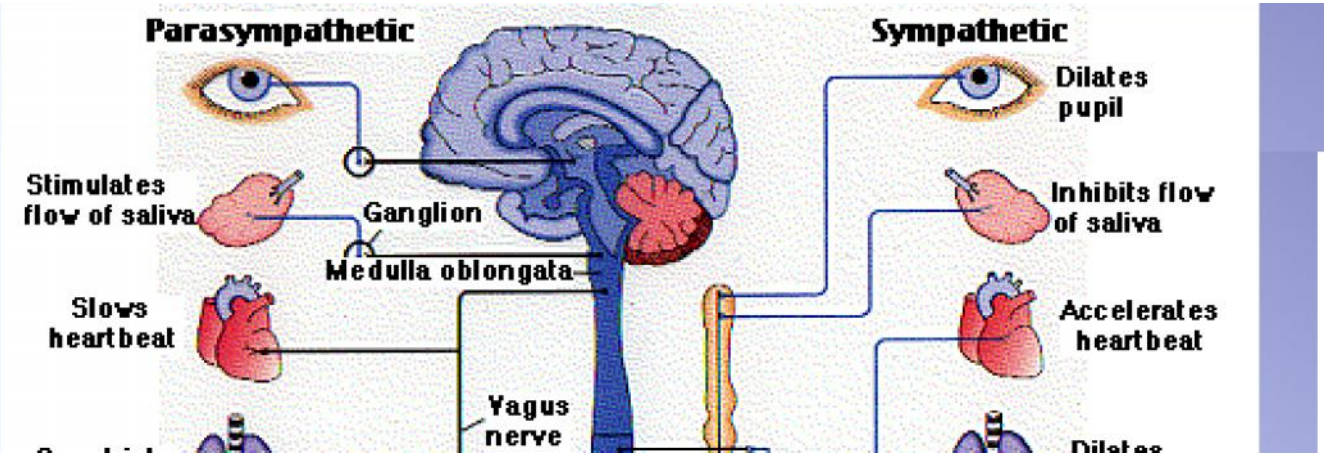


ANS

DANIL Hammoudi.MD

The autonomic nervous system consists of sensory neurons and motor neurons that run between the central nervous system (especially the **hypothalamus** and **medulla oblongata**) and various internal organs such as the:

1. heart
2. lungs
3. viscera glands (both exocrine and endocrine)

It is responsible for monitoring conditions in the internal environment and bringing about appropriate changes in them. The contraction of both smooth muscle and cardiac muscle is controlled by motor neurons of the autonomic system.

- The actions of the autonomic nervous system are largely **involuntary** (in contrast to those of the sensory- somatic system). It also differs from the sensory- somatic system is using two groups of motor neurons to stimulate the effectors instead of one.

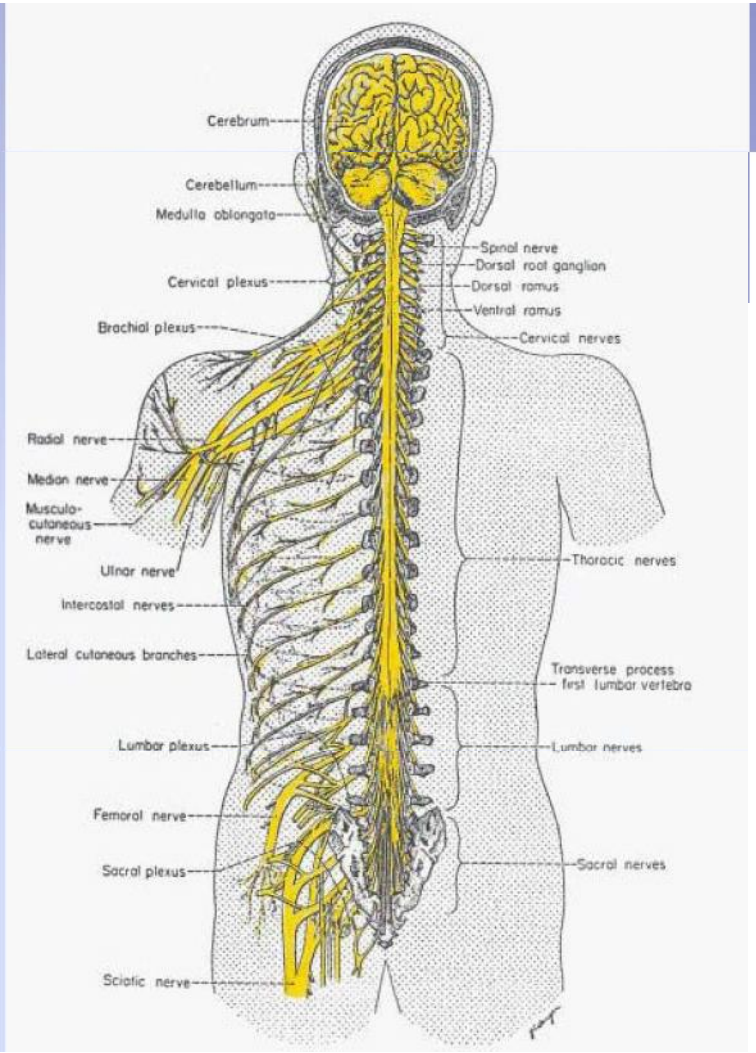
The first, the **preganglionic neurons**, arise in the CNS and run to a ganglion in the body. Here they synapse with

- **postganglionic neurons**, which run to the effector organ (cardiac muscle, smooth muscle, or a gland).

- The autonomic nervous system has two subdivisions, the **sympathetic nervous system** and the
- **parasympathetic nervous system**.

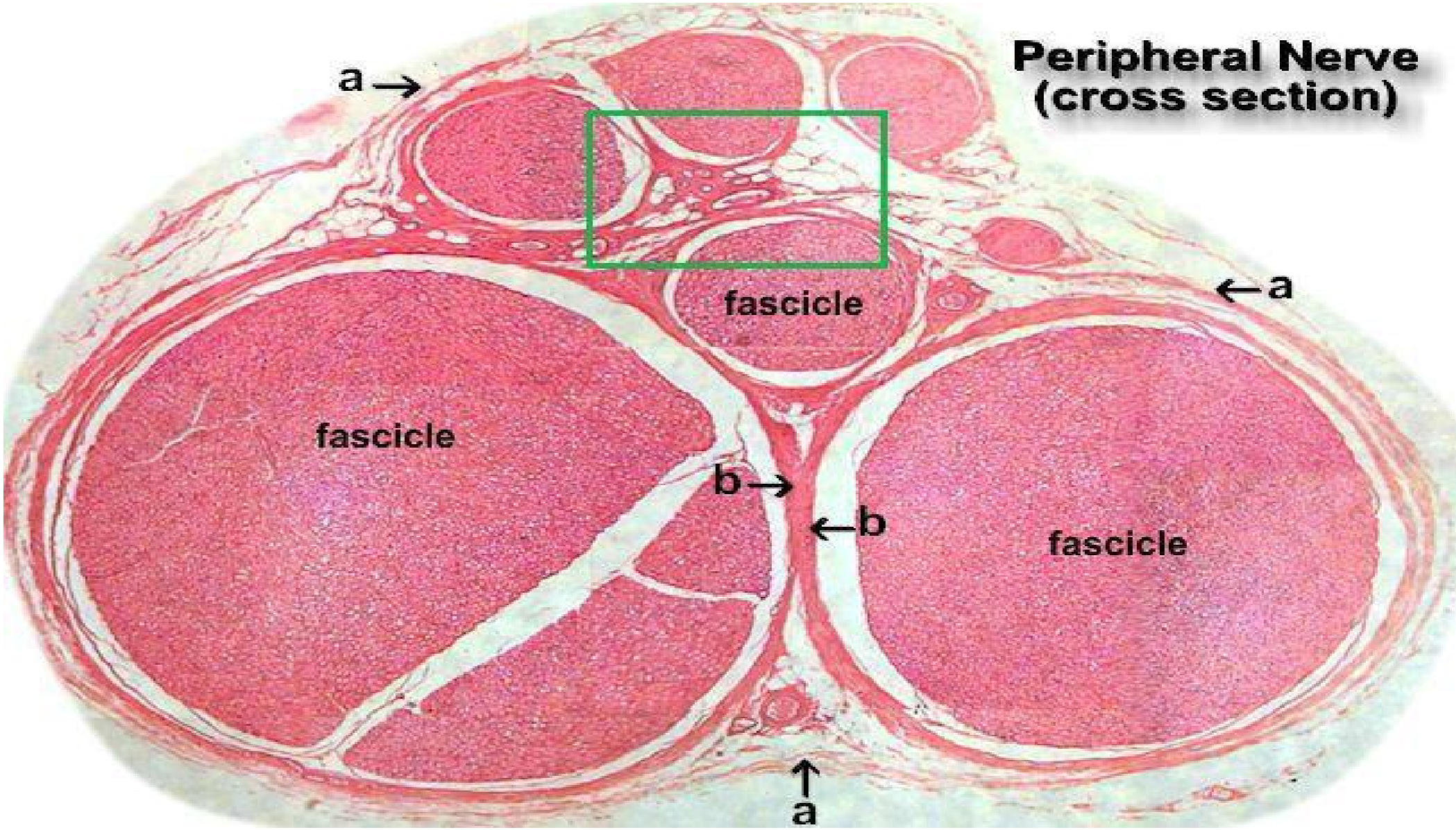
Peripheral Nervous System

- Now that we've looked at spinal and cranial nerves, we can examine the divisions of the PNS.
- The PNS is broken down into a sensory and a motor division.
- We'll concentrate on the motor division which contains the somatic nervous system and the autonomic nervous system.



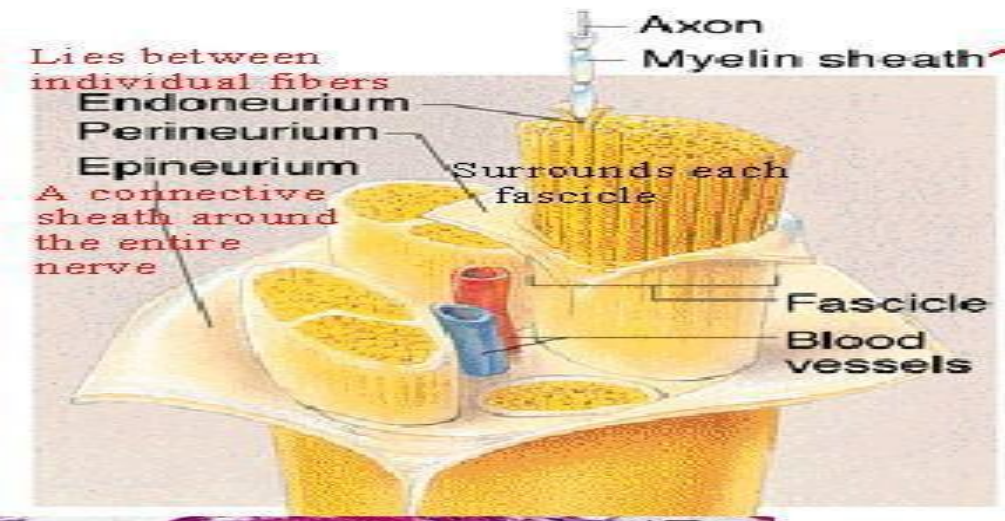
Structure of a Nerve

- Nerve – cordlike organ of the PNS consisting of peripheral axons enclosed by connective tissue
- Connective tissue coverings include:
  - Endoneurium – loose connective tissue that surrounds axons
  - Perineurium – coarse connective tissue that bundles fibers into fascicles
  - Epineurium – tough fibrous sheath around a nerve

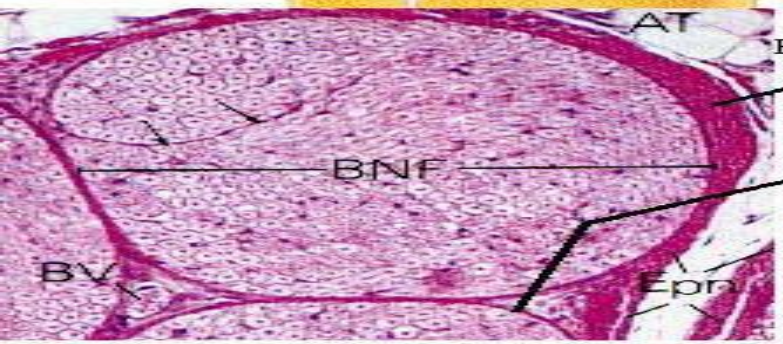

Peripheral Nerve
(cross section)
a
a
fascicle
fascicle
b
b
fascicle
a

Structure of a Nerve

Consists of a continuous series of Schwann cells wrapped around the fiber.

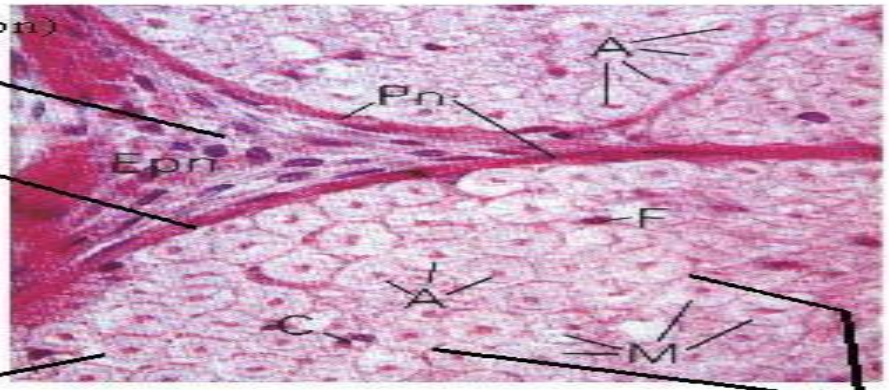


A nerve is a group of axons (nerve fibers) outside the CNS. These fibers are bundled together with connective layers. Many of the fibers are myelinated, which means they have a covering made from successive wrappings of Schwann cells.



Epineurium (Epn)

Perineurium (Pn)



BV=blood vessel, BNF=fascicle, A=axons, F=a fibroblast, C=capillary.

M = the myelin sheath, composed of wrappings of a Schwann cell. The outer membrane or layer of the myelin sheath is called the neurilemma.

Structure of a Nerve

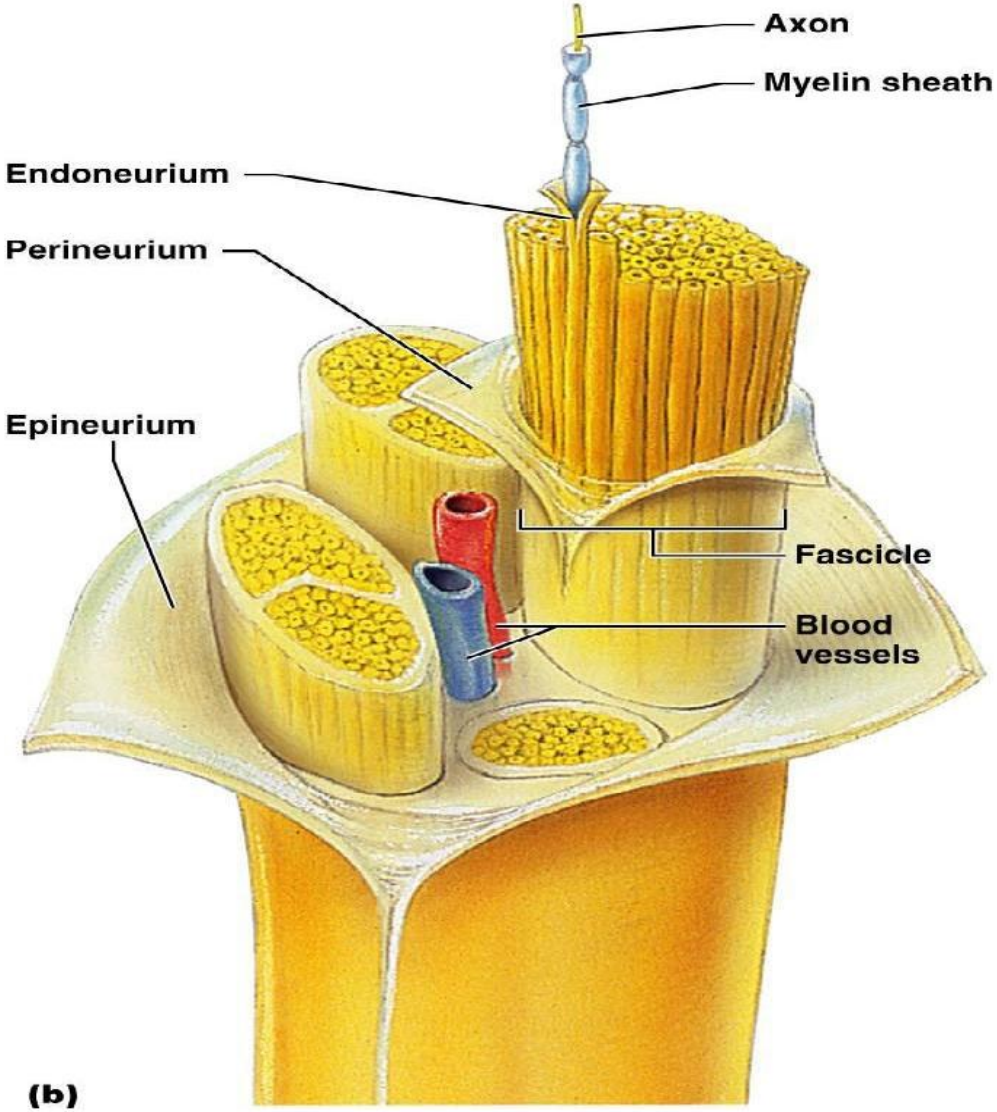


Figure 13.3b

Classification of nerves

- **Sensory and motor divisions**
- **Sensory (afferent)** – carry impulse to the CNS
- **Motor (efferent)** – carry impulses from CNS
- **Mixed** – sensory and motor fibers carry impulses to and from CNS; most common type of nerve

Cranial nerves I – VI	Sensory function	Motor function	PS* fibers
I Olfactory	Yes (smell)	No	No
II Optic	Yes (vision)	No	No
III Oculomotor	No	Yes	Yes
IV Trochlear	No	Yes	No
V Trigeminal	Yes (general sensation)	Yes	No
VI Abducens	No	Yes	No

Cranial nerves VII – XII	Sensory function	Motor function	PS* fibers
VII Facial	Yes (taste)	Yes	Yes
VIII Vestibulocochlear	Yes (hearing and balance)	Some	No
IX Glossopharyngeal	Yes (taste)	Yes	Yes
X Vagus	Yes (taste)	Yes	Yes
XI Accessory	No	Yes	No
XII Hypoglossal	No	Yes	No

(b) *PS = parasympathetic

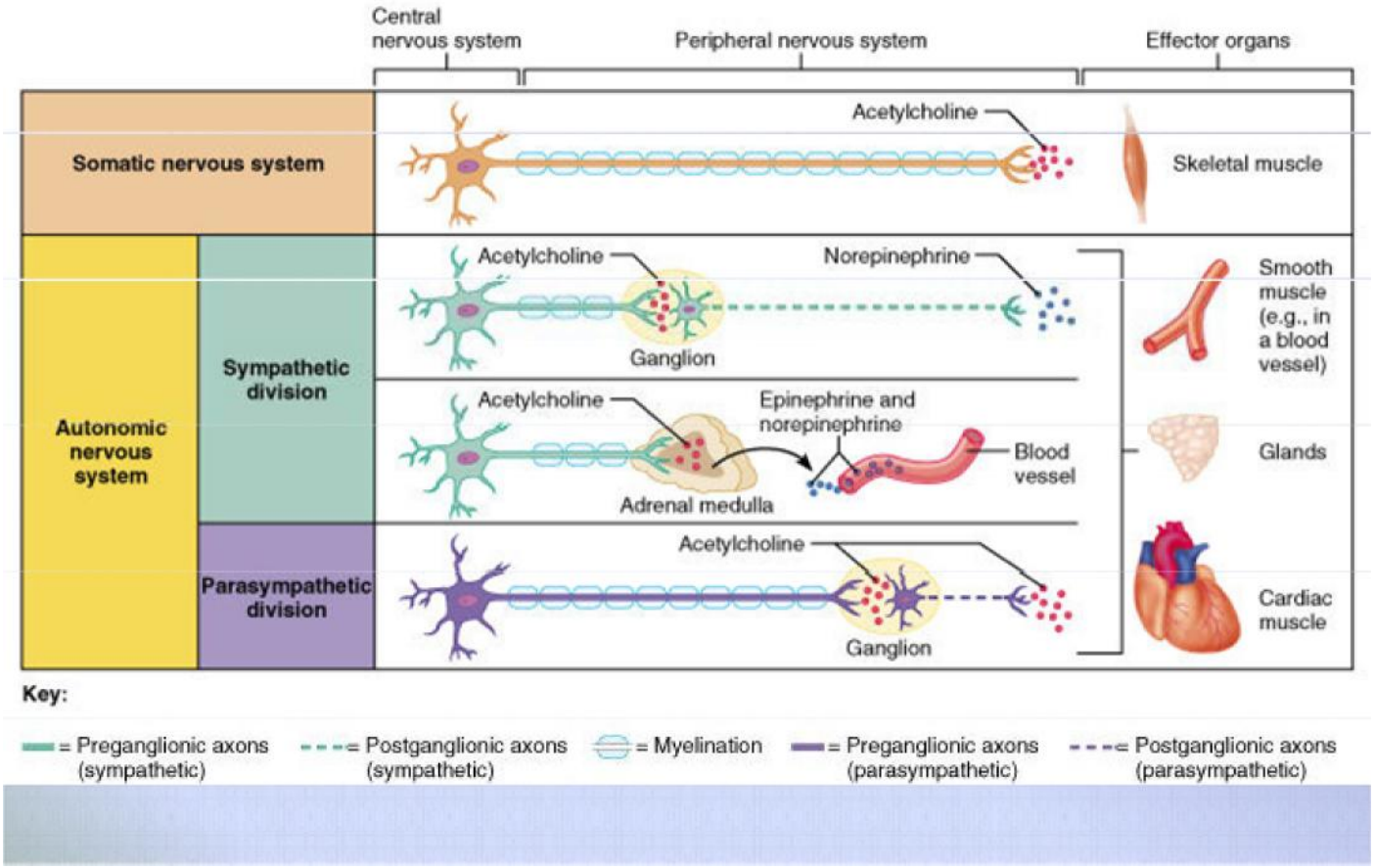
Somatic vs. Autonomic

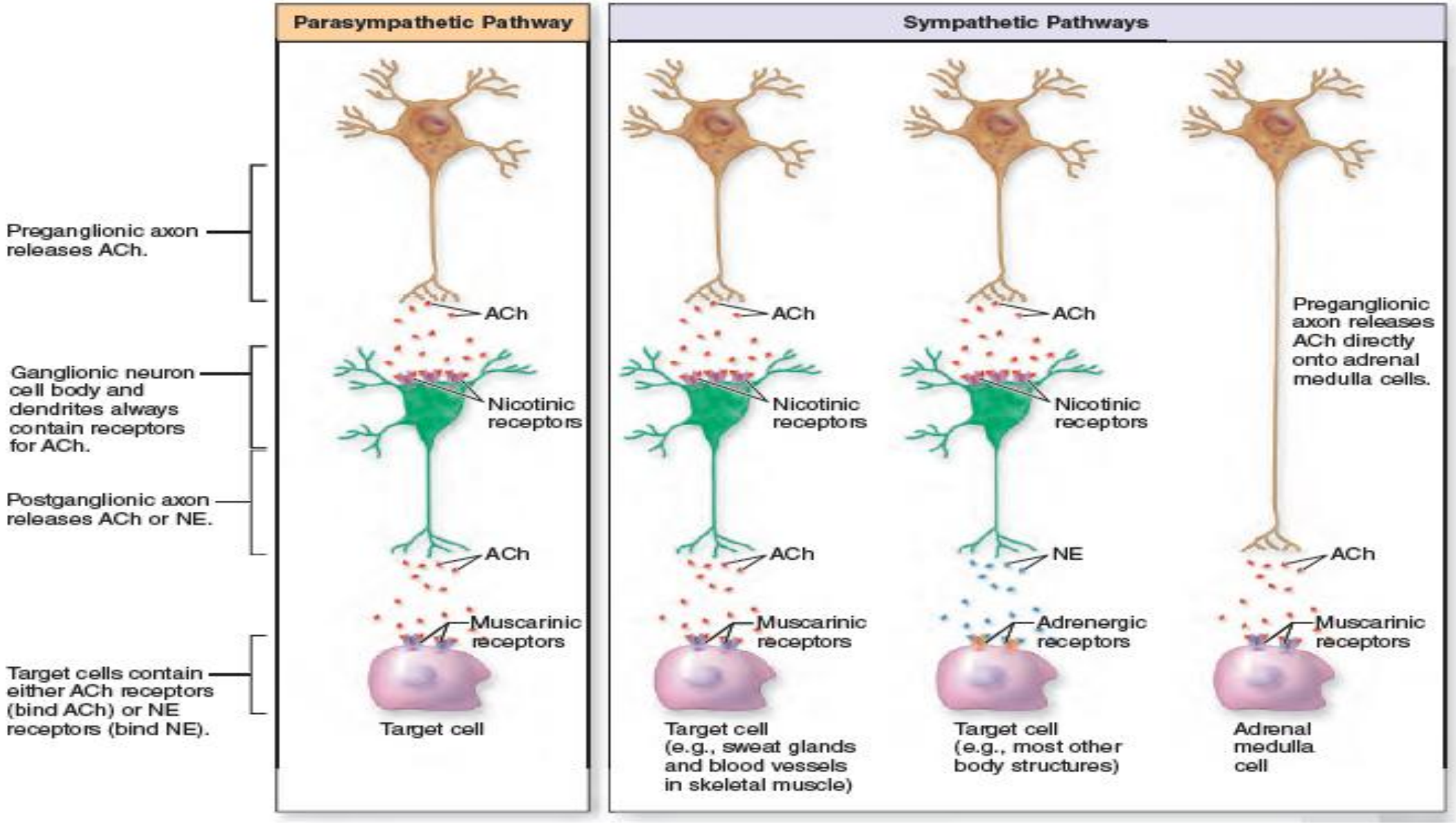
- Voluntary
- Skeletal muscle
- Single efferent neuron
- Axon terminals release acetylcholine
- Always excitatory
- Controlled by the cerebrum

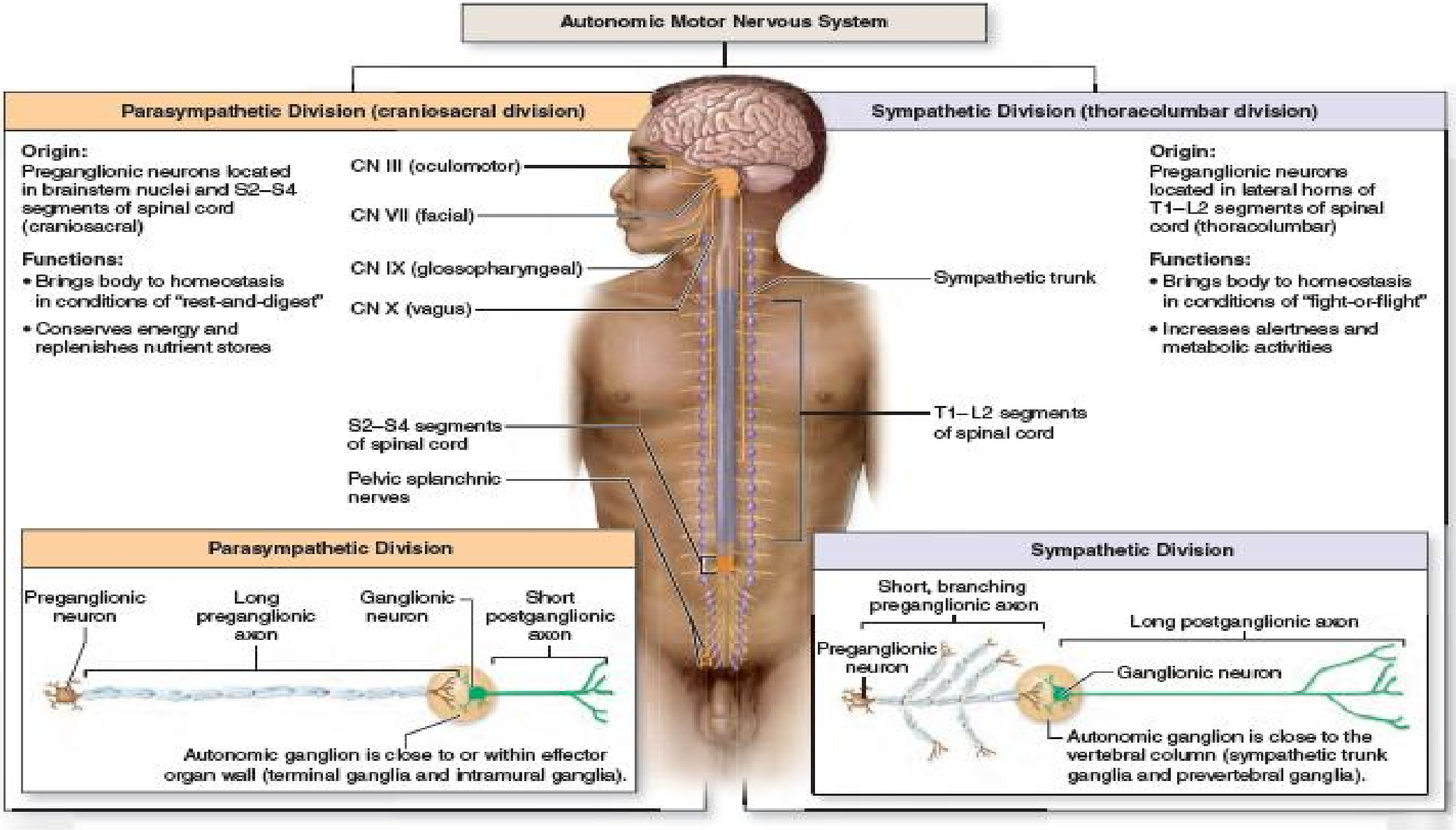
- Involuntary
- Smooth, cardiac muscle; glands
- Multiple efferent neurons
- Axon terminals release acetylcholine or norepinephrine
- Can be excitatory or inhibitory
- Controlled by the homeostatic centers in the brain – pons, hypothalamus, medulla oblongata

Autonomic Nervous System

- 2 divisions:
  - Sympathetic
    - "Fight or flight"
    - "E" division
      - Exercise, excitement, emergency, and embarrassment
  - Parasympathetic
    - "Rest and digest"
    - D division
      - Digestion, defecation, and diuresis

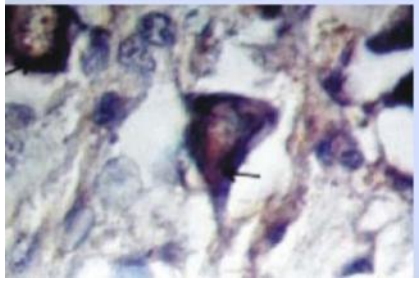

Central nervous system
Peripheral nervous system
Effector organs
Somatic nervous system
Acetylcholine
Skeletal muscle
Autonomic nervous system
Sympathetic division
Acetylcholine
Norepinephrine
Ganglion
Smooth muscle (e.g., in a blood vessel)
Acetylcholine
Epinephrine and norepinephrine
Blood vessel
Adrenal medulla
Glands
Parasympathetic division
Acetylcholine
Ganglion
Cardiac muscle
Key:
= Preganglionic axons (sympathetic)
= Postganglionic axons (sympathetic)
= Myelination
= Preganglionic axons (parasympathetic)
= Postganglionic axons (parasympathetic)

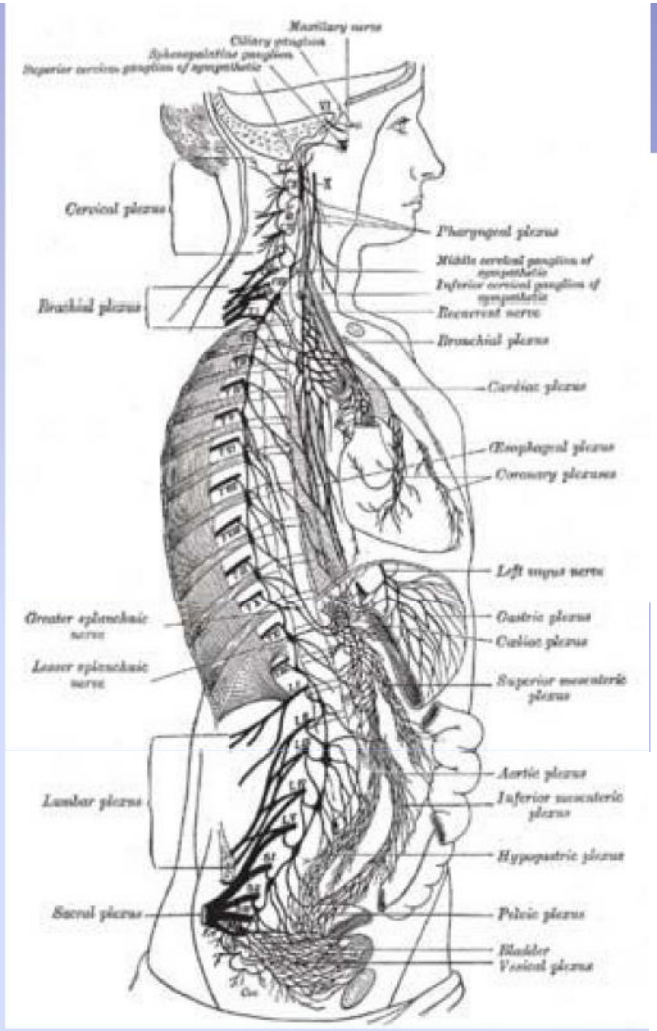

Parasympathetic Pathway
Sympathetic Pathways
Preganglionic axon releases ACh.
Ganglionic neuron cell body and dendrites always contain receptors for ACh.
Postganglionic axon releases ACh or NE.
Target cells contain either ACh receptors (bind ACh) or NE receptors (bind NE).
ACh
Nicotinic receptors
ACh
Muscarinic receptors
Target cell
ACh
Nicotinic receptors
ACh
Muscarinic receptors
Target cell (e.g., sweat glands and blood vessels in skeletal muscle)
ACh
Nicotinic receptors
NE
Adrenergic receptors
Target cell (e.g., most other body structures)
Preganglionic axon releases ACh directly onto adrenal medulla cells.
ACh
Muscarinic receptors
Adrenal medulla cell

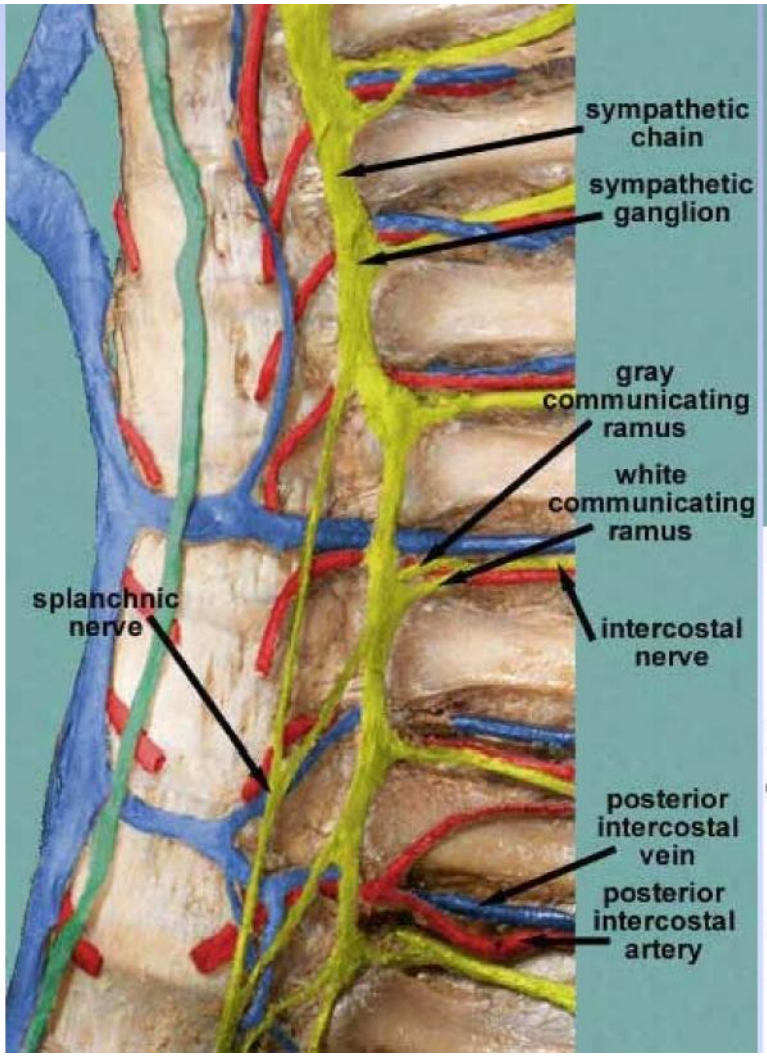

Autonomic Motor Nervous System
Parasympathetic Division (craniosacral division)
Sympathetic Division (thoracolumbar division)
Origin:
Preganglionic neurons located in brainstem nuclei and S2–S4 segments of spinal cord (craniosacral)
Functions:
• Brings body to homeostasis in conditions of "rest-and-digest"
• Conserves energy and replenishes nutrient stores
CN III (oculomotor)
CN VII (facial)
CN IX (glossopharyngeal)
CN X (vagus)
S2–S4 segments of spinal cord
Pelvic splanchnic nerves
Sympathetic trunk
T1–L2 segments of spinal cord
Origin:
Preganglionic neurons located in lateral horns of T1–L2 segments of spinal cord (thoracolumbar)
Functions:
• Brings body to homeostasis in conditions of "fight-or-flight"
• Increases alertness and metabolic activities
Parasympathetic Division
Preganglionic neuron
Long preganglionic axon
Ganglionic neuron
Short postganglionic axon
Autonomic ganglion is close to or within effector organ wall (terminal ganglia and intramural ganglia).
Sympathetic Division
Short, branching preganglionic axon
Long postganglionic axon
Preganglionic neuron
Ganglionic neuron
Autonomic ganglion is close to the vertebral column (sympathetic trunk ganglia and prevertebral ganglia).

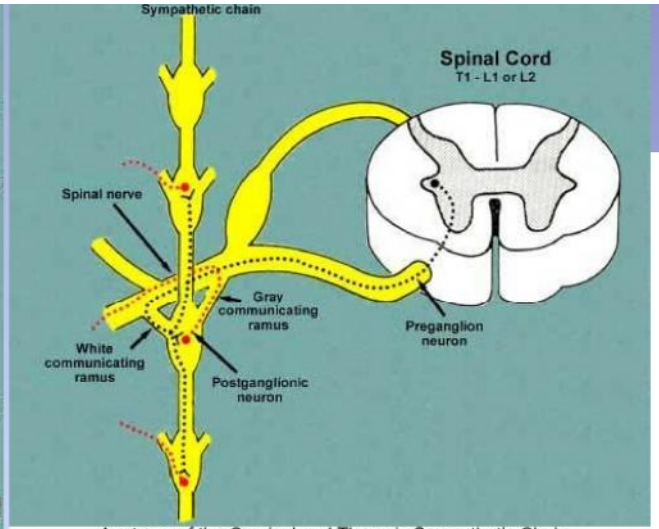
The Sympathetic Nervous System

- The preganglionic motor neurons of the sympathetic system arise in the spinal cord.
- They pass into sympathetic ganglia which are organized into two chains that run parallel to and on either side of the spinal cord.

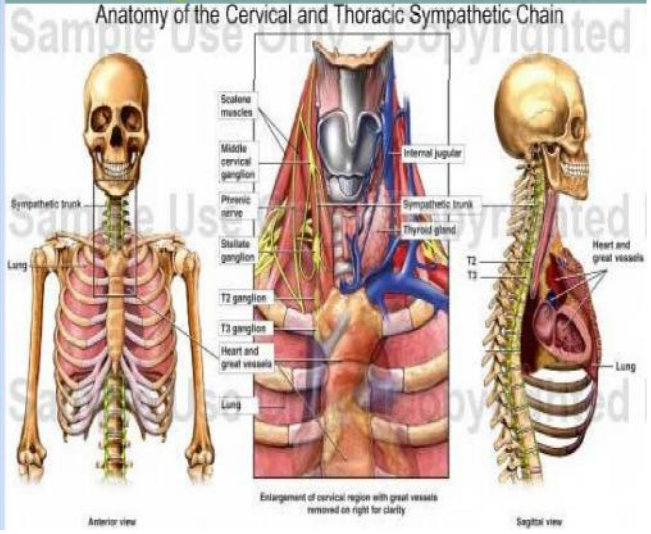


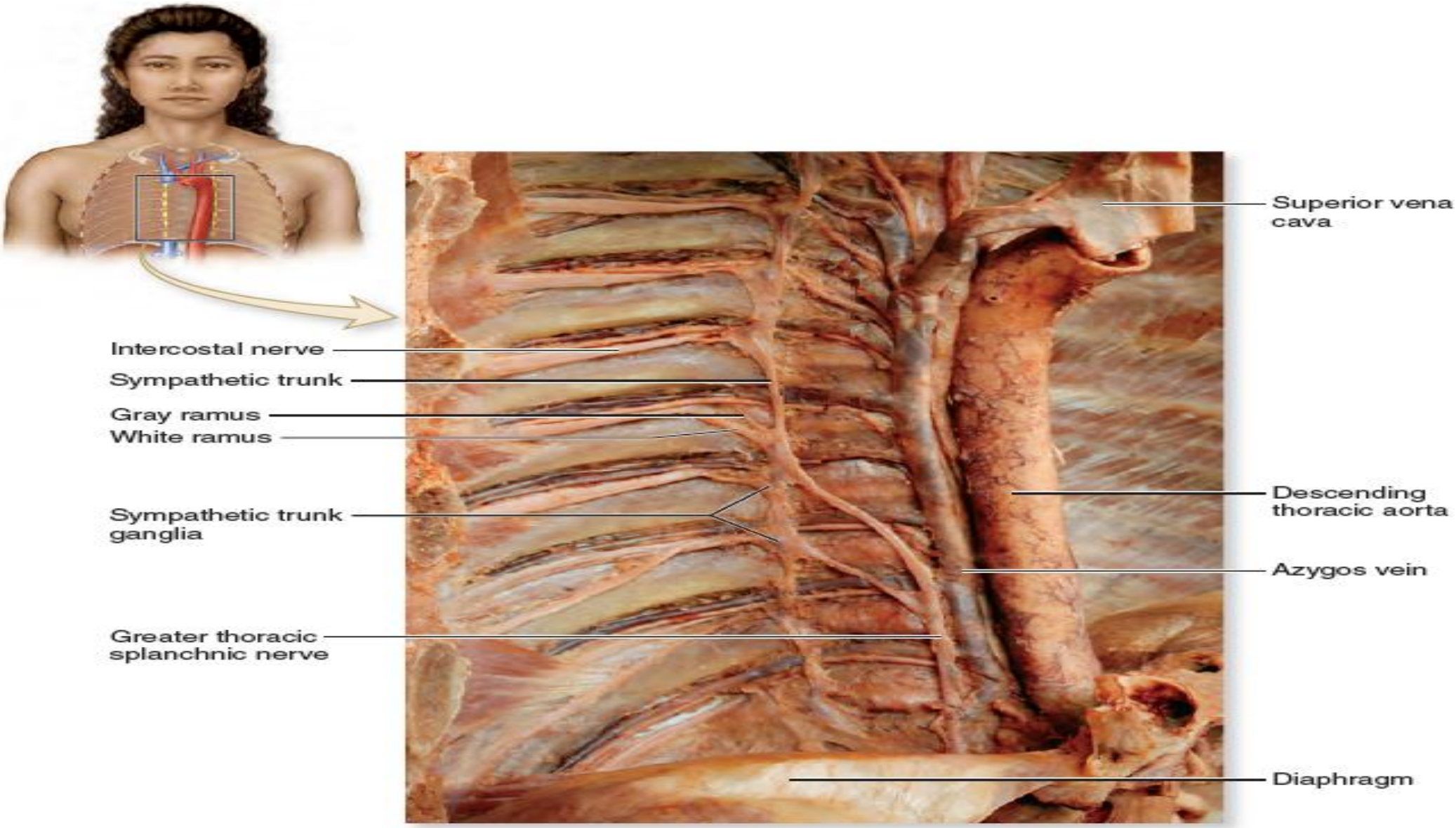






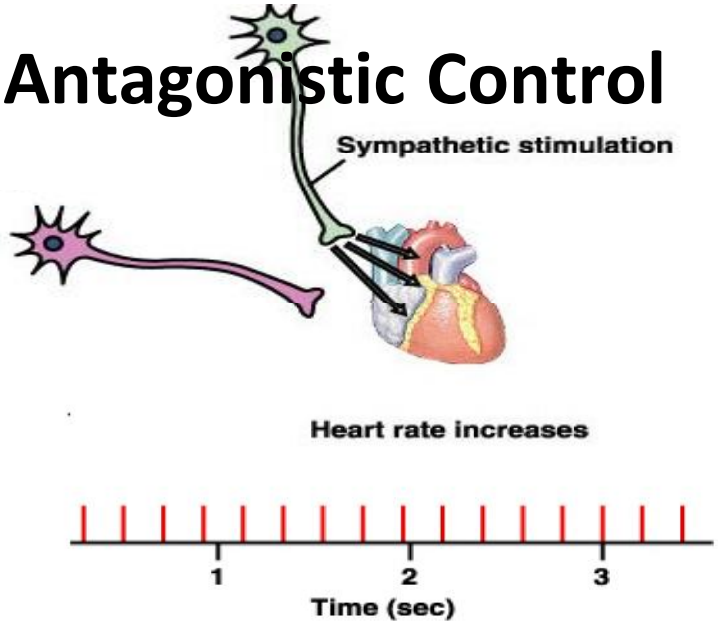
Anatomy of the Cervical and Thoracic Sympathetic Chain

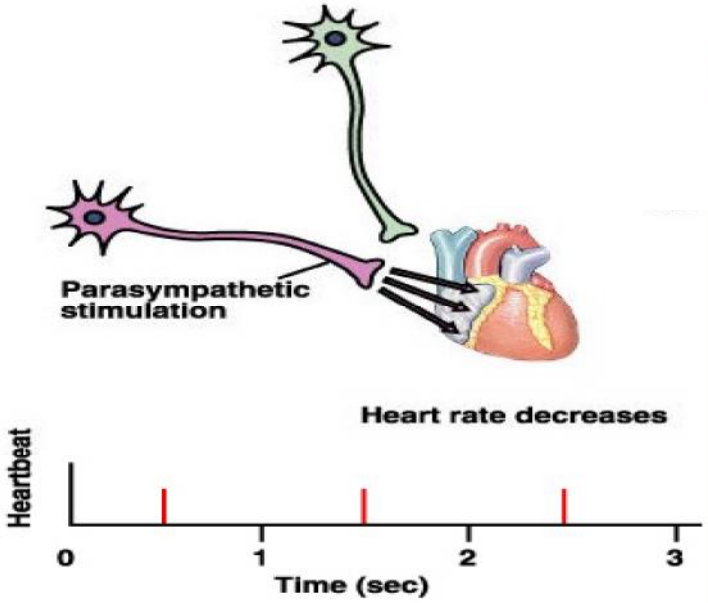



Intercostal nerve
Sympathetic trunk
Gray ramus
White ramus
Sympathetic trunk ganglia
Greater thoracic splanchnic nerve
Superior vena cava
Descending thoracic aorta
Azygos vein
Diaphragm

Antagonistic Control

- Most internal organs are innervated by both branches of the ANS which exhibit antagonistic control





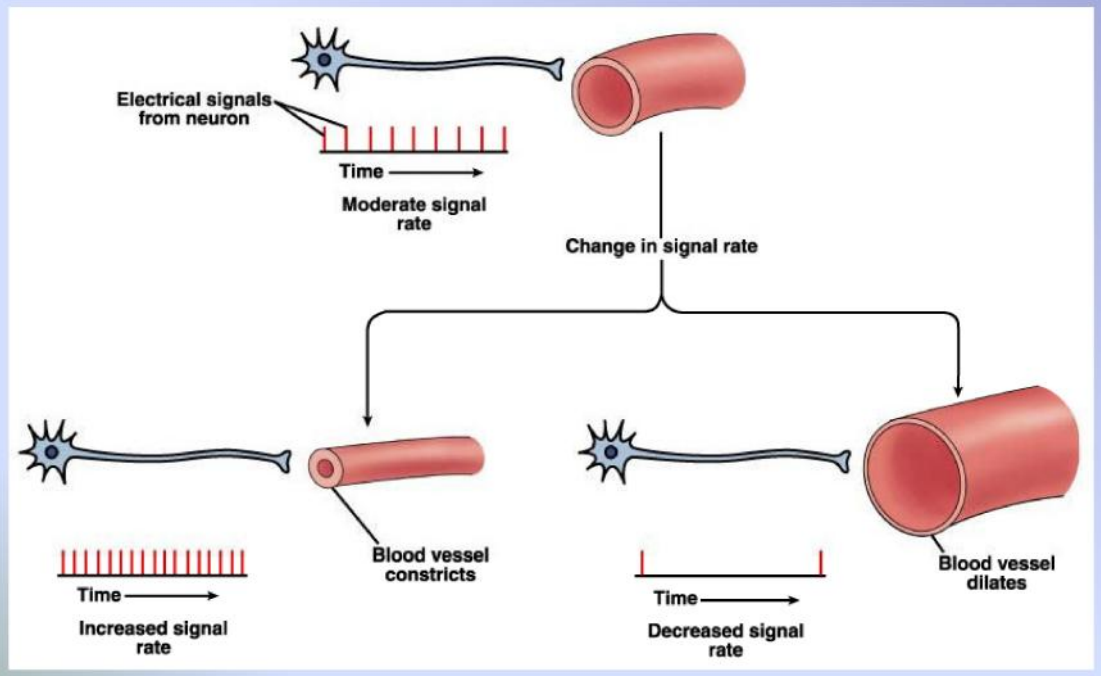
A great example is heart rate. An increase in sympathetic stimulation causes HR to increase whereas an increase in parasympathetic stimulation causes HR to decrease

Exception to the dual innervation rule:

Sweat glands and blood vessel smooth muscle are only innervated by symp and rely strictly on up-down control.

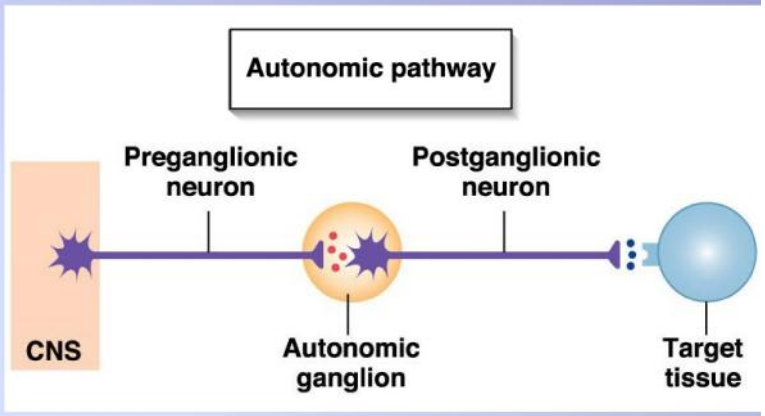
Exception to the antagonism rule:

Symp and parasymp work cooperatively to achieve male sexual function. Parasymp is responsible for erection while symp is responsible to ejaculation. There's similar ANS cooperation in the female sexual response.



ANS Structure

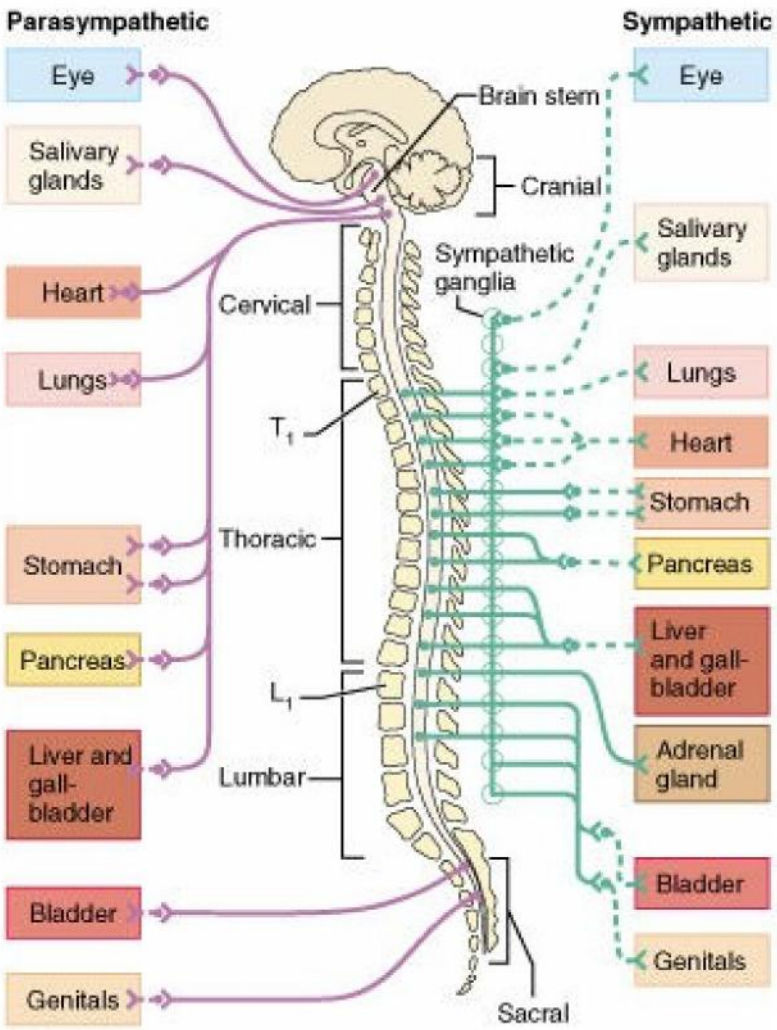
- Both ANS divisions share the same general structure.
  - Autonomic pathways always consist of 2 neurons in series.
  - They synapse in an autonomic ganglion – would this be inside or outside the CNS?
  - The 1st neuron in the autonomic pathway is the preganglionic neuron,
    - Cell body in CNS, myelinated, and projects to the autonomic ganglion.
  - While the 2nd neuron is the postganglionic neuron.
    - Cell body in autonomic ganglion, unmyelinated, and projects to the effector.

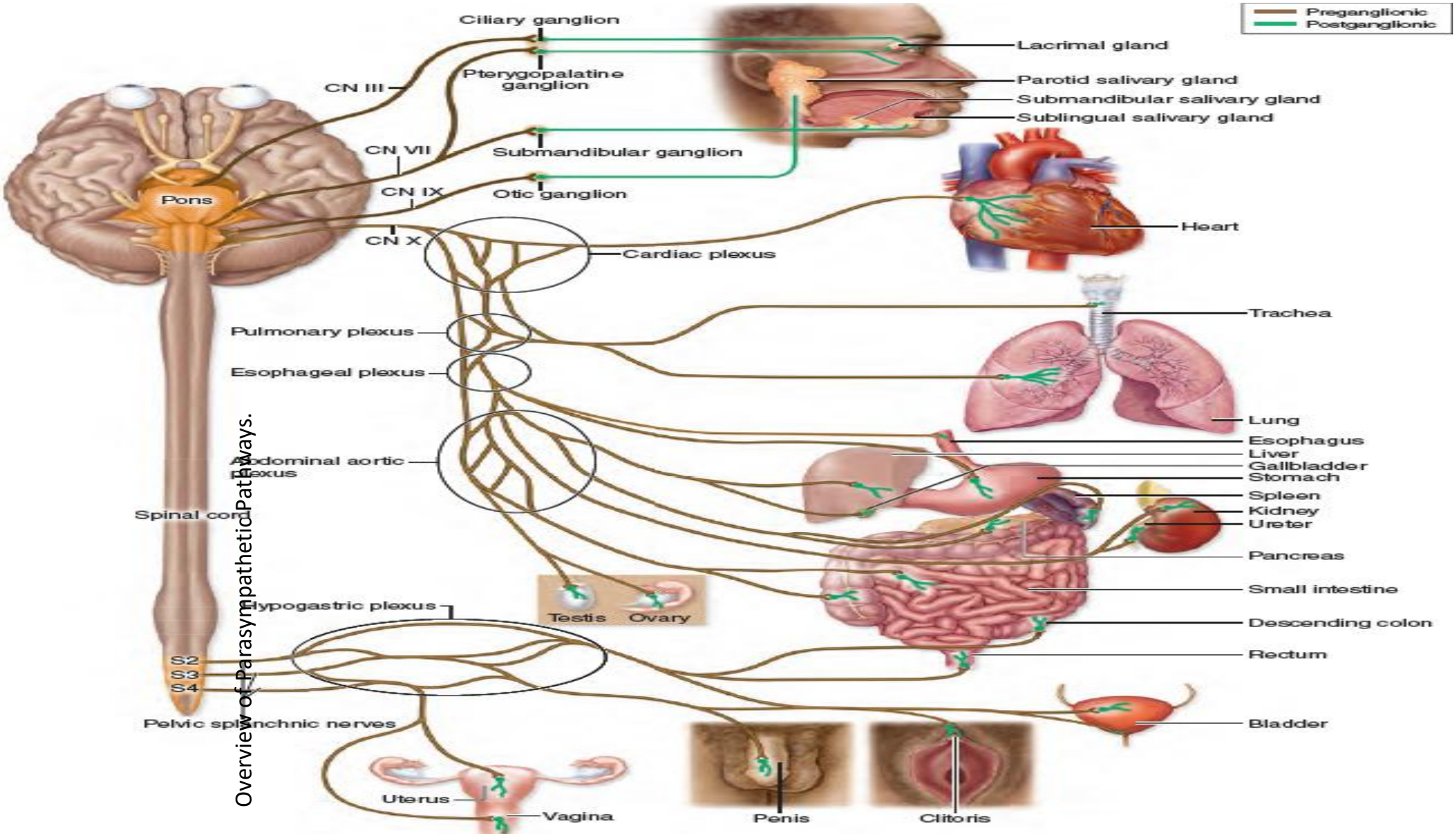


- **The Parasympathetic Nervous System**
- The main nerves of the parasympathetic system are the tenth cranial nerves, the **vagus nerves**. They originate in the **medulla oblongata**. Other preganglionic parasympathetic neurons also extend from the brain as well as from the lower tip of the spinal cord.
- Each preganglionic parasympathetic neuron synapses with just a few postganglionic neurons, which are located near - or in - the effector organ, a muscle or gland.
- **Acetylcholine** (**ACh**) is the neurotransmitter at all the pre- and many of the postganglionic neurons of the parasympathetic system.
- However, some of the postganglionic neurons release nitric oxide (NO) as their neurotransmitter.
- **Parasympathetic stimulation** causes
    - slowing down of the heartbeat
    - lowering of blood pressure
    - constriction of the pupils
    - increased blood flow to the skin and viscera
    - peristalsis of the GI tract

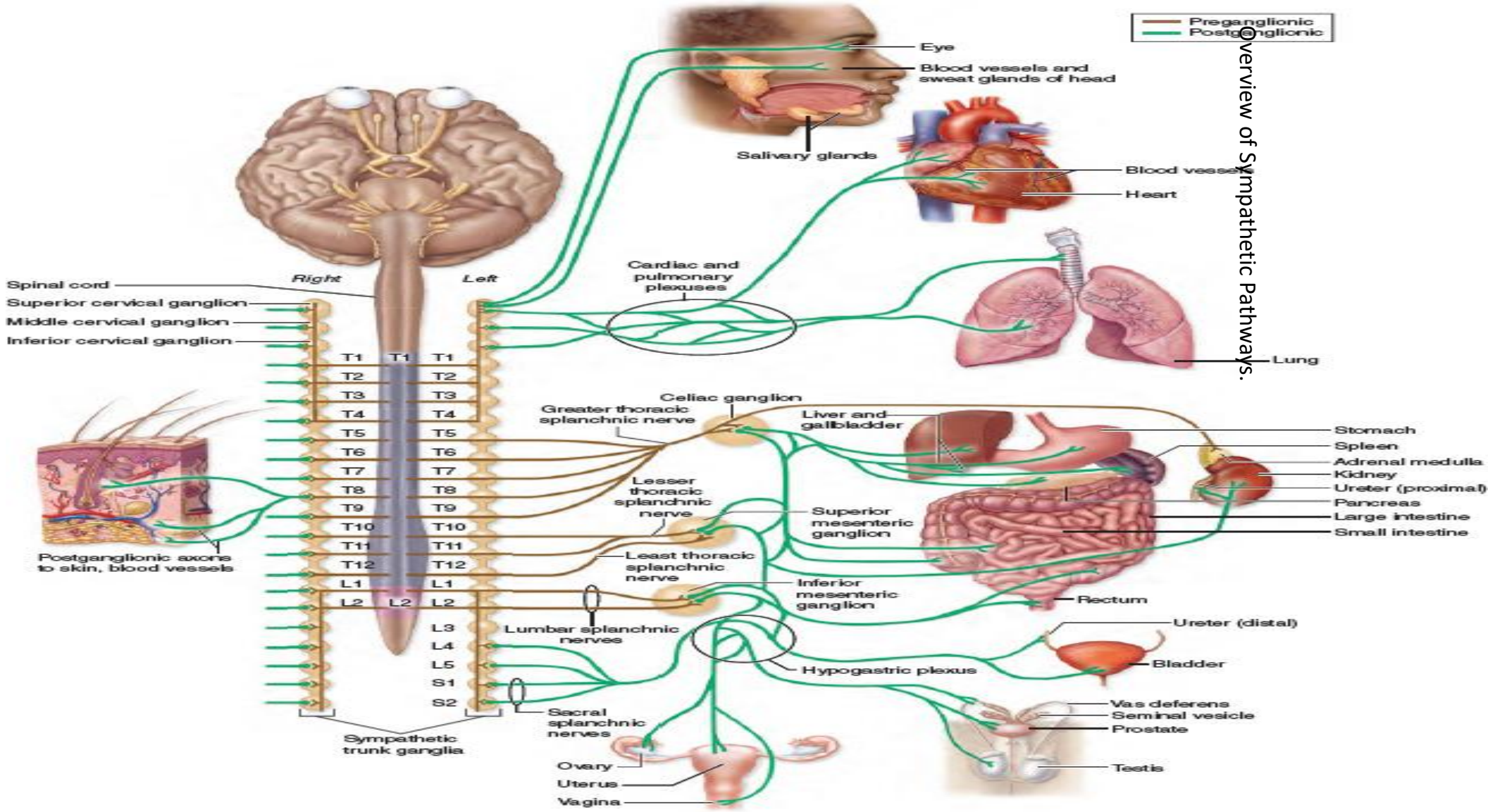
Sympathetic vs. Parasympathetic *Structural Differences*:

	Symp	Parasymp
Point of CNS Origin	T1 ⇗ L2 (thoracolumbar)	Brainstem, S2 ⇗ S4 (craniosacral)
Site of Peripheral Ganglia	Paravertebral – in sympathetic chain	On or near target tissue
Length of preganglionic fiber	Short	Long
Length of postganglionic fiber	Long	Short


Parasympathetic
Sympathetic
Eye
Salivary glands
Heart
Lungs
Stomach
Pancreas
Liver and gall-bladder
Bladder
Genitals
Brain stem
Cranial
Sympathetic ganglia
Cervical
T_1
Thoracic
L_1
Lumbar
Sacral
Eye
Salivary glands
Lungs
Heart
Stomach
Pancreas
Liver and gall-bladder
Adrenal gland
Bladder
Genitals



Overview of Parasympathetic Pathways.

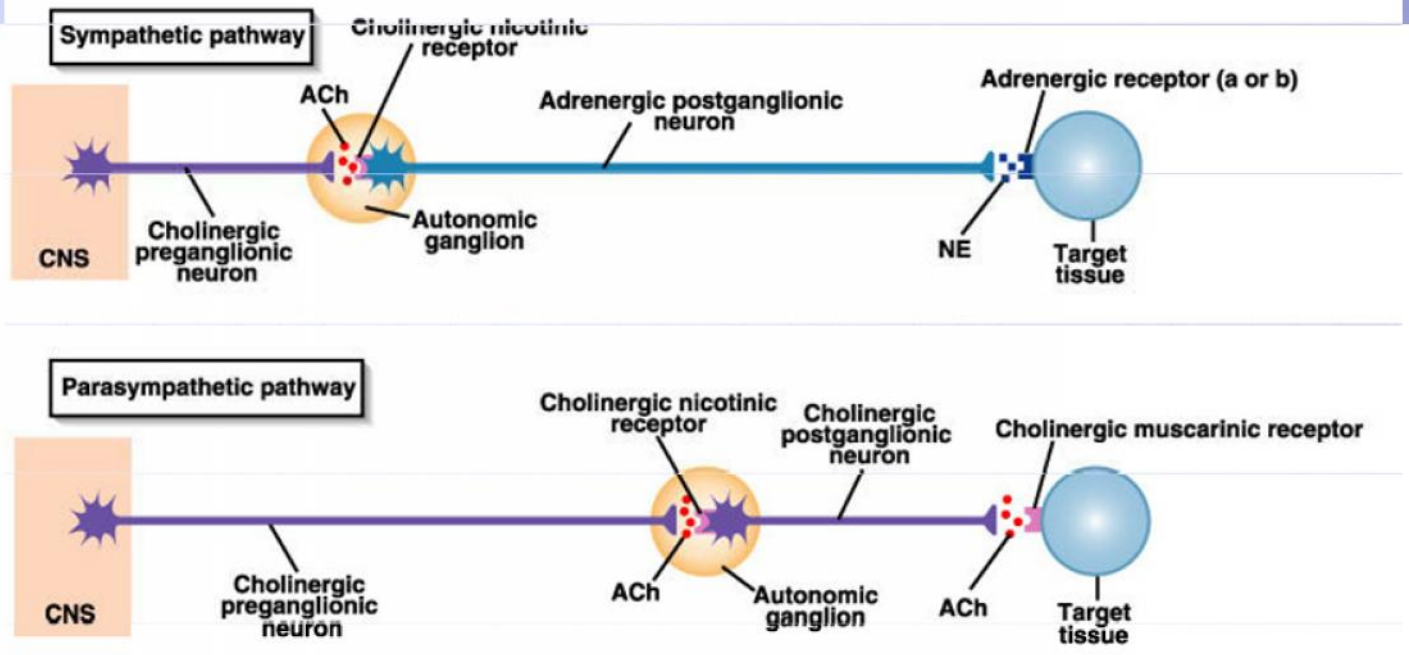


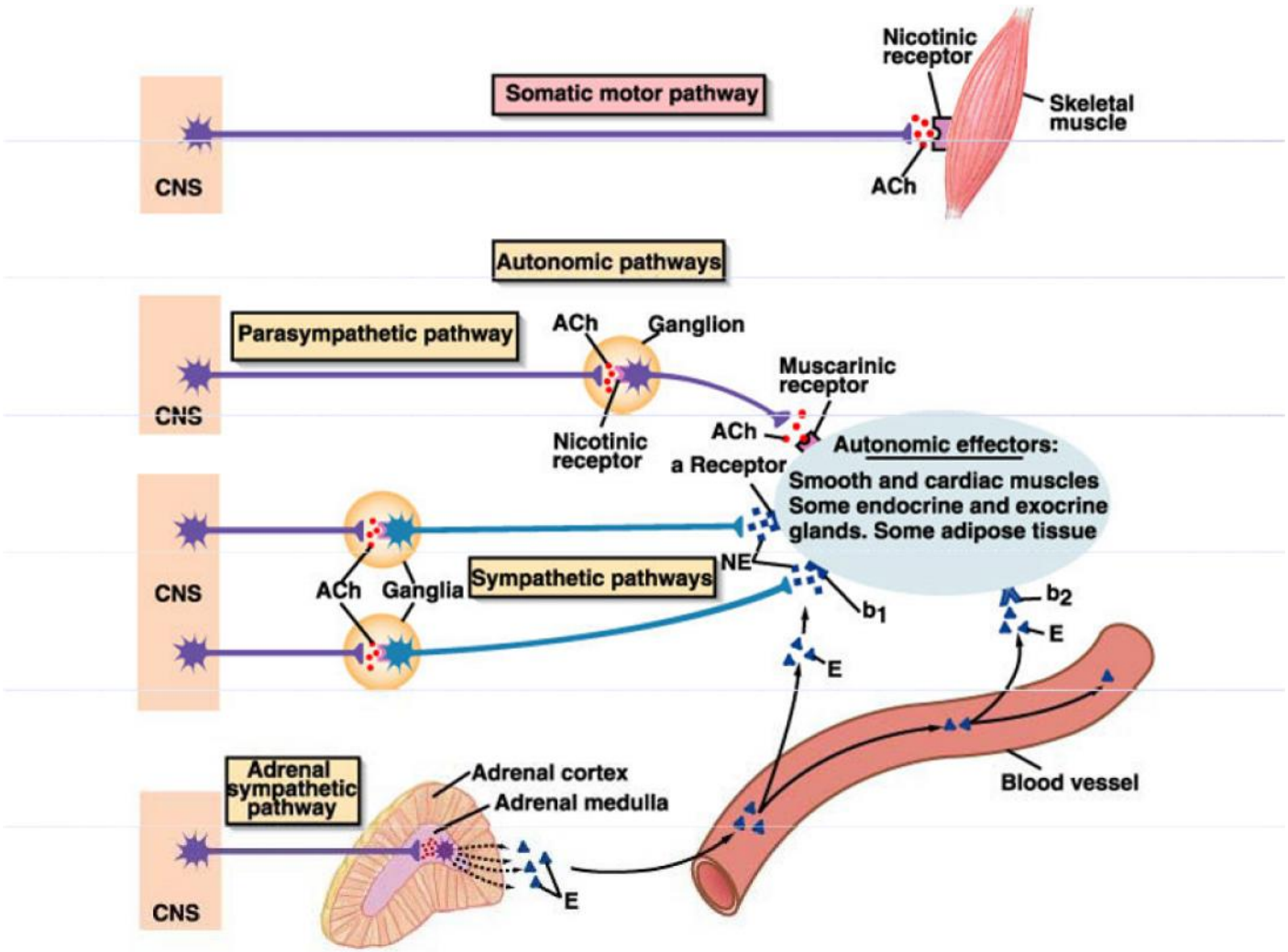
Overview of Sympathetic Pathways.

Sympathetic vs. Parasympathetic *Receptor/NT Differences:*

Symp . Parasymp.

NT at Target Synapse	Norepinephrine (adrenergic neurons)	Acetylcholine (cholinergic neurons)
Type of NT Receptors at Target Synapse	Alpha and Beta (α and β)	Muscarinic
NT at Ganglion	Acetylcholine	Acetylcholine
Receptor at Ganglion	Nicotinic	Nicotinic


Sympathetic pathway
Cholinergic nicotinic receptor
ACh
Adrenergic postganglionic neuron
Adrenergic receptor (a or b)
CNS
Cholinergic preganglionic neuron
Autonomic ganglion
NE
Target tissue
Parasympathetic pathway
Cholinergic nicotinic receptor
Cholinergic postganglionic neuron
Cholinergic muscarinic receptor
CNS
Cholinergic preganglionic neuron
ACh
Autonomic ganglion
ACh
Target tissue


Somatic motor pathway
Nicotinic receptor
Skeletal muscle
CNS
ACh
Autonomic pathways
Parasympathetic pathway
ACh
Ganglion
Muscarinic receptor
CNS
Nicotinic receptor
ACh
a Receptor
Autonomic effectors:
Smooth and cardiac muscles
Some endocrine and exocrine glands. Some adipose tissue
CNS
ACh
Ganglia
Sympathetic pathways
NE
b1
b2
E
E
Adrenal sympathetic pathway
Adrenal cortex
Adrenal medulla
Blood vessel
CNS
E

Target Organ	***Parasympathetic Effects***	***Sympathetic Effects***
Eye (Iris)	Stimulates constrictor muscles. Pupil constriction.	Stimulates dilator muscles. Pupil dilates.
Eye (Ciliary muscle)	Stimulates. Lens accommodates – allows for close vision.	No innervation.
Salivary Glands	Watery secretion.	Mucous secretion.
Sweat Glands	No innervation.	Stimulates sweating in large amounts. (Cholinergic)
Gallbladder	Stimulates smooth muscle to contract and expel bile.	Inhibits gallbladder smooth muscle.
Arrector Pili	No innervation	Stimulates contraction. Piloerection (Goosebumps)

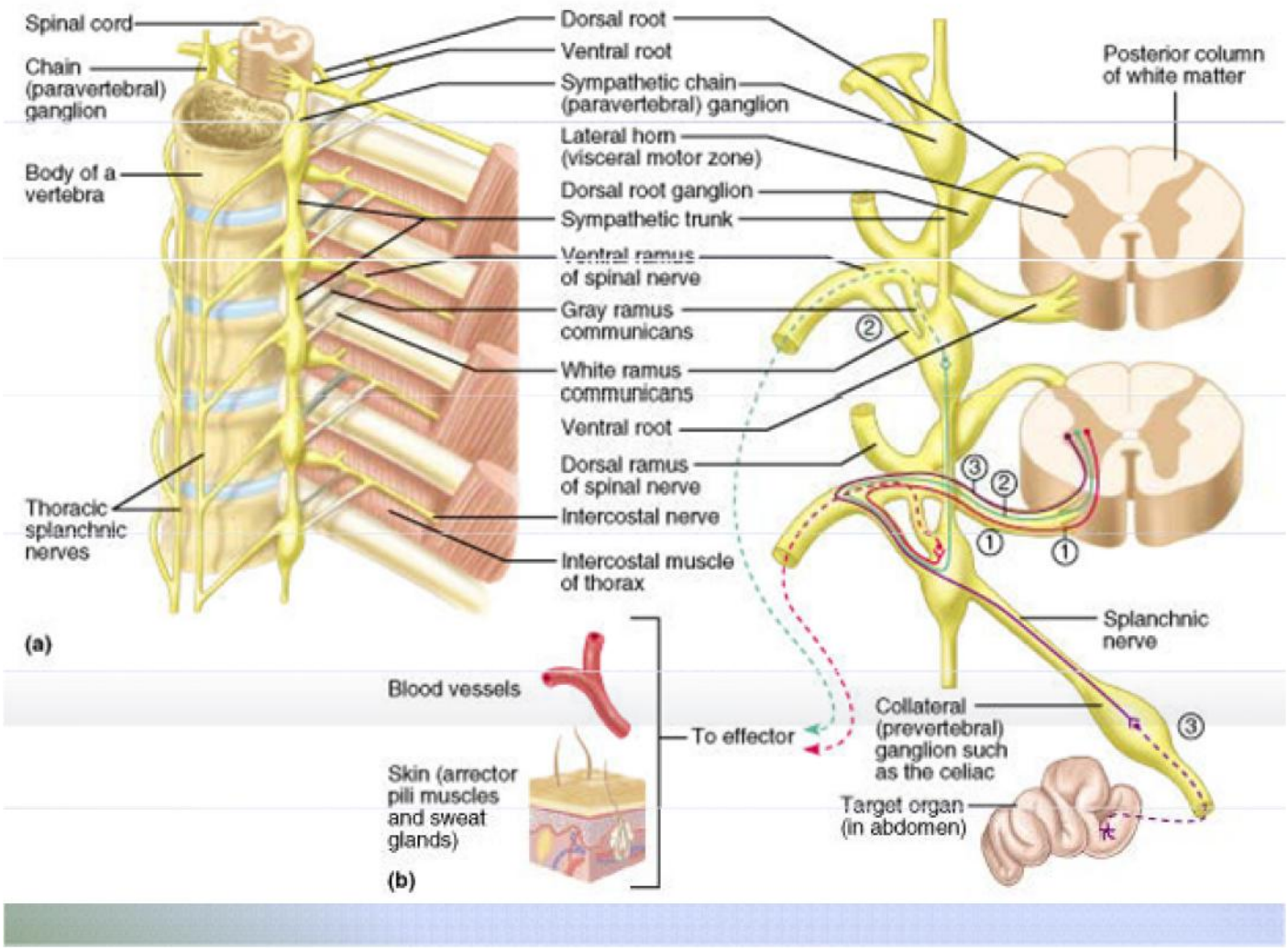
Target Organ	***Parasympathetic Effects***	***Sympathetic Effects***
Cardiac Muscle	Decreases HR.	Increases HR and force of contraction.
Coronary Blood Vessels	Constricts.	Dilates
Urinary Bladder; Urethra	Contracts bladder smooth muscle; relaxes urethral sphincter.	Relaxes bladder smooth muscle; contracts urethral sphincter.
Lungs	Contracts bronchiole (small air passage) smooth muscle.	Dilates bronchioles.
Digestive Organs	Increases peristalsis and enzyme/mucus secretion.	Decreases glandular and muscular activity.
Liver	No innervation	No innervation (indirect effect).

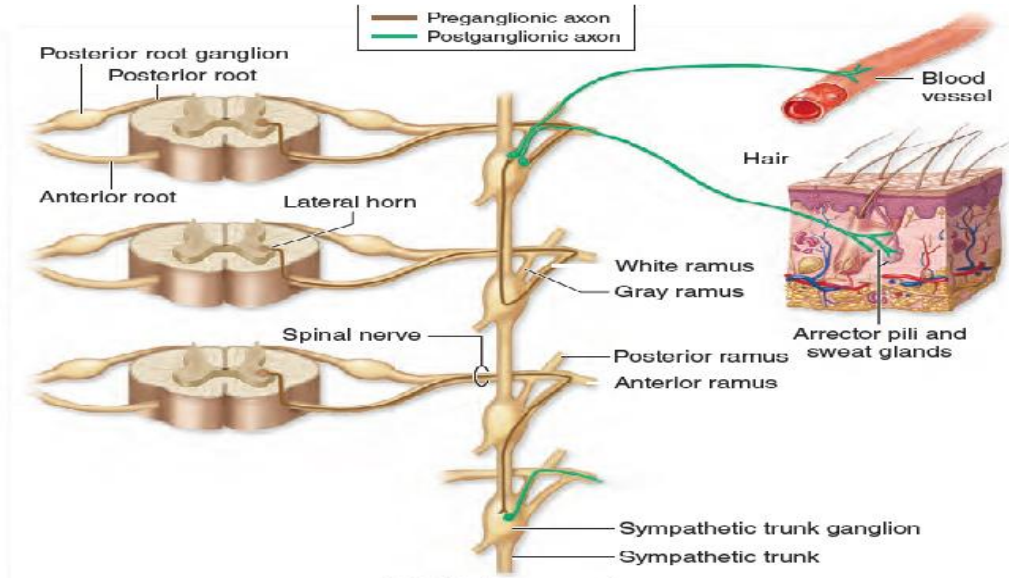
Target Organ	Parasympathetic Effects	Sympathetic Effects
Kidney	No innervation.	Releases the enzyme renin which acts to increase BP.
Penis	Vasodilates penile arteries. Erection.	Smooth muscle contraction. Ejaculation.
Vagina; Clitoris	Vasodilation. Erection.	Vaginal reverse peristalsis.
Blood Coagulation	No effect.	Increases coagulation rate.
Cellular Metabolism	No effect.	Increases metabolic rate.
Adipose Tissue	No effect.	Stimulates fat breakdown.

Target Organ	Parasympathetic Effects	Sympathetic Effects
Mental Activity	No innervation.	Increases alertness.
Blood Vessels	Little effect.	Constricts most blood vessels and increases BP. Exception – dilates blood vessels serving skeletal muscle fibers (cholinergic).
Uterus	Depends on stage of the cycle.	Depends on stage of the cycle.
Endocrine Pancreas	Stimulates insulin secretion.	Inhibits insulin secretion.

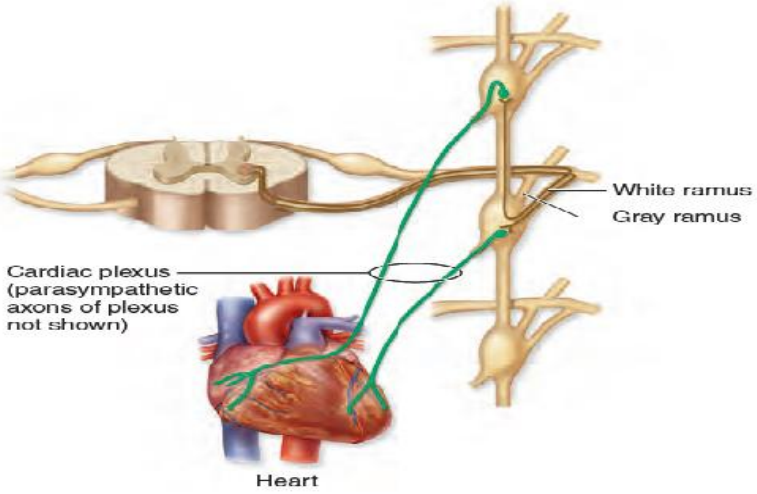
ffuse?

- Preganglionic fibers have their somata in the lateral horns of the thoracic and lumbar spinal cord.
- Preganglionic fibers leave the cord via the ventral root and enter a white ramus communicans to enter a chain ganglion – which is part of the sympathetic trunk.
- Let's look at a picture!

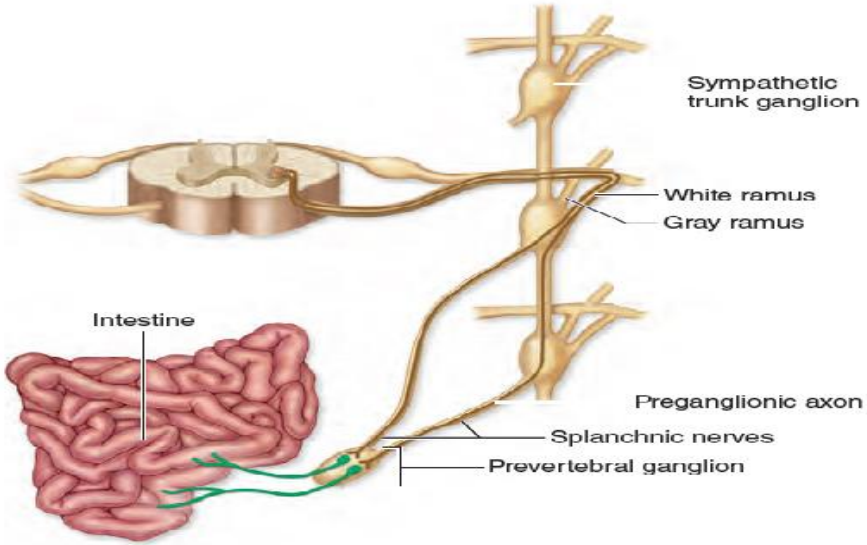

Spinal cord
Chain (paravertebral) ganglion
Body of a vertebra
Thoracic splanchnic nerves
(a)
Dorsal root
Ventral root
Sympathetic chain (paravertebral) ganglion
Lateral horn (visceral motor zone)
Dorsal root ganglion
Sympathetic trunk
Ventral ramus of spinal nerve
Gray ramus communicans
White ramus communicans
Ventral root
Dorsal ramus of spinal nerve
Intercostal nerve
Intercostal muscle of thorax
Posterior column of white matter
Splanchnic nerve
Collateral (prevertebral) ganglion such as the celiac
Target organ (in abdomen)
Blood vessels
Skin (arrector pili muscles and sweat glands)
To effector
(b)



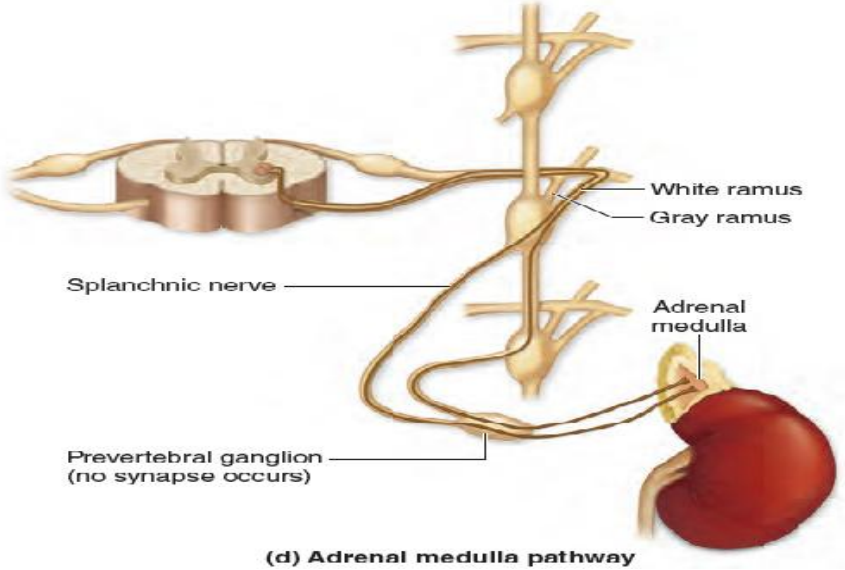
(a) Spinal nerve pathway
(to integumentary structures)



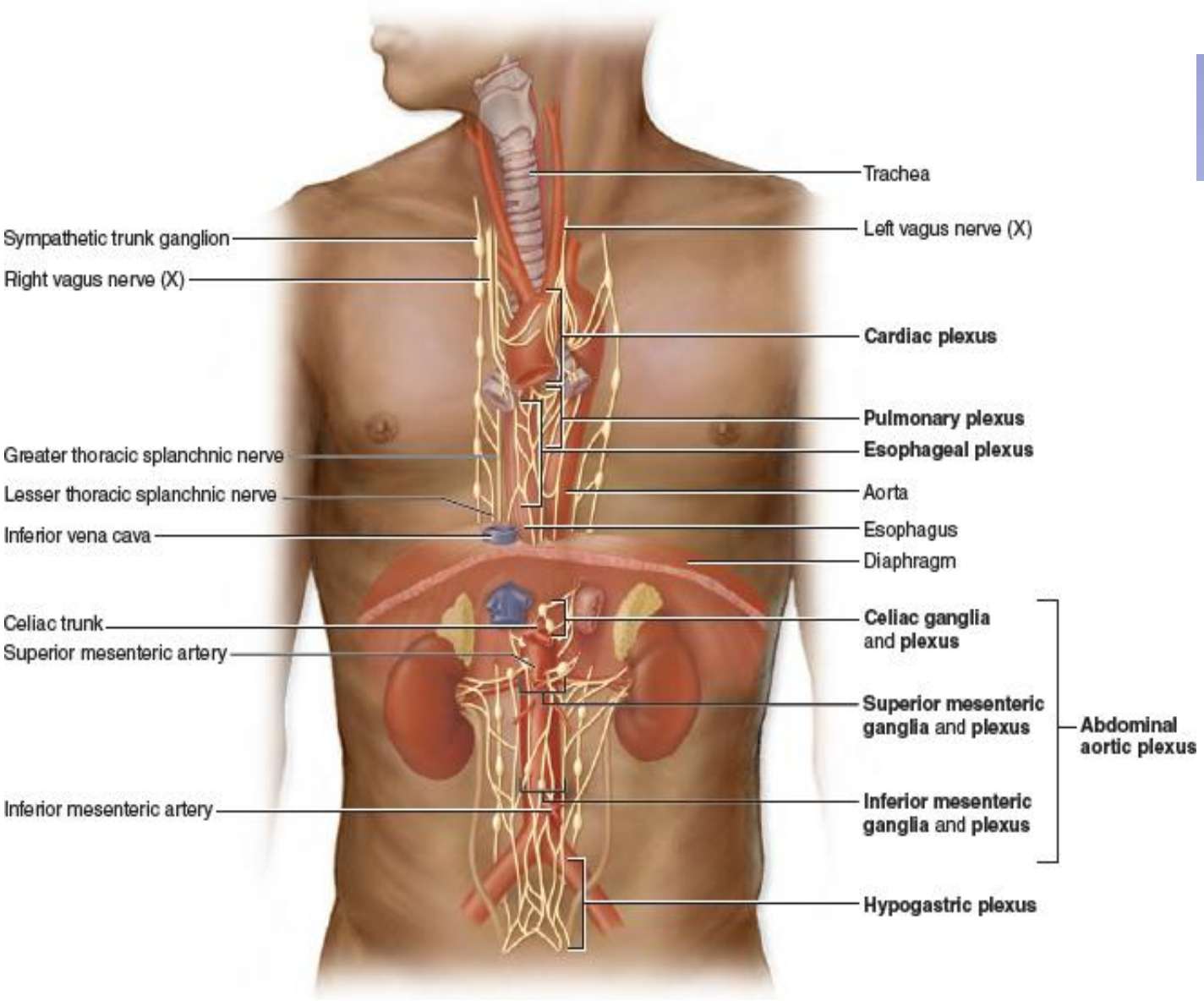
(b) Postganglionic sympathetic nerve pathway
(to head, neck, thoracic viscera)



(c) Splanchnic nerve pathway
(to abdominal and pelvic viscera)



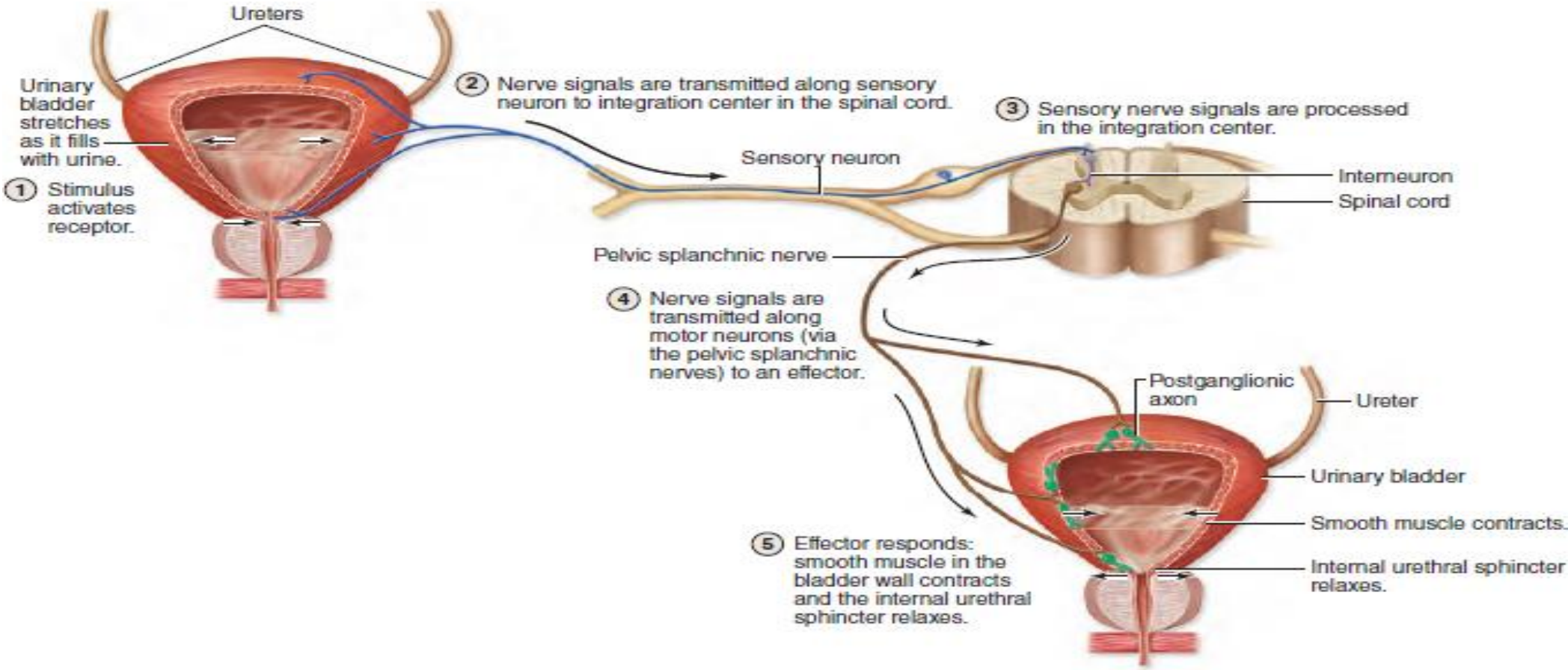
(d) Adrenal medulla pathway



Autonomic Plexuses.

Autonomic plexuses are located in the anterior body cavities in both the thoracic and abdominopelvic cavities.

This anterior view shows the cardiac, pulmonary, and esophageal plexuses in the thoracic cavity and the abdominal aortic plexus (celiac, superior mesenteric, inferior mesenteric plexuses) in the abdominopelvic cavity.



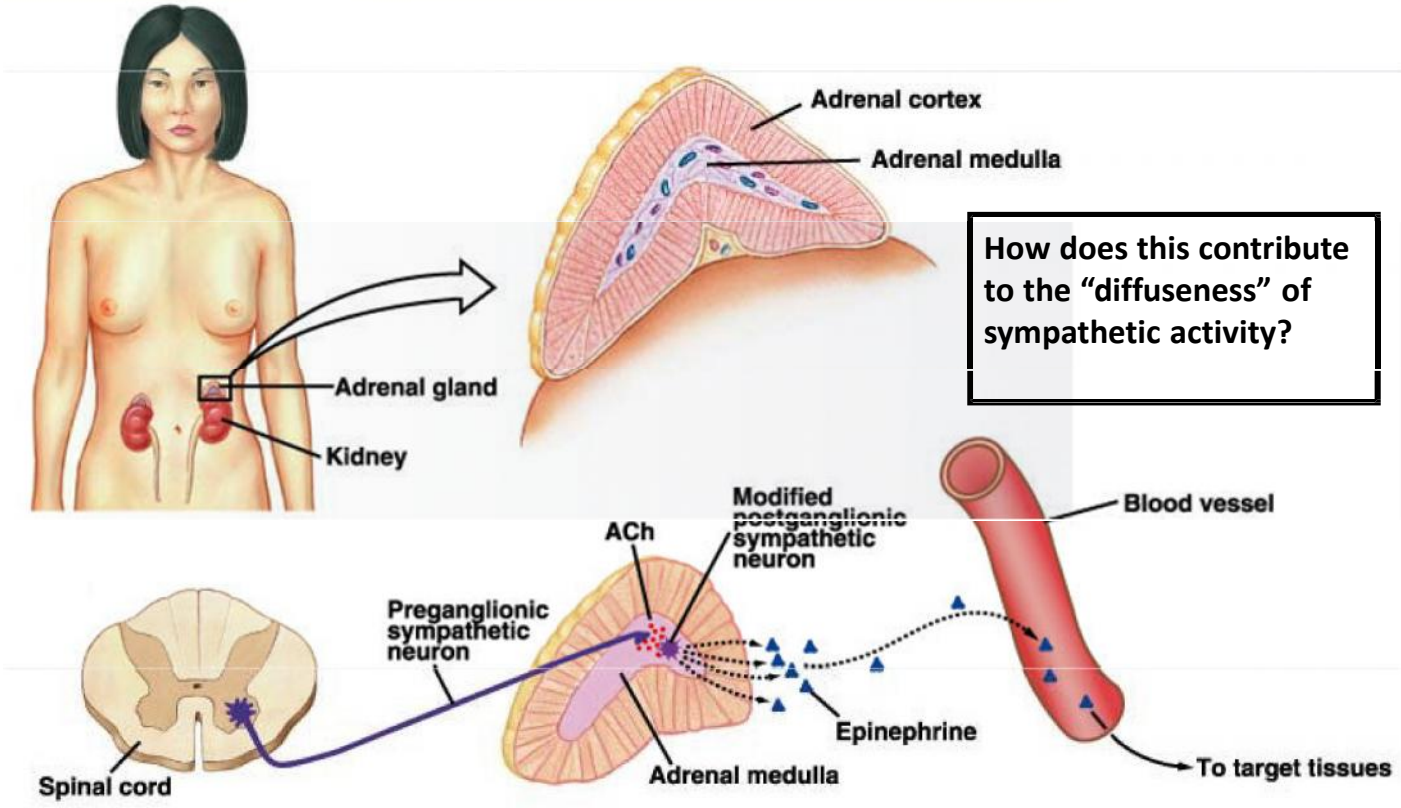
- **Autonomic Reflexes**.
- An autonomic reflex involves stimulation of an automatic effector.
- Here, the reflex is initiated as baroreceptors in the bladder wall are stretched and nerve signals are transmitted along sensory neurons to interneurons within the CNS.
- Nerve signals are then transmitted along motor neurons to stimulate the effector.
- The effector response is the contraction of the urinary bladder wall and relaxation of the internal urethral sphincter.

Once a preganglionic axon reaches the chain ganglion, it may:

1. …synapse with a ganglionic neuron w/i the same chain ganglion.

2. …ascend or descend in the trunk to synapse within another chain ganglion.

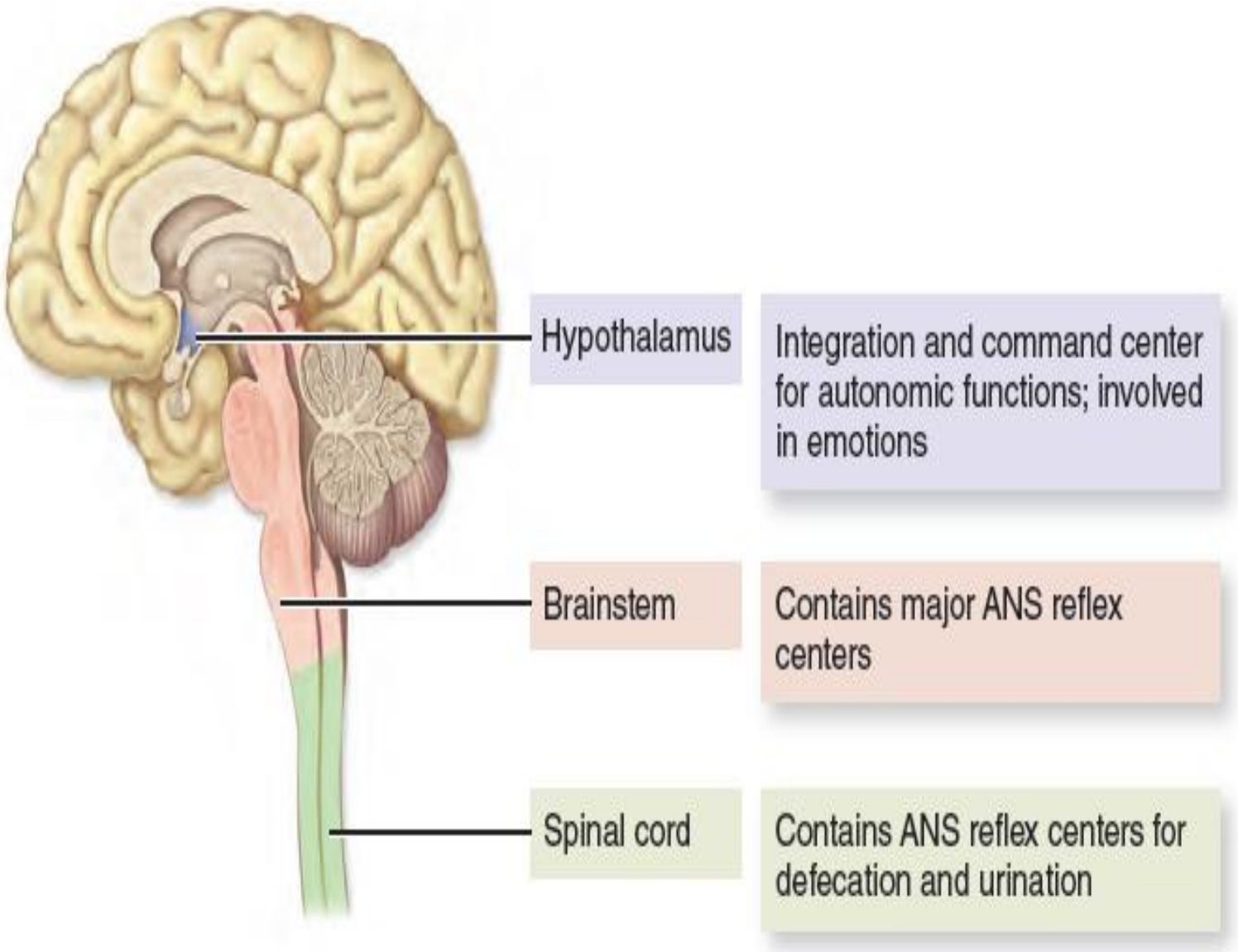
3. …pass thru the chain ganglion and emerge from the chain w/o synapsing.

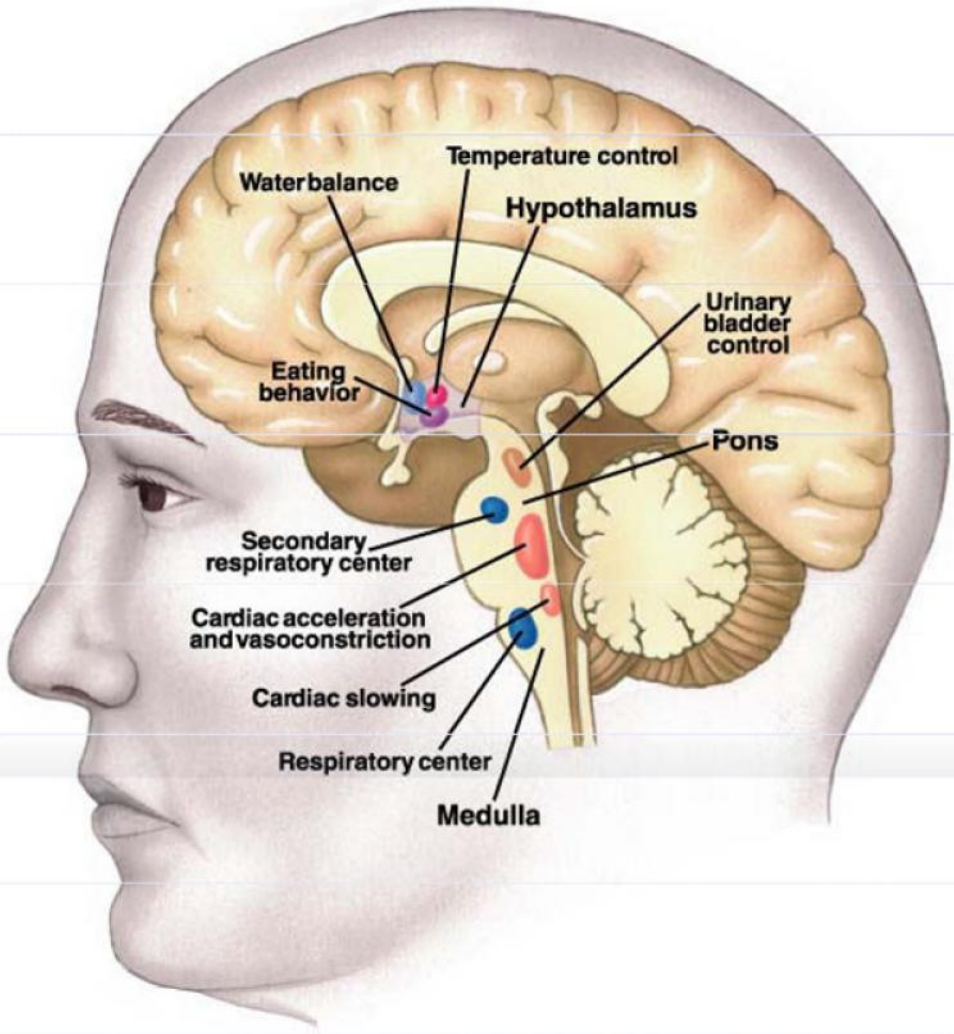


How does this contribute to the "diffuseness" of sympathetic activity?

How Does the Brain *Control* the ANS?

- The hypothalamus is the Boss:
  - Its anterior and medial regions direct parasympathetic function while its posterior and lateral regions direct sympathetic function
  - These centers exert control directly and via nuclei in the reticular formation (e.g., the cardiovascular centers in the MO, respiratory centers in MO and pons, etc.)
  - The connection of the limbic system to the hypothalamus mediates our “flight or flight” response to emotional situations.
  - The relationship btwn the hypothalamus and the amygdala and periaquaductal gray matter allow us to respond to fear.


Hypothalamus
Integration and command center for autonomic functions; involved in emotions
Brainstem
Contains major ANS reflex centers
Spinal cord
Contains ANS reflex centers for defecation and urination


Water balance
Temperature control
Hypothalamus
Urinary bladder control
Eating behavior
Pons
Secondary respiratory center
Cardiac acceleration and vasoconstriction
Cardiac slowing
Respiratory center
Medulla

Innervation of Visceral Muscle and Glands

- Autonomic motor endings and visceral effectors are simpler than somatic junctions
- Branches form *synapses en passant* via varicosities
- Acetylcholine and norepinephrine are used as neurotransmitters
- Visceral responses are slower than somatic responses

Pancoast Tumor

- **Horner's Syndrome**:
Secondary to involvement of sympathetic chain.