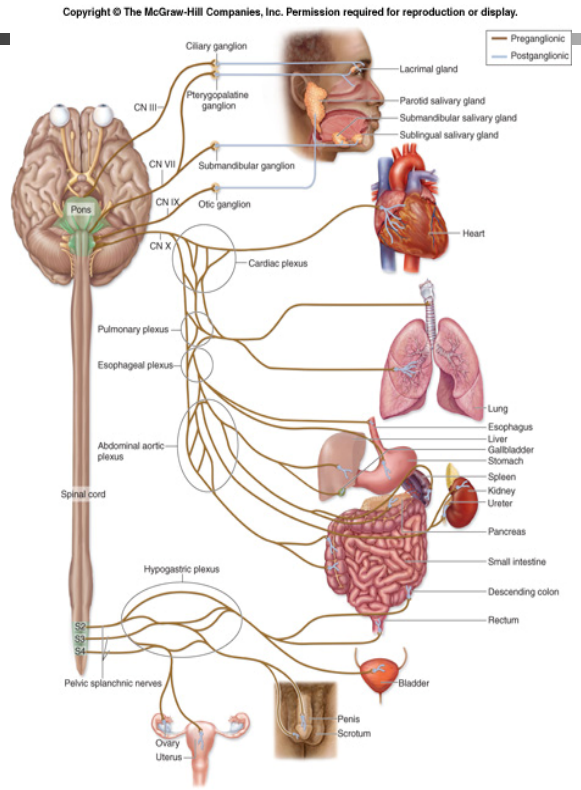
Human Anatomy



Autonomic Nervous System

Autonomic Nervous System

- ANS
  - complex system of nerves
  - controls involuntary actions.
- Works with the somatic nervous system (SNS)
  - regulates body organs
  - maintains normal internal functions.

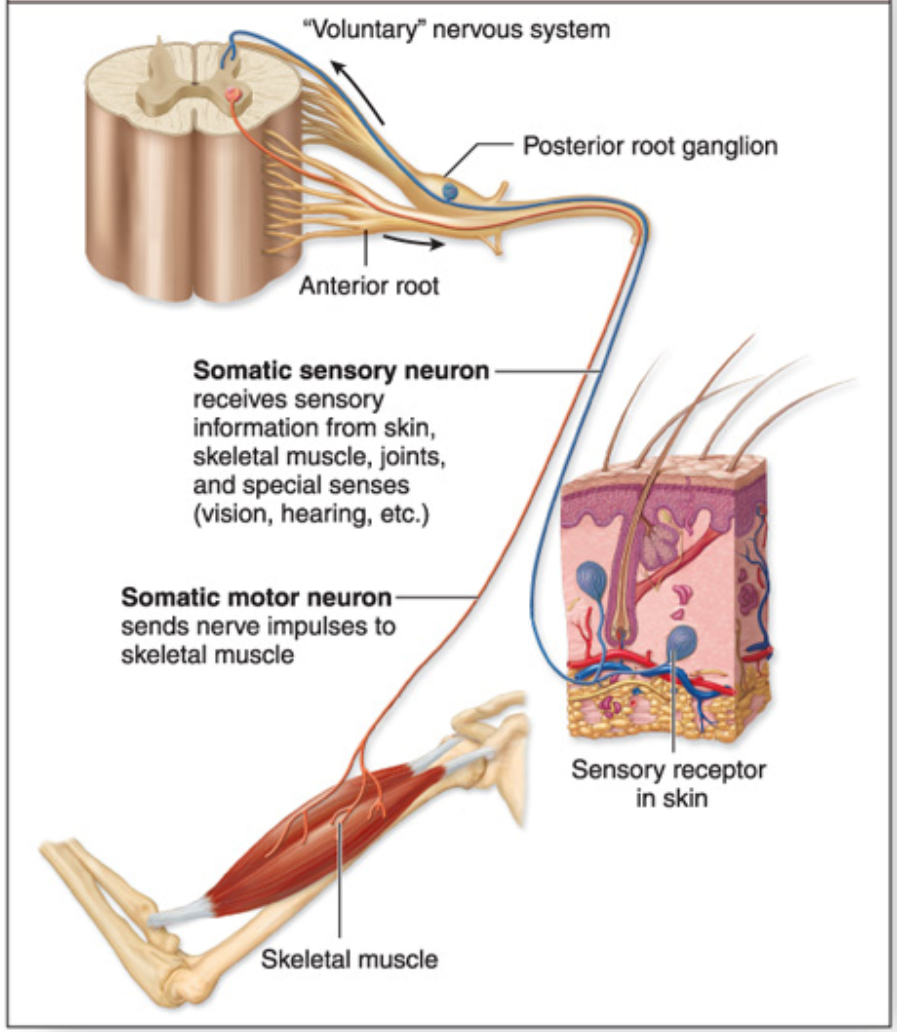
SNS, PNS, and ANS

- SNS and ANS are both part of the peripheral nervous system (PNS).
  - SNS operates under our conscious control.
  - ANS functions are involuntary.

Comparison of SNS and ANS

- SNS uses both somatic sensory and somatic motor neurons
  - Somatic sensory neurons conduct stimulus information from a sensory receptor
  - Somatic motor neurons innervate skeletal muscle fibers.
- ANS also utilizes sensory and motor neurons.
  - Visceral sensory neurons provide input to activate the ANS
  - Visceral motor neurons innervate smooth muscle, cardiac muscle, and glands

Somatic Nervous System



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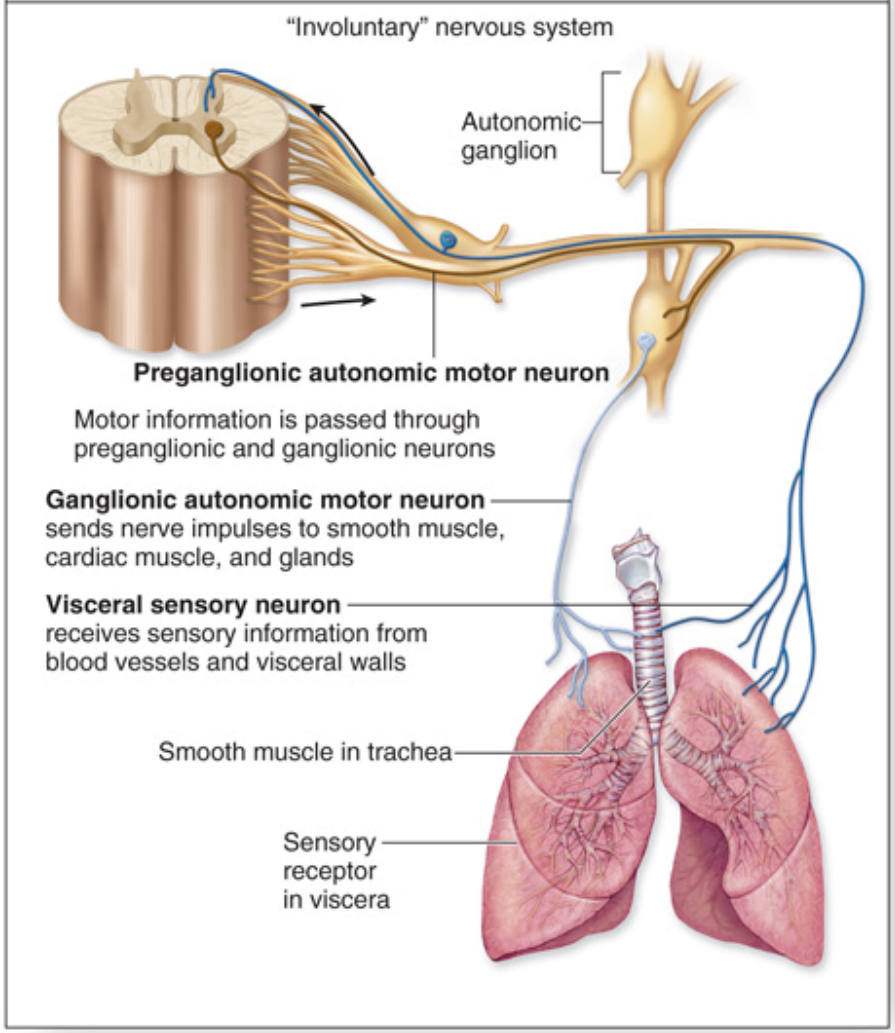
Autonomic (Visceral) Nervous System

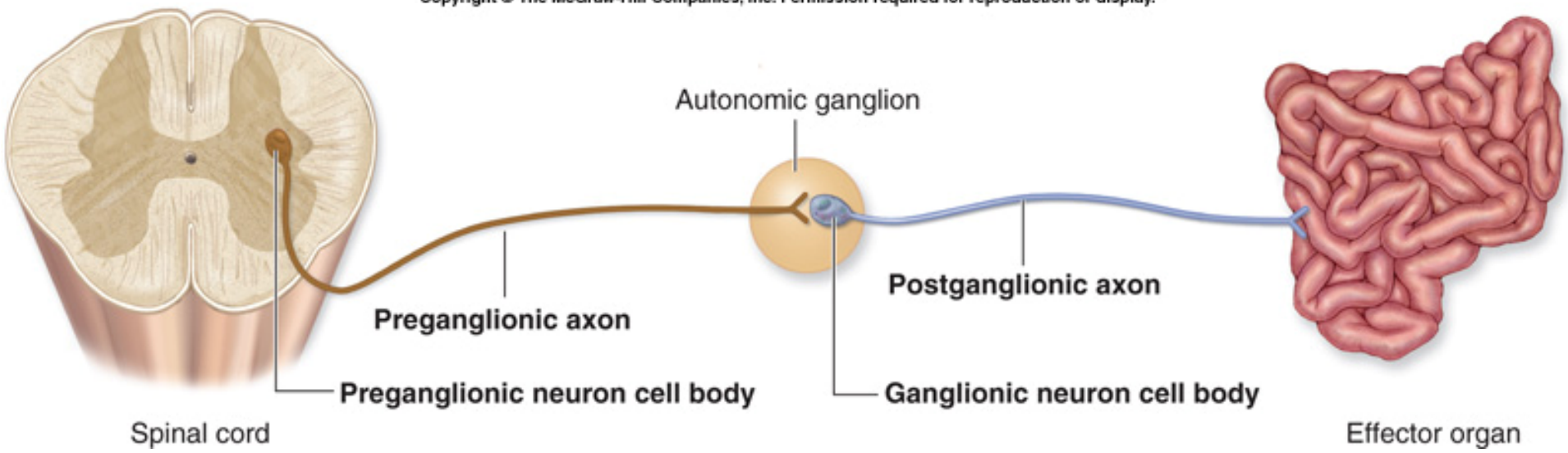


Neuron Chains in ANS

- Preganglionic neurons
  - Before the ganglion
- Ganglion
  - Synapse
  - Grey matter
- Postganlionic neurons
  - After the ganglion

Neuron Chains

- Neuronal convergence
  - occurs when axons from numerous preganglionic cells synapse (converge) on a single postganglionic cell.
- Neuronal divergence
  - occurs when axons from one preganglionic cell synapse on numerous postganglionic cells



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)
    - innervates muscles or glands.
  - Both contain autonomic ganglia
    - house the cell body of the preganglionic neurons.
  - Both are involuntary
  - Both are concerned with the body's internal environment. (homeostasis)
- Divisions perform dramatically different functions.

The Parasympathetic Division

- Also termed the craniosacral division.
- Primarily concerned with:
  - conserving energy
  - replenishing nutrient stores.
- Is most active when the body is at rest or digesting a meal.
  - nicknamed the “rest-and-digest” division
- Works with the sympathetic division in maintaining homeostasis (a constant internal environment).

The Sympathetic Division

- Also termed the thoracolumbar division.
- Primarily concerned with preparing the body for emergencies.
  - referred to as the “fight-or-flight” division
- Increased sympathetic activity results in:
  - increased alertness
  - Increased metabolic activity

Components of Autonomic (Motor) Nervous System

Parasympathetic (Craniosacral) Division

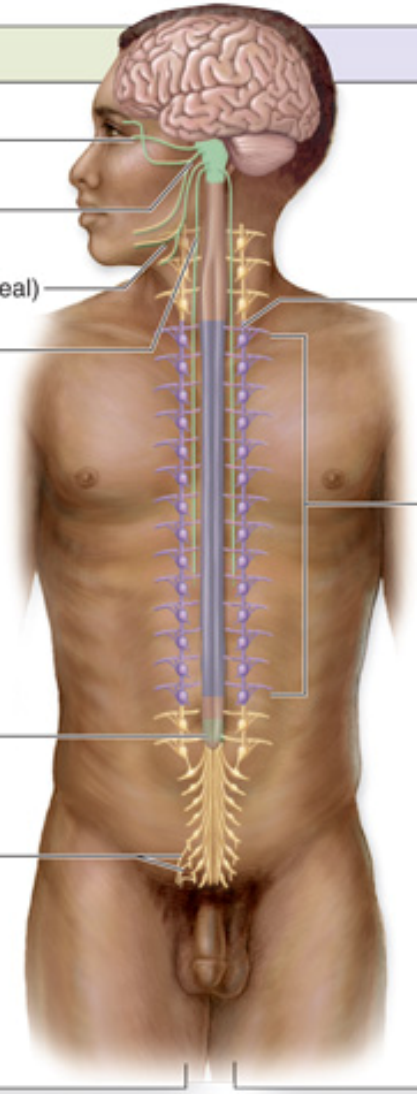
Origin:
Preganglionic neurons located in brainstem nuclei and S2–S4 regions of spinal cord

Functions:
- "Rest and digest" response
- Brings body to homeostasis

Sympathetic (Thoracolumbar) Division

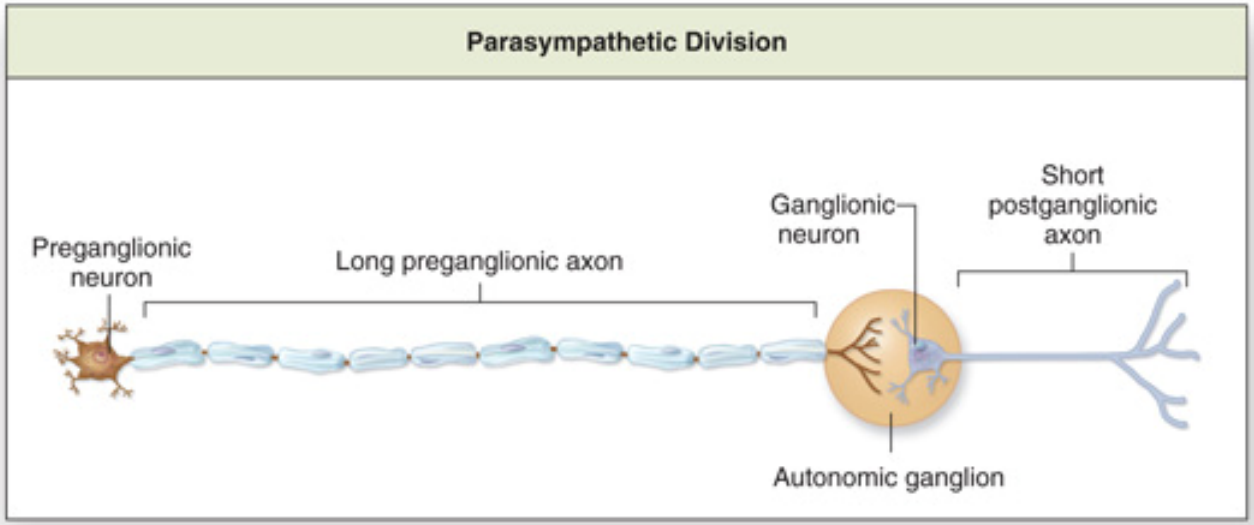
Origin:
Preganglionic neurons located in lateral horns of T1–L2 regions of spinal cord

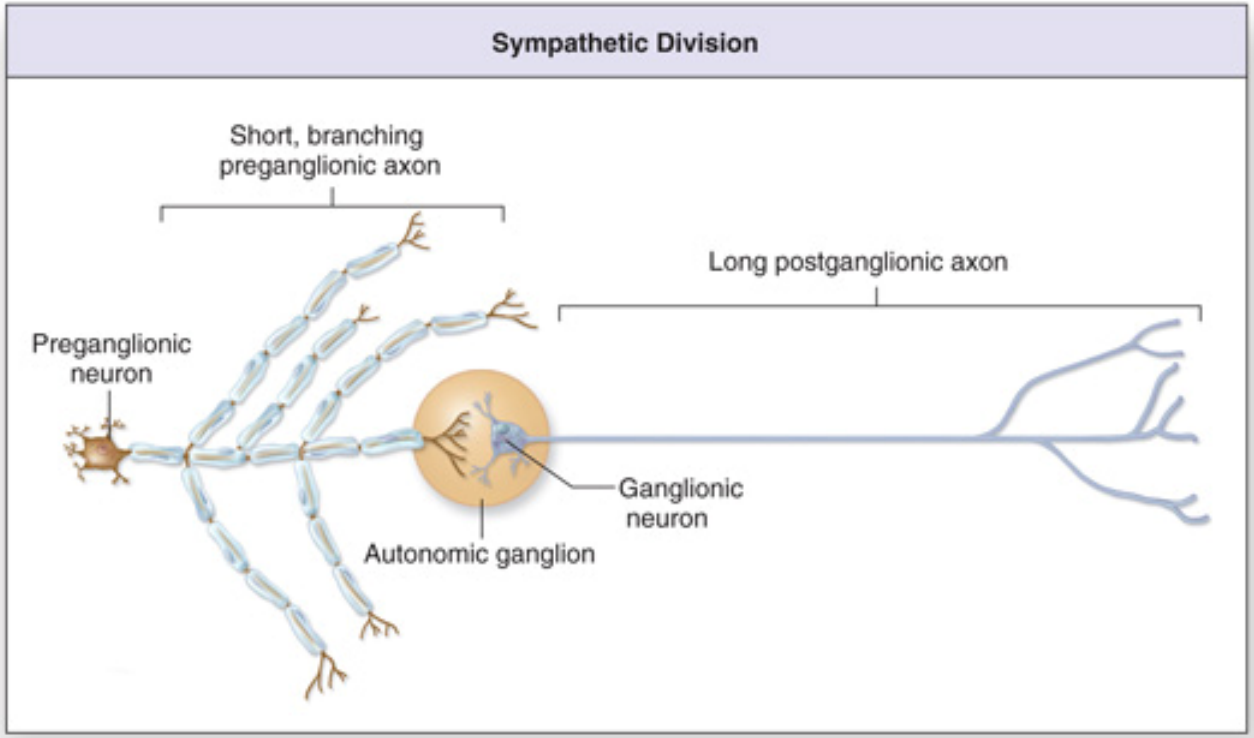
Functions:
- Activated in emergency situations
- "Fight-or-flight" response
- Also involved with homeostasis



Anatomic Differences

- Divisions are distinguished by several anatomic differences.
- Preganglionic neuron cell bodies are housed in different regions of the CNS.
  - Parasympathetic preganglionic neurons originate in either:
    - Brainstem
    - lateral gray matter of the S2–S4 spinal cord regions.
  - Sympathetic preganglionic neurons originate in:
    - lateral horns of the T1–L2 spinal cord regions





Anatomic Differences

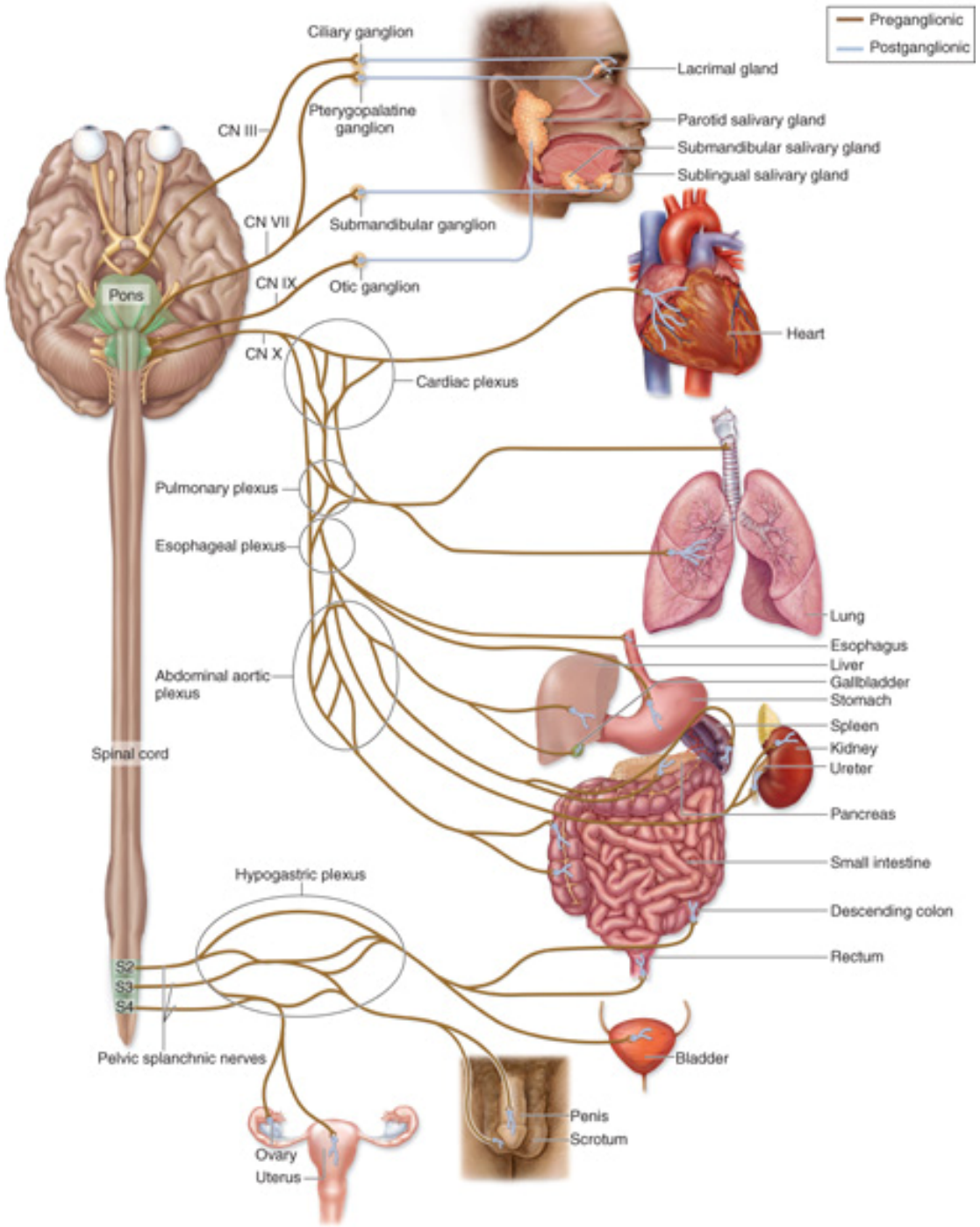
- Parasympathetic division is structurally simple.
- Parasympathetic division is also termed the craniosacral division because its preganglionic neurons are:
  - housed within nuclei in the brainstem
  - within the lateral gray regions of the S2–S4 spinal cord segments.
- Postganglionic neurons in the parasympathetic division are found in
  - terminal ganglia: are located close to the target organ
  - intramural ganglia: located within the wall of the target organ

Cranial Nerves: parasympathetic division

- Associated with the parasympathetic division:
  - the oculomotor (CN III)
  - facial (CN VII)
  - glossopharyngeal (CN IX)
  - vagus (CN X)
- First three of these nerves convey parasympathetic innervation to the head.
- Vagus nerve is the source of parasympathetic stimulation for:
  - thoracic organs
  - most abdominal organs.

Spinal Nerves: parasympathetic division

- Target organs innervated include:
  - the distal portion of the large intestine
  - the rectum
  - most of the reproductive organs
  - the urinary bladder
  - the distal part of the ureter.
- Parasympathetic innervation causes
  - increased smooth muscle motility (muscle contraction) and secretory activity in digestive tract organs
  - contraction of smooth muscle in the bladder wall
  - erection of the female clitoris and the male penis



Effects and General Functions of the Parasympathetic Division

- Parasympathetic division is most active during times when the body must process nutrients and conserve energy.
- Lack of extensive divergence in preganglionic axons
  - prevents the mass activation seen in the sympathetic division.
- Effects of the parasympathetic nervous system tend to be discrete and localized.
- Parasympathetic activity can affect one group of organs without necessarily having to "turn on" all other organs

Organization and Anatomy of the Sympathetic Division

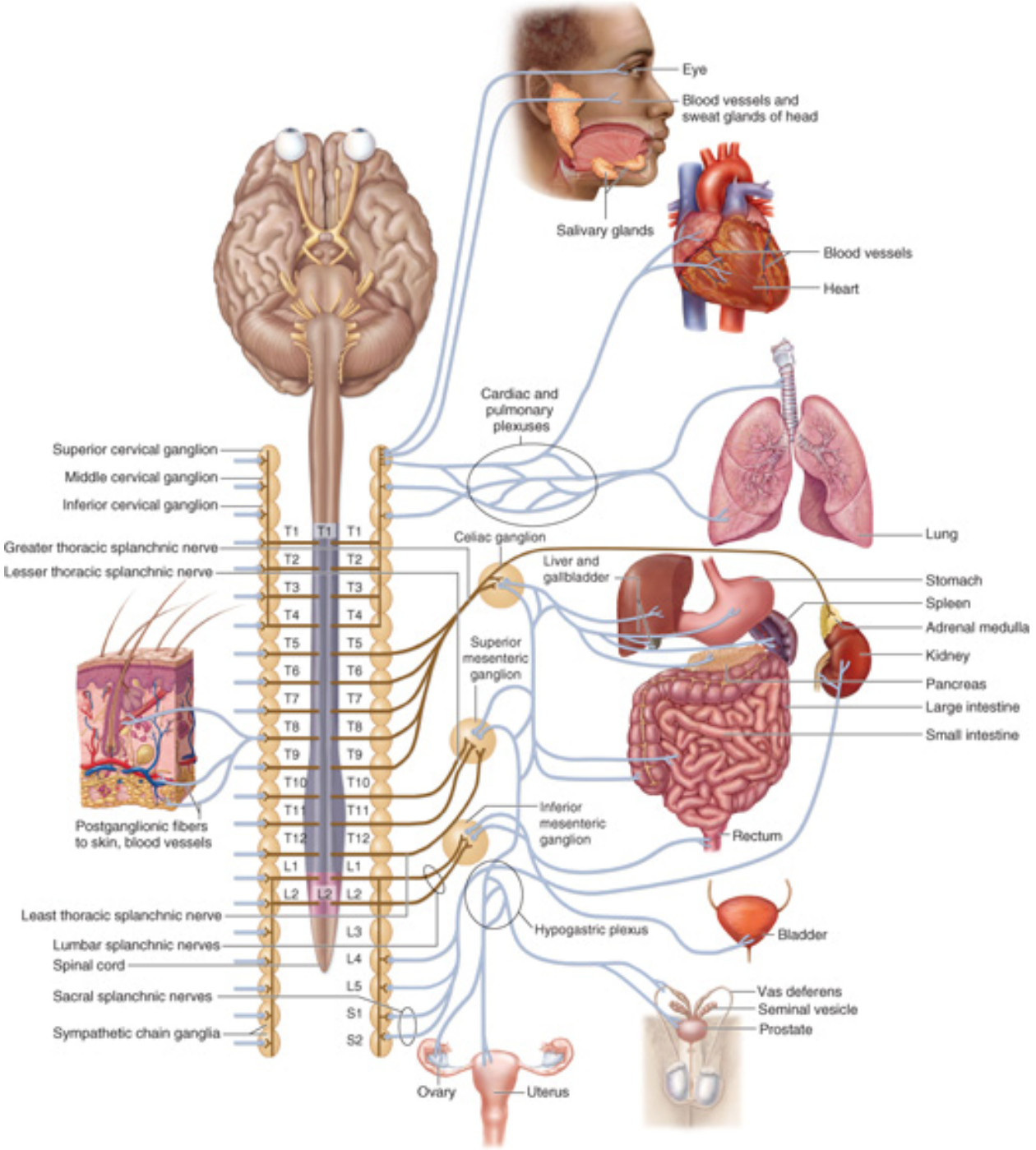
- Much more complex than the parasympathetic division.
- Sympathetic preganglionic neuron cell bodies
  - housed in the lateral horn of the T1–L2
- Preganglionic sympathetic axons:
  - travel with somatic motor neuron axons
  - exit the spinal cord
    - enter first the anterior roots
    - then the T1–L2 spinal nerves.
- Preganglionic sympathetic axons remain with the spinal nerve for a short distance
  - they branch off and leave the spinal nerve

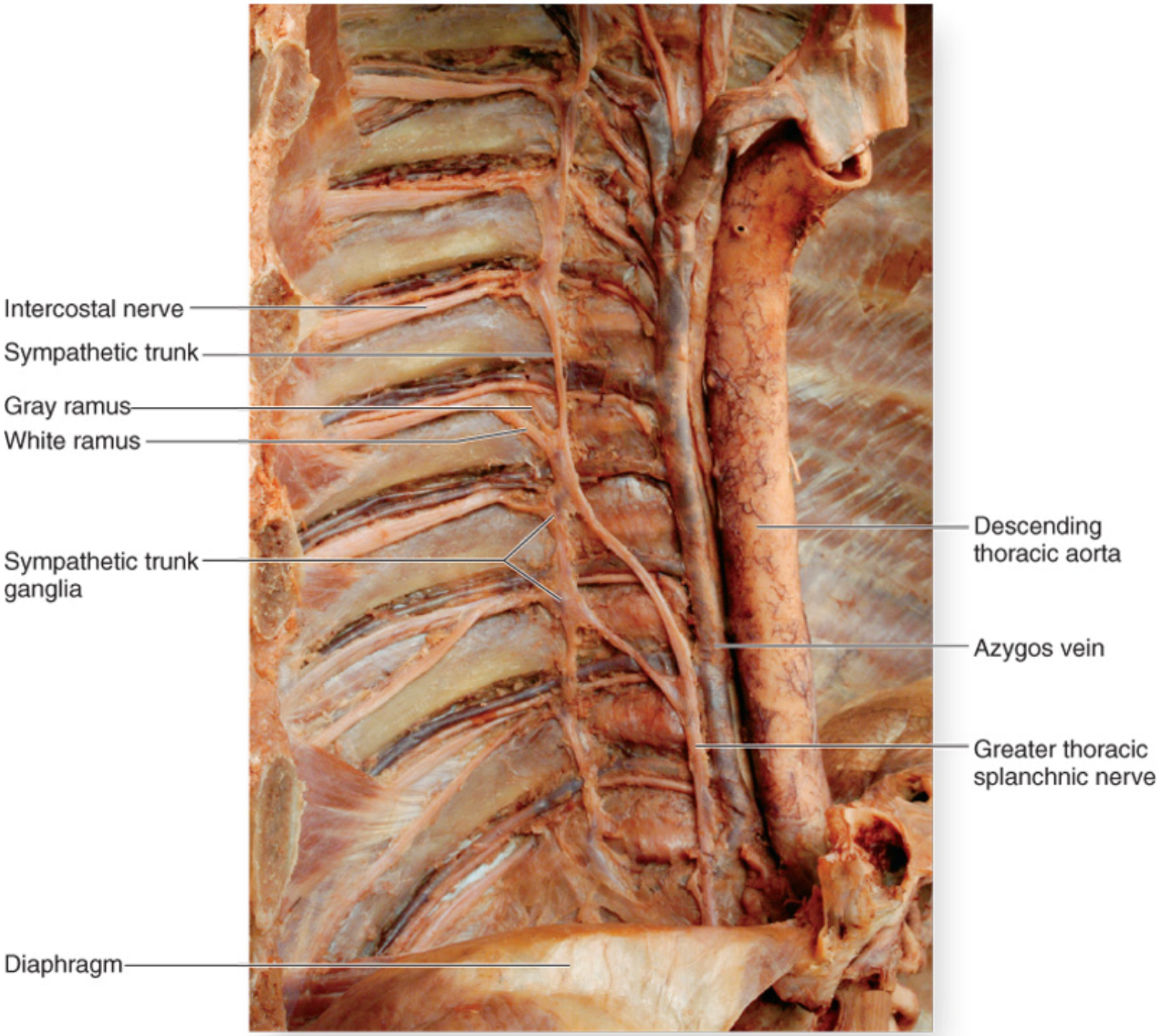
Left and Right Sympathetic Trunks

- 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

Left and Right Sympathetic Trunks

- 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.





White Rami

- Connecting the spinal nerves to each sympathetic trunk are rami communicantes.
- Carry preganglionic sympathetic axons from the T1–L2 spinal nerves to the sympathetic trunk.
- Associated only with the T1–L2 spinal nerves.
- Preganglionic axons are myelinated.
  - the white ramus has a whitish appearance
- Similar to “entrance ramps” on a highway.

Gray Rami

- Carry postganglionic sympathetic axons
  - from the sympathetic trunk to the spinal nerve.
- Axons are unmyelinated.
  - gray rami have a grayish appearance
- Similar to “exit ramps” on a highway.
- Connect to all spinal nerves.
- Sympathetic information that starts in the thoracolumbar region can be dispersed to all parts of the body.

Splanchnic Nerves

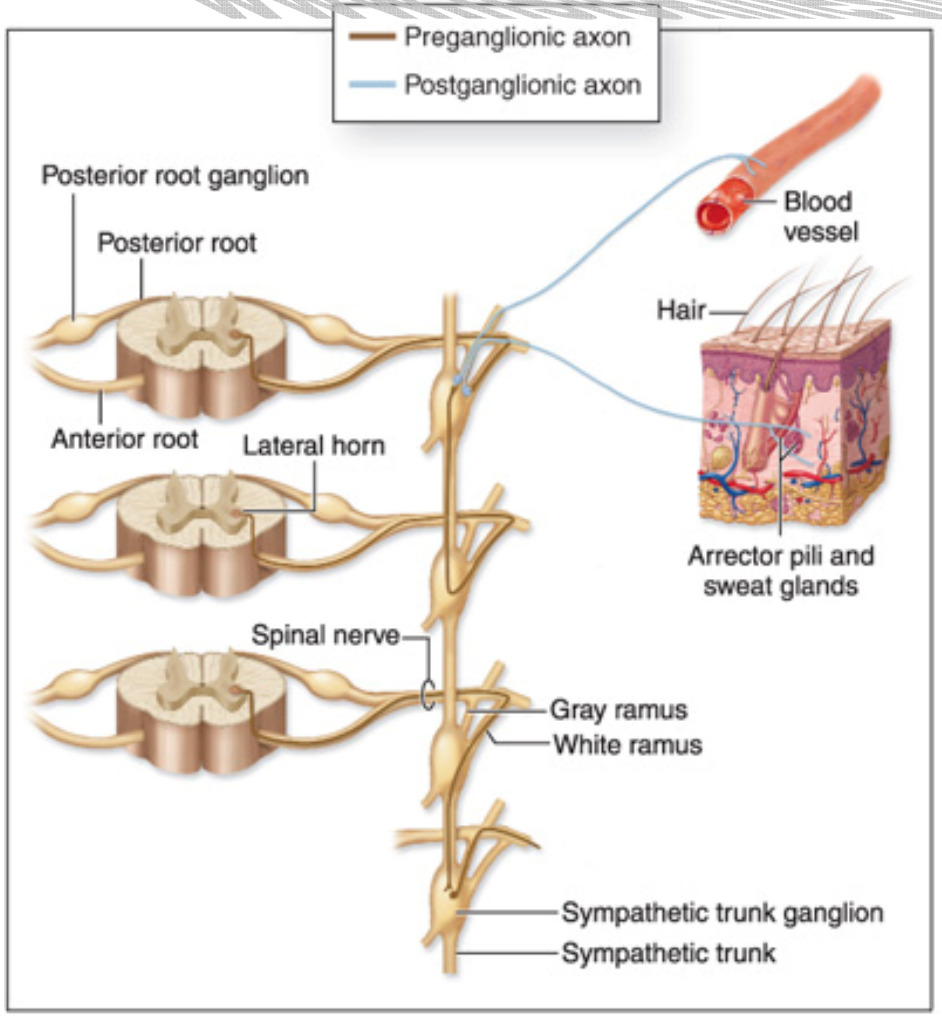
- Composed of preganglionic sympathetic axons.
- Run anteriorly from the sympathetic trunk to most of the viscera.
- Should not be confused with the pelvic splanchnic nerves associated with the parasympathetic division.
- Larger splanchnic nerves have specific names:
  - greater thoracic splanchnic nerves
  - lesser thoracic splanchnic nerves
  - least thoracic splanchnic nerves
  - lumbar splanchnic nerves
  - sacral splanchnic nerves

Splanchnic Nerves

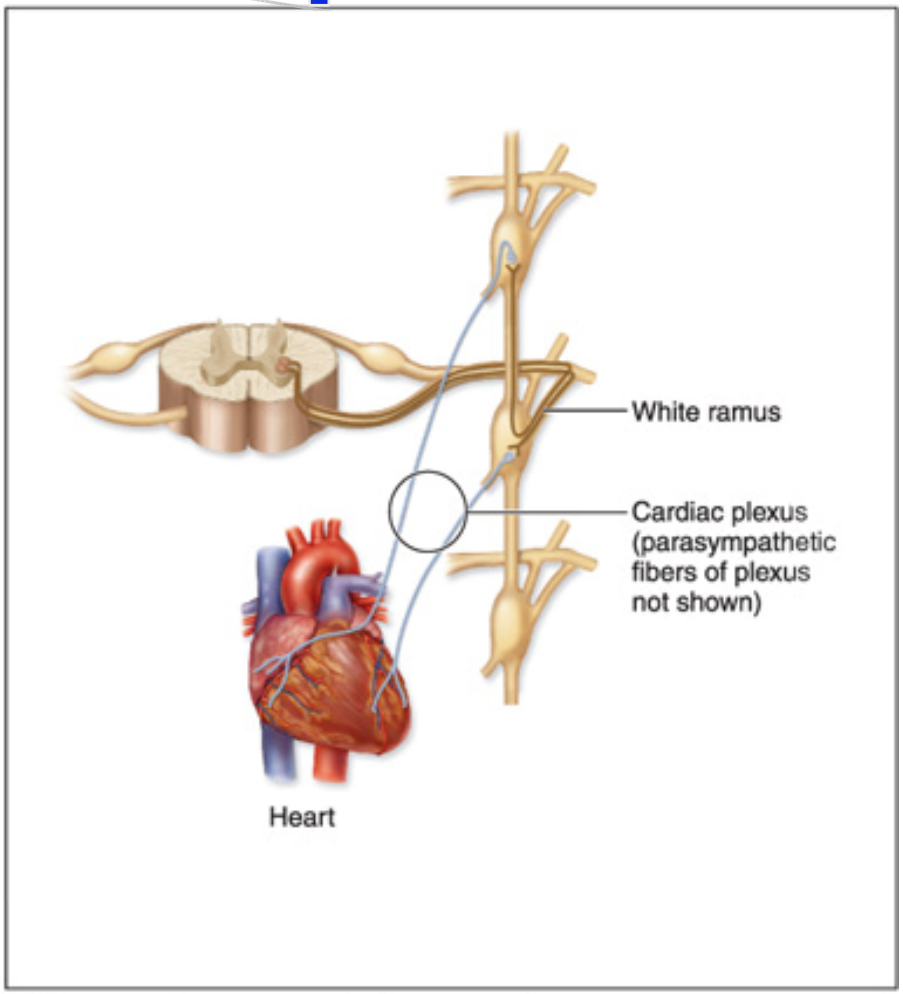
- Terminate in prevertebral (or collateral) ganglia.
- Called “prevertebral” because they are immediately anterior to the vertebral column.
- Prevertebral ganglia typically cluster around the major abdominal arteries and are named for these arteries.
  - Example: celiac ganglia cluster around the celiac trunk
- Sympathetic postganglionic axons extend away from the ganglia and innervate many of the abdominal organs.

Types of Prevertebral Ganglia

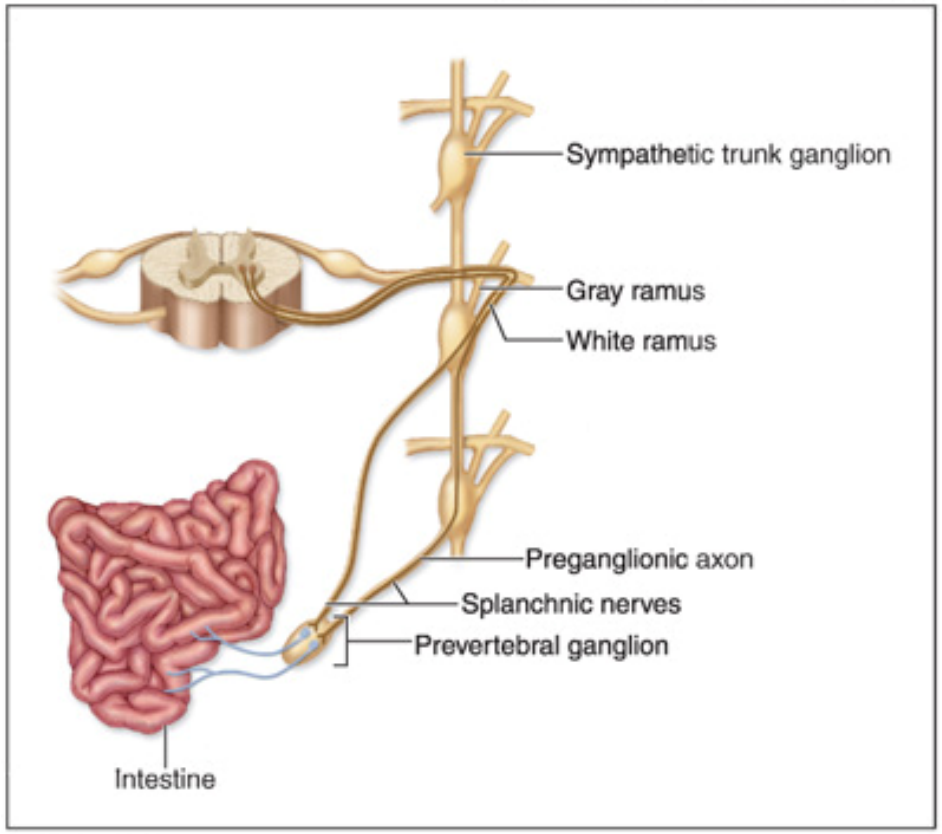
- Differ from the sympathetic trunk ganglia.
- Are single structures, rather than paired.
- Are anterior to the vertebral column on the anterior surface of the aorta.
- Located only in the abdominopelvic cavity.
- Prevertebral ganglia include:
  - the celiac ganglion
  - superior mesenteric ganglion
  - interior mesenteric ganglion.



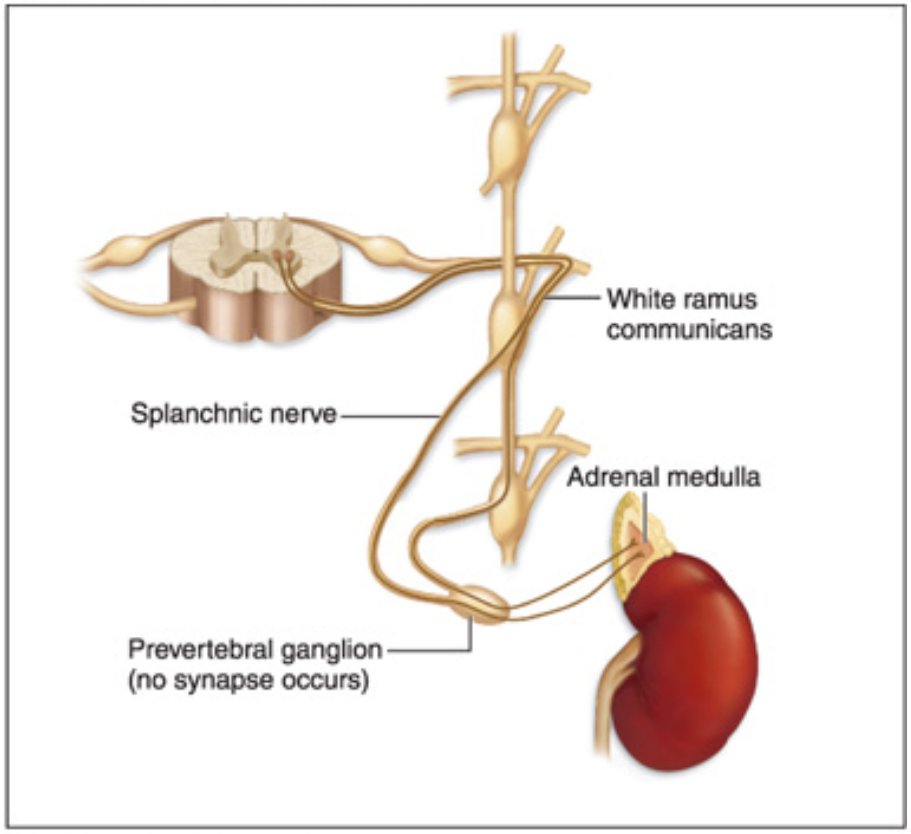
(a) Spinal nerve pathway



(b) Postganglionic sympathetic nerve pathway



(c) Splanchnic nerve pathway



(d) Adrenal medulla pathway

Sympathetic Pathways

- Spinal nerve pathway
- Postganglionic sympathetic nerve pathway
- The Splanchnic Nerve Pathway
- The Adrenal Medulla Pathway

Fight-or-Flight Function of the ANS

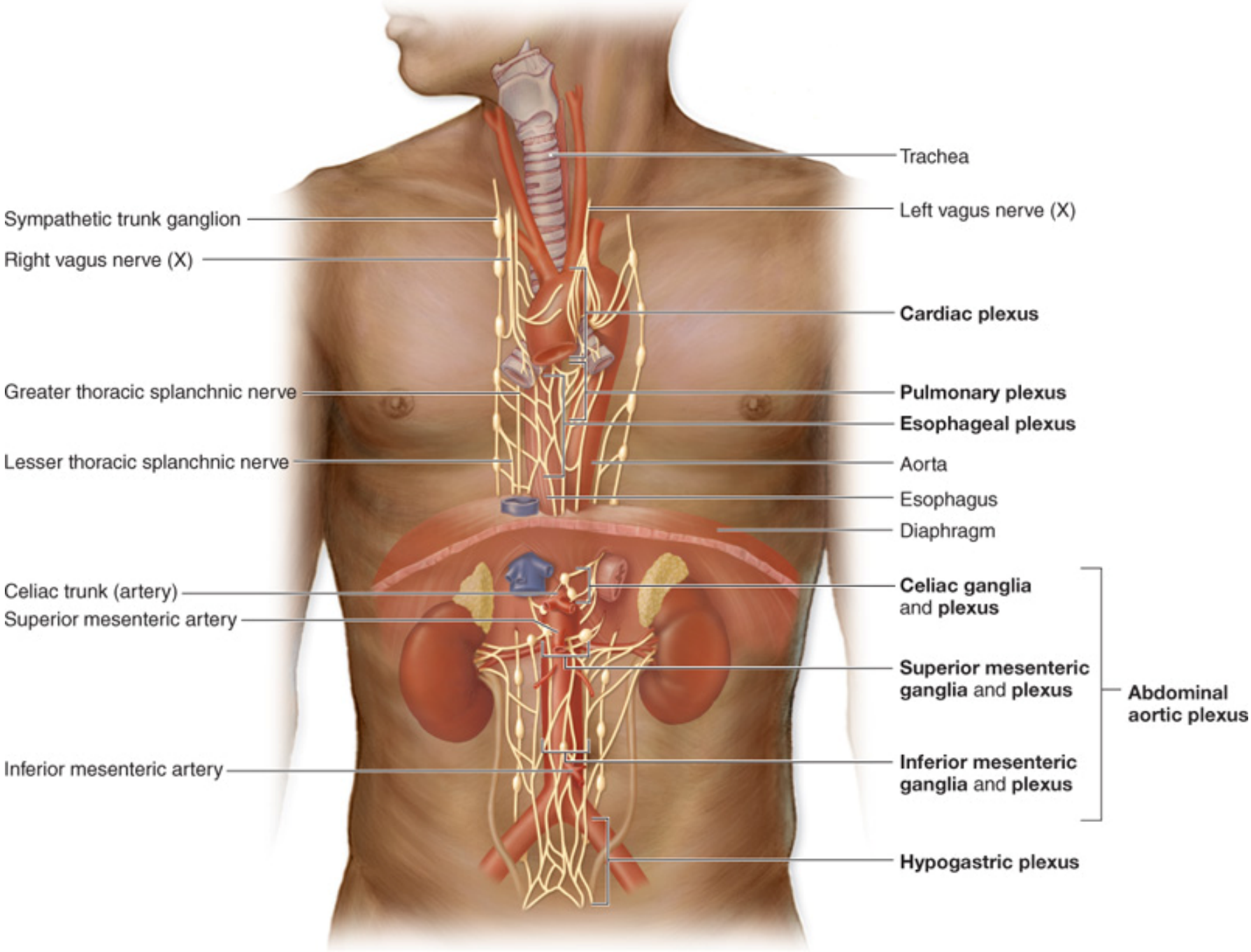
- May involve a single effector or many effectors.
- In mass activation, a large number of ganglionic neurons activate many effector organs.
  - causes a heightened sense of alertness due to stimulation of the reticular activation system

Dual Innervation by the Parasympathetic and Sympathetic Divisions of the ANS

- Innervate organs through specific axon bundles called autonomic plexuses.
- Communication by chemical messengers, called neurotransmitters.
  - specific in each division of the autonomic nervous system
- Usually all organs are innervated by both divisions of the autonomic nervous system.
- Maintains homeostasis through autonomic reflexes that occur in the innervated organs.

Autonomic Plexuses

- Collections of sympathetic postganglionic axons and parasympathetic preganglionic axons, as well as some visceral sensory axons.
- Close to one another, but they do not interact or synapse with one another.
- Provide a complex innervation pattern to their target organs.



Plexuses

- Cardiac plexus
  - increased sympathetic activity increases heart rate and blood pressure, while
  - increased parasympathetic activity decreases heart rate
- Pulmonary Plexus
  - parasympathetic pathway causes bronchoconstriction and increased secretion from mucous glands of the bronchial tree
  - sympathetic innervation causes bronchodilation
- Esophageal Plexus
  - parasympathetic axons control the swallowing reflex
- Abdominal aortic plexus
  - consists of the celiac plexus, superior mesenteric plexus, and inferior mesenteric plexus
- Hypogastric plexus

Neurotransmitters and Receptors

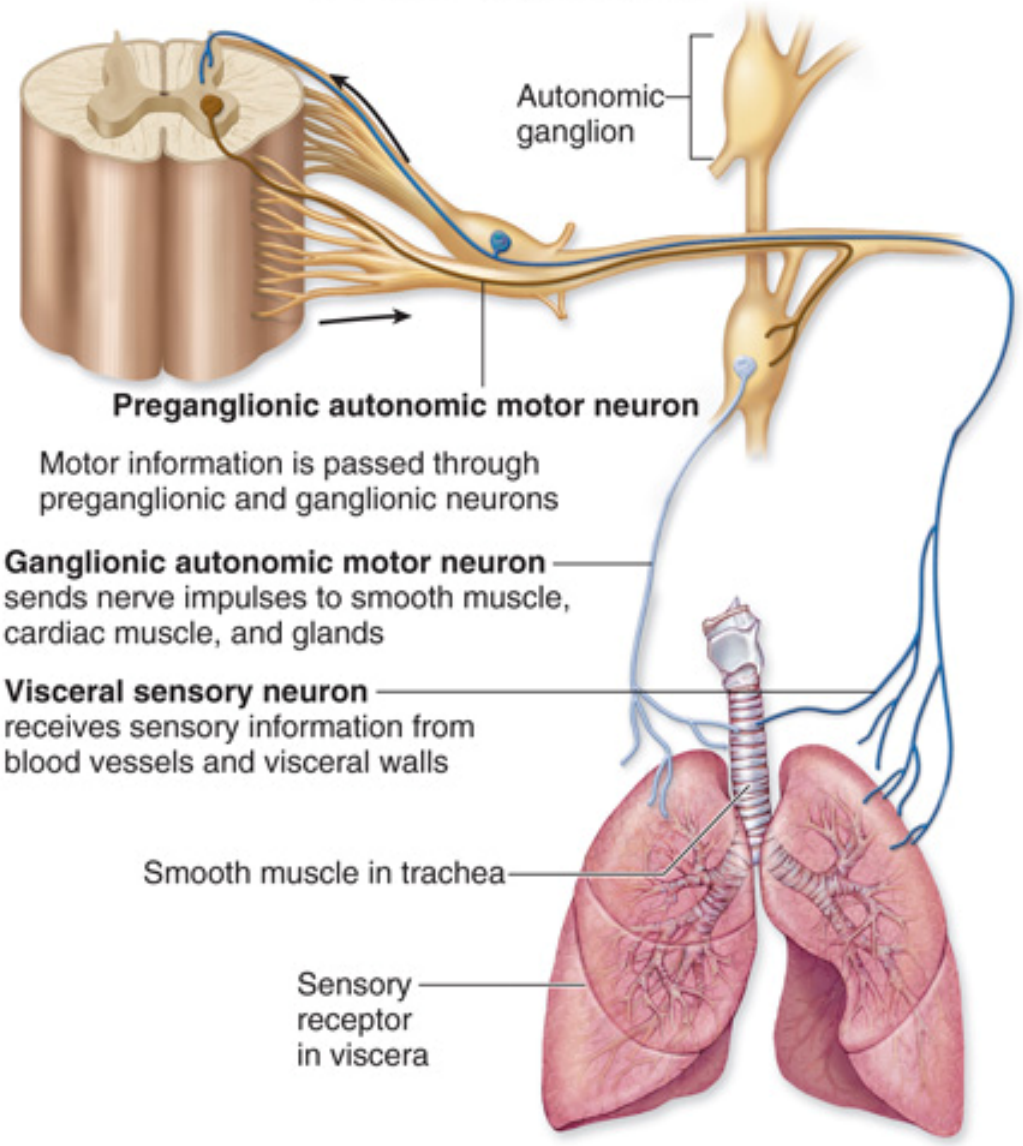
- Two neurotransmitters are used in the ANS.
  - acetylcholine (ACh)
  - norepinephrine (NE)
- Neurotransmitters are released by the presynaptic cell.
- Bind to specific receptors in the postsynaptic cell membrane.
- Binding has either an excitatory or an inhibitory effect on the effector, depending on the specific receptor.

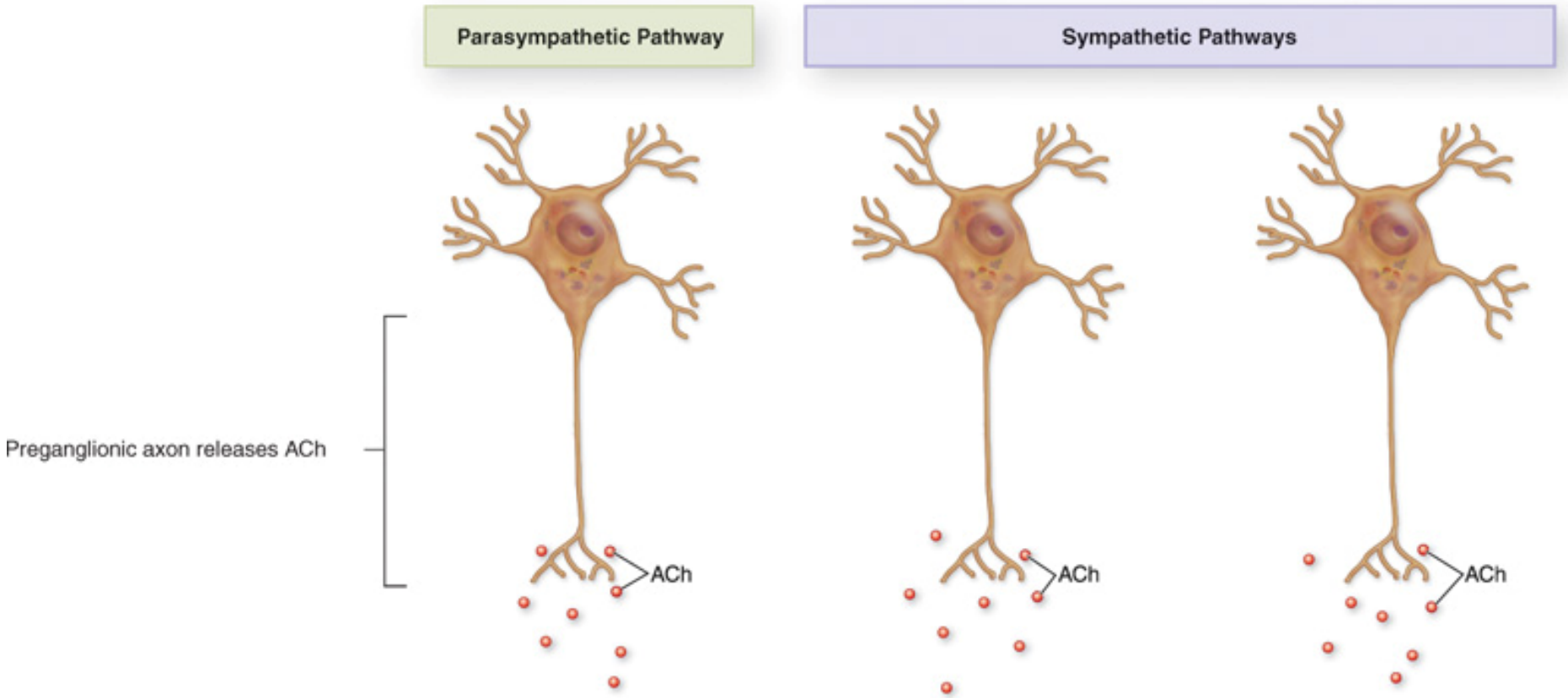
Neurotransmitters

- 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.

Autonomic (Visceral) Nervous System

"Involuntary" nervous system



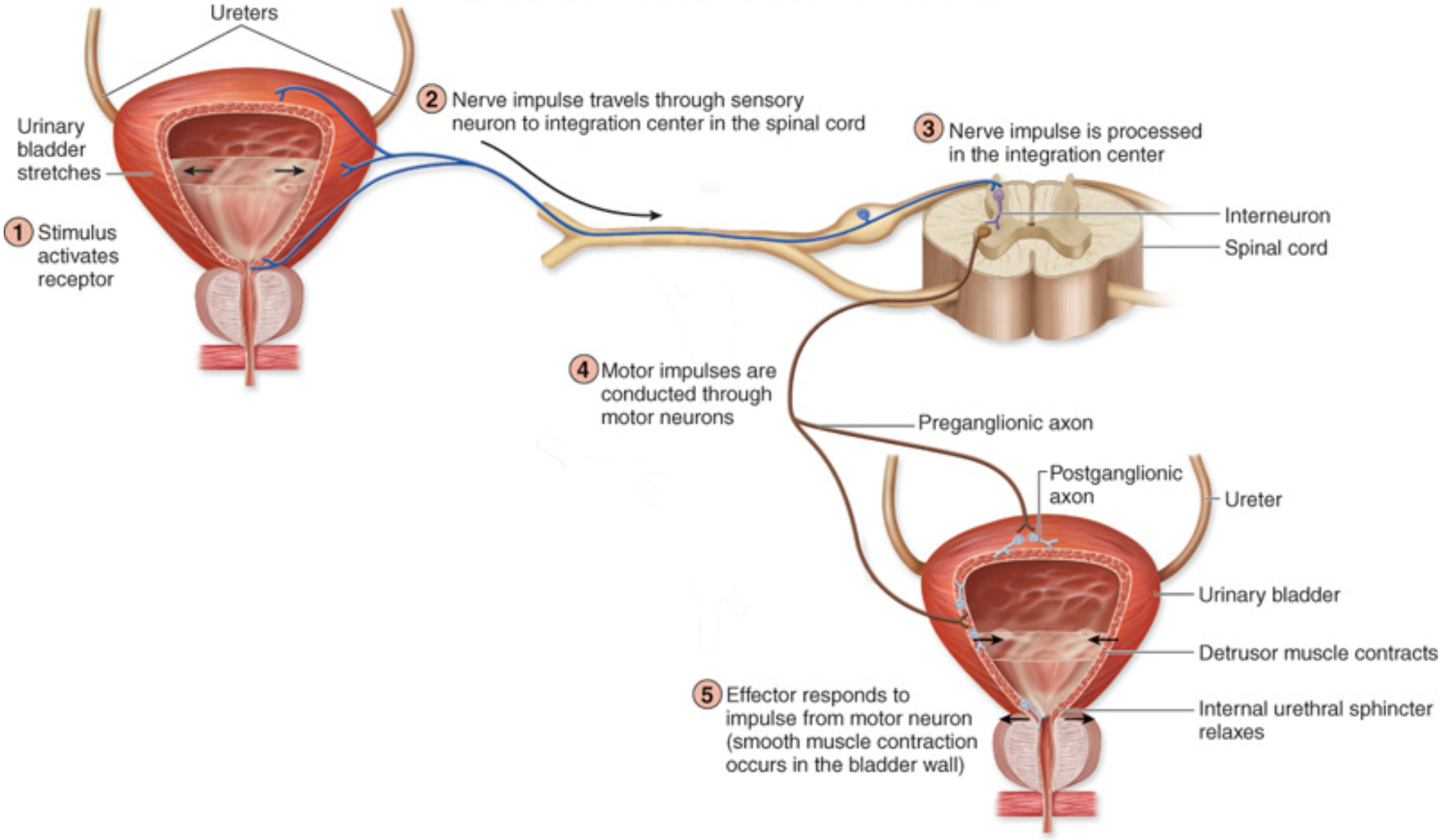


Dual Innervation

- Many visceral effectors are innervated by postganglionic axons from both ANS divisions.
- Actions of the divisions usually oppose each other.
  - exert antagonistic effects on the same organ
- Opposing effects are also achieved by increasing or decreasing activity in one division.

Autonomic Reflexes

- ANS helps maintain homeostasis through the involuntary activity of autonomic reflexes or visceral reflexes.
- Consist of smooth muscle contractions, cardiac muscle contractions, or secretion by glands that are mediated by autonomic reflex arcs in response to a specific stimulus.
  - Example: micturition reflex, which partly controls the release of urine
- Other reflexes include alteration of heart rate, changes in respiratory rate and depth, regulation of digestive system activities, and alteration of pupil diameter.
- Comparable to spinal reflexes.
- Classic autonomic reflex involves the reduction of blood pressure.

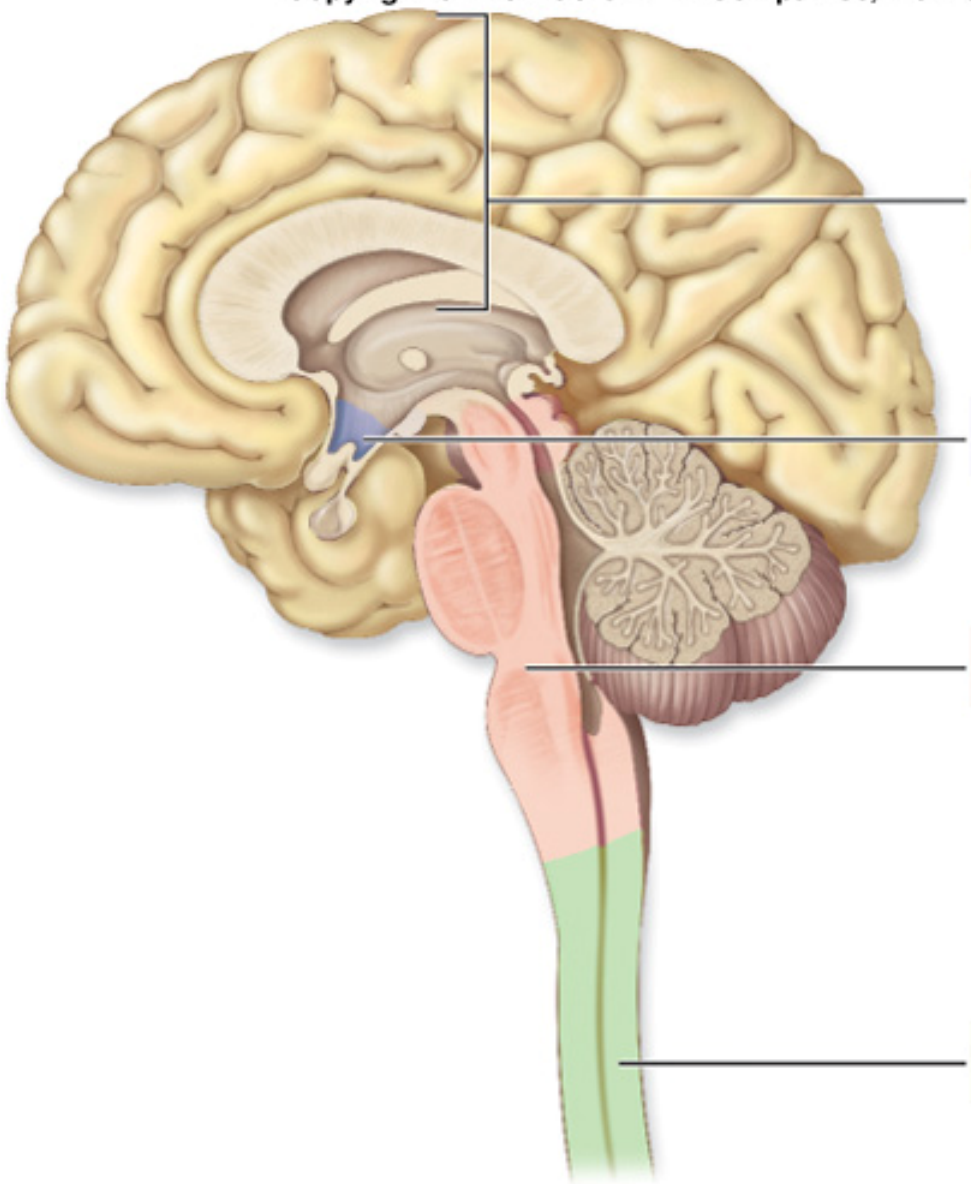


CNS Control of Autonomic Function

- Autonomic function is influenced by the cerebrum, hypothalamus, brainstem, and spinal cord.
- Sensory processing in the thalamus and emotional states controlled in the limbic system directly affect the hypothalamus.
  - the integration and command center for autonomic functions
  - contains nuclei that control visceral functions in both divisions of the ANS
  - communicates with other CNS regions, including the cerebral cortex, thalamus, brainstem, cerebellum, and spinal cord

CNS Control of Autonomic Function

- The hypothalamus is the central brain structure involved in emotions and drives that act through the ANS.
- The brainstem nuclei in the mesencephalon, pons, and medulla oblongata mediate visceral reflexes.
- Reflex centers control accommodation of the lens, blood pressure changes, blood vessel diameter changes, digestive activities, heart rate changes, and pupil size.
- The centers for cardiac, digestive, and vasomotor functions are housed within the brainstem.
- Some responses (defecation and urination), are processed and controlled at the level of the spinal cord without the involvement of the brain.
- Higher centers in the brain may consciously inhibit these reflex activities.



Cerebrum	Conscious activities in the cerebrum affect hypothalamus control of the ANS
Hypothalamus	Integration and command center for autonomic (visceral) functions; involved in emotions
Brainstem	Contains major ANS reflex centers
Spinal cord	Contains ANS reflex centers for defecation and urination