VEGETATIVE (AUTONOMIC) NERVOUS SYSTEM

1) **Classifications of nervous system**
2) **Reflex arches**
3) **Differences between the vegetative and somatic NS**
4) **Sympathetic NS**
5) **Parasympathetic NS**
6) **Dual Innervation of the organs by the ANS**
7) **Vegetative plexuses**
8) **Types of reflexes, Zakharyin-Head's areas**
9) **Development of the vegetative ganglia**

Lecturer: ***PhD, university professor Tamara Hacina***

NERVOUS SYSTEM

(MORPHOLOGYCAL CLASSIFICATION)

CENTRAL

Brain

+

Spinal cord

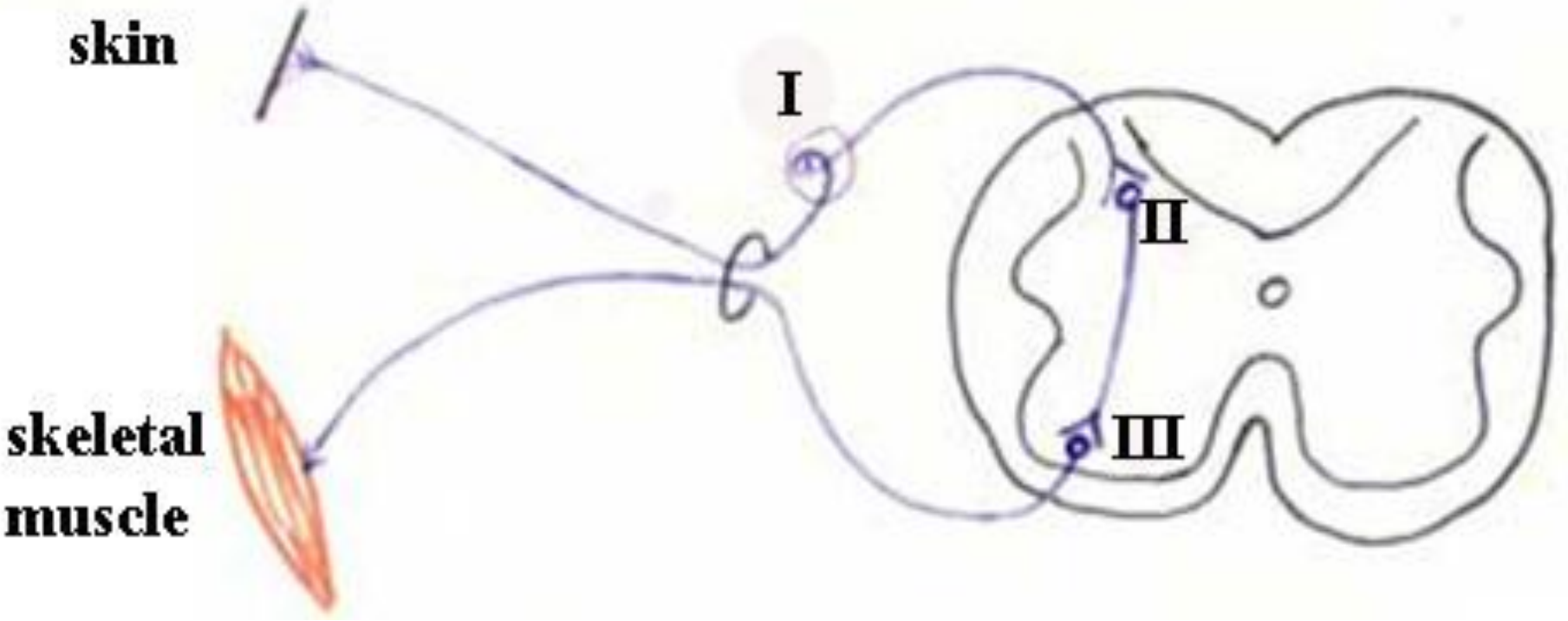
PERIPHERAL

12 pairs of cranial nerves

+

31 pairs of spinal nerve

Somatic reflex arch



5 links:

I. Receiving (receptors): *in the skin or internal organs

II. Ascending (sensory) neuron: *carries impuls to the posterior horn of the spinal cord

III central part (spinal cord or brain)

IV. Descending (motor) * carries impuls to the organ-effector.

V. organ-effector.

I neuron: *in the spinal ganglion

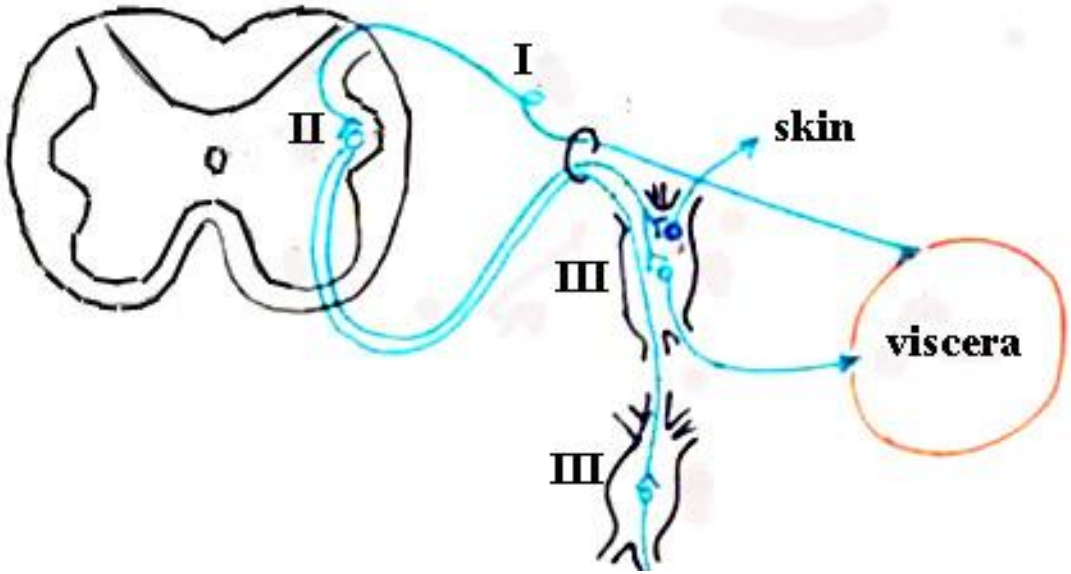
II neuron: *posterior horn of the spinal cord

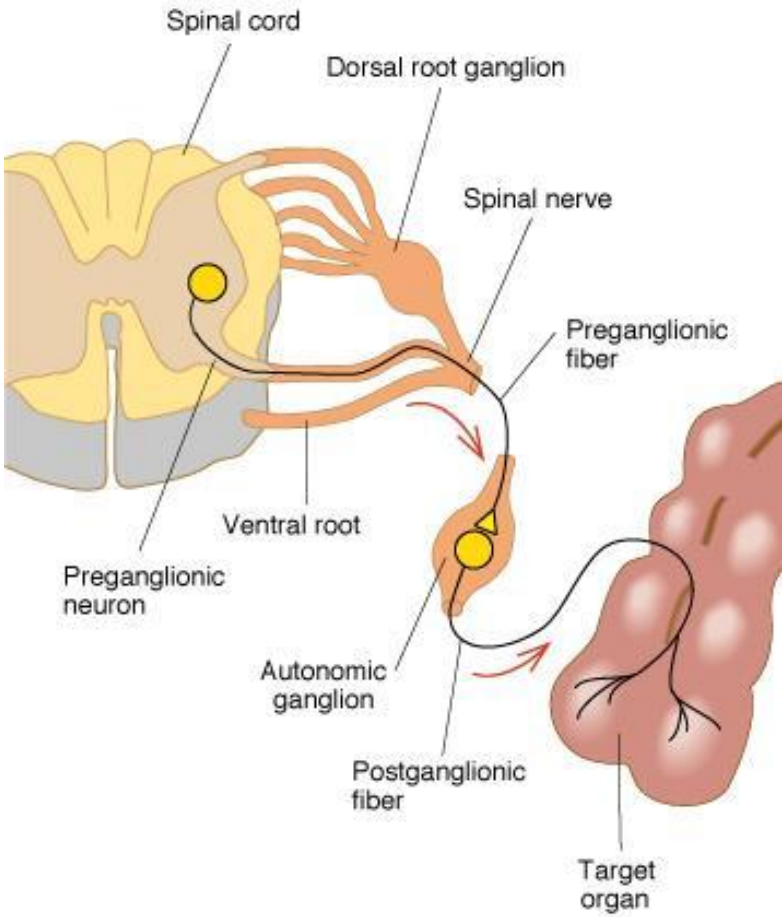
III neuron: *anterior horn

* the II neuron finishes in the spinal cord

* descending part is unineuronal

Vegetative reflex arch



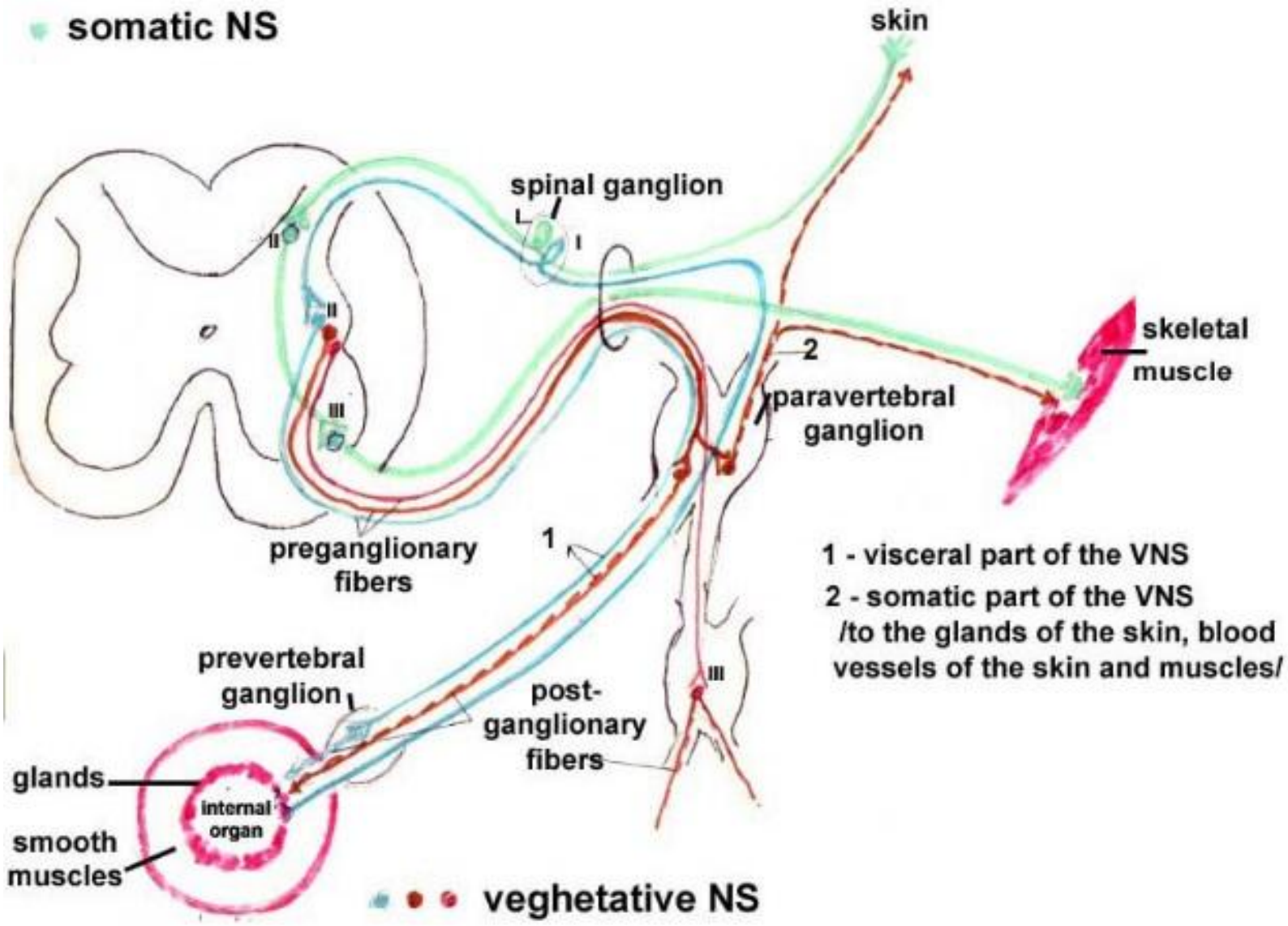


I neuron: *in the spinal ganglion

II neuron: * lateral horn of the spinal cord

III neuron: *outside of the of the spinal cord, in the vegetative ganglion

* the II neuron doesn't finish in the spinal cord
* descending part is bineuronal
* postganglionary fibers form the visceral and somatic parts
* preganglionary fibers form white communicating branch
* postganglionary fibers form gray communicating branch



According to D.M. Golub, P.I. Lobĸo et al.:

- **the vegetative lymph nodes, especially the sympathetic ones, have a multi-segmental origin;**
- **the spinal fibers are spread throughout the VNS frame at far distances from their place of origin, serving as conductors of the related collateral / compensatory visceral innervation.**

NERVOUS SYSTEM

(MORPHOFUNCTIONAL CLASSIFICATION)

	VEGETATIVE (AUTONOMIC)	SOMATIC (ANIMAL)
Functional differences		
Region of supply:	smooth muscles, glands	striated muscles (Skeletal,)
Action :	slow	fast
Duration:	permanent	during the action of excitant
Functions:	metabolism, growth, homeostasis	motion
Structural differences		
	*has not segmental structure *ascending part does not form visible nerves *vegetative nerves form plexuses around blood vessels	*has segmental structure *ascending & descending fibers form visible nerves

- **Although the vegetative nervous system at the periphery is relatively separate from the somatic one, at the central level, there is a close connection between vegetative and somatic functions.**

Main differences between somatic motor and visceral motor nerves

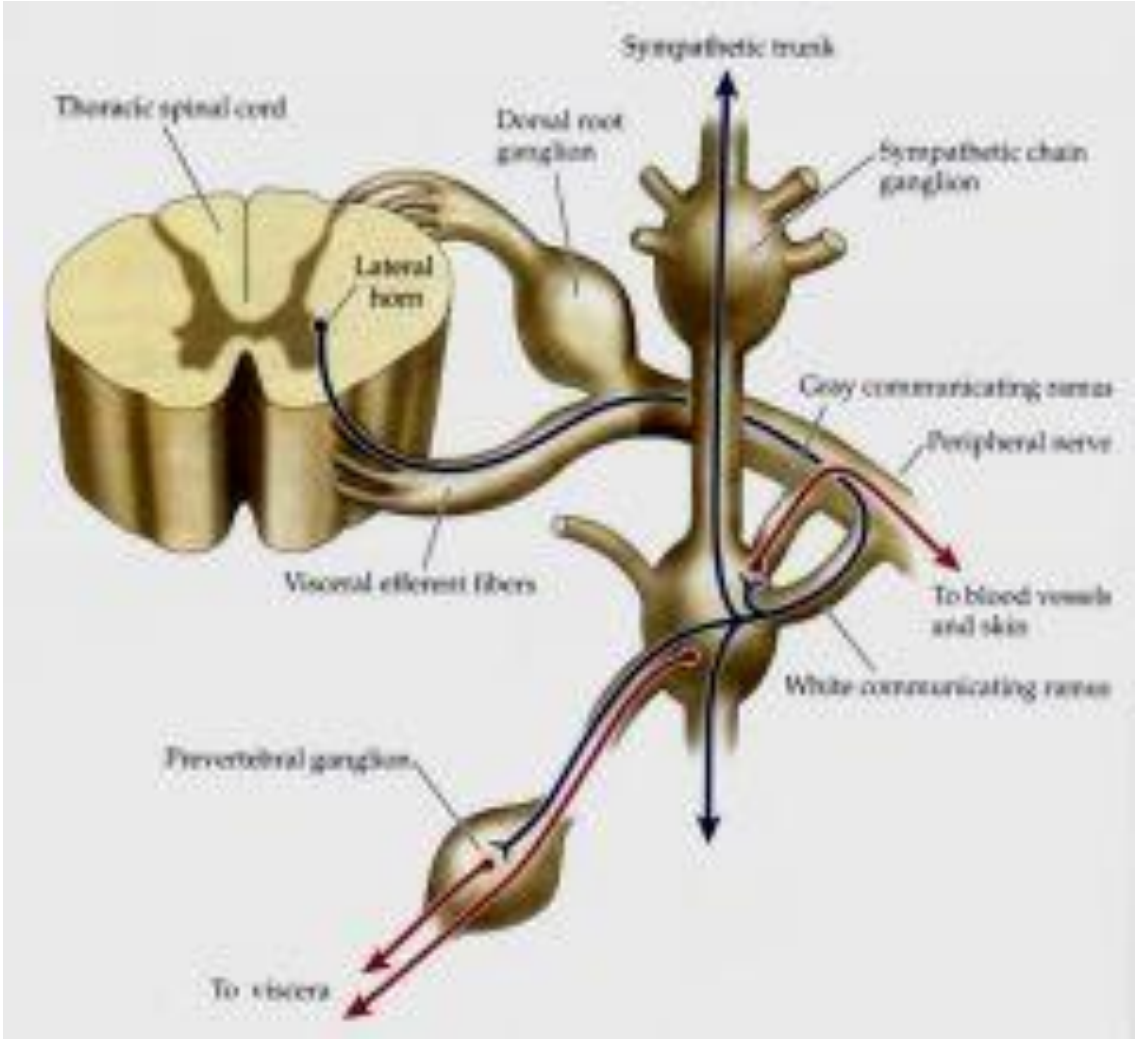
	Somatic	Visceral
Effectors	Skeletal muscles	Cardiac, smooth muscles and glands
Kind of fibers	One	Two: sympathetic and parasympathetic
From the center to effect require	Single neuron	Two neurons: preganglionic neuron (fiber) and postganglionic neuron (fiber)
Fibers	Thick myelinated	Preganglionic: thin myelinated postganglionic: unmyelinated
Distributive form	Nerve trunk	Nerve plexuses
Control	Voluntary (consciousness)	Involuntary (unconsciousness)

White Rami

- Carry preganglionic sympathetic axons from the C8–L2 spinal nerves to the sympathetic trunk.
- Preganglionic axons are myelinated.
- The white ramus has a whitish appearance
- Associated only with the C8–L2 spinal nerves.

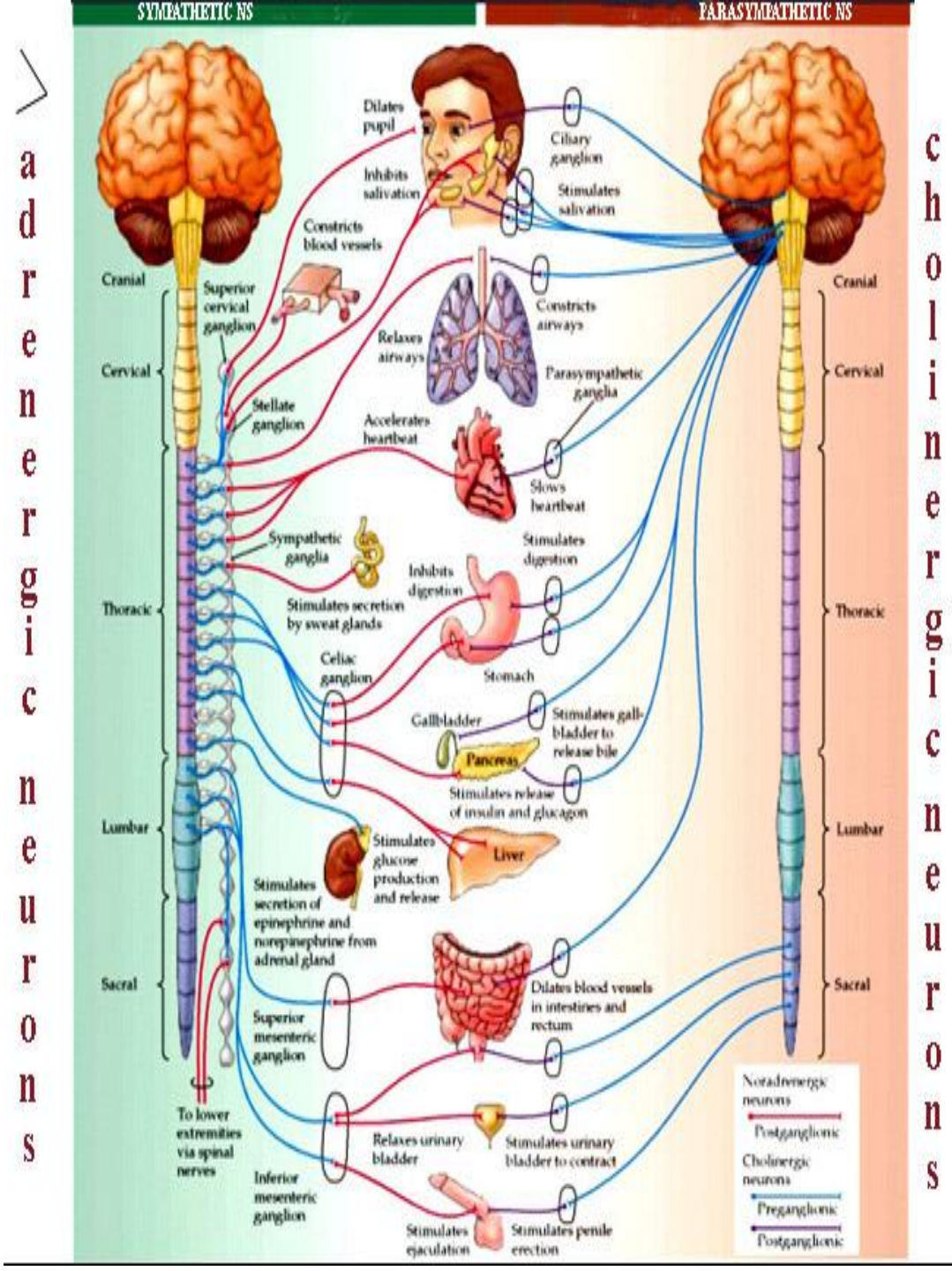
Gray Rami

- Carry postganglionic sympathetic axons from the sympathetic trunk to the spinal nerve.
- Axons are unmyelinated.
- Gray rami have a grayish appearance
- Connect to all spinal nerves.



Divisions of the ANS

- Two divisions
  - Parasympathetic division
  - Sympathetic division
- Divisions are similar:
  - both use a preganglionic neuron (cell body in the CNS)
  - Both use a postganglionic neuron (cell body in the ganglion)
  - Innervate muscles or glands
  - Both are involuntary
  - Both are concerned with the body's internal environment (homeostasis)
- Divisions perform dramatically different functions.



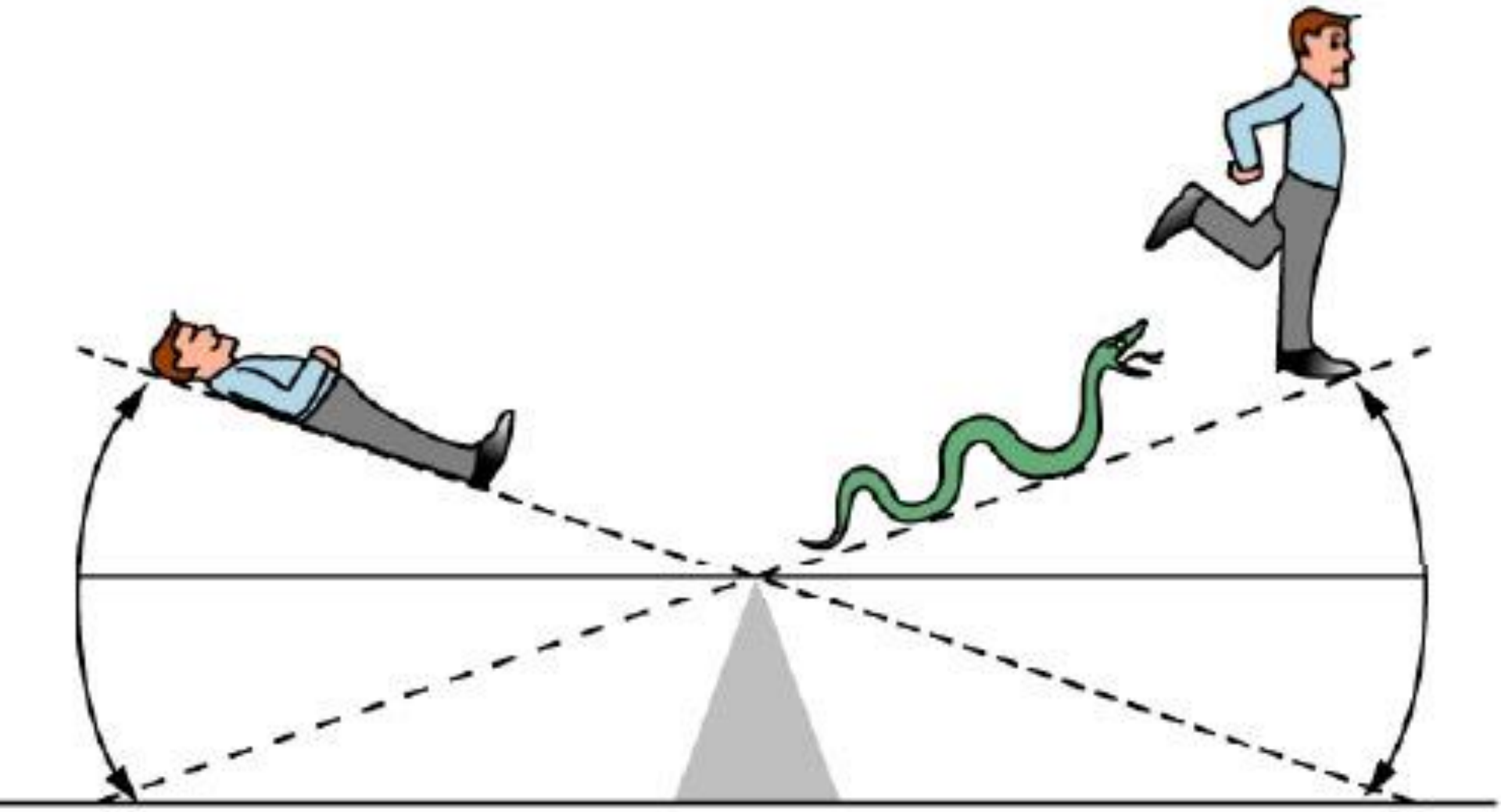
DIVISIONS OF THE VNS

Parasympathetic

"rest-and-digest" division

Sympathetic

"fight-or-flight" division



Functions: Regulates body temperature. Coordinates CV, respiratory, excretory & reproductive activities.

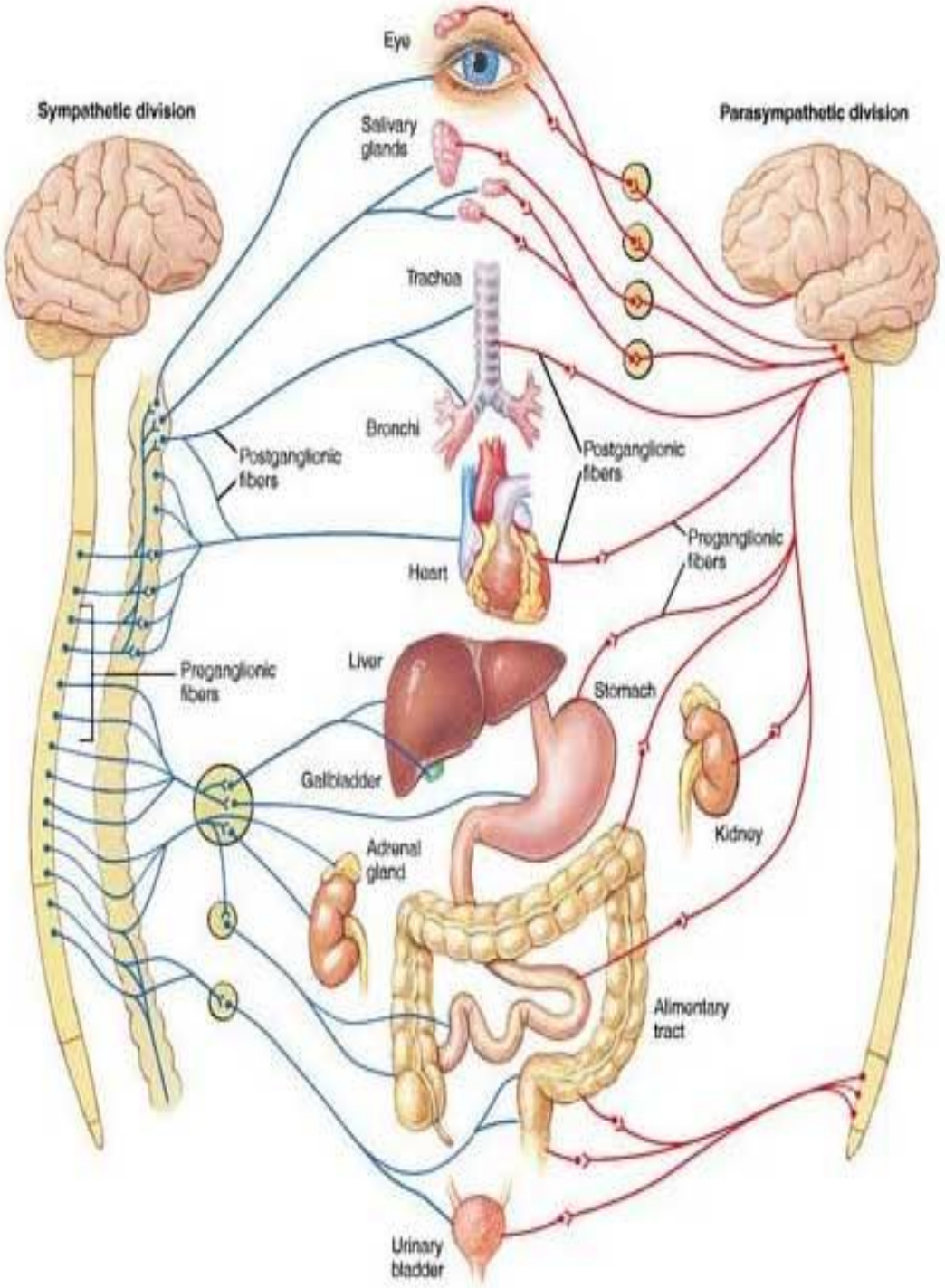
Structural differences of the sympathetic and parasympathetic nervous systems

SNS

- **central**
  - C8-L2
- **peripheral**
  - fibers
    - preganglionic
    - postganglionic
  - ganglia
    - paravertebral
    - prevertebral

PSNS

- **central**
  - Brain stem
  - S2-S4
- **peripheral**
  - fibers
    - preganglionic
    - postganglionic
  - ganglia
    - terminal
    - intramural



Location of segmentary and suprasegmentary senters of VNS

➢ ***Spinal cord:***

- ***Thoracolumbar part –*** intermediolateral nucleus in the lateral horns of the segments C8 - L3 with centers: vasomotor, ciliospinal, bronchopulmonary, sweat center, pilomotors etc., arranged metameric throughout the entire range of the intermediate column and
- ***Sacral part*** (intermediolateral nucleus S2-4);

➢ ***Brain stem:***

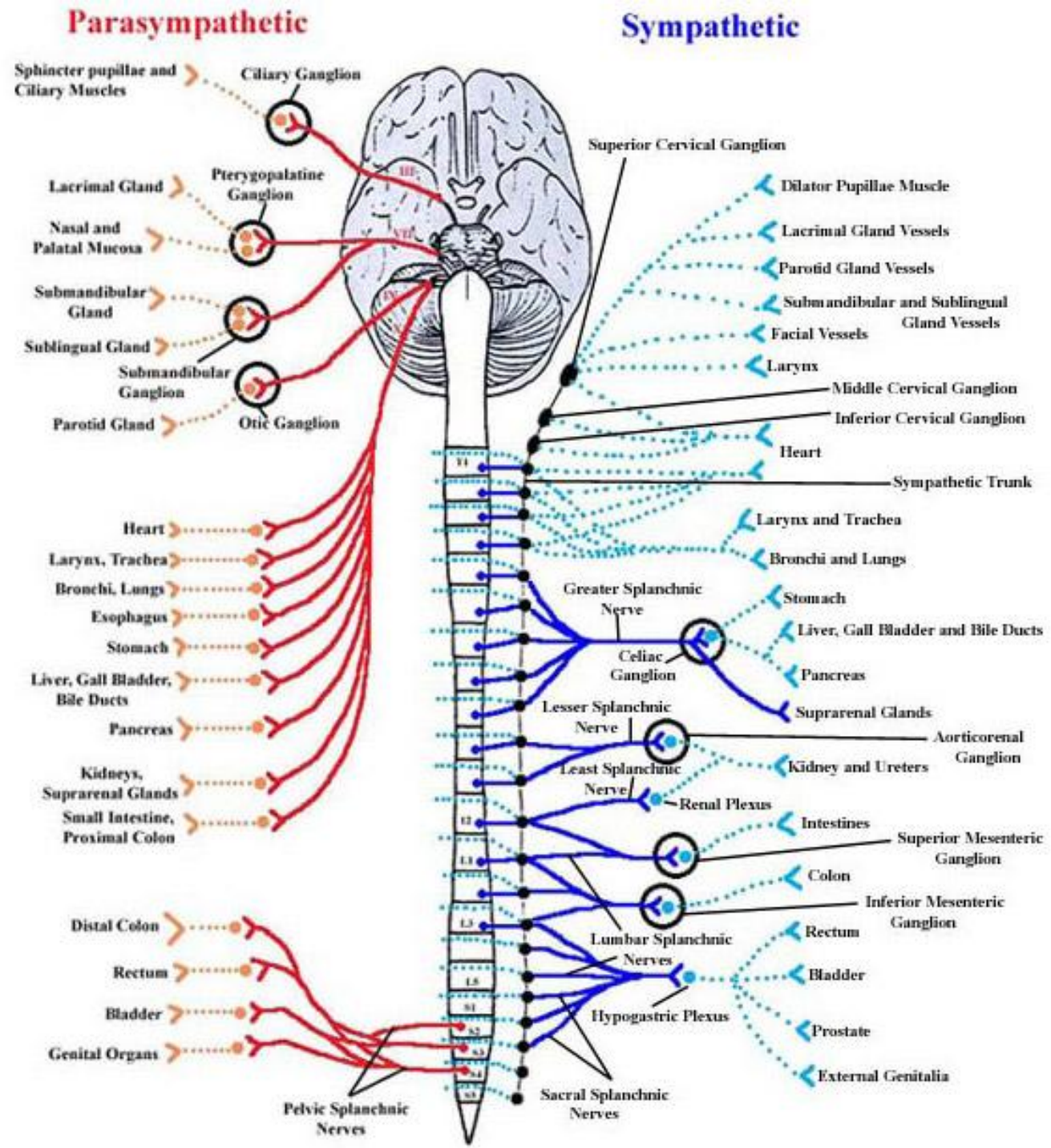
- ***Mesencephalon –*** nuclei of III-rd cr/n (Edinger-Westphal', Perl'); grey substance around the cerebral aqueduct

- ***Myelencephalon*** **-** parasympathetic nuclei of cranial nerves VII, IX, X),
- centers of cardiovascular and respiratory regulation,
- centers of protectional reflexes (swallowing, vomiting, coughing, sneezing),
- center of salivation,
- vasomotor center,
- reticular nuclei etc.

➢ ***Diencephalon*** - the hypothalamus (especially tuber cinereum) - the supreme center of vegetative integration with coordinating role of the various forms of nervous activity (regulation of blood circulation, thermoregulation, behavioral manifestations, digestion, excretion, reproduction).

➢ ***Telencephalon:*** areas of cortical projection, limbic system, basal nuclei *(caudate nucleus, lentiform nucleus),*

➢ ***Cerebellum*** - vasomotor regulation, wound regeneration, skin trophics, etc.



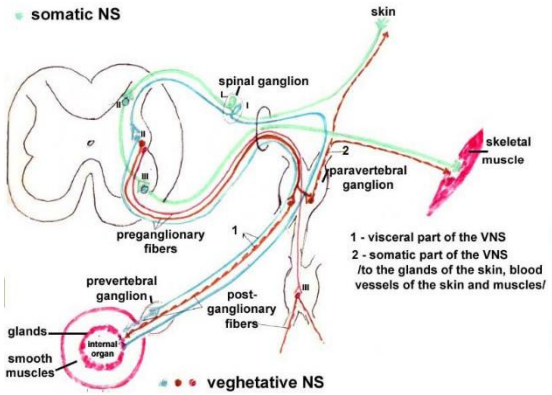
Sympathetic division

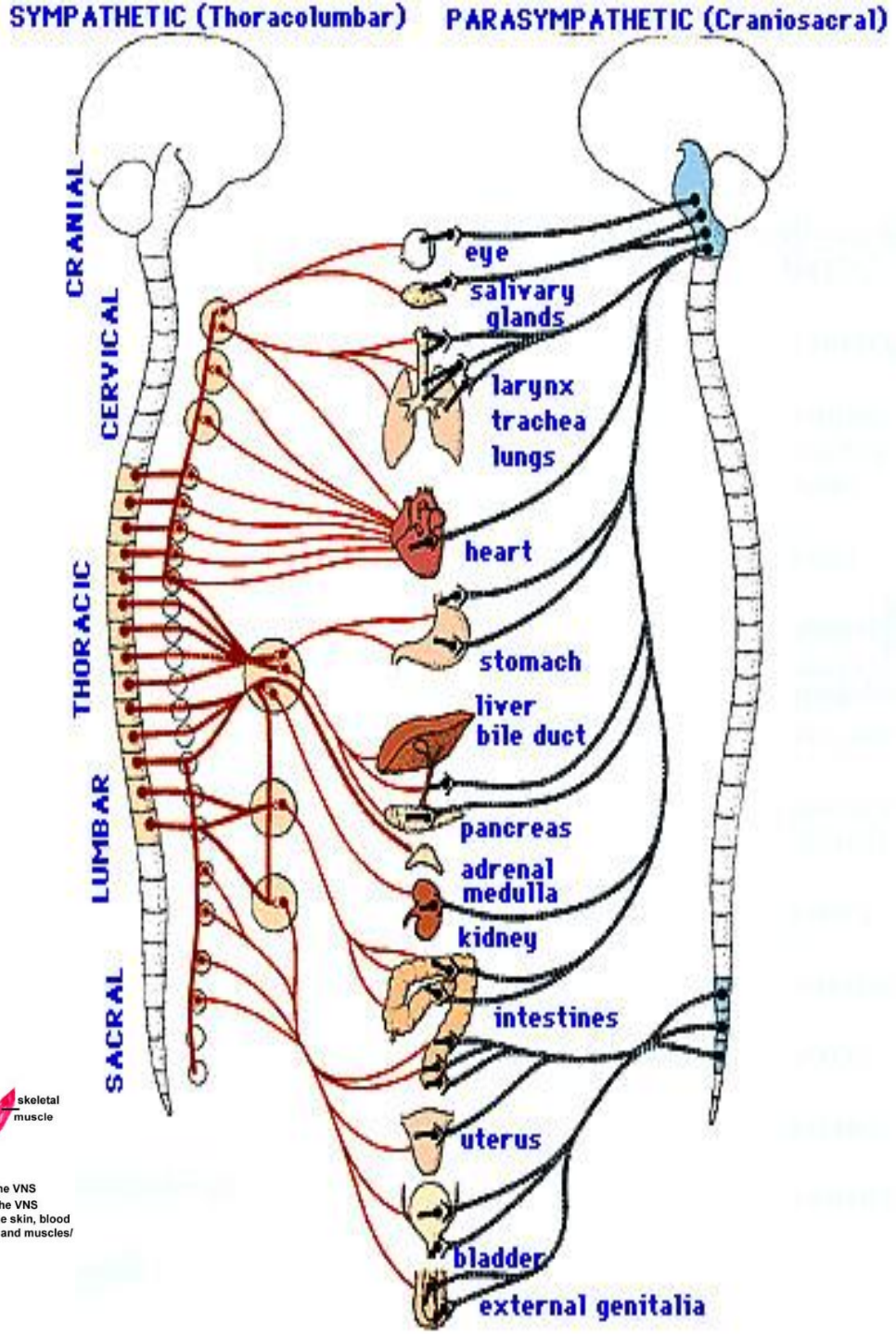
Preganglionic neurons

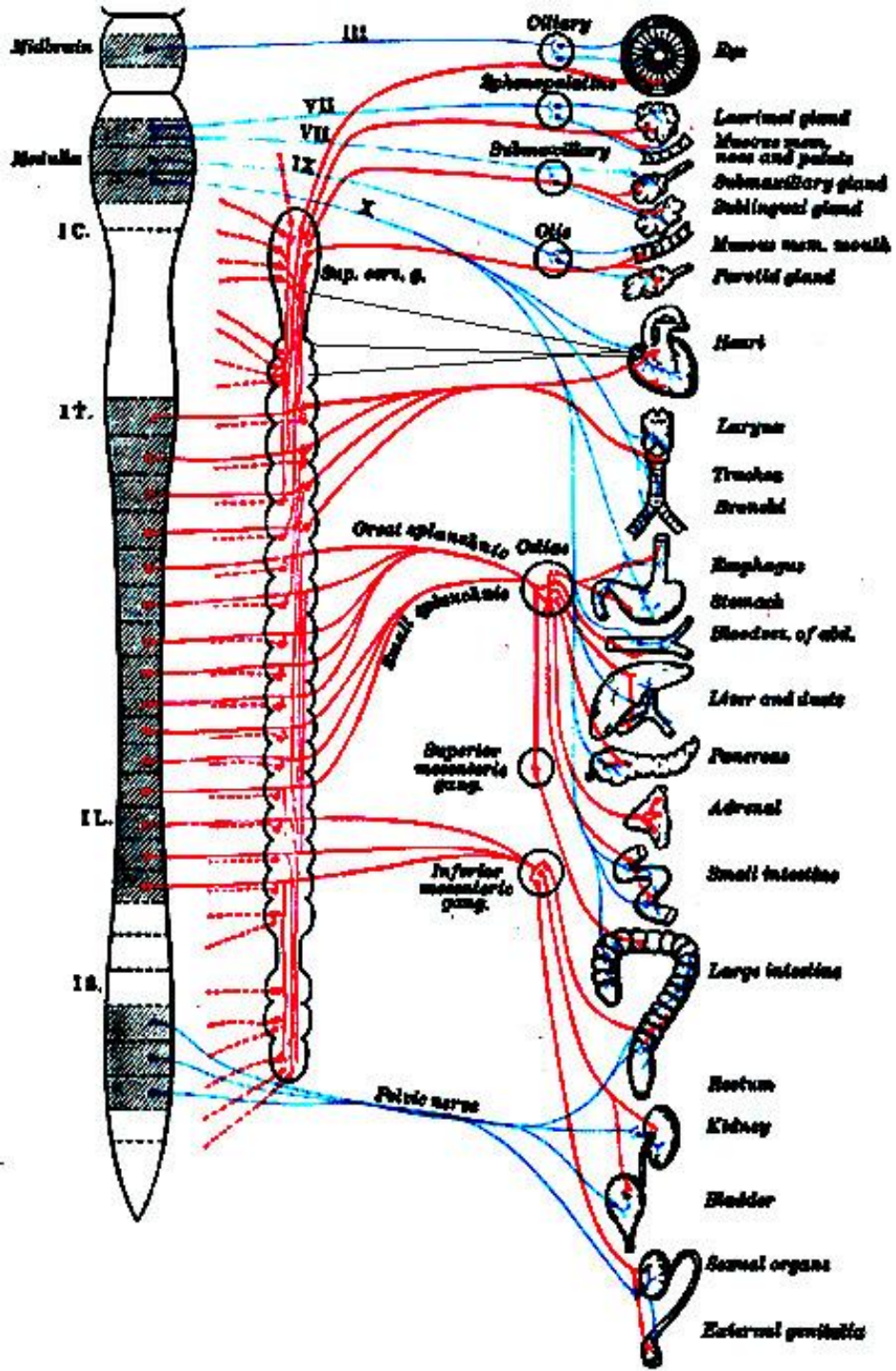
- **located within the lateral horn of the C8-L2 spinal segments**
- **their axons enter ventral roots of the C8-L3 spinal nerves**
- **axons synapse in sympathetic ganglia /para- or prevertebral/**
- **all preganglionic fibers are stimulatory**
- **fibers are divergent**
- **1 preganglionic fiber can synapse with 1 of ganglionic neurons**
- **Some of them are finished in sympathetic trunk (it consists of 20 – 23 ganglia) – 3 cervical, 10 – 12 thoracic, 3 – 4 lumbar, 4 pelvic.**
- **The rest fibers are going to the prevertebral ganglia or plexuses**

Sympathetic Nervous System

- Also called ***thoracolumbar system*** (T1-L3)
- Preganglionic cell bodies in lateral horn
- Preganglionic fibers leave spinal cord with ventral roots
- Leave spinal nerve via white rami communicans
- Postganglionic cell bodies are located in ganglia:
  - ***Paravertebral*** (sympathetic chain)
  - ***Prevertebral***





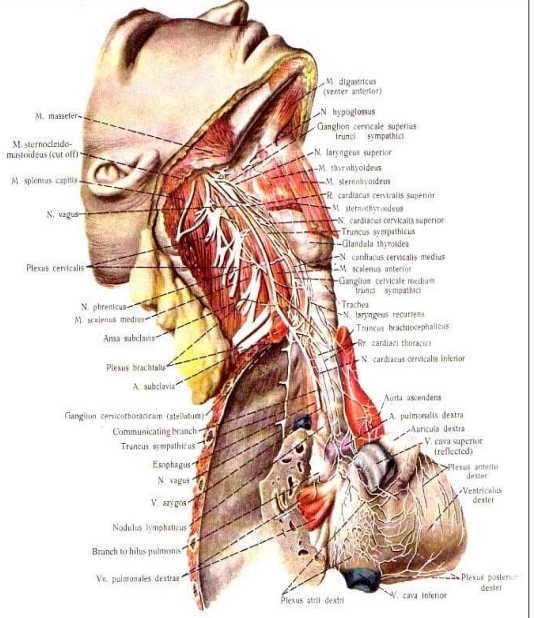


BRANCHES OF THE SYMPATHETIC CHAIN

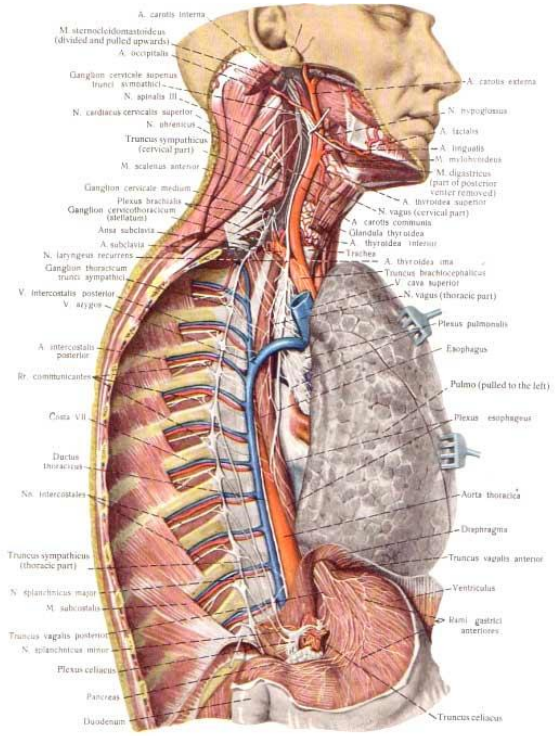
- C1 g. — carotid nerves (ext., int)
  - jugular nerve
  - the larynx and pharynx
  - superior cervical nerve of the heart
- C2 g. — middle cervical nerve of the heart
  - subclavian branches
- C3 g. — branches to the vagus
  - and phrenicus nerves
  - inferior cervical nerve of the heart
- C3 +Th1= g. stelatum
  - rr. bronchiales - plexus pulmonaris
  - rr.esophagei
- Th1-Th4-5 — plexus aorticus thoracicus
  - nervi cardiaci thoracici
- Th5-9 — n. splanchnicus major
- Th10-12 — n.splanchnicus minor
- L1-5 — plexus aorticus abdominalis
  - rectalis
  - vesicalis
- S1-Co — plexus cavernosus penis
  - ductus deferentis
  - prostaticus
  - uterovaginalis

Left and Right Sympathetic Trunks

- Immediately anterior to the paired spinal nerves are the left and right sympathetic trunks.
- Each is located immediately lateral to the vertebral column.
- A sympathetic trunk is like a pearl necklace:
  - the "string" of the "necklace" is composed of bundles of axons
  - the "pearls" are the sympathetic trunk (or paravertebral) ganglia
    - house sympathetic ganglionic neuron cell bodies
- One sympathetic trunk ganglion is approximately associated with each spinal nerve.
- Cervical portions
  - three sympathetic trunk ganglia
    - superior, middle, and inferior cervical ganglia
    - opposed to the eight cervical spinal nerves.

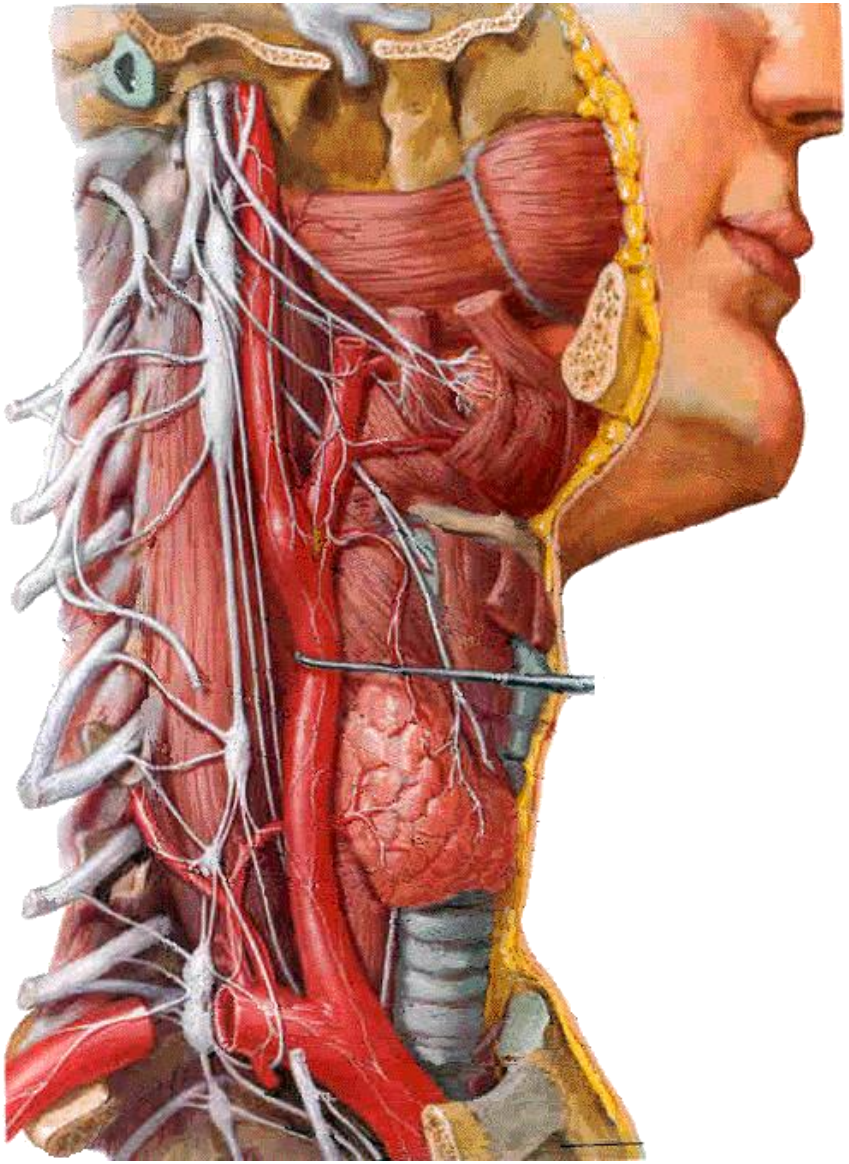


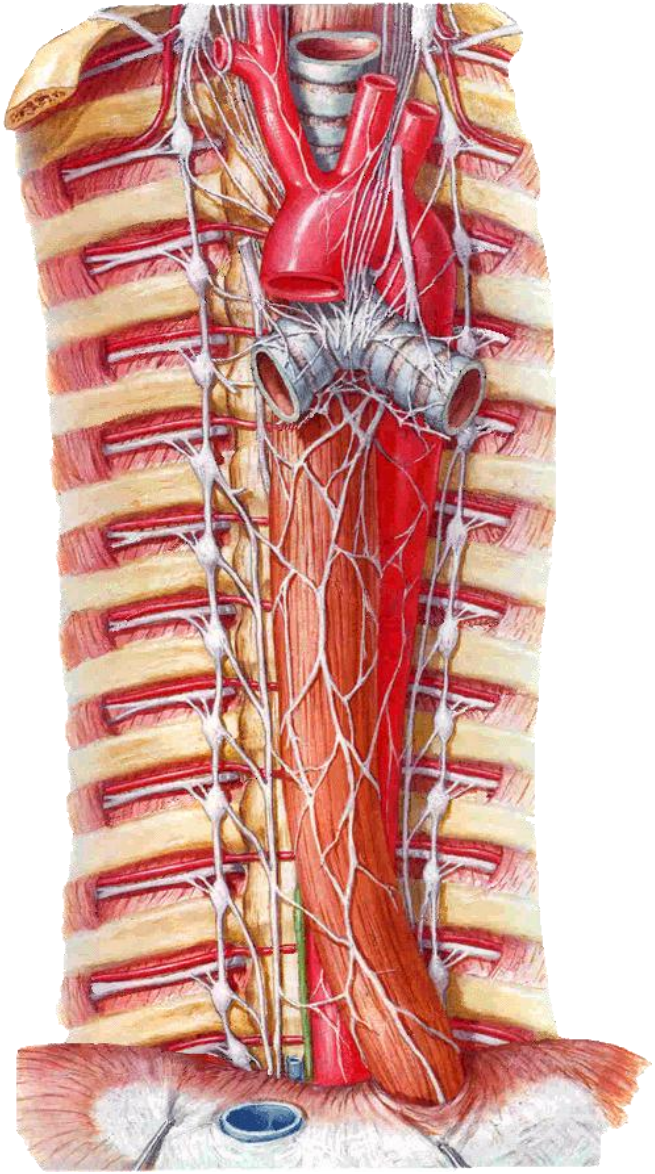
Cervical ganglia, nerves of the heart

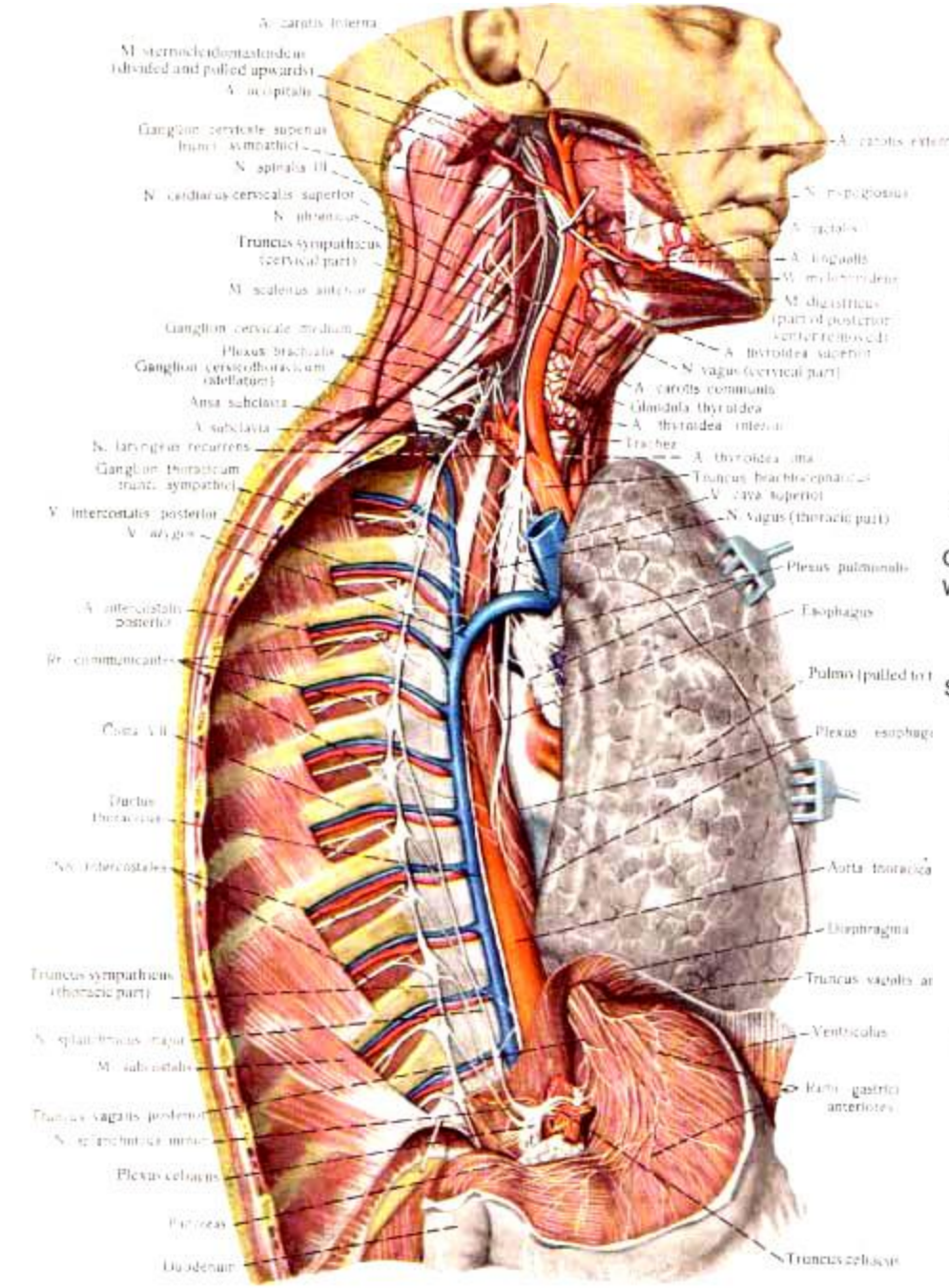


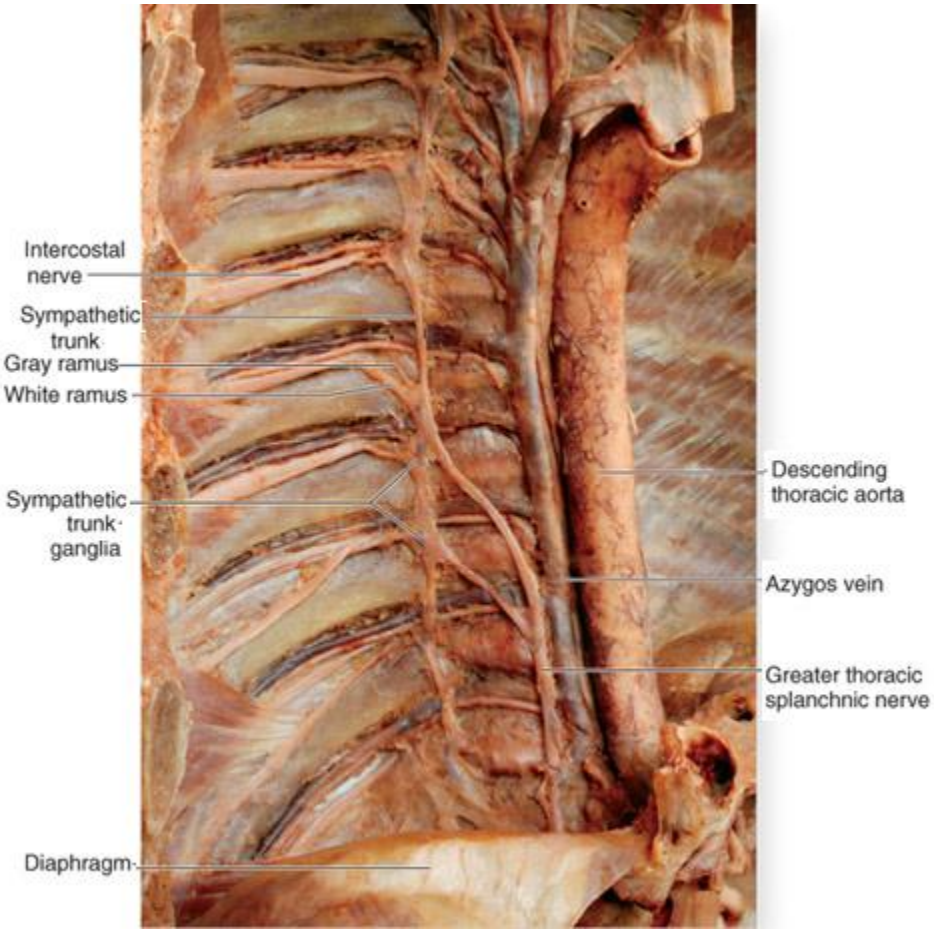
Nerves and plexuses of thoracic organs; right aspect (¾).

Cervical and thoracic divisions of the sympathetic trunk





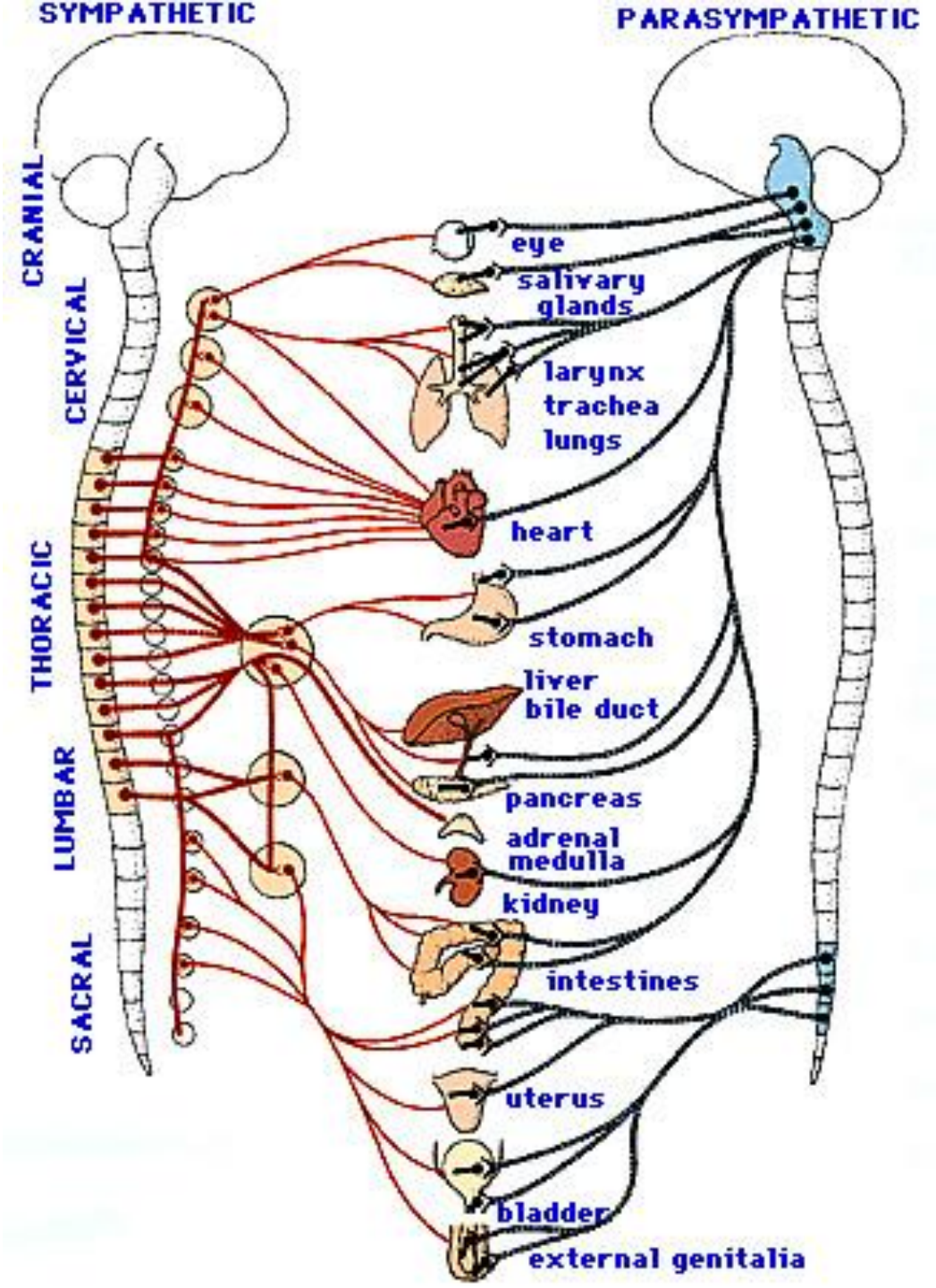




Nerves and plexuses of thoracic organs; right aspect (¼).

SPLANCHNIC NERVES

- **Composed of preganglionic sympathetic axons.**
- **Run anteriorly from the sympathetic trunk to most of the viscera.**
- **Should not be confused with the pelvic splanchnic nerves associated with the parasympathetic division.**
- **Larger splanchnic nerves have specific names:**
  - ***greater thoracic splanchnic nerves***
  - ***lesser thoracic splanchnic nerves***
  - ***least thoracic splanchnic nerves***
  - ***lumbar splanchnic nerves***
  - ***sacral splanchnic nerves***
- **Terminate in prevertebral (or collateral) ganglia called "prevertebral" because they are immediately anterior to the vertebral column.**
- **Prevertebral ganglia typically cluster around the major abdominal arteries and are named for these arteries.**



TYPES OF PREVERTEBRAL GANGLIA

Differ from the sympathetic trunk ganglia.

Are single structures, rather than paired.

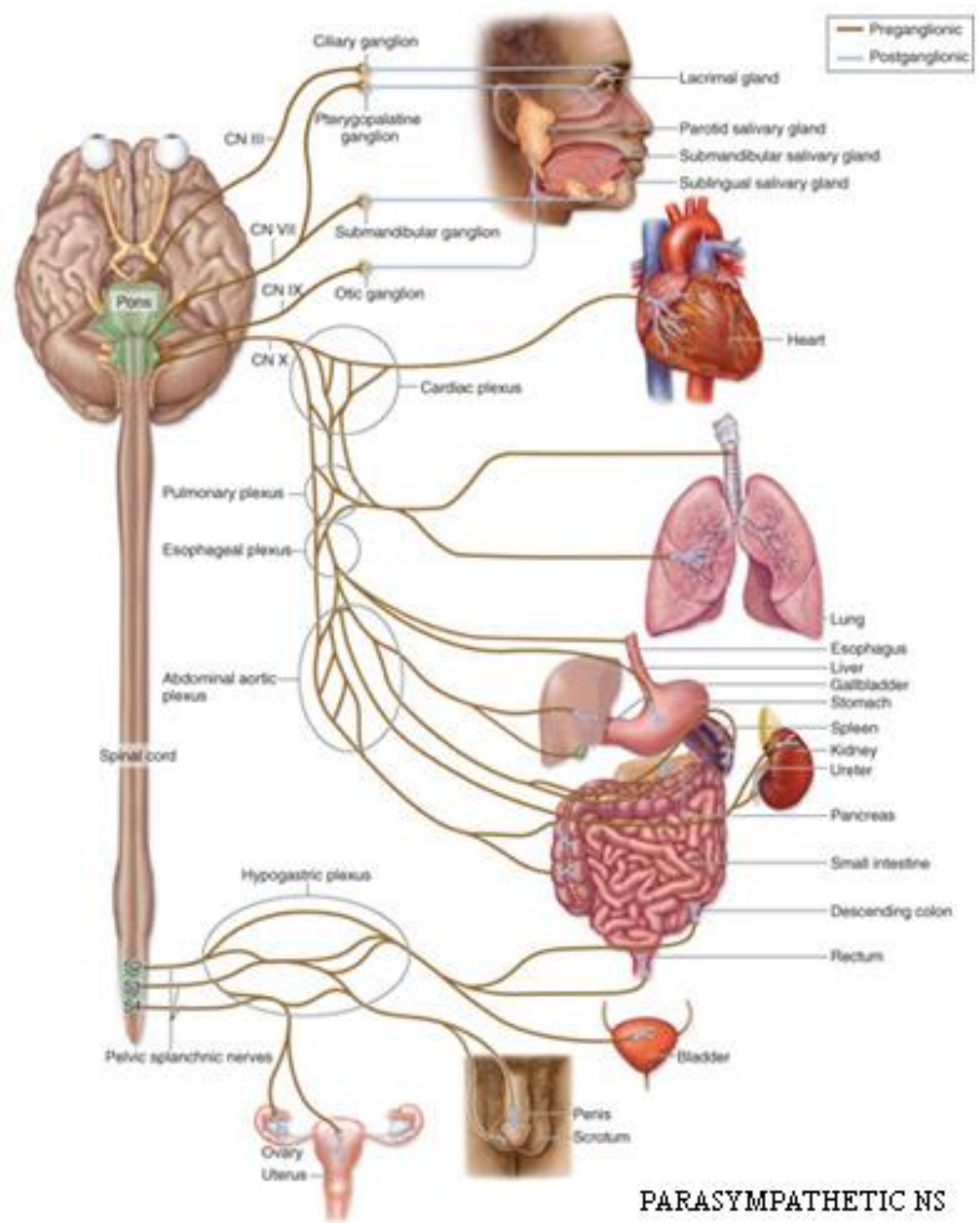
Are anterior to the vertebral column, on the

anterior surface of the aorta.

Located only in the abdominopelvic cavity.

Prevertebral ganglia include:

- **the celiac ganglion**
- **superior mesenteric ganglion**
- **inferior mesenteric ganglion.**

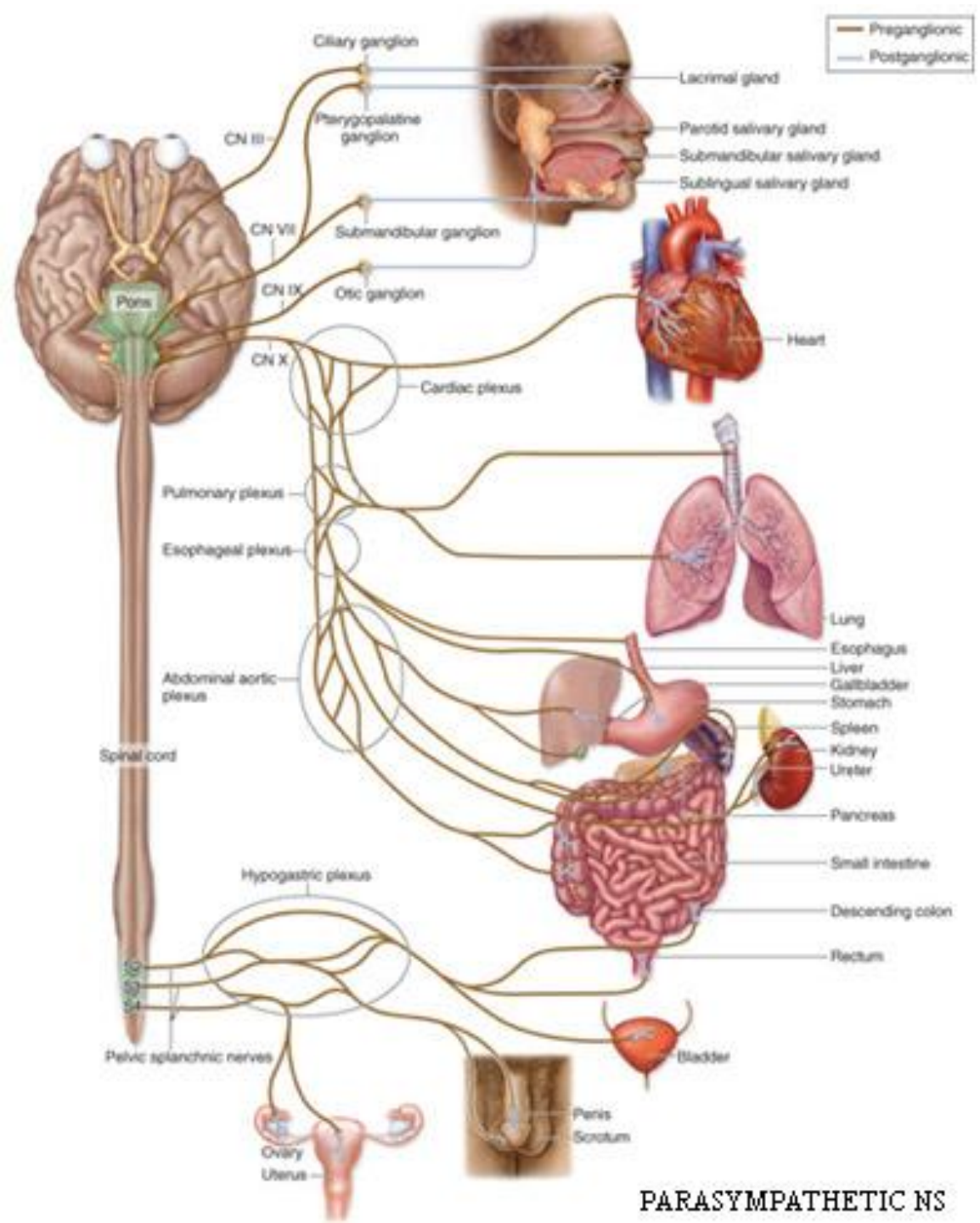


Parasympathetic division

is also termed the *craniosacral division* because its preganglionic neurons are:

- **housed within nuclei in the brainstem, within the lateral gray regions of the S2–S4 spinal cord segments.**

Postganglionic neurons in the parasympathetic division are found in *terminal ganglia:* are located close to the target organ & *intramural ganglia:* located within the wall of the target organ.



Two sources of parasympathetic preganglionic fibers

1) the brain stem via cranial nerves III, VII, IX, X
2) sacral part of spinal cord visa spinal nerves S2 through S4

parasympathetic ganglia lie in body close to organ or body part innervated, thus preganglionic parasympathetic fibers tend to be long.

Preganglionic fibers remain in cranial or sacral nerve in which they exited CNS until they reach target.

All organs of body except liver receive parasympathetic input, but skin and blood vessels generally not innervated.

Function:

When stimulated, heart rate decreases, blood pressure falls, blood is directed away from skeletal muscles to viscera
Generally relaxes body, although increases activity in digestive system and a few other organs

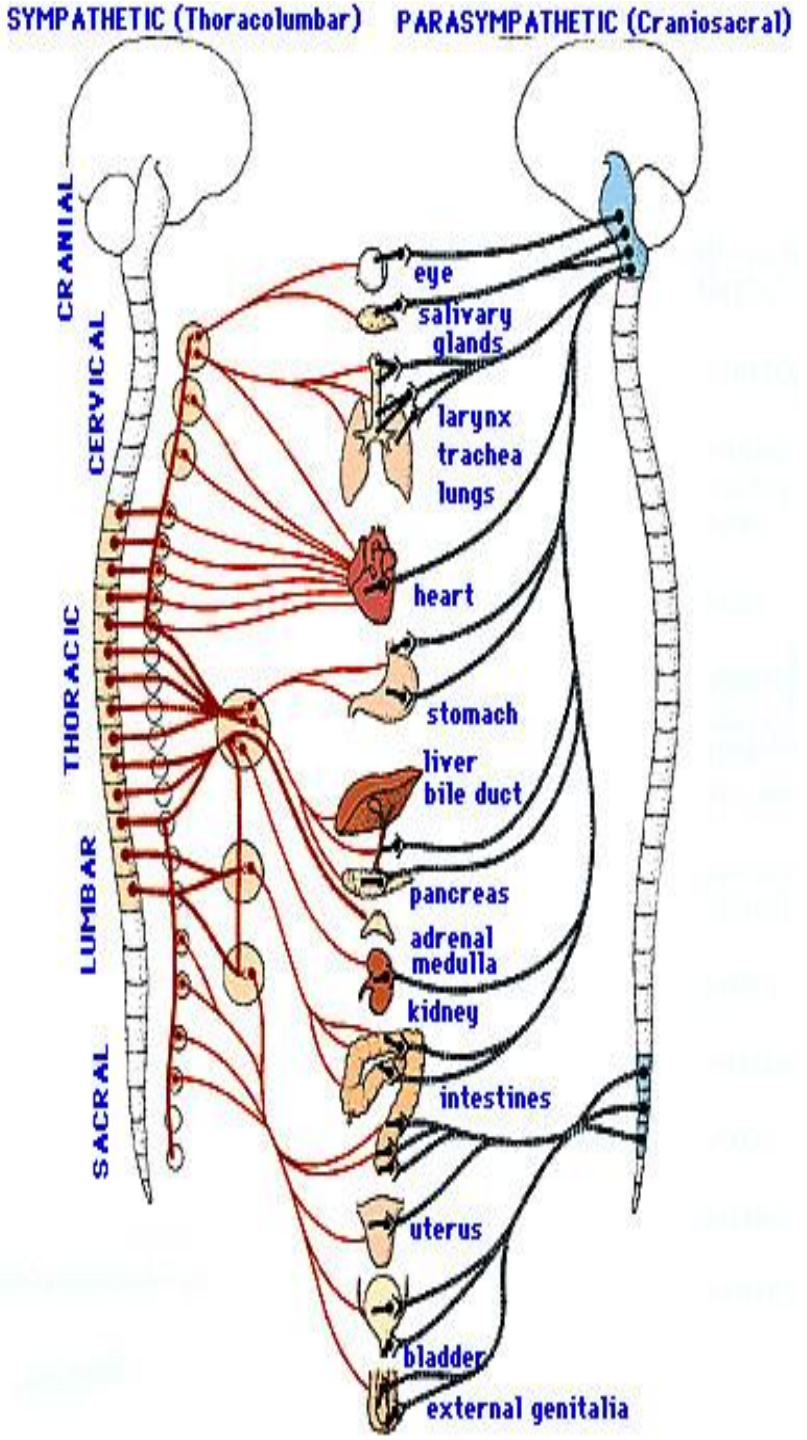
Parasympathetic nervous system

- **Mesencephalic level (nuclei of Perlea and Yakubovich), the fibers are going within the III CN and provide innervating of m. Sphincter pupillae, m. Ciliaris**

- **Pontine level (n.salivatorius superior)**

- **Bulbar (n.salivatorius inferior et n. dorsalis nervi Vagi) within VII, IX, X CN's innervate parotid, sublingual, submandibular glands and internal organs (except the pelvic organs)**

- **Sacral part – the cells of lateral horn S2 – S4 – innervating of pelvic organs**



Parasympathetic nervous system

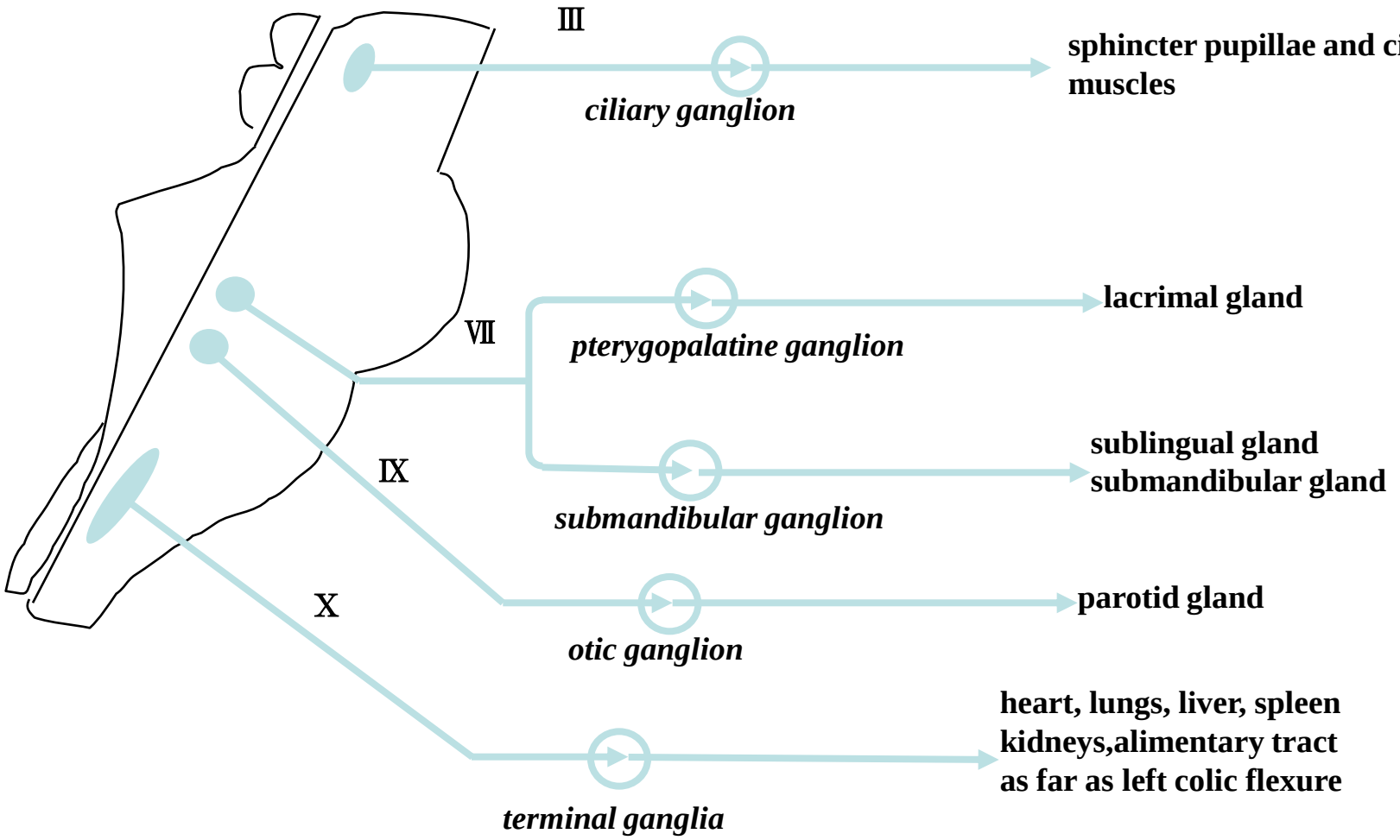
Cerebral part

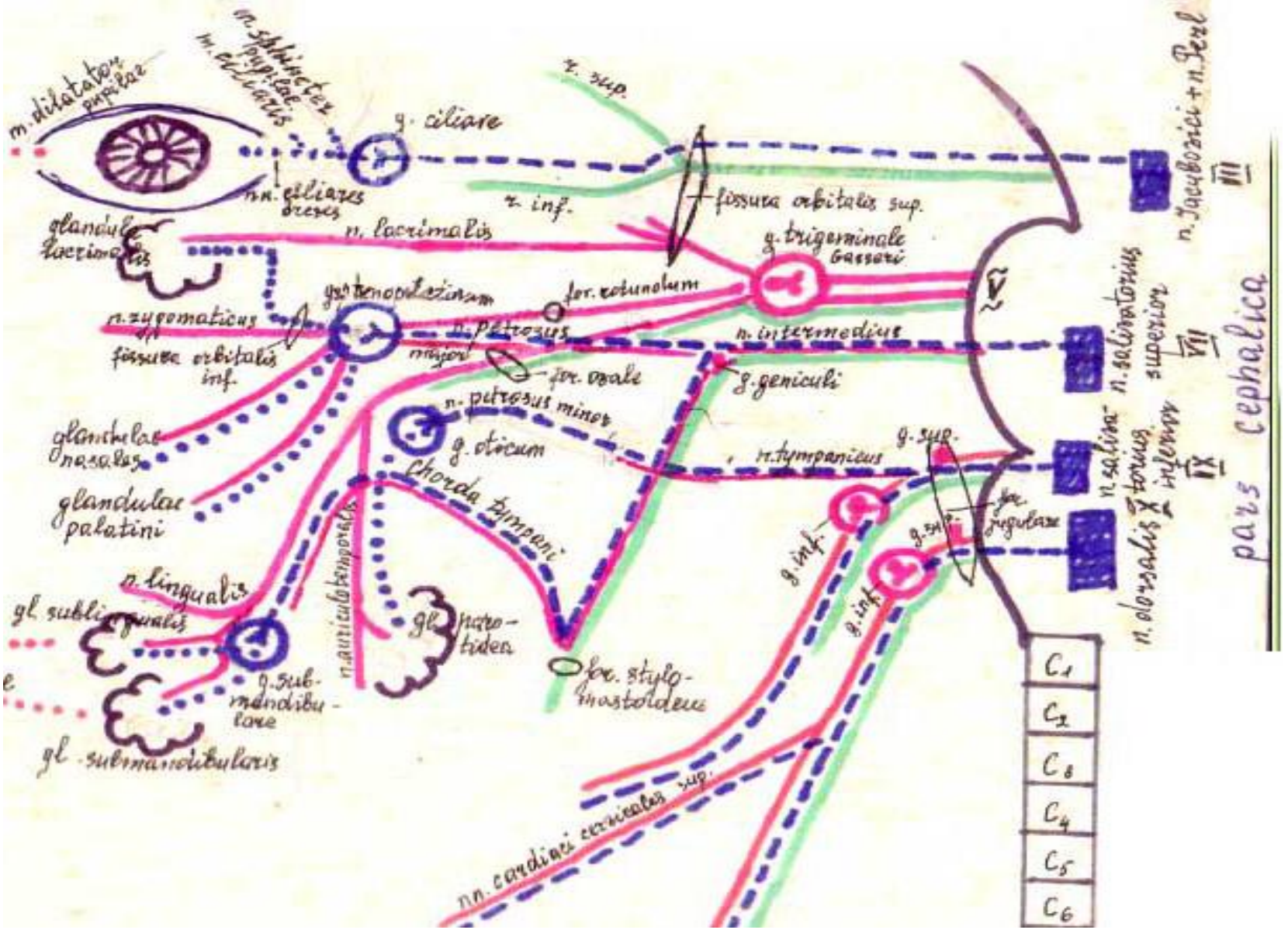
nuclei	nerve	Neuron-effector	Region of the supply
n.Iacubovich n.Perl	III */oculomotorius/*	g.ciliare /in the orbit/	m.constrictor pupilae m.ciliaris
n.salivatorius superior	VII */facial/*	g.sphenopalatinum /fossa pterygopalatina/ g.submandibulare /fossa glandlae submandibularis/	gl. lacrimalis +glandulae mucosae /nose+mouth/ gl.submandibularis gl.sublingualis
n.salivatorius inferior	IX */glossopharyngeus/*	g.oticum /foramen ovale/	gl.parotidea
n.dorsalis	X */vagus/*	gg. terminales gg. intramurales	Internal organs of the neck, thorax, abdominal cavity /to the level of the descendens colon/

Sacral part:

* supplies the descendens colon, sigmoid colon, organs of the pelvis

Cranial portion





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Dual Innervation of the organs by the ANS

Many viscera are innervated by postganglionic axons from both ANS divisions.

Both types of autonomic fibers form autonomic plexuses around each organ.

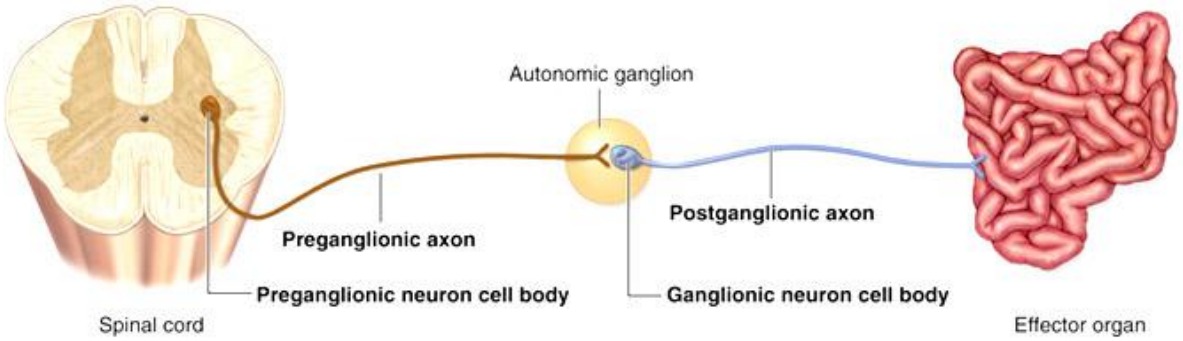
Nerve impulses are transmitted by chemical messengers, called *neurotransmitters,* specific in each division of the autonomic nervous system

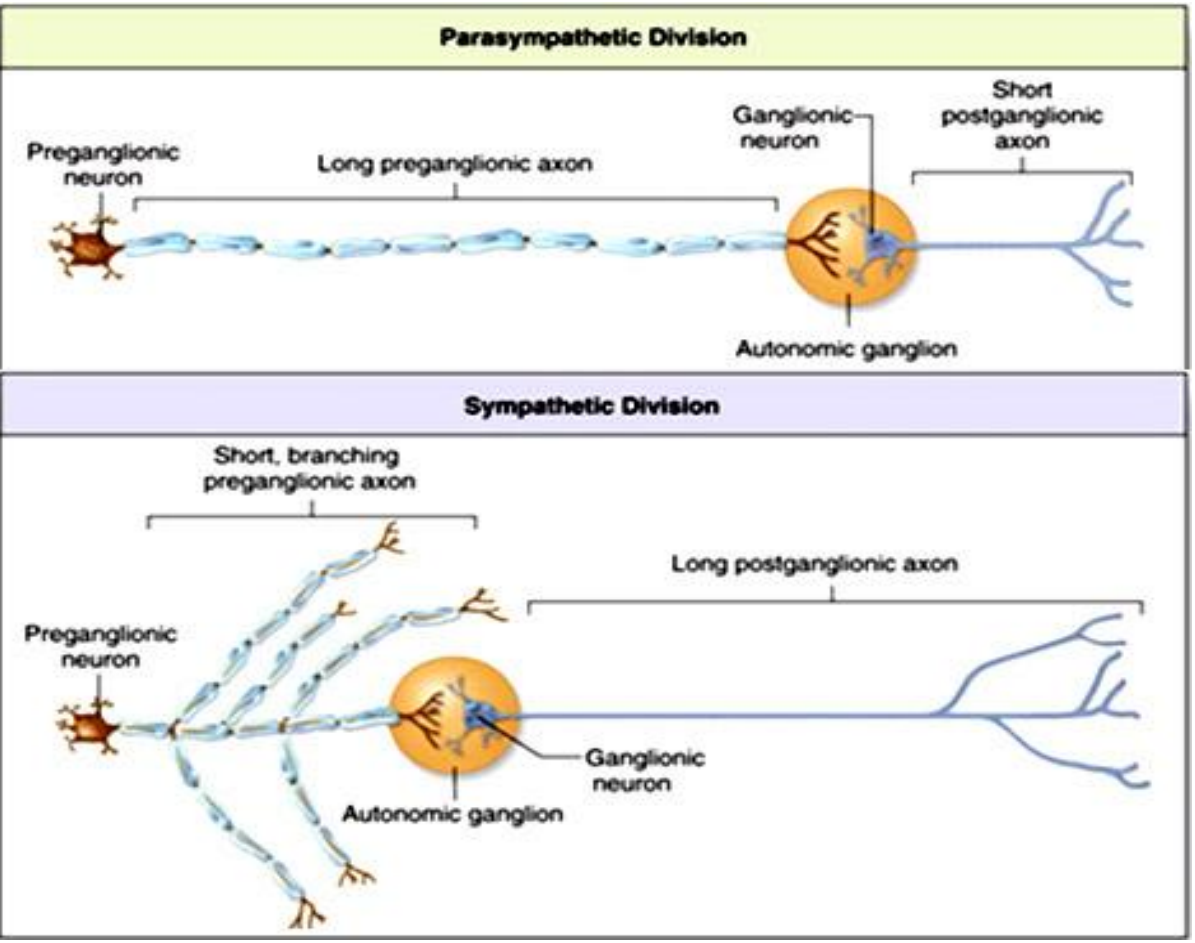
Maintains homeostasis through autonomic reflexes that occur in the innervated organs.

Actions of the divisions usually oppose each other.

Divisions of ANS exert antagonistic effects on the same organ

opposing effects are also achieved by increasing or decreasing activity in one division.





Two neurotransmitters are used in the ANS: acetylcholine (ACh)

norepinephrine (NE)

Neurotransmitters are released by the presynaptic cell.

Bind to specific receptors in the postsynaptic cell membrane.

Binding has either an excitatory or an inhibitory effect on the effector,

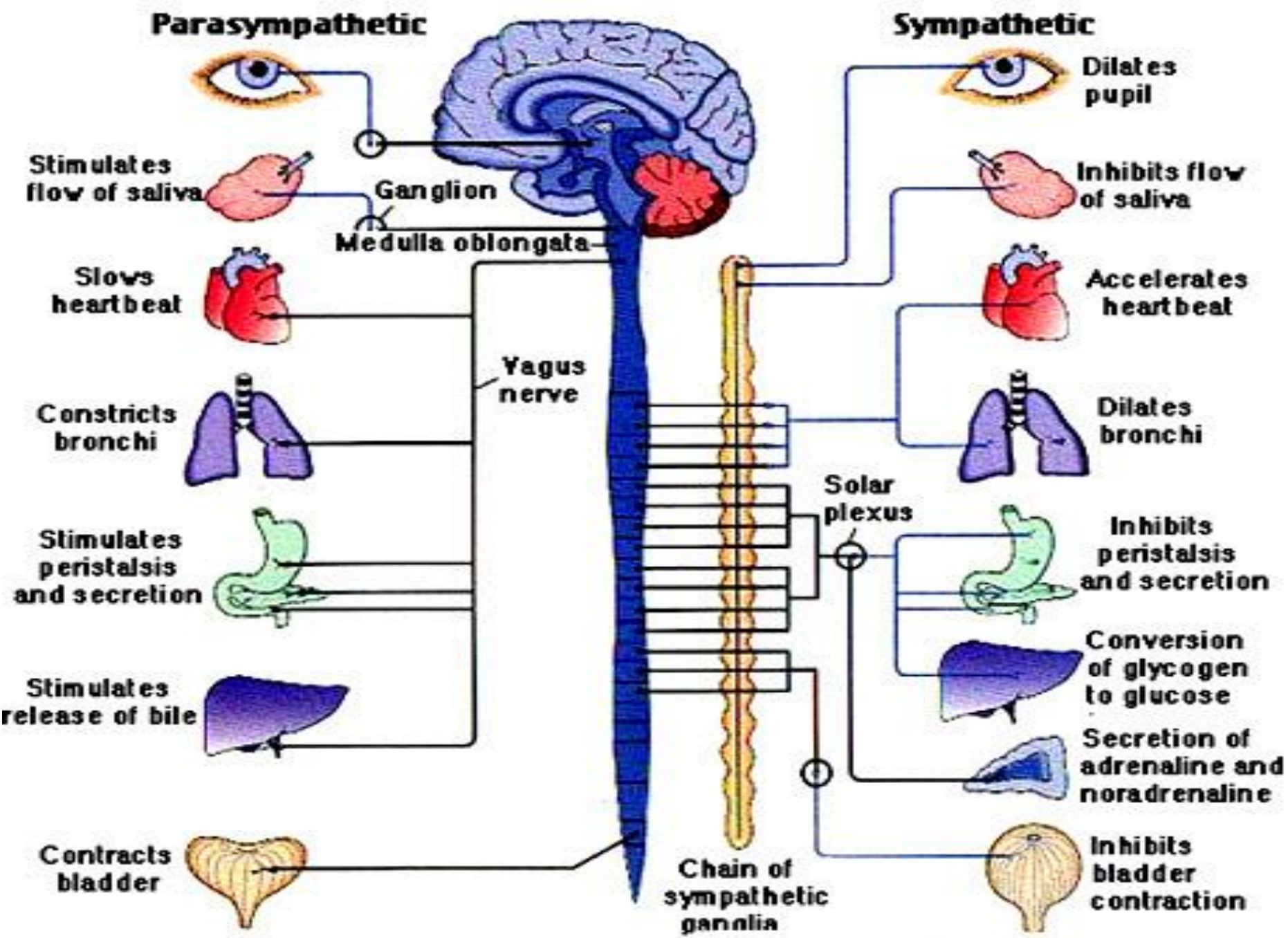
depending on the specific receptor.

Both the preganglionic and postganglionic axons in the parasympathetic division release acetylcholine and thus are called *cholinergic*.

The preganglionic axon and a few postganglionic axons in the sympathetic division are also *cholinergic*.

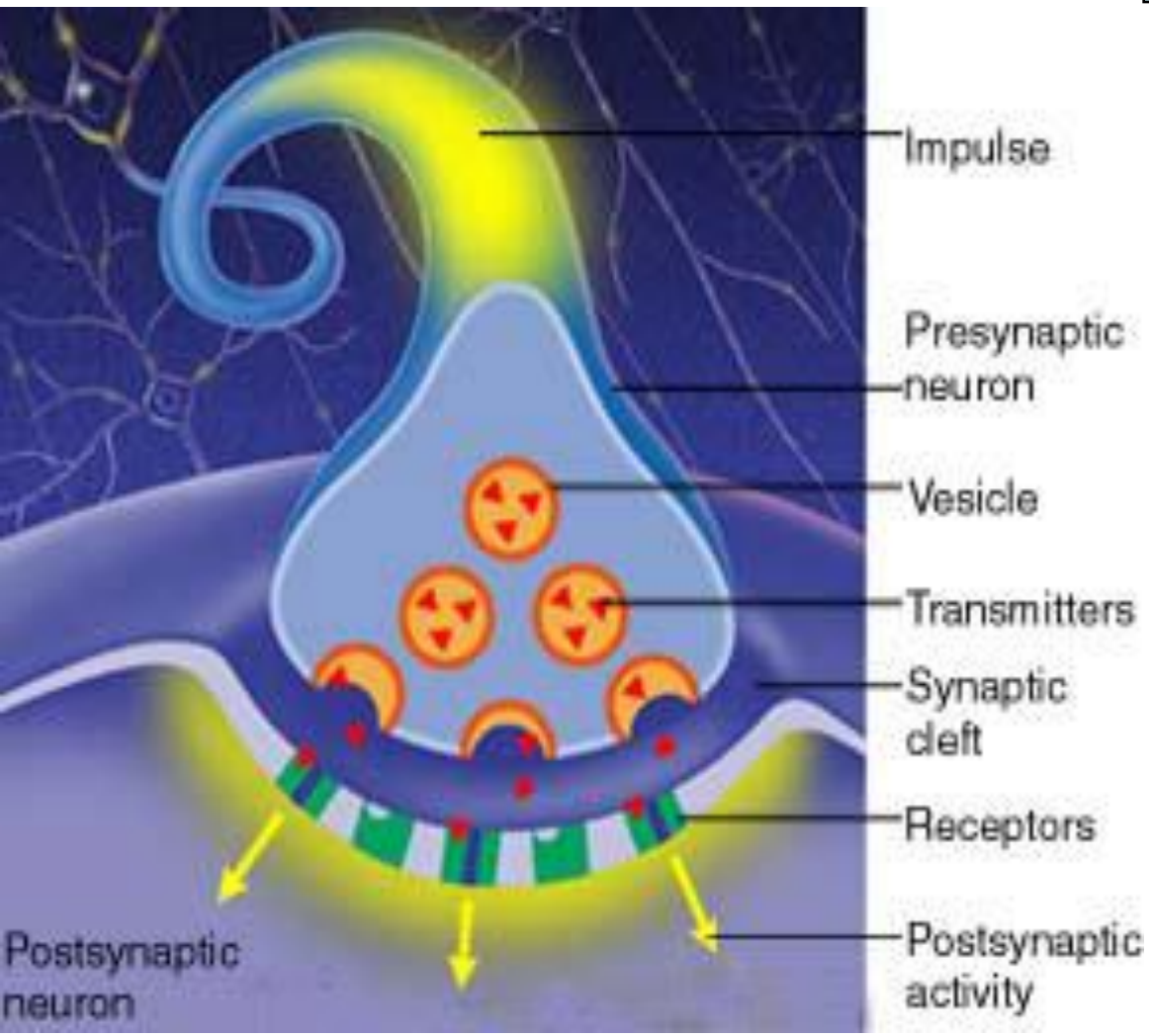
Most of the postganglionic axons of the sympathetic division release norepinephrine and are called *adrenergic*.

Neurotransmitters of metasympathetic NS are nonadrenergic and non-cholinergic – NANC.



Actions of the VNS

Neurotransmitters and Receptors



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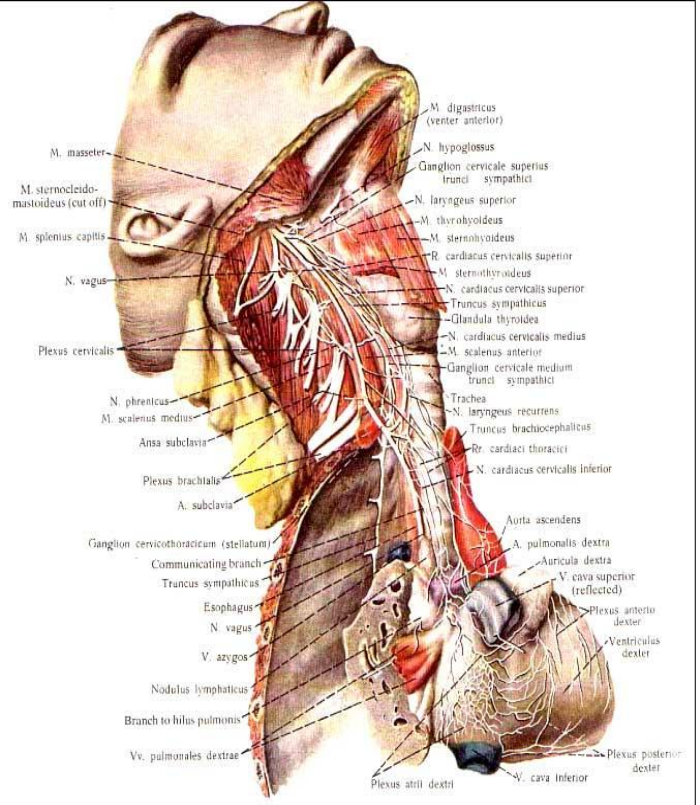
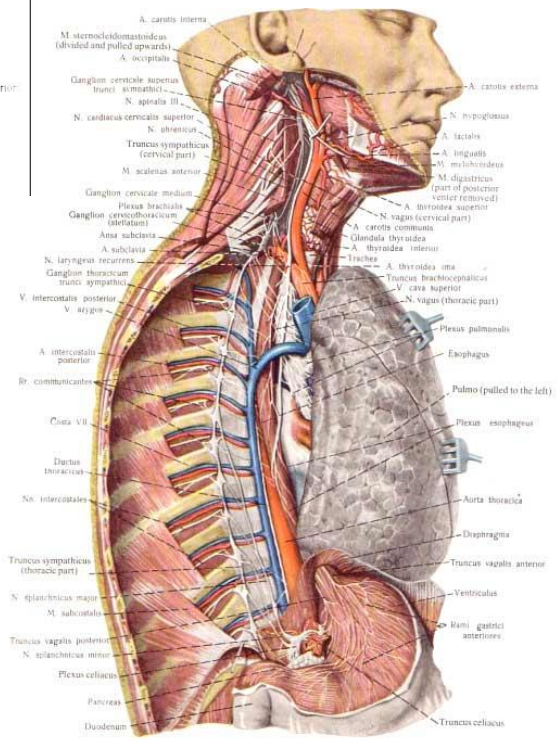
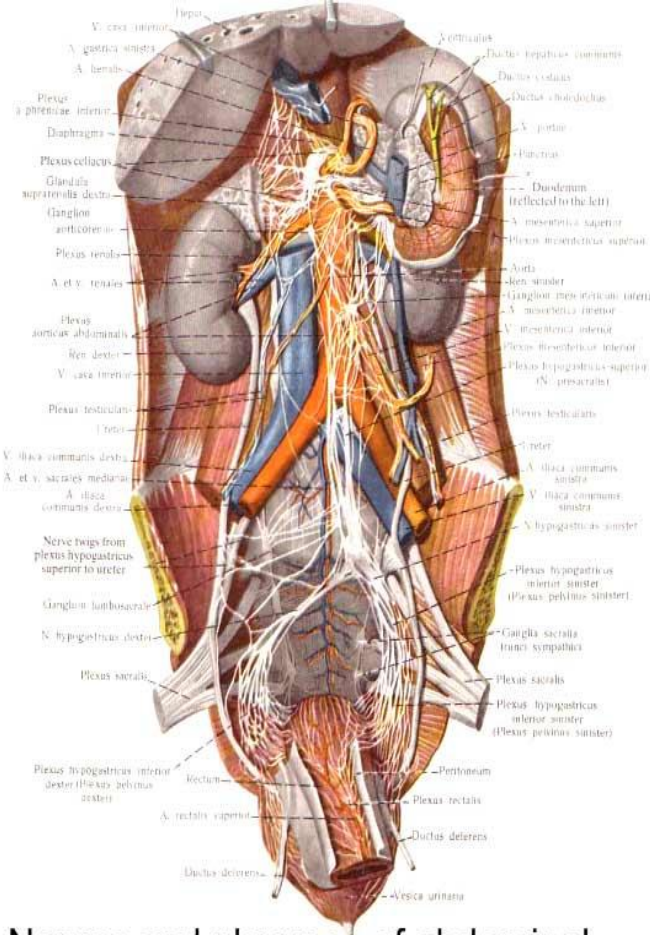
Vegetative plexuses



Cervical ganglia, nerves of the heart

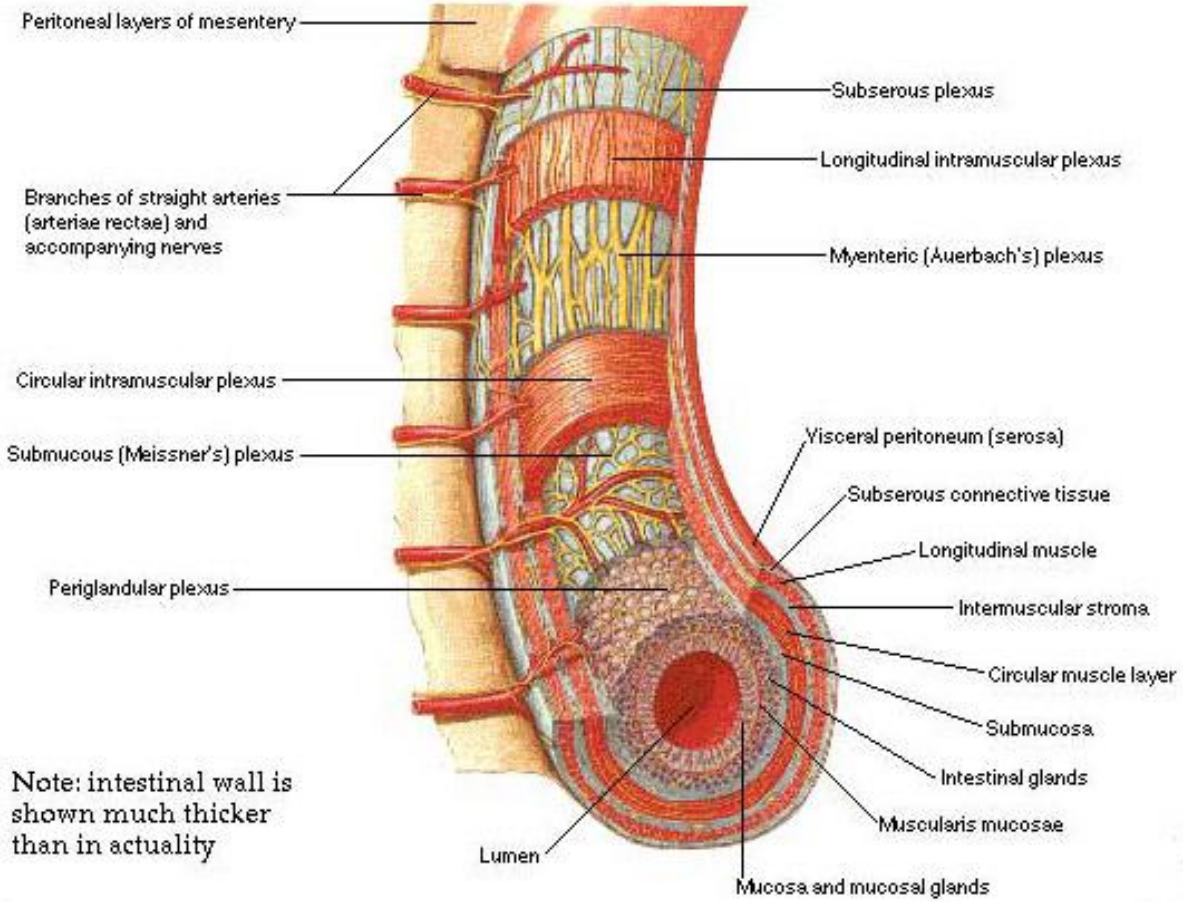


Nerves and plexuses of thoracic organs; right aspect (¼).



Nerves and plexuses of abdominal and pelvic cavities

Intrinsic Autonomic Plexuses of Intestine



Metasympathetic NS = Enteric NS

Two arrays of ganglia and nerves distributed along the gut

Myenteric plexus

Ganglia and nerves located between the longitudinal and circular muscles of the intestines

Submucosal plexus

Ganglia and nerves within the submucosa (layer of fibrous connective tissue that attaches a mucus membrane to its subadjacent parts)

Enteric ganglia receive input from both sympathetic and parasympathetic systems

Ganglia contain many local neurons that allow enteric system to function semiautonomously

Vegetative plexuses:

of the neck and head

common carotid — internal carotid
external carotid

of the thorax

cardiac
bronchial – pulmonary
oesophageal
aortic

of the abdomen

coeliac - lienal
- gastric
- hepatic
- pancreatic

upper mesenteric
lower mesenteric
Intermesenteric
renalis – uretericus

of the pelvis

upper hypogastric
2 lower hypogastric
- rectal
- prostatic
- urovaginal

*Regulation of the VNS depends on *the highest vegetative centers*:

* thalamus
* hypothalamus
* cerebellum
* basal nuclei of the brain
* reticular formation
* cortex of the brain
* grey matter surounding the aqueduct of the midbraih

Summary of reflex types

There are a number of ways of classifying reflexes.

One is in terms of the systems that receive the stimulus and give the response.

There are *somato-somatic reflexes*, like the knee jerk that follows tapping the patellar tendon;

***Somato-visceral reflexes*, such as the vasoconstriction that results from cooling the skin;**

***Viscero-visceral reflexes*, for example the decrease in heart rate that follows distention of the carotid sinus;**

and *viscero-somatic reflexes*, like the abdominal cramping that accompanies rupture of the appendix.

Referred pain:

- **The pain is reffered to a cutaneous site remote from the site of the lesion.**
- **The referred cutaneous site may be tender and painfull to touch.**
- **Examples:**

1) pain in the right shoulder region in cholecystitis;

2) pain caused by the stretching and irritation of the liver capsule may be referred to the right side of the neck, shoulder or scapula;

3) compression of the lower end of the spine causes pain to the pelvic region or upper leg;

4) pain in the left shoulder region or arm in heart diseases

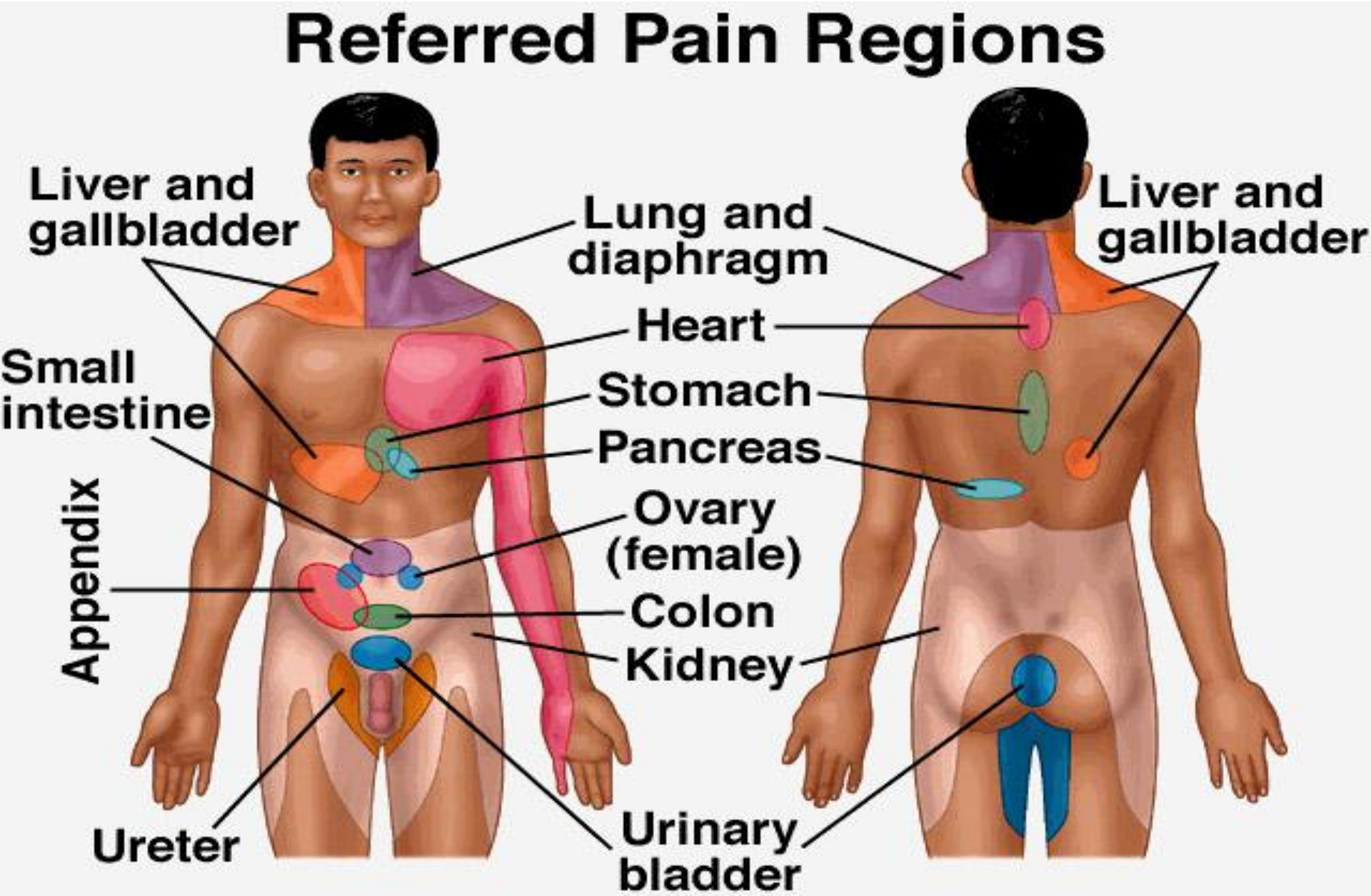
What Is Referred Pain?

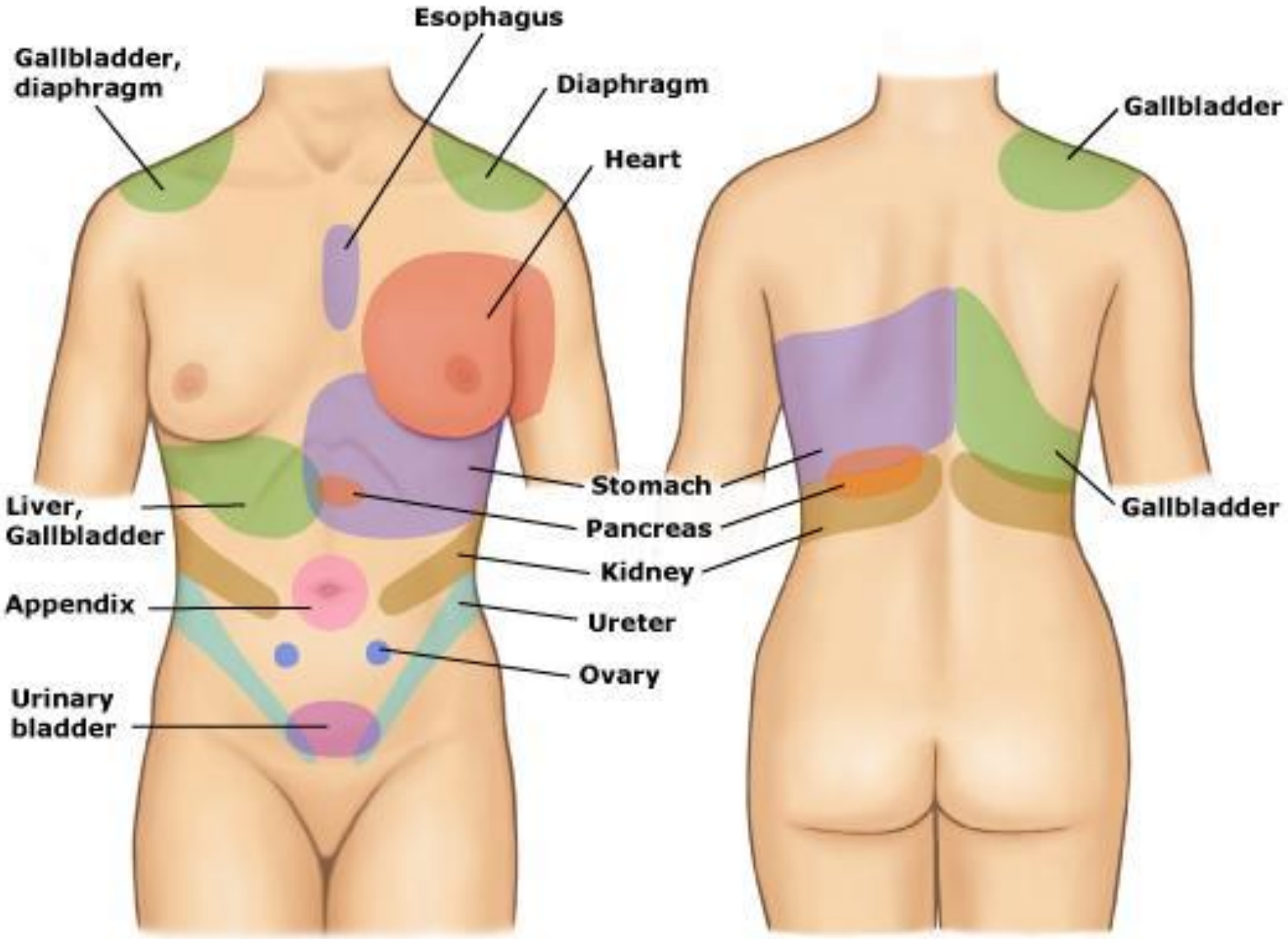
Referred pain has its source in one place but is felt in another.

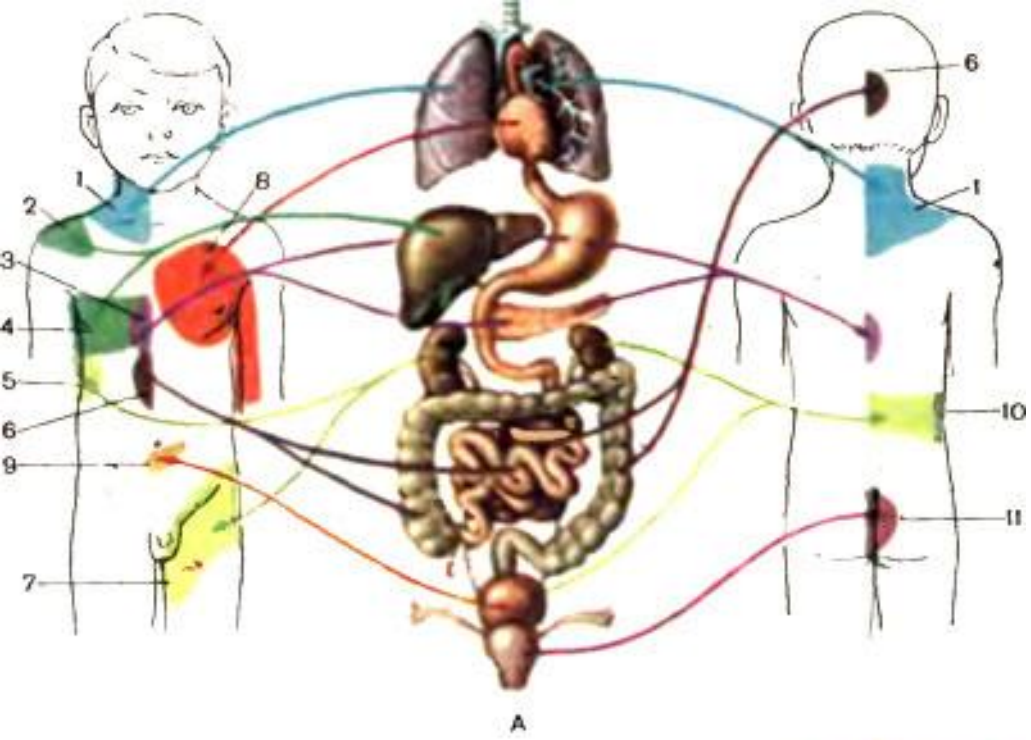
For example, pain behind the eyes may actually be caused by tense muscles in the neck and shoulders.

This means that the place that hurts may not be the part of the head that needs treatment.

When a person has a heart attack where do they have pain?
The pain usually manifests in the left arm, chest, neck -Zakharyin-Head's areas




Esophagus
Gallbladder, diaphragm
Diaphragm
Heart
Gallbladder
Stomach
Liver, Gallbladder
Pancreas
Gallbladder
Kidney
Appendix
Ureter
Ovary
Urinary bladder



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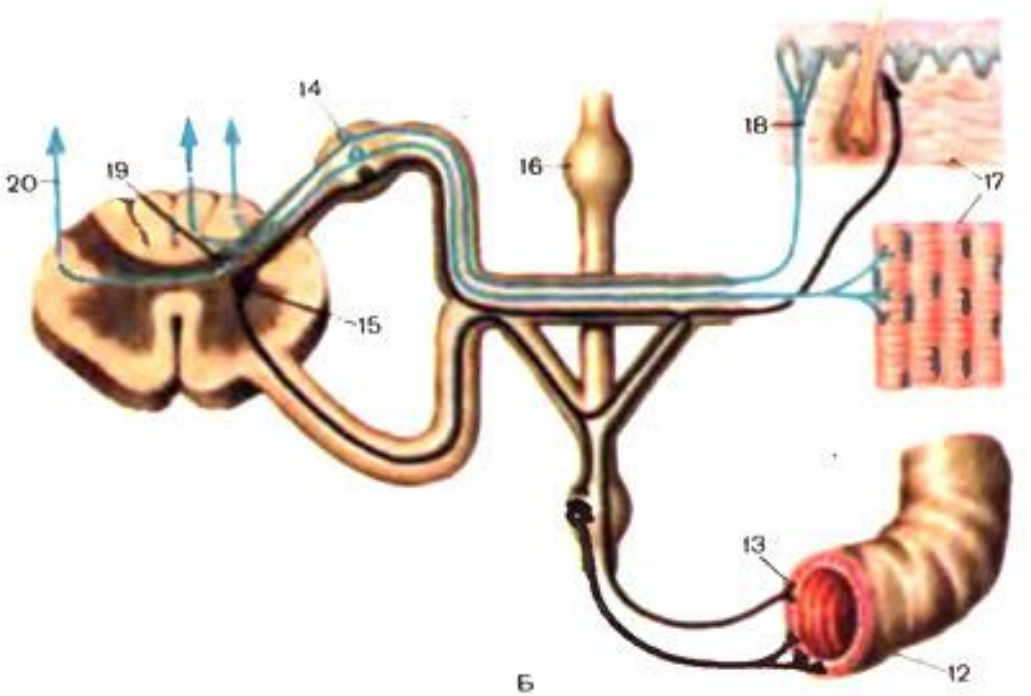

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А. Zakharyin-Head's areas regions :

1 — lungs; 2 — capsule of the liver; 3 — stomac; pancreas; 4 — liver; 5 — kidney; 6 — intestine; 7 — ureter; 8 — heart; 9 — urinary bladder; 10 — urogenital organs; 11 — uterus.

Б. Scheme of the viscero-cutaneus reflex : **12 —** affected internal organ**; 13 — interoreceptor; 14 — spinal ganglion; 15 — vegetative cell of the lateral horn; 16 — sympathetic chain; 17 — Zaharin-head region (**hyperesthesia and muscle tension**); 18 — exteroreceptor; 19 — sensory neuron of the posterior horn; 20 — lateral spino-thalamic pathway.**

End