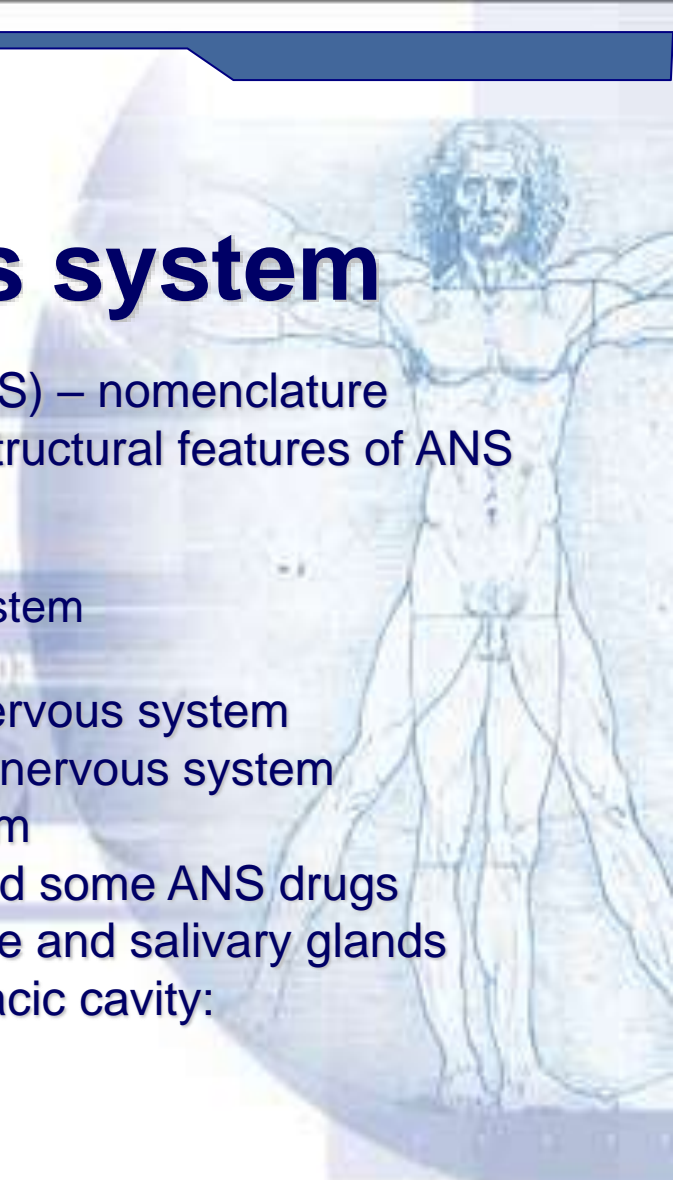
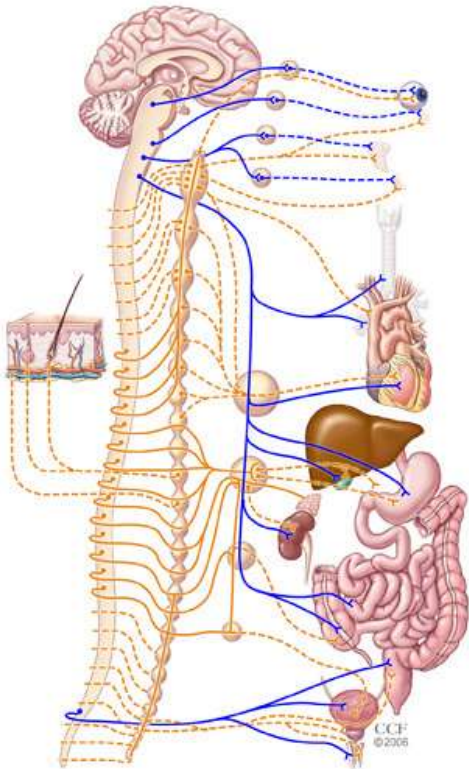




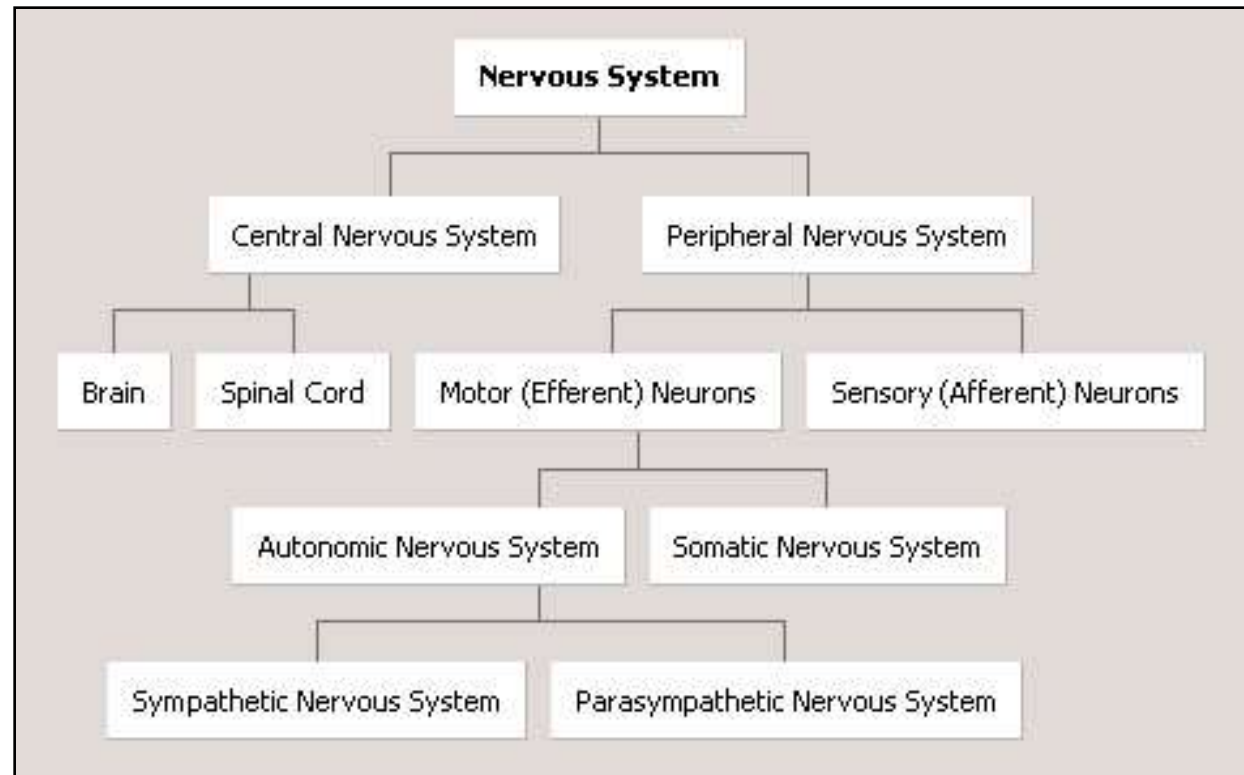
Autonomic nervous system

1. Autonomic nervous system (ANS) – nomenclature
2. Topographic organization and structural features of ANS
3. Main subdivisions of the ANS:
 - ✓ sympathetic nervous system
 - ✓ parasympathetic nervous system
 - ✓ enteric nervous system
4. Sympathetic (thoracolumbar) nervous system
5. Parasympathetic (craniosacral) nervous system
6. Enteric (intrinsic) nervous system
7. Neurotransmitters, receptors and some ANS drugs
8. Autonomic innervation of the eye and salivary glands
9. Autonomic plexuses in the thoracic cavity:
 - ✓ cardiac plexus
 - ✓ pulmonary plexus
 - ✓ thoracic aortic plexus
10. Autonomic plexuses in the abdomen – primary and secondary
 - ✓ abdominal aortic plexus
 - ✓ coeliac (solar) plexus
11. Autonomic plexuses in the pelvis – primary and secondary
 - ✓ inferior hypogastric plexus





Classification of the nervous system





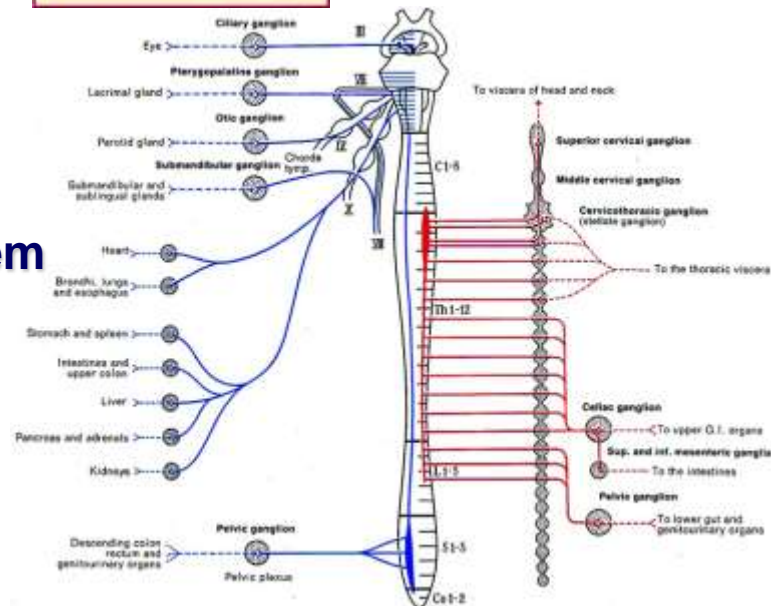
Definition and nomenclature

- **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.

The Autonomic Nervous System



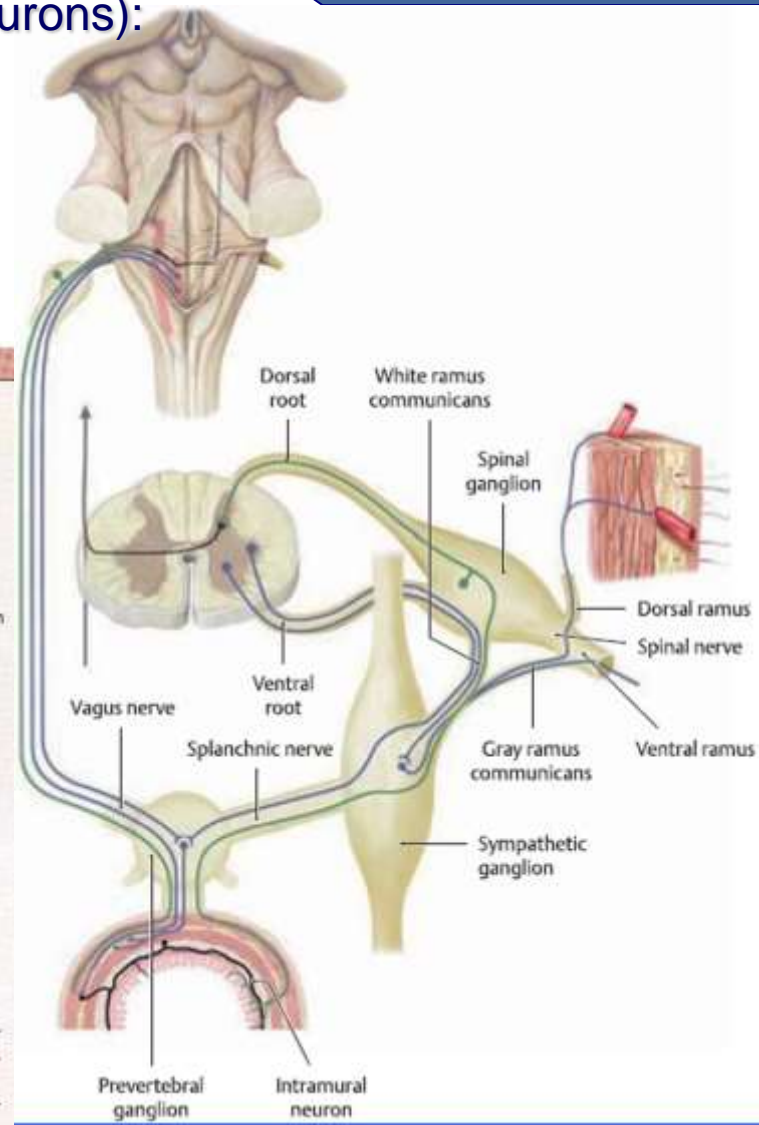
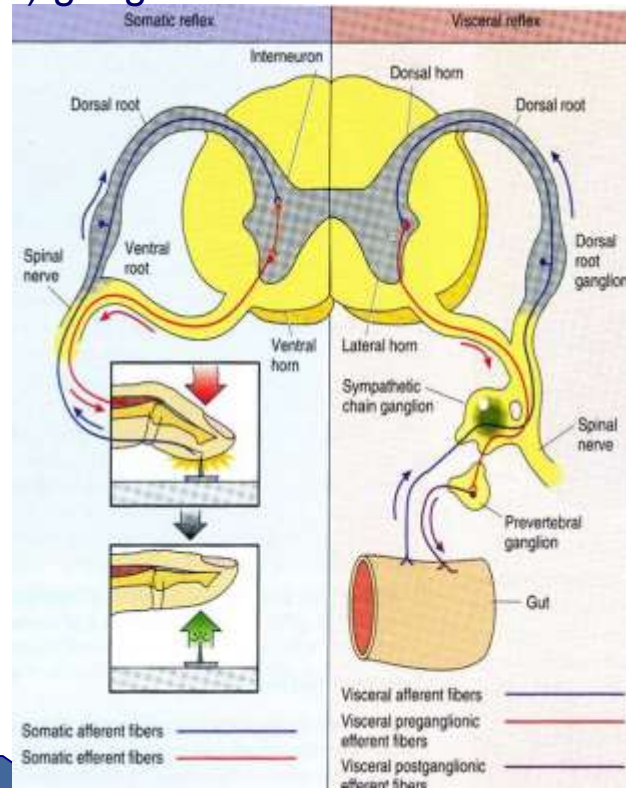
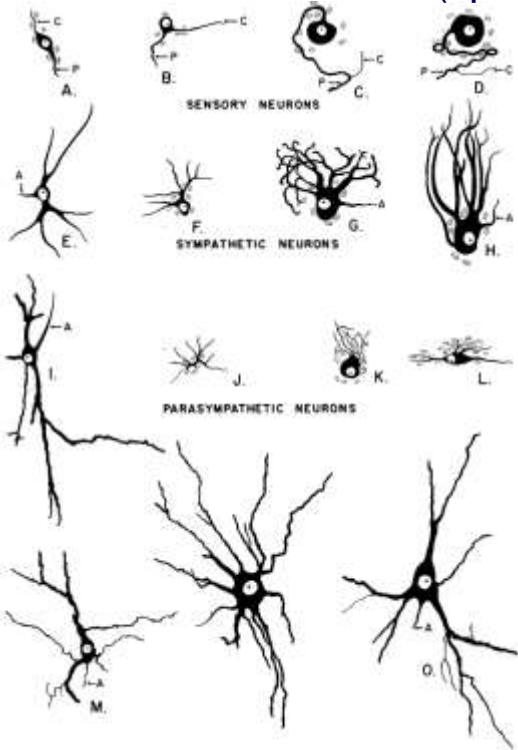
John Newport Langley
(1852–1925)





Structural organization

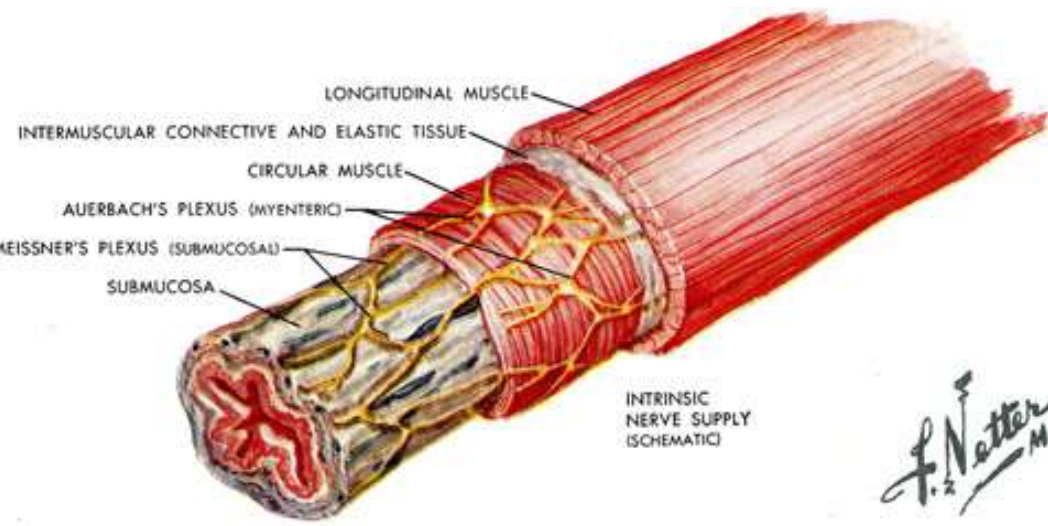
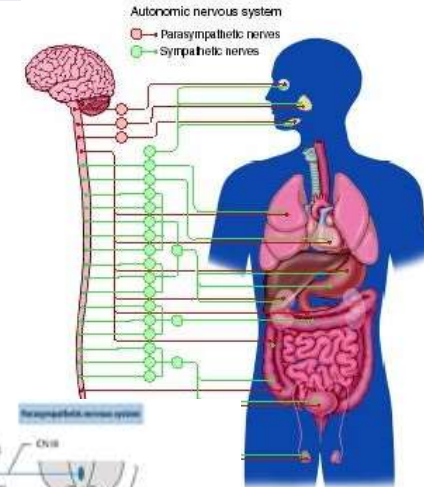
- **two-neuron efferent system (visceral efferent neurons):**
 - ✓ first (**preganglionic**) neuron – inside the CNS
 - ✓ second (**postganglionic**) neuron – in a ganglion or plexus of neurons
- **perikarya of visceral afferent neurons:**
 - ✓ in dorsal root (spinal) ganglia



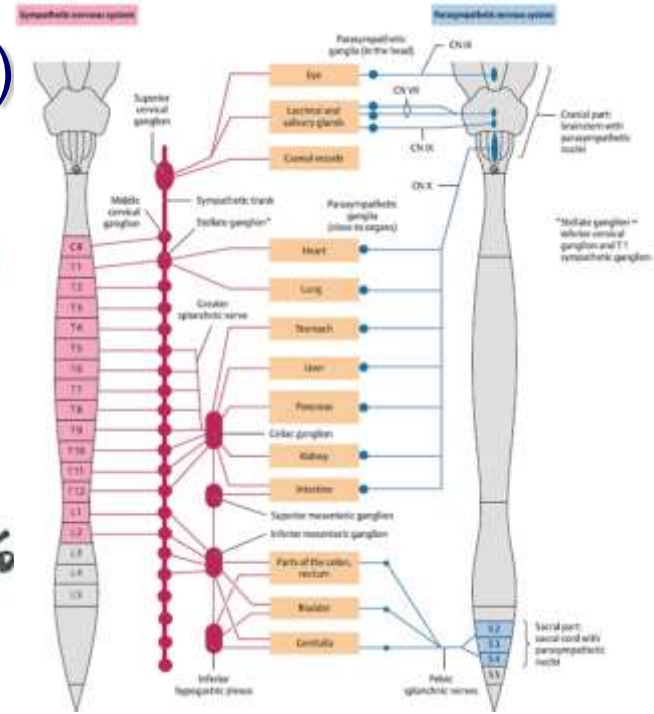


Main subdivisions

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



F. Netter M.D.





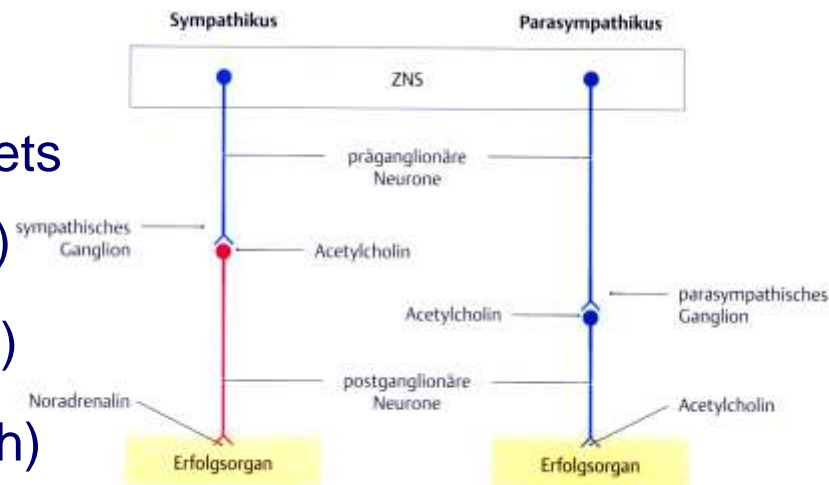
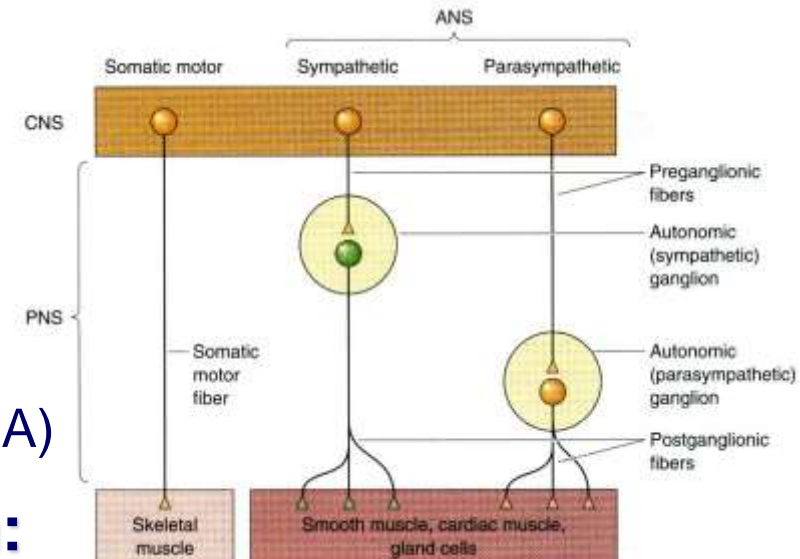
Structural and neurochemical differences

■ 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)



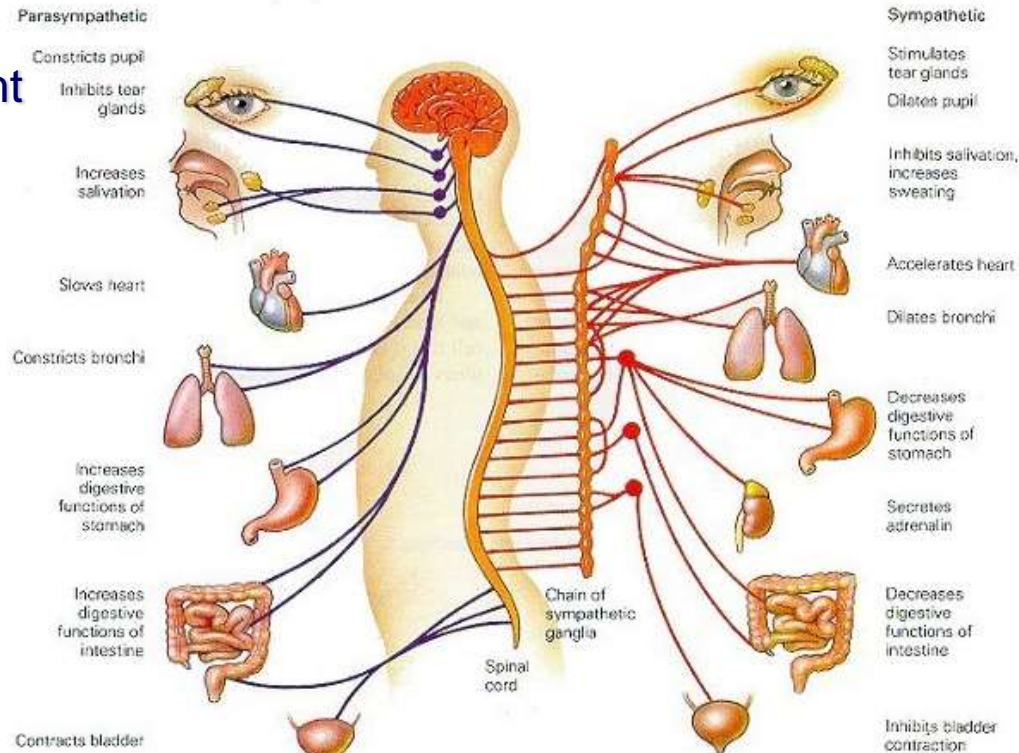
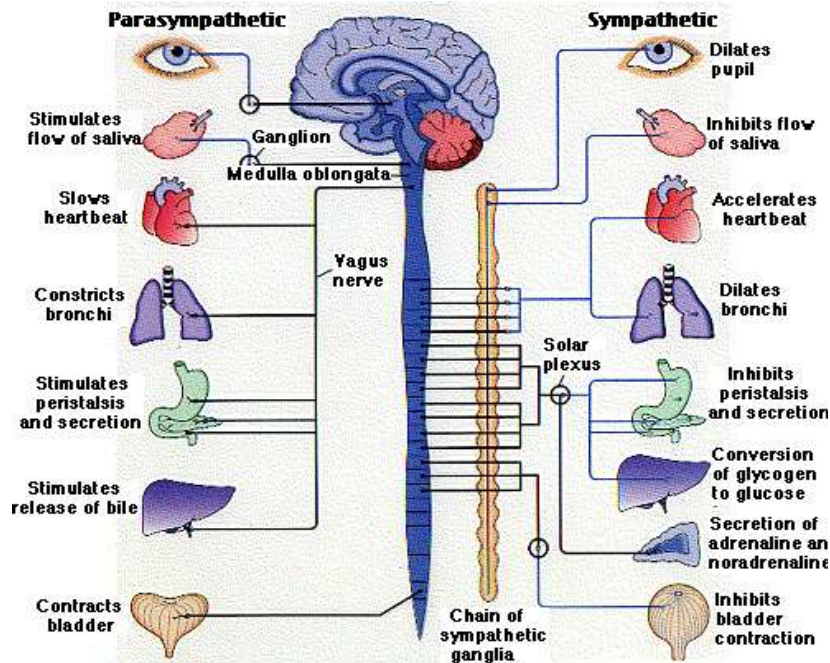


Functional considerations

- **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

THE AUTONOMIC NERVOUS SYSTEM

The parasympathetic nervous system, which regulates day-to-day internal processes and behavior, is shown on the left. The sympathetic nervous system, which regulates internal processes and behavior in stressful situations, is shown on the right. Note that, on their way to and from the spinal cord, the nerve fibers of the sympathetic nervous system innervate, or make connections with ganglia, specialized clusters of neuron chains.



NB: antagonistic actions of both components

to maintain homeostasis!

Parasympathetic nervous system

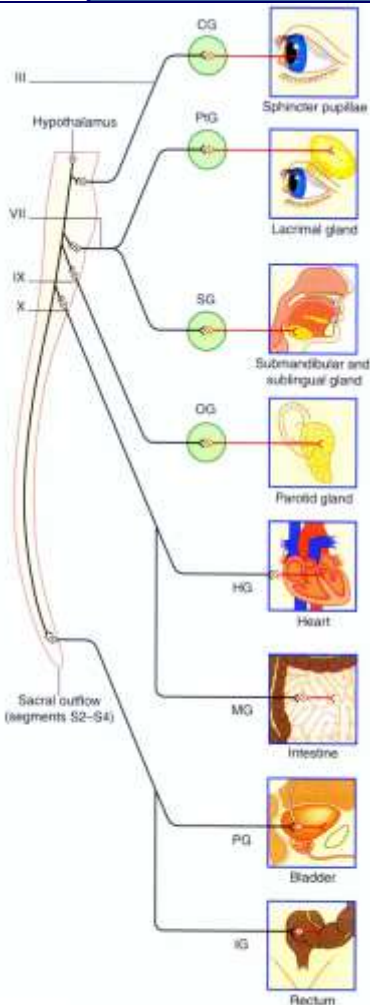
■ craniosacral division:

✓ cranial region:

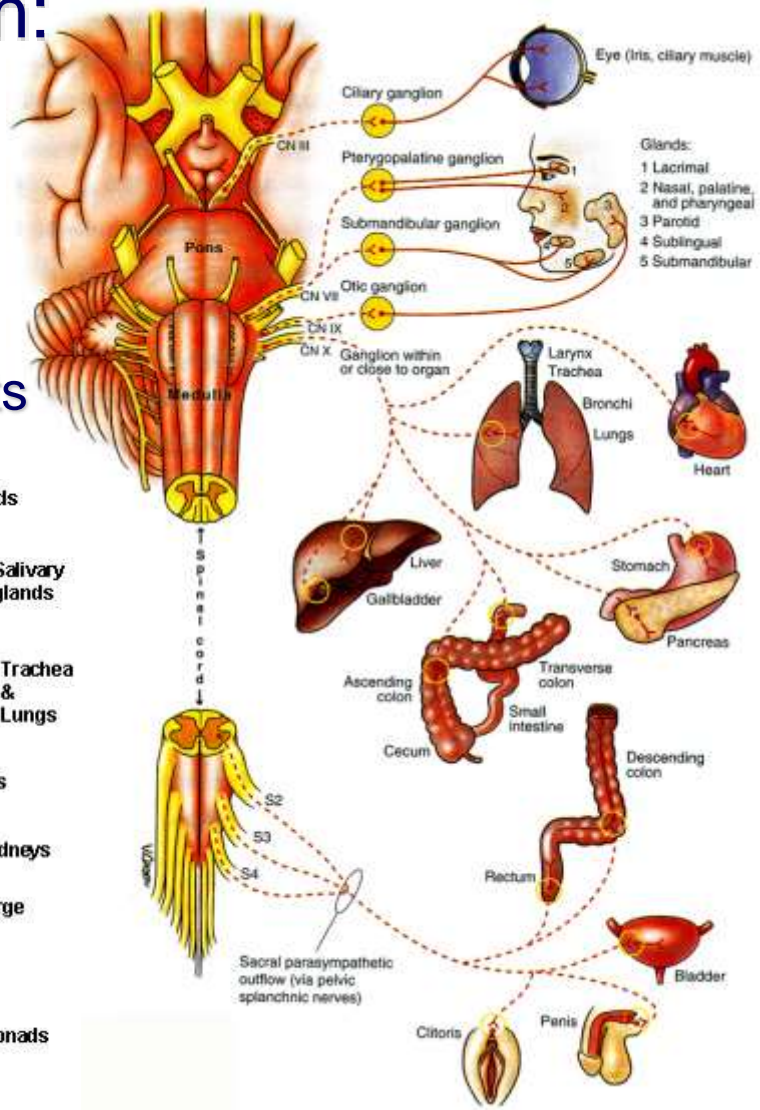
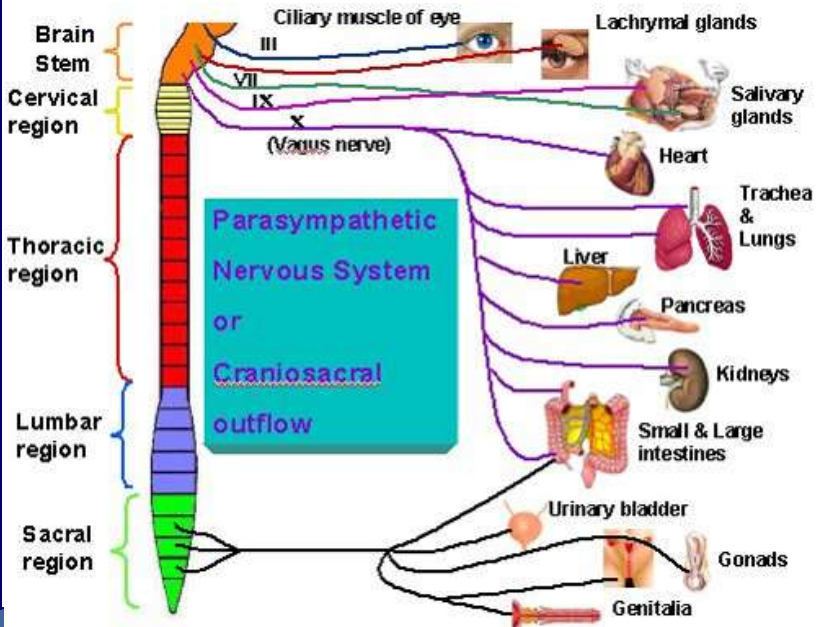
➤ cranial nerves III, VII, IX, X

✓ sacral region:

➤ spinal cord segments S2-S4

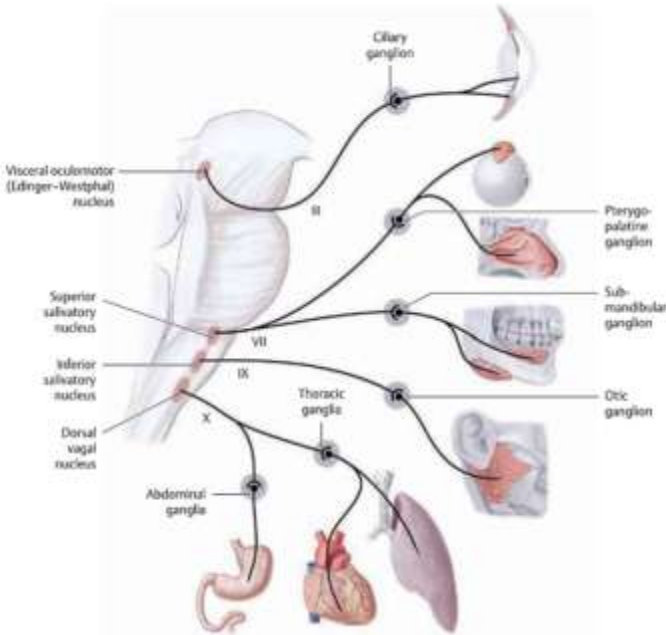


General plan of the parasympathetic system. Ganglionic neurons and postganglionic fibers are shown in red. CG, ciliary ganglion; HG, heart ganglia; IG, intramural ganglia; MG, myenteric ganglia; OG, optic ganglion; PG, pterygopalatine ganglion; SG, submandibular ganglion.

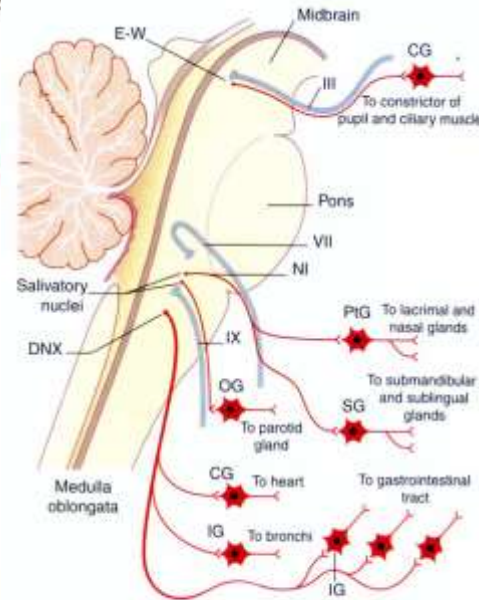
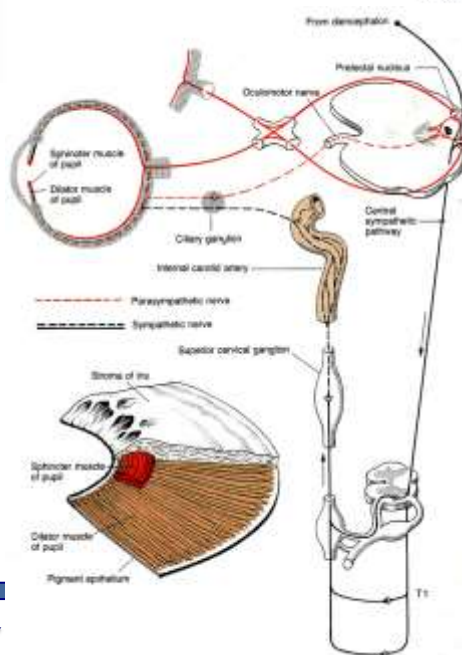


- Glands:
- 1 Lacrimal
 - 2 Nasal, palatine, and pharyngeal
 - 3 Parotid
 - 4 Sublingual
 - 5 Submandibular

Cranial division

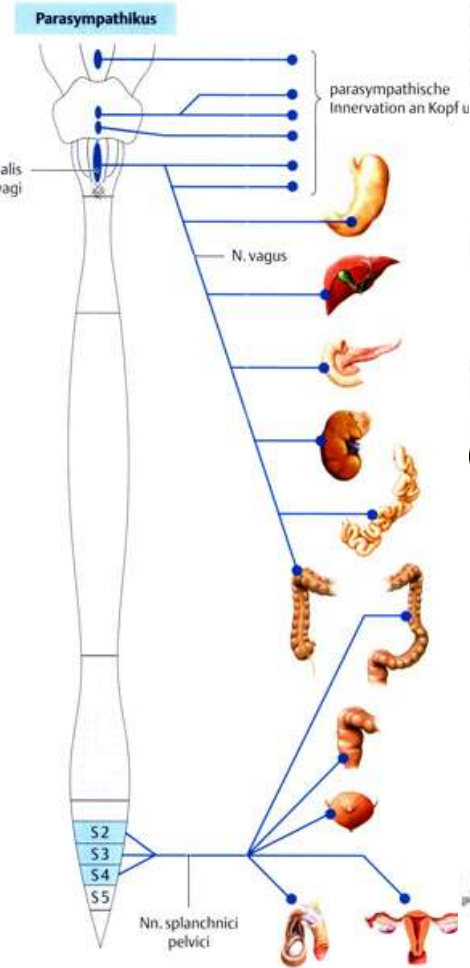


Cranial Nerve	Site of Nucleus	Preganglionic Nucleus	Postganglionic Nucleus	Effector/Function
III	Midbrain	Edinger-Westphal nucleus	Ciliary ganglion	Pupilloconstrictor muscle of iris Ciliary muscle
VII	Pons	Superior salivatory nucleus	Submandibular ganglion Pterygopalatine ganglion	Sublingual and submandibular salivary glands 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 Plexuses	S-A and A-V nodes Wall of pulmonary tree Smooth muscles and glands of gastrointestinal tract to the splenic flexure of the colon Kidney

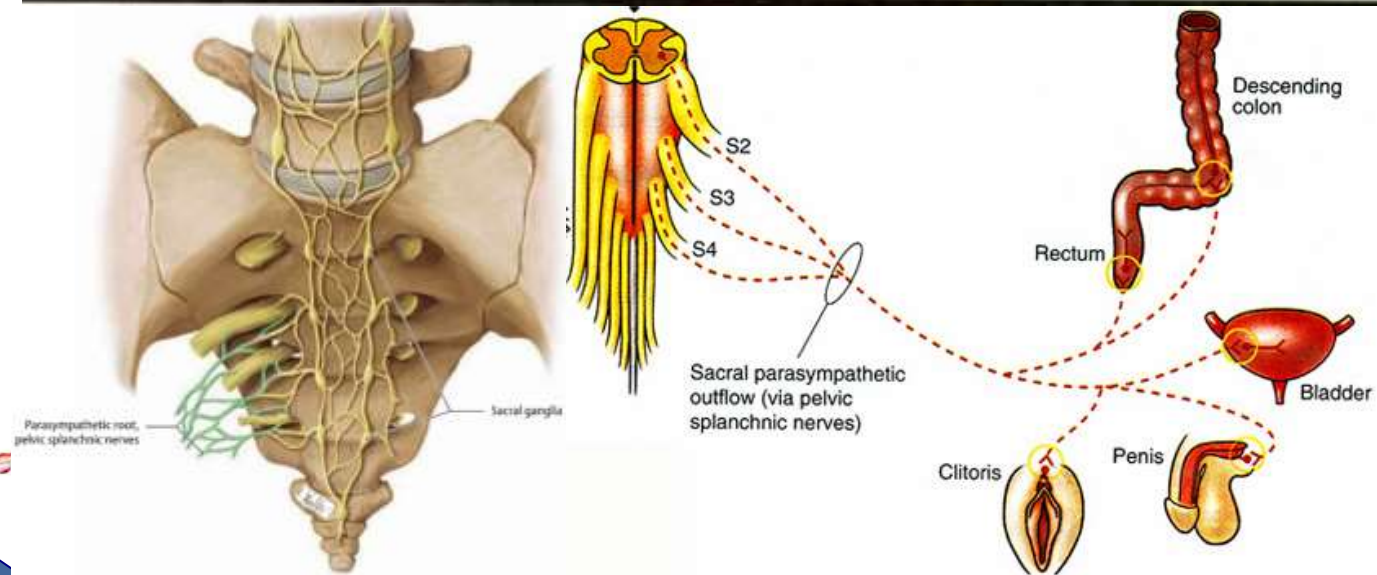


Cranial parasympathetic system. DNX, dorsal nucleus of vagus; E-W, Edinger-Westphal nucleus.

Sacral division



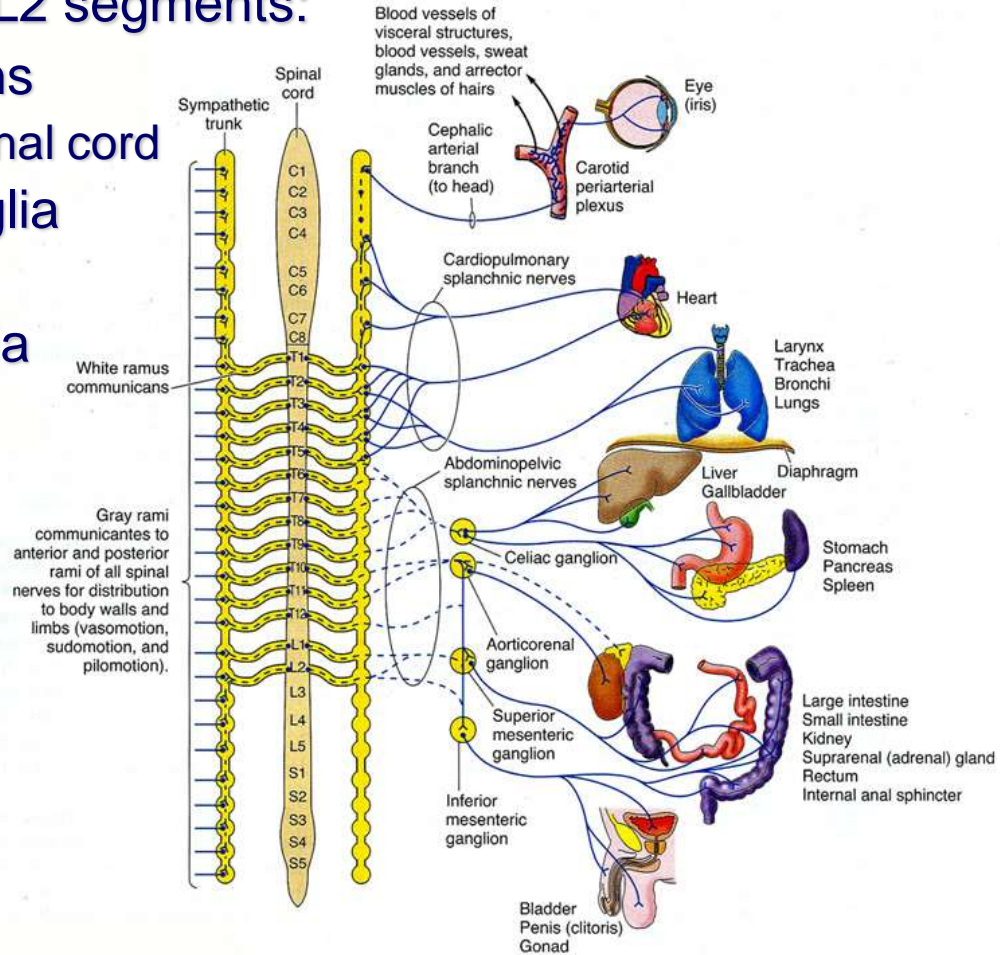
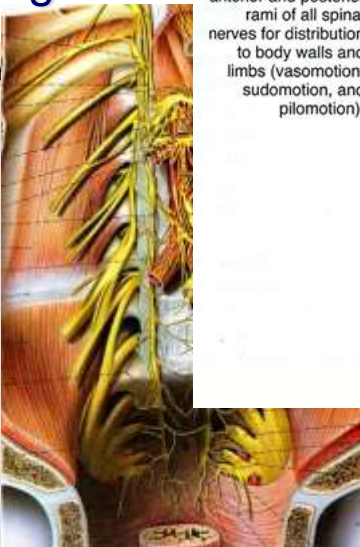
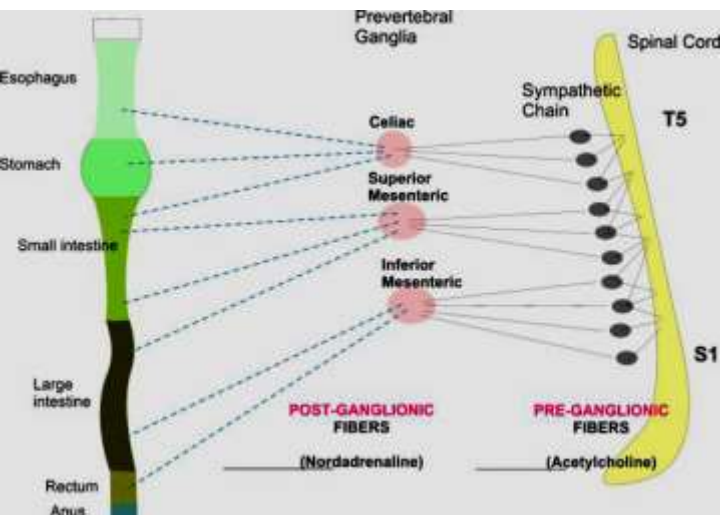
Organ	Preganglionic Neuron Level	Postganglionic Neuron Site	Effect of Stimulation
Distal colon	S2–S4	Intramural ganglion Hypogastric plexus	Enhanced peristalsis Secretion Defecation Inhibition of anal sphincter
Urinary bladder	S2–S4	Intramural ganglion (vesical plexus) Hypogastric plexus	Contraction of bladder wall 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

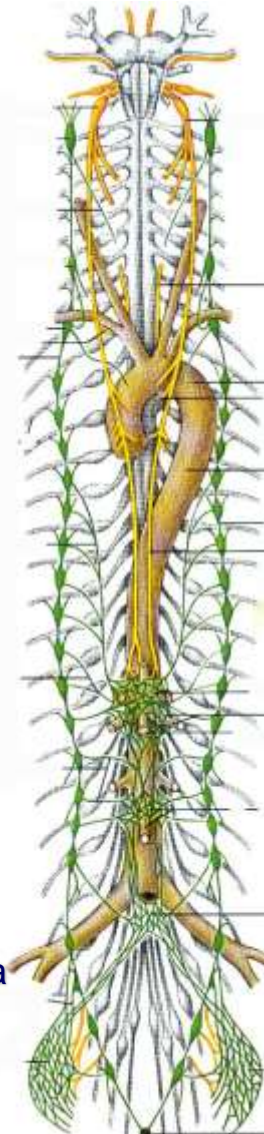




Sympathetic trunk

two symmetrical ganglionated cords:

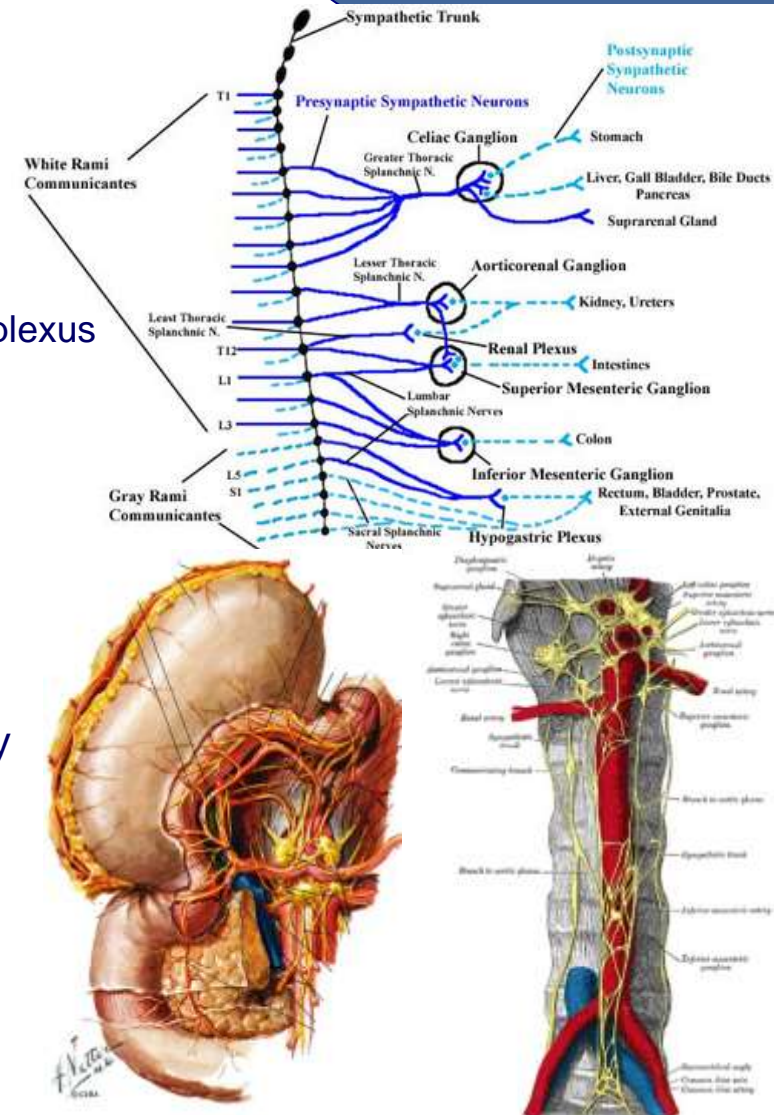
- ✓ cervical part – 3 ganglia:
 - superior cervical ganglion – 2.5-3 cm
 - jugular nerve
 - laryngopharyngeal and superior cardiac branches
 - internal and external carotid branches
 - middle cervical ganglion (60%) – 0.7-0.8 cm
 - thyroid and middle cardiac branches
 - inferior cervical ganglion ⇒ in 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





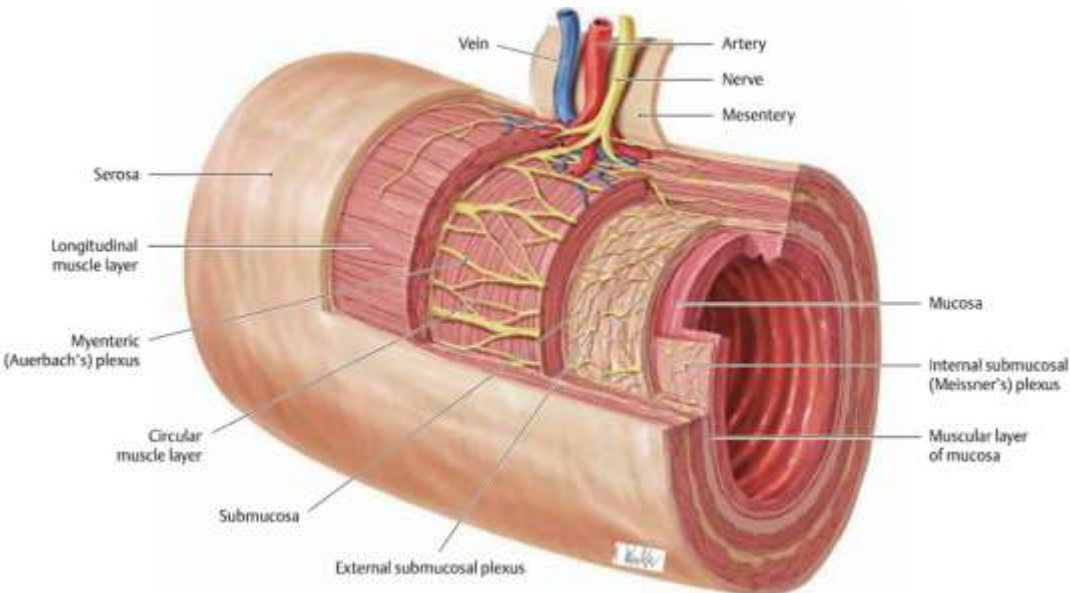
Prevertebral sympathetic ganglia

- **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



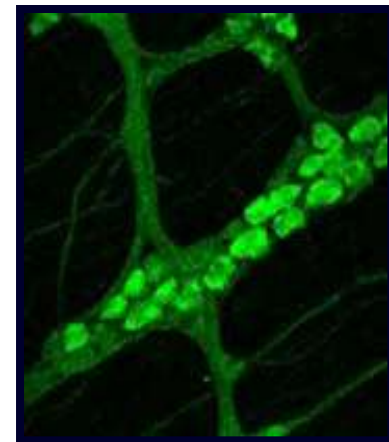


Enteric nervous system



- 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

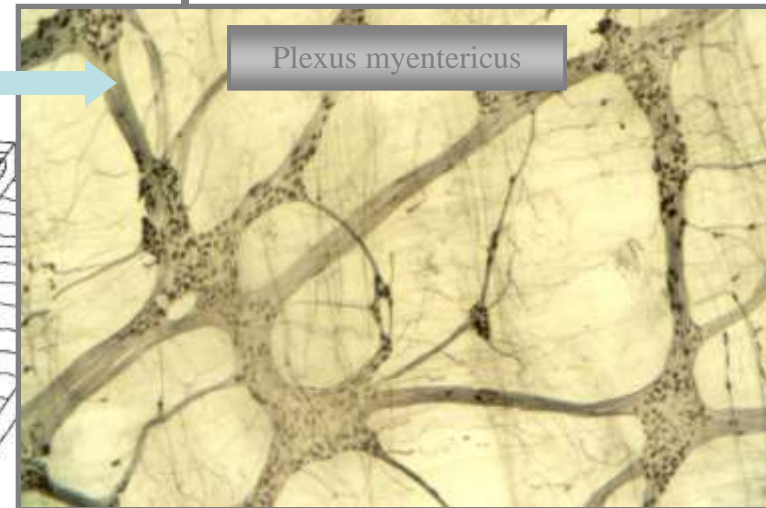
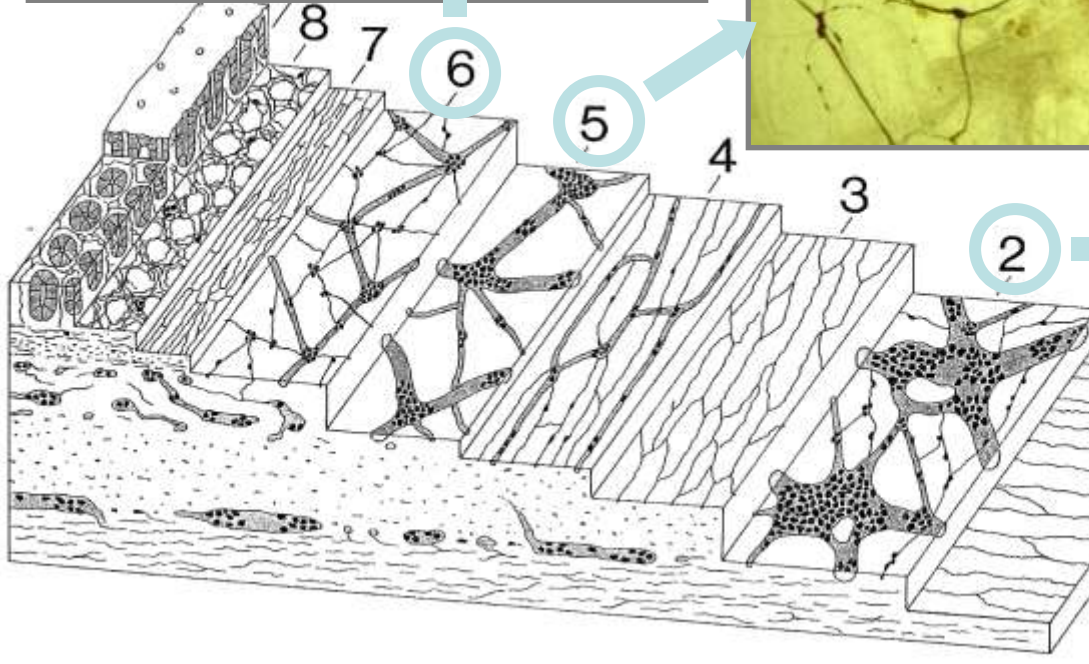
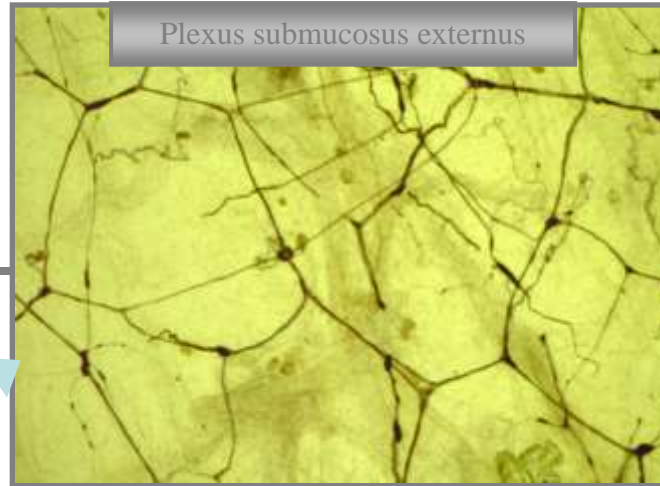
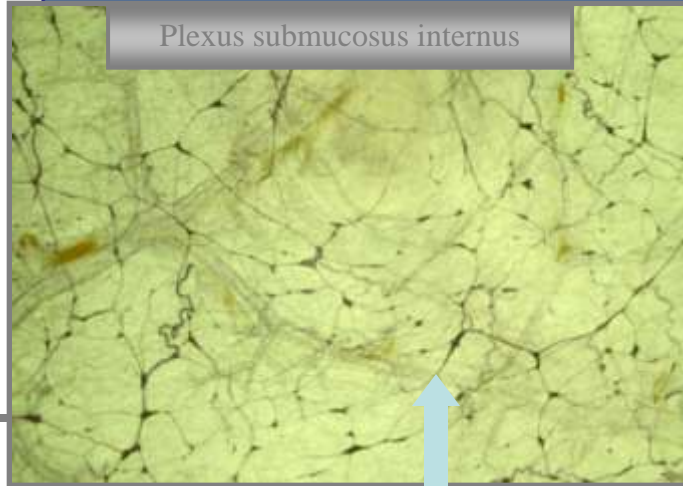
- This local nervous system, referred to as intrinsic or **enteric nervous system** (ENS), functions *independently* of the CNS and is influenced by the ANS in a limited way.
- It controls the motility, exocrine and endocrine secretions, local blood flow, and also modulates immune and inflammatory processes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





Enteric nervous system

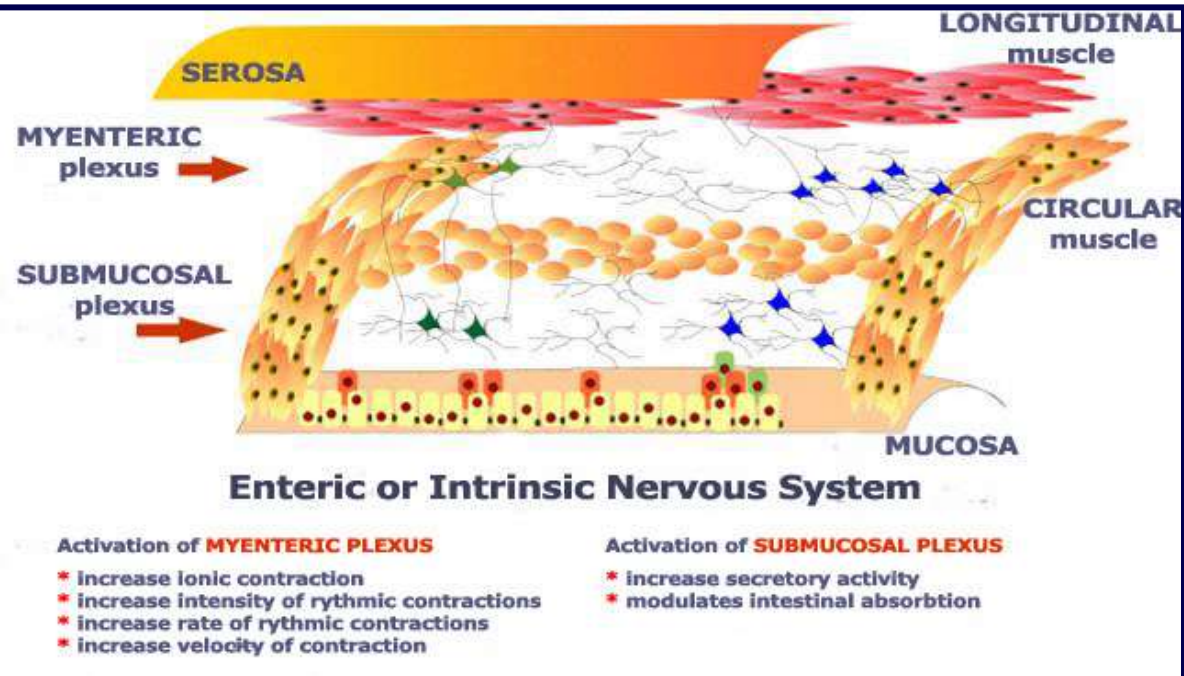
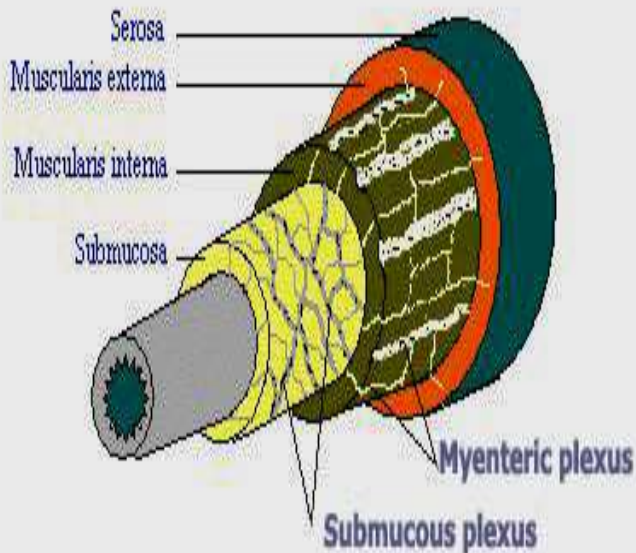
Prof. Dr. Heinz-Juergen Krammer,
University Hospital of Heidelberg at Mannheim, Germany





Plexus entericus

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



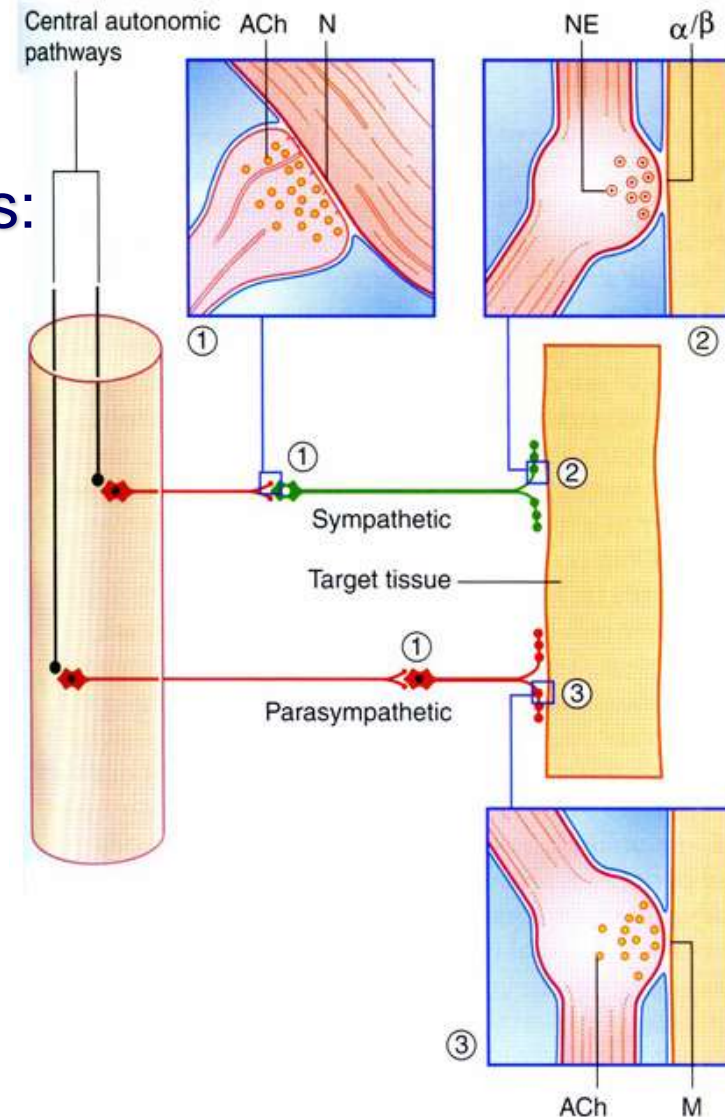
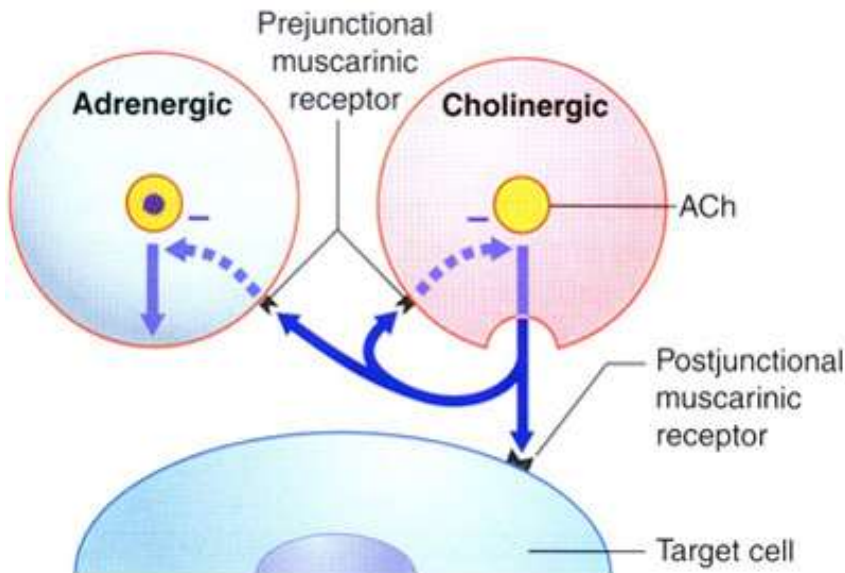
- The submucous plexus (of *Meissner*) regulates mucosal movements and epithelial cell function [*mucosal gland secretion*]
 - ✓ internal submucosal plexus (the true plexus of *Meissner*)
 - ✓ external submucosal plexus (the plexus of *Schabadasch*)



Autonomic transmitters and receptors

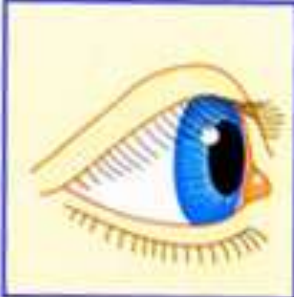
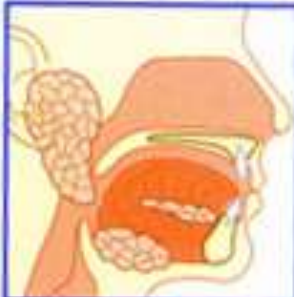




Cholinergic transmission:

- ✓ 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

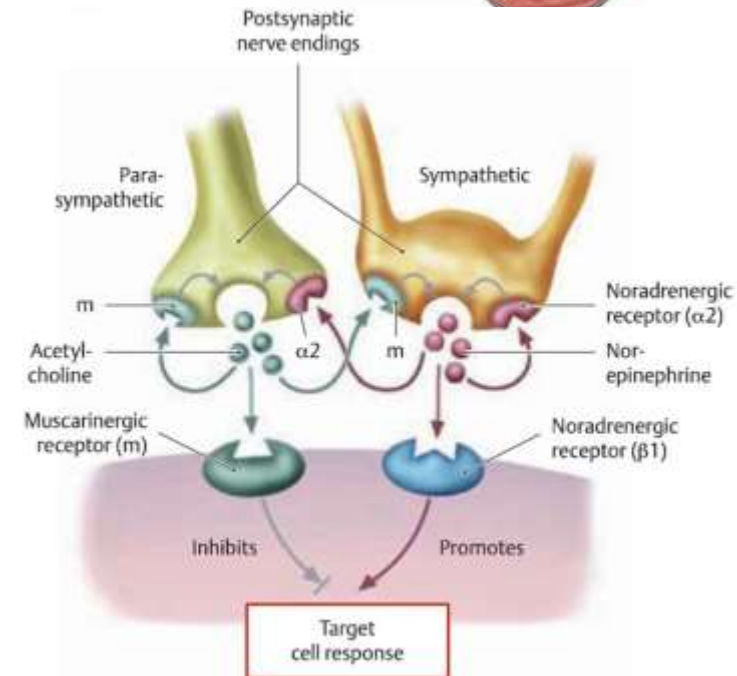
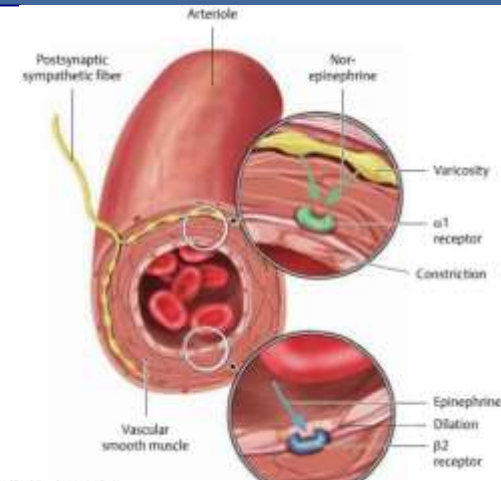
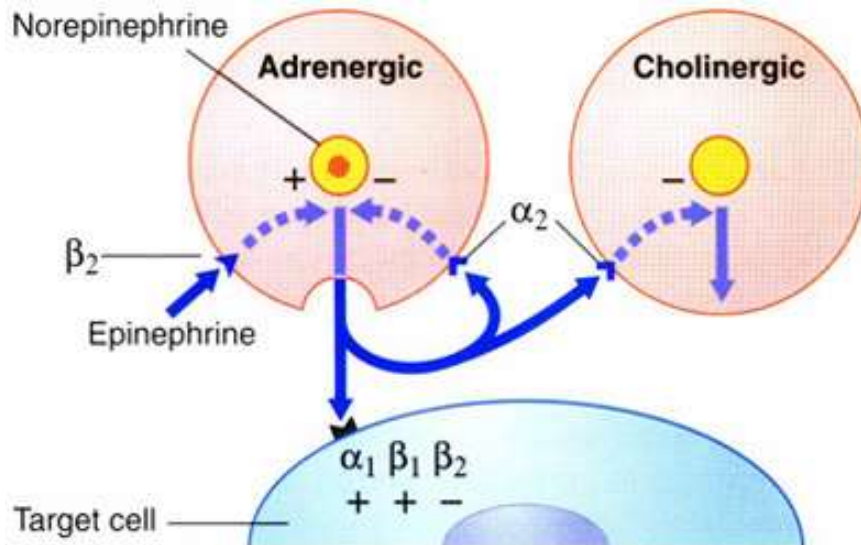
Cholinergic drugs					
Pupillary constriction Near vision	Salivation	Constriction Secretion	Slowing	Gastric secretion increased Colic Diarrhea	Voiding of urine
Eye	Salivary glands	Bronchi	Heart	GI tract	Bladder
					
Pupillary dilatation Far vision	Dry mouth	Relaxation Sticky dry	Acceleration	Gastric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



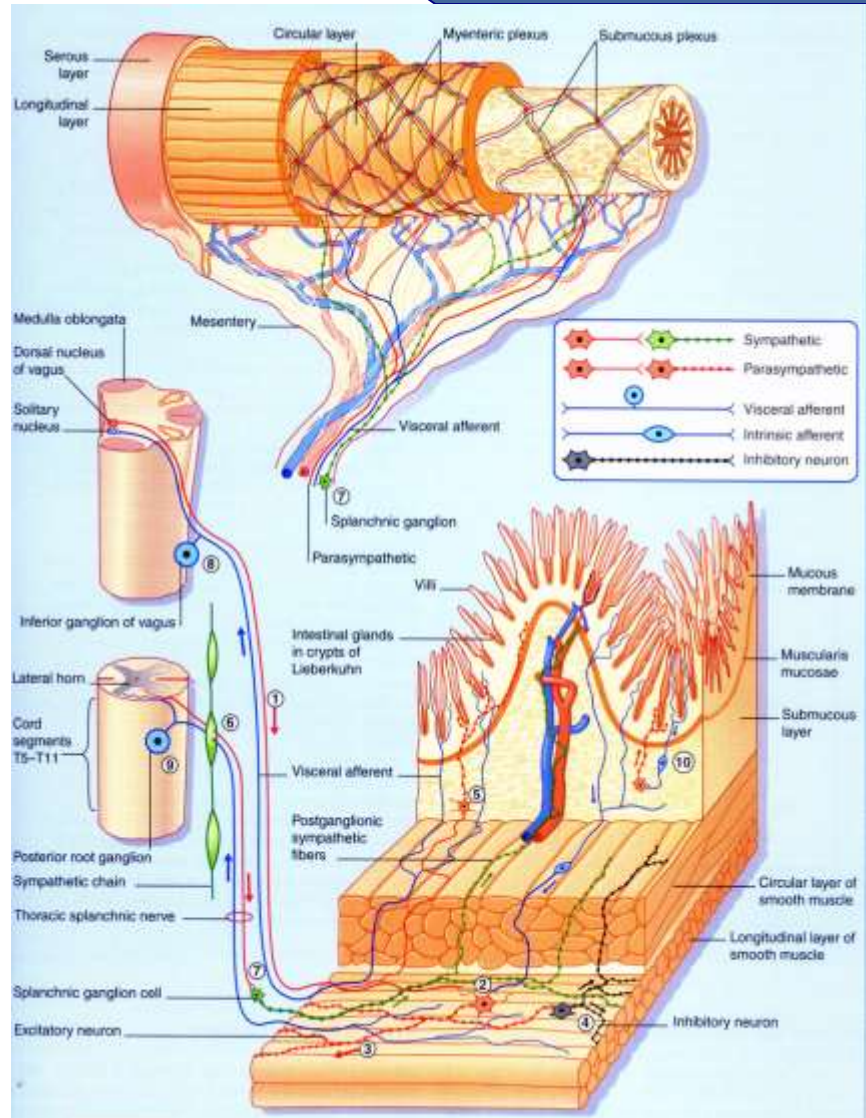
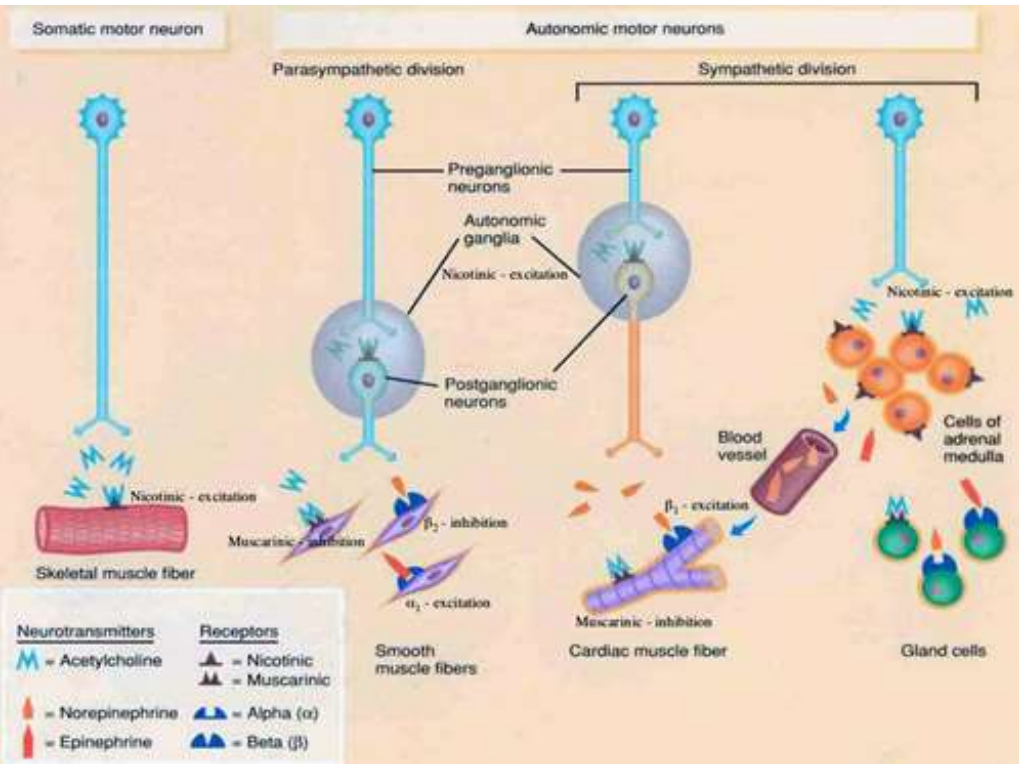
Autonomic transmitters and receptors

■ Adrenergic transmission:

- ✓ release noradrenaline (norepinephrine)
- ✓ two types of adrenergic receptors:
 - α -receptors \Rightarrow excitatory responses
 - pharmacologically α_1 - and α_2 -receptors
 - β -receptors \Rightarrow cause inhibition
 - pharmacologically β_1 - and β_2 -receptors



Adrenergic nerve endings





Enteric neurotransmitters

amines spectrum of neurotransmitters:

- amines
 - ✓ acetylcholine – excitatory
 - ✓ noradrenaline – inhibitory (norepinephrine)
 - ✓ adrenaline (epinephrine)
 - ✓ serotonin (5-Hydroxytryptamine)

amino acids

- ✓ GABA

purines

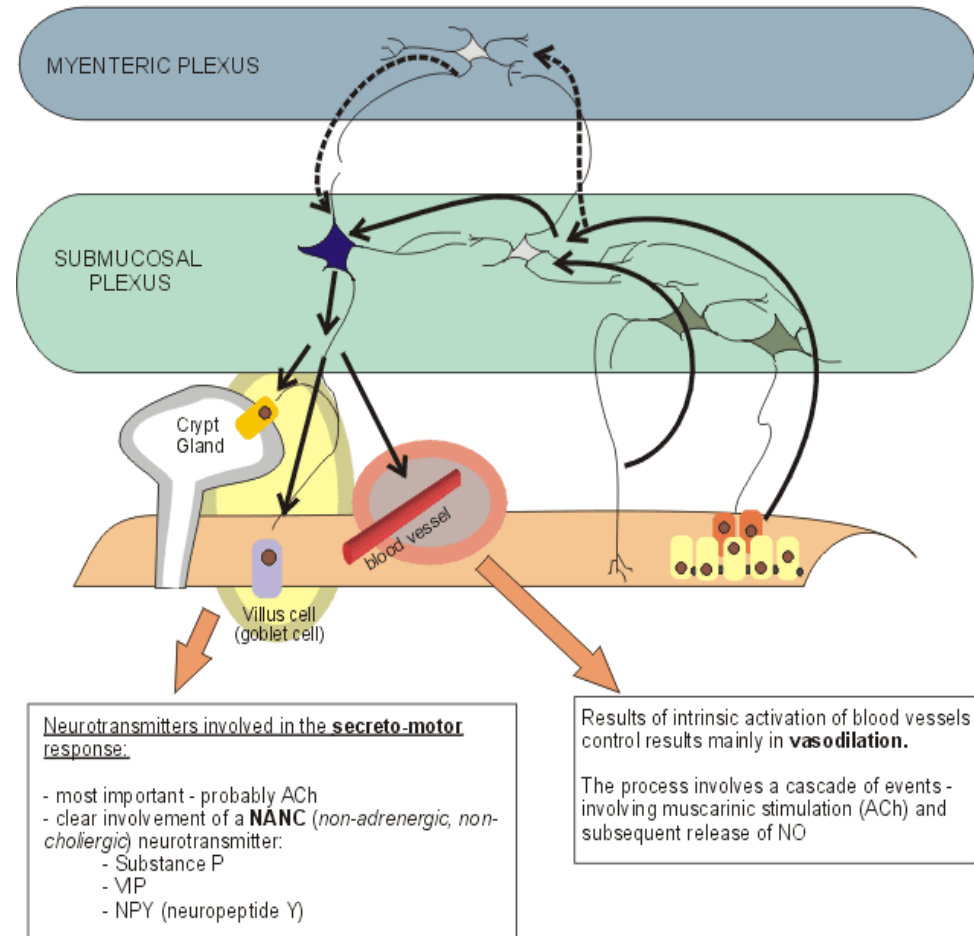
- ✓ ATP

gaseous messengers

- ✓ nitric oxide
- ✓ carbon monoxide

NANC neurotransmitters

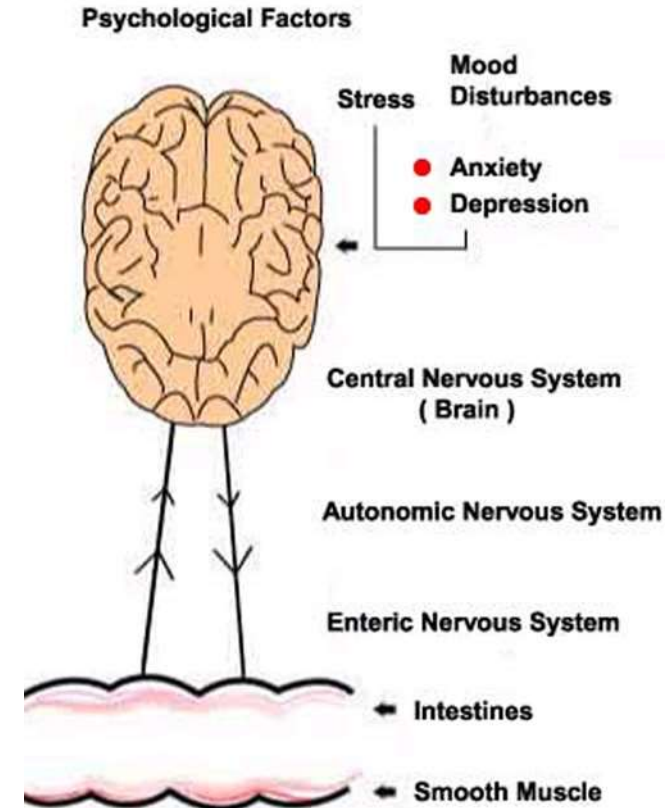
Control (inputs) from **extrinsic nervous** sources (not detailed here)





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”



Is really there a brain in the gut?

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

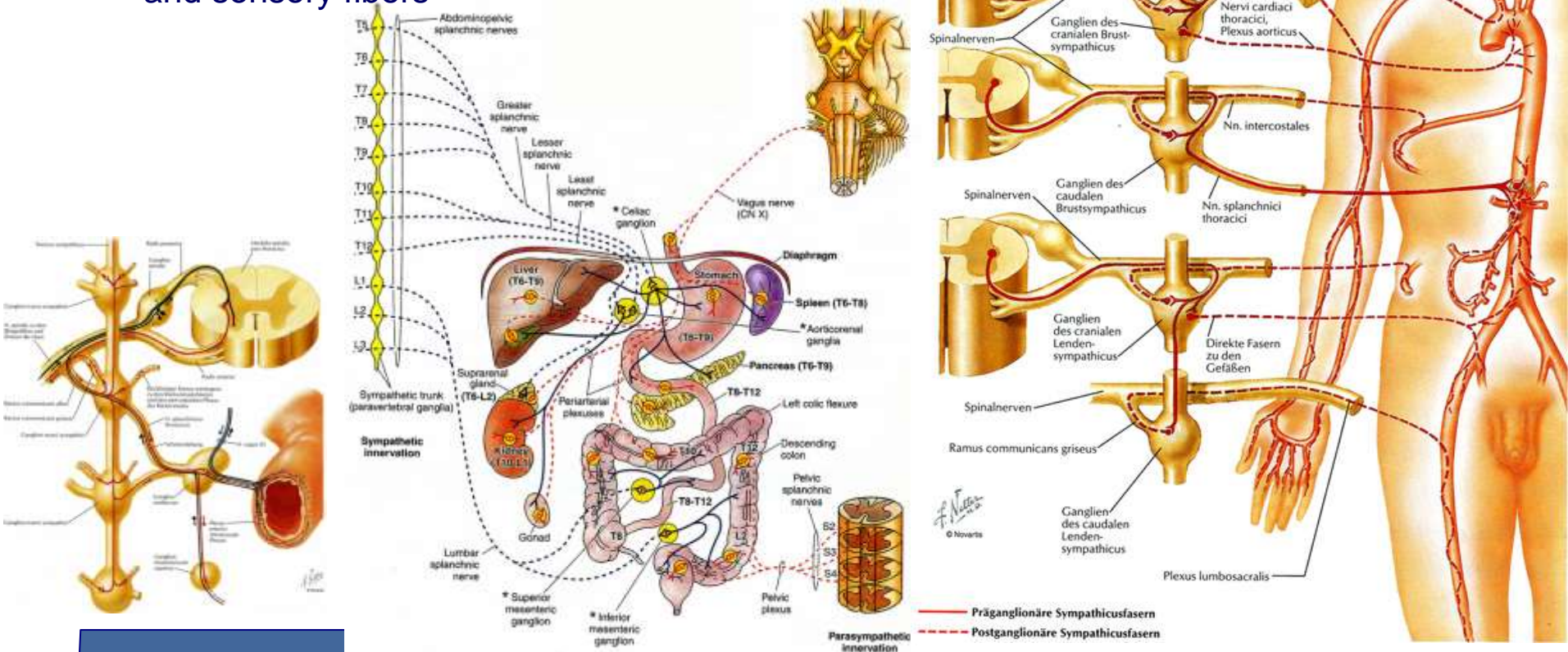




Structural organization

aggregations (a network) of autonomic nerves and ganglia:

- ✓ situated in the thoracic, abdominal and pelvic cavities
- ✓ innervate the thoracic, abdominal and pelvic viscera
- ✓ pass along branches of the arterial blood vessels
- ✓ composed of sympathetic, parasympathetic, and sensory fibers





Autonomic innervation of the eye

sympathetic innervation – SCG of sympathetic trunk:

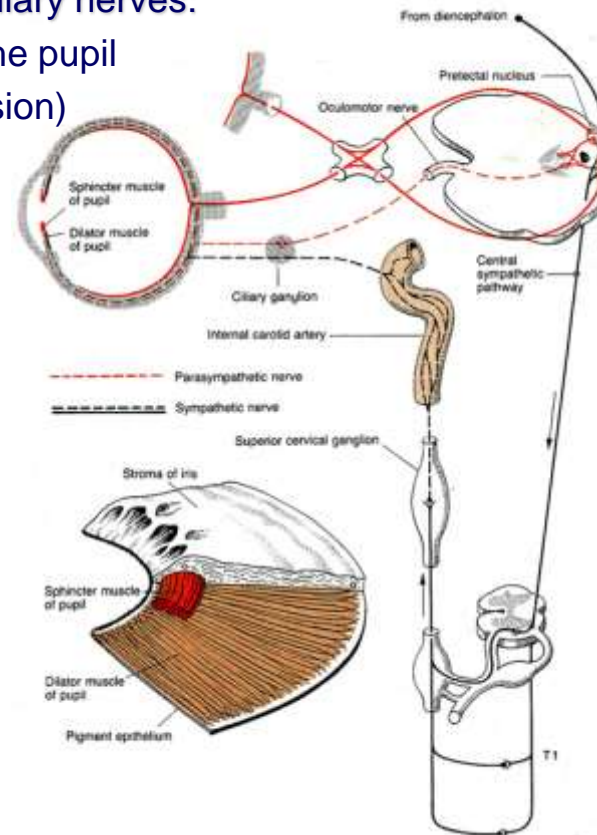
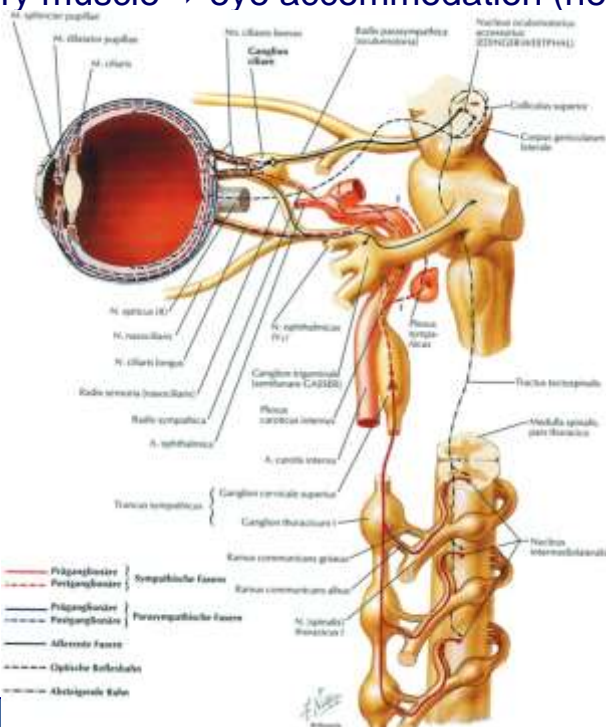
- ✓ dilator muscle of the iris
 - ✓ tarsal muscle
 - ✓ orbital muscle (of Müller)
- } *Horner's syndrome*



parasympathetic innervation – oculomotor (CNIII)

parasympathetic fibers ⇒ ciliary ganglion ⇒ short ciliary nerves:

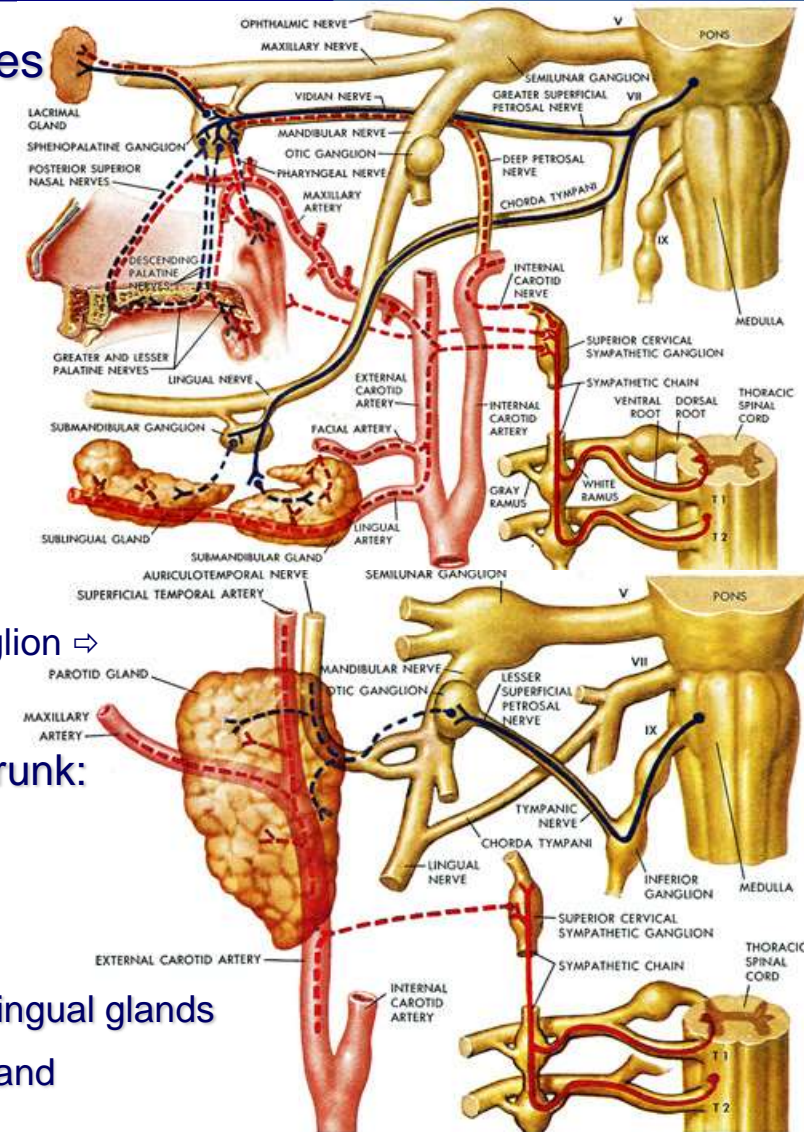
- ✓ sphincter muscle of the iris ⇒ constriction of the pupil
- ✓ ciliary muscle ⇒ eye accommodation (near vision)





Autonomic innervation of the salivary glands

- secretory fibers in cranial parasympathetic nerves
- **parasympathetic innervation:**
 - ✓ facial nerve:
 - pterygopalatine ganglion ⇒ lacrimal gland, palatine and nasal glands
 - submandibular ganglion ⇒ submandibular and sublingual glands
 - ✓ glossopharyngeal nerve:
 - pharyngeal plexus, lingual branches
 - tympanic nerve ⇒ lesser petrosal nerve ⇒ otic ganglion ⇒ auriculotemporal nerve ⇒ parotid gland
- **sympathetic innervation** – SCG of sympathetic trunk:
 - deep petrosal nerve ⇒ pterygopalatine ganglion ⇒ lacrimal gland
 - external carotid plexus ⇒ external carotid nerves ⇒ submandibular ganglion ⇒ submandibular and sublingual glands
 - external carotid nerves ⇒ otic ganglion ⇒ parotid gland





Plexuses in the thoracic cavity

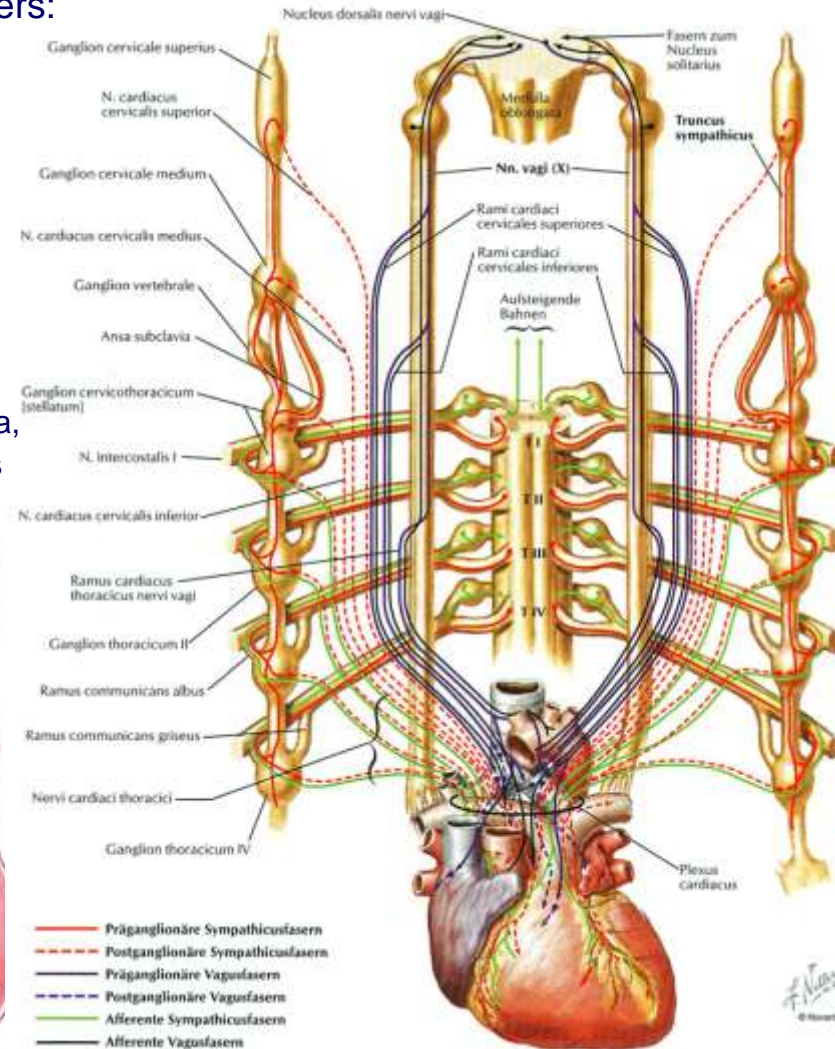
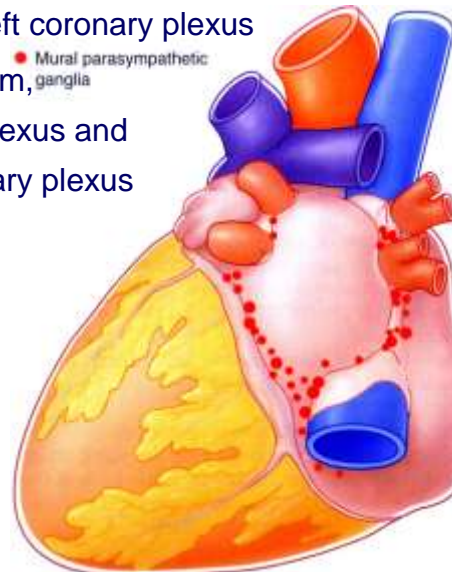
■ **cardiac plexus** – contain both afferent and efferent fibers:

✓ **superficial (ventral) part – cardiac ganglion:**

- formed by cardiac branch of SCG of sympathetic trunk and cervical cardiac branches of vagus
- gives branches to the deep part of the plexus, to the right coronary plexus and to the left anterior pulmonary plexus

✓ **deep (dorsal) part:**

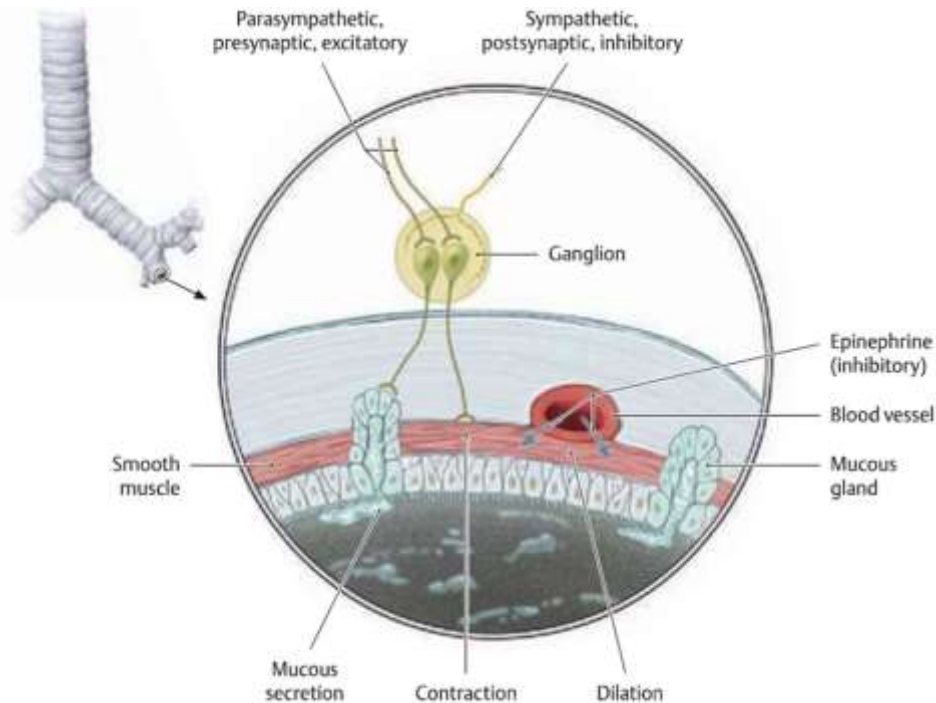
- formed by cervical and upper thoracic sympathetic ganglia, cardiac branches of vagus and recurrent laryngeal nerves
- right half supplies right anterior pulmonary plexus, right atrium and part of left coronary plexus
- left half supplies left atrium, left anterior pulmonary plexus and greater part of left coronary plexus





Plexuses in the thoracic cavity

- **pulmonary plexus** – branches from the vagus and sympathicus:
 - ✓ anterior part:
 - formed by cardiac branches of the SCG and vagus
 - ✓ posterior part:
 - formed by rami of the cardiac branches of the vagus, from the cardiac plexus and Th2-Th6 sympathetic ganglia
 - ✓ gives branches to the bronchi, pulmonary and bronchial vessels
- **thoracic aortic plexus** – branches to the oesophagus



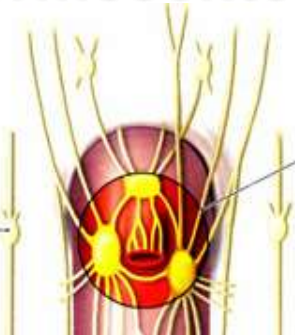
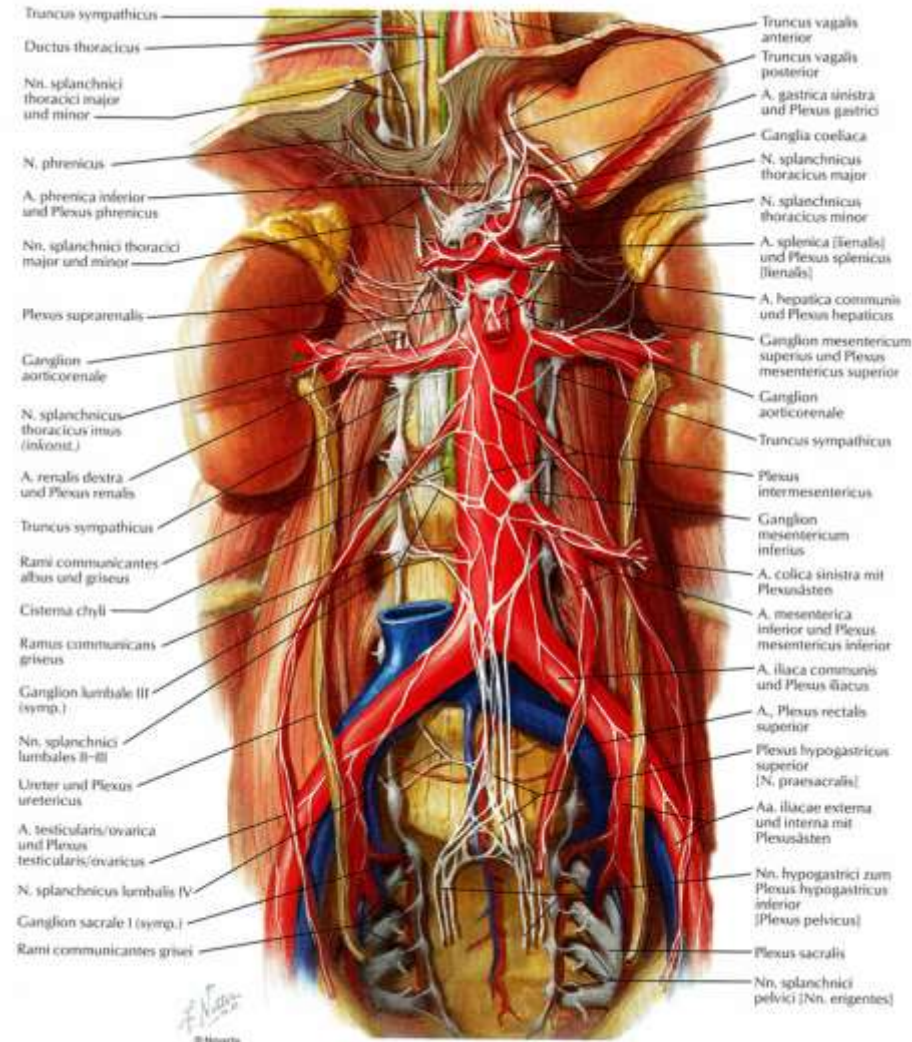


Primary plexuses in the abdominal cavity

- **coeliac (solar) plexus** – the largest autonomic plexus, located at Th12-L1:

- ✓ surrounds the coeliac artery and root of superior mesenteric artery
- ✓ unites the coeliac ganglia
- ✓ joined by greater and lesser splanchnic nerves

- **abdominal aortic plexus** ⇒ **intermesenteric plexus**



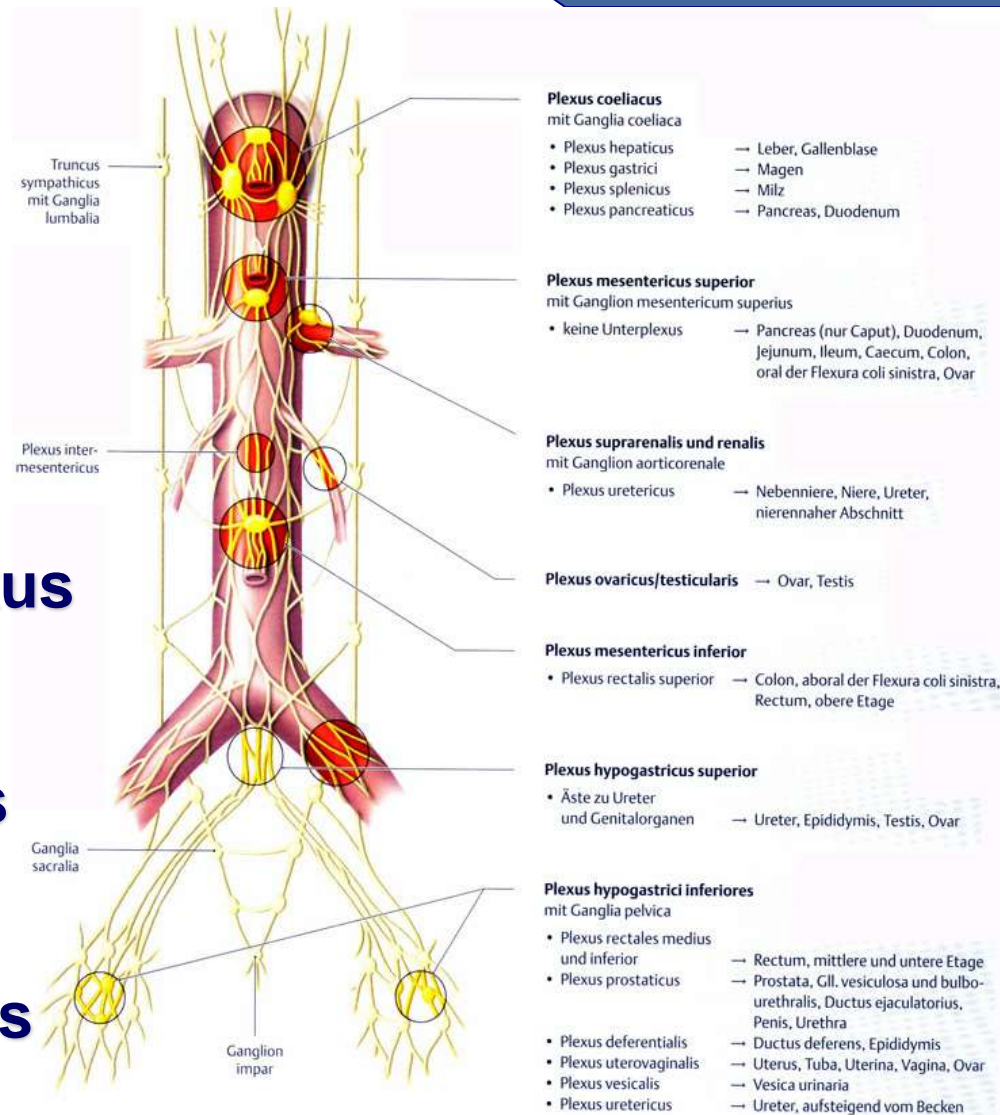
- Plexus coeliacus mit Ganglia coelestia**
- Plexus hepaticus
 - Plexus gastrici
 - Plexus splenicus
 - Plexus pancreaticus

Truncus sympathicus mit Ganglia lumbalia

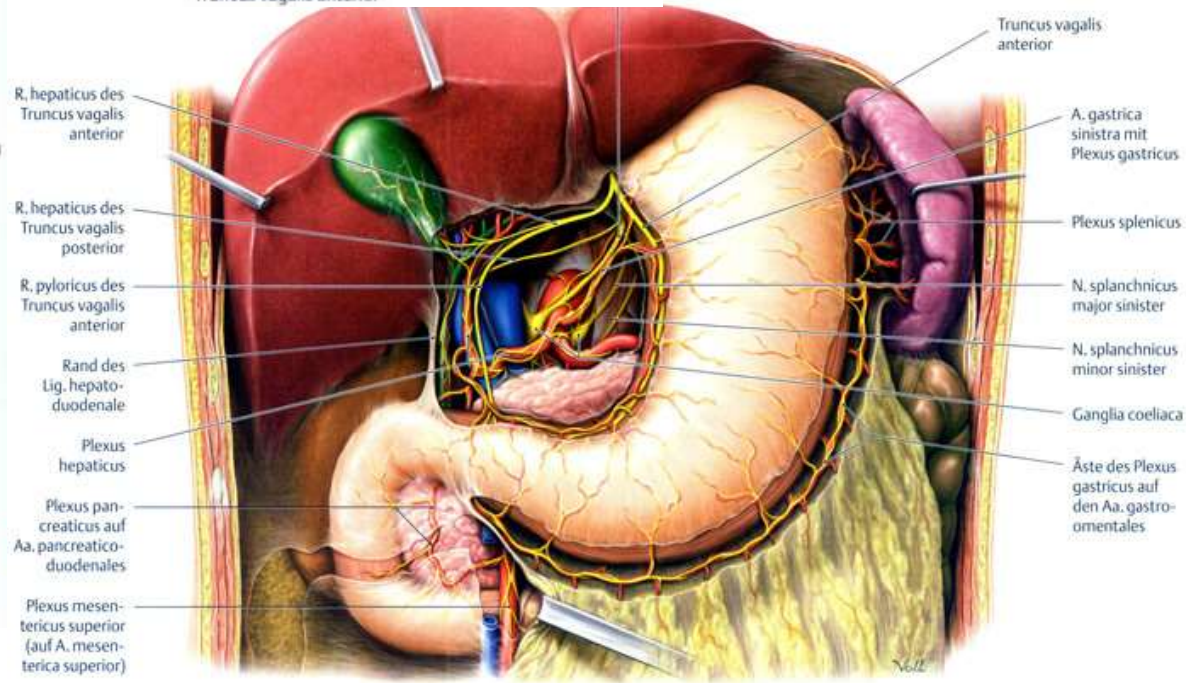
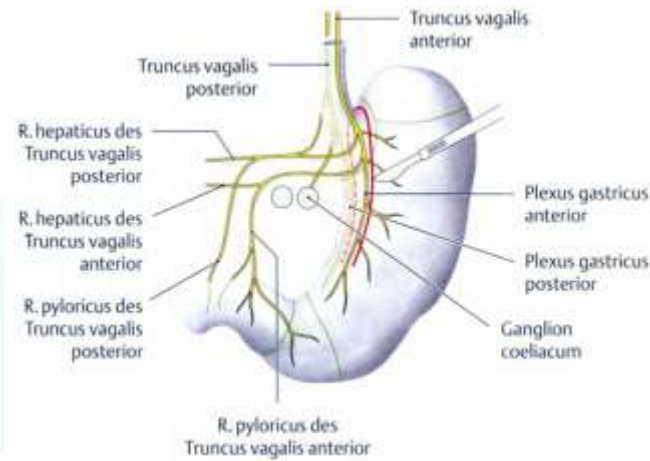
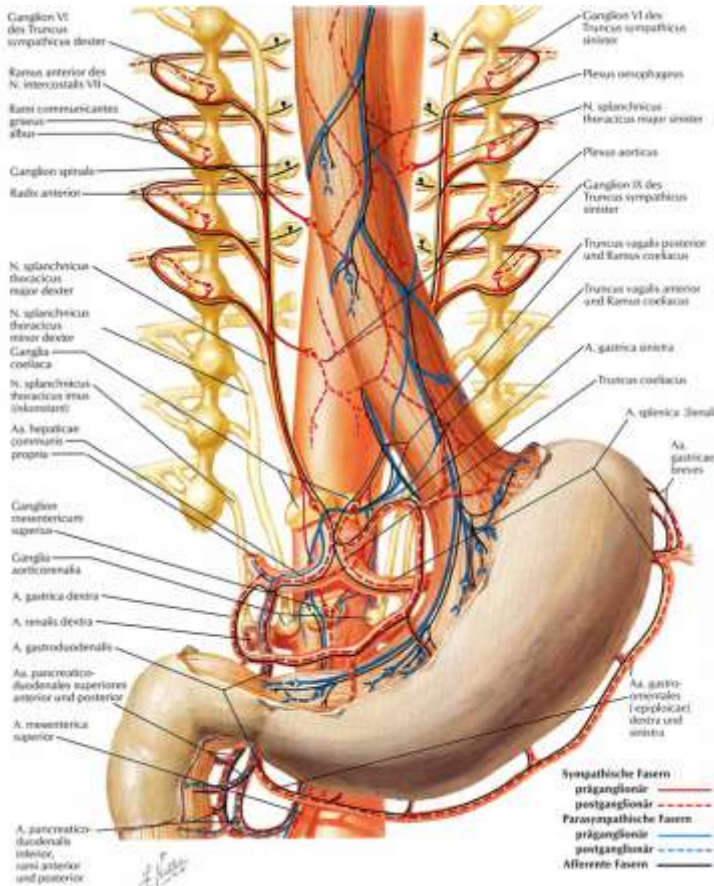


Secondary plexuses in the abdomen

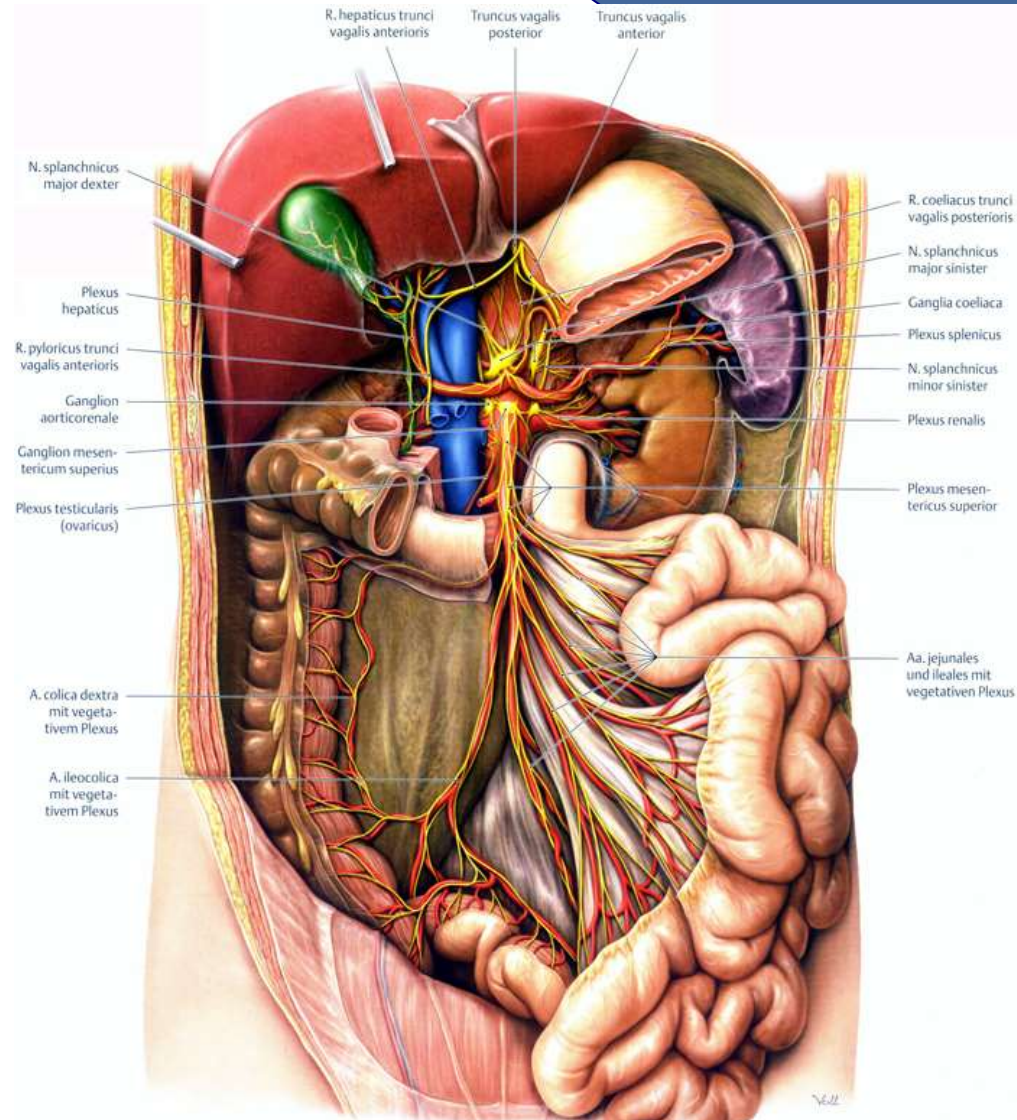
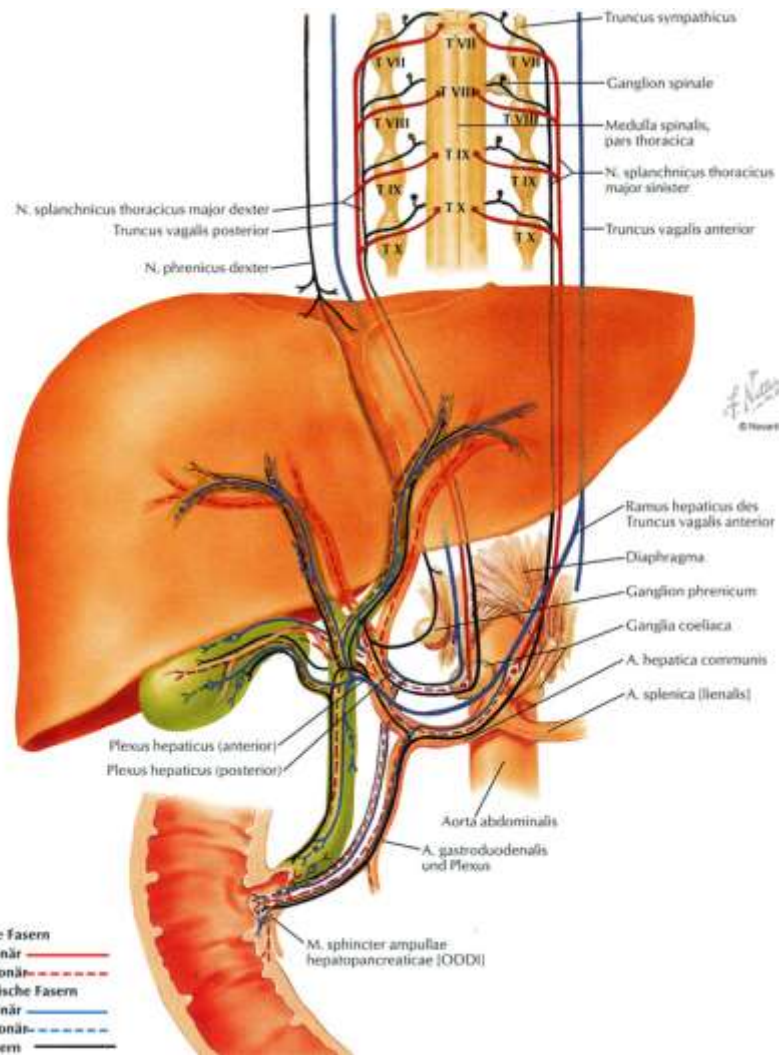
- ✓ phrenic plexus
- ✓ hepatic plexus
- ✓ left gastric plexus
- ✓ splenic plexus
- ✓ suprarenal plexus
- ✓ renal plexus ⇒ ureteric plexus
- ✓ testicular/ovarian plexus
- ✓ superior mesenteric plexus
- ✓ inferior mesenteric plexus
- ✓ superior hypogastric plexus



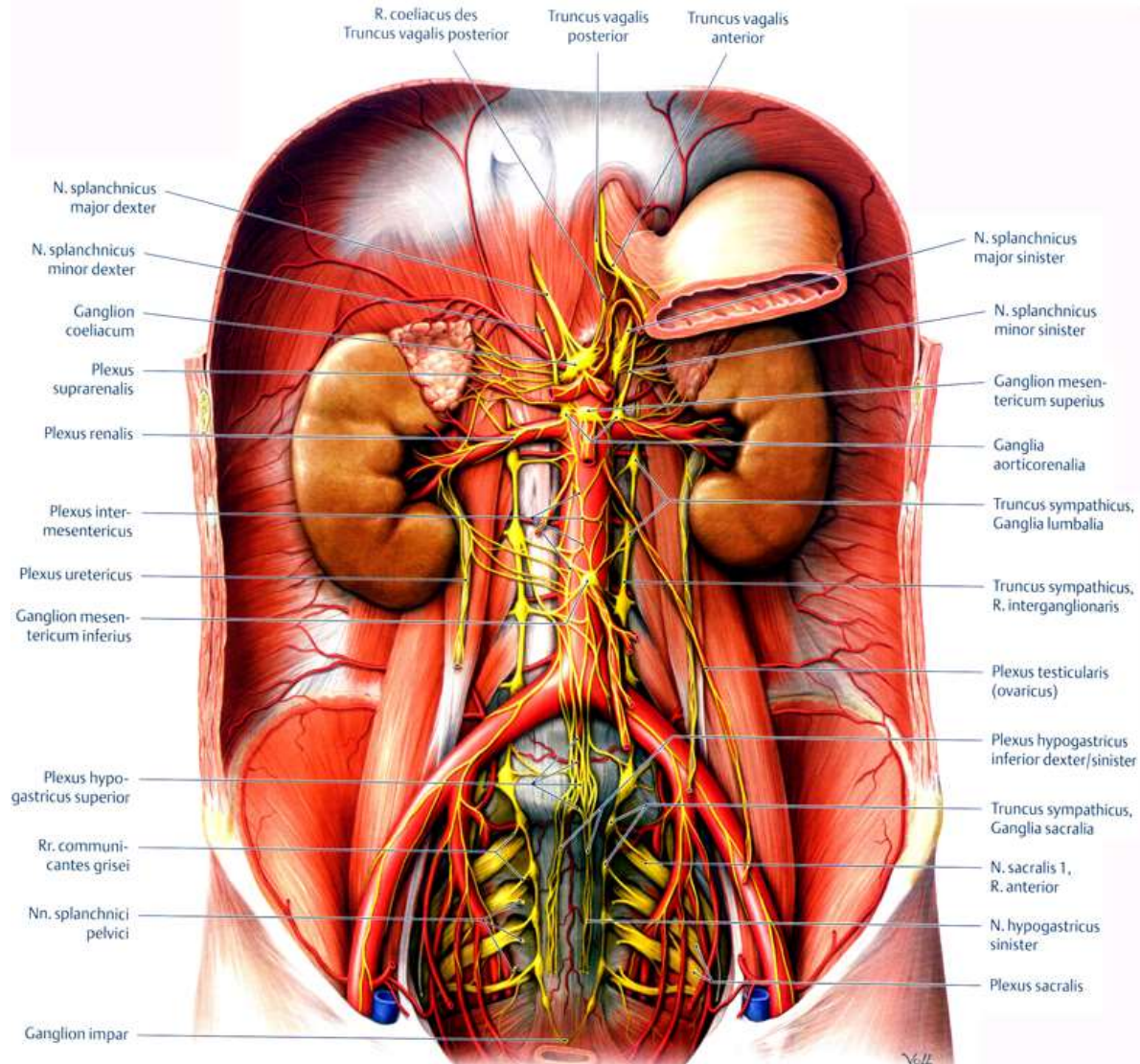
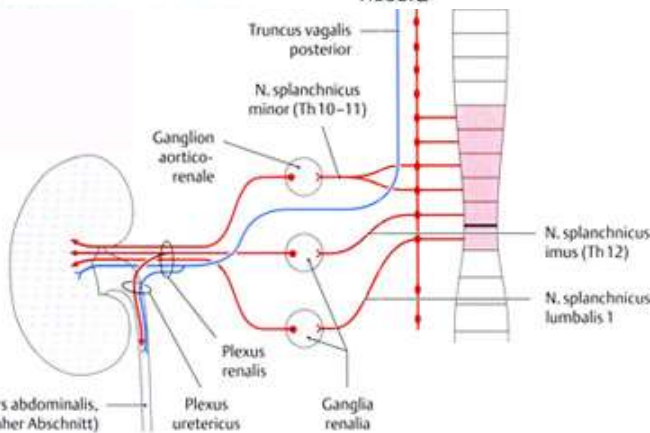
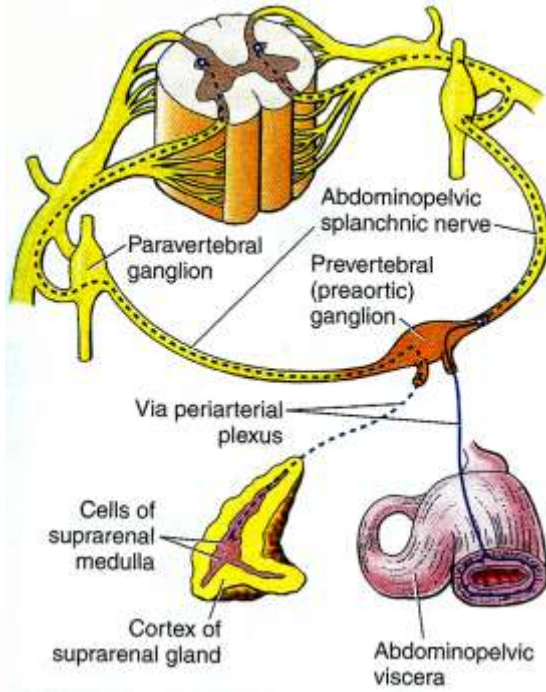
Gastric plexuses



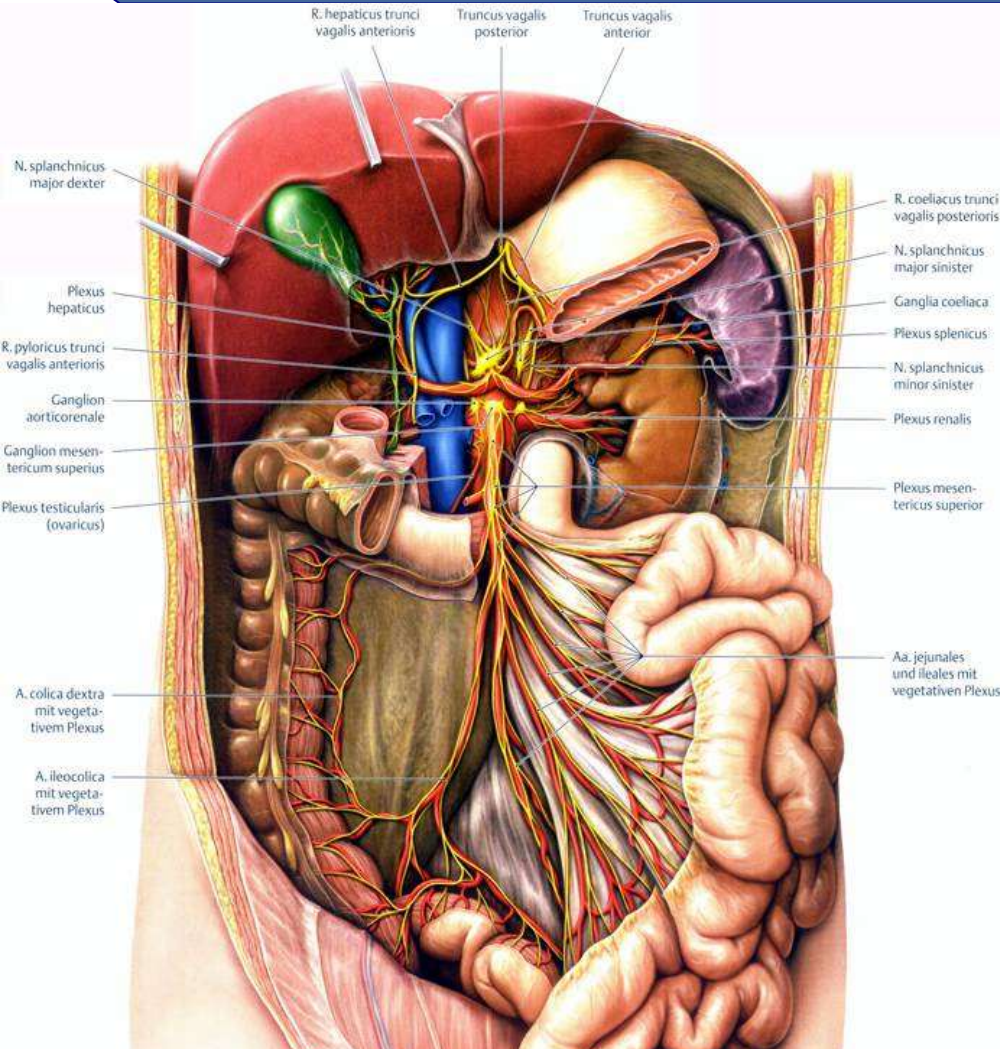
Hepatic and splenic plexuses



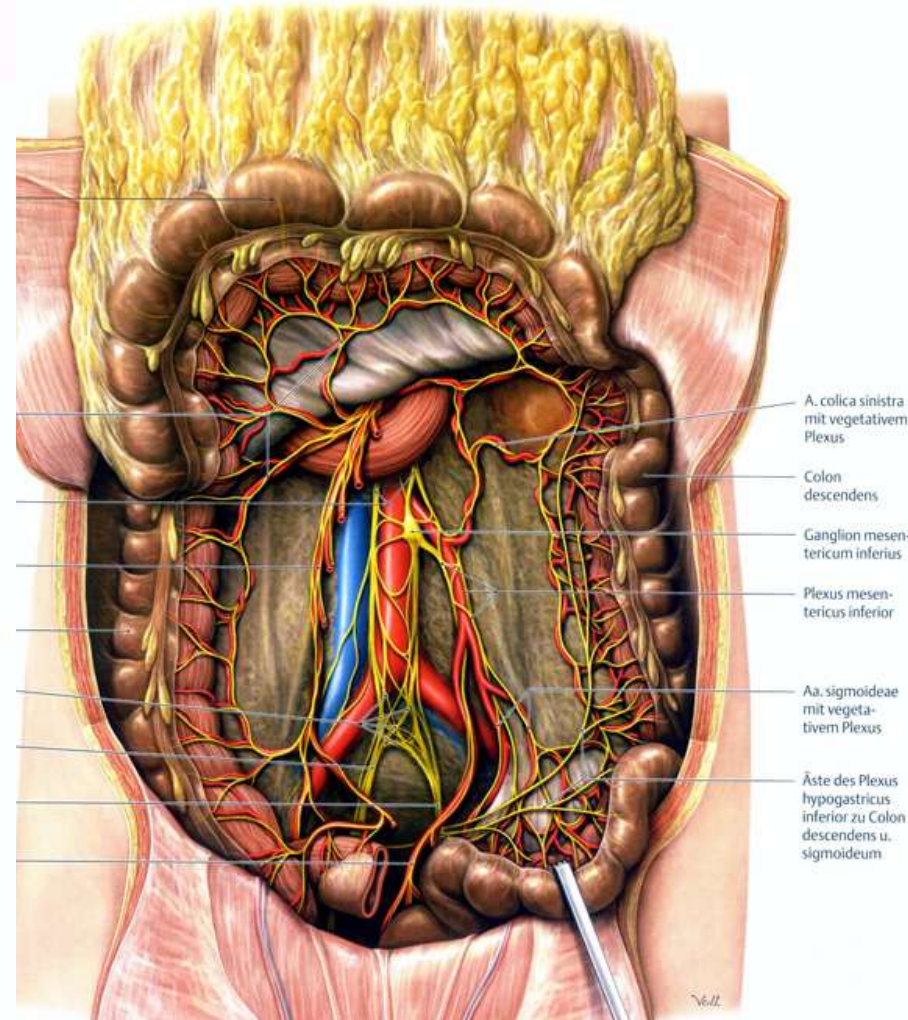
Suprarenal and renal plexuses



Superior and inferior mesenteric plexuses



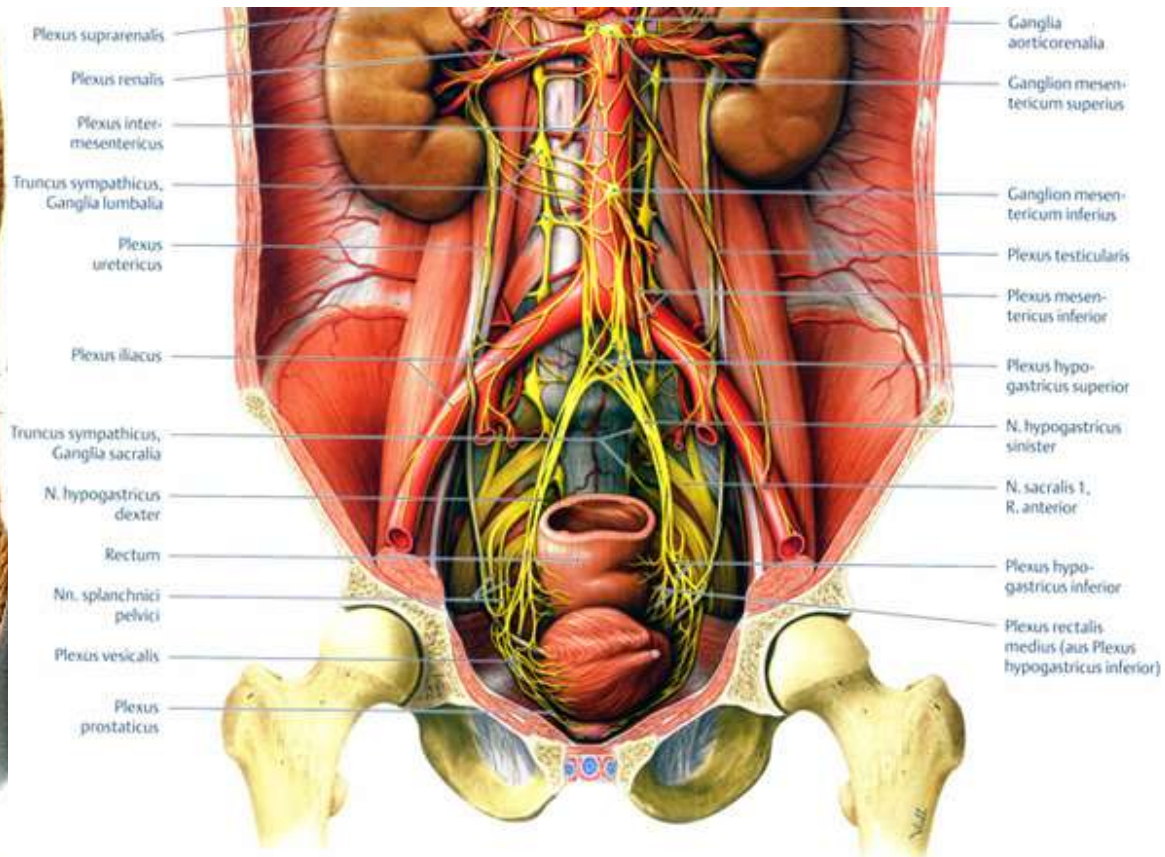
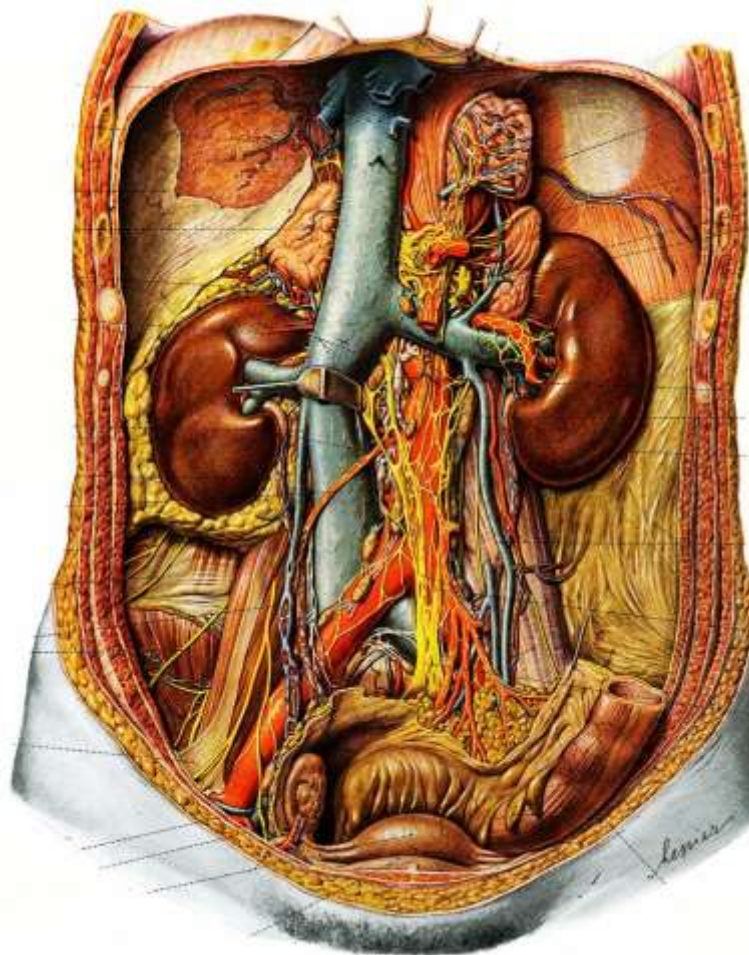
Vegetativer Innervationsbereich des Plexus mesentericus superior am Darm



Vegetativer Innervationsbereich von Plexus mesentericus und hypogastricus inferior am Darm



Ovarian/testicular plexuses

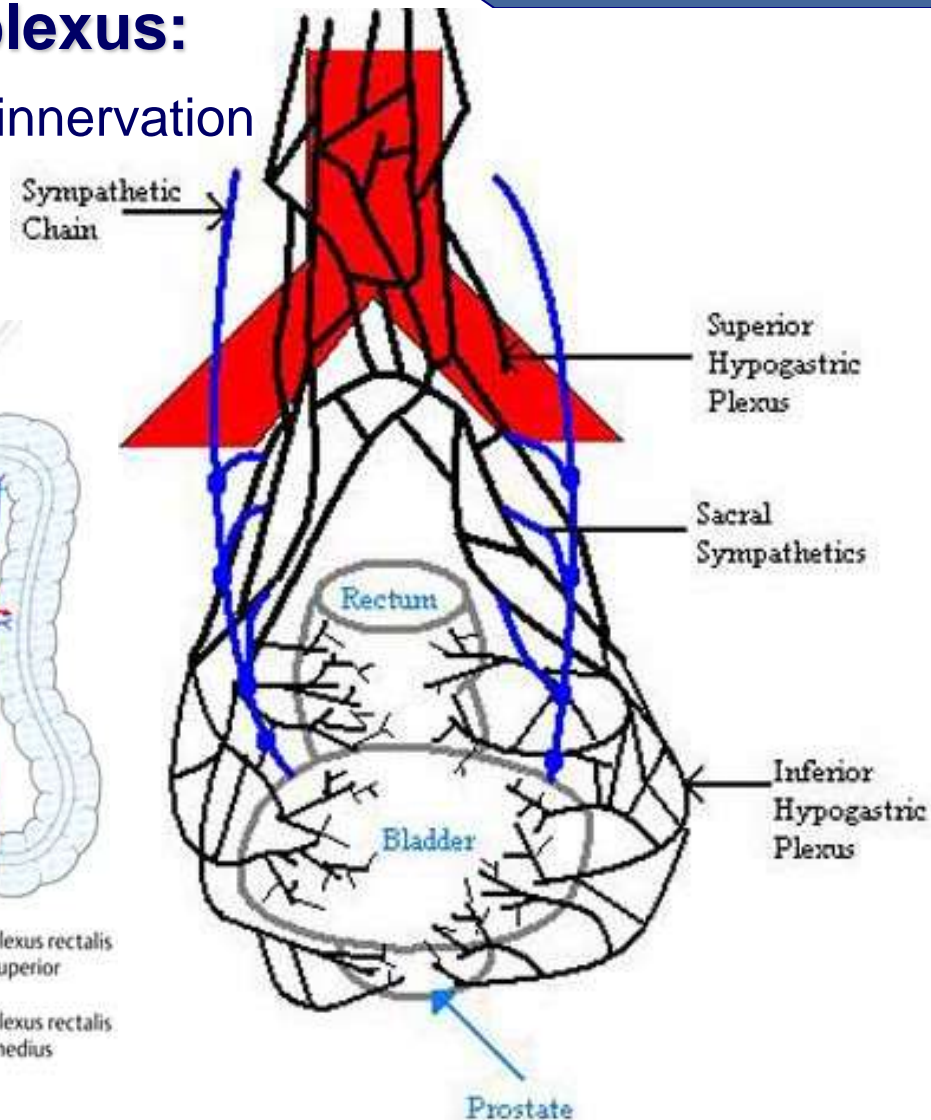
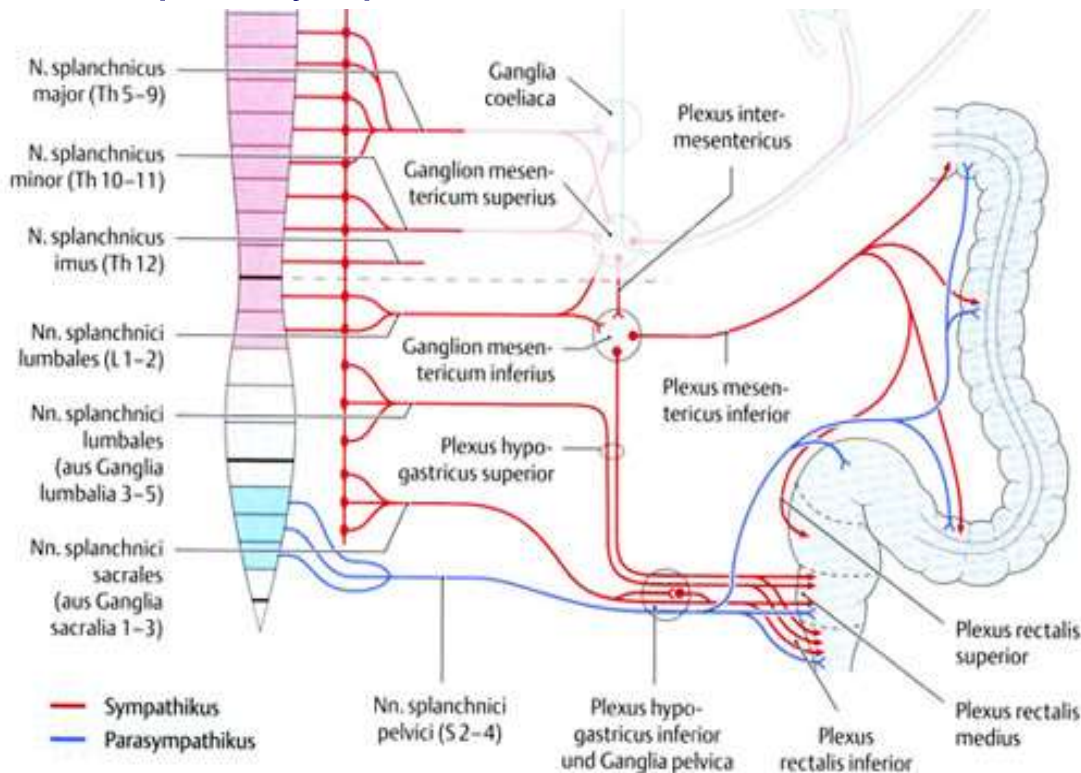




Primary plexuses in the pelvis

■ inferior hypogastric (pelvic) plexus:

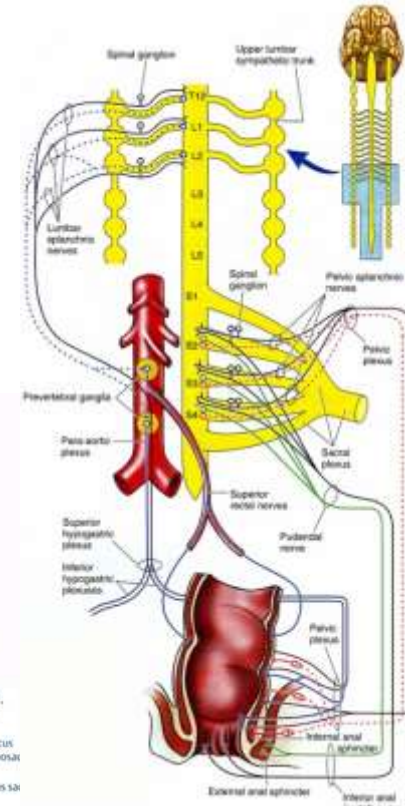
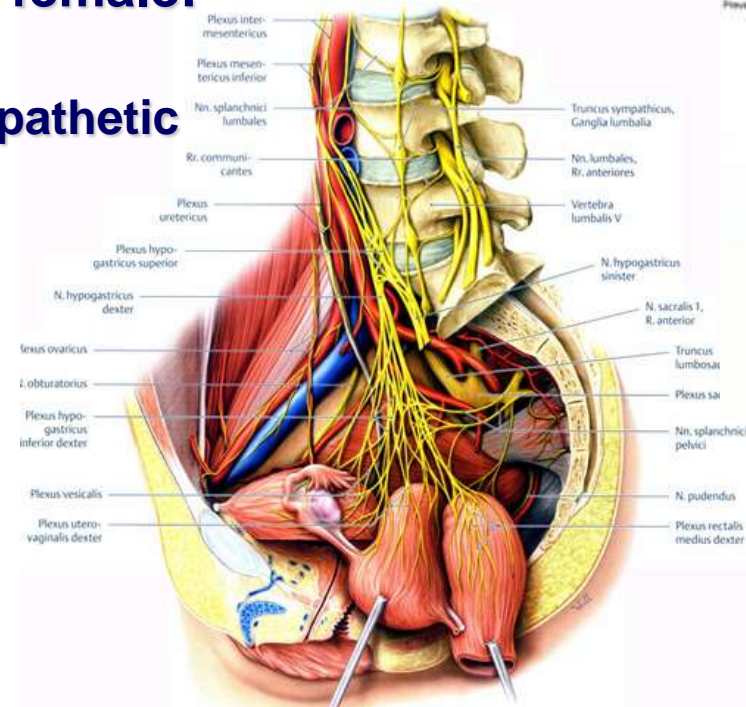
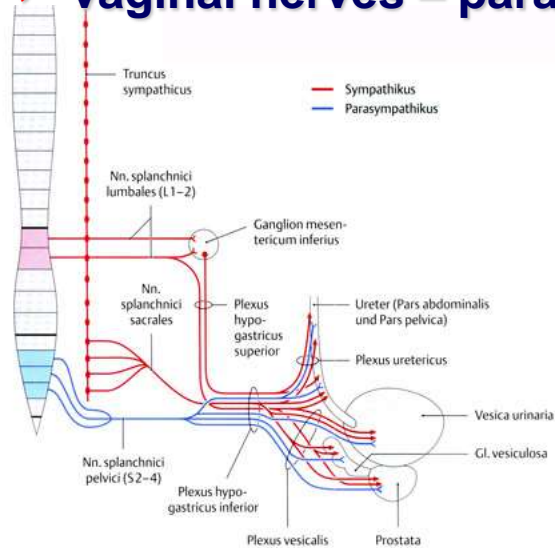
- ✓ hypogastric nerves – sympathetic innervation
- ✓ pelvic splanchnic nerves – parasympathetic innervation





Secondary plexuses in the pelvis

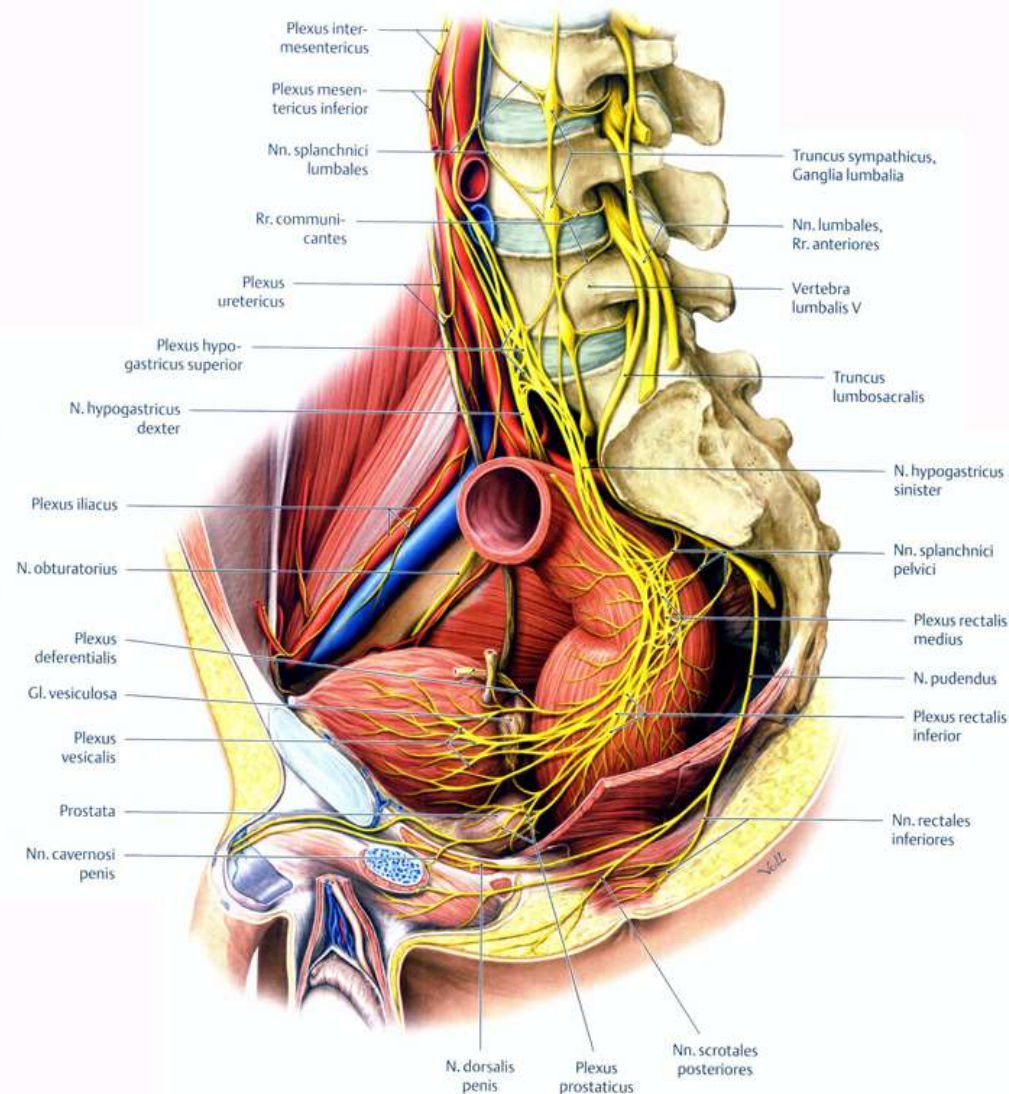
- **common (male&female) plexuses:**
 - ✓ middle and inferior rectal plexuses
 - ✓ vesical plexus
- **autonomic plexuses in the male:**
 - ✓ prostatic plexus
 - ✓ plexus of the deferent duct
- **autonomic plexuses in the female:**
 - ✓ uterovaginal plexus
 - ✓ vaginal nerves – parasympathetic





Autonomic innervation of male genitals

- innervated by both somatic and autonomic nerve fibers
- somatic innervation:**
 - ✓ pudendal nerve
- autonomic innervation** – parasympathetic and sympathetic fibers:
 - ✓ pelvic plexus ⇒ cavernous nerve ⇒ penis





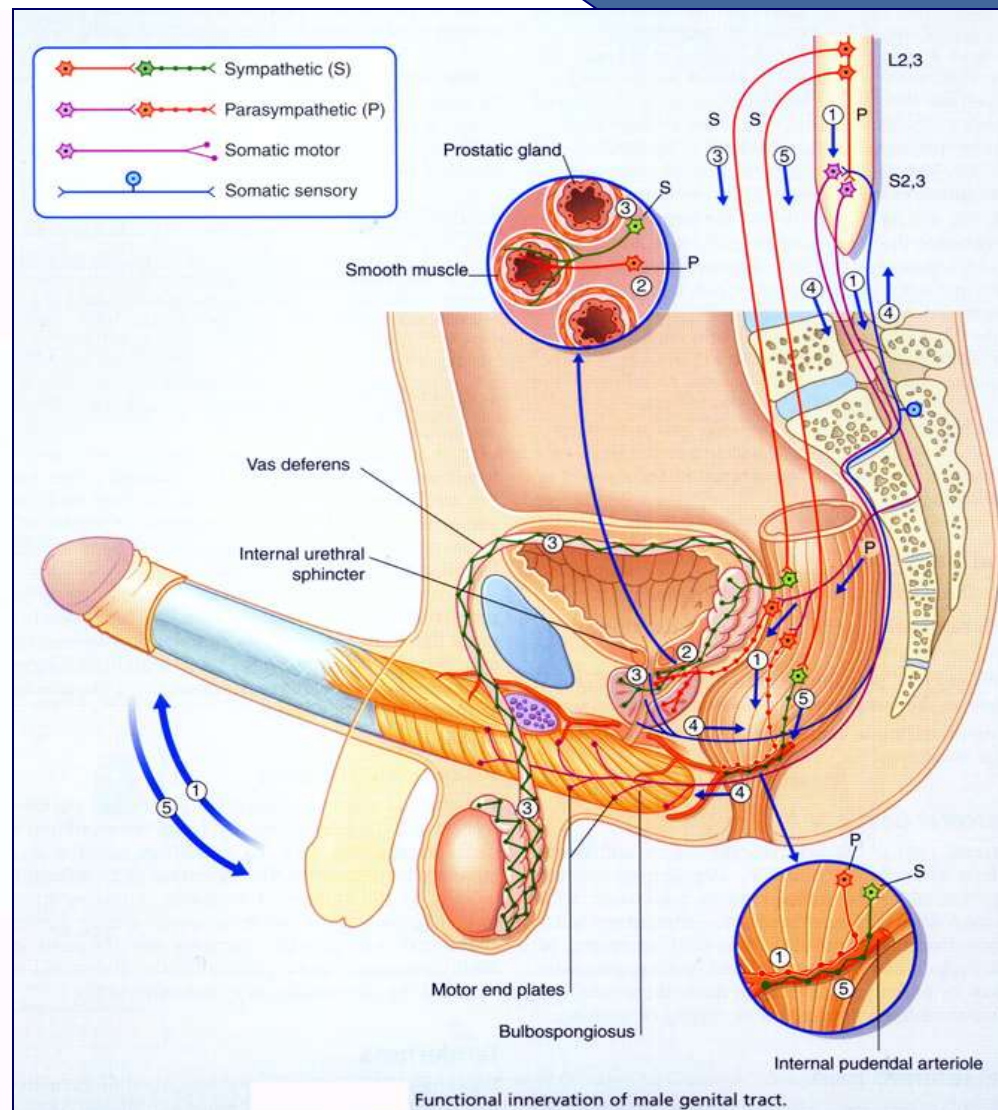
Autonomic innervation of male genitals

- innervated by both somatic and autonomic nerve fibers
- **somatic innervation:**
 - ✓ pudendal nerve
- **autonomic innervation** – parasympathetic and sympathetic fibers:
 - ✓ pelvic plexus ⇒ cavernous nerve ⇒ penis

1 **Erection.** Psychic stimulation of the central *parasympathetic* pathway activates selected preganglionic neurons (P) to pelvic ganglia supplying parasympathetic fibers to the internal pudendal artery, where muscarinic and vasoactive intestinal polypeptide receptors cause the artery to relax, allowing blood to distend the penile cavernous tissue spaces. Cholinergic fibers also cause the relaxant transmitter nitric oxide to be released from the lining epithelium of the cavernous spaces.

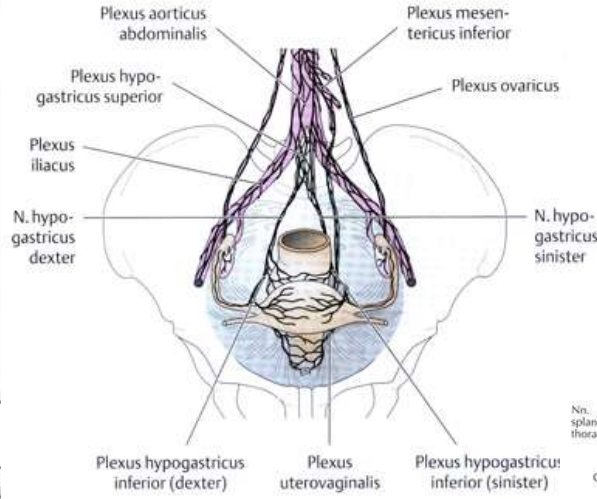
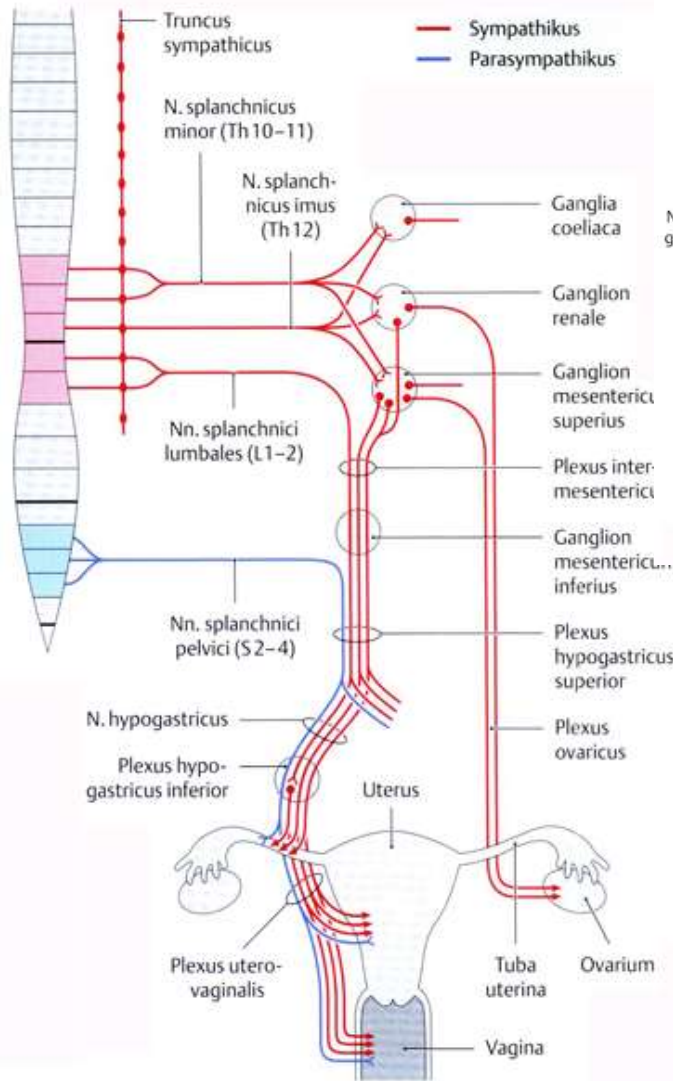
2 **Secretion.** Parasympathetic ganglia in the walls of the prostate and seminal vesicles are stimulated to cause glandular secretion (via muscarinic receptors on the acini). These secretions contribute 80% of total semen volume.

3 **Emission.** Psychic stimulation of the central *sympathetic* pathway activates preganglionic neurons to pelvic ganglia supplying fibers to α_1 receptors on the smooth muscle of vas deferens, seminal vesicles, prostate, and internal urethral

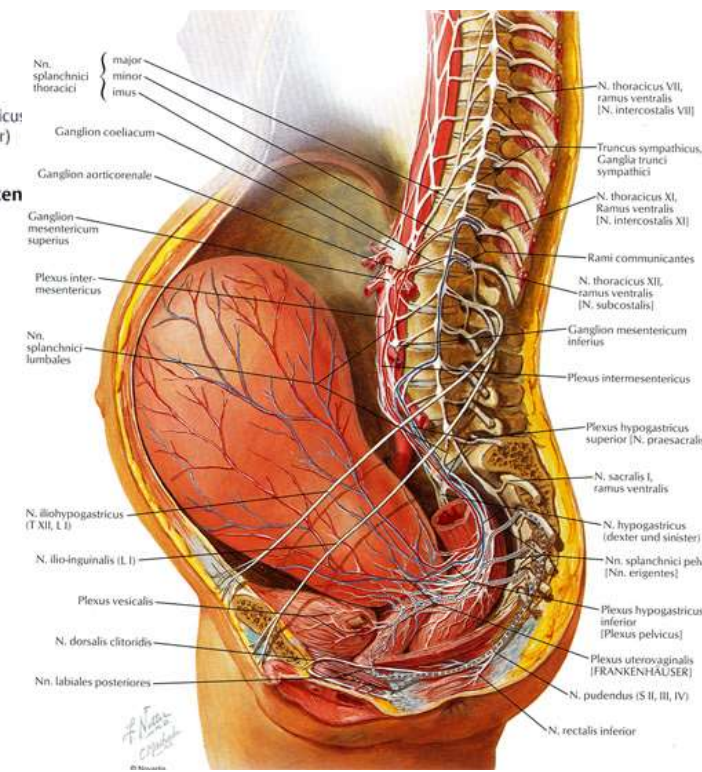




Autonomic innervation of female genitals



Übersicht über die vegetativen Plexus im weiblichen Becken

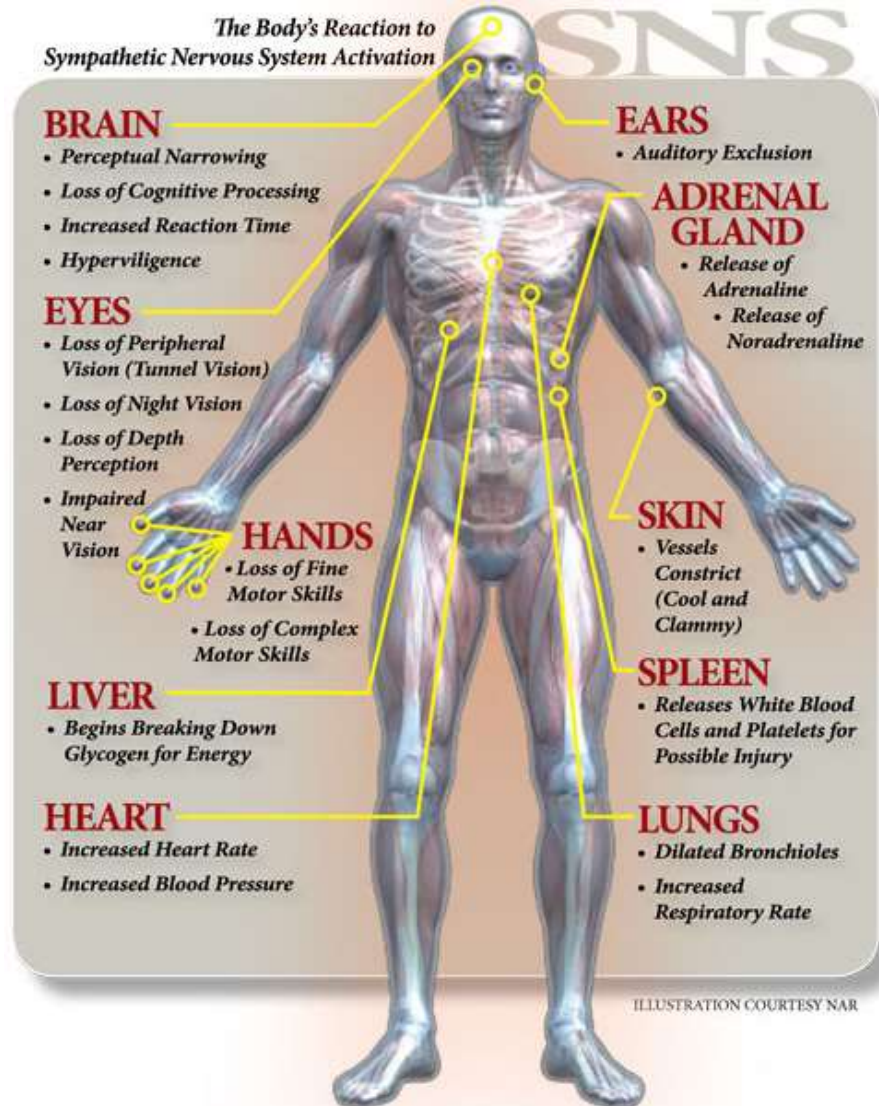


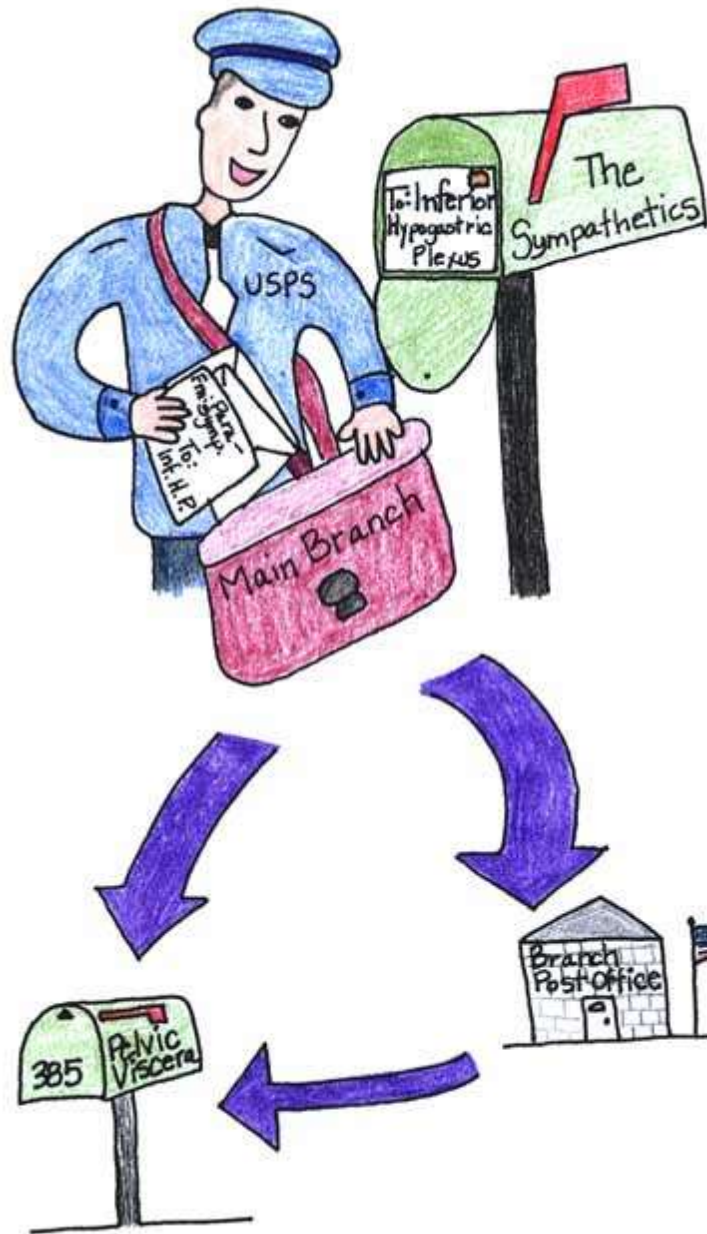
Clinical notes



the overall functional status of the body:

- ✓ vital body processes are autonomic reflex responses;
- ✓ many somatic-visceral and visceral somatic reflexes;
- ✓ metabolic and mechanical irritations of autonomic nerve fibers cause different pathologic conditions;
- ✓ an appreciation of the nuclei, fiber pathways and resulting reflex deficits from injuries are useful as a diagnostic aid in exploring the diffuse distribution of the autonomic system;
- ✓ changes in cutaneous sudomotor and vasomotor reflexes, changes in skin temperature, and increased skin resistance to passage of a minute electric current indicate the involvement of sympathetic nerve fibers;
- ✓ a knowledge of dermatomal and peripheral nerve distributions often can provide additional evidence to substantiate both the location and level of a nerve injury.





Thank you...

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