

Sheet no. 27

Lecture Date: 31/3/2021

Lecture Title: Sympathetic Nervous System

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Lecture Objectives

- Review the subdivisions of the nervous system.
- Review the general arrangement and compare the sympathetic and parasympathetic parts.
- Describe the following:
Para vertebral ganglia, Prevertebral ganglia, Parasympathetic ganglia, Splanchnic nerves, Autonomic plexuses.
- Map out the various plexuses in head and neck, thorax, abdomen and pelvis.
- Make a list of the components of the system.
- Review the basic structure of sympathetic trunk.
- Describe the source of sympathetic system in the neck and make a list of target organs.
- Describe the Para vertebral sympathetic ganglia in the abdomen; their locations and target organs.
- Discuss the relation of this system to the adrenal medulla.
- Discuss the sympathetic innervation of blood vessels.

The Autonomic Nervous System

- Regulates activity of smooth muscle, cardiac muscle & certain glands (the efferent part of it)
- Structures involved:
 - general visceral afferent neurons (GVA)
 - general visceral efferent neurons (GVE)
 - integration center within the brain which receives information from afferent then gives order to efferent fibers.
- connects directly to the Hypothalamus which is a part of the limbic system (because as you know autonomic system is related to emotions) and other regions of the cerebrum.

Autonomic versus Somatic NS

✓ Somatic nervous system

- consciously perceived sensations
- excitation of skeletal muscle
- one neuron connects CNS to organ (efferent part)

✓ Autonomic nervous system

- unconsciously perceived visceral sensations
- involuntary inhibition or excitation of smooth muscle, cardiac muscle or glandular secretion
- two neurons needed to connect CNS to organ (efferent part)
 - preganglionic and postganglionic neurons

The Autonomic Nervous System

✓ see the figure in the next page & notice that:

- The somatic nervous system connects directly to skeletal muscle by one myelinated neuron.
- But Autonomic system needs 2 neurons to reach the viscera = preganglionic (myelinated) & postganglionic (unmyelinated).
 - All cell bodies of motor neurons are in the CNS (including preganglionic neurons), except the cell bodies of **postganglionic** neurons, which are in the Autonomic ganglia outside the CNS.
- The neurotransmitters of:
 - somatic neurons and preganglionic Autonomic (Sympathetic & parasympathetic) neurons are **ACH**
 - postganglionic of Parasympathetic are **ACH**
 - postganglionic of sympathetic are **norepinephrine mainly or epinephrine**.

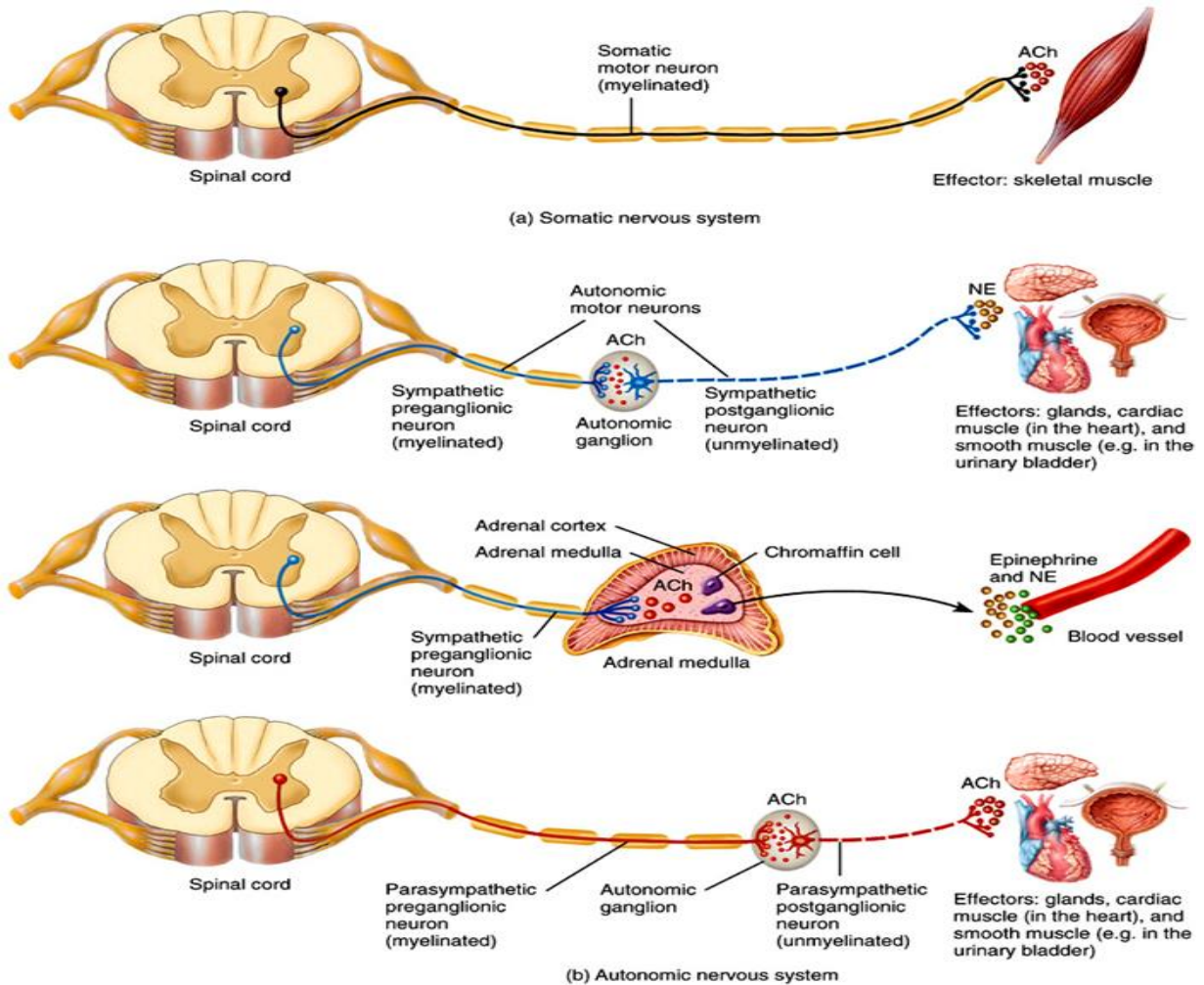


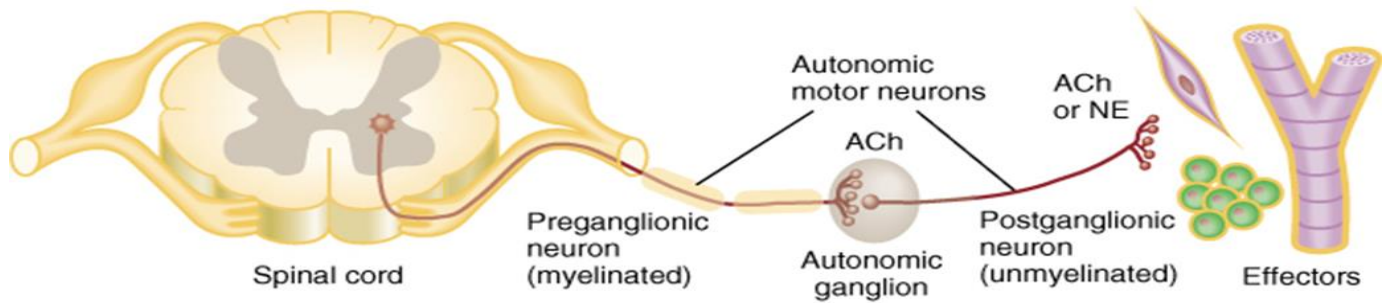
Figure 15.01 Tortora - PAP 12/e
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TABLE 15.1

Comparison of the Somatic and Autonomic Nervous Systems

	SOMATIC NERVOUS SYSTEM	AUTONOMIC NERVOUS SYSTEM
Sensory input	Somatic senses and special senses.	Mainly from interoceptors; some from somatic senses and special senses.
Control of motor output	Voluntary control from cerebral cortex, with contributions from basal ganglia, cerebellum, brain stem, and spinal cord.	Involuntary control from hypothalamus, limbic system, brain stem, and spinal cord; limited control from cerebral cortex.
Motor neuron pathway	One-neuron pathway: Somatic motor neurons extending from CNS synapse directly with effector.	Usually two-neuron pathway: Preganglionic neurons extending from CNS synapse with postganglionic neurons in an autonomic ganglion, and postganglionic neurons extending from ganglion synapse with a visceral effector. Alternatively, preganglionic neurons may extend from CNS to synapse with chromaffin cells of adrenal medullae.
Neurotransmitters and hormones	All somatic motor neurons release ACh.	All sympathetic and parasympathetic preganglionic neurons release acetylcholine (ACh). Most sympathetic postganglionic neurons release norepinephrine (NE); those to most sweat glands release ACh. All parasympathetic postganglionic neurons release ACh. Chromaffin cells of adrenal medullae release epinephrine and norepinephrine.
Effectors	Skeletal muscle.	Smooth muscle, cardiac muscle, and glands.
Responses	Contraction of skeletal muscle.	Contraction or relaxation of smooth muscle; increased or decreased rate and force of contraction of cardiac muscle; increased or decreased secretions of glands.

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Basic Anatomy of Motor ANS:

<ul style="list-style-type: none"> Preganglionic neuron 	<ul style="list-style-type: none"> Postganglionic neuron
cell body in brain or spinal cord	cell body lies outside the CNS in an autonomic ganglion
axon is myelinated type B fiber that extends to autonomic ganglion	axon is unmyelinated type C fiber that terminates in a visceral effector

❖ **Divisions of the ANS:** (see the figure in next page)

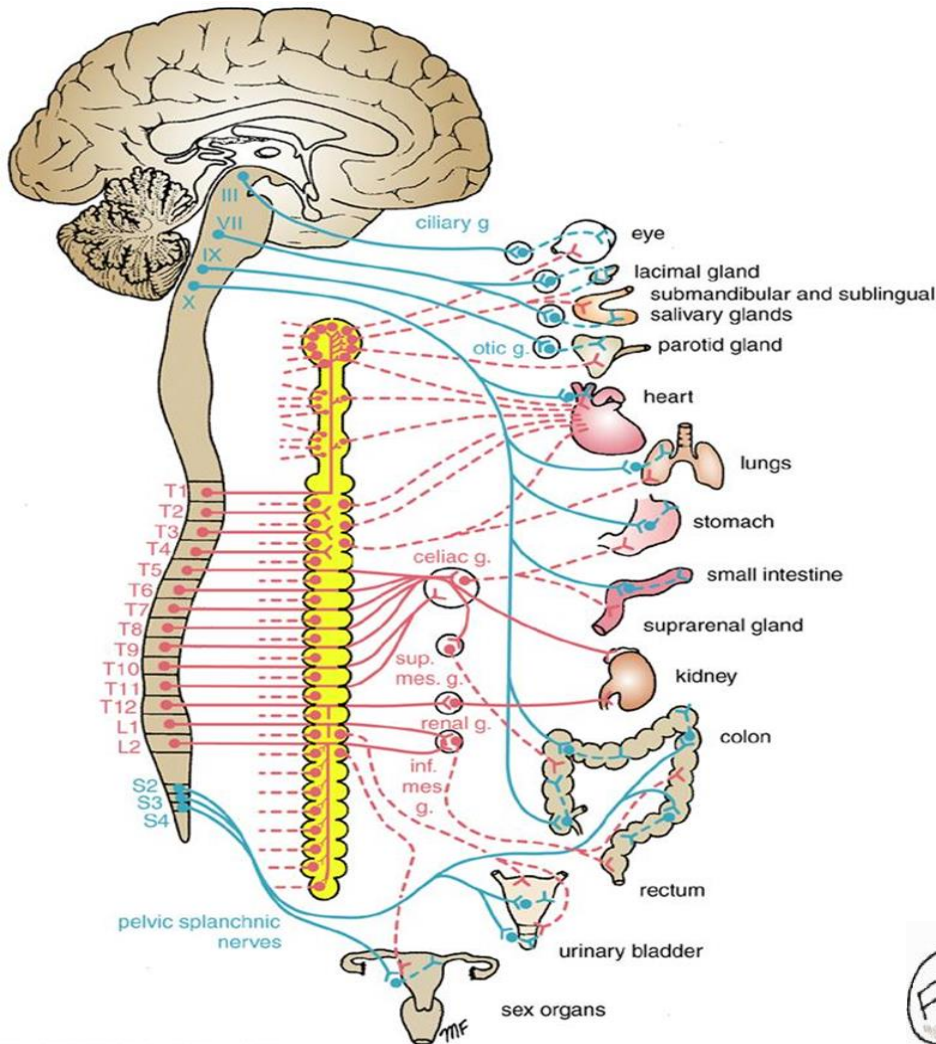
1. **Sympathetic** division

- Called thoracolumbar division
 - Preganglionic cell bodies are within the intermediolateral cell column, throughout thoracic and lumbar segments (T1-L2)
 - In general, the connection between preganglionic & postganglionic is near the CNS
- = preganglionic neurons are shorter than postganglionic

- So, single sympathetic preganglionic fiber has many axon collaterals and may synapse with 20 or more postganglionic neurons.
- The postganglionic axons typically terminate in **several** visceral effectors and *therefore the effects* of sympathetic stimulation are more widespread than the effects of parasympathetic stimulation
- Therefore, emergency situations are mostly controlled by sympathetic; because of the quick & more diffused action of Sympathetic.

2. **Parasympathetic** division

- Called craniosacral
 - has 2 divisions: Cranial & Sacral (S2-S4) divisions
 - preganglionic cell bodies in nuclei of 4 cranial nerves and the sacral spinal cord
 - The connection between preganglionic & postganglionic are near the viscera
- = preganglionic neurons are longer than postganglionic
- So, single parasympathetic preganglionic neuron synapse with only 3-5 postganglionic neuron within the wall of the viscera & and their target is to the same organ (So preganglionic neuron is targeted to a specific organ)



✓ **Note:** the visceral organs that innervated by ANS are (**Dual innervated**) = innervated by both (sympathetic & parasympathetic), because the actions of them are opposing each other, and so they control the functions of the viscera. (one speeds up organ/one slows down organ, ex: Sympathetic NS increases heart rate, Parasympathetic NS decreases heart rate)

red neurons =
sympathetic
blue neurons =
parasympathetic



Sympathetic nervous system

❖ **Structure** (see the figure in next page)

- Preganglionic neurons originate from the thoracic and lumbar levels of the spinal cord (T1-L2)
- intermediolateral column (IML) is continuous along (T1-L2) then this continuation is followed by cut. IML column appears again in the sacral region as parasympathetic.
(preganglionic sympathetic neurons are continuous (unlike parasympathetic))
Remember that: IML column in the thoracic region makes lateral horn.
- multipolar neuron
- axons of preganglionic efferent exit spinal cord through the ventral root (like somatic efferent)
 - so ventral root contains axons of autonomic and somatic motor neurons

- they go to the sympathetic ganglia (2 types):

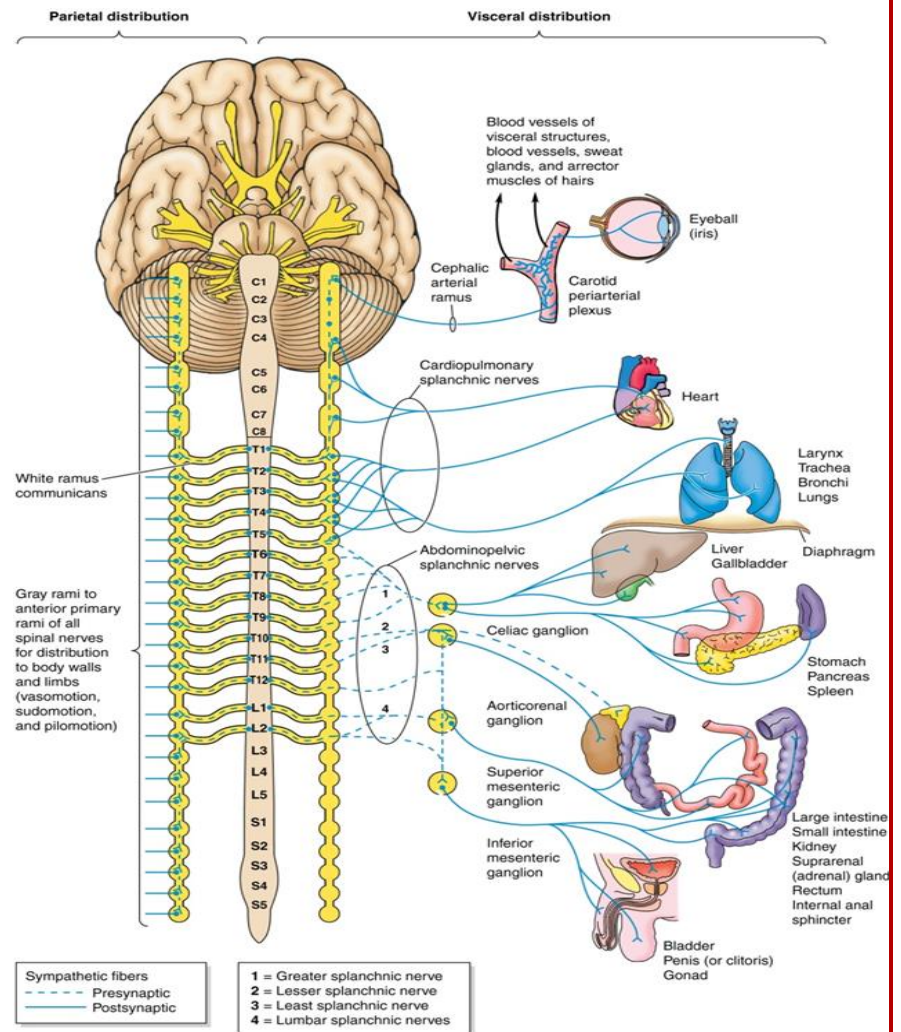
1) Paravertebral ganglia

- o called sympathetic trunk (vertebral chain) ganglia
- o located just lateral to the vertebral column on both sides.
- o extends from the cervical region of the **vertebral column** all over to the sacral region of the **vertebral column**.

- o contain cell bodies of postganglionic neurons.

2) Prevertebral ganglia

- o called collateral ganglia
- o located within the abdomen near the major branches of abdominal aorta, that's why it's named is related to these branches (celiac, superior mesenteric, inferior mesenteric, aorticorenal)
- o contain cell bodies of postganglionic neurons.

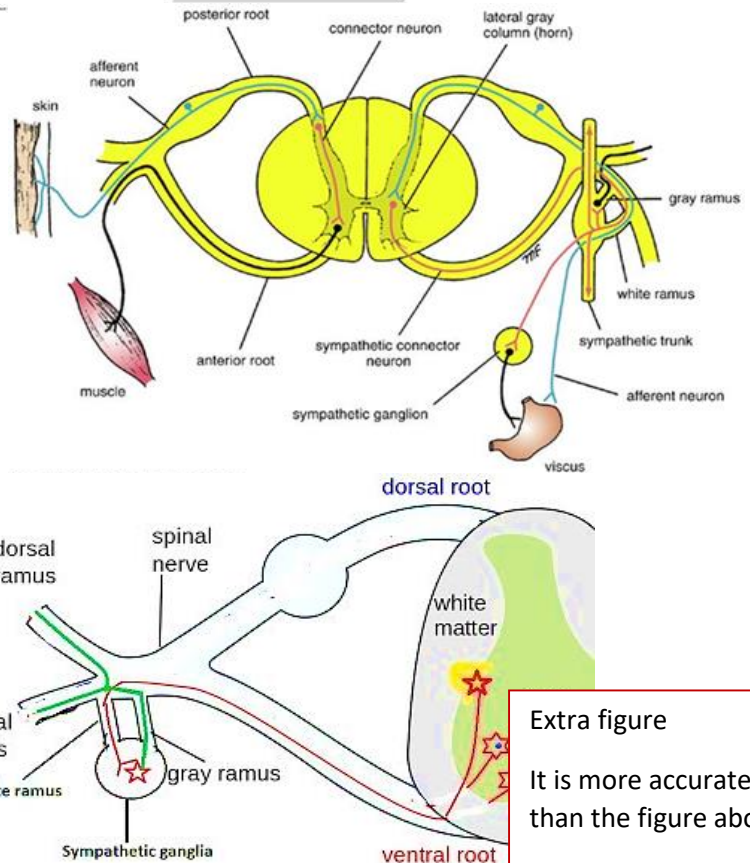


❖ Fate of Preganglionic neurons.

when the spinal nerve emerges from vertebral foramen, it branches into:

1. Major rami:
 - A. Dorsal ramus
 - B. Ventral ramus
2. Rami communicants:
 - A. Gray ramus
 - B. **White ramus**

structures containing sympathetic preganglionic axons that connect the anterior ramus of the spinal nerve with the ganglia of the sympathetic trunk.



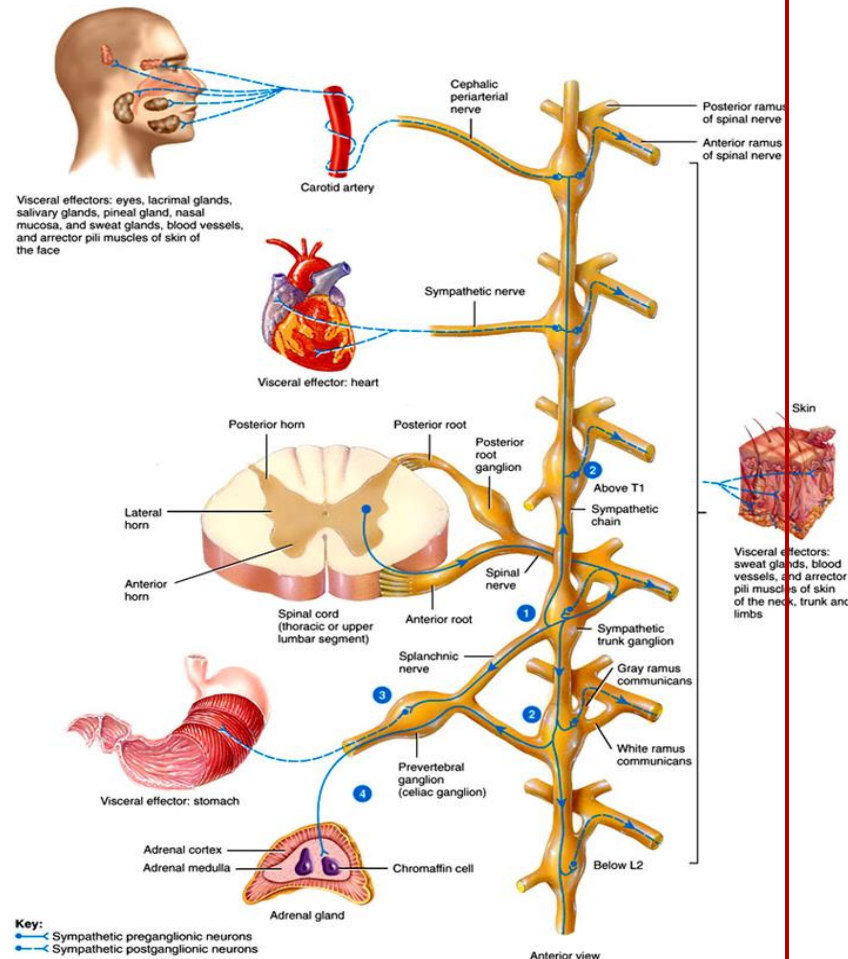
Extra figure

It is more accurate than the figure above

❖ Neurons in Sympathetic Trunk:

- Cell bodies in the IML column → Preganglionic axons → anterior root → spinal nerve (after fusing with dorsal root and leaving intervertebral foramen) → white ramus → sympathetic trunk ganglion.
- Preganglionic fibers exit the spinal segment with the same nerve of that segment
ex: preganglionic sympathetic fiber of first thoracic segment exits with the first thoracic nerve T1
in other words, sympathetic fibers exit with T1 nerve – L2 nerve.
- Then undergo to one of the four pathways:

1. **Synapse** in the ganglion it first reaches in the sympathetic trunk
 - at the same level of entry, ex:
sympathetic fiber that leaves with T1 nerve will go to the paravertebral ganglion T1 which located at the same level of them and synapse with cell bodies of postganglionic neurons there.
2. **After leaving the white ramus they ascend or descend** in the sympathetic trunk and then synapse with postganglionic neurons in a distant (upper or lower) ganglion within the sympathetic trunk
 - not at the same level
 - so preganglionic neurons may reach the cervical sympathetic ganglion, (that's why the sympathetic trunk has a cervical part and sacral part)

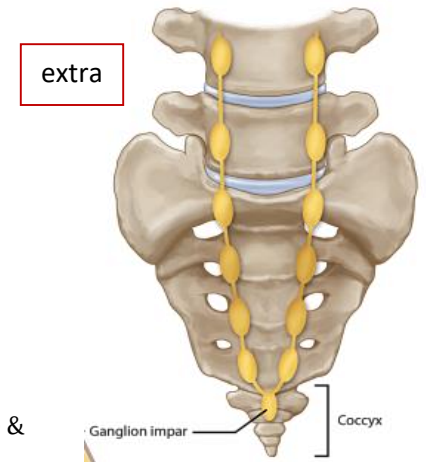


3. **Continue**, without synapsing in the sympathetic trunk ganglion and leaves it as splanchnic nerves (this occur in the thoracic cavity), then ends at the **prevertebral ganglion** (in the abdominal cavity) and synapse there.
 - So, preganglionic fibers (splanchnic nerves) need to penetrate the crura of diaphragm to reach the prevertebral ganglion (which is in the abdomen) and synapse with cell bodies of postganglionic neurons there.
 - particular for innervating viscera in the **abdominopelvic organs**.
4. **Pass** through the sympathetic trunk ganglion & prevertebral ganglion (without synapsing) and then to the medulla of adrenal gland
 - Recall; Adrenal medullary cells (chromaffin cells) are derived from the neural crest (so they have neural origin). Therefore, they were a postganglionic neuron. Later, differentiated into chromaffin cells that secrete epinephrine & norepinephrine (as a hormone, not a neurotransmitter). In other words, chromaffin cells act as postganglionic neurons.

** So, preganglionic neurons >> leave the sympathetic trunk without synapsing >> continue as splanchnic nerves >> leave the prevertebral ganglia without synapsing again >> reach the chromaffin cells which will act as postganglionic neurons.

❖ Organization of Sympathetic Trunk Ganglia

- Two **sympathetic trunks** along the vertebral column (all over it) & parallel to it.
- Each sympathetic trunk has: 3 cervical (at least 2; because sometimes the middle and inferior cervical ganglia are fused together), 11 or 12 thoracic, 4 or 5 lumbar, 4 or 5 pelvic and both trunks end caudally in one joint ganglion (ganglion impar)
- **ganglion impar**: at the middle anterior to the sacrum within pelvis, connects the two sympathetic trunks on both sides.
- **Postganglionic neurons from the**
 - superior cervical ganglion → innervates only head, neck and heart.
→ larger than inferior and middle ganglion
 - middle cervical ganglion → innervates heart.
 - inferior cervical ganglion → innervates heart.
- **Thoracic sympathetic trunk** → innervates heart, lungs, and bronchi (thoracic viscera)
>> **sympathetic innervation of the heart** is cervical ganglion (superior, middle, inferior) & upper 6 or 5 thoracic ganglia from the sympathetic trunk.



❖ Pathways from Sympathetic Trunk Ganglia to Visceral Effectors

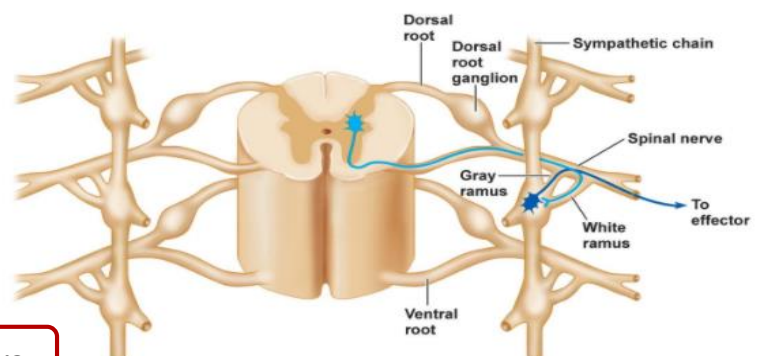
➤ Axons leave the sympathetic trunk in 4 possible ways:

Note: these axons are postganglionic (synapse with cell bodies within the sympathetic trunk) or preganglionic (they don't synapse here, just pass).

1. Spinal nerves:

- They are postganglionic.
- = axons of postganglionic neurons that leave the sympathetic trunk will return back to the spinal nerve by entering a short pathway called a gray ramus and merge with the anterior ramus of a spinal nerve. The aim of this is to reach their target organs within somatic territories. Because as you know, spinal nerves go to the somatic territories so they walk with them.
- **Innervate** the organs within somatic territories (skin & skeletal muscle) in the trunk, upper and lower limbs = Blood vessels within the skin (vasomotion), arrector mm (muscles attached to hair follicles), (pilomotion), and sweat glands (sudomotion)

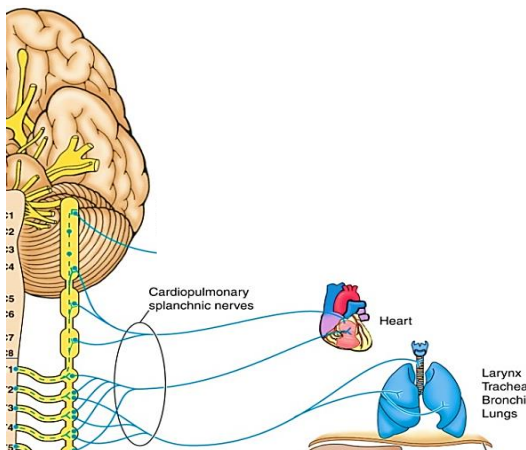
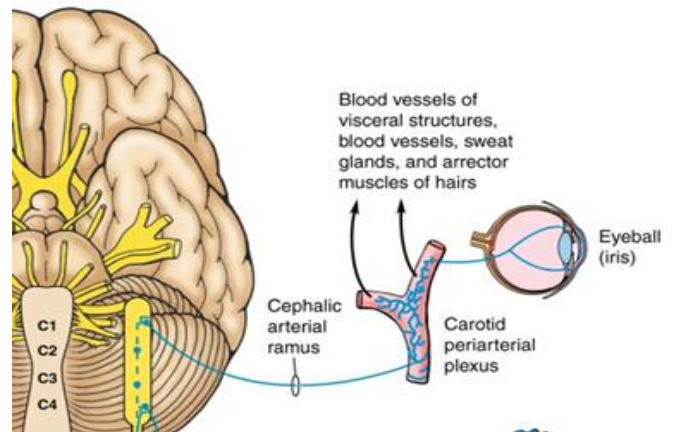
** Note: Gray rami communicants: structures containing sympathetic postganglionic axons that connect the ganglia of the sympathetic trunk to spinal nerves



Extra

2. Cephalic Periarterial Nerves:

- They are postganglionic.
- Some sympathetic preganglionic neurons enter the sympathetic trunk, ascend to the superior cervical ganglion where they synapse with postganglionic neurons. Some of these leave the sympathetic trunk by forming cephalic arterial nerves, which heading directly to the common, internal, external carotid arteries and their branches, forming periarterial PLEXUS & when they reach near a cranial nerves, they merge with them to reach their targets. And again the aim of this is that cranial nerves supply head and neck so they walk with them.
- **Innervate** the organs within somatic regions (skin & skeletal muscles) of head, neck and face, & iris dilator muscle (Cephalic Periarterial Nerve reaches the iris dilator muscle through the nasociliary artery and from there, through the long and short ciliary)
- ex: deep petrosal nerve (sympathetic branch of periarterial PLEXUS) merge with the greater petrosal nerve to form the nerve of the pterygoid canal
- Note: most of branches of cranial nerves have efferent sympathetic fibers walk with them to reach their targets.

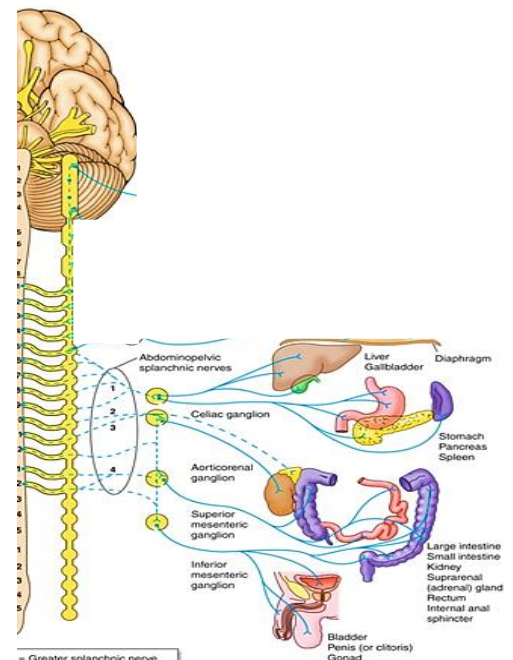


3. Sympathetic Nerves

- They are postganglionic.
- = postganglionic fibers from cervical ganglia (superior, middle, inferior) & upper part of sympathetic trunk ganglia.
- some books called it Cardiopulmonary splanchnic nerves but it is misleading
- merge with parasympathetic fibers forming Autonomic PLEXUS within the thorax.
- **Innervate** thoracic viscera (heart, lungs, bronchial tree, trachea and esophagus)

4. Splanchnic Nerves

- They are preganglionic (the only)
- = nerves that pass through the sympathetic trunk without terminating in it. Beyond the trunk they form nerves called splanchnic nerves which extend to prevertebral ganglia where it synapsing.
 - T5-T9 or T10- Greater splanchnic nerve
 - T10-T11- Lesser splanchnic nerve
 - T12- least splanchnic nerve
 - L1-L4- Lumbar splanchnic nerve
- Recall: The first 3 emerge from the thoracic region, therefore, they need to pass through the diaphragm to reach the prevertebral ganglia



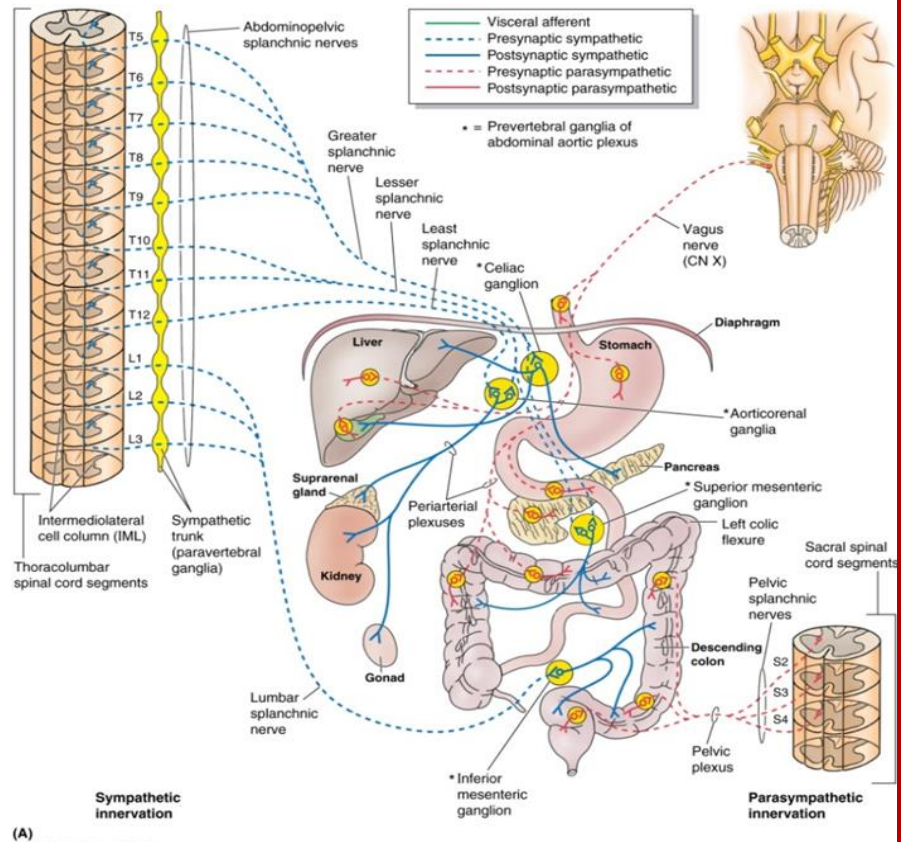
❖ Prevertebral ganglia:

- within the abdomen
- some books set each splanchnic nerve with its ganglion but it's debatable. However, the areas that innervated by each ganglion are constant (they innervate the same areas that the related major aortic branches supply, ex: fibers from celiac ganglion will innervate the same areas that are supplied by celiac trunk)
- axons from these ganglia merge with parasympathetic forming **Prevertebral plexus**
- so the innervation of the viscera is from the prevertebral plexus not only from postganglionic sympathetic fibers

- Celiac ganglion** → innervates viscera in the upper part of the abdomen (forgot)
- Superior mesenteric ganglion** → innervates midgut (small intestine, up to 2/3 of the transverse colon)
- Inferior mesenteric ganglion** → innervates hindgut and some of pelvic organs.
- Aorticorenal ganglion** → innervates only the kidney (**not** suprarenal gland)

**** Notes:**

- >> the names of the ganglia here are related to the major aortic branches.
- >> these ganglia are located near the roots of the major aortic branches.
- >> so, they are considered as retroperitoneal structures.



❖ Splanchnic Nerves to the Adrenal Medulla:

Again: Some sympathetic preganglionic axons pass, without synapsing, through the sympathetic trunk, greater splanchnic nerves and celiac ganglion into the adrenal medulla (modified sympathetic ganglia).

Release hormones into blood (80% epinephrine, 20% norepinephrine).

❖ Organs Innervated by Sympathetic NS

- ✓ Structures innervated by each **spinal nerve**:
 - sweat glands, arrector pili mm., blood vessels to skin & skeletal mm.
- ✓ **Thoracic & cranial plexuses** supply:
 - heart, lungs, esophagus & thoracic blood vessels
 - plexus around carotid artery to head structures
- ✓ **Splanchnic nerves** to prevertebral ganglia supply:
 - GI tract from stomach to rectum, urinary & reproductive organs

❖ Sympathetic Afferent Fibers

- Receptors in Viscera → sympathetic ganglion → white rami communicants → spinal nerve → dorsal root ganglion → spinal cord
- the same path of sympathetic efferent
- Recall: the dorsal root ganglion has the cell bodies of the somatic sensory neurons. Therefore, we have referral pain.
- ex: the afferent of sympathetic that come from heart travel to the (cervical ganglia and upper thoracic ganglia → white rami communicants of the upper thoracic region (T1-T6) → spinal nerve (T1-T6) → dorsal root ganglion of T1-T6 nerve → T1-T6 spinal segment. So referral pain of heart attack sense in chest, neck, upper limb.

The End

