

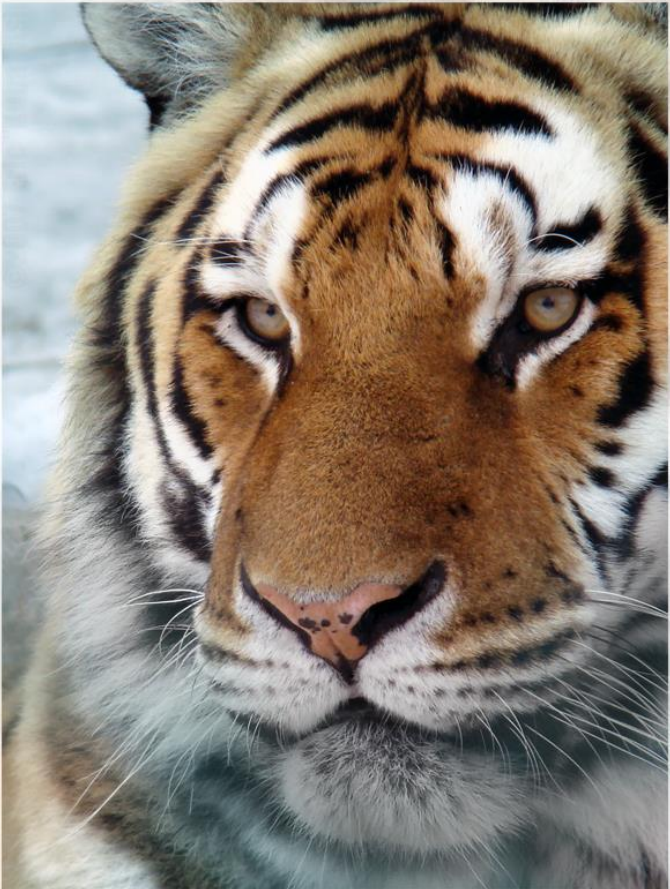
Vegetative (Autonomous) nervous system



Nervous system

Somatic (animal) nervous system

“soma” – Latin “body”



Vegetative (autonomous) nervous system

- Common with plants
- Autonomous from conscious control



The **nervous system** is subdivided into the

Somatic nervous system		Autonomous (vegetative) nervous system	
Sensory: 1) General: <ul style="list-style-type: none">- Tactile- Pain- Pressure- Vibration- Temperature 2) Specific: <ul style="list-style-type: none">- Vision- Hearing- Smell- Taste- Equilibrium	Motor: <ul style="list-style-type: none">- Striated skeletal muscles	Parasympathetic: <ul style="list-style-type: none">- Smooth muscles of internal organs- Glands	Sympathetic: <ul style="list-style-type: none">- Smooth muscles of the blood vessels- Piloerector (erector muscles of hairs)- Sweat glands

The main functions of ANS – regulation of:

- Metabolism
- Digestion
- Blood circulation
- Respiration
- Excretion
- Growth
- Reproduction



Functional classification of the ANS

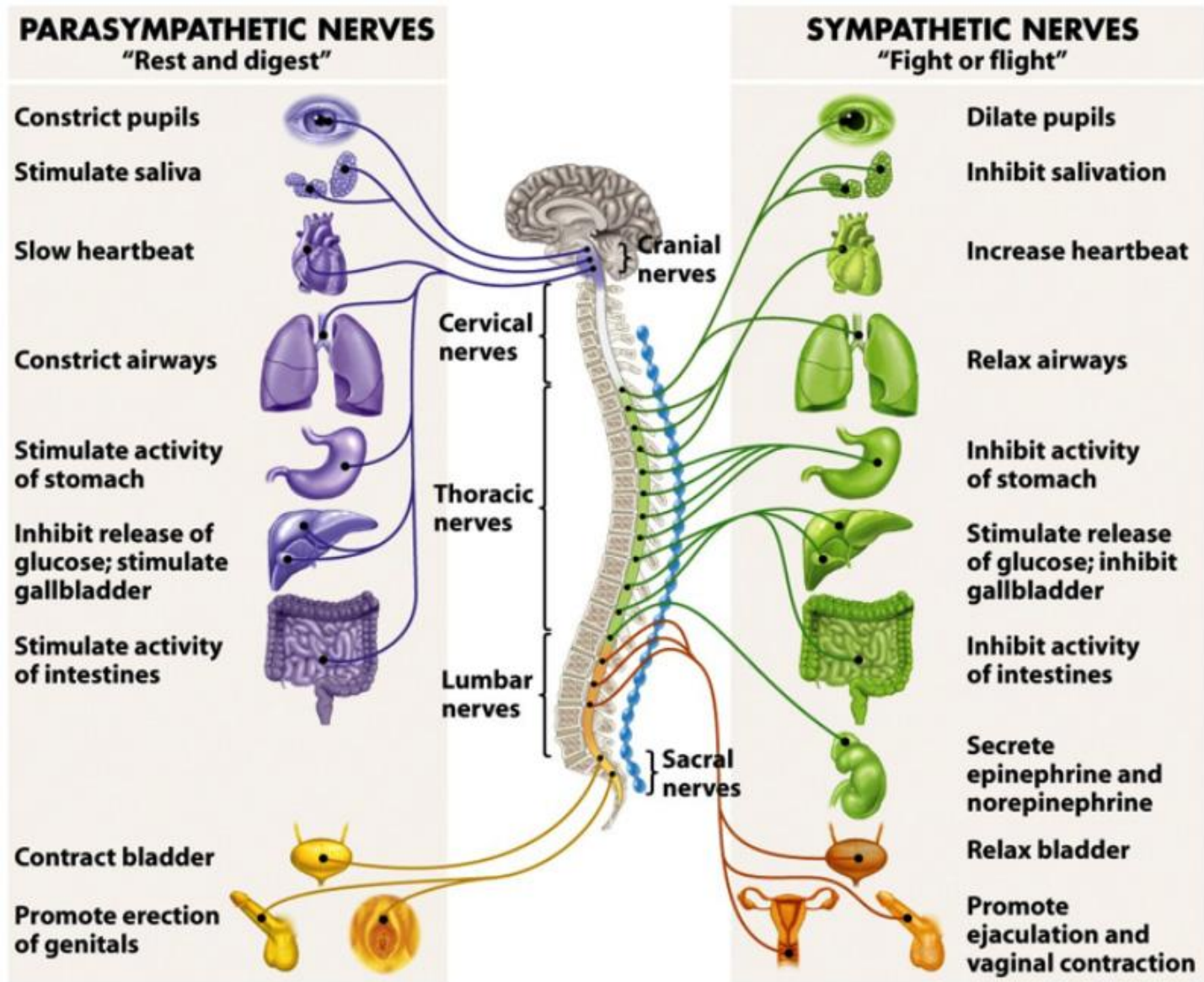


Figure 45-20 Biological Science, 2/e
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Autonomic nervous system

Central part

Sympathetic nuclei:

- Substantia intermedia lateralis (lateral horns) of the spinal cord C₈-L₂
- Totally 15 pairs of nuclei

Parasympathetic nuclei

(Latin “near sympathetic”):

1) Cranial –

parasympathetic nuclei of CN III, CN VII, CN IX, CN X

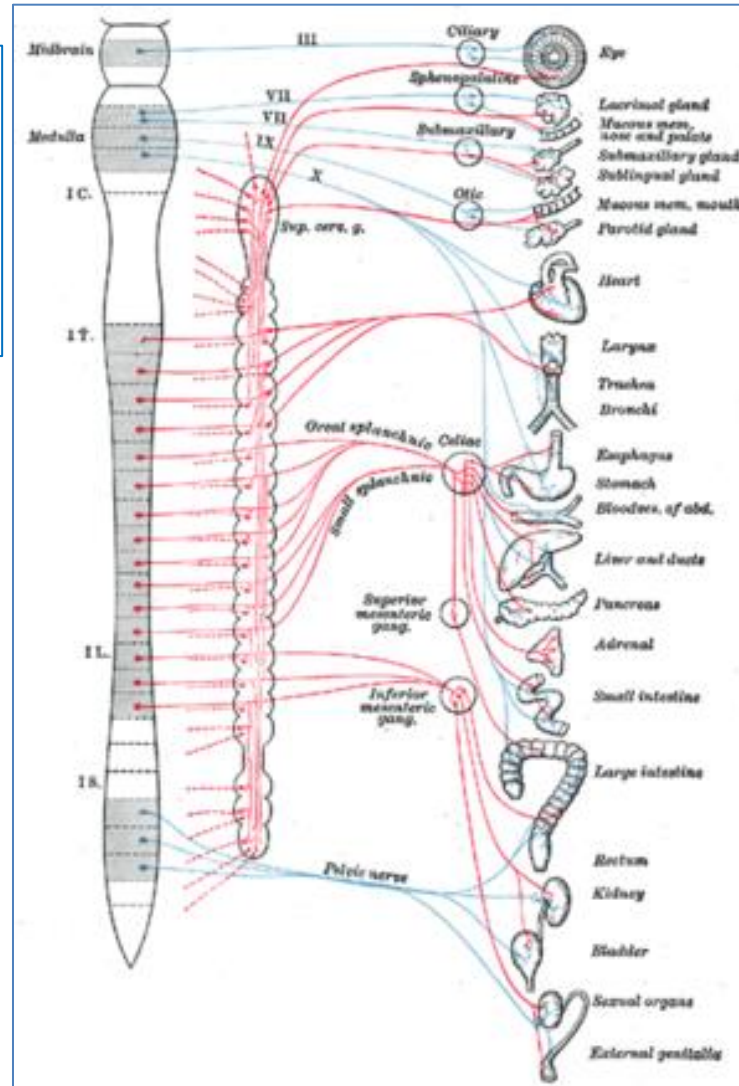
2) Sacral – parasympathetic nuclei of the spinal cord

S₂-S₄

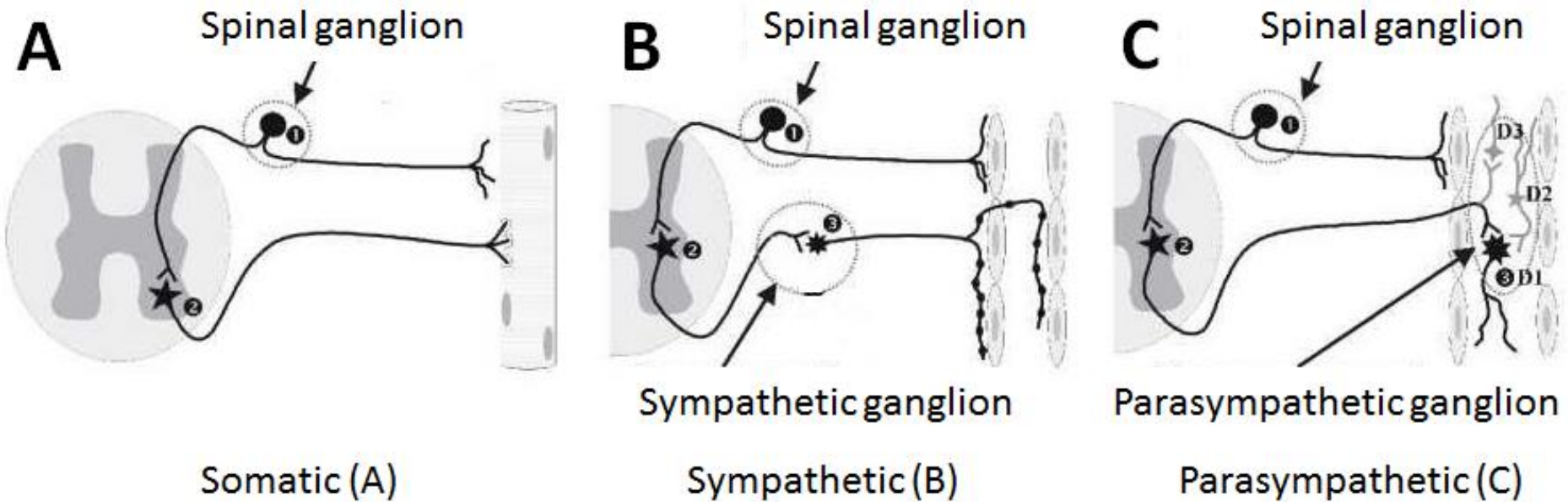
- Totally 15 nuclei

Peripheral part

- Fibers
- Ganglia
- Branches and nerves
- Plexuses
- Nerve endings

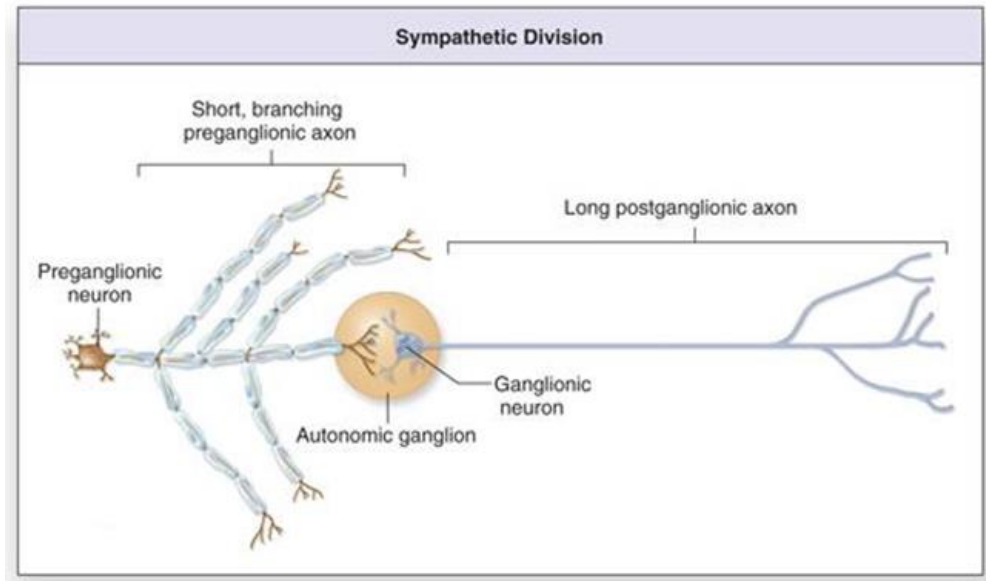
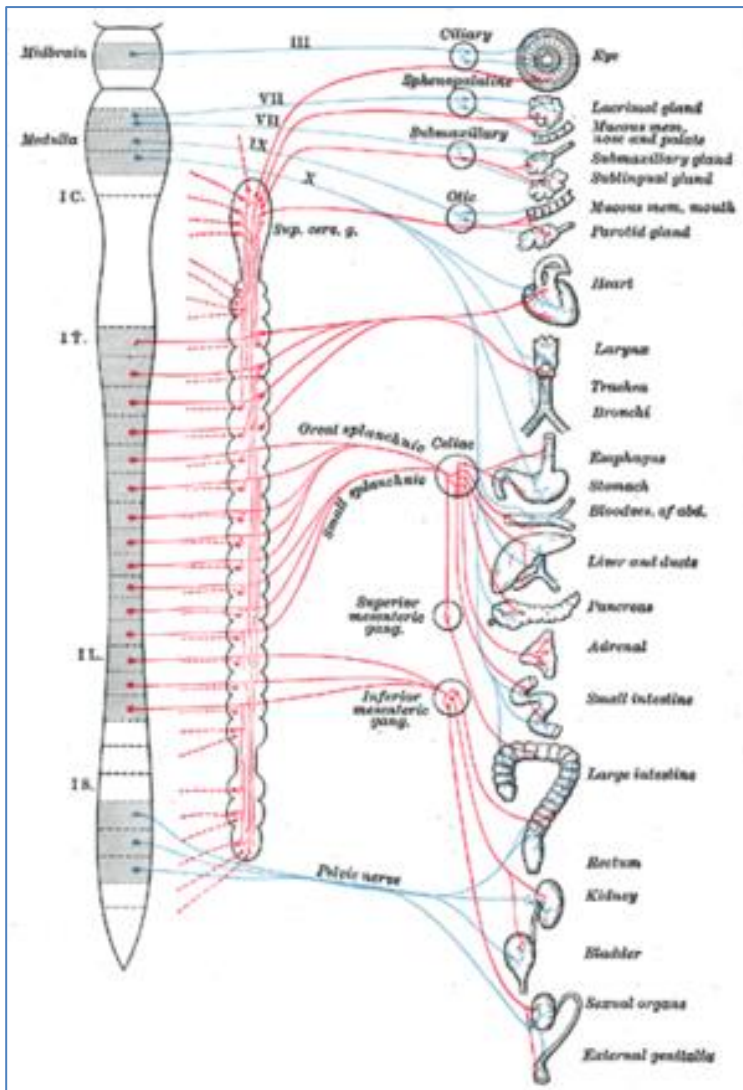


Reflex arches of the nervous system



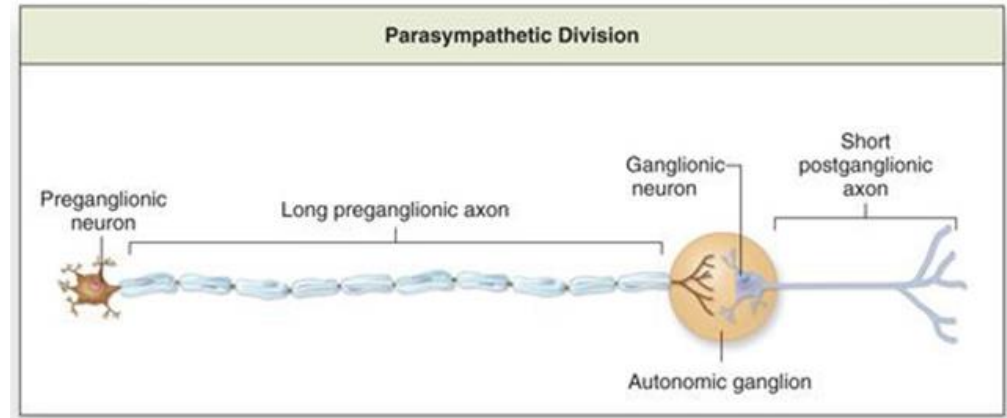
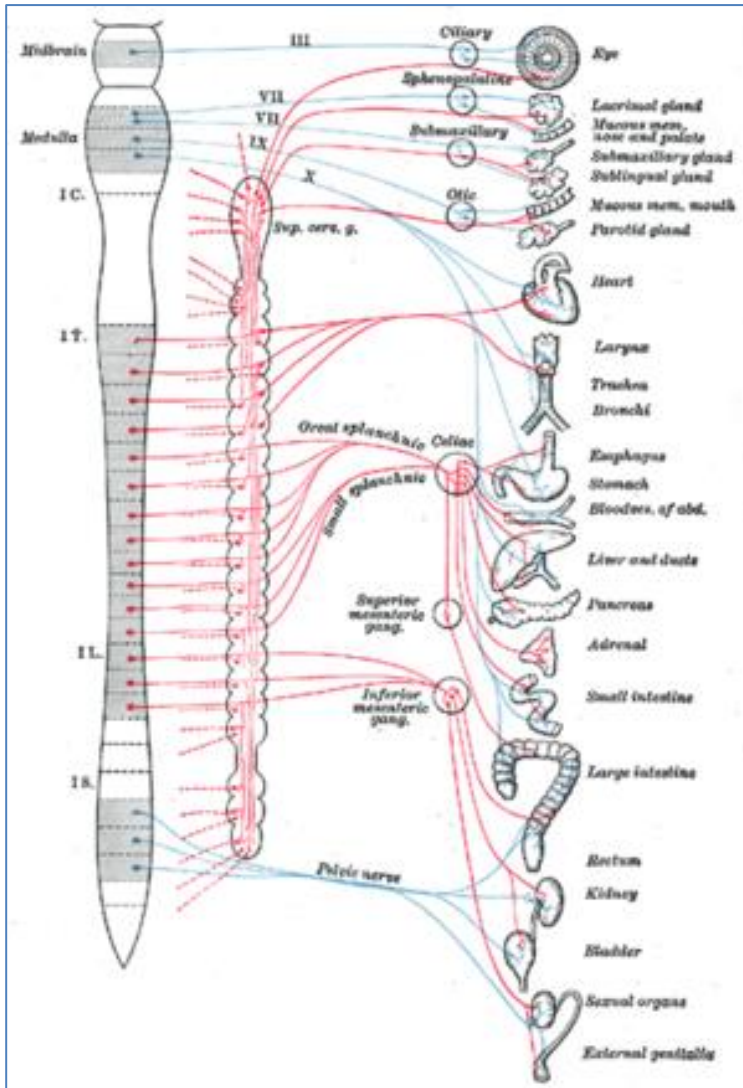
- 1 — Sensory pseudounipolar neuron
- A: 2 — Motor neuron
- B, C: 2 — Preganglionic neuron
- 3 — Postganglionic neuron
- D1 — Dogiel cell I (Postganglionic neuron, Motor)
- D2 — Dogiel cell II (Conductory)
- D3 — Dogiel cell III (Sensory)

The Sympathetic Branch of the ANS



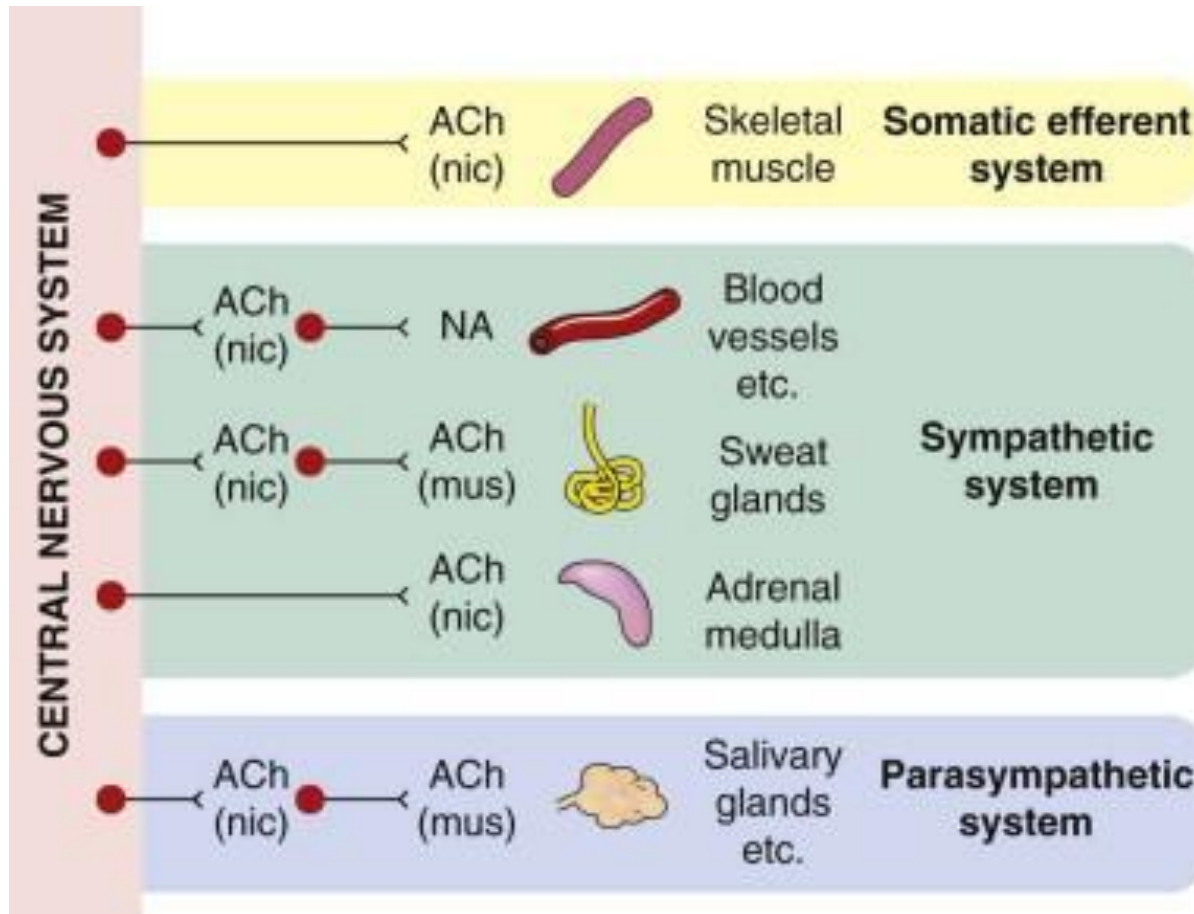
- The preganglionic nerves are short and synapse in paired ganglia adjacent to the spinal cord
- Fast and systemic effect
- Postganglionic axons reach organs forming plexus along the arterial blood vessels

The Parasympathetic Branch of the ANS



- They have long preganglionic nerves which synapse at ganglia near or on the organ innervated
- Slow and directed (to organ or tissue) effect

Mediators of the ANS



On ganglion: **acetylcholine** (ACh)

On organ:

Parasympathetic – ACh (fast decay) – limited and short effect.

Sympathetic – **noradrenaline** (stable), easily absorbed into blood – diffuse effect of sympathetic nervous system.

Effects of the ANS

Parasympathetic
Nervous System



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REST & DIGEST

Sympathetic
Nervous System



FIGHT or
FLIGHT

Effects of the ANS on eye

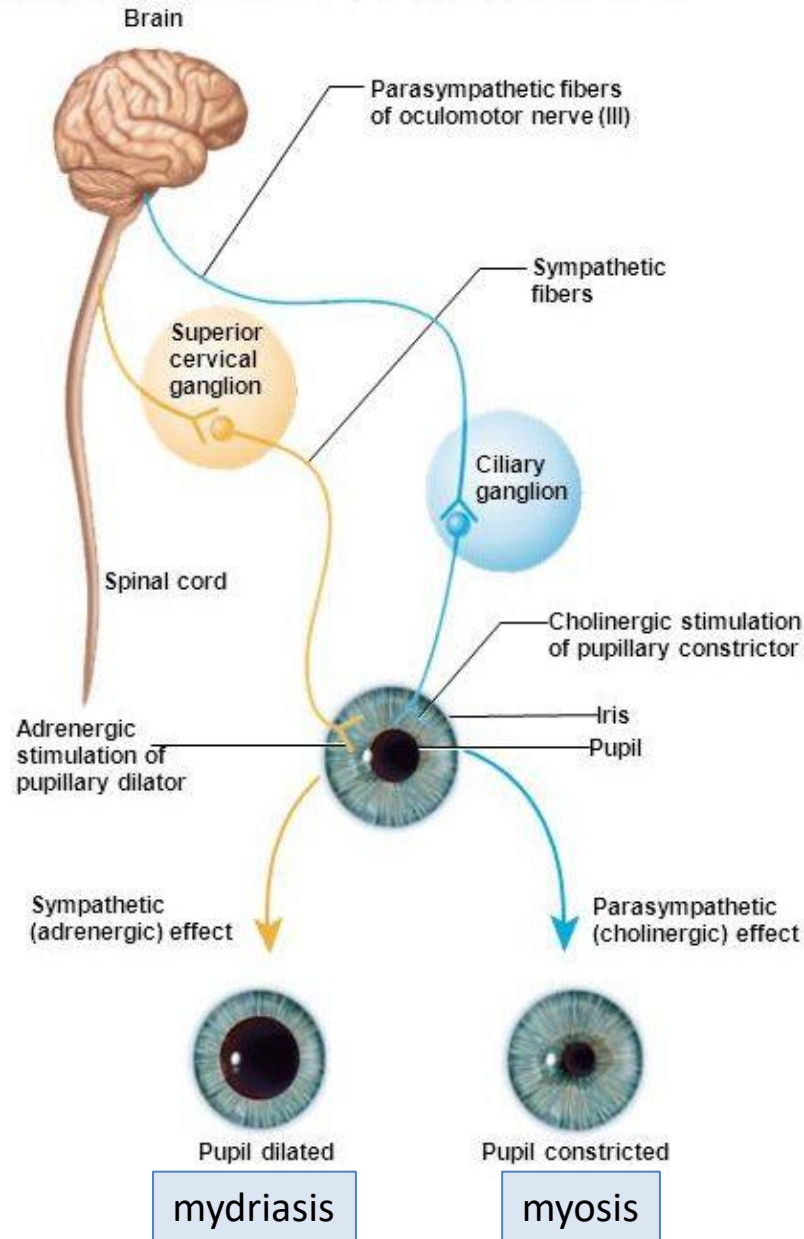
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Sympathetic nervous system

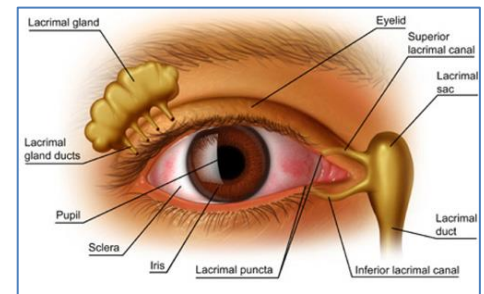
- Dilate pupil (distance vision)
- Decrease function of lacrimal gland

Parasympathetic nervous system

- Contract pupil (near vision)
- Stimulate lacrimal gland



"Dry eye"



Lacrimal gland and ducts

Light test



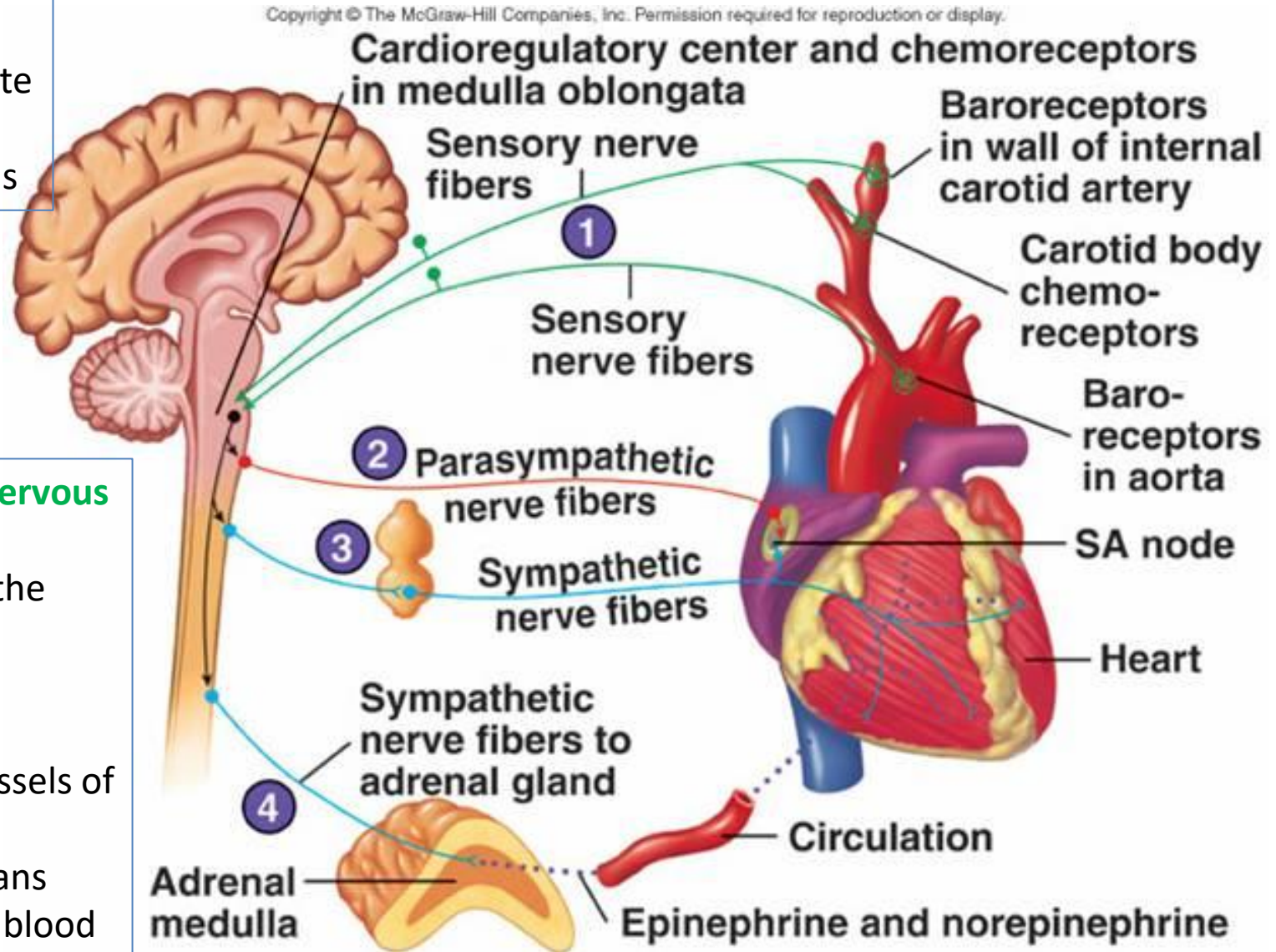
Effects of the ANS on CVS

Parasympathetic nervous system

- Decrease of the heart rate
- Constrict heart vessels

Sympathetic nervous system

- Increase of the heart rate
- Dilate heart vessels
- Constrict vessels of the skin and internal organs (increase of blood pressure)



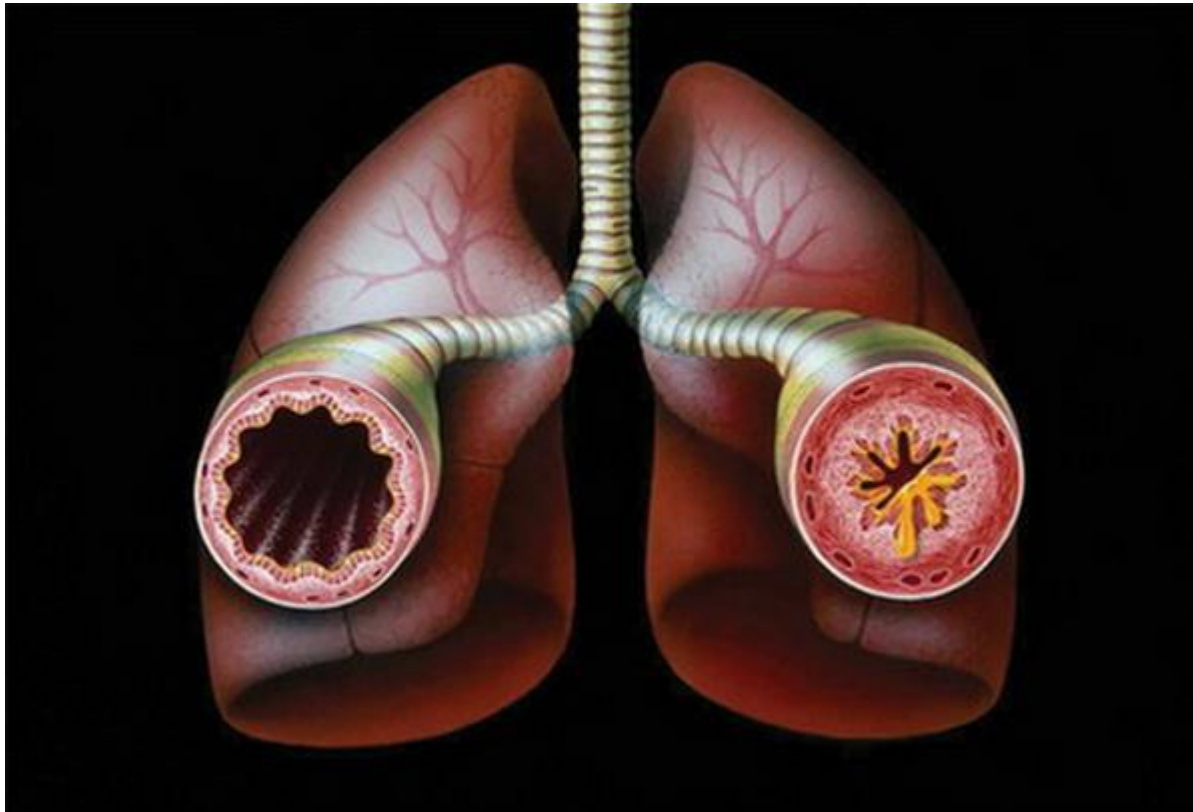
Effects of the ANS respiratory system

Sympathetic nervous system

- Dilate bronchi
- Decrease mucus production
- Increase respiratory rate

Parasympathetic nervous system

- Constrict bronchi
- Increase mucus production
- Decrease respiratory rate



Attack of
bronchial
asthma is
often at night
("kingdom of
nervus
vagus")

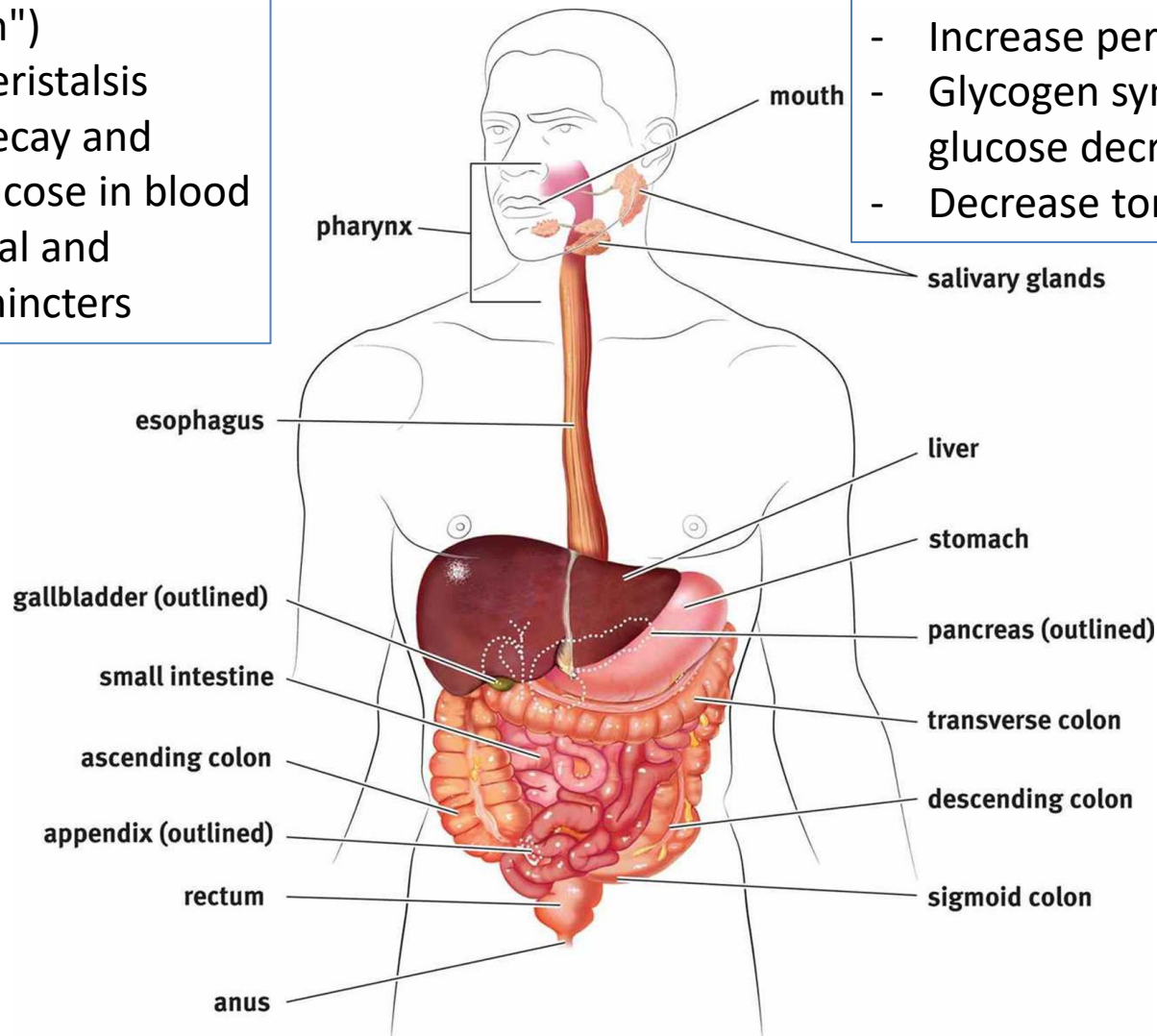
Effects of the ANS on digestive system

Sympathetic nervous system

- Decrease saliva secretion ("dry mouth")
- Decrease peristalsis
- Glycogen decay and increase glucose in blood
- Contract anal and urethral sphincters

Parasympathetic nervous system

- Stimulate saliva secretion
- Increase peristalsis
- Glycogen synthesis and glucose decrease in blood
- Decrease tonus of sphincters



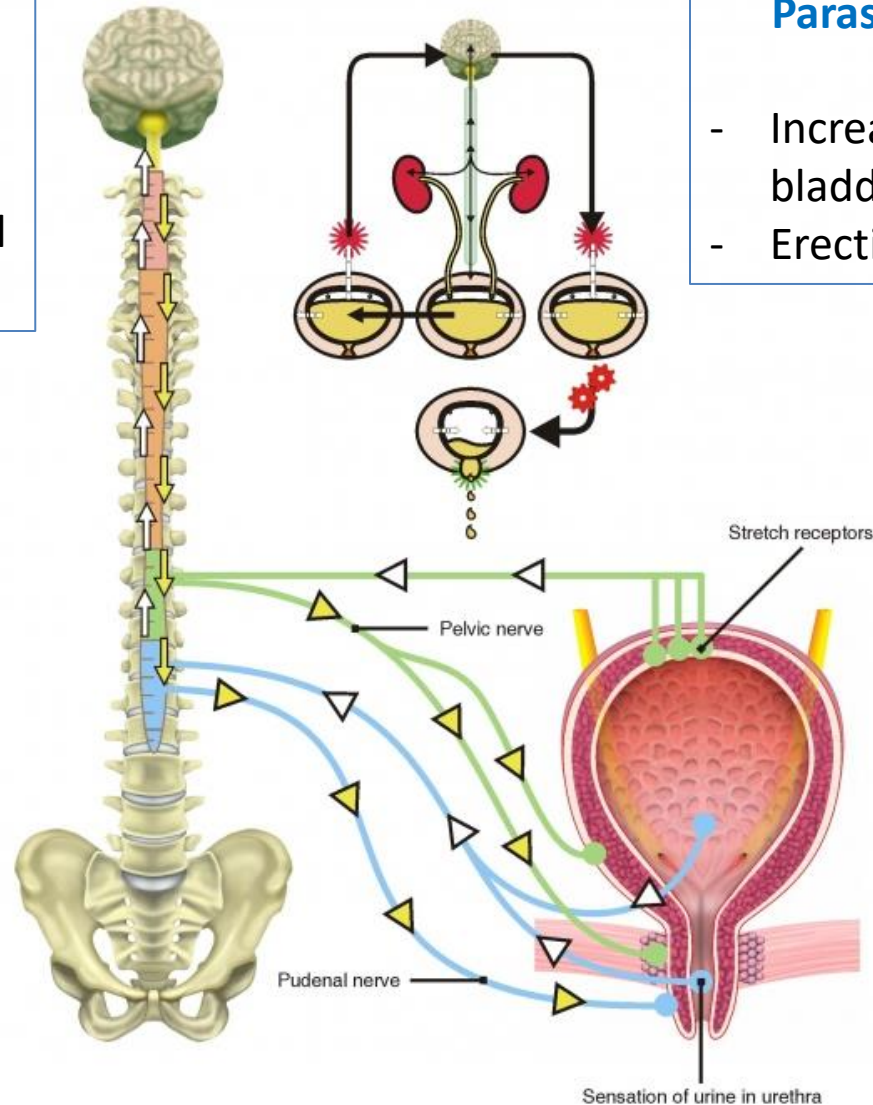
Effects of the ANS on excretory and reproductive system

Sympathetic nervous system

- Relax walls of the urinary bladder
- Ejaculation and vaginal contraction

Parasympathetic nervous system

- Increase tonus of urinary bladder
- Erection of genitals



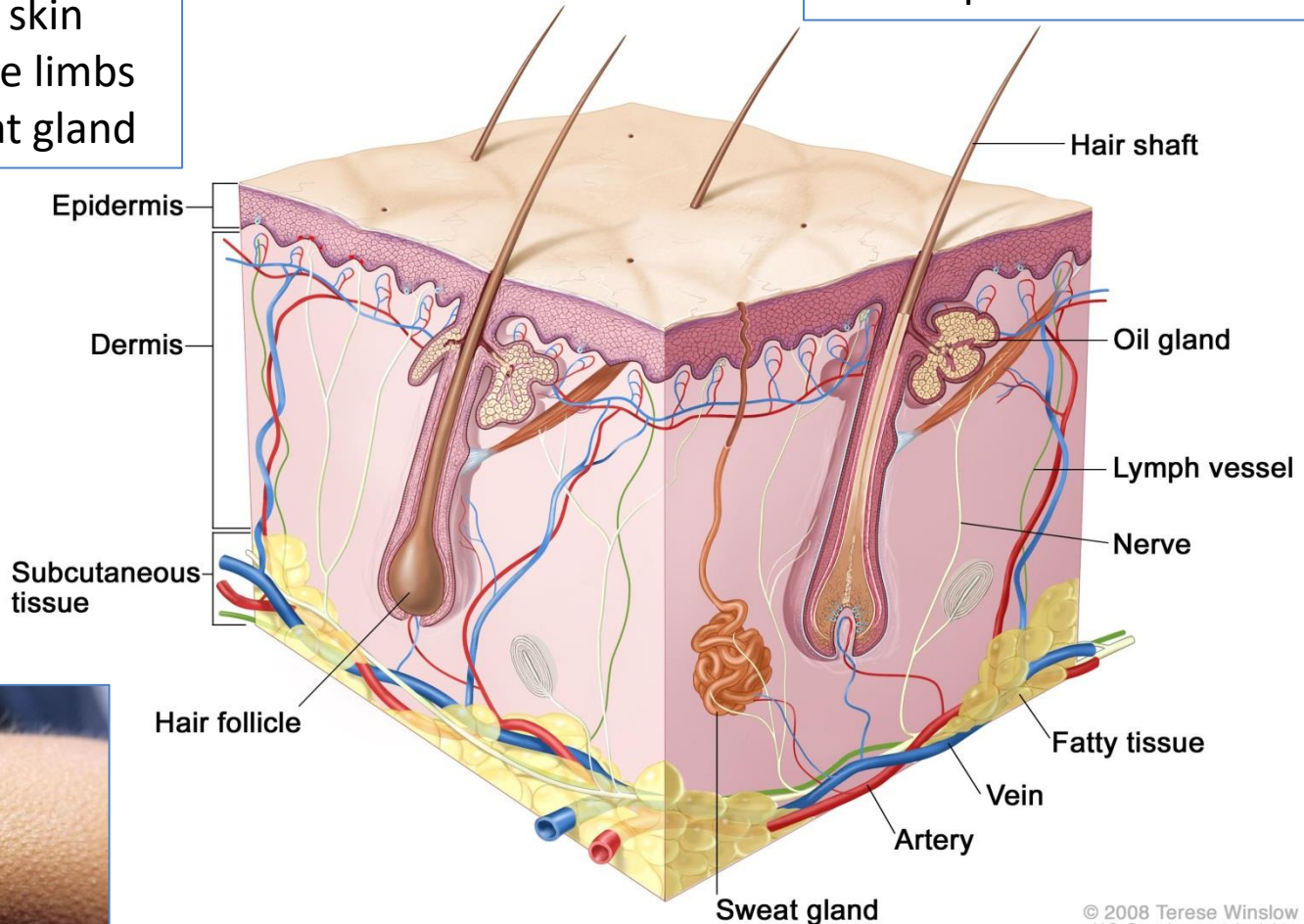
Effects of the ANS on skin

Sympathetic nervous system

- Piloerector muscle
- Constriction of skin arterioles of the limbs
- Stimulate sweat gland

Parasympathetic nervous system

- Not present



Lesion of the spinal cord – no pilomotor and skin reflex

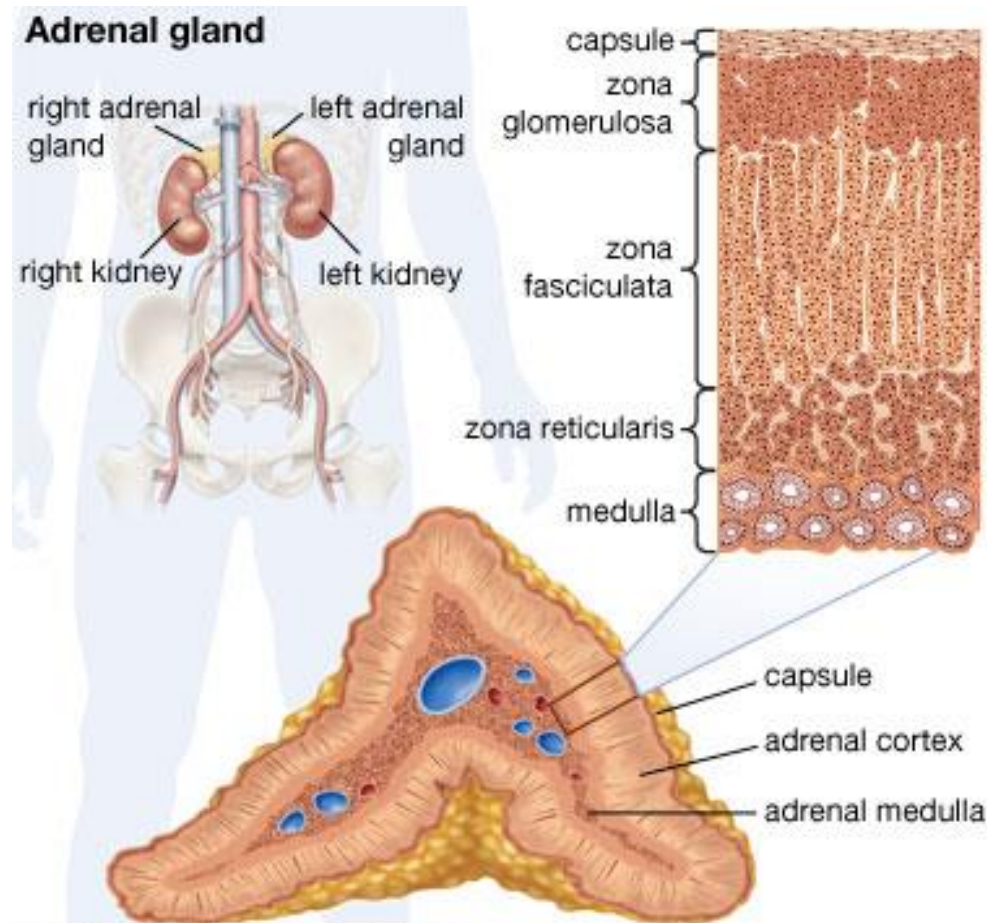
Effects of the ANS on adrenal gland

Sympathetic nervous system

- Secretion of adrenaline into the blood

Parasympathetic nervous system

- Not present



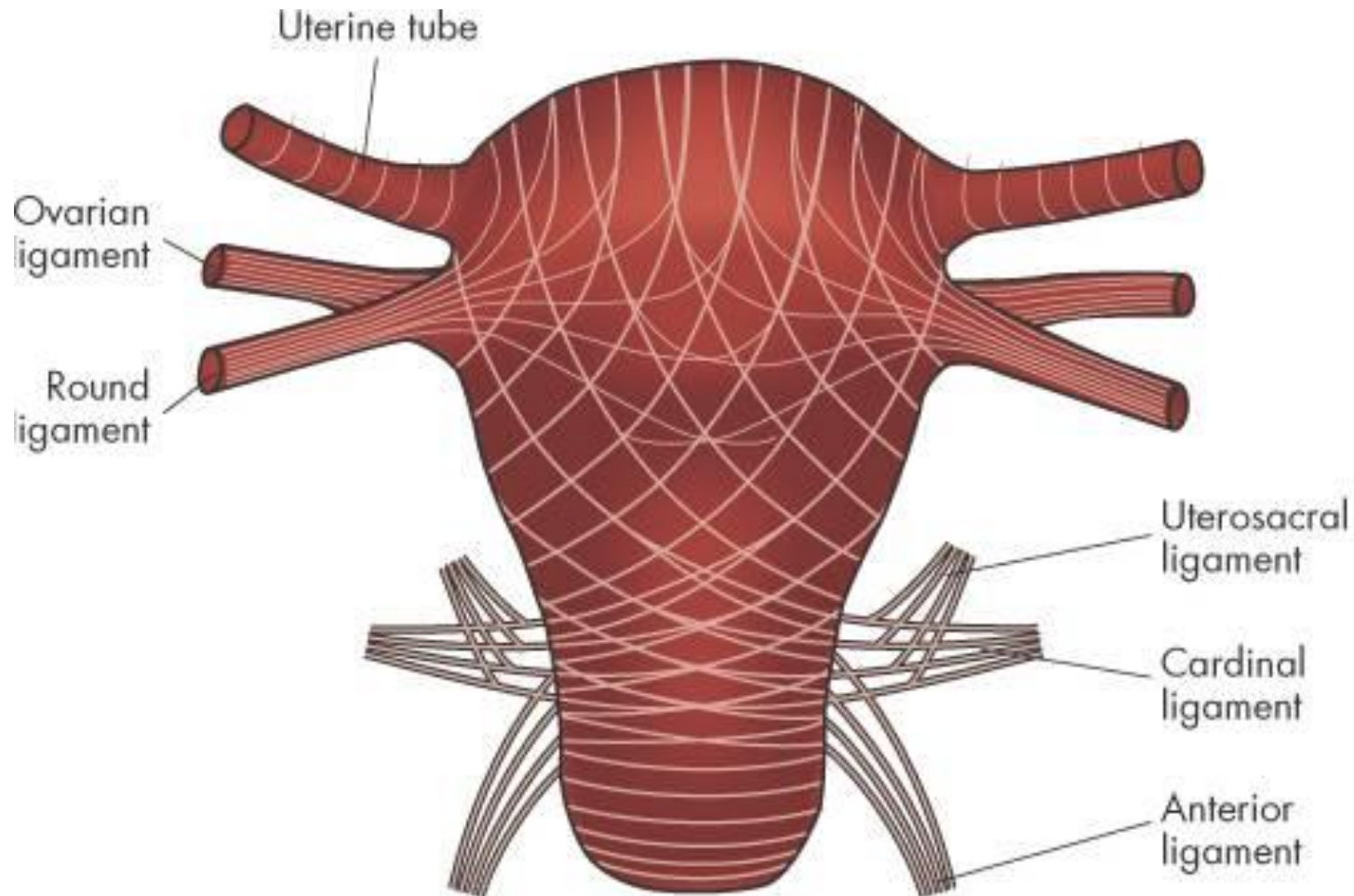
Effects of the ANS on uterus

Sympathetic nervous system

- Longitudinal muscles of the uterus fundus and body
- Contraction

Parasympathetic nervous system

- Transverse muscles of the neck and isthmus
- Contraction





Atropine

– anticholinergic drug.

Effects:

- 1) Dilated pupil
- 2) Constricted pupil
- 3) Stimulate salivation
- 4) “dry mouth”
- 5) Dilatation of bronchi
- 6) Constriction of bronchi
- 7) Increased heart rate
- 8) Decreased heart rate
- 9) Inhibit digestion
- 10) Stimulate digestion



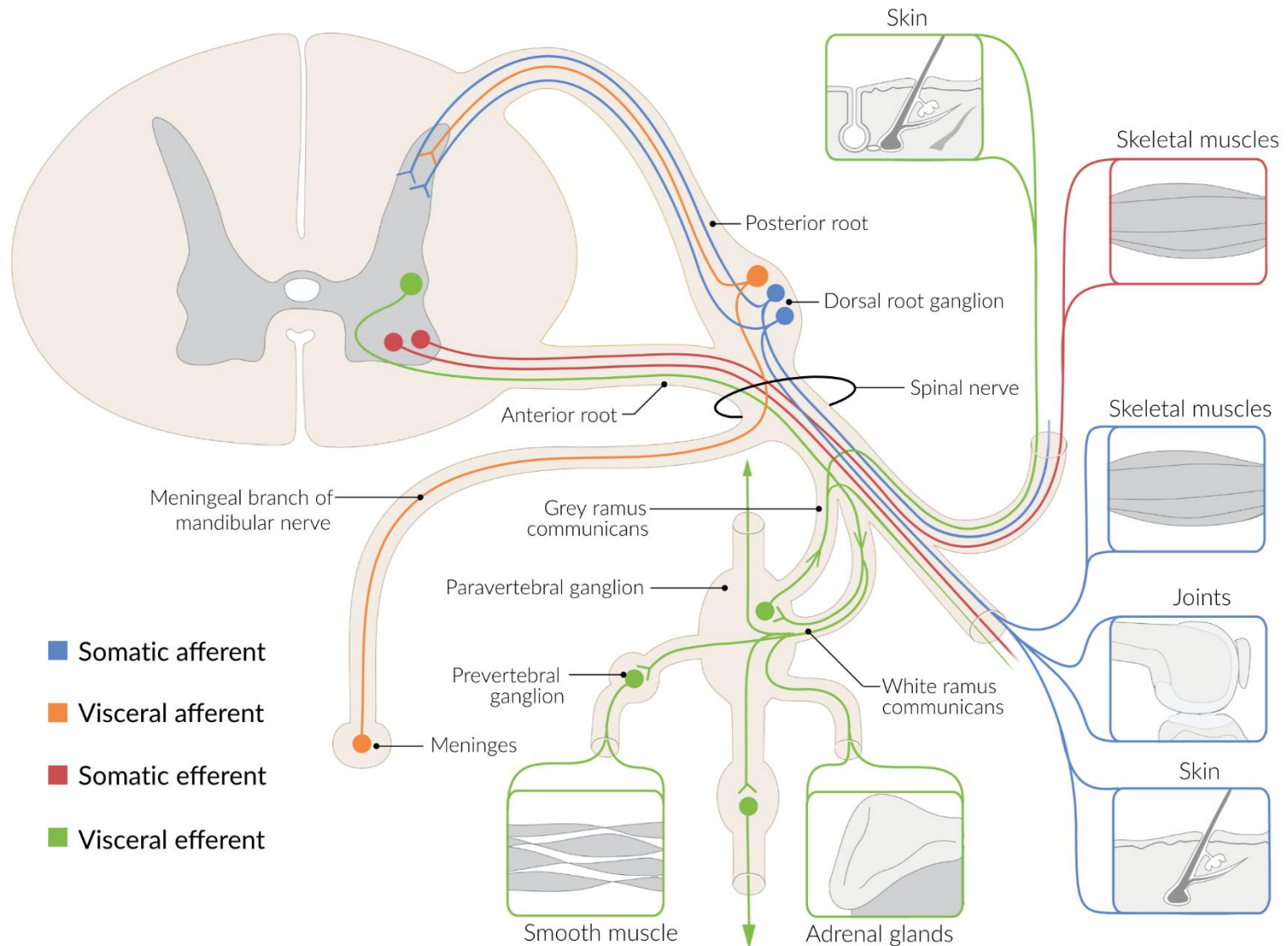
Atropine

– anticholinergic drug.

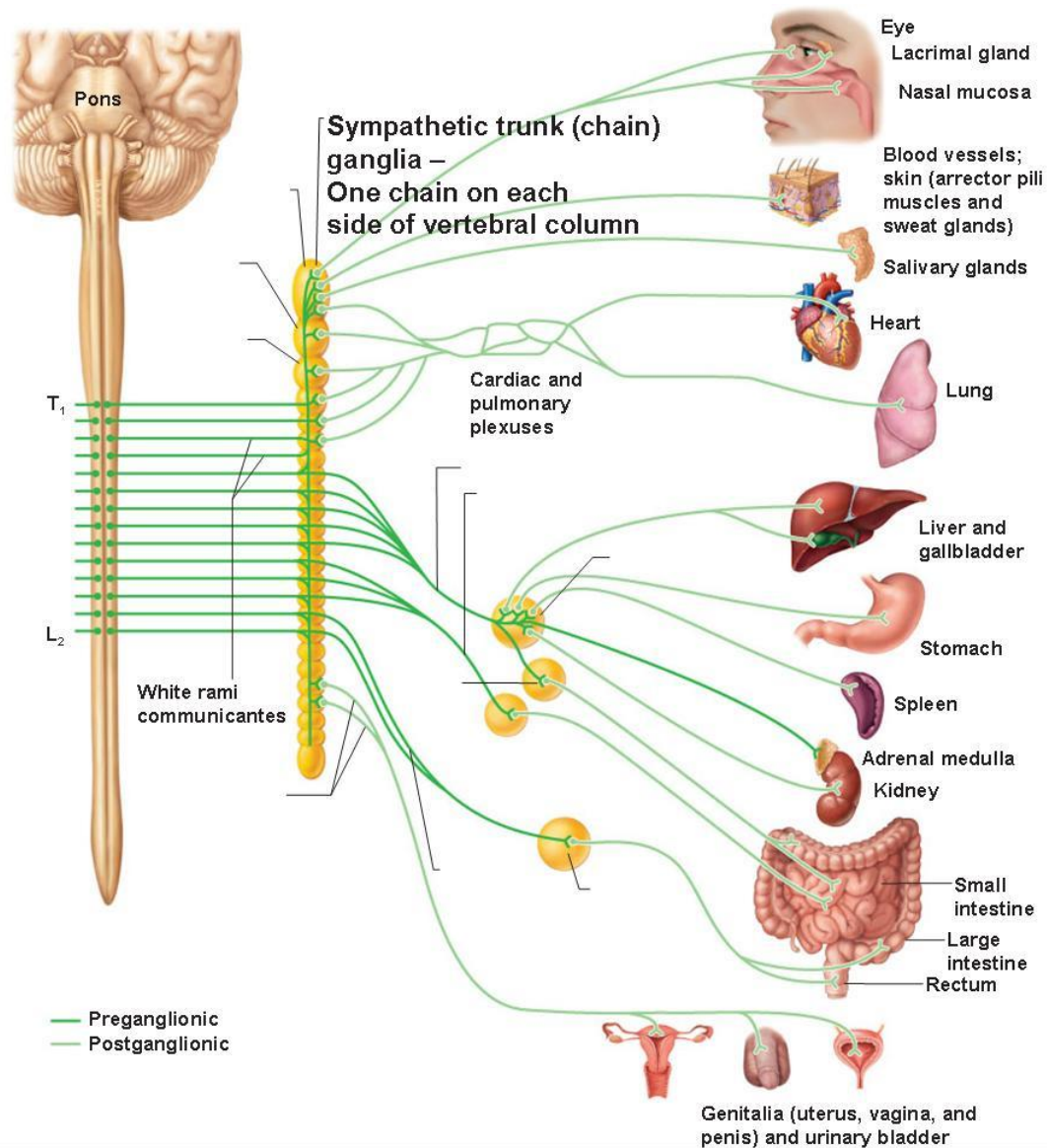
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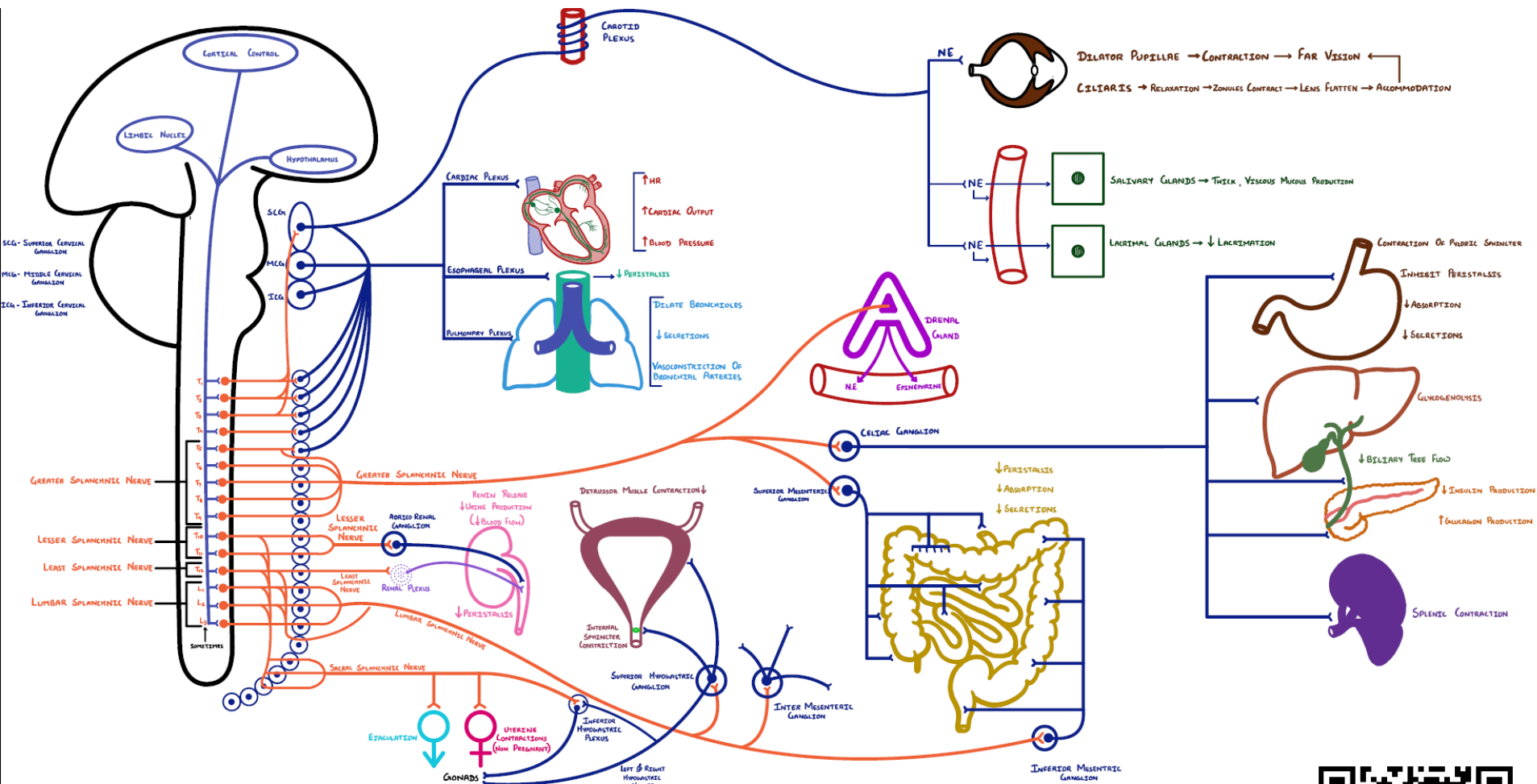
Spinal nerve formation



Anatomy of the sympathetic nervous system



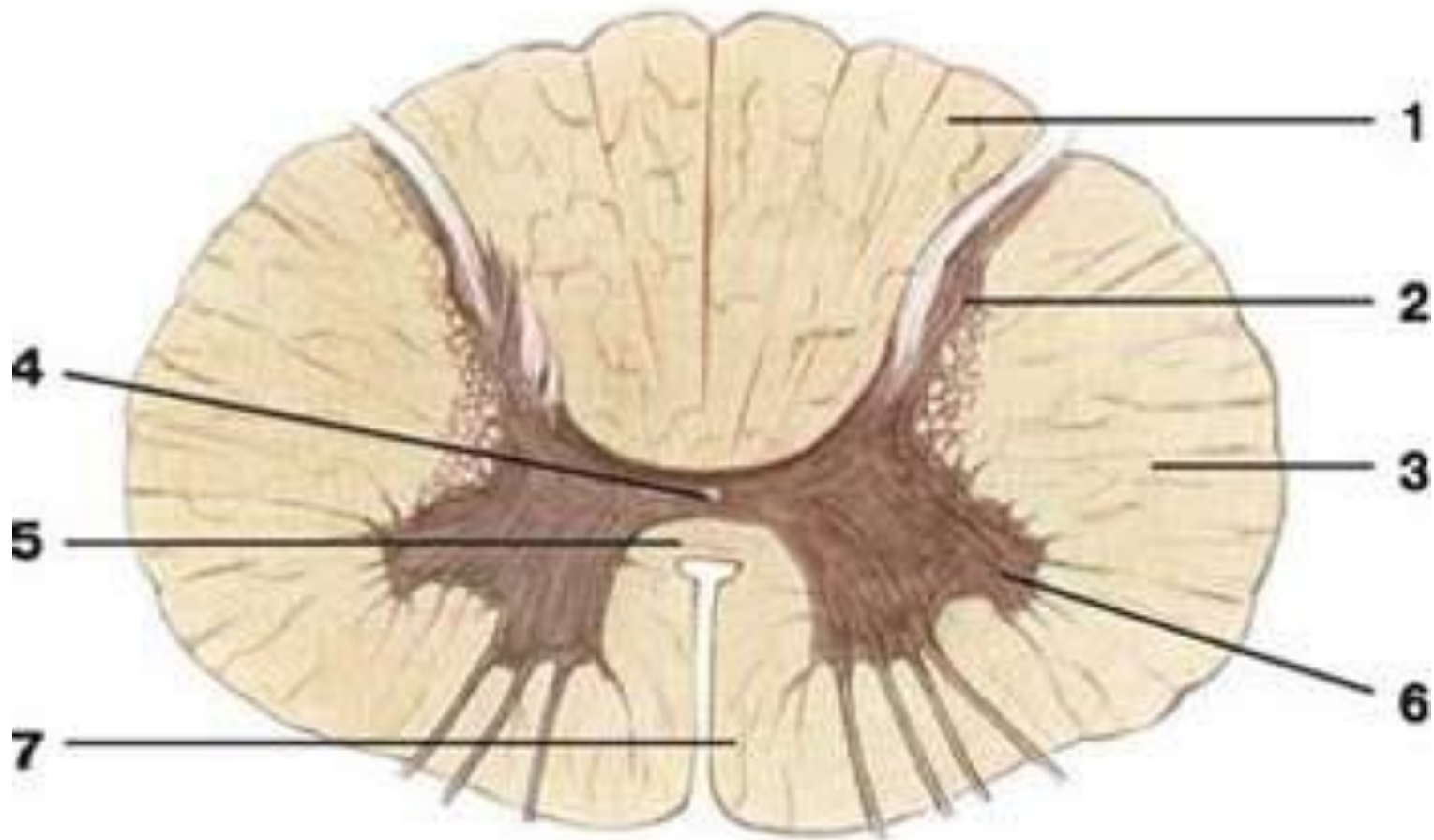
Anatomy of the sympathetic nervous system



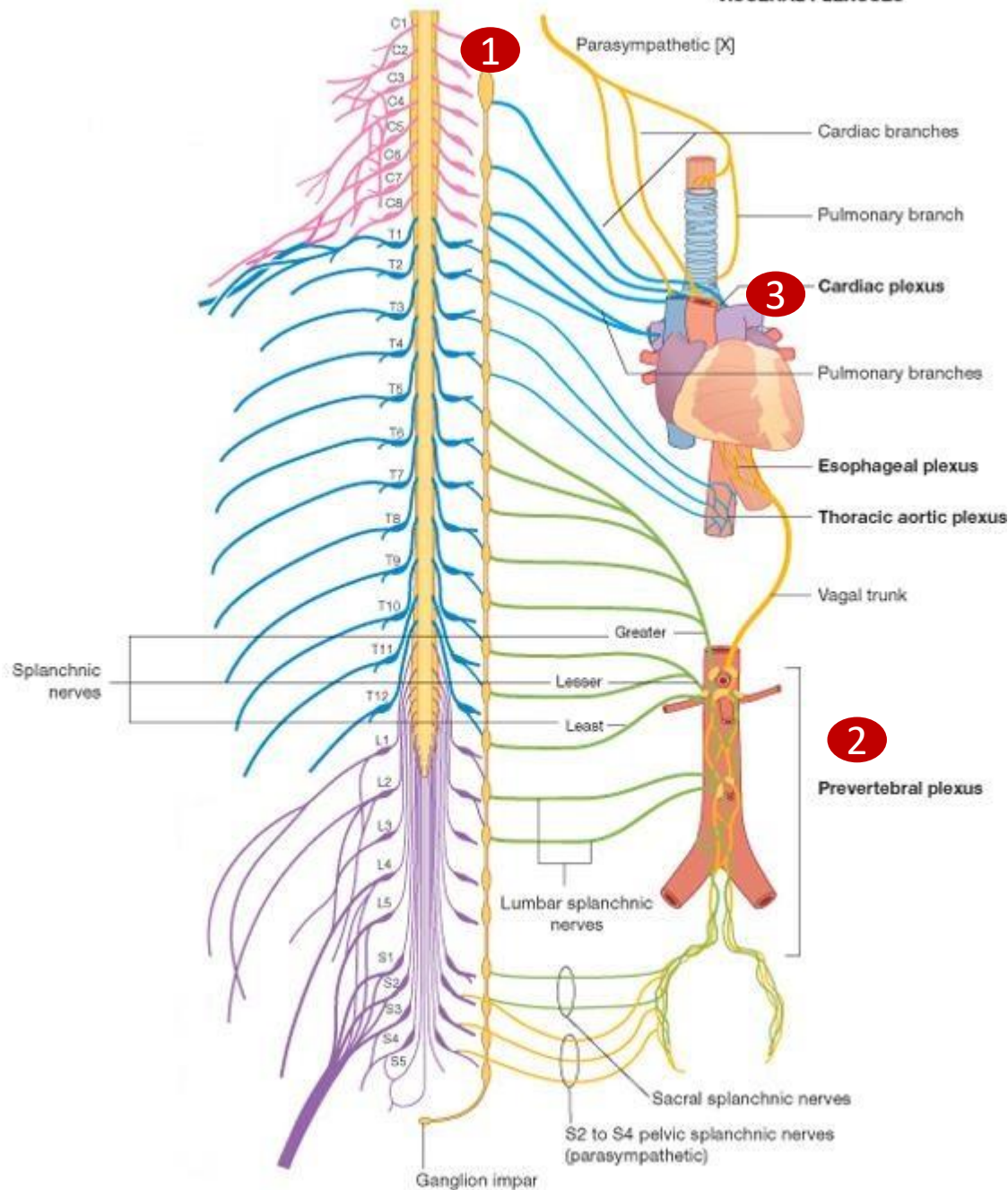
The link to download the scheme



1st neuron – *Substantia intermedia lateralis* (lateral horns) of the spinal cord C₈-L₂



VISCERAL PLEXUSES



2nd neuron – in ganglion –
3 Variants:

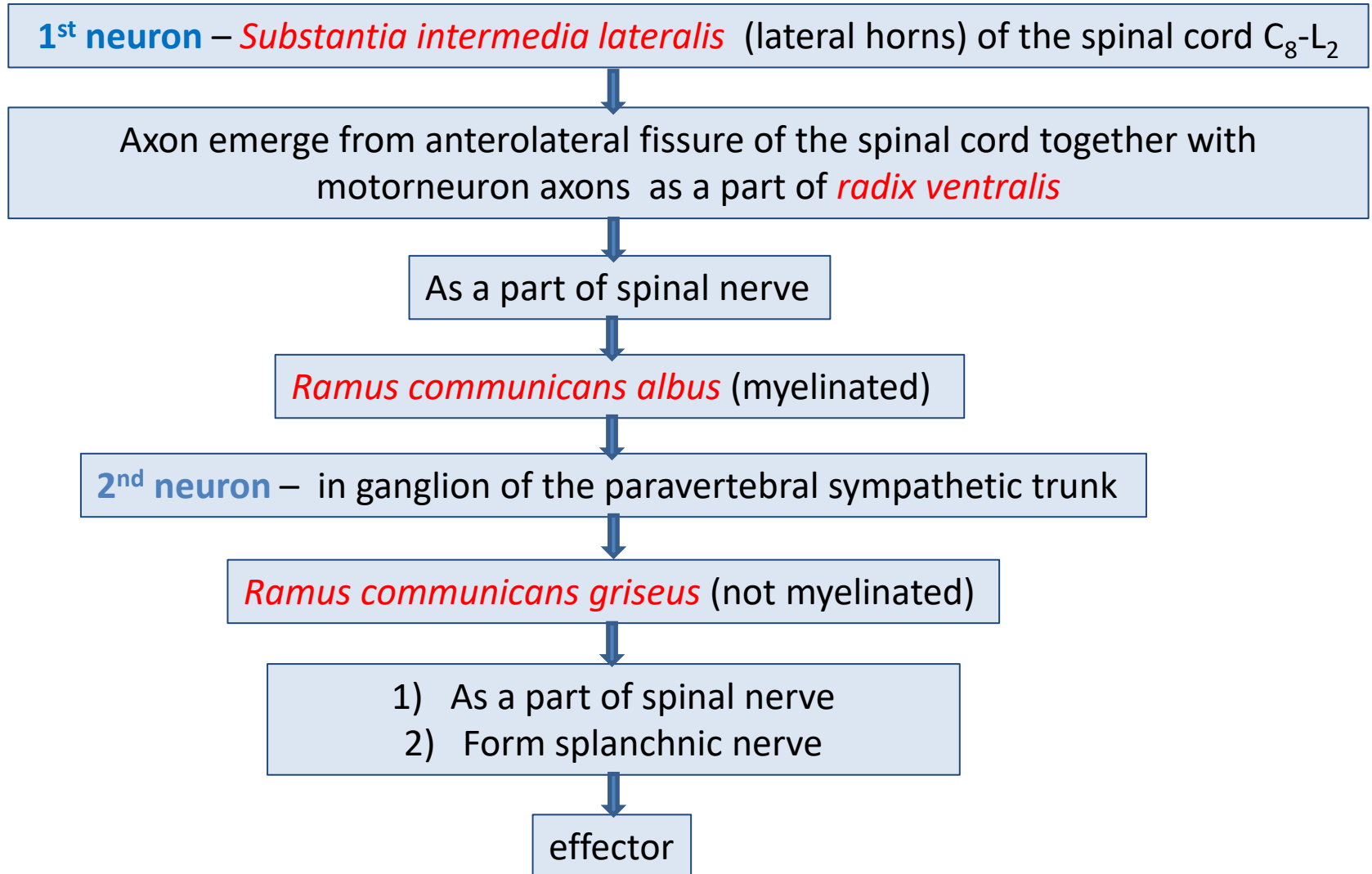
1) Paravertebral sympathetic trunk: ganglia

- Cervical (2-3)
- Thoracic (10-12)
- Lumbar (5)
- Sacral (5)
- Coccygeal (1 unpaired)

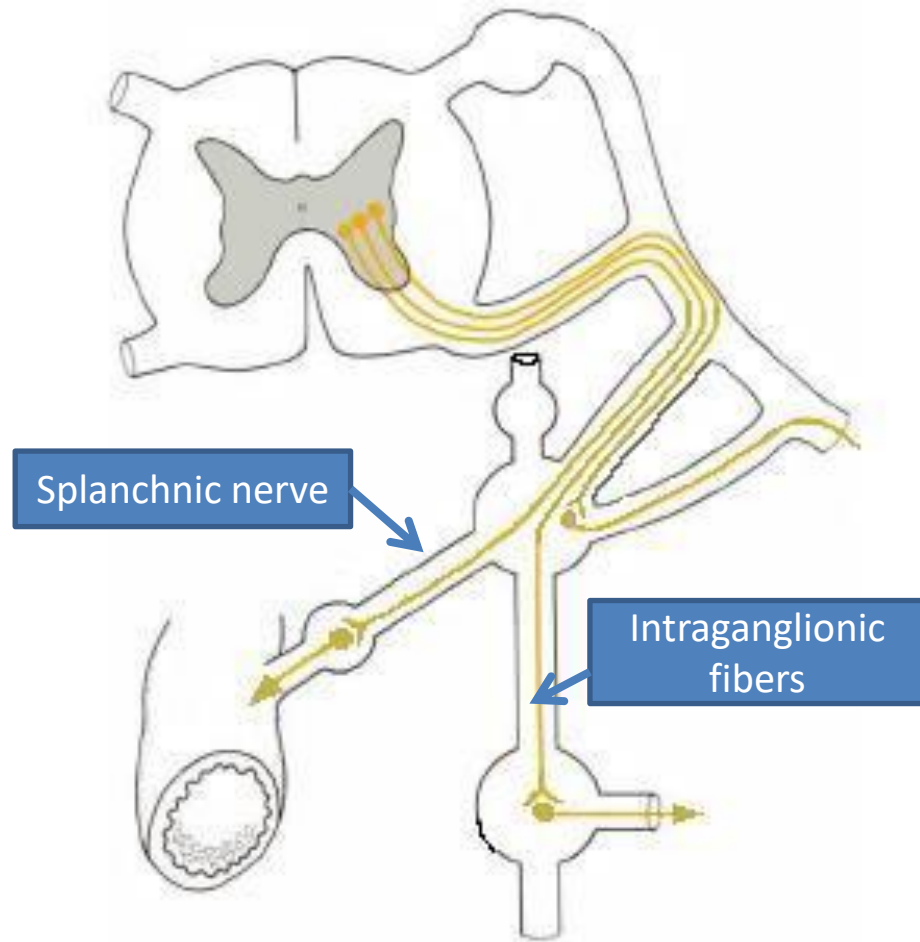
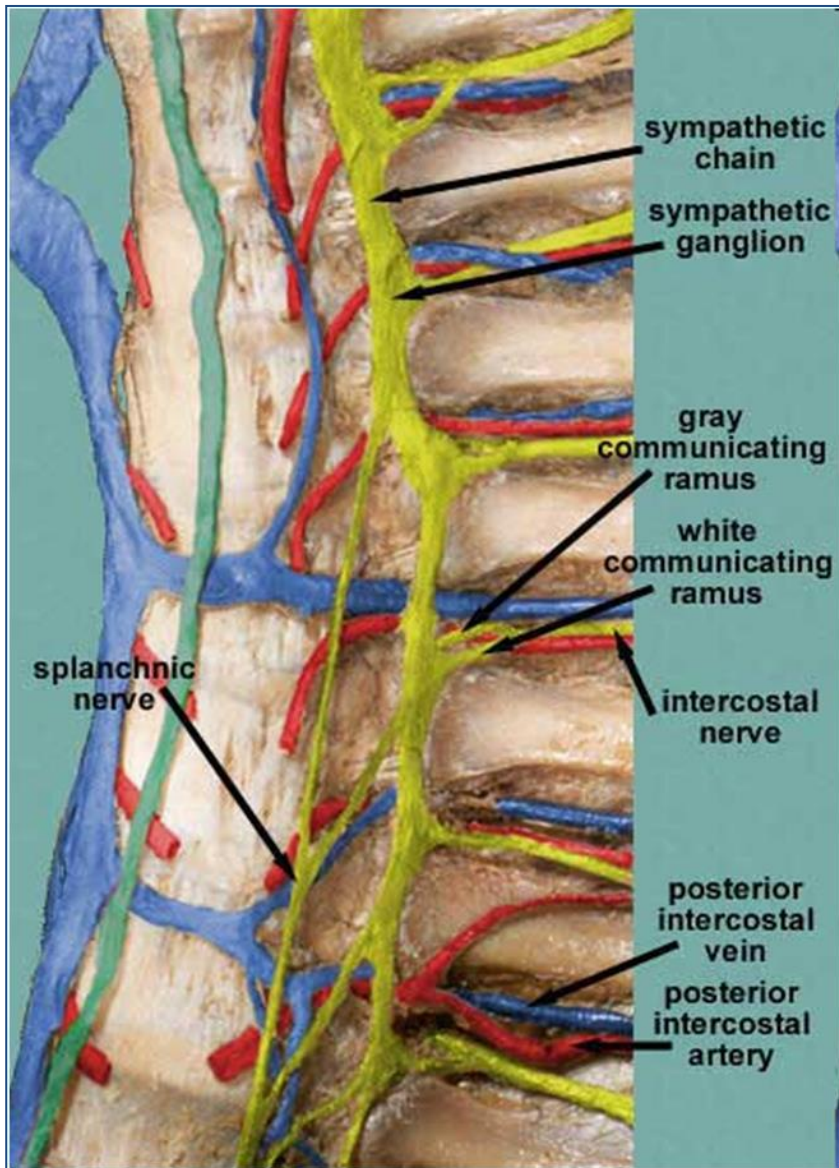
2) Prevertebral sympathetic plexuses of the thorax and abdomen (on vessels)

3) Sympathetic plexuses of the organs

If the 2nd neuron in ganglia of the sympathetic trunk - pathway



Splanchnic nerve



Intraganglionic fibers of the sympathetic trunk - arising and descending fibers
preganglionic sympathetic fibers

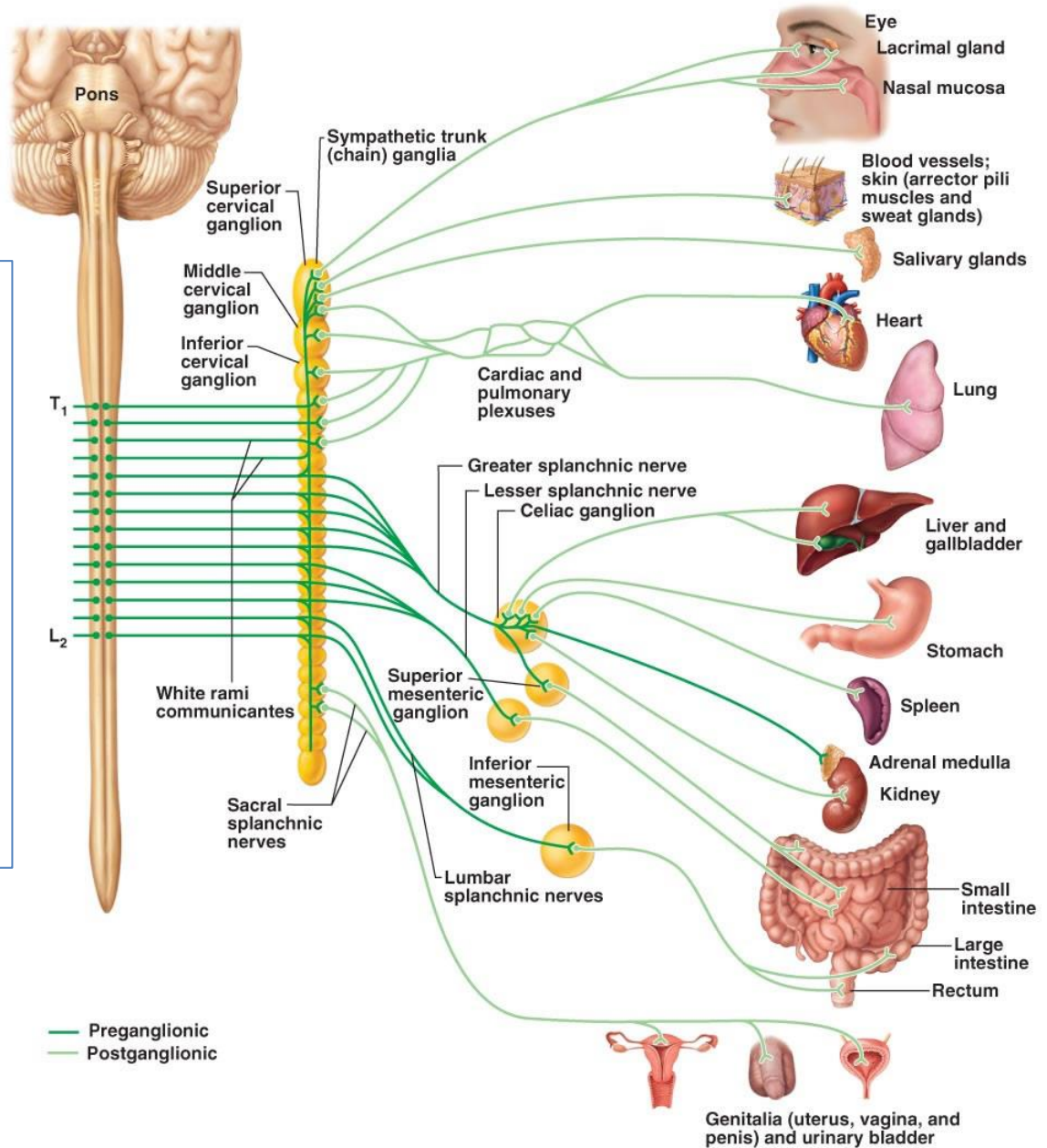
Splanchnic nerve

Splanchnic nerves:

- Thoracic (POSTganglionic!)

- Abdominal (PREganglionic!):

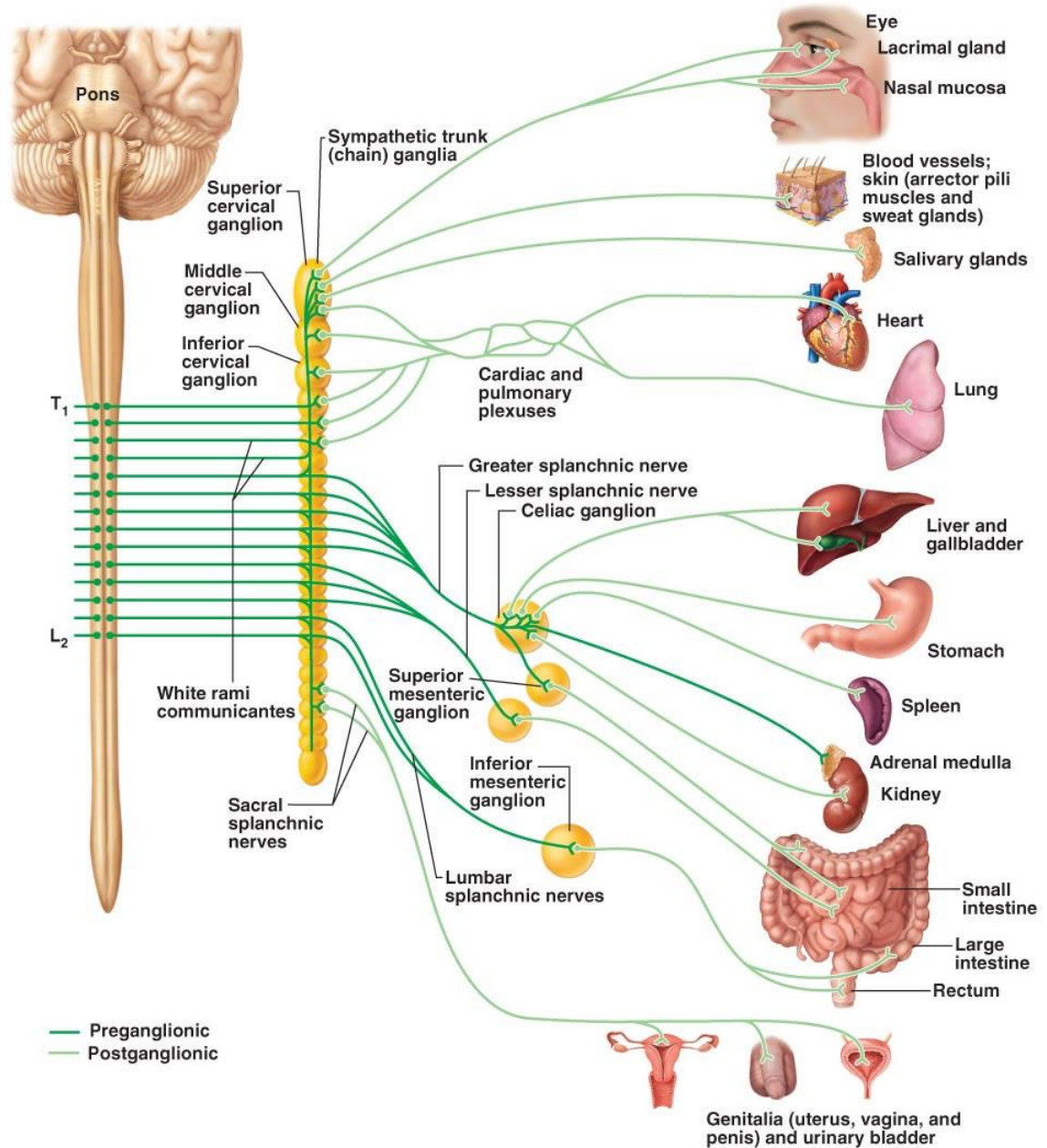
- 1) Greater splanchnic nerve
- 2) Lesser splanchnic nerve
- 3) Least splanchnic nerve
- 4) Lumbar splanchnic nerve
- 5) Sacral splanchnic nerve



Splanchnic nerve

Thoracic splanchnic nerves

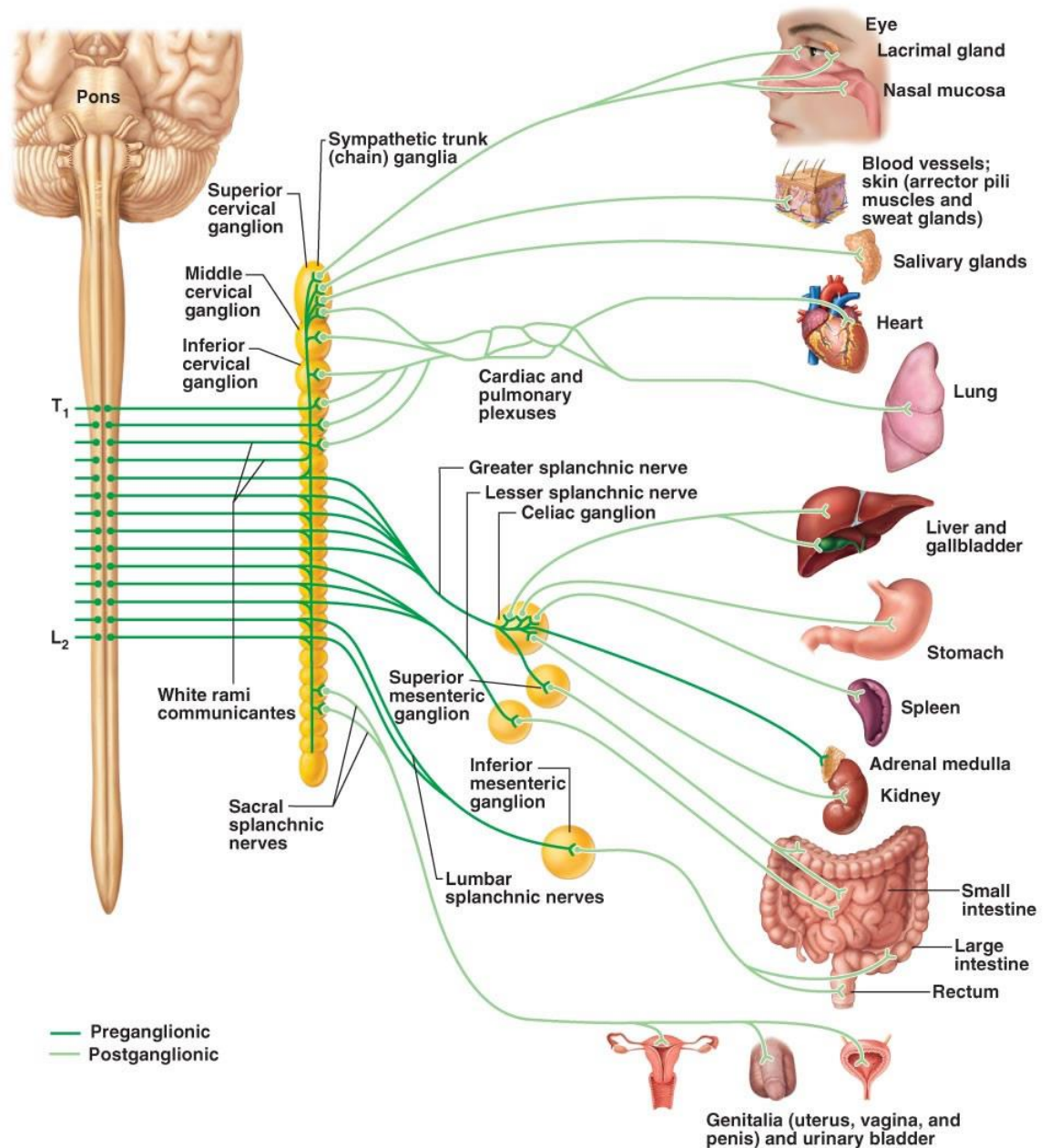
- **POST**ganglionic fibers
- Innervation of head, neck and thorax
- **2nd neuron** - ganglia of the sympathetic trunk



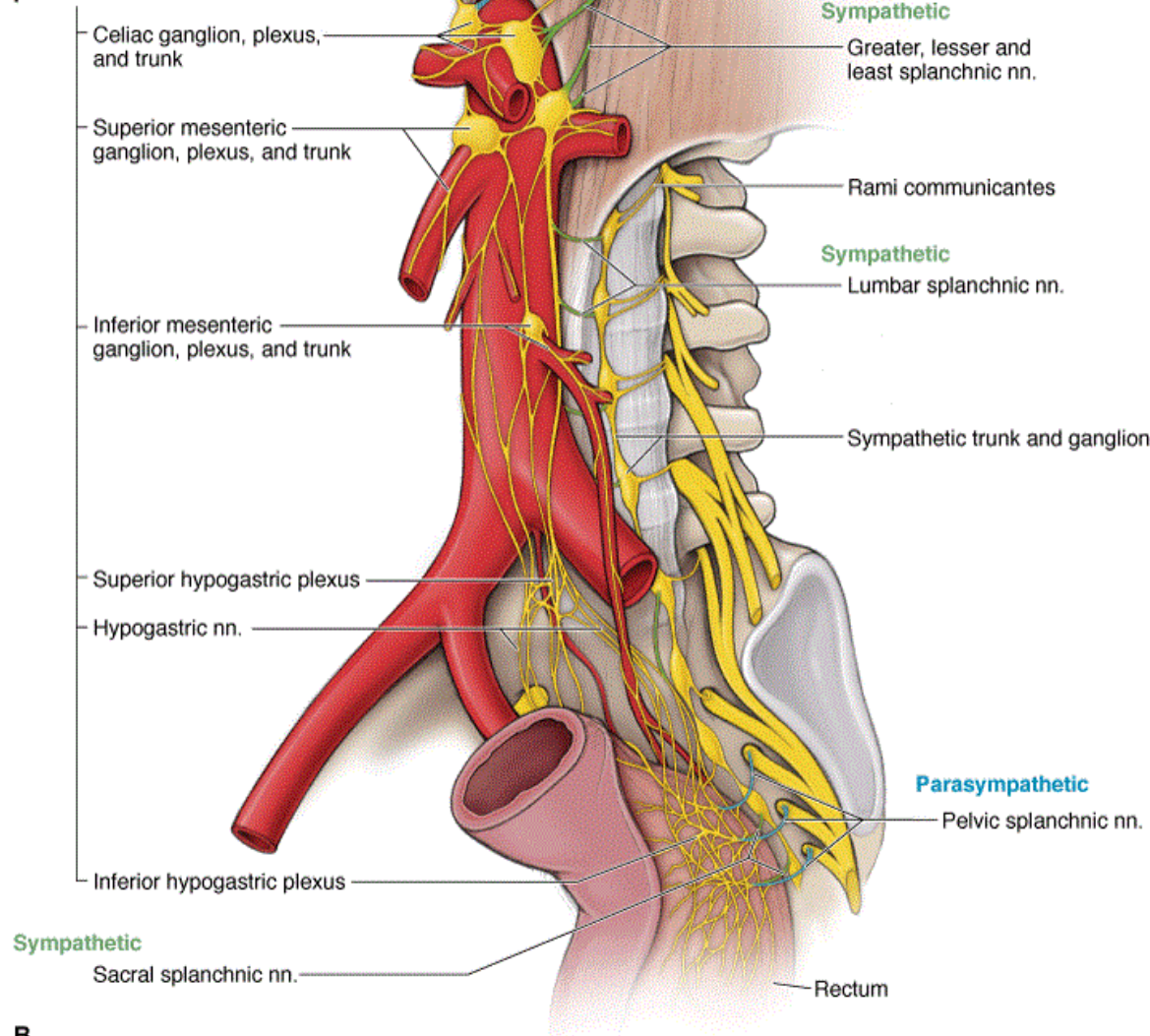
Splanchnic nerve

Abdominal splanchnic nerves

- PREganglionic fibers
- 2nd sympathetic neuron - ganglia of plexuses
- Innervation of abdomen and pelvis organs



Prevertebral ganglia and plexus on the aorta



B

Source: Morton DA, Foreman KB, Albertine KH: *The Big Picture: Gross Anatomy*; www.accessmedicine.com
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Prevertebral plexuses on the aorta are **formed by**:

- 1) Thoracic (great and lesser) splanchnic nerves
- 2) Lumbar splanchnic nerves

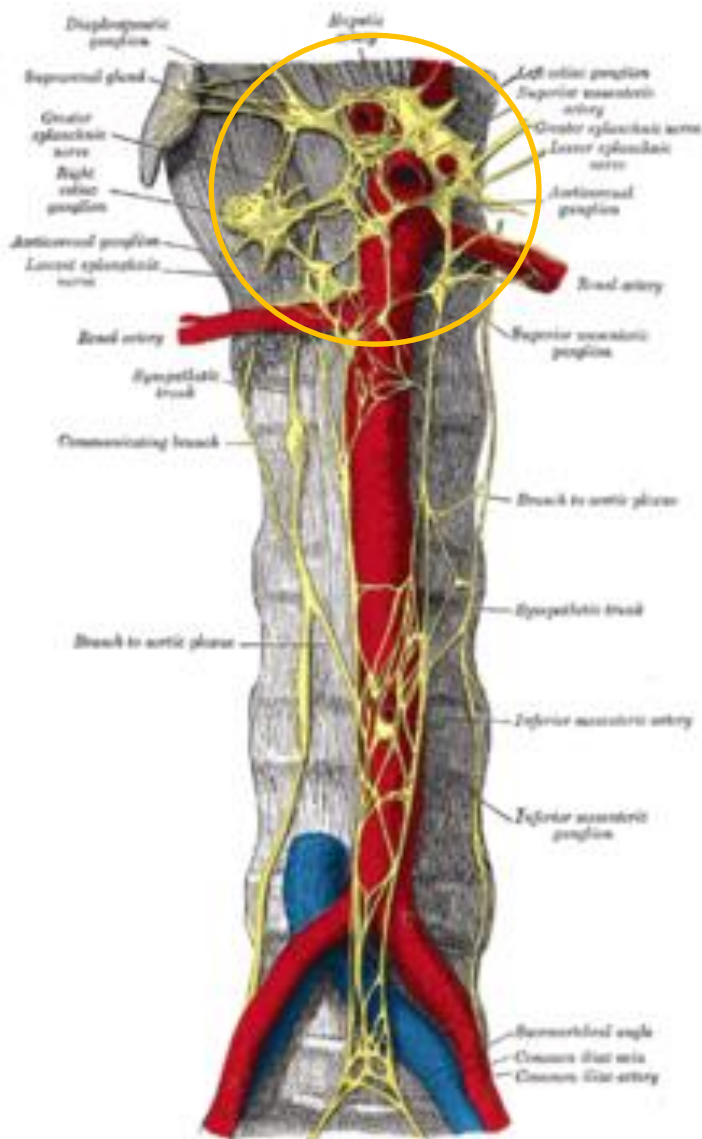
Prevertebral plexuses on the aorta:

- 1) Coeliac
- 2) Superior mesenteric
- 3) Inferior mesenteric
- 4) Iliac (right and left)
- 5) Superior hypogastric
- 6) Inferior hypogastric (pelvic)

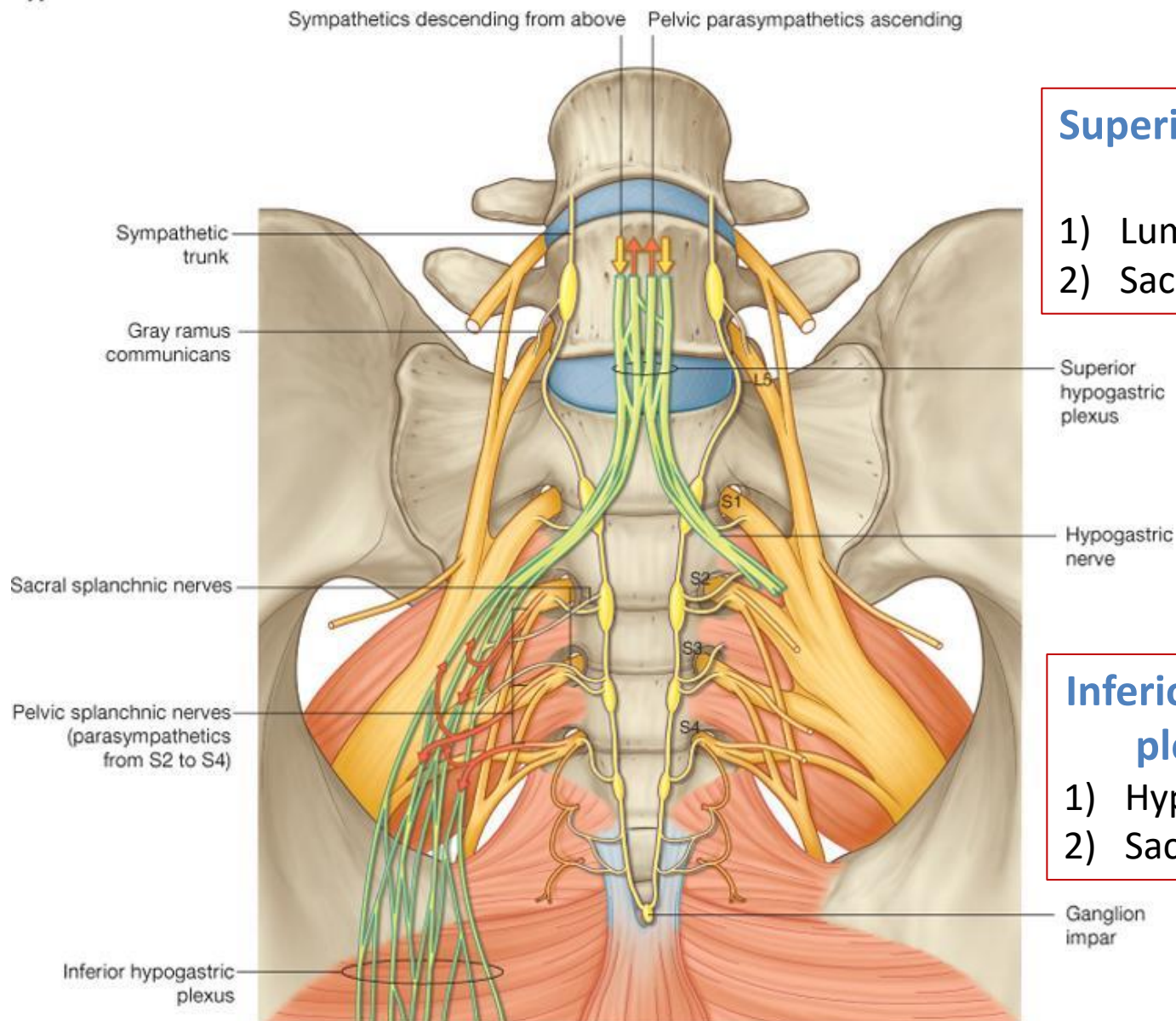
Prevertebral ganglia on the aorta:

- 1) Coeliac
- 2) Superior mesenteric
- 3) Inferior mesenteric
- 4) Aortorenal

Plexus coeliacus = “plexus solaris”



A



Superior hypogastric plexus
is **formed by:**

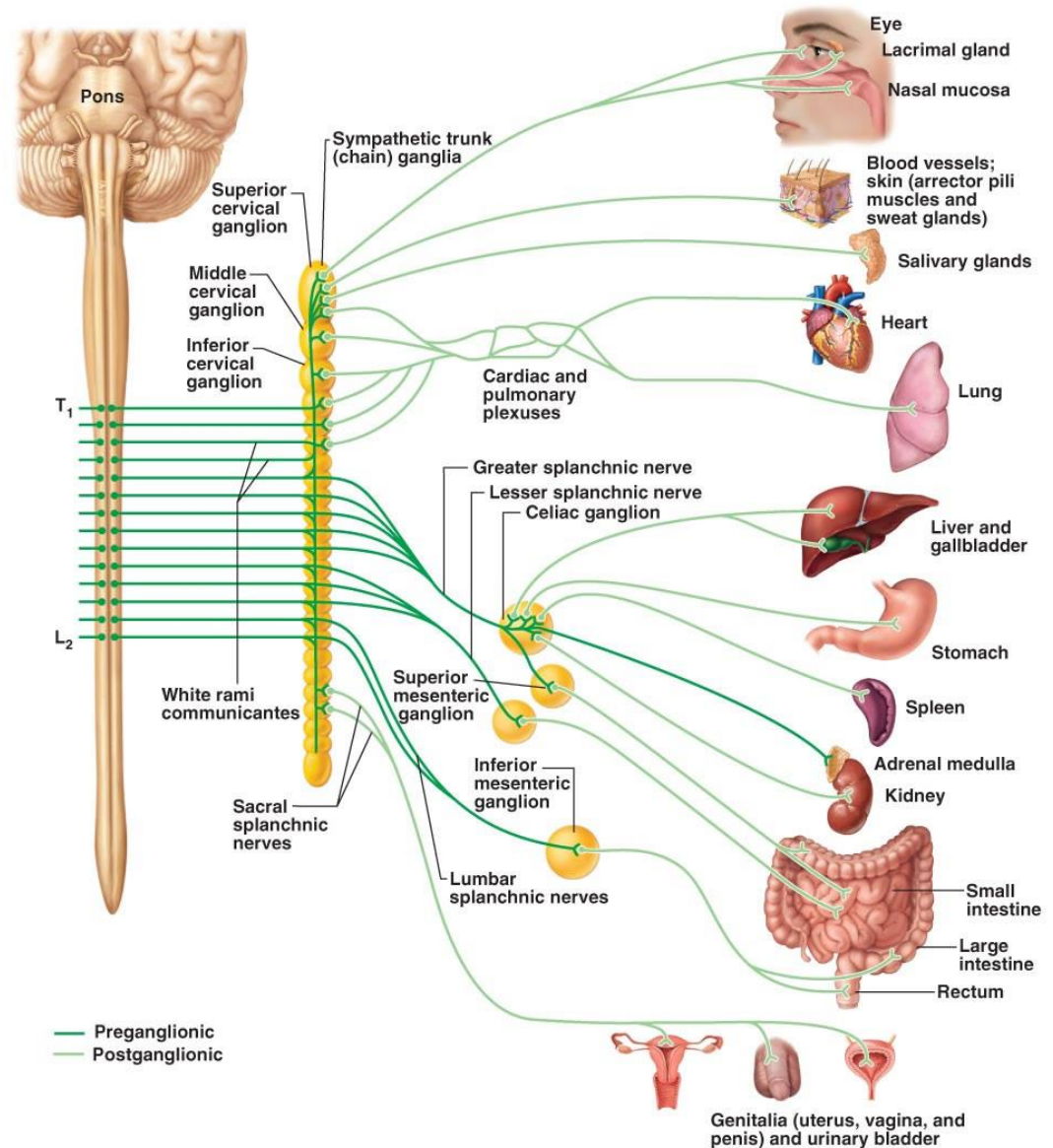
- 1) Lumbar splanchnic nerves
- 2) Sacral splanchnic nerves

Inferior hypogastric (pelvic) plexus is **formed by:**

- 1) Hypogastric nerves
- 2) Sacral splanchnic nerves

Localization of the organ – localization of the ganglia with 2nd sympathetic neuron

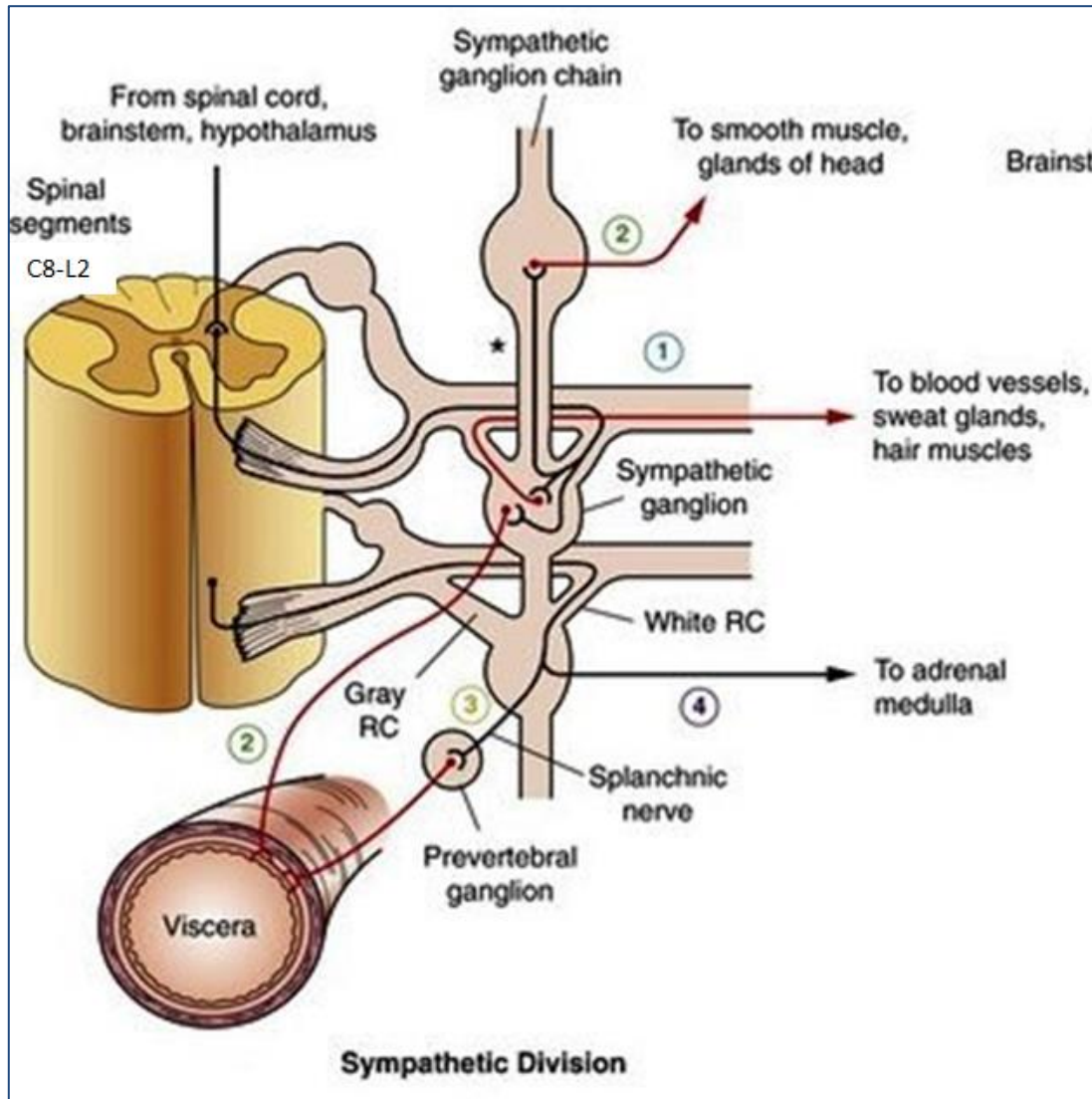
- **Organs of head and neck** – 1st and 2nd cervical ganglia of the sympathetic trunk
- **Organs of the thorax** – ganglia of the sympathetic trunk on the same level
- **Organs of abdomen and pelvis** – prevertebral ganglia
- **Plexus of the organs** – all organs



Innervation of the viscera

Organs of neck, thorax and abdomen (till descending colon)	Lower abdominal and pelvic viscera
1. Sympathetic	
2. Parasympathetic - Nervus vagus (CN X)	2. Parasympathetic - S2-S4 segments of the spinal cord
3. Sensory: 1) Spinal ganglia 2) Bulbar – superior and inferior ganglia of the nervus vagus (CN X) – no pain receptors!	3. Sensory: 1) Spinal ganglia only!!!

Sympathetic innervation of the viscera

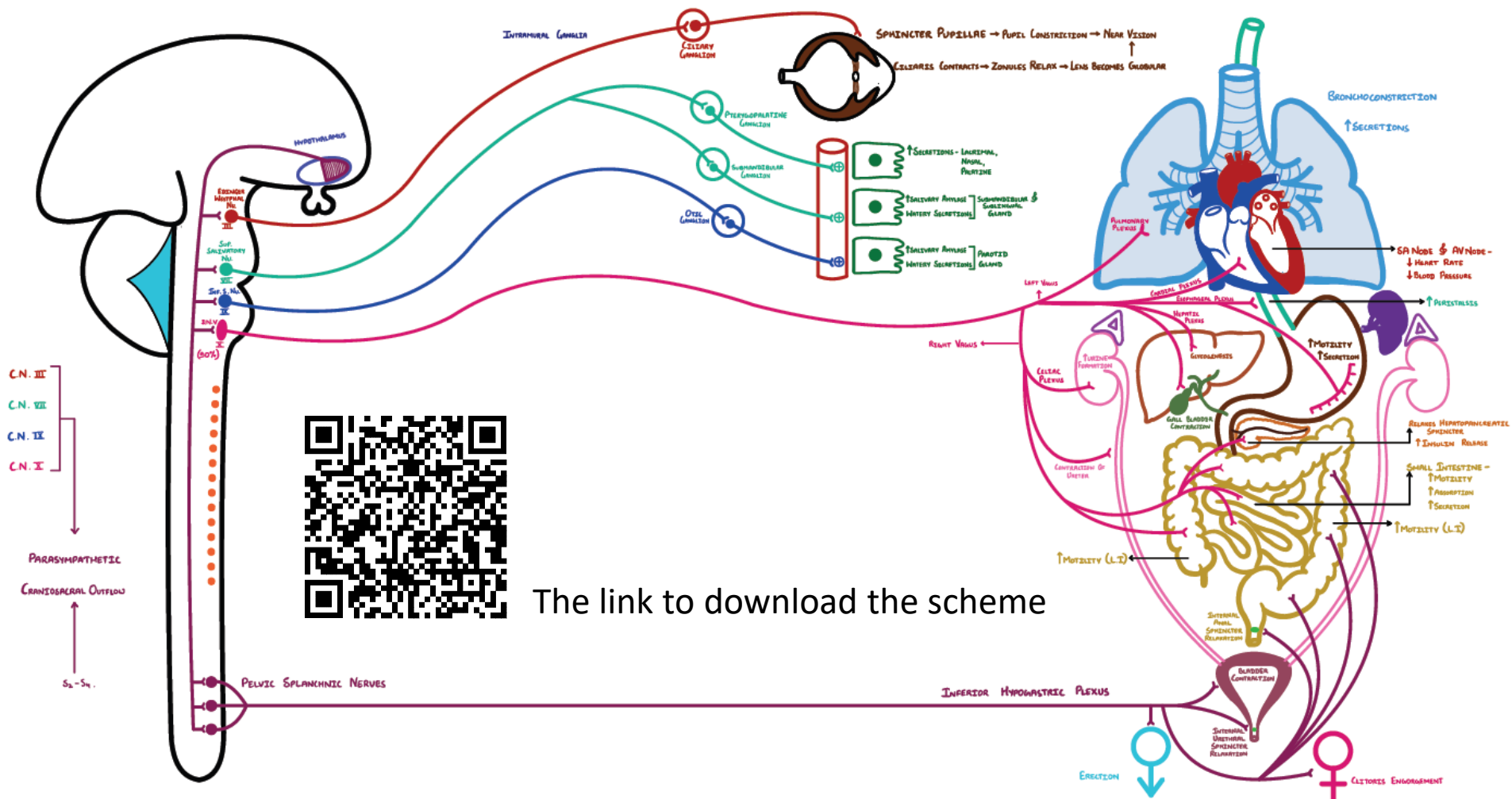


1st neuron – lateral intermediate substance of the spinal cord (C8-L2) – antero-lateral sulcus of the spinal cord – a part of the anterior rootlet - intervertebral foramen - a part of mixed spinal nerve - white rami communicantes – **2nd neuron** (pre-/paravertebral ganglia, sympathetic plexus of the organ) – postganglionic fibers form plexus along blood vessel (or gray RC – spinal nerve) - **organ**

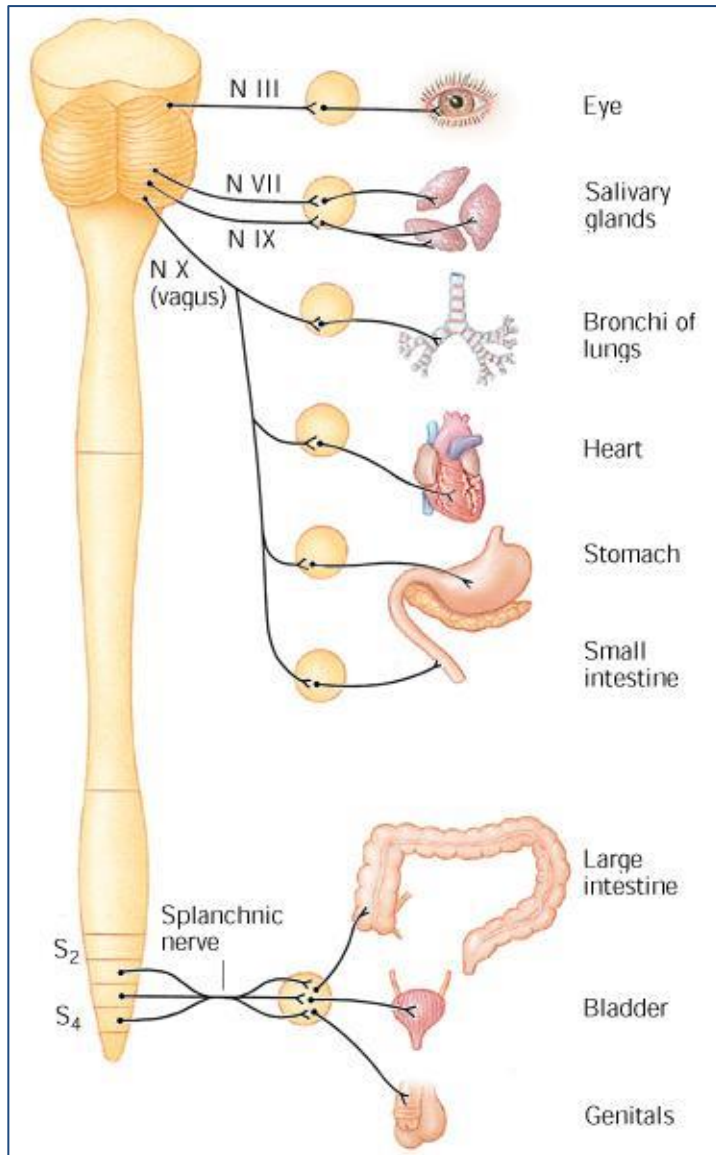
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Anatomy of the parasympathetic nervous system



Parasympathetic innervation of the viscera



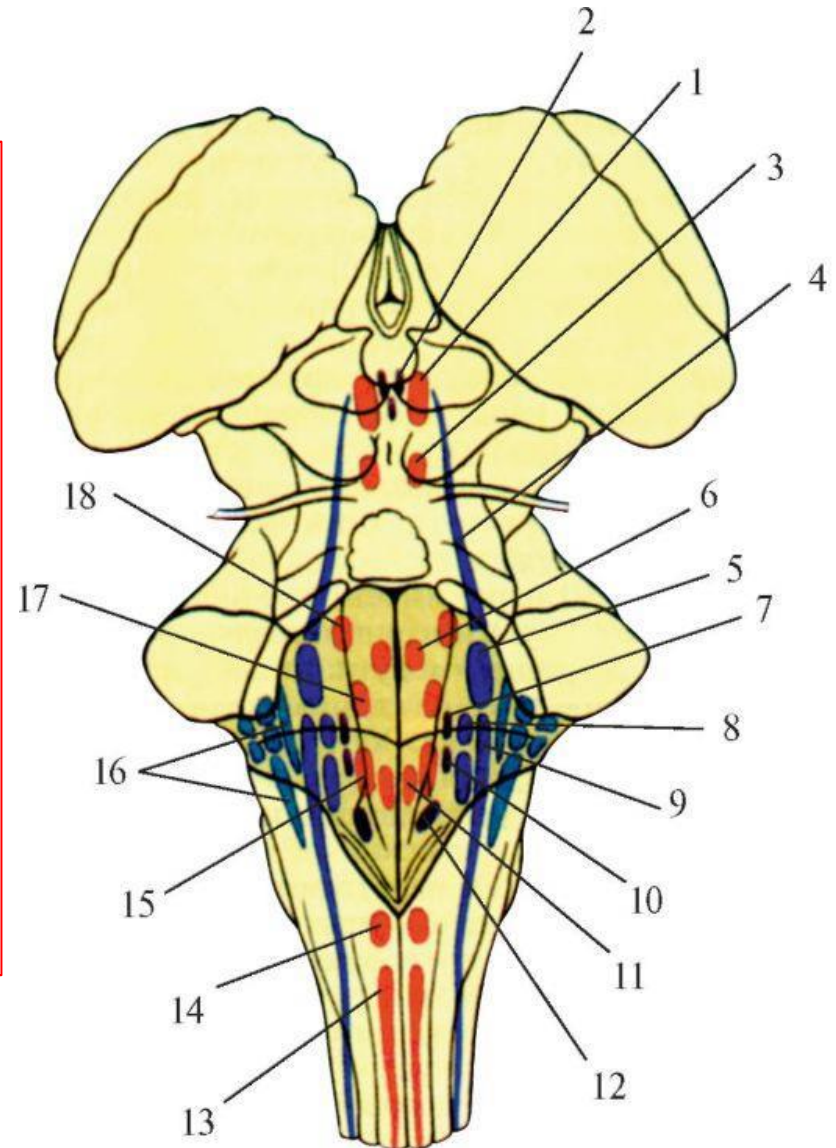
CN X – 1st neuron - dorsal nucleus of CN X in medulla oblongata
2nd neuron – Dogiel I cells in peripheral ganglia (intra-/, paraorganic, intramural)

1st neuron - parasympathetic nuclei in **S2-S4 segments of spinal cord** – axons are a part of sacral spinal nerve- through foramina sacralia anteriora – a part of anterior rami (spinal nerves) – pass through inferior hypogastric sympathetic plexus (without synapse, placed on the m.levator ani) – **2nd neuron** Dogiel I cells in ganglia (intra-/, paraorganic, intramural)

Cranial portion of the parasympathetic nervous system

- Nuclei of the cranial nerves:

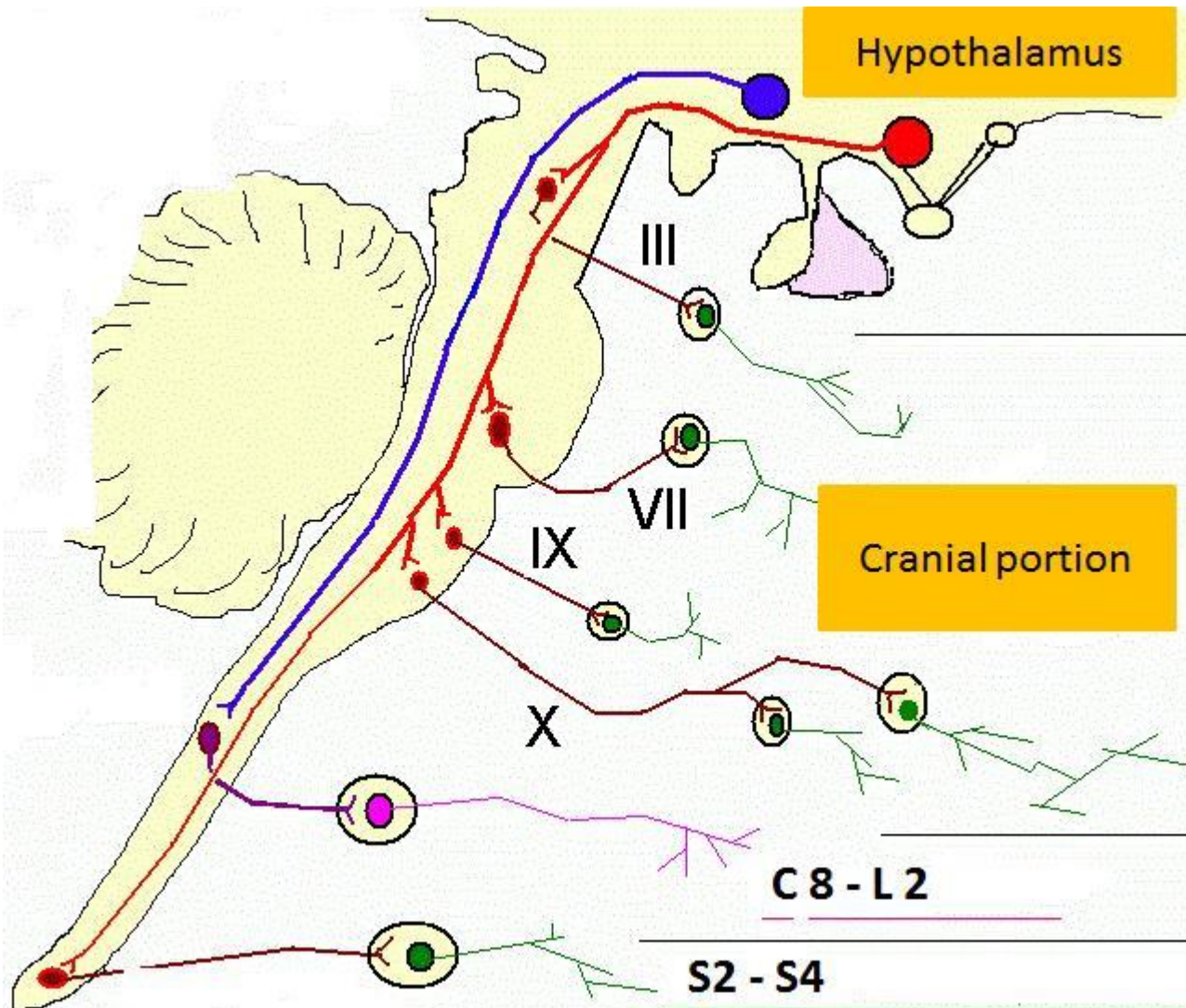
- 1) *Nucleus accessorius nervi oculomotorii* (CN III)
- 2) *Nucleus salivatorius superior* (CN VII)
- 3) *Nucleus salivatorius inferior* (CN IX)
- 4) *Nucleus dorsalis nervi vagi* (CN X)



Innervation of the viscera

Organs of neck, thorax and abdomen (till descending colon)	Lower abdominal and pelvic viscera
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All vegetative nuclei (parasympathetic and sympathetic) are connected by *fasciculus longitudinalis posterior* – vegetative innervation of the organs



Hypothalamus nuclei

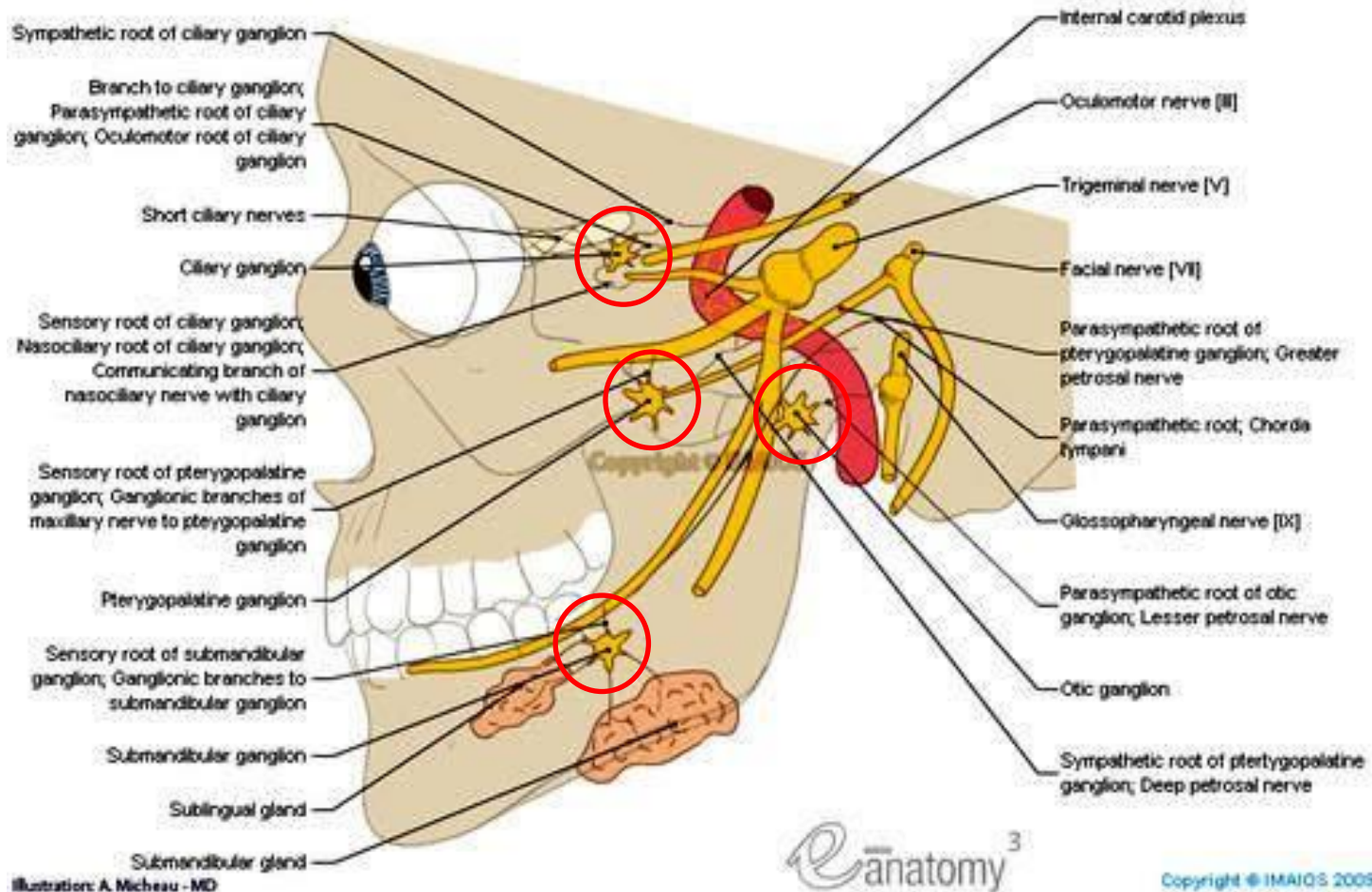


Parasympathetic
nuclei of the CN III,
VII, IX, X

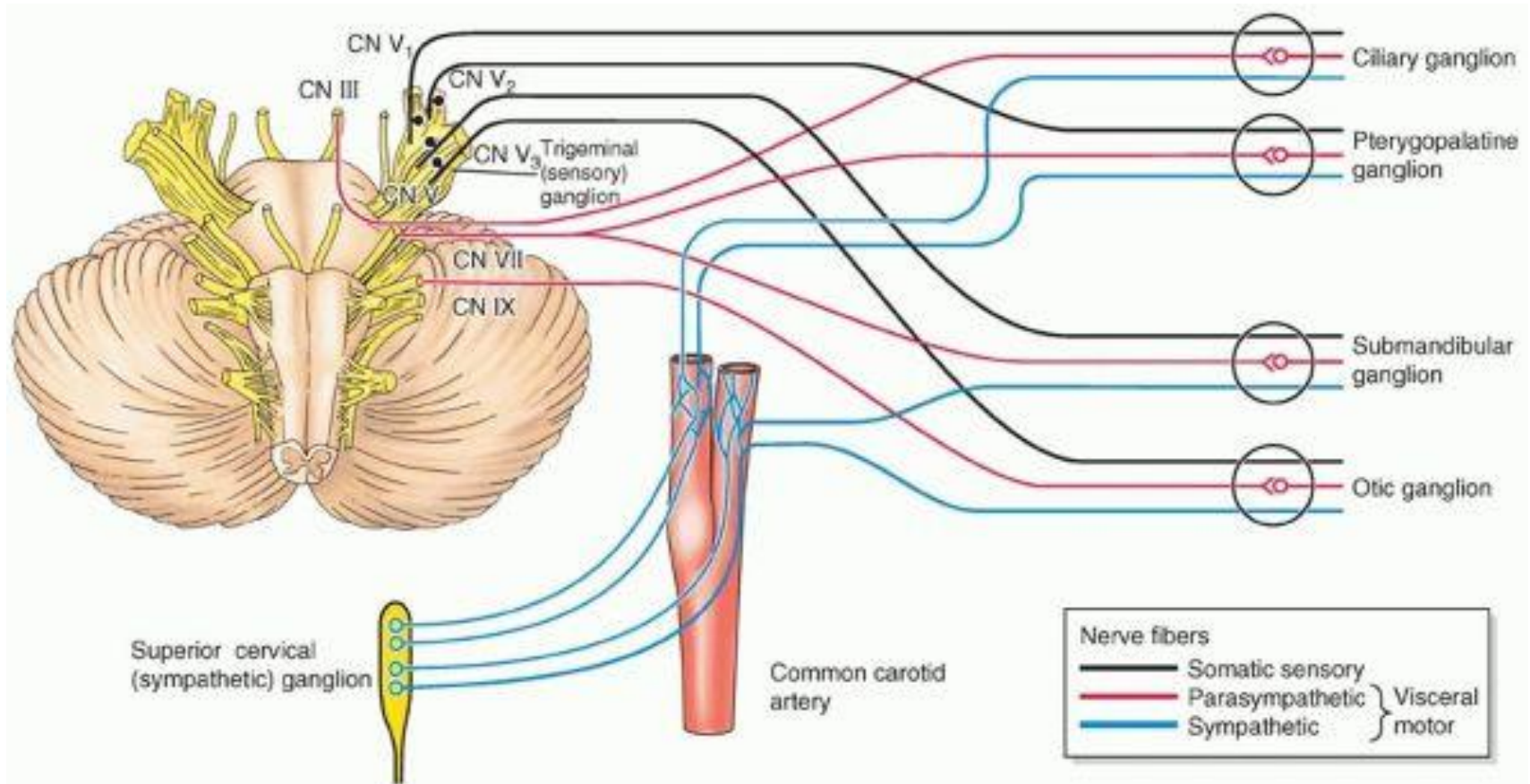


Sympathetic nuclei of
the spinal cord
(*substantia
intermedia lateralis*)

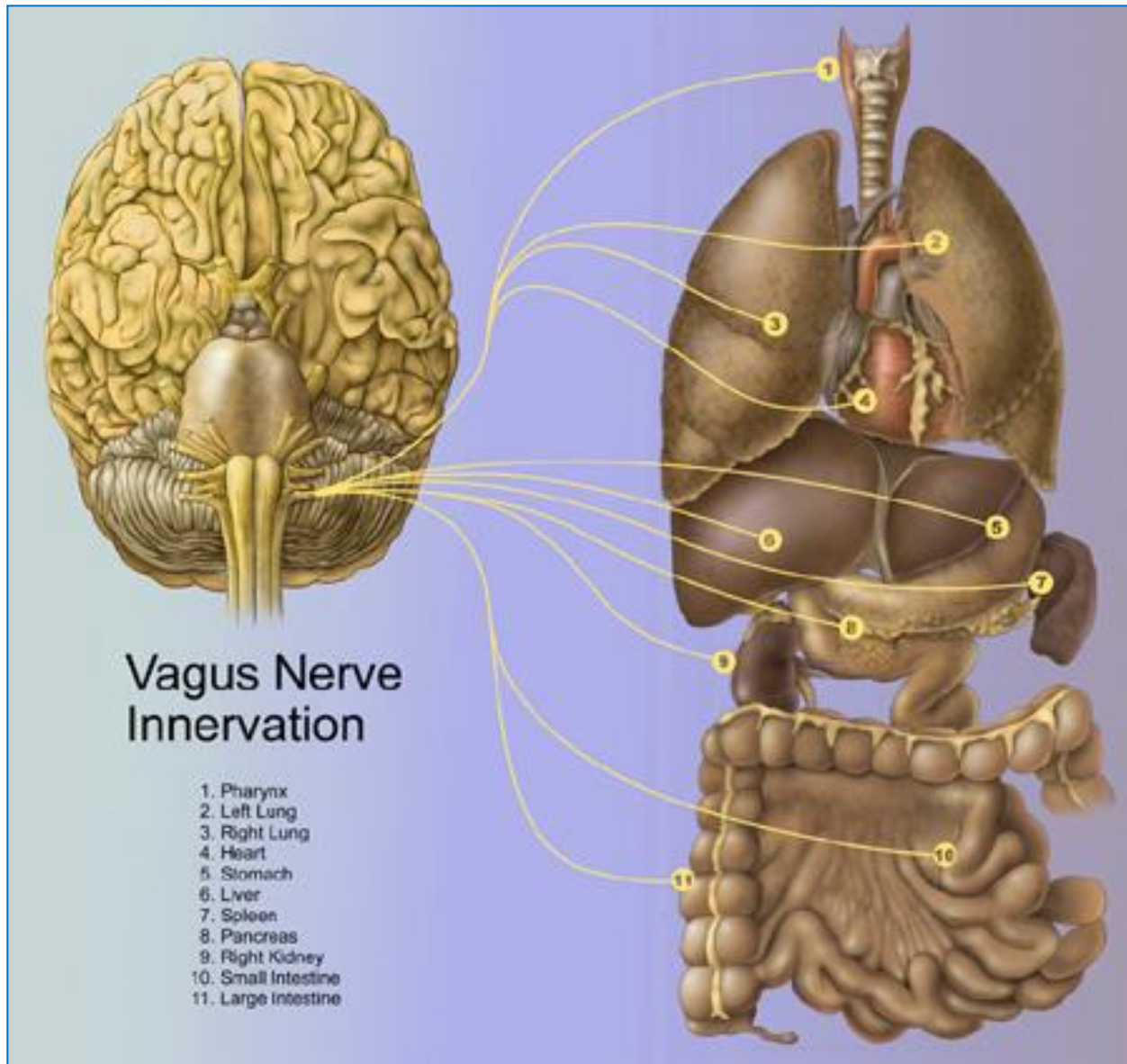
The 2nd parasympathetic neurons are in ganglia



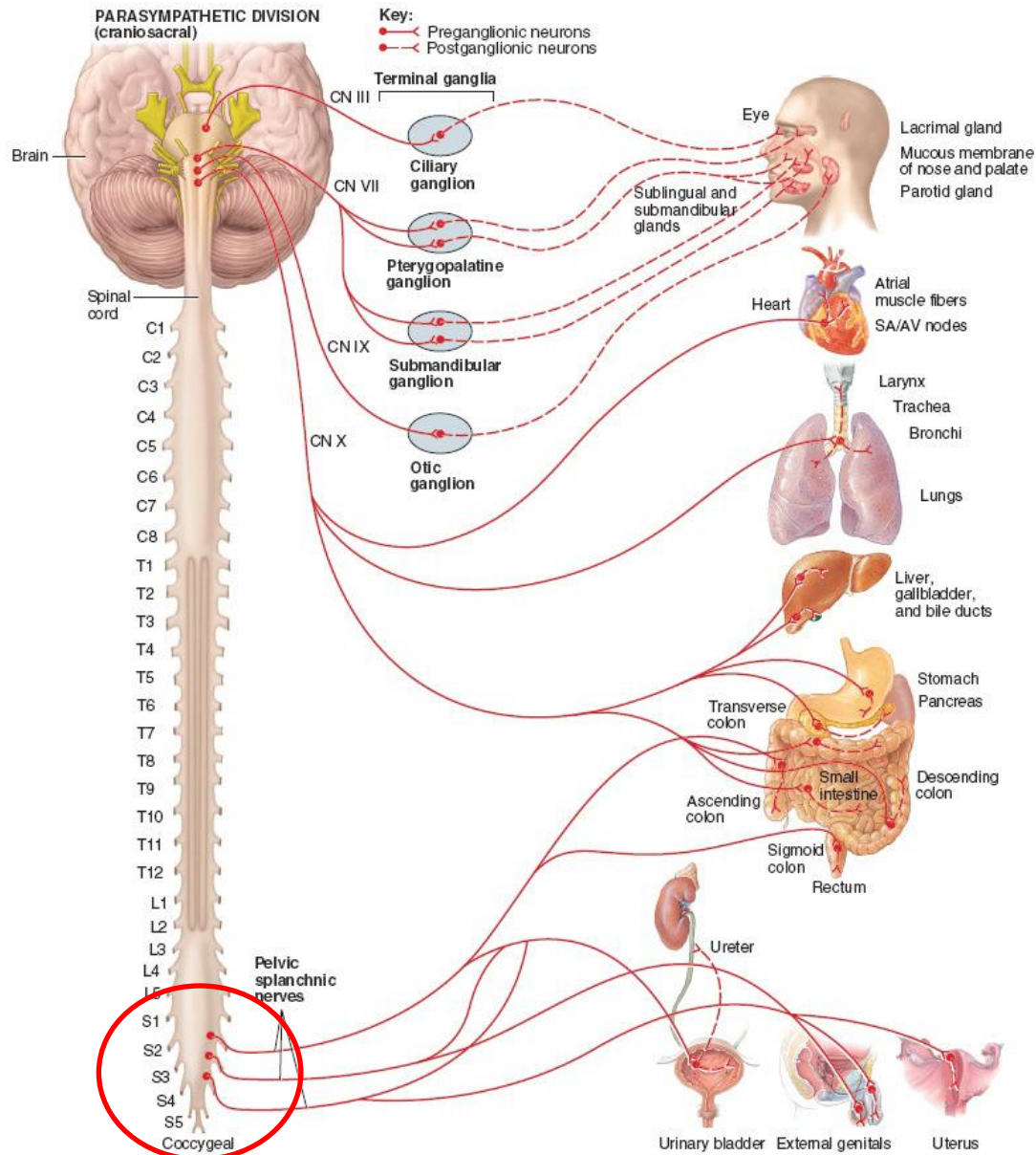
Sensory and sympathetic fibers transit through the parasympathetic ganglia without synapse



Parasympathetic innervation of the organs



Parasympathetic innervation of the organs



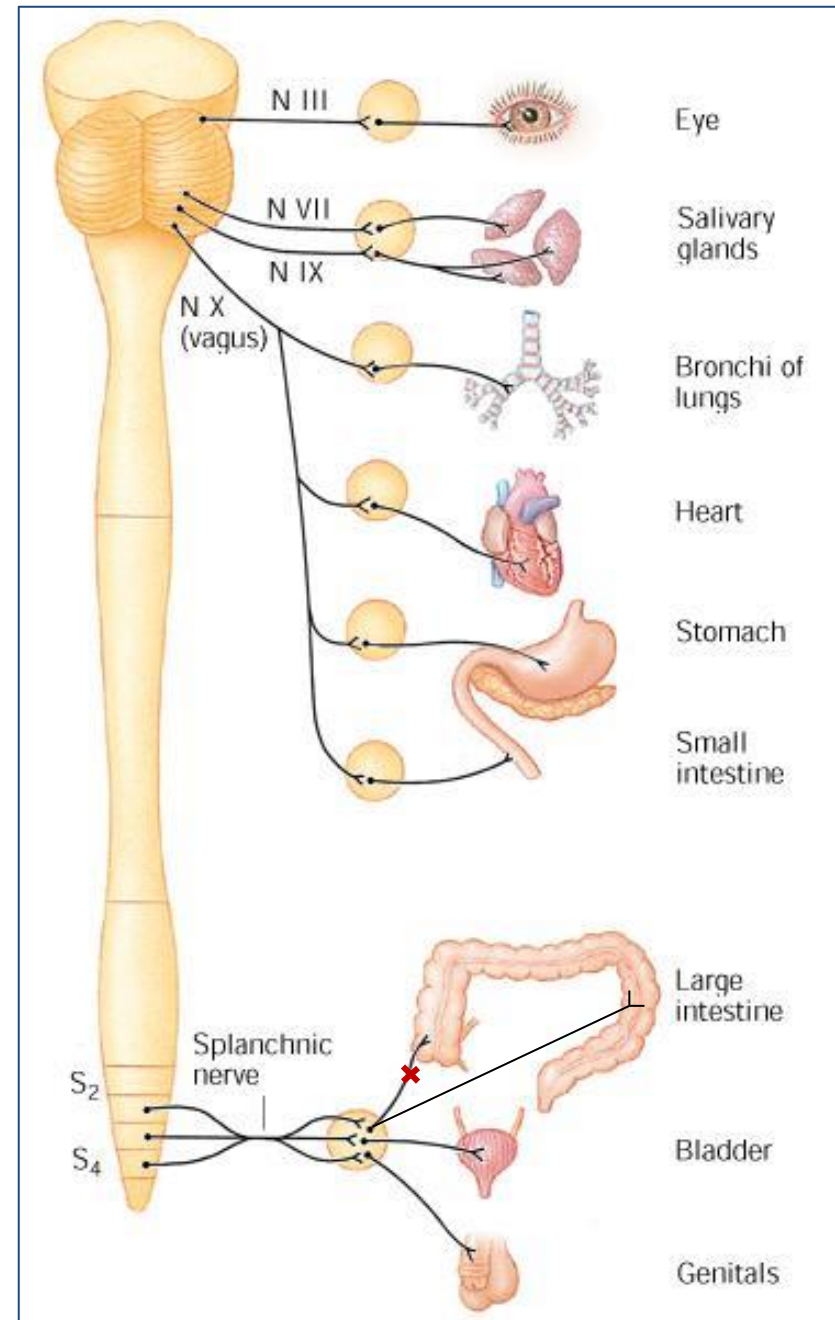
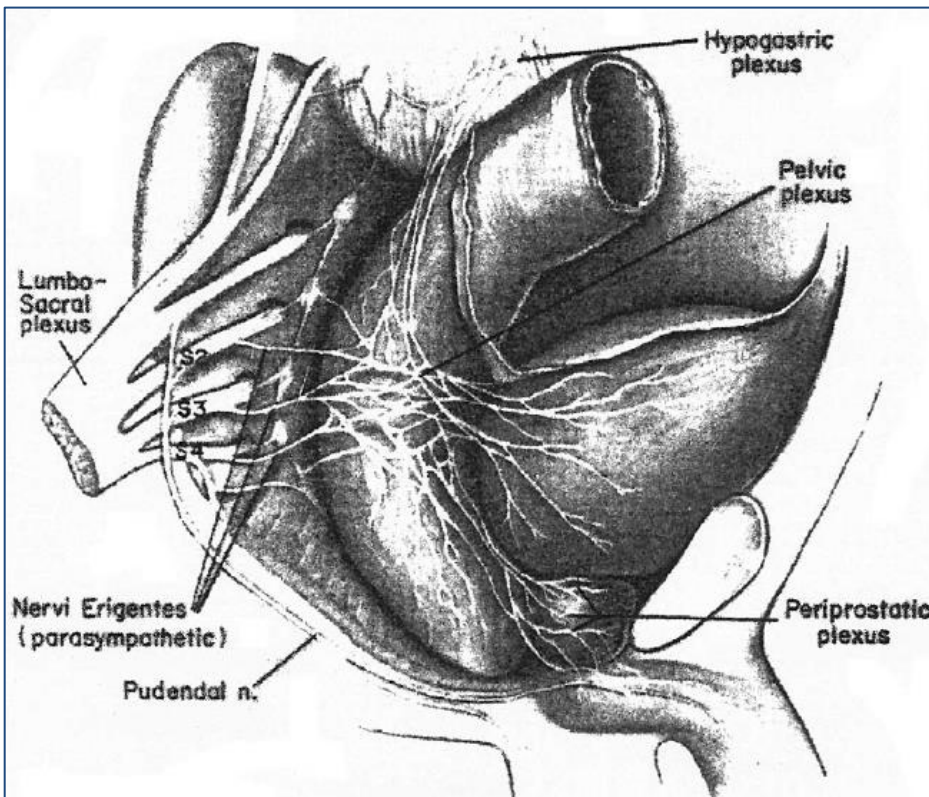
1st neuron - sacral nuclei of the spinal cord, S₂-S₄



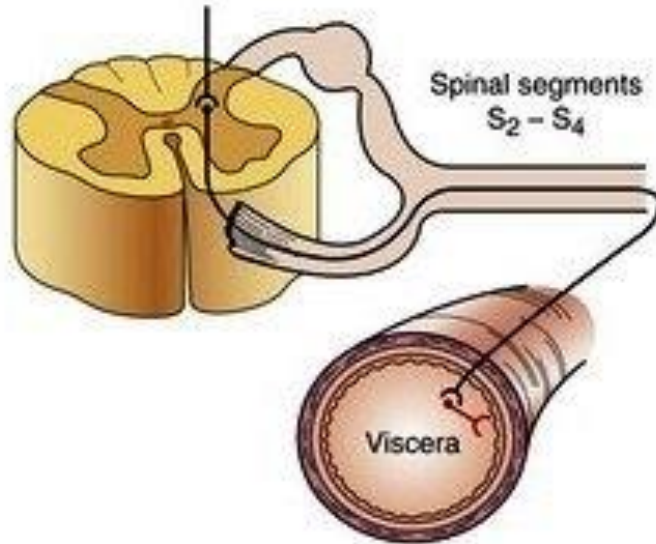
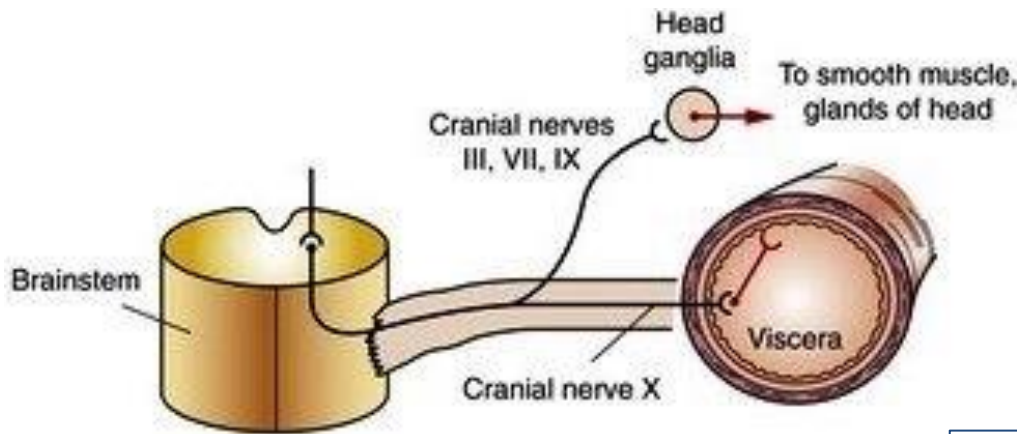
2nd neuron – intra/paraorganic parasympathetic ganglia

The sacral parasympathetic outflow is through sacral spinal levels S2 through S4 as the **nervi erigents** or **pelvic splanchnic nerves**.

- 1) The sacral spinal cord supplies innervation to lower abdominal and pelvic viscera.
- 2) It is involved with urination, defecation, and sexual function.



Parasympathetic component of the spinal nerve



Parasympathetic Division

- Long preganglionic and short postganglionic fibers
- Parasympathetic ganglia located close to the organ innervated

The **enteric nervous system** is comprised of the neural networks and plexuses of the gastrointestinal canal, which are considered a distinct division of the autonomous nervous system.

Parasympathetic fibers

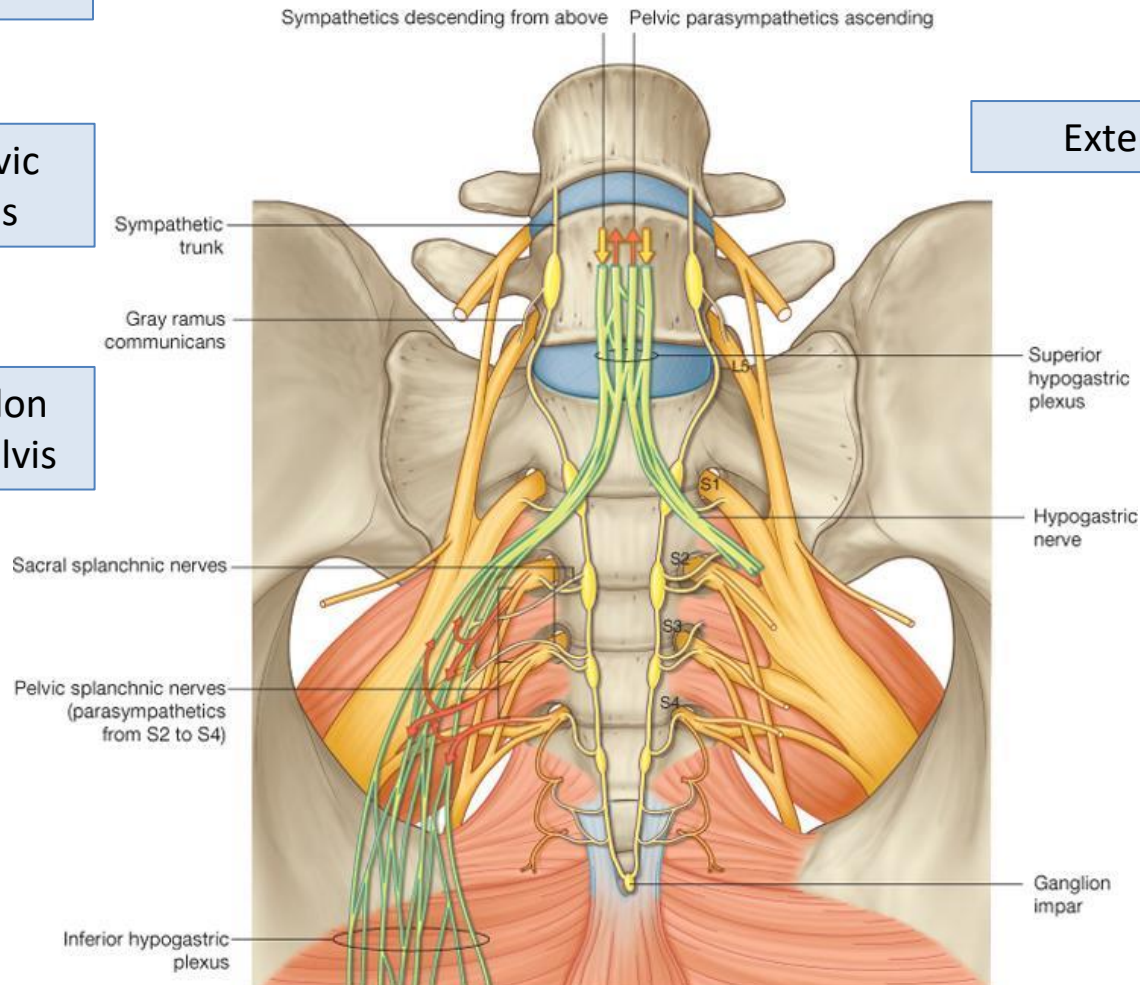
Pelvic splanchnic nerves

Transit through pelvic
sympathetic plexus

Distal part of the colon
and organs of the pelvis

Nervus pudendus

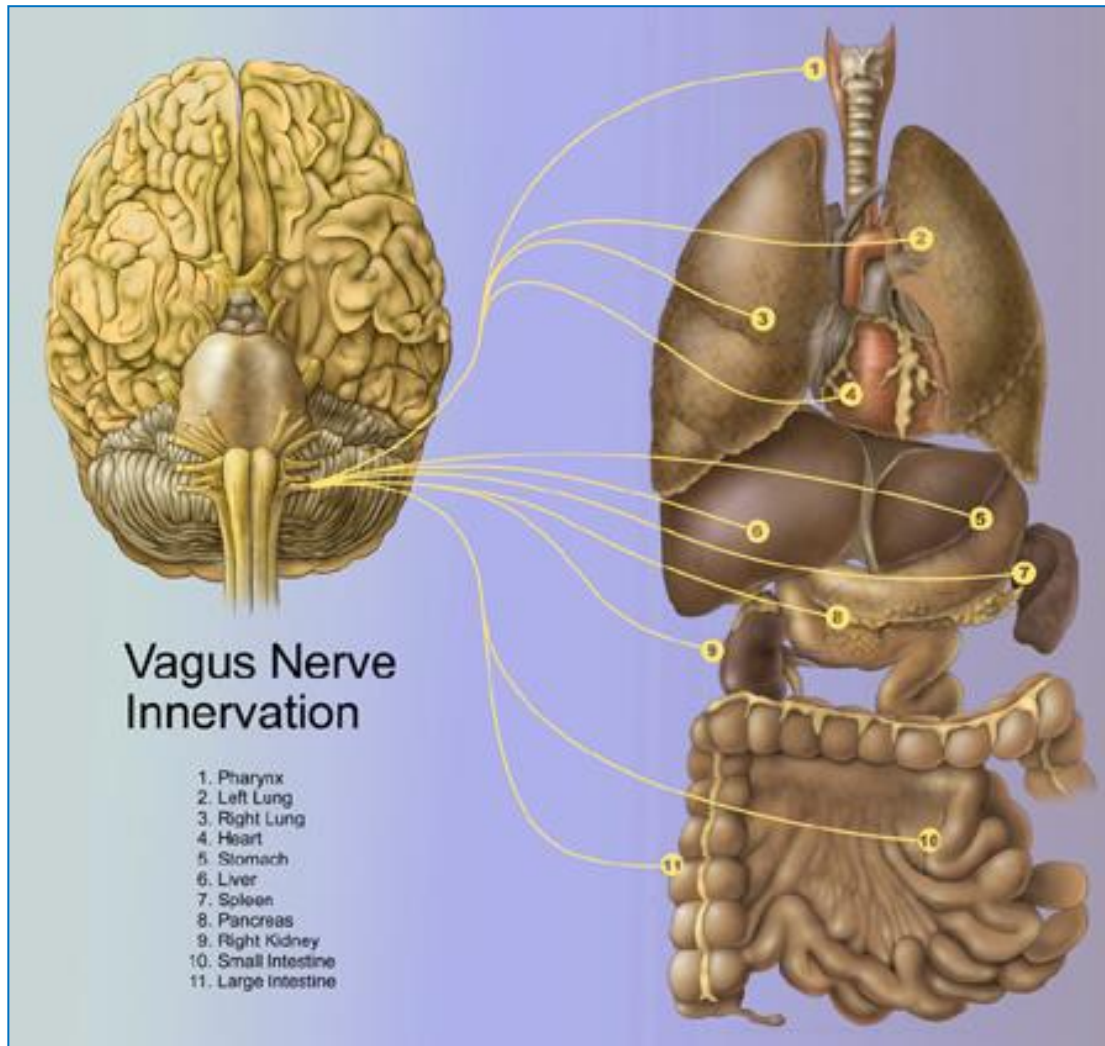
External genitalia



Innervation of the viscera

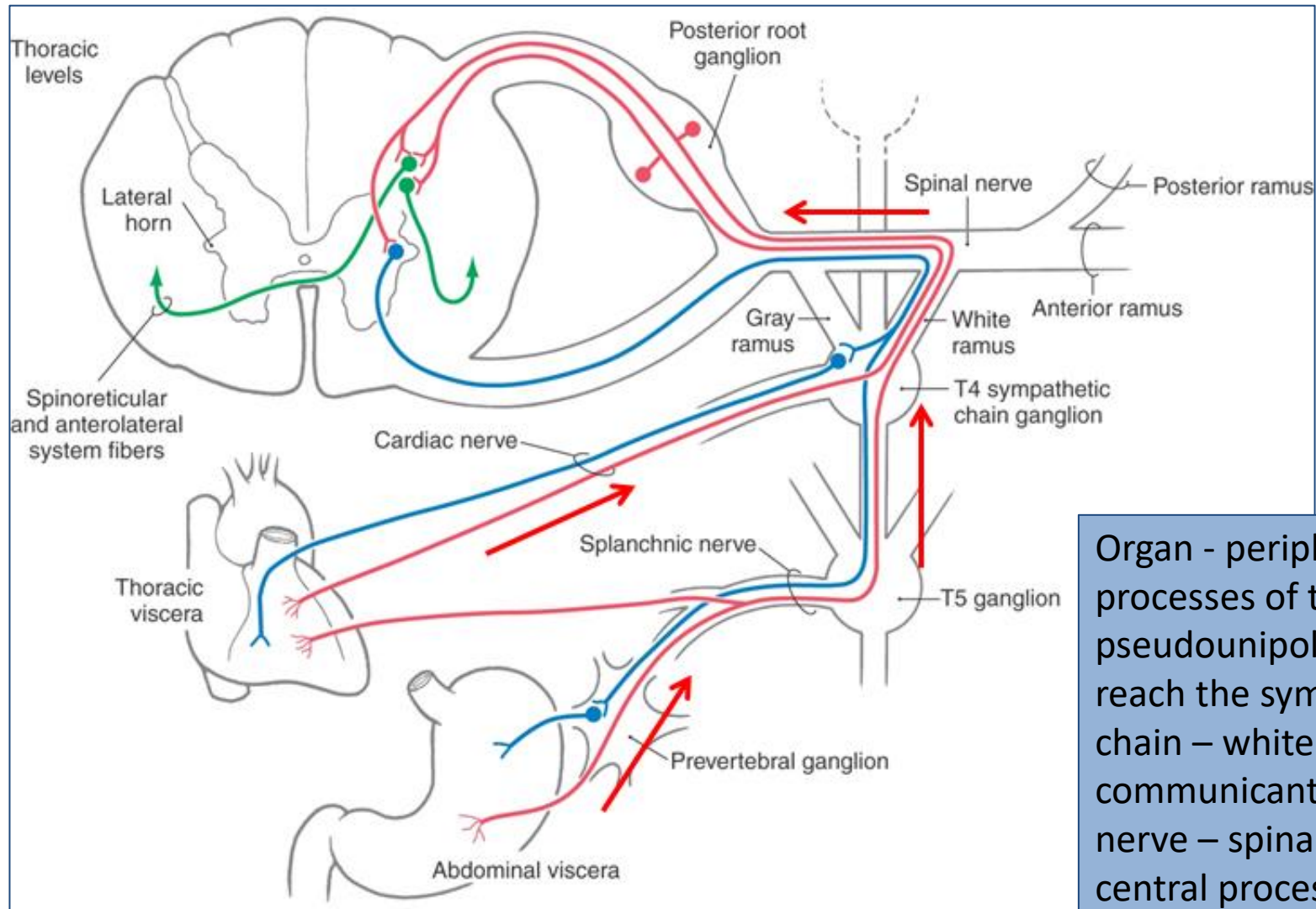
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Sensory innervation of the viscera by CN X

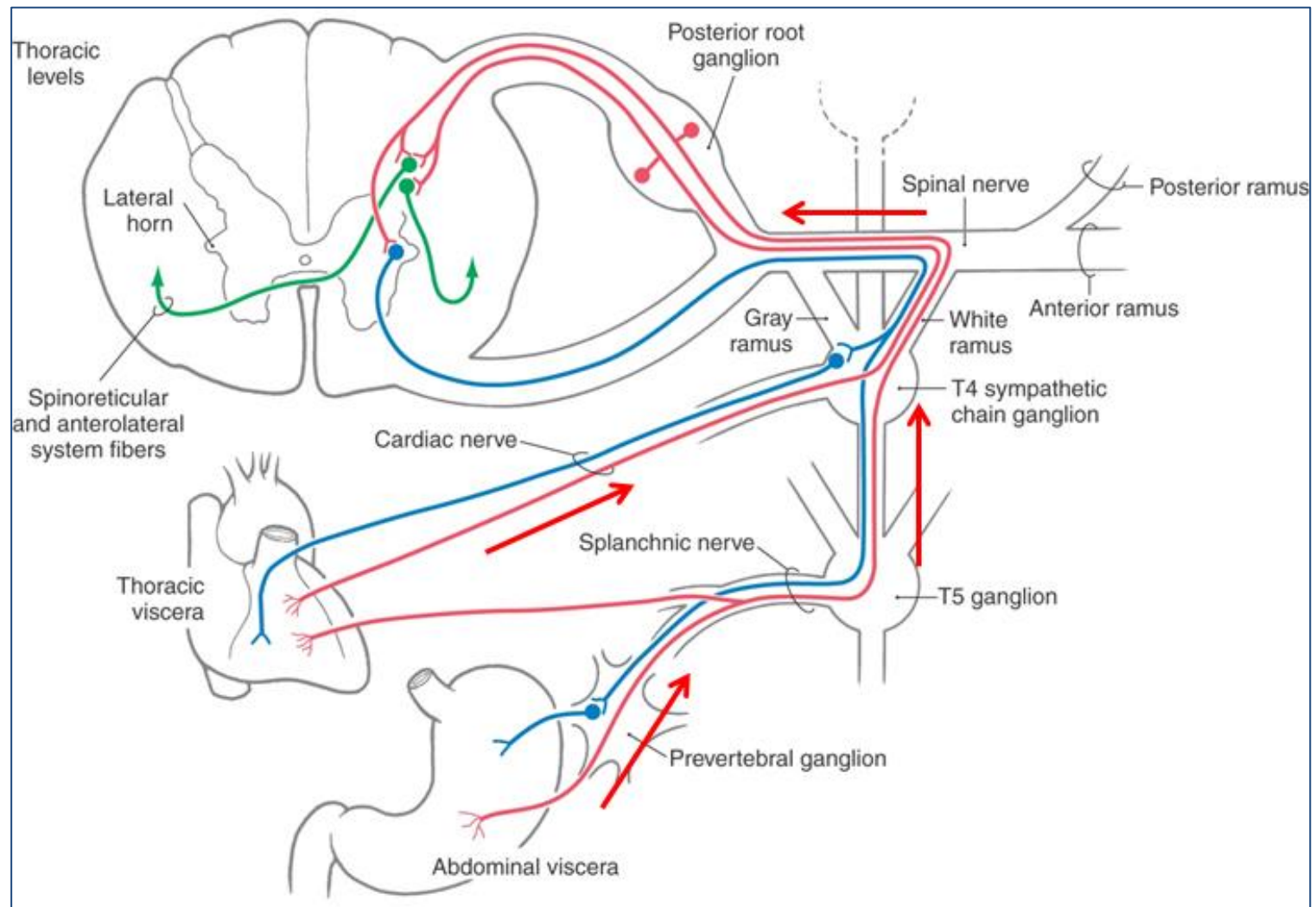


- CN X – 1st neuron** – pseudounipolar neuron in superior and inferior ganglia of the CNX:
- Peripheral process – organ
 - Central process – nucleus tractus solitarius

Visceral afferent fibers pass retrogradely along the autonomic along the autonomic pathways.

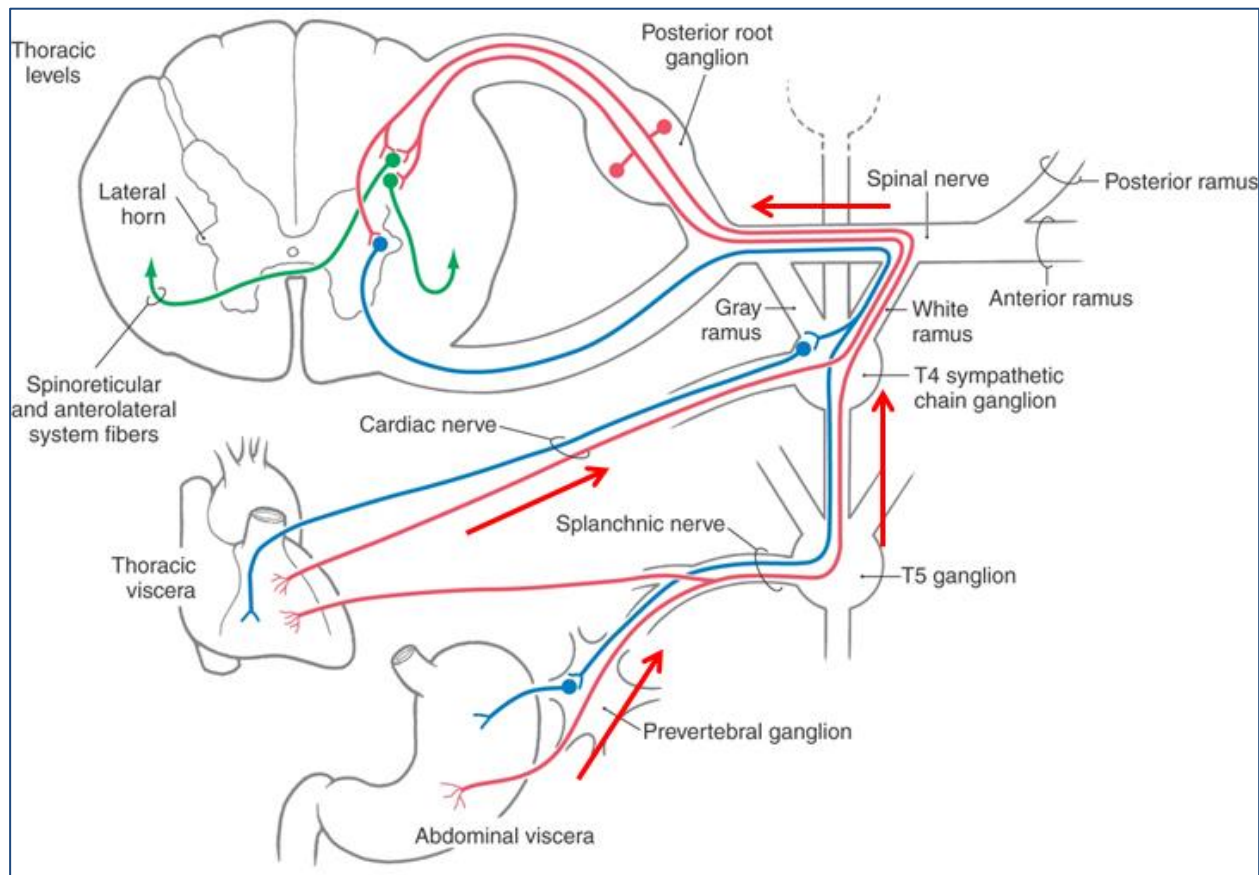


Organ - peripheral processes of the pseudounipolar neurons reach the sympathetic chain – white rami communicantes– spinal nerve – spinal ganglion – central process - CNS



a) In the cervical region

- along cervical splanchnic nerves (cardiac accelerator nerves), to reach the sympathetic chain, thence down the chain to the white rami communicantes of the upper thoracic levels to gain access to the spinal nerves and the upper thoracic levels of the spinal cord.

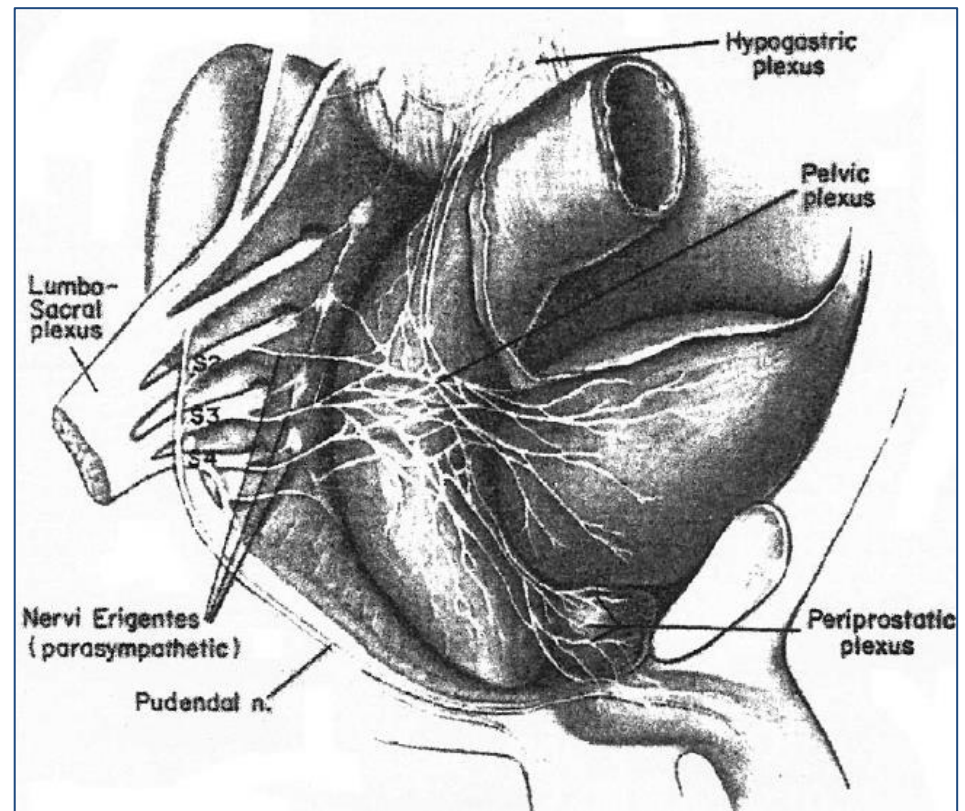
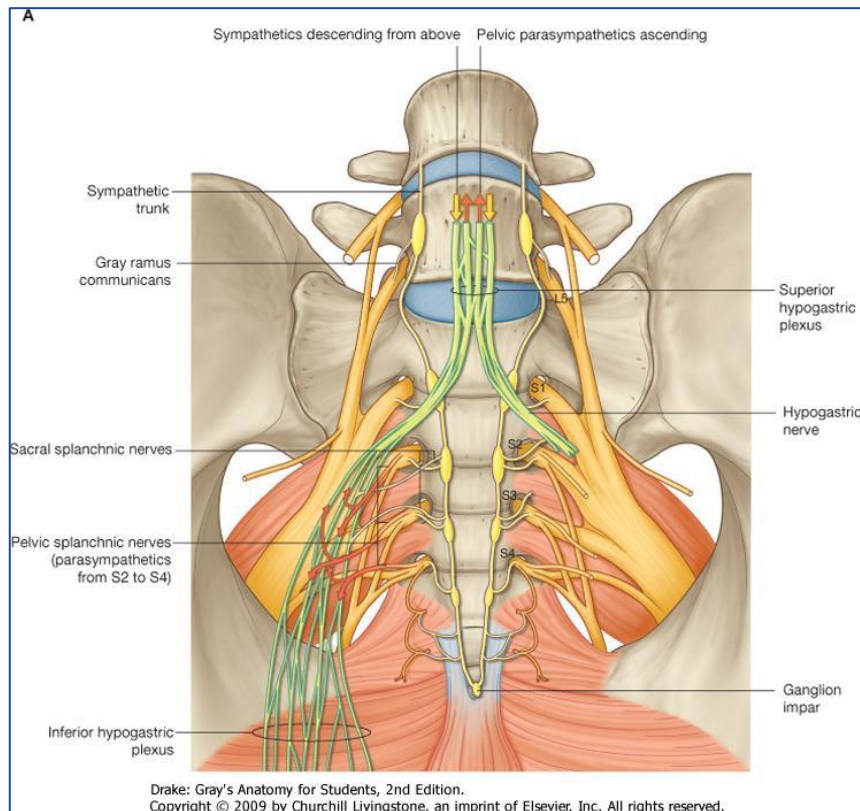


b) In the thorax and abdomen

- along splanchnic nerves to the sympathetic chain:

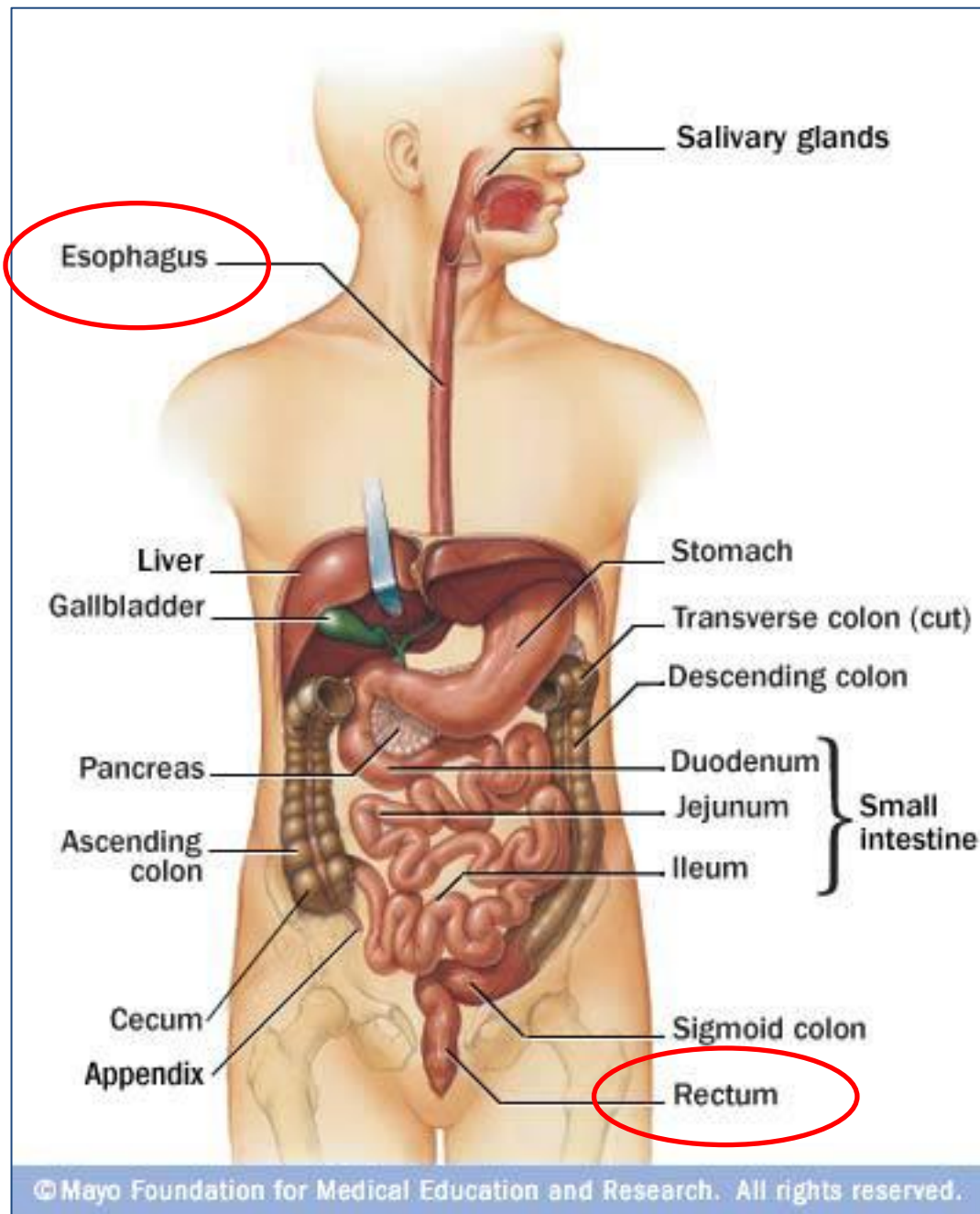
1- on reaching the sympathetic chain, the afferents pass through the white rami communicantes to gain access to a spinal nerve.

2- if there is no white ramus communicans (above C8 and below L2), the afferent course down or up the sympathetic chain until a white ramus is reached so that the spinal cord may be accessed.



c) In the pelvic region - two distinct afferent pathways:

- (1) – from upper pelvic viscera, afferent neurons travel along sympathetic pathways to the **lumbar splanchnic nerves**, thence along white rami communicantes to the lumbar spinal nerves that bring the sensory information to the upper lumbar levels of the spinal cord.
- (2) - from the lower pelvic viscera, afferent neurons travel along the parasympathetic **nervi erigentes** (pelvic splanchnic nerves) to reach midsacral (S2-S4) levels of the spinal cord.



NB!

Esophagus and rectum –
skeletal striated muscles!

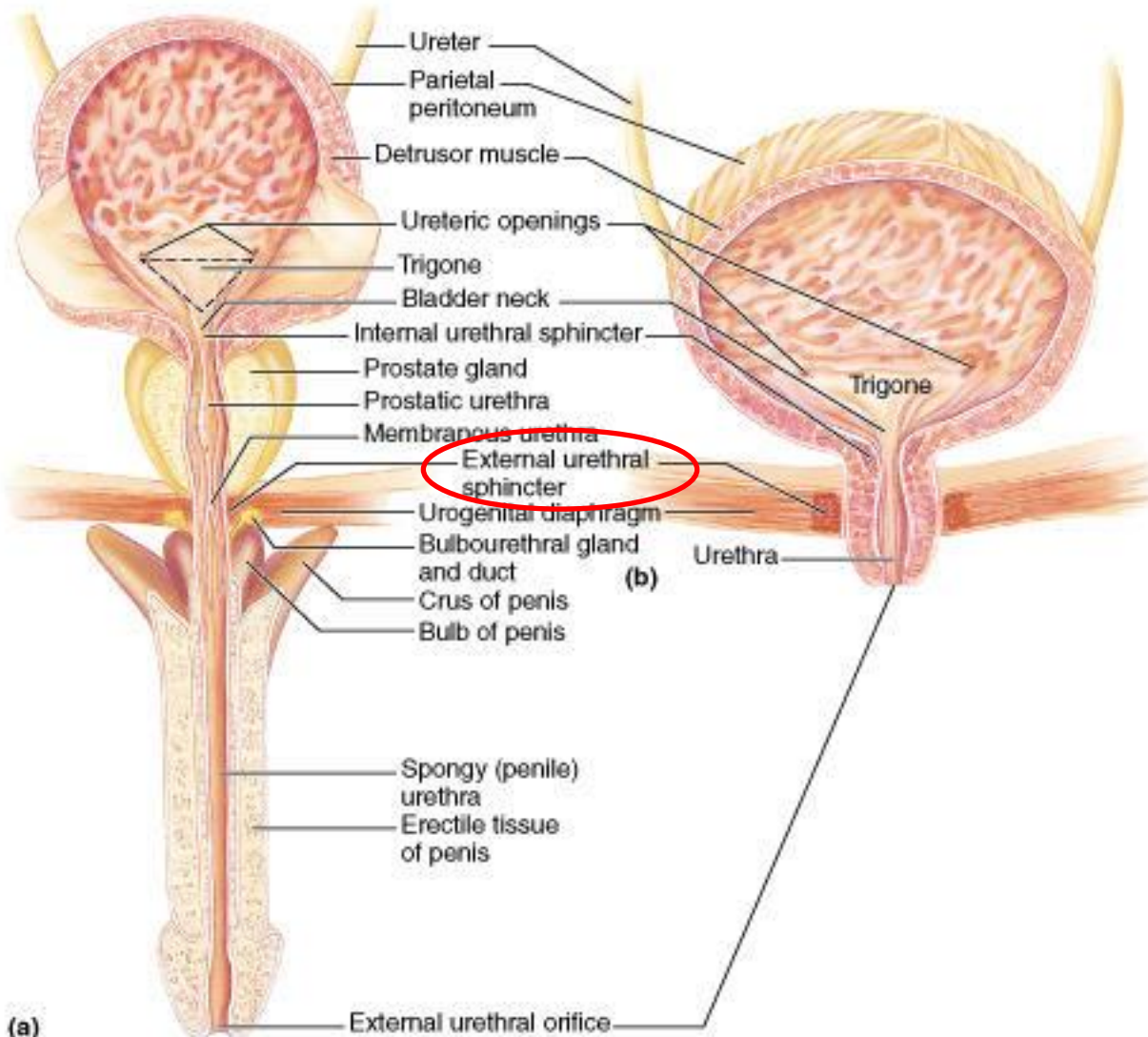
+ Somatic efferent
innervation:

- Esophagus – CN X
(n.ambiguus)
- Rectum – motor
neurons of the spinal
cord – sacral plexus –
nervus pudendus

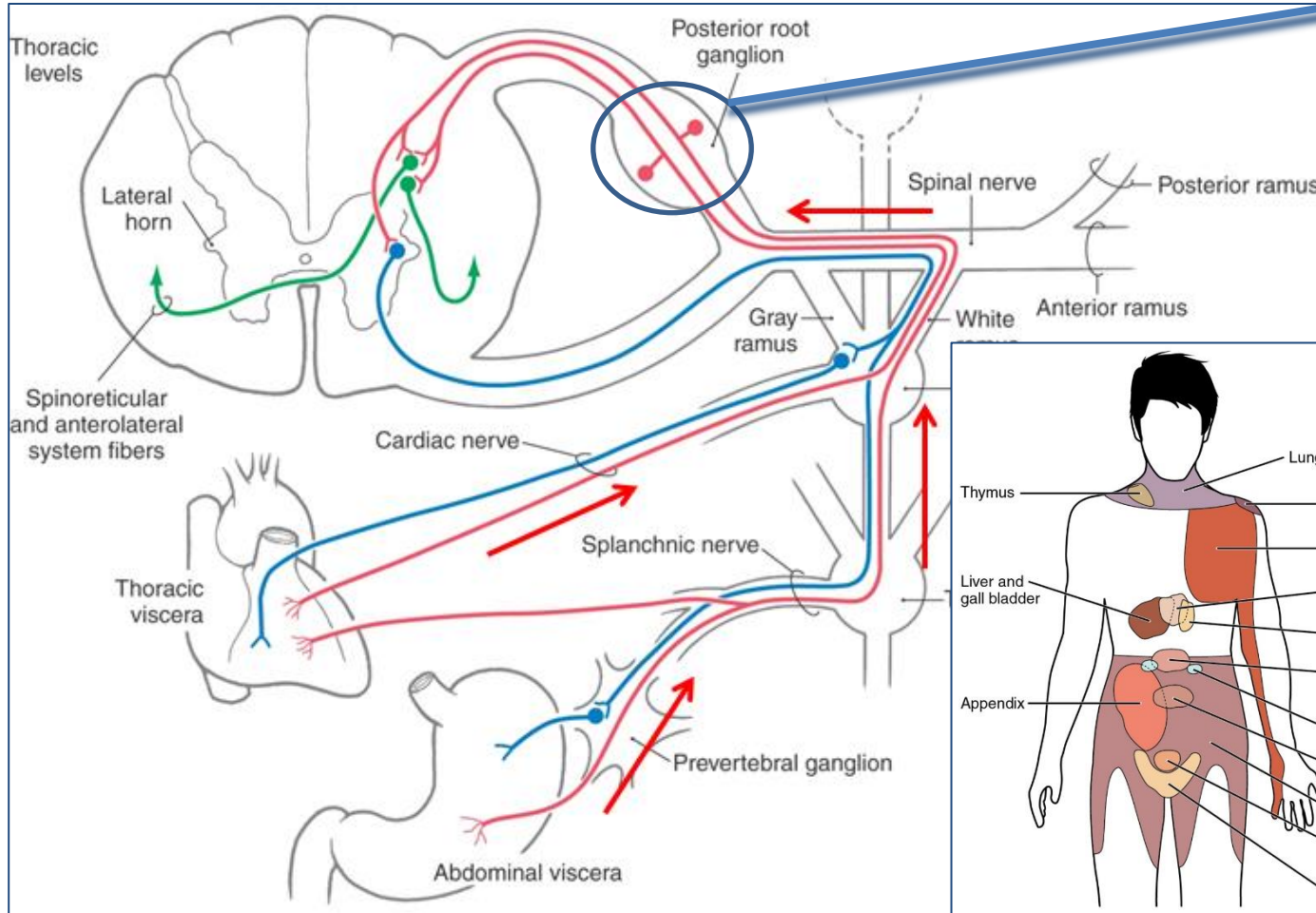
NB!

External urethral sphincter – **skeletal muscle**

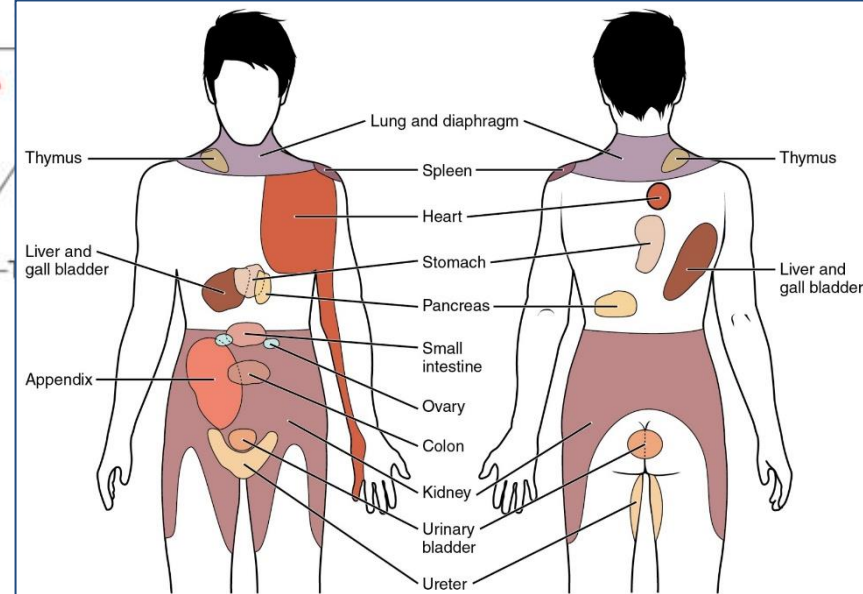
+ Somatic efferent innervation:
- motor neurons of the spinal cord – sacral plexus – nervus pudendus



Referred pain



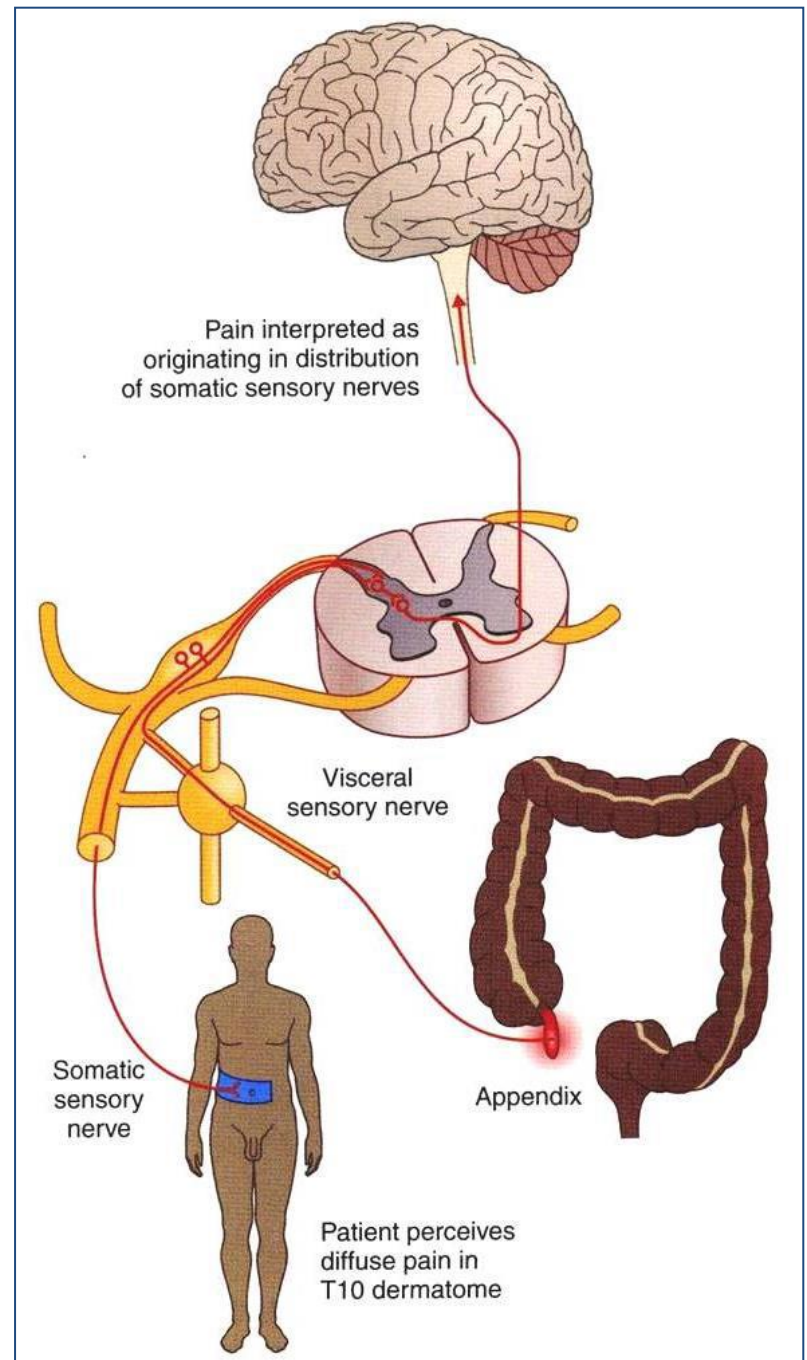
Somatic and visceral afferent pseudounipolar neurons are in the same dorsal root ganglia



The visceral afferent pathways provide the anatomic basis for **referred pain**, whereby sensation from a visceral structure appears as if it originates from the somatic dermatome associated with the spinal level at which the visceral afferents enter the spinal cord.

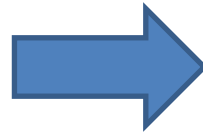
Reflexes:

1. Viscero-visceral
2. Viscero-somatic
3. Somato-visceral



Viscero-somatic reflexes

Irritation of chemoreceptors of carotid sinus by high levels of CO₂



Contraction of intercostal muscles and increase of breathing rate

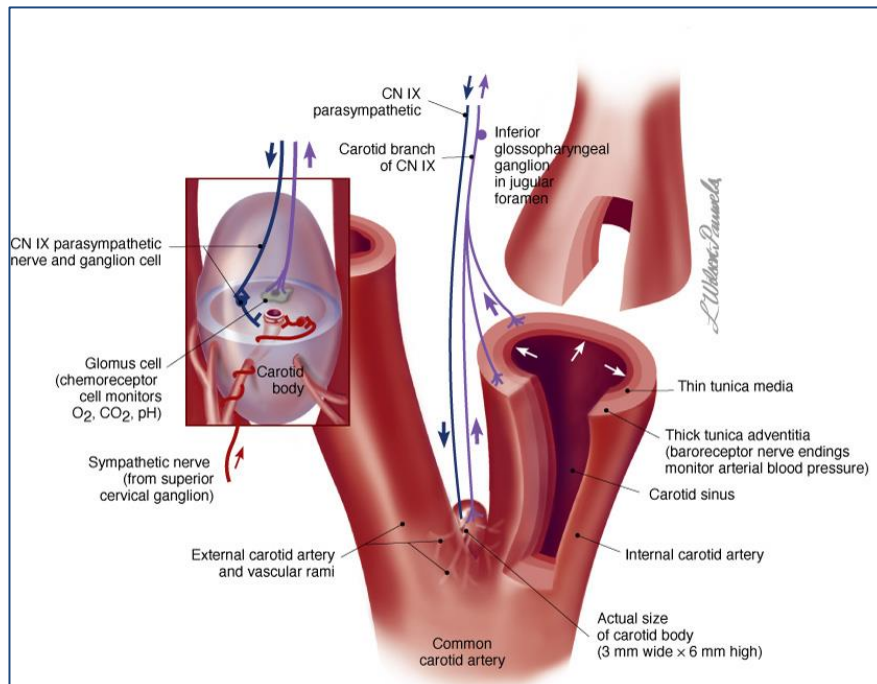
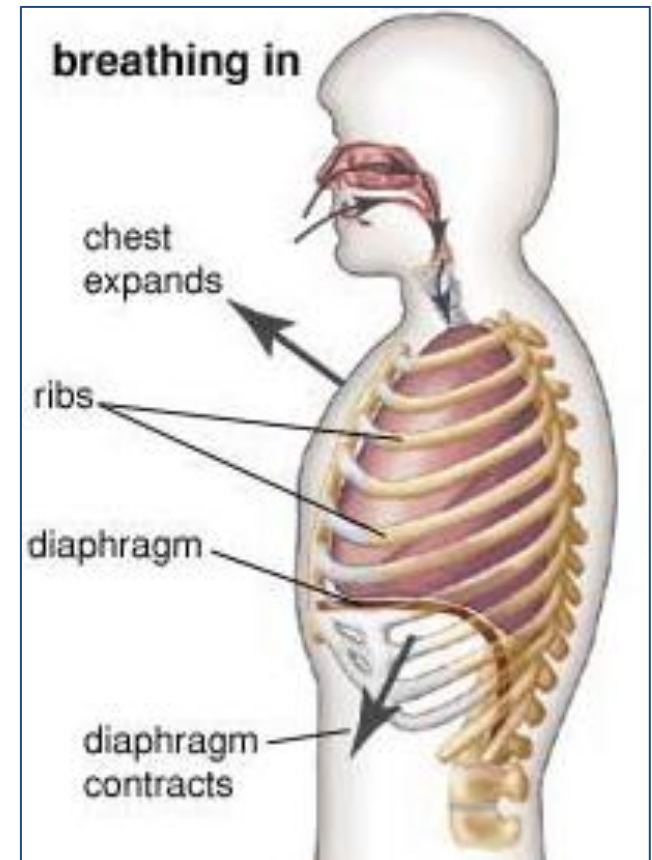


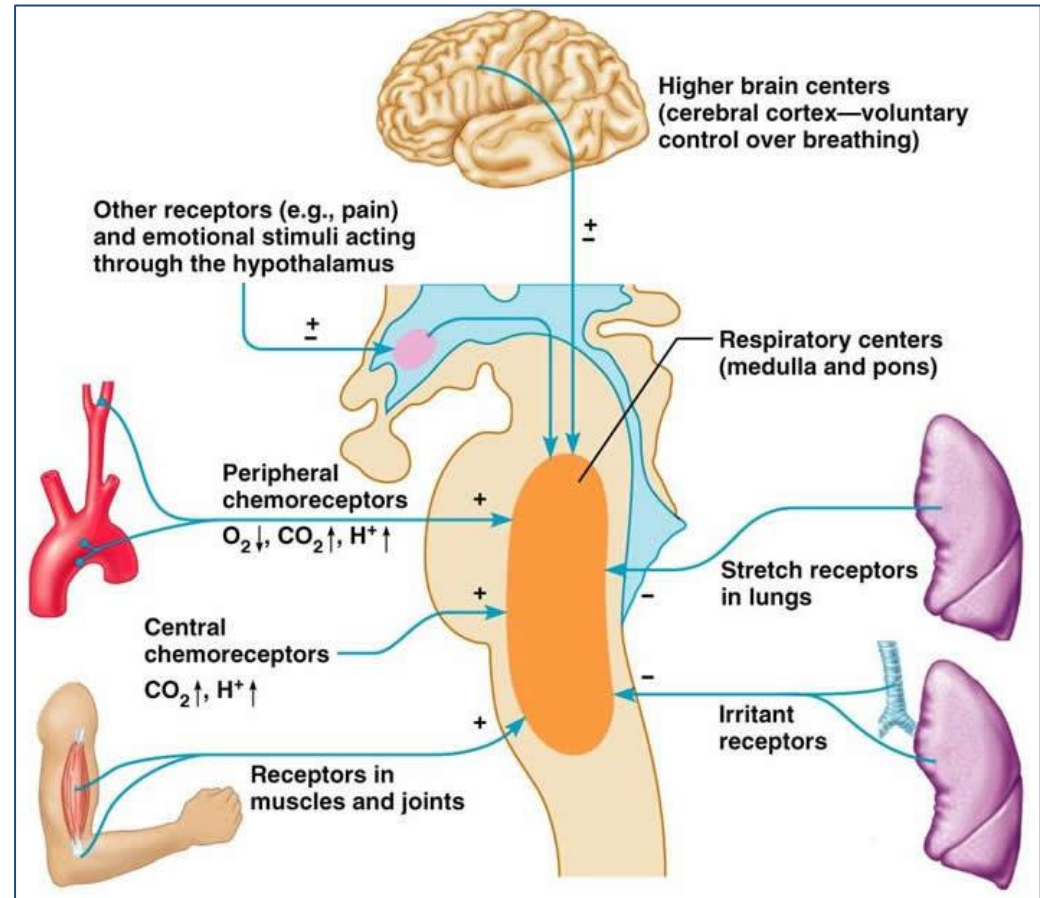
Figure IX-6 The bifurcation of the common carotid artery demonstrating baroreceptors in the wall of the carotid sinus and chemoreceptors within the carotid body.

From "Cranial Nerves in Health and Disease" 2002, © Wilson-Pauwels, Akesson, Stewart, Spacey, B C Decker Inc.



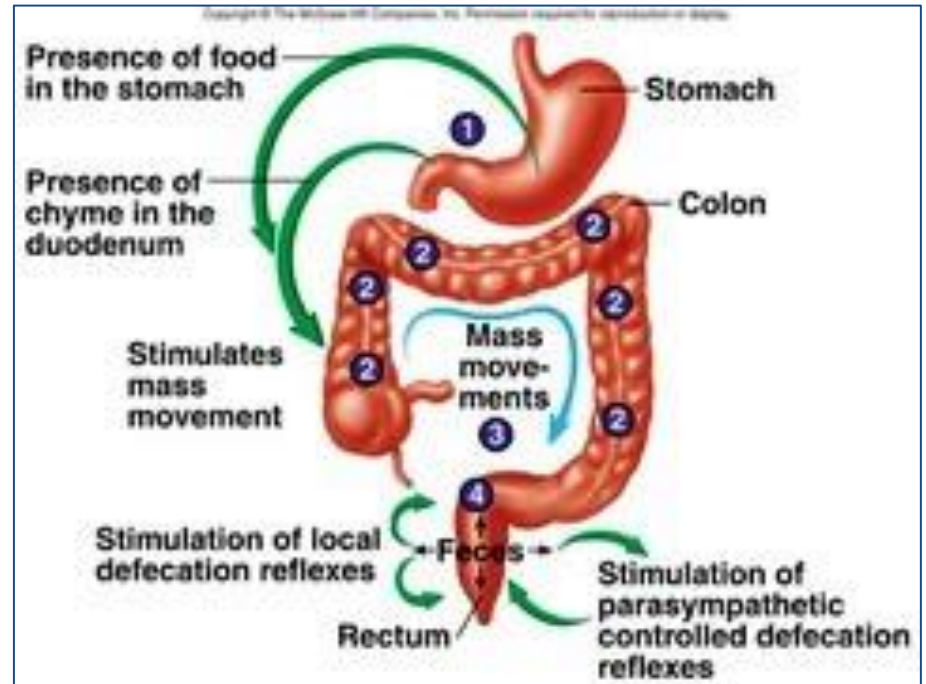
Viscero-visceral reflexes (Hering-Breuer Reflex)

- Limits the degree of inspiration and **prevents overinflation** of the lungs
- Depends of **stretch-receptors** in the walls of bronchi and bronchioles of the lung
- **Inhibitory influence** on the respiratory center and results in expiration (expiration – stretch-receptors no longer stimulated)
- **Infants** – role in regulation basic rhythm of breathing and preventing overinflation of lungs
- **Adults** – when tidal volume large as in exercise



Viscero-visceral reflexes

- **Gastroileal reflex:**
 - Increased gastric activity – increased motility of ileum and movement of chyme.
 - Movement through ileocecal sphincter.
- **Ileogastric reflex:**
 - Distention of ileum – decreased gastric motility
- **Intestino-intestinal reflex:**
 - Overdistention in 1 segment – relaxation of rest of intestine



Somato-visceral reflexes

Somatic afferent nerves
irritation



Vegetative reflex

High-temperature irritation of
the skin



Dilatation of skin vessels and
constriction of vessels
of abdominal viscera



Somato-visceral reflexes

Irritation of skin afferent
somatic receptors



Changes in blood supply of
corresponding organs



Somato-visceral reflexes

Aschner-Dagnini reflex (more in infants)

Somatic afferent nerves
irritation

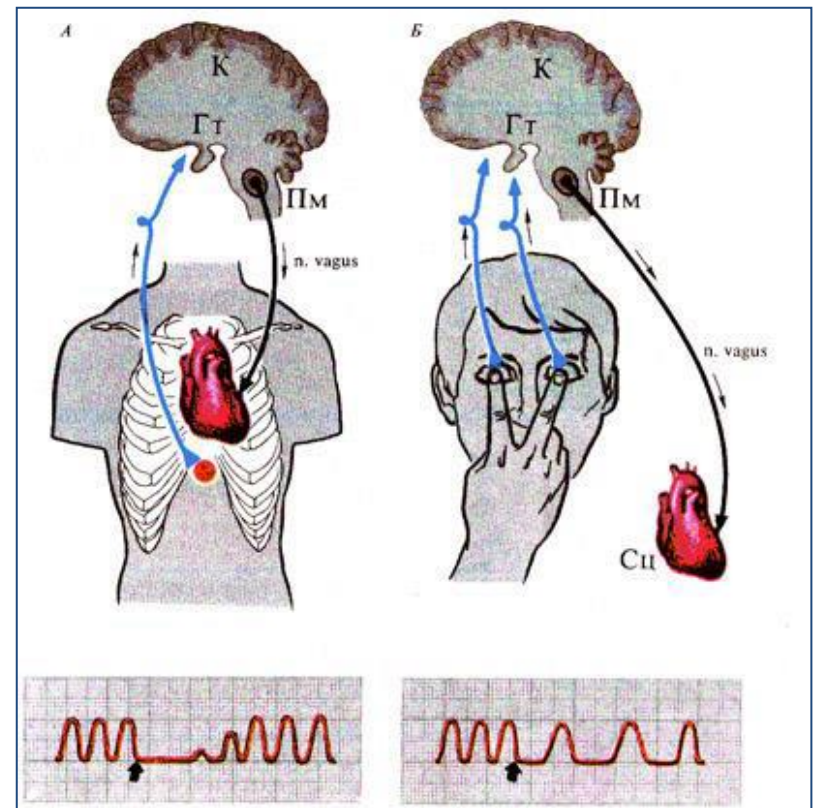
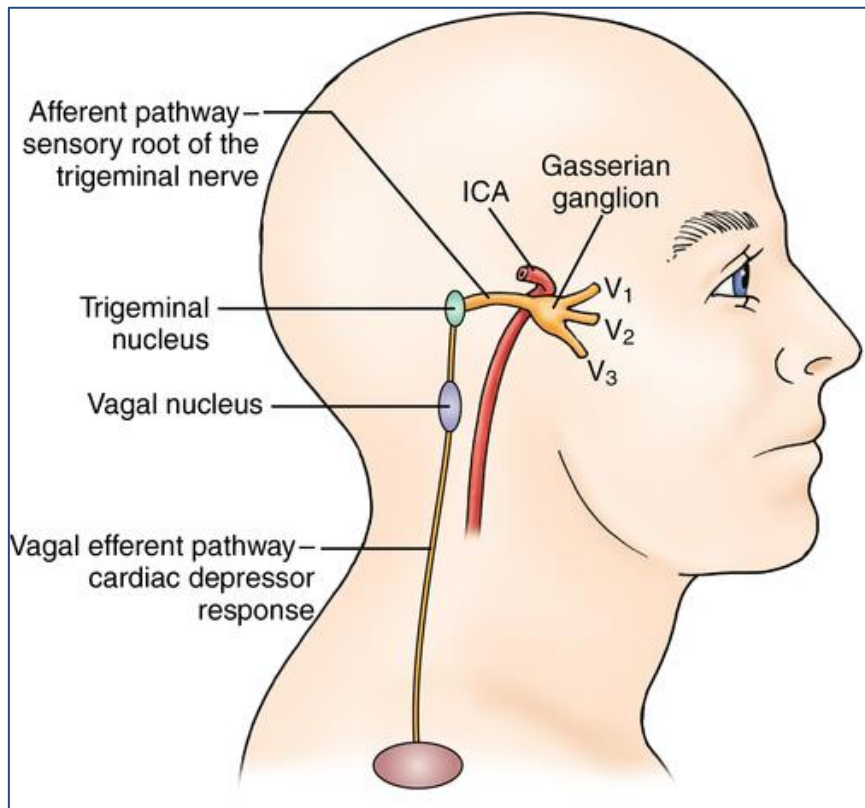


Vegetative reflex

Pressure of eyeballs



Decrease of heart rate



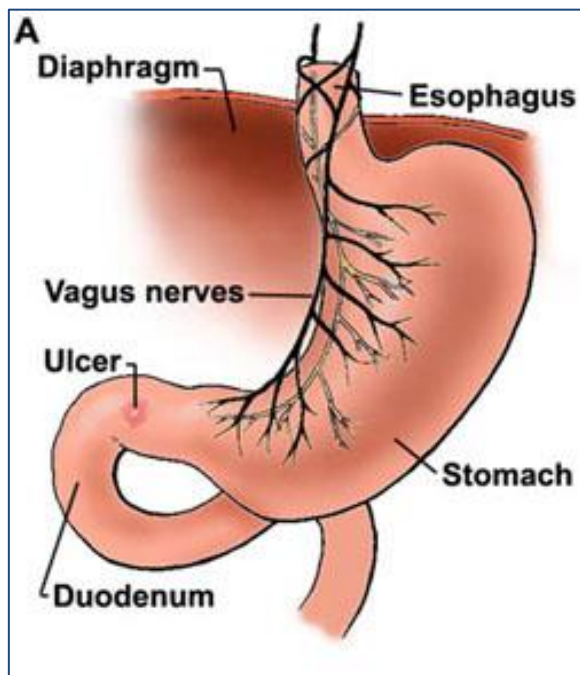
ANS in childhood

- Incomplete myelination of the nerves
- Parasympathetic nervous system starts to function earlier

9-12 months – stabilization of the vegetative reaction, central regulation

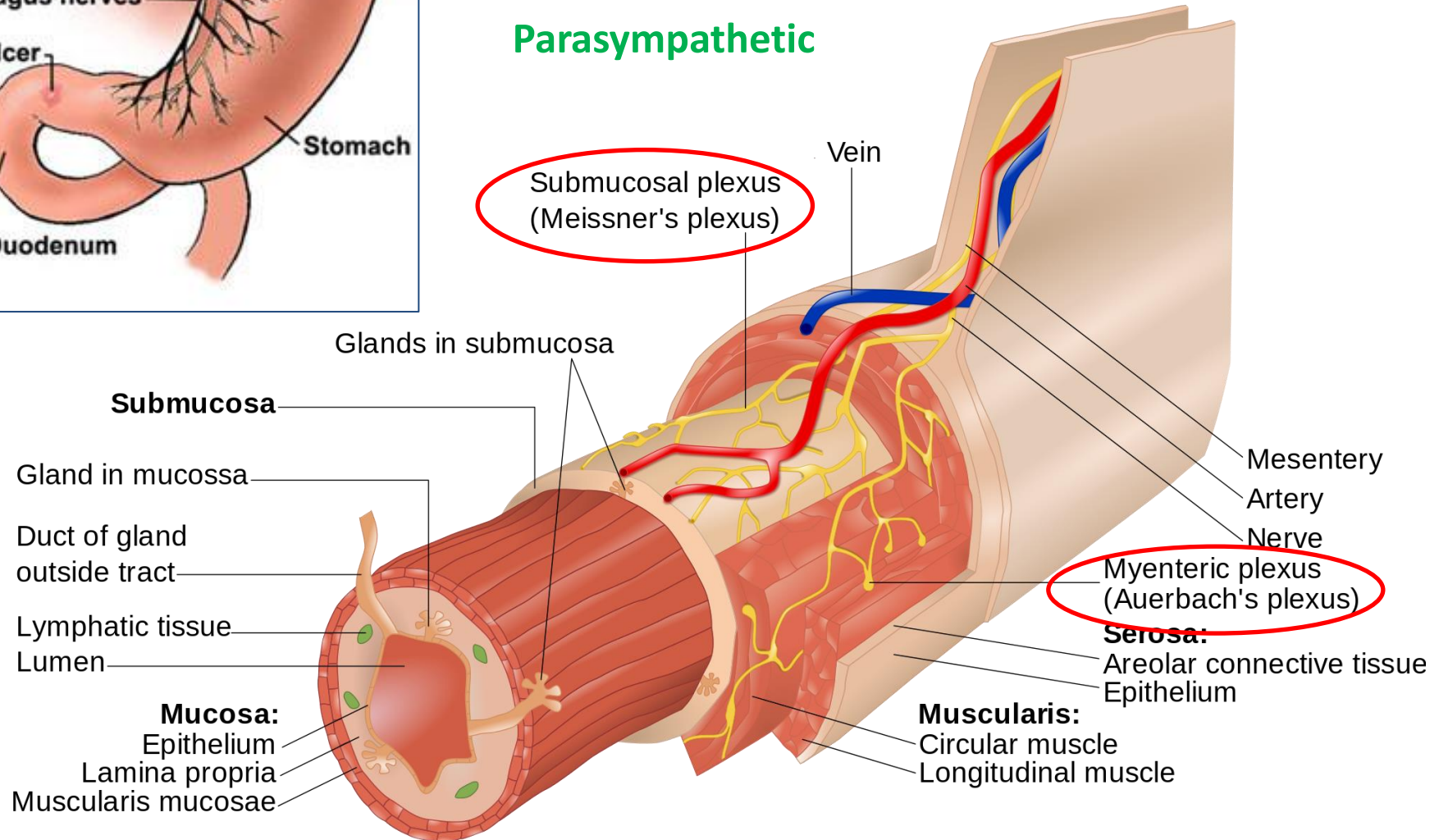
11-12 years – completed development of the vegetative regulation



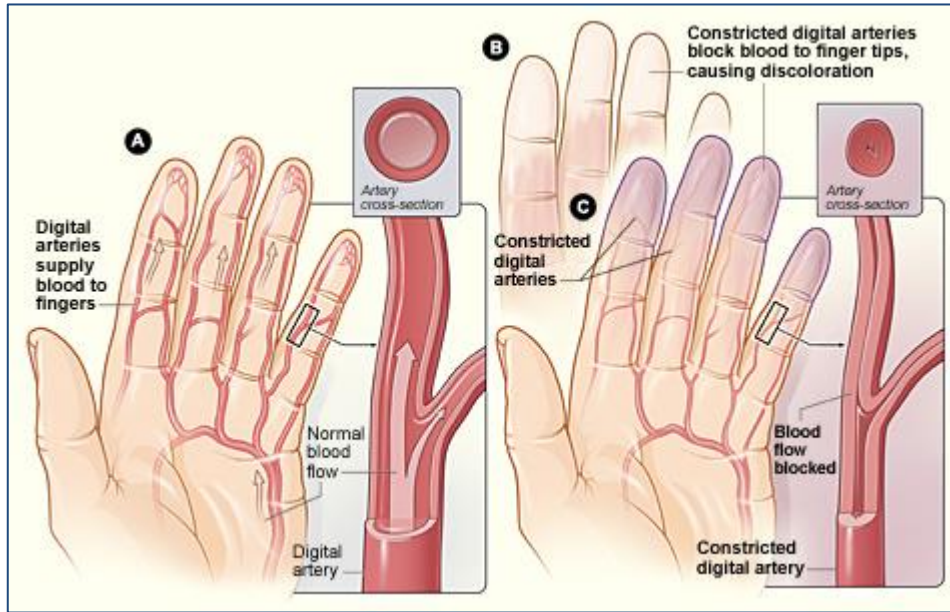


Vagotomy

Parasympathetic



Sympathectomy



Raynaud's syndrome



Hyperhidrosis



**Sympathetic NS
vs
Parasympathetic NS**

**Sprinter
vs
Stayer**

