Autonomic nervovous system

Sympathicus

fight or flight

Parasympathicus

rest or digest

Main functions

involuntary (visceromotor)

- contraction and relaxation of smooth muscles
- function of all endocrine and some exocrine glands
- heart rhythm
- some metabolic processes

obsolete synonym: „vegetative system"

Classification of ANS

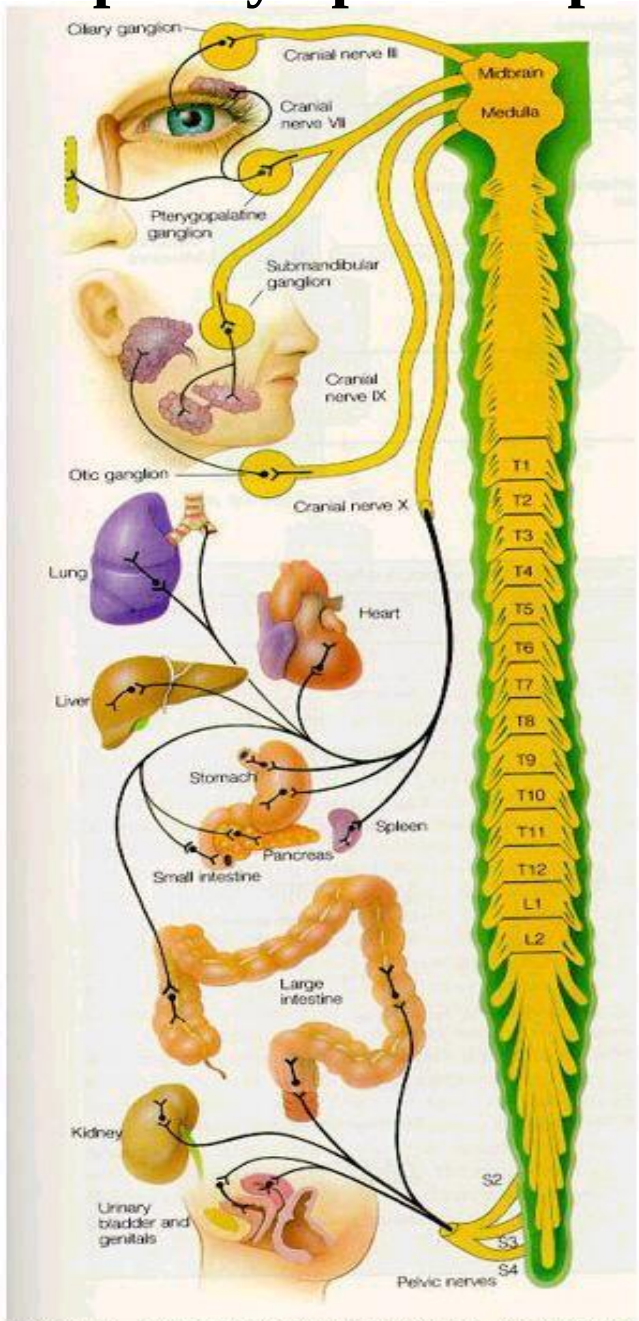
- sympathetic system
  - *fight or flight*
- parasympathetic system
  - *rest or digest*
- enteric system

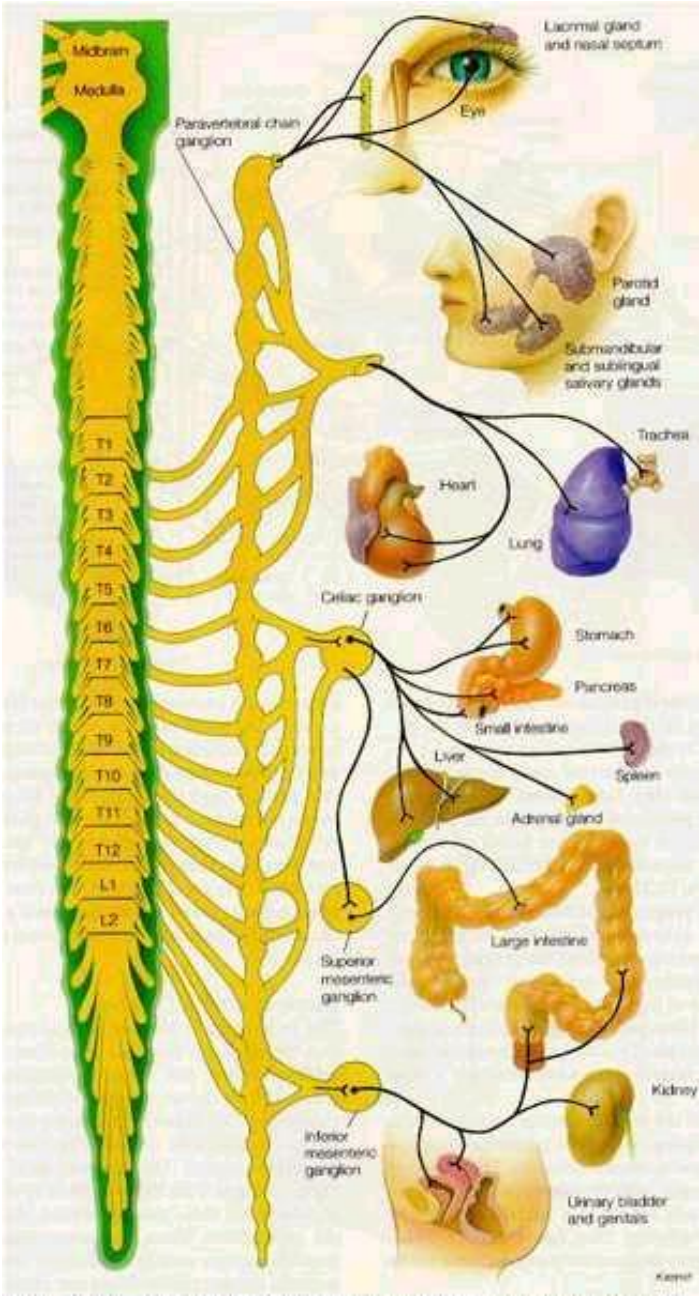
Types of impulses conducted by fibers of ANS

- nuclei in CNS → **visceromotor fibers** → autonomic ganglia (integration of information from CNS and ANS)
- free nerve endings → viscerosensory fibers → ggl. spinale or ggl. n. VII, IX, X
  - *are not functional part of ANS !!!*
  - mechanoreceptors, chemoreceptors
  - afferent fibers of reflectory pathways (coughing, defecation, vasomotor…)
  - visceral pain (e.g. colic, angina)

parasympathetic part

sympathetic part





Hole JW Jr . Human Anatomy and Physiology. 5th WCB IA USA. 1990

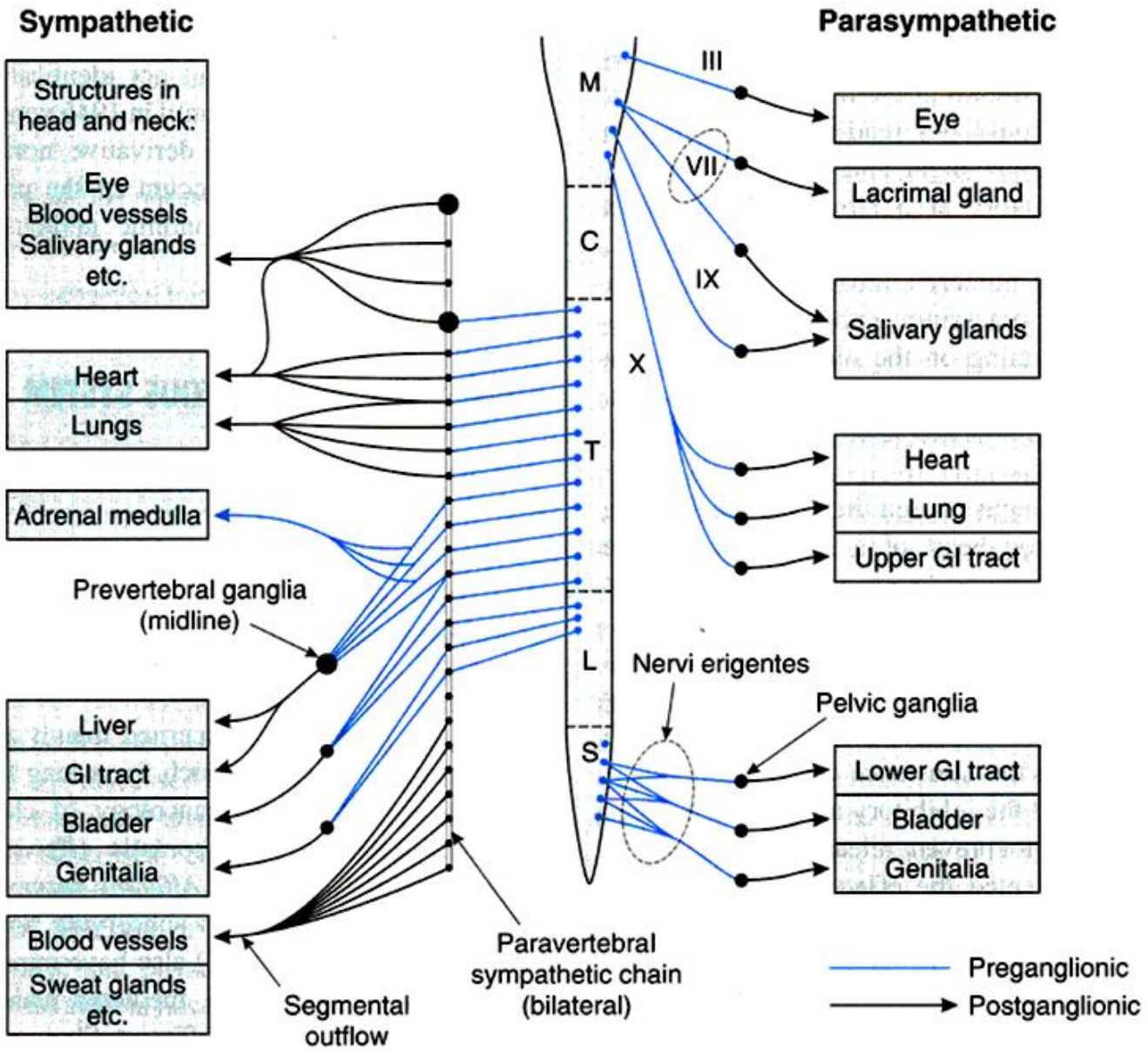
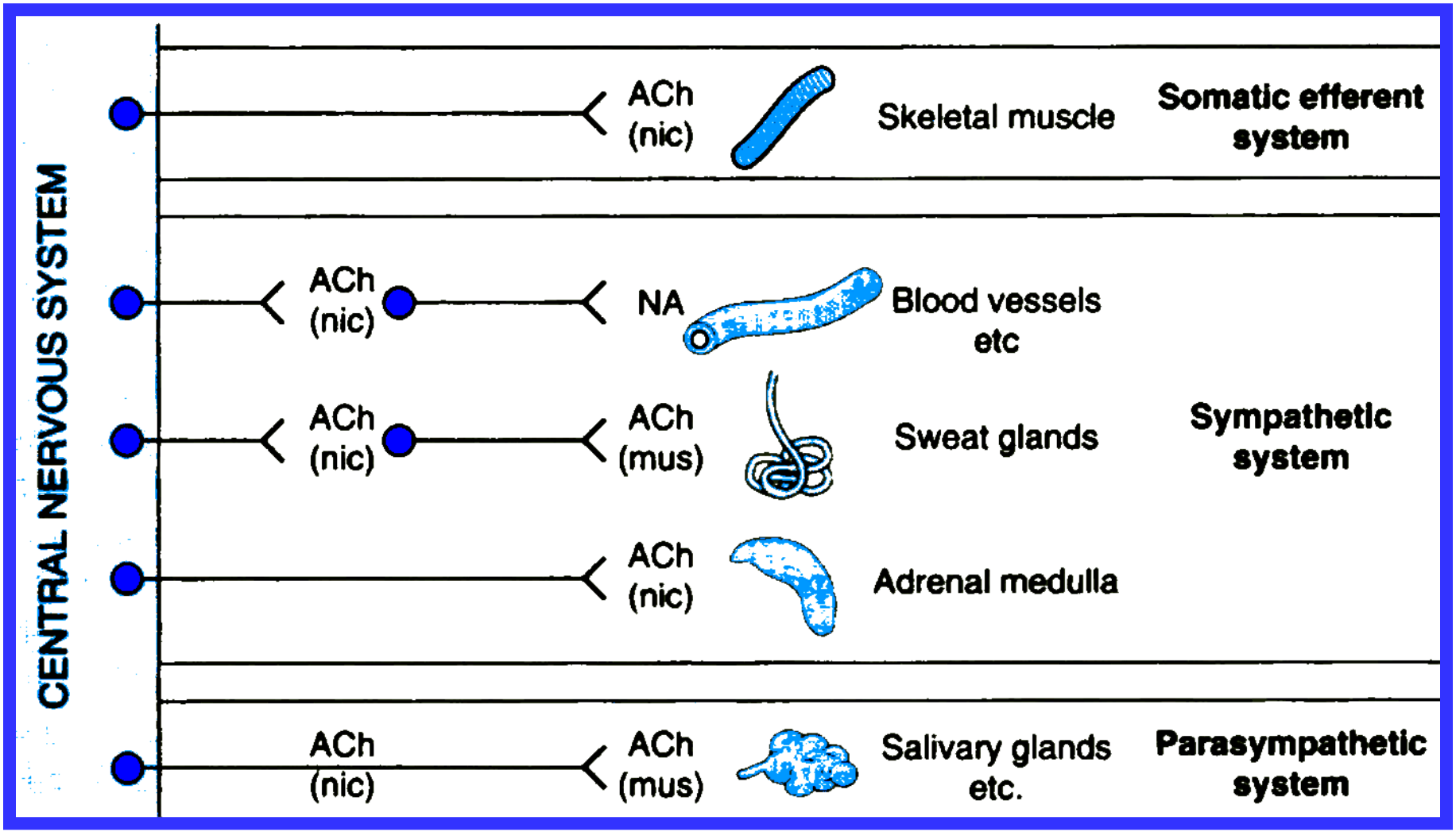


Fig. 6.1 Basic plan of the mammalian autonomic nervous system. (M = medullary; C = cervical; T = thoracic; L = lumbar, S = sacral)

Nicotin receptor („nic“)

ganglia, neuromuscular plate, CNS
– ligand-gated ion channel

Muscarin receptor („mus“): M1-M5
target tissue of parasympathetic, CNS
– G-protein-gated
(→ enzymes / ion channels)



Noradrenergic receptor („NA“): a1, a2, β1, β2
target tissue of sympathetic **– G-protein-gated**

Medicaments influencing ANS

+

- **Sympathomimetics**
  - diect: **adrenaline, noradrenaline, dopamine**, dobutamine, isoprenaline
  - selective
  - indirect
- **Parasympathomimetics**
  - **acetylcholine**, pilocarpine, karbachole, physoostigmine, organophosphates

-

- **Sympatholytics**: alfa- and beta blockers
  - α phentolamine, prazosine, yohimbine, ergotamine
  - β atenolole, propranolole, labetanole, pindolole, bopindolole
- **Parasympatholytics**
  - **atropine, scopolamine**, ipratropium
  - **contraindication: glaucoma (with closed angle), hyperplasia of prostate, paralytic ileus**


Deadly nightshade (*Atropa bella-donna*)

Sympathetic part - stimulation of receptors

receptor	*tissue*	*effect*
α_1	majority of vascular smooth muscle cells	contraction (vascular resistance)
	m. dilatator pupillae	contraction (mydriasis)
	uterus	contraction
	penis, glandulae vesiculosae	ejaculation
	GIT - sphincters	contraction
α_2	presynaptic receptors in synpases	inhibition of mediator releasing
	trombocyti	stimulation of aggregation
β_1	heart	positive chrono-, dromo-, bathmo-, inotropic effect
	juxtaglomerulal cells of kidneys b-cells of pancreas	release of renine
	B-cells of insulae pancreaticae	release of insuline
β_2	smooth muscle cells of bronchi, vessels, longitdudinal layer in intesine, uterus	relaxation
	liver	stimulation of glycogenolysis
	striated muscles	shivering (uptake K^+)
β_3	lipocytes	lipolysis
D_1	smooth muscle cells	relaxation of splanchnic vessels
D_2	nerve endings	modification of mediators release

Stimulation of α_1 receptor

- **vasoconstriction** of skin, mucous and splanchnic vessels, minimal in coronary and cerebral circulation, higher peripheral resistance, higher blood pressure → following bradycardia (both local and peripheral)
- **mydriasis** (contraction of m. dilatator pupillae), reduction of intraocular pressure (elevated reabsorption and reduced production of humor aquosus by means of vasoconstriction of vessels in corpus ciliare)
- **contraction of pregnant uterus**
- **ejaculation**
- **contraction of m. sphincter vesicae**

Stimulation of α_2 receptor

- (presynaptic) **reduction of noradrenaline release** (mainly in CNS)
- stimulation of **thrombocytes aggregation**
- **vasoconstriction in local application,** otherwise by stimulation of central receptors → reduced tonus of sympathetic part and blood pressure = **hypotensive effect by central mechanism**

Stimulation of β_1 receptor

heart:

- ⇧ frequency (**chronotropy**) - SA node
- ⇧ automatism (**bathmotropy**) - AV node, ventricles
- ⇧ contractility (**inotropy**)
- ⇧ conduction of speed (**dromotropy**)
- ⇧ oxygen consumption

kidneys:

- ⇧ secretion of renin (start of RAA system)

Stimulation of β_2 receptor

- **vasodilatation in skeletal muscles** („preparation to flight or fight"), ⇩ diastolic blood pressure
- **bronchodilatation**
- **relaxation of uterus** (indication in threatening premature delivery)
- **relaxation of intestinal wall** (+ α_2)
- **slowing of intestinal passage**
- **relaxation of urinary bladder wall**
- **glycogenolysis** → elevated glycaemia, elevated insulin secretion
- **tremor of skeletal muscles**

Stimulation of β_3 receptor

- lipolysis

Parasympathetic part – cholinergic receptors
Muscarine (**M**) and nicotine (**N**) receptors

Receptor	Localization	G protein	Receptor stimulation activates following actions
M_1	Nerves	+	↑IP_3, DAG cascade
M_2	Heart, nerves, smooth muscles	+	↓ production of cAMP
M_3	Glands, smooth muscles	+	↑IP_3, DAG cascade
M_4	CNS?	+	↓ production of cAMP
M_5	CNS?	+	↑IP_3, DAG cascade
N_M	Neuromuscular plate	-	Opening of Na^+/K^+ canal and depolarization
N_N	Receptors in ganglia	-	Opening of Na^+/K^+ canal and depolarization

Parasympathetic part

Stimulation of muscarine receptor (M)

Organ	*Part of organ*	*Effect*
Eye	M. sphincter pupillae	Contraction – miosis
	M. ciliaris	Contraction – accommodation, vision at near
Heart	SA node	↓ frequency (negative chronotropic)
	Atria	↓ contractility (negative inotropic)
	AV node	↓ conductive speed (negative dromotropic) prolonged refractory phase
	Ventricles	↓ contractility (negative inotropic)
Vessels		Dilatation (EDRF=NO)
RT	Smooth muscles cells of bronchi	Bronchoconstriction
	Glands	Stimulace
GIT	Motility	↑ motility
	Sphincters	Relaxation
	Glands	↑ secretion
Urinary bladder	M. sphincter vesicae + m. trigoni vesicae	Relaxation
	M. detrusor	Contraction
Glands	Sweat, salivatory, lacrimal, nasopharyngeal	↑ secretion

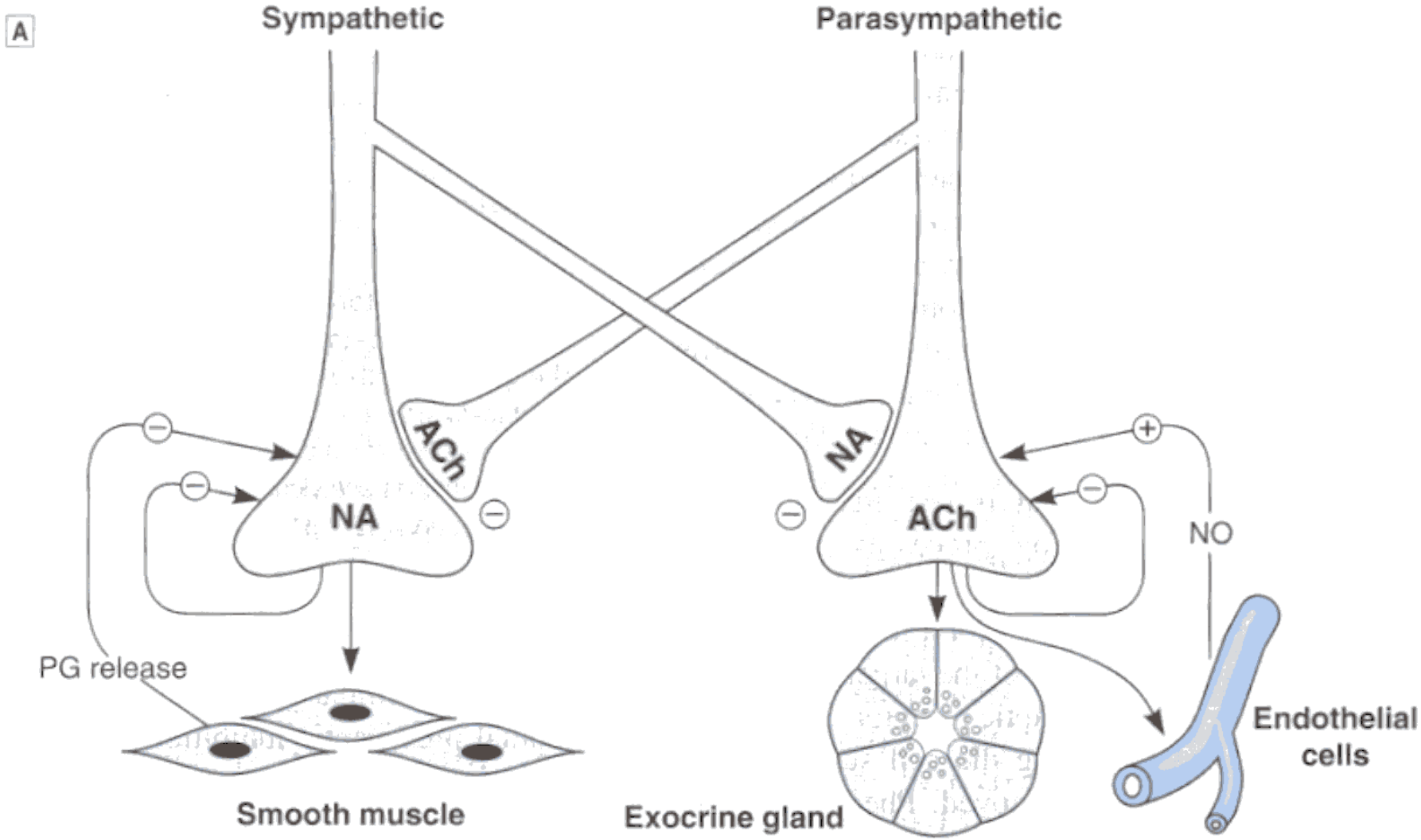
Parasympathetic part
Stimulation of nicotine receptor (**N**)

depends on prevailing if certain organ innervation

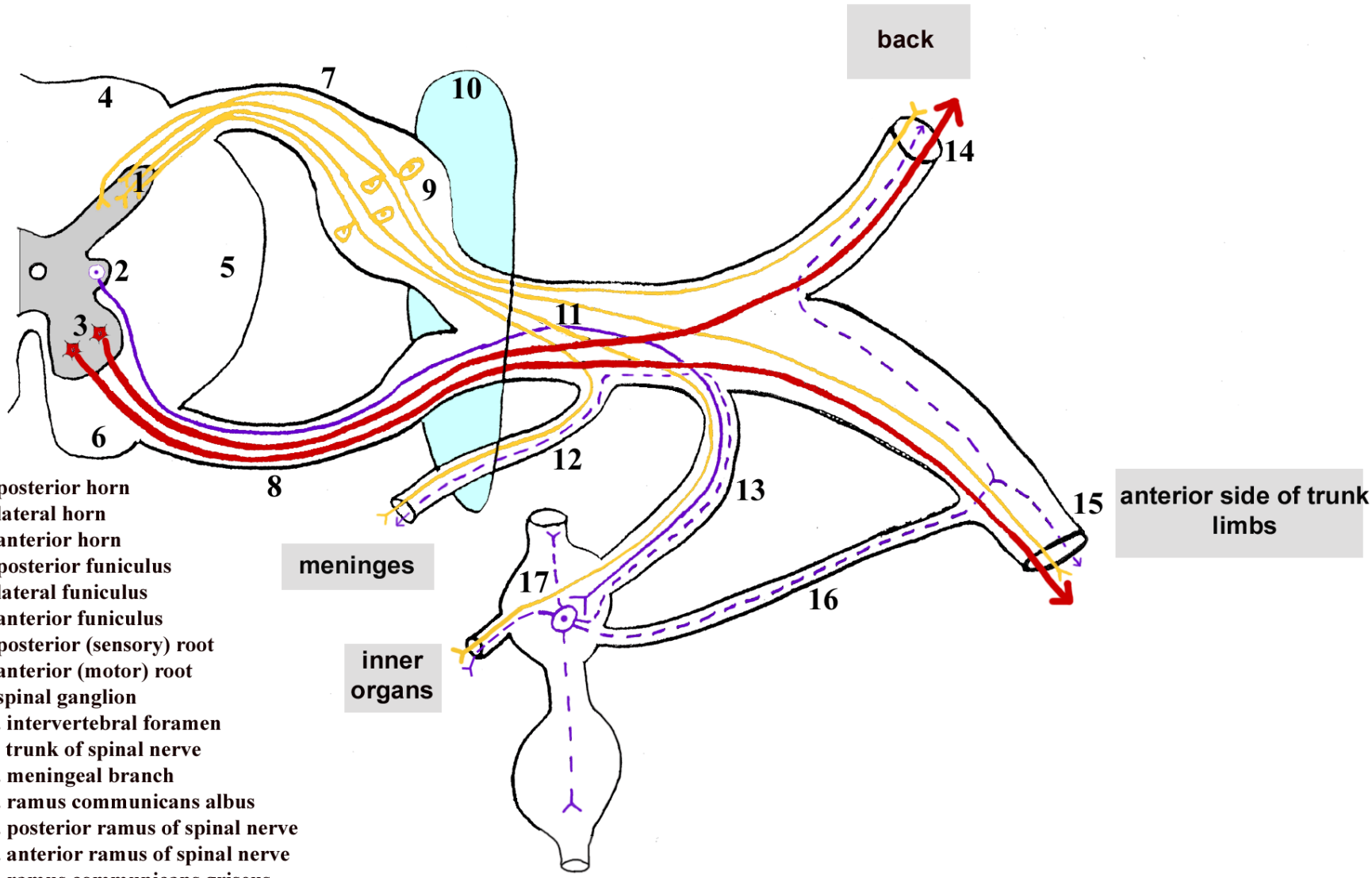
- **Vessels (arteriolae)** are innervated mainly by sympathetic part → stimulation of N-receptors in ganglia → *elevated transmission of impulse in postganglinoic neuron* of sympathetic and followed *activation of sympathetic receptors (α_1)* in corresponding effector cell → **elevation of blood pressure**
- **Heart (atria) + GIT** – parasympathetic tonus is prevailing tonus → stimulation of N-receptors in ganglia → *elevated transmission of impulse in postganglinoic neuron* of parasympathetic and *activation of M receptors* → **elevated motility of GIT**
- **Stimulation of suprarenal glands** – *release of adrenaline and noradrenaline* → **clonus up to spasm of striated muscles**

Homotropic anf heterotropic **inhibition**

individual and mutual inhibition of S and PS



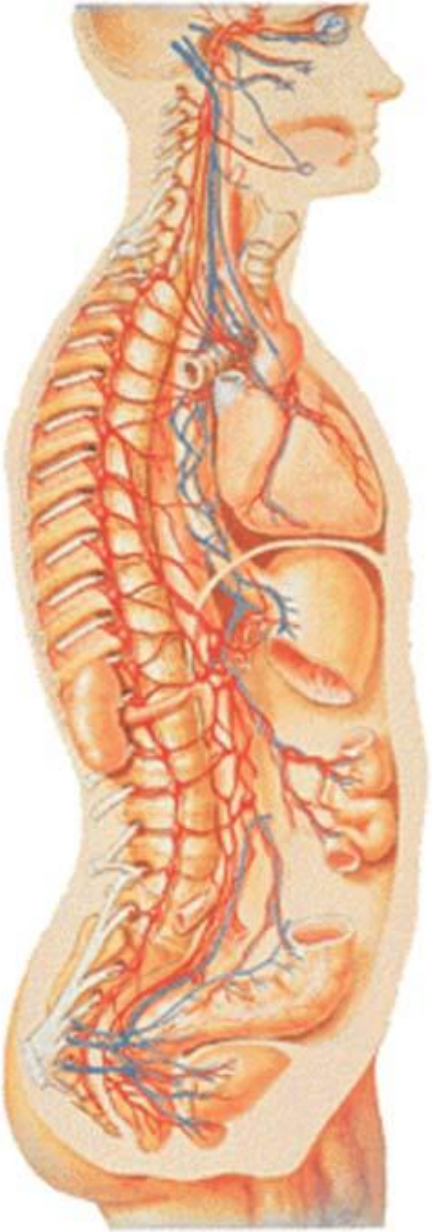
SCHEME OF SPINAL NERVE BRANCHING



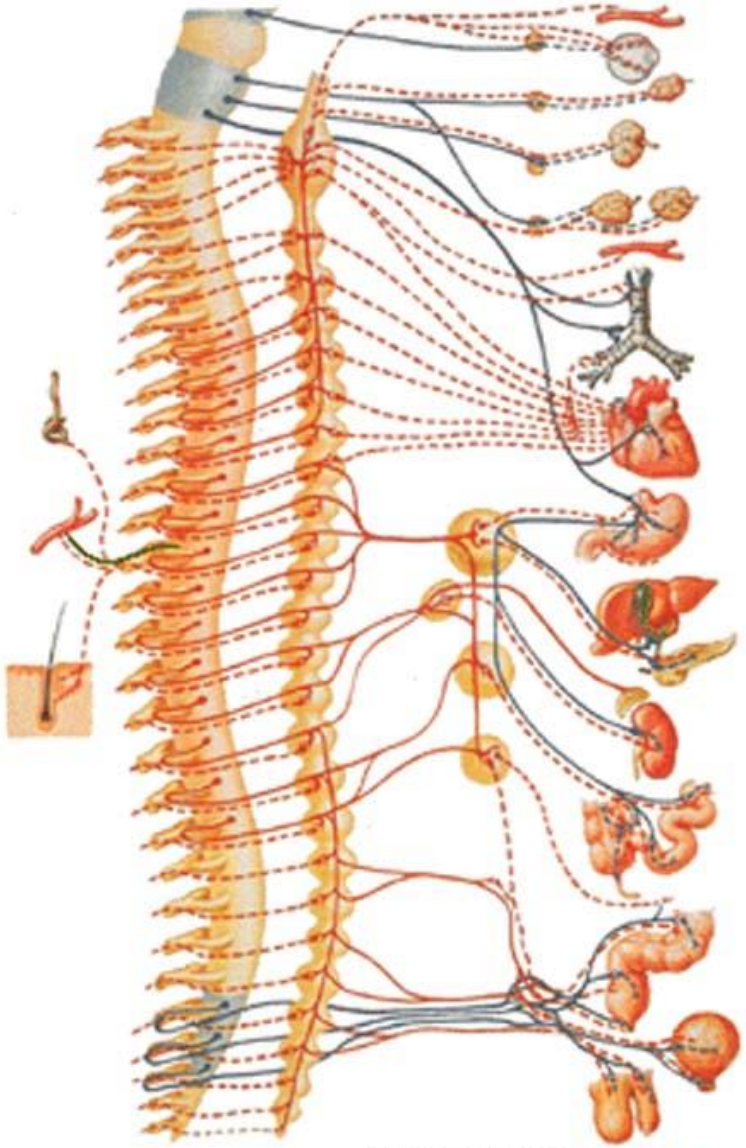
1. posterior horn
2. lateral horn
3. anterior horn
4. posterior funiculus
5. lateral funiculus
6. anterior funiculus
7. posterior (sensory) root
8. anterior (motor) root
9. spinal ganglion
10. intervertebral foramen
11. trunk of spinal nerve
12. meningeal branch
13. ramus communicans albus
14. posterior ramus of spinal nerve
15. anterior ramus of spinal nerve
16. ramus communicans griseus
17. ganglion of sympathetic trunk

SYMPATHETIC PART

„thoracolumbar system“

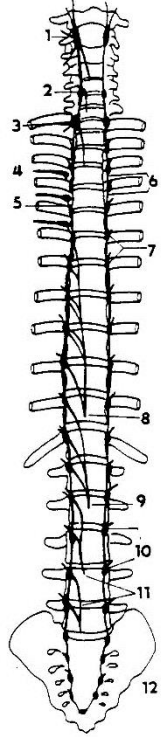


Sympathetic fibers
Parasympathetic fibers



Sympathetic fibers — Presynaptic
Postsynaptic
Parasympathetic fibers — Presynaptic
Postsynaptic
Antidromic conduction

Truncus sympathicus



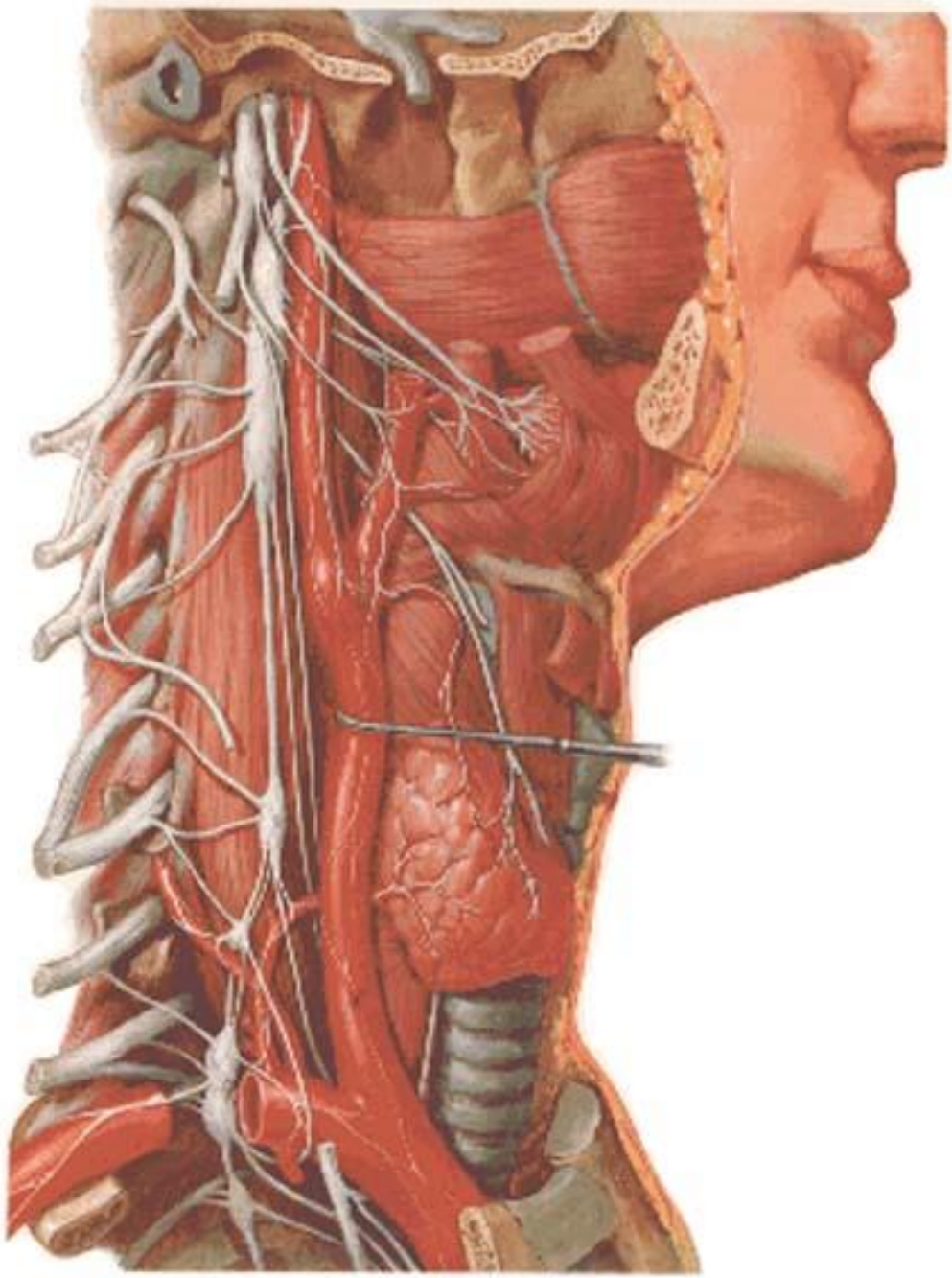
- ganglia trunci sympathici (21-25) = *paravertebral ganglia*
- rr. interganglionares
- rr. communicantes: albus + griseus
- topography: in front of vertebral column, on lateral sides of vertebrae within parietal fascia
  - spatium parapharyngeum (paraviscerale)
  - mediastinum superius, posterius inferius – in front of caput costae
  - retroperitoneally – medial to m. psoas major and to foramina sacralia anteriora

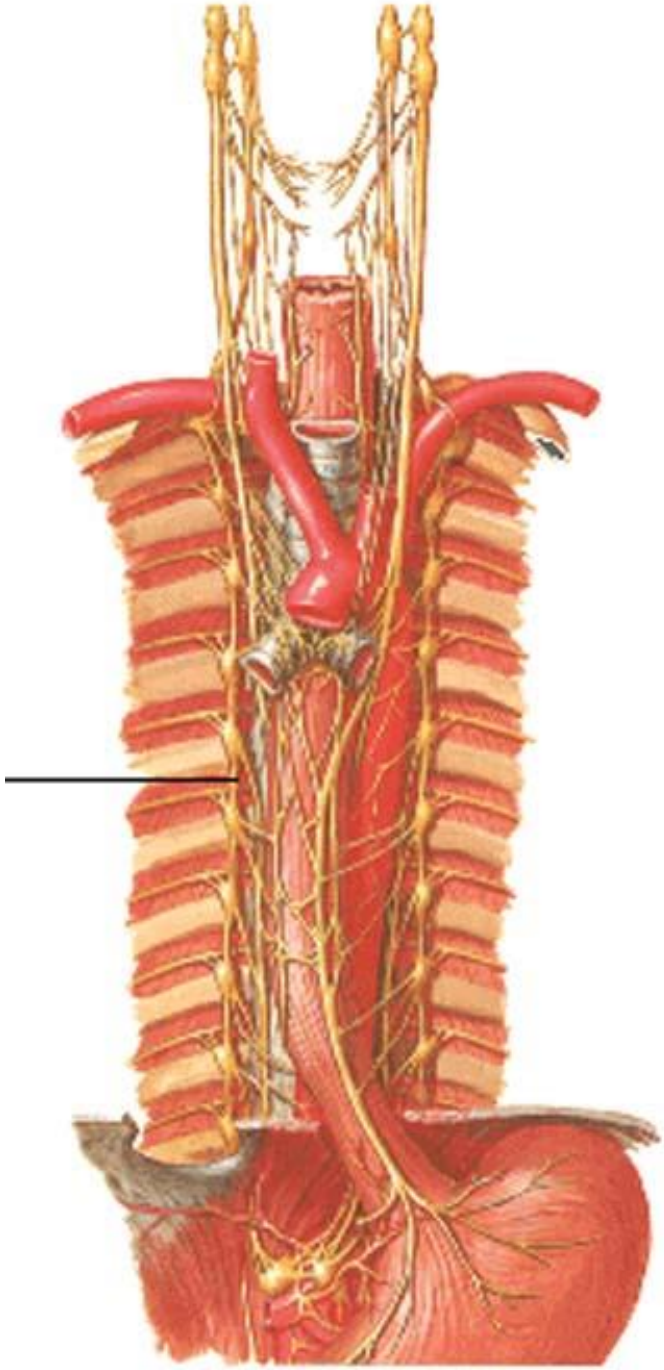
Truncus sympathicus

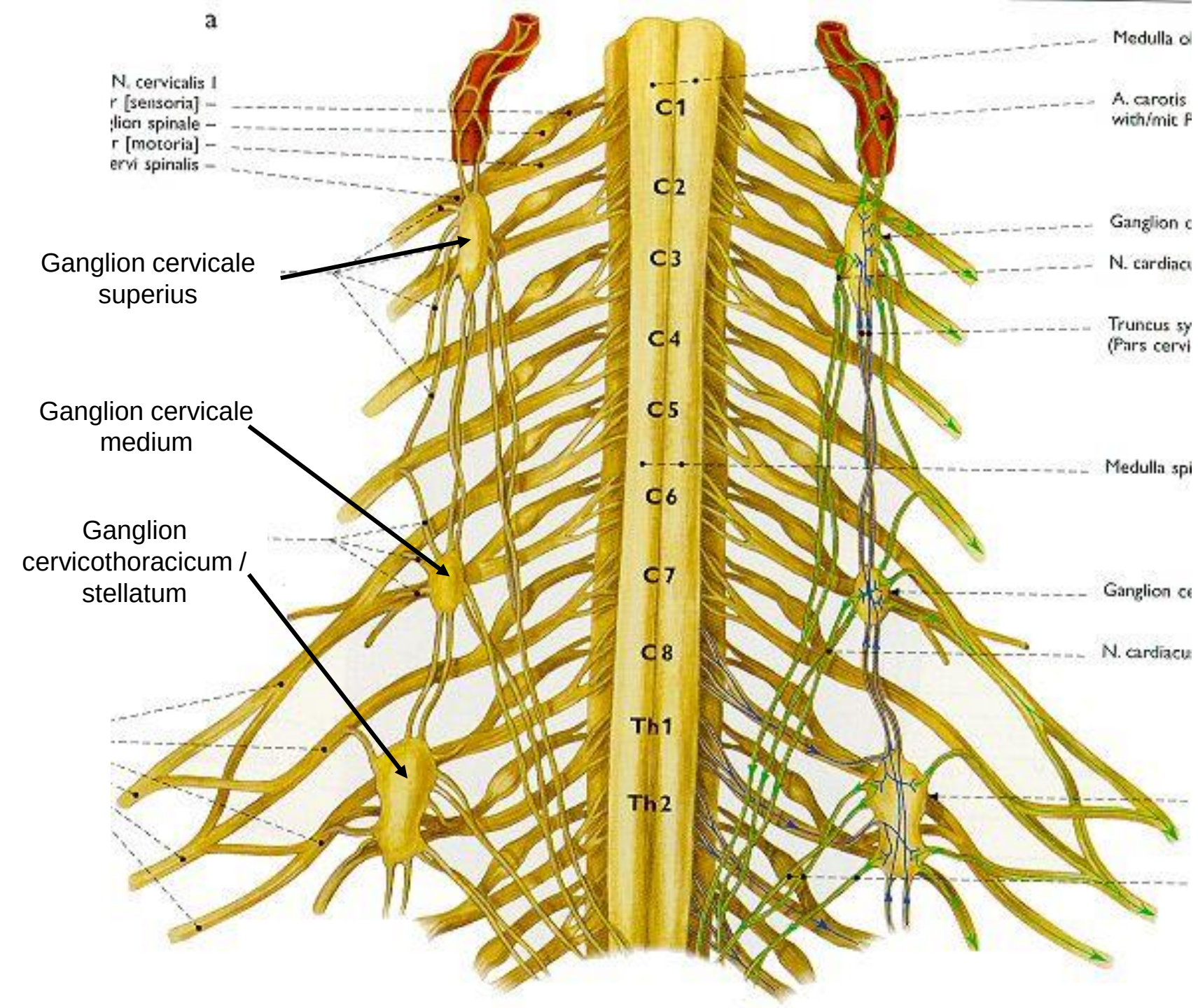
- ganglion trunci sympathici (21-25) = *paravertebral ganglia*
- rr. intergaglionares
- rr. communicantes albus + griseus
- in front of vertebral column, on lateral sides of vertebrae within fascia
- spatium parapharyngeum (paraviscerale), mediastinum posterius, retroperitoneum

Ganglion cervicale superius

- rr. comunicantes grisei do C1-4 (+ n. XII)
- n. jugularis do n. IX a n. X.
- n. caroticus internus → **plexus caroticus internus**
  - nn. caroticotympanici
  - n. petrosus profundus → (ggl. pterygopalatinum)
  - plexus ophthalmicus → (ggl. ciliare)
    → rr. orbitales → *m. orbitalis + mm. tarsales*
- n. caroticus externus → **plexus caroticus externus**
  - plexus a. meningeae mediae → (ggl. oticum)
  - plexus a. facialis → (ggl. submandibulare)
- nn. laryngopharyngei → plexus pharyngeus
- n. cardiacus cervicalis superior → plexus cardiacus



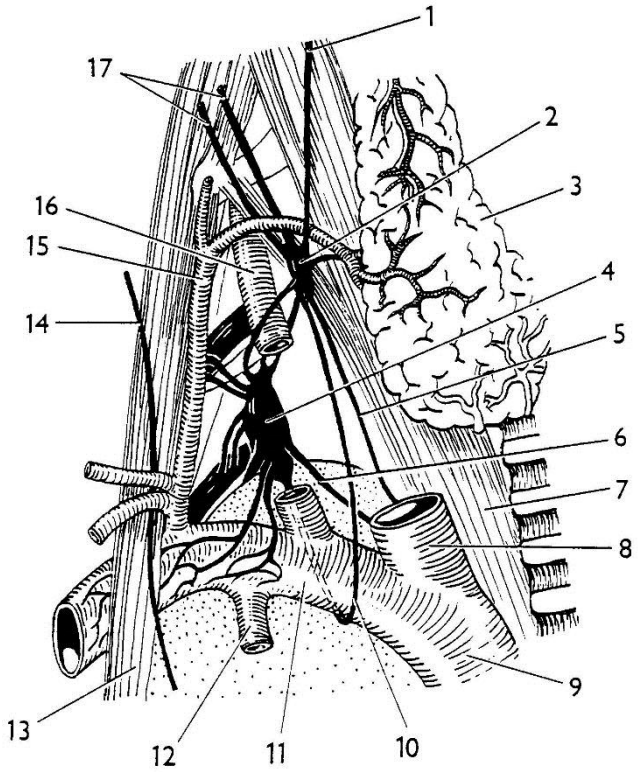



a
N. cervicalis I
r [sensoria] –
lion spinale –
r [motoria] –
ervi spinalis –
C1
C2
C3
C4
C5
C6
C7
C8
Th1
Th2
Medulla o
A. carotis
with/mit
Ganglion c
N. cardiac
Truncus sy
(Pars cervi
Medulla spi
Ganglion c
N. cardiacu
Ganglion cervicale superius
Ganglion cervicale medium
Ganglion cervicothoracicum / stellatum

Ganglion cervicale medium

- rr. comunicantes grisei into C5-6
- branches to plexus thyroideus inferior
- n. cardiacus cervicalis medius → plexus cardiacus

- ansa subclavia *(Vieussensi)*
  - loop to ggl. cervicothoracicum / stellatum in front of arteria subclavia



Ganglion cervicothoracicum / stellatum

= ggl. cervicale inferius + thoracicum primum (90%)

← rr. communicantes albi from C8-T3

- rr. communicantes grisei into C7-T3
- plexus subclavius
- n. vertebralis → plexus vertebalis
- n. cardiacus cervicalis inferior → plexus cardiacus

Claude Bernard-Horner´s syndrome

- **Johann Friedrich Horner** (1831–1886) ophthalmologist, Switzerland

- **Claude Bernard** (1813–1878) physiologist, France

Claude Bernard-Horner´s syndrome

- **miosis (→ anisocoria)**
- **ptosis**
- **anhidrosis**
- **enophthalmus**

disturbance of cervical sympathetic system

Claude Bernard-Horner´s syndrome

- in children (inborn Horner‘s syndrome) sometimes leads to a difference in eye color between the two eyes = *heterochromia*
- mnemonics „Horny **PAMEL**a"

for **P**tosis, **A**nhidrosis, **M**iosis, **E**nophthalmos and **L**oss of ciliospinal reflex

- **ciliospinal reflex** = dilation of the ipsilateral pupil on painful stimulation of the skin at the side of the neck

CBH sy

- *First-order neuron disorder:*

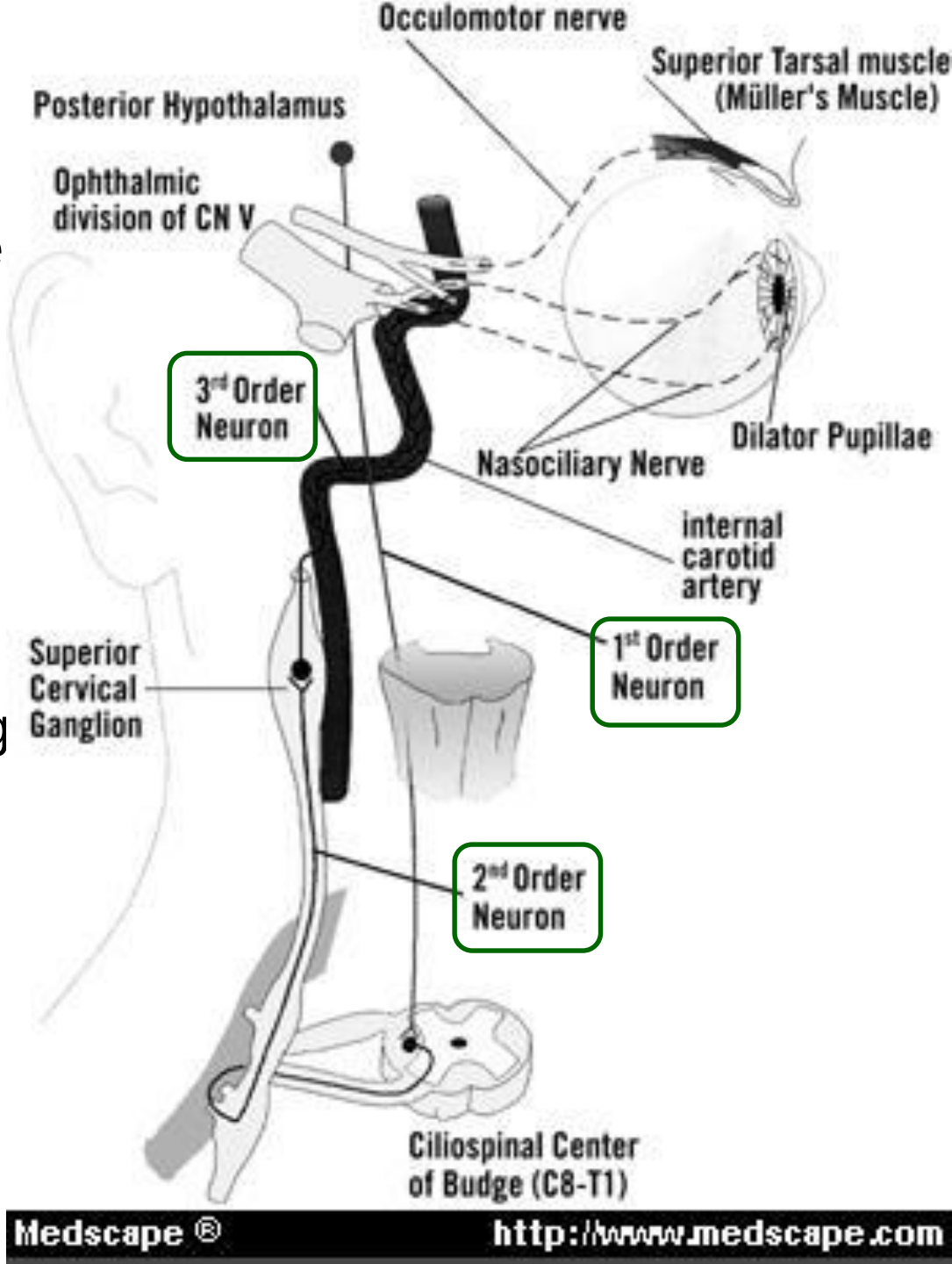
central lesions that involve the **hypothalamospinal pathway** (e.g. transsection of the cervical spinal cord)

- *Second-order neuron disorder:*

preganglionic lesions (e.g. compression of the sympathetic chain by a lung tumor)

- *Third-order neuron disorder:*

postganglionic lesions at the level of the internal carotid artery (e.g. a tumor in the sinus cavernosus)

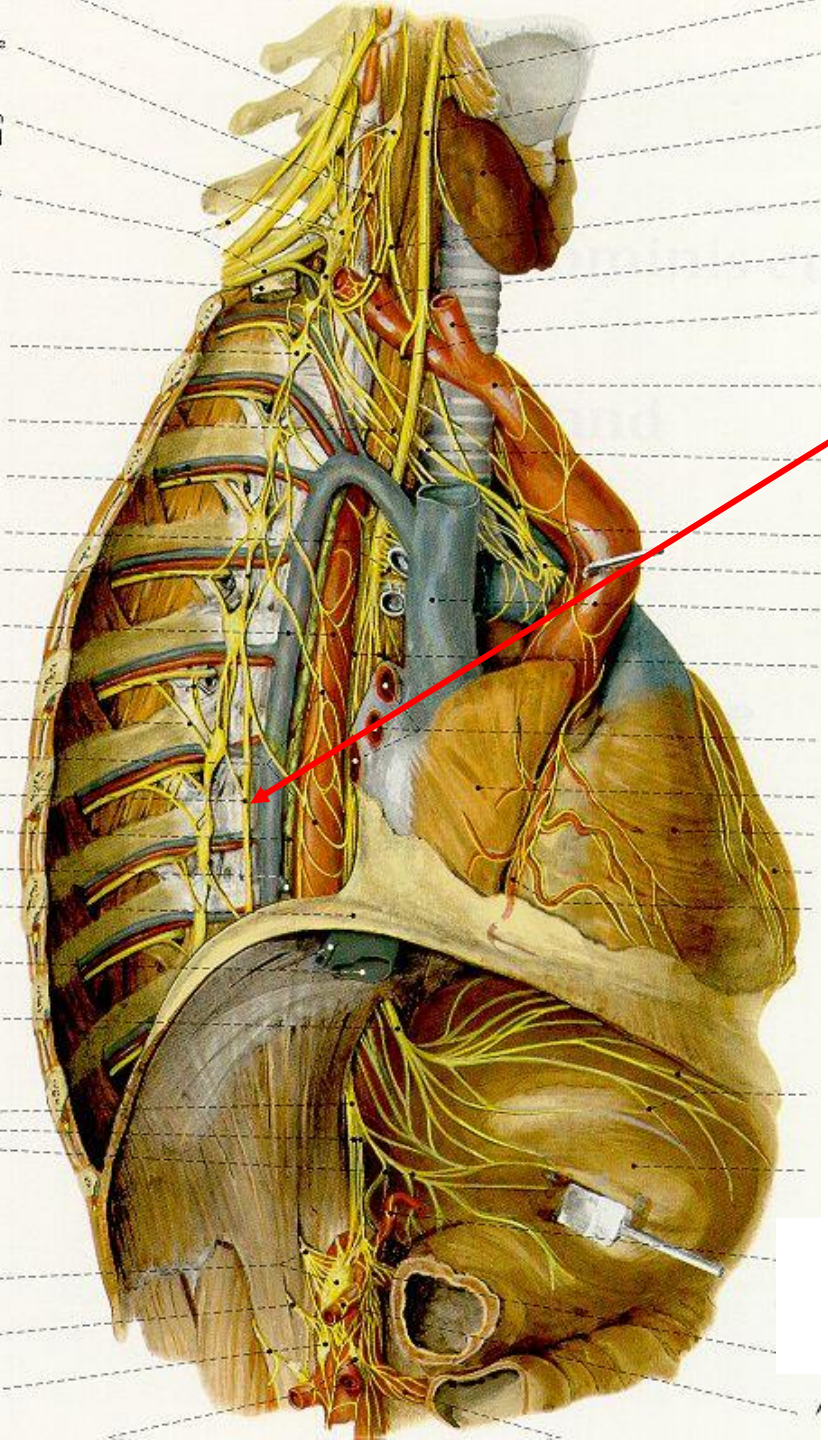


Ganglia thoracica

10 pairs of ganglia (90 %) ← rr. communicantes albi

- rr. communicantes grisei into nn. intercostales
- rr. vaculares → plexus aorticus thoracicus
- nn. cardiaci thoracici from T2-T4(5)
- rr. pulmonales thoracici from T2-4
- rr. oesophageales
- n. splanchnicus thoracicus major from T5(6)-9 → ggll. coeliaca
- n. splanchnicus thoracicus minor from T10,11 → ggll. coeliaca
- n. splanchnicus thoracicus imus from T12 → ggll. aorticorenalia

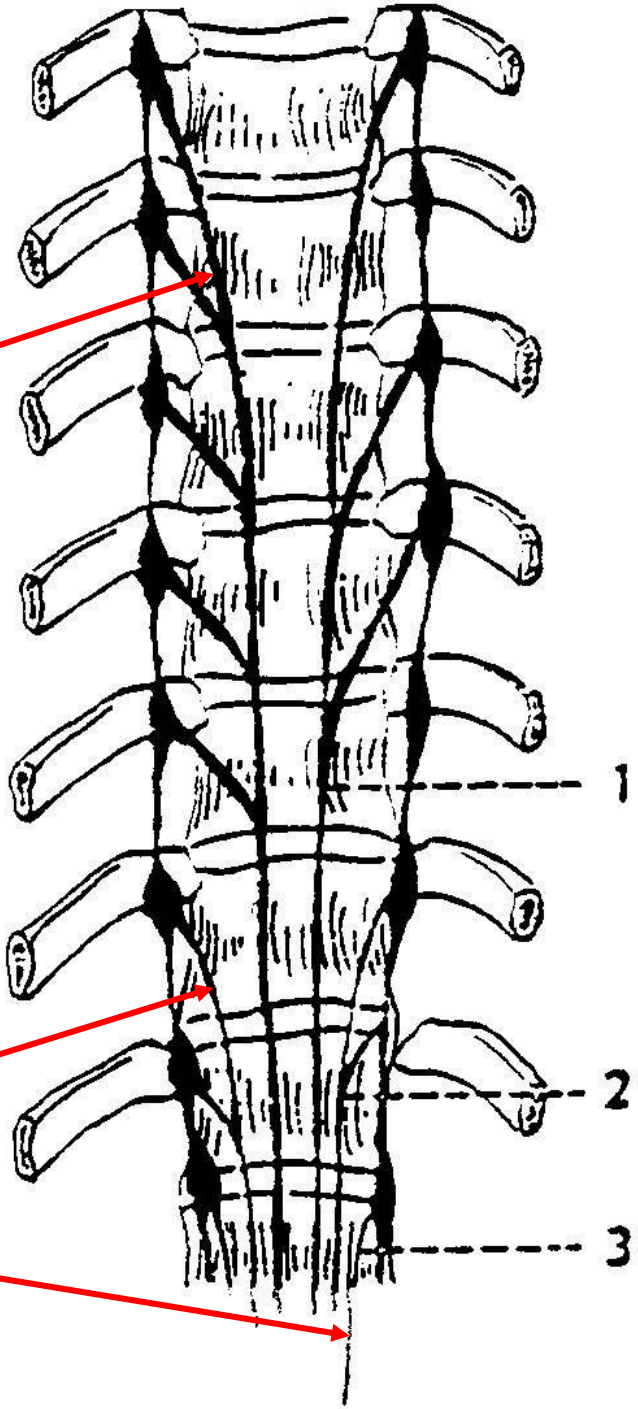
ganglia thoracica splanchnica are inserted in nn. splanchnici on their way

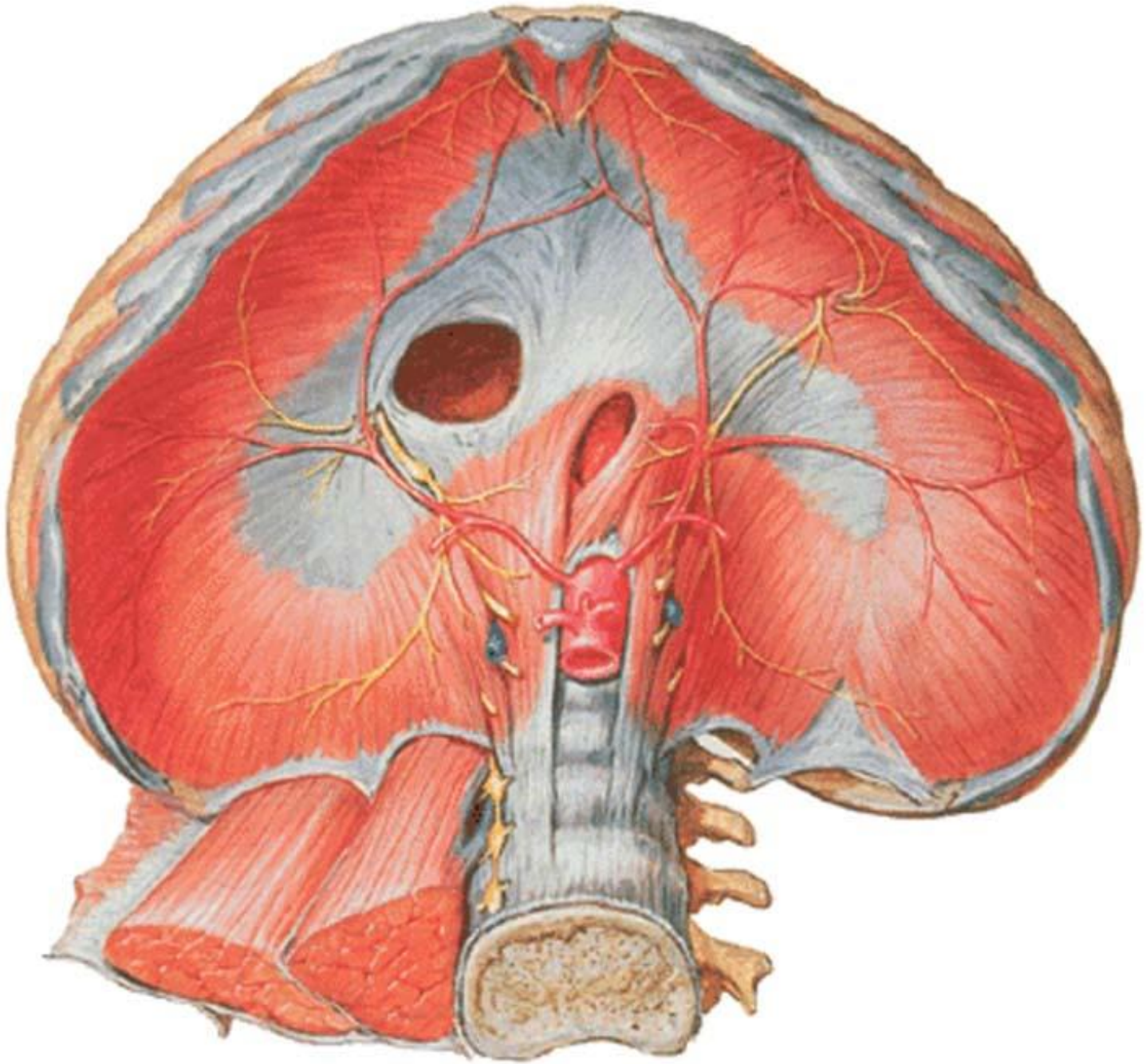


N. splanchnicus thoracicus **major** (T5/6-9)

N. splanchnicus thoracicus **minor** (T9-11)

N. splanchnicus thoracicus **imus** (T12)

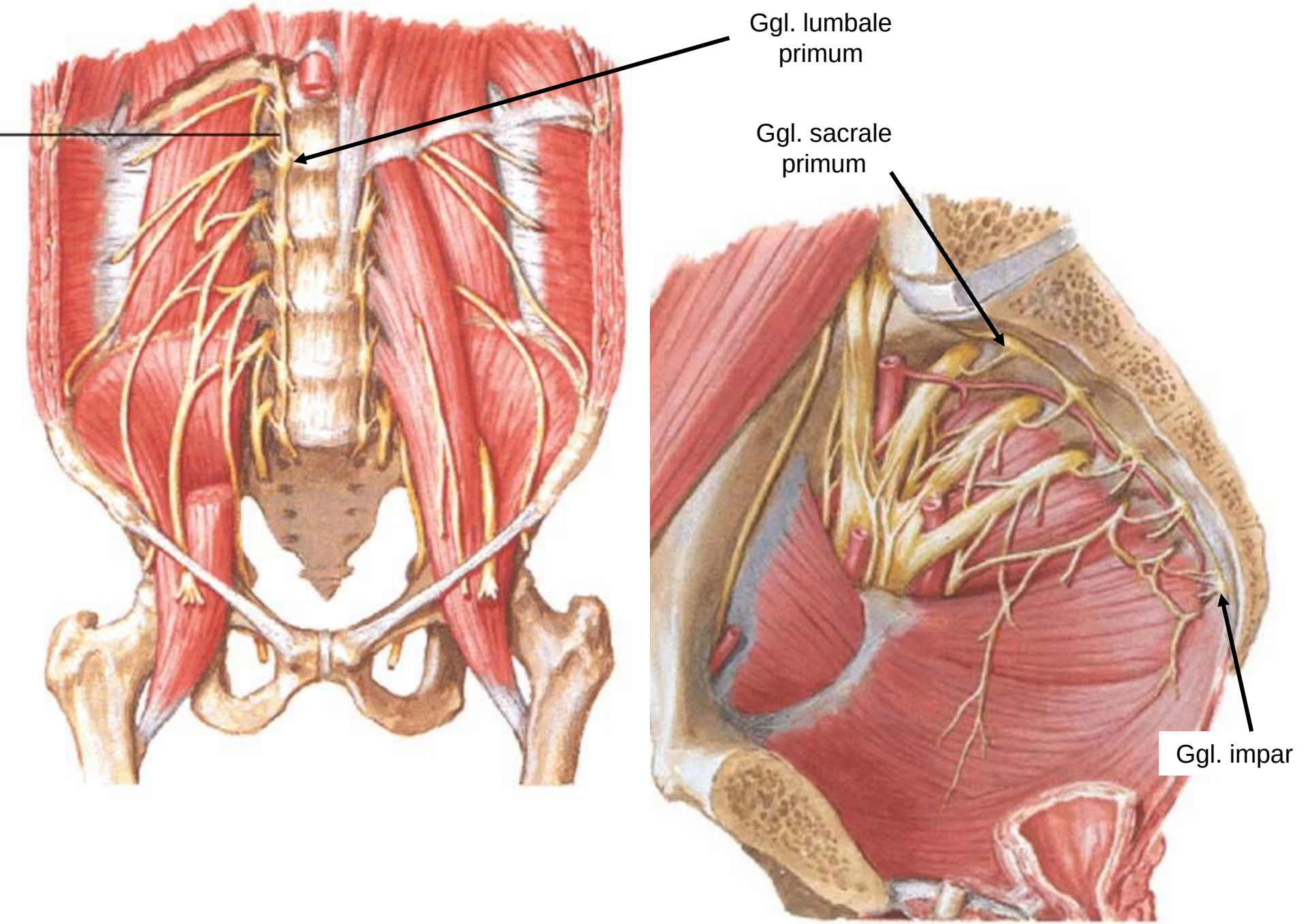




Ganglia lumbalia

4-5 pairs of ganglia ← rr. communicantes albi from L1-3 into upper 3 ganglia

- rr. communicantes grisei → nn. spinales lumbales
- rr. vasculares → plexus aa. lumbalium
- n. splanchnici lumbales 1-3 → plexus aorticus abdominalis
- n. splanchnici lumbales 4-5 → plexus hypogastricus superior


Ggl. lumbale primum
Ggl. sacrale primum
Ggl. impar

Ganglia sacralia

4 pairs of ganglia + unpaired ganglion impar

rr. communicantes grisei → nn. spinales sacrales

- rr. vasculares → plexuses around parietal branches from a. iliaca interna
- n. splanchnici sacrales S1-S4 → plexus hypogastricus superior

ansa sacralis – loop between ganglia sacralia quarta and ganglion impar

Plexus aorticus abdominalis

sympathetic fibers: nn. splanchnici thoracici (major, minor, imus), lumbales 1-3

parasympathetic fibers: rr. coeliaci nn. vagorum

mixed plexus around aorta abdominalis + prevertebral ganglia

- paired **ggl. coelicum** + **ggl. aorticorenale**
- unpaired **ggl . mesentericum sup. + inf.**

→ along arteries → homonymous plexuses

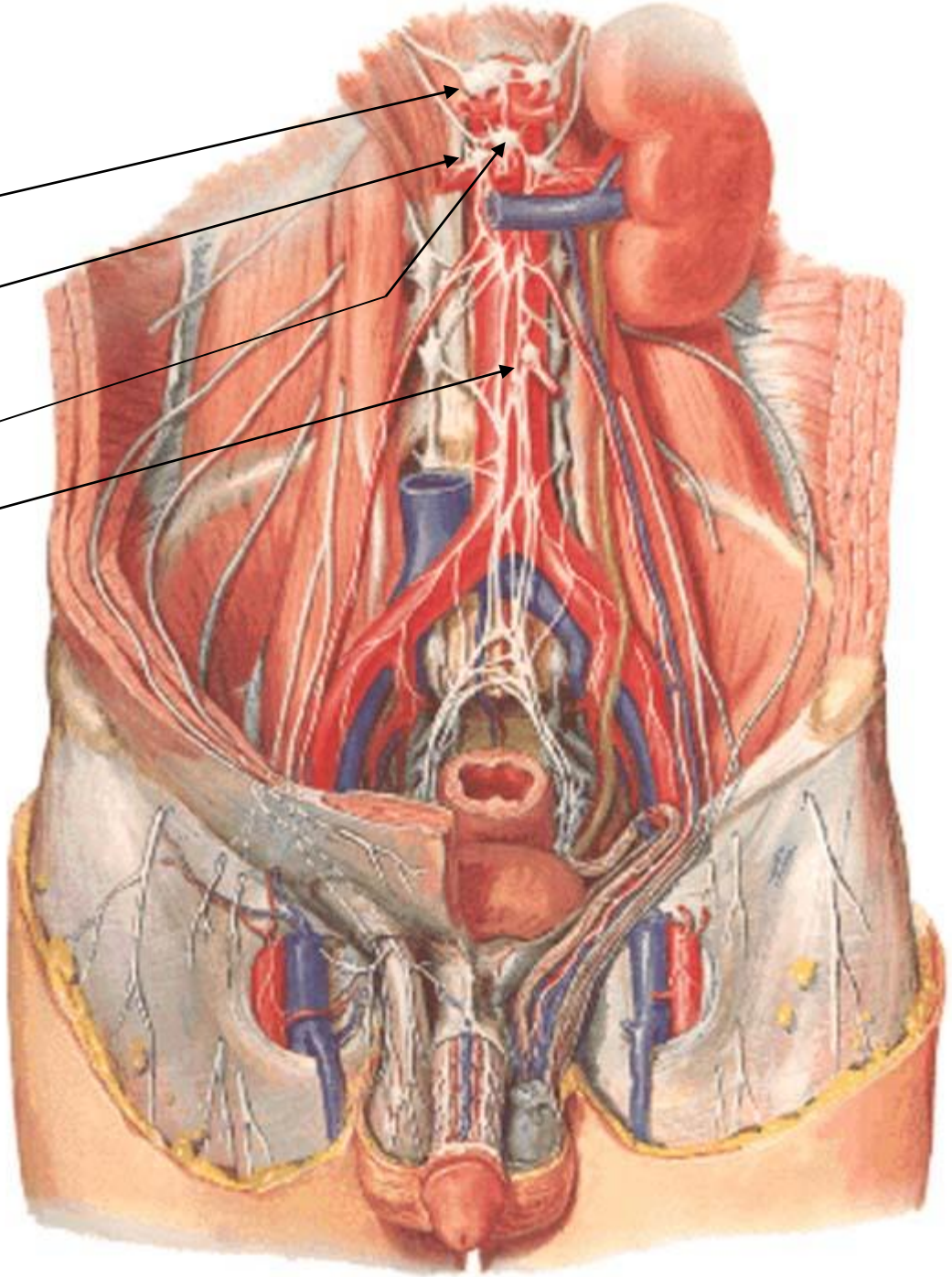
- stomach → oral majority of rectum (enteric system), pancreas, liver
- spleen, suprarenal glands, kidneys, ureters, testes♂ / ovaries♀, uterine tubes (1/2) ♀

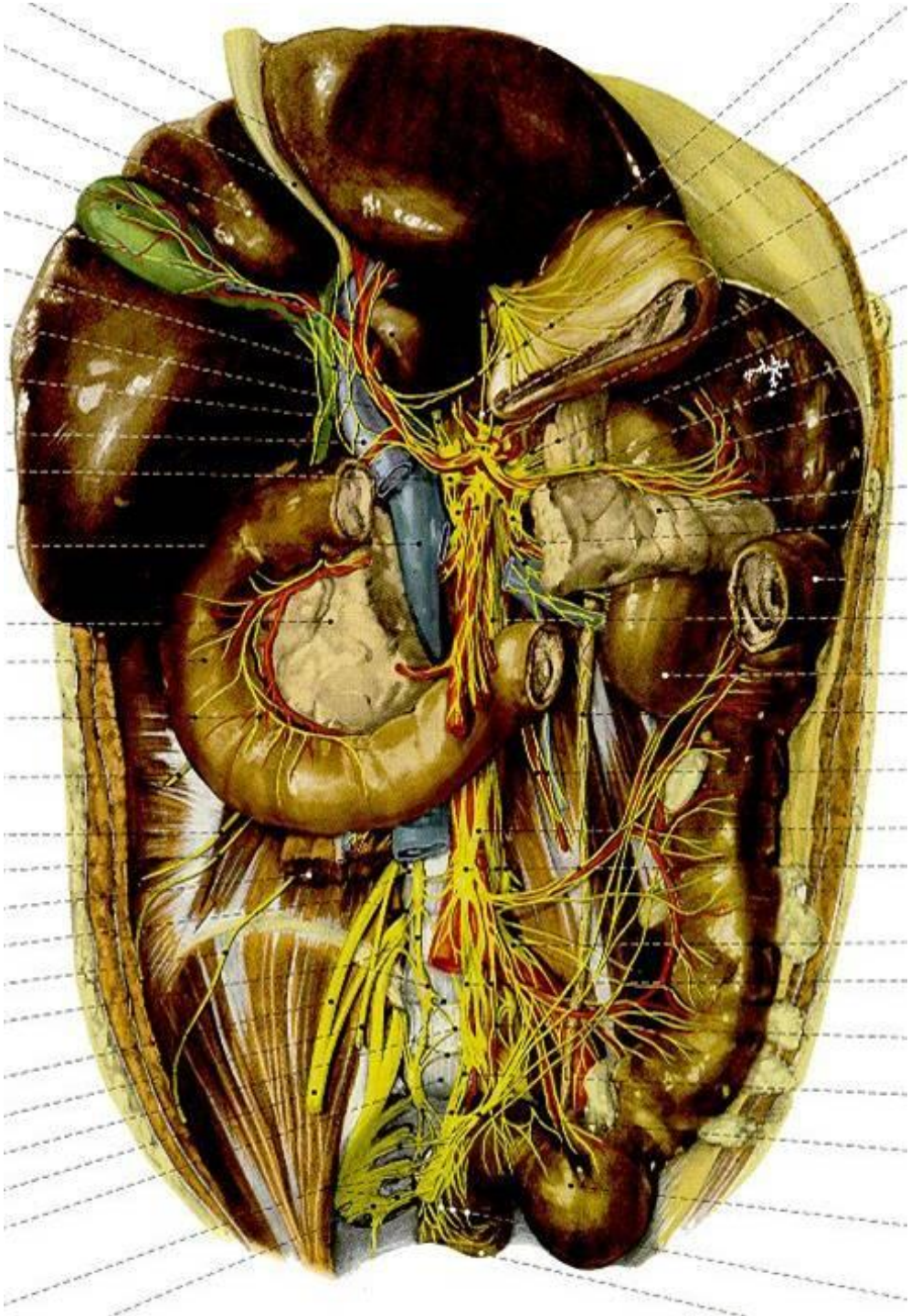
ggl. coelicum

ggl. aorticorenale

ggl. mesentericum sup.

ggl. mesentericum inf.





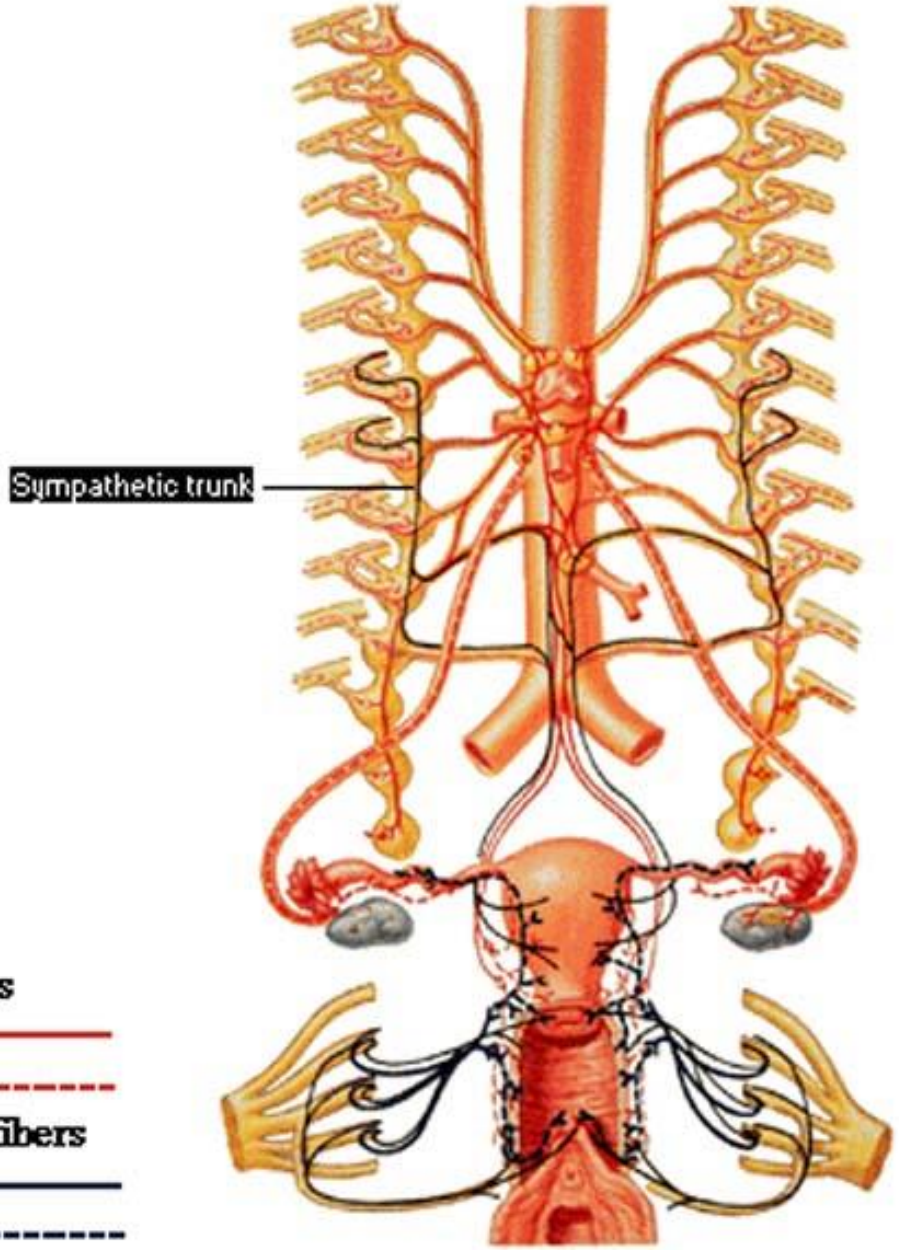
Plexus aorticus abdominalis continuation

- **plexus hypogastricus superior** (pure sympathetic (from bifurcatio across promontorium)

→ n. hypogastricus dx. + sin. → **plexus hypogastricus inferior** s. pelvicus (mixed plexus) → pelvic organs except ovaries♀, uterine tubes (1/2)♀, fundus uteri♀ and urinary bladder

- **plexus iliacus** dx. + sin. (pure sympathetic) → lower limb

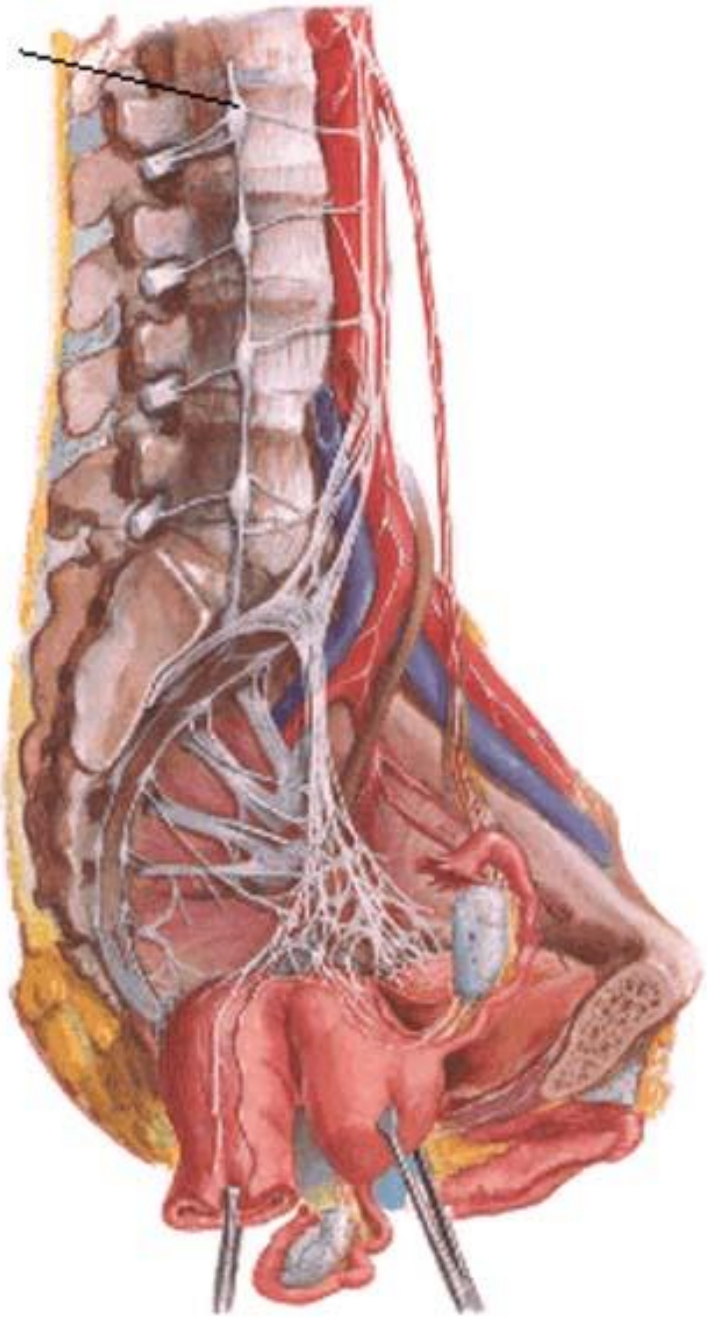
Innervation of Female Reproductive Organs

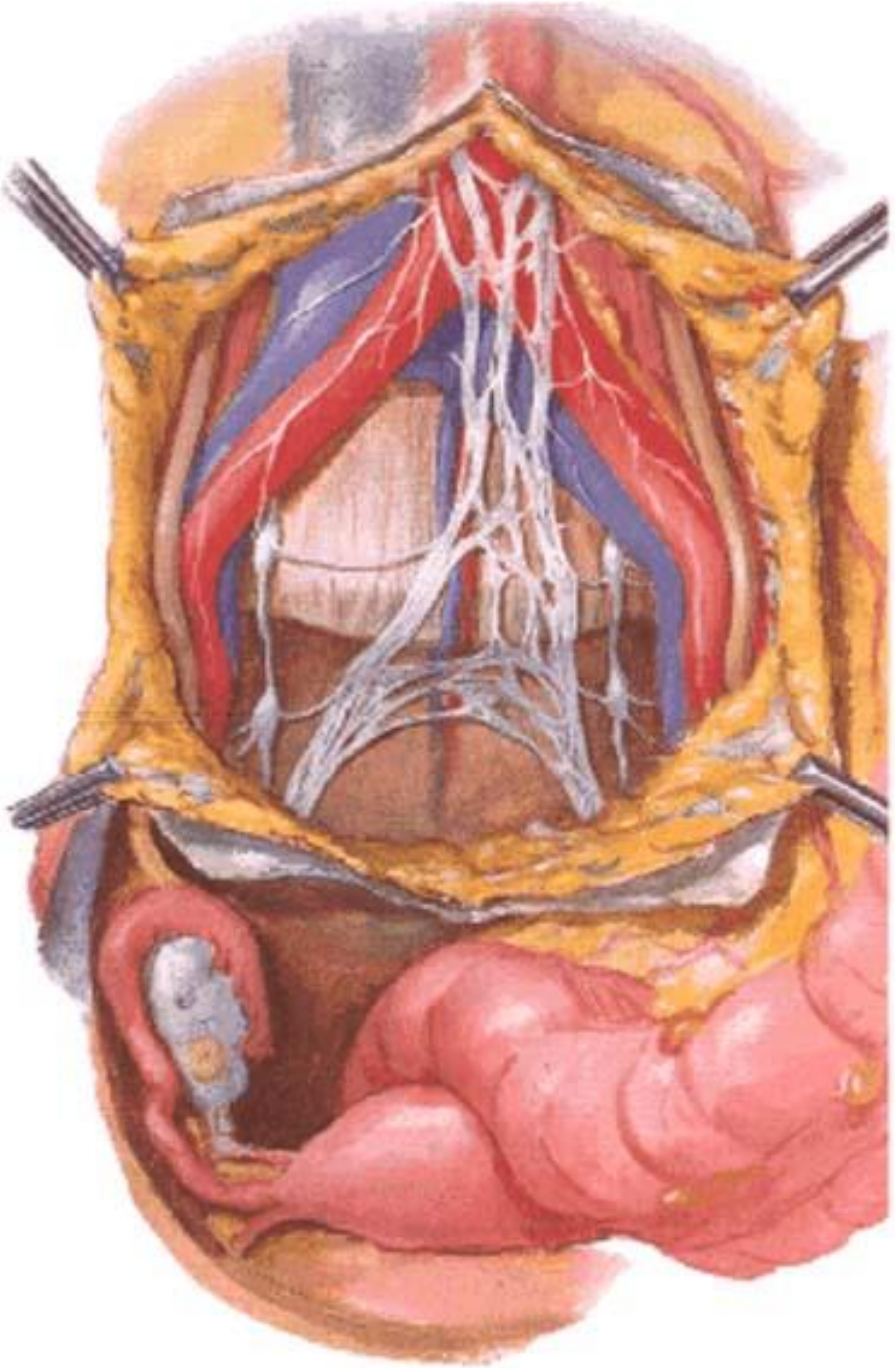


Sympathetic fibers
- Presynaptic
- Postsynaptic

Parasympathetic fibers
- Presynaptic
- Postsynaptic

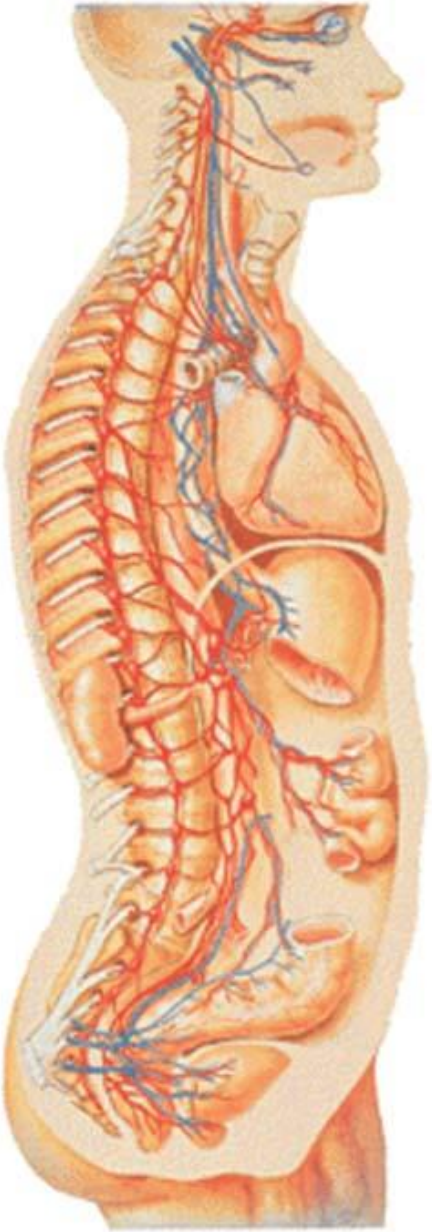
Afferent fibers



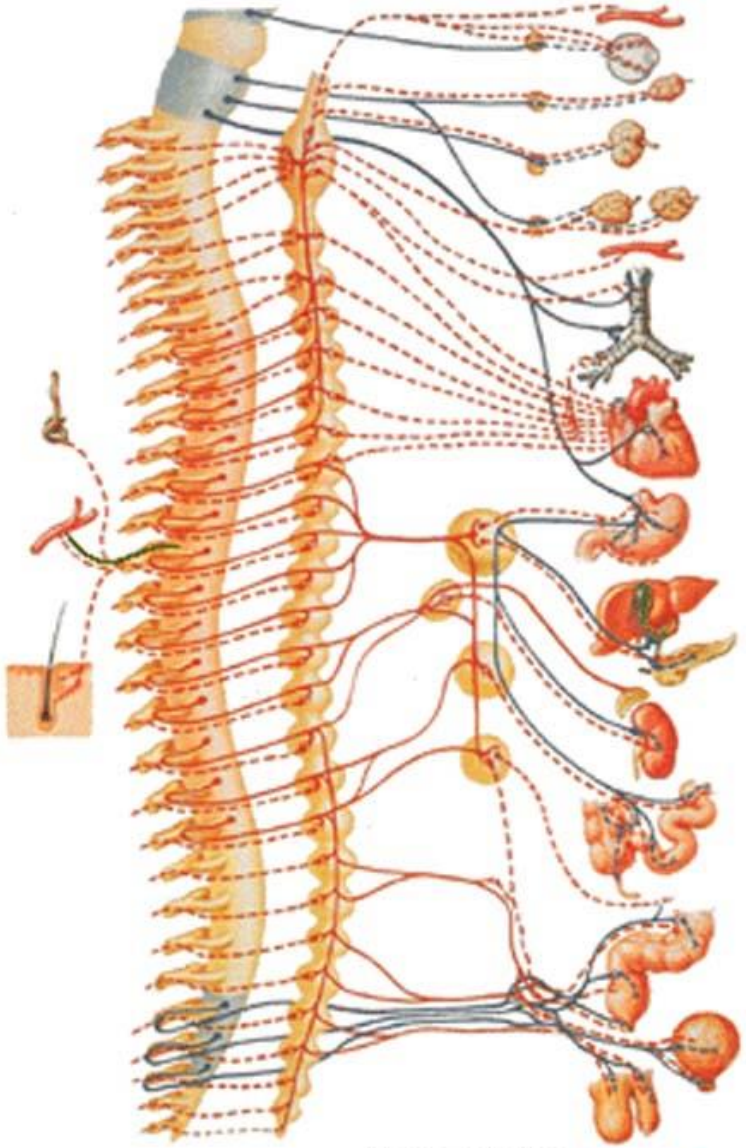


PARASYMPATHICUS

„kraniosakrální systém “



Sympathetic fibers
Parasympathetic fibers



Sympathetic fibers — Presynaptic
Postsynaptic
Parasympathetic fibers — Presynaptic
Postsynaptic
Antidromic conduction

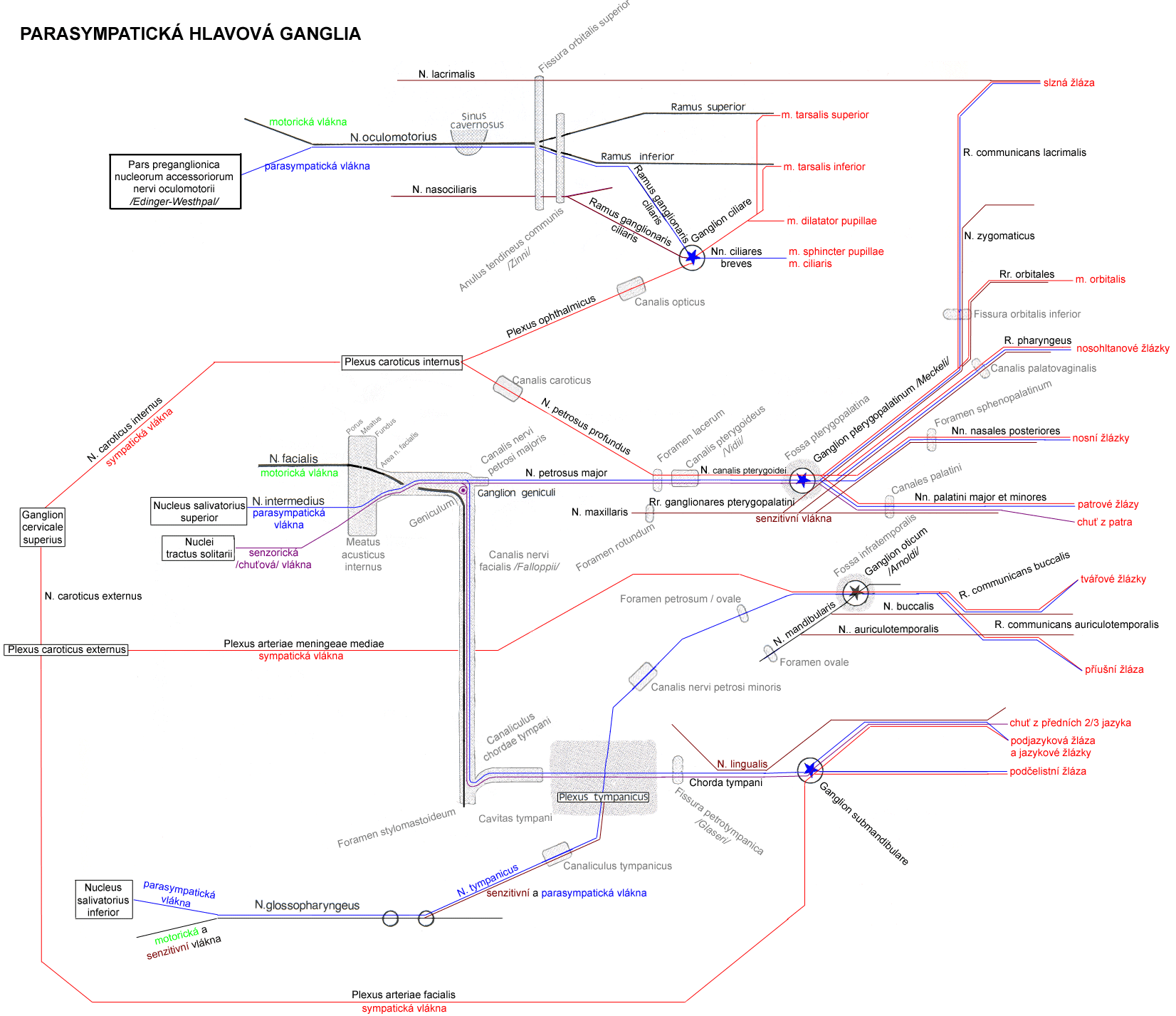
Parasympathetic part = „craniosacral system“

- nuclei of cranial nerves
  - preganglionic part of ncll. accessorii n. III *Edinger-Westphal*
  - ncl. salivatorius superior (VII.)
  - ncl. salivatorius inferior (IX.)
  - ncl. posterior n. X
- ncl. intermediolateralis S2-4

ganglia situated within skull or within organs walls

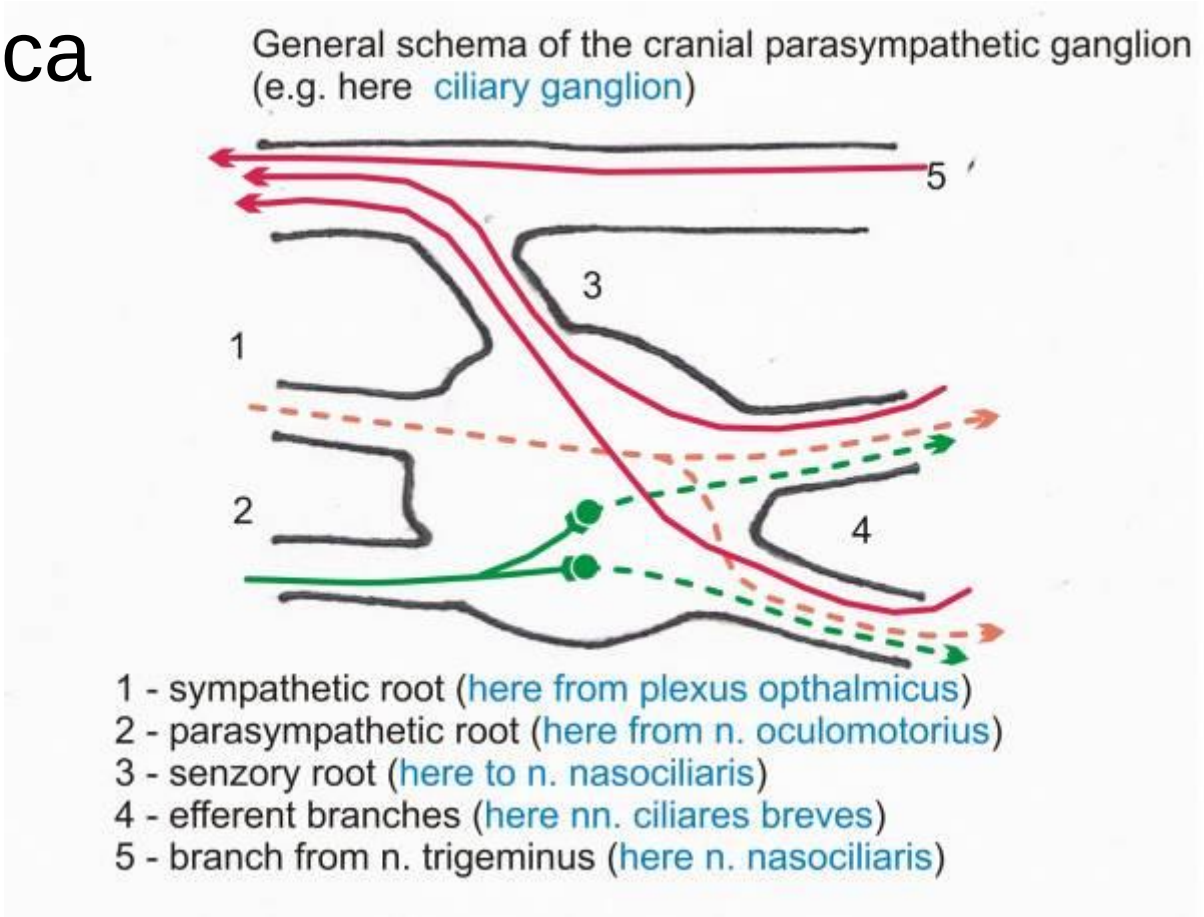
ganglia situated close to effector organs

PARASYMPATICKÁ HLAVOVÁ GANGLIA



Gerenal schme of parasympathetic ganglion

- radix parasympatica
- radix sympathica
- radix sensoria



Ganglion ciliare *Schacheri*

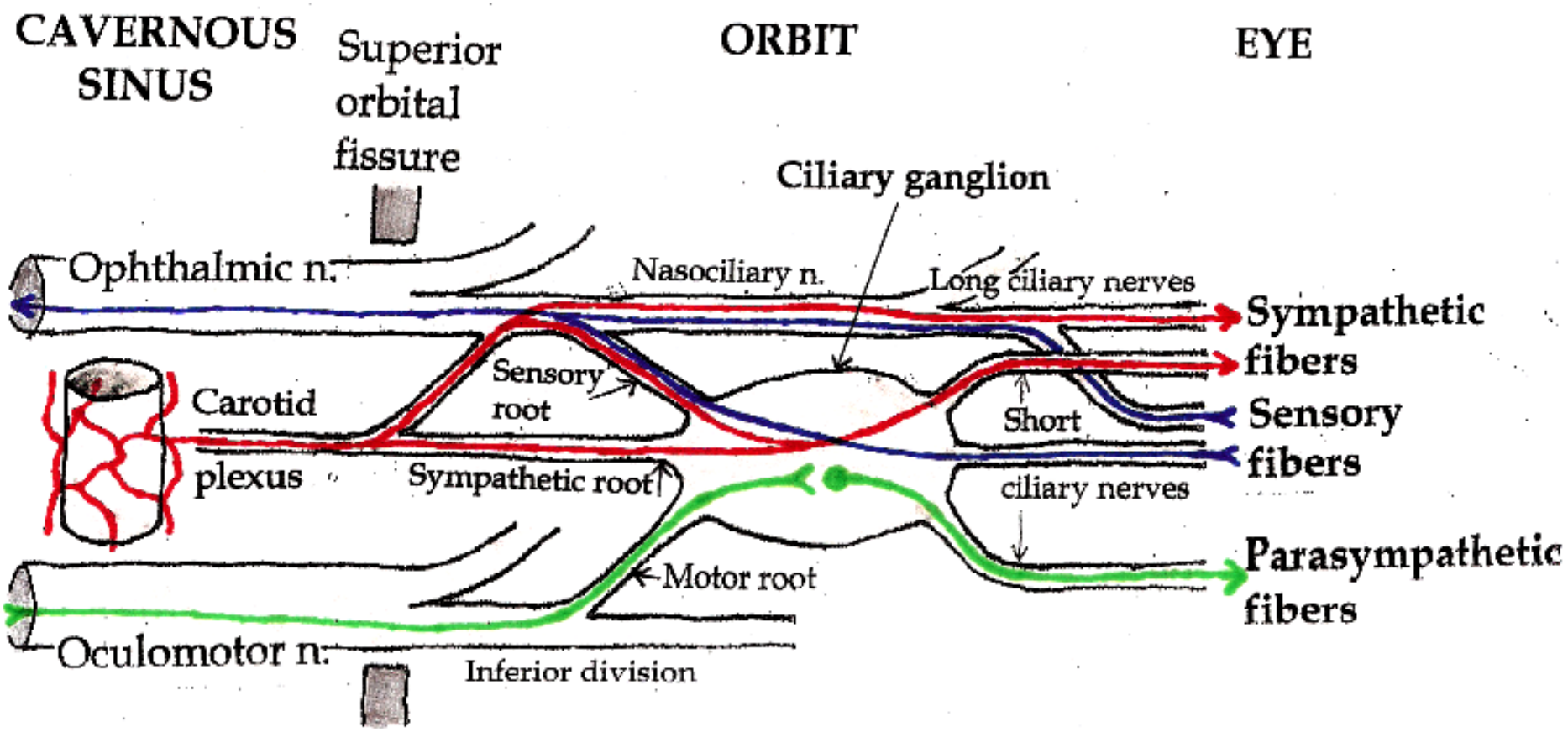
- orbit
- dorsally to bulbus oculi and laterally to n. opticus

AF-PS: preganglionic part of ncll. accessorii n. III *Edinger-Westphal* → n.III → ramus ganglionaris ciliaris

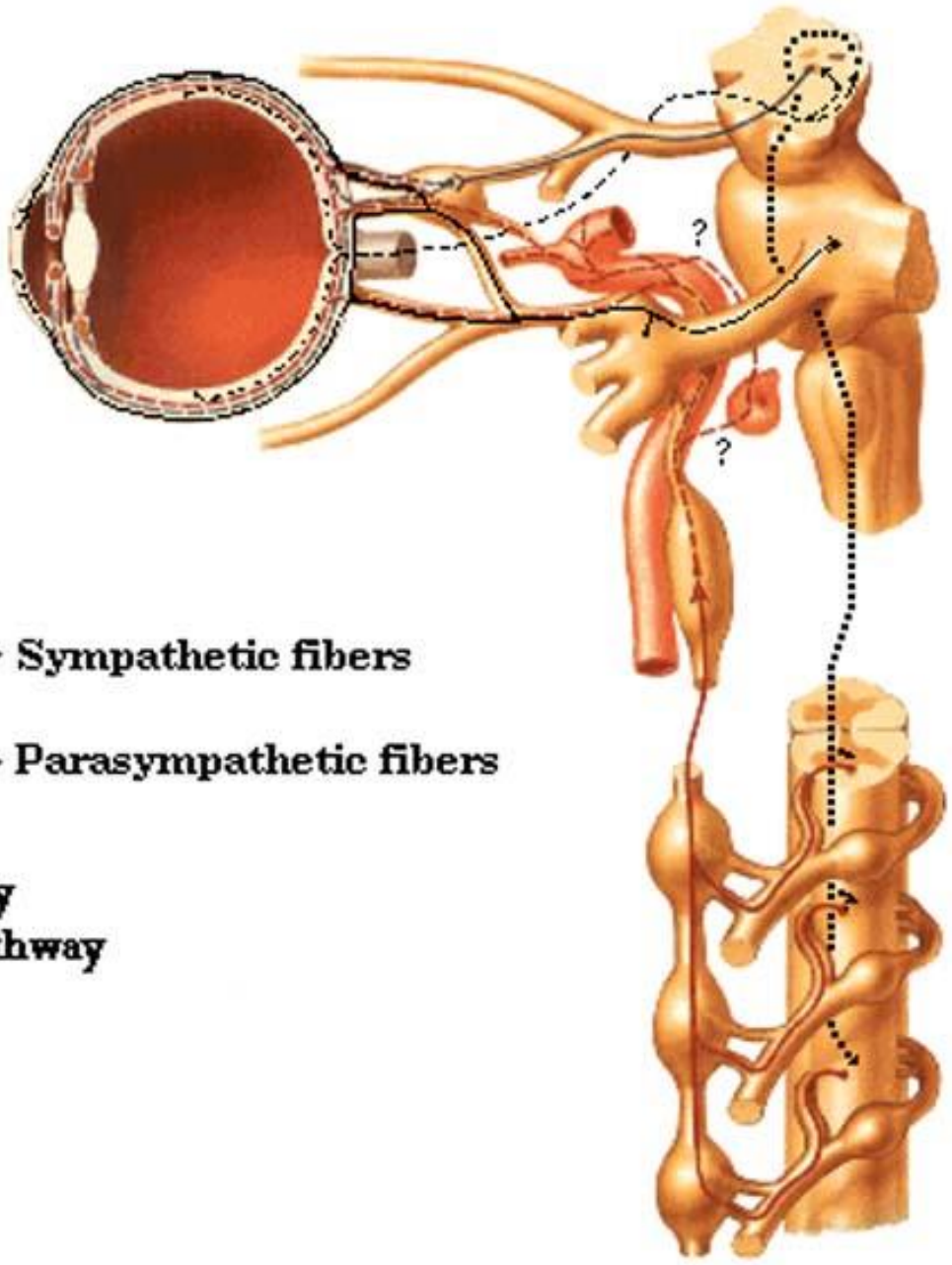
AF-S: ncl. intermediolateralis C8-T1 → ggl. cervicale superius → n. et plexus caroticus internus → plexus ophthalmicus (not synapsed)

EF: nn. ciliares breves (mixed) → **m. ciliaris, m. sphincter pupillae**, m. dilatator pupillae, m. tarsalis sup. + inf. (m. orbitalis)

Ganglion ciliare *Schacheri*



Ciliary Ganglion



Presynaptic
Postsynaptic
} Sympathetic fibers

Presynaptic
Postsynaptic
} Parasympathetic fibers

Afferent fibers

Visual pathway

Descending pathway

Ganglion pterygopalatinum *Meckeli*

- fossa pterygopalatina, below n. maxillaris

AF-PS: ncl. salivatorius superior (VII.) → n. VII → n. intermedius → n. petrosus major → n. canalis pterygoidedi *Vidii* (mixed) →

AF-S: ncl. intermediolateralis C8-T1 → ggl. cervicale superius → n. et plexus caroticus internus → n. petrosus profundus → n. canalis pterygoidedi *Vidii* (mixed) → (not synapsed in ganglion)

EF: → n. zygomaticus → r. communicans lacrimalis → **gl. lacrimalis**

EF: → rr. nasales posteriores → **gll. nasales**

EF: → nn. palatini major + minores → **gll. palatinae**

EF: → n. pharyngeus → **gll. nasopharyngeae**

Ganglion submandibulare *Langleyi*

- trigonum submandibulare
- at crossing of n. lingualis and ductus submandibularis

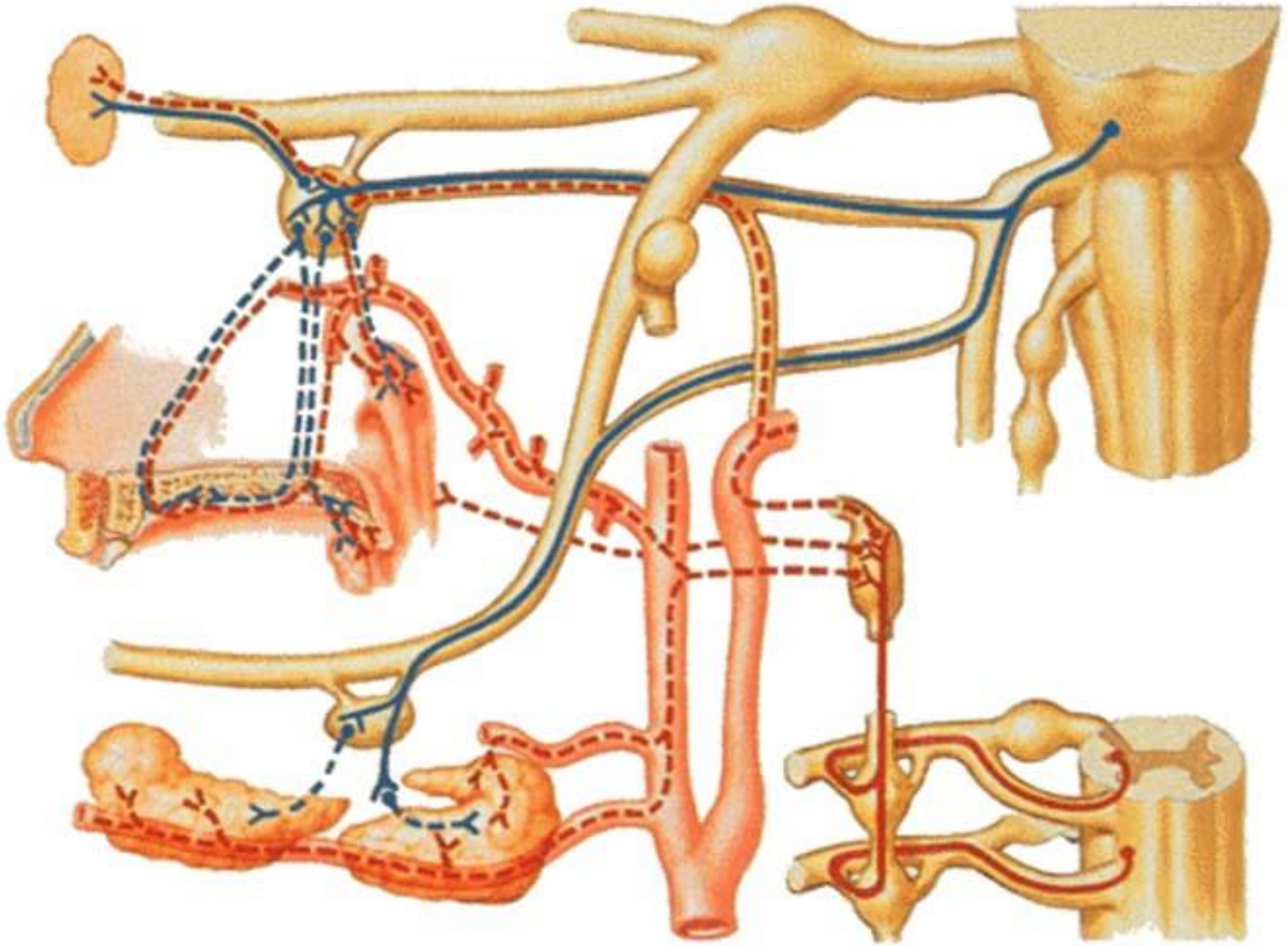
AF-PS: ncl. salivatorius superior (VII) → n. intermedius → n. VII → chorda tympani → n. lingualis (from n.V3) → r. communicans lingualis

AF-PS: ncl. intermediolateralis C8-T1 → ggl. cervicale superius → n. et plexus caroticus externus → plexus a. facialis (not synapsed)

EF: n. lingualis → **gl. sublingualis + gll. linguales**

EF: rr. glandulares → **gl. submandibularis**

Pterygopalatine and Submandibular Ganglia



Sympathetic presynaptic fibers
Sympathetic postsynaptic fibers
Parasympathetic presynaptic fibers
Parasympathetic postsynaptic fibers

Ganglion oticum *Arnoldi*

- fossa infratemporalis, medially to n. mandibularis

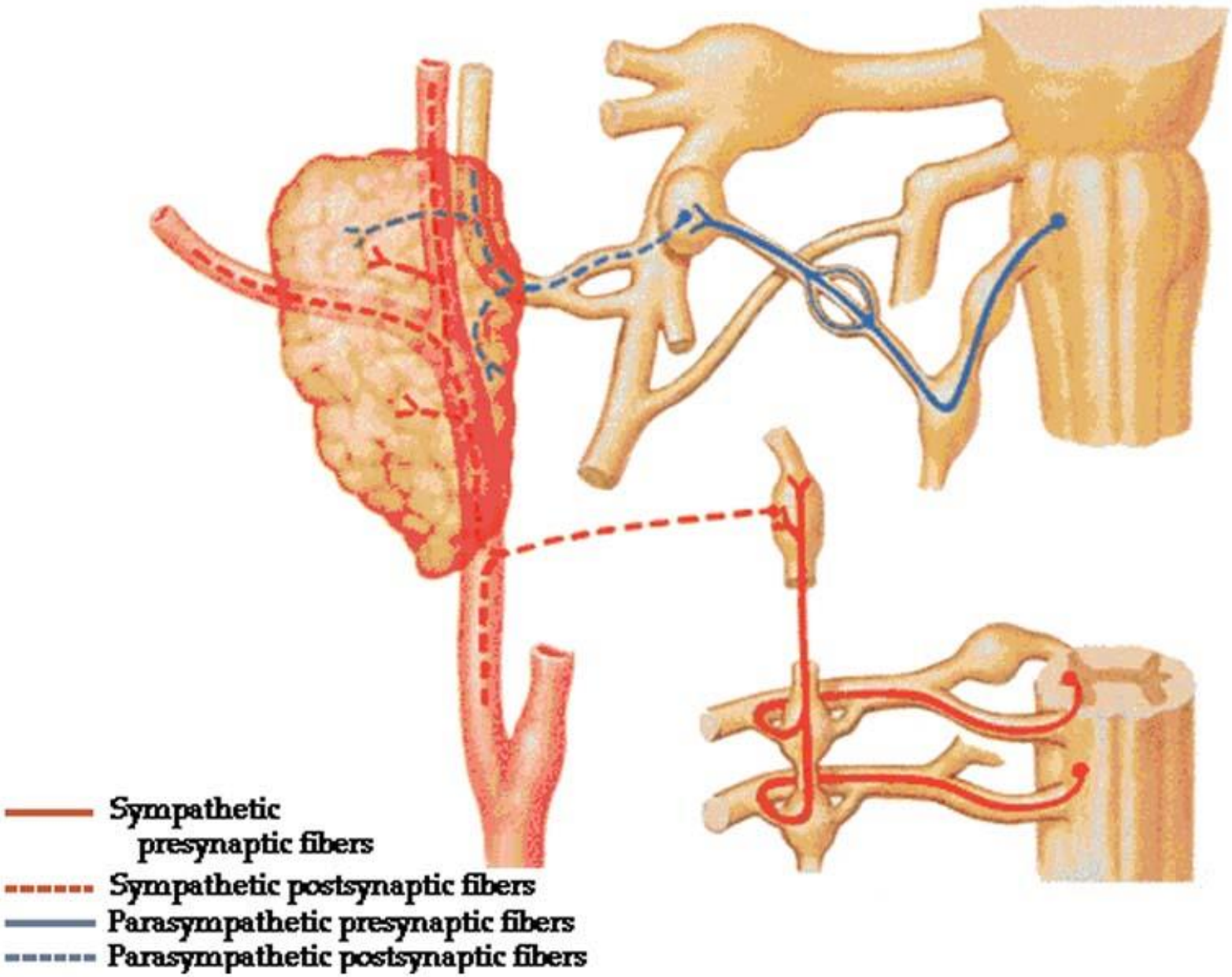
AF-PS: ncl. salivatorius inferior (IX.) → n. IX → n. tympanicus → plexus tympanicus → n. petrosus minor

AF-S: ncl. intermediolateralis C8-T1 → ggl. cervicale superius → n. et plexus caroticus externus → plexus a. meningeae mediae (not synapsed)

EF: r. communicans auriculotemporalsi (mixed) → n. auriculotemporalis → **gl. parotidea**

→ r. communicans buccalis (mixed) → n. buccalis → **gll. buccales**

Otic Ganglion



Plexus hypogastricus inferior s. pelvicus

mixed plexus

AF-PS: nn. splanchnici pelvici S2-4 (*obsoletely nn. erigentes*)

AF-S: truncus sympathicus → plexus aorticus abdominalis → plexus hypogastricus superior → nn. hypogastrici

AF-S: truncus sympathicus → ganglia sacralia → nn. splanchnici sacrales

- pelvic organs except ovaries♀, uterine tubes (1/2)♀, fundus of uterus♀ and fundus of urinary bladder

EF (mixed): → plexus rectalis (aboral minority of rectum)

→ parasympathetic fibers ascend as orally as *Cannon-Bőhm´s* point = hindgut

→ plexus prostaticus + deferentialis♂/ uterovaginalis♀

→ plexus vesicalis

- m. sphincter urethrae (nucleus n. pudendi *Onufi* in spinal cord segments S2-4)

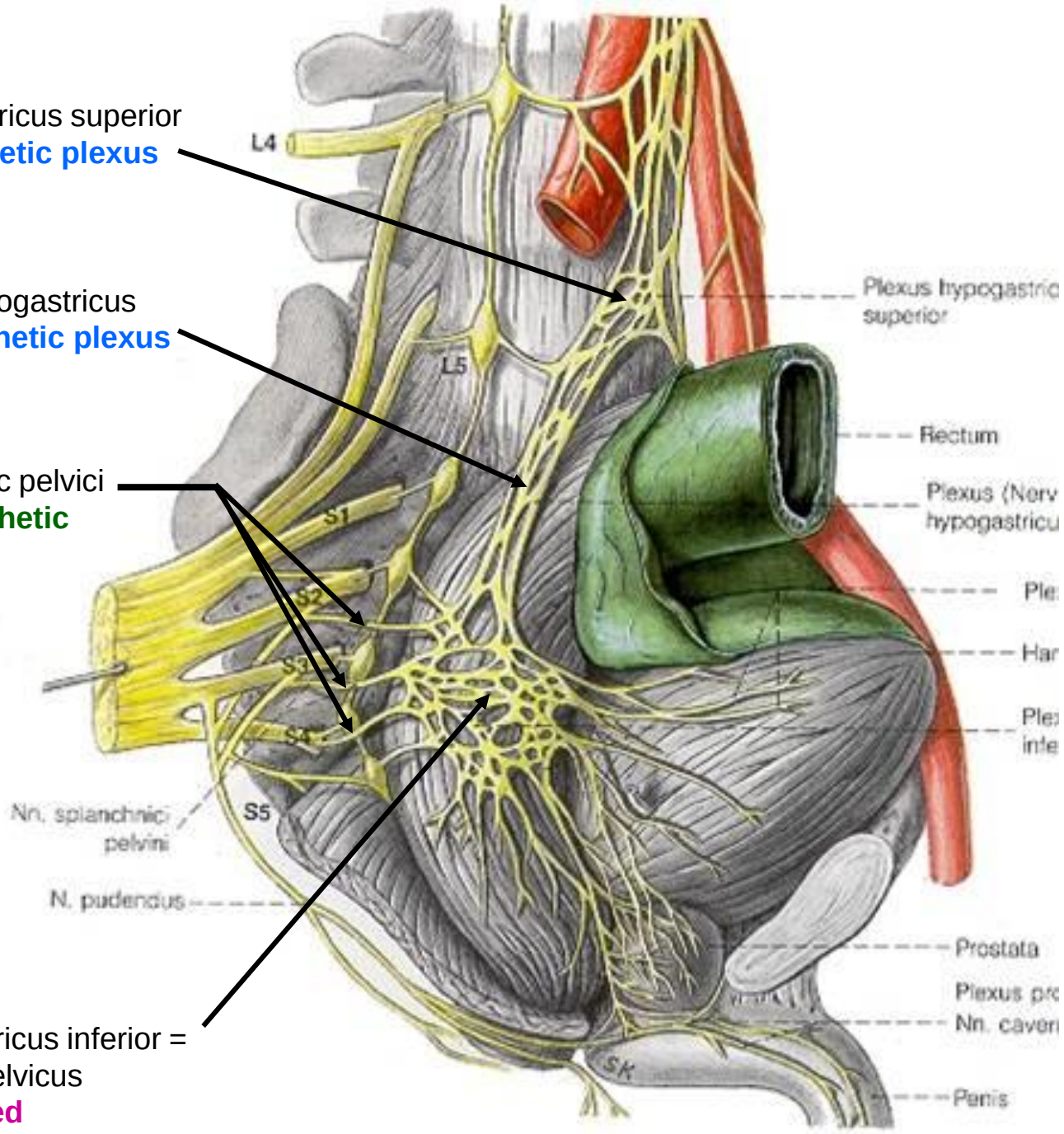
→ n. cavernosus penis ♂ / clitoridis ♀ (erectile bodies)

plexus hypogastricus superior
pure sympathetic plexus

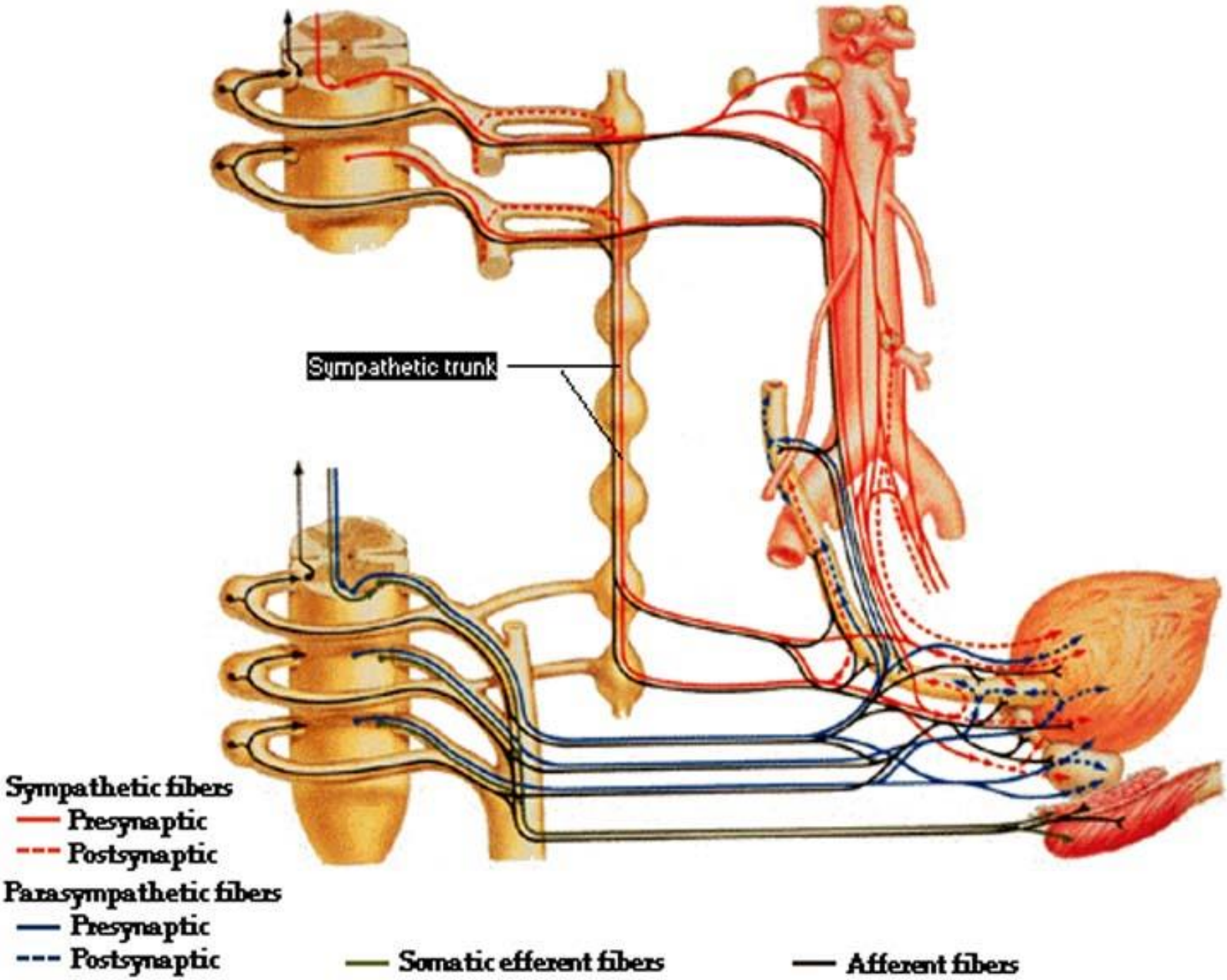
nervus hypogastricus
pure sympathetic plexus

nervi splanchnic pelvici
parasympathetic

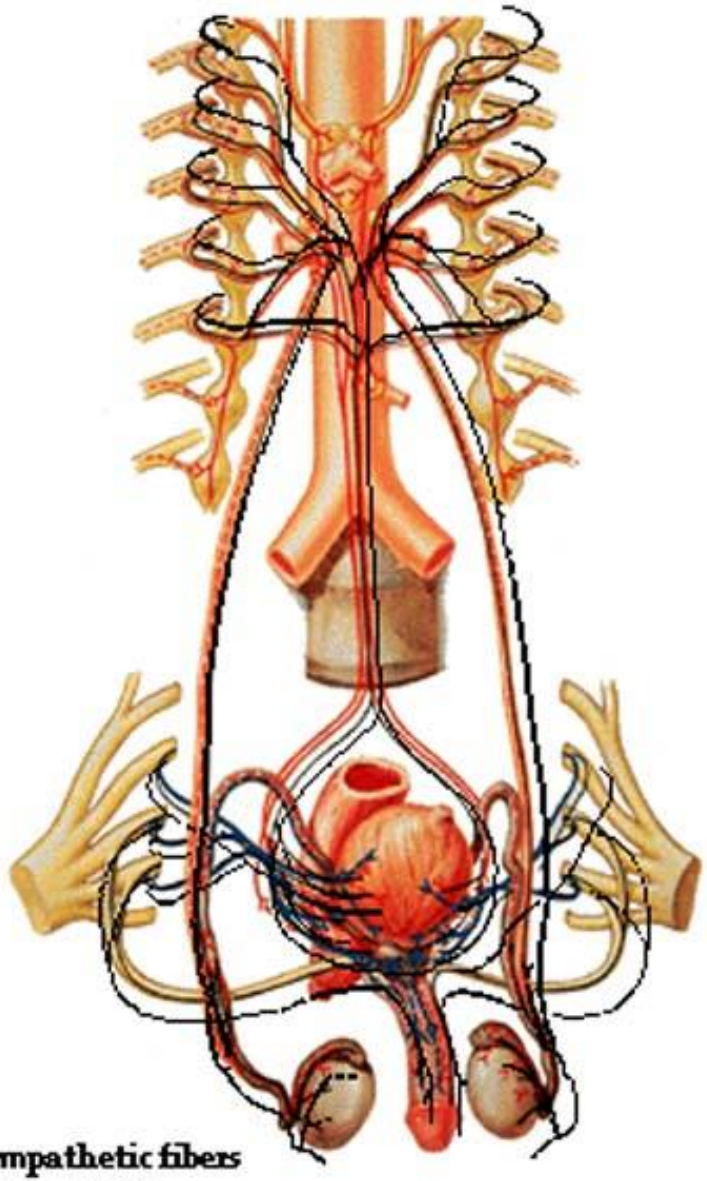
plexus hypogastricus inferior =
plexus pelvicus
mixed



Innervation of Urinary Bladder



Innervation of Male Reproductive Organs



Sympathetic fibers
— Presynaptic
--- Postsynaptic

Parasympathetic fibers
— Presynaptic
--- Postsynaptic

— Afferent fibers

Paraganglia

- **chromafine** (*paraganglia sympathica*)
  - paraganglion aorticum abdominale *Zuckerkandli*
  - glomus coccygeum *Luschkae*
  - glomus jugulare, tympanicum…
- **without chromafine reaction** (*former* paraganglia parasympathica)
  - baro- a chemoreceptors
  - glomus caroticum
  - glomus supracardiacum (aorticum)

Enteric system

cardia of stomach → upper margin of m. sphincter ani internus, biliary ducts and gallblader, pancreas

- **plexus myentericus** *Auerbachi*
- **plexus submucosus** *Meissneri*
- ganglia within the intestinal wall
- fibers
  - visceromotor sympathetic + parasympathetic
  - viscerosensory via both systems + reflectory ones
- Cajal interstitial cells
  - pacemaker of intestinal muscle layers

CNS

- highest autonomic center = hypothalamus
- controled by limbic system (insula)
- nuclei influenced by reticular formation (reflexes)