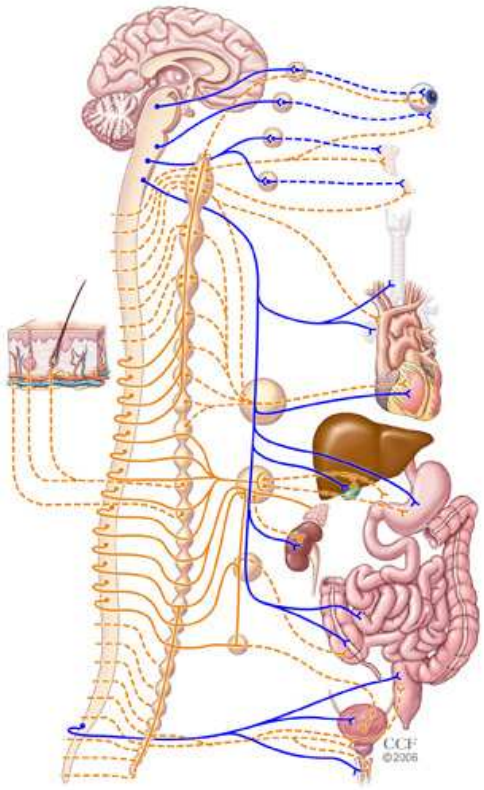
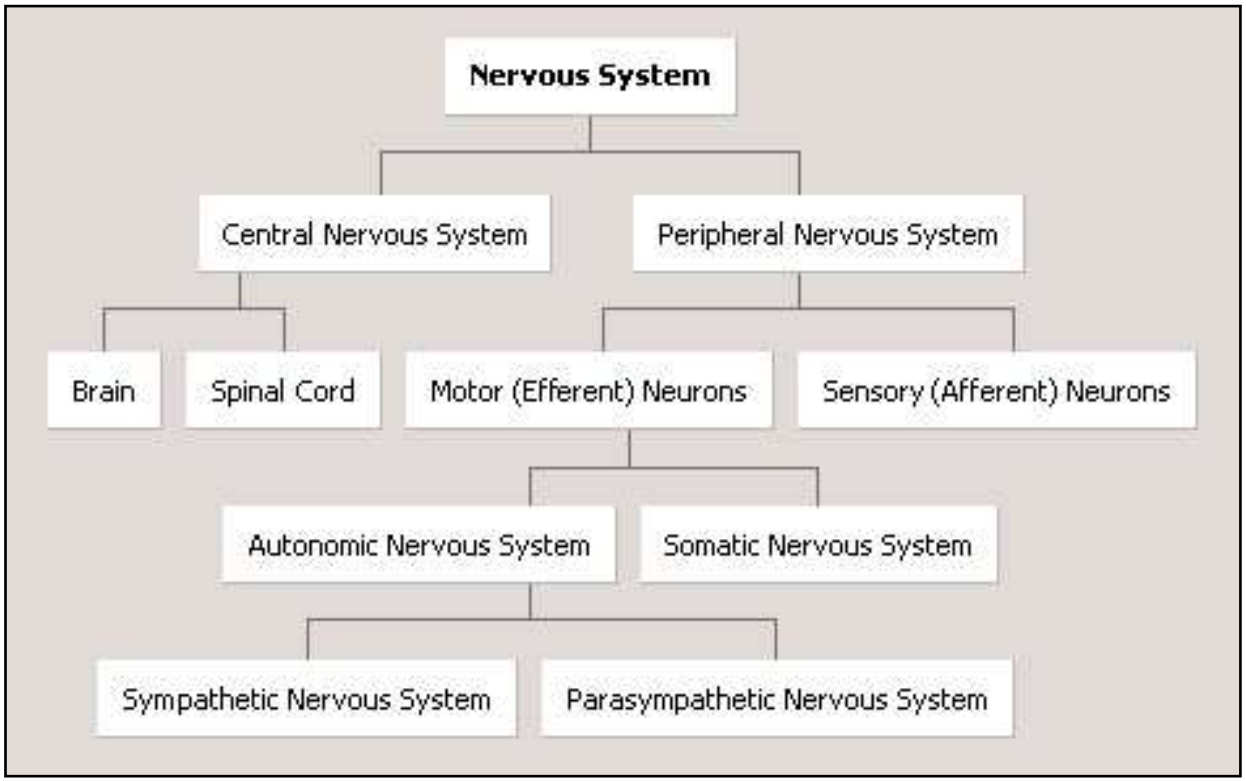


Peripheral Nervous System, Autonomic Nervous System

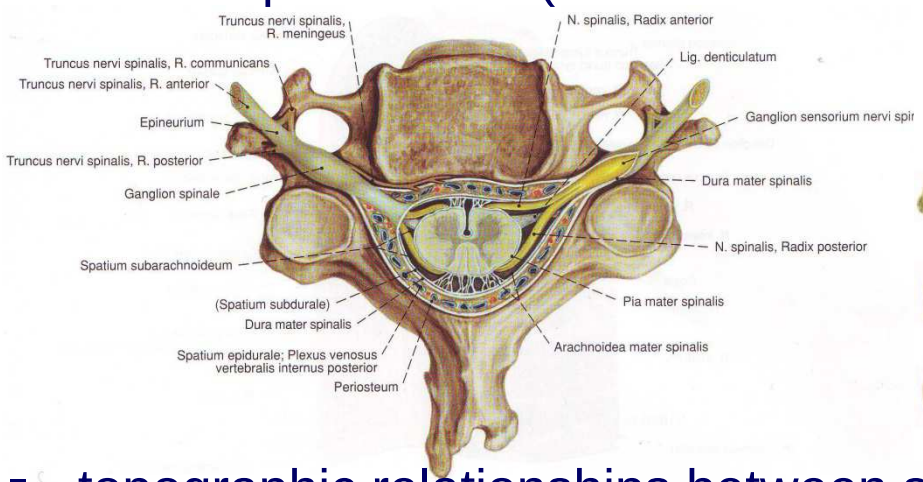
1. Spinal nerves – formation and general organization
2. Cranial nerves – overview:
   - ✓ origin and peripheral distribution
   - ✓ functional components and modality
   - ✓ innervation zones
3. Topographic organization and structural features of ANS
4. Main subdivisions of the ANS:
   - ✓ sympathetic nervous system
   - ✓ parasympathetic nervous system
   - ✓ enteric nervous system

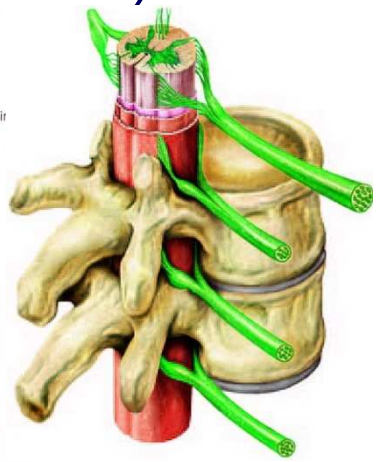
Classification of the nervous system

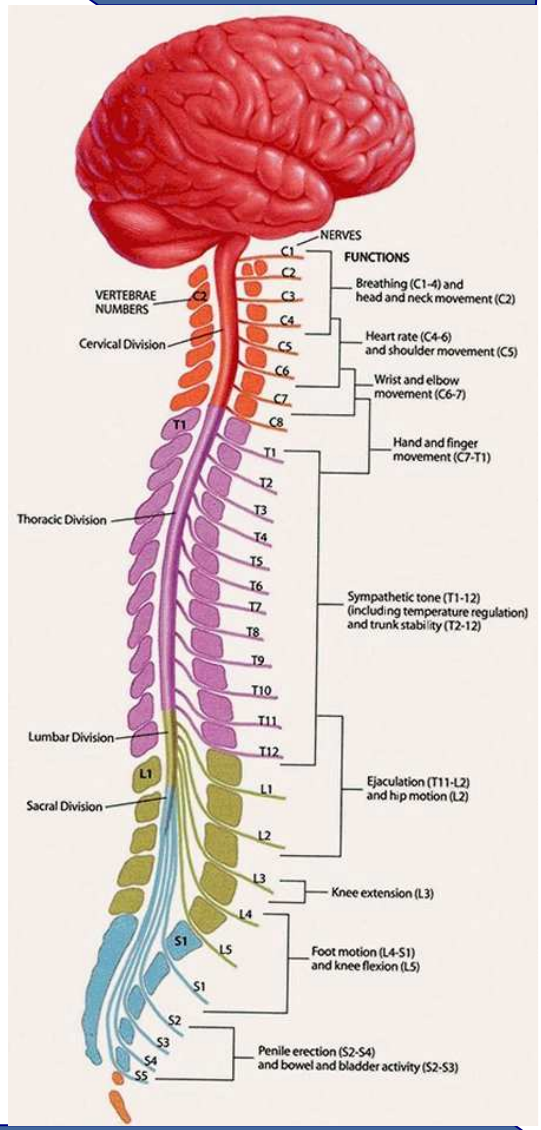


General organization of the spinal nerves

- 31 pairs of segmentally arranged nerves:
  - ✓ 8 cervical – C1-C8
  - ✓ 12 thoracic – Th1-Th12
  - ✓ 5 lumbar – L1-L5
  - ✓ 5 sacral – S1-S5
  - ✓ 1 coccygeal – Co1
- corresponds to a pair of embryonic somites
- emerges through the intervertebral foramen
- mixed spinal nerve (common nerve trunk)



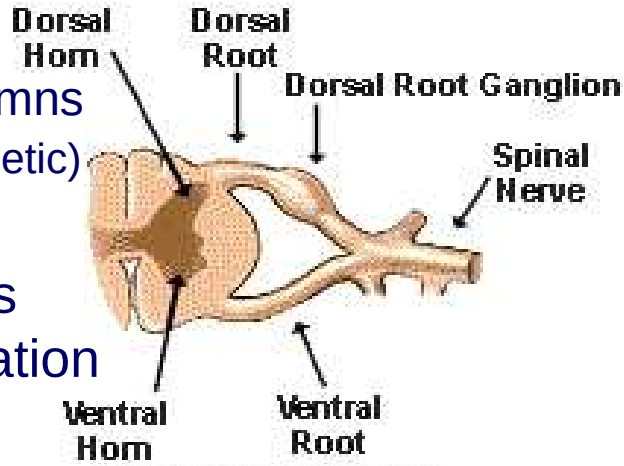


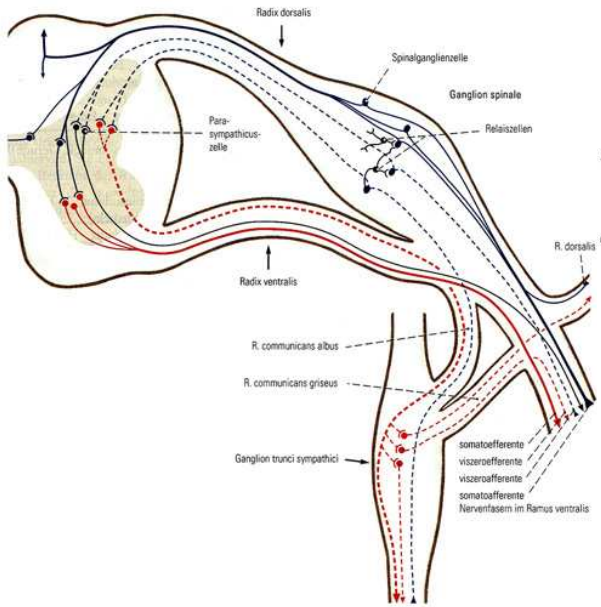


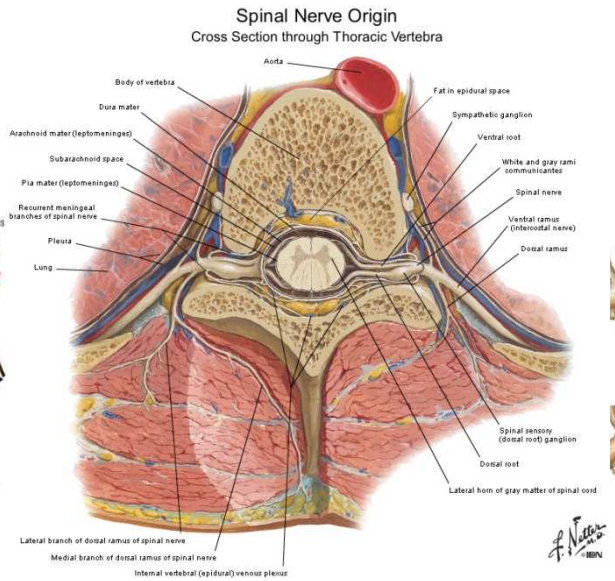
- topographic relationships between spinal nerves, segments and vertebrae

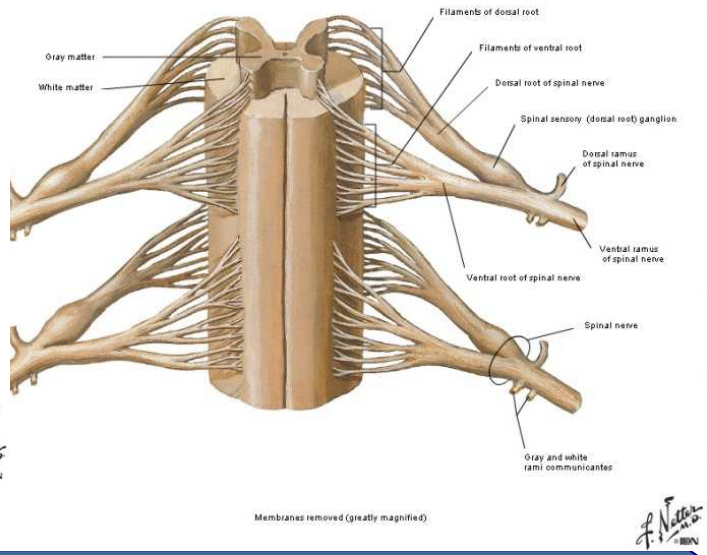
Spinal nerve formation

- ventral (motor) root:
  - ✓ axons of neurons in anterior and lateral grey columns
  - ✓ motor and autonomic (sympathetic and parasympathetic)
- dorsal (sensory) root:
  - ✓ central processes of the dorsal ganglion cells
  - ✓ convey somatic and visceral sensory information



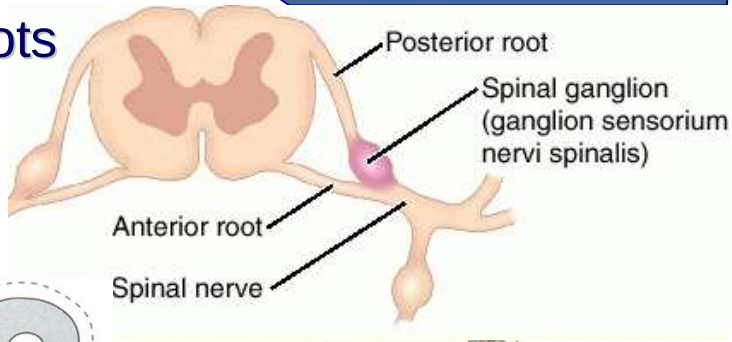


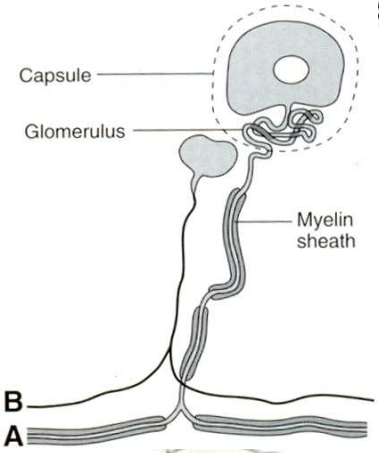


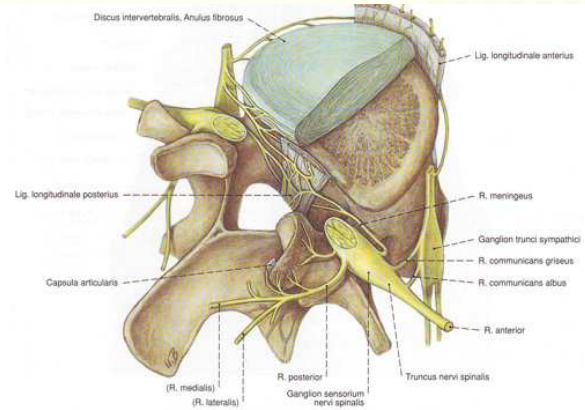


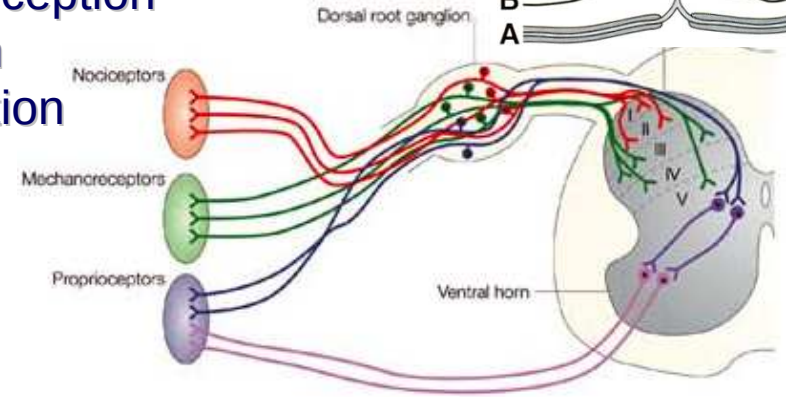
Spinal ganglion

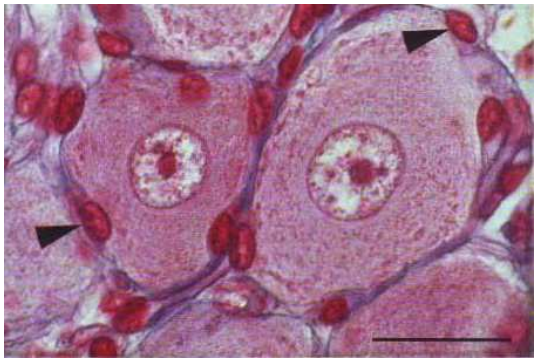
- spindle-shaped aggregations on the dorsal roots – **dorsal root ganglion**
  - ✓ (pseudo)unipolar neurons – ovoid or spherical (primary afferent neurons)
  - ✓ satellite cells (capsular cells, amphicytes)
  - ✓ Schwann cells and blood vessels
- embryonic origin – neural crest cells
- location – in intervertebral foramina
- axons (afferents) – proximal and distal processes
- functional modalities:
  - ✓ mechanoreception
  - ✓ nociception
  - ✓ proprioception





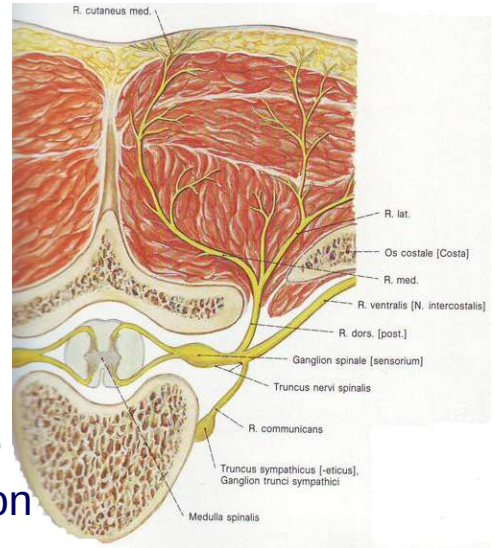


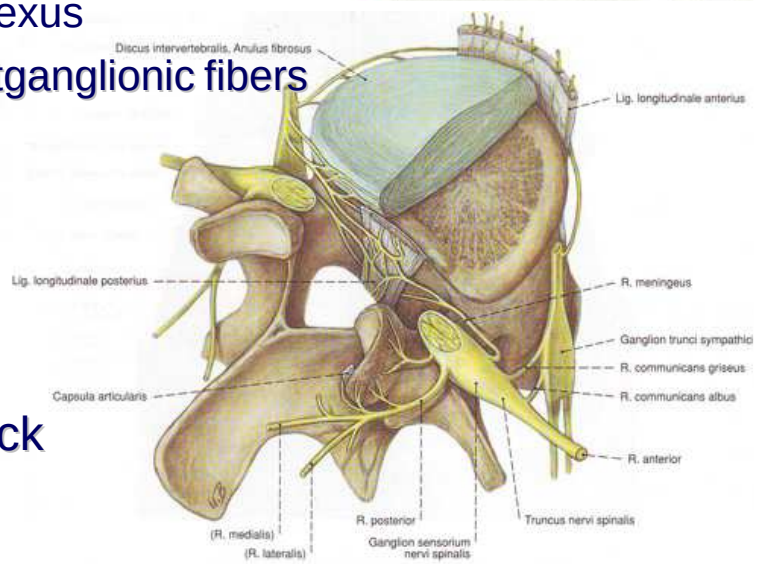




Spinal nerve trunks

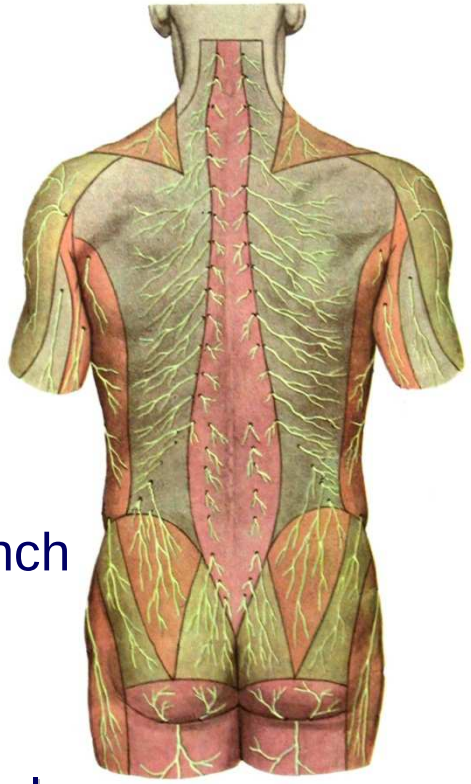
- Spinal nerve functional components:
  - ✓ somatic components – efferent and afferent fibers
  - ✓ visceral components – sympathetic or parasympathetic
- Spinal nerve branches:
  - ✓ meningeal branch – at all vertebral levels (recurrent meningeal nerve)
  - ✓ white ramus communicans – myelinated preganglionic fibers
    - ➢ all thoracic and L1-L2 to corresponding sympathetic ganglion
    - ➢ S2-S4 nerves to the parasympathetic pelvic plexus
  - ✓ grey ramus communicans – unmyelinated postganglionic fibers
    - ➢ from paravertebral sympathetic ganglia
  - ✓ ventral (anterior) ramus – thicker
    - ➢ ventrolateral muscles
    - ➢ skin of the trunk and extremities
  - ✓ dorsal (posterior) ramus – thinner
    - ➢ intrinsic dorsal muscles of the back and neck
    - ➢ overlying skin from vertex to coccyx





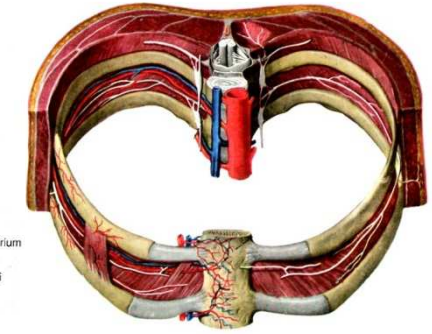
Dorsal rami of the spinal nerves

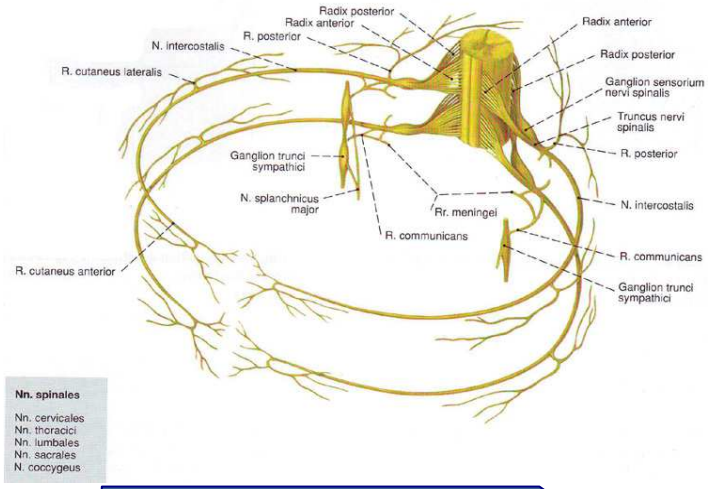
- divide into medial and lateral branches (exception C1)
- have a typical segmental distribution
- cervical dorsal rami:
  - ✓ suboccipital nerve (C1) – purely motor
  - ✓ greater occipital nerve (C2) – mixed
  - ✓ C3 medial cutaneous branch, third occipital nerve
- thoracic dorsal rami:
  - ✓ Th1-Th6 – medial (mixed) and lateral (motor) branch
  - ✓ Th7-Th12 – medial (motor) and lateral (mixed)
- lumbar dorsal rami:
  - ✓ L1-L3 lateral cutaneous branches – superior clunial nerves
- sacral dorsal rami:
  - ✓ S1-S3 lateral cutaneous branches – medial clunial nerves

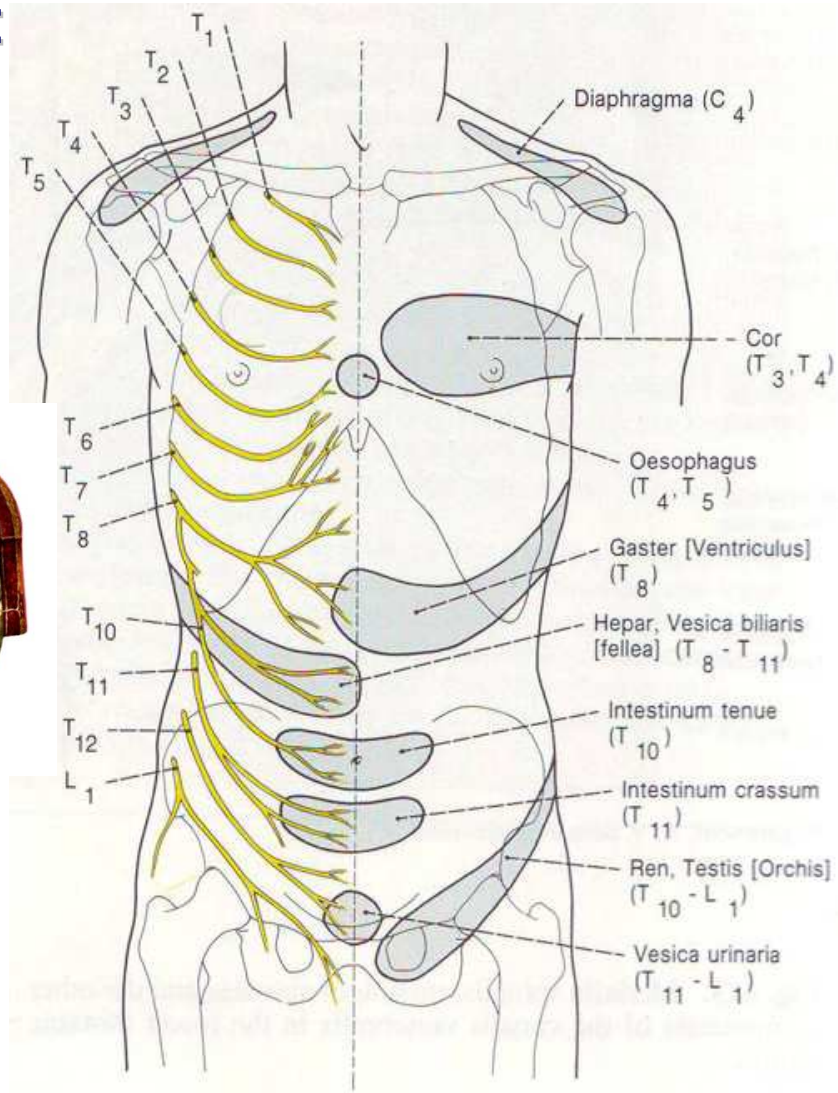


Ventral rami of the spinal nerves

- Thoracic ventral rami – 12 pairs:
  - ✓ segmental distribution – **intercostal nerves**
  - ✓ Th12 – subcostal nerve
  - ✓ anterior cutaneous branches
  - ✓ lateral cutaneous branches

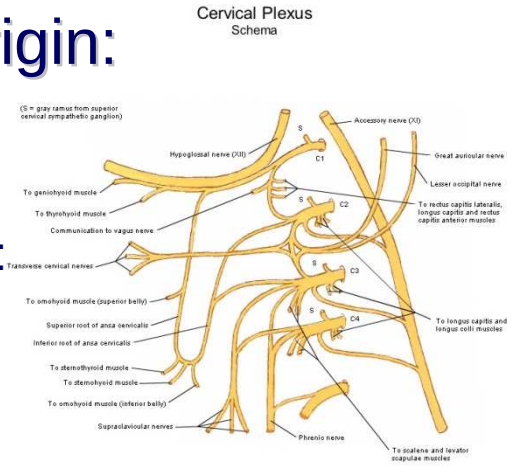


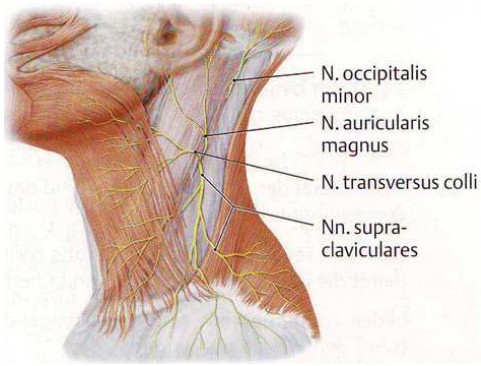


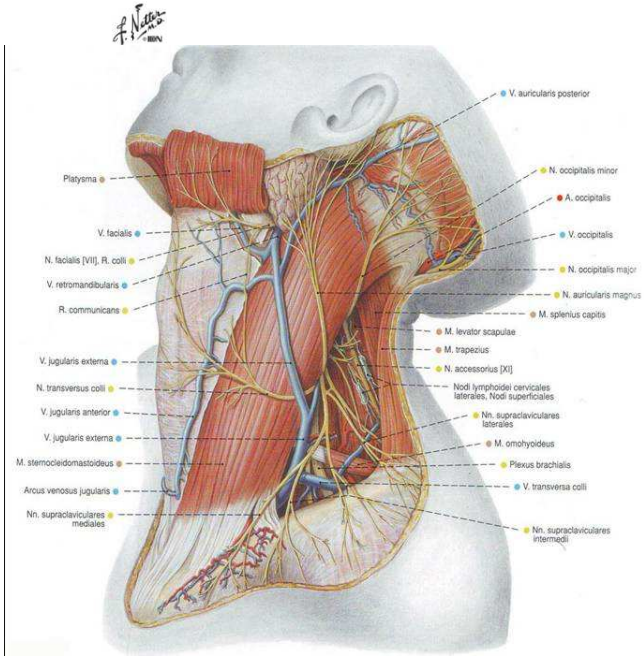


Cervical plexus, *plexus cervicalis*

- Formation and segmental origin:
  - ✓ ventral rami of C1-C4 nerves
- Branches:
  - ✓ superficial (sensory) branches:
    - ➢ lesser occipital nerve, *n. occipitalis minor*
    - ➢ great auricular nerve, *n. auricularis magnus*
    - ➢ transverse colli nerve, *n. transversus colli*
    - ➢ supraclavicular nerves, *nn. supraclaviculares*
  - ✓ deep (motor) branches:
    - ➢ muscular branches, *rr. musculares*
    - ➢ inferior root of the ansa cervicalis, *radix inferior ansae cervicalis*
    - ➢ trapezius root, *ramus trapezius*
    - ➢ sternocleidomastoid root, *r. sternocleidomastoideus*
    - ➢ phrenic nerve, *n. phrenicus*

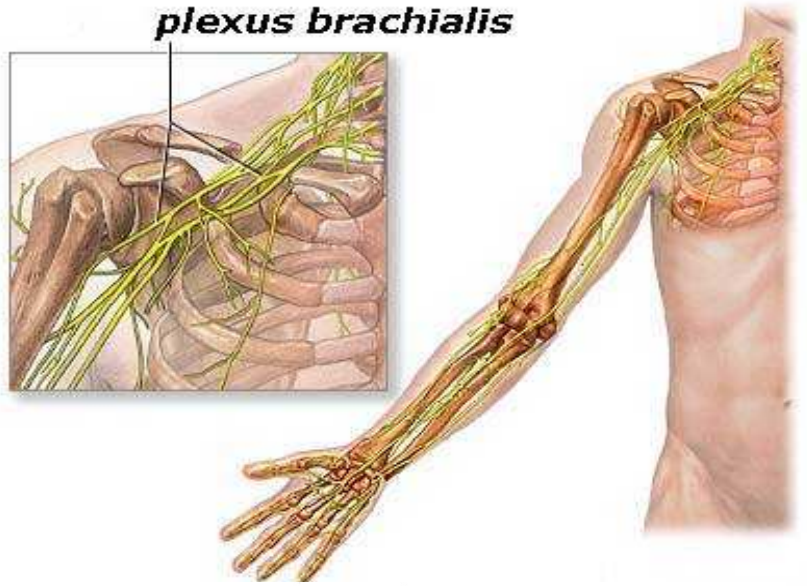


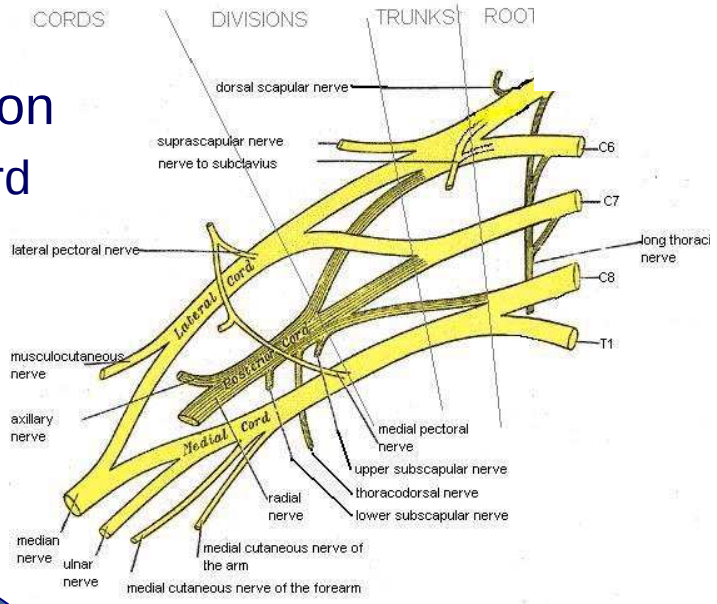


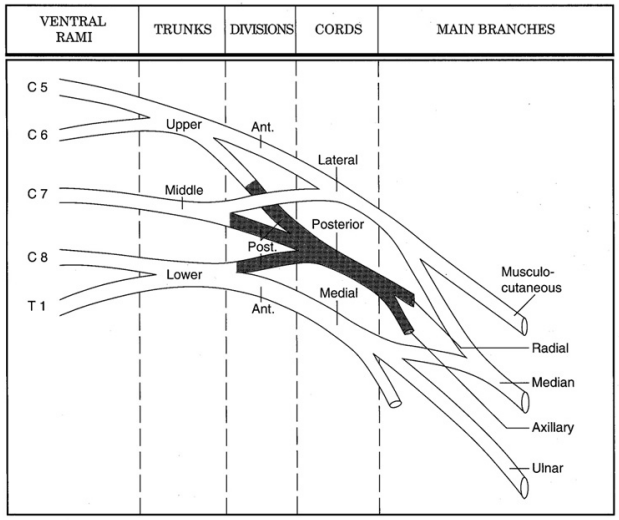


Brachial plexus, *plexus brachialis*

- Formation and segmental origin:
  - ✓ ventral rami of C5-C8, Th1 nerves
- Three primary trunks:
  - ✓ superior (upper) trunk – C5-C6
  - ✓ middle trunk – C7
  - ✓ inferior (lower) trunk – C8-Th1
- Divisions:
  - ✓ posterior division
    - ➢ posterior cord
  - ✓ anterior
    - ➢ lateral cord
    - ➢ medial cord

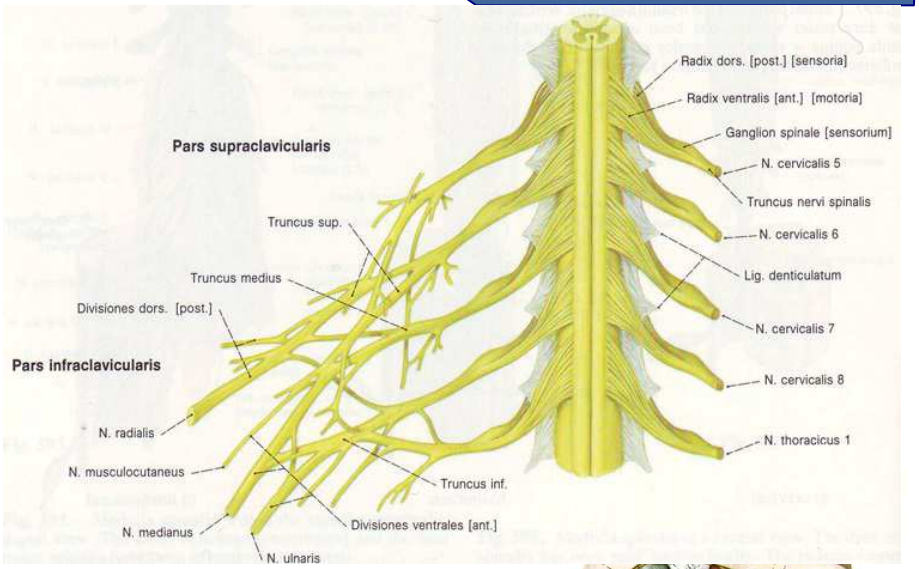


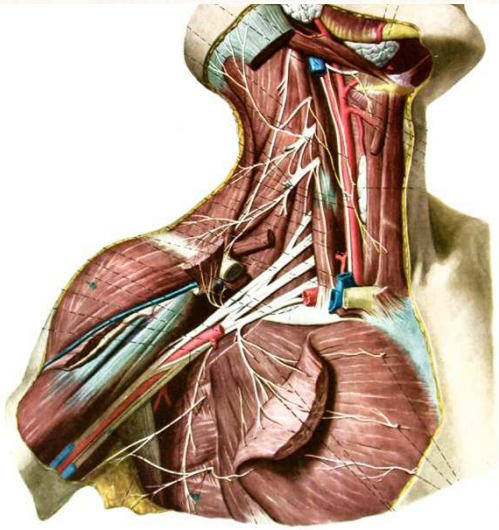




Brachial plexus, *plexus brachialis*

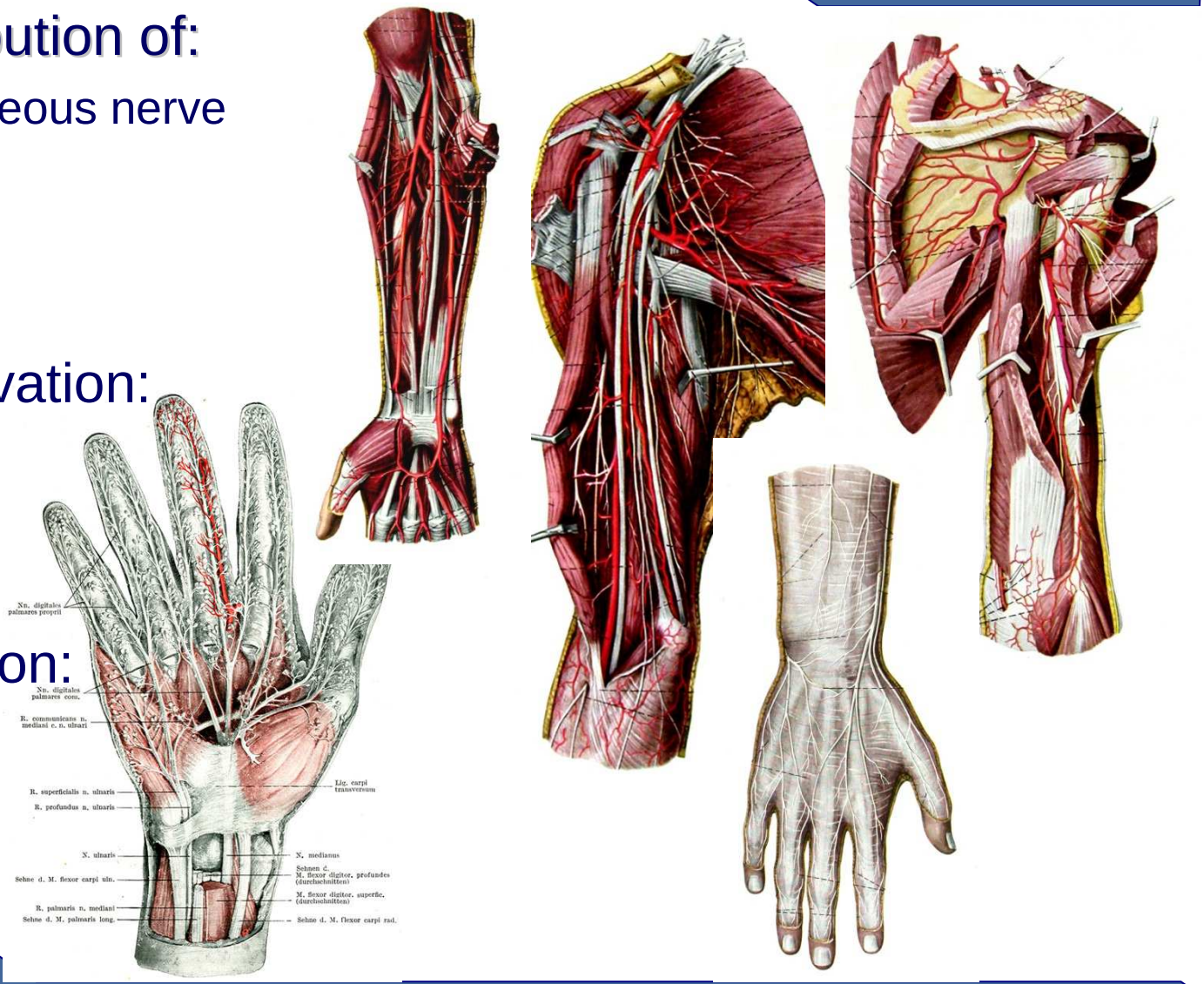
- Main branches:
  - ✓ supraclavicular part:
    - ➢ dorsal scapular nerve, *n. dorsalis scapulae*
    - ➢ long thoracic nerve, *n. thoracicus longus*
    - ➢ nerve to the subclavius, *n. subclavius*
    - ➢ suprascapular nerve, *n. suprascapularis*
  - ✓ infraclavicular part:
    - ➢ lateral cord, *fasciculus lateralis:*
      - musculocutaneous nerve, *n. musculocutaneus*
      - lateral root of median, *radix lateralis n. mediani*
    - ➢ medial cord, *fasciculus medialis:*
      - medial root of median, *radix medialis n. mediani*
      - ulnar nerve, *n. ulnaris*
      - medial cutaneous of arm, *n. cutaneus brachii medialis*
      - medial cutaneous of forearm, *n. cutaneus antebrachii medialis*
    - ➢ posterior cord, *fasciculus posterior:*
      - axillary nerve, *n. axillaris*
      - radial nerve, *n. radialis*





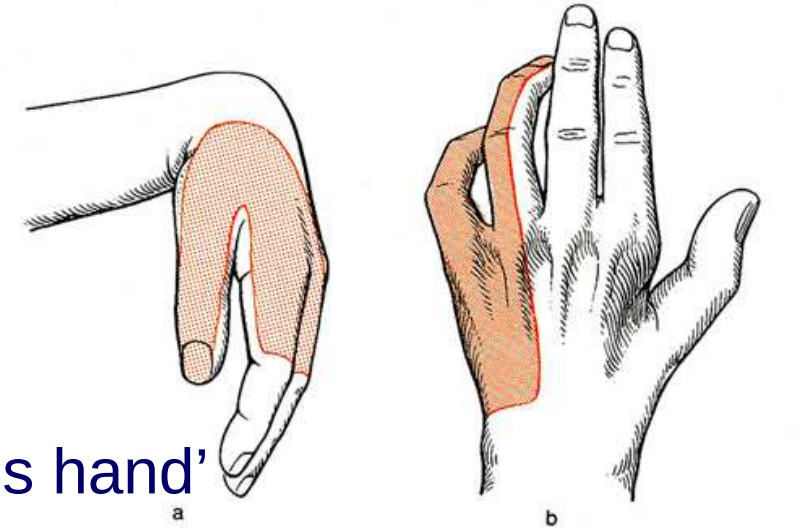
Brachial plexus, *plexus brachialis*

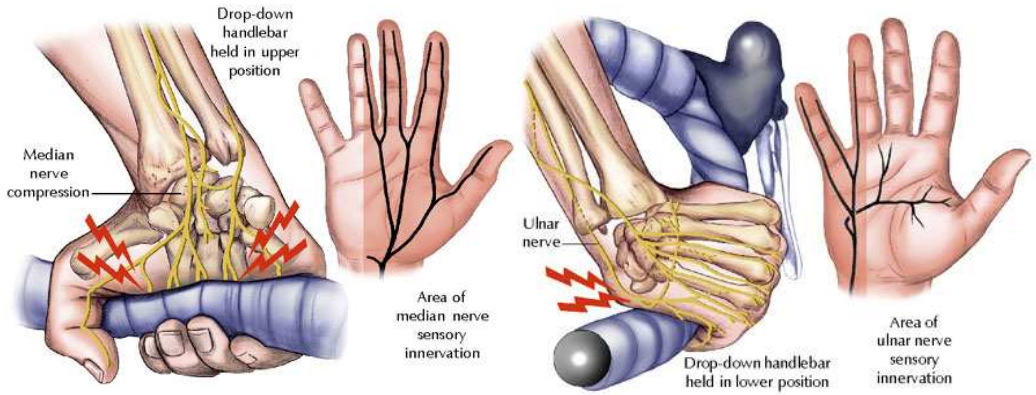
- Brachial distribution of:
  - ✓ musculocutaneous nerve
  - ✓ median nerve
  - ✓ ulnar nerve
  - ✓ radial nerve
- Forearm innervation:
  - ✓ median nerve
  - ✓ ulnar nerve
  - ✓ radial nerve
- Hand innervation:
  - ✓ median nerve
  - ✓ ulnar nerve

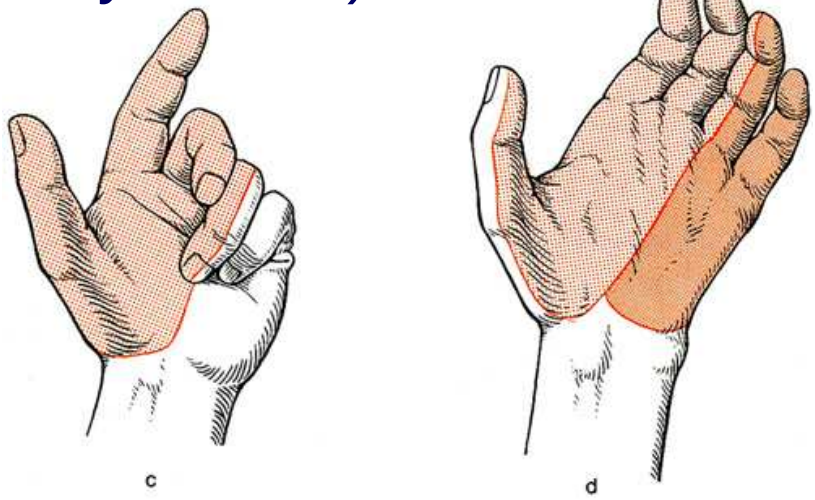


Peripheral neuropathies

- Radial nerve palsy, wrist drop (Saturday night palsy)
- Ulnar nerve palsy, ‘claw hand’ handlebar palsy – cyclist’s hands
- Median nerve palsy,‘accoucheur's hand’ median neuropathy (Carpal tunnel syndrome)

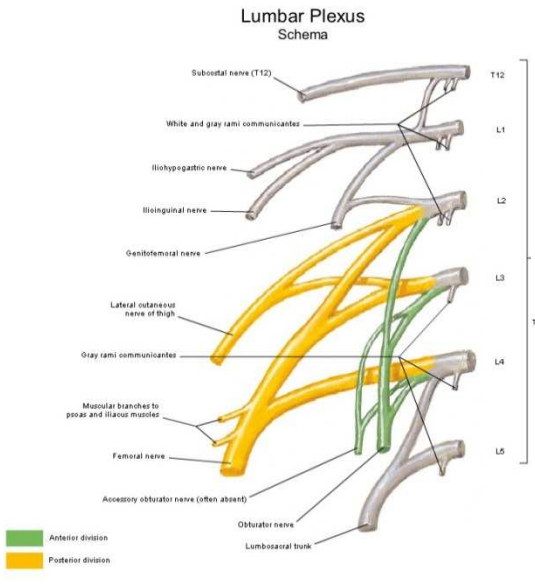


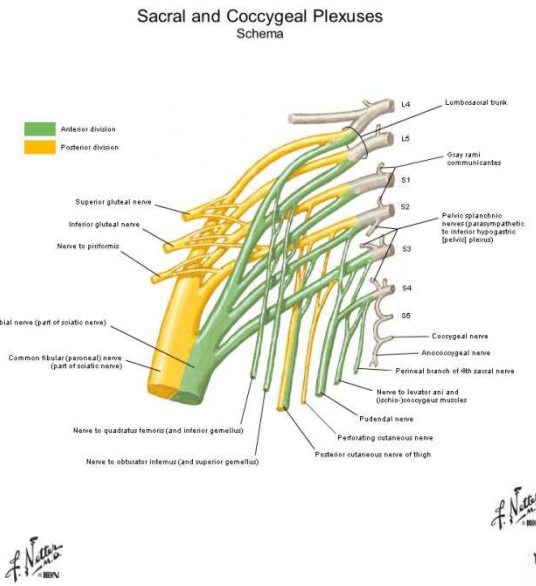


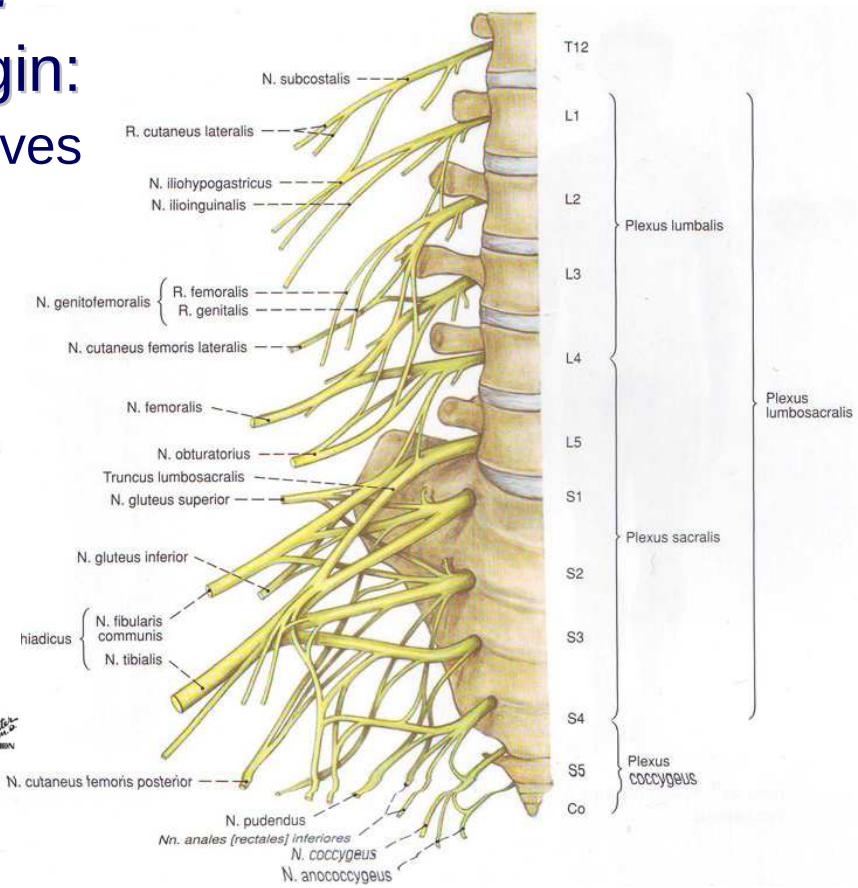


Lumbosacral plexus, *plexus lumbosacralis*

- Lumbar plexus, *plexus lumbalis:*
  - ✓ formation and segmental origin:
    - ➢ ventral rami of Th12, L1-L4 nerves





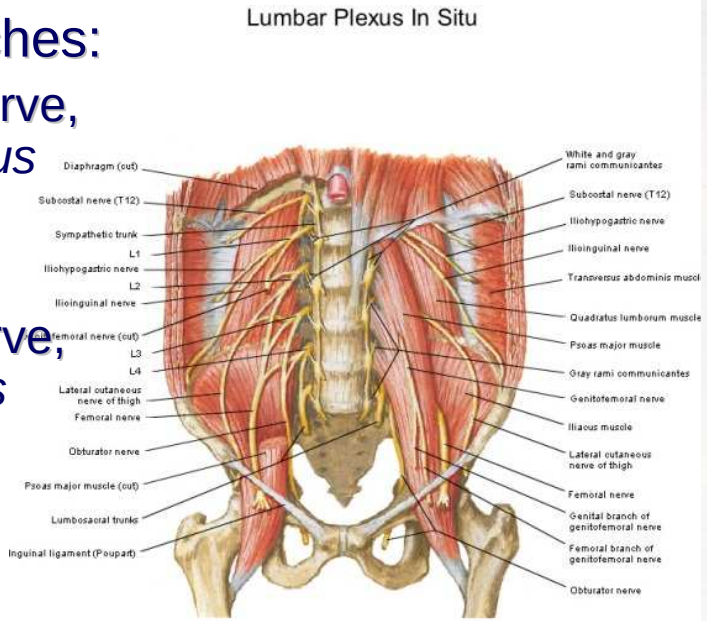


- Sacral plexus, *plexus sacralis:*
  - ✓ formation and segmental origin:
    - ➢ ventral rami of L5, S1-S5, Co1 nerves

- Coccygeal plexus, *plexus coccygeus:*
  - ✓ ventral rami of S5,Co1

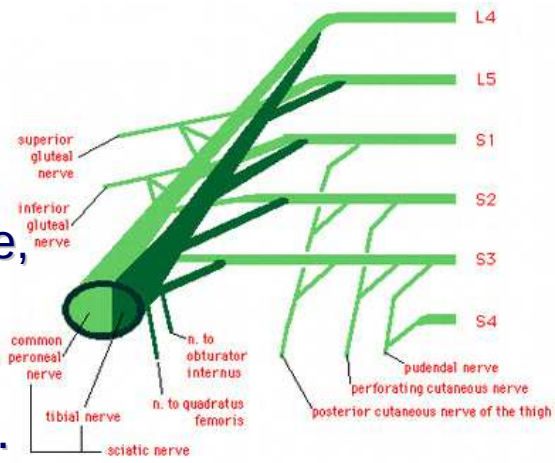
Lumbar plexus, *plexus lumbalis*

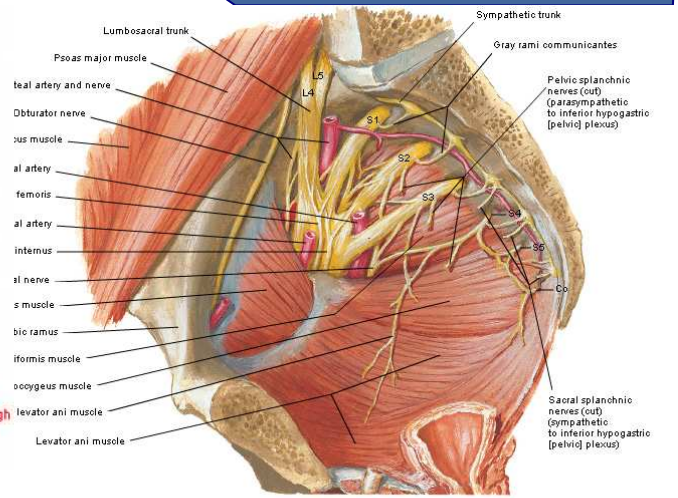
- Branches:
  - ✓ muscular branches,
    rr. musculares
  - ✓ purely sensory branch:
    - ➢ lateral femoral cutaneous nerve,
      n. cutaneus femoris lateralis
  - ✓ sensorimotor branches:
    - ➢ iliohypogastric nerve,
      n. iliohypogastricus
    - ➢ ilioinguinal nerve,
      n. ilioinguinalis
    - ➢ genitofemoral nerve,
      n. genitofemoralis
    - ➢ obturator nerve,
      n. obturatorius
    - ➢ femoral nerve,
      n. femoralis

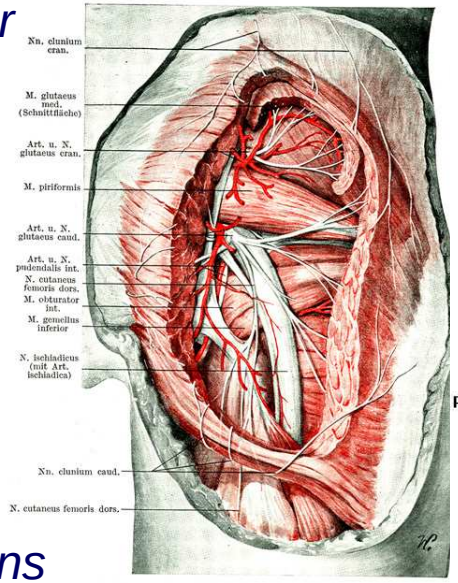


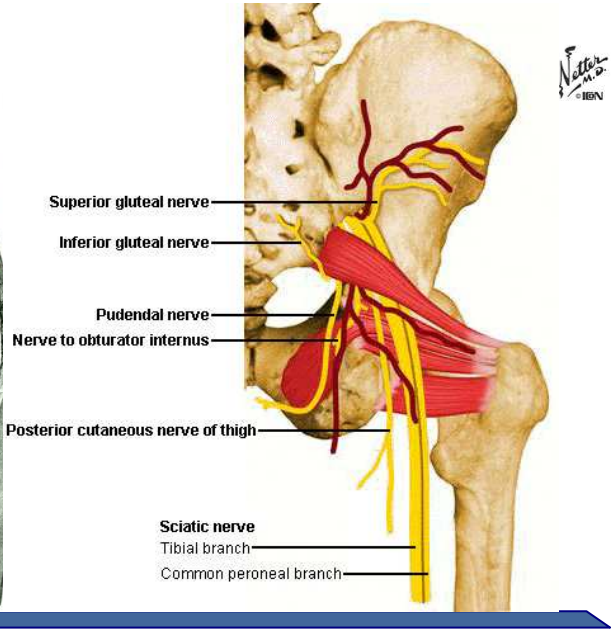
Sacral plexus, *plexus sacralis*

- Branches:
  - ✓ motor branches:
    - ➢ muscular branches, *rr. musculares*
    - ➢ superior gluteal nerve, *n. gluteus superior*
    - ➢ inferior gluteal nerve, *n. gluteus inferior*
  - ✓ purely sensory branch:
    - ➢ posterior femoral cutaneous nerve *n. cutaneus femoris posterior*
  - ✓ sensorimotor branches:
    - ➢ pudendal nerve, *n. pudendus*
    - ➢ coccygeal nerve, *n. coccygeus*
    - ➢ sciatic nerve, *n. ischiadicus*
  - ✓ visceral branch:
    - ➢ pelvic splanchnic nerve, *nervus erigens*



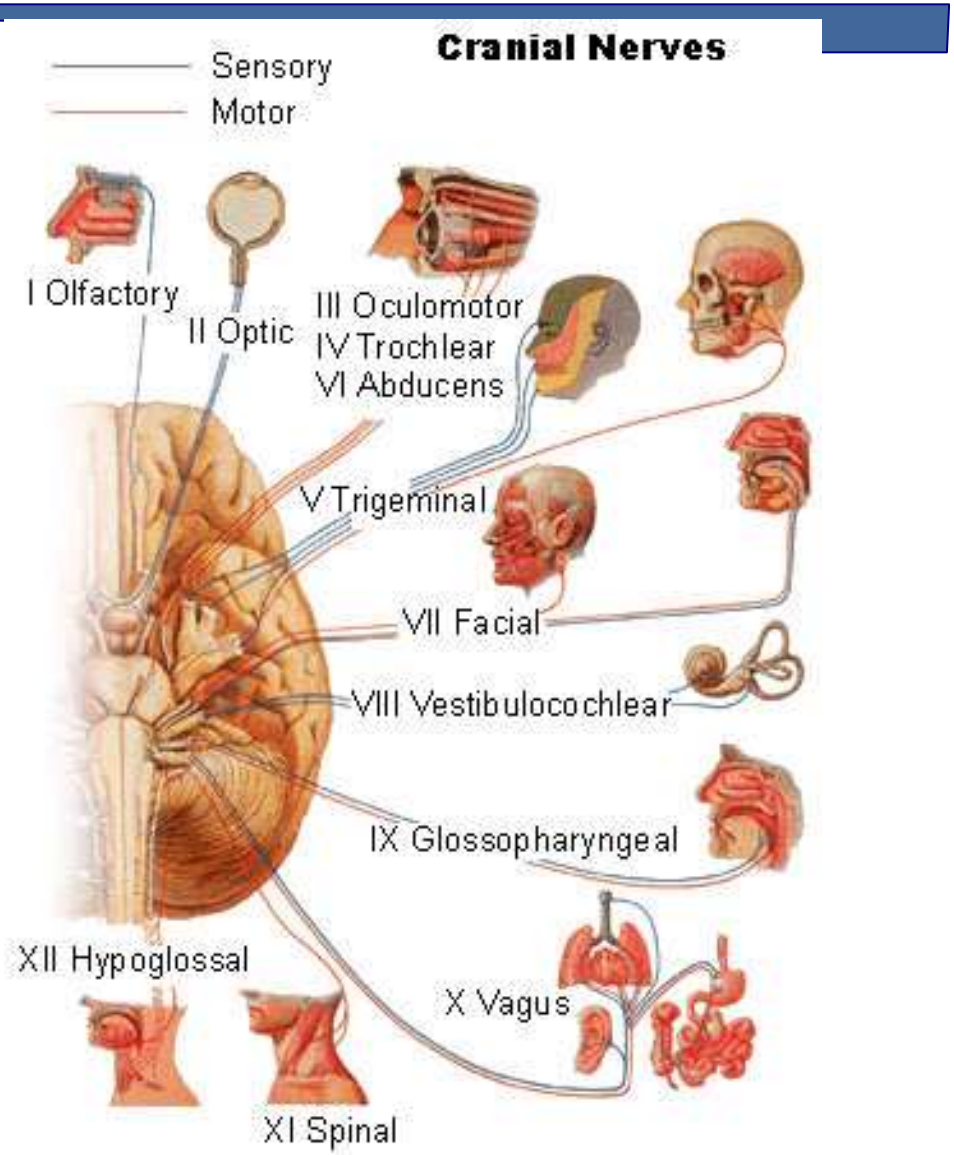




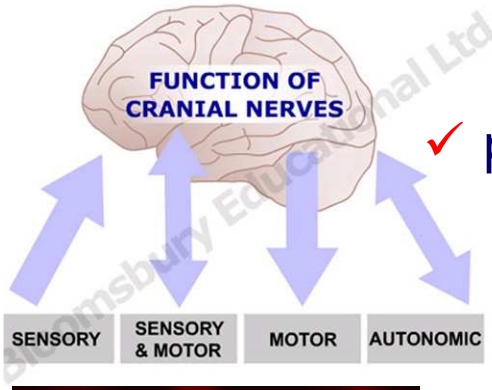


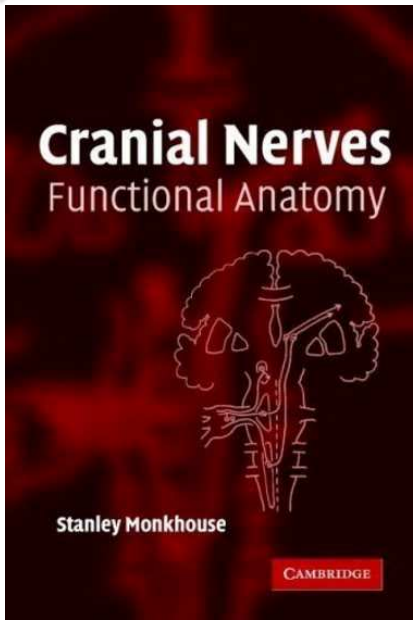
Cranial nerves

I. N. olfactorius
II. N. opticus
III. N. oculomotorius
IV. N. trochlearis
V. N. trigeminus
VI. N. abducens
VII. N. facialis
VIII. N. vestibulocochlearis
IX. N. glossopharyngeus
X. N. vagus
XI. N. accessorius
XII. N. hypoglossus

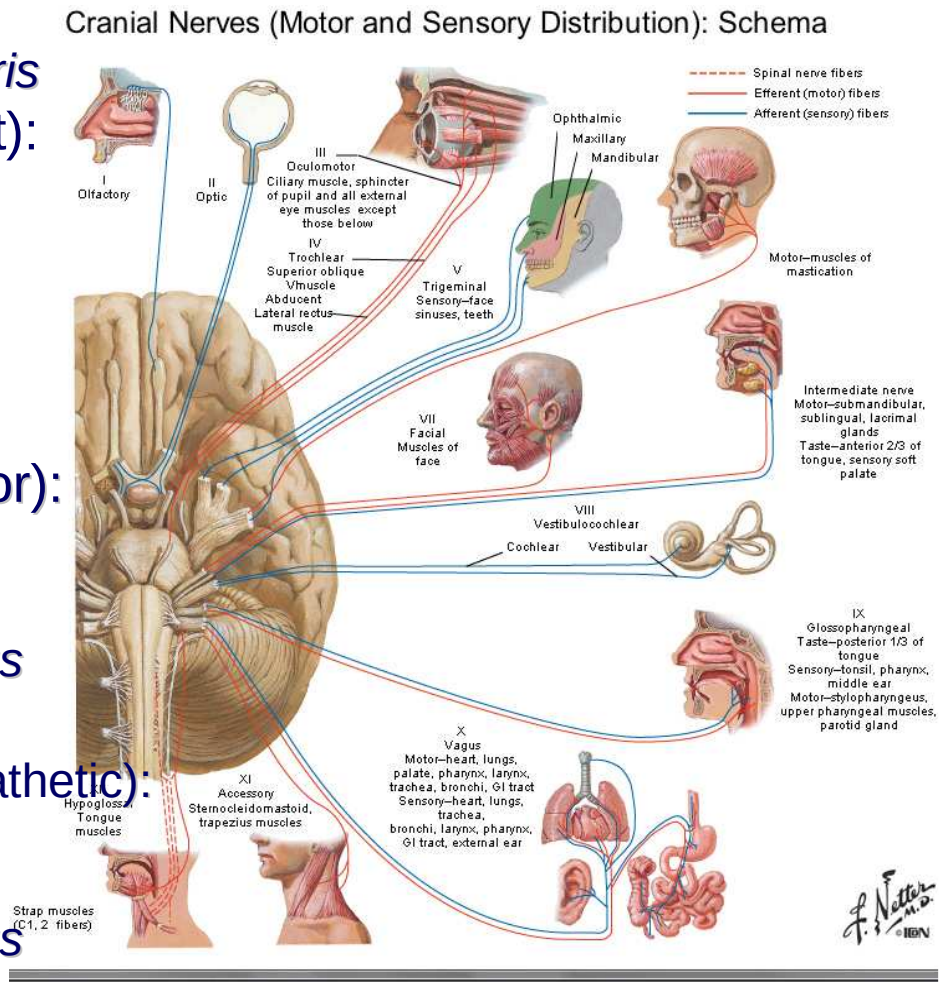


Functional classification



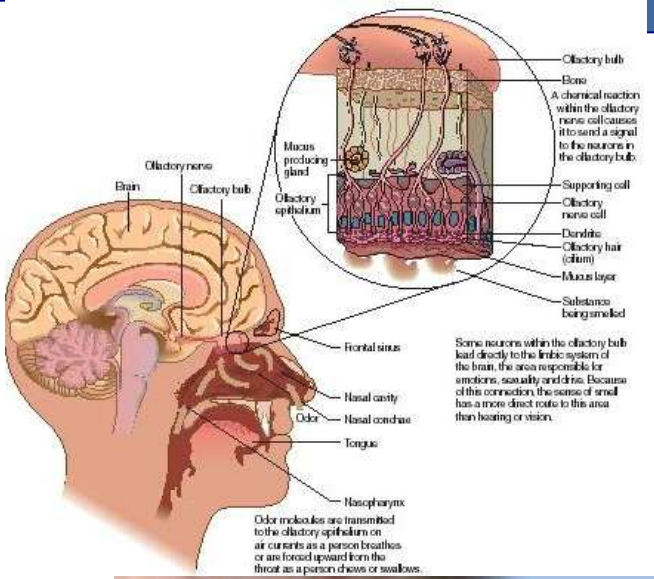


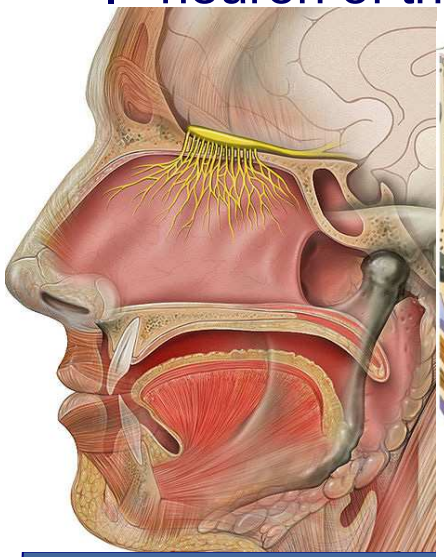
- ✓ purely sensory (afferent):
  - ➢ *n. olfactorius*
  - ➢ *n. opticus*
  - ➢ *n. vestibulocochlearis*
- ✓ purely motor (efferent):
  - ➢ *n. oculomotorius*
  - ➢ *n. trochlearis*
  - ➢ *n. abducens*
  - ➢ *n. accessorius*
  - ➢ *n. hypoglossus*
- ✓ mixed (sensory&motor):
  - ➢ *n. trigeminus*
  - ➢ *n. facialis*
  - ➢ *n. glossopharyngeus*
  - ➢ *n. vagus*
- ✓ autonomic (parasympathetic):
  - ➢ *n. oculomotorius*
  - ➢ *n. facialis*
  - ➢ *n. glossopharyngeus*
  - ➢ *n. vagus*

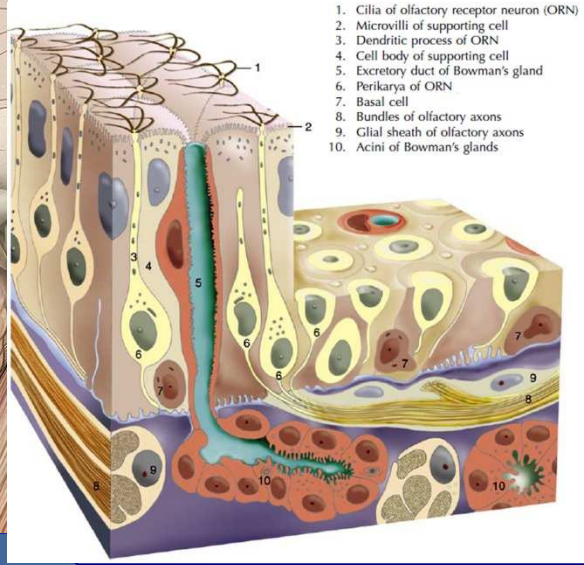


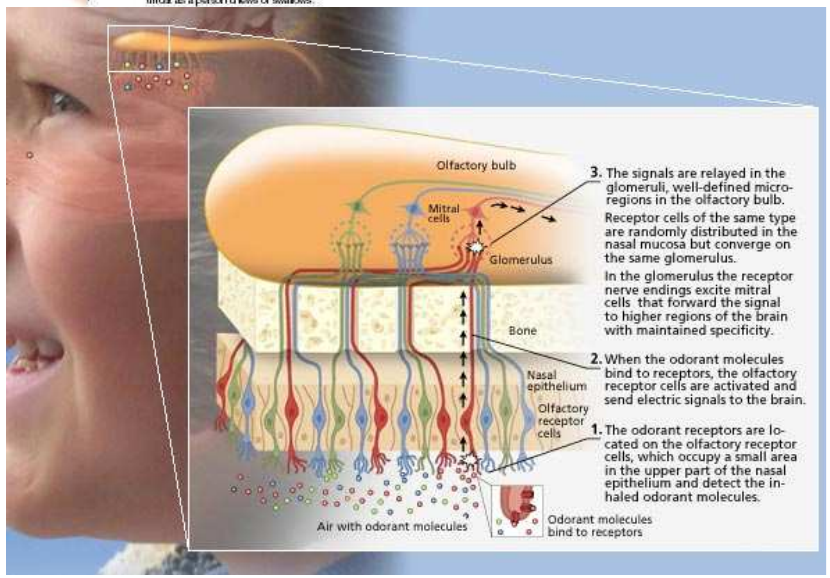
Olfactory nerves, *nn. olfactorii*

- specific sense of smell (olfaction)
- the shortest cranial nerve – cribriform plate *(lamina cribrosa)*
- 18-20 bundles, *fila olfactoria* – non-myelinated axons
  - ✓ olfactory receptor neurons – 40 millions in olfactory epithelium
- I[st] neuron of the olfactory pathway

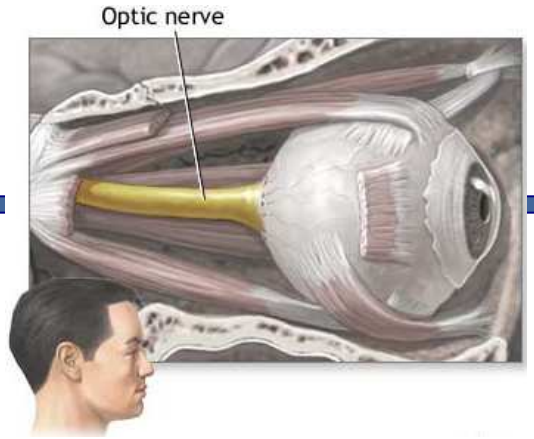






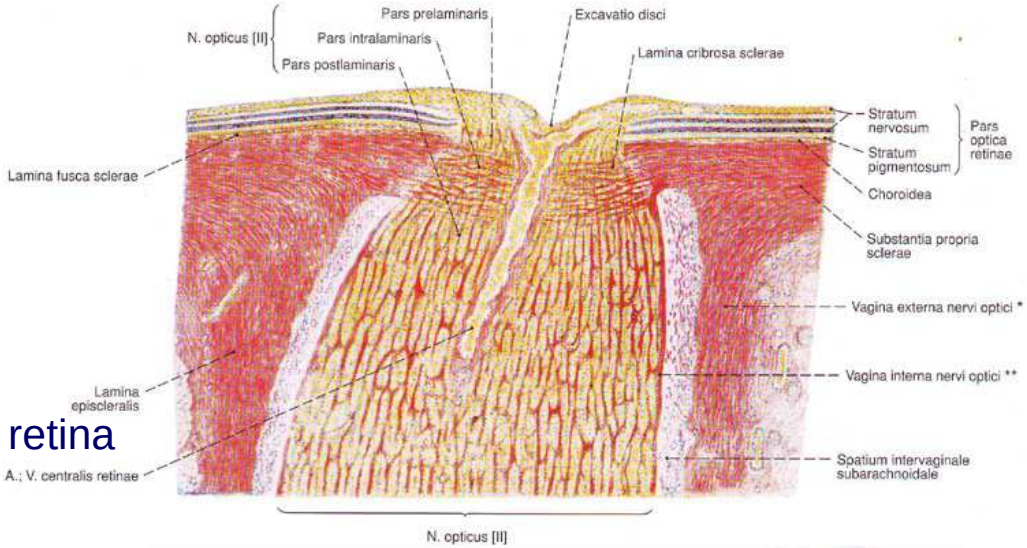


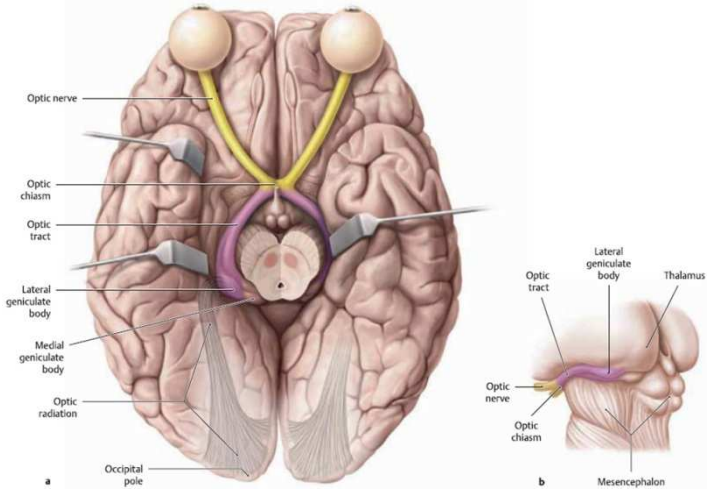
Optic nerve, *n. opticus*

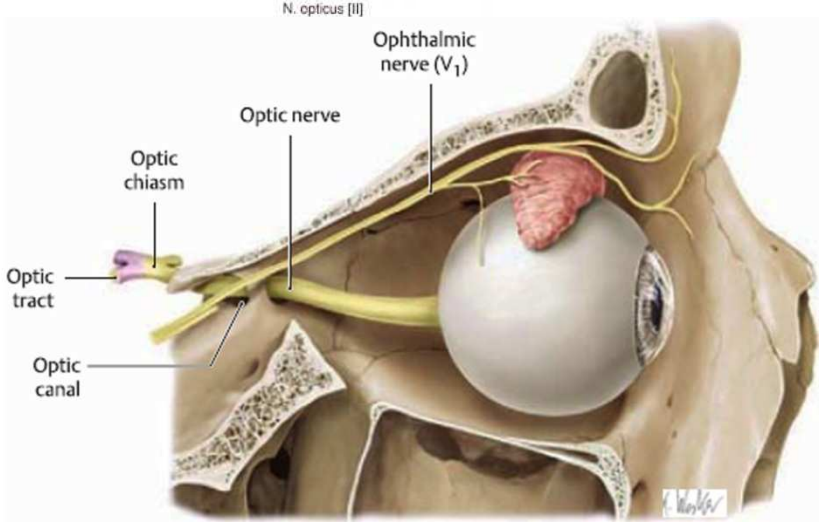


~ 4 cm long

- specific sense of sight (vision)
  - ✓ intraorbital part – 25 mm long
  - ✓ canal part ~ 5 mm long
  - ✓ intracranial part ~ 10 mm long
- 1 million axons of ganglion cells in the retina
- IIIrd neuron of the visual pathway

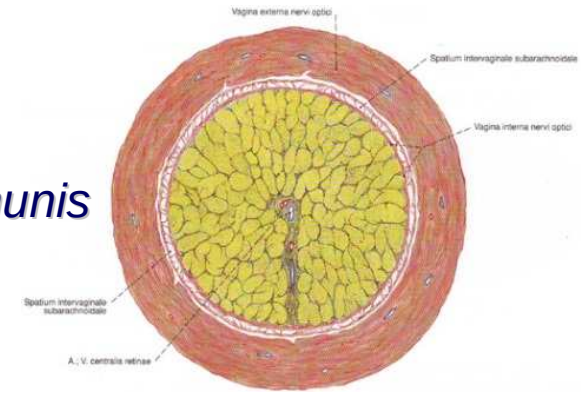


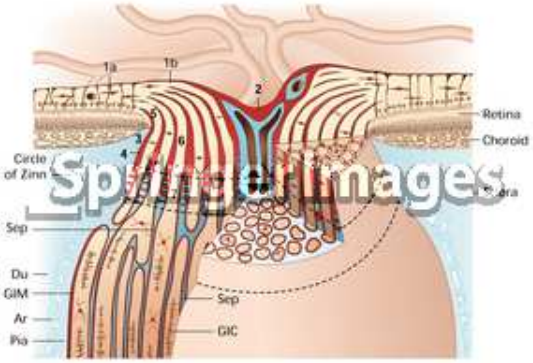


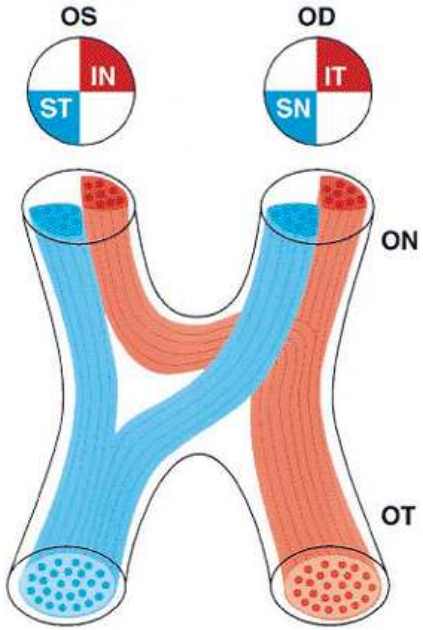


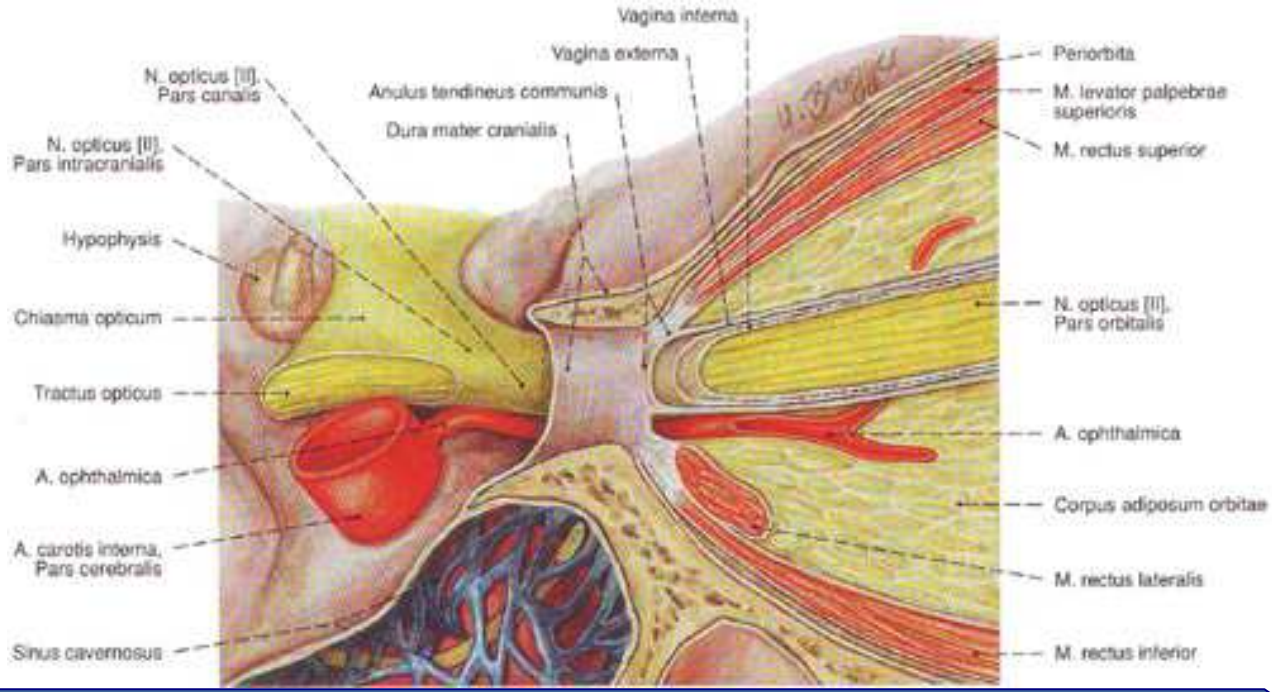
Optic nerve, *n. opticus*

- optic disc (optic nerve head)
- *a. et v. centralis retinae*
- optic canal
- through *anulus tendineus communis*
- optic chiasm ⇨ optic tract:
  - ✓ partial (~ 53%) decussation of the (medial) fibers



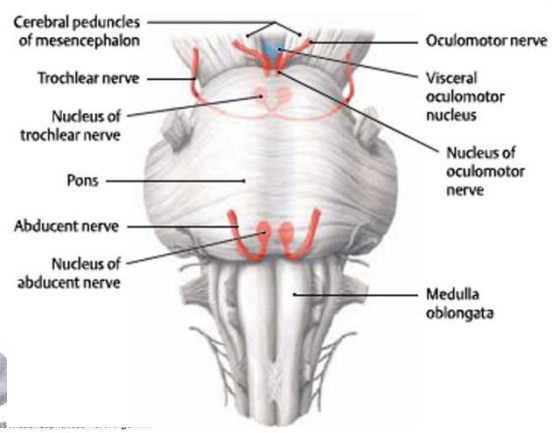


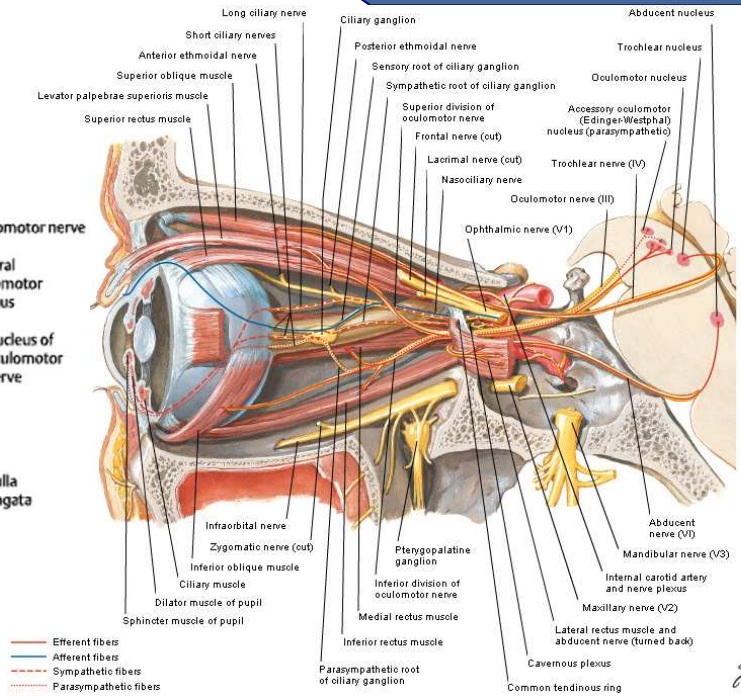


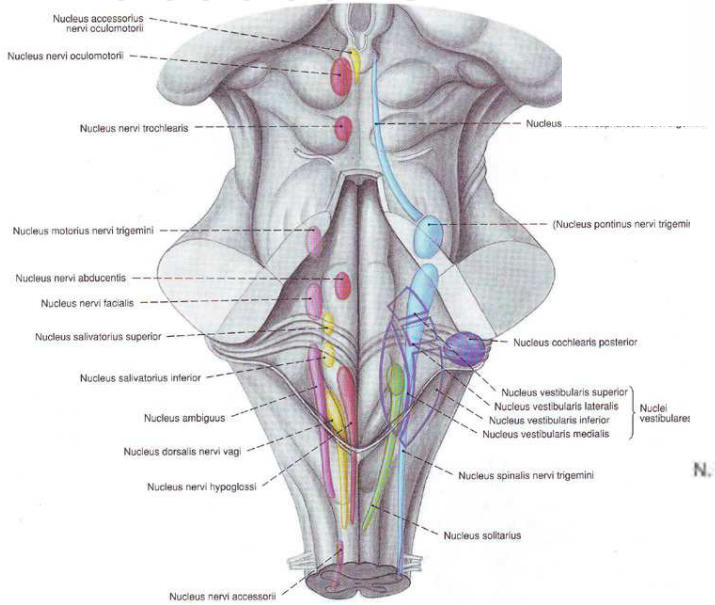


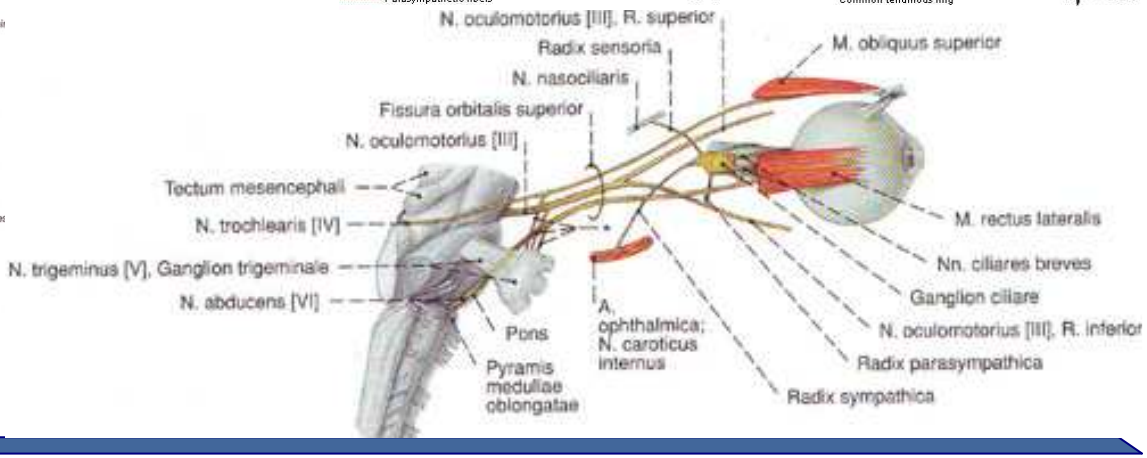
Optomotor group

- oculomotor nerve, *n. oculomotorius*
- trochlear nerve, *n. trochlearis*
- abducent nerve, *n. abducens*



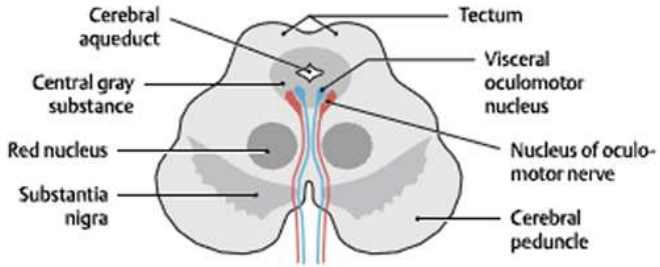


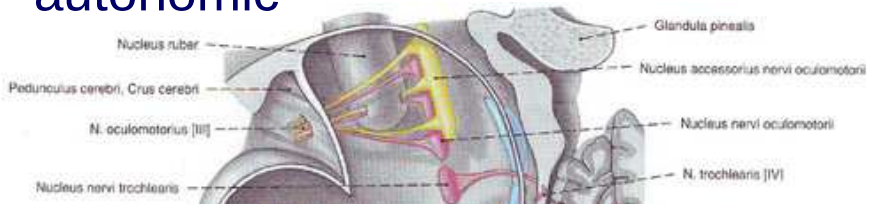


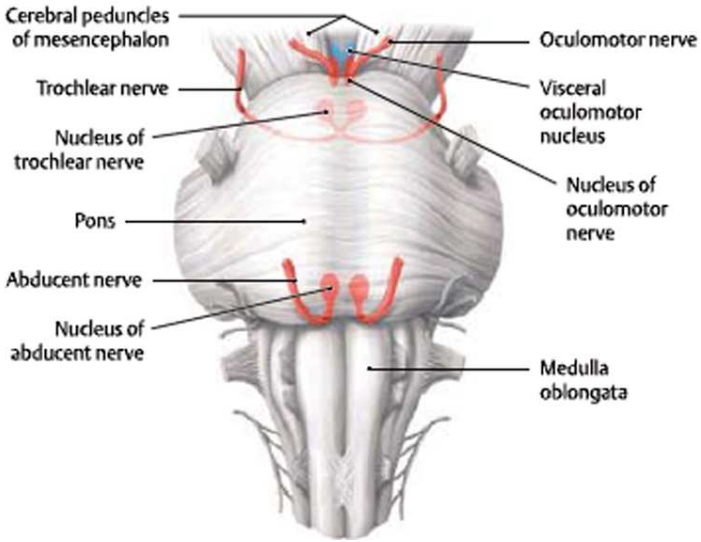


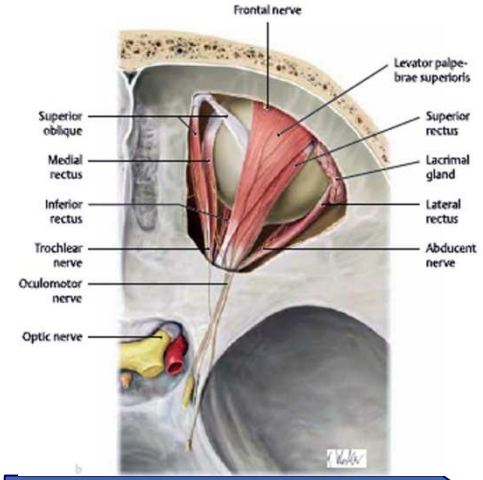
Oculomotor nerve, *n. oculomotorius*

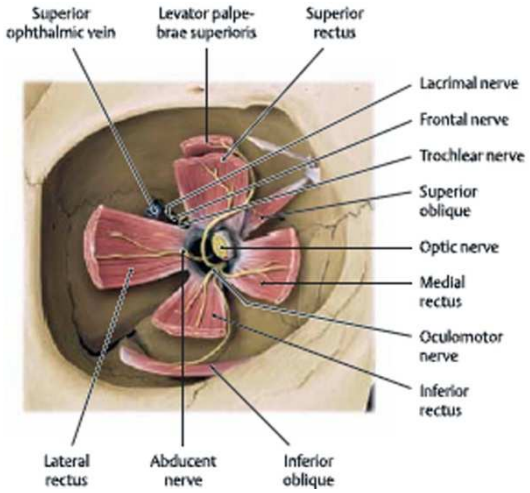
- III[rd] cranial nerve – somatomotor and parasympathetic
- nuclei at the level of superior colliculus:
  - ✓ *nucleus nervi oculomotorii* – motor
  - ✓ *nucleus oculomotorius accessorius (of Edinger-Westphal)* – autonomic
- *sulcus medialis cruris cerebri*
- *fissura orbitalis superior*
- *anulus tendineus communis*







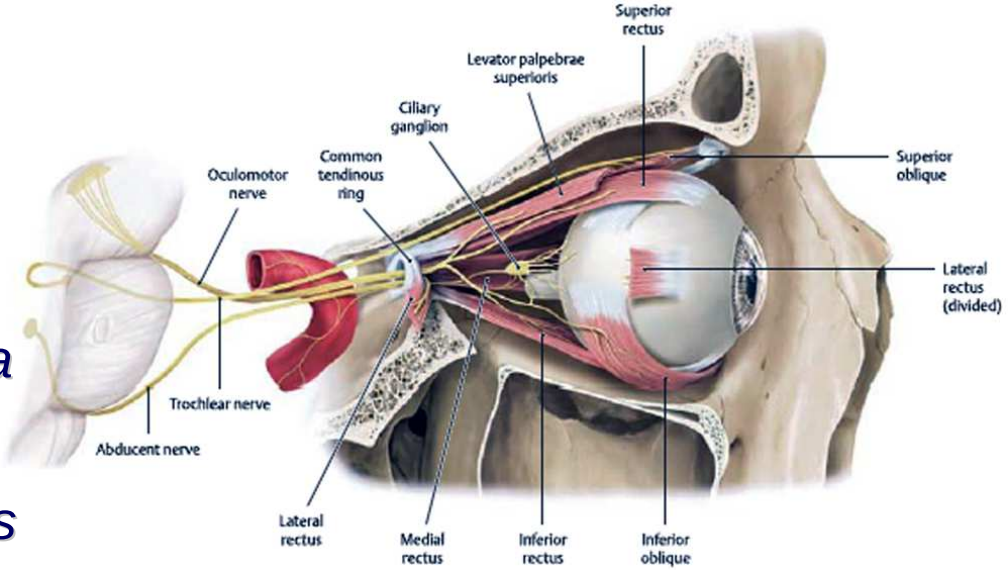


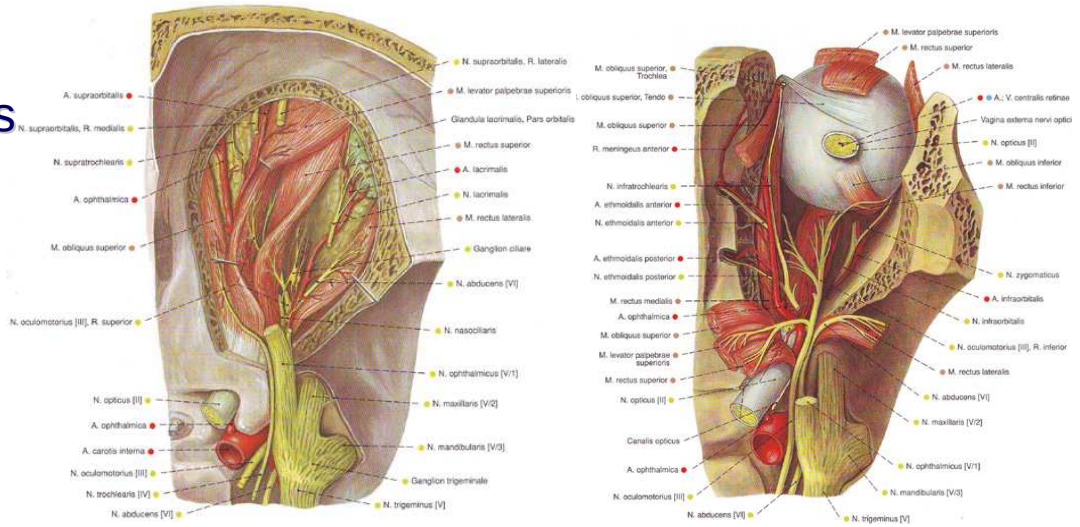


Oculomotor nerve, *n. oculomotorius*

- *ramus superior:*
  - ✓ *m. rectus superior*
  - ✓ *m. levator palpebrae superioris*
- *ramus inferior* – motor fibers:
  - ✓ *mm. rectus inferior et medialis*
  - ✓ *m. obliquus inferior*
- *radix oculomotoria parasympathica (ramus ad ganglion ciliare)* – autonomic fibers from *ramus inferior*
- *ganglion ciliare – nn.ciliares breves*
  - ✓ *m. ciliaris*
  - ✓ *m. sphincter pupillae*

  in injury ⇨ divergent strabismus



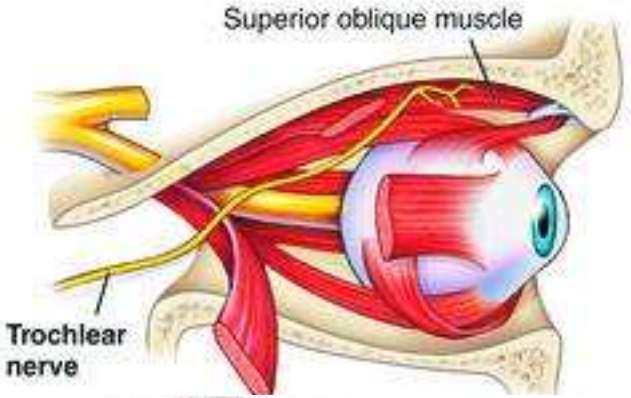


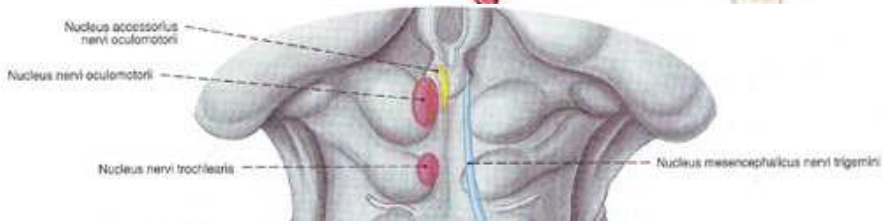
Prof. Dr. Nikolai Lazarov

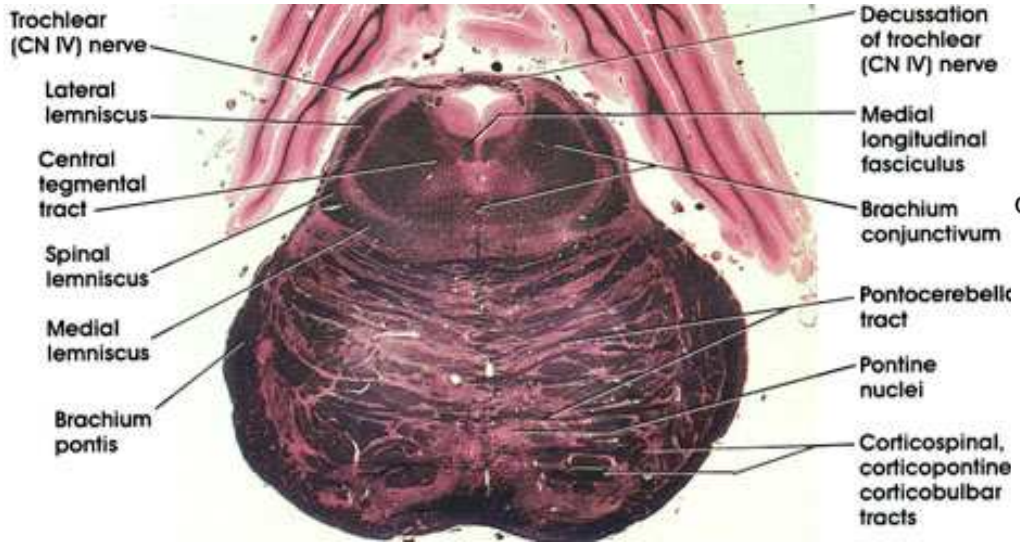
NB: Modern Latin, from Greek strabismos; squint-eyed

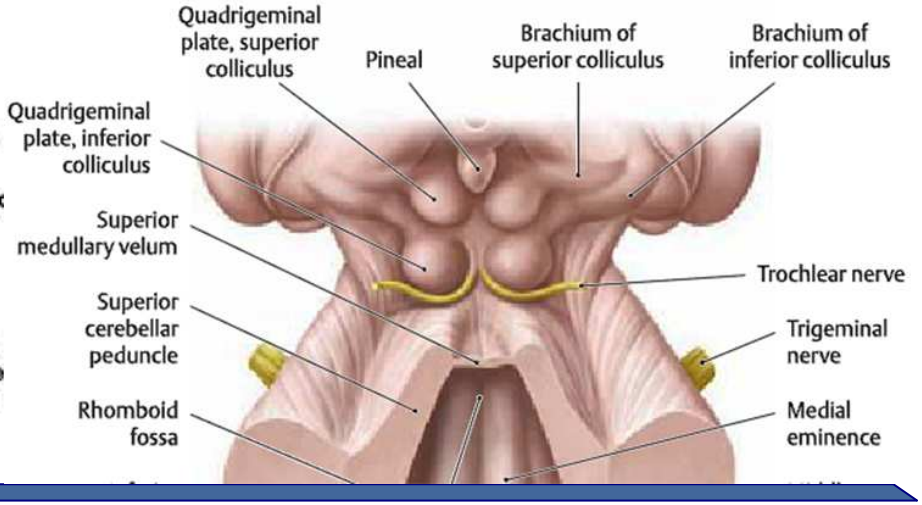
Trochlear nerve, *n. trochlearis*

- IVth cranial nerve – motor (optomotor) nerve
- nucleus – upper part of the inferior colliculus:
  - ✓ *nucleus nervi troclearis*
- dorsal emergence – below the inferior colliculus
- trochlear decussation



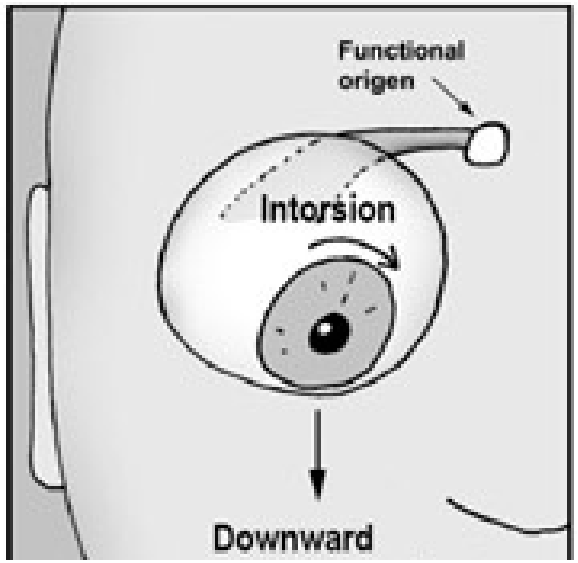


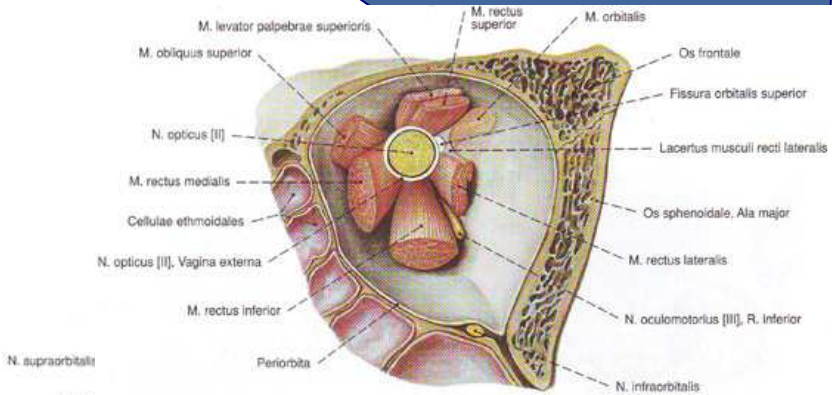


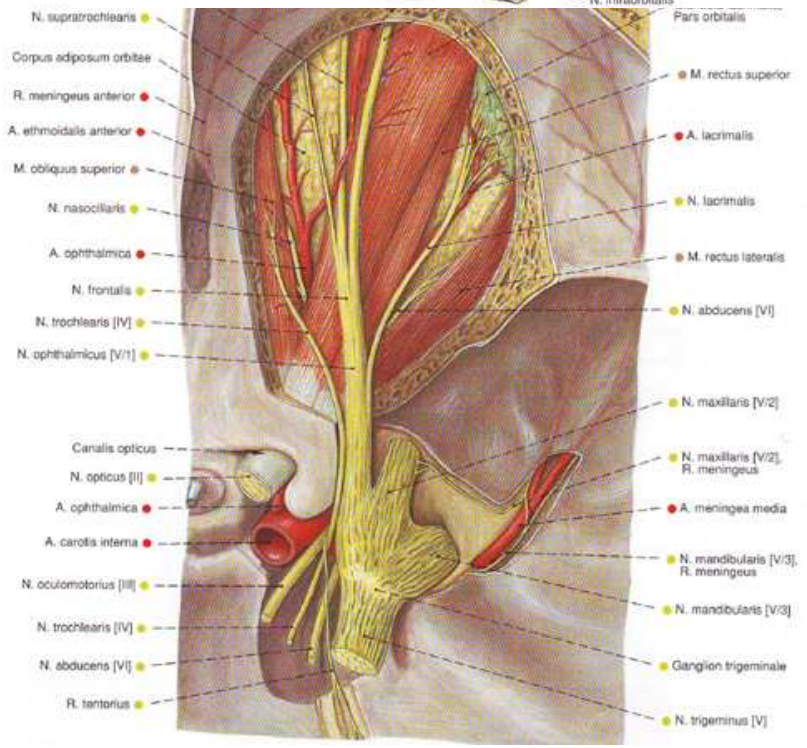


Trochlear nerve, *n. trochlearis*

- *fissura orbitalis superior*
- above *anulus tendineus communis (Zinn)*
- innervation:
  - ✓ *m. obliquus superior*
- in injury ⇨ torsional diplopia

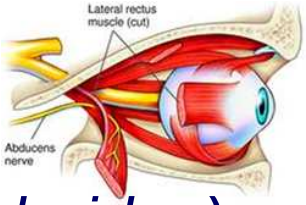


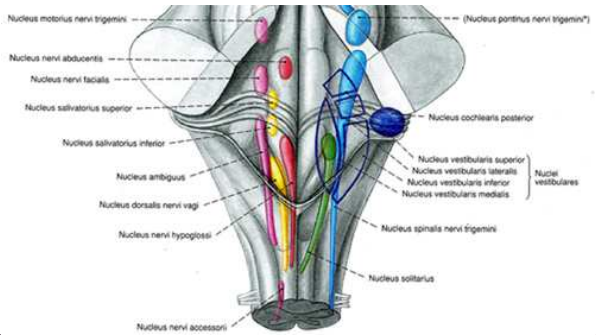


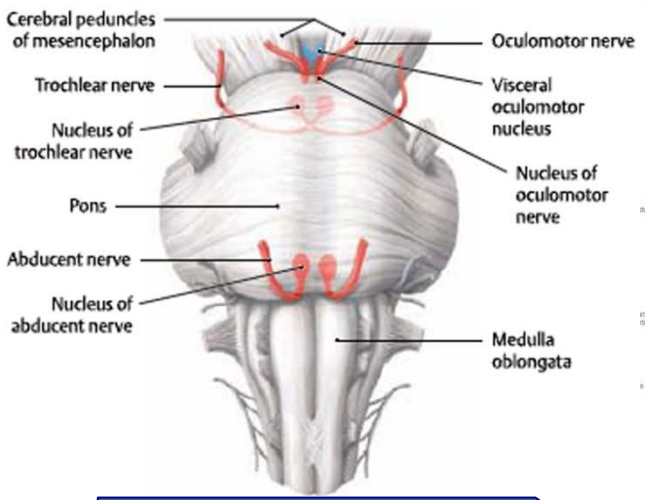


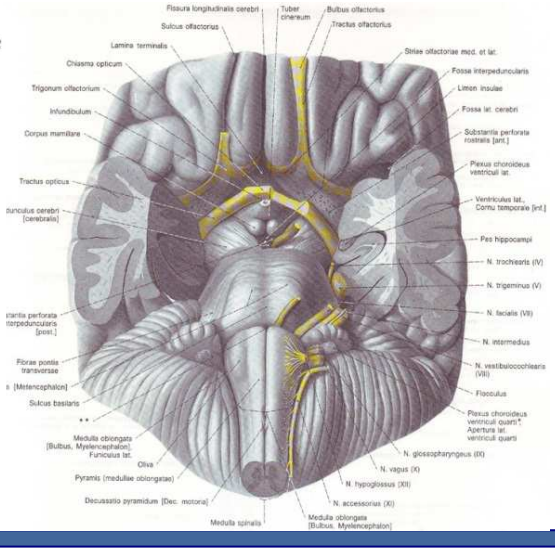
Abducent nerve, *n. abducens*

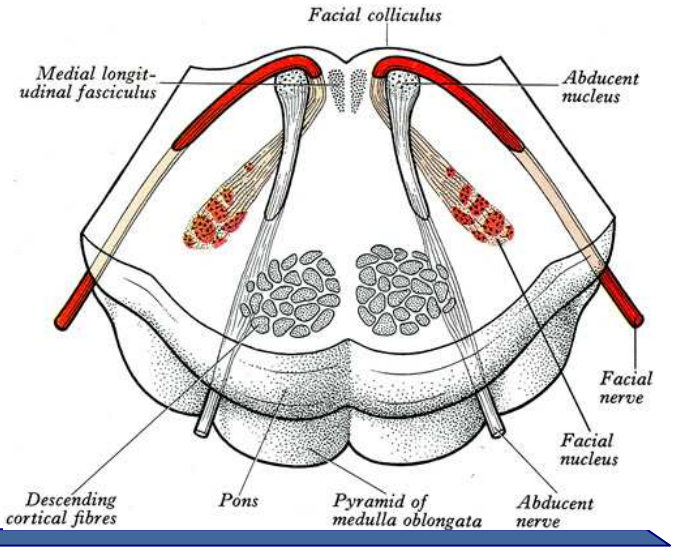
- VIth cranial nerve – motor (optomotor) nerve
- nucleus – in pons *(fossa rhomboidea)* beneath the *colliculus facialis:*
  - ✓ *nucleus nervi abducentis*
- emergence between the pons and the medullar pyramid





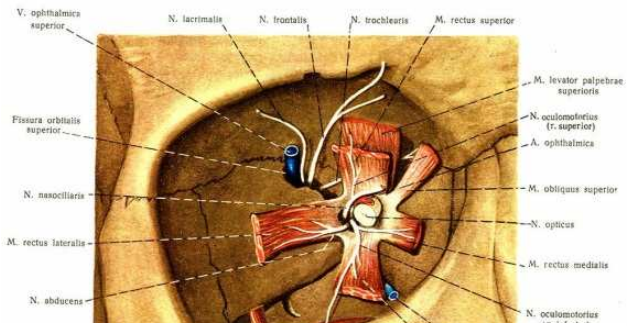


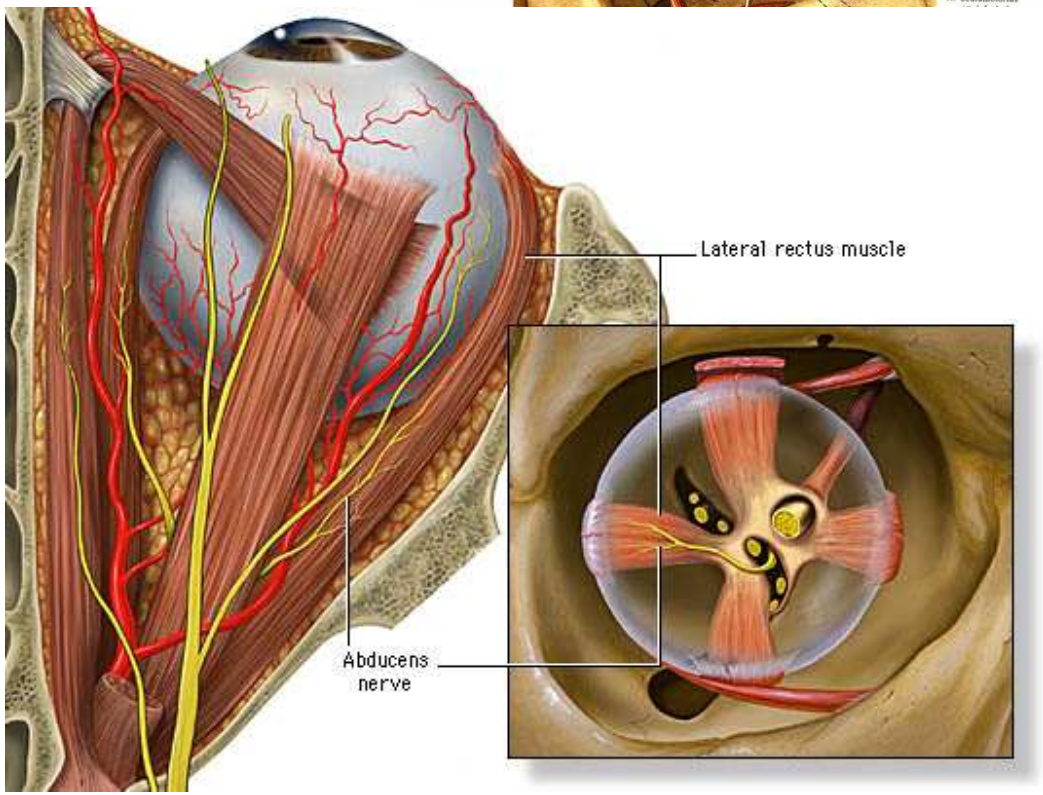




Abducent nerve, *n. abducens*

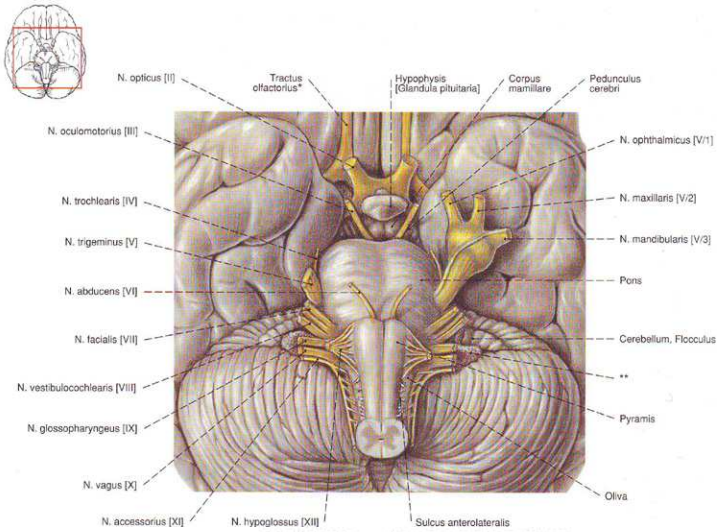
- through *anulus tendineus communis*
- innervation:
  - ✓ *m. rectus lateralis*
- in injury ⇨ convergent strabismus

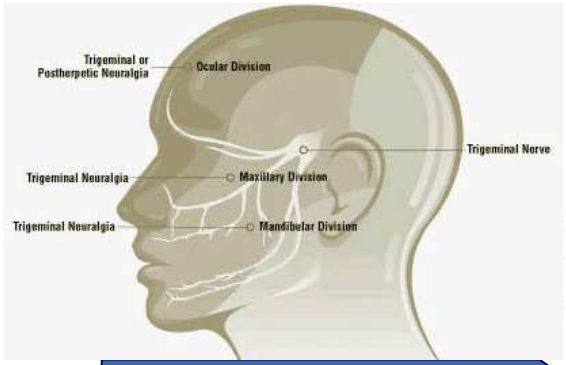


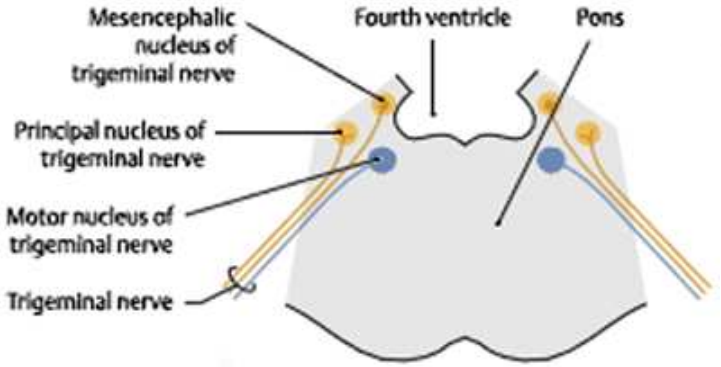


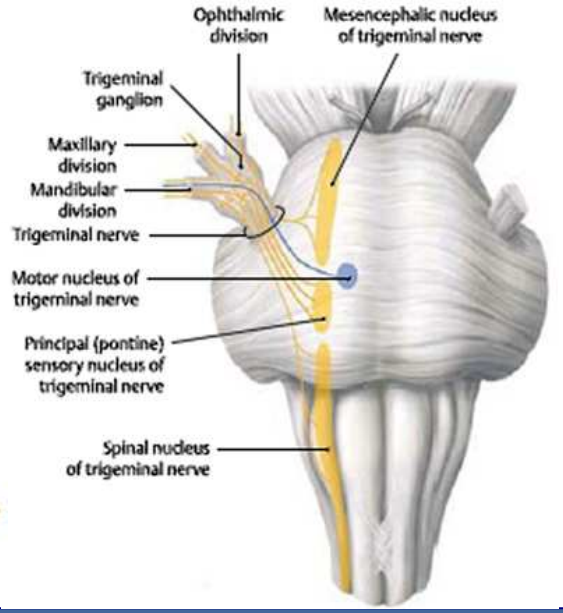
Trigeminal nerve, *n. trigeminus*

- Vth cranial nerve – the largest cranial nerve
- Mixed nerve:
  - ✓ sensory – sensory innervation of orofacial region
  - ✓ motor *(n. mandibularis)* – supply of masticatory muscles
- Formation:
  - ✓ larger sensory root, *radix sensoria (major)*
  - ✓ smaller motor root, *radix motoria (minor)*
- Emergence – at the level of the pons



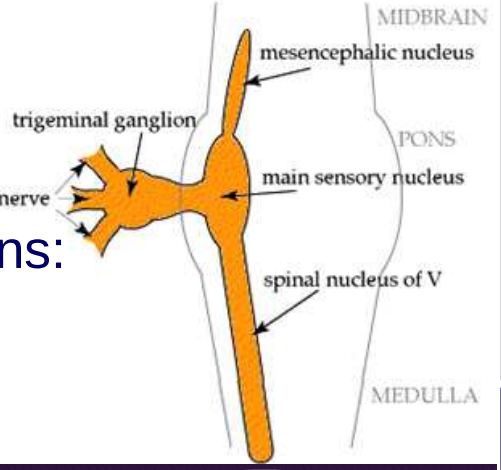


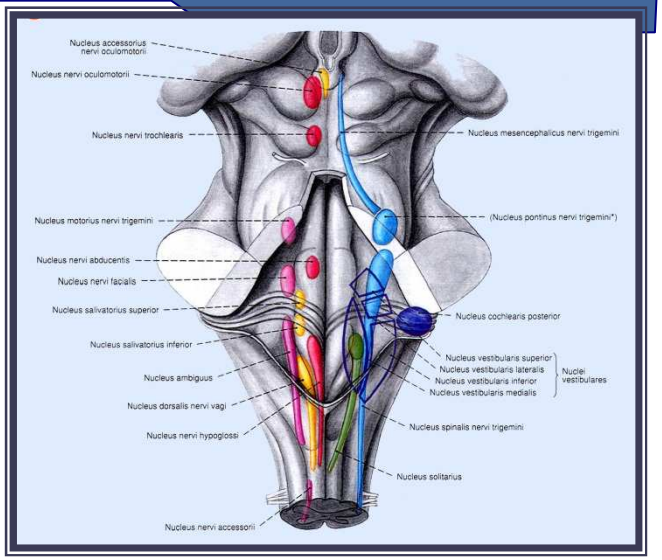


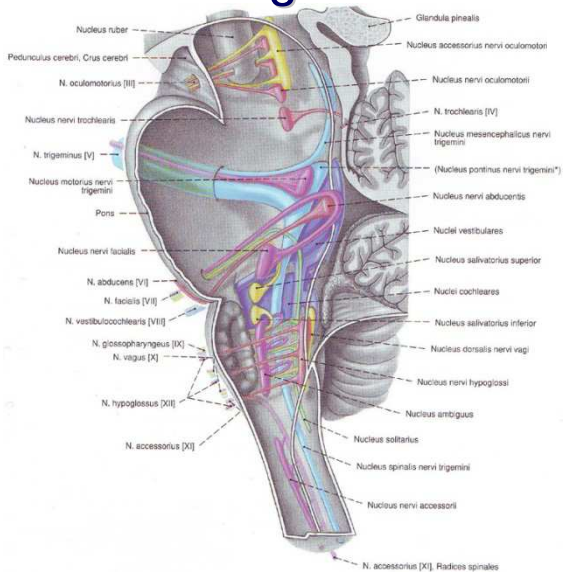


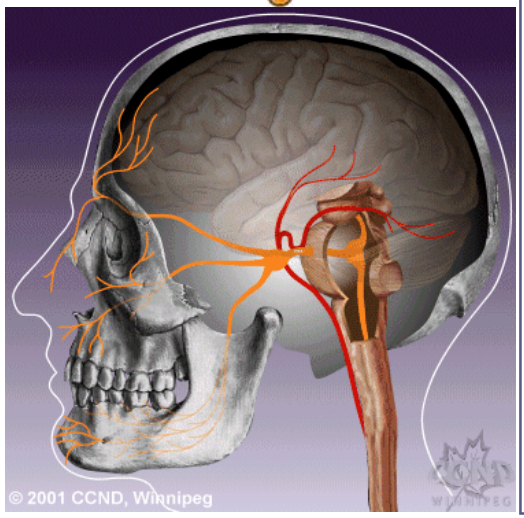
Trigeminal nuclear complex

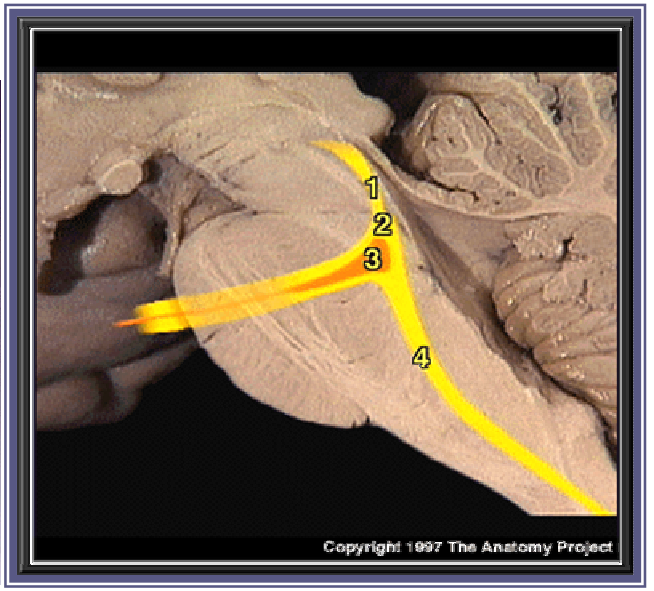
- Three sensory nuclei – in the brainstem:
  - ✓ main (principal) sensory nucleus – pontine
  - ✓ spinal trigeminal nucleus
  - ✓ mesencephalic nucleus
- Motor nucleus – in the pons:
  - ✓ motor trigeminal nucleus



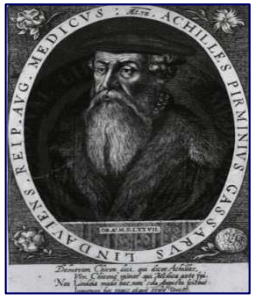






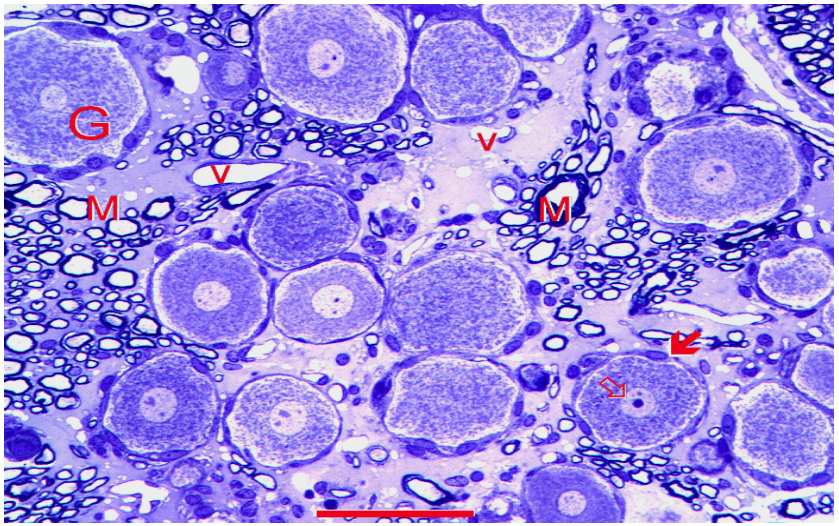


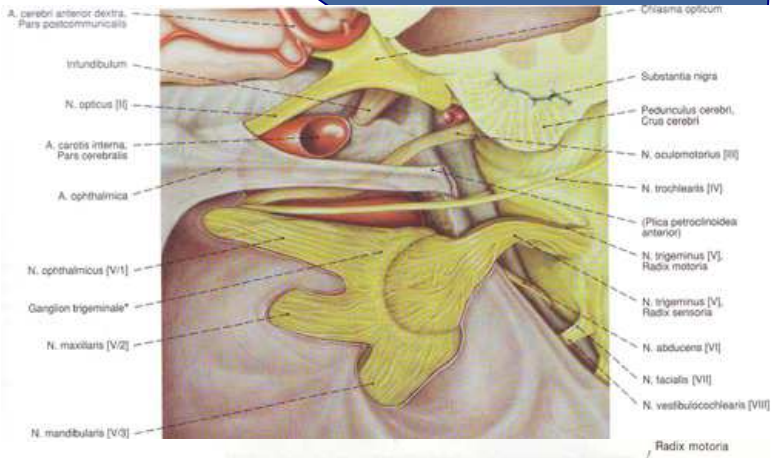
Trigeminal ganglion, *ganglion trigeminale*

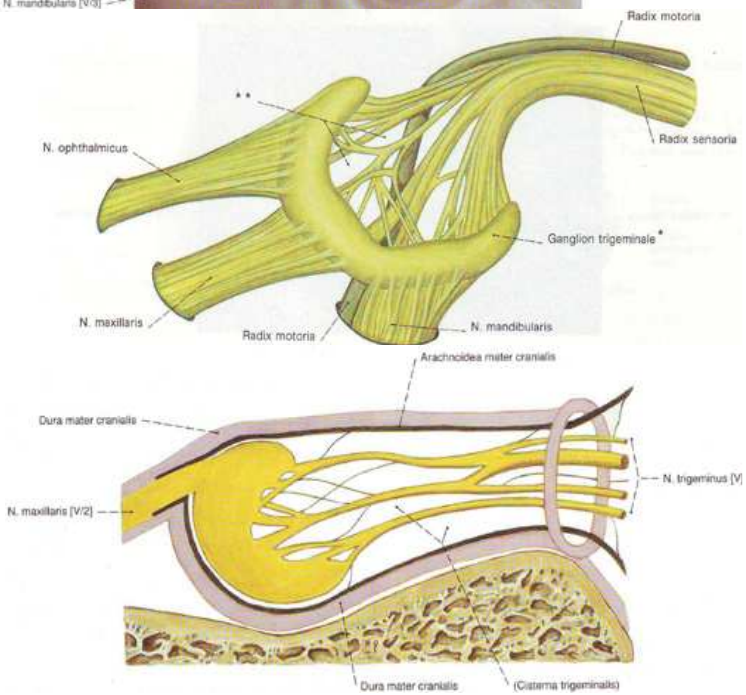


Johann Lorentz Gasser
1723-1765

- ✓ *ganglion trigeminale, (semilunare, Gasseri)*
- ✓ *impressio trigeminalis*
- ✓ *cavum trigeminale (Meckeli)*
- ✓ pseudounipolar neurons

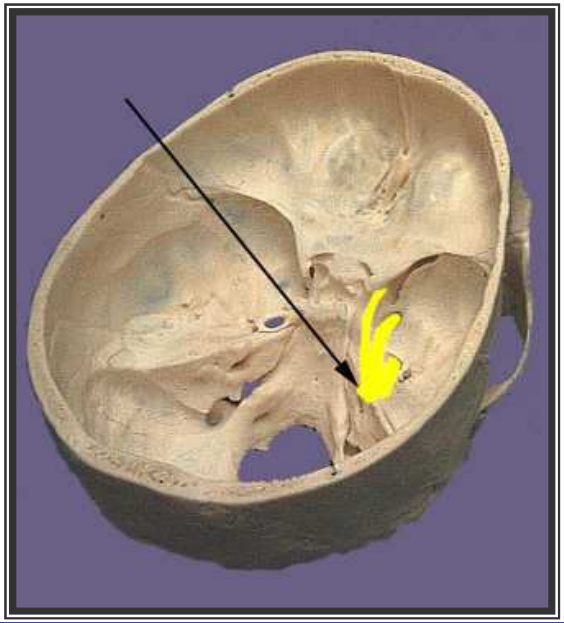


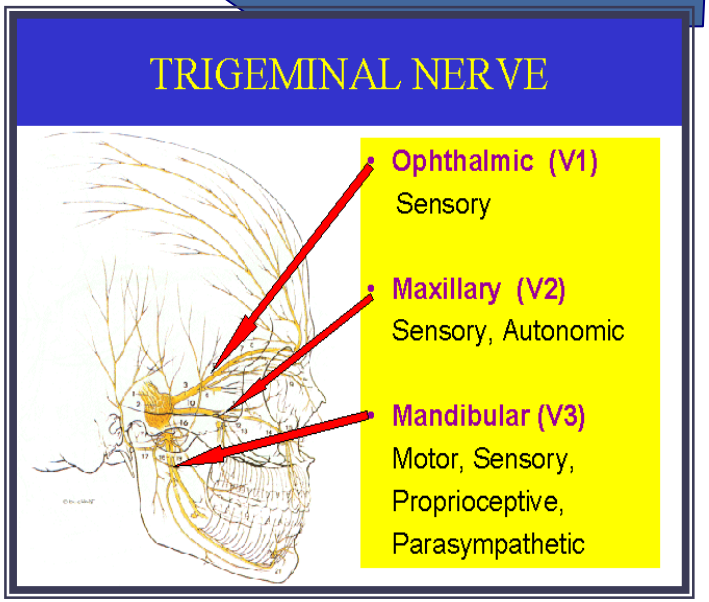


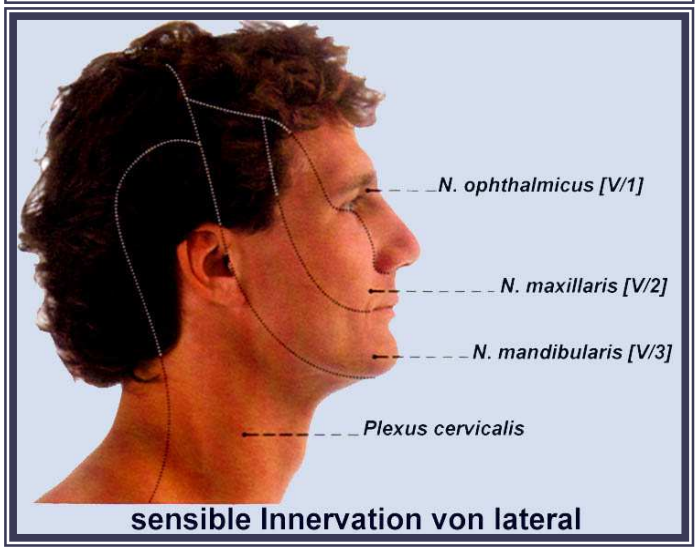


Trigeminal nerve, *n. trigeminus*

- Major branches:
  - ✓ ophthalmic nerve – pure sensory
    n. ophthalmicus
  - ✓ maxillary nerve – pure sensory
    n. maxillaris
  - ✓ mandibular nerve – mixed, motor&sensory
    n. mandibularis

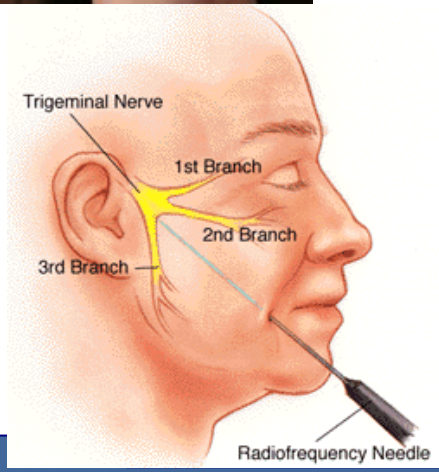


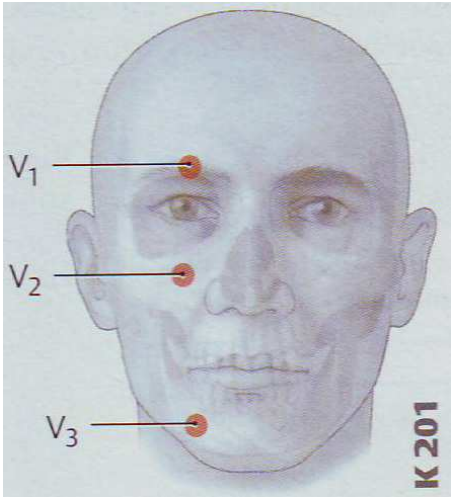


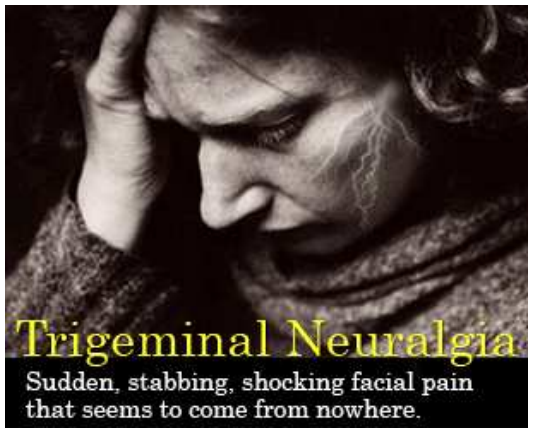


Trigeminal neuralgia

- "The Suicide Disease“ or *tic douloureux* (also known as prosopalgia)
  - ✓ key trigger points
  - ✓ trigeminal nerve block

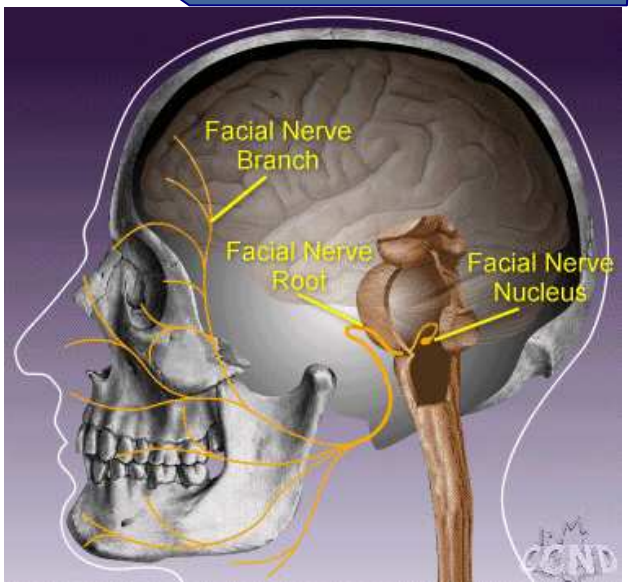


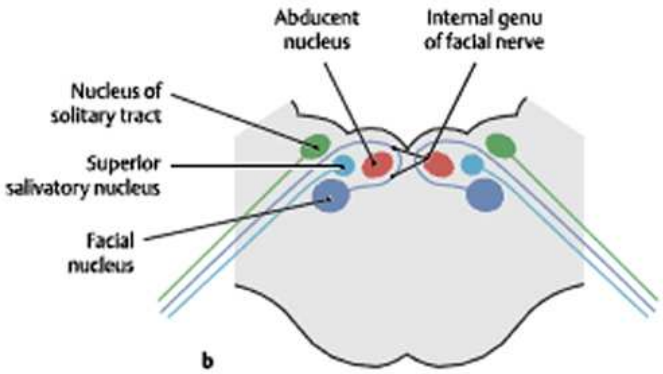


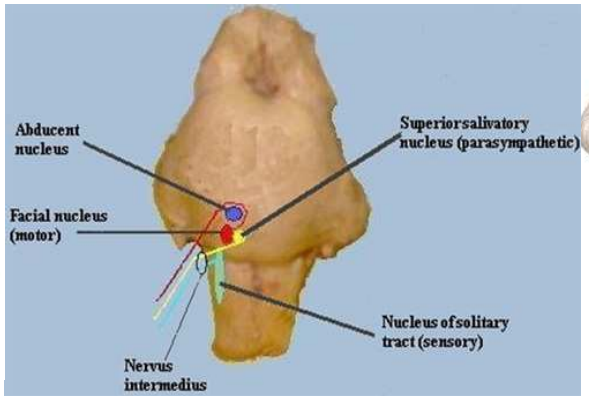


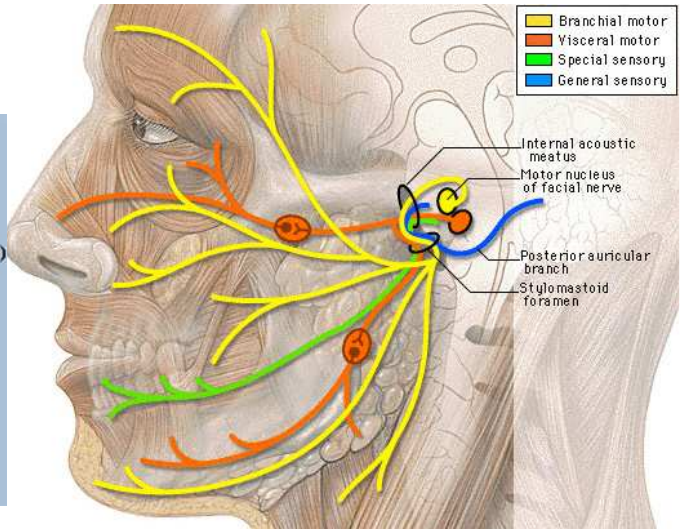
Facial nerve, *n. facialis*

- mixed nerve: motor root ⇨ facial (mimic) muscles, sensory and parasympathetic root ⇨ glands (*nervus intermedius)* ⇨ tongue and soft palate
- motor nucleus – in pons at the level of facial colliculus:
  - ✓ *facial nucleus*
- parasympathetic nucleus:
  - ✓ *superior salivatory nucleus,* incl. *nucl. lacrimalis*
- sensory nucleus – common nucleus with nn. IX and X:
  - ✓ *solitary tract nucleus*



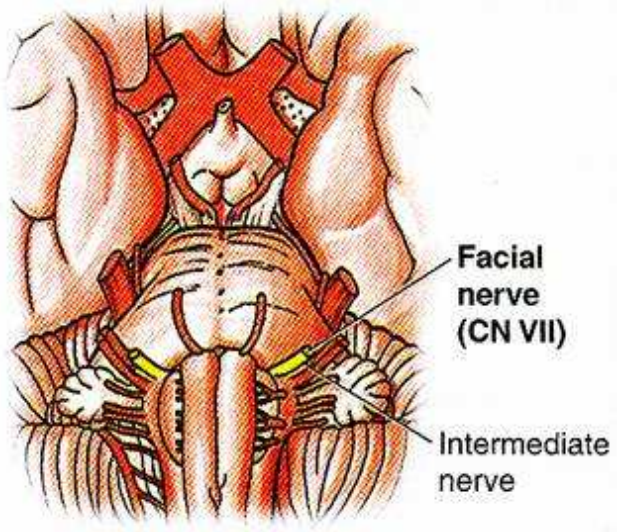


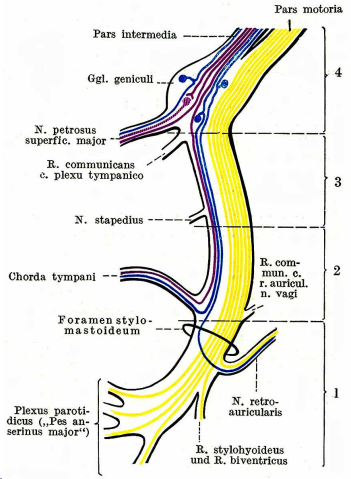


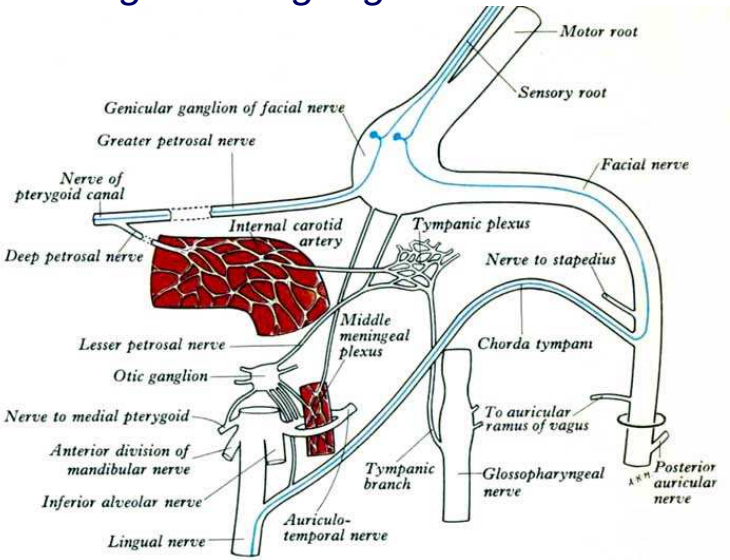


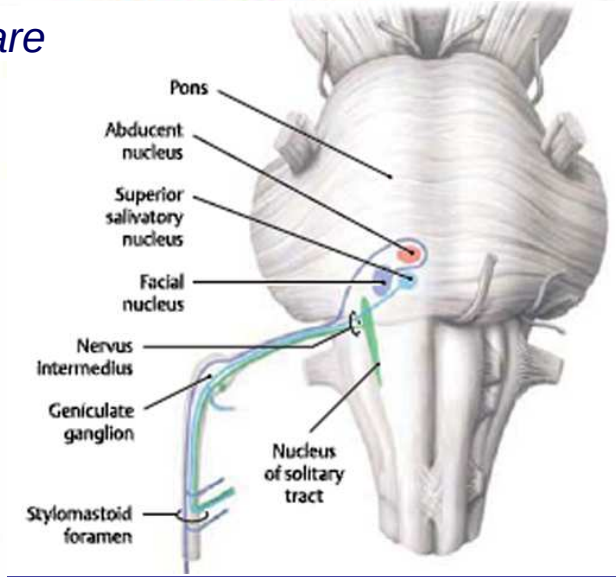
Facial nerve, *n. facialis*

- emergence – between the olive and inferior cerebellar peduncle
- course into *meatus acusticus internus*
  ⇨ branch off *n. intermedius* (somatosensory)
- genicular ganglion *(ganglion geniculatum)*
- branches inside the internal acoustic meatus
- in the facial canal:
  - ✓ *n. petrosus major* ⇨ *ganglion pterygopalatinum*
  - ✓ *n. stapedius* ⇨ *m. stapedius*
  - ✓ *chorda tympani* ⇨ *n. lingualis* ⇨ *ganglion submandibulare*



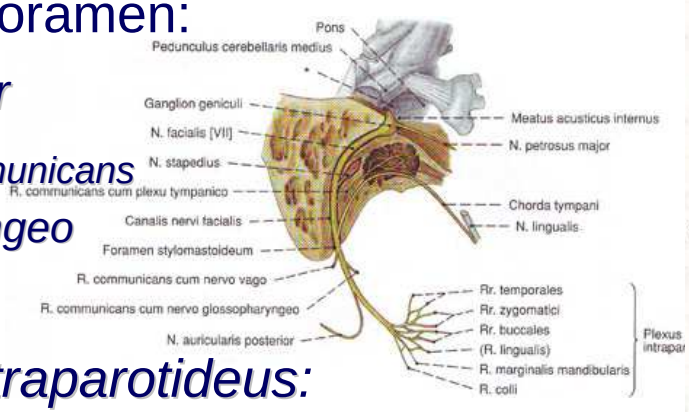


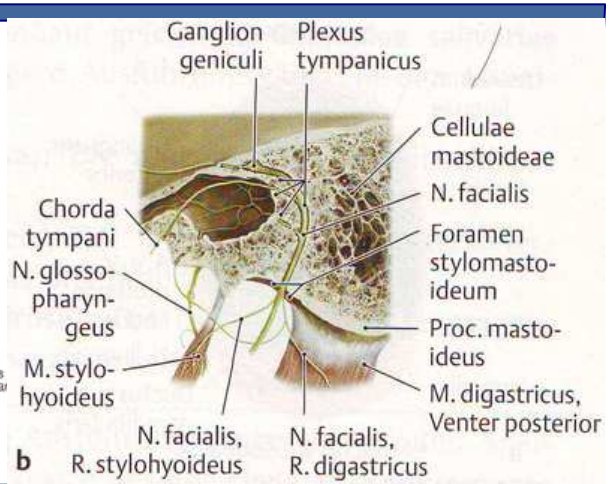


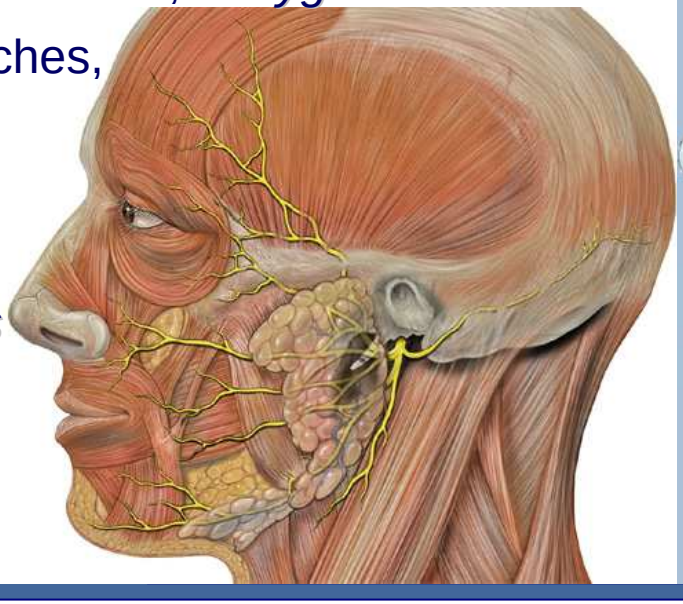


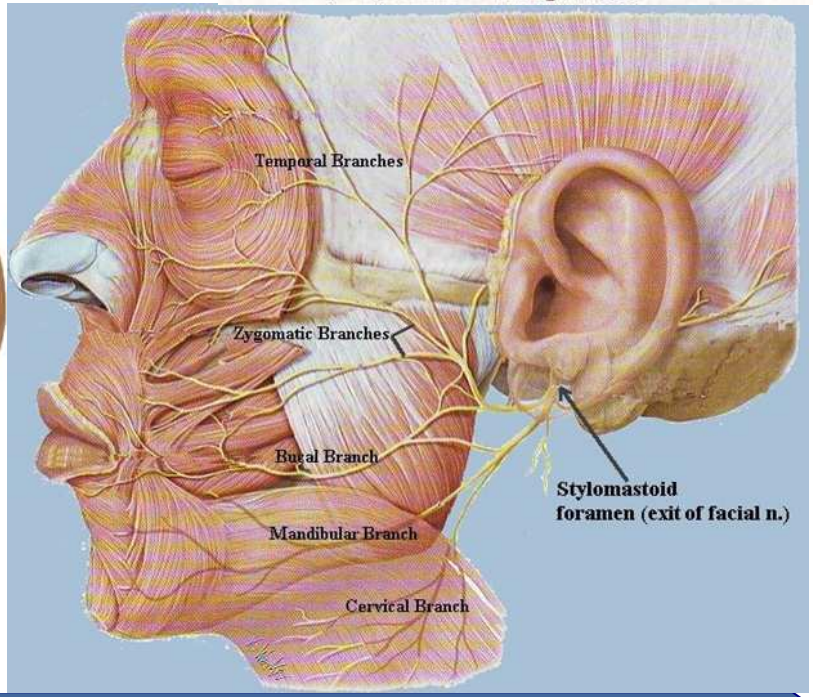
Nerve branches outside skull

- at exit of stylomastoid foramen:
  - ✓ *n. auricularis posterior*
  - ✓ *r. digastricus* ⇨ *r. communicans cum nervo glossopharyngeo*
  - ✓ *r. stylohyoideus*
- on the face – *plexus intraparotideus:*
  - ✓ temporal branches, *rr. temporales*
  - ✓ zygomatic branches, *rr. zygomatici*
  - ✓ buccal branches, *rr. buccales*
  - ✓ marginal mandibular, *r. marginalis mandibulae*
  - ✓ cervical, *r. colli*



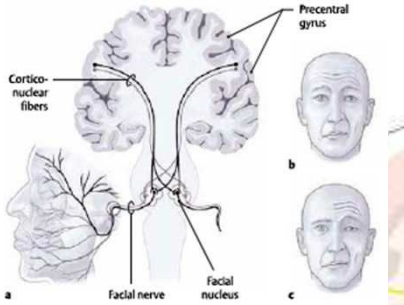


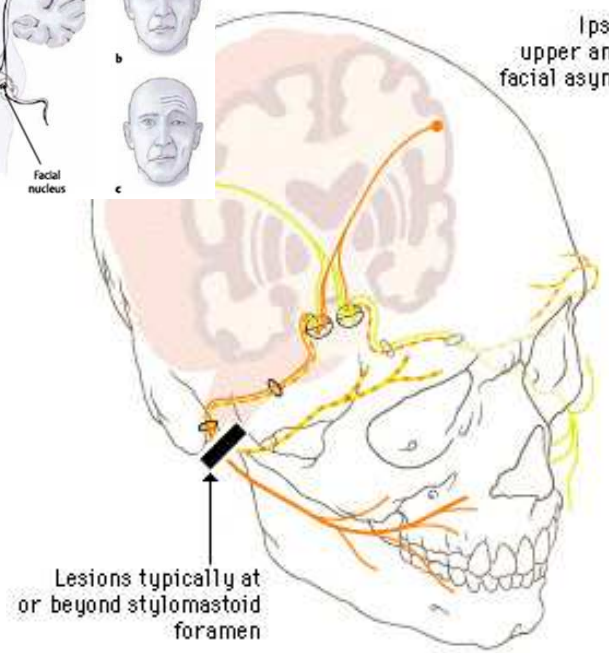


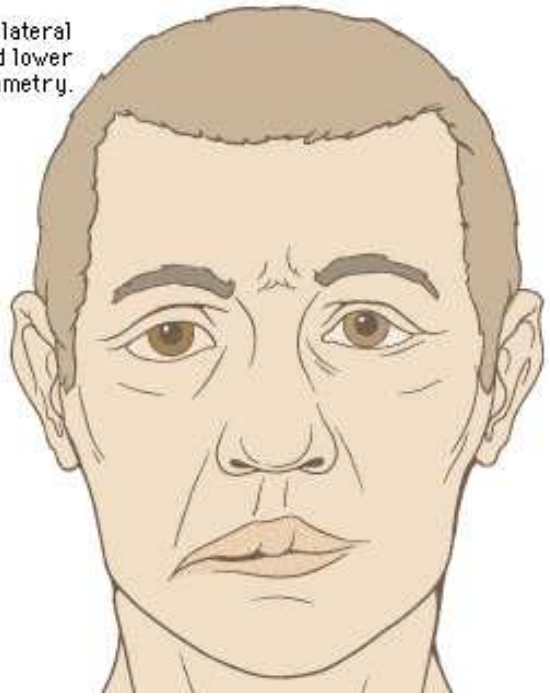


Facial (Bell's) palsy

- ✓ motor innervation of the face
- ✓ sensory innervation of the anterior ⅔ of the tongue
- ✓ paralysis of cranial nerve VII resulting in inability to control facial muscles on the affected side

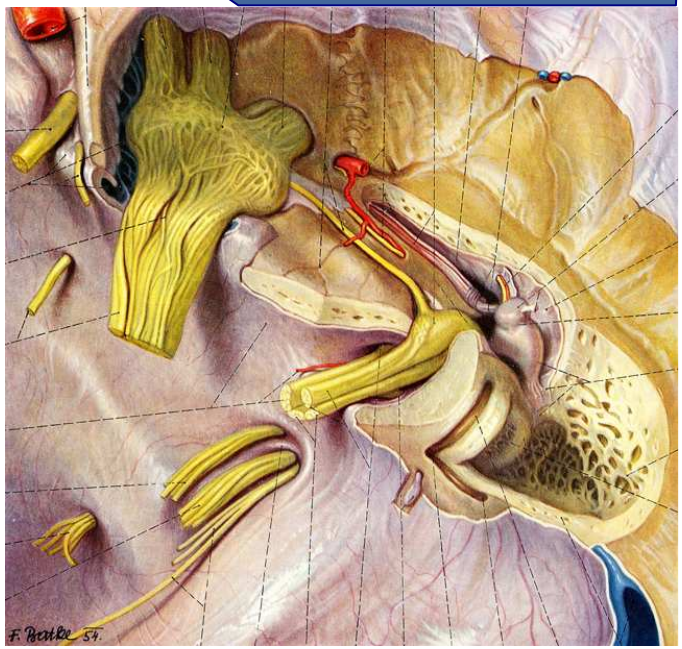


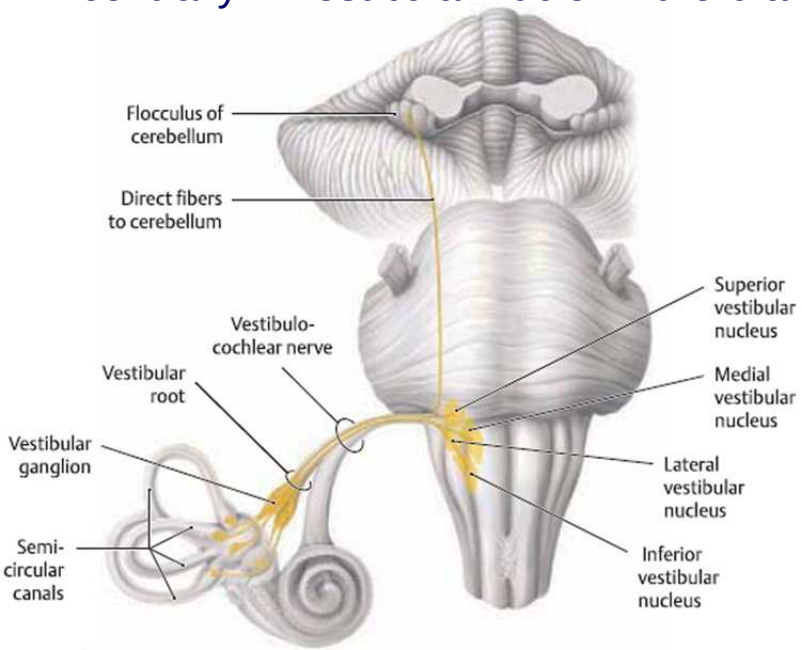


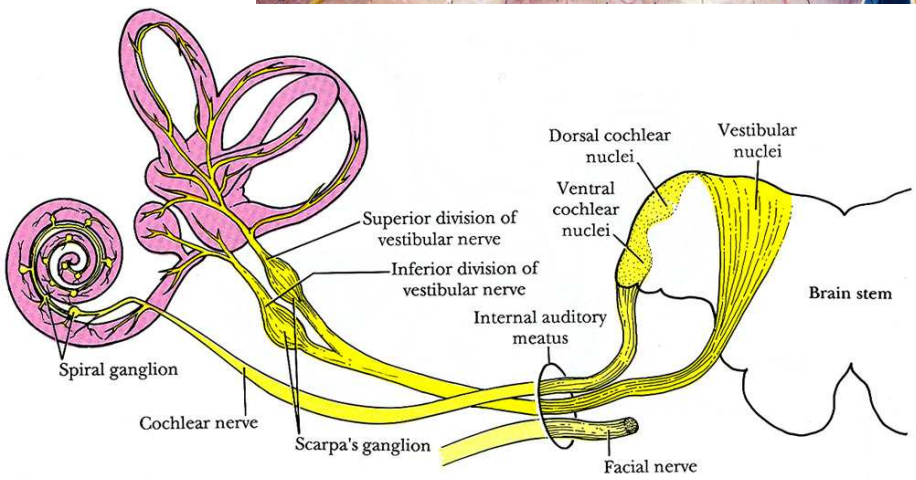


Vestibulocochlear nerve

- specific sense of sound and equilibrium (balance):
  - ✓ vestibular nerve (upper root)
  - ✓ cochlear nerve (lower root)
- vestibular nerve:
  - ✓ Scarpa's ganglion *(ganglion vestibulare)* – superior&inferior
  - ✓ peripherally ⇨ receptor cells of the maculae and cristae
  - ✓ centrally ⇨ vestibular nuclei in the brainstem

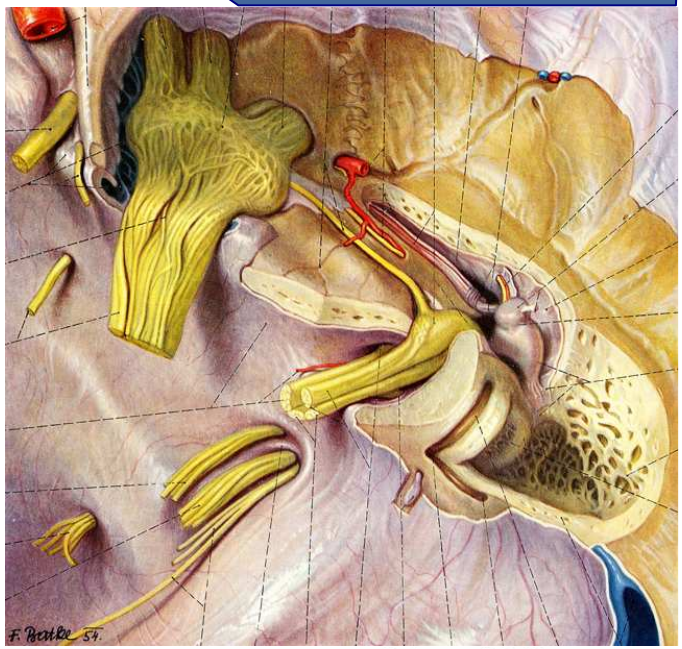


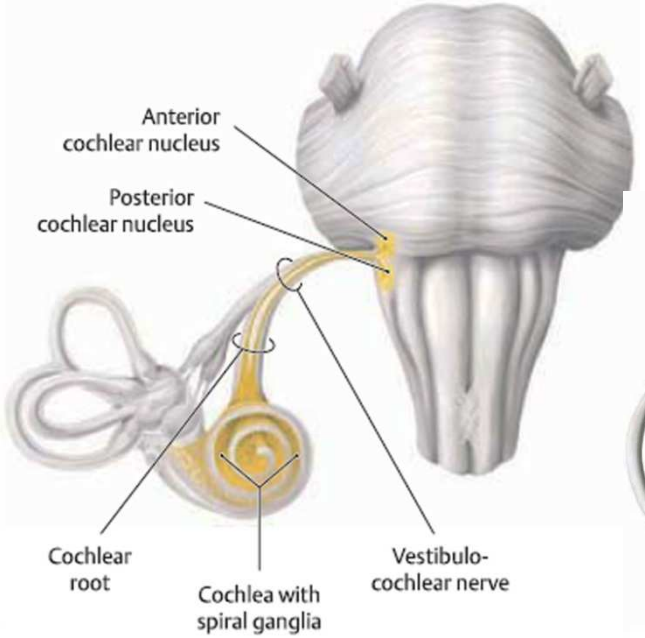


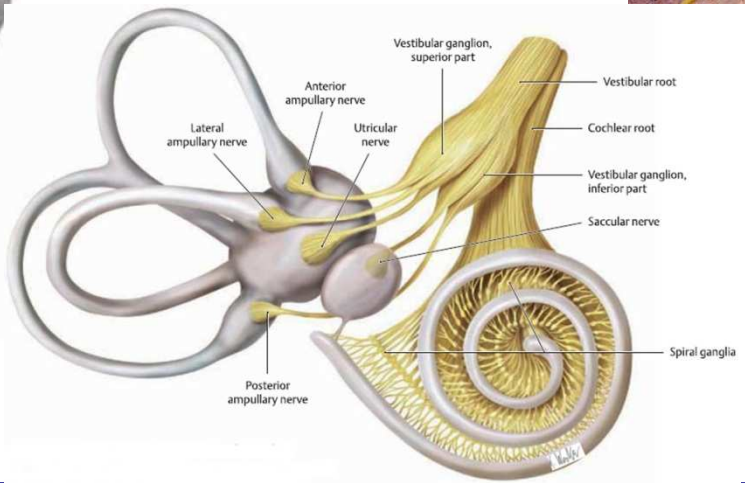


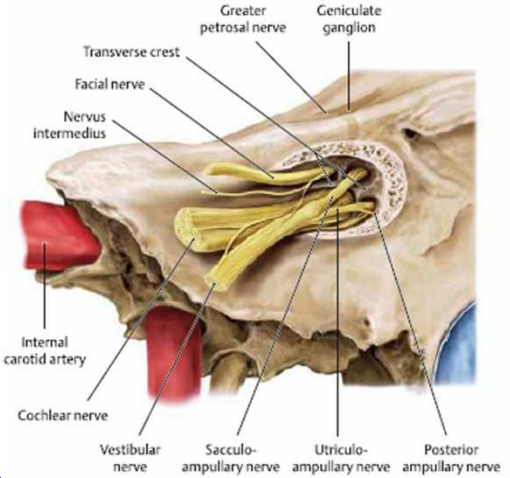
Vestibulocochlear nerve

- specific sense of sound and equilibrium (balance):
  - ✓ vestibular nerve (upper root)
  - ✓ cochlear nerve (lower root)
- cochlear nerve:
  - ✓ spiral ganglion *(ganglion cochleare)* – bipolar neurons
  - ✓ peripherally ⇨ hair cells of the organ of Corti
  - ✓ centrally ⇨ cochlear nuclei in the brainstem



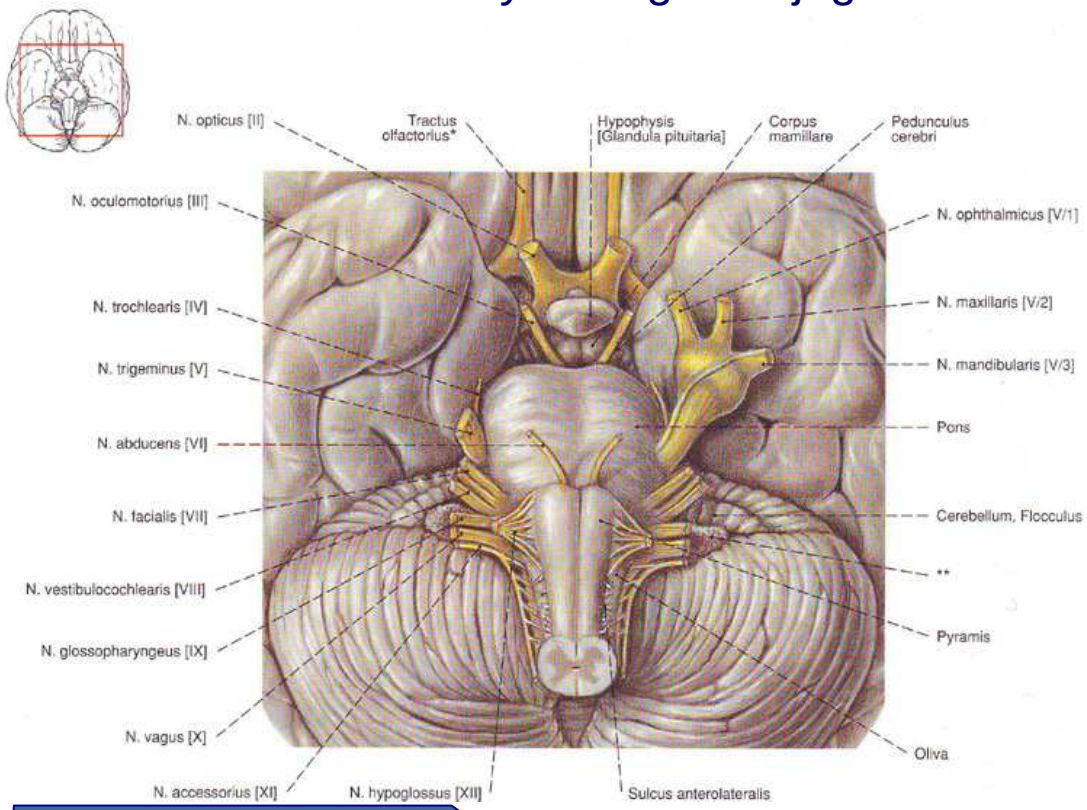


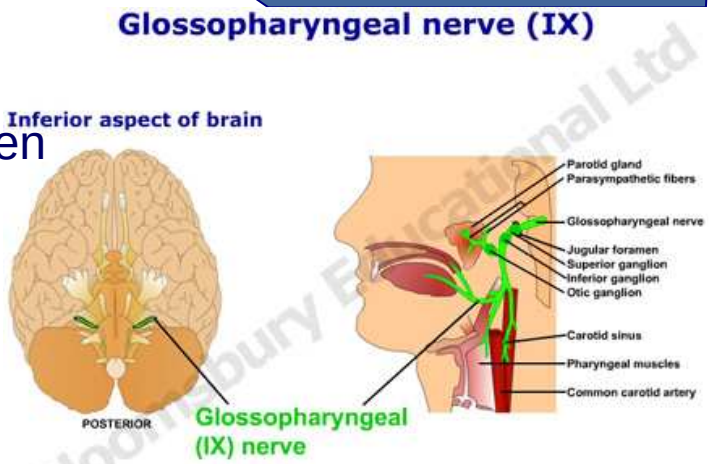


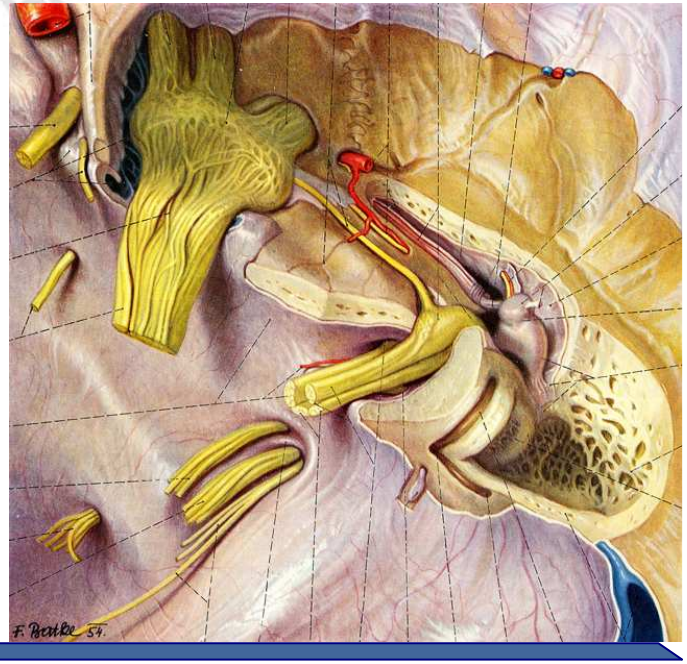


Glossopharyngeal nerve

- mixed branchiomeric nerve – motor, somatosensory, special visceral afferent and parasympathetic fibers
- site of emergence – 3-4 rootlets in the groove between the olive and inferior cerebellar peduncle
- leaves the cranial cavity through the jugular foramen

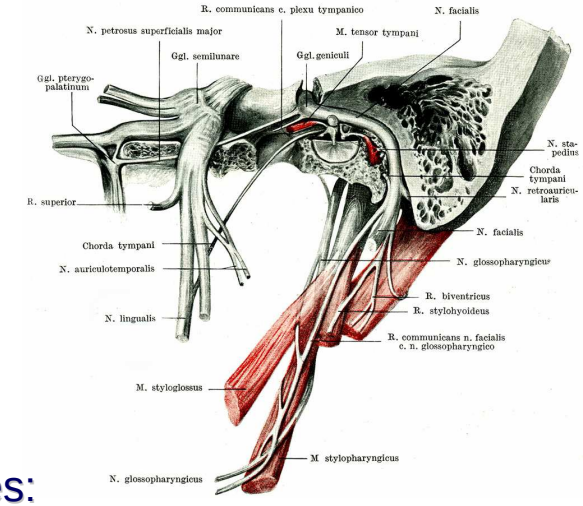


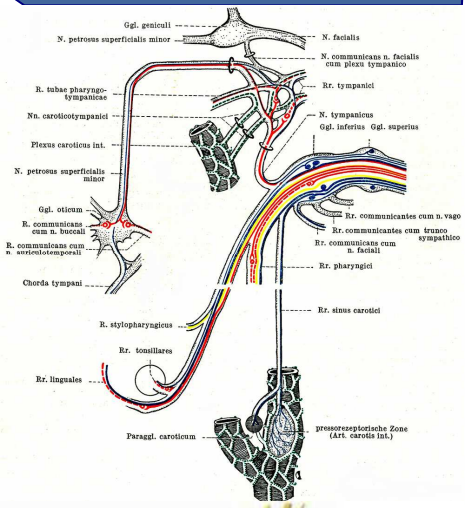


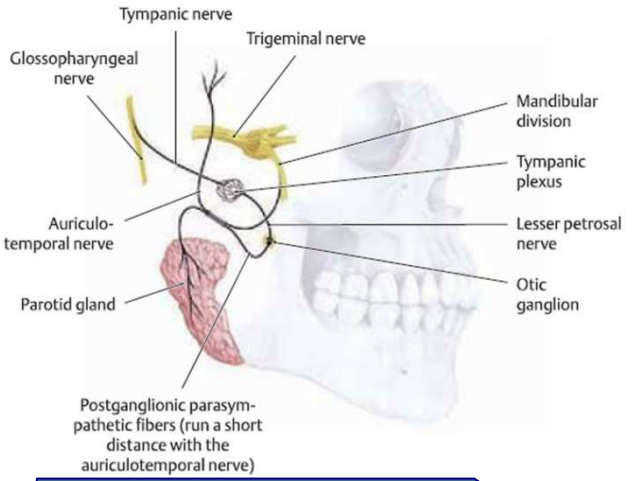


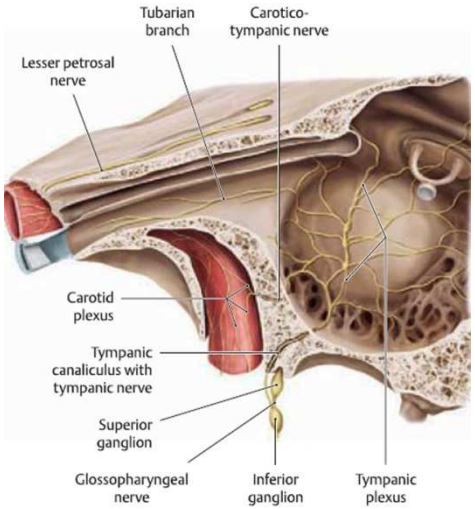
Glossopharyngeal nerve branches

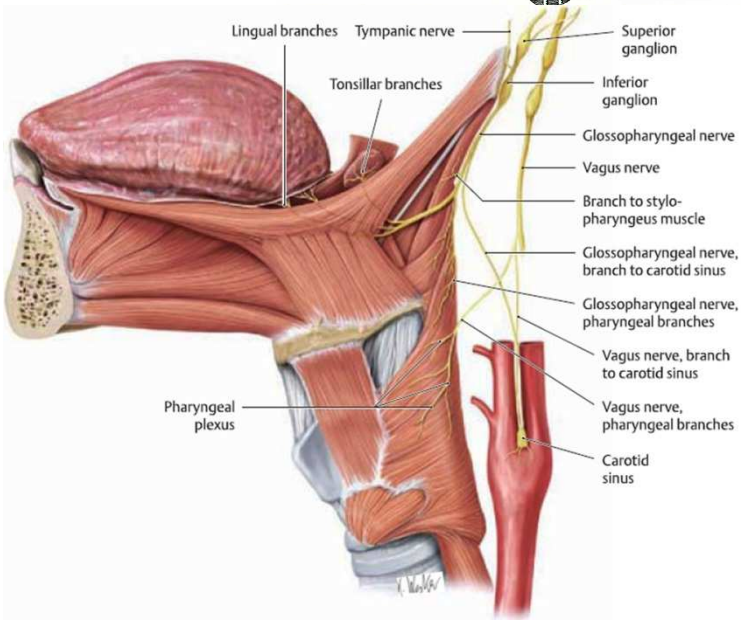
- muscular branches ⇨ *stylopharyngeal*
- sensory branches:
  - ✓ tympanic nerve ⇨ *plexus tympanicus*
  - ✓ carotid sinus nerve
  - ✓ pharyngeal branches
  - ✓ tonsillar branches
  - ✓ lingual branches – posterior ⅓ (postsulcal) part of tongue
- parasympathetic (secretomotor) branches:
  - ✓ lesser petrosal nerve ⇨ otic ganglion ⇨ auriculotemporal nerve ⇨ parotid gland





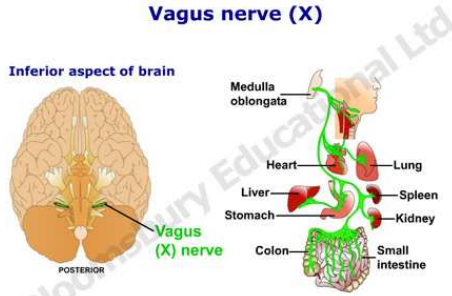


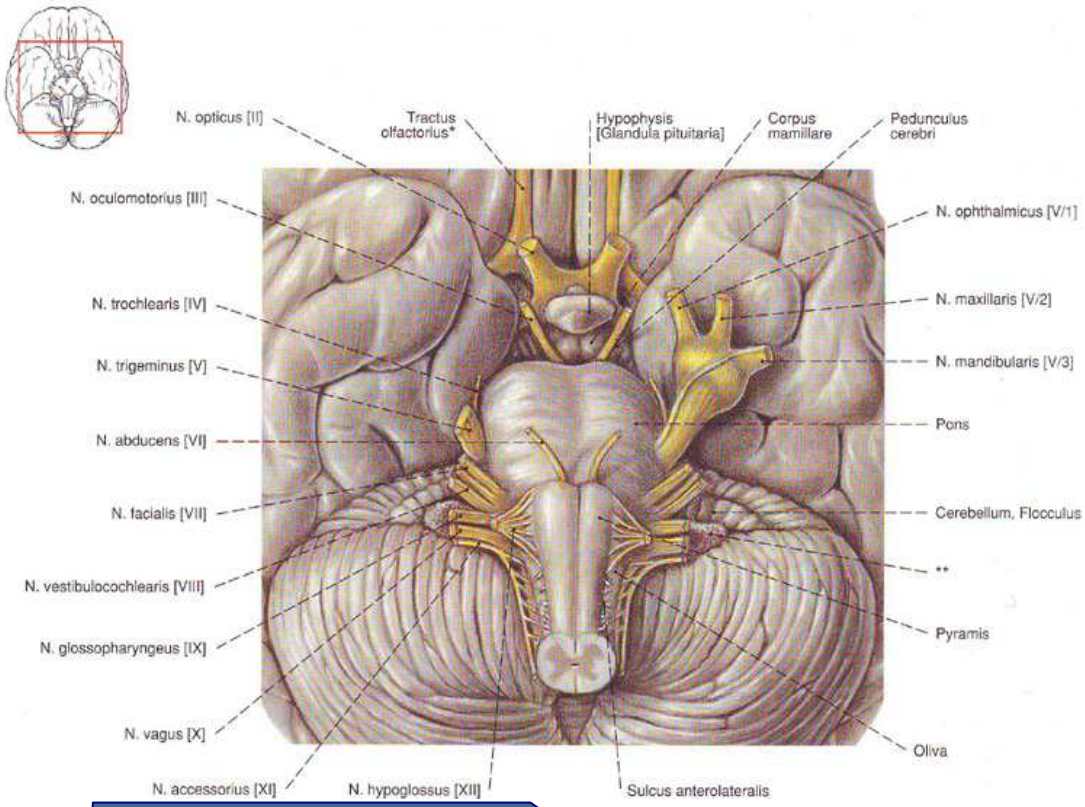


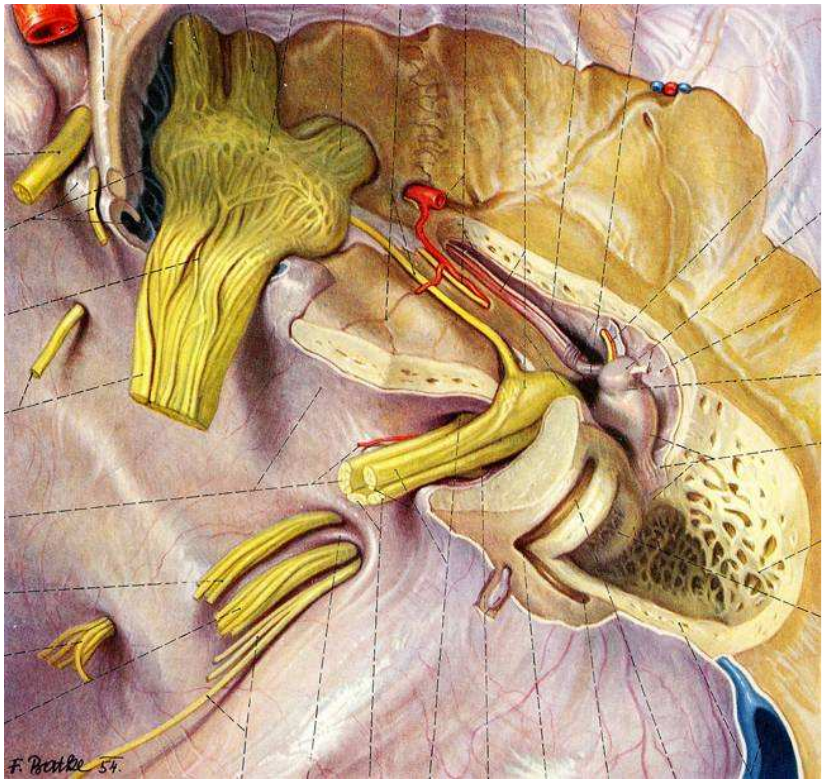


Vagus nerve, *n. vagus*

- mixed (pneumogastric) nerve – motor, somatosensory, special visceral afferent and parasympathetic fibers
- emergence – below the n. IX; with 8-10 rootlets in posterolateral sulcus between the olive and inferior cerebellar peduncle
- leaves the cranial cavity through the jugular foramen



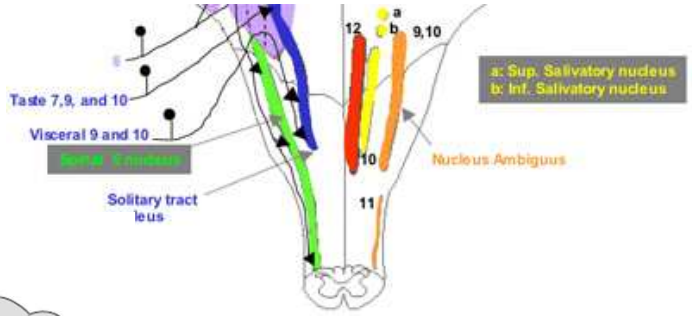


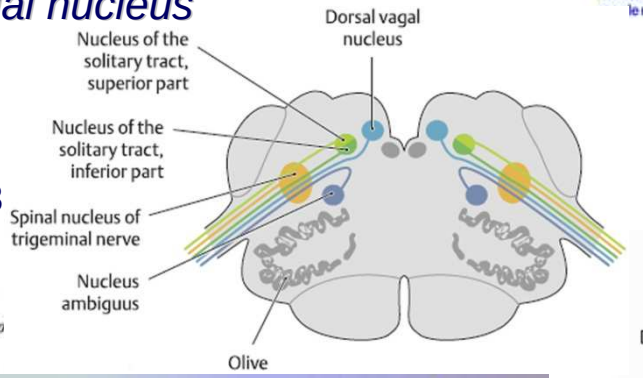


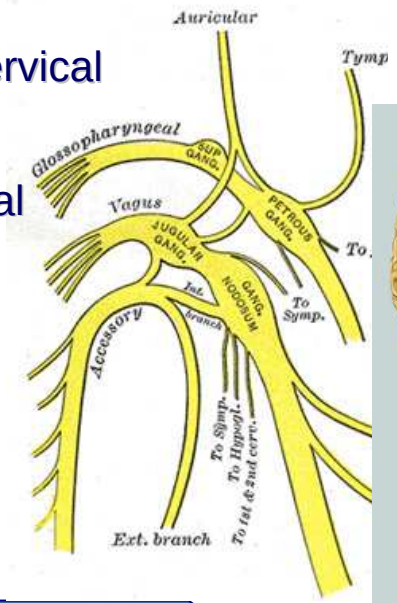
NB: Latin *vagus* means literally "Wandering"

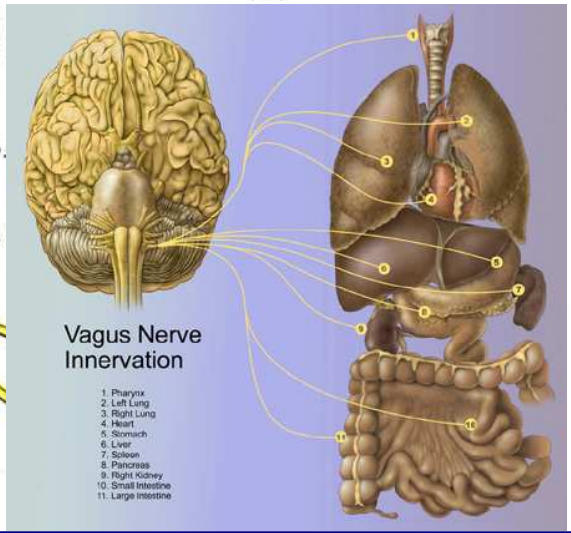
Nuclei and parts of the vagus nerve

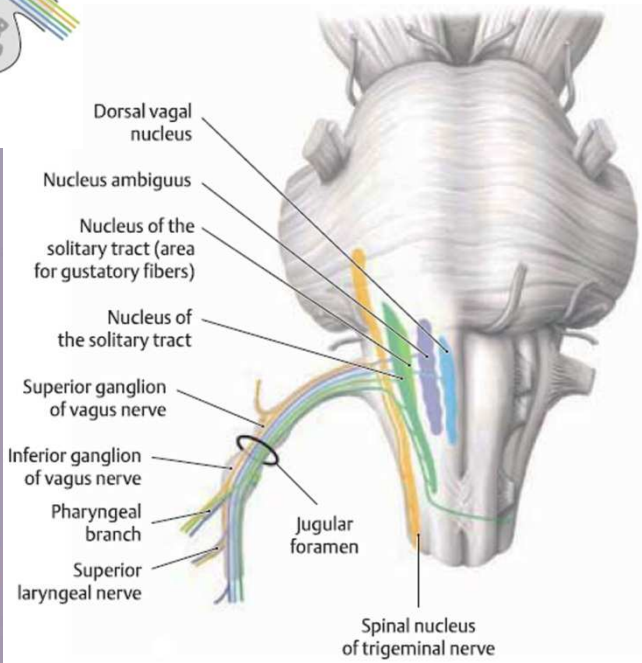
- nuclei – in the medulla oblongata:
  - ✓ motor – *nucleus ambiguus* (common with nn. IX and XI)
  - ✓ sensory – *solitary tract nucleus* (common with VII and IX)
  - ✓ parasympathetic – *dorsal vagal nucleus*
- in *foramen jugulare:*
  - ✓ *superior (jugular) ganglion*
  - ✓ *inferior (nodose) ganglion* – C2-C3
- parts:
  - ✓ cranio-cervical
  - ✓ thoracic
  - ✓ abdominal







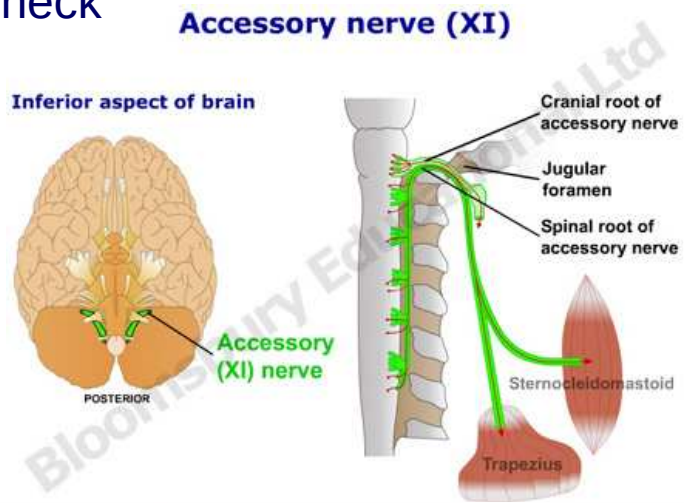


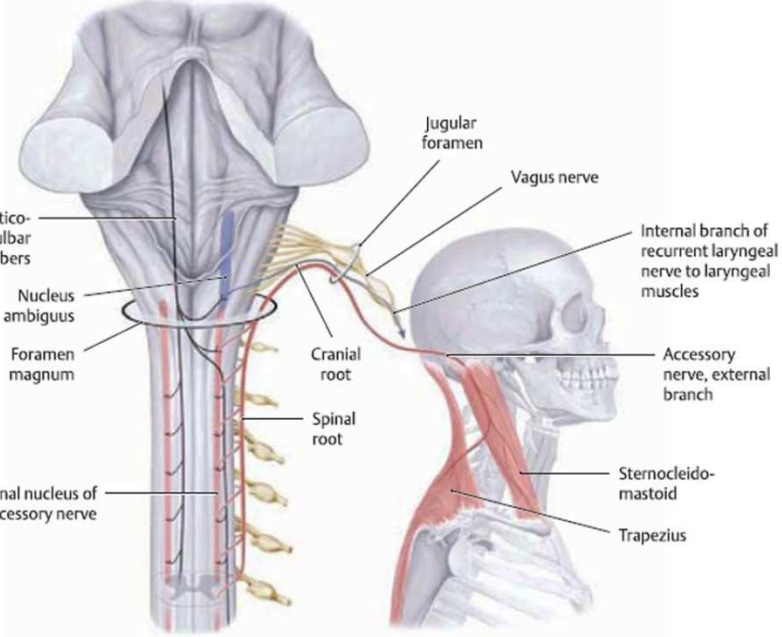


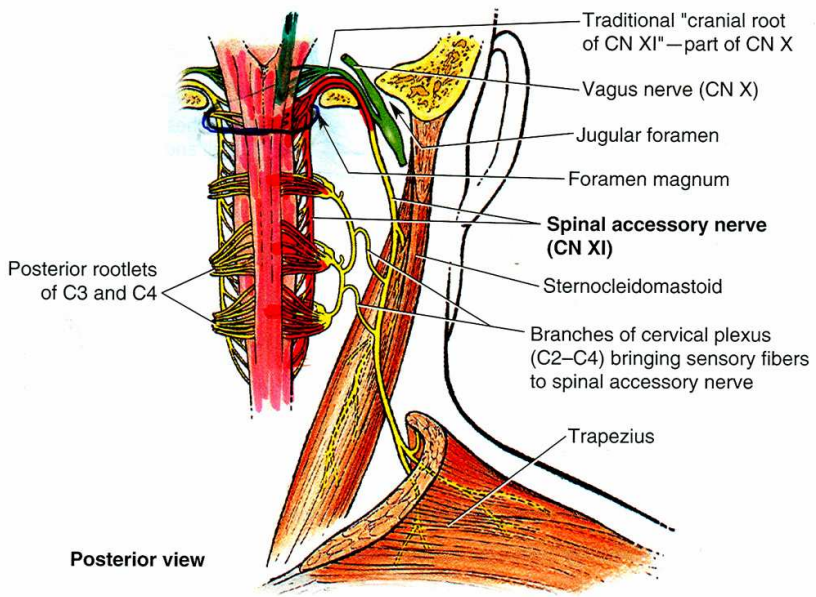
NB: Latin *vagus* means literally "Wandering"

Accessory nerve, *n. accessorius*

- purely motor nerve – controls specific muscles of the neck
- origin:
  - ✓ cranial root – smaller, part of the vagus nerve *(pars vagalis)*
  - ✓ spinal root – *pars spinalis* ⇨ spinal accessory nerve
- nuclei – in the medulla and spinal cord:
  - ✓ *nucleus ambiguus* (common with nn. IX and X)
  - ✓ spinal nucleus – in the upper spinal cord (C1-C5)

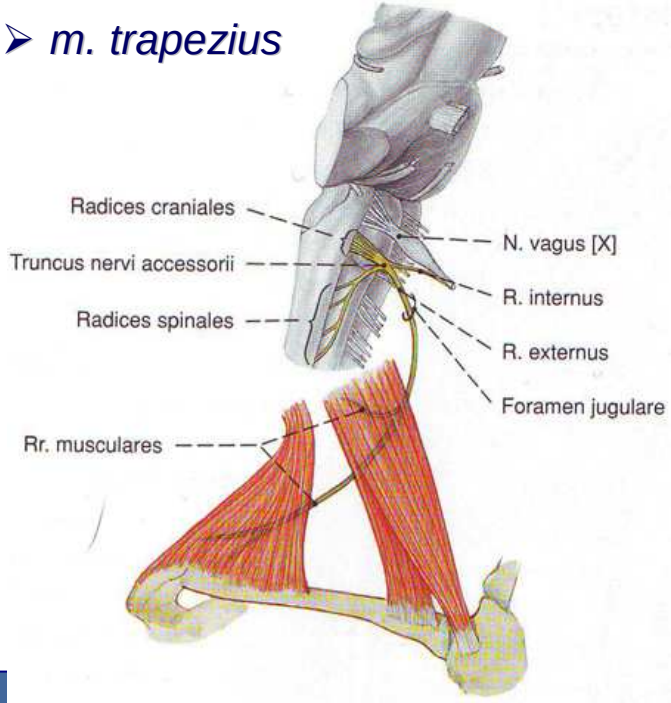


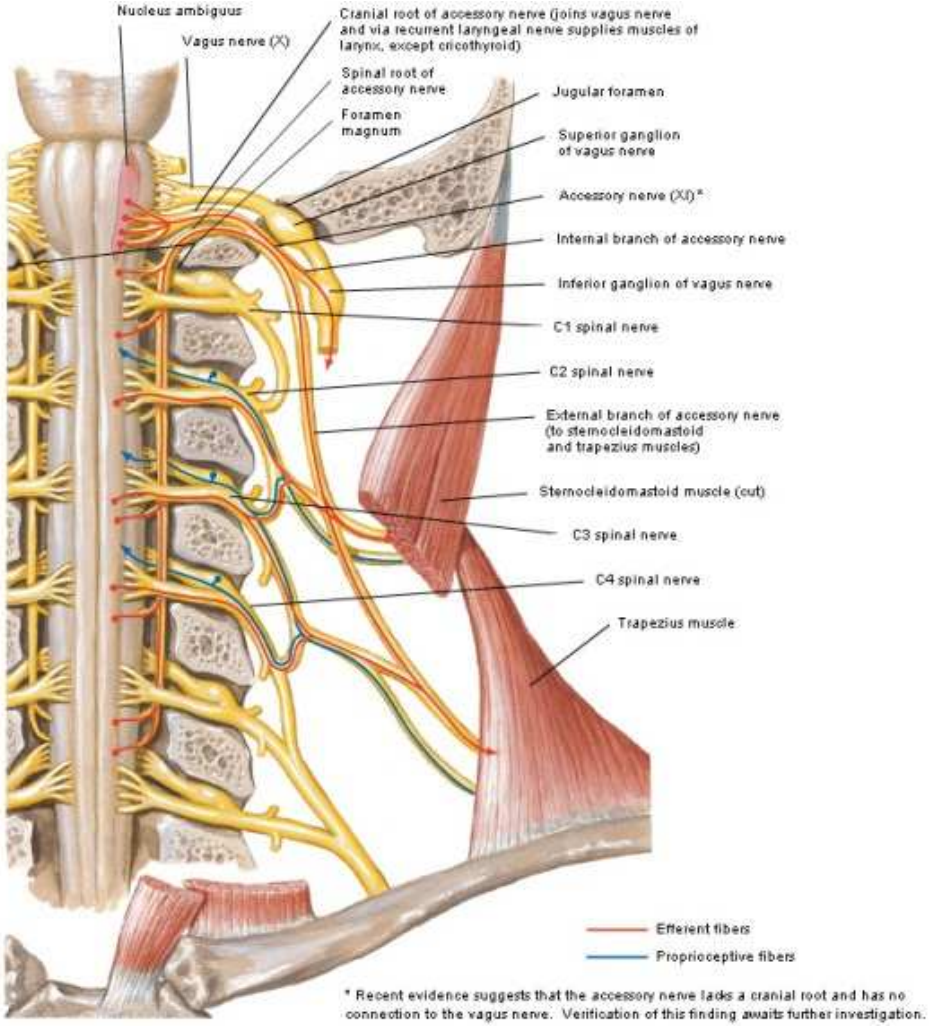




Accessory nerve, *n. accessorius*

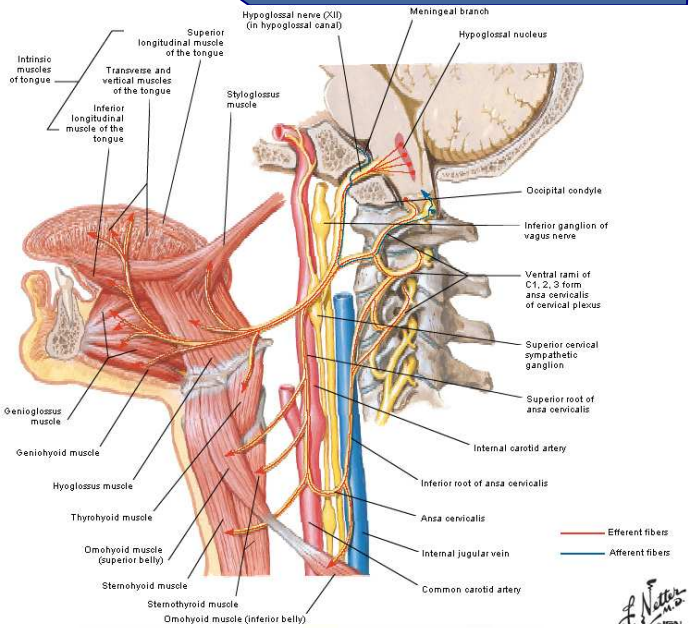
- two parts join in *foramen jugulare*
  - ✓ *truncus nervi accessorii*
- branches:
  - ✓ *internal ramus* ⇨ *n. vagus*
    ⇨ *n. laryngeus recurrens*
  - ✓ *external ramus* – motor supply:
    - ➢ *m. sternocleidomastoideus*
    - ➢ *m. trapezius*

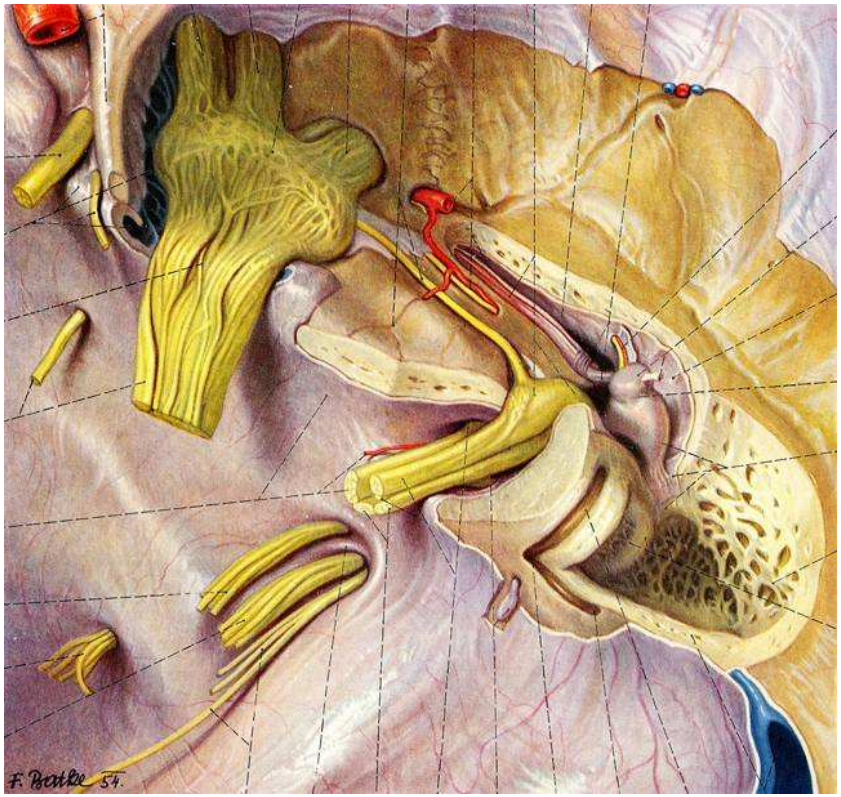


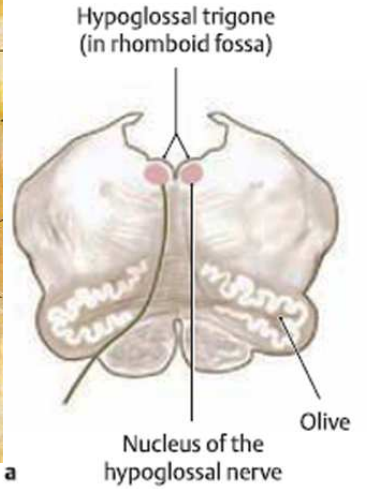


Hypoglossal nerve, *n. hypoglossus*

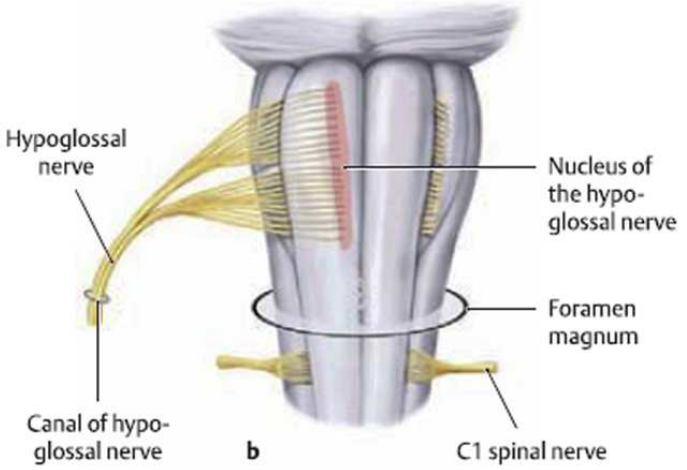
- purely motor nerve – motor nerve of the tongue
- emergence – with 10-15 rootlets in anterolateral sulcus
- nucleus – in hypoglossal triangle of the fourth ventricle:
  - ✓ hypoglossal nucleus – 2 cm long
- leaves cranium through *canalis nervi hypoglossi*







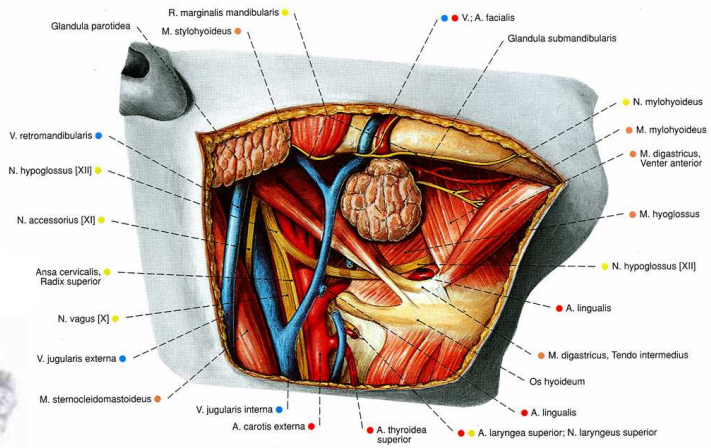
a

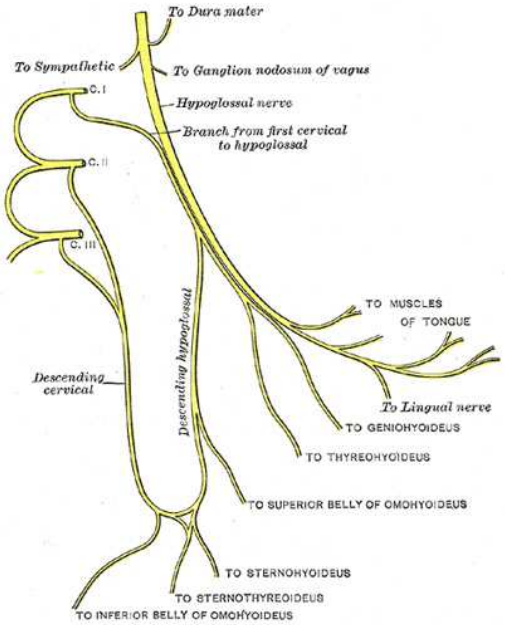


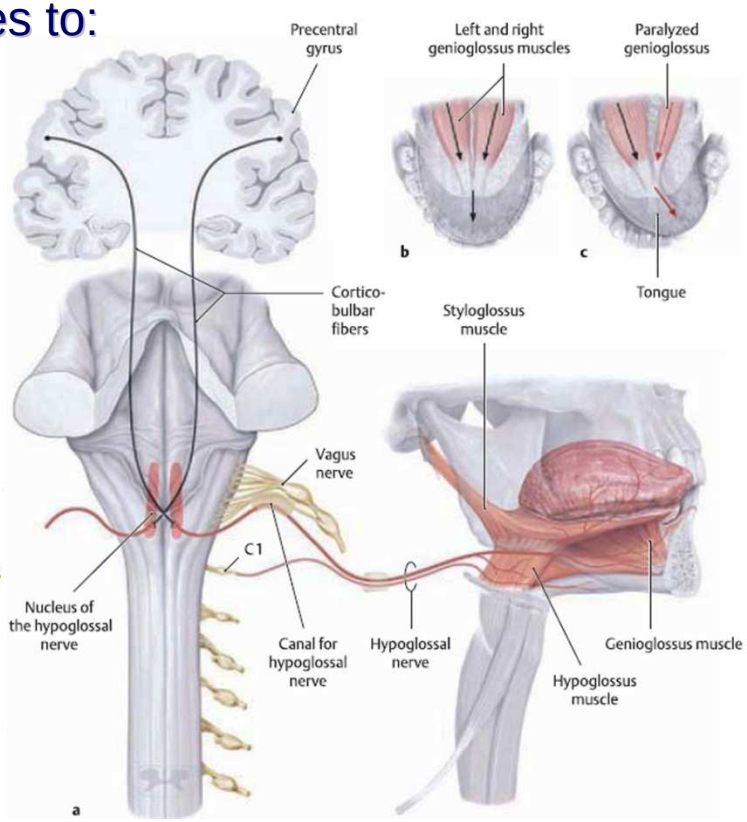
b

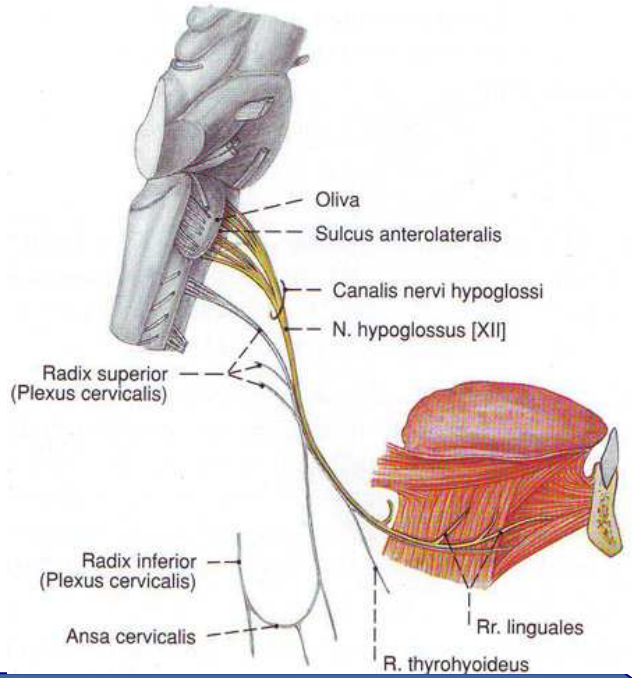
Hypoglossal nerve, *n. hypoglossus*

- branches:
  - ✓ meningeal branch
  - ✓ descending branch *(radix superior ansae cervicalis)*
  - ✓ muscular branches to thyrohyoid&geniohyoid
  - ✓ lingual branches to:
    - ➢ styloglossus
    - ➢ hyoglossus
    - ➢ genioglossus



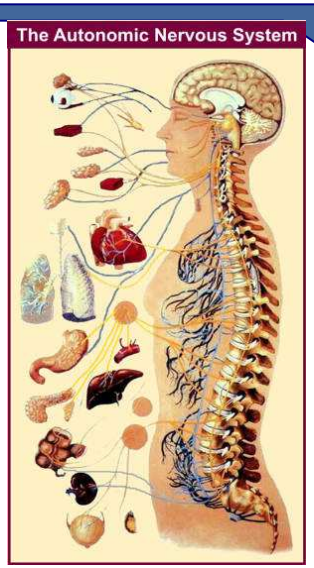


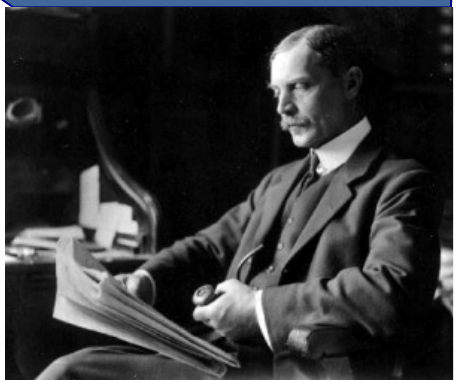




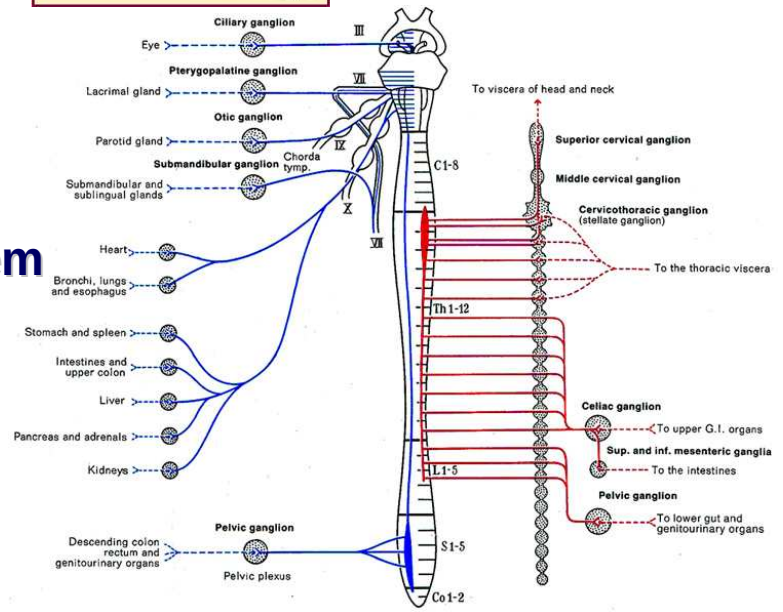
Definition and nomenclature

- **Autonomic Nervous System (ANS):**
  - ✓ part of the peripheral nervous system
- **autonomic** = auto (self) + nomos, *Gr. νόμος* (law)
  - ✓ reflex, involuntary actions
  - ✓ automatic, independent, unconscious system
- innervation of:
  - ✓ viscera
  - ✓ glands
  - ✓ blood vessels
  - ✓ nonstriated (smooth and cardiac) muscles
- synonyms: **visceral (vegetative) nervous system**
- main function – control system to maintain life:
  - ✓ regulation and control of visceral functions
    - ➢ reproduction
    - ➢ vital body processes – circulation, digestion, secretion and excretion etc.



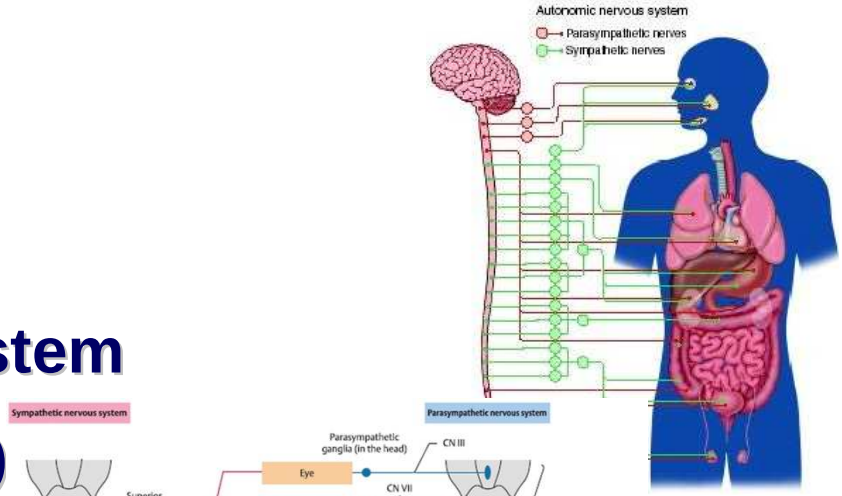


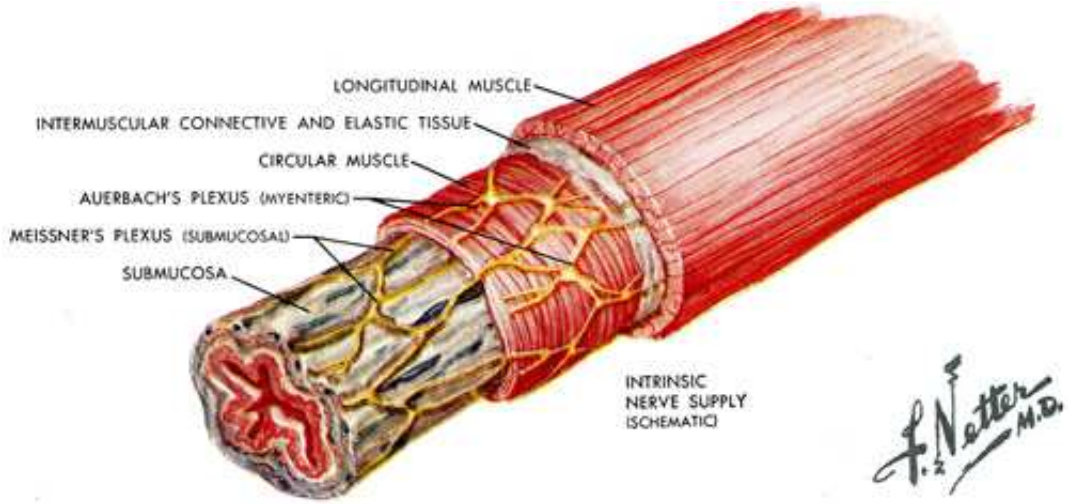
John Newport Langley (1852–1925)

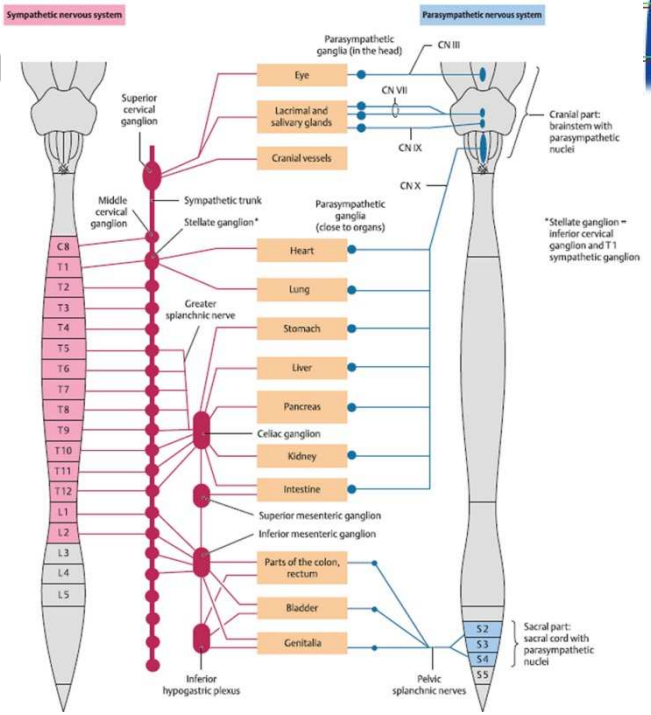


Main subdivisions

- **tripartite integrated system** (Langley, 1921):
  - ✓ **sympathetic nervous system**
  - ✓ **parasympathetic nervous system**
  - ✓ **enteric nervous system** (ENS)

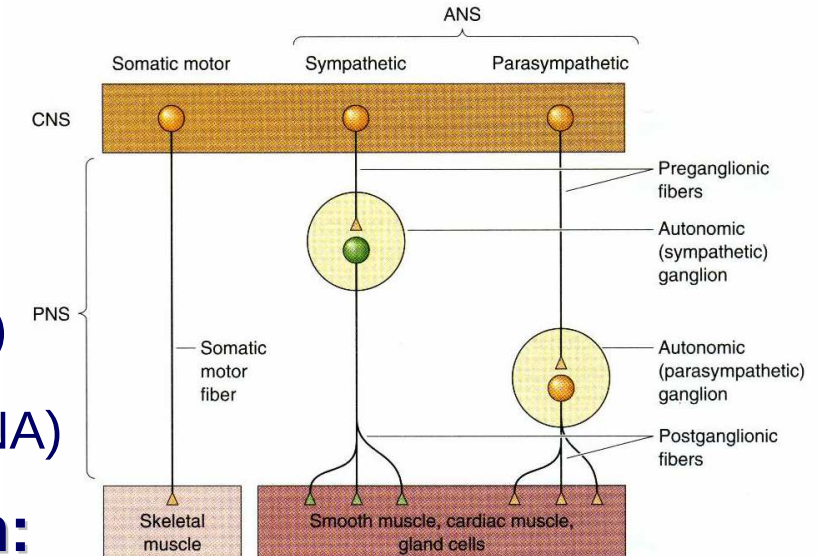


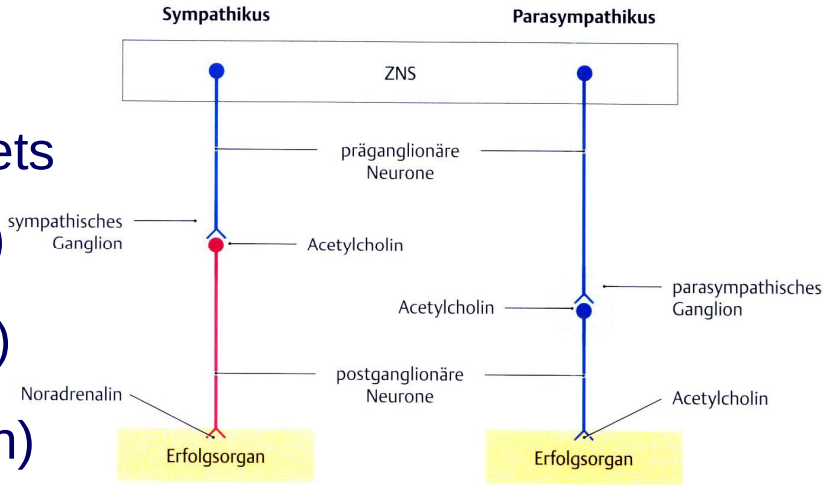




Structural and neurochemical differences

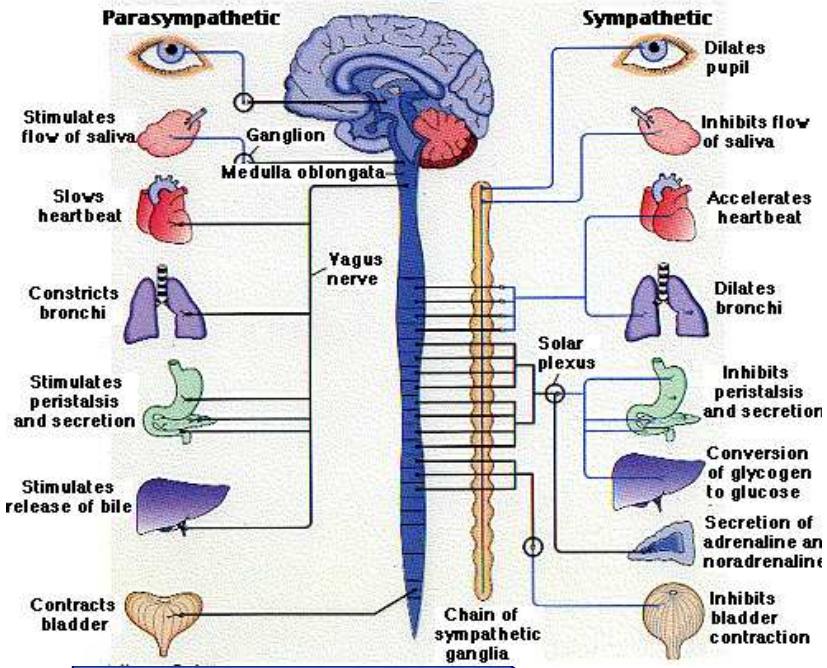
- **Sympathetic nervous system:**
  - ✓ equal pre- and postganglionic fibers
  - ✓ autonomic ganglia proximally located
  - ✓ preganglionic fibers – cholinergic (ACh)
  - ✓ postganglionic fibers – adrenergic (A, NA)
- **Parasympathetic nervous system:**
  - ✓ longer pre- vs. postganglionic fibers
  - ✓ autonomic ganglia located nearby targets or within their walls (intramural ganglia)
  - ✓ preganglionic fibers – cholinergic (ACh)
  - ✓ postganglionic fibers – cholinergic (ACh)

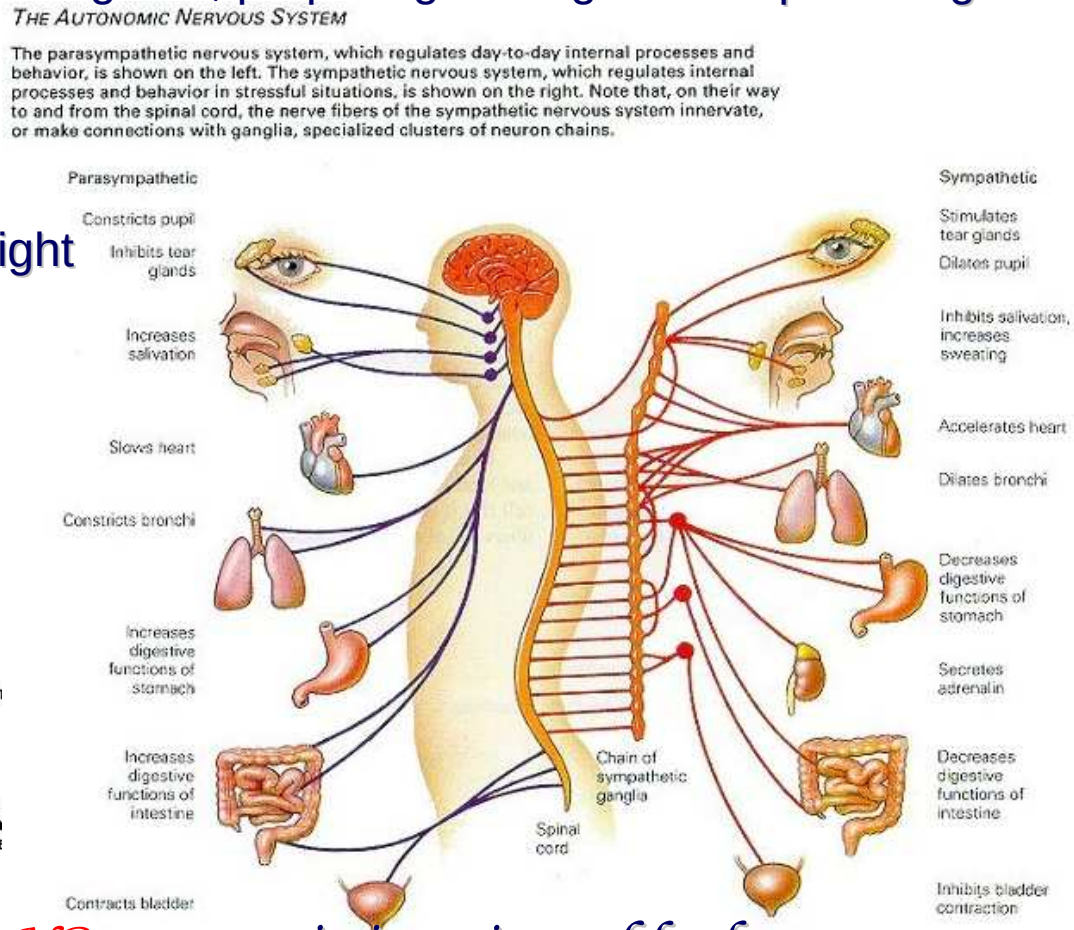




Functional considerations

- **parasympathetic reactions:**
  - ✓ generally localized and **anabolic** – day-to-day internal processes and behavior
  - ✓ conservation of body energies during rest, preparing us to go to sleep and digest
- **sympathetic reactions** :
  - ✓ mass responses – **catabolic**
  - ✓ mobilize body energies in stressful situations, preparing us for fight, flight or fright

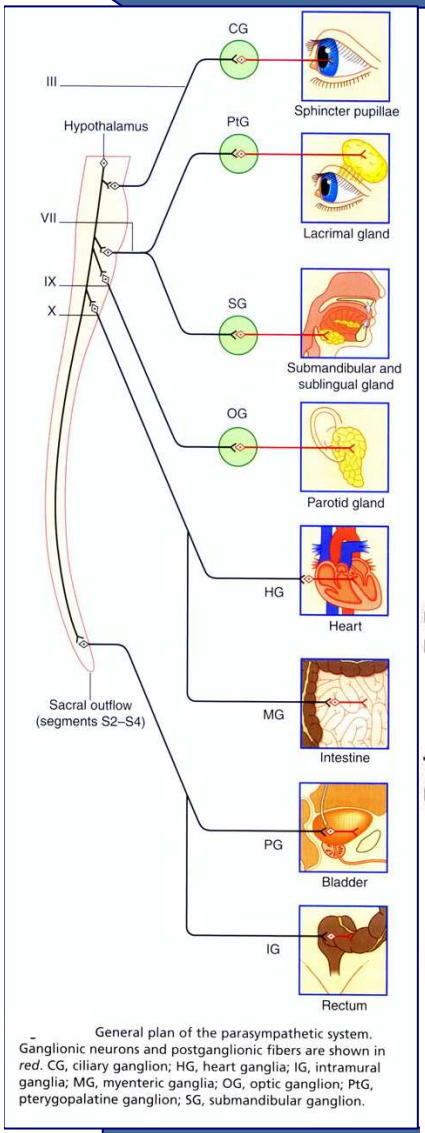




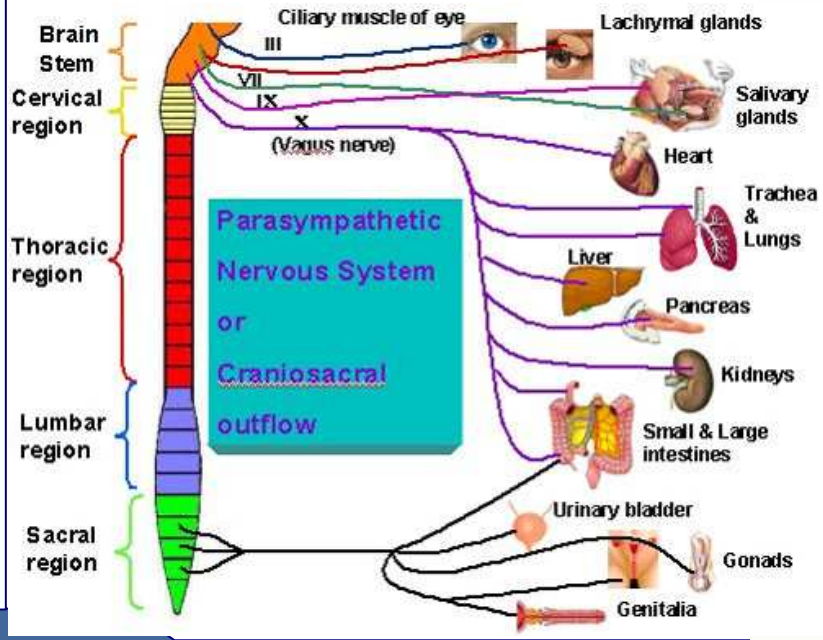
NB: antagonistic actions of both components to maintain homeostasis!

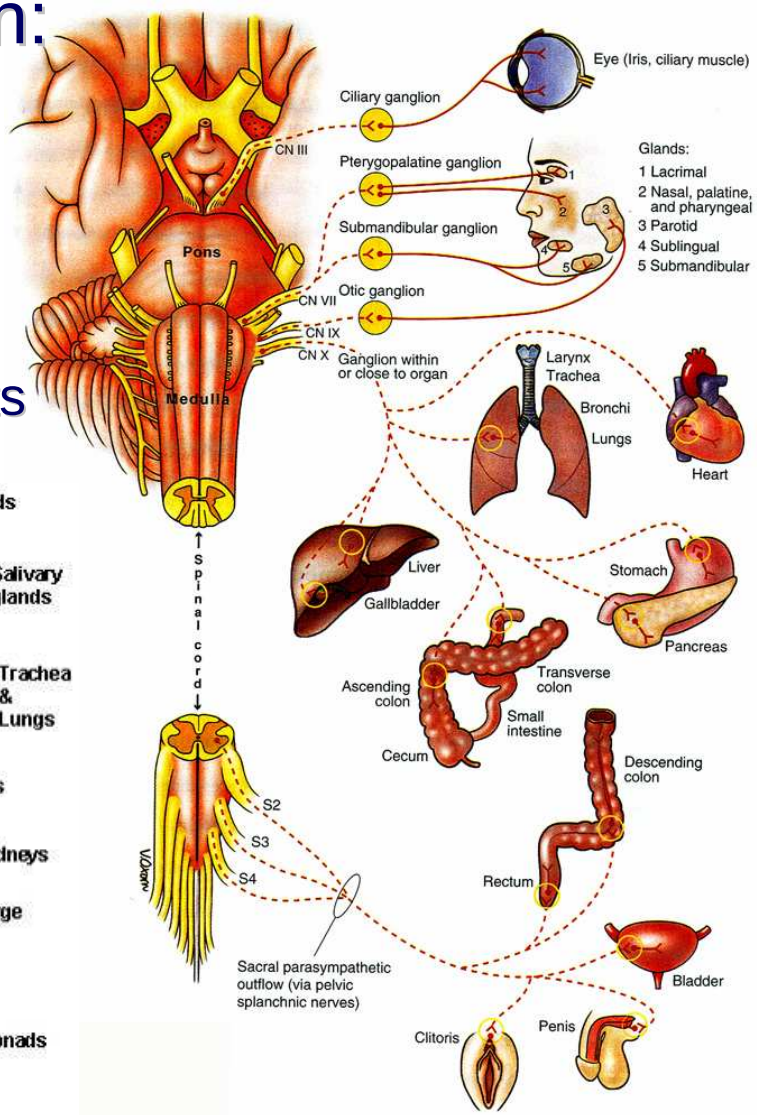
Parasympathetic nervous system

- craniosacral division:
  - ✓ cranial region:
    - ➢ cranial nerves III, VII, IX, X
  - ✓ sacral region:
    - ➢ spinal cord segments S2-S4

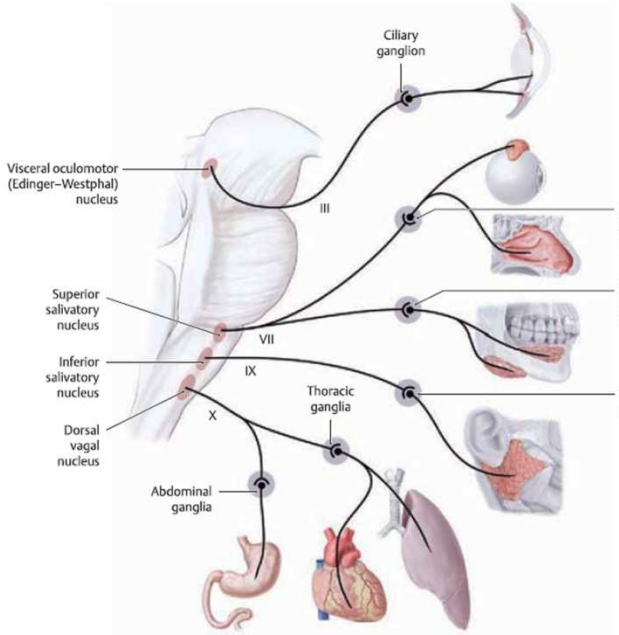


General plan of the parasympathetic system. Ganglionic neurons and postganglionic fibers are shown in *red*. CG, ciliary ganglion; HG, heart ganglia; IG, intramural ganglia; MG, myenteric ganglia; OG, optic ganglion; PtG, pterygopalatine ganglion; SG, submandibular ganglion.

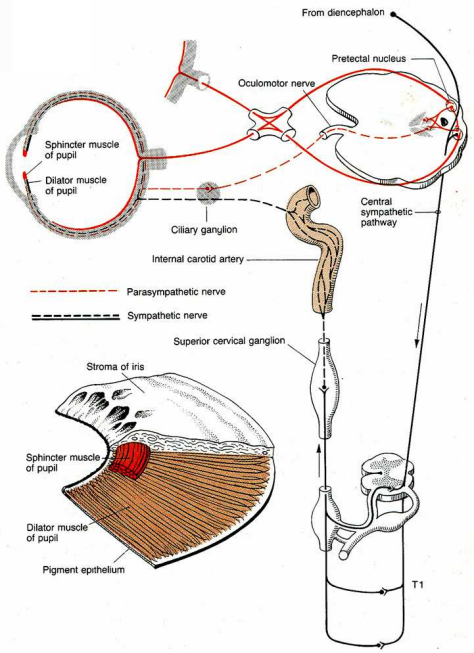


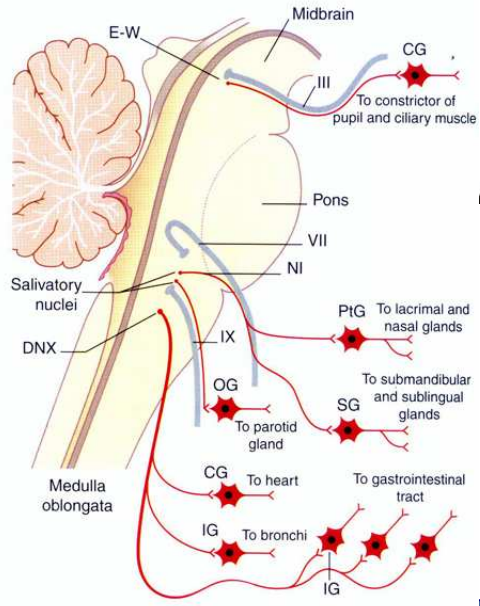


Cranial division



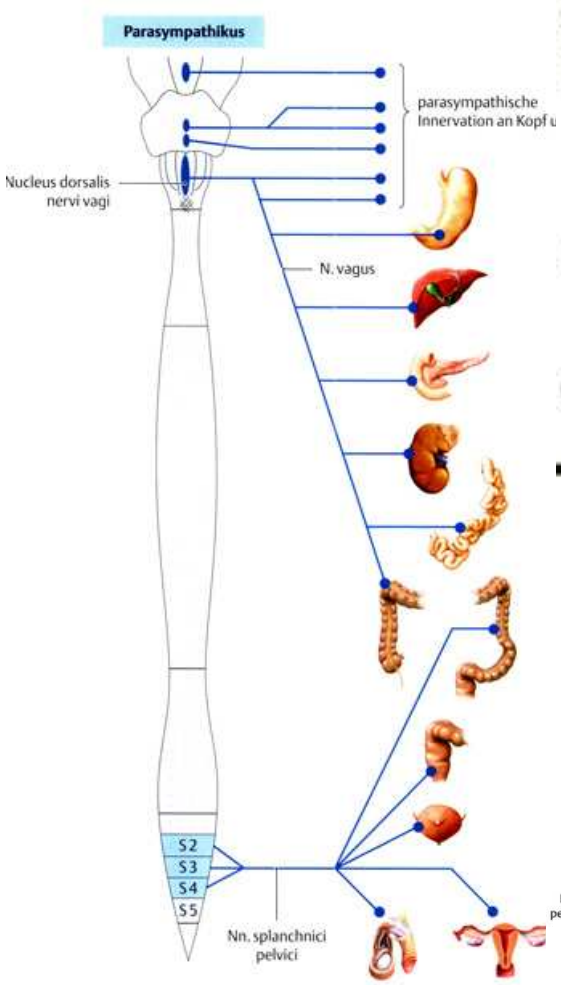
Cranial Nerve	Site of Nucleus	Preganglionic Nucleus	Postganglionic Nucleus	Effector/Function
III	Midbrain	Edinger-Westphal nucleus	Ciliary ganglion	Pupilloconstrictor muscle of iris
				Ciliary muscle
VII	Pons	Superior salivatory nucleus	Submandibular ganglion	Sublingual and submandibular salivary glands
			Pterygopalatine ganglion	Tear glands and glands of the nasal mucosa
IX	Medulla oblongata	Inferior salivatory nucleus	Otic ganglion	Parotid gland
X	Medulla oblongata	Dorsal motor nucleus of the vagu	Cardiac ganglion	S-A and A-V nodes
			Plexuses	Wall of pulmonary tree
				Smooth muscles and glands of gastrointestinal tract to the splenic flexure of the colon
				Kidney



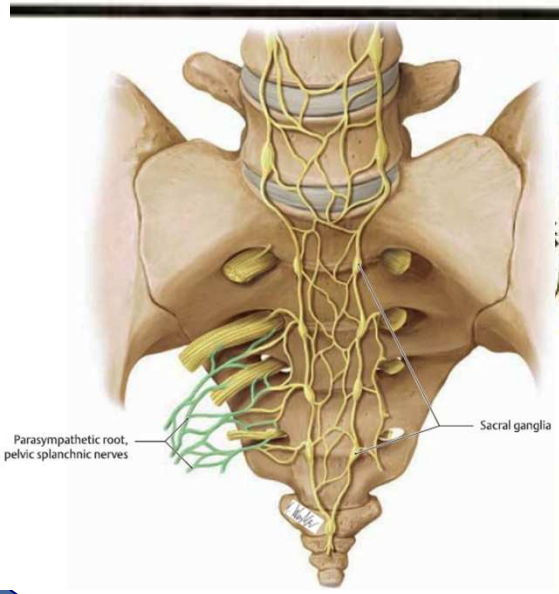


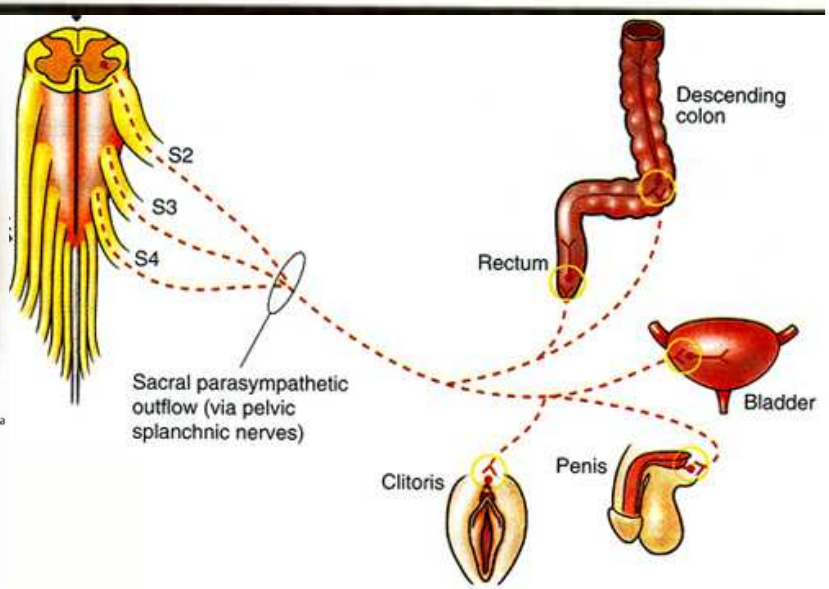
Cranial parasympathetic system. DNX, dorsal nucleus of vagus; E–W, Edinger–Westphal nucleus.

Sacral division



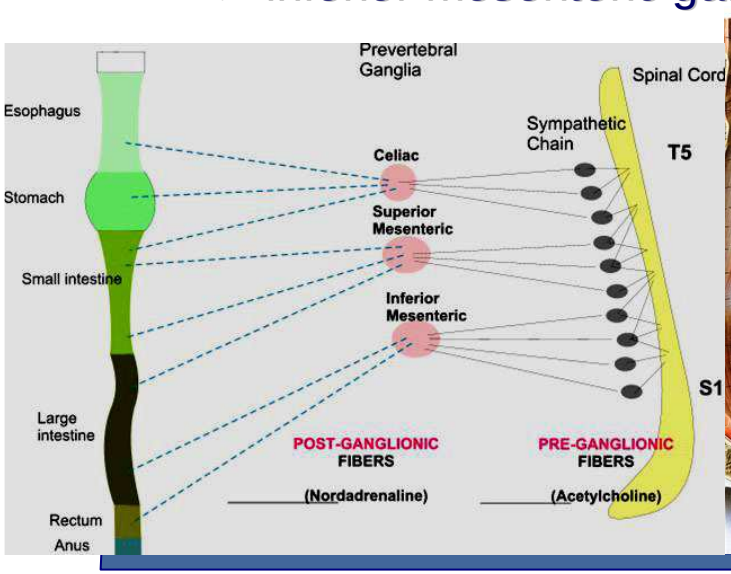
Organ	Preganglionic Neuron Level	Postganglionic Neuron Site	Effect of Stimulation
Distal colon	S2–S4	Intramural ganglion	Enhanced peristalsis
		Hypogastric plexus	Secretion
			Defecation
			Inhibition of anal sphincter
Urinary bladder	S2–S4	Intramural ganglion (vesical plexus)	Contraction of bladder wall
		Hypogastric plexus	Inhibition of urethral sphincter
Genitals	S2–S4	Hypogastric plexus (pelvic plexus)	Vasodilation, penile/clitoral erection

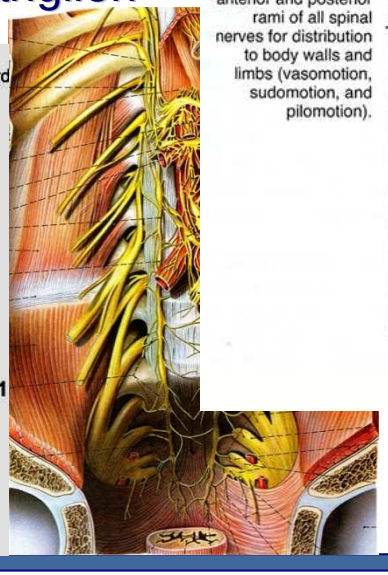


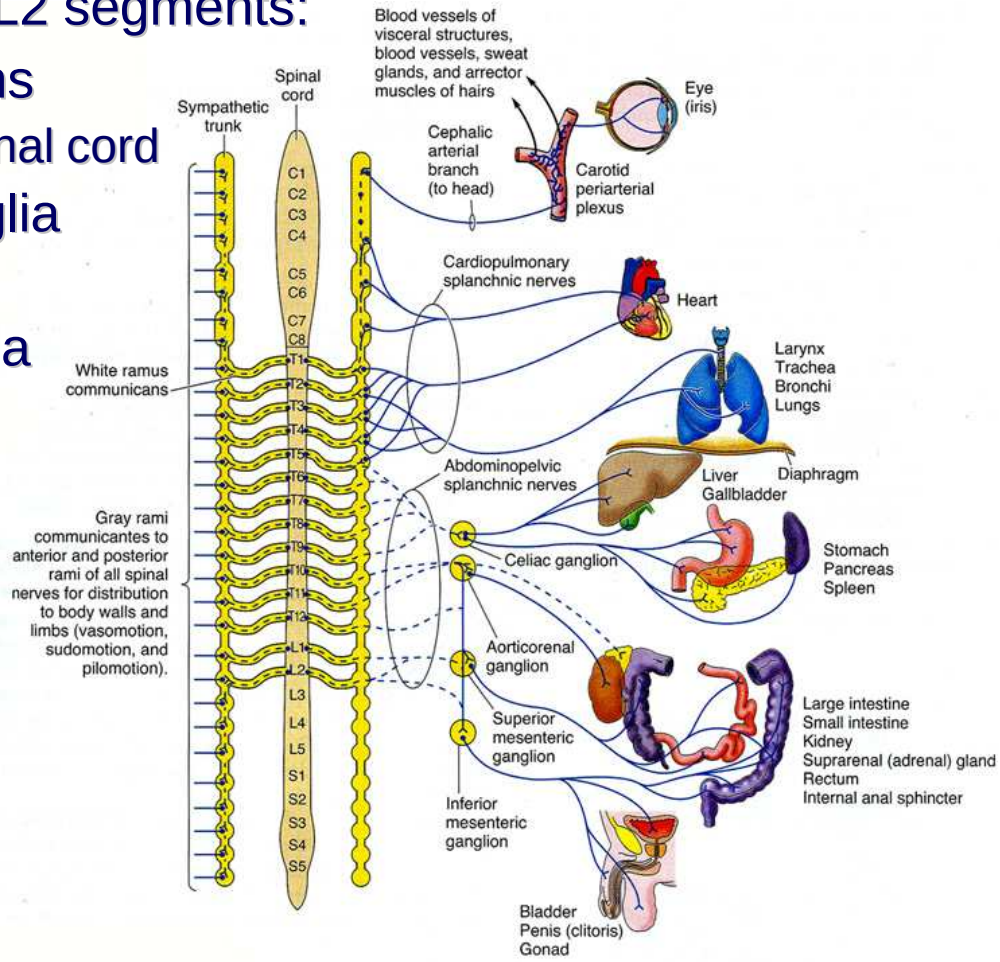


Sympathetic nervous system

- thoracolumbar division – Th1-L2 segments:
  - ✓ preganglionic sympathetic axons
    - ➢ intermediolateral column of spinal cord
  - ✓ paravertebral sympathetic ganglia
    - ➢ sympathetic chain (trunk)
  - ✓ prevertebral sympathetic ganglia
    - ➢ celiac ganglion
    - ➢ superior mesenteric ganglion
    - ➢ inferior mesenteric ganglion

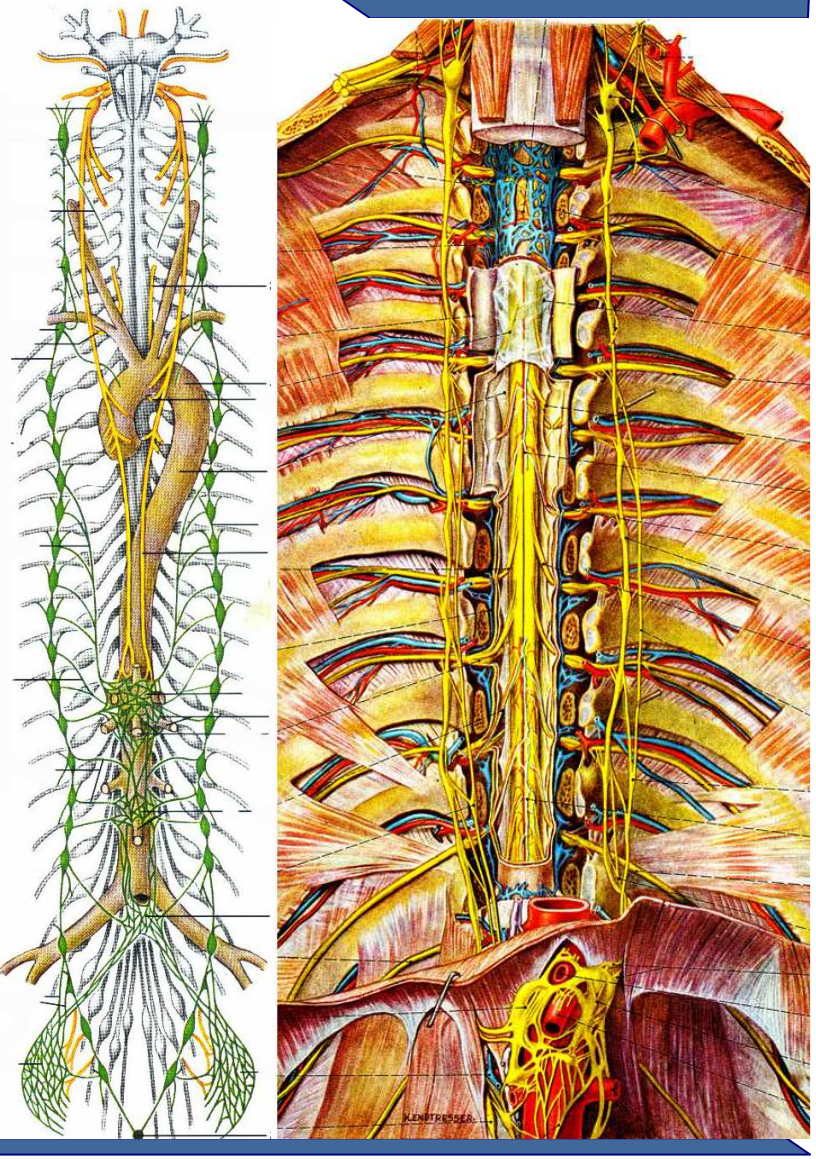






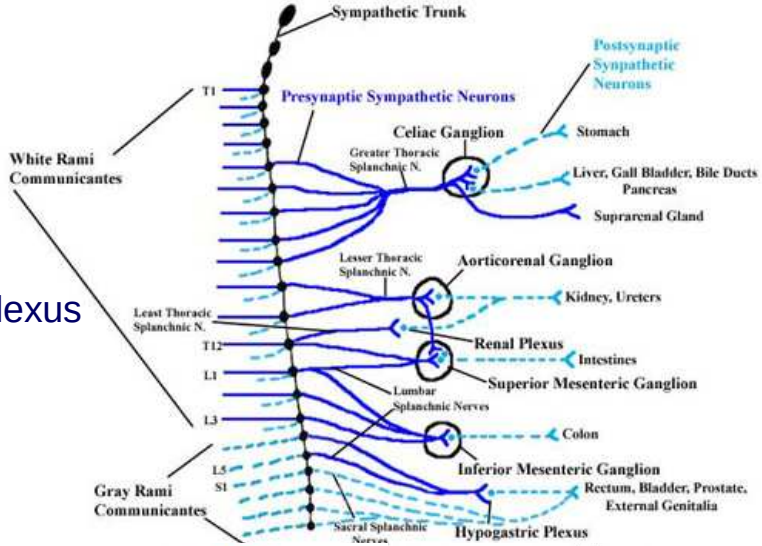
Sympathetic trunk

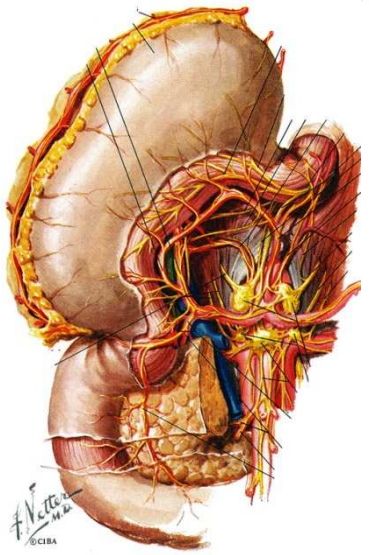
- two symmetrical ganglionated cords:
  - ✓ cervical part – 3 ganglia:
    - ➢ superior cervical ganglion – 2.5-3 cm
      - jugular nerve
      - laryngopharyngeal and superior cardiac branches
      - internal and external carotid branches
    - ➢ middle cervical ganglion (60%) – 0.7-0.8 cm
      - thyroid and middle cardiac branches
    - ➢ inferior cervical ganglion ⇨ in 75%
      cervicothoracic (stellate) ganglion – up to 2.8 cm
      - inferior cardiac branch
  - ✓ thoracic part – 11-12 segmentally arranged ganglia
    - ➢ greater splanchnic nerve – ganglion VI-IX
    - ➢ lesser splanchnic nerve – ganglion X-XI
    - ➢ lowest (renal) splanchnic nerve – ganglion XII
  - ✓ lumbar part – 3-4 segmentally arranged ganglia
    - ➢ 4 lumbar splanchnic nerves
  - ✓ sacral (pelvic) part – 4-5 segmentally arranged ganglia
    - ➢ sacral splanchnic nerves
  - ✓ terminal *ganglion impar* – anterior to the coccyx

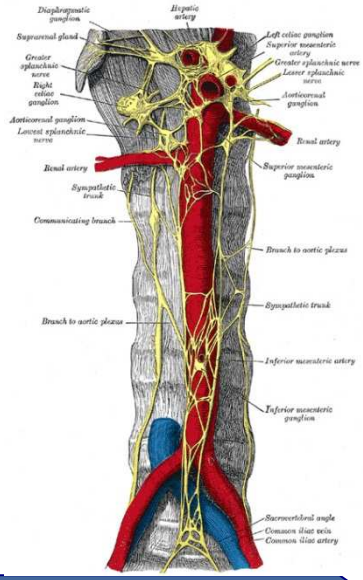


Prevertebral sympathetic ganglia

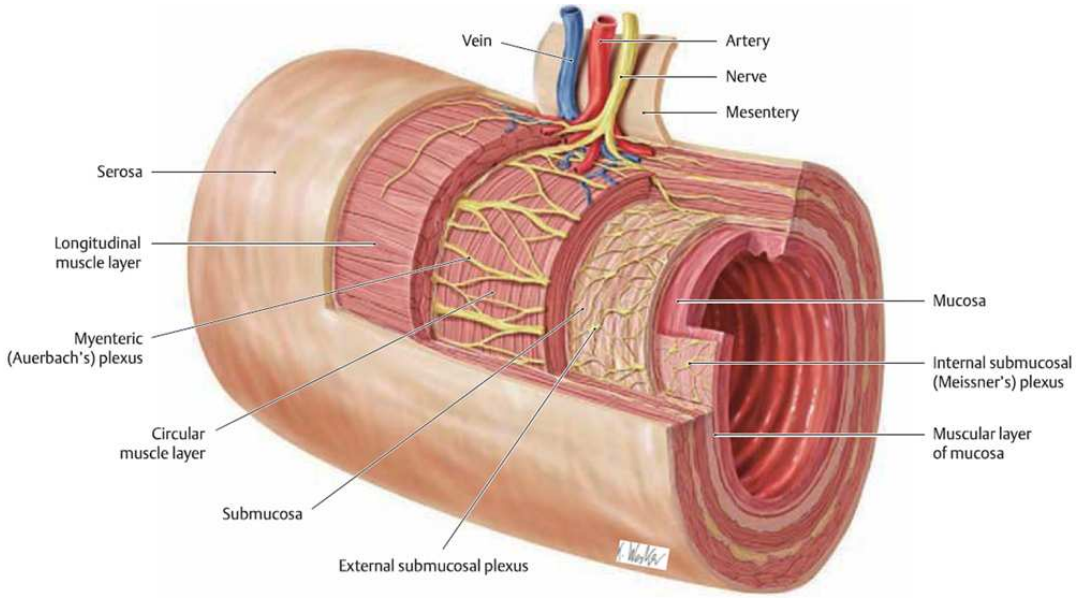
- **celiac ganglion** (**semilunar** or **solar ganglia**):
  - ✓ largest ganglion in the ANS
  - ✓ postganglionic sympathetic neurons
  - ✓ paired, with variable position:
    - ➢ upper part joined with greater splanchnic nerve
    - ➢ lower part receives lesser splanchnic nerve ⇨ renal plexus
- **aorticorenal ganglion**
  - ✓ lower part of celiac ganglion ⇨ kidney, ureters
- **phrenic ganglion**
  - ✓ small ganglion on the diaphragm
  - ✓ located at the junction of the right phrenic nerve
- **superior mesenteric ganglion**
  - ✓ close to the origin of the superior mesenteric artery
  - ✓ unpaired, innervates part of the large intestine
- **inferior mesenteric ganglion**
  - ✓ several small bodies
  - ✓ close to the origin of the inferior mesenteric artery
  - ✓ innervate part of the large intestine





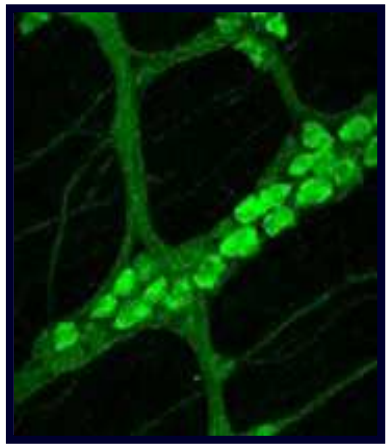


Enteric nervous system



- embedded in the walls of the:
  - ✓ esophagus
  - ✓ stomach
  - ✓ small intestine
  - ✓ colon
- triggered to act when the walls of the hollow organs are stretched by food

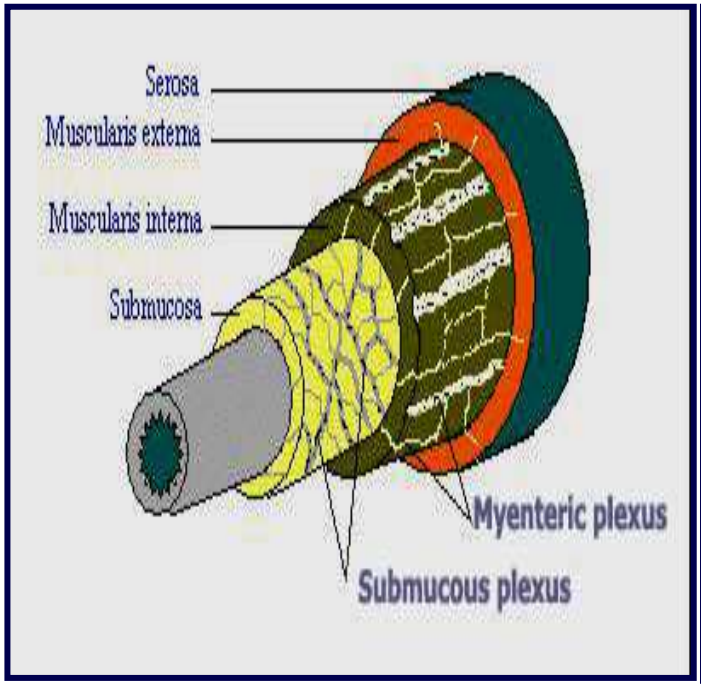
- This local nervous system, referred to as intrinsic or **enteric nervous system** (ENS), functions *independently* of the CNS and is influenced by the ANS in a limited way.
- It controls the motility, exocrine and endocrine secretions, local blood flow, and also modulates immune and inflammatory processes of GI tract.

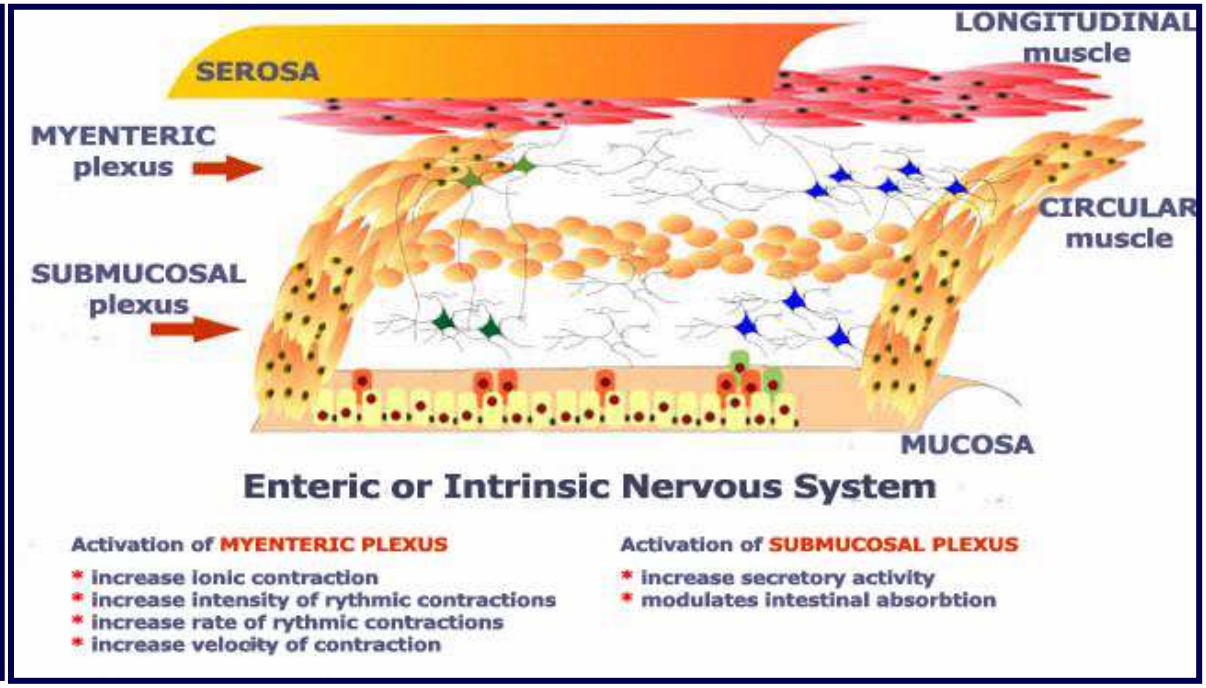


NB: neither sympathetic nor parasympathetic!

Enteric nervous system

- **The myenteric plexus (of *Auerbach*)** primarily controls digestive tract motility [*strength & frequency*]

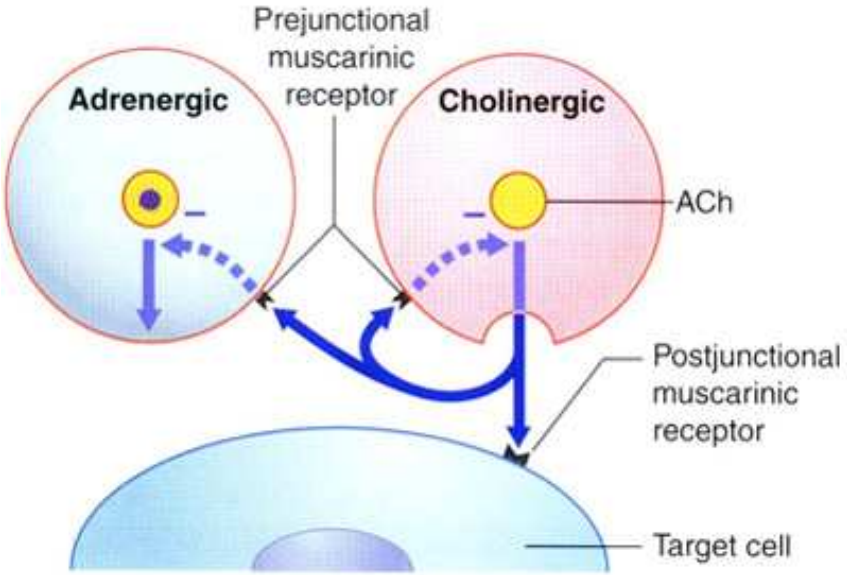


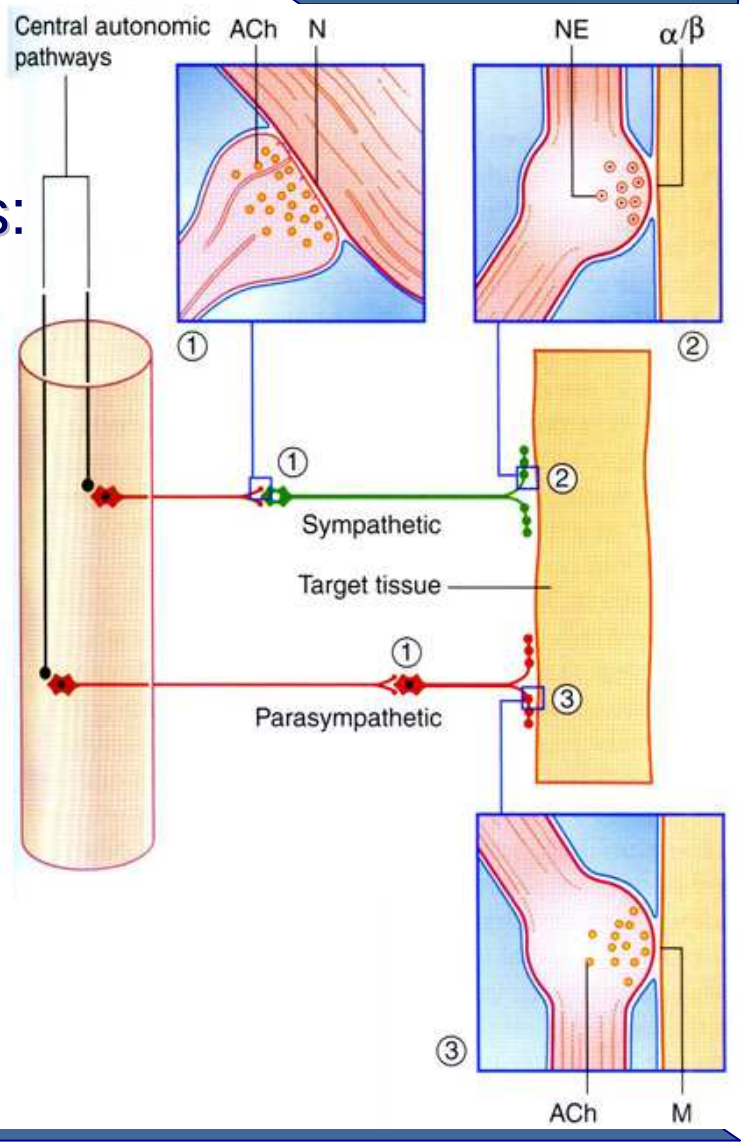


- **The submucous plexus (of *Meissner*)** regulates mucosal movements and epithelial cell function [*mucosal gland secretion*]
  - ✓ internal submucosal plexus (the true plexus of *Meissner*)
  - ✓ external submucosal plexus (the plexus of *Schabadasch*)

Autonomic transmitters and receptors

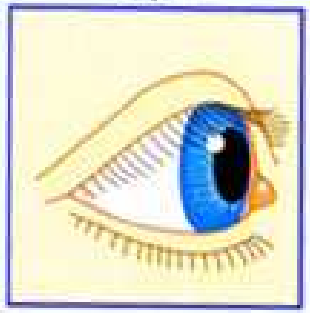
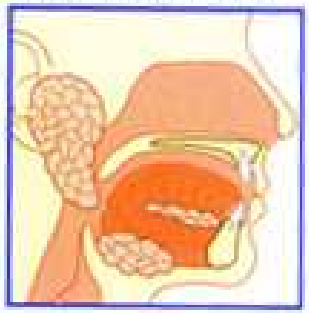
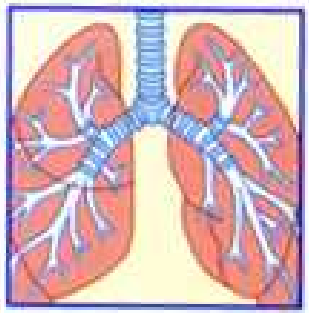
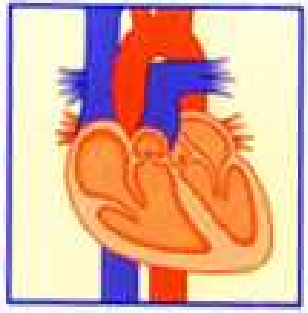
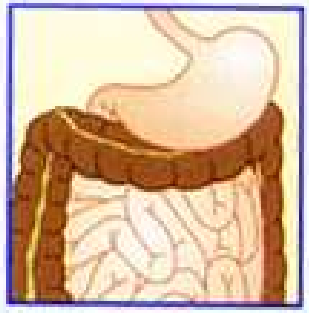
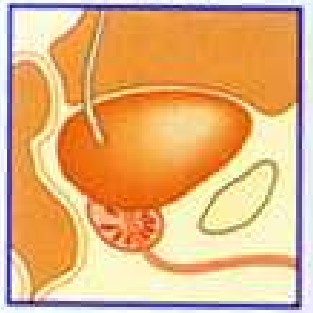
- **Cholinergic transmission:**
  - ✓ release acetylcholine (ACh)
  - ✓ two types of acetylcholine receptors:
    - ➢ nicotinic receptors (*nAChR*, also known as “ionotropic" receptors)
    - ➢ muscarinic receptors (*mAChR*, also known as “metabotropic" receptors)





Cholinergic drug effects

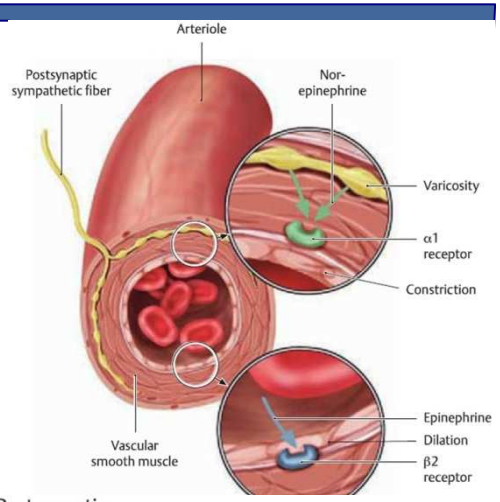
Cholinergic drugs

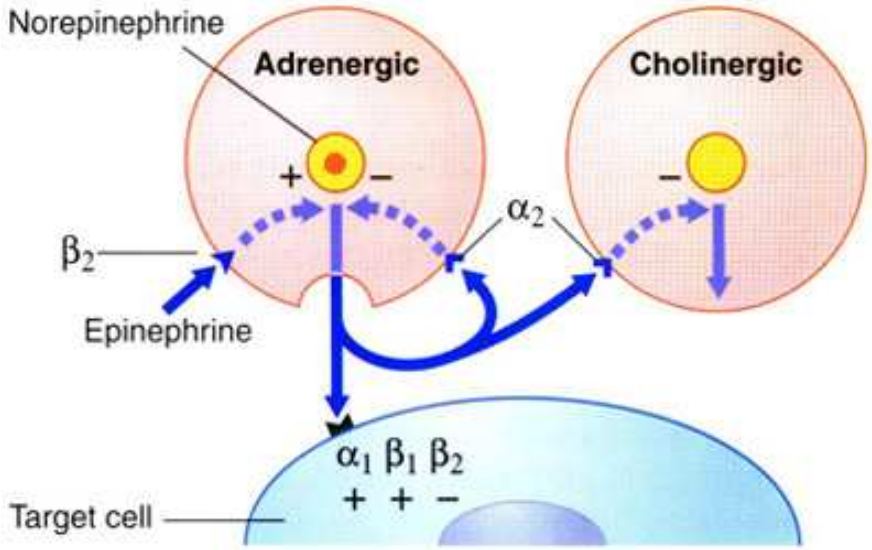
Eye	Salivary glands	Bronchi	Heart	GI tract	Bladder
Pupillary constriction Near vision	Salivation	Constriction Secretion	Slowing	Gastric secretion increased Colic Diarrhea	Voiding of urine
					
Pupillary dilatation Far vision	Dry mouth	Relaxation Sticky dry	Acceleration	Gastric secretion reduced Constipation	Retention of urine

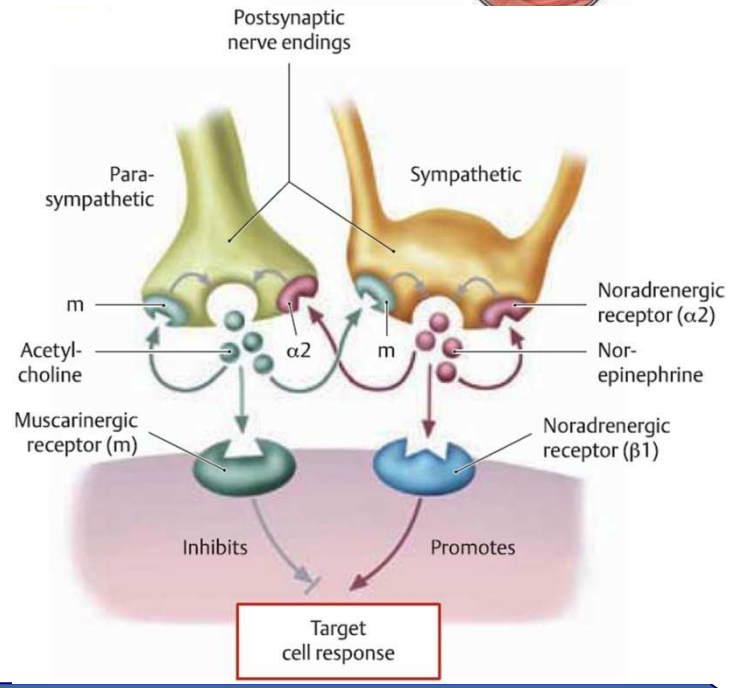
Anticholinergic drugs

Autonomic transmitters and receptors

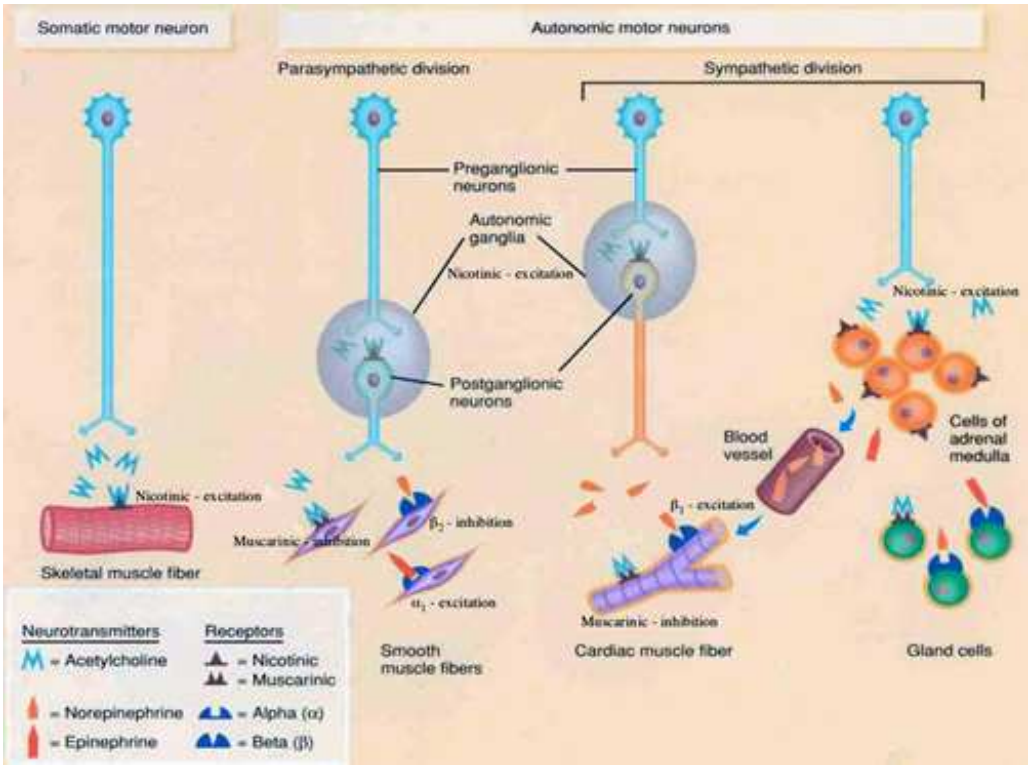
- **Adrenergic transmission:**
  - ✓ release noradrenaline (norepinephrine)
  - ✓ two types of adrenergic receptors:
    - ➢ α-receptors ⇨ excitatory responses
      - pharmacologically α_1- and α_2-receptors
    - ➢ β-receptors ⇨ cause inhibition
      - pharmacologically β_1- and β_2-receptors

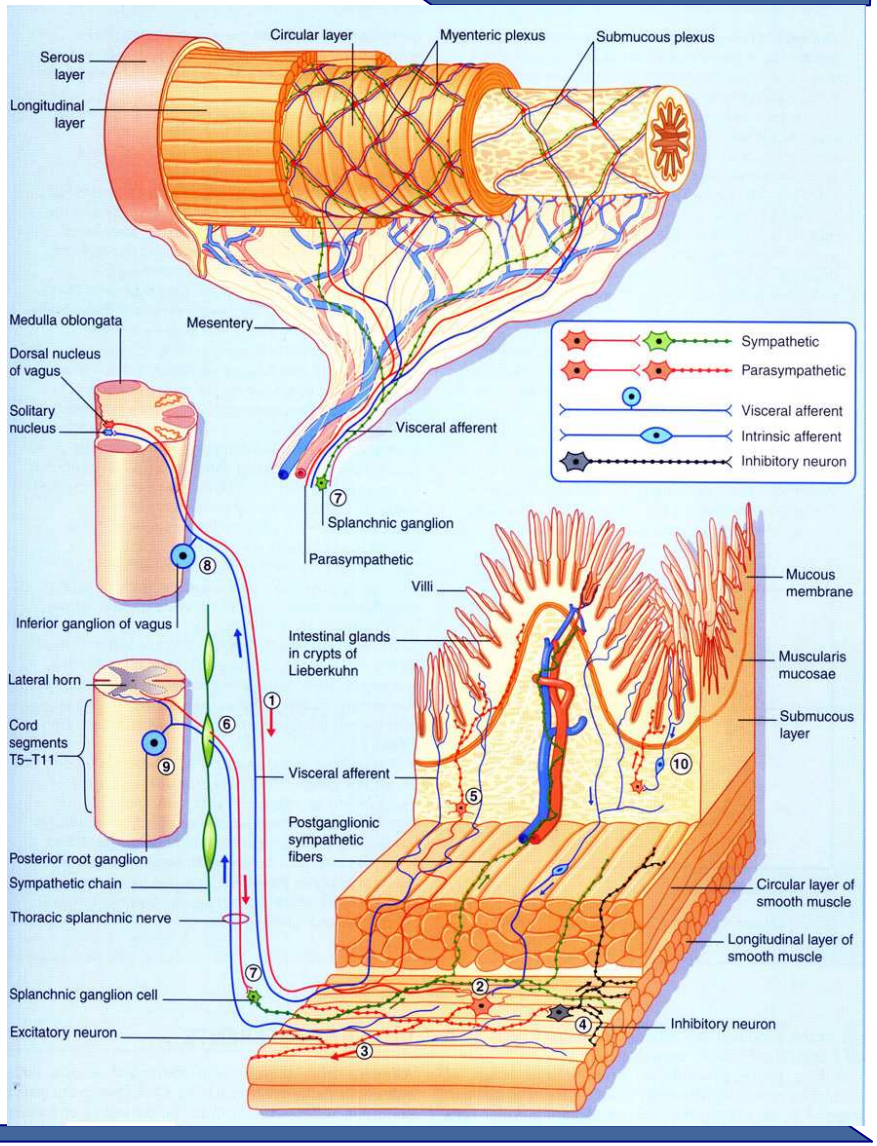






Adrenergic nerve endings

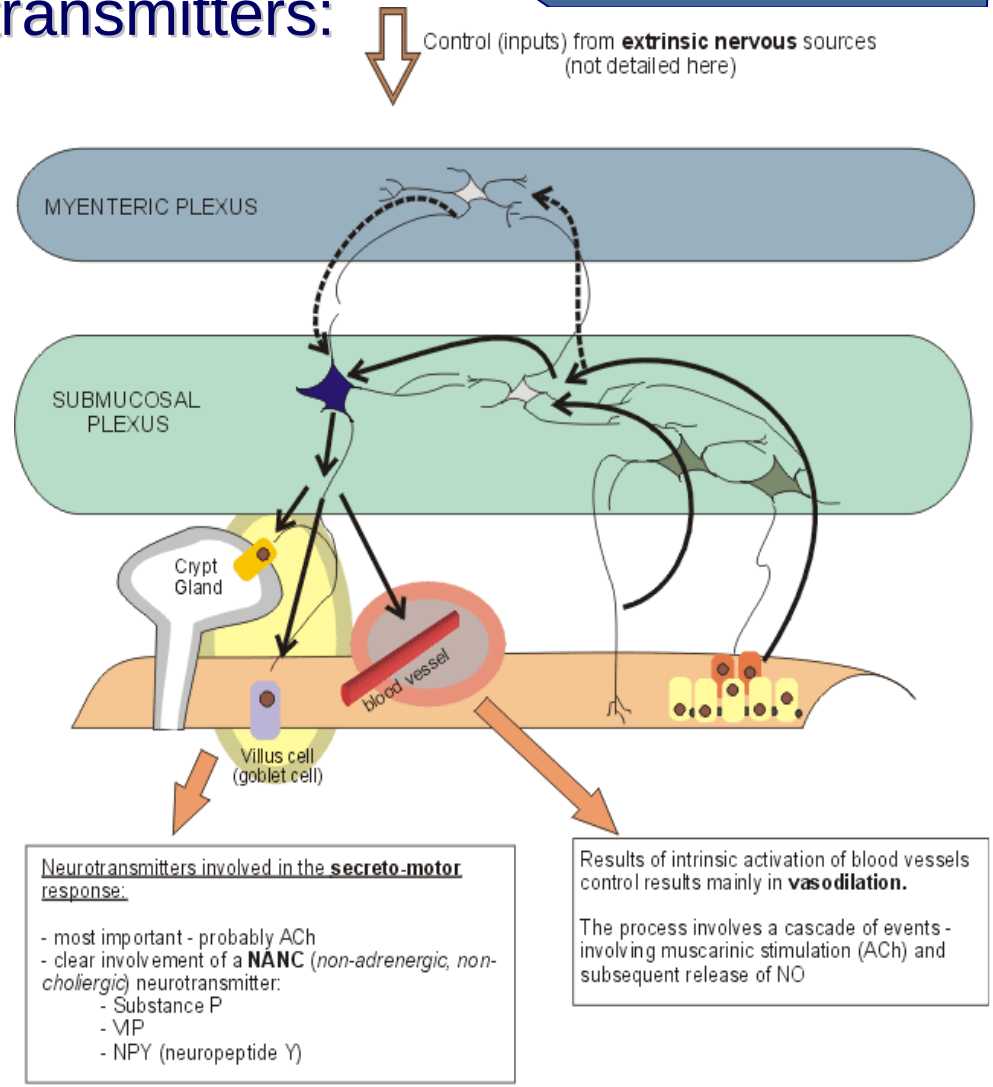




Enteric neurotransmitters

spectrum of neurotransmitters:

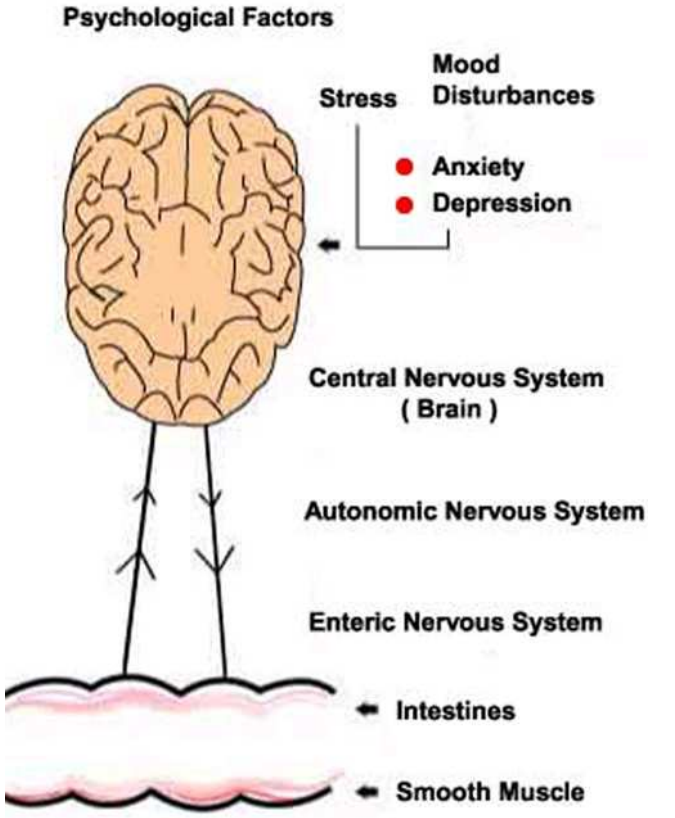
- amines
  - ✓ acetylcholine – excitatory
  - ✓ noradrenaline – inhibitory (norepinephrine)
  - ✓ adrenaline (epinephrine)
  - ✓ serotonin (5-Hydroxytriptamine)
- amino acids
  - ✓ GABA
- purines
  - ✓ ATP
- gaseous messengers
  - ✓ nitric oxide
  - ✓ carbon monoxide
- NANC neurotransmitters



NB: enteric transmitters = CNS neurotransmitters

Is really there a brain in the gut?

- *here are some reasons...*



"The fate of a nation has often depended on food or bad digestion of a prime minister"

Voltaire

Is really there a brain in the gut?

Two brains are better than one, especially if you are hungry!

Thank you…