Autonomic Nervous System
(the visceral motor system)

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“hot as a hare, blind as a bat, dry as a bone, red as a beet, and mad as a hatter”

-symptoms of a person suffering from belladonna poisoning

Autonomic Nervous System

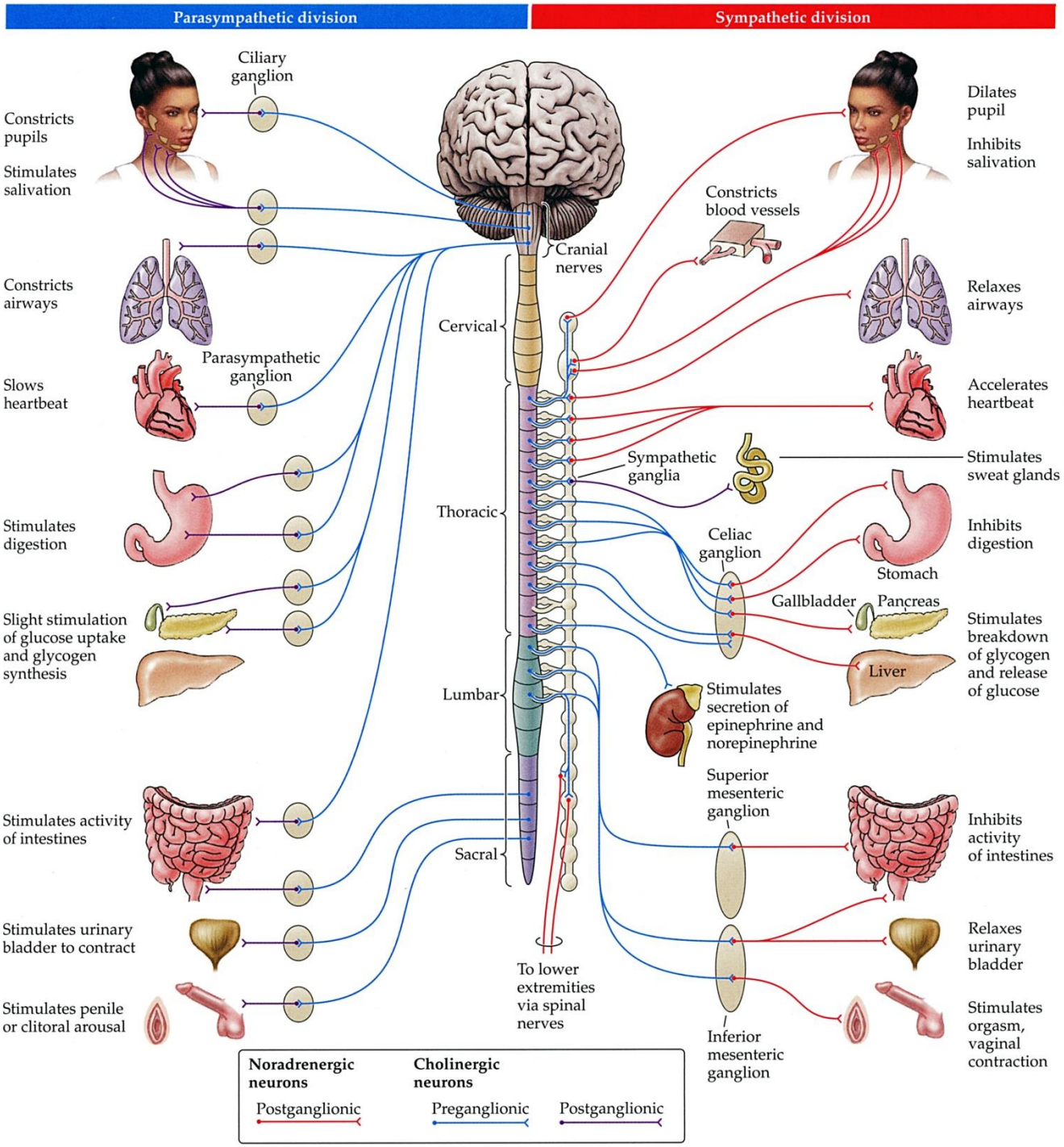
- The autonomic nervous system (or visceral motor system) maintains homeostasis of the body by coordinating the physiological state of multiple organ systems.

- The autonomic nervous system innervates smooth muscle, cardiac muscle, glands and blood vessels in all parts of the body.

Autonomic Nervous System

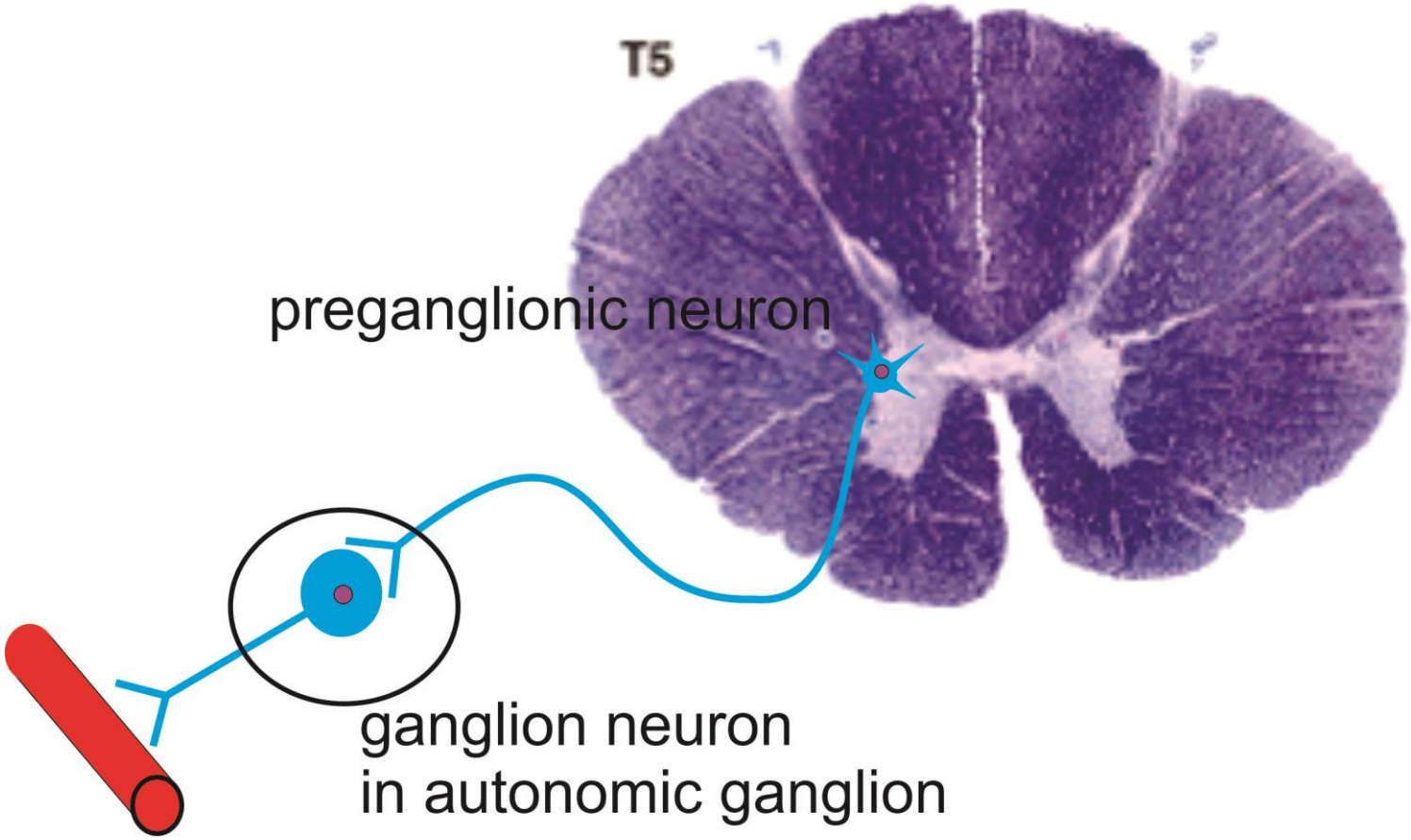
The autonomic nervous system controls several systems including the:

- cardiovascular system
- respiratory system
- gastrointestinal system
- urogenital system
- integumentary system (skin)


Parasympathetic division
Sympathetic division
Ciliary ganglion
Constricts pupils
Stimulates salivation
Constricts airways
Parasympathetic ganglion
Slows heartbeat
Stimulates digestion
Slight stimulation of glucose uptake and glycogen synthesis
Stimulates activity of intestines
Stimulates urinary bladder to contract
Stimulates penile or clitoral arousal
Cranial nerves
Cervical
Thoracic
Lumbar
Sacral
To lower extremities via spinal nerves
Dilates pupil
Inhibits salivation
Constricts blood vessels
Relaxes airways
Accelerates heartbeat
Sympathetic ganglia
Stimulates sweat glands
Celiac ganglion
Inhibits digestion
Stomach
Gallbladder
Pancreas
Stimulates breakdown of glycogen and release of glucose
Liver
Stimulates secretion of epinephrine and norepinephrine
Superior mesenteric ganglion
Inhibits activity of intestines
Relaxes urinary bladder
Inferior mesenteric ganglion
Stimulates orgasm, vaginal contraction
Noradrenergic neurons
Postganglionic
Cholinergic neurons
Preganglionic
Postganglionic

Autonomic Nervous System

- It is a two neuron motor system, a preganglionic neuron in the brainstem or spinal cord and a ganglion neuron in a ganglion. The postganglionic axon synapses with its target.



Autonomic Nervous System

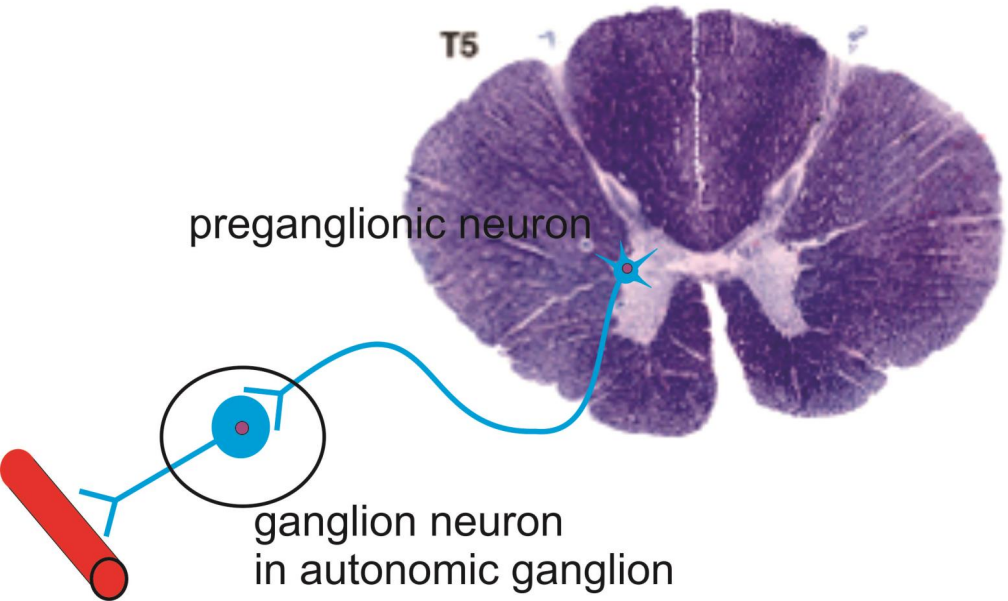
The autonomic system has three subdivisions:

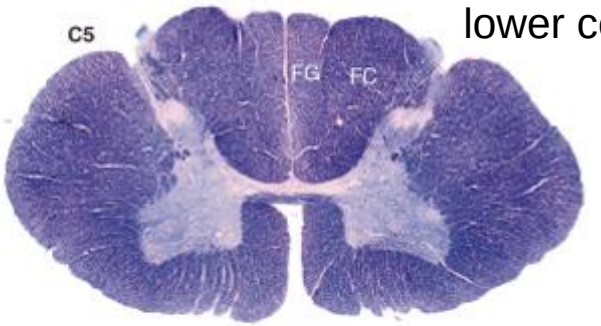
- Sympathetic nervous system
- Parasympathetic nervous system
- Enteric nervous system

Sympathetic Nervous System

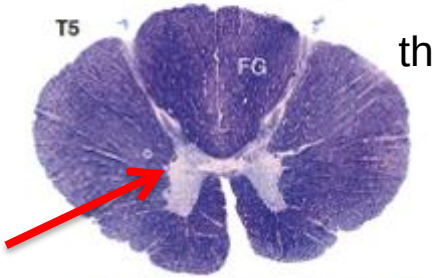
- Preganglionic sympathetic neurons are in the intermediolateral cell column (lateral horn) in thoracic and upper lumbar spinal cord (spinal segments T1 to L2).

- Preganglionic axons exit the spinal cord in the ventral root with other motor axons.

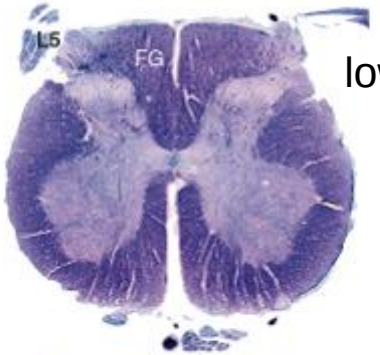




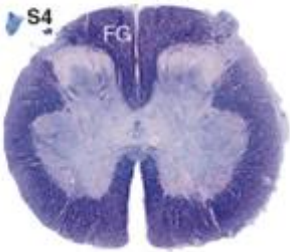
lower cervical



thoracic



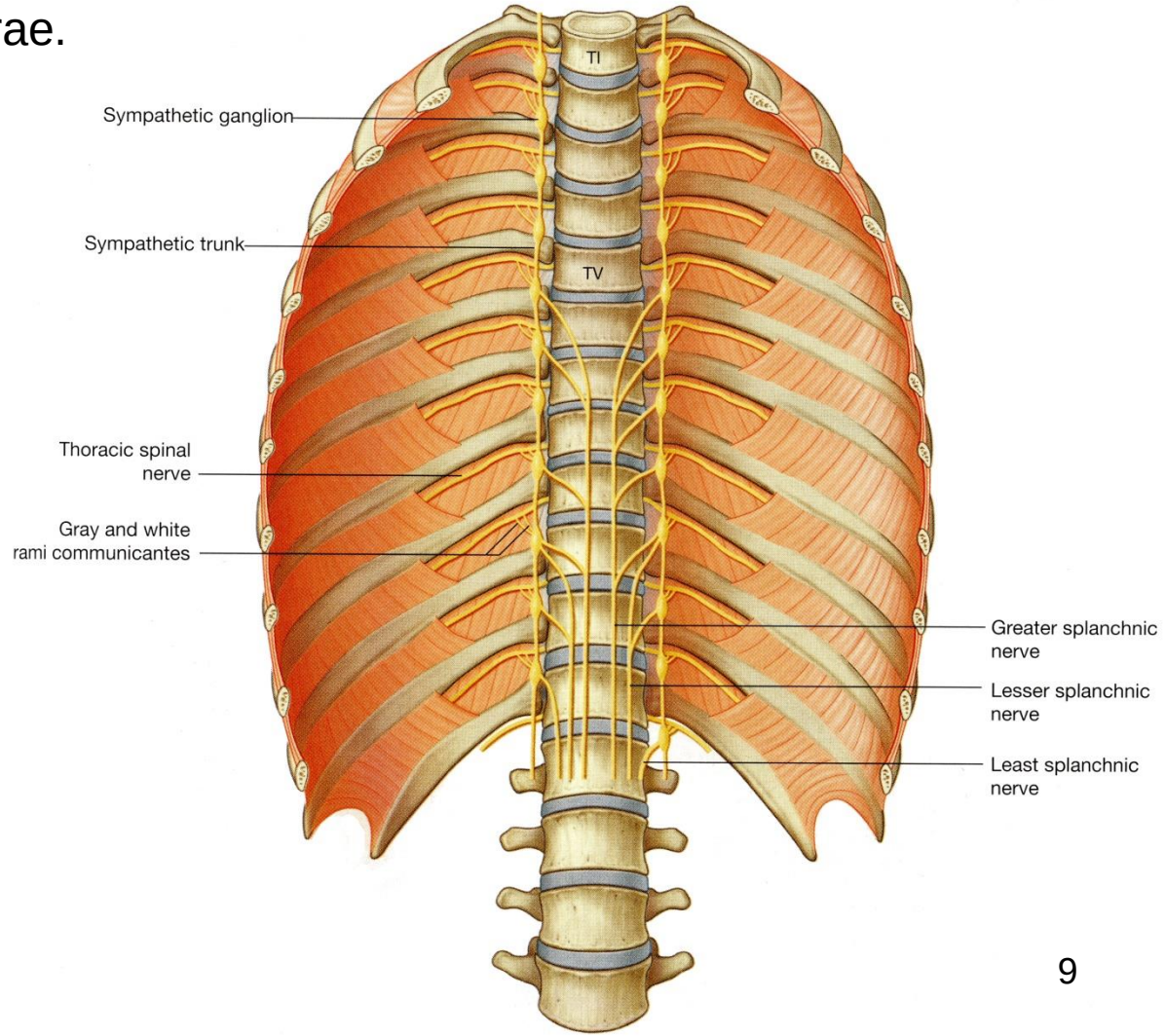
lower lumbar



upper sacral

Sympathetic Nervous System

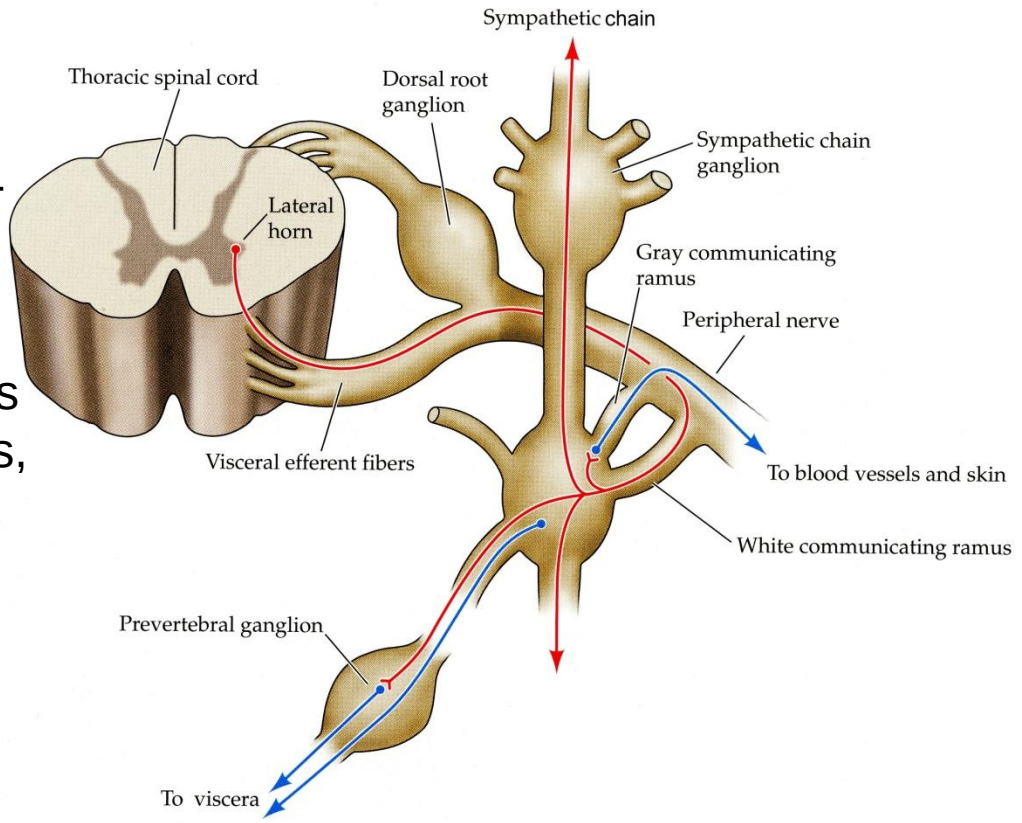
- Preganglionic axons can ascend or descend in the sympathetic chain on the sides of the vertebrae.



Sympathetic Nervous System

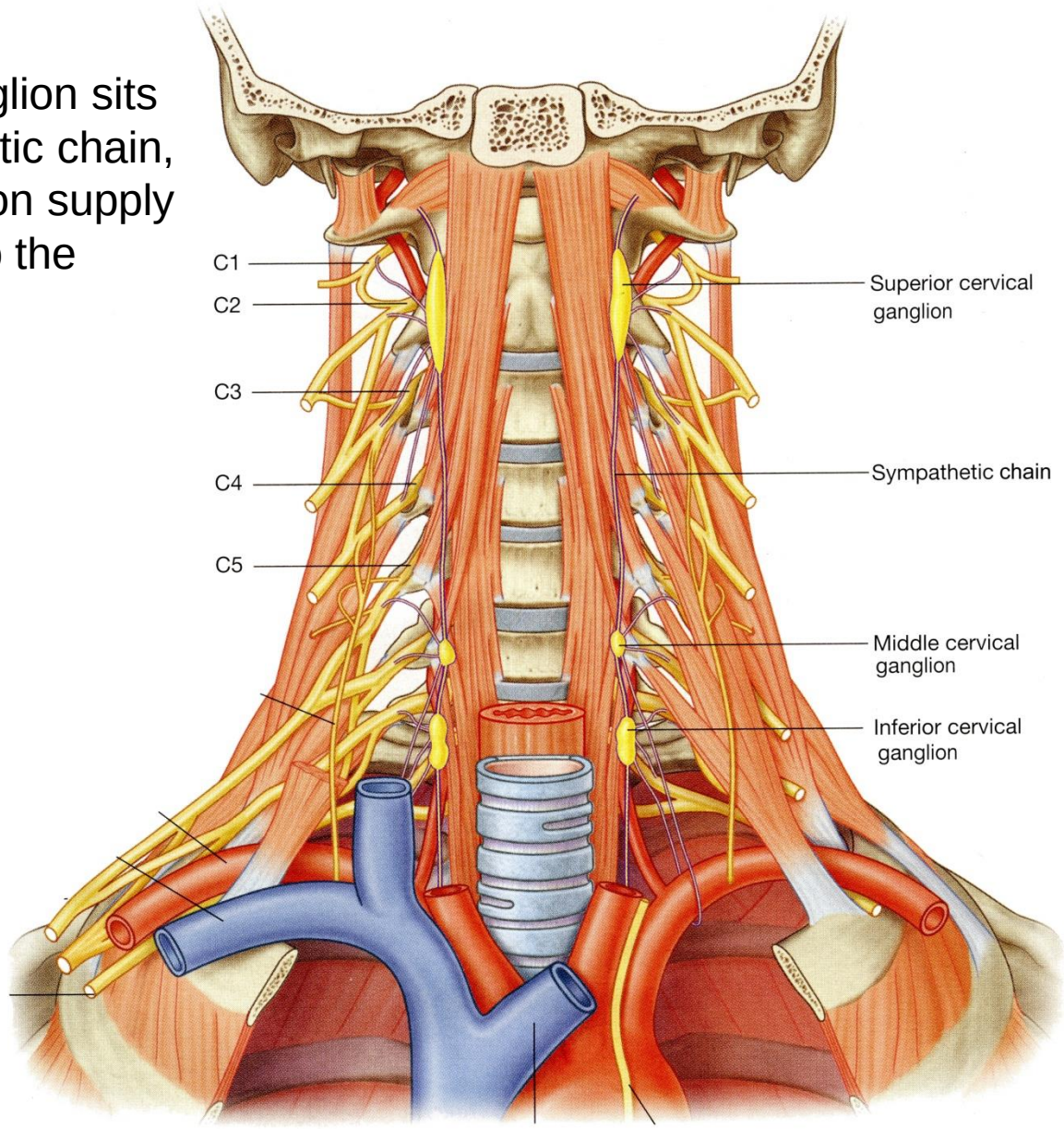
- Preganglionic sympathetic axons synapse in sympathetic chain ganglia (paravertebral ganglia) or prevertebral ganglia.

- Postganglionic sympathetic axons (blue) synapse with blood vessels, glands and other tissues throughout the body.



Sympathetic Nervous System

- The superior cervical ganglion sits at the top of the sympathetic chain, and neurons in the ganglion supply sympathetic innervation to the head.



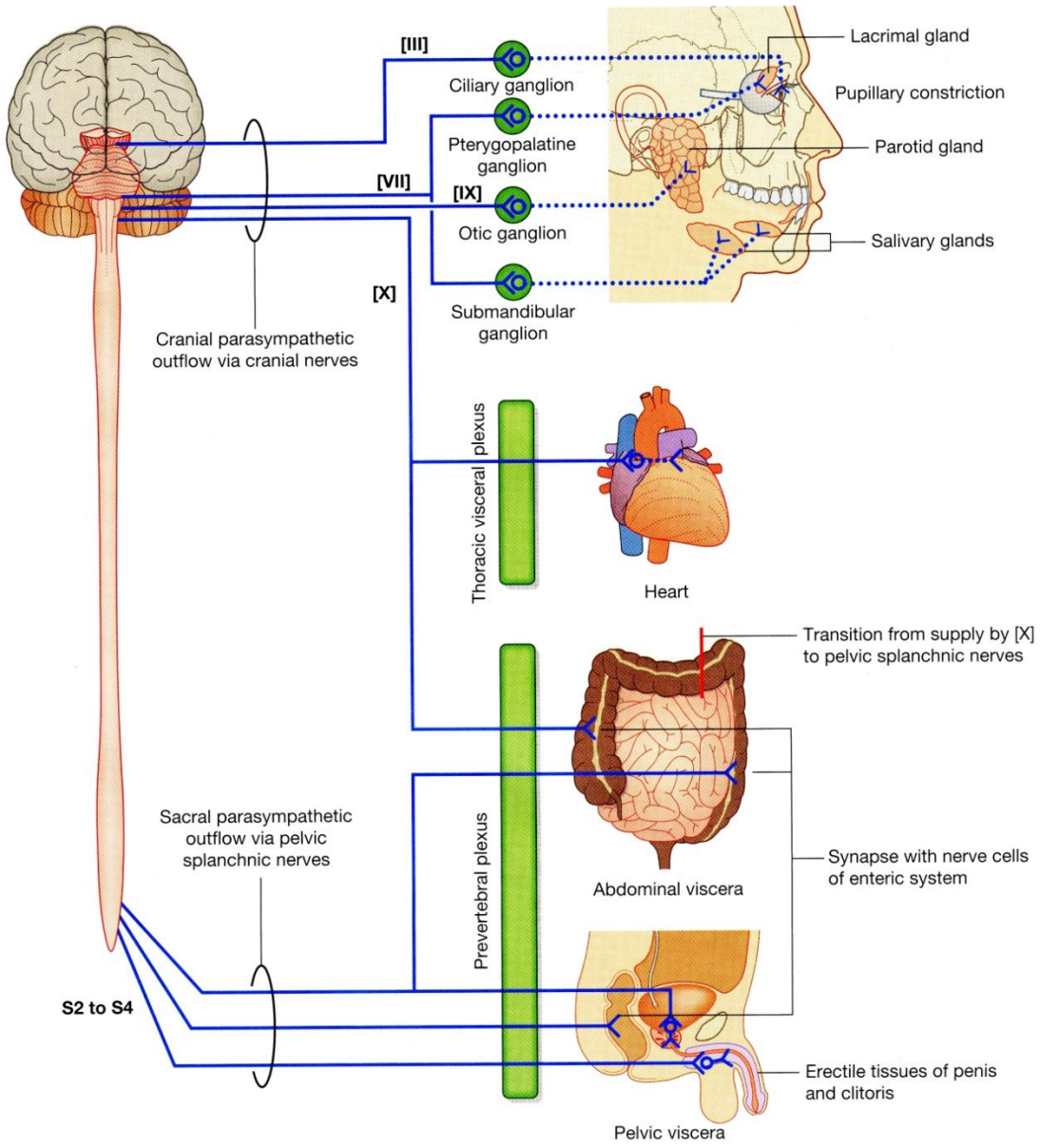
Sympathetic Nervous System

- Ganglion neurons are in sympathetic ganglia , which are typically near the CNS.

- Preganglionic axons typically are short, and postganglionic axons typically are long.

Parasympathetic Nervous System

- Preganglionic parasympathetic neurons are in the brainstem and sacral spinal cord.



cranial nerve		***function***			
		general motor	***parasympathetic***	***general sensory***	***special sensory***
I	Olfactory				X (olfaction)
II	Optic				X (vision)
III	Oculomotor	X[a]	X		
IV	Trochlear	X[a]			
V	Trigeminal	X[b]		X[c]	
VI	Abducens	X[a]			
VII	Facial	X[b]	X	X	X (taste)
VIII	Vestibulocochlear				X (auditory & vestibular)
IX	Glossopharyngeal	X[b]	X	X[c]	X (taste)
X	Vagus	X[b]	X	X[c]	X (taste)
XI	Accessory *	X[a]			
XII	Hypoglossal	X[a]			

* cervical component; cranial component included with vagus

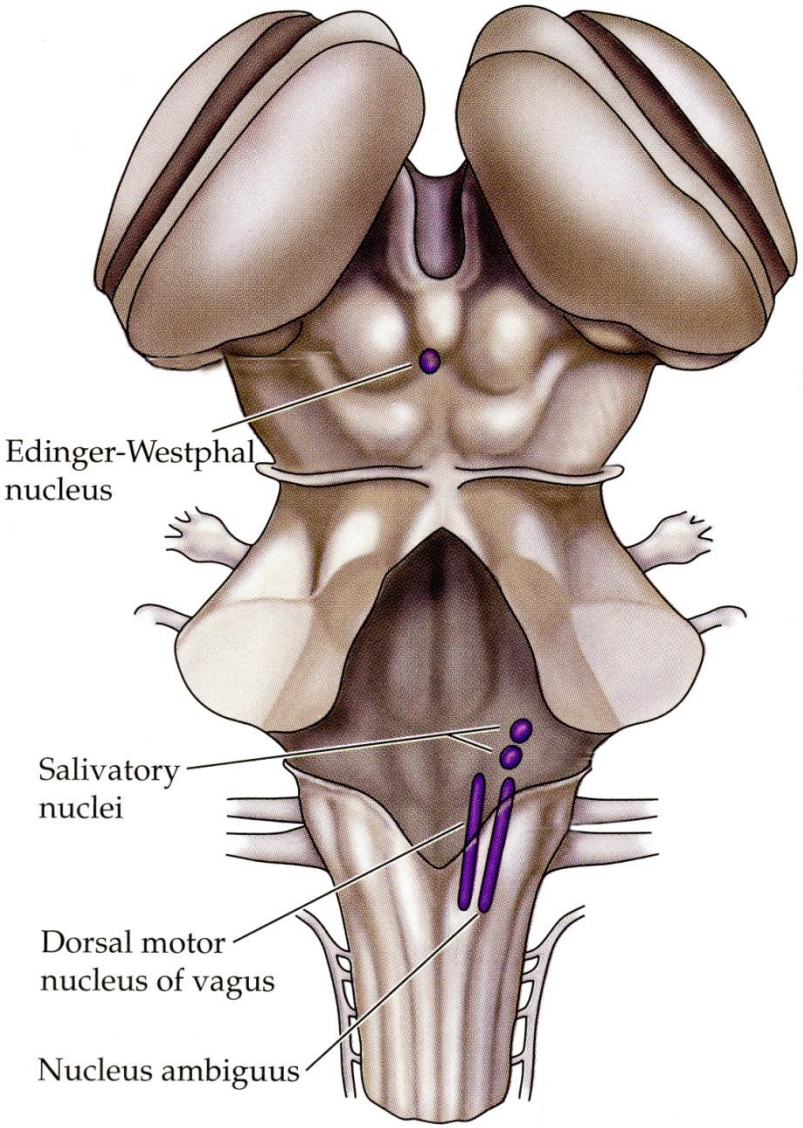
[a] somatic motor – innervates muscles that develop from somites

[b] branchial motor – innervates muscles that develop from pharyngeal arches

[c] includes visceral sensory as well as somatosensory

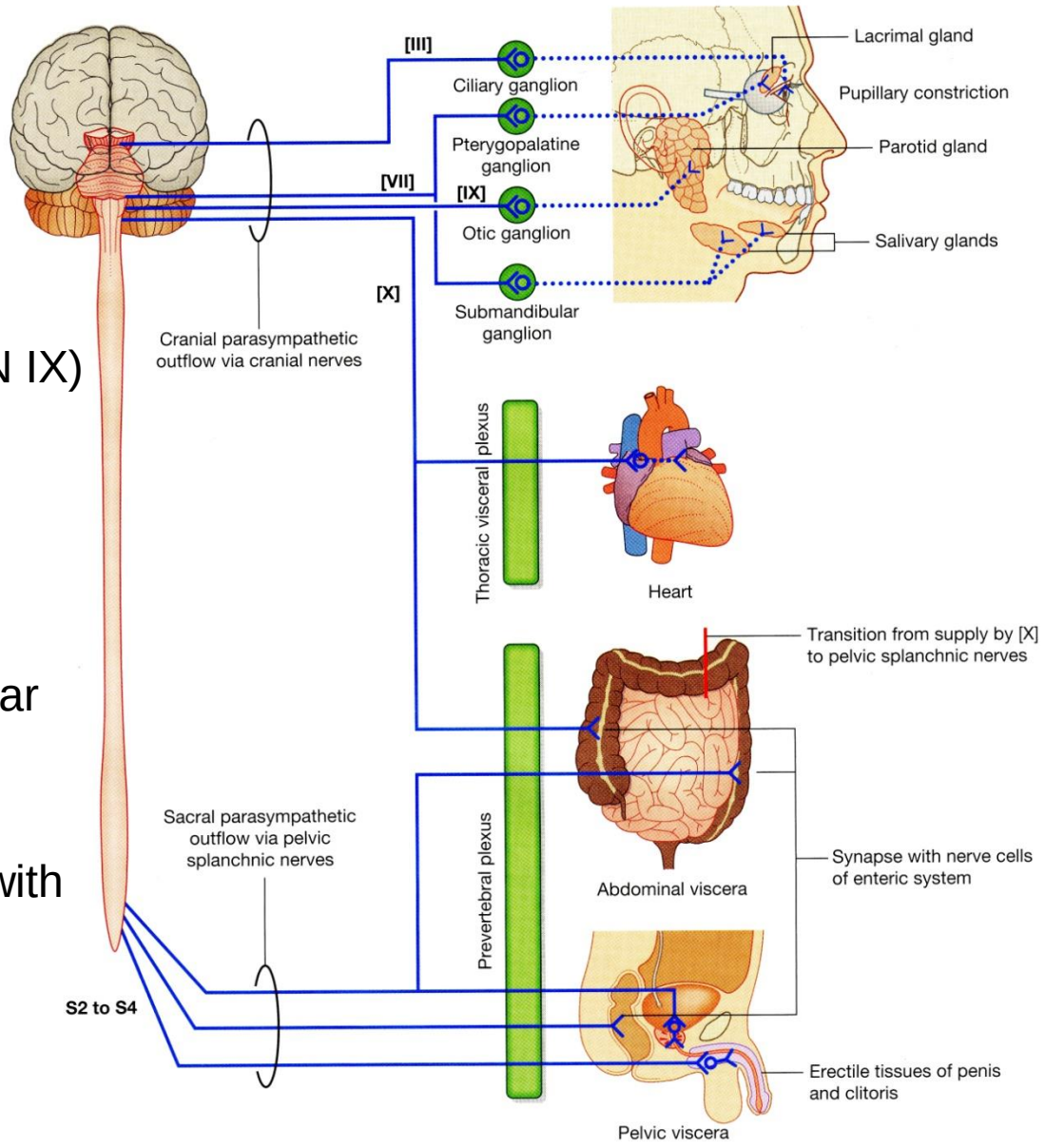
Parasympathetic Nervous System

- Brainstem preganglionic parasympathetic neurons are in parasympathetic motor nuclei in the midbrain, pons and medulla.



Parasympathetic Nervous System

- Preganglionic parasympathetic axons run in:
  - Oculomotor nerve (CN III)
  - Facial nerve (CN VII)
  - Glossopharyngeal nerve (CN IX)
  - Vagus nerve (CN X)
  - Sacral spinal nerves
- Parasympathetic ganglia are near or in their target tissues.
- Postganglionic axons synapse with tissues throughout the body.



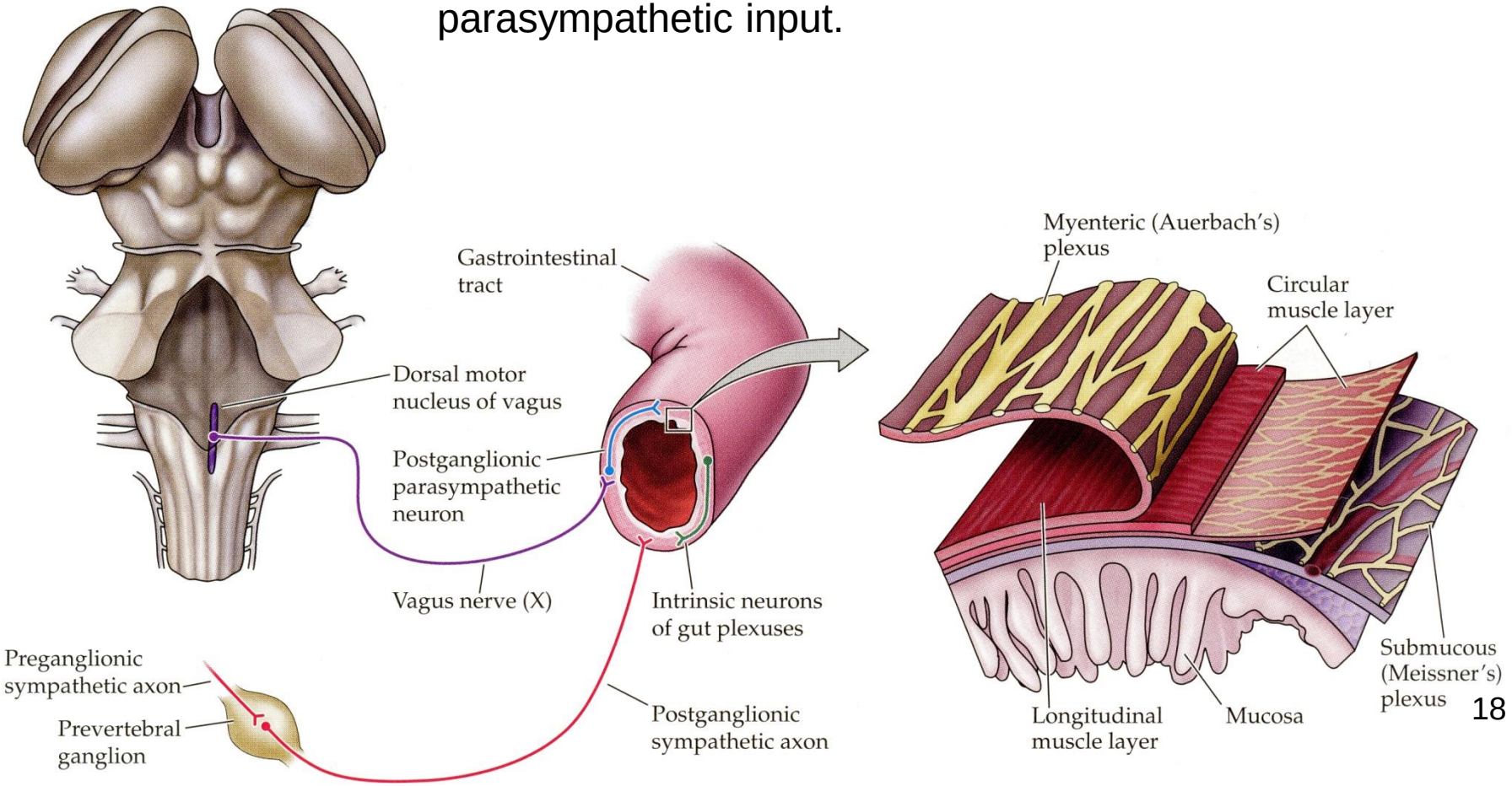
Parasympathetic Nervous System

- Ganglion neurons are in parasympathetic ganglia, which are typically near their target tissue.

- Preganglionic axons typically are long, and postganglionic axons typically are short.

Enteric Nervous System

- Neurons of the enteric nervous system are in the wall of the gastrointestinal system.
- Enteric neurons are highly interconnected in local circuits.
- Enteric circuits are controlled by sympathetic and parasympathetic input.



Visceral Sensory System

- Visceral sensory receptors include:
  - Various mechanoreceptors such as baroreceptors for detecting blood pressure.
  - Various chemoreceptors such as for detecting oxygen or CO_2.

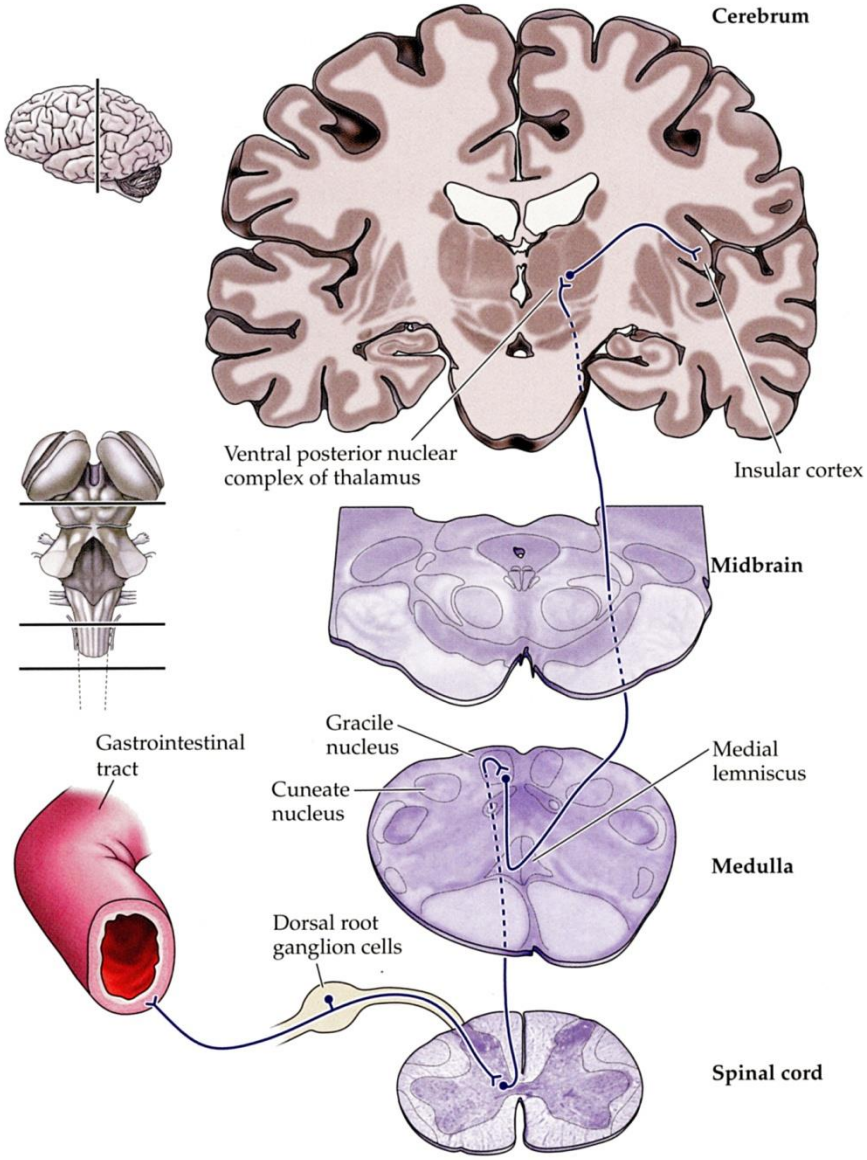
- Visceral sensory neurons have cell bodies in dorsal root ganglia and cranial nerve sensory ganglia just like somatosensory neurons.

- Somatosensory and special sensory information also influence autonomic function.

Visceral Sensory System

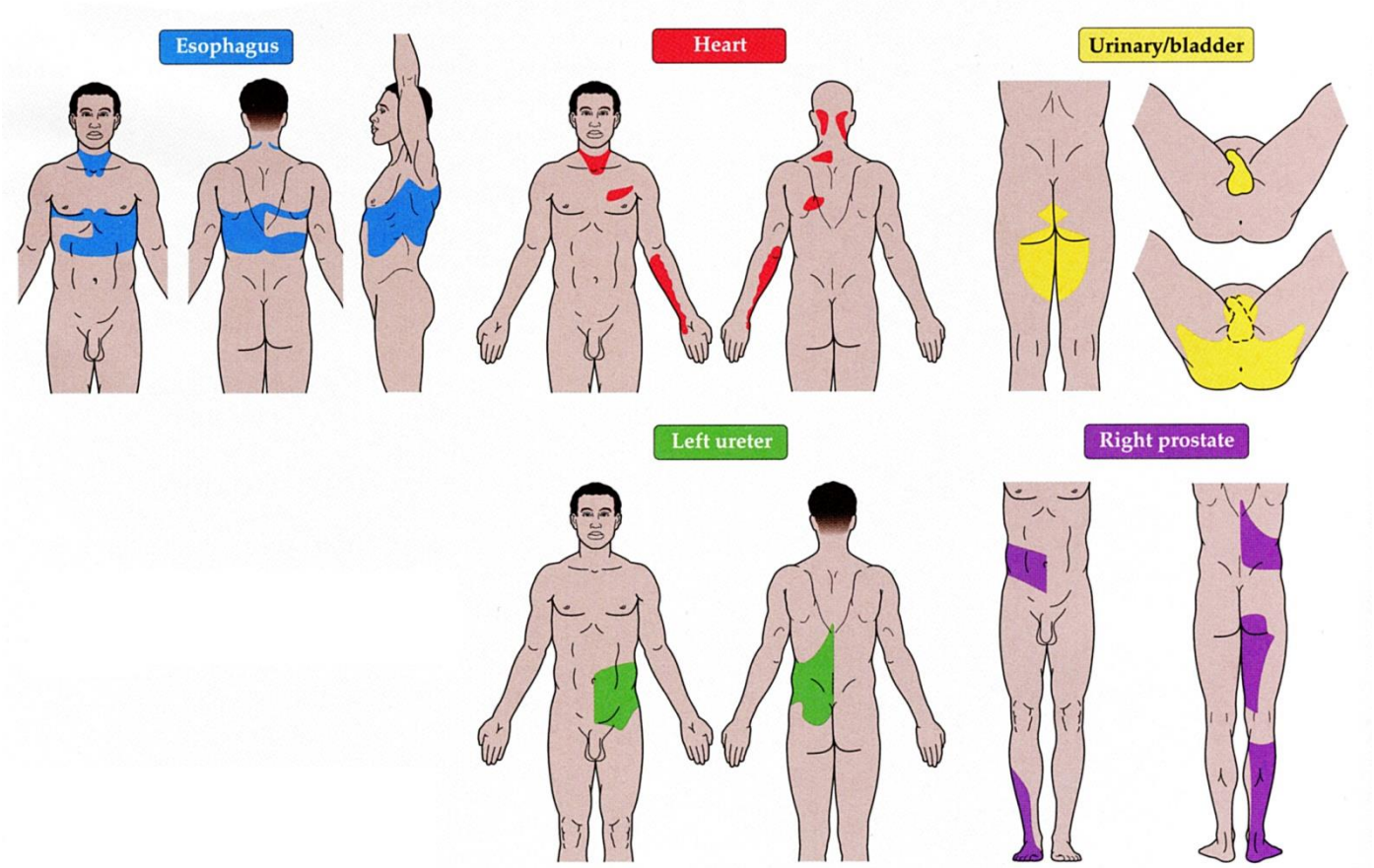
- Sensory information from the viscera is carried to the cortex in a path slightly different than the somatosensory system.

- Visceral sensation is represented in insular cortex.



Visceral Sensory System

- Some axons carrying pain sense from the viscera synapse on neurons in the dorsal horn that also receive somatosensory pain fibers from the skin.
- Our mind interprets visceral pain as arising from parts of the body served by the somatosensory system. We call this referred pain.



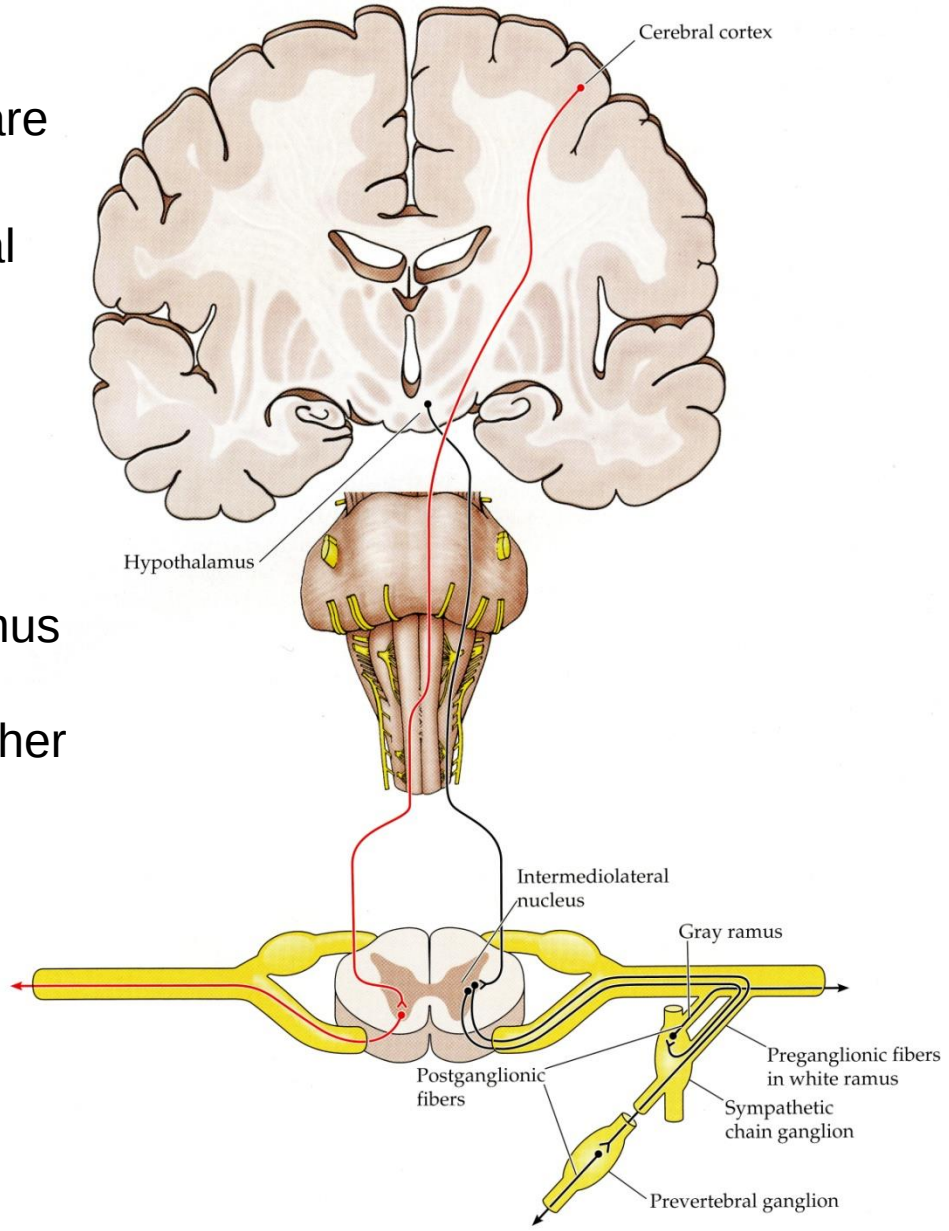
Visceral Sensory System

- Visceral sensory information from cranial nerves are relayed by the solitary nucleus in the medulla.

Autonomic Control

- Preganglionic autonomic neurons are controlled by:
  - local reflex circuits with visceral sensory neurons
  - descending input from hypothalamus and brainstem reticular formation

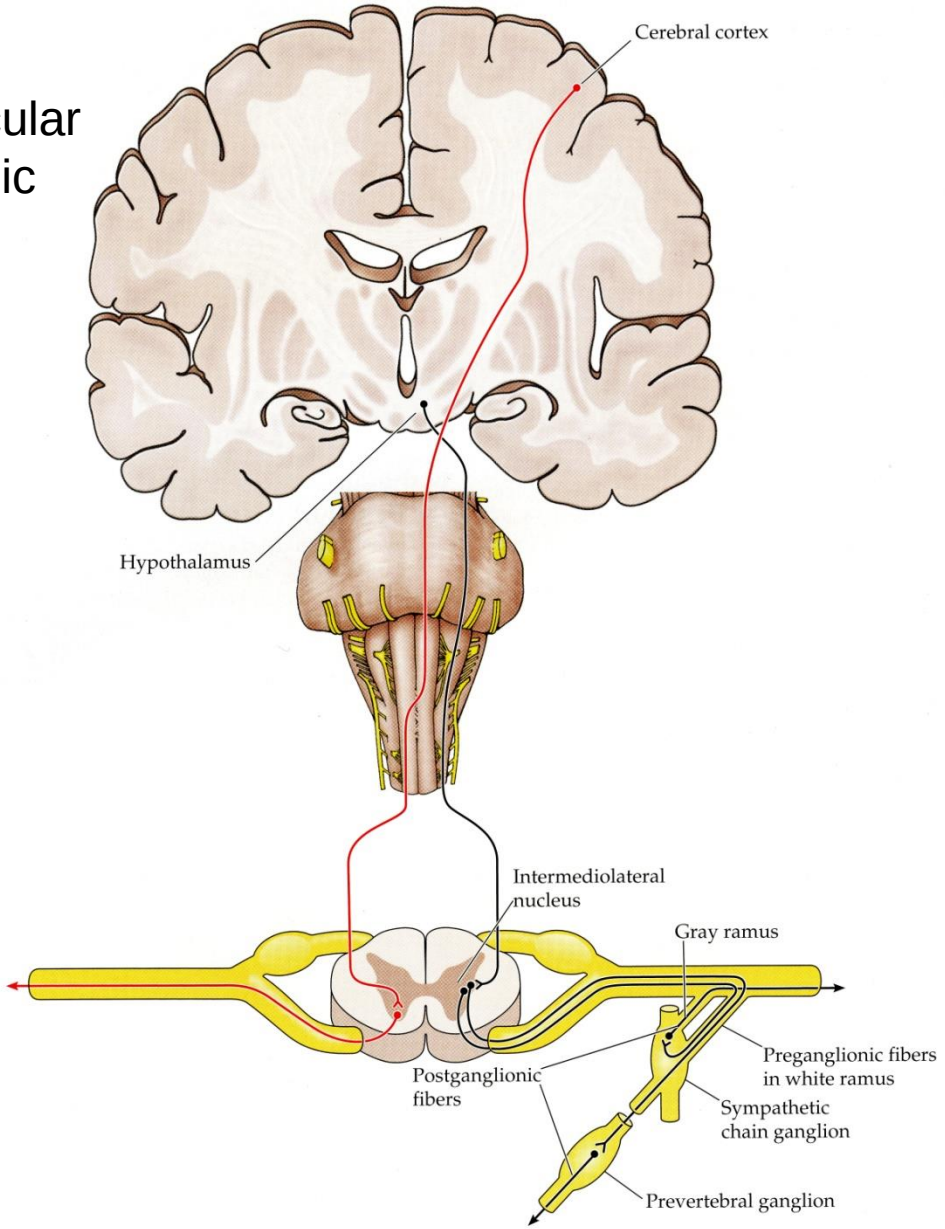
- Reticular formation and hypothalamus receive inputs from insular cortex, limbic system, basal ganglia and other higher brain areas.



Autonomic Control

- Axons from hypothalamus and reticular formation to preganglionic autonomic neurons are largely ipsilateral.

- Many hypothalamic axons run with lateral corticospinal tract axons.



Autonomic Function

- Autonomic nervous system function is mostly subconscious and is often described as reflex.

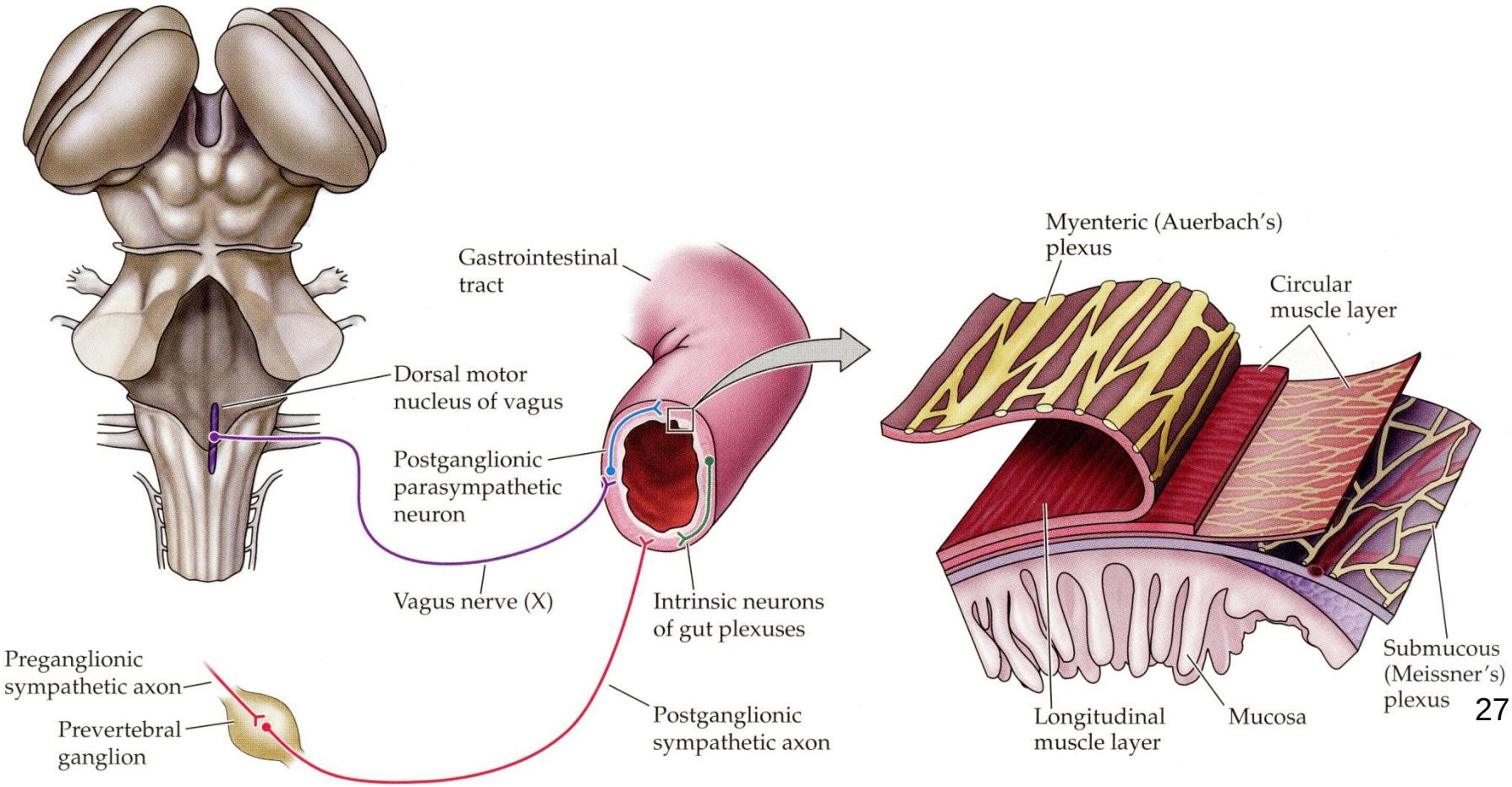
- Conscious thought processes can activate the autonomic nervous system; e.g.:
  - Blushing in response to something embarrassing …
  - Think about a slice of your favorite pizza …
  - Think about a beautiful person of your favorite sex undressing …

Autonomic Function

- Major functions of the autonomic nervous system include regulation of:
  - blood pressure
  - body fluid electrolytes
  - body temperature
  - energy metabolism
  - reproduction

Autonomic Function

- Enteric neurons regulate gut motility, secretion into the gastrointestinal system, and water and ion movement across the gastrointestinal epithelium.



Autonomic Function

- The sympathetic system is described as the ‘fight-or-flight’ system.
- The sympathetic system prepares your body to deal with stress.
- Maximum sympathetic activation constricts blood vessels in the skin and gut making more blood available to the muscles, heart and brain.

  Bronchi in the lungs dilate increasing the supply of oxygen.

  The heart accelerates.

  Certain ‘vegetative’ activities like gastrointestinal function are reduced.

Autonomic Function

- The parasympathetic system is described as the ‘rest-and-digest’ system.

- Parasympathetic activation promotes restoring energy supplies.

Autonomic Function

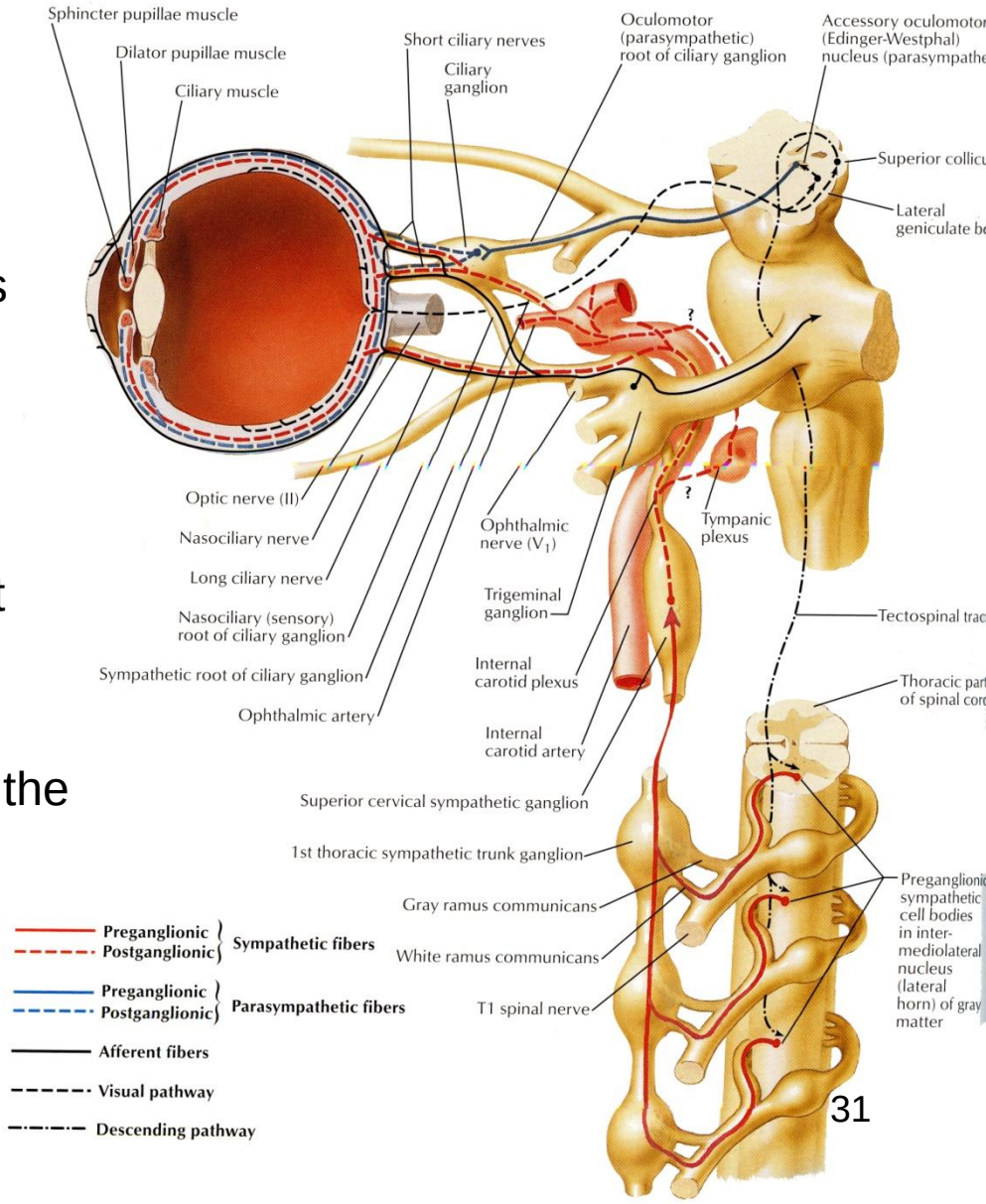
- Actually both systems are always functioning. The balance of activation of the two systems tilts one way or the other as needed.

- In most organs, the two systems have important functions outside of extreme situations.

- In some organs, if one system is eliminated, then the other system is unopposed and is always fully active.

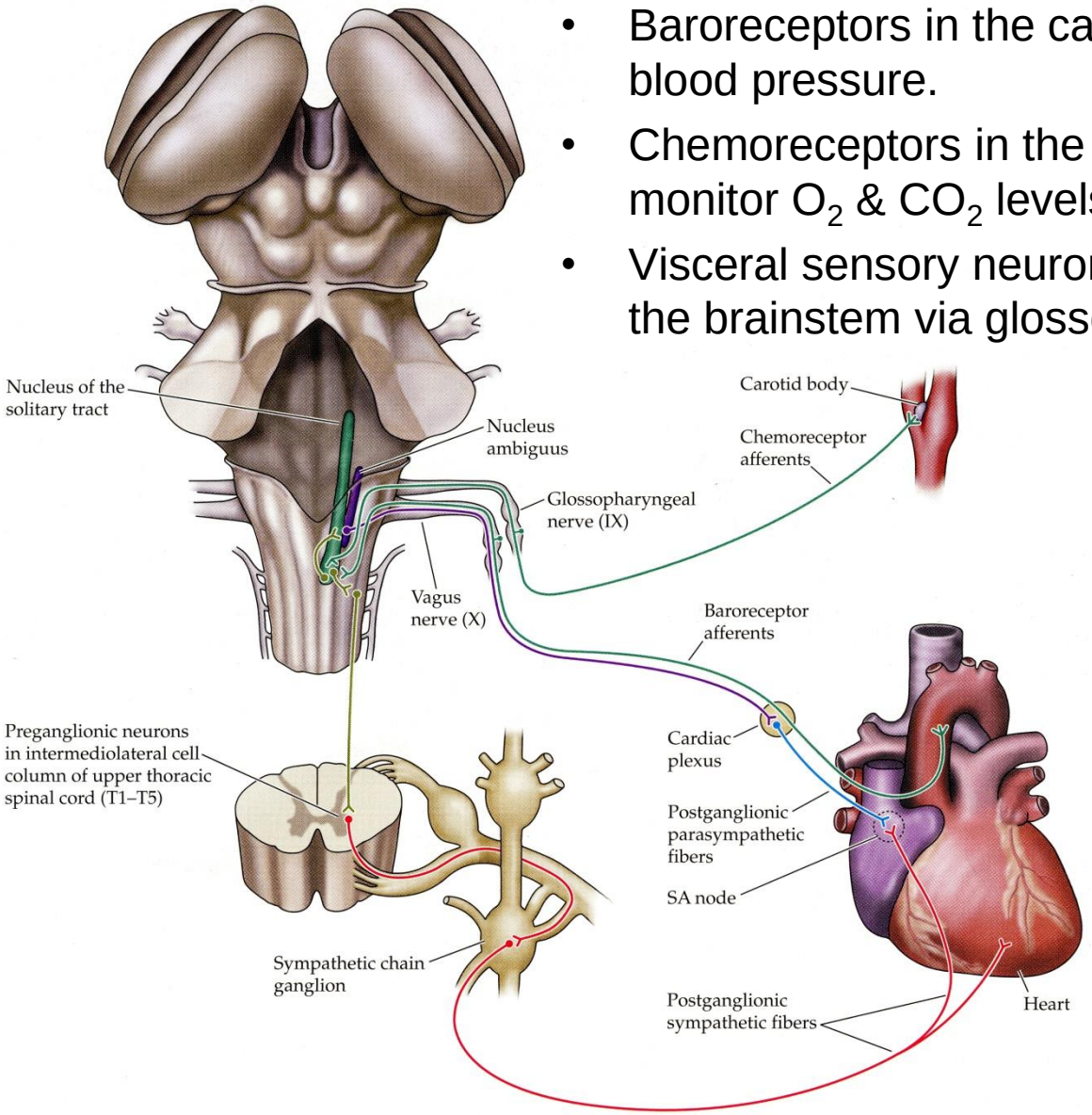
Autonomic Function

- The iris dilator muscle receives sympathetic innervation.
- The iris sphincter muscle receives parasympathetic innervation.
- The balance of activity normally changes to dilate or constrict the pupil based on the amount of light and focal distance.
- After a cervical spinal cord injury, the parasympathetic innervation is unopposed, and the pupil is permanently constricted.



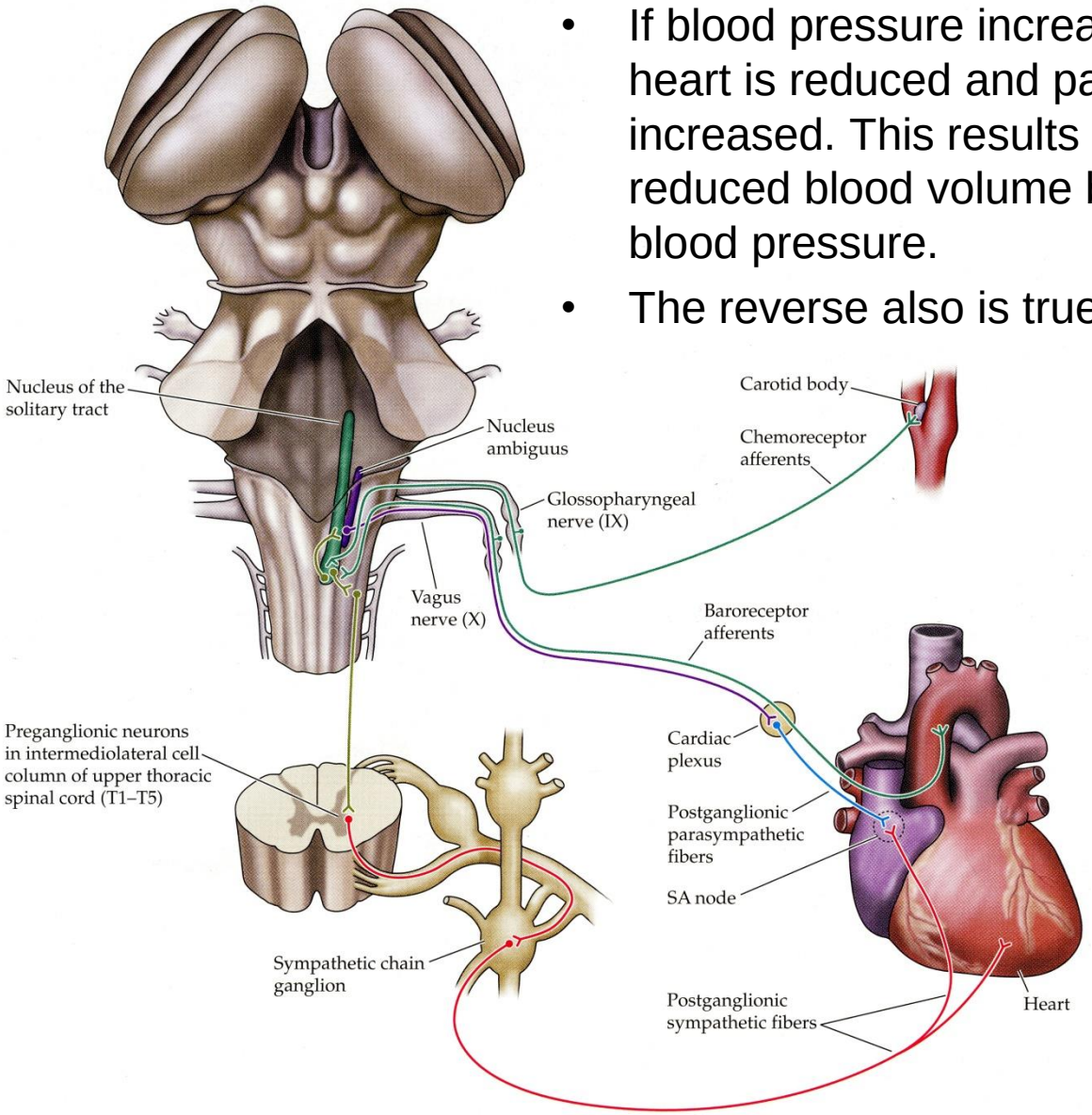
Autonomic Function

- Baroreceptors in the carotid artery and aorta monitor blood pressure.
- Chemoreceptors in the carotid artery and other tissues monitor O_2 & CO_2 levels.
- Visceral sensory neurons carry this information into the brainstem via glossopharyngeal and vagus nerves.



Autonomic Function

- If blood pressure increases, sympathetic activity to the heart is reduced and parasympathetic activity is increased. This results in a slower heart beat and a reduced blood volume being pumped. This lowers blood pressure.
- The reverse also is true.



Autonomic Function

- Some structures, such as the iris or heart, receive input from the sympathetic and parasympathetic systems.

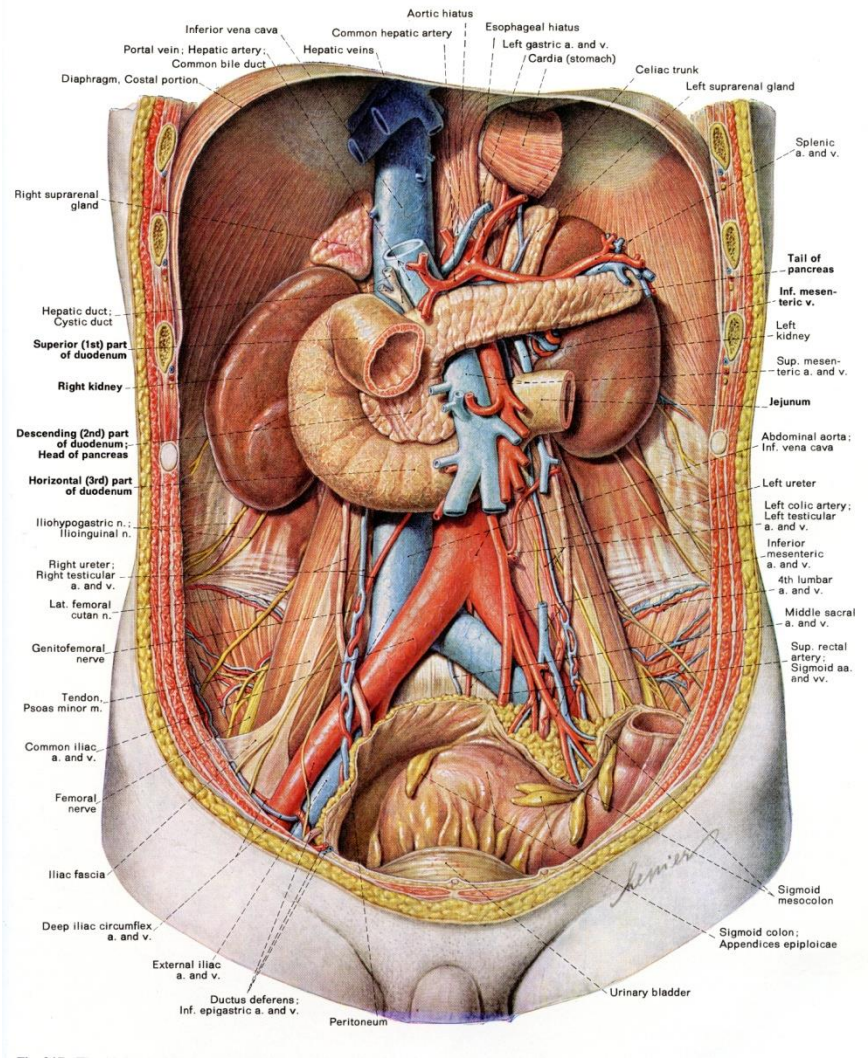
- Other structures, such as many blood vessels or the piloerector muscles in skin attached to hair, receive only sympathetic innervation.

Neurochemical Communication

- Acetylcholine is the primary neurotransmitter used by most preganglionic sympathetic and parasympathetic neurons.
- Acetylcholine is the primary neurotransmitter used by most parasympathetic ganglion neurons.
- Norepinephrine (noradrenaline) is the primary neurotransmitter used by most sympathetic ganglion neurons.

Neurochemical Communication

- The adrenal medulla (the center of the suprarenal gland, which sits above the kidneys) receives direct preganglionic sympathetic innervation.
- The adrenal medulla is activated by stress.
- When activated, the adrenal medulla releases epinephrine and norepinephrine into the blood, which potentiates sympathetic activity throughout the body.

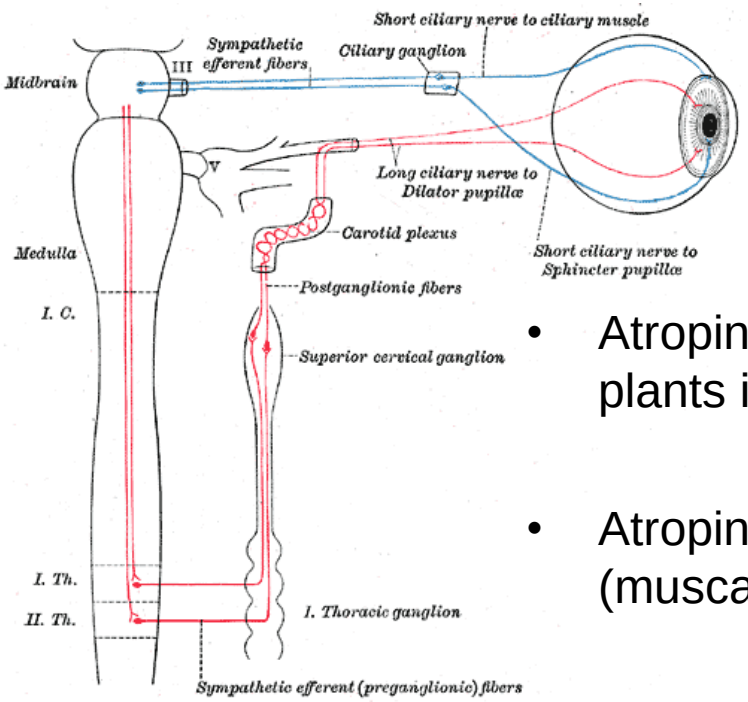


Neurochemical Communication

- There are a variety of transmitter receptor types used by cells in different organs that receive autonomic innervation.

- There are many drugs designed to influence neurochemical communication in specific parts of the autonomic nervous system.

Neurochemical Communication

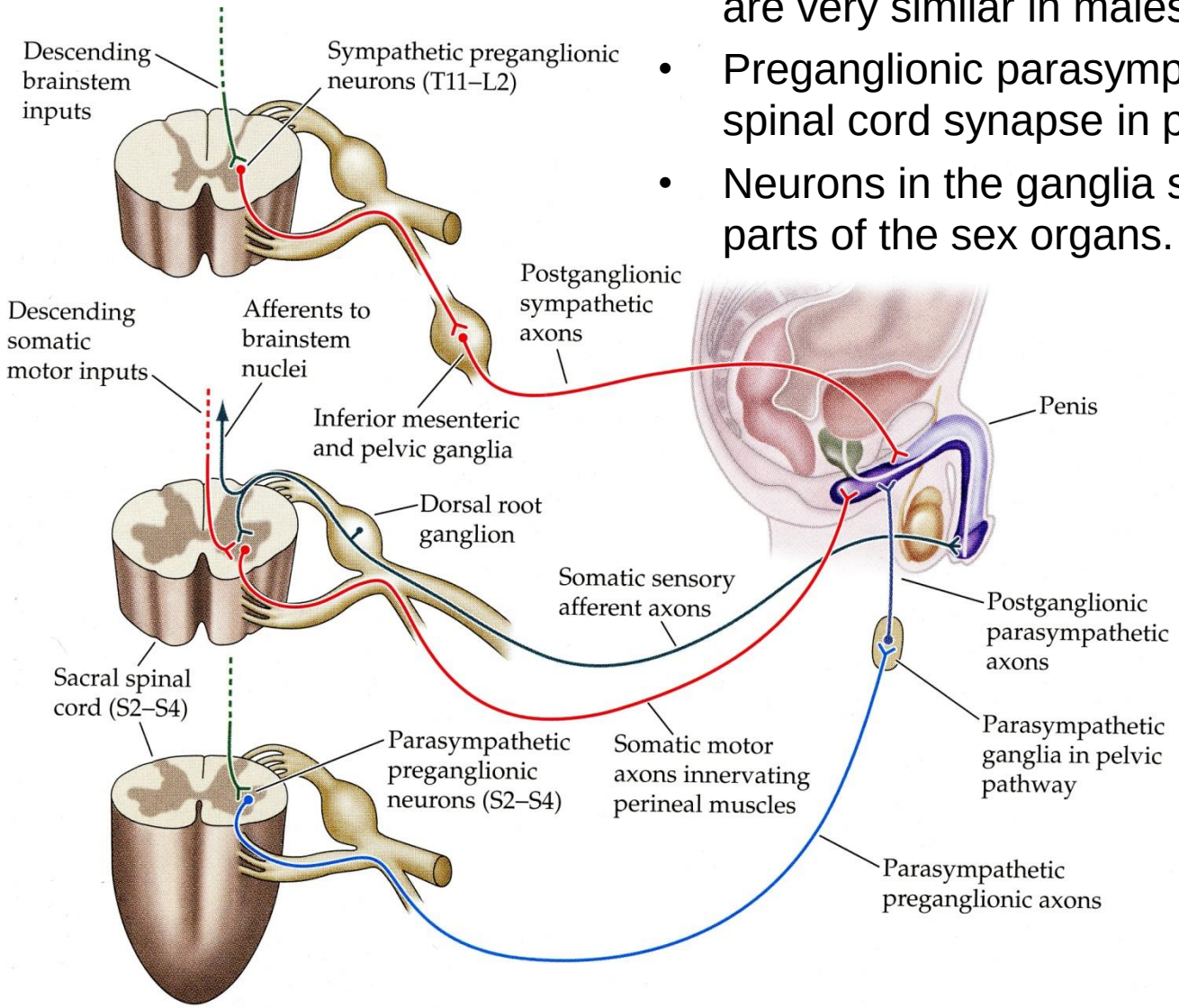


- Atropine (or belladonna) is a drug extracted from certain plants including deadly nightshade.
- Atropine is an antagonist for an acetylcholine receptor (muscarinic acetylcholine receptors).
- It was once used clinically to dilate the pupil in order to examine the retina.
- Phenylephrine, an adrenergic receptor agonist, is now commonly used because atropine's effect is so long lasting.

*** Think about the systemic effects of belladonna poisoning.***

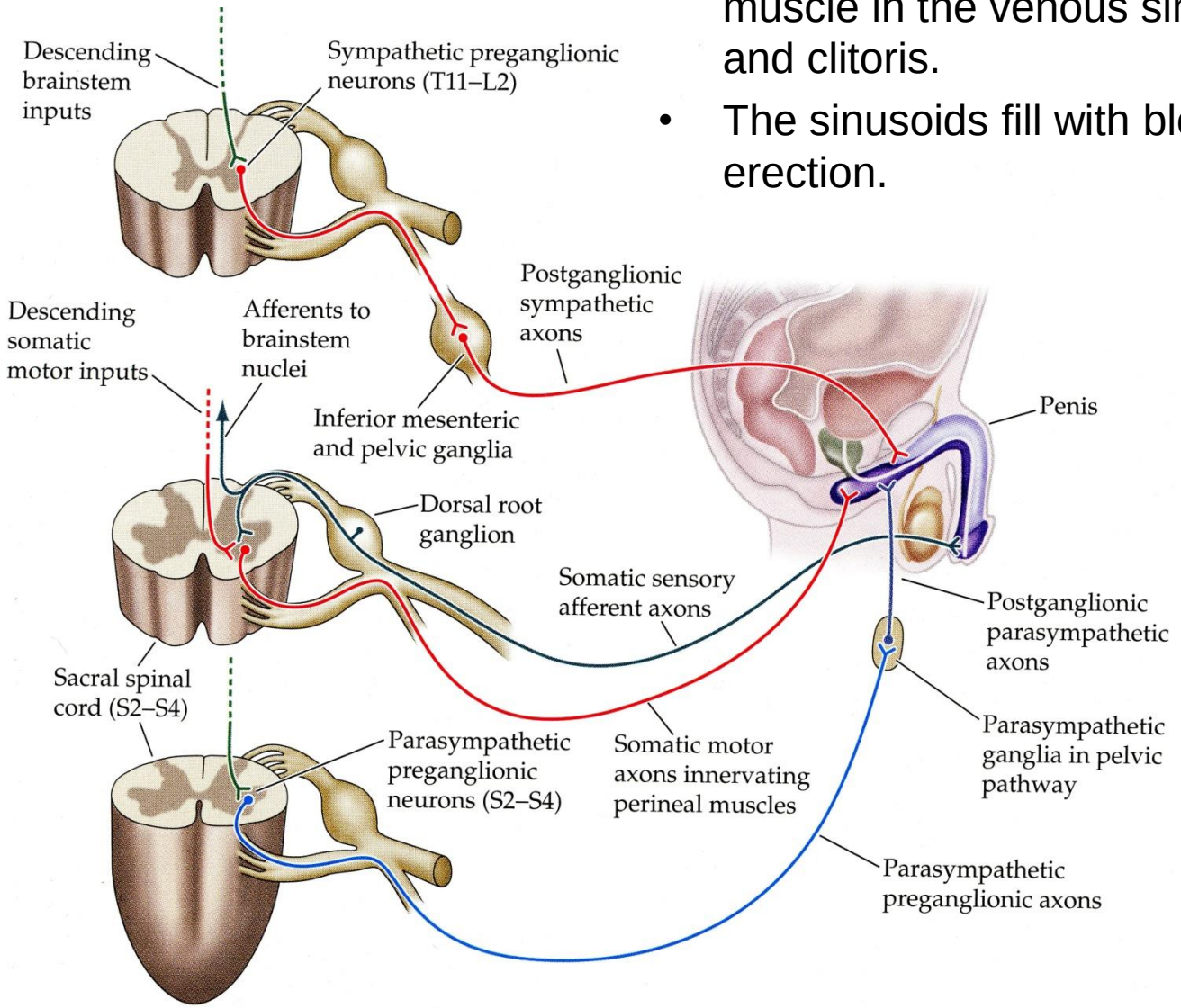
Sex

- The neural circuitry and most of the sex organs are very similar in males and females.
- Preganglionic parasympathetics from sacral spinal cord synapse in pelvic ganglia.
- Neurons in the ganglia send axons to several parts of the sex organs.



Sex

- Parasympathetic activity relaxes the smooth muscle in the venous sinusoids of the penis and clitoris.
- The sinusoids fill with blood resulting in an erection.

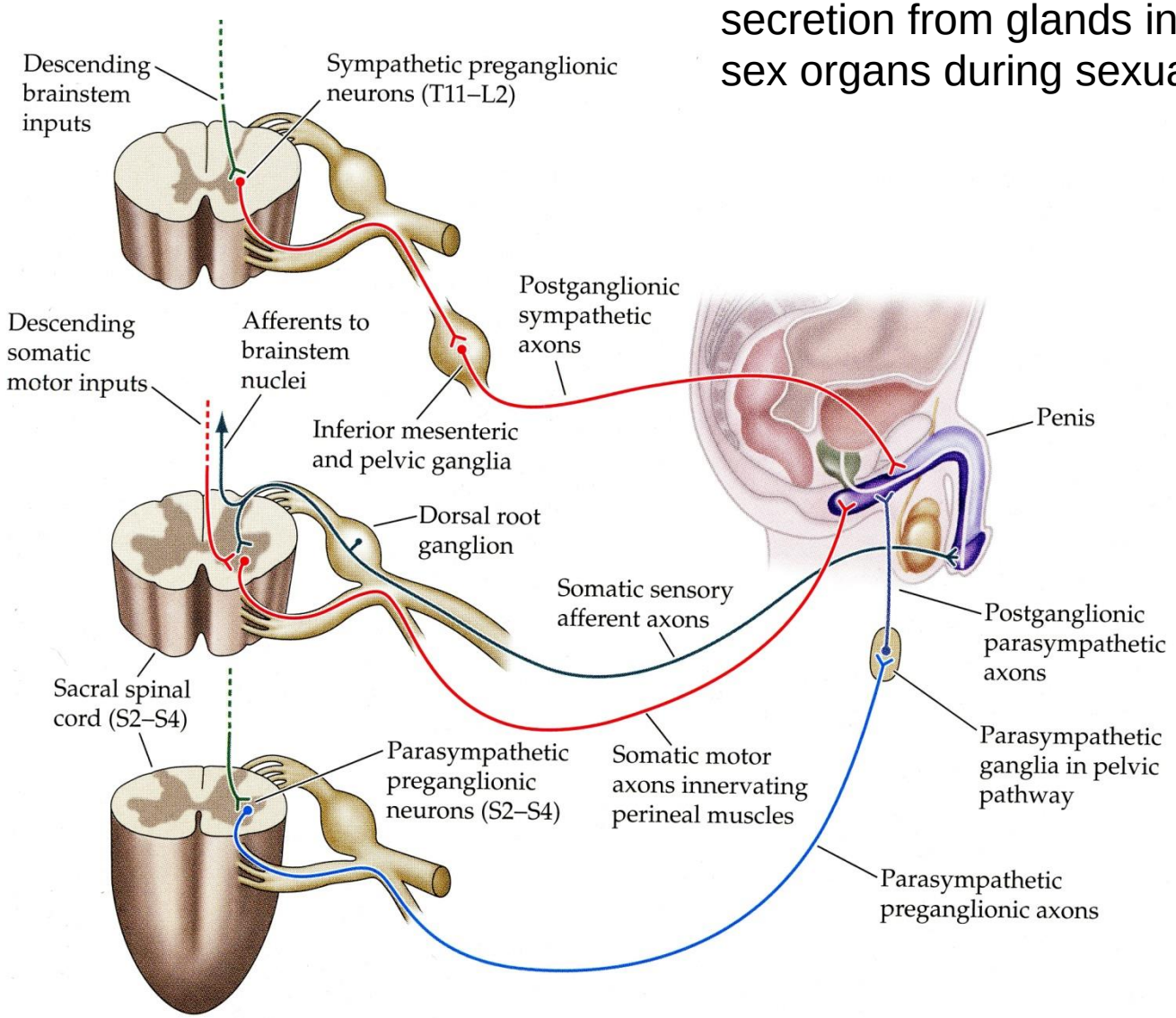


Sex

- The parasympathetic postganglionic axons to the venous sinusoids use nitric oxide as the neurotransmitter (rather than norepinephrine).
- Nitric oxide activates the second messenger, cyclic GMP (cGMP).
- Increased levels of cGMP relax the smooth muscle in the walls of the sinusoids.
- The drug, Viagra, blocks degradation of cGMP in the smooth muscle cells of the venous sinusoids resulting in a prolonged erection (in men?).

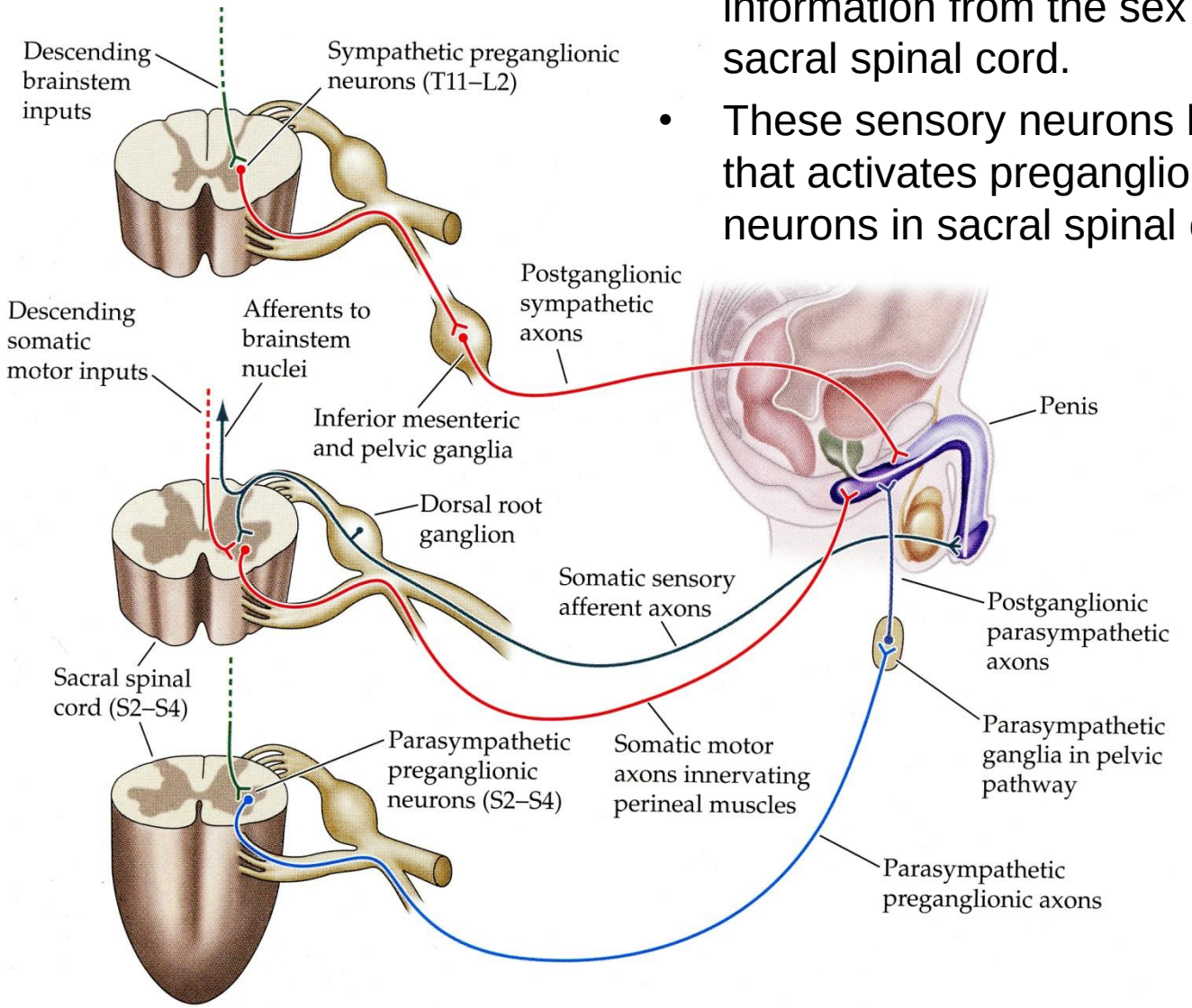
Sex

- Parasympathetic activity also increases secretion from glands in the male and female sex organs during sexual arousal.



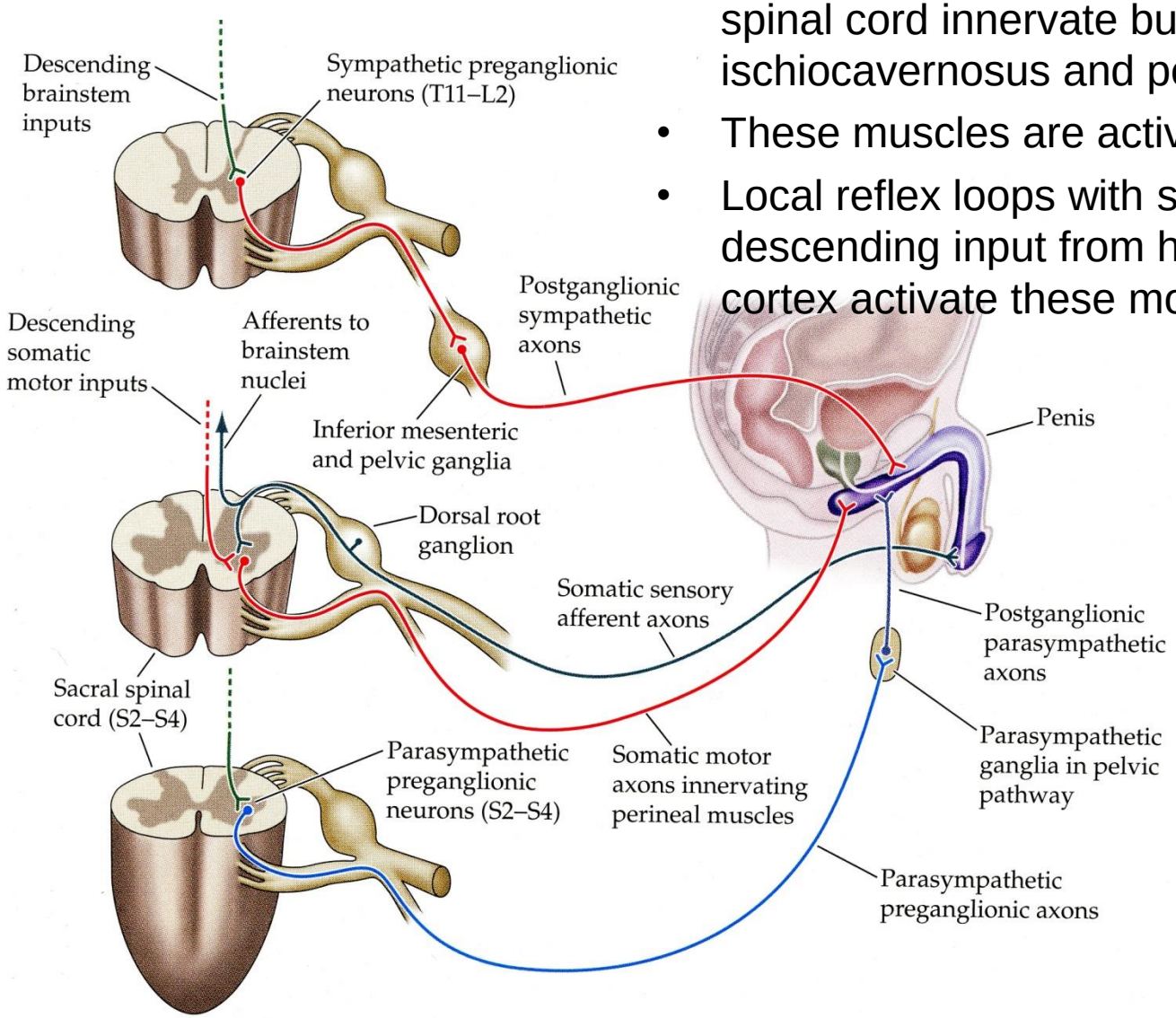
Sex

- Somatosensory neurons carry touch information from the sex organs to lumbar and sacral spinal cord.
- These sensory neurons have a reflex circuit that activates preganglionic parasympathetic neurons in sacral spinal cord.



Sex

- Somatic motor neurons in lumbar and sacral spinal cord innervate bulbocavernosus, ischiocavernosus and pelvic floor muscles.
- These muscles are activated during orgasm.
- Local reflex loops with sensory neurons and descending input from hypothalamus and cortex activate these motor neurons.



Sex

- Sympathetic activity causes vasoconstriction in the venous sinusoids of the penis and clitoris.
- Sympathetic activity inhibits sexual arousal and all sex related functions.
- Stress activates the sympathetic system.
- A woman will never be aroused by non-consensual sex – i.e. rape.