

The sympathetic and the parasympathetic nervous system



Zsuzsanna Tóth, PhD

Institute of Anatomy, Histology and Embryology

Semmelweis University

The role of the autonomic nervous system

Claude Bernard

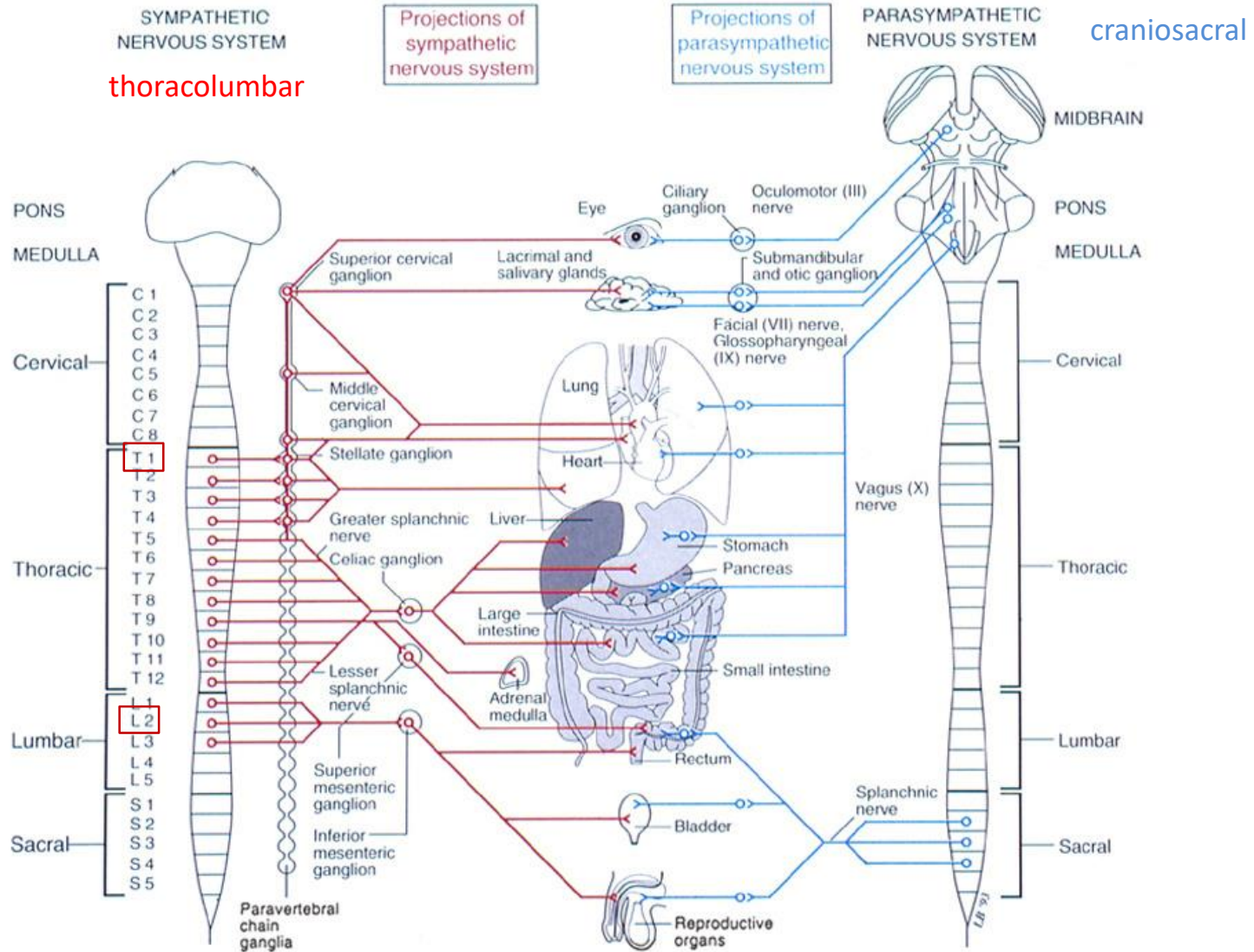
- „milieu intérieur” concept; every organism lives in its internal environment that is constant and independent from the external environment

Walter Bradford Cannon

homeostasis;

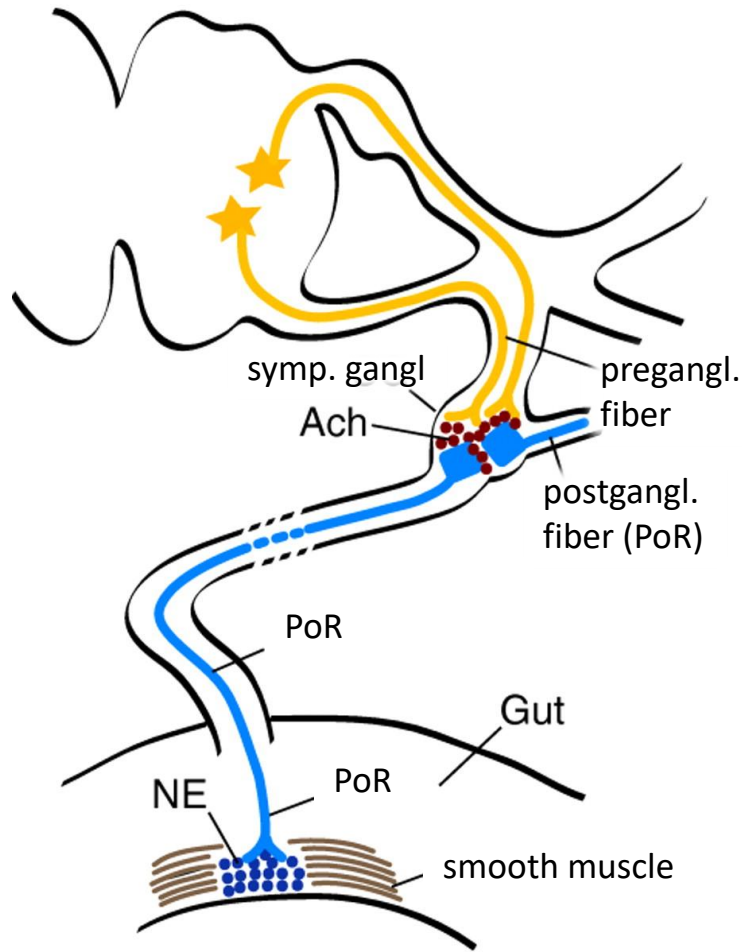
- an extension of the “milieu interieur” concept
- consistence in an open system requires mechanisms that act to maintain that consistency
- steady-state conditions require that any tendency toward change automatically meets with factors that resist that change
- *regulating systems that determine the homeostatic state :*
 - *autonomic nervous system (sympathetic, parasympathetic, enteral)*
 - *endocrine system*

General structure of the autonomic nervous system

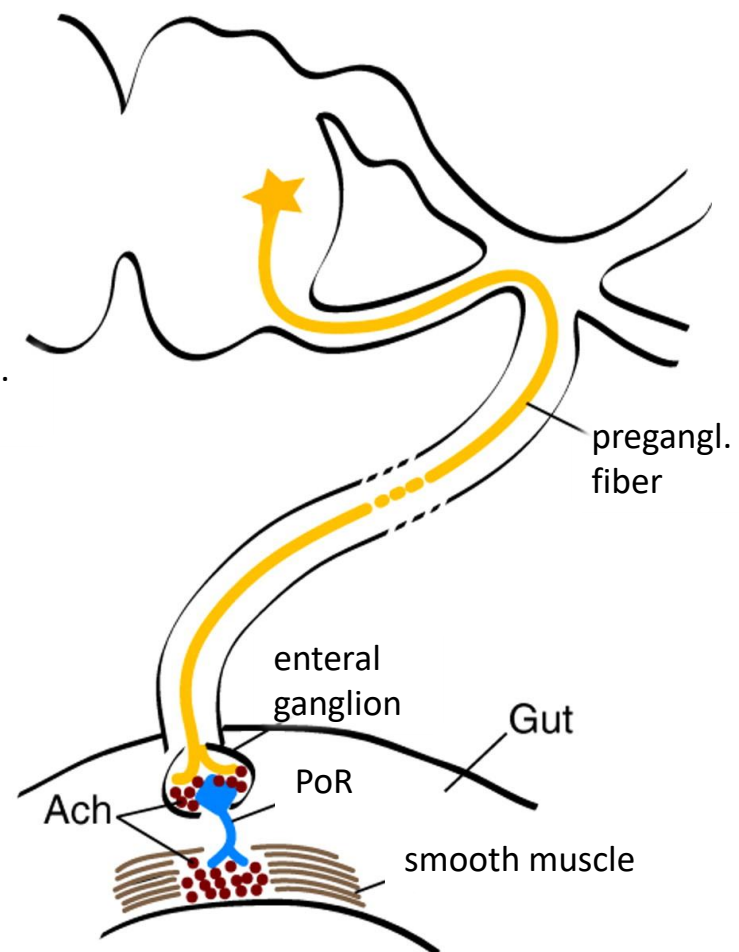


Neurotransmitters

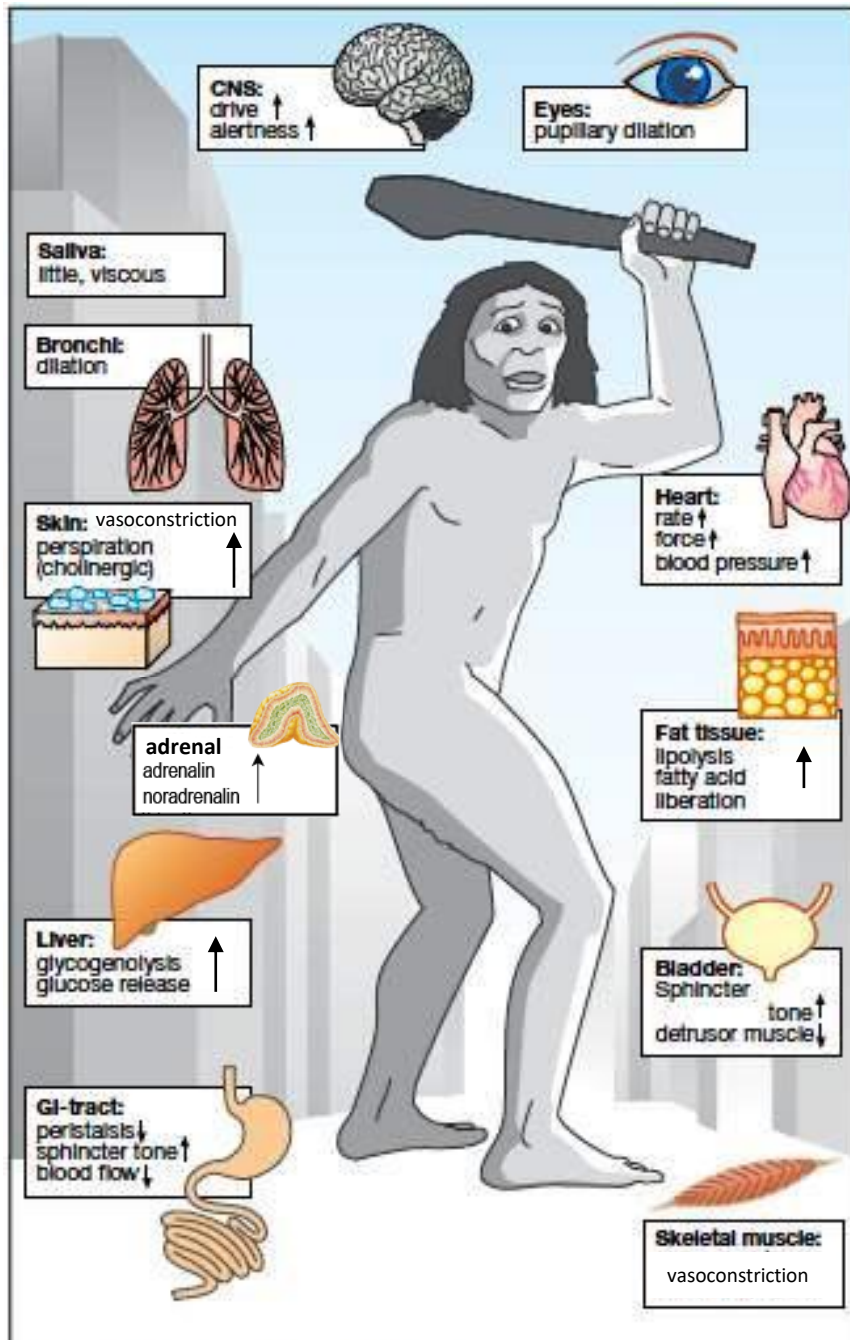
A Sympathetic system



B Parasympathetic system



Kuratani S Development 2009;136:1585-1589



A. Responses to sympathetic activation

Sympathetic activation: Fight or flight reaction

- energy mobilization
- preparation for escape, or fight
- generalized

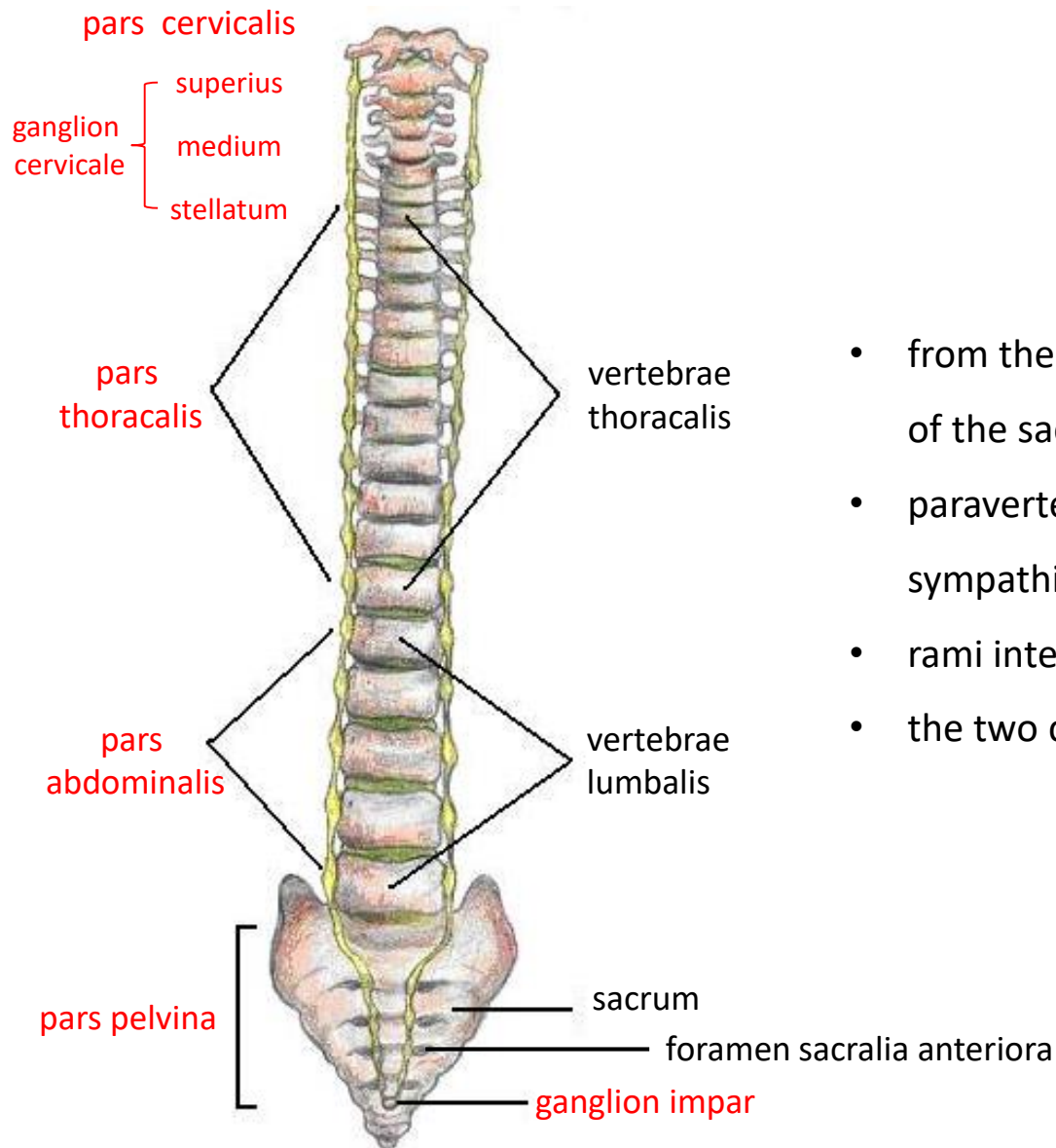
Parasympathetic activation:

- energy saving and restoring
- „rest and digest” system
- more localized

Comparison of Anatomical, Physiologic, and Pharmacologic Characteristics of the Sympathetic and Parasympathetic Parts of the Autonomic Nervous System

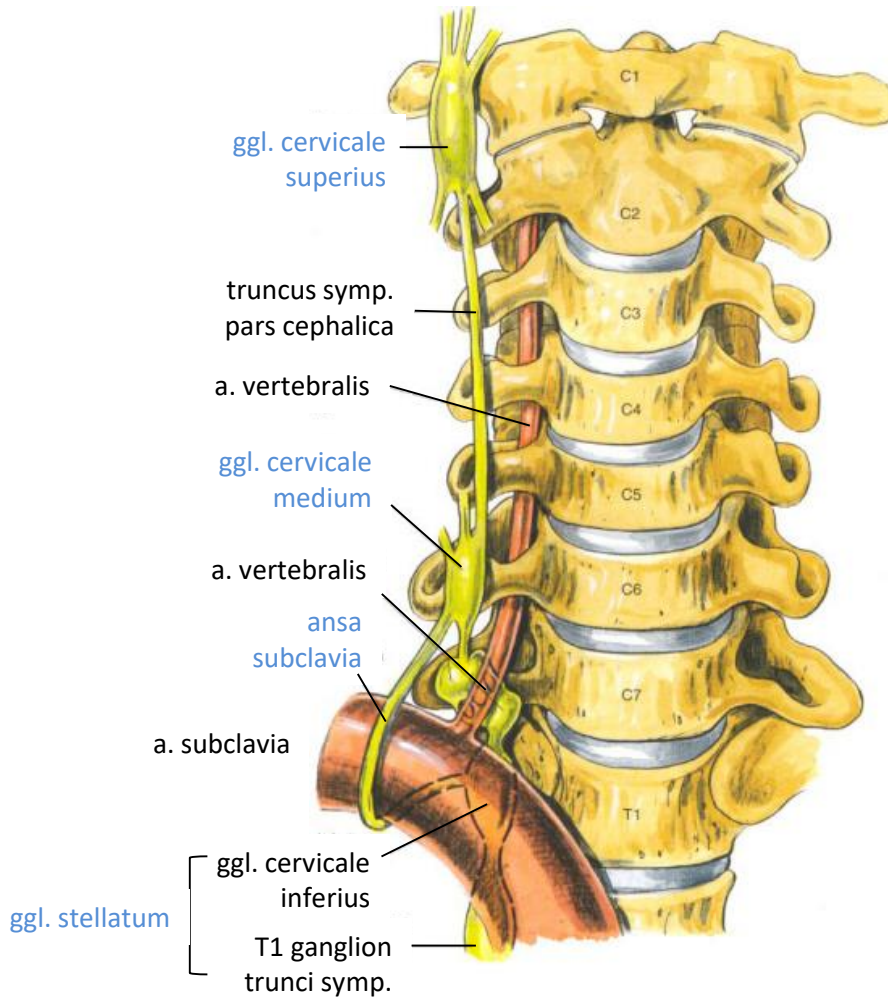
	Sympathetic	Parasympathetic
Action	Prepares body for emergency	Conserves and restores energy
Outflow	T1-L2 (3)	Cranial nerves III, VII, IX, and X; S2-4
Preganglionic fibers	Myelinated	Myelinated
Ganglia	Paravertebral (sympathetic trunks), prevertebral (e.g., celiac, superior mesenteric, inferior mesenteric)	Small ganglia close to viscera (e.g., otic, ciliary) or ganglion cells in plexuses (e.g., cardiac, pulmonary)
Neurotransmitter within ganglia	Acetylcholine	Acetylcholine
Postganglionic fibers	Long, nonmyelinated	Short, nonmyelinated
Characteristic activity	Widespread due to many postganglionic fibers and liberation of epinephrine and norepinephrine from suprarenal medulla	Discrete action with few postganglionic fibers
Neurotransmitter at postganglionic endings	Norepinephrine at most endings and acetylcholine at few endings (sweat glands)	Acetylcholine at all endings
Blocking agents on receptors of effector cells	Alpha-adrenergic receptors-phenoxybenzamine β-adrenergic receptors-propranolol	Atropine, scopolamine
Drugs mimicking autonomic activity	Sympathomimetic drugs Phenylephrine: alpha receptors; Isoproterenol: beta receptors	Parasympathomimetic drugs Pilocarpine Methacholine
Higher control	Hypothalamus	Hypothalamus

Paravertebral ganglia and the sympathetic chains



- from the base of the skull to the caudal end of the sacrum
- paravertebral ganglia (ganglia trunci sympathici)
- rami interganglionares
- the two chains fuses at the ganglion impar

Anatomy of the cervical part of the sympathetic trunk



superior cervical ganglion

- behind the sheath of the carotid, fusiform
- IML T1-3 vegetative motoneurons- preganglionic fibers

middle cervical ganglion

in the fossa scalenotrachealis

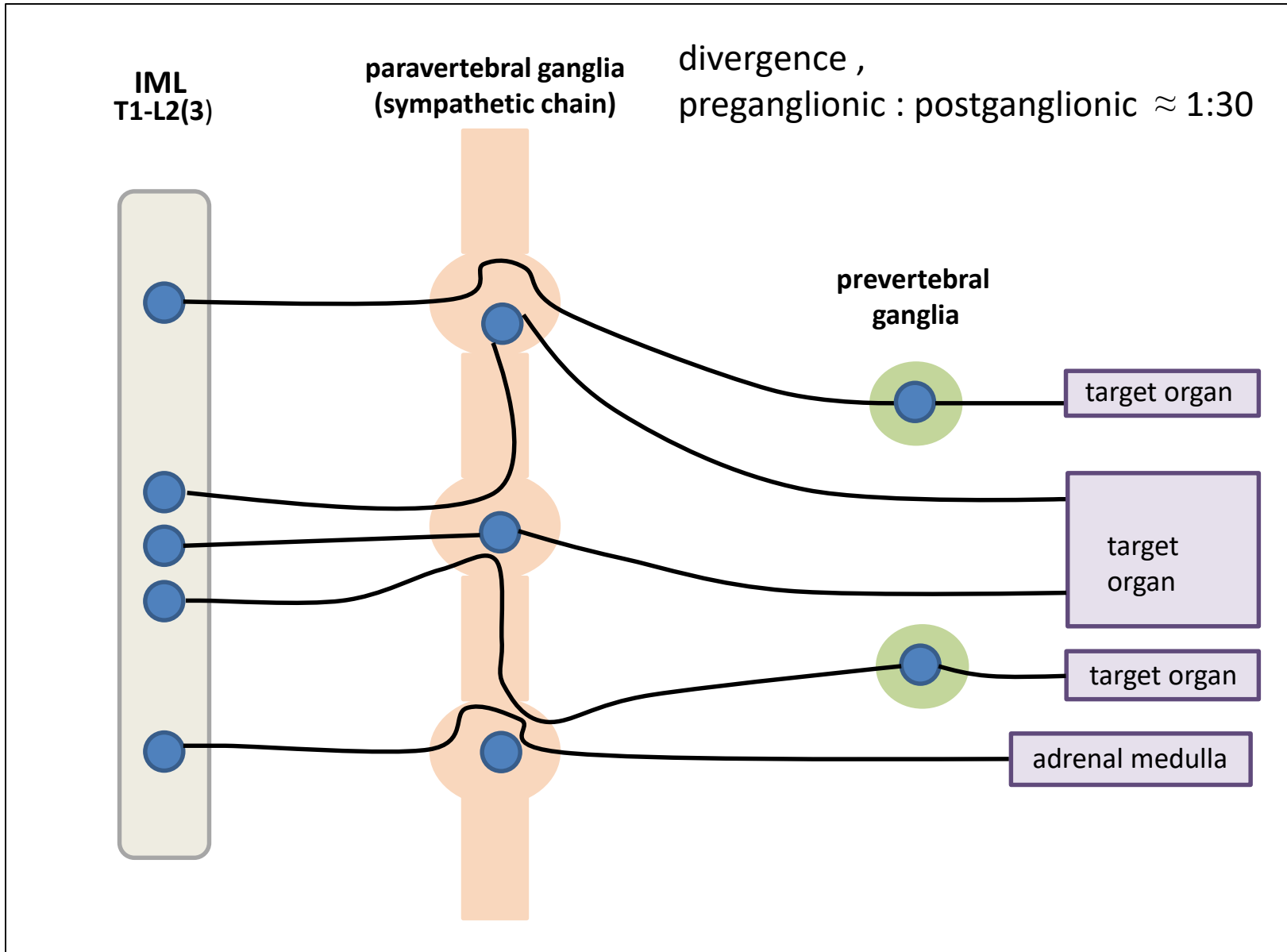
ansa subclavia

- connects the middle cervical and the stellate ganglia
- a loop of the trunk around the subclavian artery

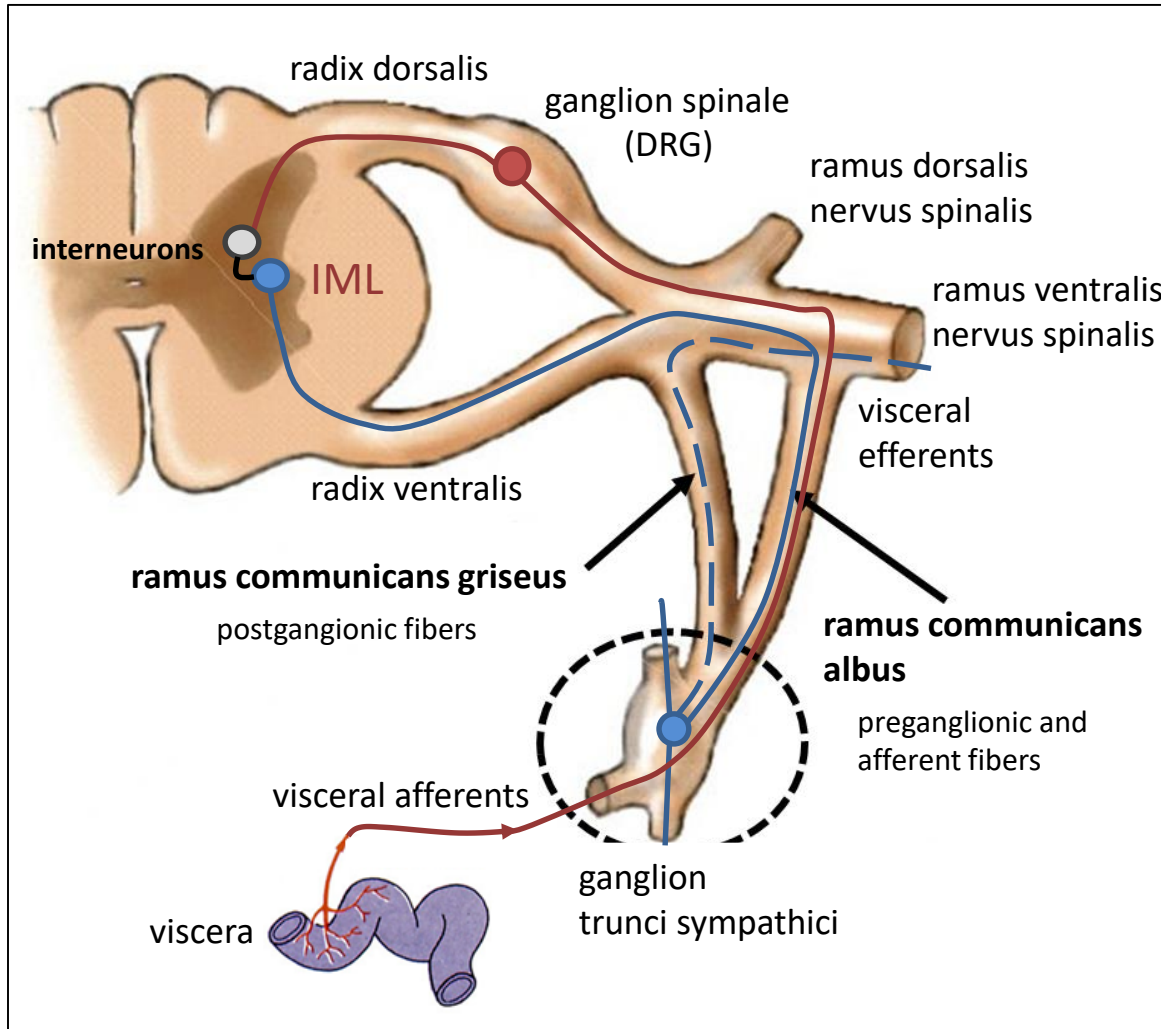
stellate ganglion

- lies superior to the neck of the first rib
- formed by the fusion of the inferior cervical ganglion and the first thoracic ganglion (80%)

Sympathetic efferents



Rami communicantes



white rami communicantes:

- distal
- myelinated,
- preganglionic fibers and visceral afferents
- only at T1-L2 spinal nerves
- run longitudinal within the trunk

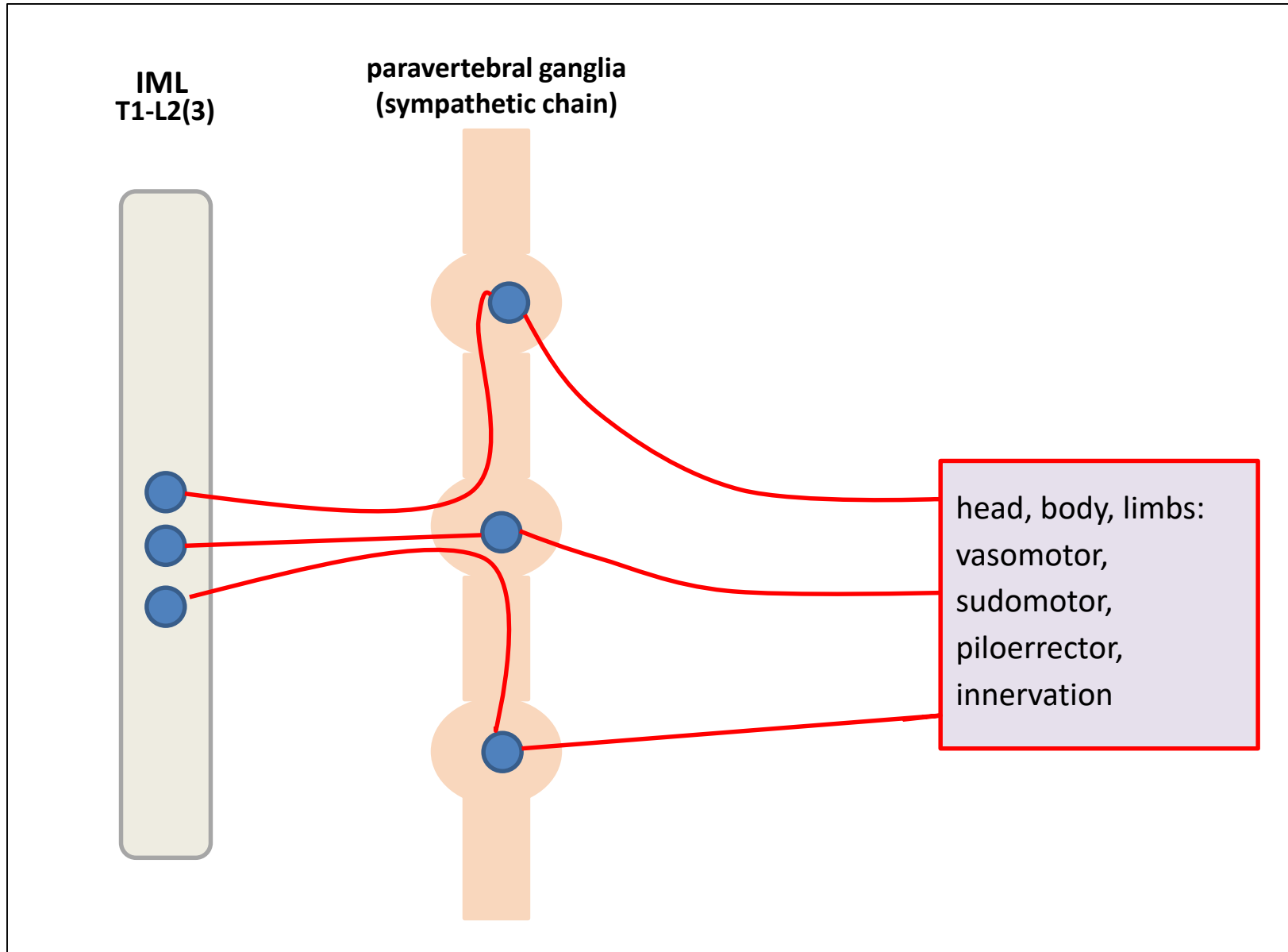
gray rami communicantes:

- proximal
- non-myelinated,
- postganglionic fibers
- each spinal nerves has one

visceral afferents:

- with sympathetic efferents via the r.c. albus,
- with parasympathetic efferents
- terminate in the DRG

Parietal sympathetic efferents



Sympathetic innervation of the skin

pathway:

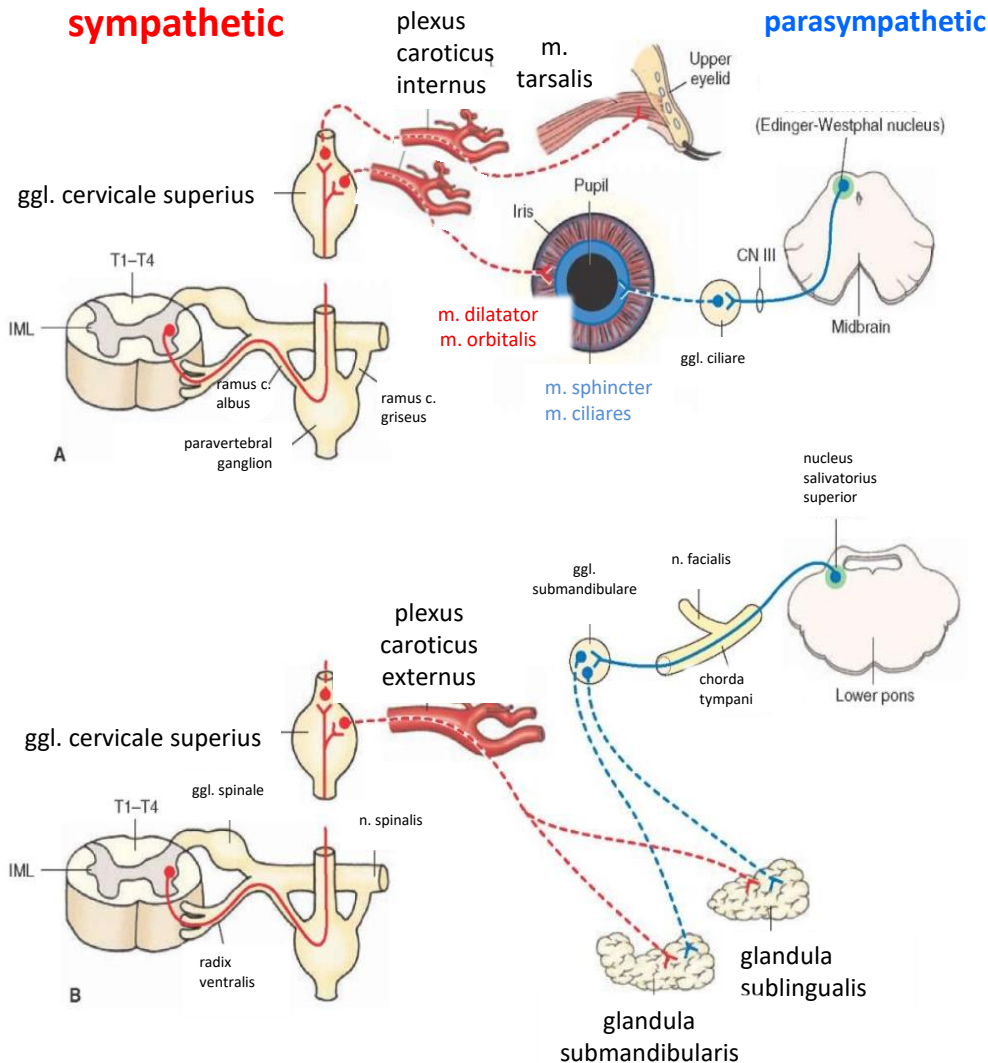
- IML → preganglionic fiber, spinal nerve → white ramus → paravertebral ganglion → postganglionic fiber, grey ramus → spinal nerve → skin

functions:

- vasomotor, sudomotor, piloerector – vasoconstriction, perspiration, goose bumps

intermediolateral cell column (IML)	Paravertebral ganglion	Spinal nerve	Target area
T1-7	ggl. cerv. superius	nn. C1-4 (cervical plexus)	head, neck
	ggl. cerv. medius	nn. C4-7 (plexus brachialis)	upper limbs
	ggl. stellatum	nn. C7-T1 (plexus brachialis)	upper limbs
T1-11	T1-11	nn. T1-11 (nn. intercostales)	body
T8-L2	L1-4	plexus lumbalis, plexus ischiadicus	hips, lower limbs
	S1-4(5)	plexus sacralis	hips, perineum, lower limbs

Superior cervical ganglion I.



Preganglionic fibers

- IML upper thoracic segments (spinociliar center)
- **Relay:** SCG

Postganglionic fibers :

- internal and external carotid plexuses
- jugular plexus

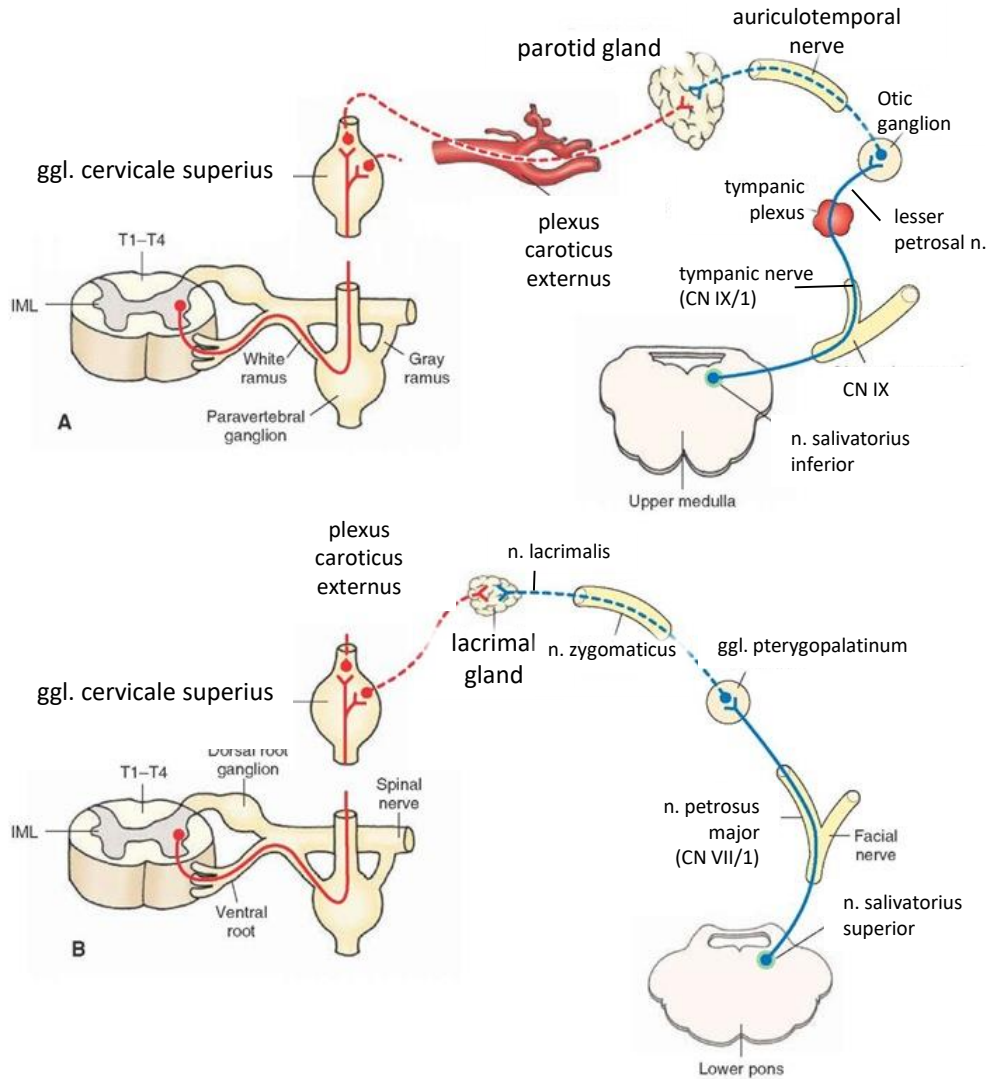
Functions:

- vaso- and sudomotor innervation of the head
- dilatation of the pupil (relaxed state)
- raising the upper eyelid (m. tarsalis,)
- m. orbitalis
- viscous salivary secretions
- vasomotor innervation of the pia mater
- fibers to the heart, pharynx, corpus pineale

Superior cervical ganglion II-parotid and lacrimal glands

sympathetic

parasympathetic



Sympathetic innervation:

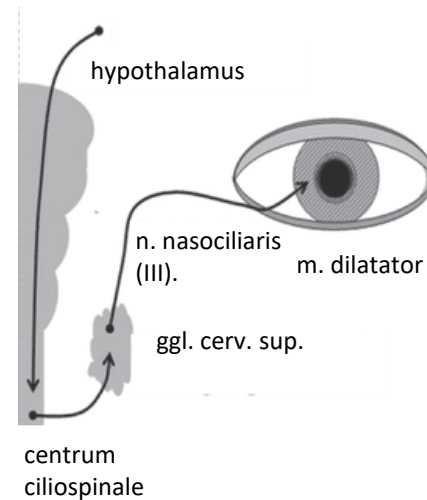
Same pathway as in case of the submandibular and sublingual glands

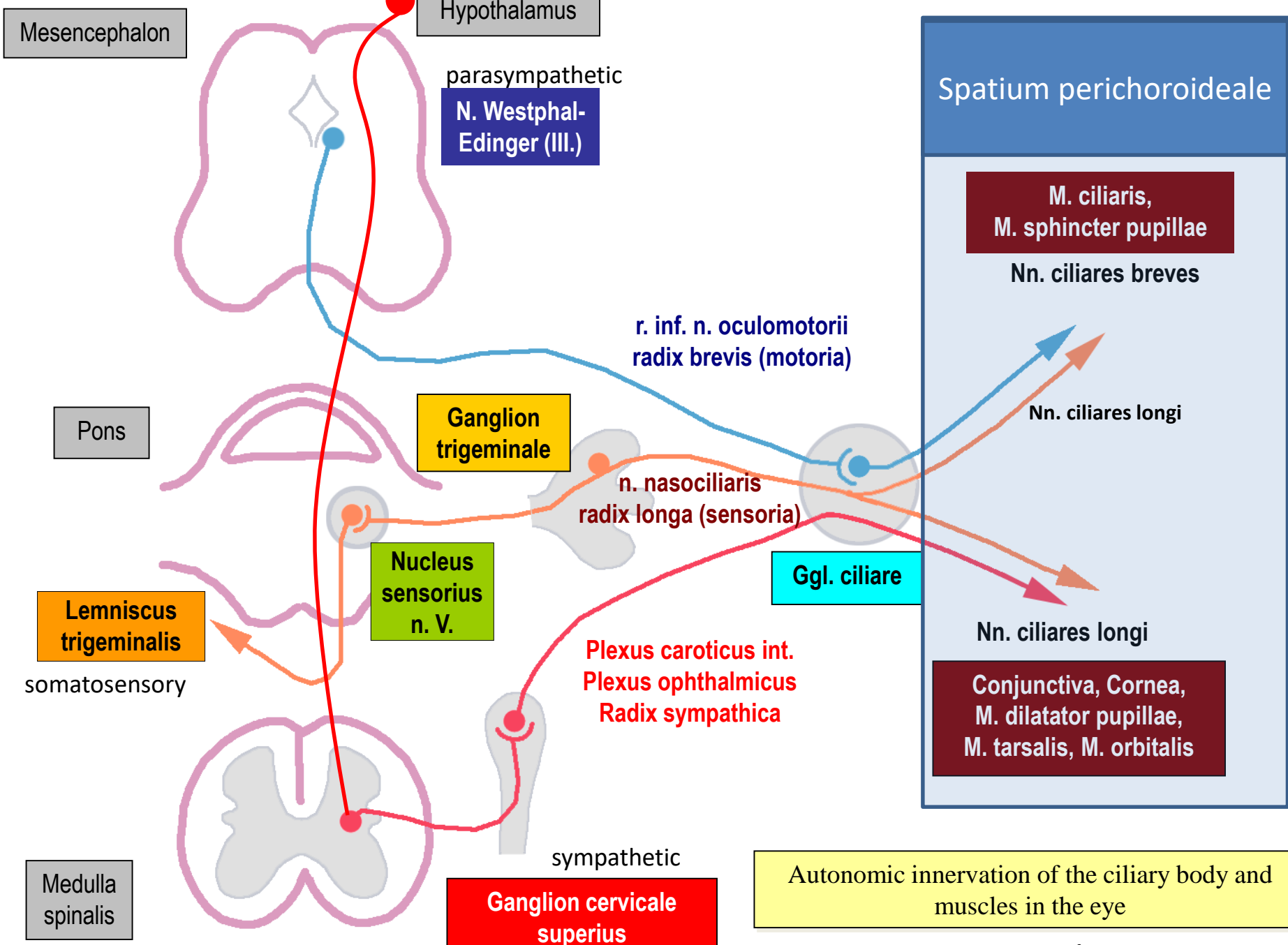
Horner's syndrome



Symptoms:

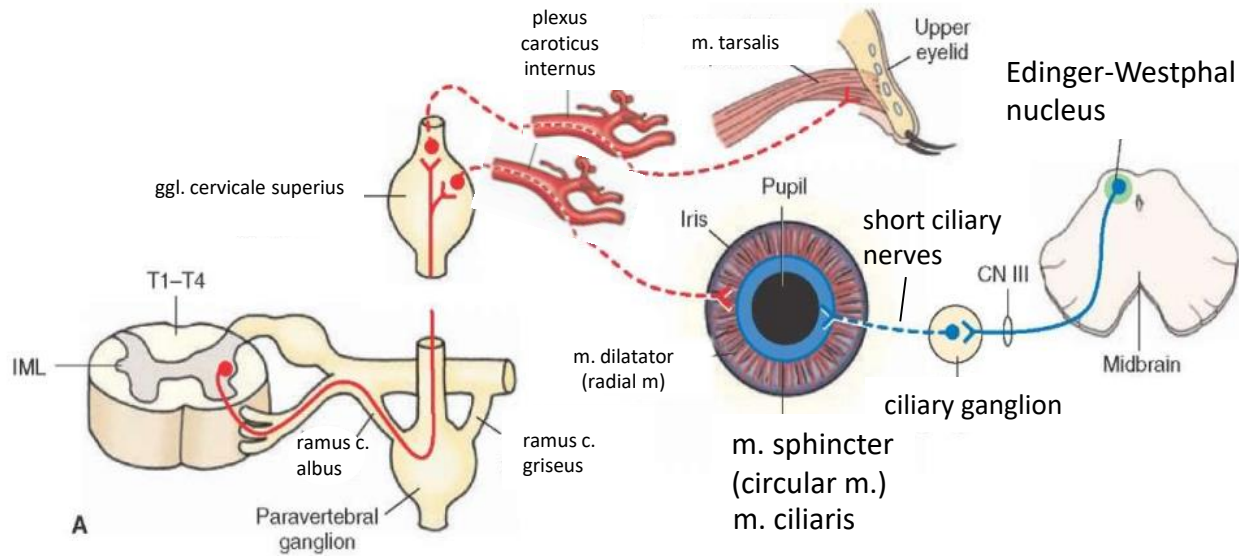
- ptosis (drooping of the upper eyelid),
- miosis (a constricted pupil)
- enophthalmos (sinking of the eyeball in the orbit)
- anhidrosis (decreased sweating over the ipsilateral forehead)
- dilation of arterioles of the skin
- ciliospinal reflex (pupillary-skin reflex) is absent





From prof. Ágoston Szél

Parasympathetic innervation of the pupil



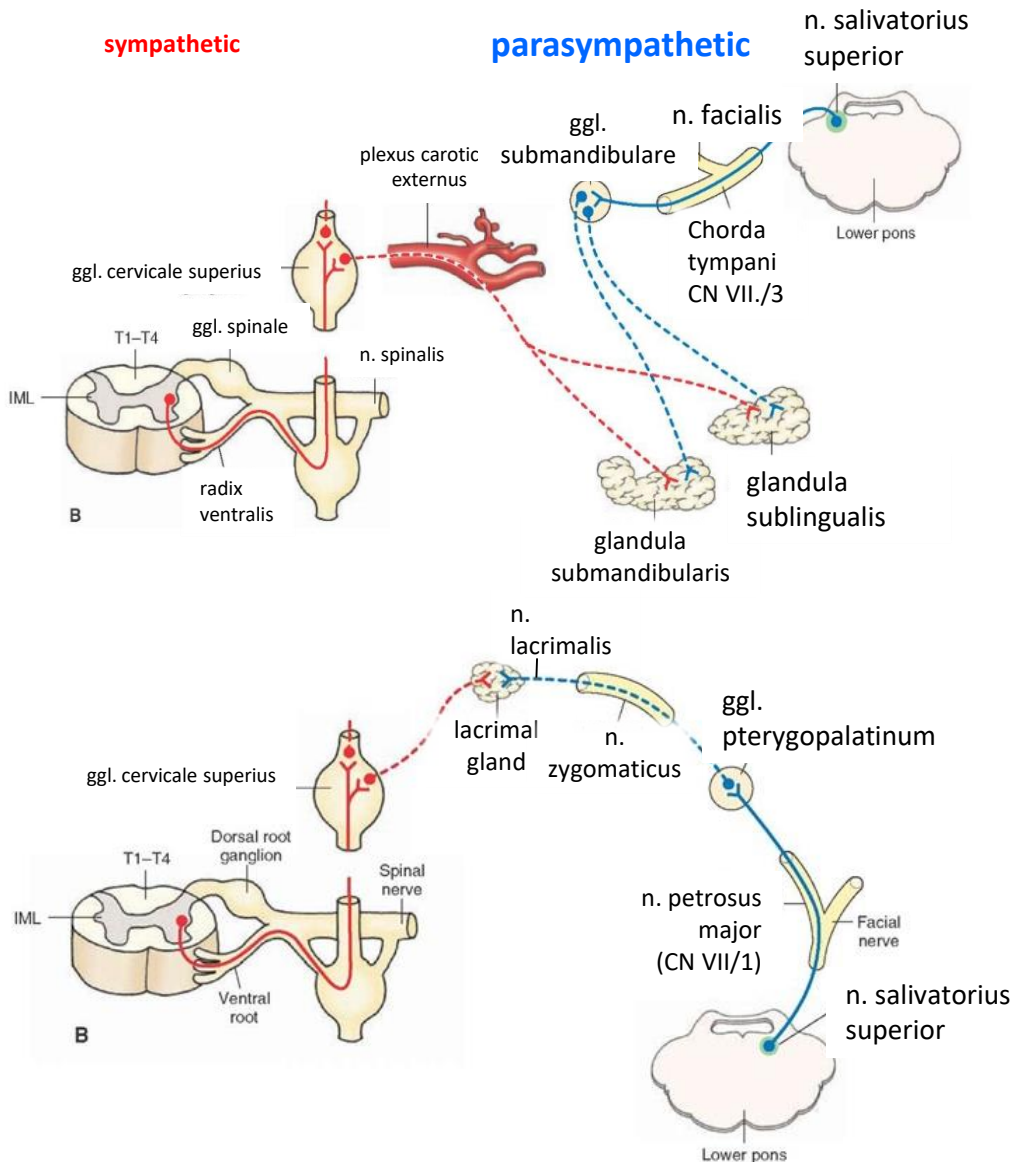
Preganglionic fibers: Edinger-Westphal nucleus, CN III

Relay: ciliary ganglion

Postganglionic fibers: short ciliary nerves

Function: constriction of the pupil and the ciliary muscle (accommodation)

Parasympathetic innervation the submandibular, sublingual and lacrimal glands



Submandibular and sublingual glands

Preganglionic fibers:

- superior salivatory nucleus, chorda tympani (CN VII/3)

Relay: submandibular ganglion

Function: secretion of watery saliva

Lacrimal gland

Preganglionic fibers:

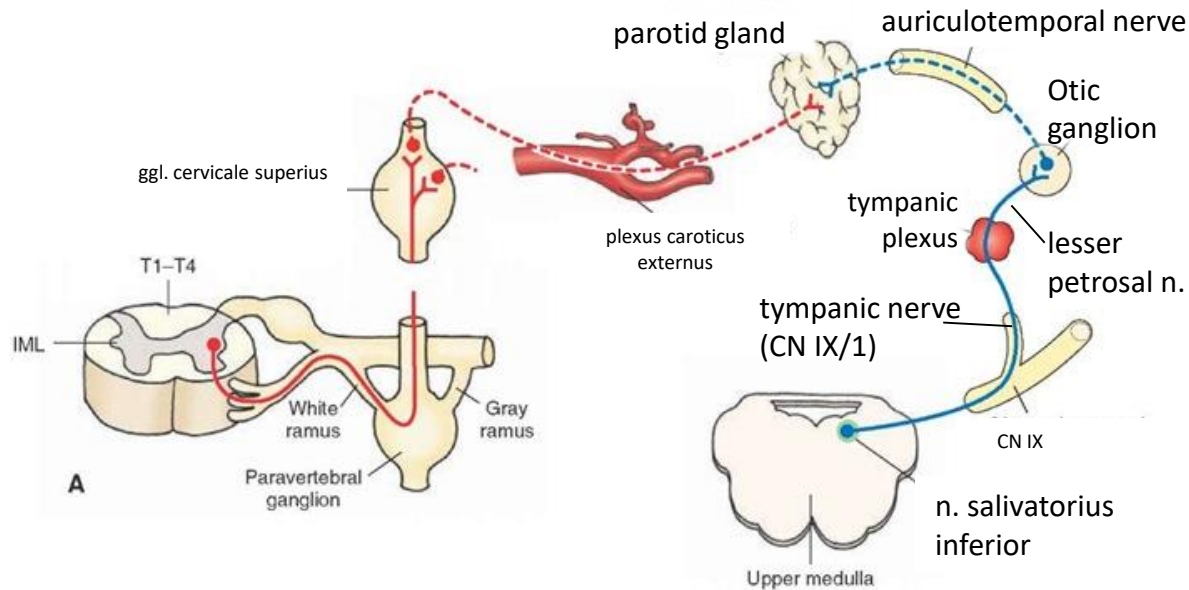
- superior salivatory nucleus, greater petrosal nerve (CN VII/1)

Relay: pterygopalatin ganglion

Postganglionic fibers: zygomatic nerve, communicating branch, lacrimal nerve

Function: secretion of tears

Parasympathetic innervation of the parotid gland



Preganglionic fibers: inferior salivatory nucleus, glossopharyngeal nerve (CN IX)

tympanic nerve (CN IX/1), tympanic plexus, lesser petrosal nerve

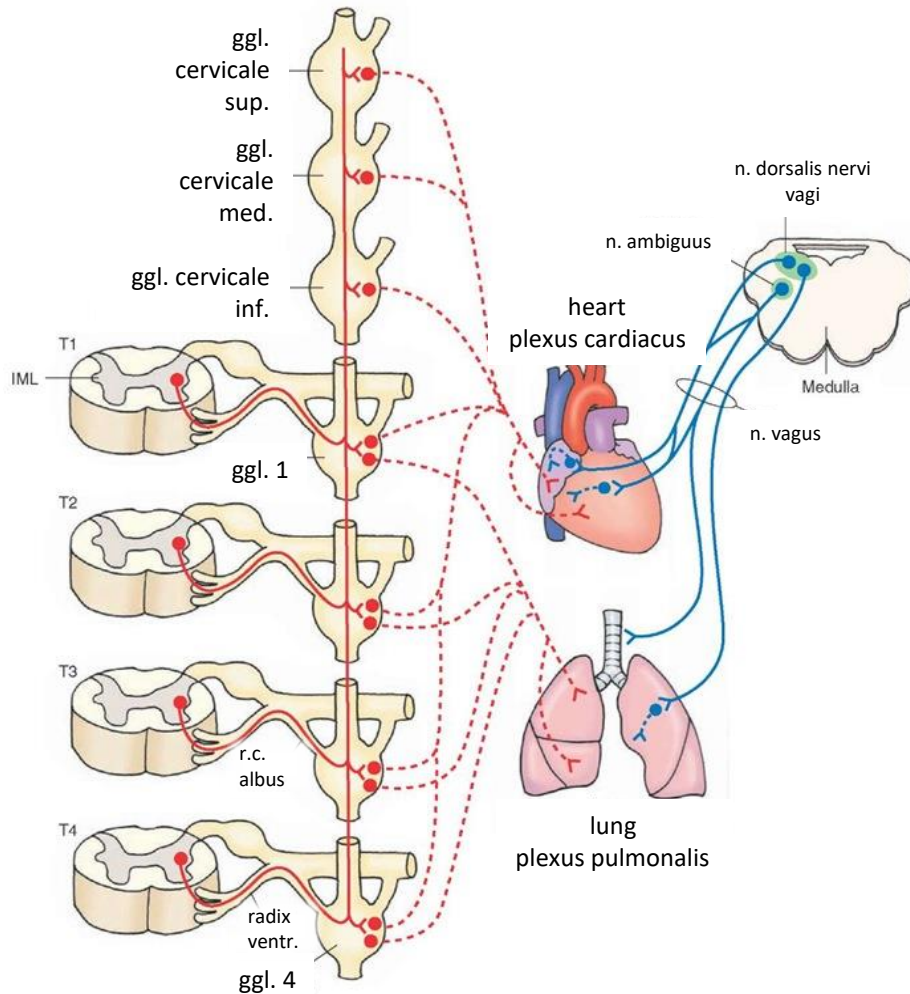
Relay: otic ganglion

Postganglionic fibers: auriculotemporal nerve

Sympathetic innervation of the heart and lung

sympathetic

parasympathetic



Heart:

- **Preganglionic fibers:** IML T1-T4
- **Relay:** cervical ganglia and T1-4 ganglia of the trunk
- **Postganglionic fibers:** cardiac plexus -SA and AV nodes, atrium and ventricle - heart rate and force increases

Lung:

- **Preganglionic fibers:** IML T1-T4
- **Relay:** T1-T4 ganglia of the trunk , stellate ganglion
- **Postganglionic fibers:** pulmonal plexus -bronchodilatation

Upper third of the esophagus:

- **Preganglionic fibers:** IML T1-T6
- **Relay:** stellate ganglion
- **Postganglionic fibers:** cardiac and pulmonal plexuses

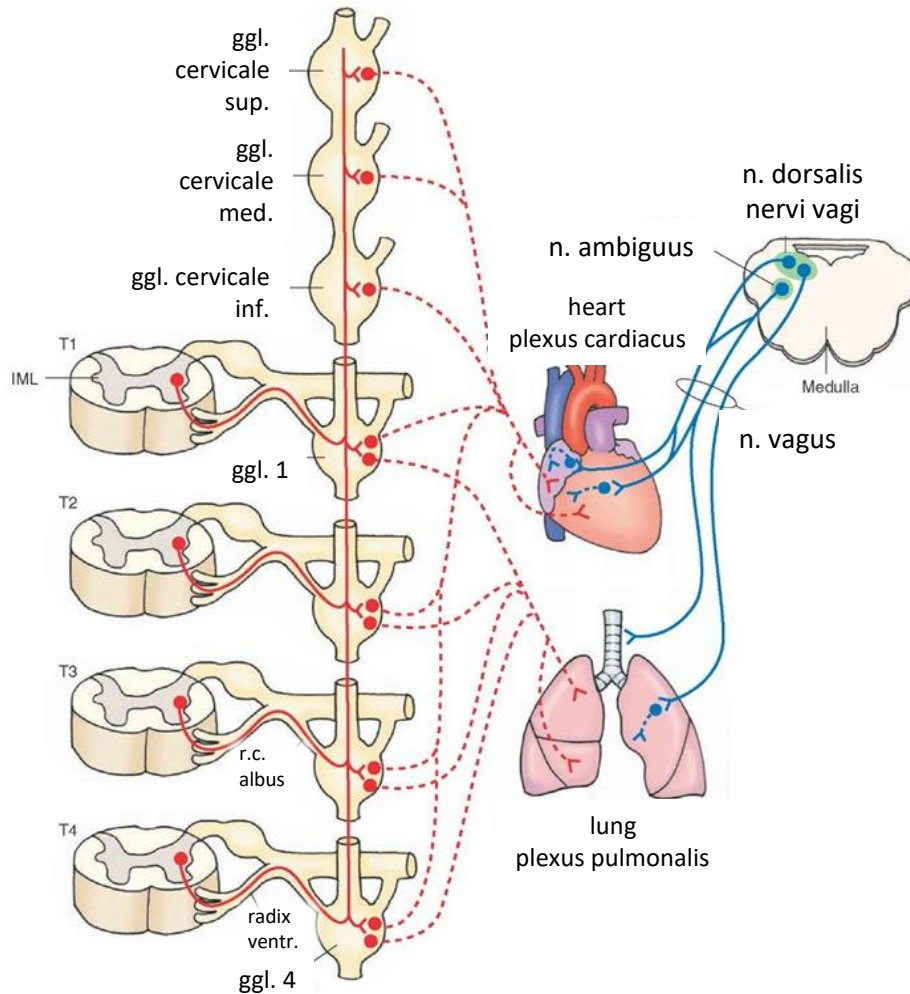
Others:

- ggl. cervicale medium: larynx, pharynx, thyroid-vasoconstriction
- ggl. stellatum - n. vertebralis:
 - upper limbs (vaso- and sudomotor, piloerector)

Parasympathetic innervation of the heart and lung

sympathetic

parasympathetic



Heart:

- **Preganglionic fibers:** n. ambiguus, dorsal motor nucleus of vagus- vagus nerve
- **Relay:** cardiac plexus
- **Function:** fibers innervate SA and AV nodes, - heart rate decreases, force does not change

Lung:

- **Preganglionic fibers:** dorsal motor nucleus of vagus- vagus nerve
- **Relay:** pulmonal plexus
- **Function:**-bronchoconstriction, increase in the secretion of the bronchial glands

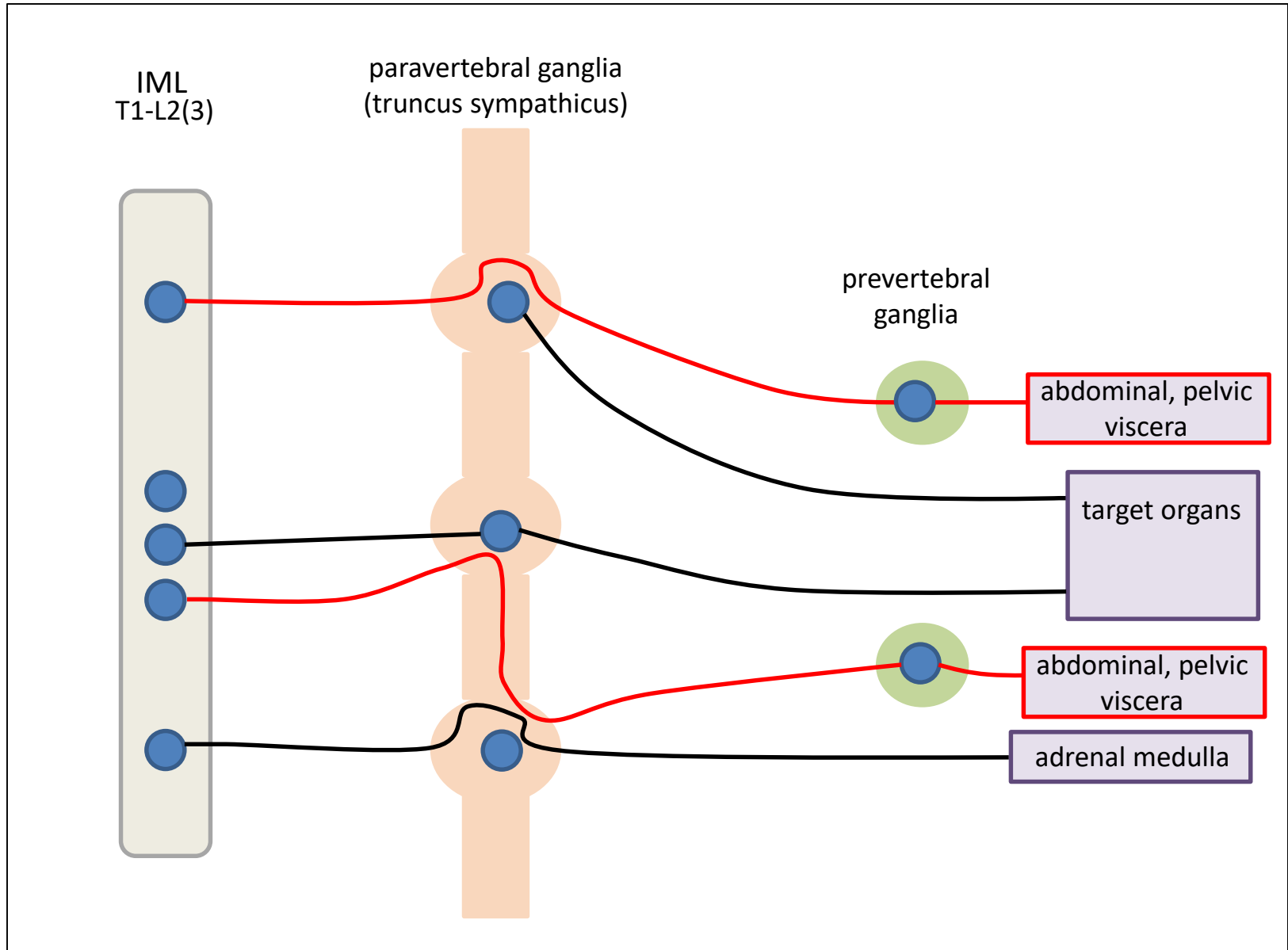
Upper third of the esophagus:

- **Preganglionic fibers:** n. ambiguus, dorsal motor nucleus of vagus- vagus nerve
- **Relay:** submucosal and myenteric plexuses

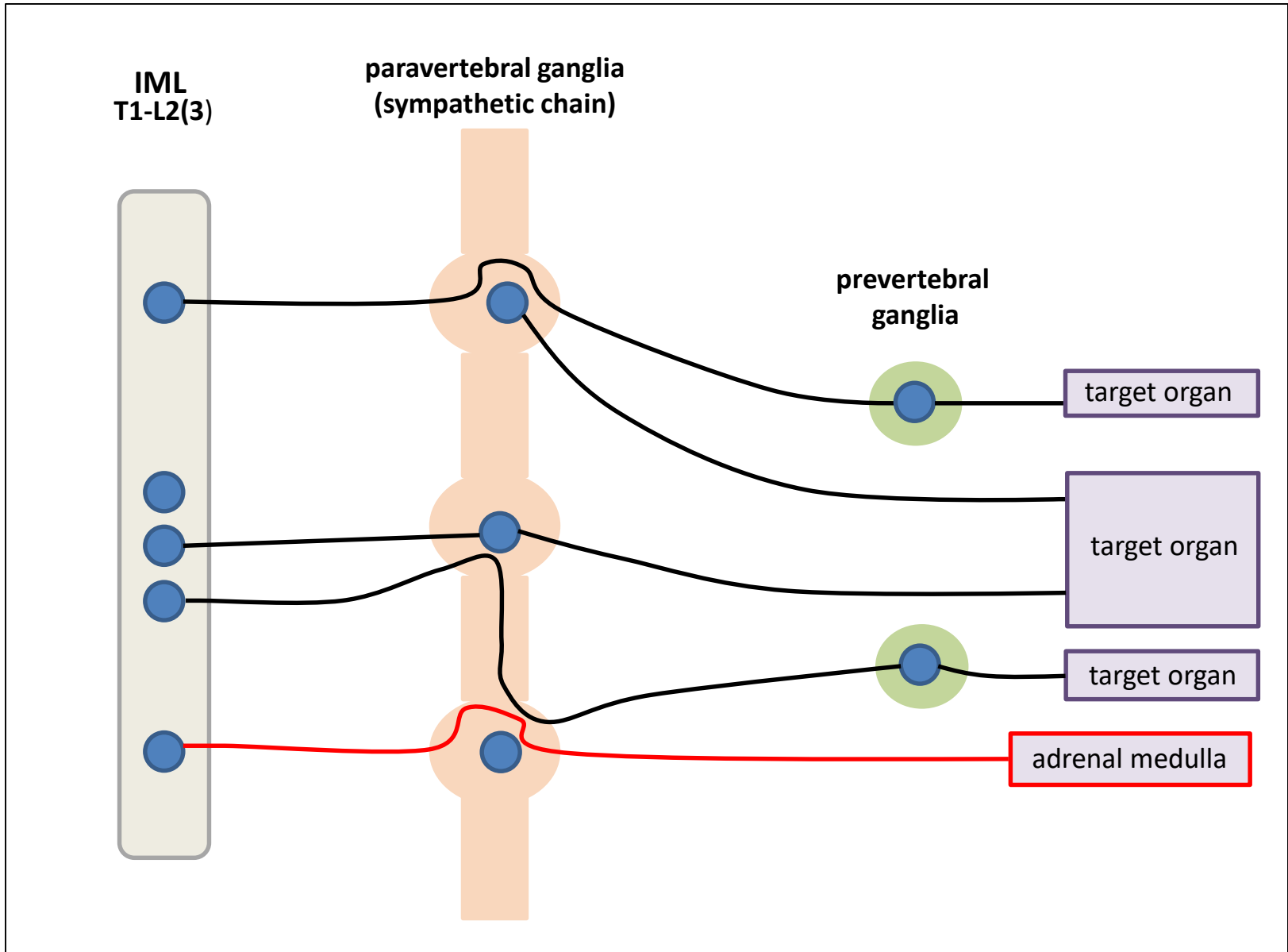
Others:

- pharynx, larynx –vagus – innervation of the musculature
- *pia mater vessels vasodilatation!*
- corpus pineale no functional relevance

Sympathetic efferents



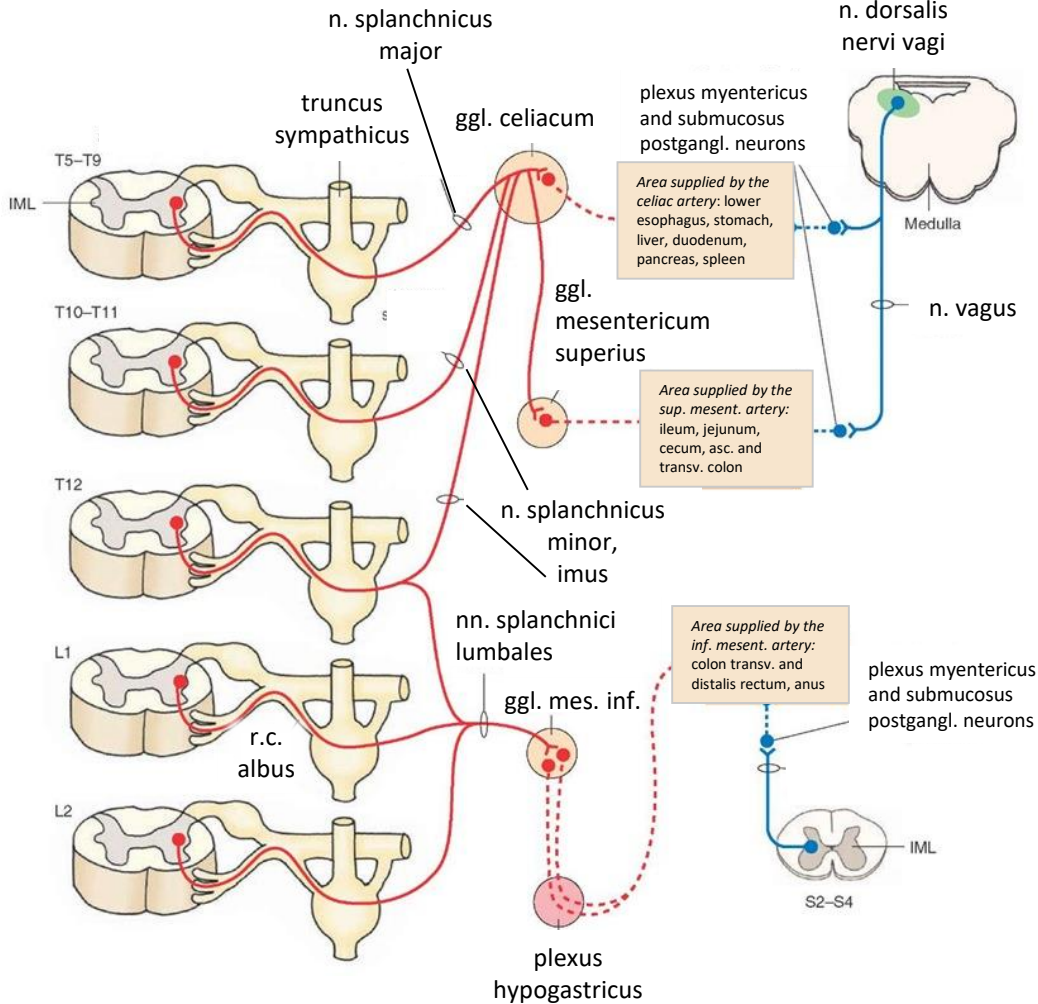
Sympathetic efferents



Sympathetic innervation of the GI tract

sympathetic

parasympathetic



Lower esophagus, stomach, liver, spleen, duodenum, pancreas:

- **Preganglionic fibers:** IML T5-11, greater and lesser splanchnic nerves
- **Relay:** celiac ganglion

Ileum, jejunum, cecum, asc. and transverse (2/3rd) colon :

- **Preganglionic fibers:** IML T5-12, greater, lesser and least splanchnic nerves
- **Relay:** superior mesenteric ganglion

Transverse (1/3rd), descending, sigmoid colon, rectum, anus:

- **Preganglionic fibers:** A, IML T12-L2(3), lumbar splanchnic nerves
- **Relay:** inferior mesenteric ganglion
- **Relay:** superior and inferior hypogastric plexuses

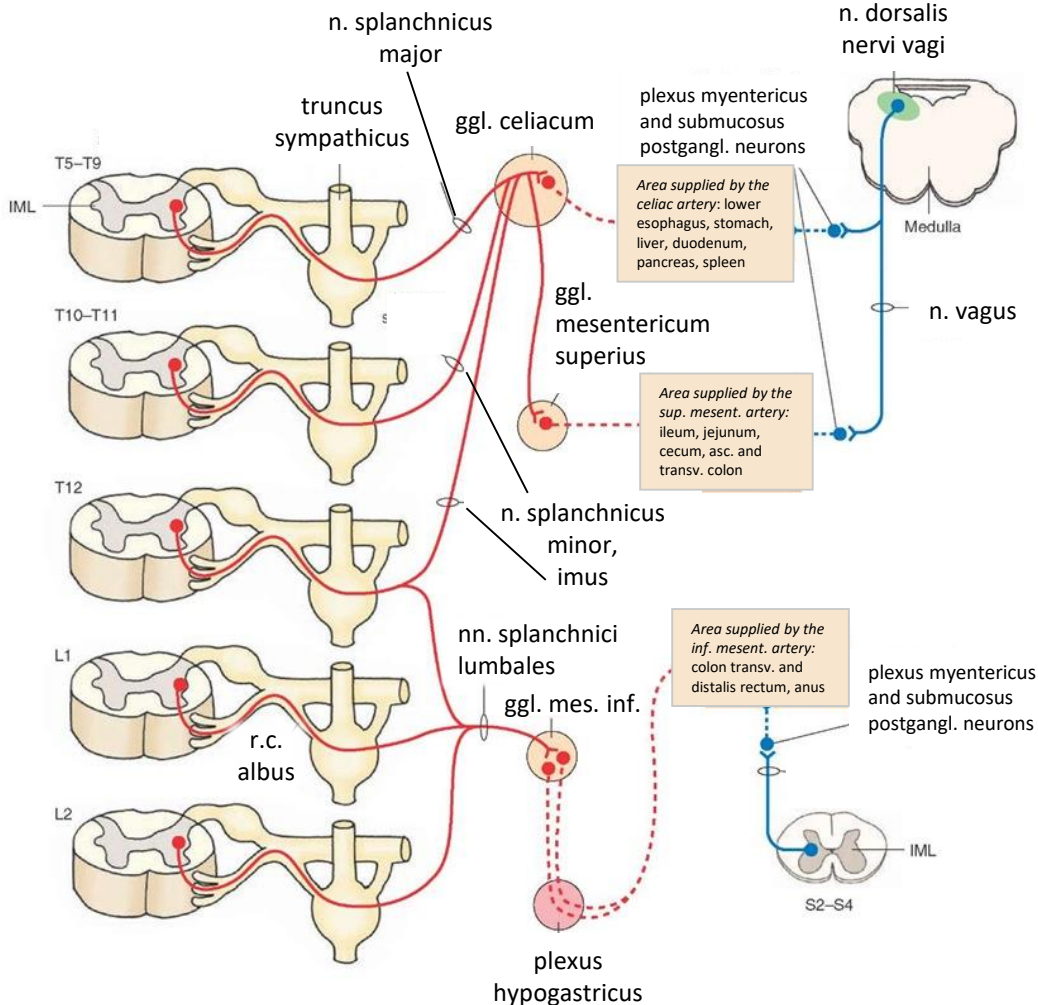
Functions:

- inhibition of peristalsis and the secretions of glands
- contraction of the sphincters and vasoconstriction

Parasympathetic innervation of the GI tract

sympathetic

parasympathetic



Lower esophagus, stomach, liver, spleen, pancreas, small intestine, cecum, ascending and transverse (2/3rd) colon:

- **Preganglionic fibers:** dorsal motor nucleus of vagus, vagus nerve
- **Relay:** submucosal and myenteric plexuses

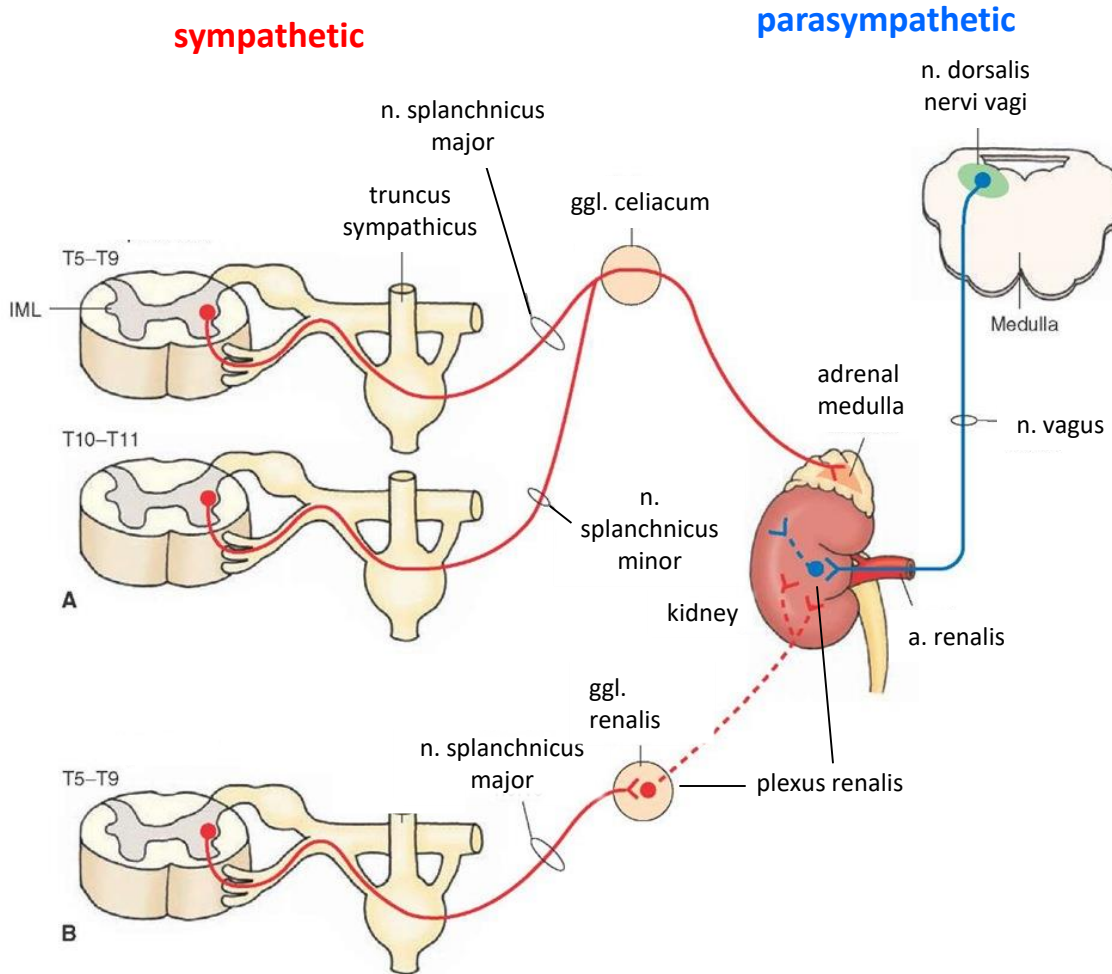
Transverse (1/3rd), descending, sigmoid colon, rectum, anus:

- **Preganglionic fibers:** IML S2-S4, ventral root of the spinal nerves, pelvic nerves
- **Relay:** submucosal and myenteric plexuses

Functions:

- stimulation of peristalsis and secretions of glands
- relaxation of the sphincters
- no direct effect on vessels

Autonomic innervation of the kidney and the adrenal medulla



Effects on kidney arteries:
sympathetic: vasoconstriction

Adrenal medulla: functionally analogous to a sympathetic ganglion

Preganglionic fibers:

- A, T5-T11 IML greater and lesser splanchnic nerves
- *Celiac ganglion: there is **no relay!***
- adrenaline, noradrenaline release

Kidney:

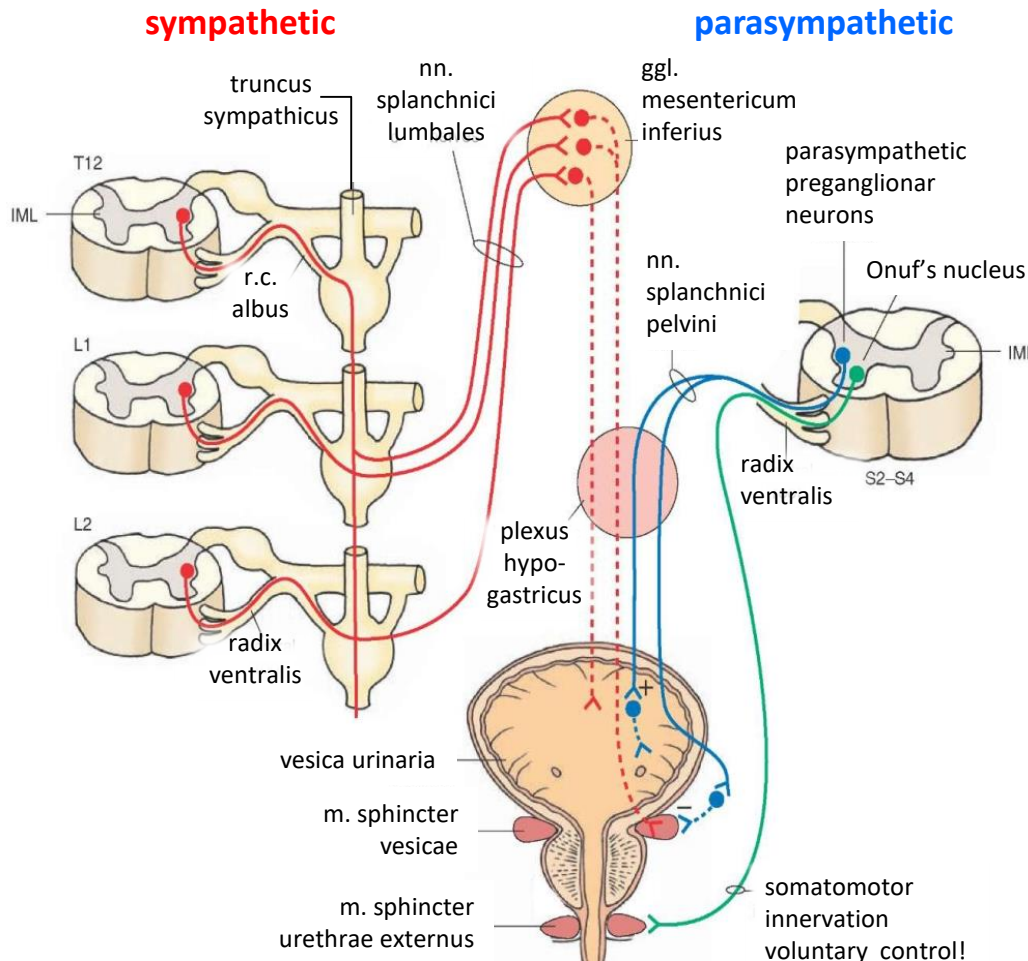
Sympathetic

- **Preganglionic fibers:** T5-T9 IML, greater splanchnic nerve
- **Relay:** renal ganglion
- **Postganglionic fibers:** renal plexus (mixed with parasympathetic)

Parasympathetic:

- **Preganglionic:** dorsal motor nucleus, of vagus, vagus nerve
- **Relay:** renal plexus

Autonomic innervation of the bladder



Sympathetic:

- **Preganglionic fibers:** IML T12-L2(3), lumbar splanchnic nerves
- **Relay:** A, inferior mesenteric ganglion
B, inferior hypogastric plexus (rectal, uterovaginal, prostatic and vesical plexuses)
- **Postganglionic fibers:** pelvic and hypogastric nerves

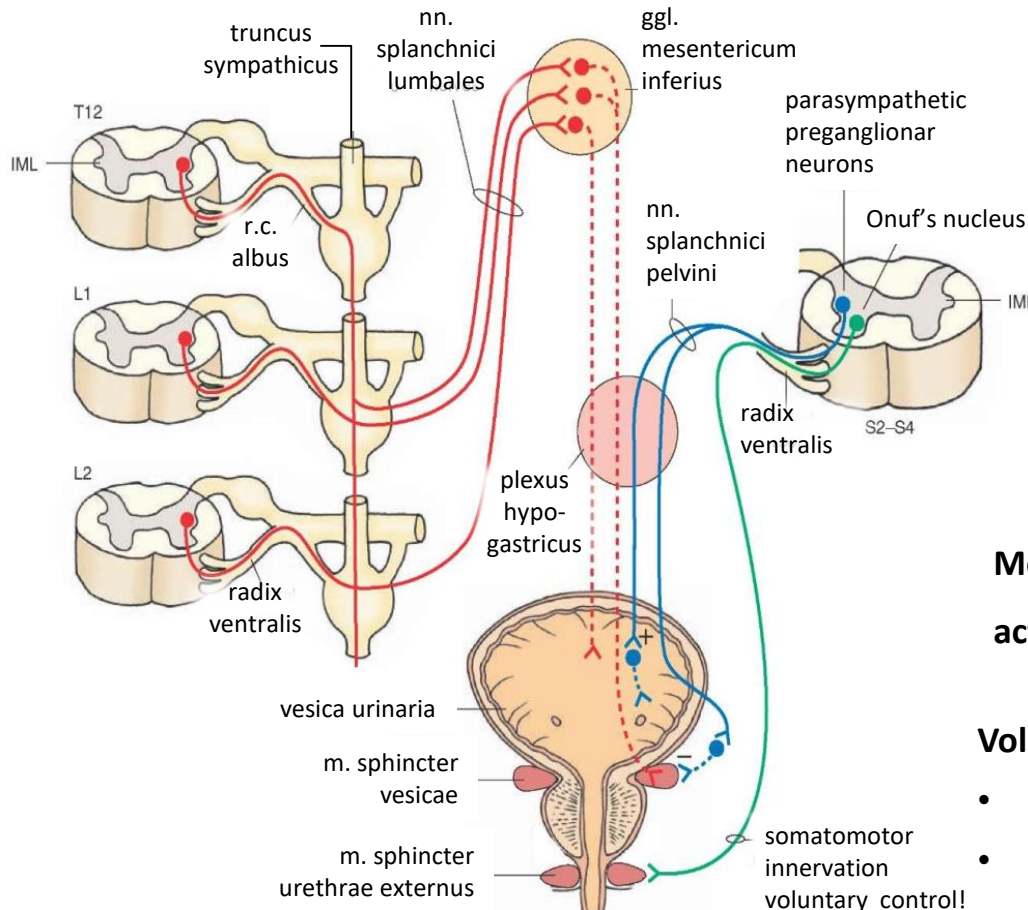
Parasympathetic:

- **Preganglionic fibers:** IML S2-S4, ventral roots, pelvic nerves, passing through the hypogastric plexus
- **Relay:** postganglionic neurons in the bladder wall

Control of micruition

sympathetic

parasympathetic



Sympathetic effects

Allows the bladder to fill, inhibits emptying:

- closing the internal sphincter
- relaxing the detrusor muscle (bladderwall)

Parasympathetic effects

Allows the bladder to empty:

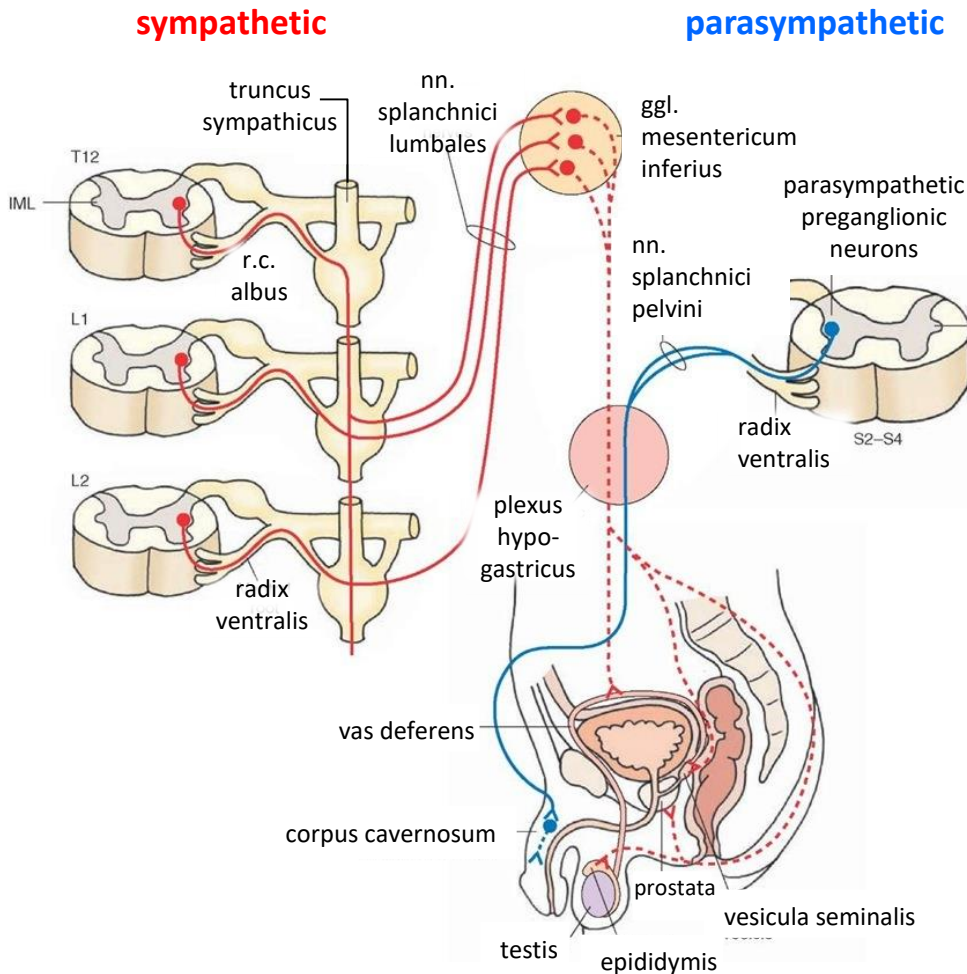
- relaxing the internal sphincter
- contraction the detrusor muscle

Moderate bladder distension inhibits parasympathetic activity, fullnes of the bladder stimulates it (afferents).

Voluntary control of m. sphincter urethrae externus:

- S2-4 ventral horn alpha motoneurons (Onuf's n.)
- tonic activity
- central coordination: pons and higher centers

Autonomic innervation of the sexual organs



Sympathetic:

- **Preganglionic fibers:** IML T12-L2(3), lumbar splanchnic nerves
- **Relay:**
 - A, inferior mesenteric ganglion (epididymis, vas deferens, seminal vesicles, and prostate glands/ vagina, uterus)
 - B, inferior hypogastric plexus (penis/clitoris)
- **Postganglionic fibers:** pelvic and hypogastric nerves

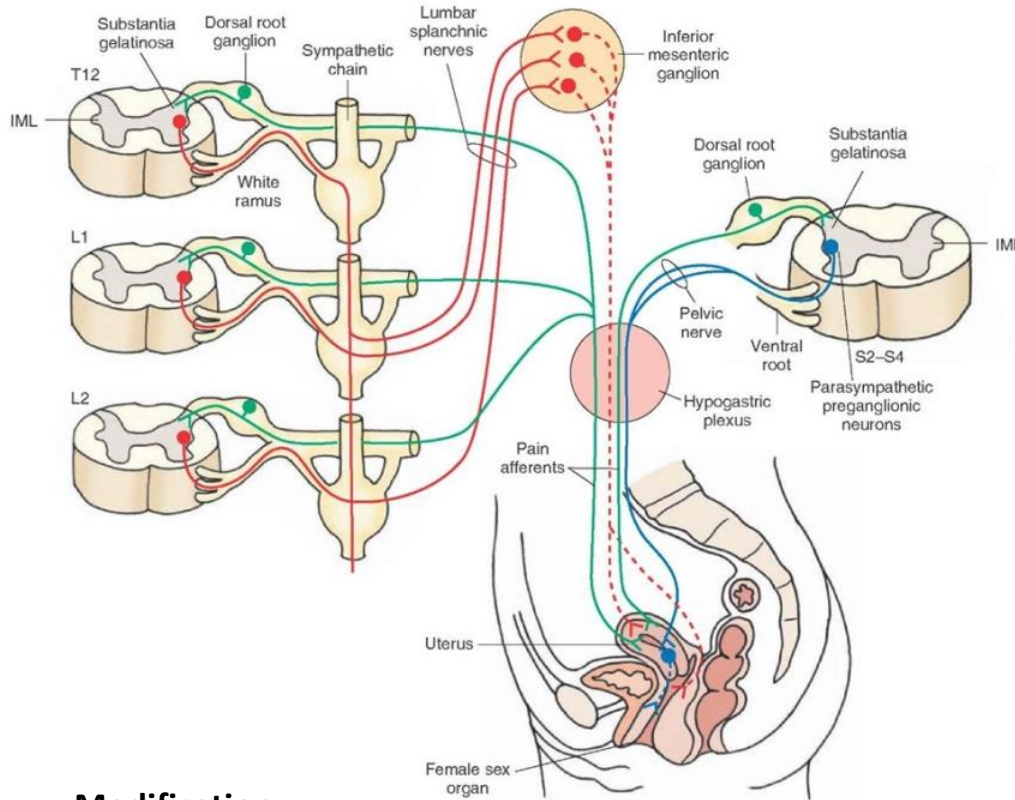
Parasympathetic:

- **Preganglionic fibers:** IML S2-S4, ventral roots, pelvic nerves, passing through the hypogastric plexus
- **Relay:** neurons in corpora cavernosa or clitoris

Autonomic innervation of the sexual organs

sympathetic

parasympathetic



Parasympathetic effects

- dilation of the arteries
- increased blood flow in the corpora cavernosa causes erection

Non-adrenergic and non-cholinergic terminals:

- nitric oxide (NO) release
- cGMP level increase in the nonvascular smooth muscle -relaxation
- indirect contribution to erection

Sympathetic effects

- contraction of smooth muscles;
- vas deferens, seminal vesicles, and prostate - ejaculation
- contraction of uterine musculature

Modification

- psychiatric factors
- somatosensory inputs
- integration in higher centers (cortex, limbic system, sexually dimorph nuclei)

Thank you for your attention!



Anatomy: 5*