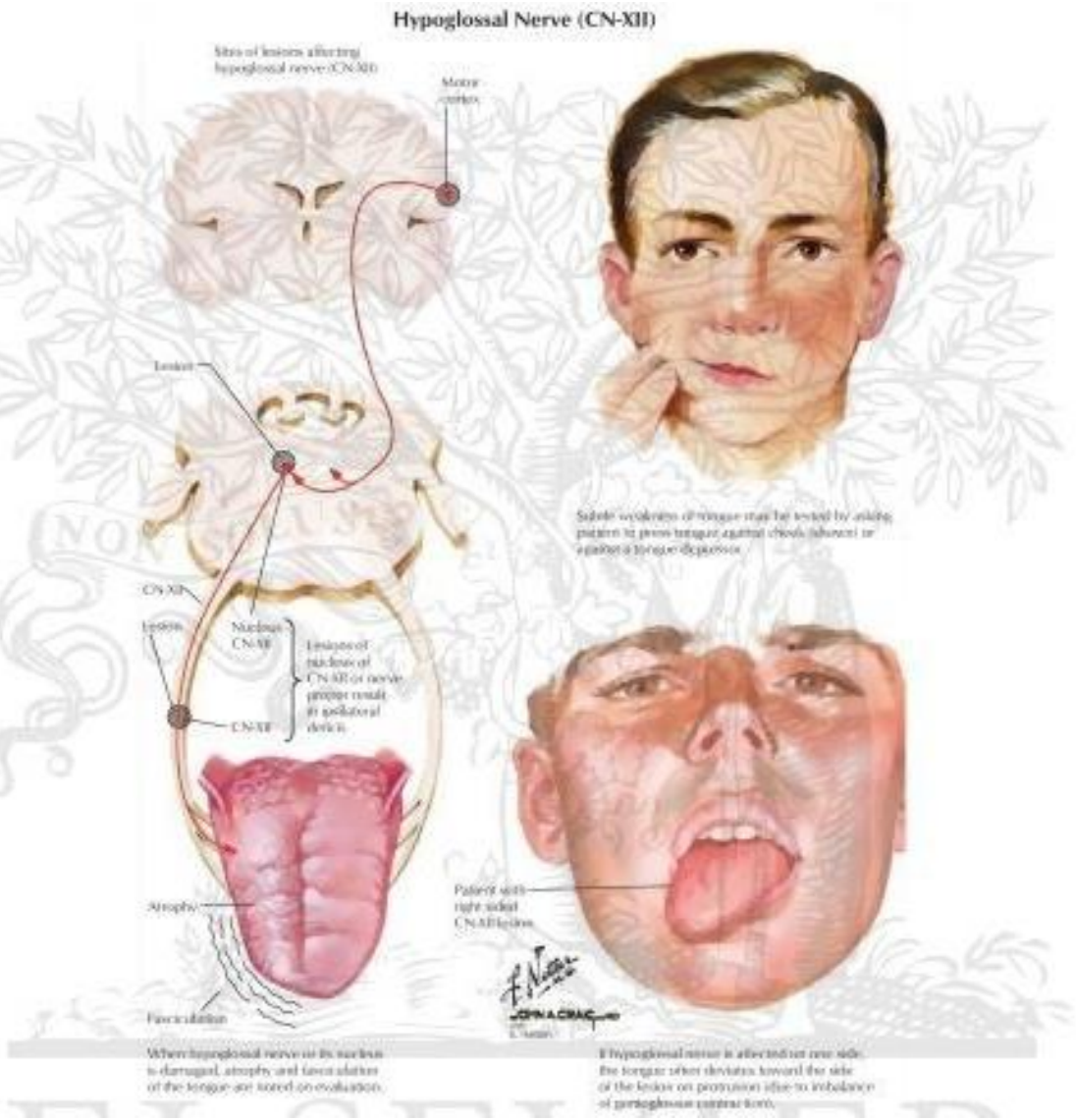
Lesions cause:

- Difficulty turning the head
- Shoulder droop”

Hypoglossal nerve (XII)



Hypoglossal nerve (XII) disorders



A lesion causes:

- Tongue deviation toward the side of the lesion
- Dysarthria
- Difficulty in swallowing

Sensory organs

= organs consisting of groups of interrelated sensory cells that detect and transduce a specific type of physical stimulus.

Senses:

"Classical 5"

- Sight
- Hearing
- Smell
- Taste
- Touch

Other perception abilities - human

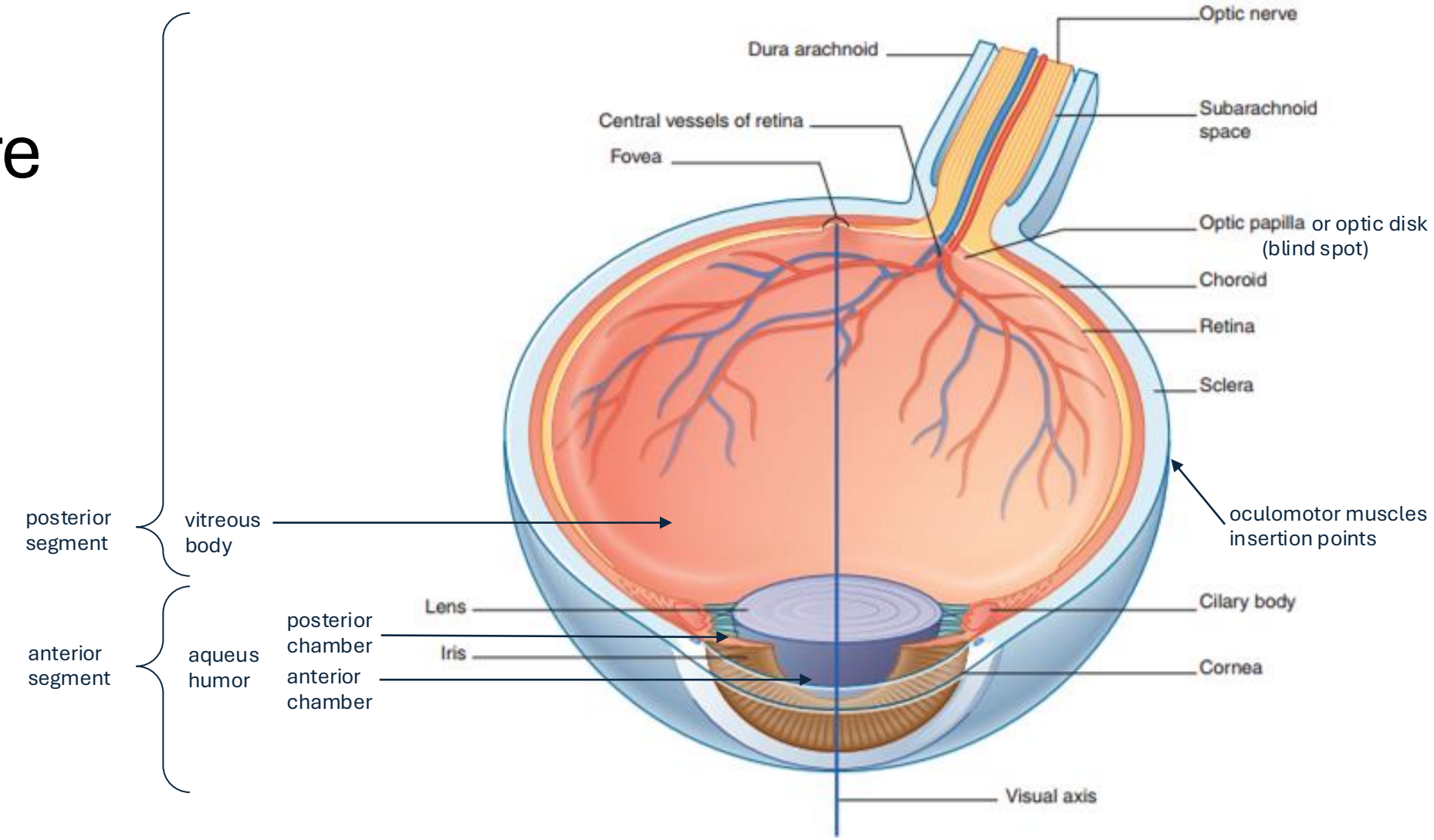
- Spatial orientation (balance)
- Proprioception
- Nociception
- Other internal sensations (e.g. hunger, thirst, suffocation, nausea)

Other perception abilities - non-human

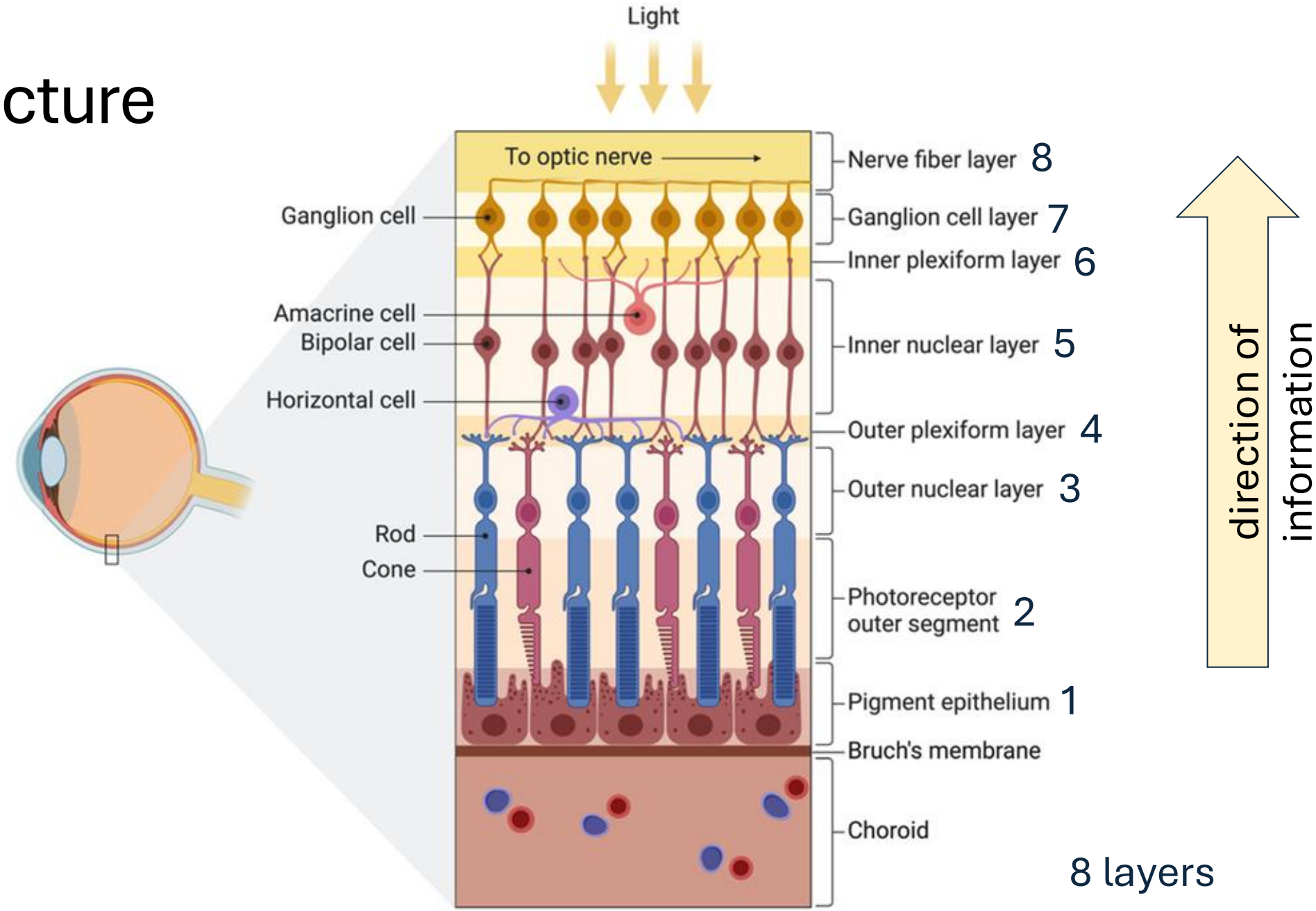
- Electrical and magnetic fields perception
- Air moisture perception
- Polarized light perception
- ...

Sight

Eye structure



Retinal structure



Retinal structure

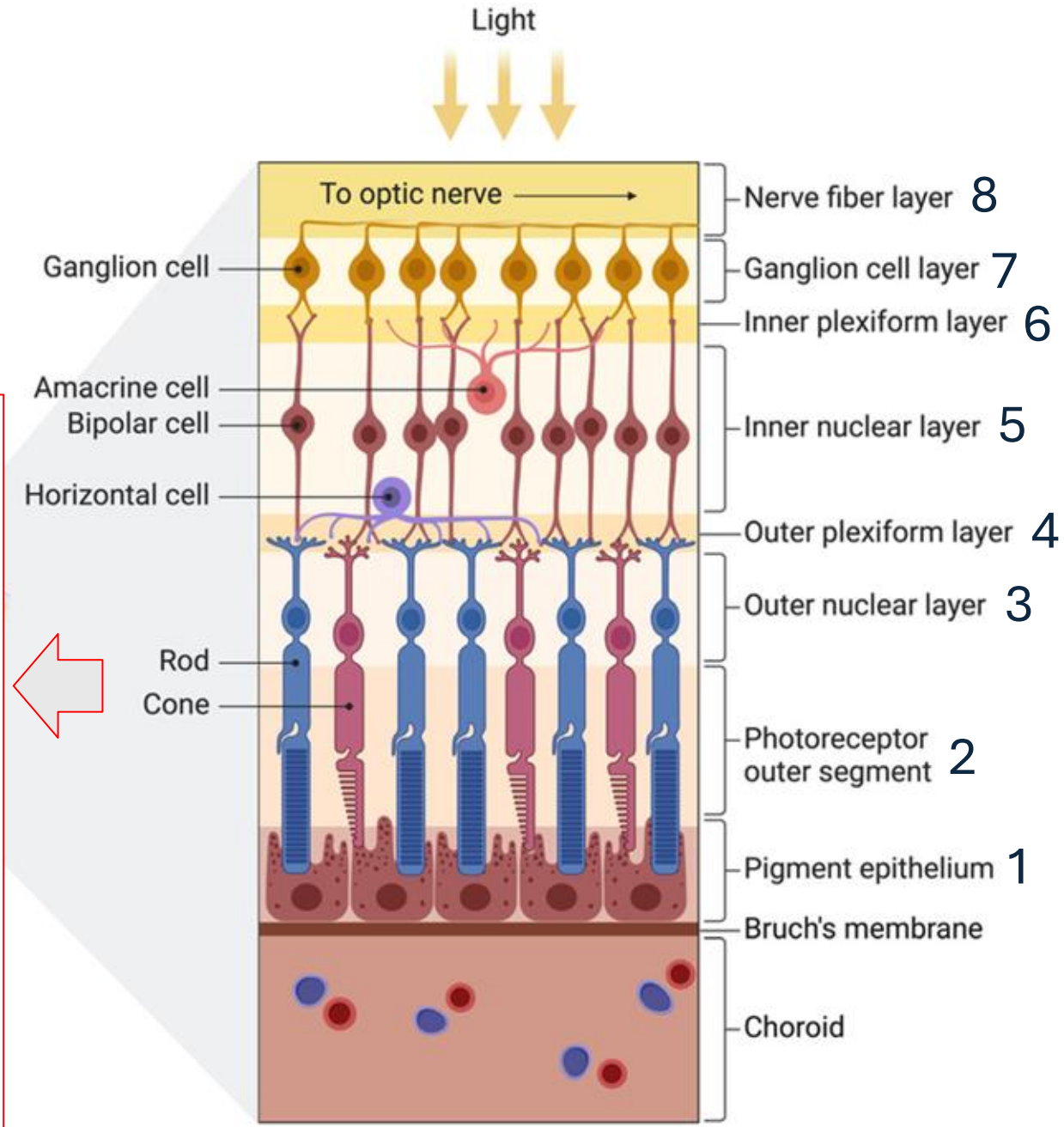
Photoceptors:

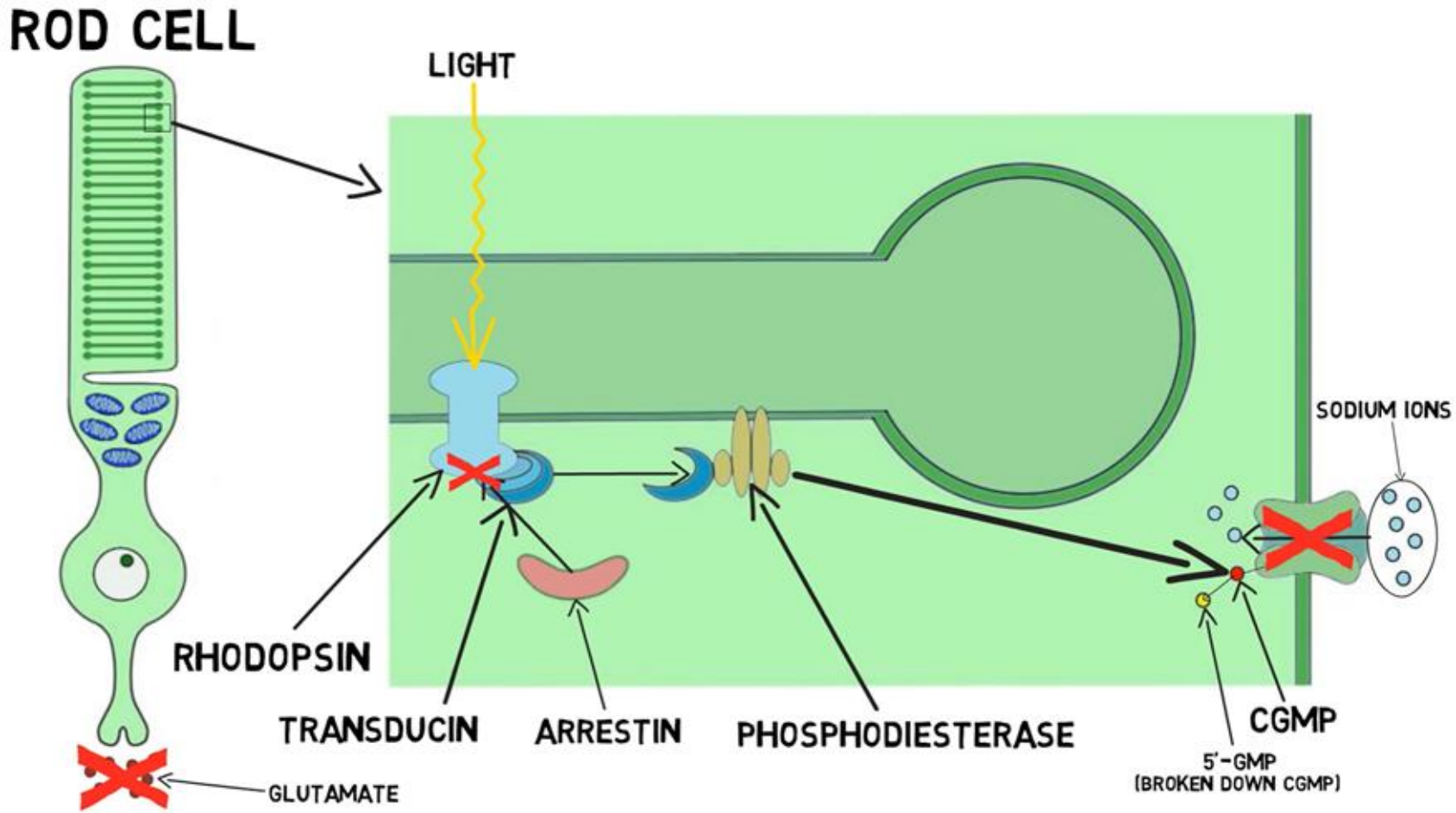
Rods:

- scotopic vision (dim light)
- retinal sensitivity
- 1 type of rodopsin

Cones:

- photopic vision (bright light)
- visual acuity and color vision
- 3 types of photopsins (blue, green, red)





lack of glutamate tonic release = light detection

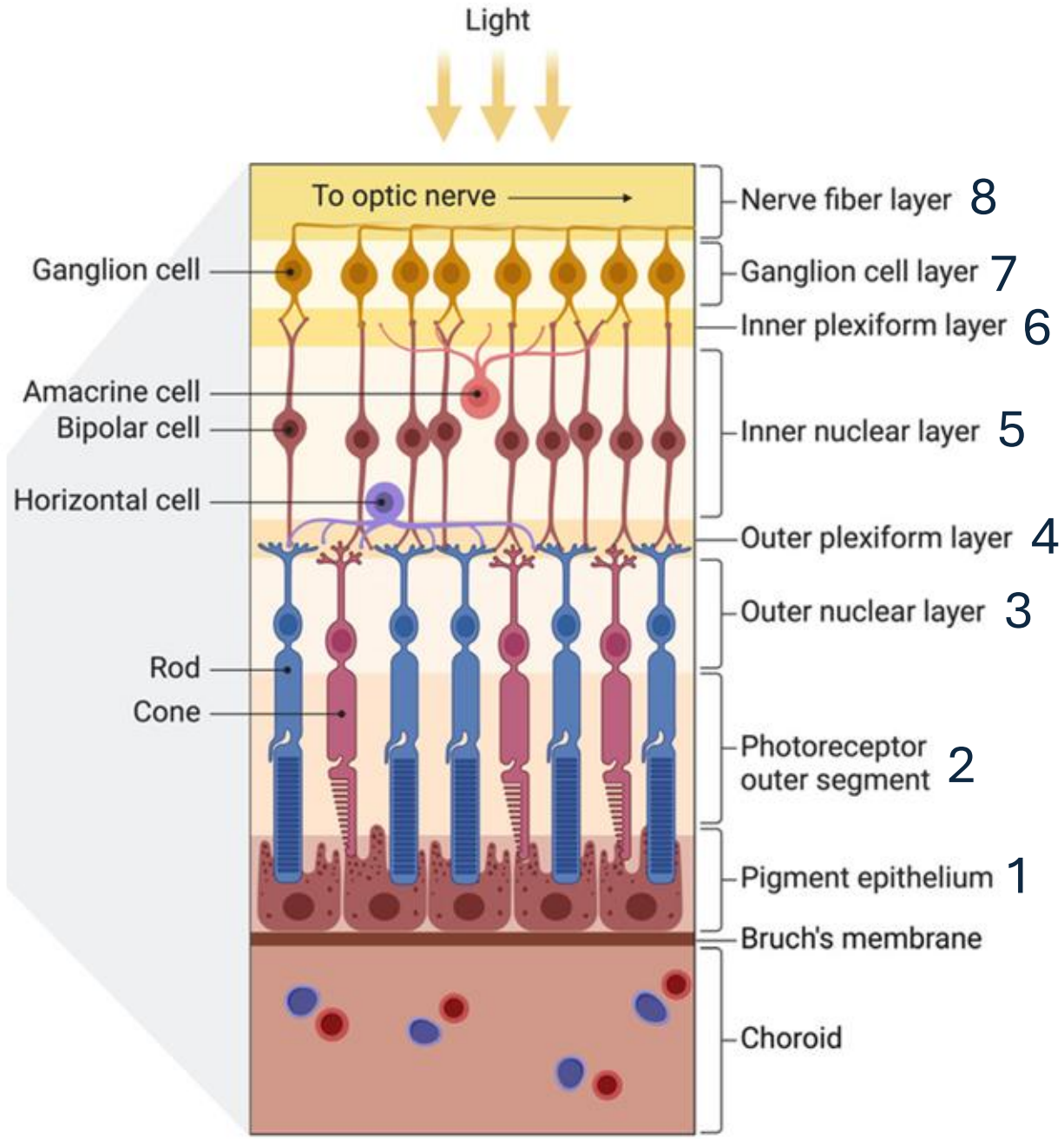
rhodopsin = opsin (G protein coupled receptor) + retinal (vitamin A derived chromophore)

when light is absorbed, a double bond changes conformation

Retinal structure

First level of sensory integration = edge detection:

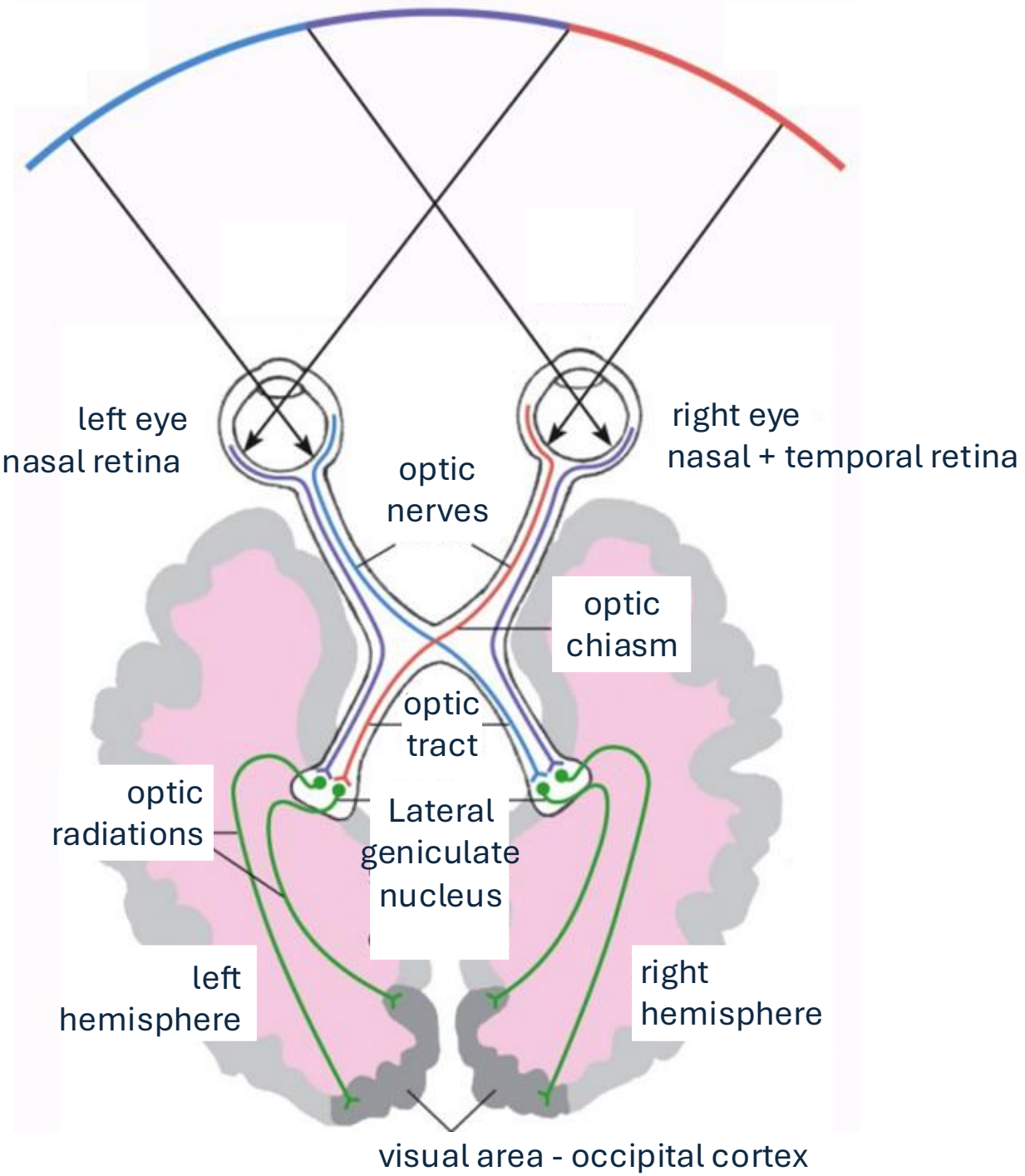
- **ON-center** retinal ganglion cells fire when a receptor detects light while being surrounded by receptors detecting dark
- **OFF-center** retinal ganglion cells work the opposite way

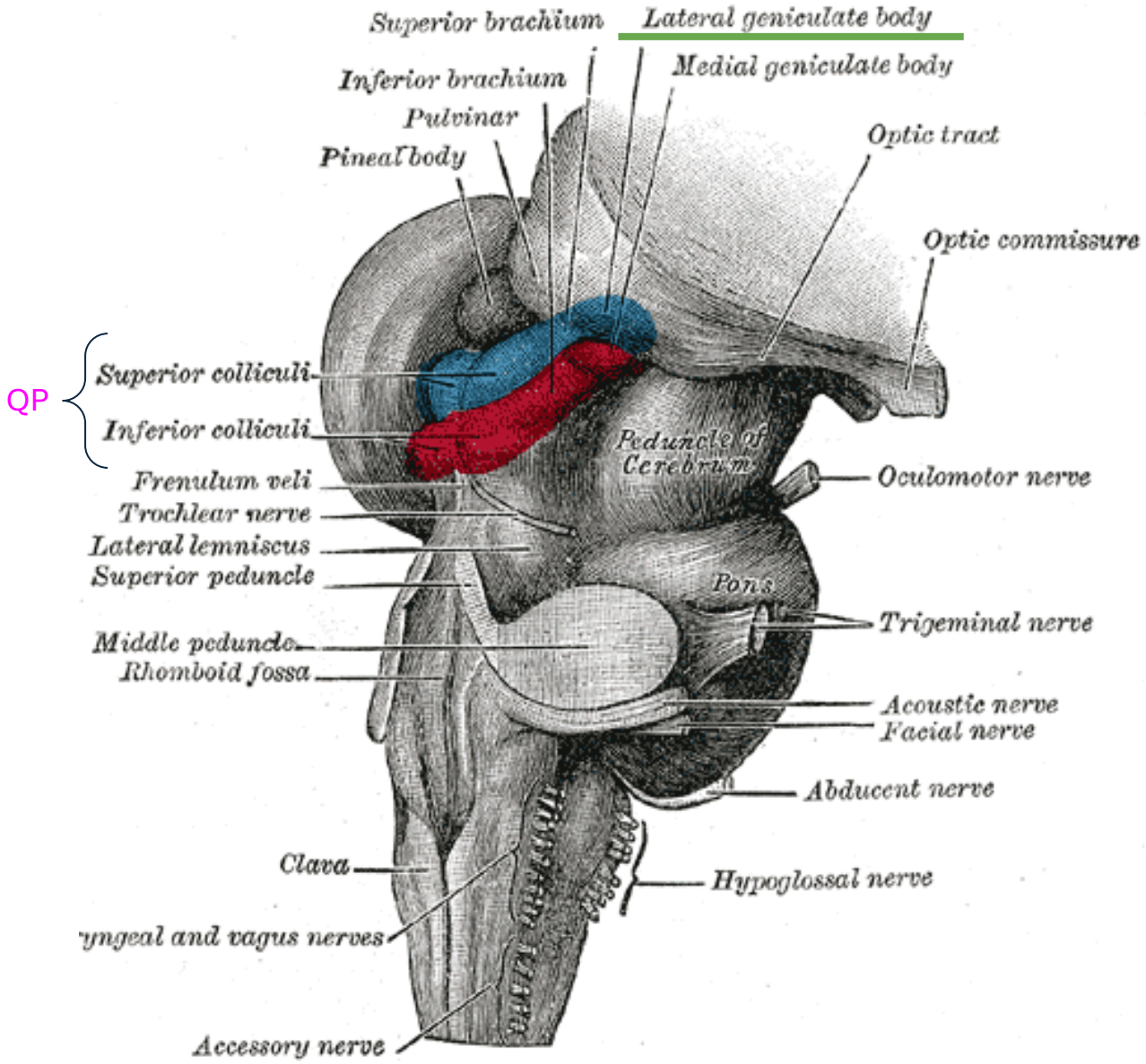


Visual pathways

1. Retina
2. Optic nerve (2nd pair of cranial nerves)
3. Optic chiasm
4. Lateral geniculate nucleus
5. Optic radiations
6. Visual area in the occipital cortex
7. Supplementary visual areas

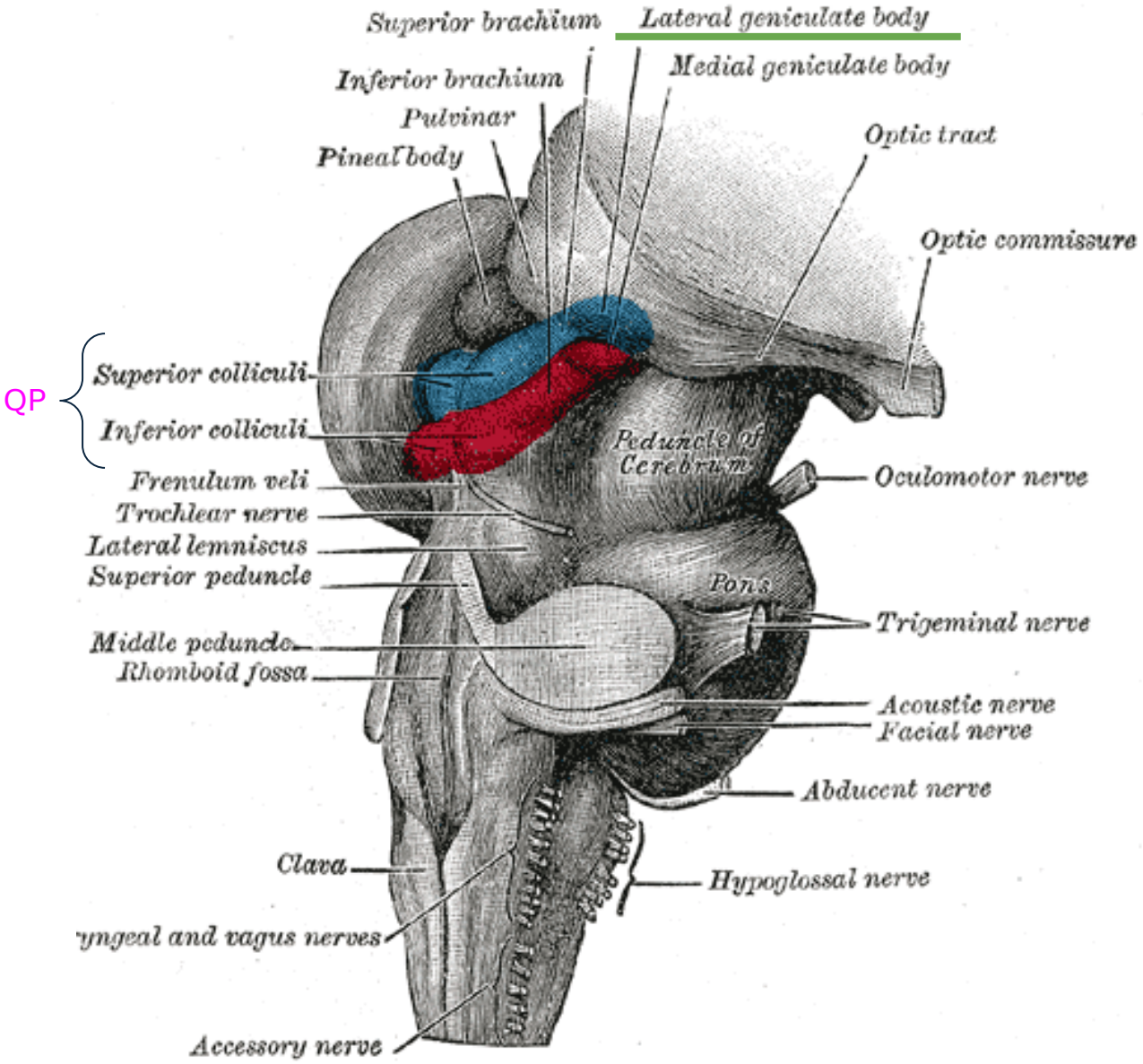
bold = where synapses occur





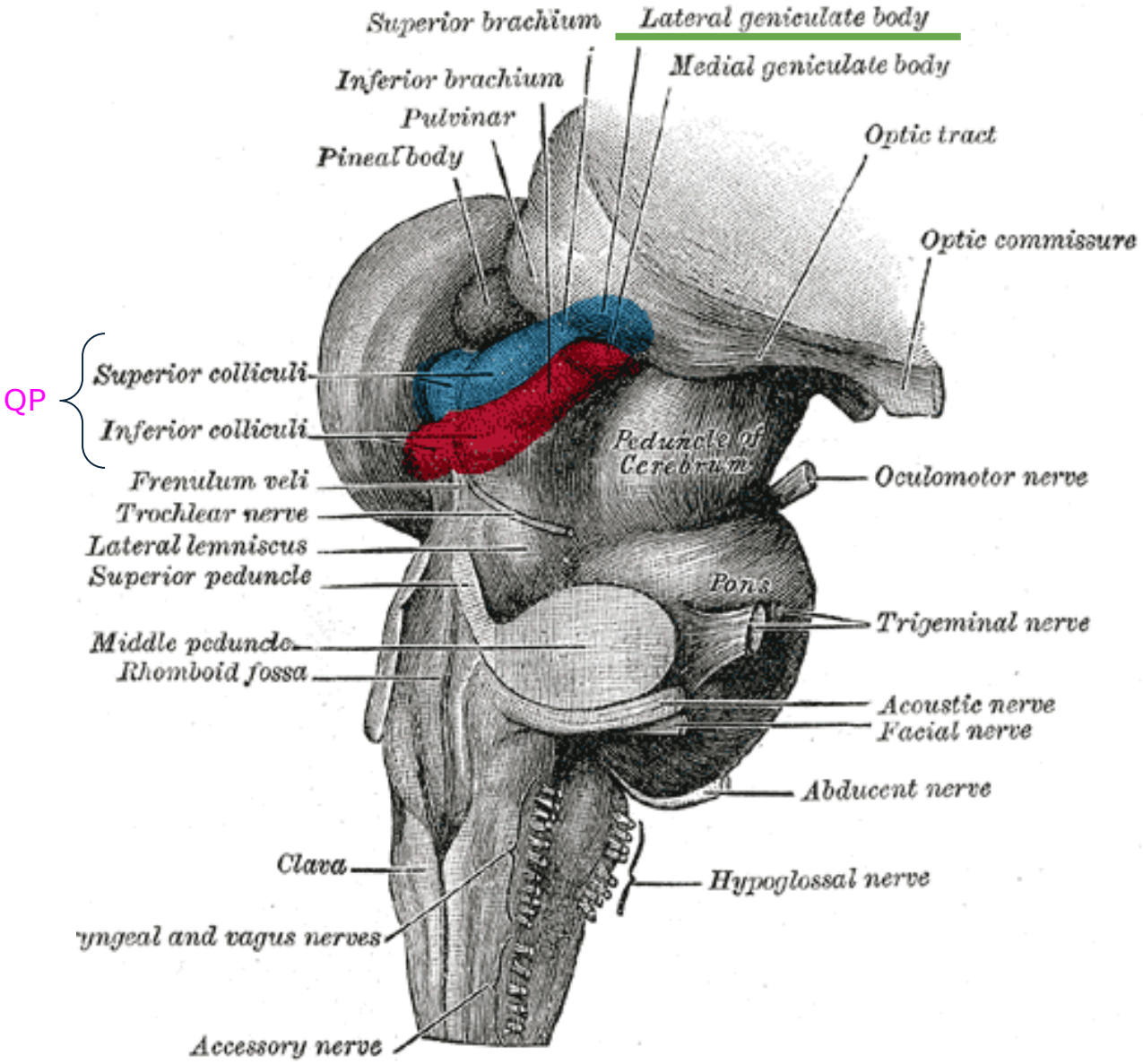
Lateral geniculate nucleus (LGN) (/body /complex): even structure in the ventral thalamus. 6 layers of neurons alternating with optic fibers. Receives from the optic tract, the reticular activating system, and the primary visual cortex (feedback). Projects to thalamus and to the superior colliculus.

Quadrigeminal plate (/tectal plate): located dorsally in the



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Quadrigeminal plate (/tectal plate): located dorsally in the midbrain. General function = mapping body-centered space and directing behavioral responses.

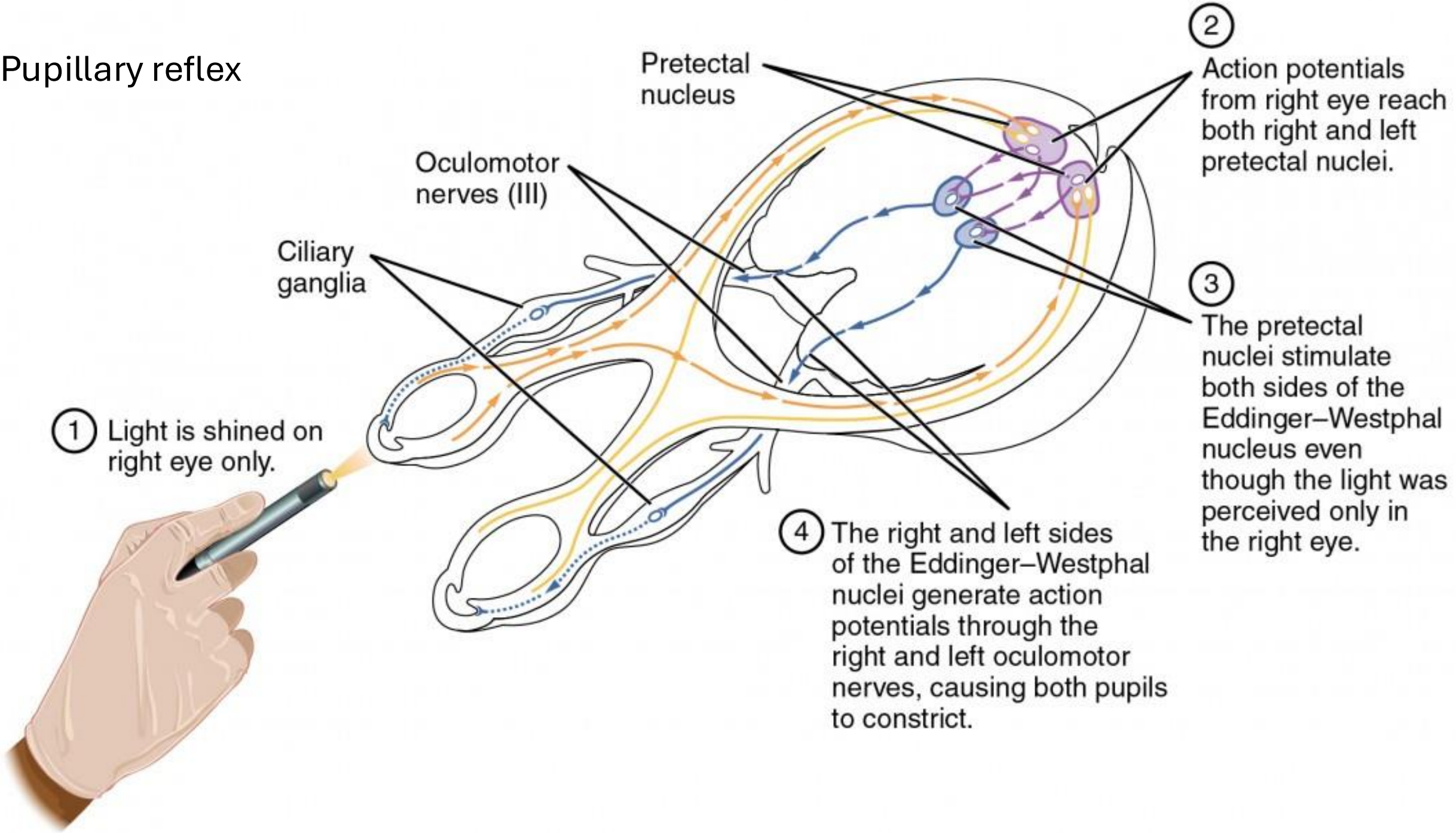


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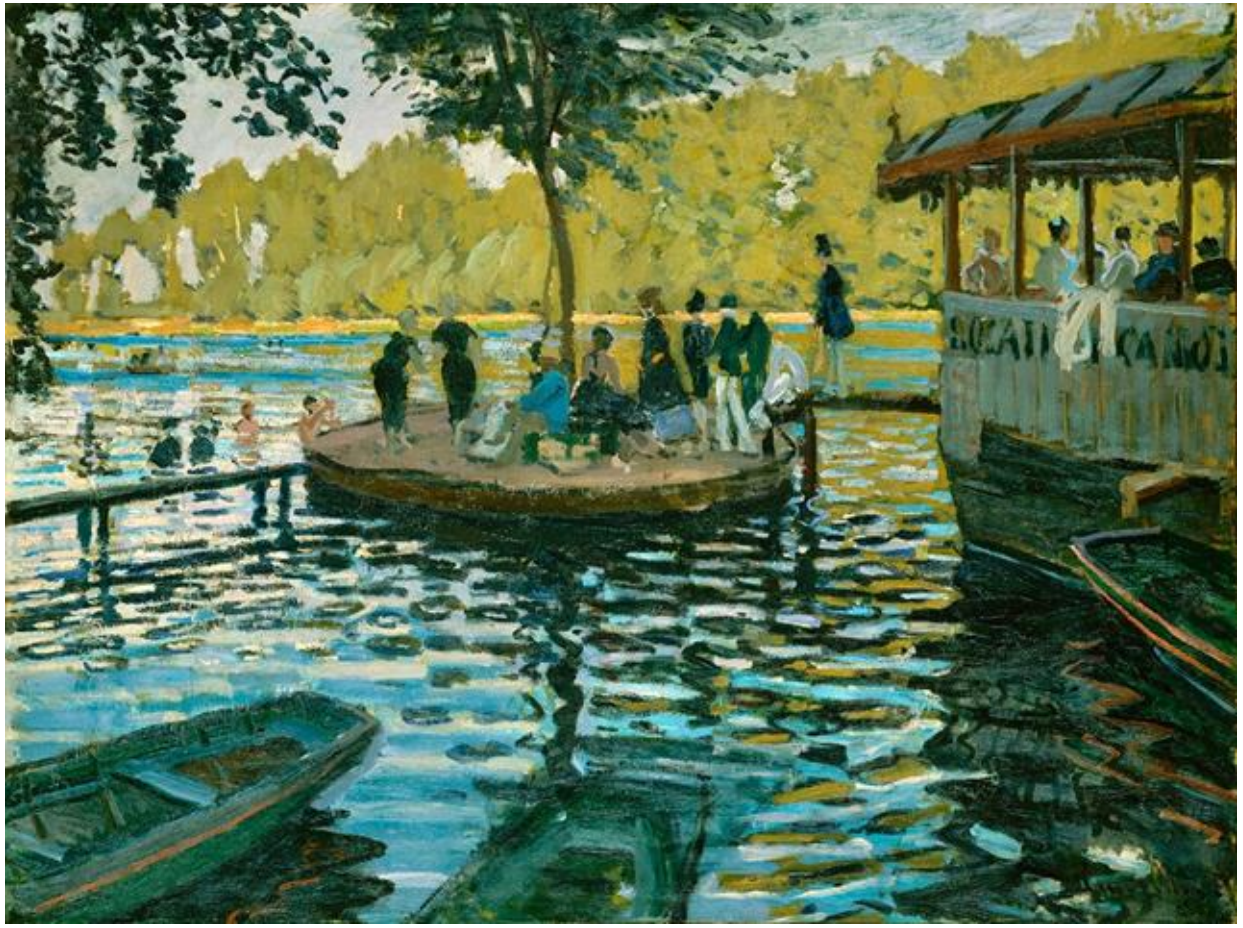
Quadrigeminal plate (/tectal plate): located dorsally in the midbrain. General function = mapping body-centered space and directing behavioral responses.

Superior colliculi: superficial layers receive direct retinal input. Deeper layers respond to multiple sensory modalities and is involved in saccadic eye movements, head turns, arm-reaching movement, attention shifting, pupillary reflex. Maintains topographic maps of space in retinotopic coordinates. Dysfunction are associated with parkinsonisms and autism spectrum conditions.

Pupillary reflex



Defects in visual pathways

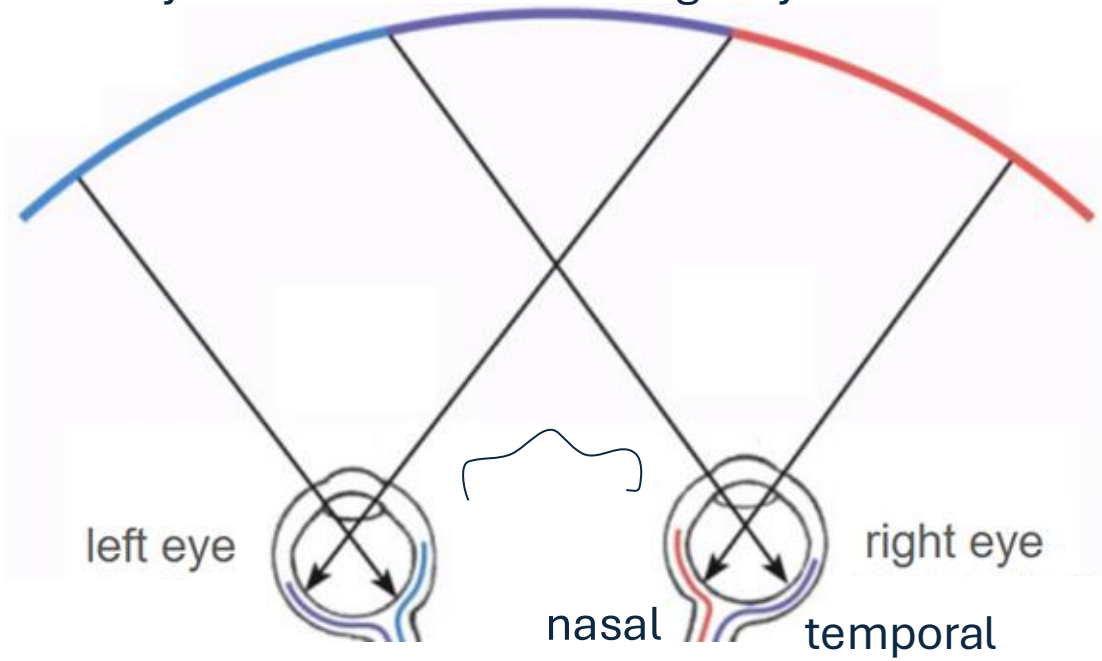


field of view (both eyes)



left eye field of view

right eye field of view



!: NOT a radiological standard representation

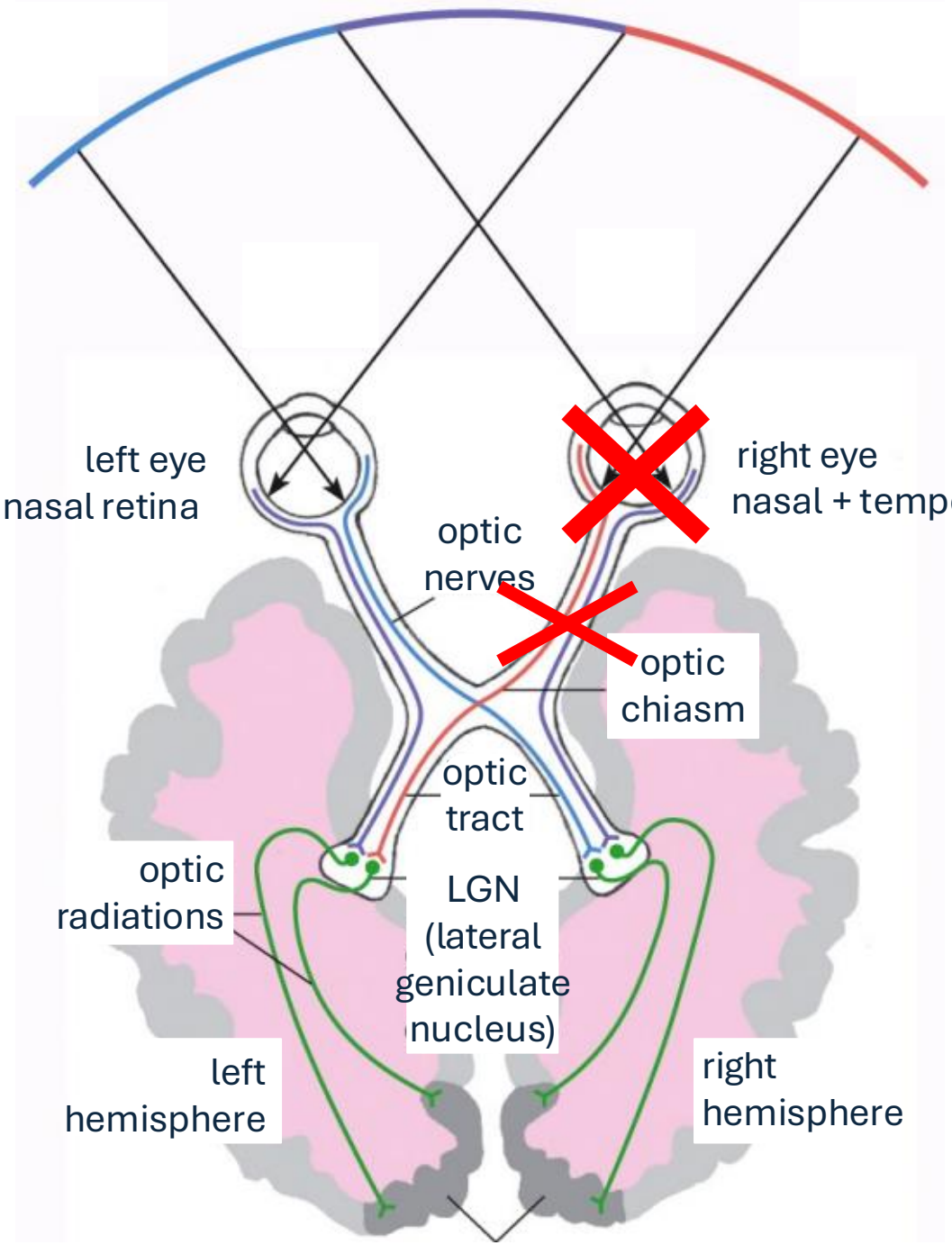


left eye





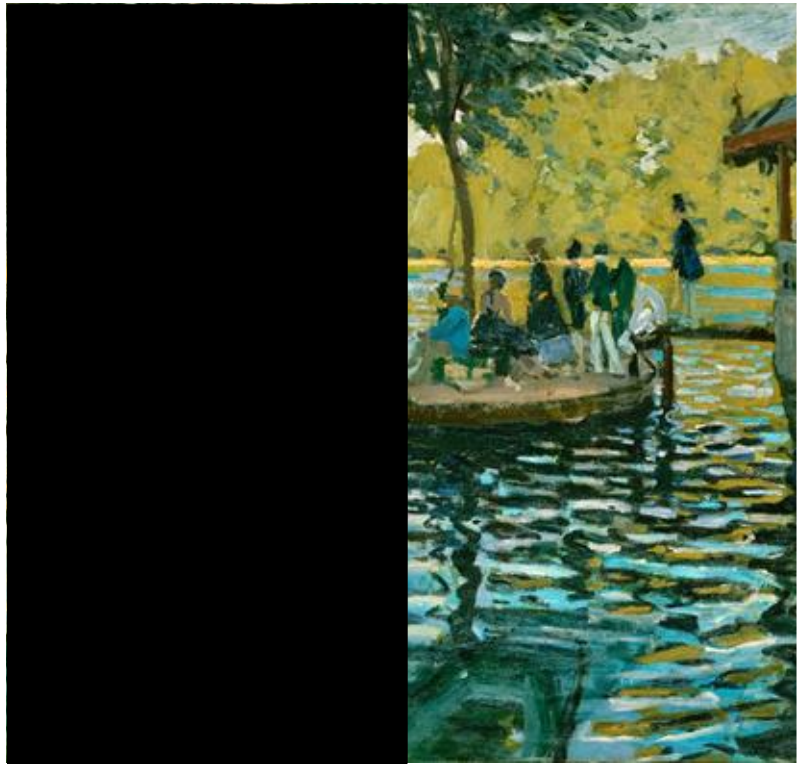
right eye



Right eye blindness
or right optic nerve deficit

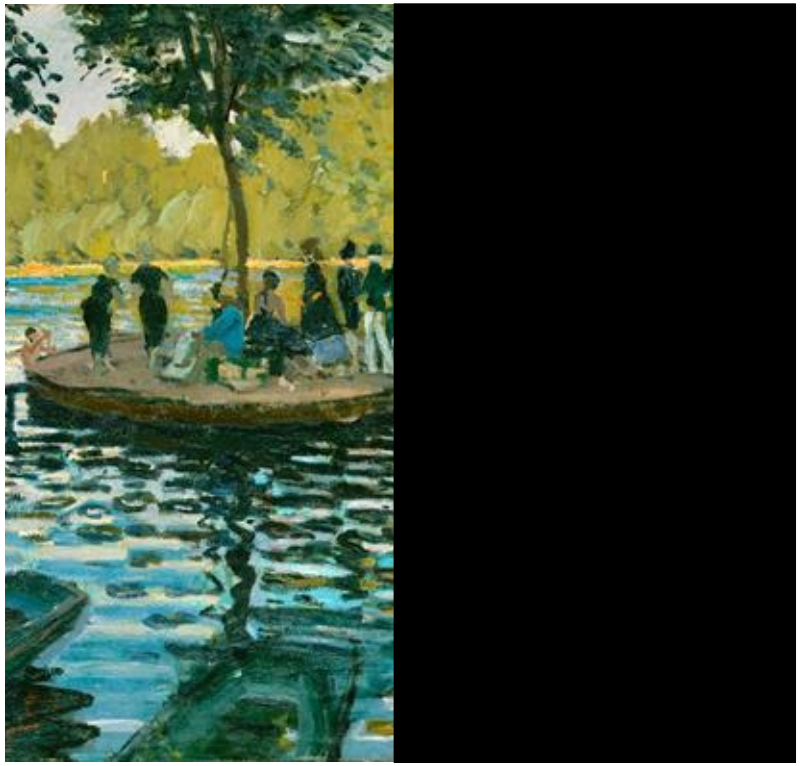




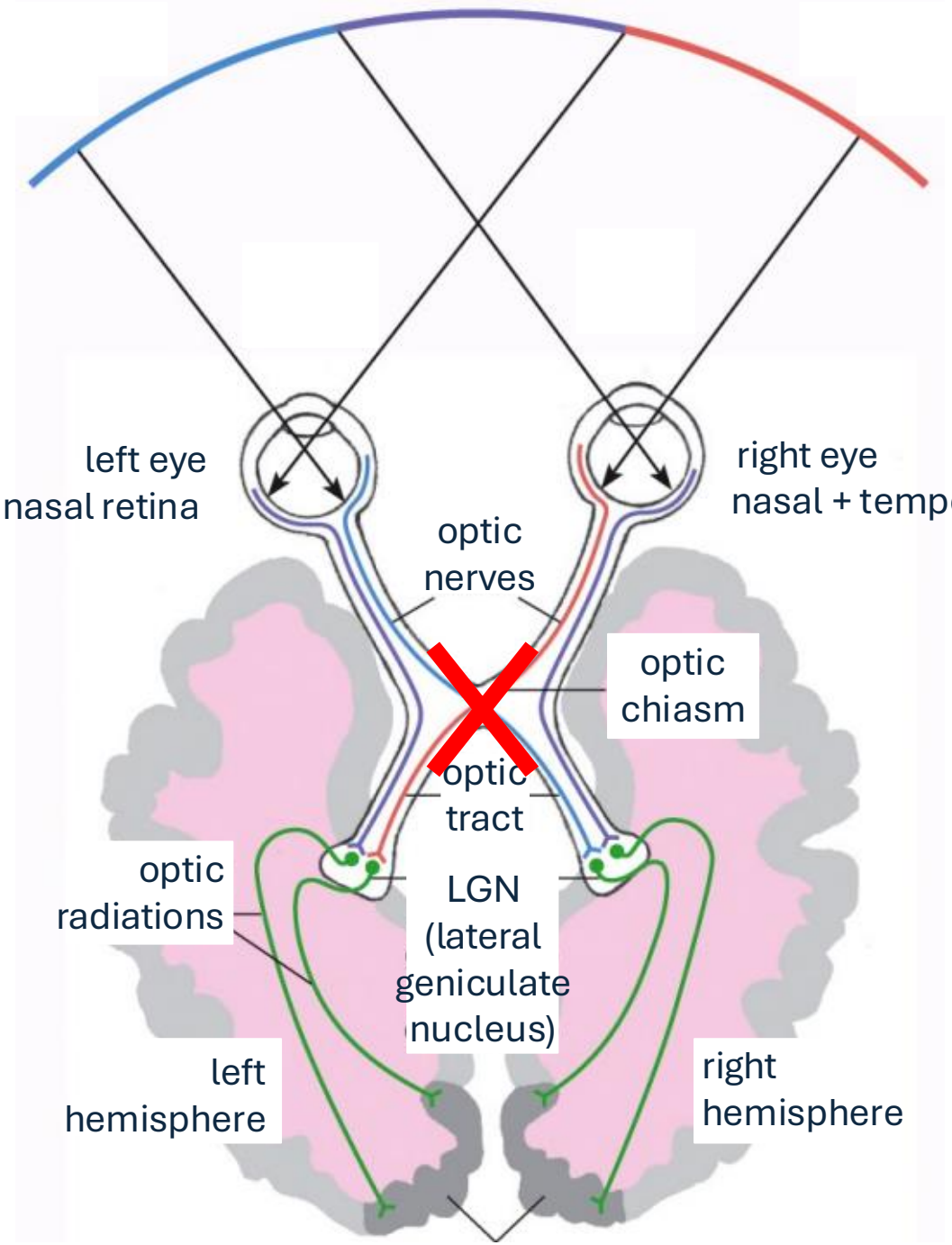


left eye



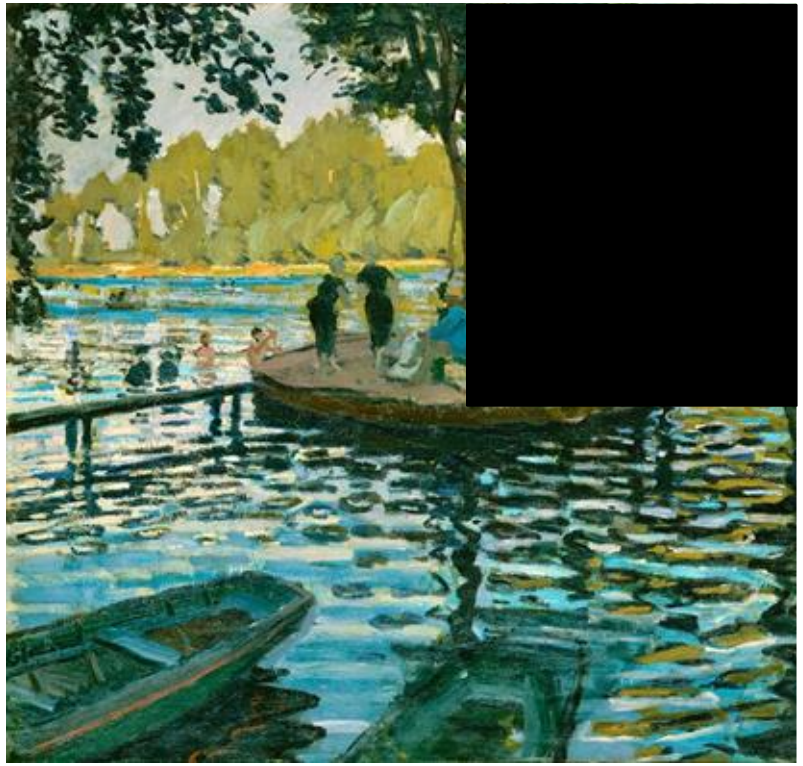


right eye



Bitemporal (heteronymous) hemianopia



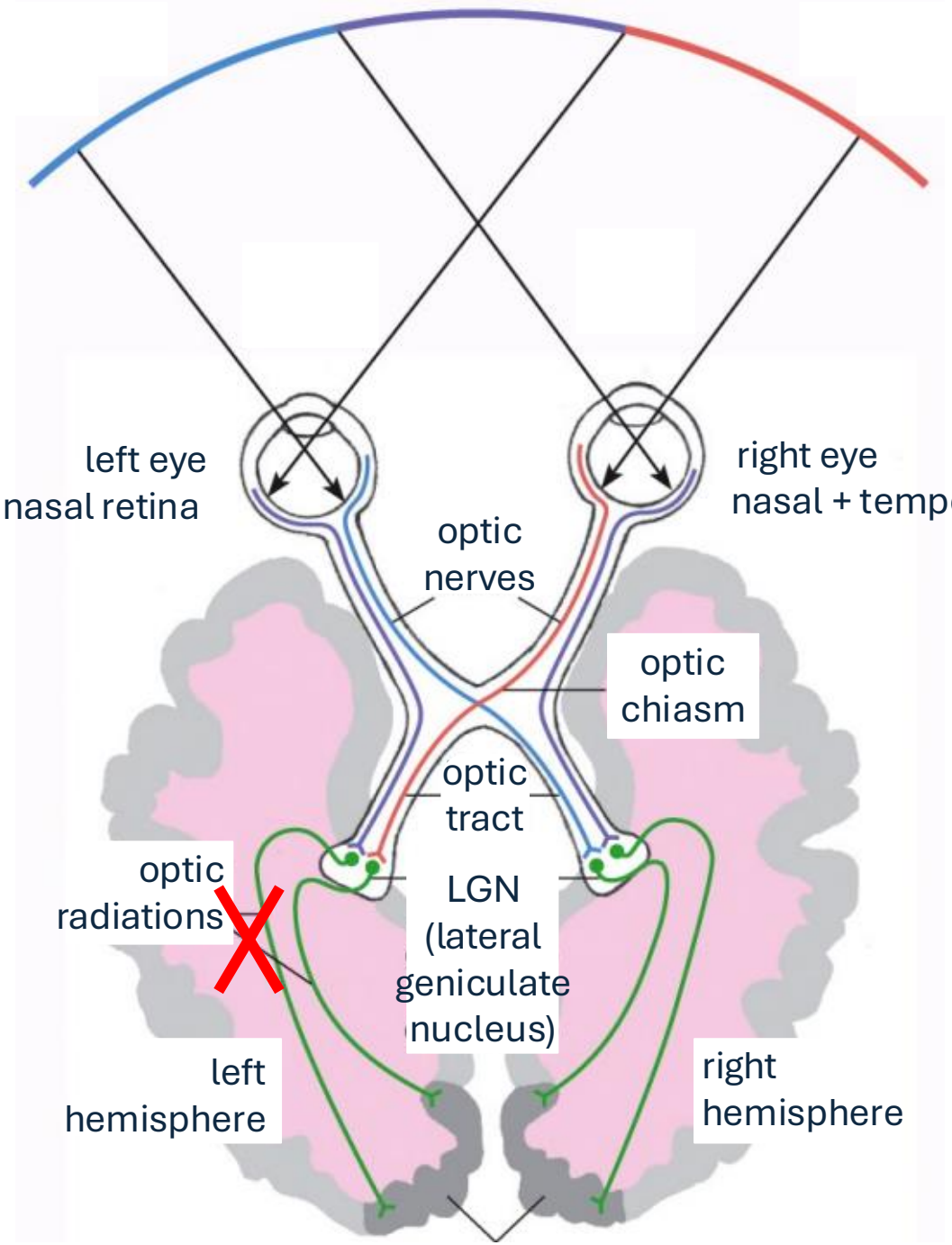


left eye





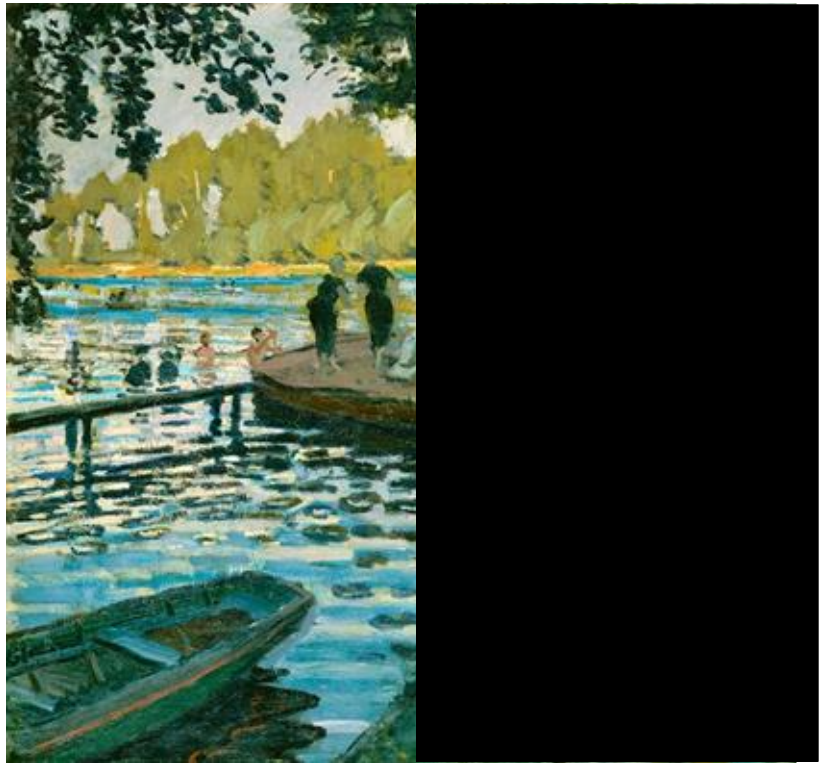
right eye



Upper right quadrantopsia (or quadrantanopsia)

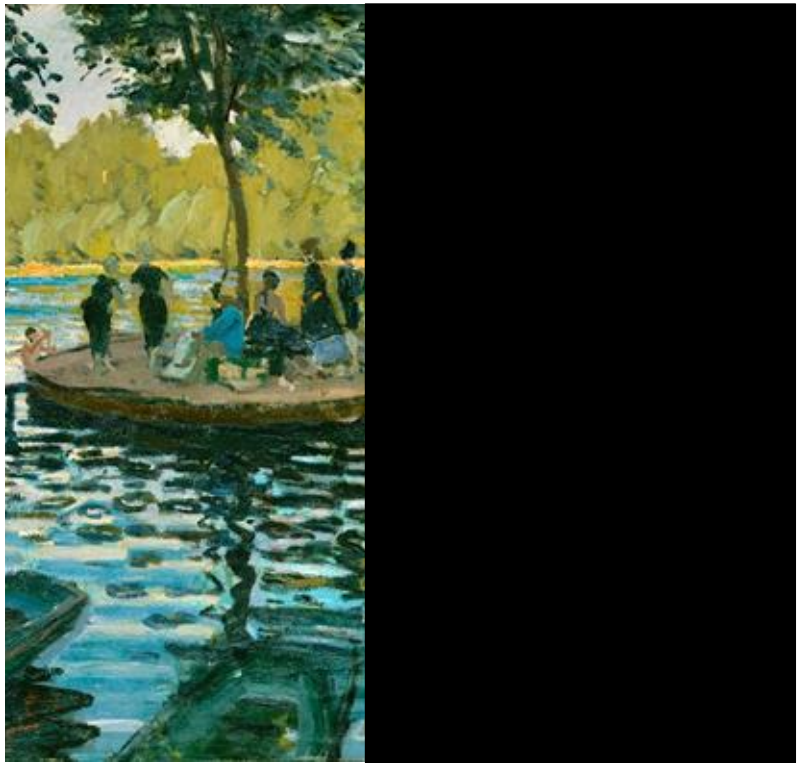




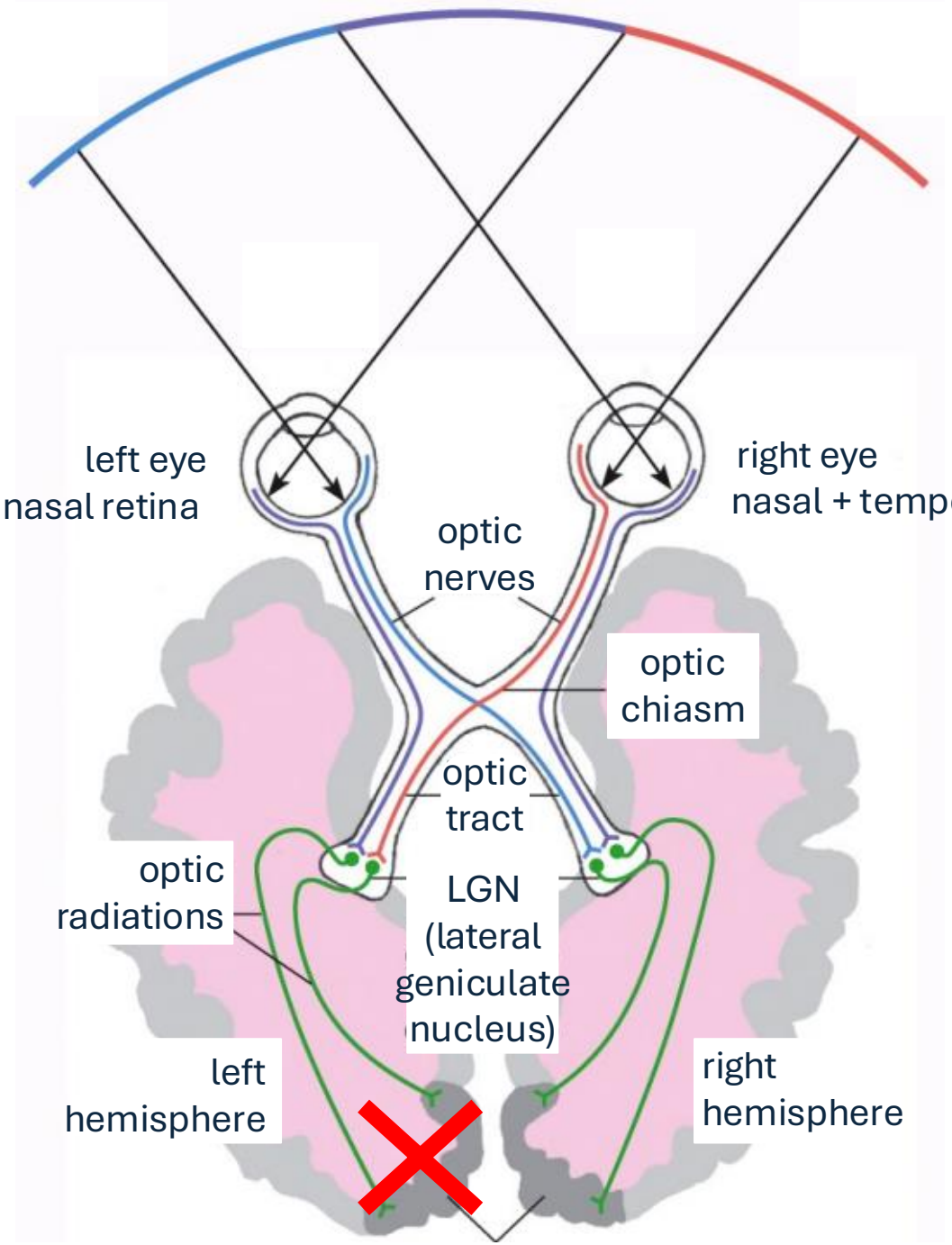


left eye





right eye



Right homonymous hemianopia

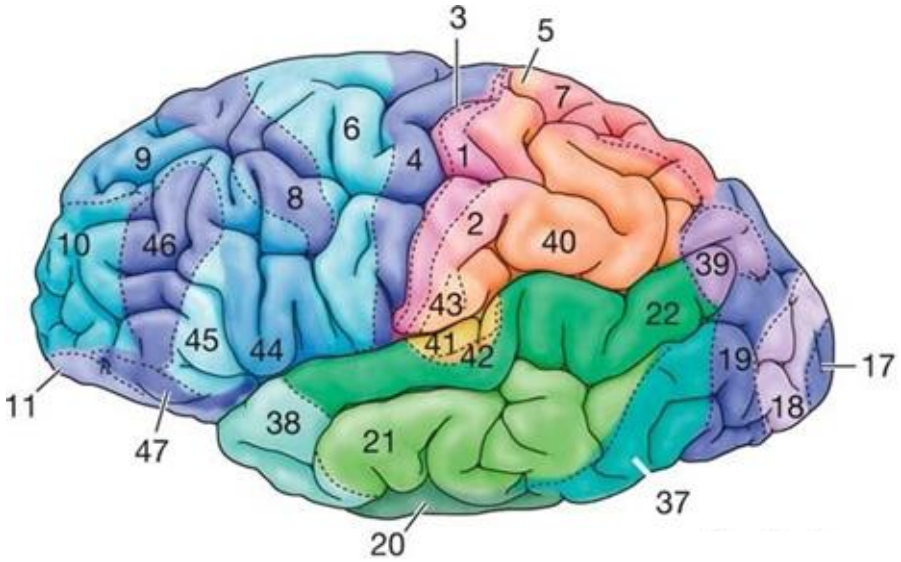


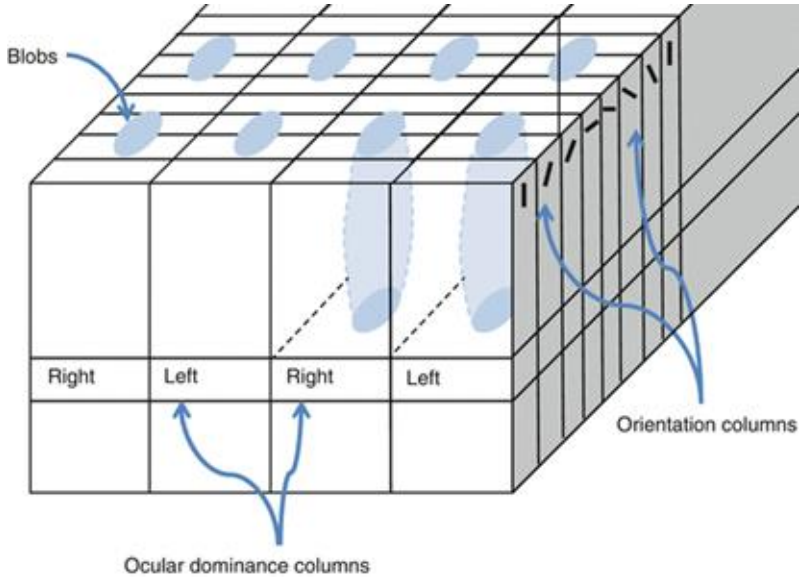


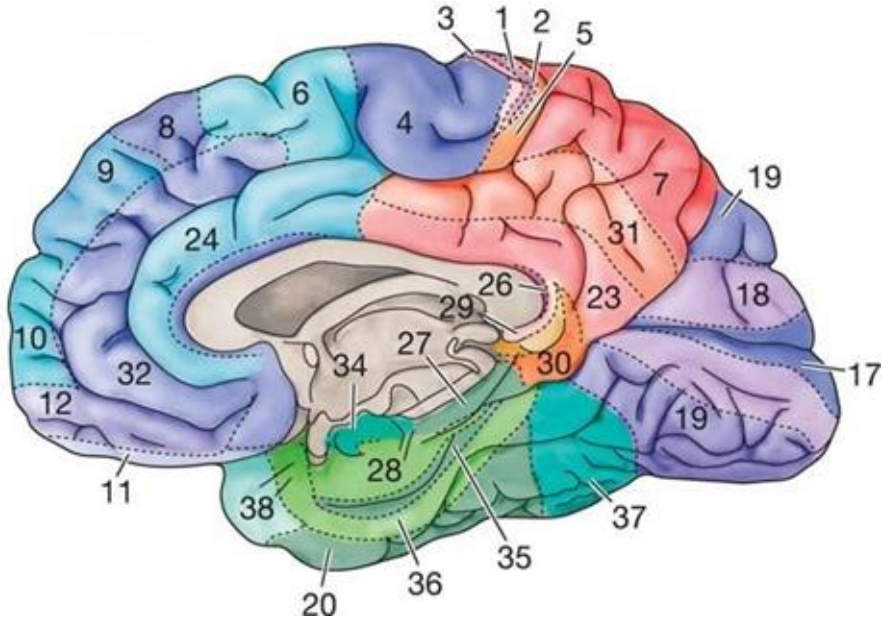
Visual areas - occipital cortex

Primary visual cortex or striate cortex, from the incoming myelinated tract (Brodmann area 17): arranged in alternating columns, each contiguous with the one receiving input from the contralateral eye → modules in hierarchical connection → visual information are progressively transformed into a range of elementary properties: contour, direction of motion, size, orientation.

Bilateral cortical damage → Anton syndrome.







Visual areas - occipital cortex

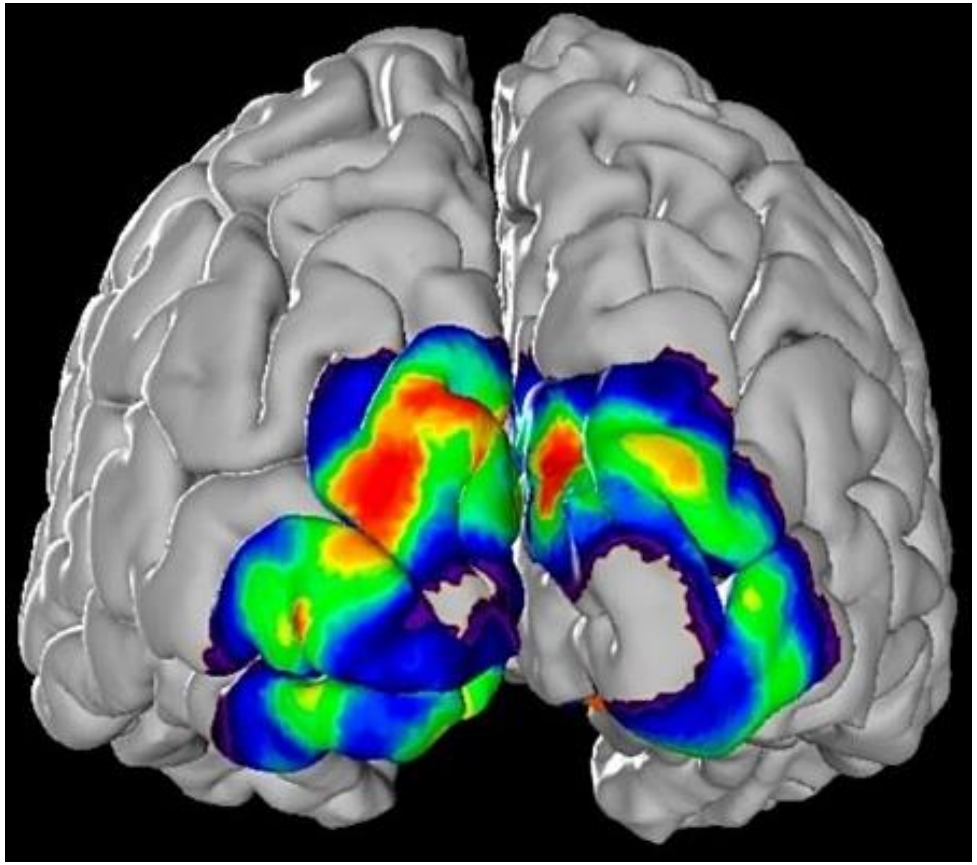
Visual association cortex (/peristriate /extrastriate cortex) (Brodmann areas 18 and 19):

Receives mainly from area 17, plus some direct thalamic projections.

Function = feature extraction (geometric shapes, color, stereopsis, facial recognition, other complex representations).

Most functionally advanced **visual association modules**, operating in parallel:

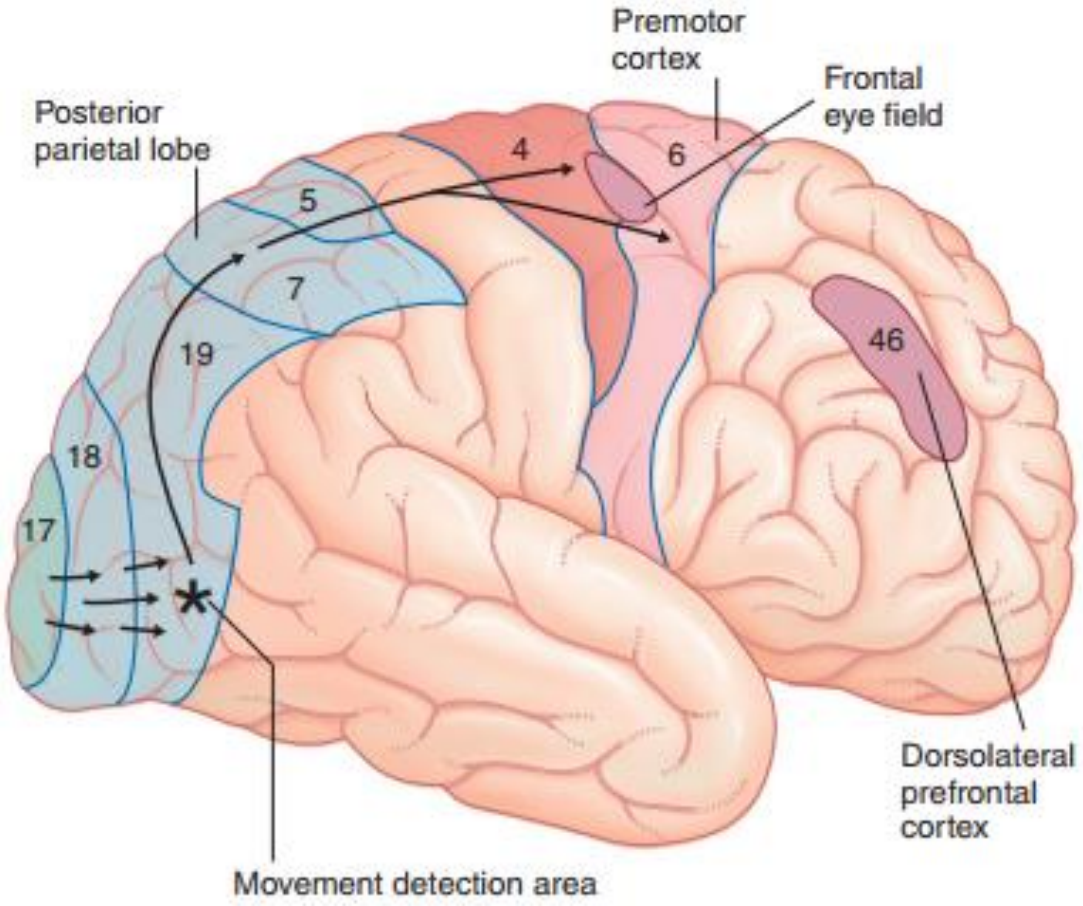
- Where pathway
- What pathway



Visual areas - occipital cortex

'**Where**?' pathway:

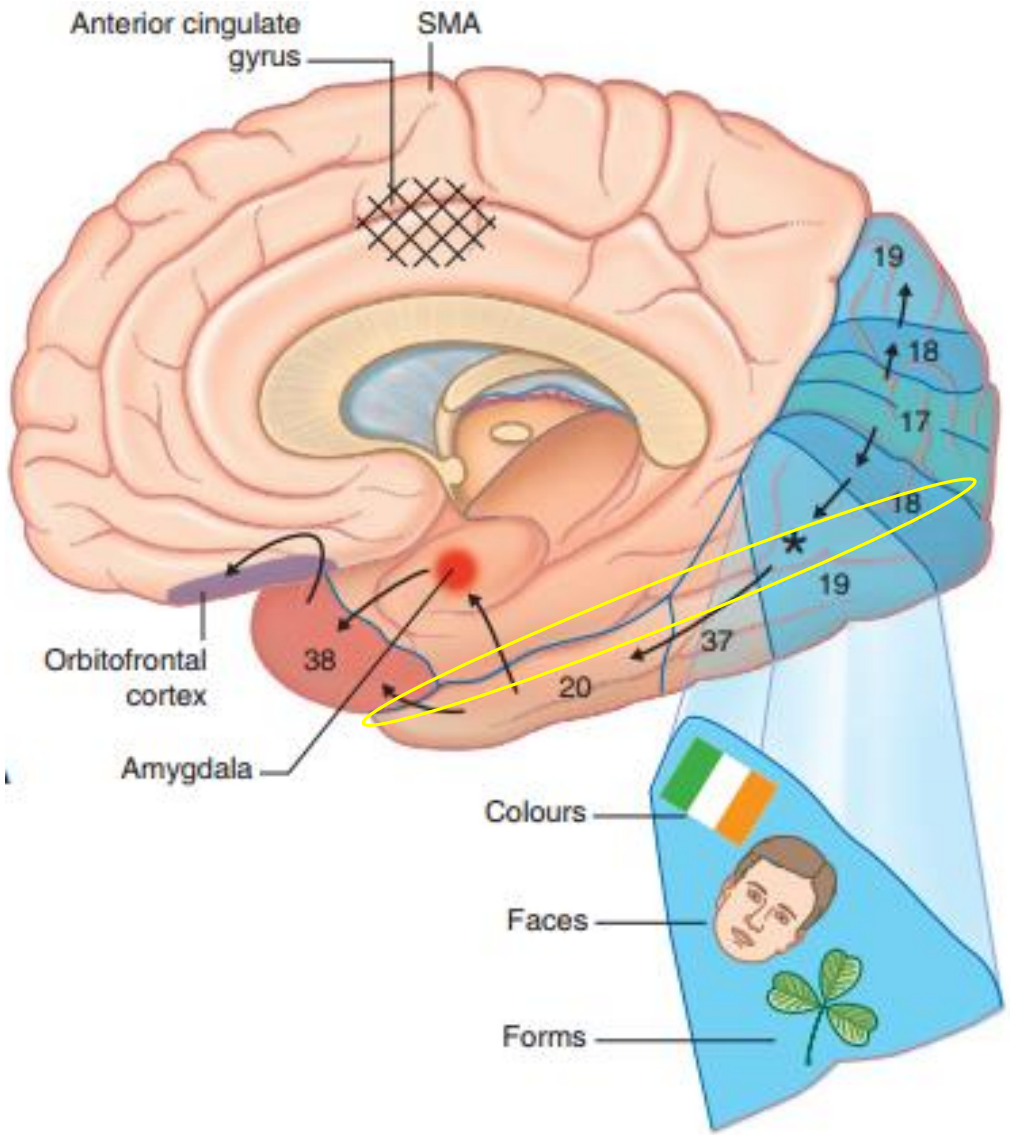
- Dorsal.
- Responsive to **movement** and involved in spatial sense.
- Projects to posterior parietal cortex (area 7) → increases firing rate in frontal eye field and premotor cortex, enabling covert attention (movement is not directly produced, but it will be more precise and ready).
- When items of special interest appear in the field of view, information is also sent to the dorsolateral prefrontal cortex (DLPFC), a decision-making area for approach vs withdrawal behaviors, which in turn activates the anterior cingulate gyrus.



Visual areas - occipital cortex

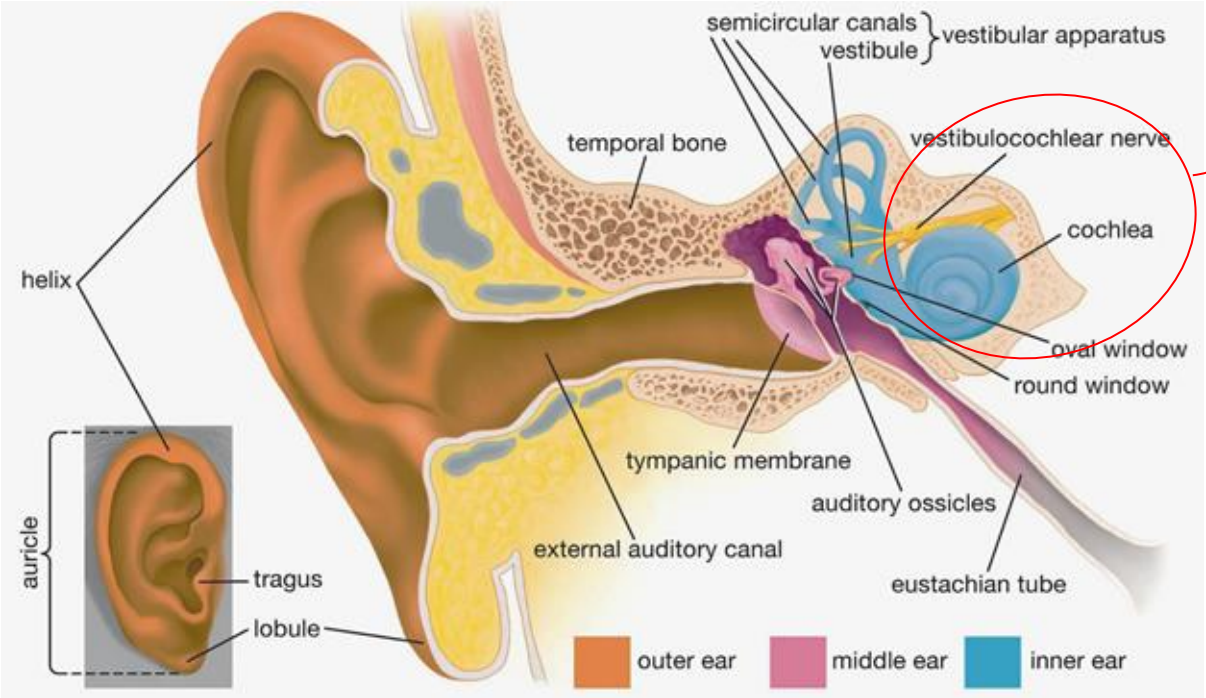
'**What**?' pathway:

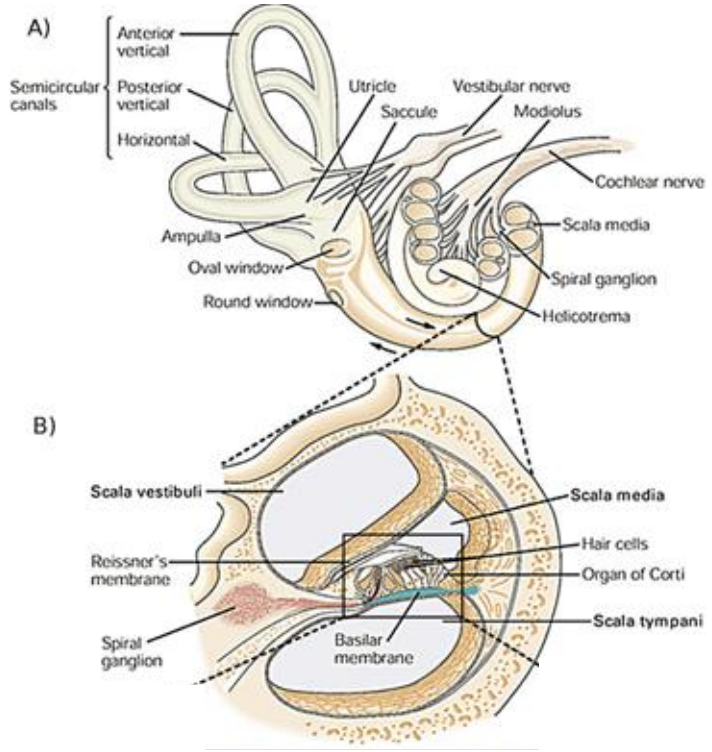
- Medial and ventral, mainly within the fusiform gyrus part of the occipitotemporal gyrus.
- Responsible for 3 kinds of general visual identification: **shapes** (including letters), human **faces**, **colors** (except black and white). Lesions → achromatopsia, prosopagnosia.
- Integration of further nonsensory cognitive and behavioural variables:
  - threatening sights cause amygdala activation;
  - during visual searching, the frontal lobe activate memory stores within the visual association areas, so that the relevant memories are held online during the search (if we don't pay attention, frontal cortex is less active, and we *look* but we don't *see* objects);
  - attention and expectation circuits interact with earlier steps of visual processing, allowing stabilization and interpretation of the visual scene and attributing a meaning.



Hearing

Ear structure





Mechanical vibrations from the middle ear are transmitted by middle ear ossicles (malleus, incus and stapes) → oval window of the inner ear

Hearing

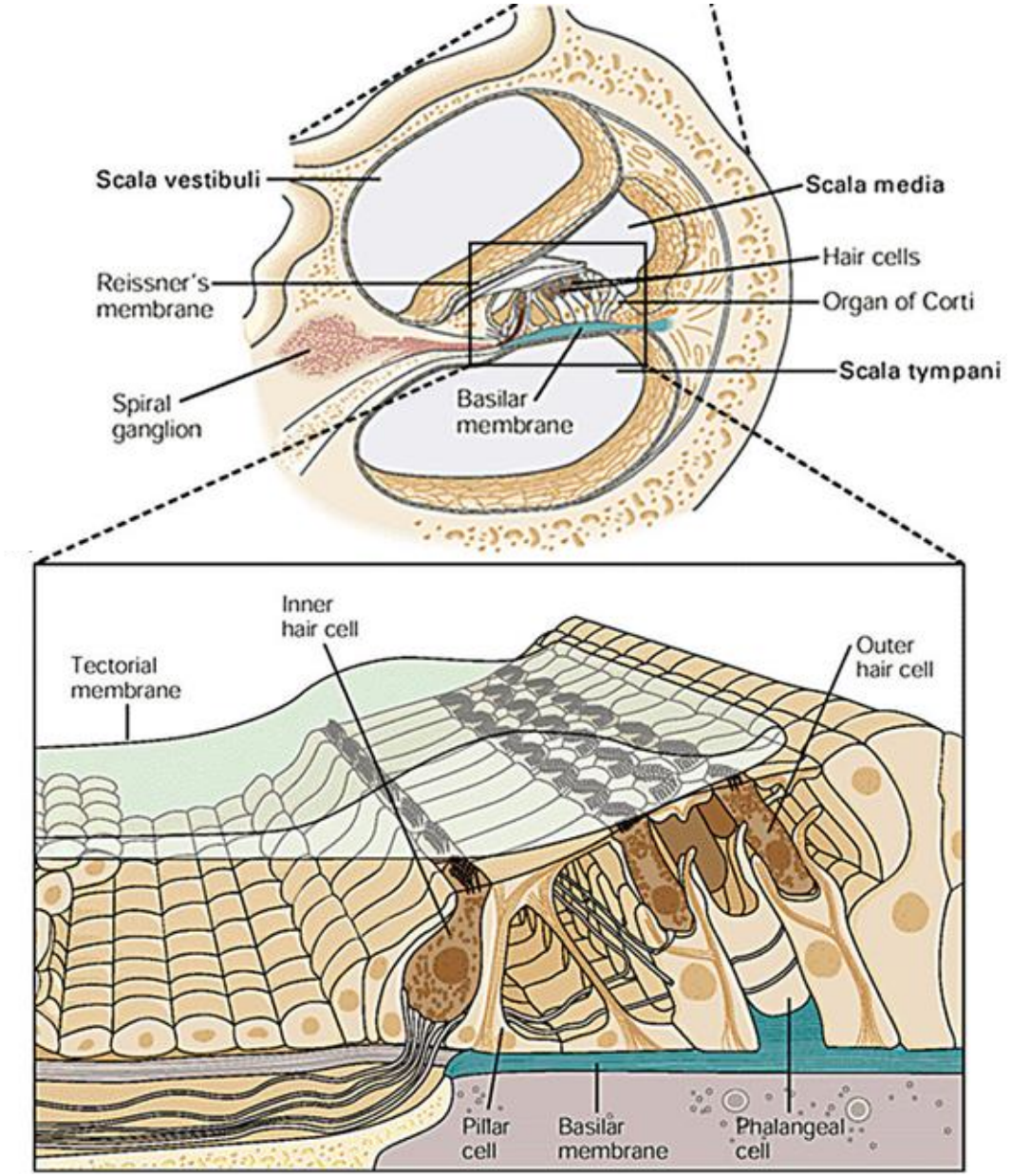
Internal ear structure

Cochlea: snail-shaped organ located in the inner ear that converts sound into nerve impulses.

Tonotopy: high-pitched sounds at the base, low-pitched sounds at the apex.

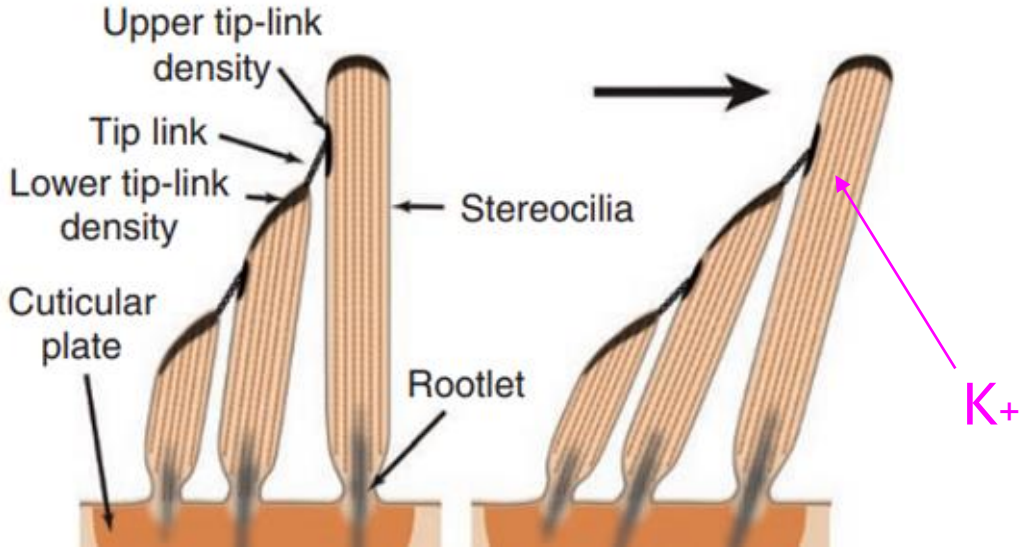
Divided in 3 chambers: scala vestibuli (perilymph), scala media (endolymph), scala tympani (perilymph).

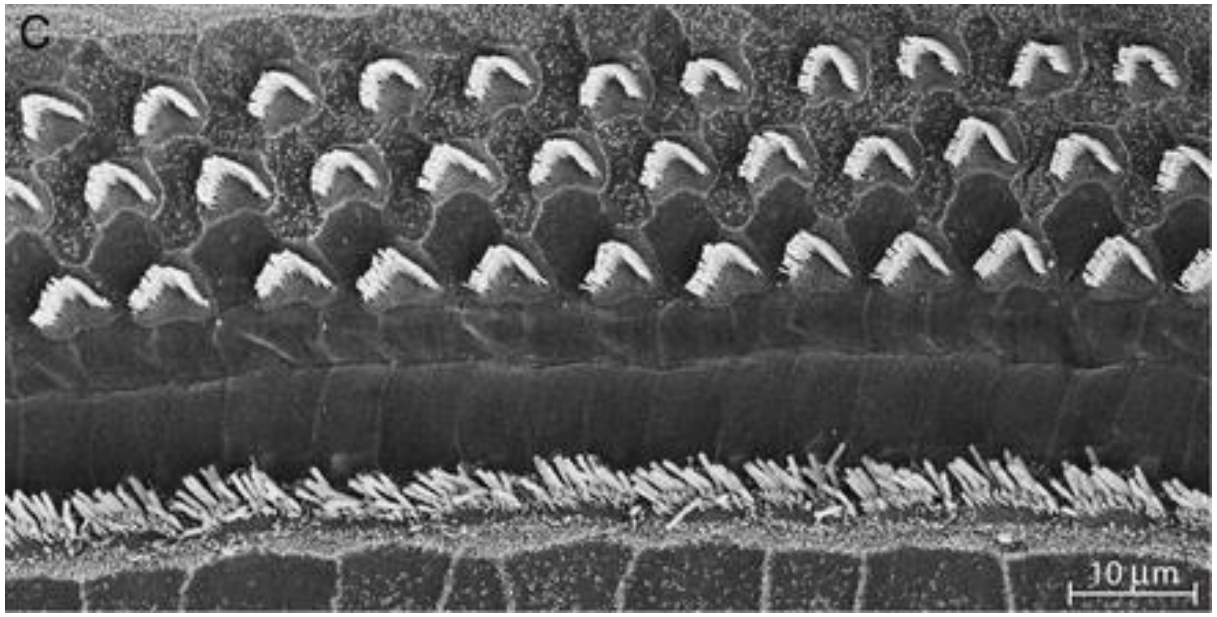
Scala media contains **organ of Corti**

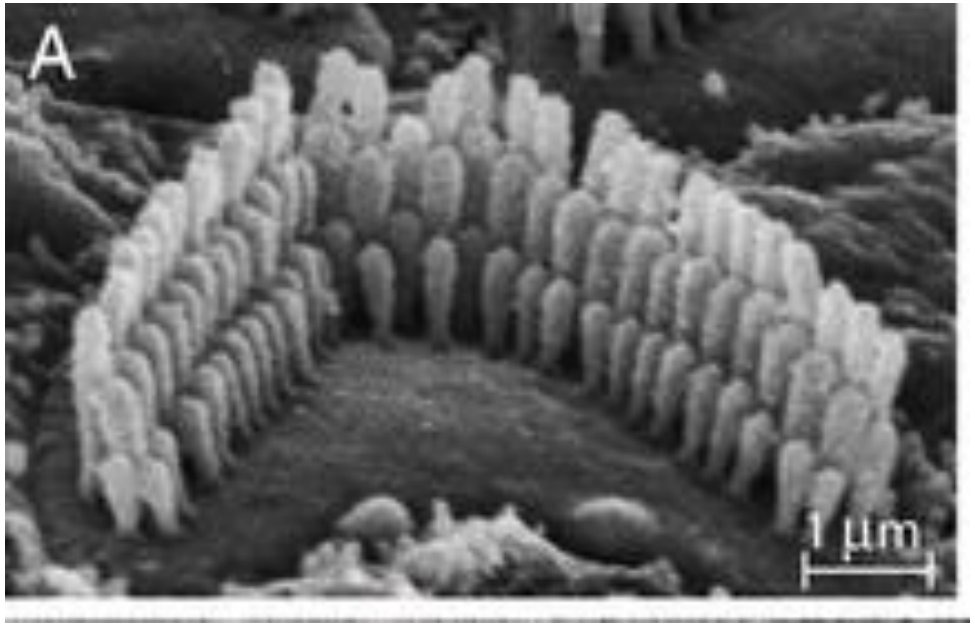


Receptors: inner hair cells

Endolymph moves → basilar membrane resonance + outer hair cells amplification → stereocilia of inner hair cells bend → tip links stretch → cation channels open → potassium ions enter the cells → depolarization → electrical signal.



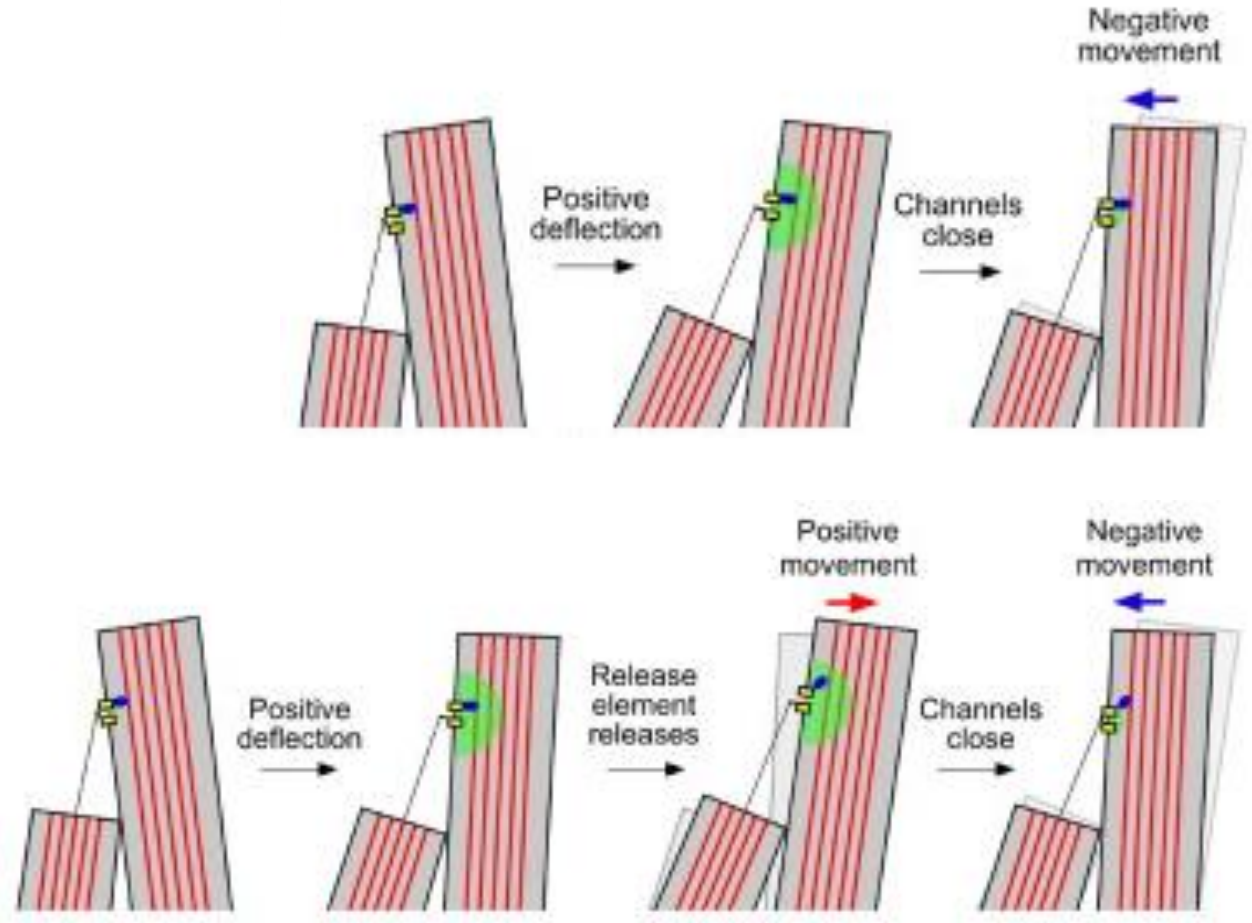




Receptors: inner hair cells

First level of signal elaboration: amplification of new signal and “cancellation” of constant sounds.

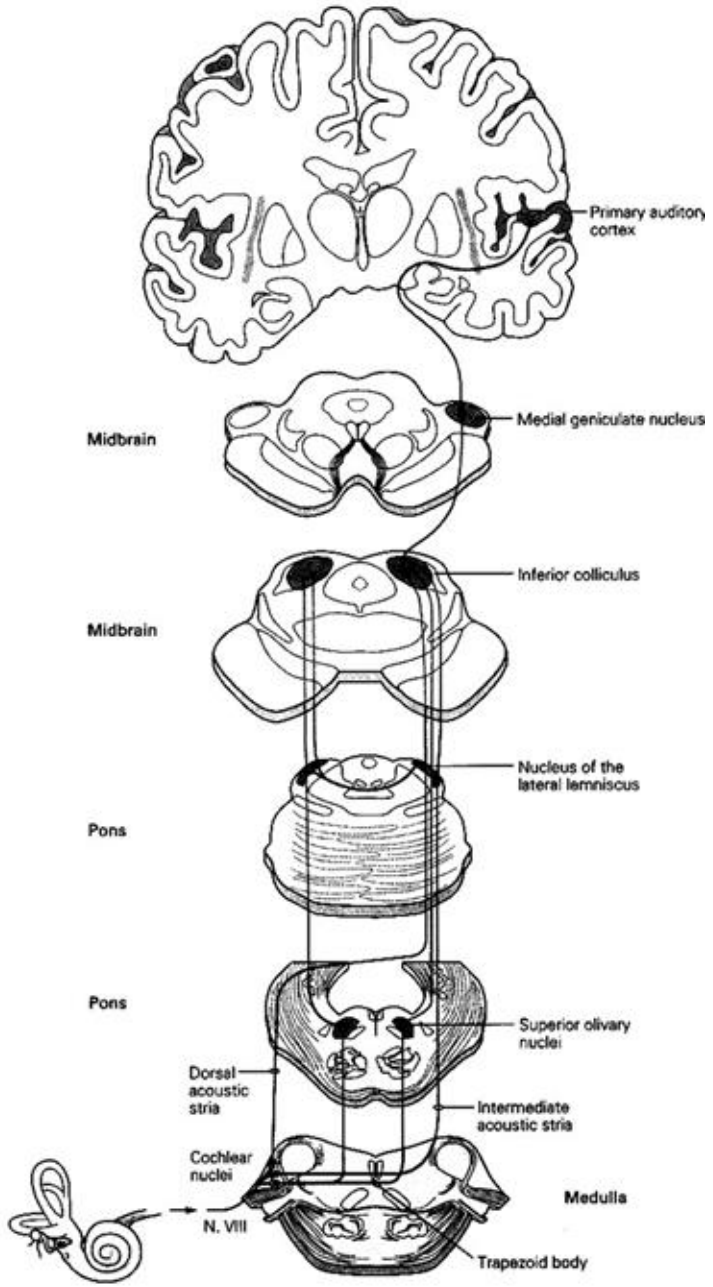
- **Fast adaptation**: Ca2+ ions enter a stereocilium → bind on/near the channel → channel closure → increased tension in the tip link → bundle is pulled in the opposite direction.
- **Slow adaptation**: elevated tension during bundle displacement → myosin-1c protein slides down the stereocilium → tension decreases → channels close → decline in transduction current.

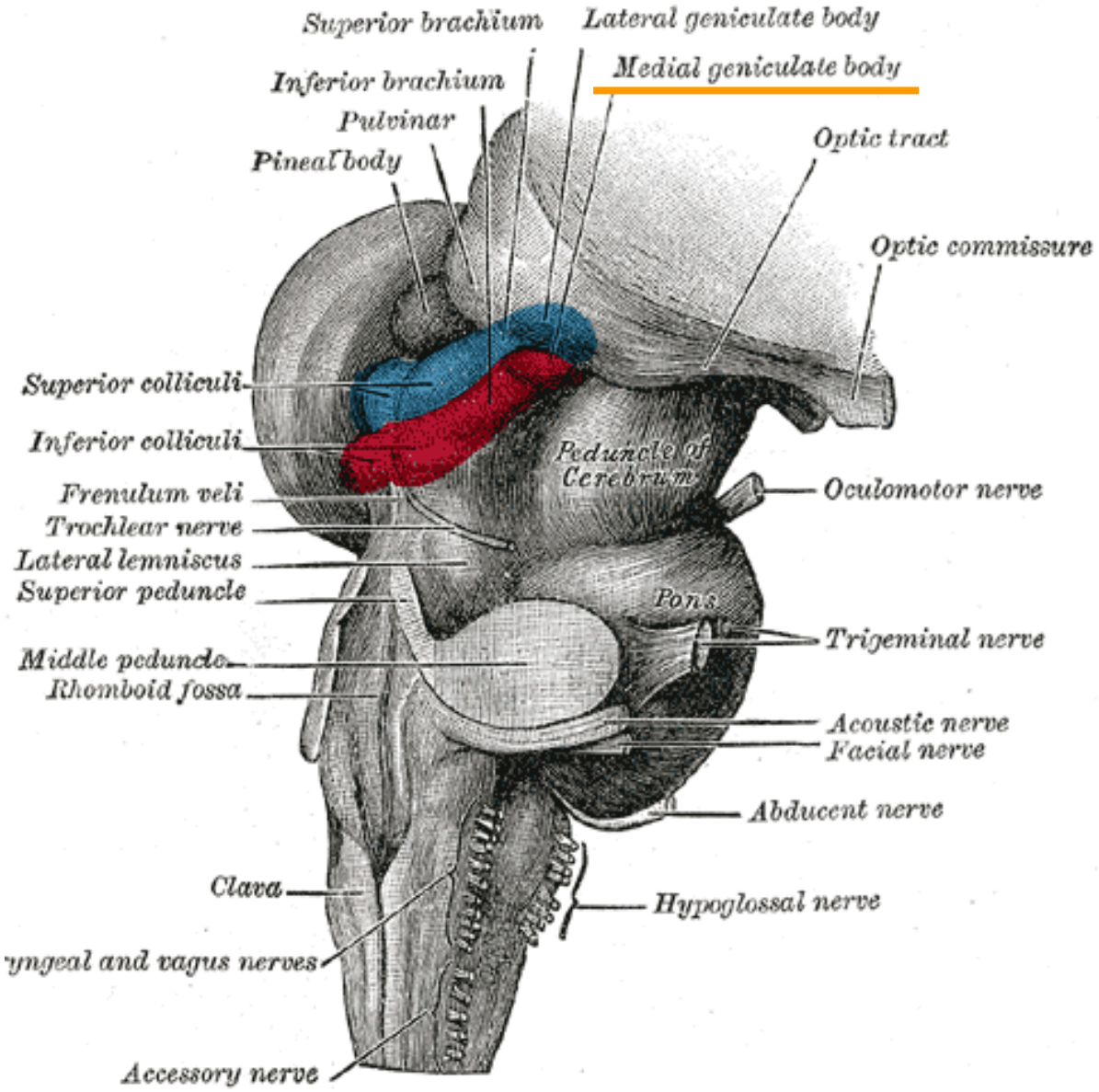


Auditory pathways

1. Ipsilateral auditory (**cochlear**) **nerve**: traverses the subarachnoid space together with the vestibular nerve and close to facial nerve, and it enters the brainstem at the pontomedullary junction. Its neuronal bodies are in the spiral ganglion.
2. Ipsilateral **cochlear nucleus**
3. **Superior olivary complex** (the majority of fibers decussate to the contralateral superior olivary complex)
4. Contralateral and ipsilateral **lateral lemniscus nuclei**
5. Contralateral and ipsilateral **inferior colliculus**
6. Contralateral and ipsilateral **medial geniculate nuclei**
7. Contralateral and ipsilateral **transverse temporal gyrus** (auditory region)

Some neurons ascend directly from the cochlear nucleus to the contralateral medial geniculate body.





Inferior colliculi: part of the quadrigeminal plate. Functions: auditory inputs localization, integration with other sensory modalities, auditory reflexes control (e.g. startle response, head and eye movements). Project to thalamus.
Bilateral lesions → deafness; unilateral lesions → inability to localize sounds. E.g. tumors, hydrocephalus.

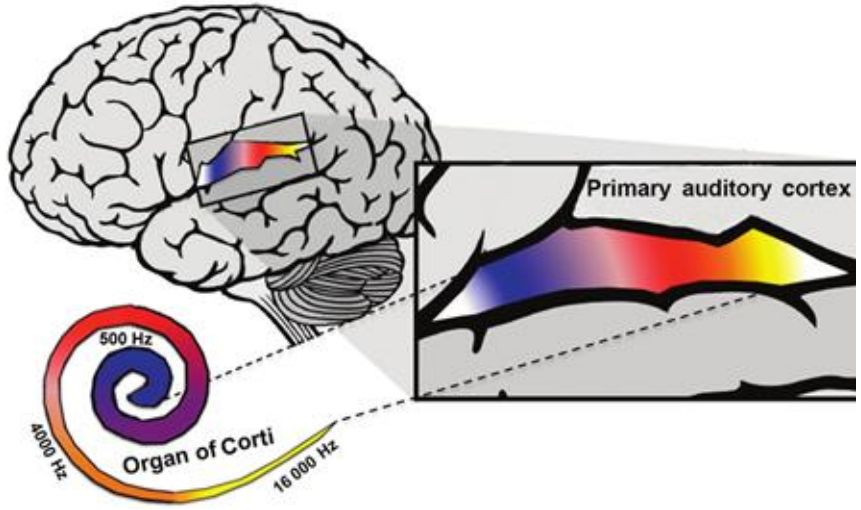
Medial geniculate nucleus (MGN) (/body): final subcortical relay station in the auditory pathway. Located in the caudal thalamus. Receives from the inferior colliculus, projects to the primary auditory cortex.

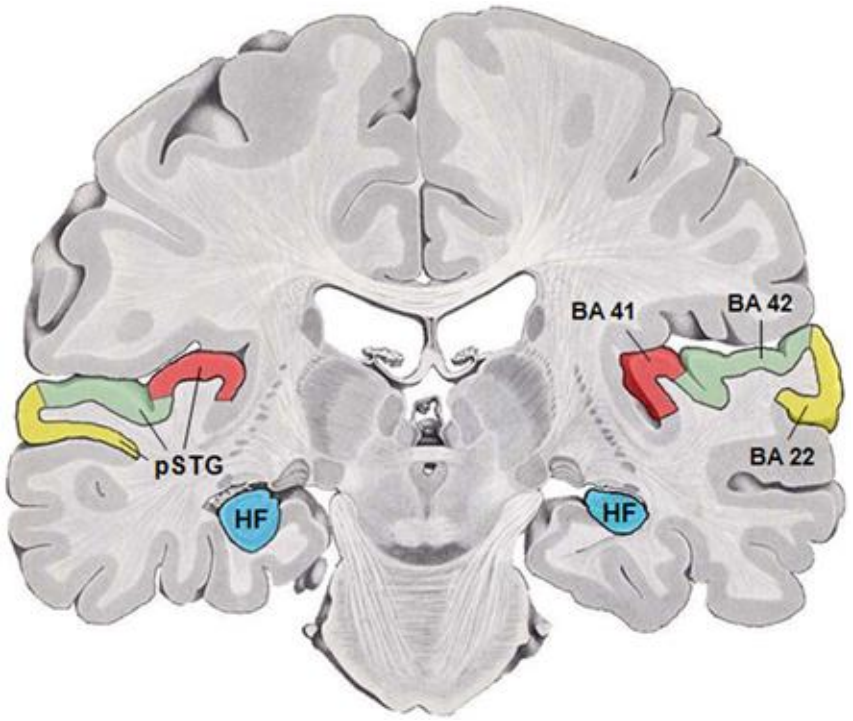
Auditory cortex

Curves over and down into the other side of the Sylvian fissure.

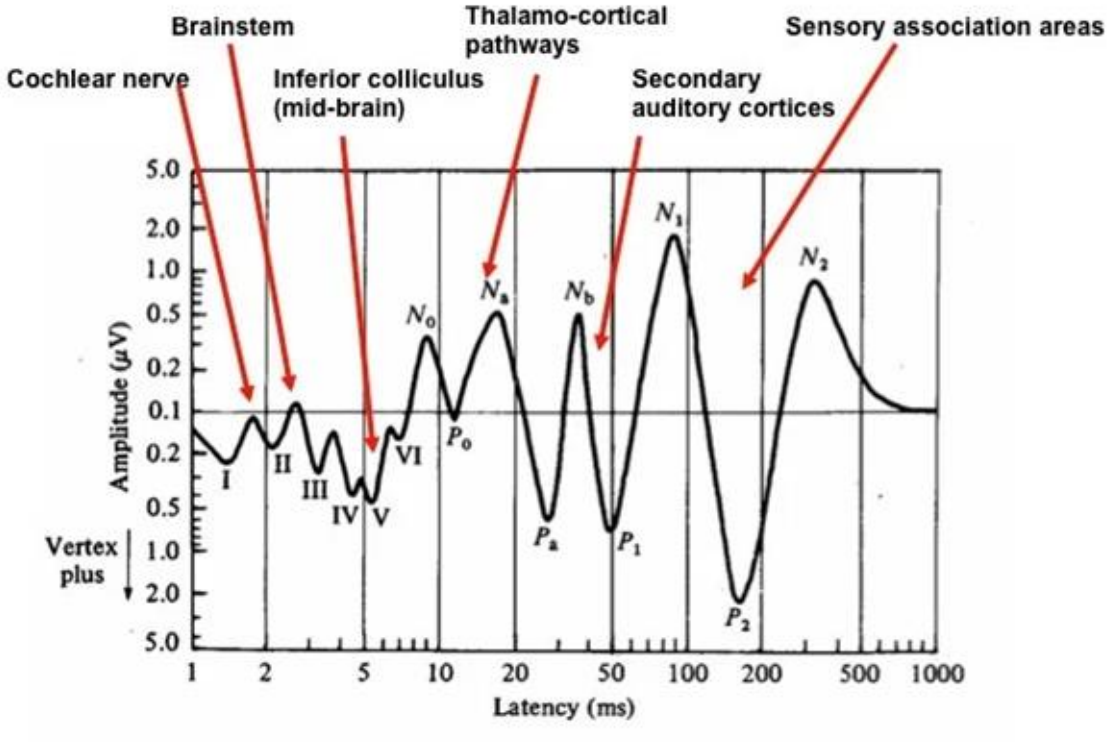
Primary (A1 /core), secondary (A2 /belt) and tertiary (A3 /parabelt) areas.

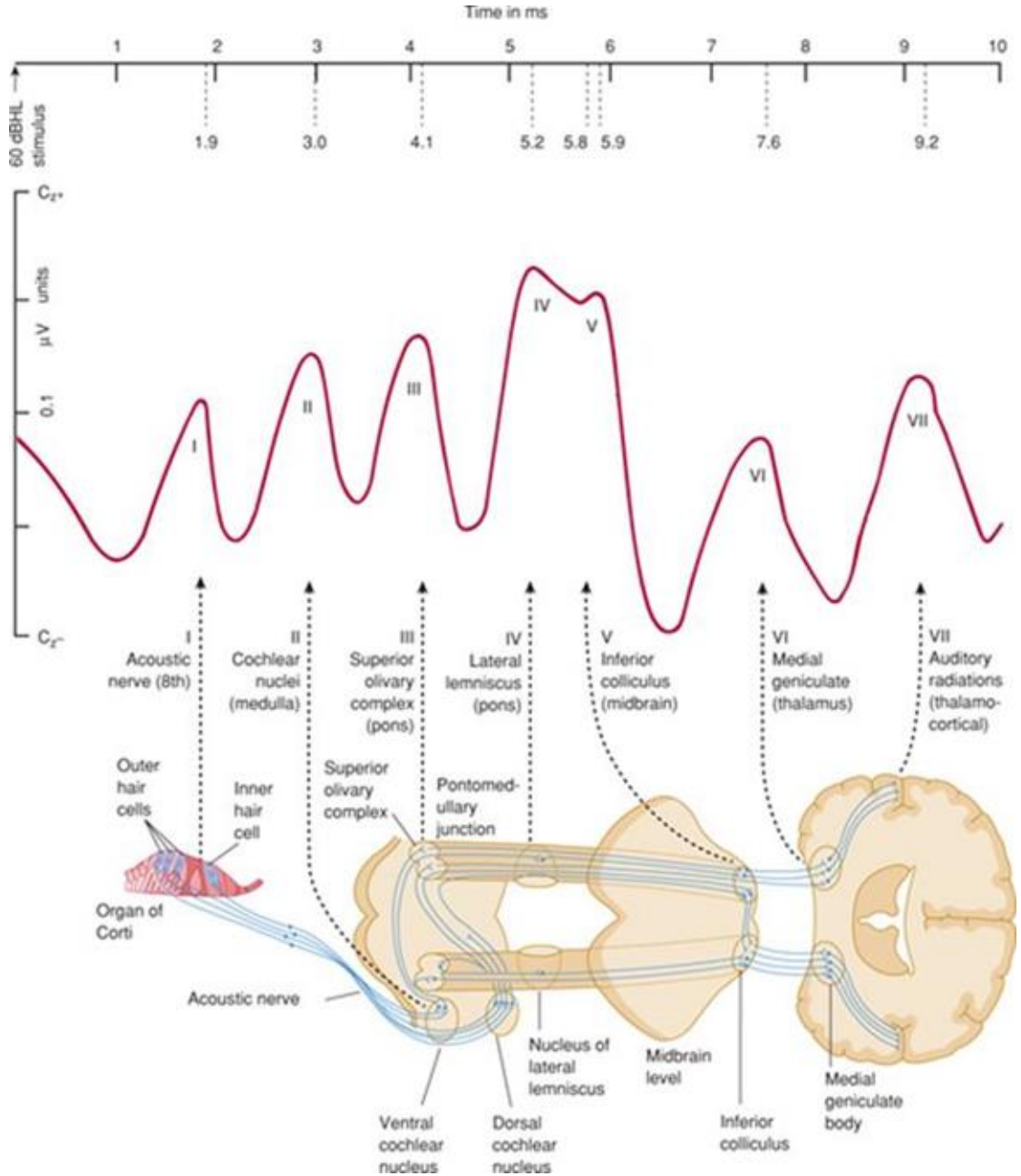
- **Attenuation**: specialized neurons at multiple levels of the auditory pathway respond optimally to sounds within defined intensity ranges, permitting discrimination between louder and softer environmental stimuli.
- Most of the auditory pathway is binaural → **spatial location** is encoded within the superior olivary complex through comparison of auditory input delays from right vs left sides of the head.
- **Tonotopy** → frequency is perceived as pitch.
- **Combination-sensitive** units = subset of auditory neurons that respond selectively to specific acoustic elements. Present at all levels of the auditory pathway, contribute to the detection of salient auditory cues.



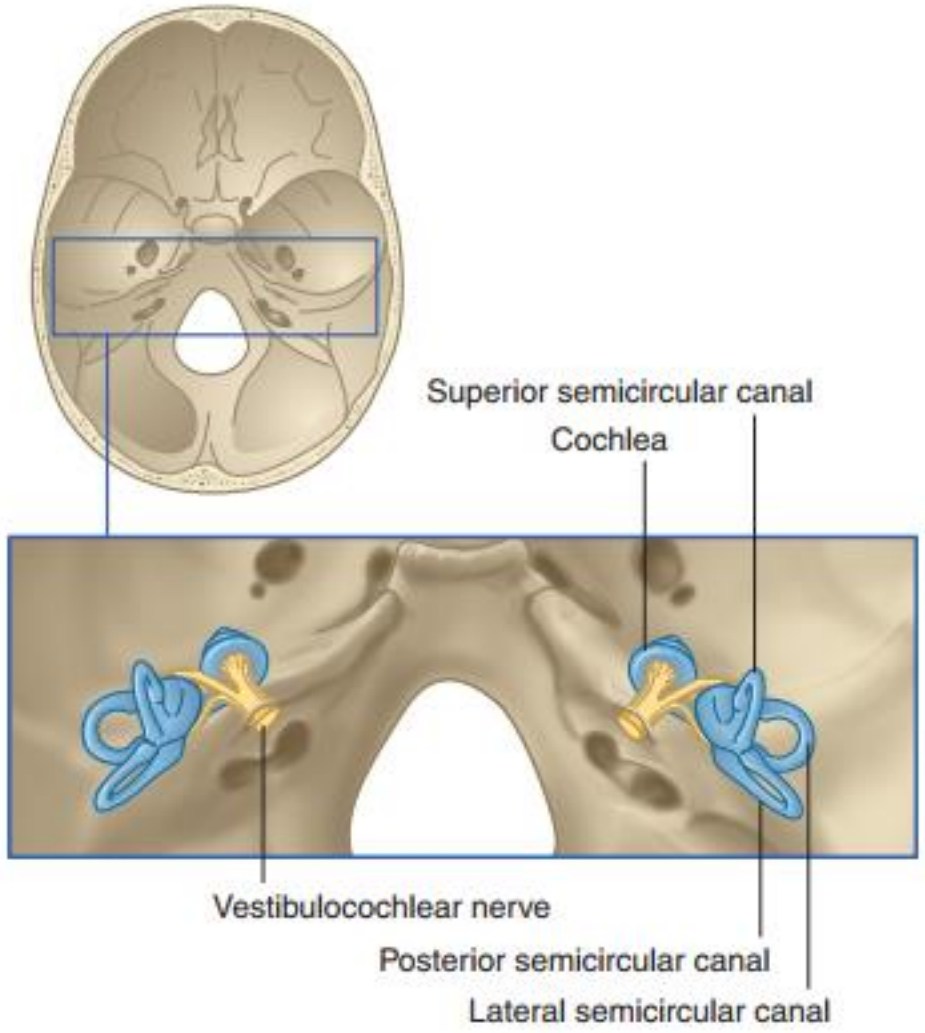


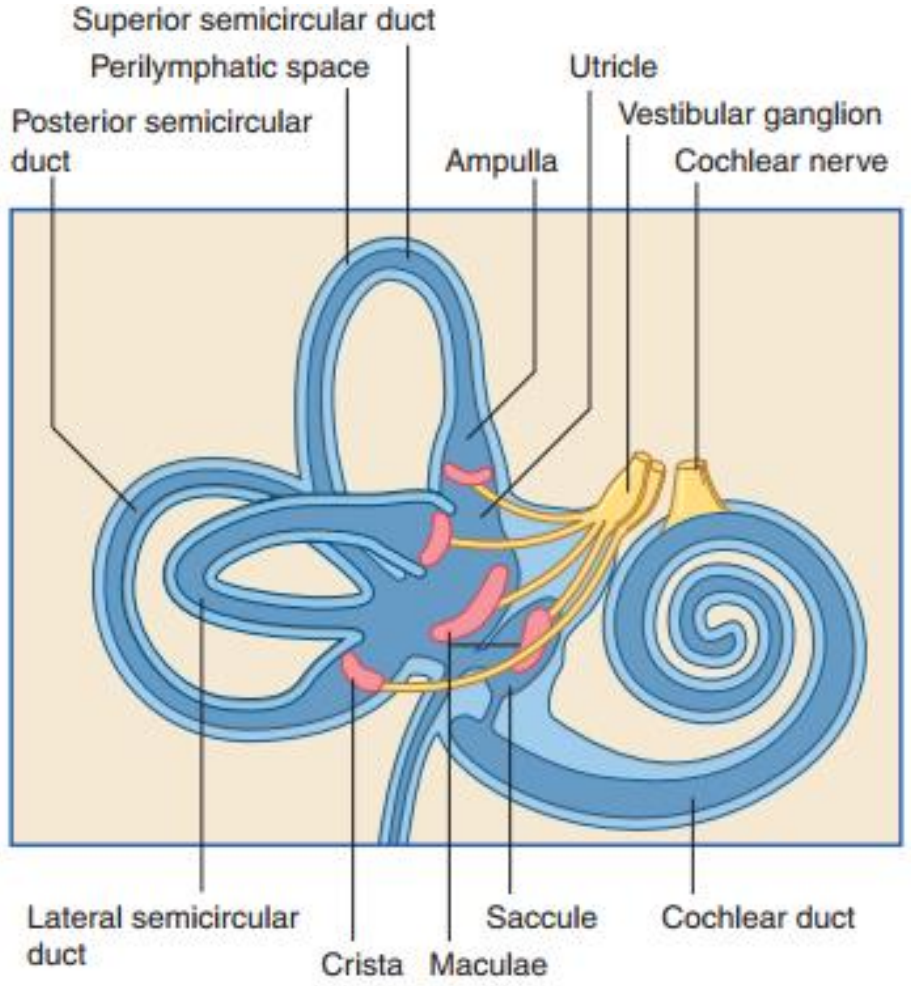
Auditory evoked potentials





Spatial orientation and balance

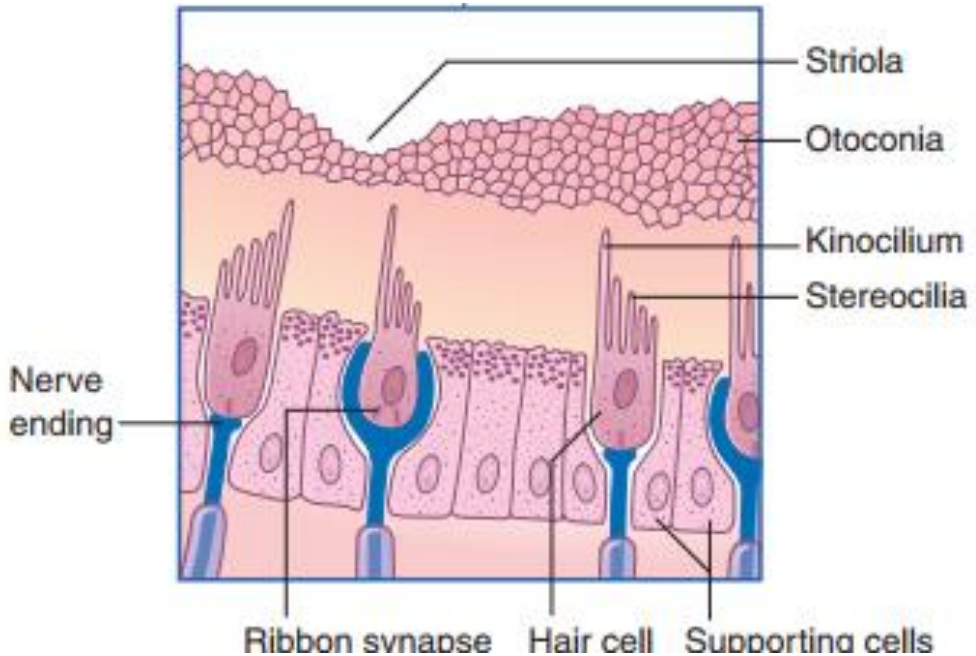


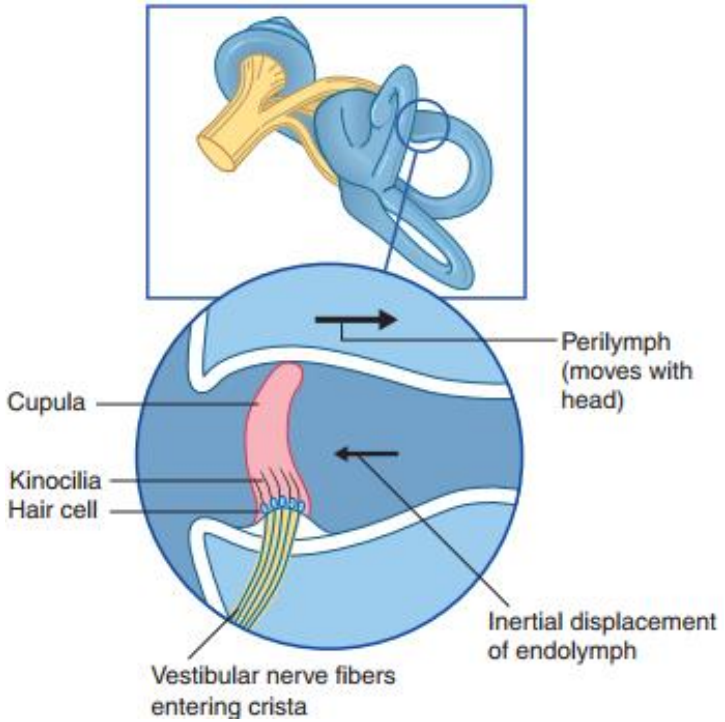


Receptors = **hair cells**. They have a single long kinocilium and approximately 100 stereocilia. Their continuous discharge is modulated by depolarization (cilia towards kinocilium) or hyperpolarization (cilia away from kinocilium).

- Static labyrinth (head positioning): hair cells' cilia are embedded in the **otolithic membrane** containing otoconia (protein-bound calcium carbonate crystals) in 2 **maculas**, in **utricle** and **saccule**. They move when gravity displaces the otoconia.
- Kinetic or dynamic labyrinth (head movement): hair cells' cilia are embedded in the **cupulae** in 3 **cristae**, located in the ampulla of each one of the **semicircular ducts** (/canals). They move when the endolymph displaces the cupula (≅ sail) during angular accelerations.

5 **vestibular organs**



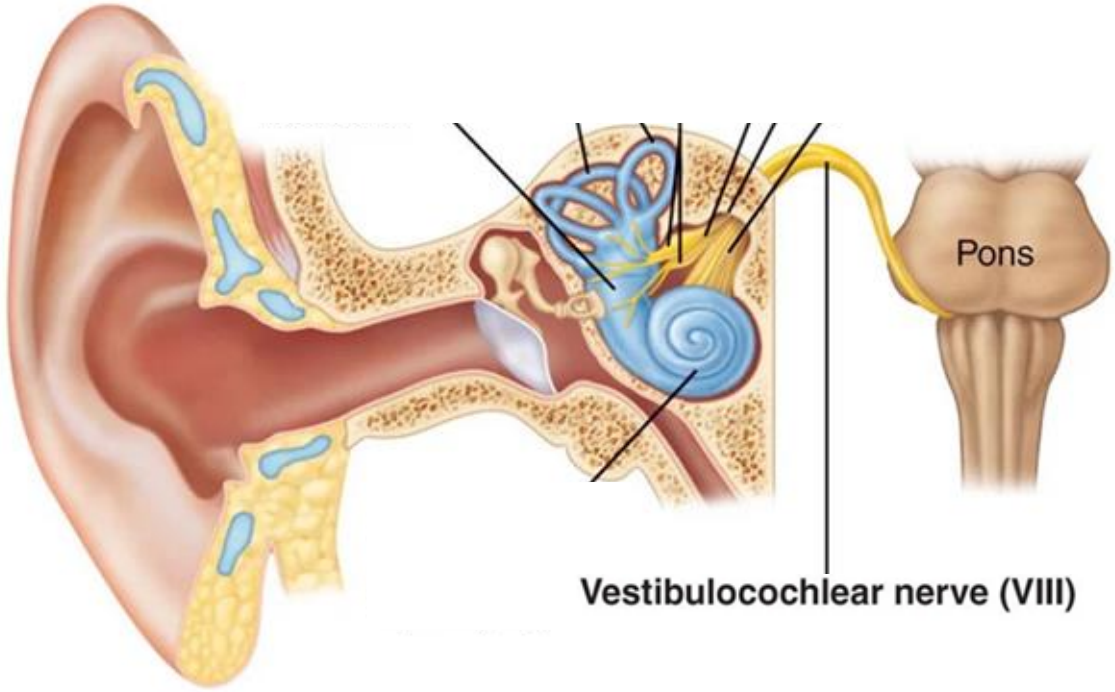


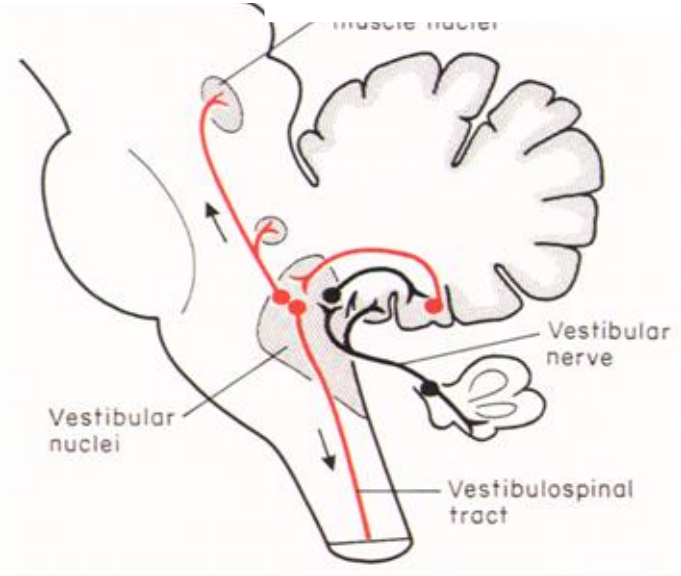
Vestibular pathways

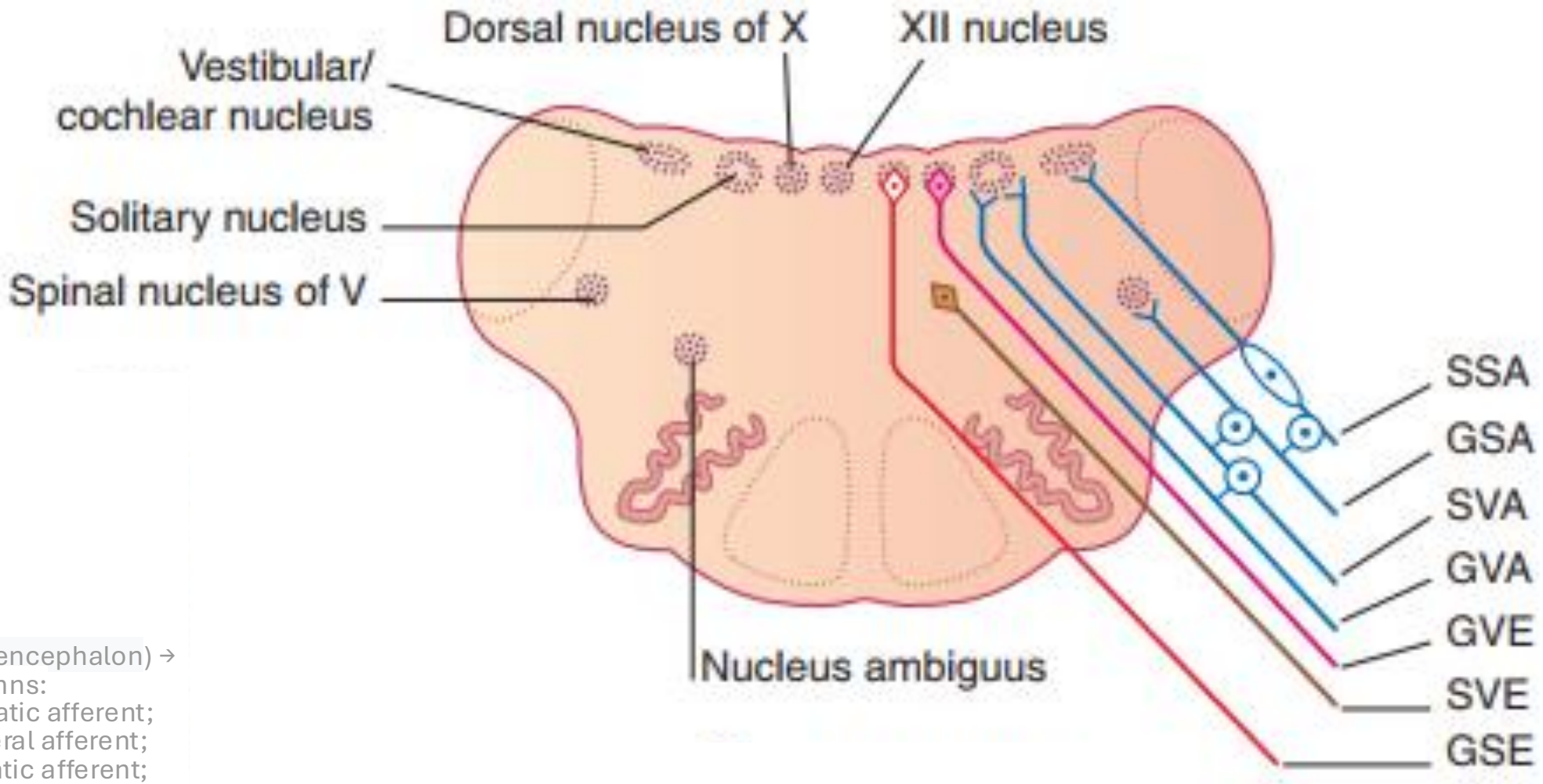
Information from the 5 vestibular organs travels through the bipolar cells that constitute the vestibular part of the **vestibulocochlear nerve**.
Neuronal bodies = in the vestibular (Scarpa) ganglion.

The nerve passes in the internal acoustic meatus, cross the subarachnoid space and synapse in the ipsilateral **vestibular nucleus**.

Vestibular nuclei are two-way connected with the flocculonodular lobe of the cerebellum.



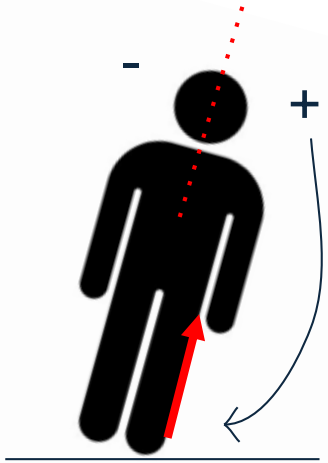




Hindbrain (rhombencephalon) →
Afferent cell columns:
GSA, general somatic afferent;
GVA, general visceral afferent;
SSA, special somatic afferent;
SVA, special visceral afferent.
Efferent cell columns:
GSE, general somatic efferent;
GVE, general visceral efferent;
SVE, special visceral efferent.

Vestibular pathways

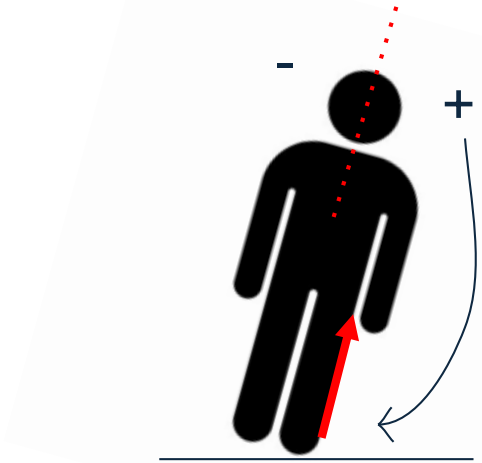
Afferents from the static labyrinth reach the **lateral vestibular nucleus**
→ **lateral vestibulospinal tract** in the medulla oblongata descends in the ipsilateral ventral funiculus of the spinal cord → increases muscle tone in the lower extremity antigravity extensors. Functions = standing, walking, fall landing, balance.

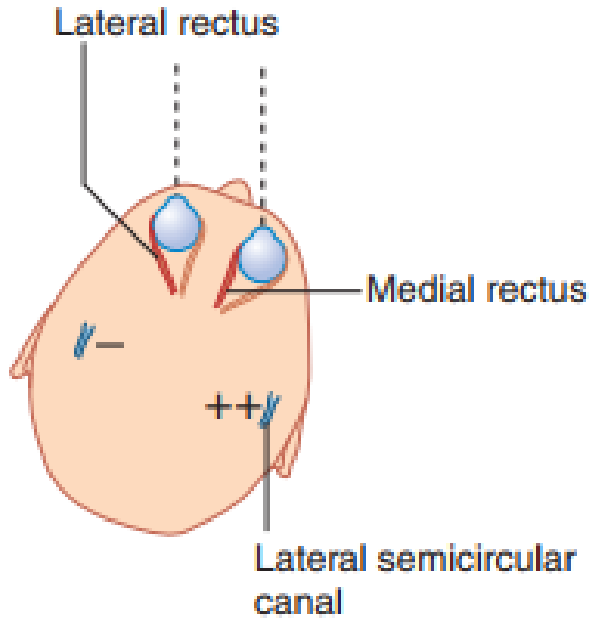


Vestibular pathways

Afferents from the static labyrinth reach the **lateral vestibular nucleus**
→ **lateral vestibulospinal tract** in the medulla oblongata descends in the ipsilateral ventral funiculus of the spinal cord → increases muscle tone in the lower extremity antigravity extensors. Functions = standing, walking, fall landing, balance.

Afferents from kinetic labyrinth reach **medial and superior vestibular nuclei**, key component of vestibulo-ocular reflexes (compensatory movements of the eyes in response to movement of the head). Functions = gaze stability. If dysfunctions → nystagmus.



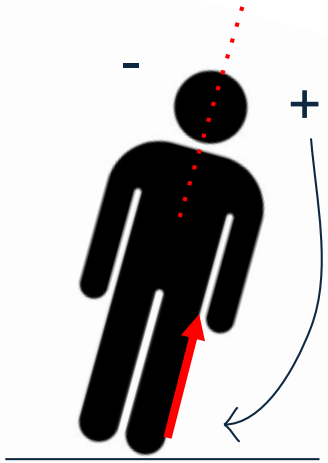


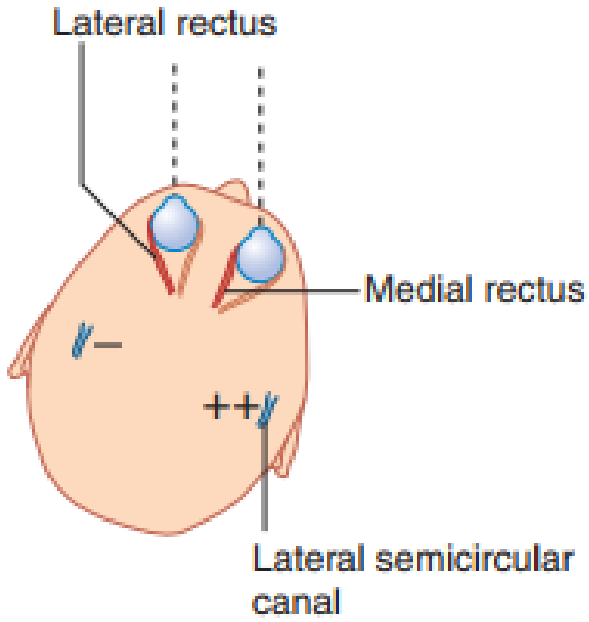
Vestibular pathways

Afferents from the static labyrinth reach the **lateral vestibular nucleus**
→ **lateral vestibulospinal tract** in the medulla oblongata descends in the ipsilateral ventral funiculus of the spinal cord → increases muscle tone in the lower extremity antigravity extensors. Functions = standing, walking, fall landing, balance.

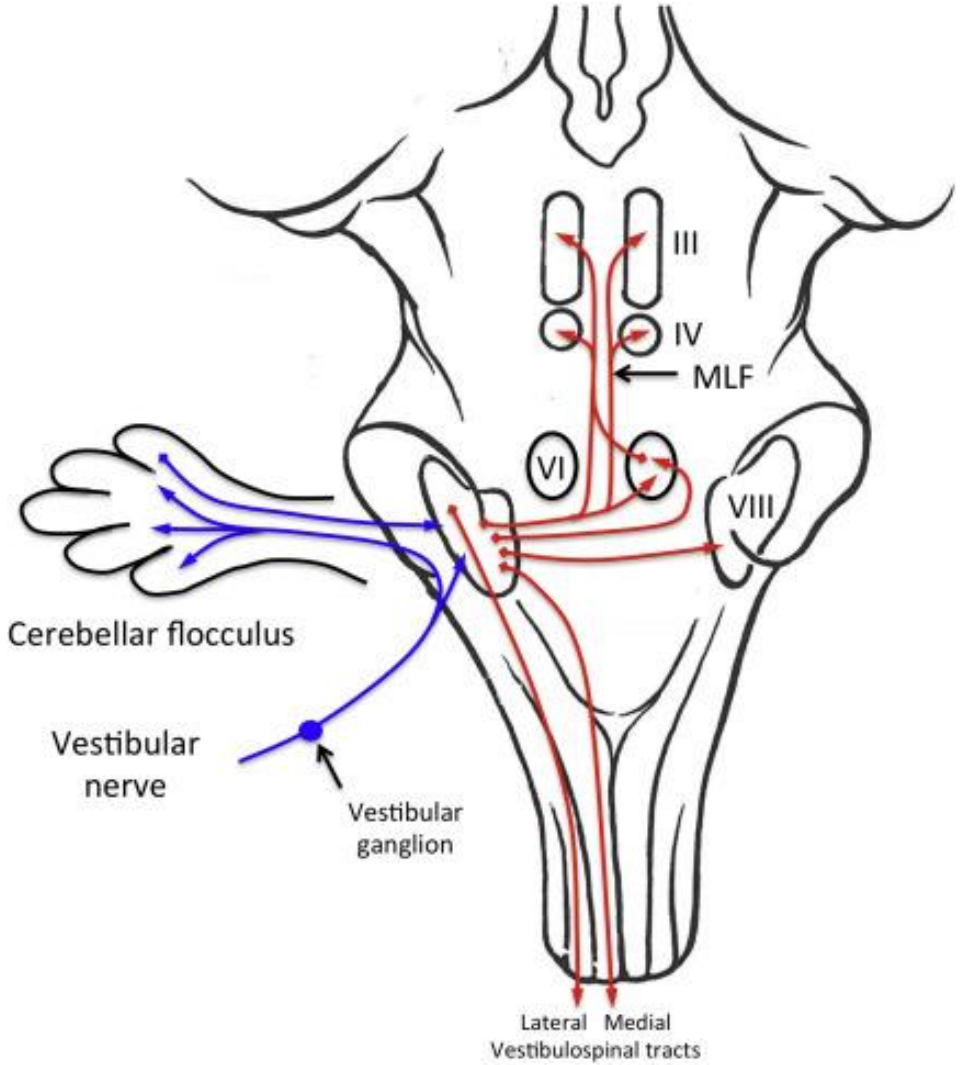
Afferents from kinetic labyrinth reach **medial and superior vestibular nuclei**, key component of vestibulo-ocular reflexes (compensatory movements of the eyes in response to movement of the head). Functions = gaze stability. If dysfunctions → nystagmus.

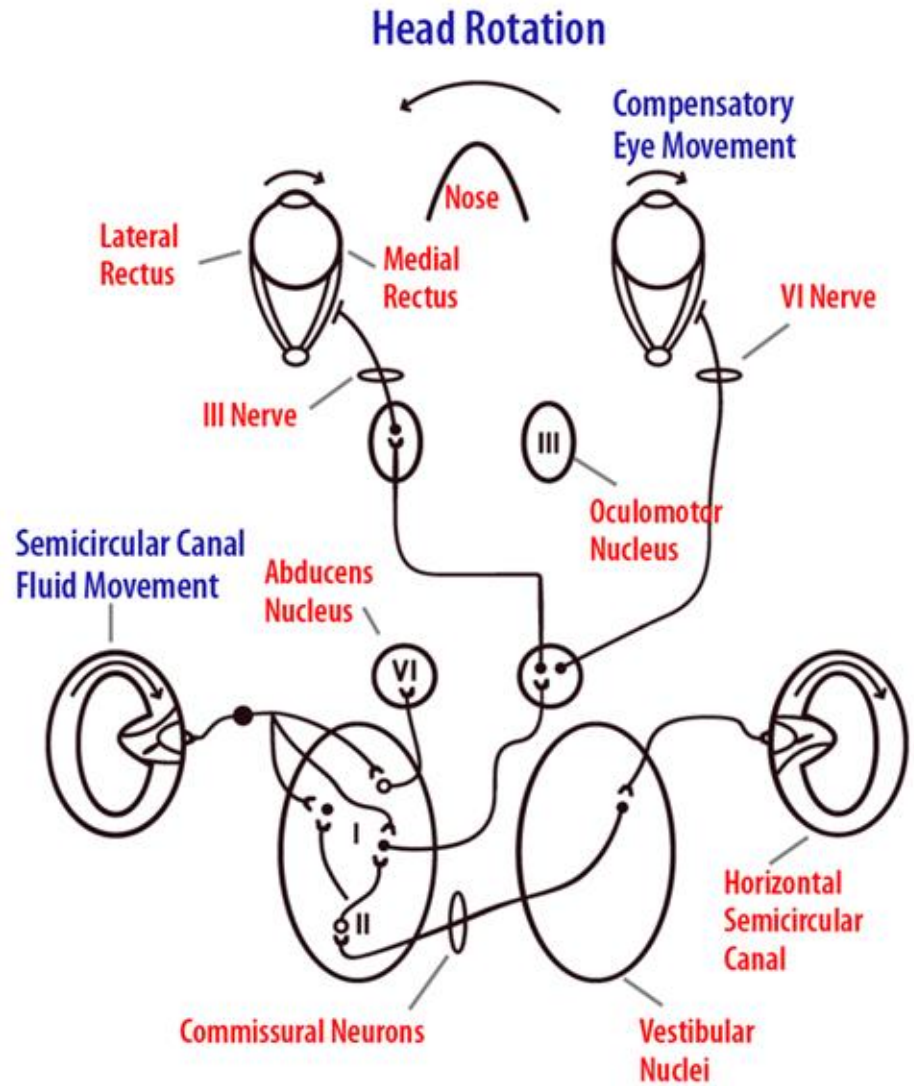
Information from both the labyrinths (medial and inferior vestibular nuclei) enter the **medial vestibulospinal tract**, involved in head-righting reflexes (keep the head and the gaze horizontal when the body is tilted).



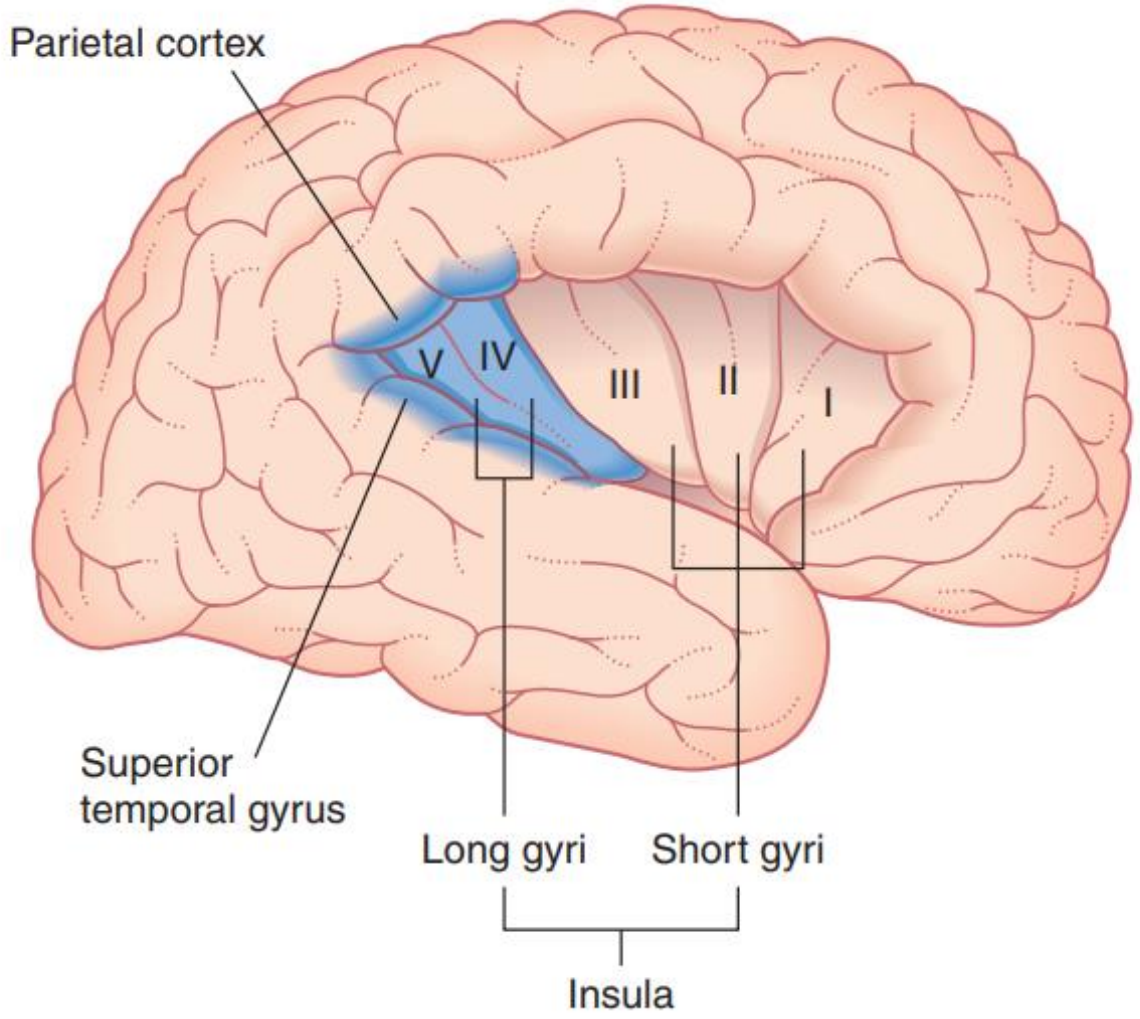





III
IV
MLF
VI
VIII
Cerebellar flocculus
Vestibular nerve
Vestibular ganglion
Lateral Medial
Vestibulospinal tracts


Head Rotation
Compensatory Eye Movement
Nose
Lateral Rectus
Medial Rectus
VI Nerve
III Nerve
III
Oculomotor Nucleus
Semicircular Canal Fluid Movement
Abducens Nucleus
VI
I
II
Horizontal Semicircular Canal
Commissural Neurons
Vestibular Nuclei

Parietoinsular vestibular cortex

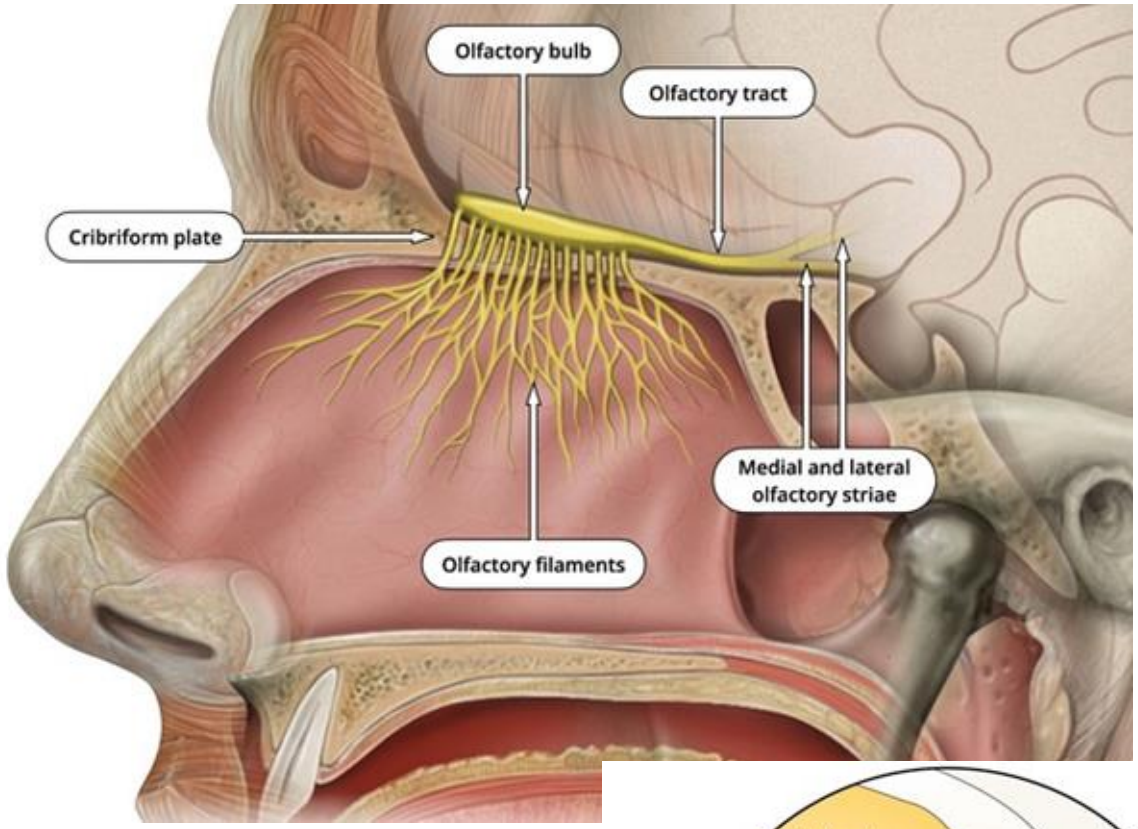


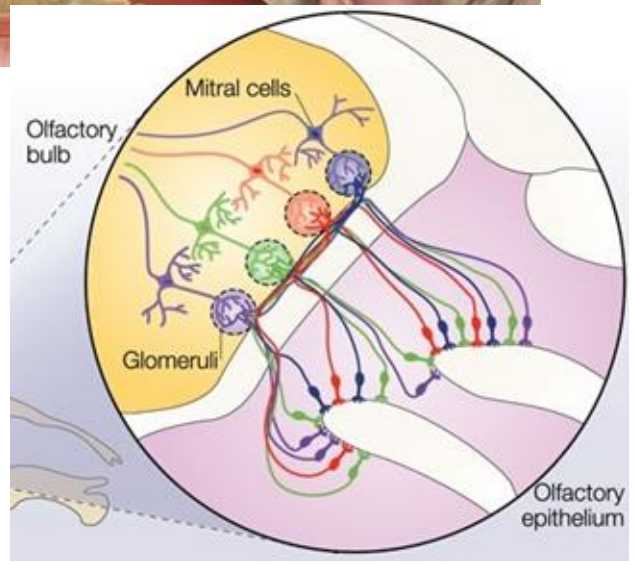
Second-order neurons from the vestibular nuclei project to the ventral posterior nucleus of the ipsilateral thalamus → to parietoinsular vestibular cortex (PIVC) and adjacent regions.

The PIVC is not a primary vestibular sensory area, as it is multisensory (visual, tactile, vestibular).

Smell (olfaction)

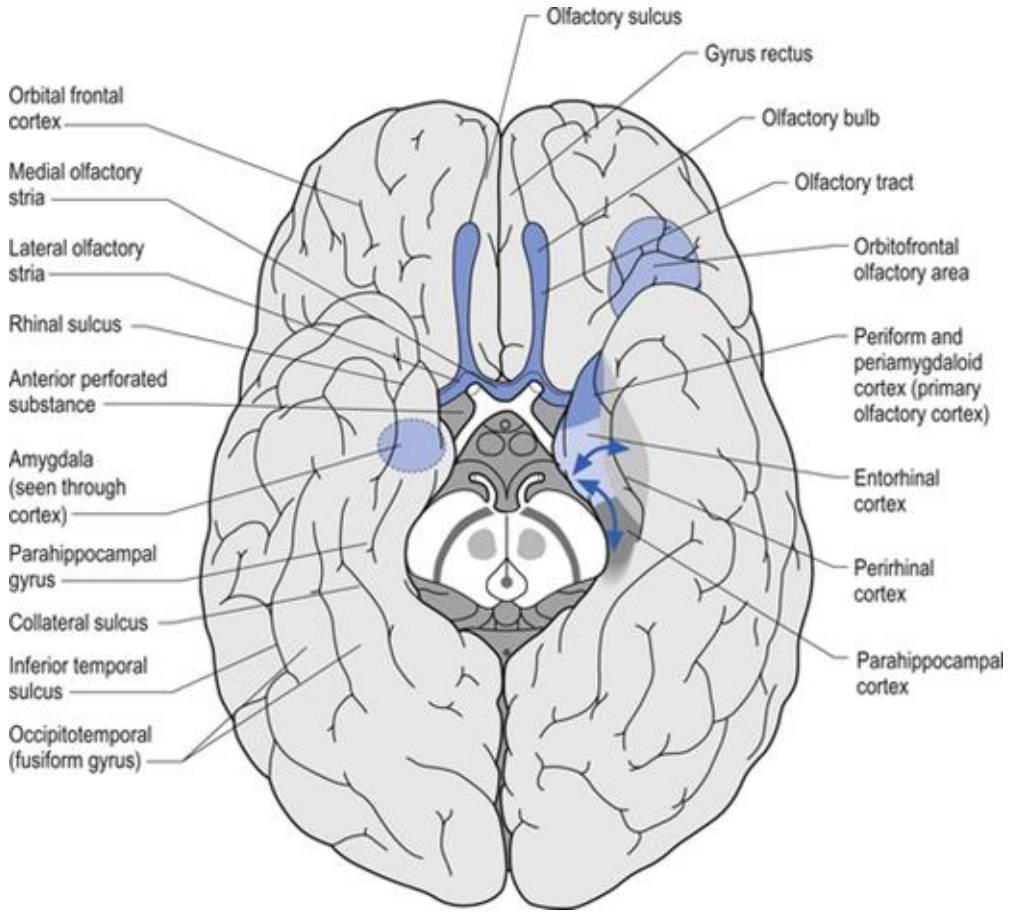
- Olfactory **epithelium**: in the superior nasal cavity. Olfactory sensory neurons have cilia that selectively bind odorant molecules.
- Olfactory **nerve** (CN I): axons of the olfactory sensory neurons, unmyelinated, pass through the cribriform plate.
- Olfactory **bulb**: synapse point, input is processed in olfactory glomeruli.
- Olfactory **tract**: bundle of axons from the mitral/tufted cells (second-order neurons).

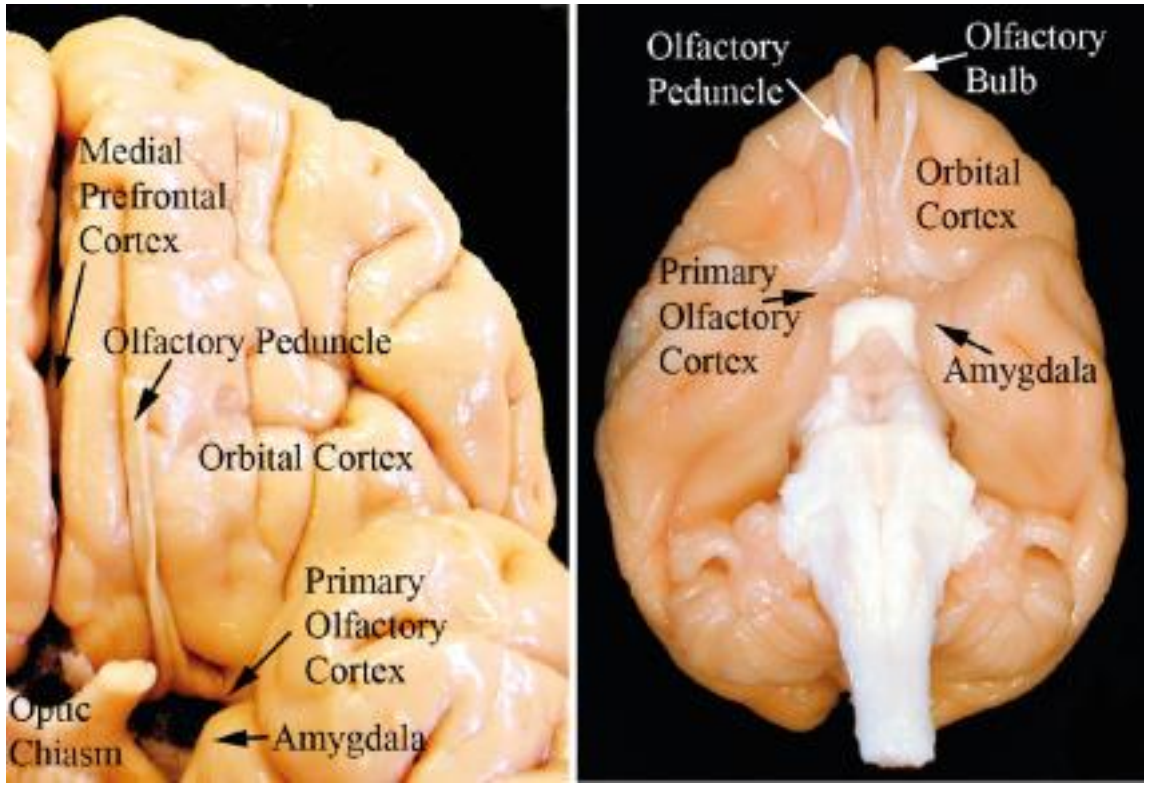




Lateral olfactory tract

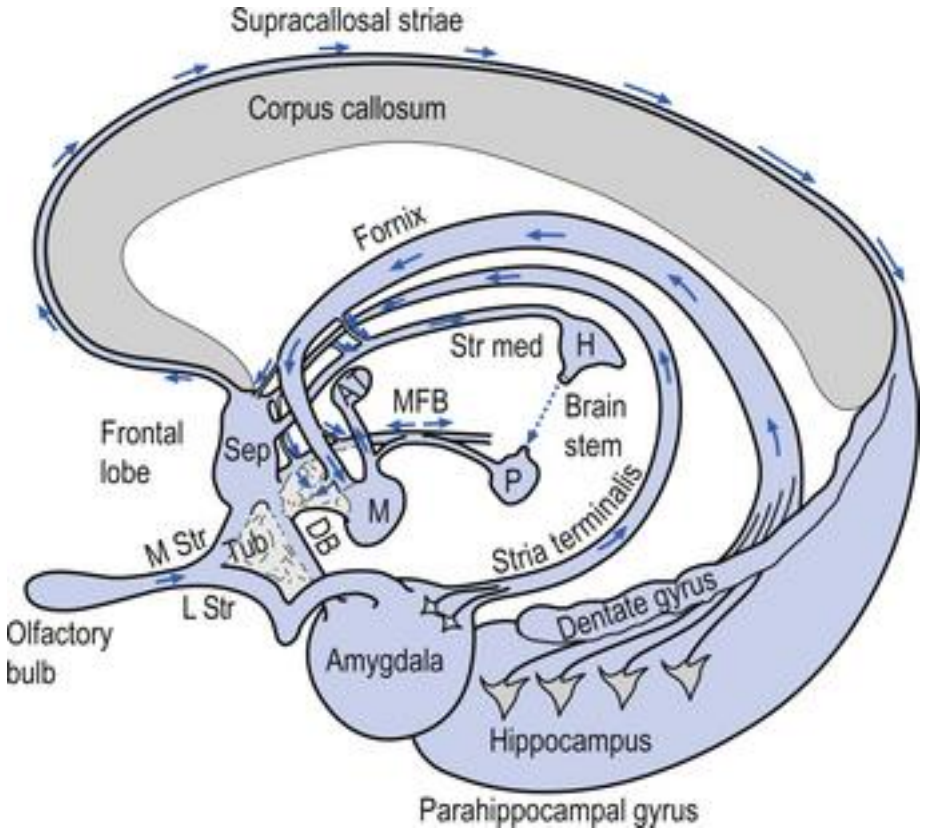
Main pathway. Conveys odor information to the primary olfactory cortex, located on the ventral surface of the frontal and temporal lobes and composed of uncus, piriform cortex, entorhinal cortex, and amygdala.

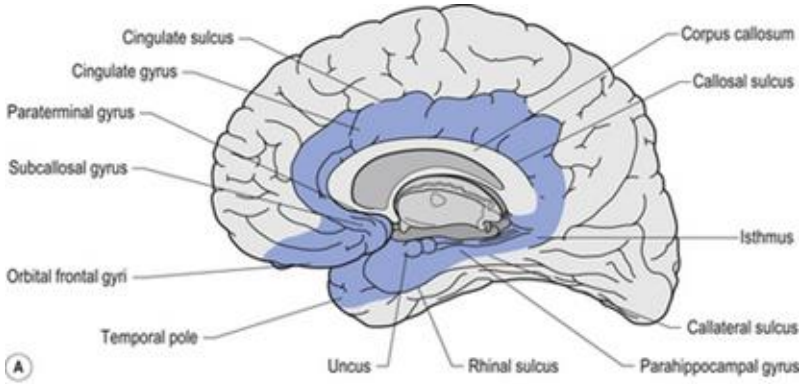


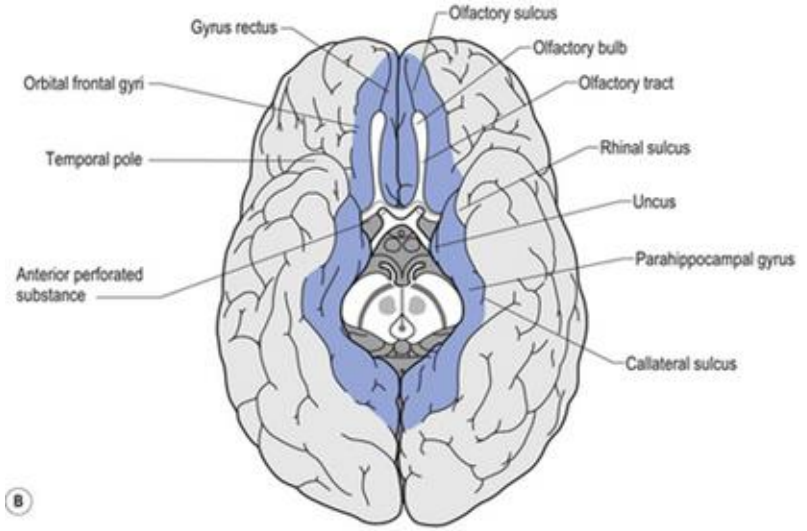


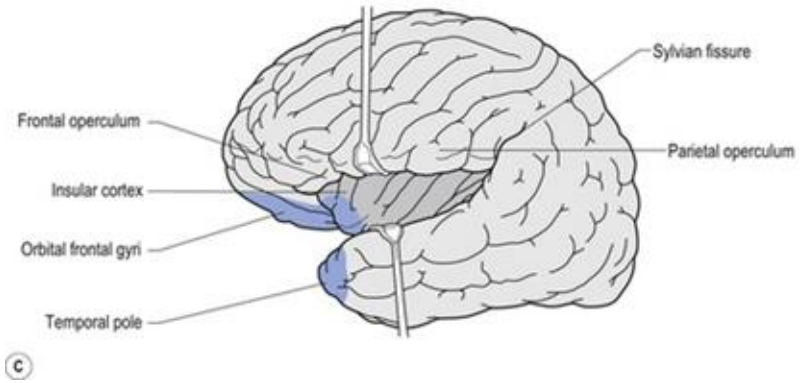
Medial olfactory tract

- Projects to the **limbic system** and contralateral bulb via the anterior commissure.
- Mediates emotional, memory, and autonomic responses to olfactory stimuli.







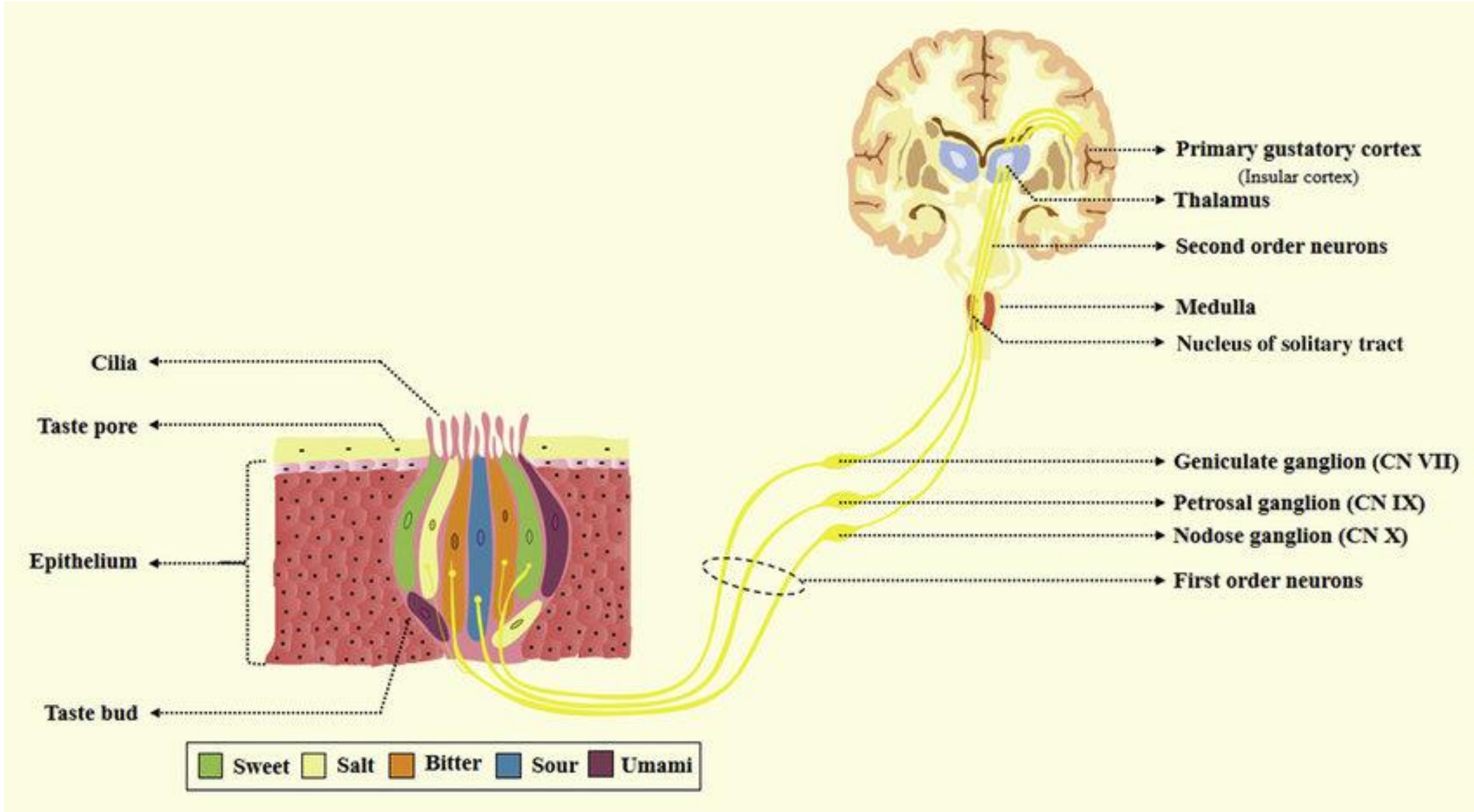


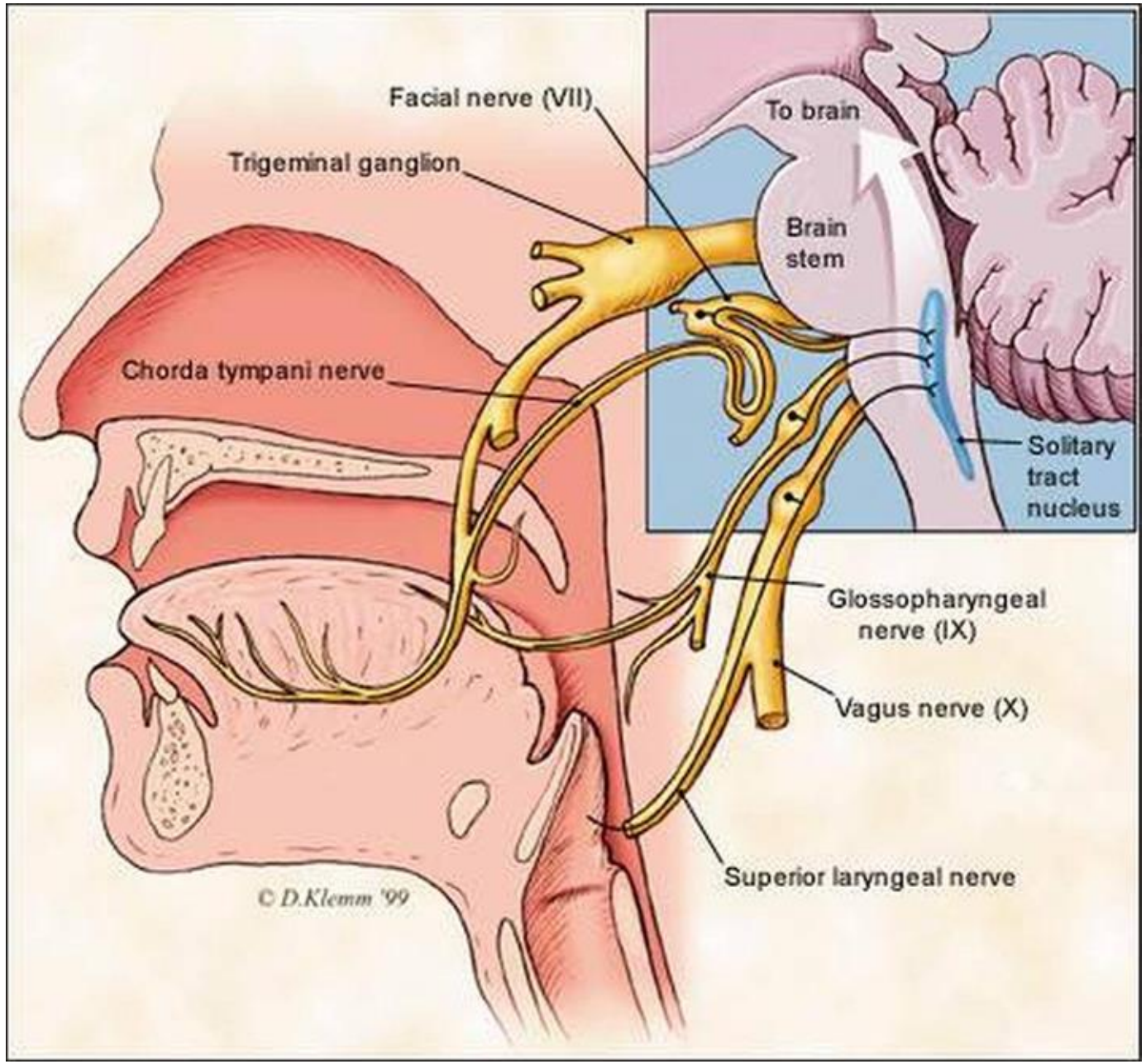
Taste

Gustatory pathway:

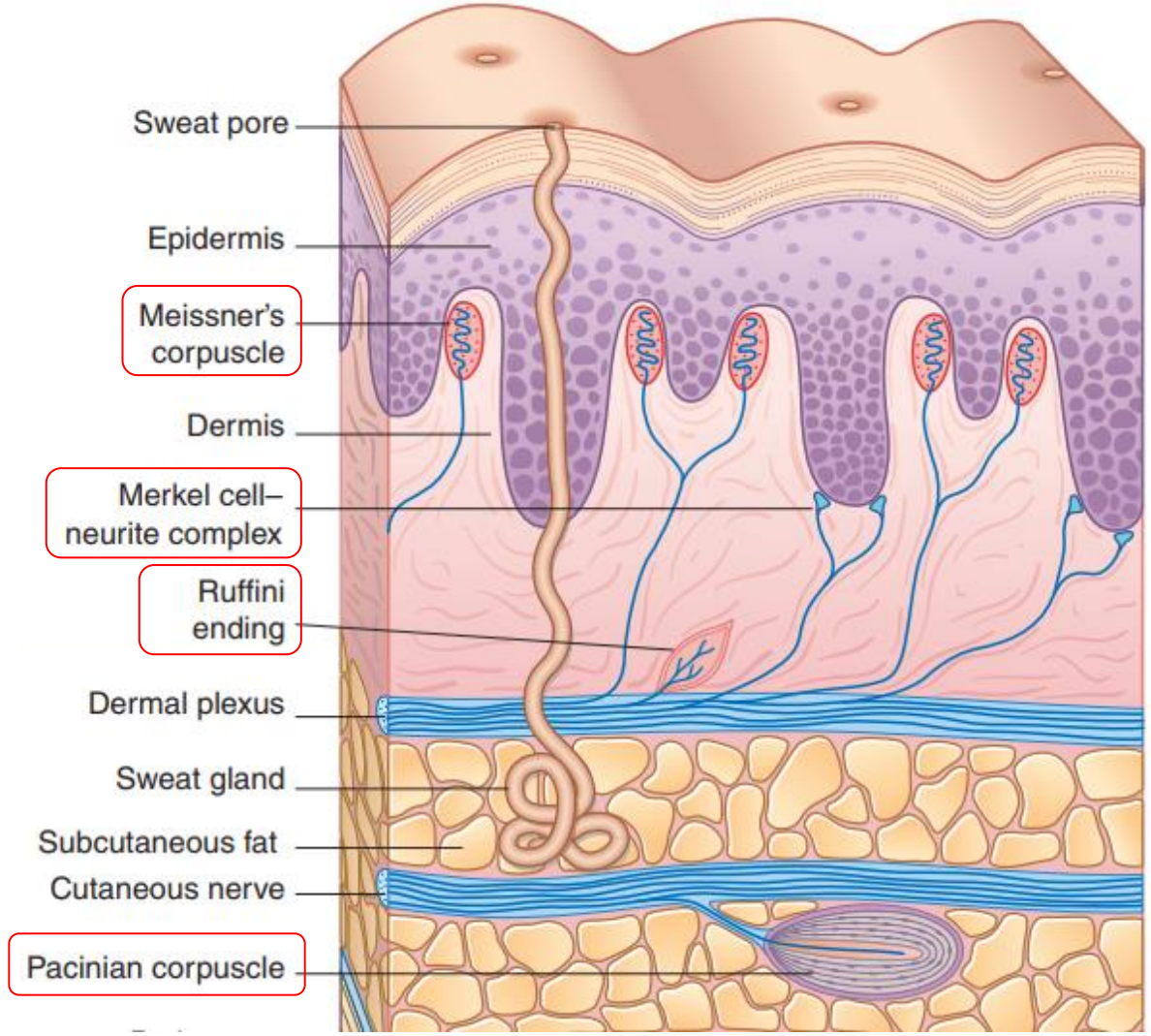
- **Receptors**: taste buds in tongue, pharynx, epiglottis. 4 types of papillae on the tongue: circumvallate, fungiform, foliate and filiform; except the latter all have taste buds.
- **Cranial nerves**:
  - facial nerve (VII) - chorda tympani and greater petrosal nerves - from anterior 2/3 of tongue
  - glossopharyngeal nerve (IX) - lingual branch - from posterior 1/3 of tongue
  - vagus nerve (X) - internal laryngeal branch - from epiglottis and pharynx
- All fibers converge at the **nucleus of the solitary tract** (NTS) in medulla.
- Secondary neurons project to **thalamus** (VPM nucleus).
- Primary gustatory **cortex** (insula and frontal operculum).
- Higher centers (e.g. orbitofrontal cortex) integrate taste with smell → perception of flavor.

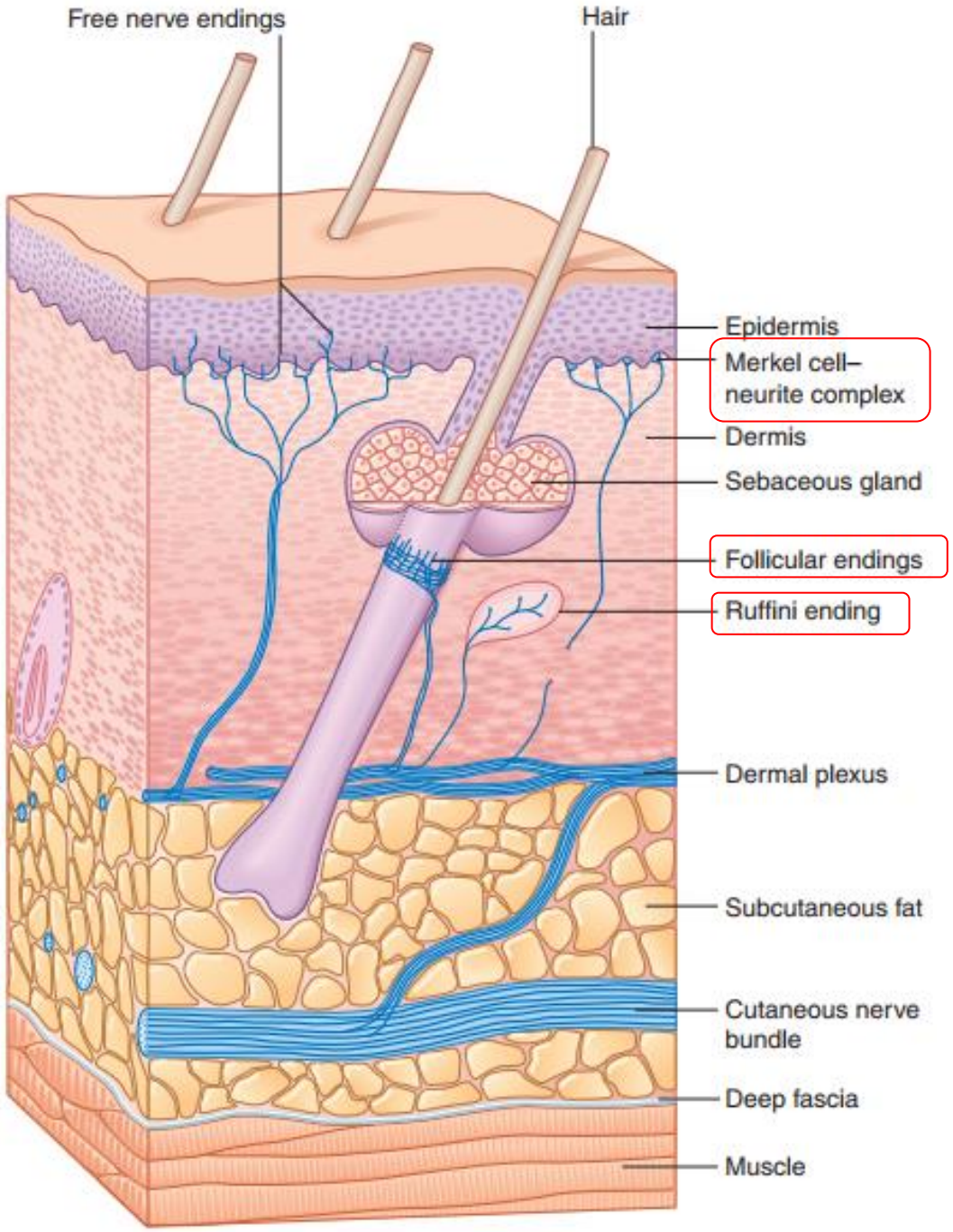
Dysfunctions: ageusia, hypogeusia, dysgeusia.
Potential causes: nerve damage, iatrogenic cause (drugs, radiations), zinc deficiency, infections, neurodegenerative diseases (Parkinson's, Alzheimer's).

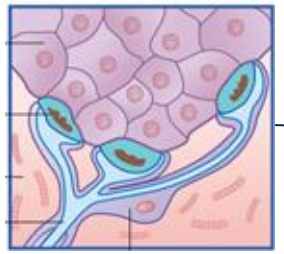

Primary gustatory cortex
(Insular cortex)
Thalamus
Second order neurons
Medulla
Nucleus of solitary tract
Geniculate ganglion (CN VII)
Petrosal ganglion (CN IX)
Nodose ganglion (CN X)
First order neurons
Cilia
Taste pore
Epithelium
Taste bud
Sweet
Salt
Bitter
Sour
Umami


Facial nerve (VII)
Trigeminal ganglion
Chorda tympani nerve
To brain
Brain stem
Solitary tract nucleus
Glossopharyngeal nerve (IX)
Vagus nerve (X)
Superior laryngeal nerve
© D.Klemm '99

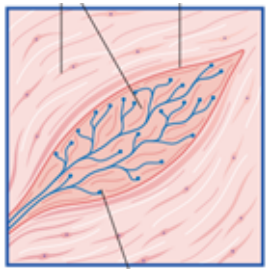
Touch and nociception

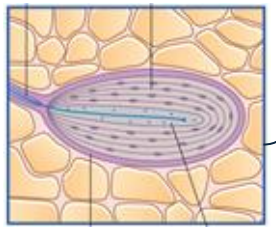


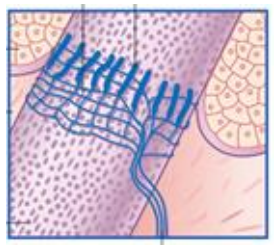












Receptor	*Adaptation*	*Receptive field*	*Main function*
Merkel cells (/discs)	Slow	Small → high spatial resolution	Form, edges, texture
Meissner corpuscles	Rapid	Small	Light touch, flutter, low-frequency vibration (10-50 Hz). Important for grip control
Ruffini endings	Slow	Large	Skin stretch, hand shape, finger position. Important for proprioception and object manipulation.
Pacinian corpuscles	Rapid	Large	High-frequency vibration (150-300 Hz). Extremely sensitive to minute mechanical changes.
Hair follicle receptors	Rapid	Small	Hair movement → direction of motion.
C-tactile afferents	Slow	Variable	Affective touch
Muscle spindles	—	—	Muscle stretch
Golgi tendon organs	—	—	Tension
Joint receptors	—	—	Joint position

not-touch sensations

Nociceptors

= **free nerve endings**, not encapsulated structures.

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- Activated by strong mechanical forces (pinching, cutting, crushing).
- Typically A-delta fibers (fast, sharp pain).

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E.g.: mutations in Nav1.7 (sodium channel) can cause congenital insensitivity to pain or extreme pain disorders.

Somatosensory pathway

<u>Touch</u>:

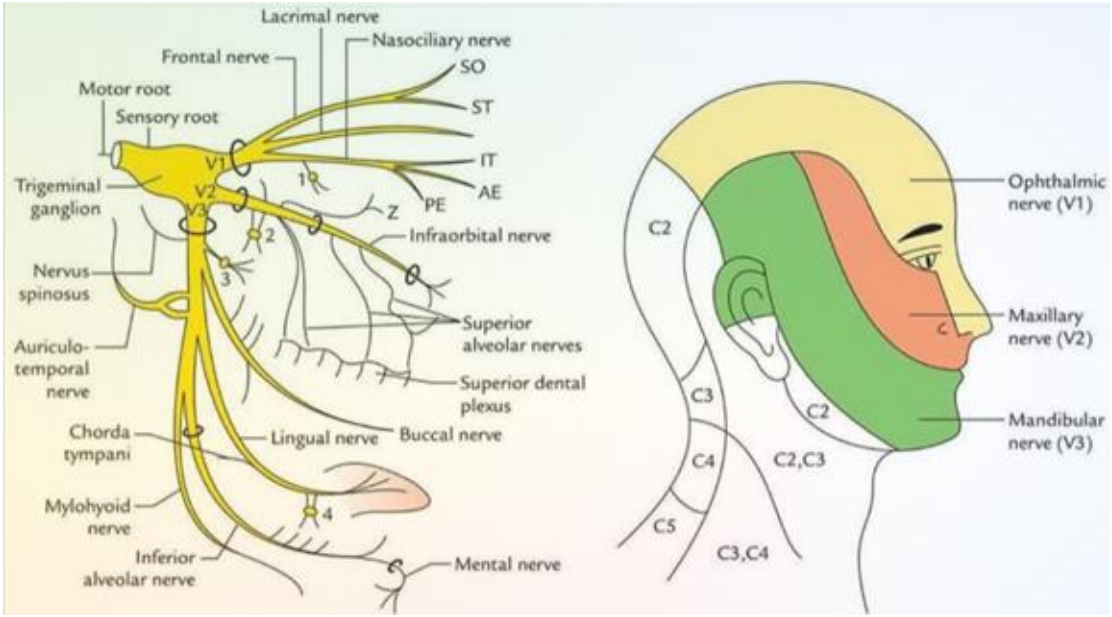
Body: dorsal column → medial lemniscus

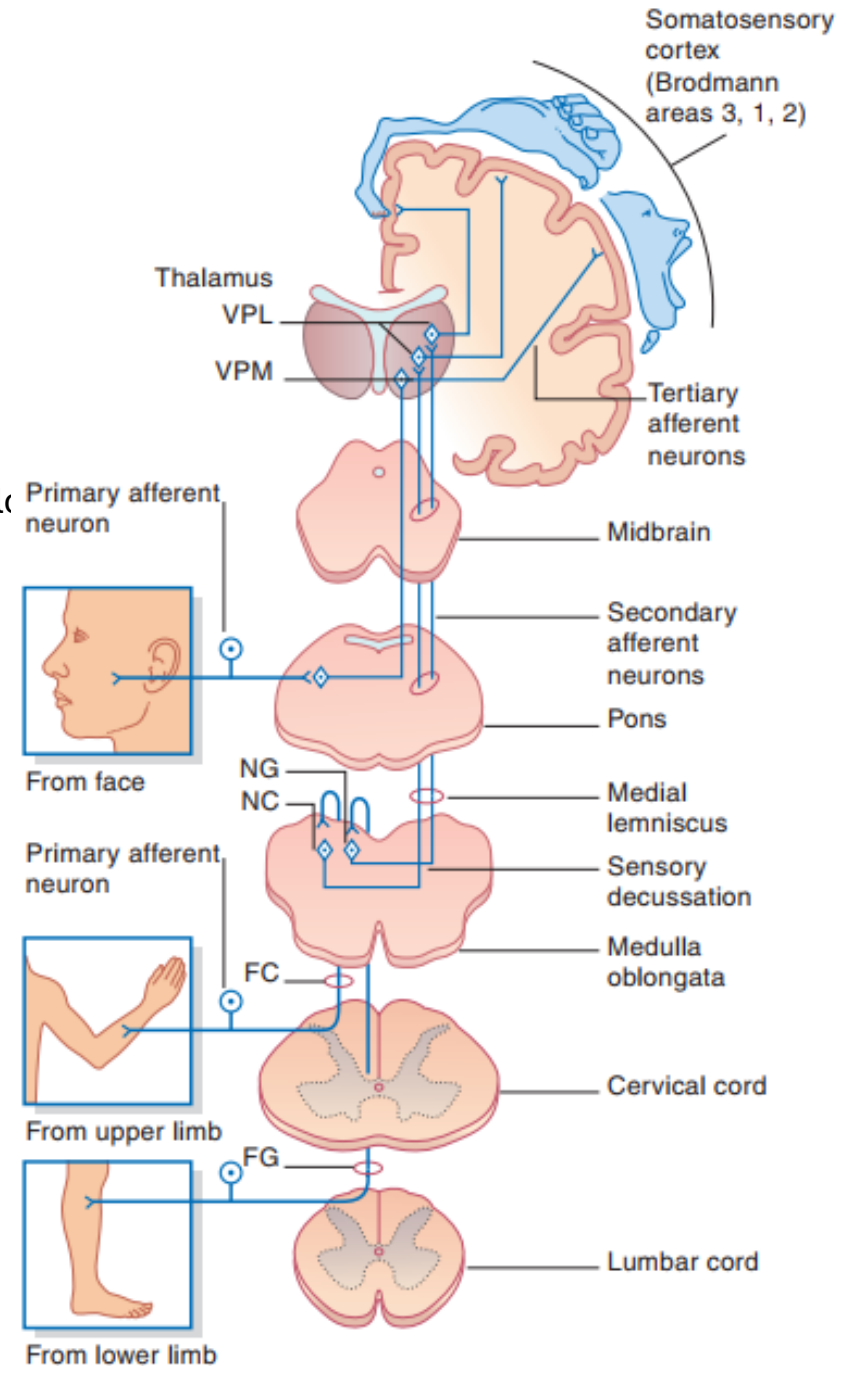
↘

thalamus → somatosensory cortex (parietal l

↗

Face: trigeminal nerve → trigeminal lemniscus





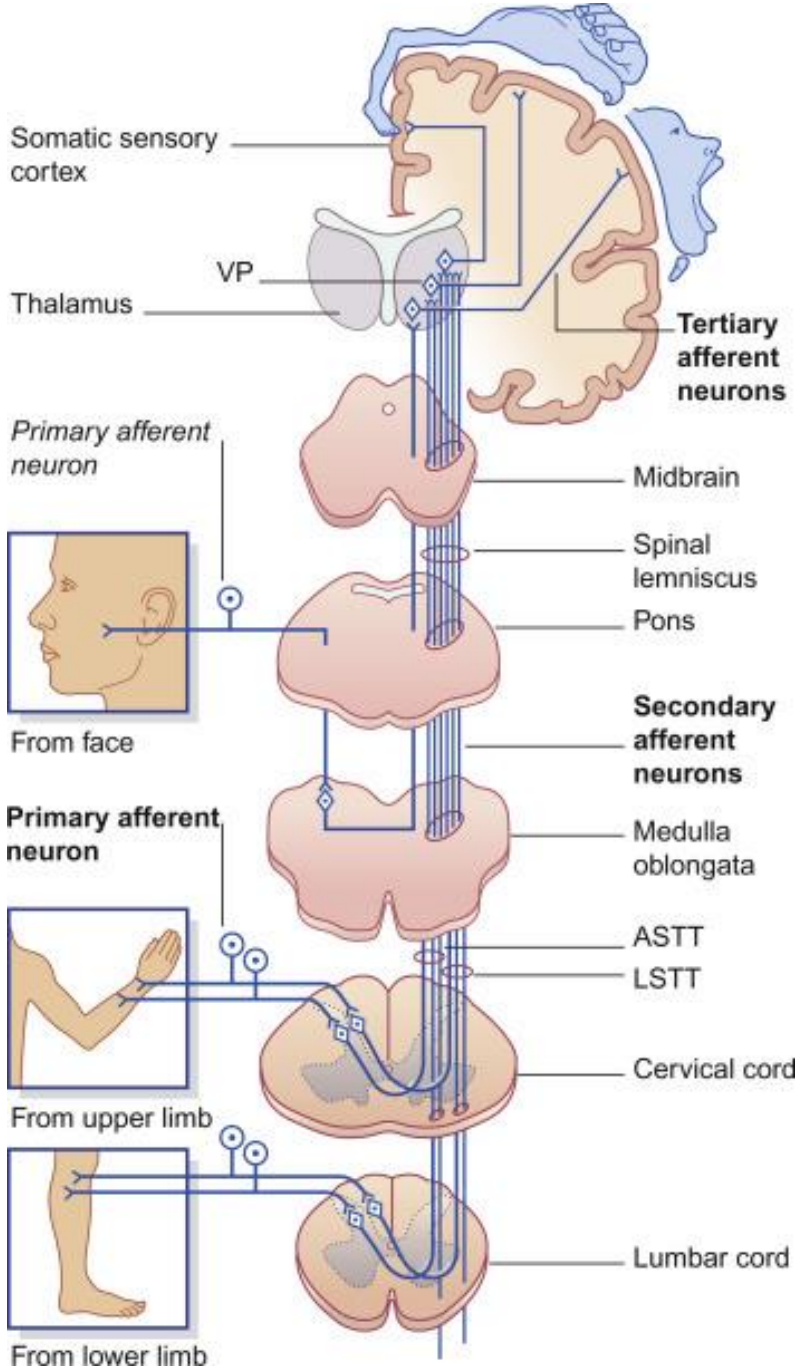
Somatosensory pathway

<u>Pain</u>:

Body: dorsal horn → spinothalamic tract

Thalamus → somatosensory cortex

Face: trigeminal nerve → trigeminal nucleus



Cranial nerves seen so far

I - olfactory

II - optic

III - oculomotor

IV - trochlear

V - trigeminal

VI - abducens

VI - facial **(chorda tympani)**

VIII - vestibulocochlear /statoacoustic

IX - glossopharyngeal **(lingual branch)**

X - vagus **(internal laryngeal branch)**

XI - accessory

XII - hypoglossal