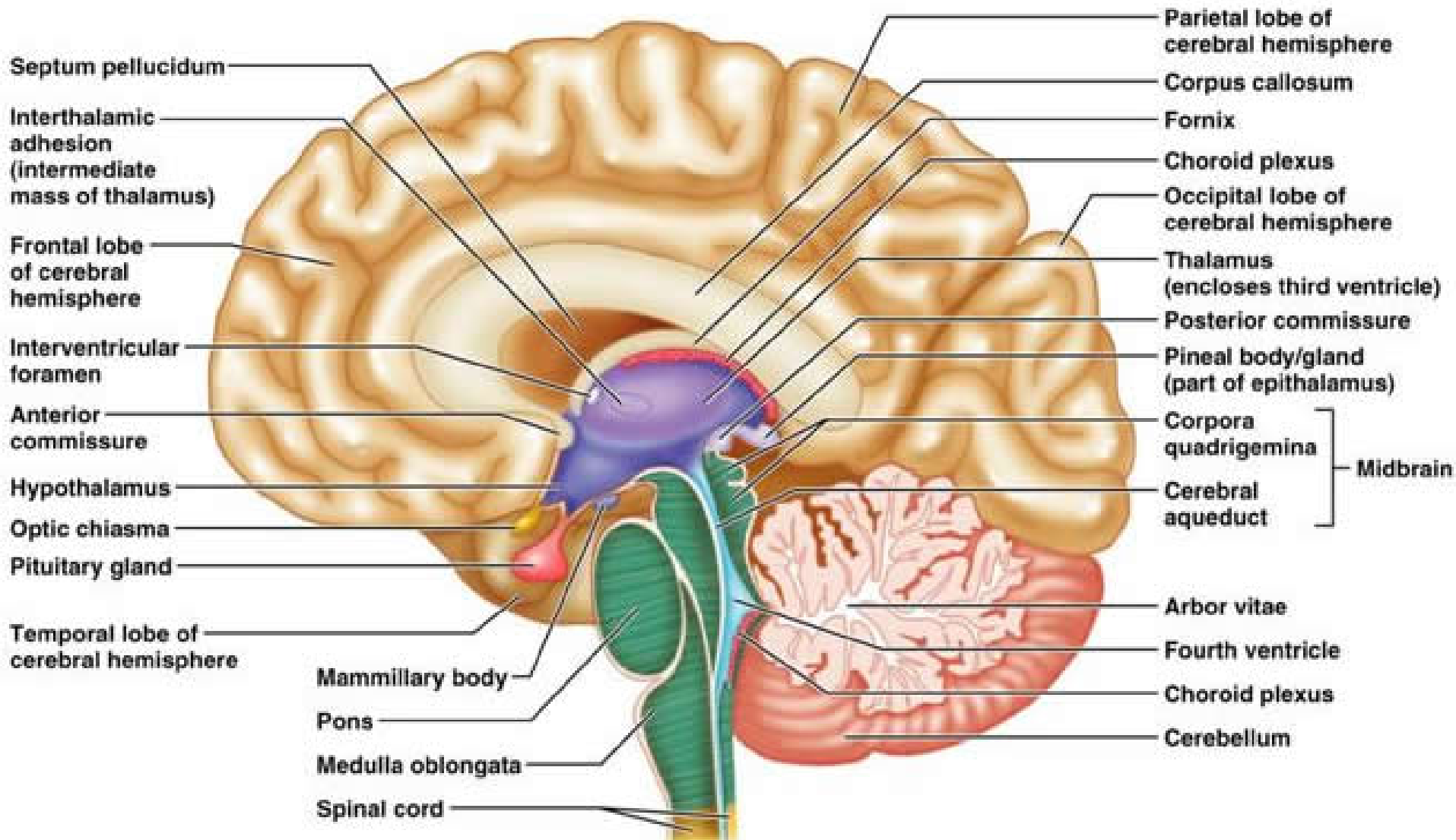


ORGANIZATION OF THE CNS - BRAINSTEM AND CEREBELLUM -

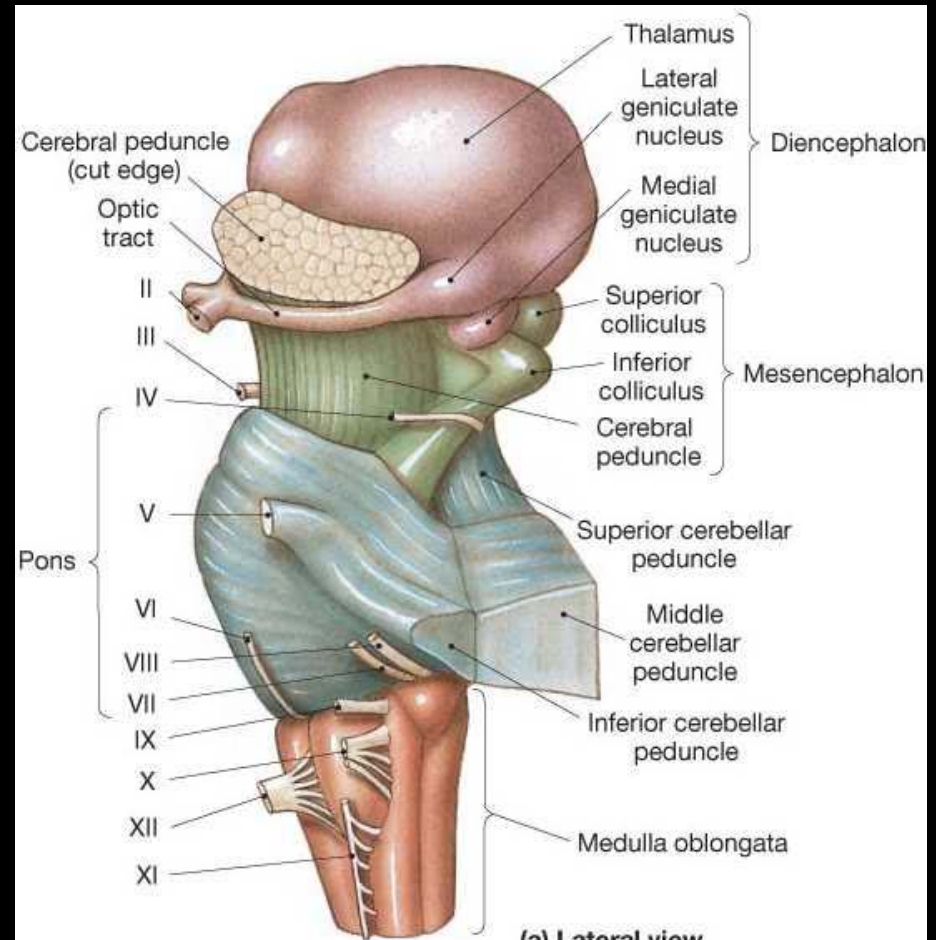
Ivana Pavlinac Dodig, M.D., Ph.D.



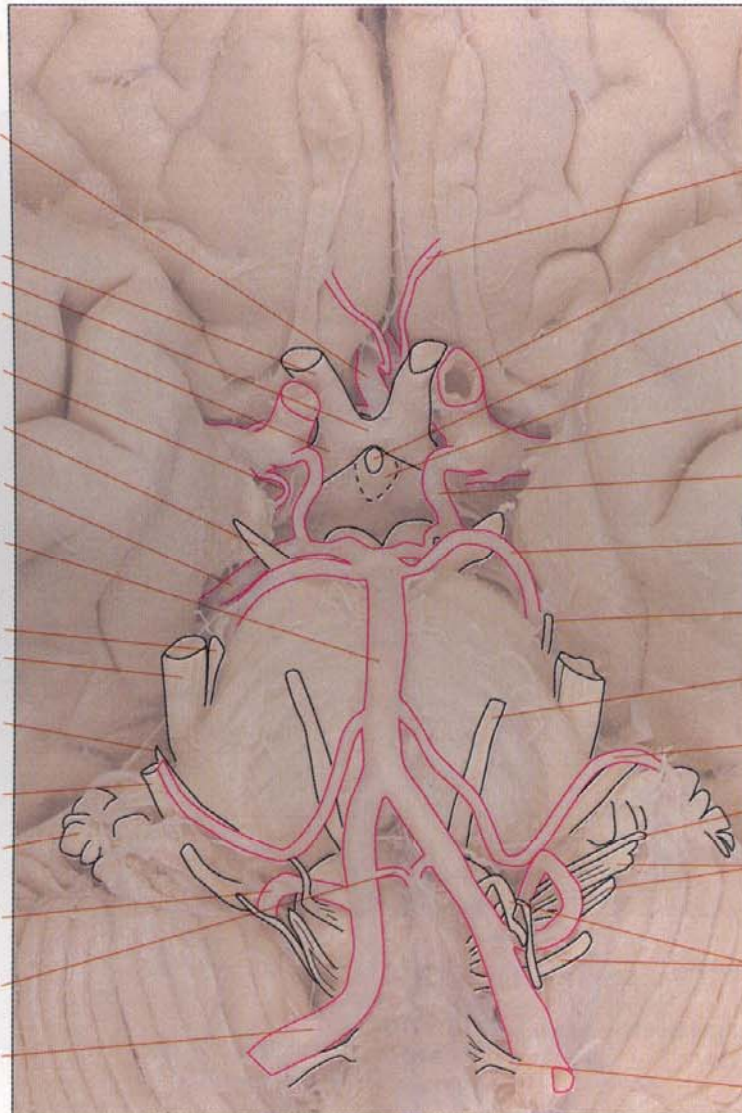
ORGANIZATION OF THE CNS

- BRAINSTEM AND CEREBELLUM -

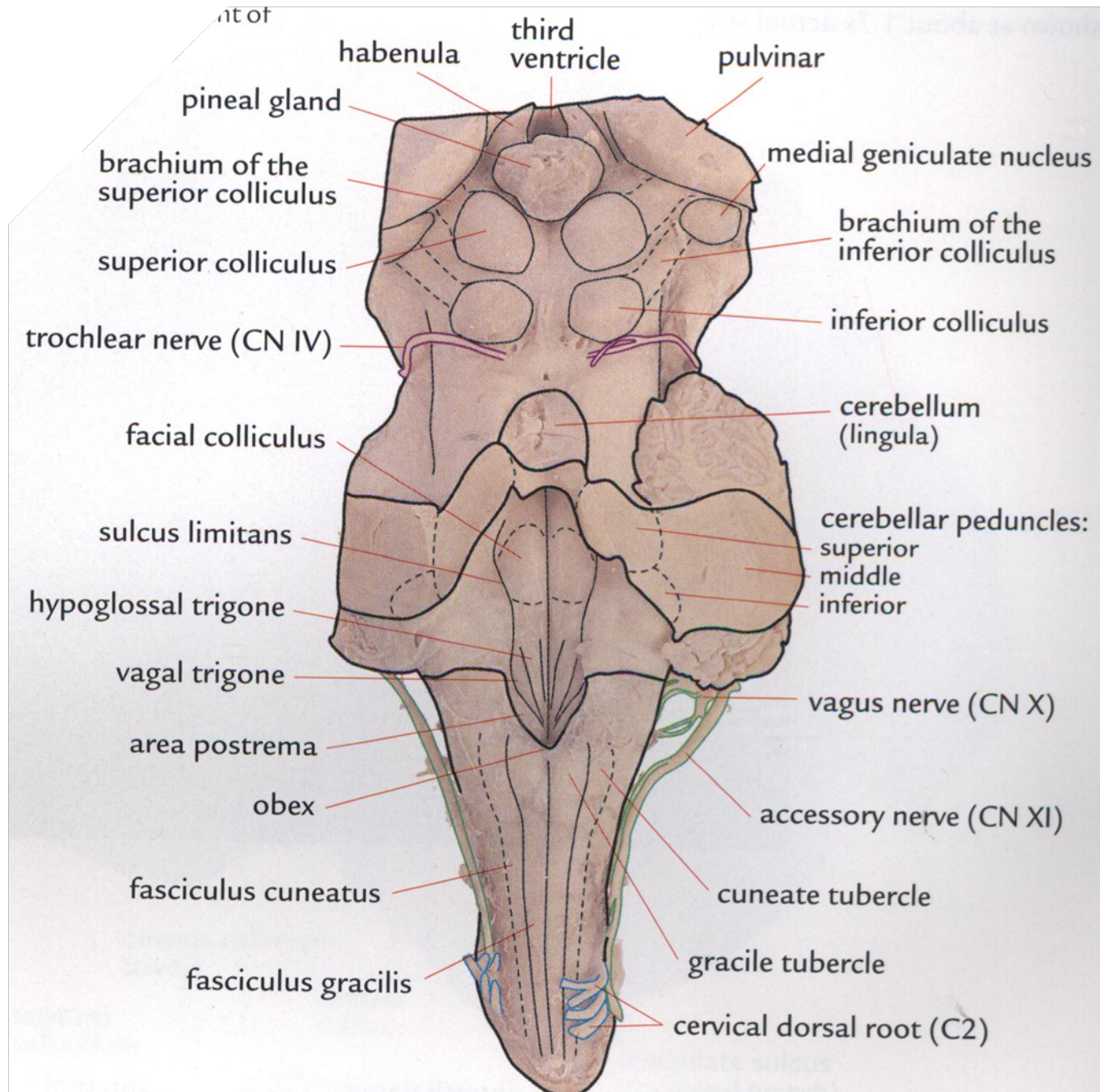
1. Brainstem
 1. Medulla oblongata
 2. Pons
 3. Mesencephalon
2. Cranial nerves
 3. Cerebellum



anterior cerebral artery
 optic:
 nerve (CN II)
 chiasm
 tract
 anterior choroidal artery
 oculomotor nerve (CN III)
 posterior cerebral artery
 basilar artery
 trigeminal nerve (CN V)
 motor root
 sensory root
 facial nerve (CN VII)
 vestibulocochlear nerve (CN VIII)
 cerebellum (flocculus)
 posterior inferior cerebellar artery
 anterior spinal artery
 vertebral artery



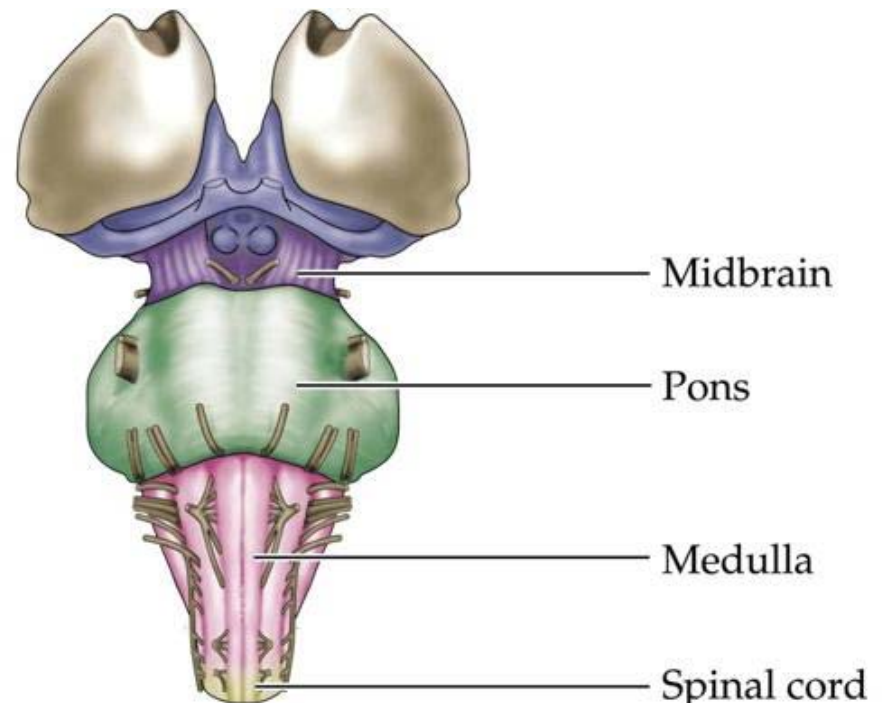
medial striate artery
 internal carotid artery
 infundibulum
 tuber cinereum
 middle cerebral artery
 posterior communicating artery
 superior cerebellar artery
 trochlear nerve (CN IV)
 abducens nerve (CN VI)
 anterior inferior cerebellar artery
 glossopharyngeal nerve (CN IX)
 vagus nerve (CN X)
 hypoglossal nerve (CN XII)
 cervical ventral root (C1)



Brainstem

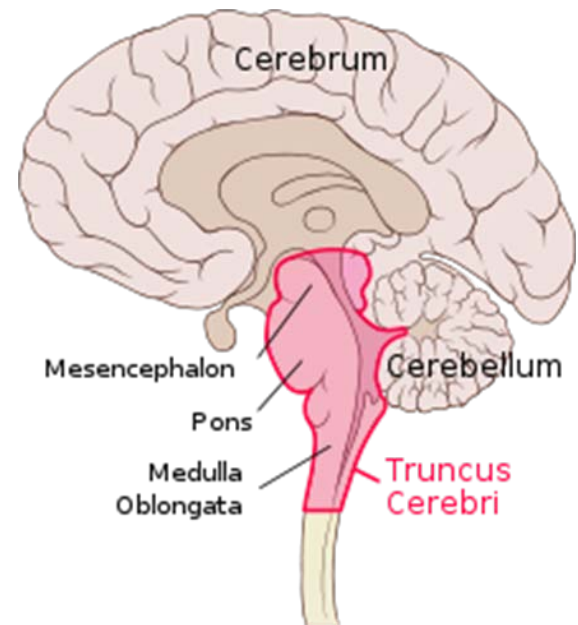
Connecting spinal cord to cerebrum and cerebellum.
Suprasegmental region of CNS.

- *Medulla oblongata*
- *Pons*
- *Mesencephalon*



Brainstem

- *Grey matter continuity* – from spinal cord via brainstem tegmentum to diencephalon
- *White matter continuity* – long ascending and descending fibers



Brainstem

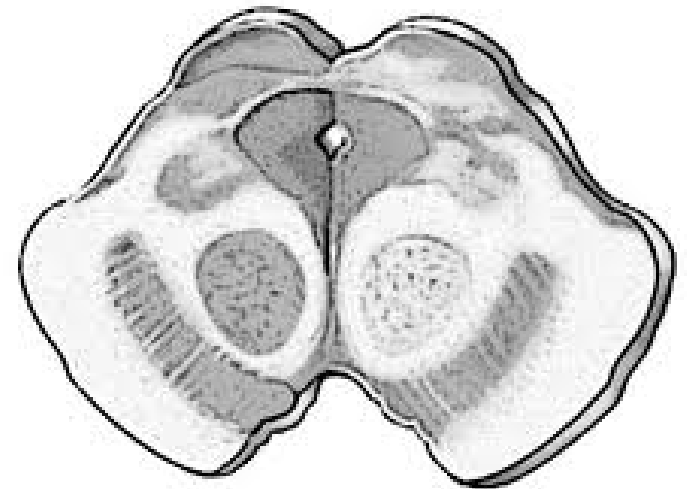
Physiological roles:

- Regulation of breathing
- Regulation of cardiovascular system
- Regulation of gastro-intestinal system
- Regulation of movements
- Regulation of body balance
- Regulation of eyes movements



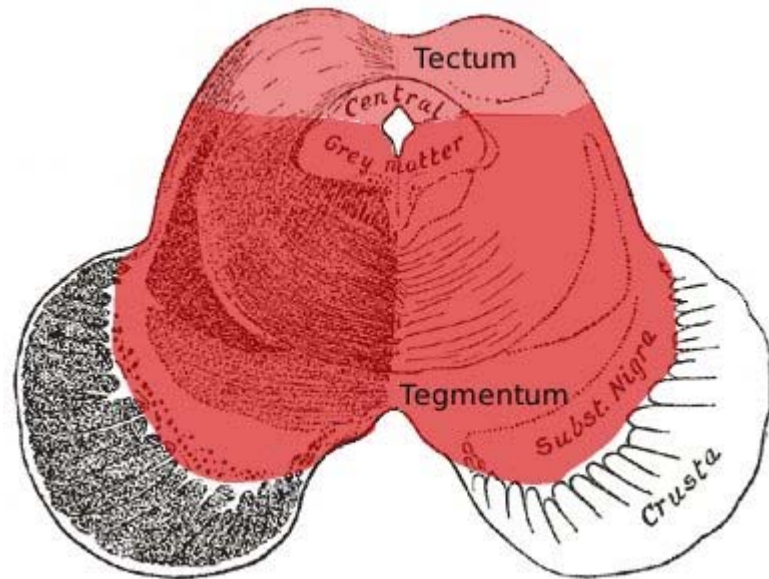
Brainstem - cross section

1. Ventral or basal part (*basis*) = motor pathways
2. Middle part or *tegmentum* = sensory pathways, reticular formation, cranial nerve nuclei
3. Dorsal part or *tectum* – only in midbrain; visual and auditory system



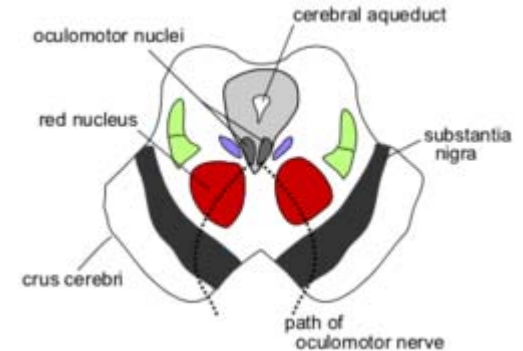
Basis

- Long descending motor pathways:
 - Corticospinal
 - Corticobulbar
 - Corticopontine



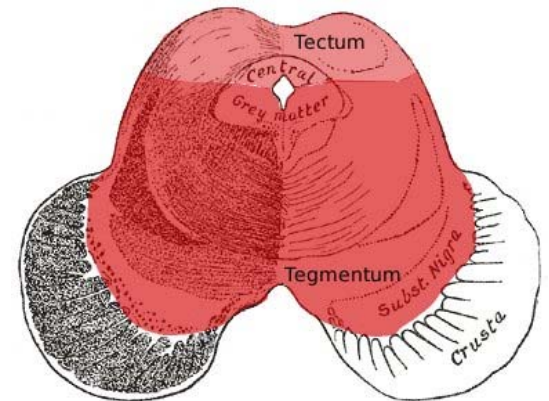
Tegmental nuclei

- Cranial nerves nuclei
- Reticular formation
- Big extrapyramidal motor nuclei (nucl. ruber and substantia nigra)
- Special monoaminergic tegmental nuclei (nucl. raphe, VTA, locus coeruleus)



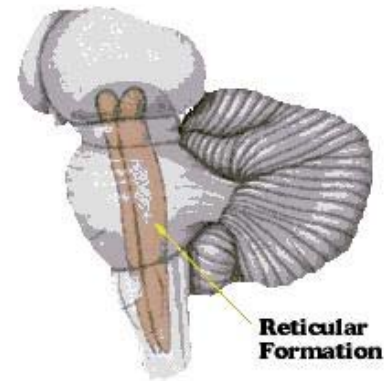
Tegmental pathways

- Sensory: lemniscus medialis, tractus spinothalamicus and trigeminothalamicus
- Extrapyramidal
- Non-specific ascendent pathways (serotoninergetic, noradrenergic and cholinergic)

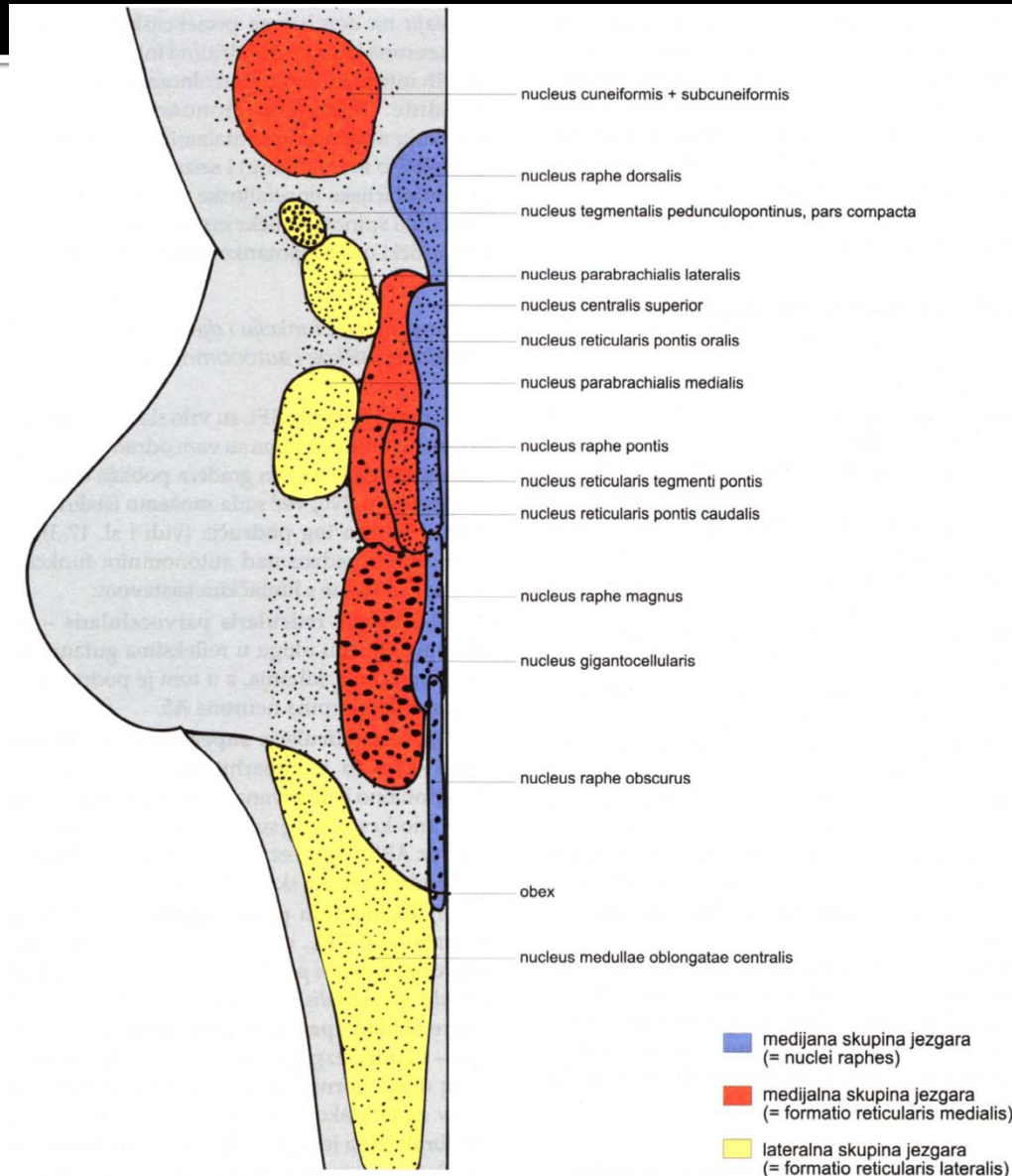


Reticular formation (RF)

- 50 nuclei
 - Paramedial area – raphe + reticul. nuclei
 - Medial area
 - Lateral area
- Physiological roles:
 - Modulation of sensory transmission to the cortex
 - Regulation of motor activity
 - Autonomic regulation
 - Sleep and wakefulness cycle
 - Modulation of emotional behaviour



Reticular formation



Reticular nuclei

- Reticular nuclei of the pons – excitation of the antigravity muscles
- Medullary reticular nuclei – inhibition of the antigravity muscles



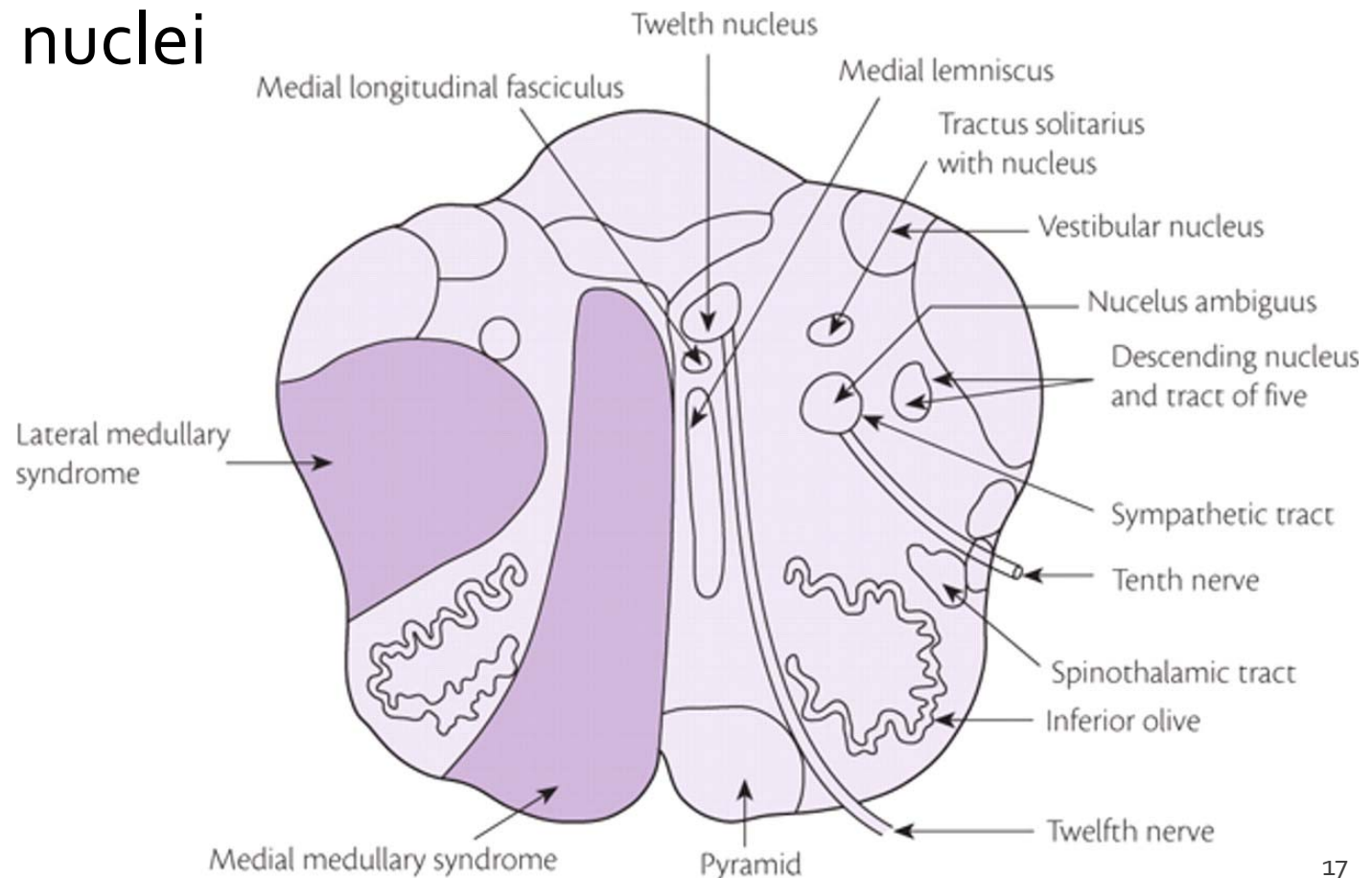
antagonistic action

Medulla oblongata

- Rostral third = open medulla
- Caudal 2/3 = closed medulla
- Dorsal surface of tegmentum = bottom of IV. ventricle
- Lissauer's zone = tractus spinalis n. trigemini
- Pyramids = corticospinal tract; decussation
- Olives = inferior olivary nucl.
- Nucl. gracilis and cuneatus

Medulla – internal organization

- Major fiber tracts
- Internal nuclei



Medulla oblongata

- Tegmentum = extrapyramidal motor and sensory pathways (lemniscus medialis, tractus spinothalamicus*, spinotectalis, spinoreticularis* and spinocerebellaris) and RF
- FLM (connecting vestibul. nuclei and lower motor neurons)

* lemniscus spinalis

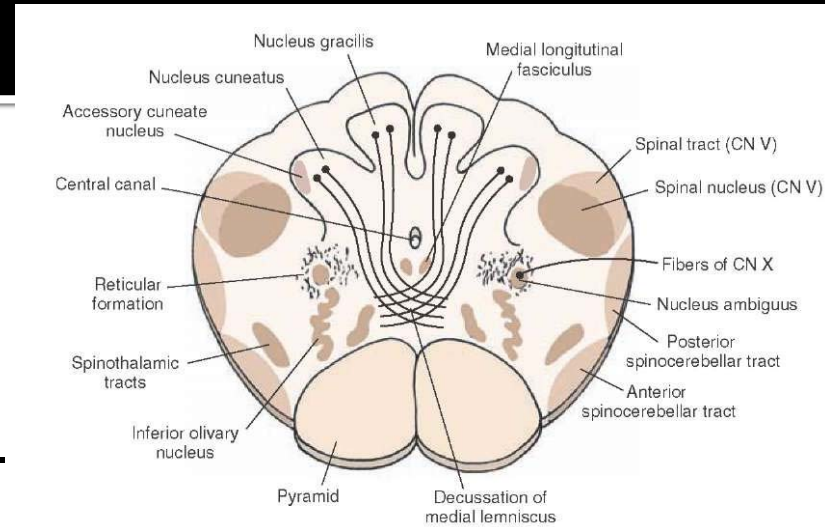
Medulla – major fiber tracts

motor

- Tractus corticospinalis
- Tractus tectospinalis
- Tractus rubrospinalis
- Tractus reticulospinalis lat. and med.
- Fasciculus longitudinalis medialis
 - Descending part (medial vestibulospinal tract)
 - Ascending part (from medial, lateral, and superior vestibular nuclei to pons and midbrain; information about head position to cranial nerves)

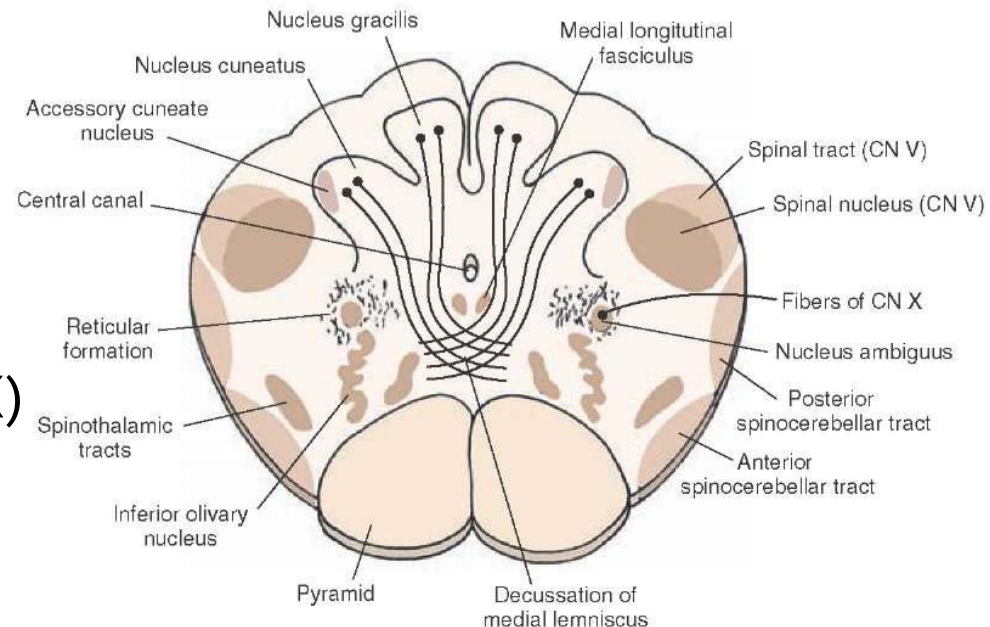
sensory

- Lemniscus medialis
- Tractus spinalis n. trigemini – somatosensory information from the head (Neuron II)
- Tractus spinothalamicus
- Tractus spinocerebellaris



Medulla – internal nuclei

- Reticular formation
- Nucl. gracilis and cuneatus
- Inferior olivary nuclei (spino-olivary and rubro-olivary fibers; to cerebellum)
- Nucl. spinalis n. trigemini (pain and temperature from head)
- Cochlear nuclei (n.VIII)
- Vestibular nuclei (n.VIII)
- Hypoglossal nucl. (n.XII)
- Nucl. ambiguus (n.IX & X)
- Nucl. tractus solitarii (n.IX & X)
- Dorsal motor vagal nucl. (n.X)



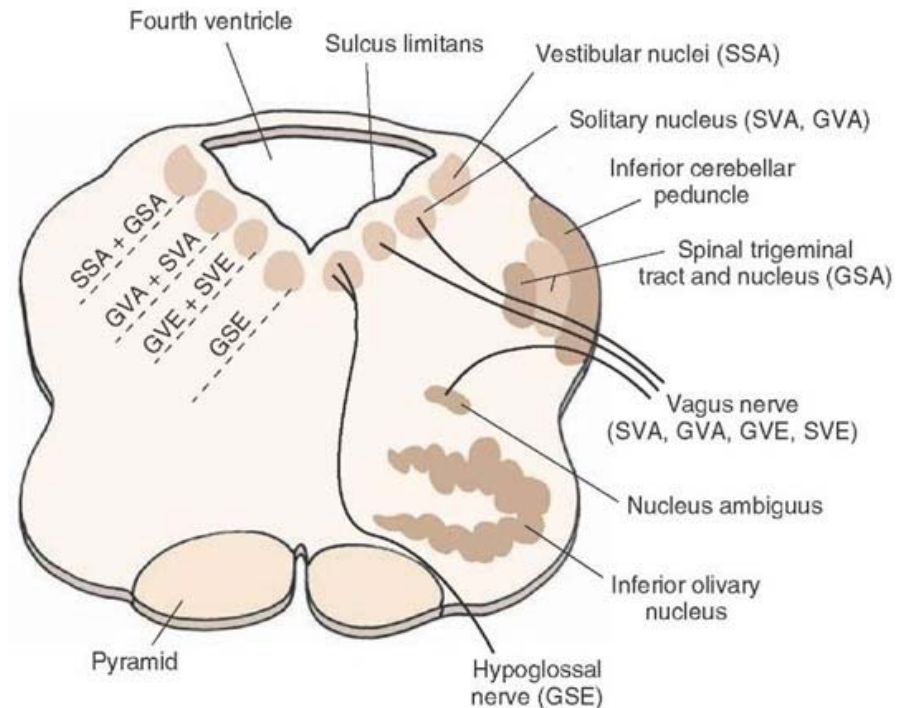
Levels of the medulla

1. Level of pyramidal decussation
2. Level of medial lemniscus decussation
(+accessory cuneate nucl. – external arcuate fibers
– cuneocerebellar tract – inferior cerebellar
peduncle: unconscious proprioception from upper
limbs)
3. Rostral half of medulla – cranial nerve nuclei

Cranial nerve nuclei

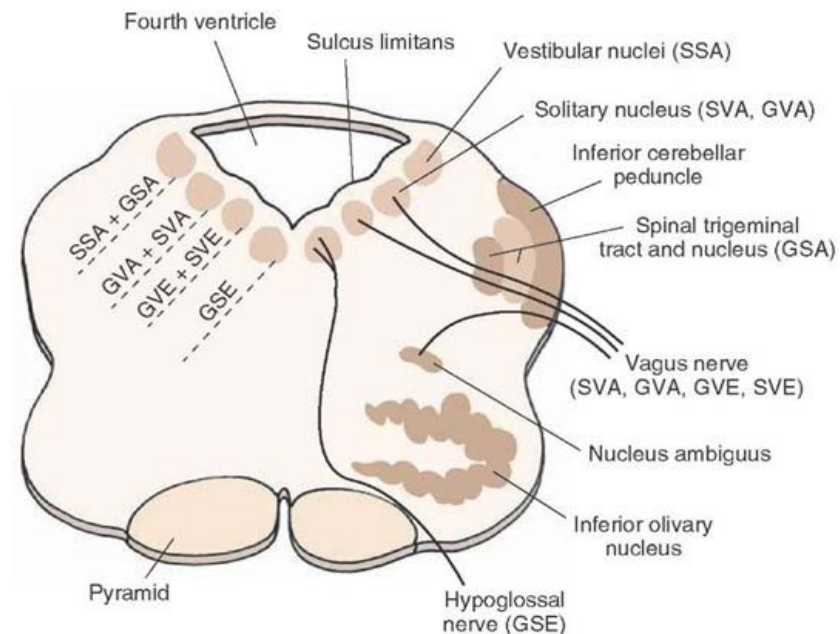
Medial to lateral arrangement:

- General somatic efferent neurons (GSE)
- Special visceral efferent neurons (SVE)
- General visceral efferent neurons (GVE)
- General visceral afferent neurons (GVA)
- Special visceral afferent neurons (SVA)
- General sensory afferent neurons (GSA)
- Special sensory afferent neurons (SSA)

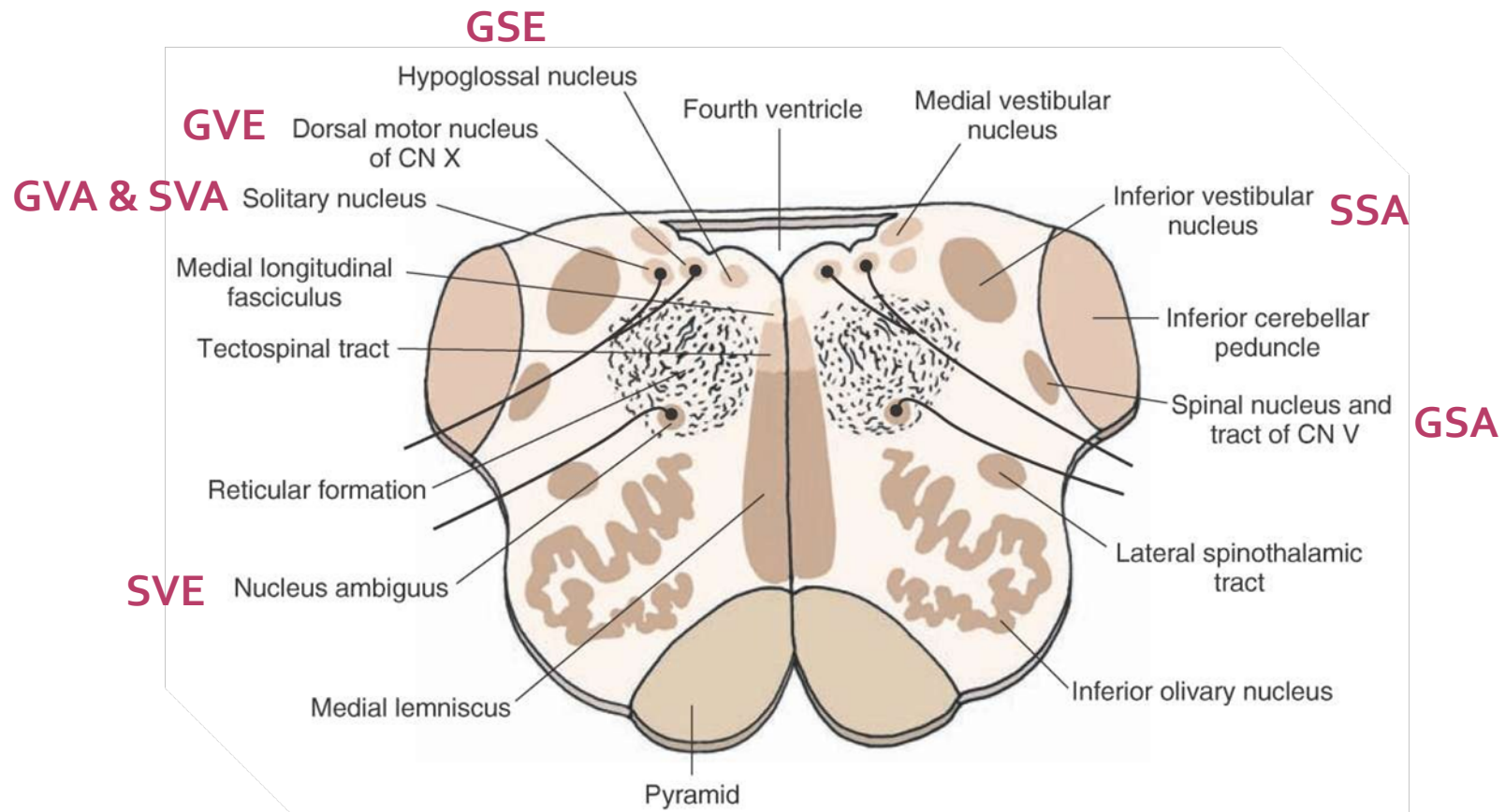


Cranial nerve nuclei

- GSE – hypoglossal nucl.
- SVE – nucl. ambiguus (IX, X)
- GVE – parasympathetic (dorsal motor vagal nucl., nucl. salivatorius inferior)
- GVA – solitary nucl. (IX, X) – cardiovascular and respiratory reflexes
- SVA – gustatory portion of the solitary nucl. (taste)
- GSA – spinal nucl. of trigeminal nerve
- SSA – vestibular and cochlear nuclei



GSE – SVE – GVE – GVA & SVA – GSA – SSA





Clinical considerations

Lateral medullary syndrome (Wallenberg's)

- Contralateral body and ipsilateral face loss of pain and temperature (spinothalamic and spinal trigeminal tract), loss of gag reflex, hoarseness, difficulty with speech and swallowing (nucl. ambiguus)
- *Horner's syndrome* = loss of sympathetic functions

Medial medullary syndrome (Dejerine's)

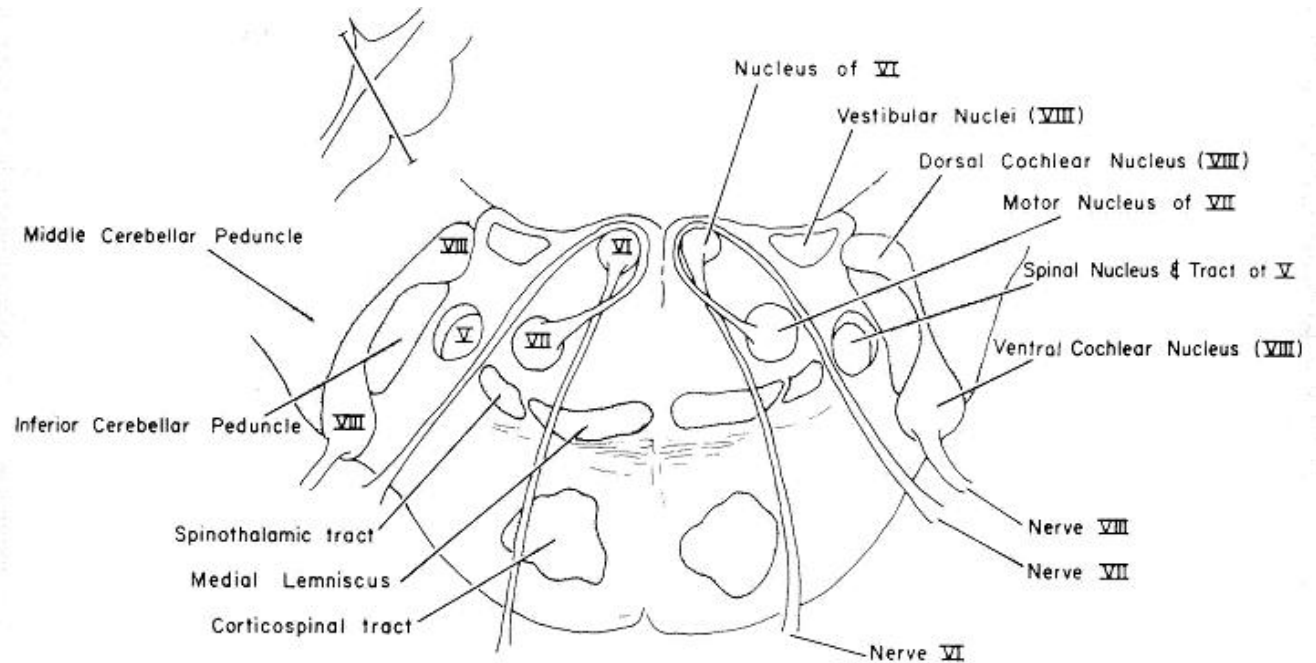
- Pyramid, medial lemniscus and root fibers of n. XII

Dorsal medullary syndrome

- Inf. cerebellar peduncle (ataxia), vestibular nuclei (nystagmus, vomiting, vertigo)

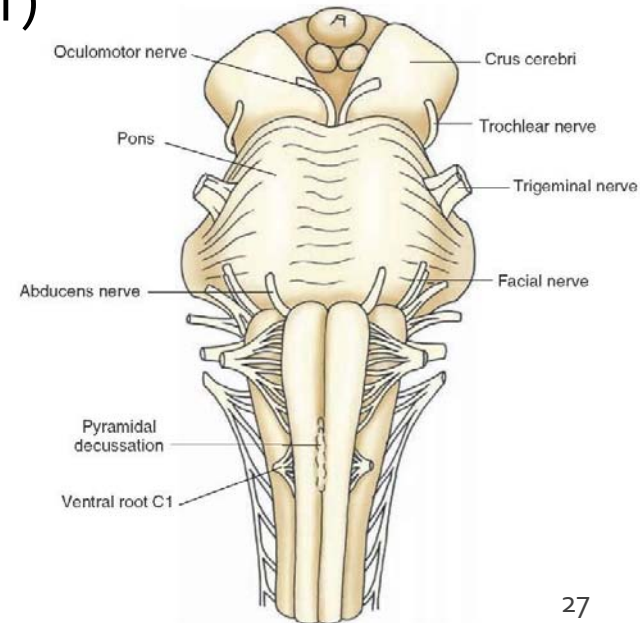
Pons

- Basis:
 - fibers
 - nuclei
- Tegmentum:
 - fibers
 - nuclei



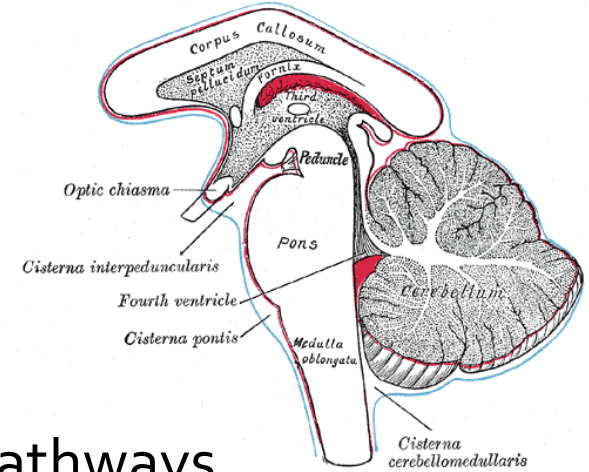
Basilar pons

- Fasciculi longitudinales
 - corticospinal
 - corticobulbar (corticonuclear) ➡ interneurons of RF
 - corticopontine
- Transverse pontine fibers (pontocerebellar)
- Nuclei pontis (deep) ↗



Tegmental pons

- Fibers:
 - fasciculus longitudinalis medialis
 - lemniscus medialis
 - spinothalamic and trigeminothalamic pathways
 - lemniscus lateralis (auditory pathway)
 - extrapyramidal pathways
 - tractus rubrospinalis
 - tractus tectospinalis

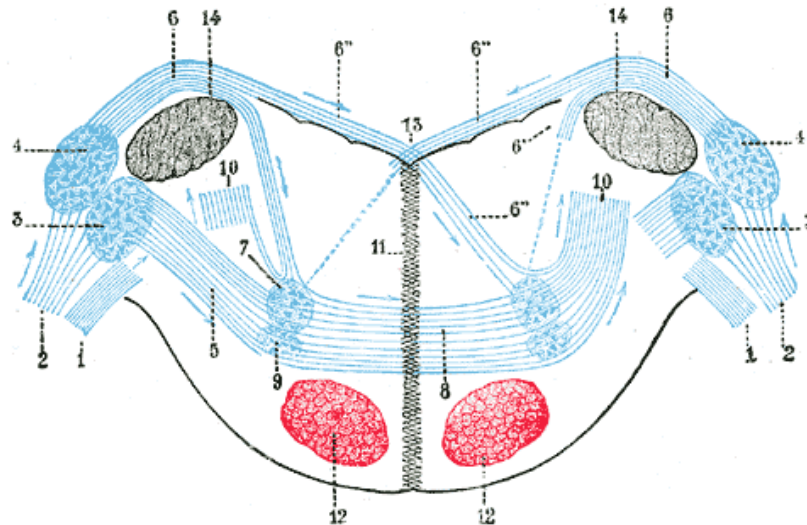


Tegmental pons

- Nuclei pontis:
 - RF (including raphe nuclei),
 - auditory relay structures: corpus trapeziodium, superior olivary nucleus (from cochlear nuclei)
 - nucleus locus coerulei,
 - cranial nerves nuclei (V, VI, VII, superior and lateral vestibular nuclei)

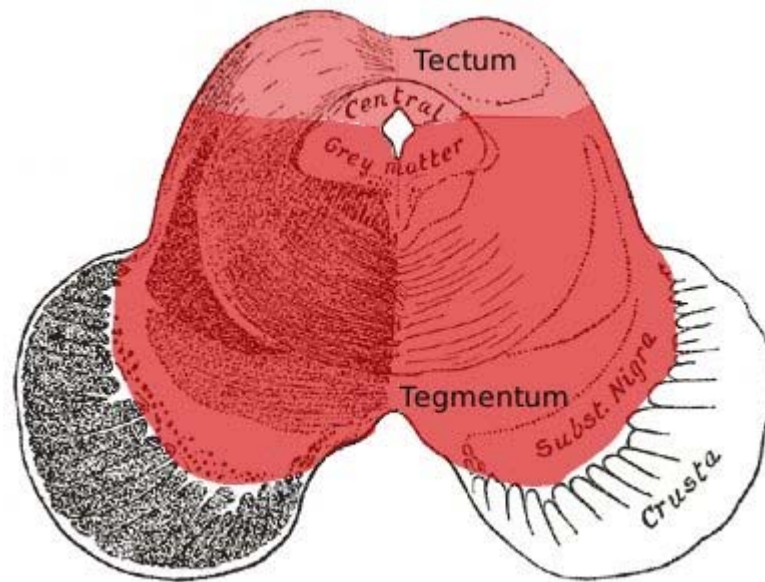
Clinical considerations

- The locked-in syndrome
 - large infarct of the basilar pons – corticobulbar and corticospinal tracts
 - communication by blinking and moving eyes



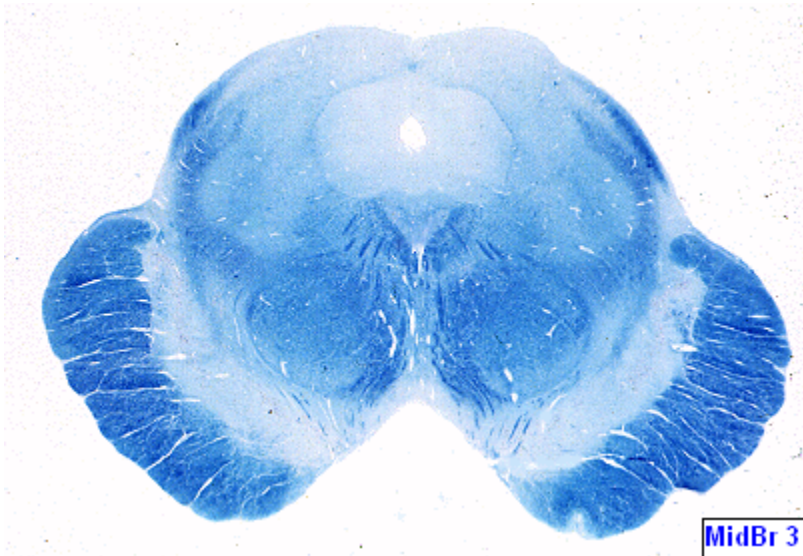
Midbrain (mesencephalon)

- Tectum (corpora quadrigemina)
- Tegmentum
- Basis (crus cerebri)



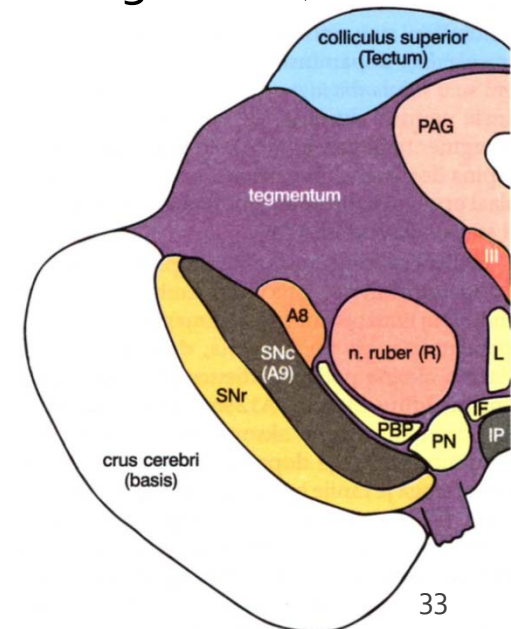
Tectum mesencephali

- Colliculi inferiores (auditory relay component; fibers of lemniscus lateralis from cochlear, sup.olivary nucl., and trapeziod body; to CGM – brachium of the inf. colliculus)
- Colliculi superiores (inputs from retina; projects to cervical spinal cord via tectospinal tract)



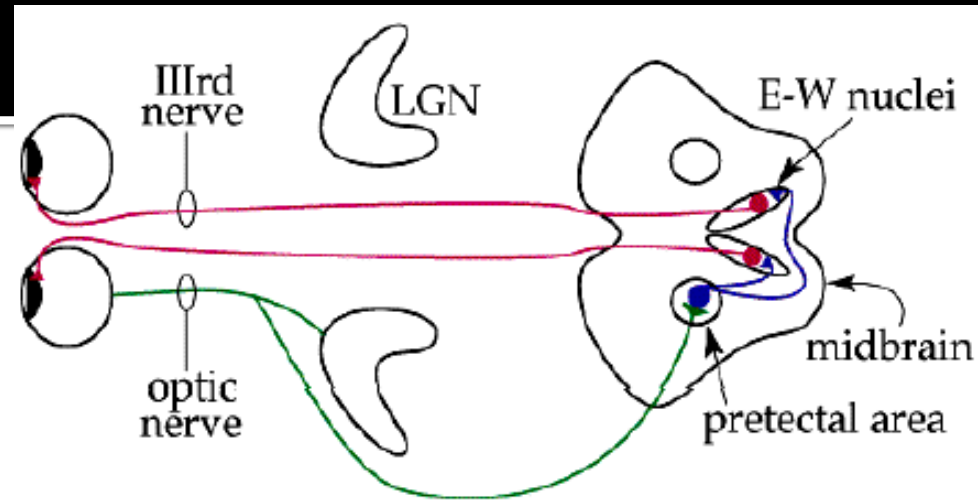
Tegmentum mesencephali

- PAG (enkephalin-modulation of pain; regulation of autonomic, affective and emotional functions)
- Cranial nerves nuclei (III, IV+MLF)
- L&M lemniscus, spinothalamic, trigeminothalamic pathways
- RF (including raphe – somatomotor, autonomic and visceral regulation)
- Decussation of the superior cerebellar peduncle
- Substantia nigra
- Nucleus ruber (rostral half, motor functions)
- VTA – dopaminergic mezocortical system



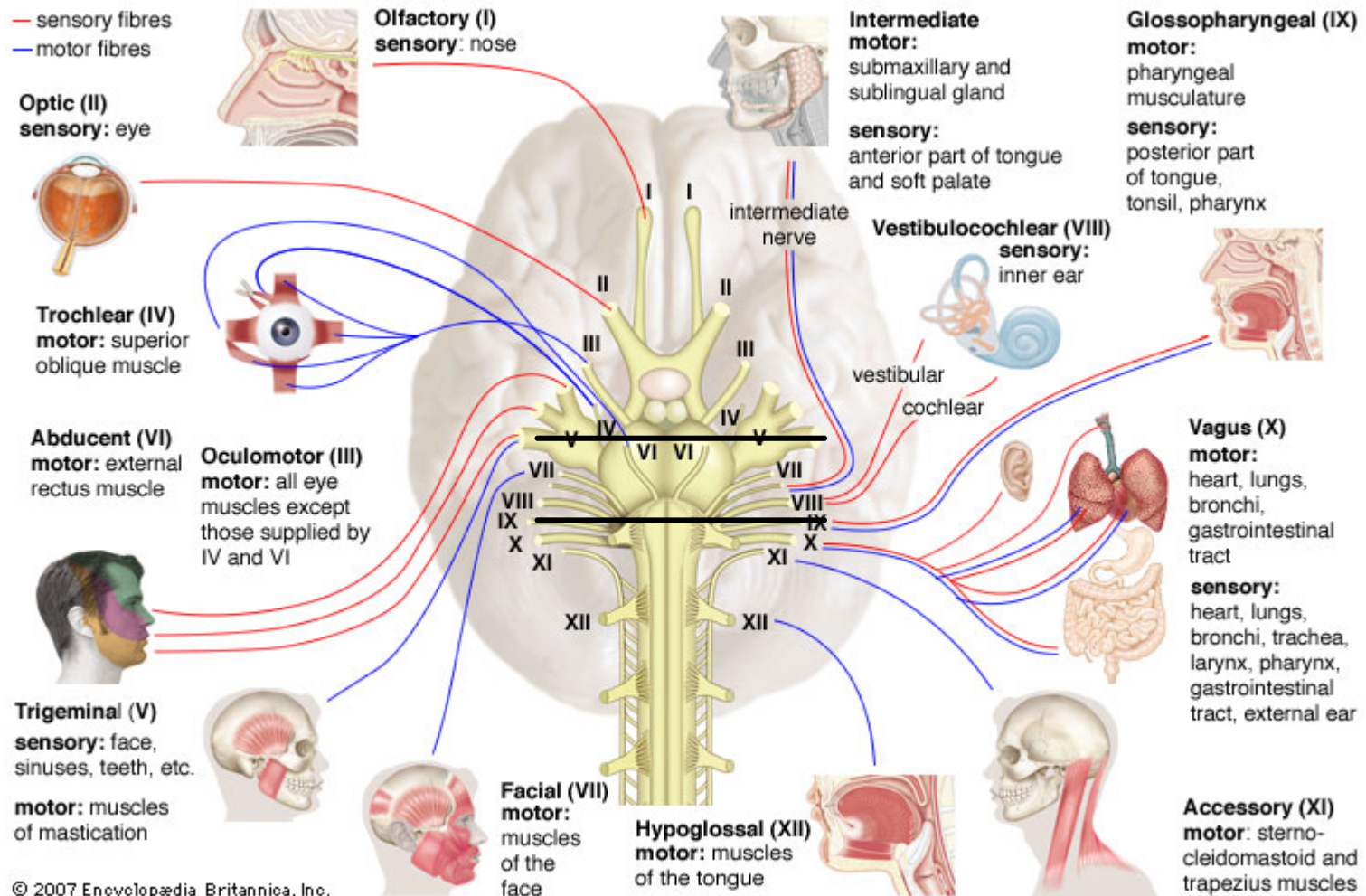
Crus cerebri

- Pretectal area (pupillary light reflex)

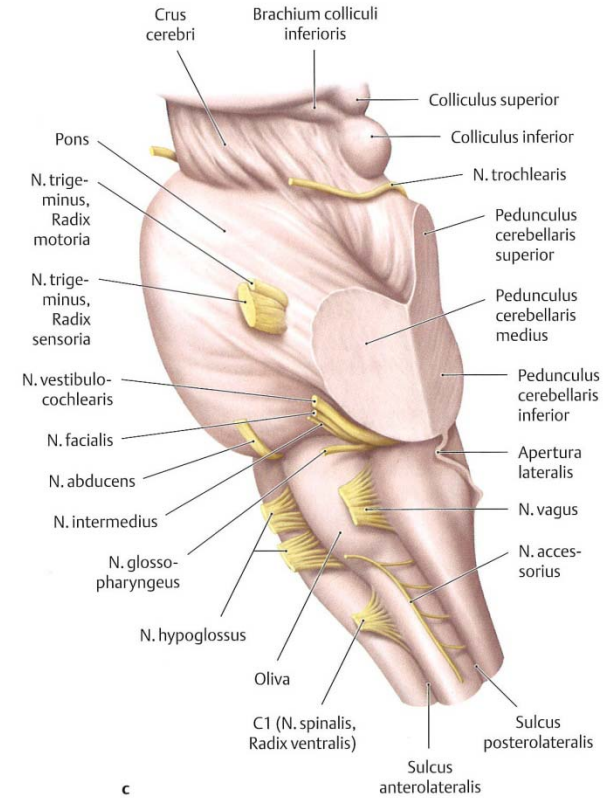
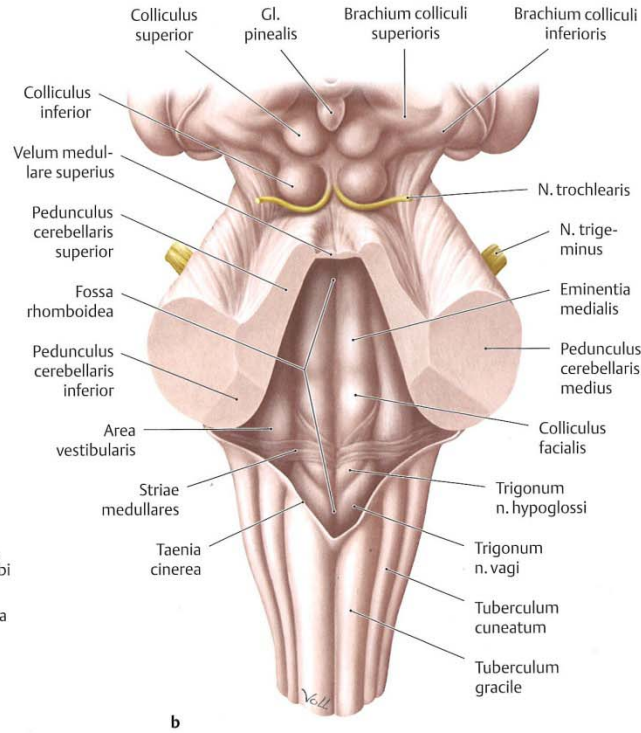
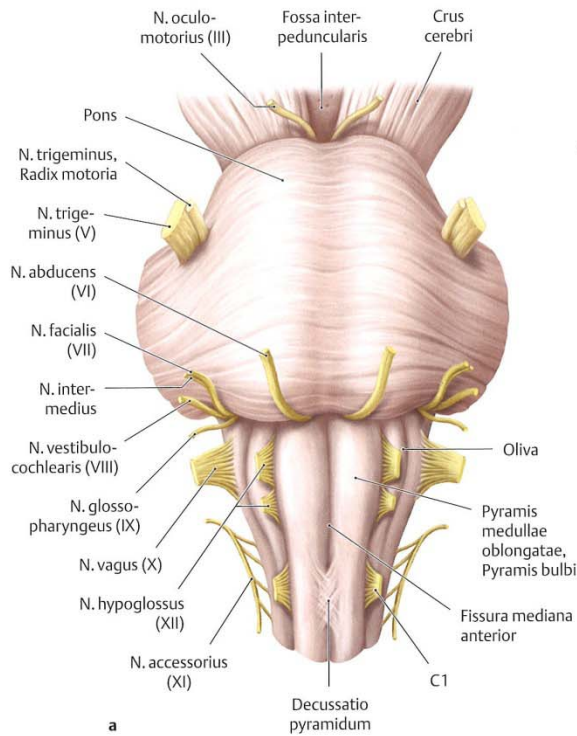


- Posterior commissure (pretectal area – coordination of eyes' movements)
- Thalamic structures (pulvinar, medial and lateral geniculate nuclei)

Cranial nerves



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Cranial nerves

■ Sensory:

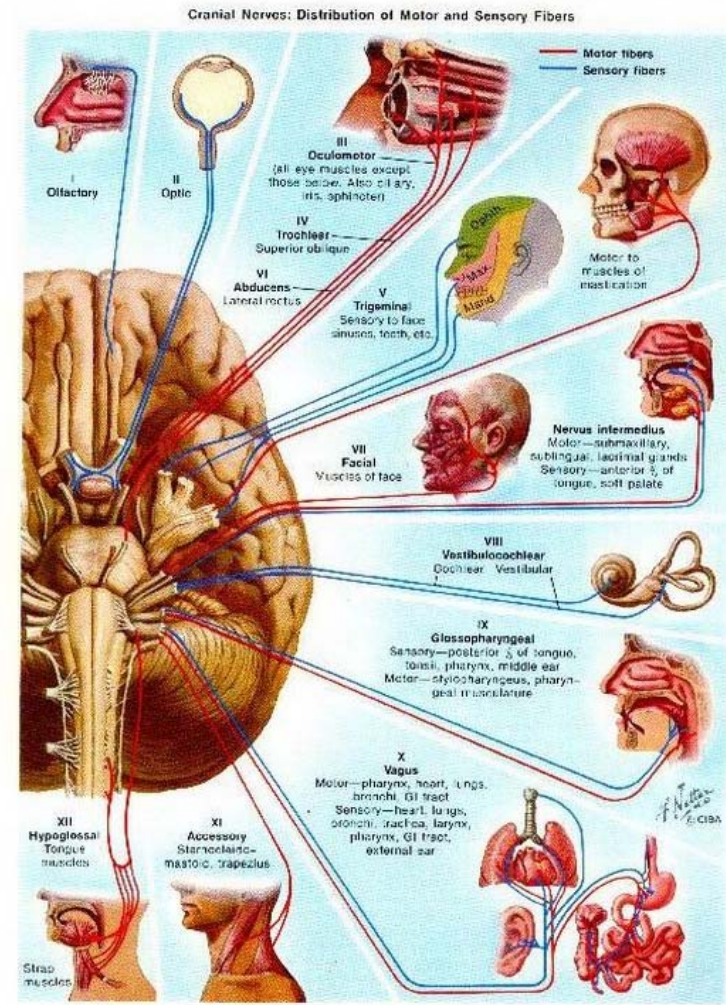
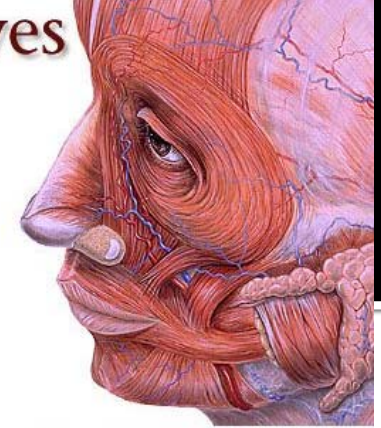
- I.
- II.
- VIII.

■ Motor:

- IV.
- VI.
- XI.
- XII

Cranial Nerves

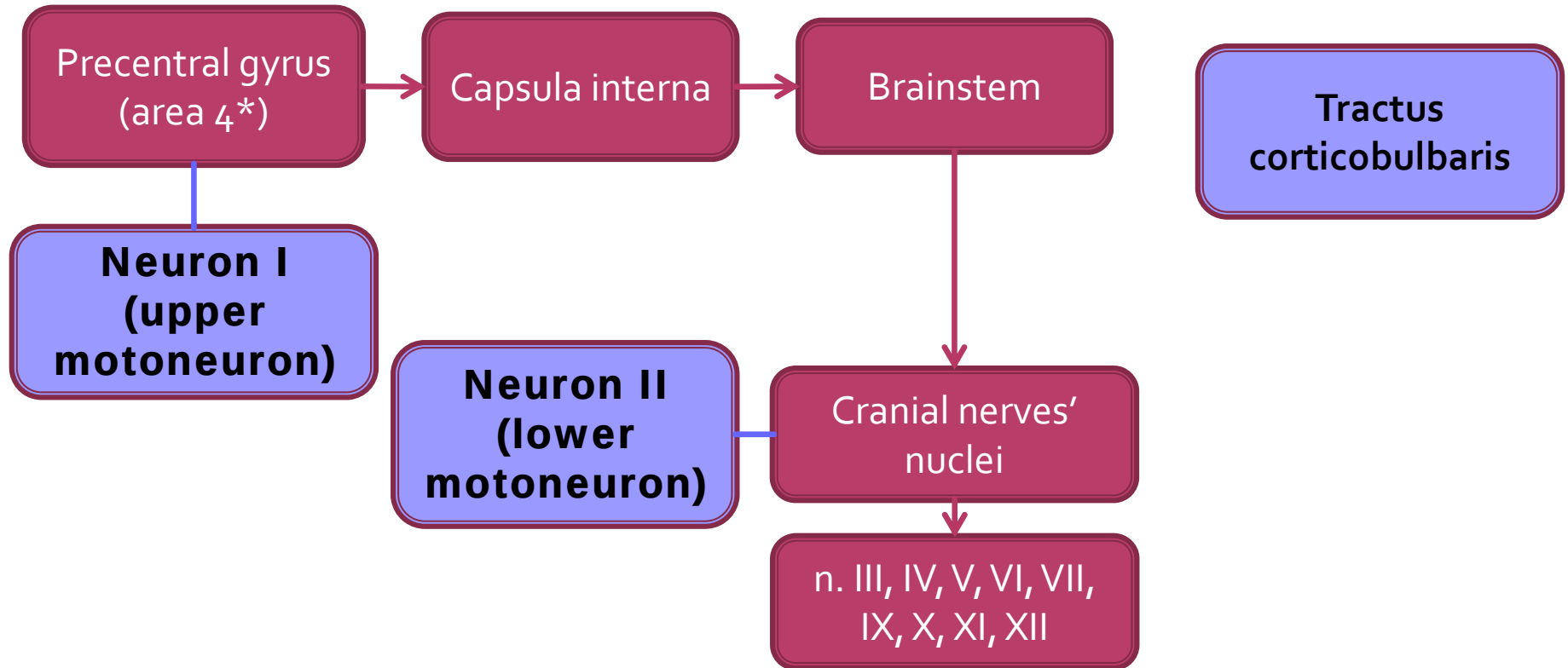
- I Olfactory
- II Optic
- III Oculomotor
- IV Trochlear
- V Trigeminal
- VI Abducens
- VII Facial
- VIII Vestibulocochlear
- IX Glossopharyngeal
- X Vagus
- XI Accessory
- XII Hypoglossal



Efferent nerves (from the CNS)

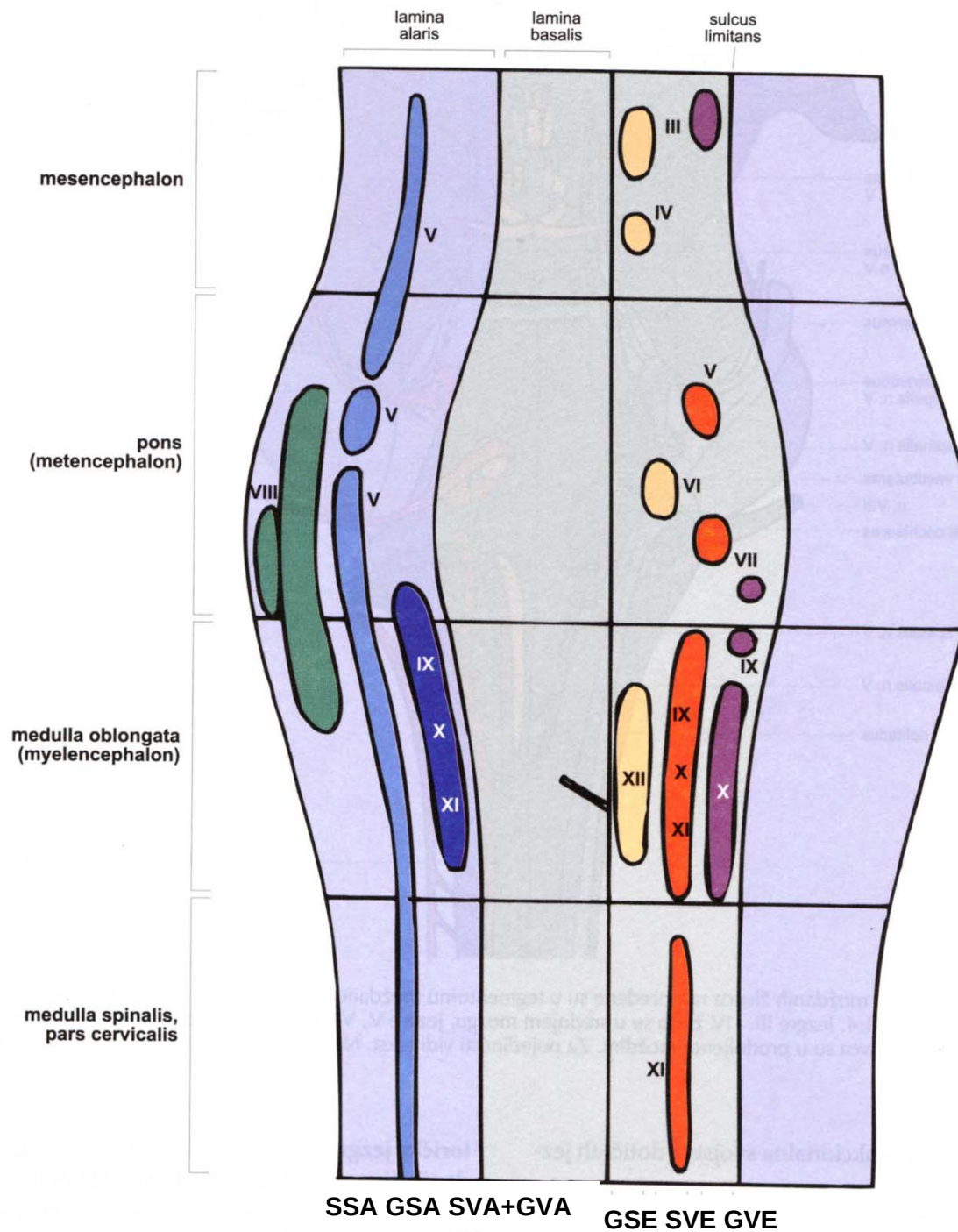
- **Genereal somatic efferents (GSE):**
 - CN III, IV, VI, XII
 - skeletal muscles derived from somites
- **Special visceral efferents (SVE):**
 - CN V, VII, IX, X, XI
 - skeletal muscles derived from branchial arches
- **General visceral efferents (GVE = autonomic):**
 - CN III, VII, IX, X
 - smooth muscles and glands

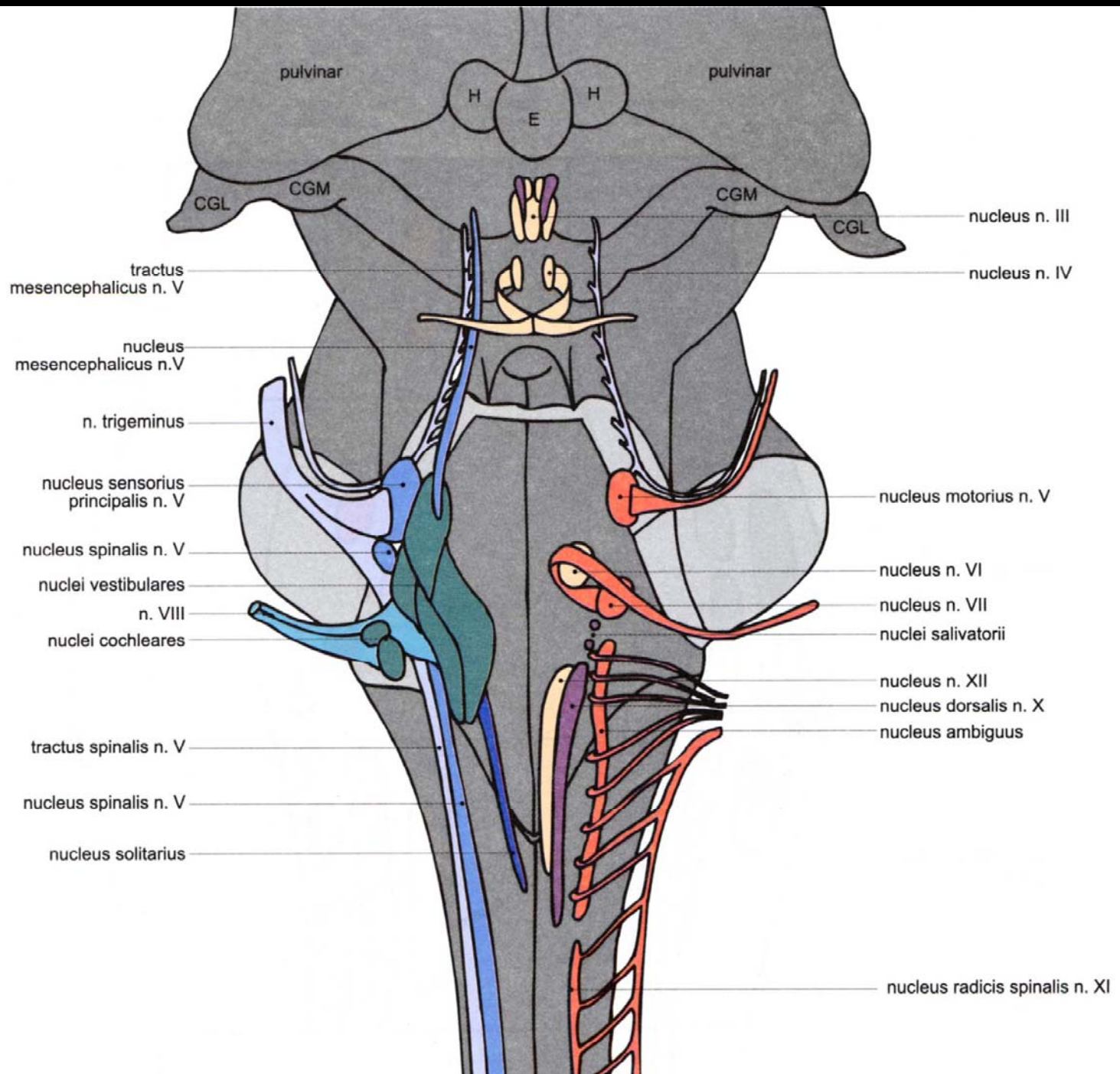
Motor innervation of the head (GSE+SVE)



Afferent nerves (to the CNS)

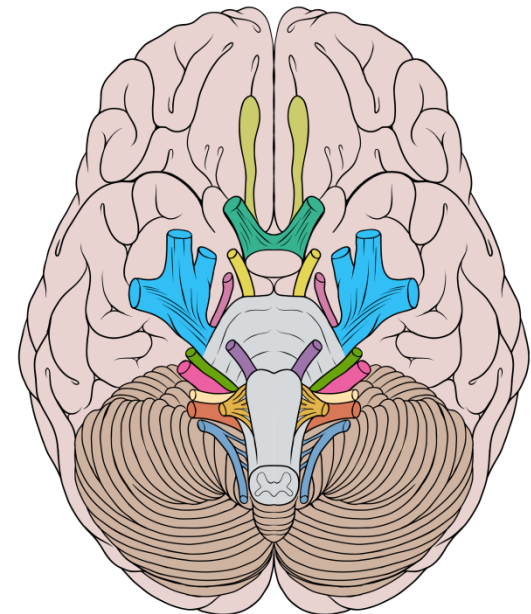
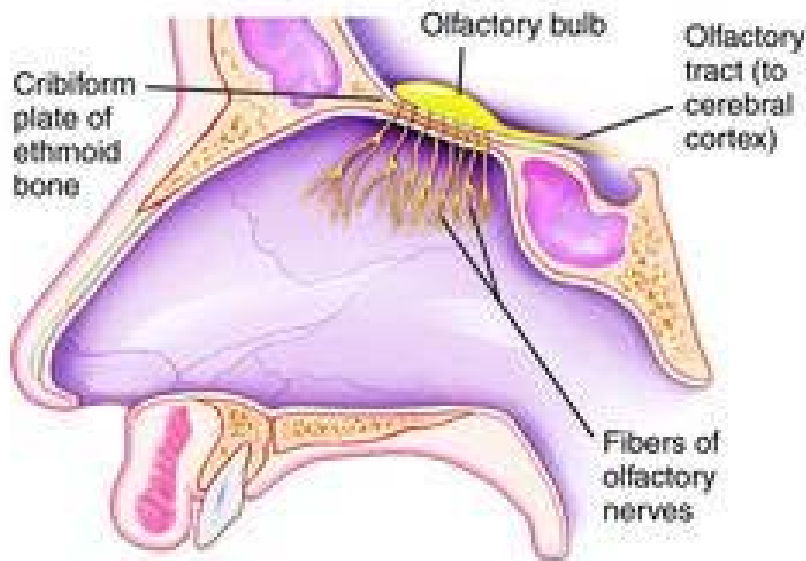
- **General somatic afferents (GSA)**
 - CN V, VII, IX, X
 - sensations of pain, temp, touch, pressure
- **Special sensory afferents (SSA)**
 - CN II, VIII
 - From highly specialized somatic receptors
- **Special visceral afferents (SVA)**
 - CN I (olfaction), CN VII, IX, X (taste) – chemoreceptors
- **General visceral afferents (GVA)**
 - CN IX and X (visceral pain, chemoreception, general unpleasant feelings)



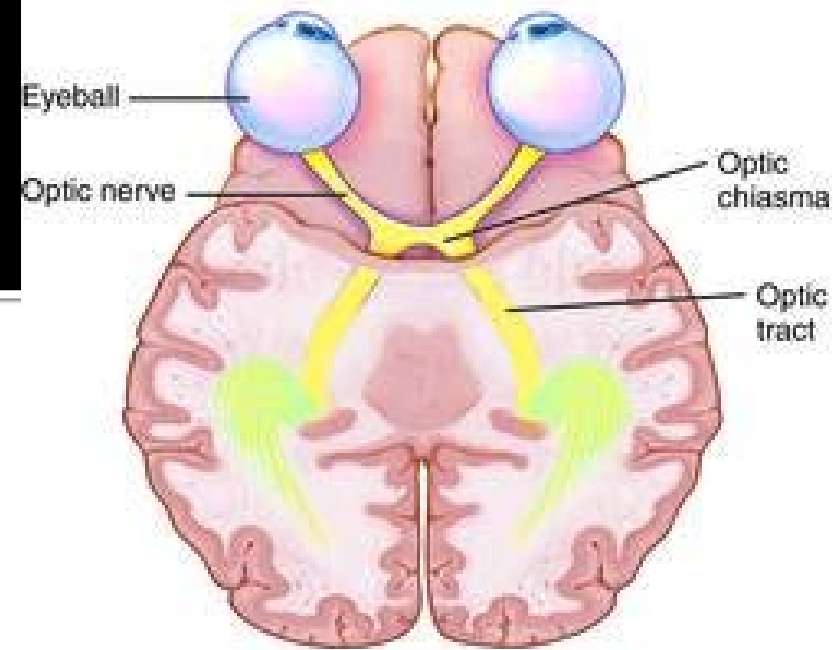


N. olfactorius (I)

- SVA (receptors are chemoreceptors)
- Enters the brain through the cribriform plate and supplies the olfactory bulb



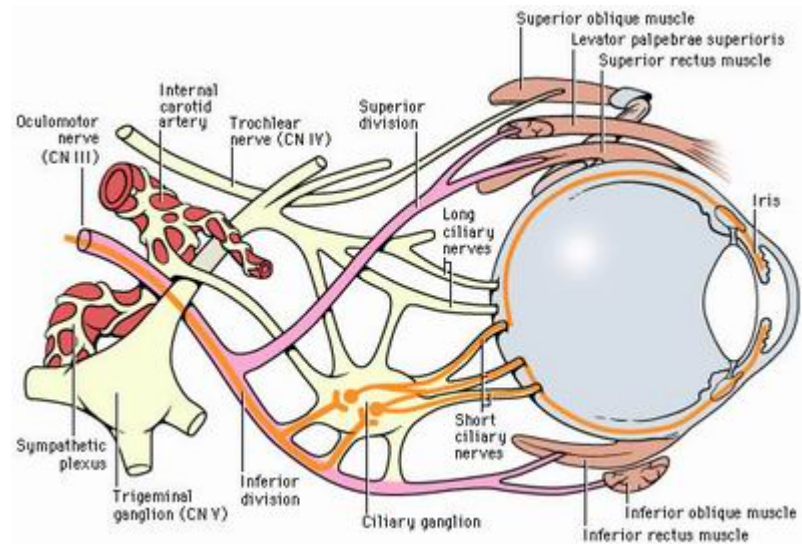
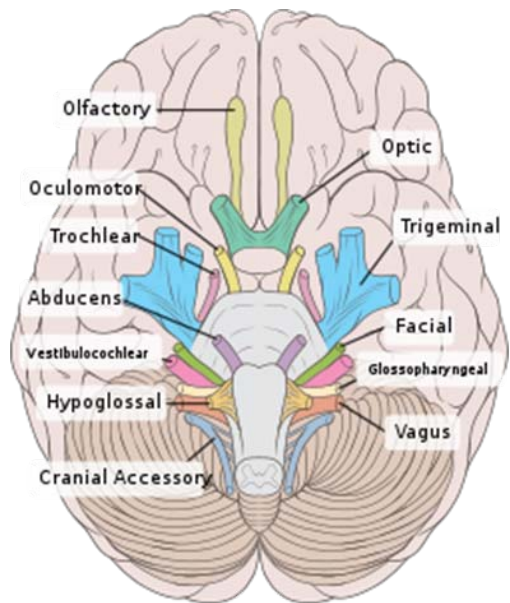
N. opticus (II)



- SSA
- Conveys visual signals to the CNS
- Enters the brain at the level of the preoptic region of the diencephalon

N. oculomotorius (III)

- **GSE** – extraocular eye muscles
- **GVE** – parasympathetic innervation of the pupillary and ciliary muscles



N. oculomotorius (III)

Motor nucleus:

- situated in the mesencephalon (level of the superior colliculus) – fossa interpeduncularis – the orbit
- Superior, medial, and inferior rectus muscles, inferior oblique and levator palpebrae superior muscle
- *Bilateral corticobulbar innervation*

N. oculomotorius (III)

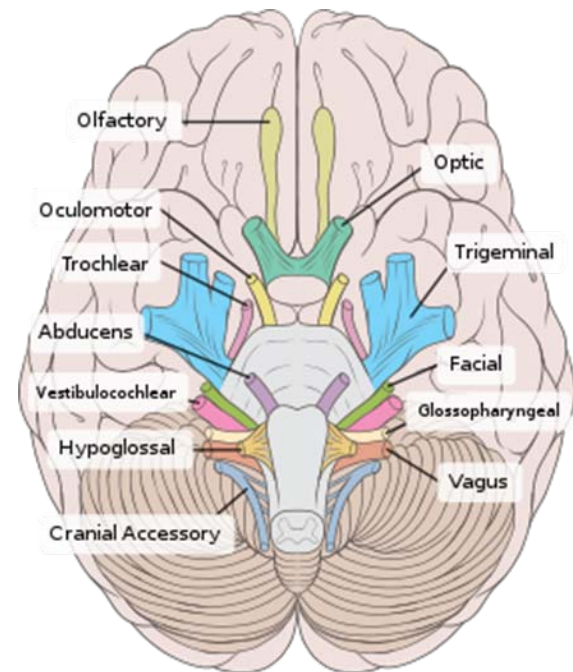
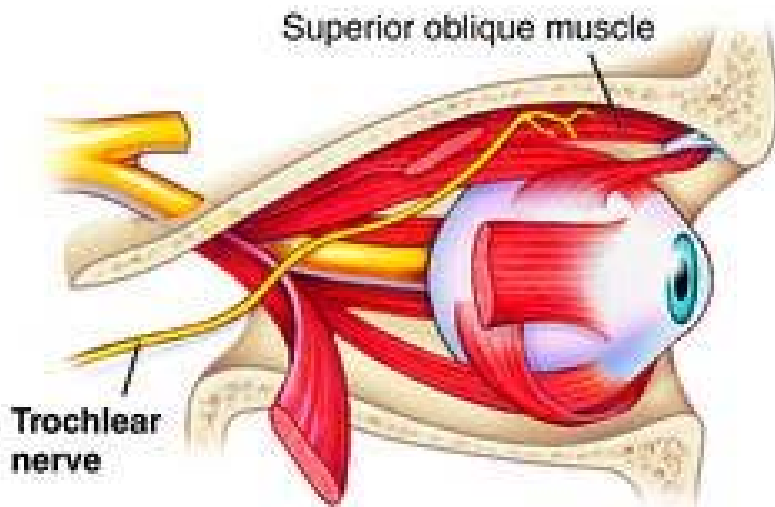
Westphal – Edinger nucleus

- Most of the fibers: ciliary ganglion (m. constrictor pupillae*)
- Some fibers pass through ciliary ganglion and synapse in episcleral ganglion – ciliary muscle (accommodation)

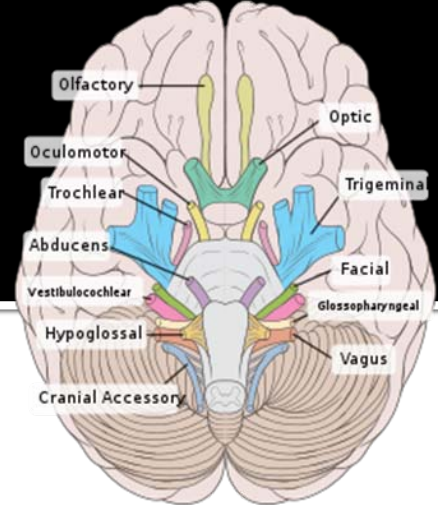
* M. dilatator pupillae – sympathetic fibers from superior cervical gangl.

N. trochlearis (IV)

- GSE
- M. obliquus superior – moves eye downward while in medial position



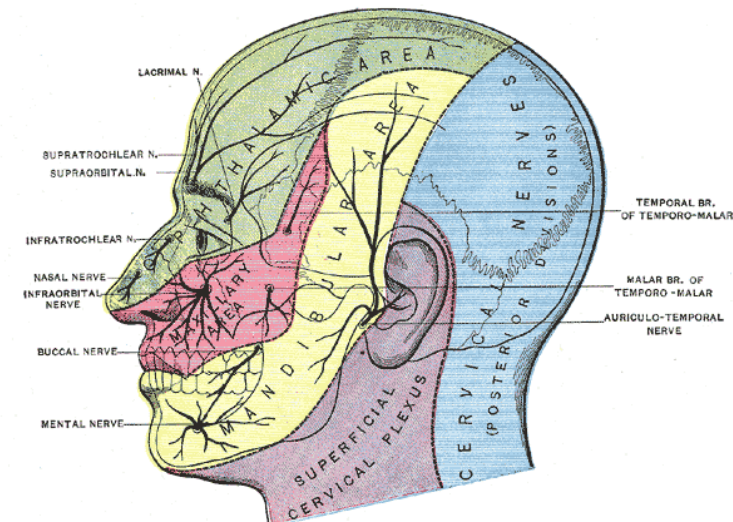
N. trigeminus (V)



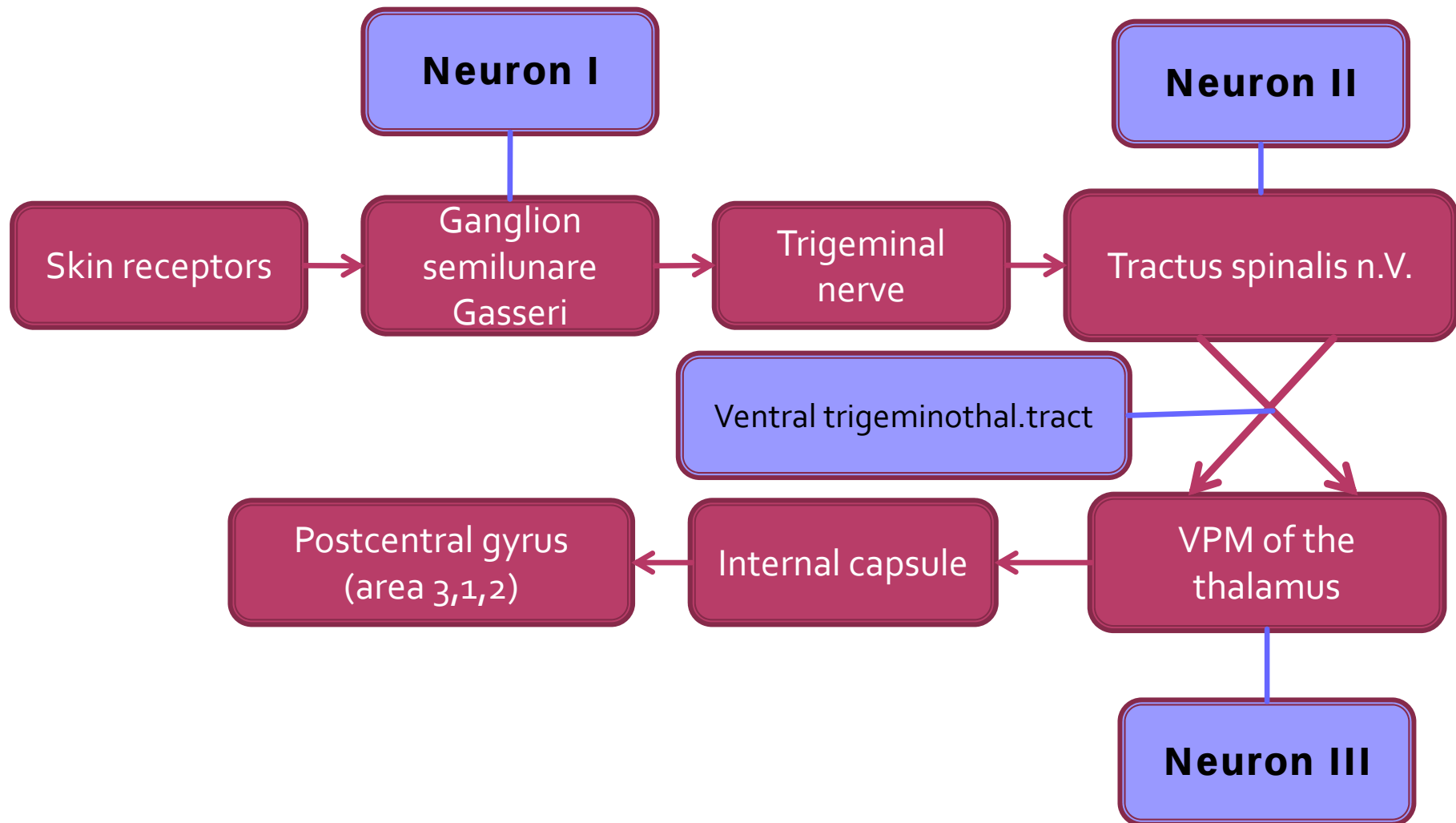
- **SVE** (muscles of mastication; upper motoneuron = bilateral inputs from the cortex; lower motoneuron lesions – difficulties in chewing and biting responses)
- **GSA** (somatosensory inputs from the anterior 2/3 of the head)

Somatosensory component of n. V.

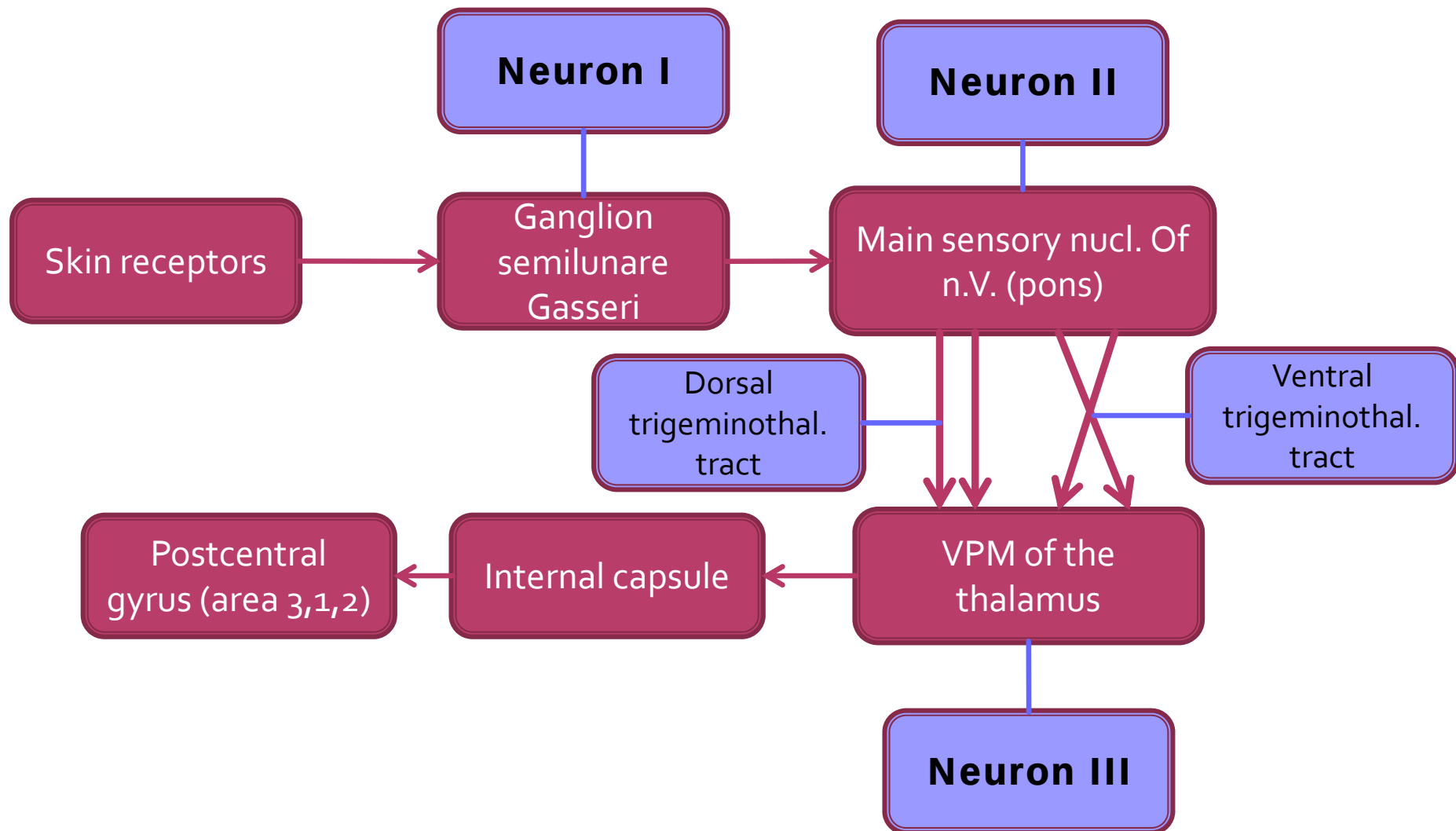
- GSA from the anterior 2/3 of the head
- Three principal divisions:
 - Ophthalmic
 - Maxillary
 - Mandibular



Pain and temperature

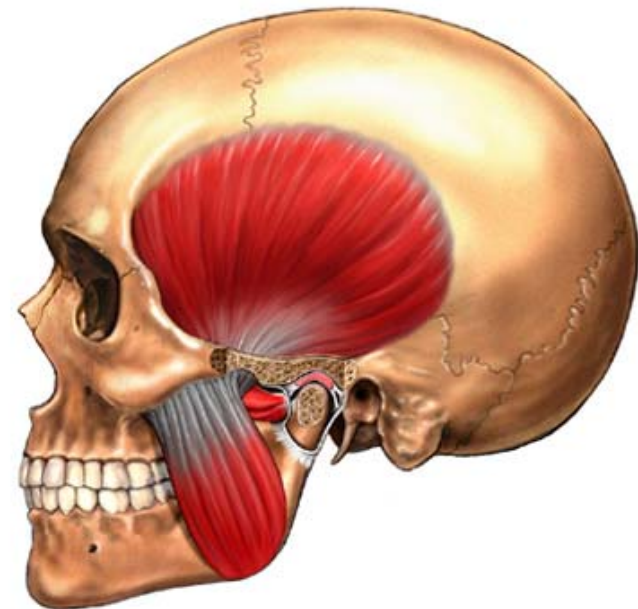


Touch and pressure



Unconscious proprioception

- Muscle spindles in masticatory muscles and temporomandibular joint – via mandibular branch
- ***Neuron I = mesencephalic nucleus***



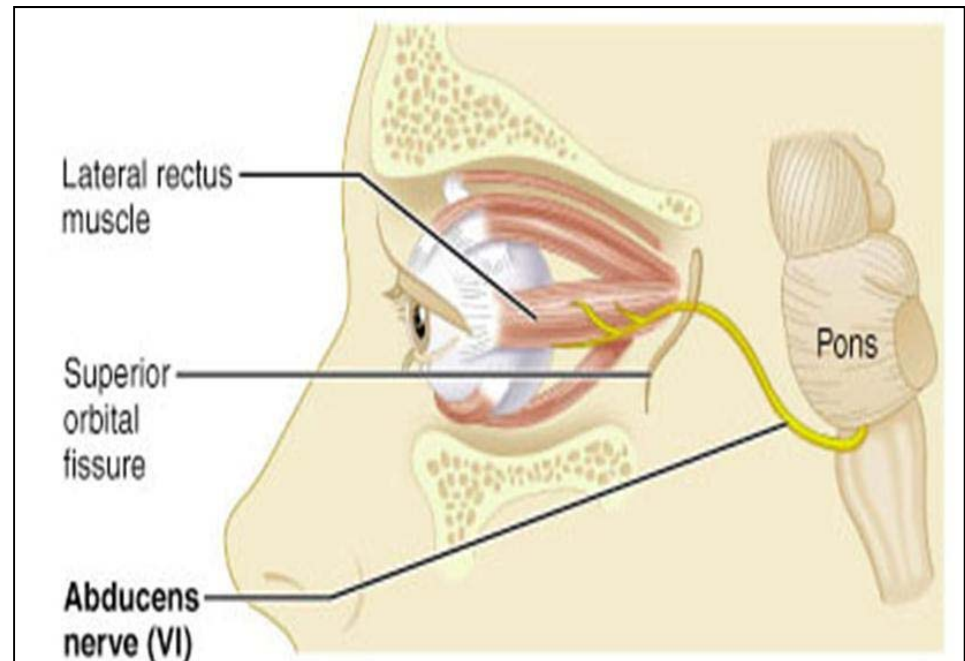
Clinical importance

Trigeminal neuralgia (tic douloureux)

- Often localized to a portion of one side of the face (associated with a specific branch)
- Unknown etiology (irritation of the trigeminal nerve by inflammation, tumor, or vascular lesion)
- Therapy? Surgery?

N. abducens (VI)

- GSE
- M. rectus lateralis – moves eye laterally
- Clinical disorder: medial strabismus



N. facialis (VII)

- **Motor components:**

- **SVE** (muscles derived from the second branchial arch)
- **GVE** (parasympathetic: salivation, lacrimation, nasal cavity mucosal secretion)

- **Sensory components:**

- **GSA** (somesthetic impulses from the back of the ear and external auditory meatus)
- **SVA** (taste)

N. facialis – motor components

■ SVE

- Muscles of facial expression, auricular, posterior belly of digastric, stylohyoid, platysma and stapedius muscle

■ GVE - parasympathetic innervation

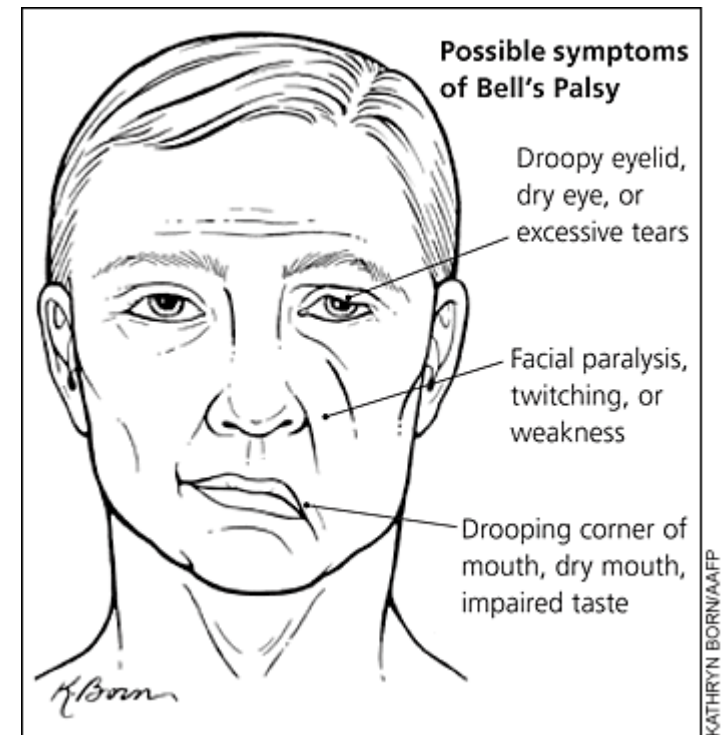
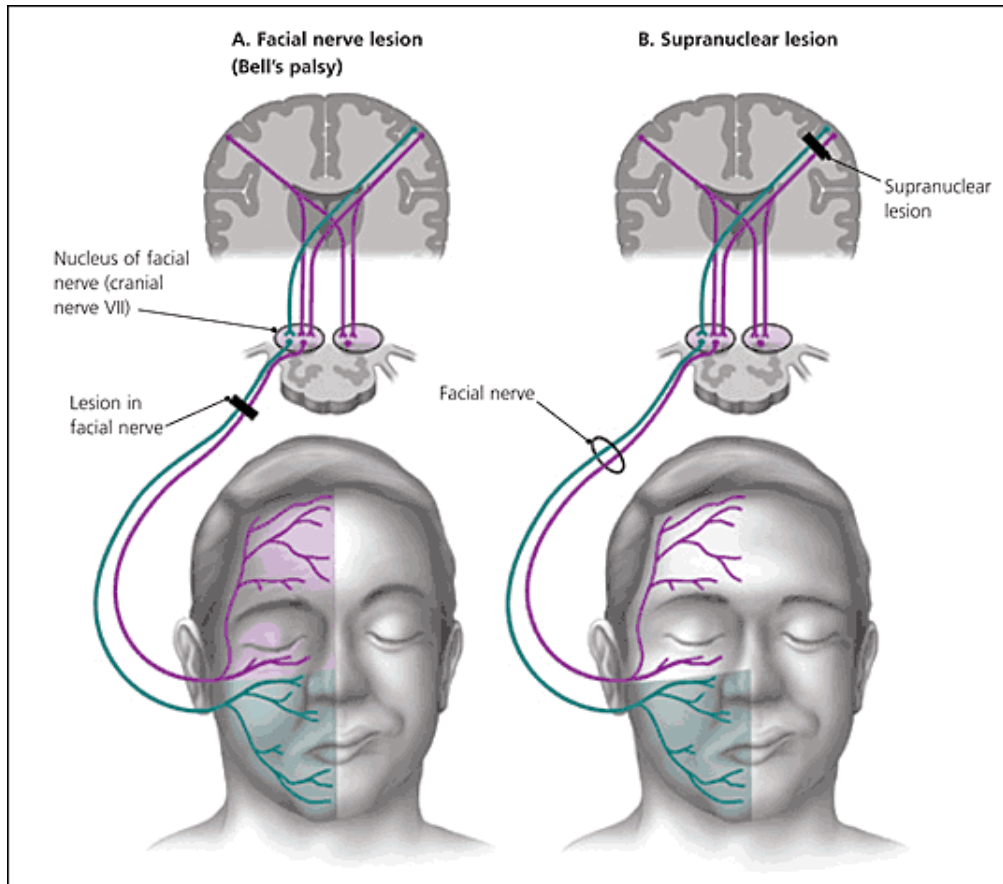
- from the superior salivatory nucl. to the submandibular (submandibular and sublingual glands) and pterygopalatine ganglion (lacrimal, nasal and palatine glands)

N. facialis – sensory components

- **SVA** – taste from the anterior 2/3 of the tongue – geniculate ganglion – solitary nucl. – thalamic VPM nucl.
- **GSA** – back of the ear and external auditory meatus – geniculate ganglion – spinal tract of the trigeminal nucl.
 - Pain and temp, pressure, tactile stimuli

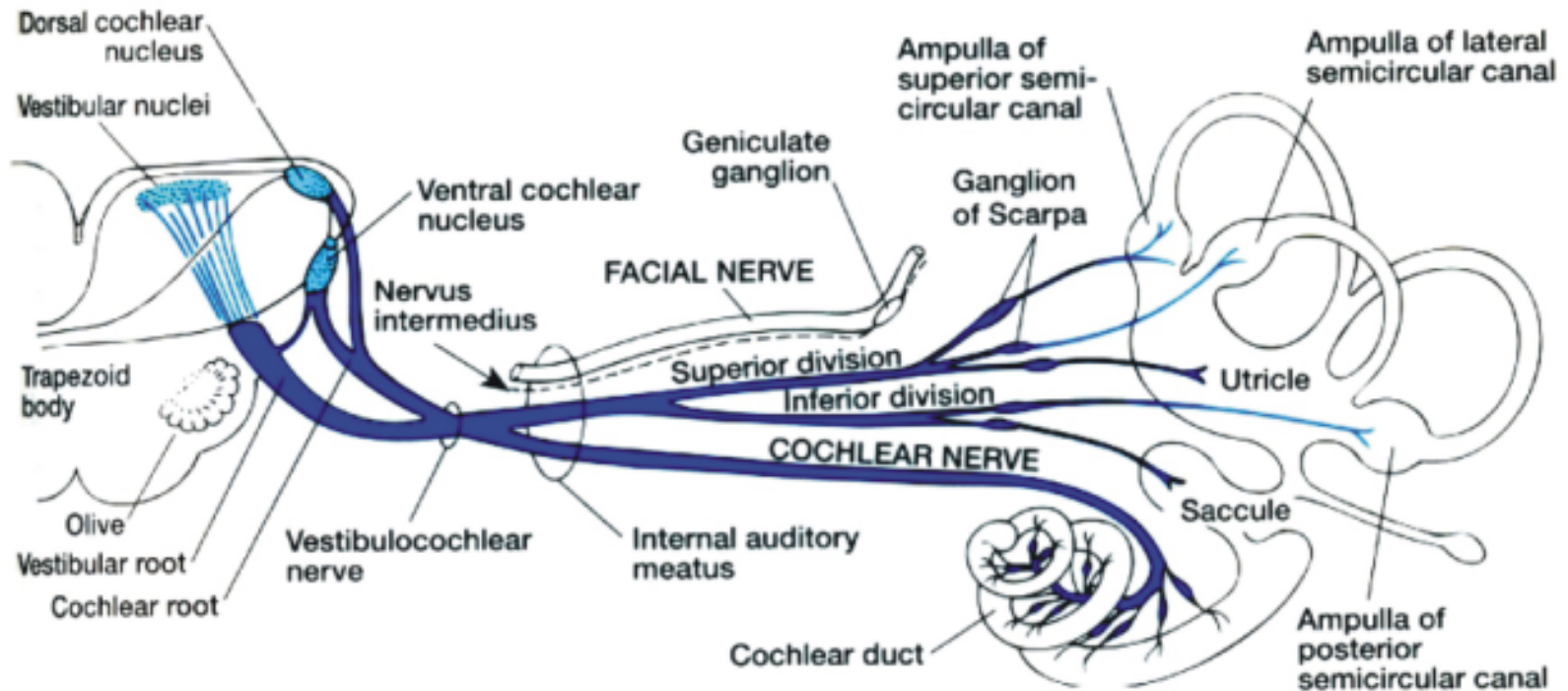
Clinical disorders

- Upper part of the face = bilateral innervation
- Lower part of the face = contralateral innervation



N. vestibulocochlearis (VIII)

- SSA
- Auditory and vestibular signals for the CNS



N. glossopharyngeus (IX)

- **Motor components:**

- **SVE** (muscles derived from the branchial arches)
- **GVE** (salivation)

- **Sensory components:**

- **GSA** (somesthetic impulses from the back of the ear)
- **GVA** (changes of the blood pressure)
- **SVA** (taste and blood oxygen level)

N. glossopharyngeus – motor components

- **SVE** – from the nucl. ambiguus
 - M. stylopharyngeus – speech and swallowing
- **GVE** – from the inferior salivatory nucl. to the otic ganglion
 - Parasympathetic innervation of the parotid gland - salivation

N. glossopharyngeus – sensory components

- **GVA** – baroreceptors in carotid sinus – inferior (petrosal) ganglion – solitary nucl.
 - Carotid sinus baroreflex
- **GSA** – tympanic membrane and skin of the external ear, posterior third of the tongue, eustachian tube, tonsil and upper part of the pharynx – superior ganglion – spinal trigeminal nucl.
 - Pain and temp, pressure, tactile stimuli

N. glossopharyngeus – sensory components

■ SVA

- ***Respiratory functions:*** chemoreceptors (PaO₂, PaCO₂, pH of the blood) in the carotid body – inferior ganglion – solitary nucleus, RF
 - Carotid body chemoreflex
- ***Taste functions:*** taste buds in posterior third of the tongue – inferior ganglion – solitary nucl. – VPM thalamic nucl.

N. vagus (X)

- **Motor components:**

- **SVE** (muscles derived from the branchial arches)
- **GVE** (body viscera)

- **Sensory components:**

- **GSA** (somesthetic impulses from the back of the ear)
- **GVA** (changes of the blood pressure)
- **SVA** (taste and blood oxygen level)

N. vagus (X) – motor components

- **SVE** – from the nucl. ambiguus
 - Muscles of the pharynx and larynx – role in speech
- **GVE** – from the dorsal motor nucl.
 - Parasympathetic innervation of the body viscera to left colic flexure
 - Bronchoconstriction, speeding up of peristalsis, cardiac cycle slowing, increases in bronchi, stomach, pancreas and intestines' secretion

N. vagus (X) – sensory components

- **GVA** – body viscera and aortic arch – inferior (nodose) ganglion – solitary nucl.
 - Unconscious (baroreceptors in aortic arch, part of baroreceptor reflex) and conscious (thirst, hunger) sensory inputs from the viscera
- **GSA** – back of the ear and external auditory canal – superior (jugular) ganglion – spinal trigeminal nucl.
 - Pain and temp, pressure, tactile stimuli

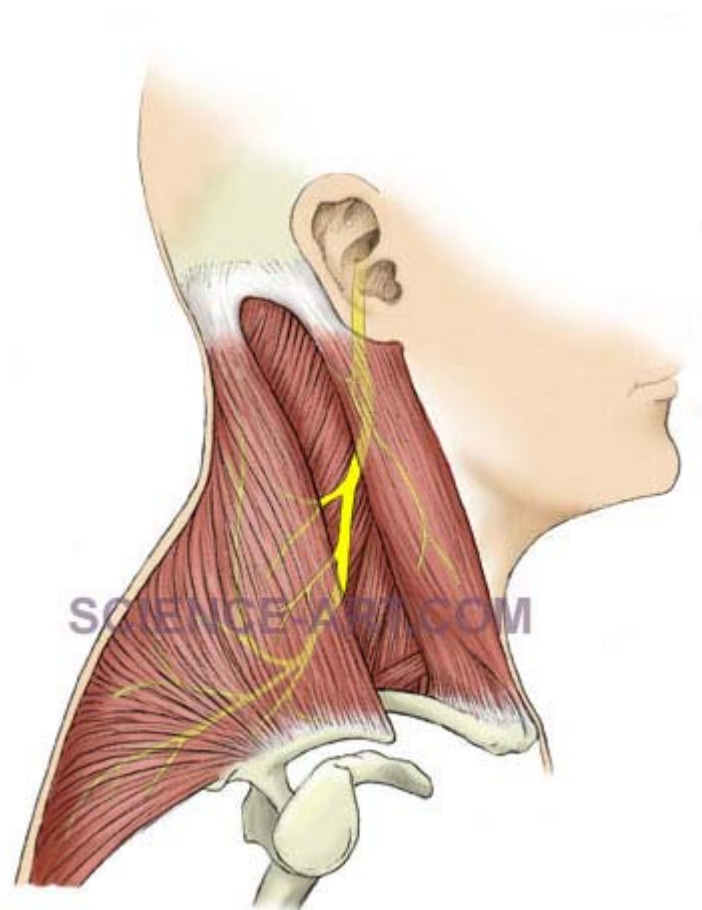
N. vagus (X) – sensory components

■ SVA

- ***Respiratory functions:*** chemoreceptors (PaO₂, PaCO₂, pH of the blood) in the aortic body – inferior ganglion – reticular formation
- ***Taste functions:*** taste buds in epiglottis and posterior pharynx wall – inferior ganglion – solitary nucl. – VPM thalamic nucl.

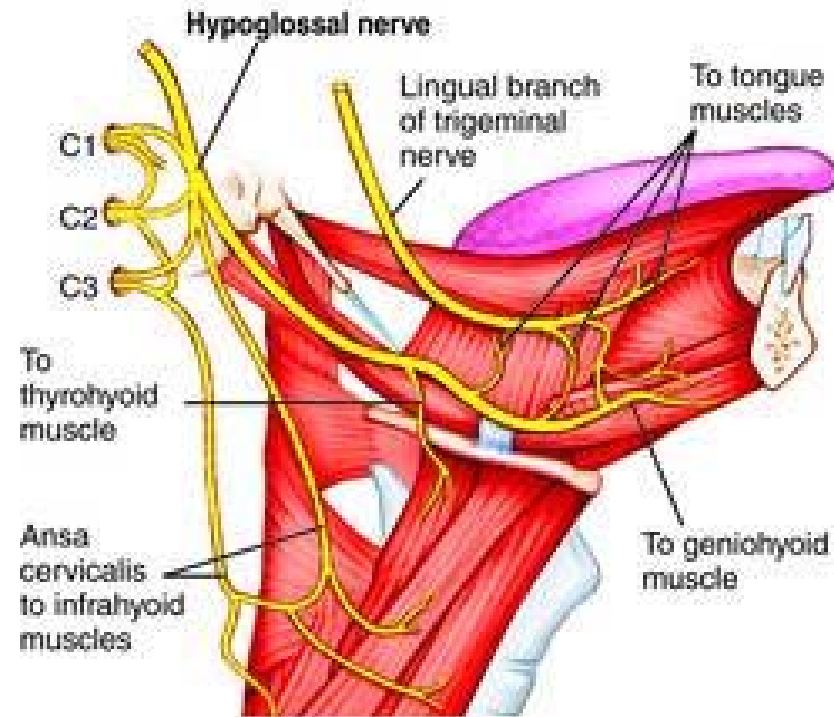
N. accessorius (XI)

- SVE / GSE
- Ventral horn cells of first 5-6 cervical segments
- M. trapezius and sternocleidomastoideus
- Contralateral turning and lifting of the head
- Supranuclear paralysis = contralateral



N. hypoglossus (XII)

- GSE
- Control of the shape and position of the tongue
- Extrinsic (styloglossus, hyoglossus, genioglossus) and intrinsic muscles of the tongue
- Damage – protruded tongue deviates to the side of the lesion
- ***Contralateral innervation!***

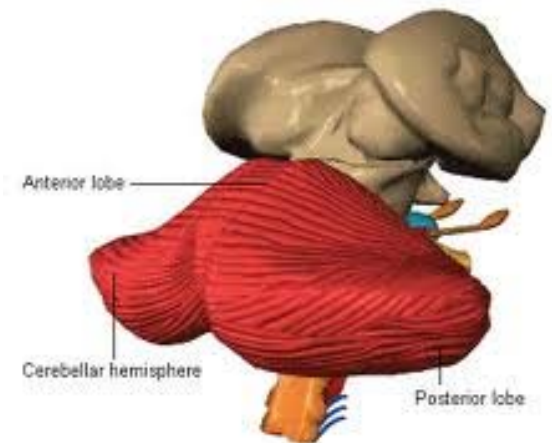


Parasympathetic nuclei and ganglia of the cranial nerves

Nerve	Nucleus	Ganglion	Brainstem location
N. oculomotorius	Westphal-Edingerova	Ciliary	Mesencephalon
N. facialis	Nucl. salivatorius sup.	Submandibulary Pterygopalatine	Pons
N. glossopharyngeus	Nucl. salivatorius inf.	Oticum	M. oblongata
N. vagus	Nucl. dorsalis n. vagi	At visceral organs	M. oblongata

Cerebellum

- Integration of information from spinocerebellar pathways, vestibular nuclei and cortex (via pons and cerebellar peduncles)
- Cortex, white matter, deep nuclei
- Two hemispheres + vermis
- Main neurotransmitter: GABA



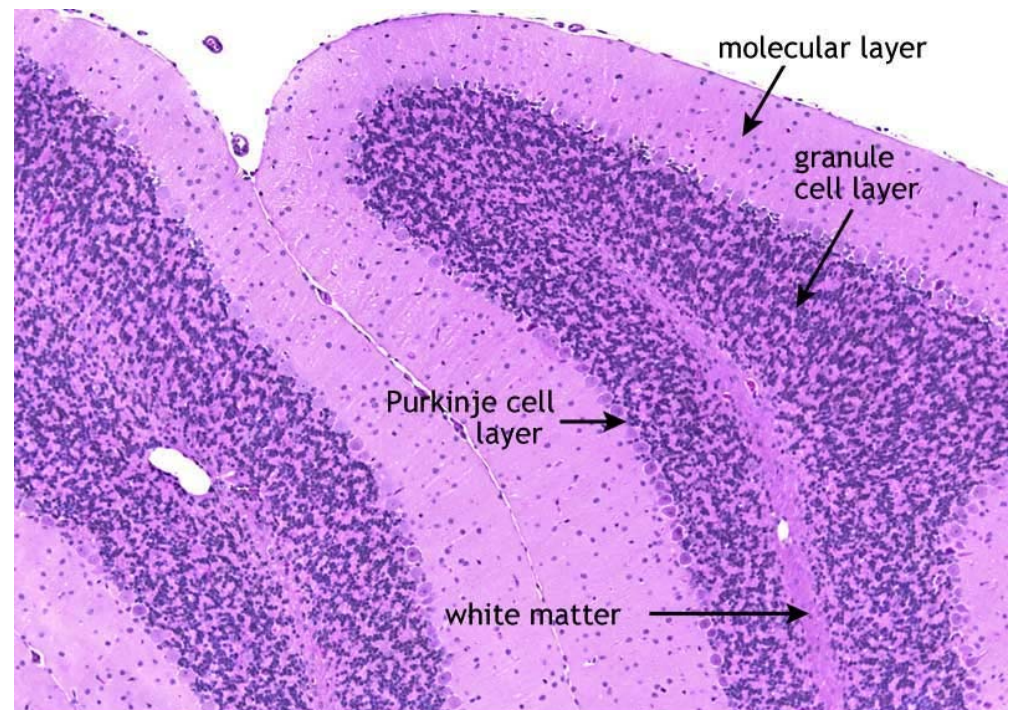
Cerebellum

- Attached to the brainstem by:

- afferent** {
 - **Inferior cerebellar peduncle** – fibers from spinal cord and lower brainstem regions
 - **Middle cerebellar peduncle** – cortex – pons – cortex cerebelli
- efferent** {
 - **Superior cerebellar peduncle** – to nucl. ruber and VLN of thalamus

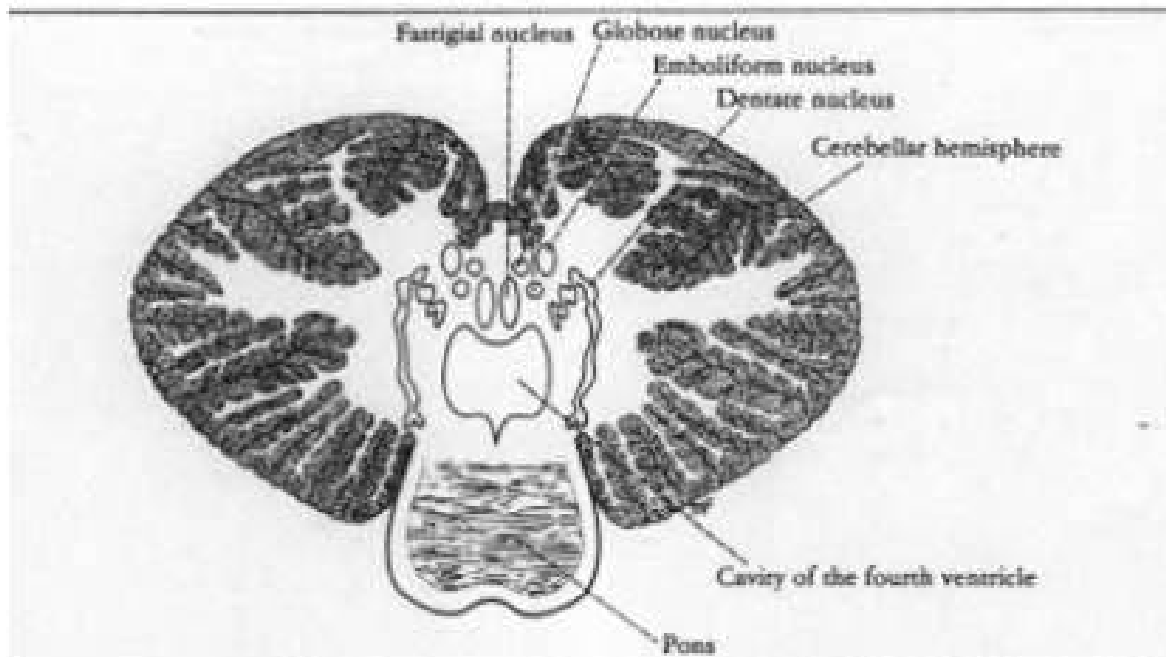
Cortex cerebelli

- Folia; no gyri and sulci
- 3 layers of the cells:
 - Purkinje cells layer
 - Molecular layer
 - Granule cell layer

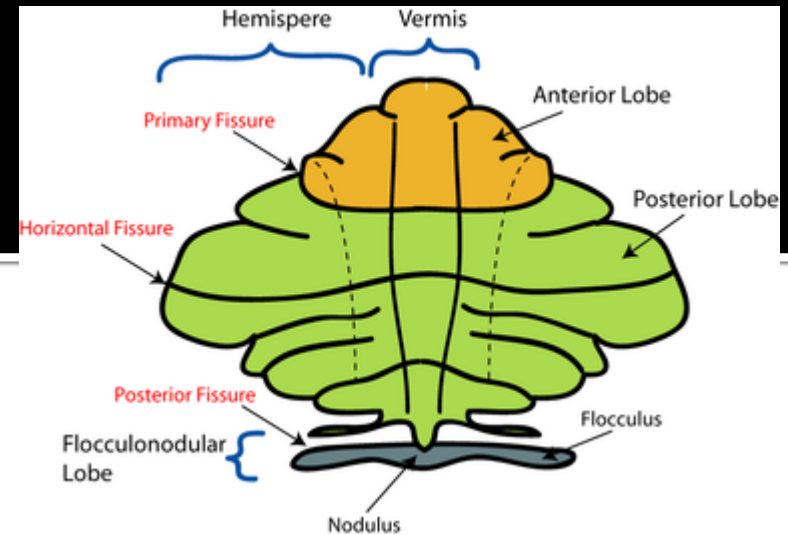


Deep cerebellar nuclei

- Nucleus fastigii (=nucl.medialis) – to RF and vestibular neurons
 - Nucleus globosus
 - Nucleus emboliformis
 - Nucleus dentatus (=nucl.lateralis) – to VLN of thalamus
- } = nucl.interpositus – to nucl. ruber

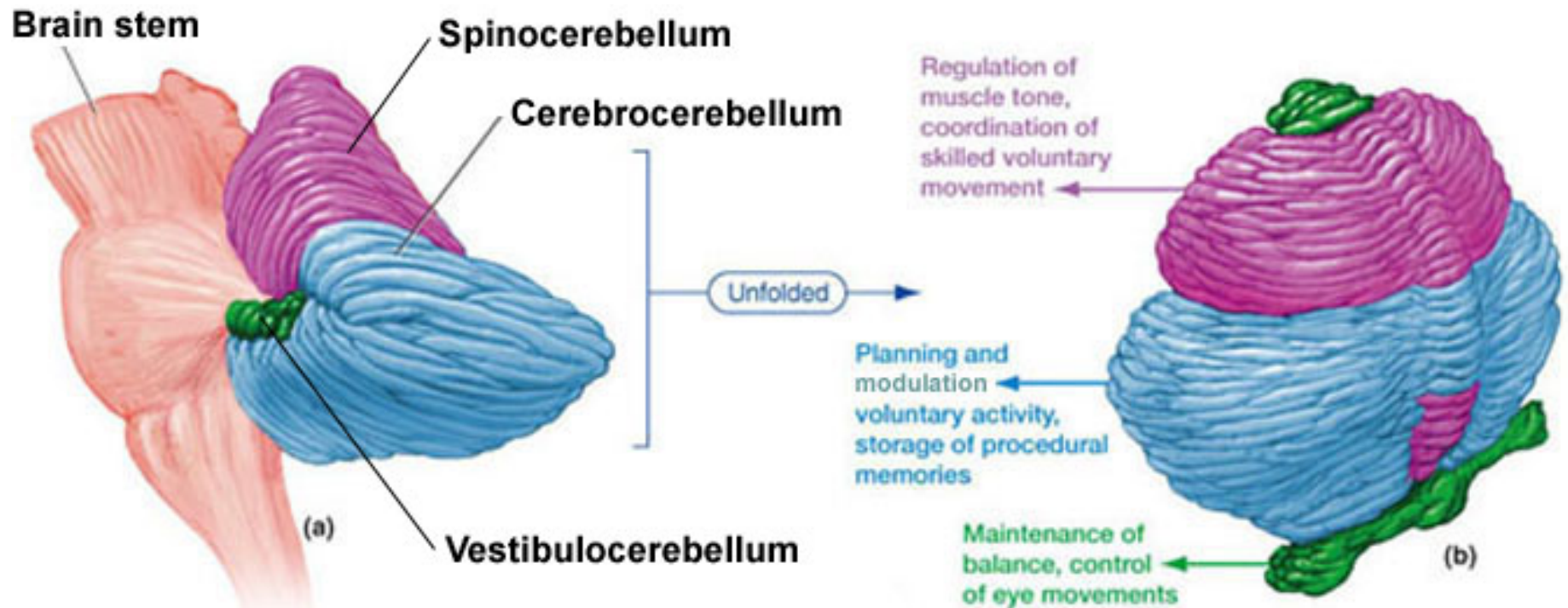


Cerebellum



Anatomical name	Filogenetic name	Functional name
Lobus anterior	Paleocerebellum	Spinocerebellum
Lobus posterior	Neocerebellum	Pontocerebellum / Cerebrocerebellum
Lobus flocculonodularis	Archicerebellum	vestibulocerebellum

Cerebellum



Damage of the cerebellum

- Loss of balance
- Tremors
- Lack of coordination of muscles
- Reduced muscle tone

