Physiology of autonomic nervous system, its role in regulation of visceral functions.

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The Autonomic Nervous System and Visceral Sensory Neurons

- The Autonomic Nervous System is concerned with regulation of visceral or vegetative functions.

ANS provides two functions:

1. Maintenance of a homeostasis of an organism.
2. Adaptative-trophic function is an adaptation to conditions of an environment and maintenance of physical and mental activity.

- Innervates smooth muscle, cardiac muscle, and glands
- Regulates visceral functions
  - Heart rate, blood pressure, digestion, urination
- The general visceral motor division of the PNS

The Autonomic Nervous System and Visceral Sensory Neurons

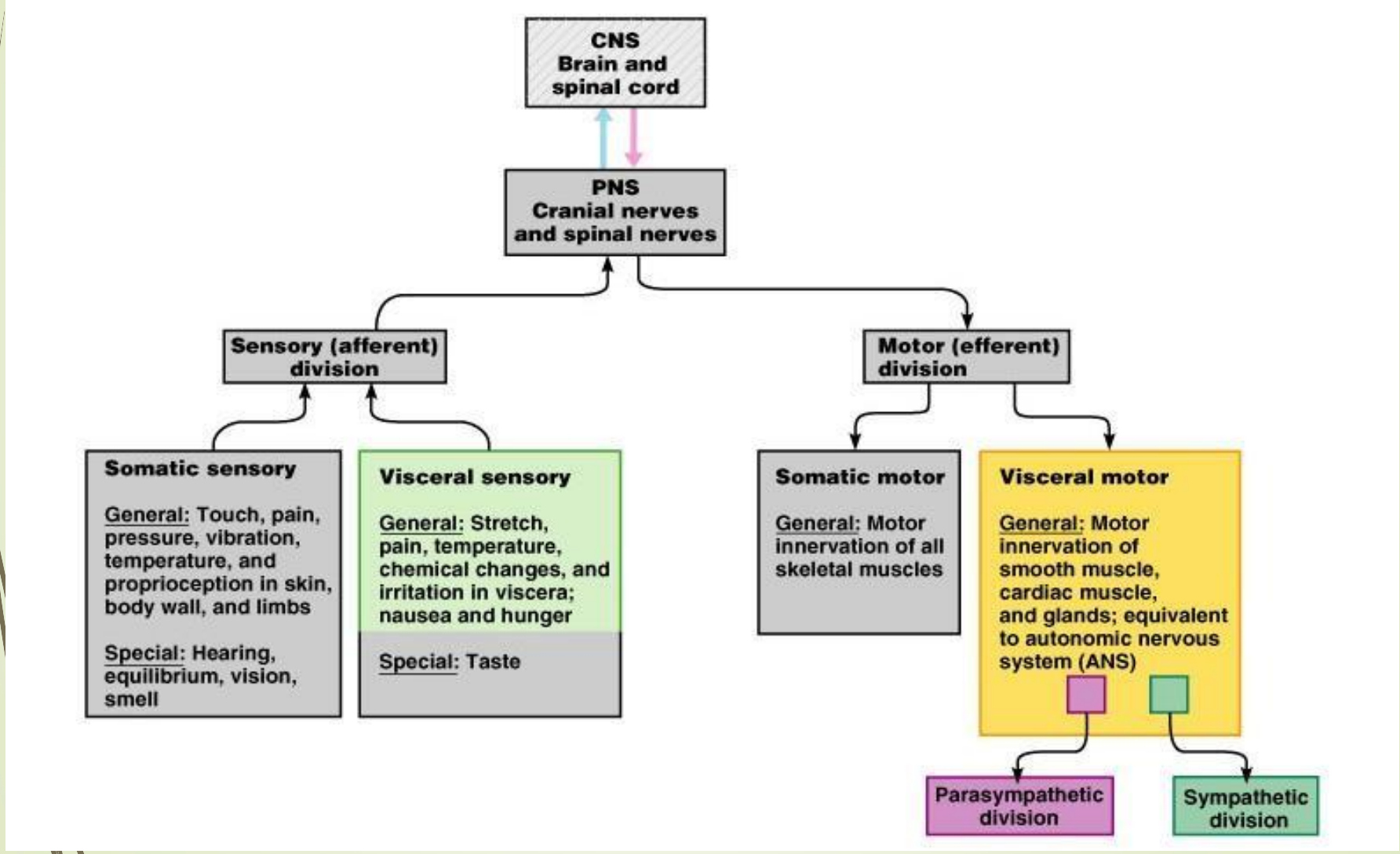


Figure 15.1

Comparison of Autonomic ic Motor Systems

- One motor neuron extends from the CNS to skeletal muscle
- Axons are well myelinated, conduct impulses rapidly

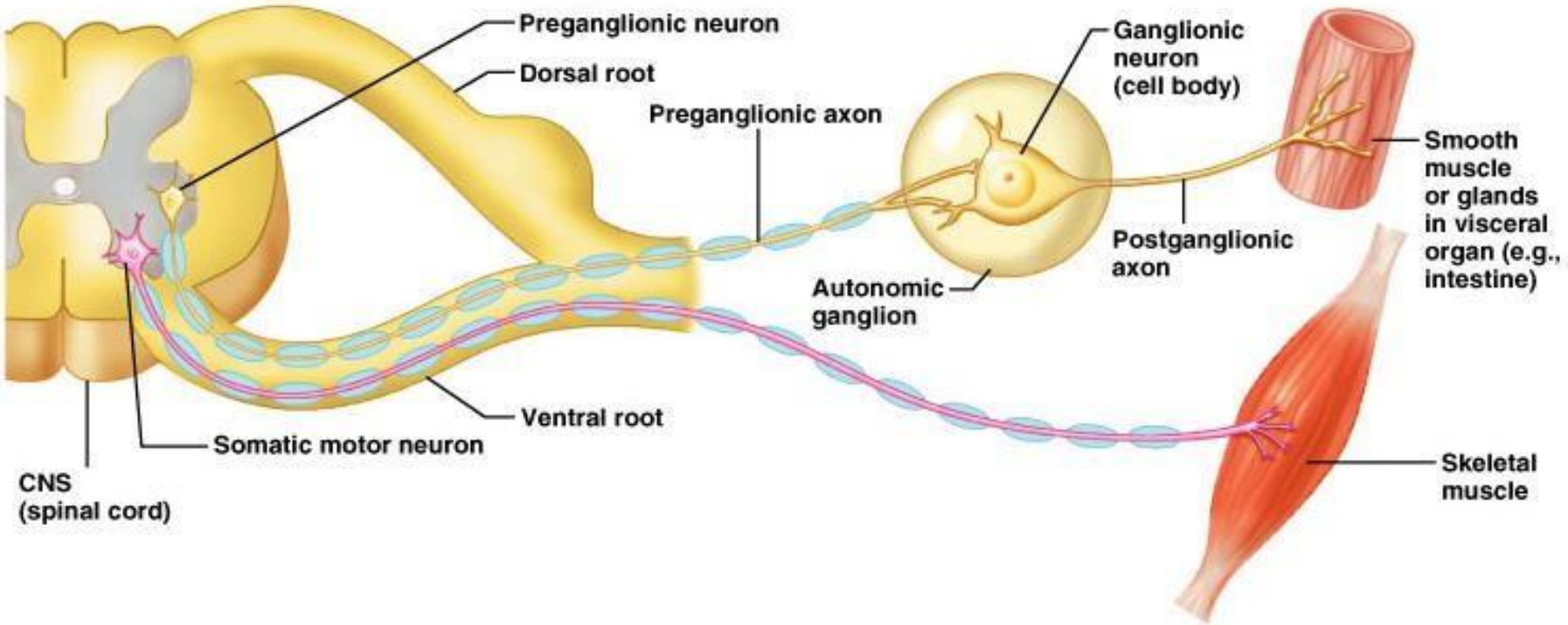
Autonomic nervous fibers comparatively to the somatic nervous fibers are interrupted in ganglion. Vegetative nervous system first neuron is located in CNS and its axons are directed to the ganglion. The second neuron is in the ganglion. Its axon innervates an organ. The I-st neuron fibers are called preganglionic, the II-nd one – postganglionic.

Comparison of Autonomic and Somatic Motor Systems

Autonomic nervous system

- Chain of two motor neurons
  - Preganglionic neuron
  - Postganglionic neuron
- Conduction is slower due to thinly or unmyelinated axons. AUTONOMIC fibers belong to the fibers of B- and C-types. They are thin. Impulse conductance velocity through sympathetic fibers is 0,4-0,5 m/sec, through parasympathetic ones – 10-20 m/sec.

Autonomic and Somatic Motor Systems



Divisions of the Autonomic Nervous System

- **The ANS borrows two levels depending on structure and functions :**
- **OVERSEGMENTARY ANS**:

  1) limbic region cortex, medio-basal parts of frontal and temporal gyruses;

  2) subcortical structures – thalamus, hypothalamus, amygdale, septum, olfactory tract, olfactory triangle;

  3) stem structures – reticular formation.
- **SEGMENTARY ANS**:

  1) Sympathetic and parasympathetic

  Innervate mostly the same structures

  Cause opposite effects

- **VEGETATIVE GANGLII CLASSIFICATION.**
- They are divided into 3 groups:
- **Vertebral** – they form sympathetic chains along vertebral column. Pre-ganglionar fibers come to the ganglii from spine through white (myelinated) fibers. Post-ganglionar sympathetic fibers are grey (myeline-free).
- **Prevertebral** – are located at bigger distance from vertebral column. Example: superior and middle cervical sympathetic nodes, solar plexus, superior and inferior mesenterial ganglii.
- **Intramural** ganglii are located in inner (visceral) organs (in heart, bronchi, intestine, gallblader, endocrine glands).

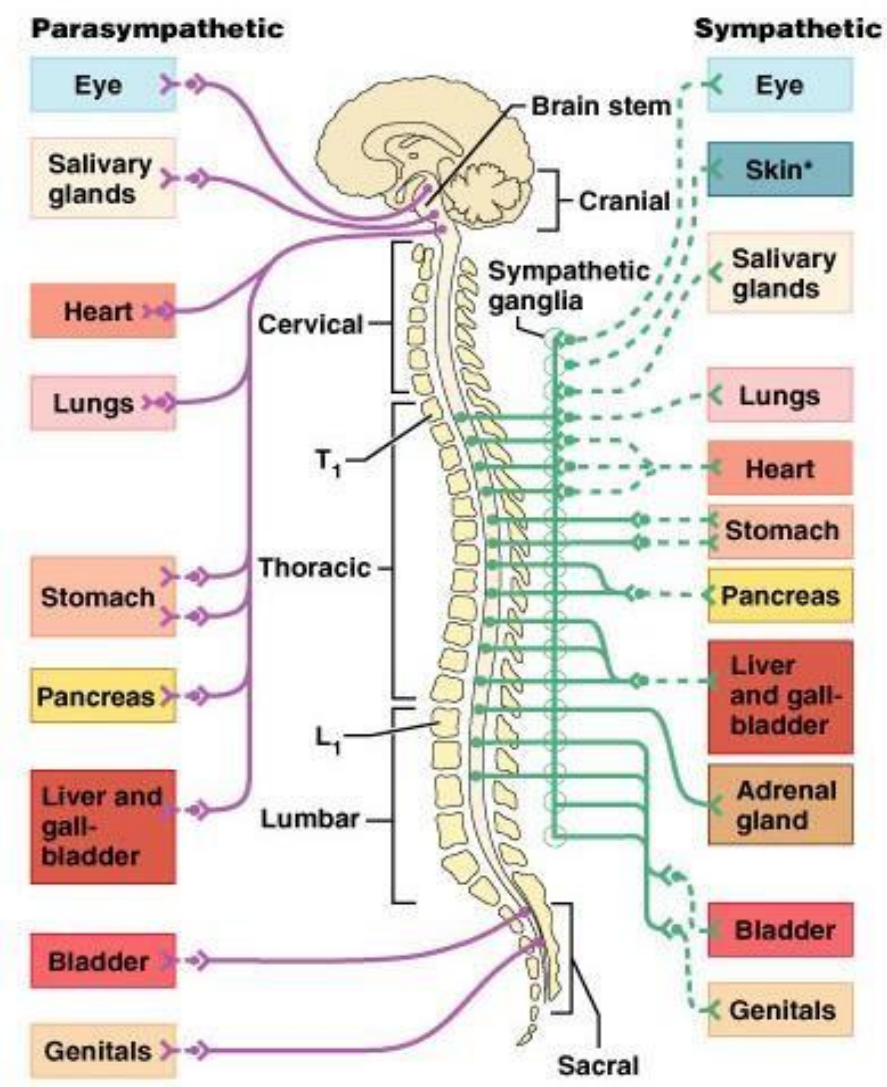
- **VEGETATIVE GANGLII FEATURES:**
- Vegetative ganglii spread pre-ganglionar fibers influence zone.
- They are able to nervous impulses spatial and temporary summation.
- Nervous impulses one-sided transmittance.
- They are able to rhythm transformation and conduct only 10-15 impulses per 1 sec.

Divisions of the Autonomic Nervous System

- Sympathetic – "fight, flight, or fright"
  - Activated during exercise, excitement, and emergencies
- Parasympathetic – "rest and digest"
  - Concerned with conserving energy

Anatomical Differences in Sympathetic and Parasympathetic Divisions

- Issue from different regions of the CNS
  - Sympathetic – also called the thoracolumbar division
  - Parasympathetic – also called the craniosacral division



Anatomical Differences in Sympathetic and Parasympathetic Divisions

- Length of postganglionic fibers
  - Sympathetic – long postganglionic fibers
  - Parasympathetic – short postganglionic fibers
- Branching of axons
  - Sympathetic axons – highly branched
    - Influences many organs
  - Parasympathetic axons – few branches
    - Localized effect

Neurotransmitters of Autonomic Nervous System

Mediators IN SYMPATHETIC AND PARASYMPATHETIC PARTS

- **Acetylcholin** is mediator in all **preganglionar synapses** (sympathetic and parasympathetic). Receptors binding acetylcholin on postsynaptic membrane are named cholinergic. They belong to **nicotin**-sensitive in preganglionar synapses.
- They are designated as **N-cholinoreceptors**.
- N-cholinoreceptors ***blockers*** are following: kurare-like substances (benzohexonium, penthaminum). Preganglionar synapses have little number of **M-cholinoreceptors** (muscarin-sensitive). **Postganglionar synapses** formed by conductor on effector are different in vegetative nervous system 2 parts.

Postganglionar sympathetic synapses

Main mediators are **norepinephrinum and epinephrinum**.

- ***Adrenoreceptors*** :

  Alpha-adrenoreceptors (α1 and α2 subtypes).

  Their *blockers* (***sympatholythics***)are: phentholaminum, tropaphenum, dihydroergotaminum.

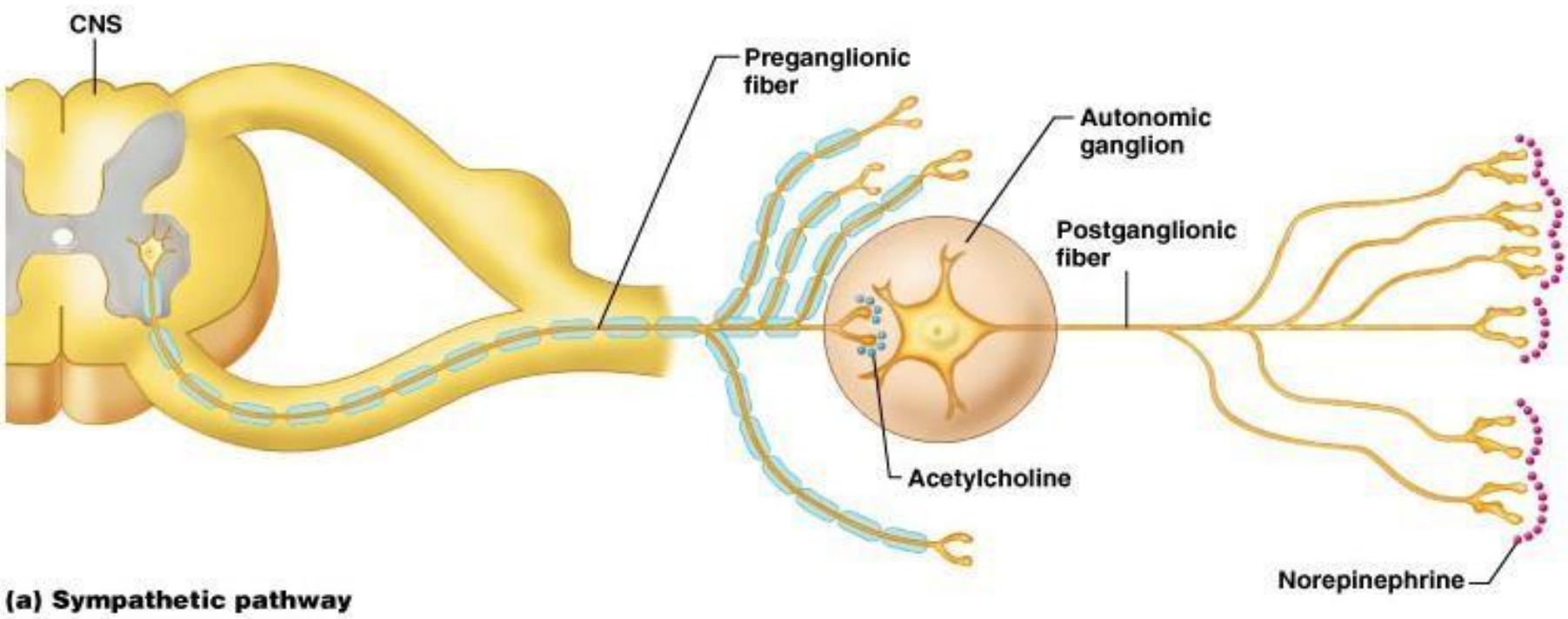
  Adrenomimetics cause effects similar to the ones of norepinephrinum.

  Beta-adrenoreceptors (B1and B2 sybtypes).

  Their *blocker* is anaprilinum (obsidanum). Both adrenoreceptors types are present in some organs. The results of their excitement can be opposite.

- For example, alpha- and beta-adrenoreceptors are in artery smooth muscle. Alpha- adrenoreceptors excitement causes arterioles constriction, beta ones – dilation. Organ reaction to epinephrinum and norepinephrinum under physiological conditions depends on alpha- or beta-adrenergic action dominance. Only one adrenoreceptors type is located in other visceral organs. Alpha-receptors are absent in ***heart*** and ***bronchi*** and norepinephrinum excites only beta-adrenoreceptors. It leads to heart contraction rate increasing and to bronchial dilation.

Anatomical Differences in Sympathetic and Parasympathetic Divisions



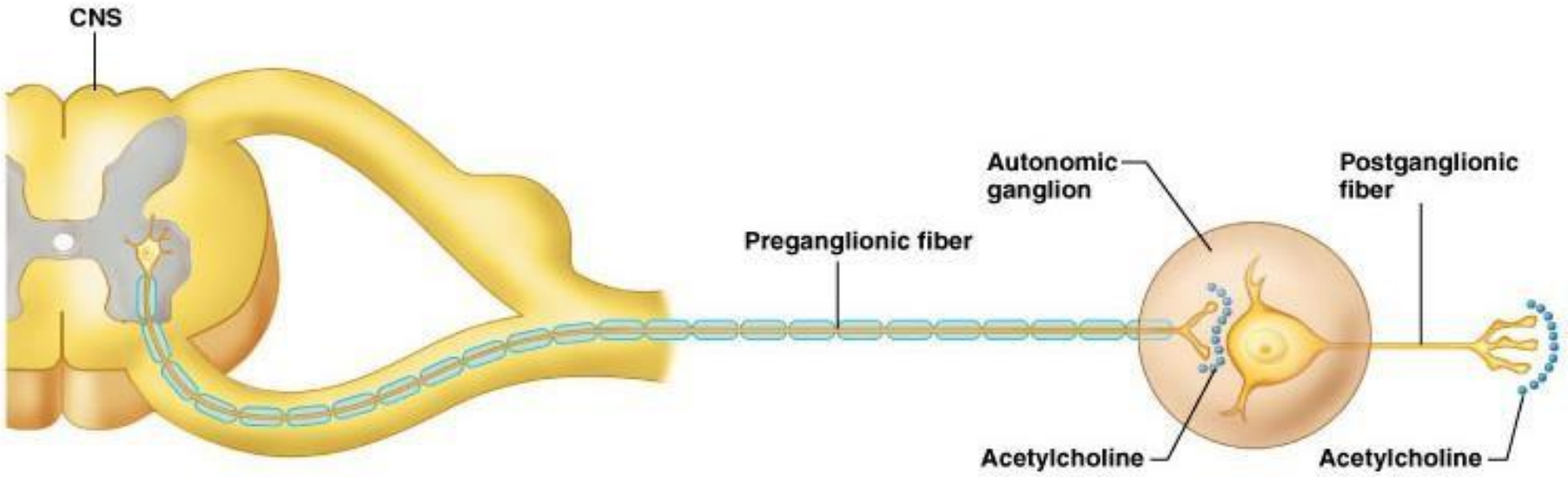
Norepinephrinum effects

- increases cardiac output;
- bronchodilating and antispasmic action;
- reflectory decreasing of respiration rate and altitude;
- antidiuretic-like effect with decreasing sodium and potassium ions releasing reducing with urine;
- inhibits alimentary tract peristalsis but contracts sphincters in uro-sexual and intestinal systems;
- inhibits alimentary secretion;
- increases skeletal muscles contractiveness.

- **Parasympathetic postganglionar synapses** use mediator ***acetylcholinum***. The mediator releasing occurs in portions. It is Ca-dependent process. Released acetylcholinum binds with **M-cholinoreceptors**.
- M-cholinoreceptors blockers (cholinolithics) preventing parasympathetic effects are atropinum, scopolaminum, platyphillinum.

- **Acetylcholinum effects:**
- Enforces pulmonary ventillation, gastral-intestinal peristalsis, secretion of gastral, intestinal and pancreatic glands.
- Inhibits bronchial secretion, contracts bronchial musculature, myocardial excitability, conductiveness and automatism.

Anatomical Differences in Sympathetic and Parasympathetic Divisions

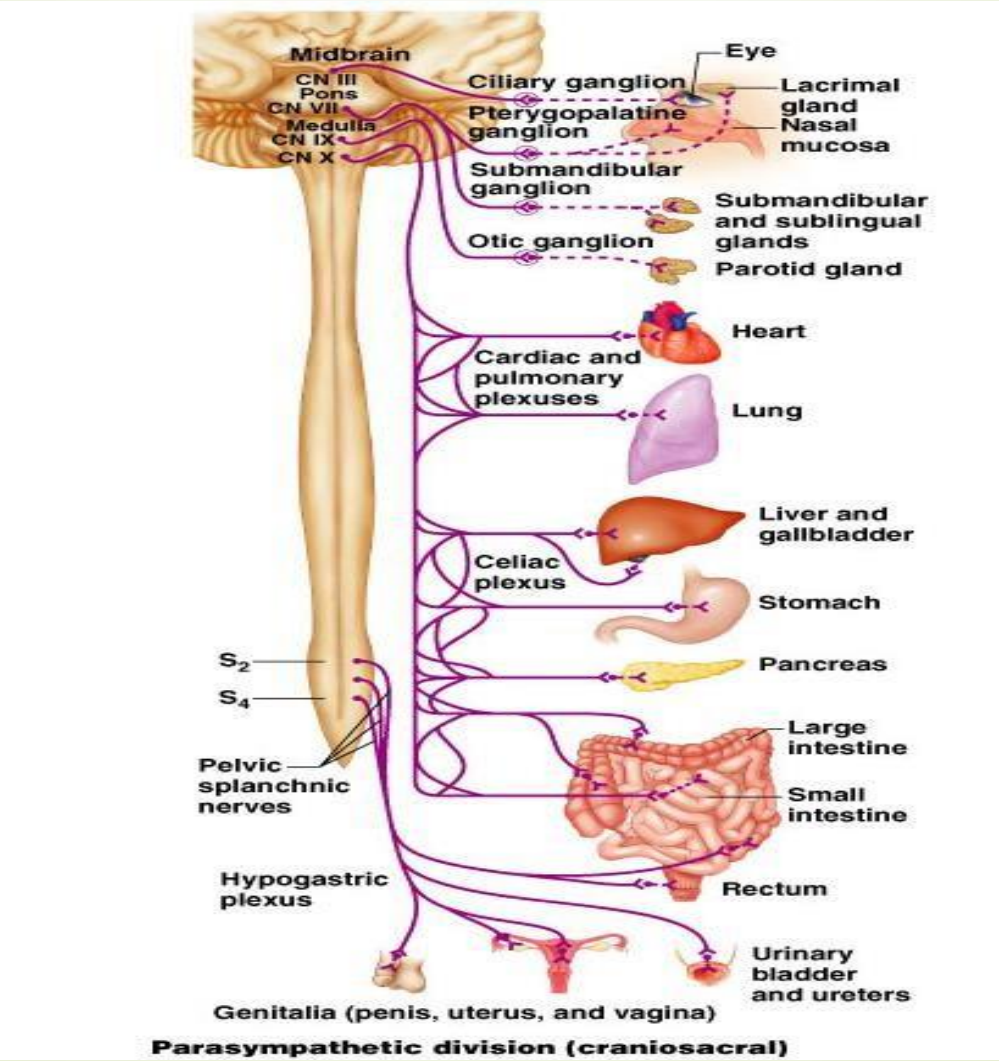


(b) Parasympathetic pathway

The Parasympathetic Division

The parasympathetic division of ANS: the fibers of this arise from brain and sacral segments of spinal cord. The cranial portion of parasympathetic division in brainstem innervates the blood vessels of the head and neck and many thoracoabdominal viscera. The sacral portion in sacral segments of the spinal cord innervates the smooth muscles forming the walls of viscera and the glands such as large intestine, liver, spleen, kidneys, bladder, genitalia, etc.

The Parasympathetic Division

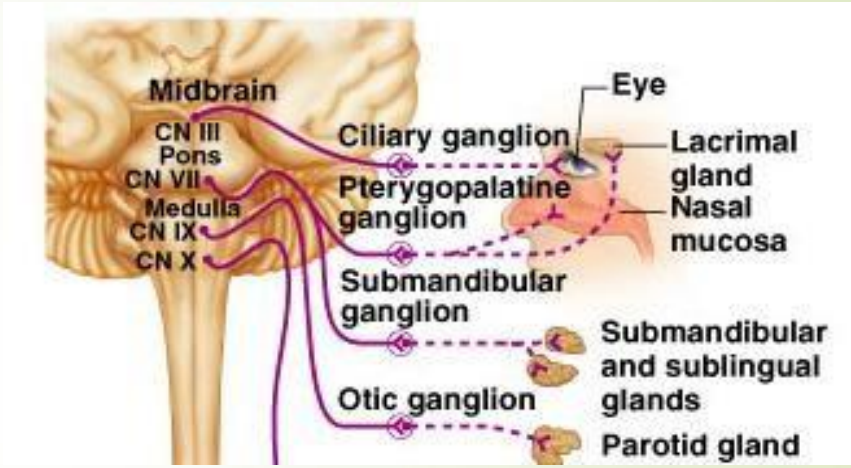


Cranial Outflow

- **Preganglionic fibers** run via:
  - Oculomotor nerve (III)
  - Facial nerve (VII)
  - Glossopharyngeal nerve (IX)
  - Vagus nerve (X)
- Cell bodies located in cranial nerve nuclei in the brain stem
- The preganglionic fibers are longer and reach the postganglionic neurons, which are situated within the organs or close to the organs innervated by these nerves. Preganglionic fibers are myelinated, but the postgangionic fibers are non-myelinated.

Outflow via the Vagus Nerve (X)

- Fibers innervate visceral organs of the thorax and most of the abdomen
- Stimulates - digestion, reduction in heart rate and blood pressure
- Preganglionic cell bodies
  - Located in dorsal motor nucleus in the medulla
- Ganglionic neurons
  - Confined within the walls of organs being innervated



Parasympathetic Nervous System: Sacral Outflow

- . *Sacral Outflow*
- The preganglionic fibers arise from anterior gray horn cells of 2nd, 3rd and 4th (some times from 1st also) sacral segments of spinal cord and form the pelvic nerve (Nervous erigens). The fibers end on the postganglionic neurons, which are situated on or near the visceral organs. The fibers from the postganglionic neurons supply descending colon, rectum, urinary bladder, internal sphincter, urethra and accessory sex organs.

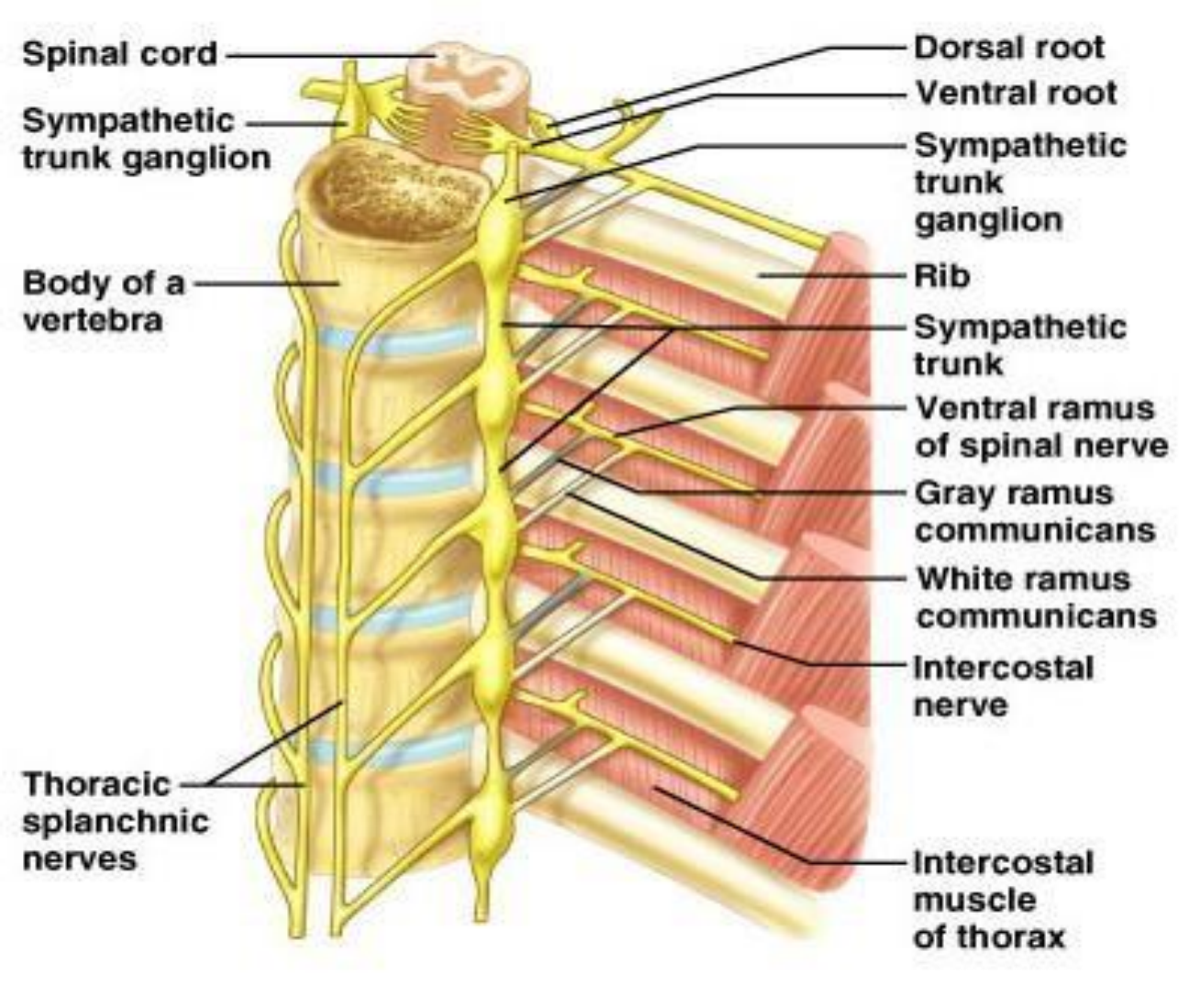
The Sympathetic Division

- Basic organization
  - Issues from T_1-L_2
  - Preganglionic fibers form the lateral gray horn
  - Supplies visceral organs (blood vessels, heart, lungs, glands, viscera) and structures of superficial body regions
  - Contains more ganglia than the parasympathetic division

Sympathetic Trunk Ganglia

- Located on both sides of the vertebral column
- Linked by short nerves into sympathetic trunks
- Joined to ventral rami by white and gray rami communicantes
- Fusion of ganglia → fewer ganglia than spinal nerves

Sympathetic Trunk Ganglia



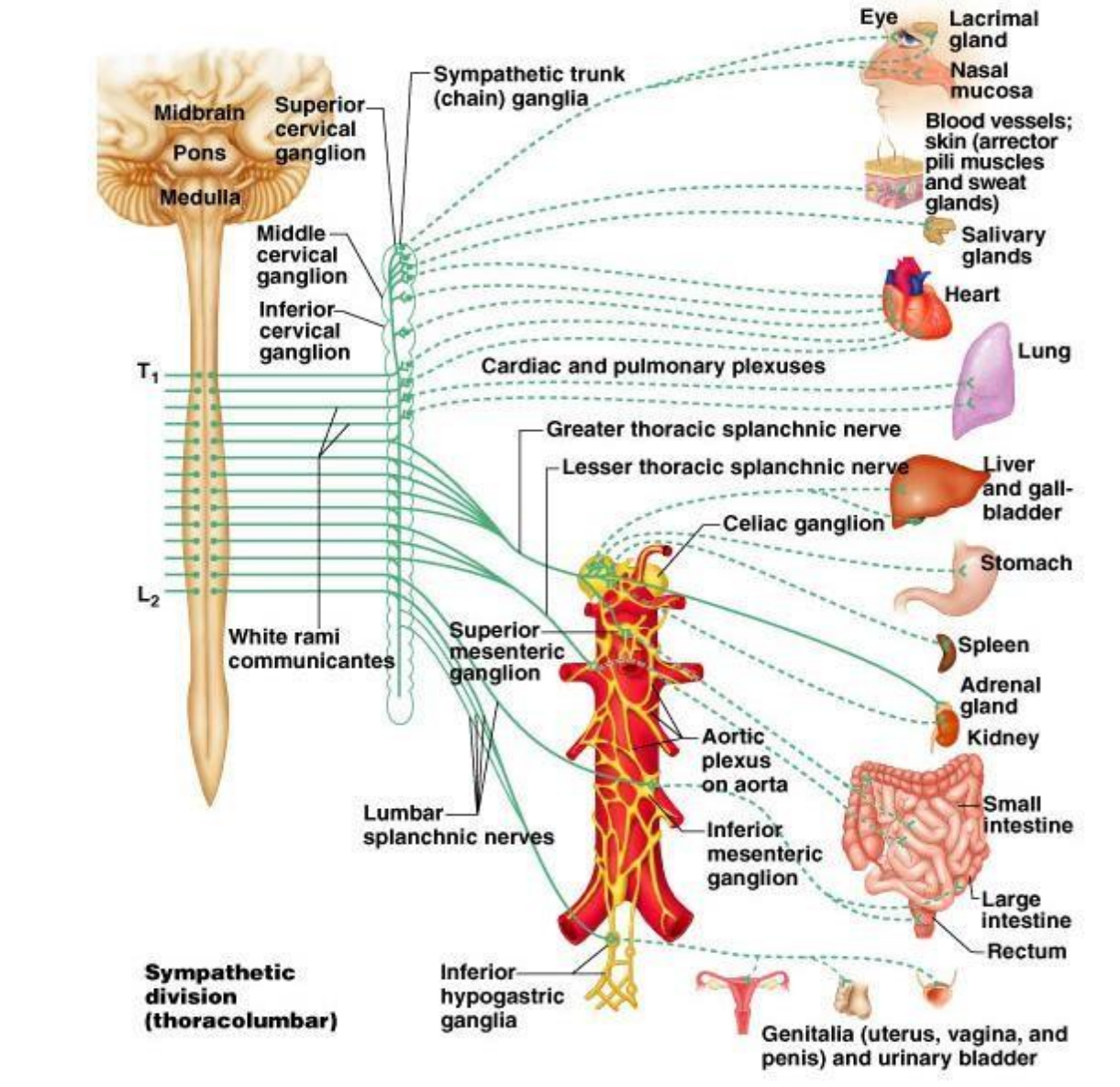
Sympathetic Ganglia

- The ganglia of sympathetic division are classified into three groups.
- Paravertebral or sympathetic chain ganglia
- A. Prevertebral or collateral ganglia
- Terminal or peripheral ganglia
- B. A. *Paravertebral or Sympathetic Chain Ganglia*
- C. Paravertebral or sympathetic chain ganglia are arranged in a segmental fashion along the anterolateral surface of vertebral column.

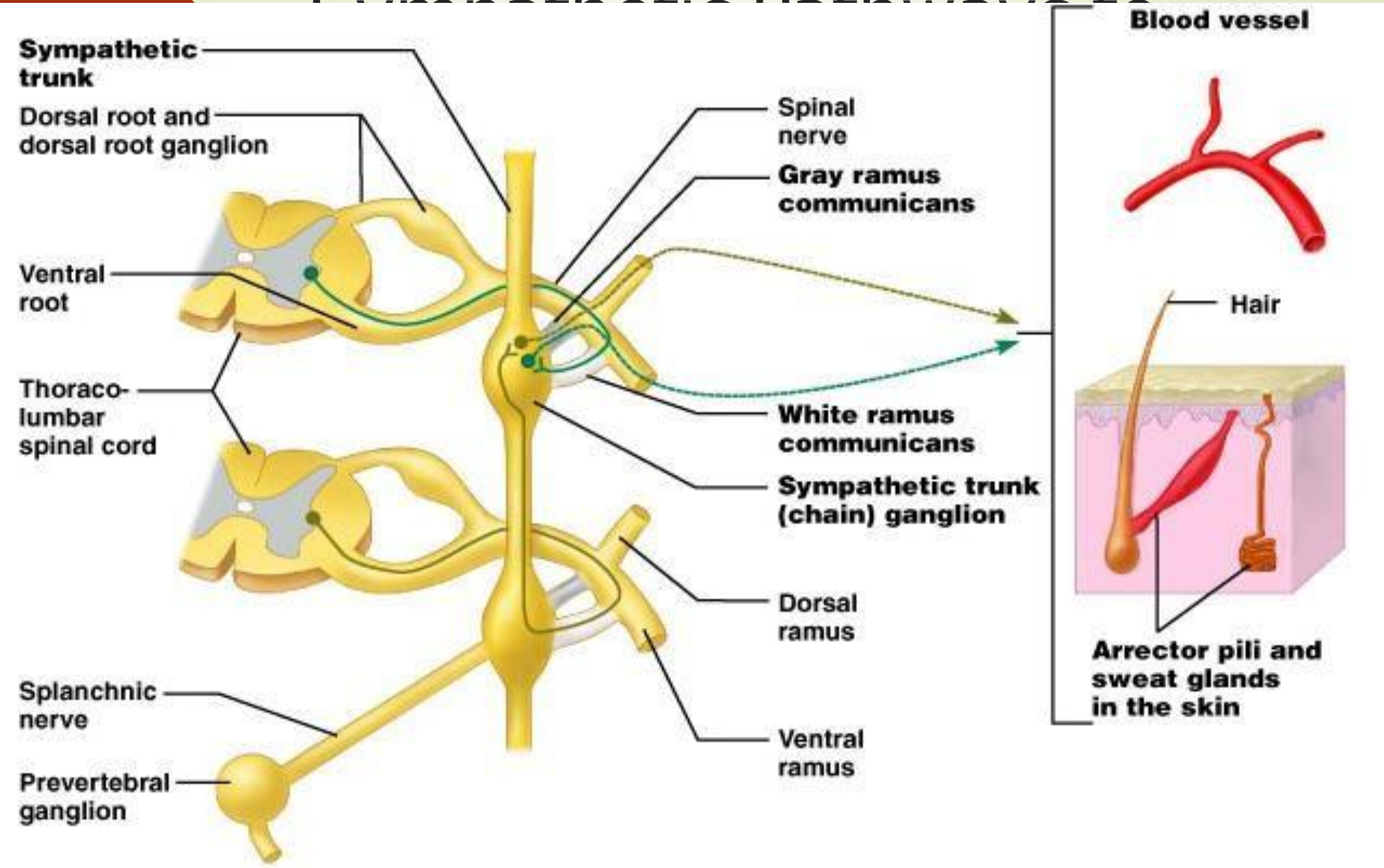
A. *Paravertebral or Sympathetic Chain Ganglia*

- Paravertebral or sympathetic chain ganglia are arranged in a segmental fashion along the anterolateral surface of vertebral column.
- B. ***Prevertebral or Collateral Ganglia***
- Prevertebral ganglia are situated in thorax, abdomen and pelvis in relation to aorta and its branches. Following are the prevertebral ganglia:
- Celiac ganglion
- Inferior mesenteric ganglion
- Superior mesenteric ganglion
- C. ***Terminal or Peripheral Ganglia***
- Terminal ganglia are situated within or close to structures innervated by them. Heart, bronchi, pancreas and urinary bladder are innervated by the terminal ganglia.

Sympathetic Division of the



Sympathetic Pathways to



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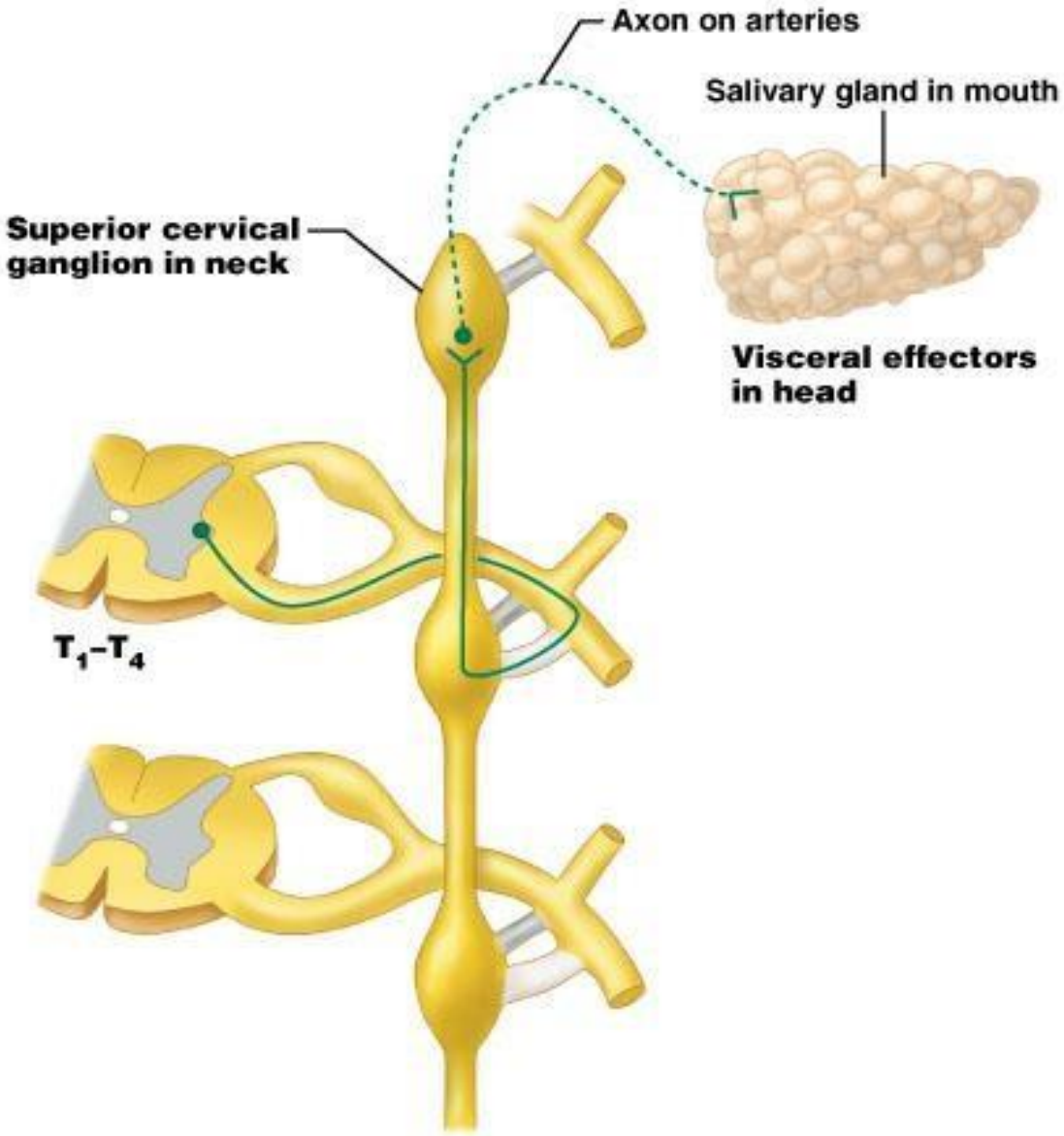
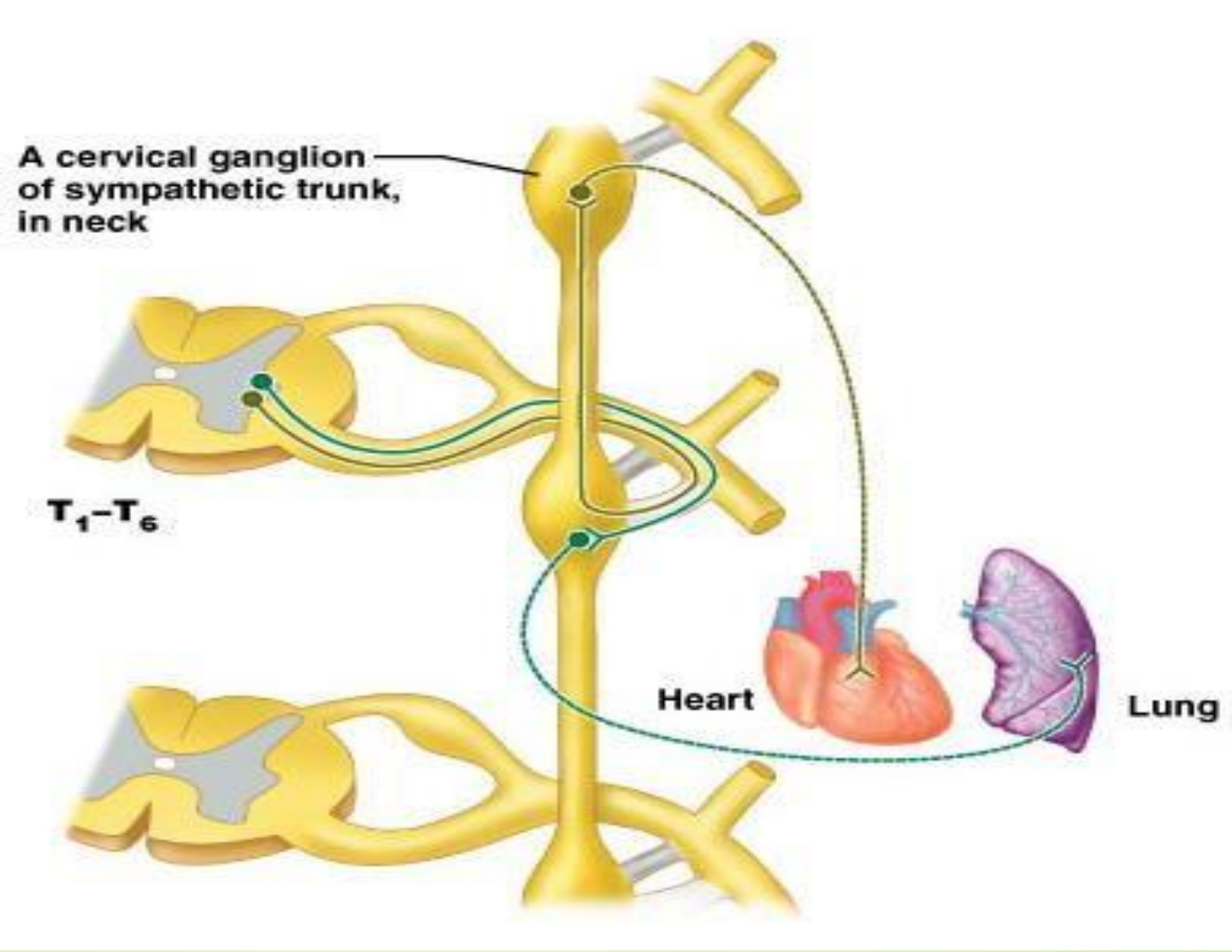
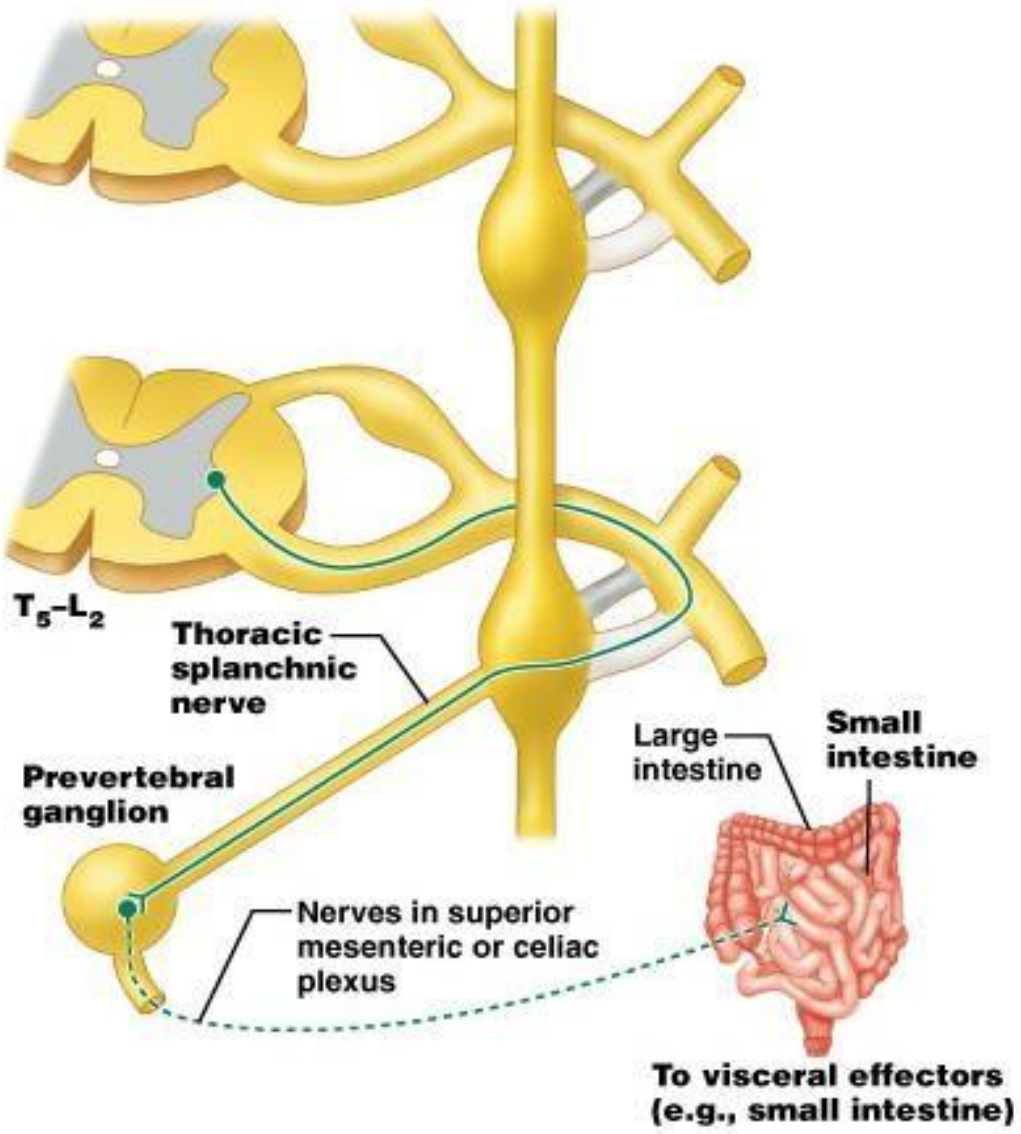


Sympathetic Pathways to Thoracic Organs



Sympathetic Pathways to



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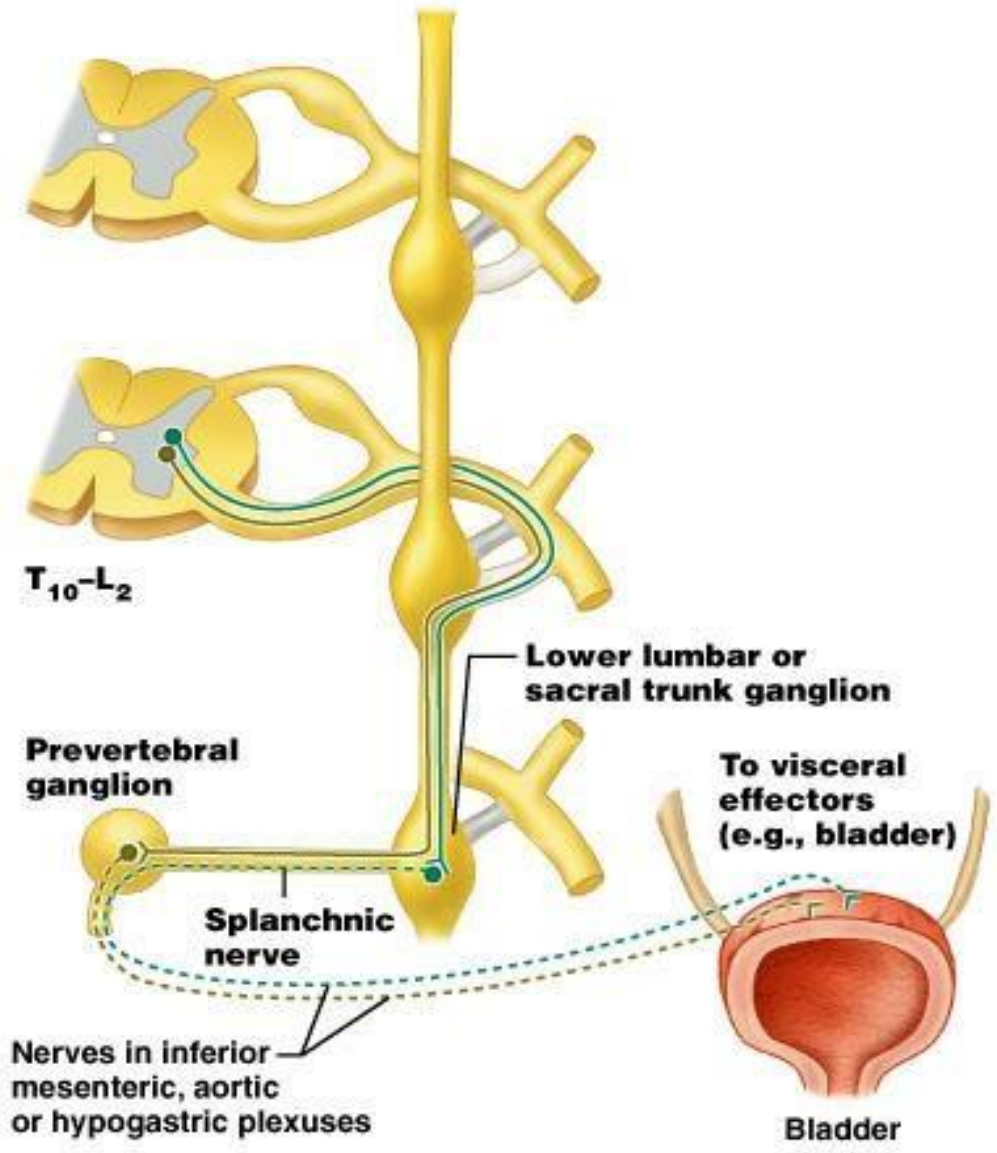


FUNCTIONS OF ANS

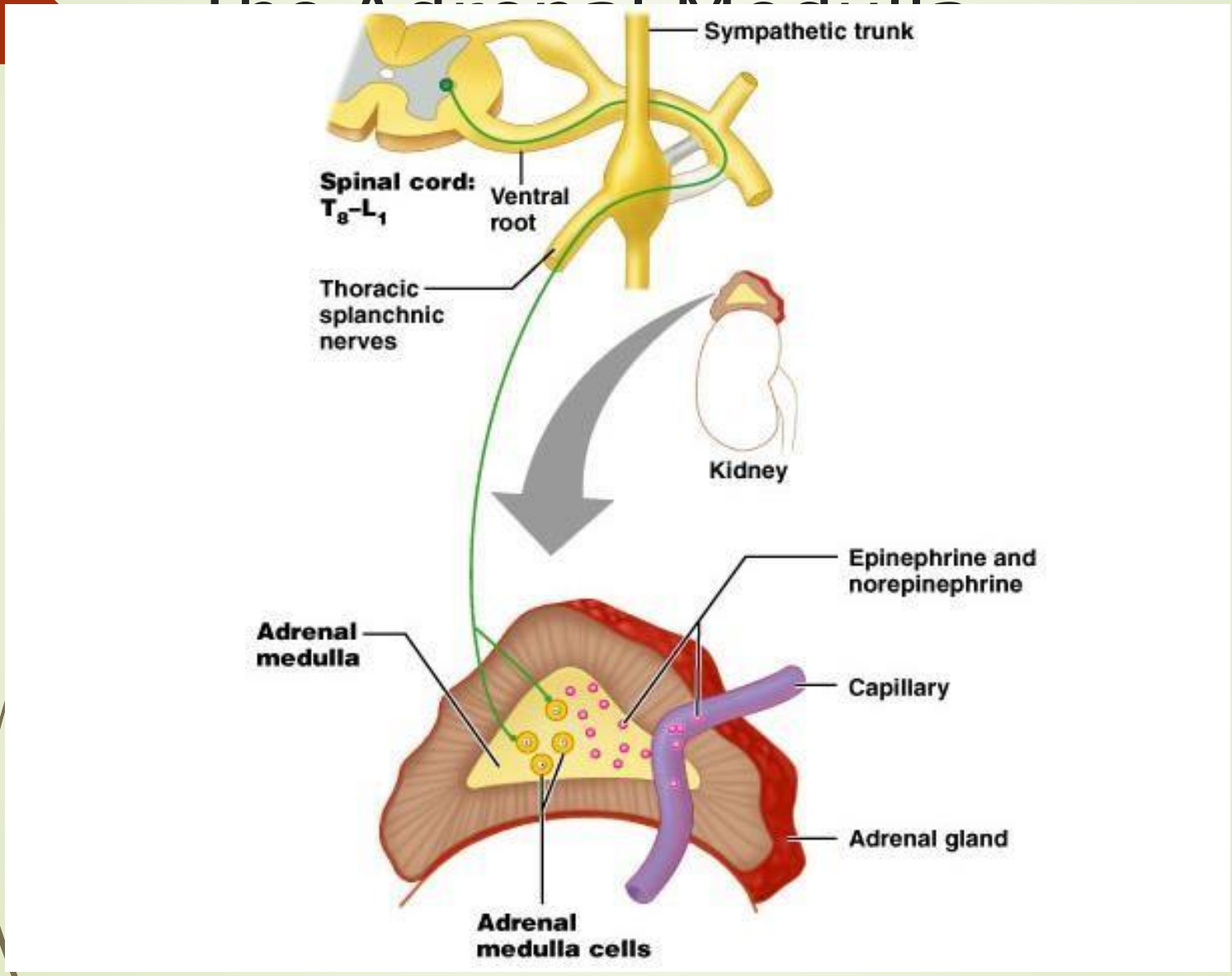
- The ANS is concerned with regulation of functions, which are beyond voluntary control. By controlling the various vegetative functions, ANS plays an important role in maintaining the constant internal environment (homeostasis).

- Almost all the visceral organs are supplied by both sympathetic and parasympathetic divisions of ANS and, the two divisions produce antagonistic effects on each organ. When the fibers of one division supplying to an organ is sectioned or affected by lesion, the effects of fibers from other division on the organ become more prominent.

The Role of the Adrenal Medulla in the Sympathetic Division

- Major organ of the sympathetic nervous system
- Secretes great quantities epinephrine (a little norepinephrine)
- Stimulated to secrete by preganglionic sympathetic fibers

The Adrenal Medulla



Effector organ		Sympathetic division	Parasympathetic division
1. Eye	Ciliary muscle	Relaxation Dilatation	Contraction Constriction
	Pupil		
2. Lacrimal glands		Decrease in secretion	Increase in secretion
3. Salivary secretion		Decrease in secretion and vasoconstriction	Increase in secretion and vasodilatation
4. Gastrointestinal tract	Motility	Inhibition	Acceleration
	Secretion	Decrease	Increase
	Sphincters	Constriction	Relaxation
5. Gallbladder		Relaxation	Contraction
6. Urinary bladder	Detrusor muscle	Relaxation	Contraction
	Internal sphincter	Constriction	Relaxation
7. Sweat glands		Increase in secretion	—
8. Heart – rate and force		Increase	Decrease
9. Blood vessels		Constriction of all blood vessels except those in heart and skeletal muscle	Dilatation
10. Bronchioles		Dilatation	Constriction

- **SYMPATHETIC FIBERS**
- Preganglionic fibers – Acetylcholine
- Postganglionic noradrenergic fibers – Noradrenaline
- Postganglionic cholinergic fibers – Acetylcholine The postganglionic sympathetic cholinergic nerve
- fibers supply sweat glands and blood vessels in heart and in skeletal muscle.
- **PARASYMPATHETIC FIBERS**
- Preganglionic fibers – Acetylcholine
- Postganglionic fibers – Acetylcholine
- *Synthesis and Fate of Neurotransmitters*
- *Catecholamines*

SYMPATHOMIMETIC DRUGS

- *Drugs stimulating the receptors directly:*
- Phenylephrine - alpha receptors
- Isoproterenol - beta receptors
- Albuterol -beta2 receptors.
- *Drugs inducing the release of noradrenaline:*
- Ephedrine
- Tyramine
- Amphetamine

SYMPATHETIC BLOCKERS

- Prevention of synthesis and storage of noradrenaline.
- Example – Reserpine
- Prevention of release of noradrenaline. Example Quanethidine
- Blockage of alpha receptors. Examples – Phenoxybenzamine and phentolamine
- Blockage of beta receptors. Example – Metaprolal
- Blockage of transmission of nerve impulse through sympathetic ganglia. Example –Hexamethonium

PARASYMPATHOMIMETIC DRUGS

- *1. Drugs, which act on muscarinic receptors:* Pylocarpine and methacholine produce their effects by acting on the muscarinic receptors
- *2.Drugs, which prolong the action of acetylcholine the* action of acetylcholine can be prolonged by preventing its destruction. The drugs like neostigmine and physostigmine inhibit the activity of acetylcholinesterase and thereby the acetylcholine is not destroyed quickly

PARASYMPATHETIC BLOCKERS

- The drugs, which prevent the actions of parasympathetic neurotransmitter, are known as para-sympathetic blockers. The drugs atropine, homatropine and scopolamine inhibit the actions of acetylcholine by blocking the muscarinic receptors.

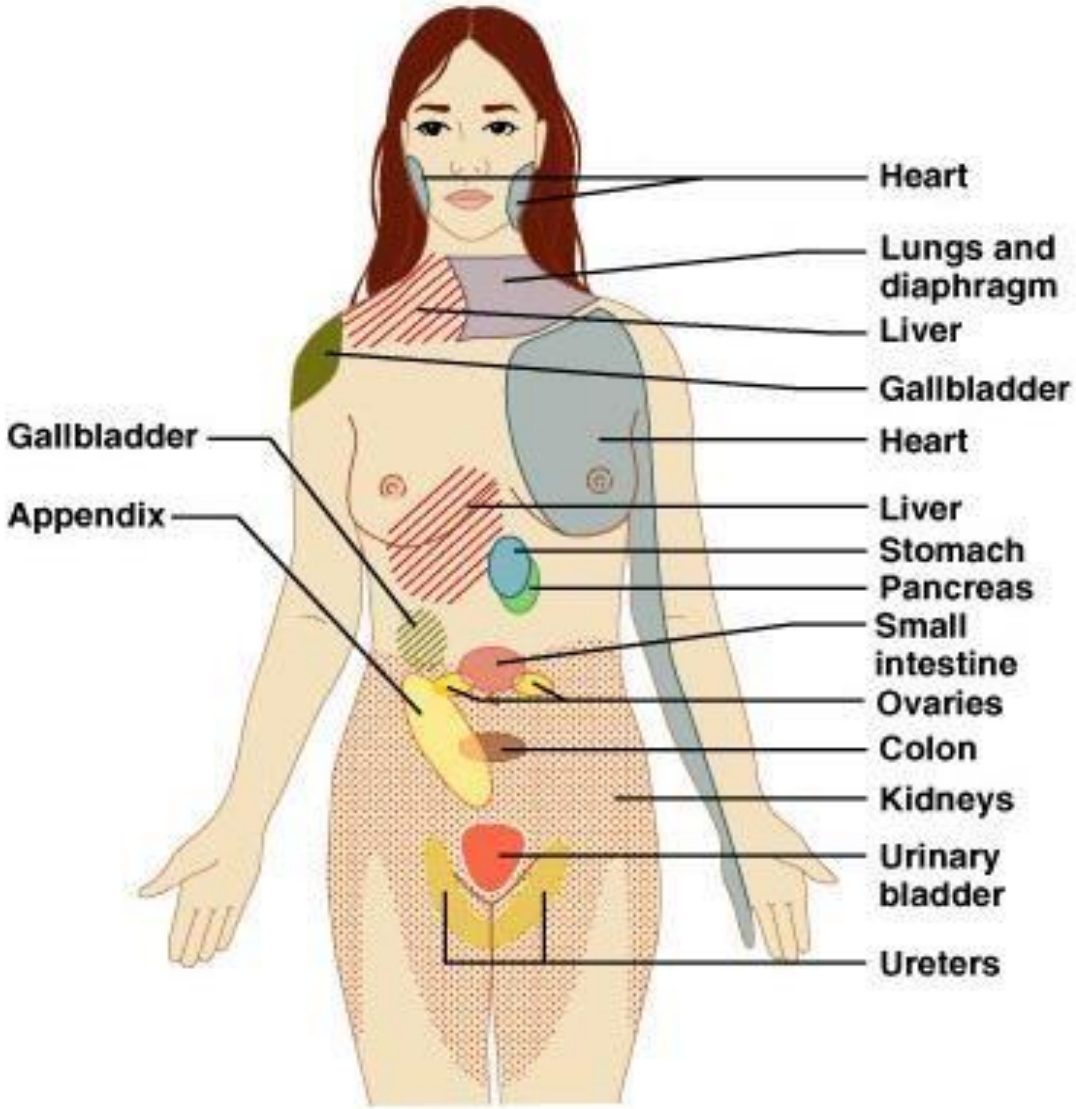
GANGLIONIC BLOCKERS

- The drugs, which prevent the transmission of impulses from the preganglionic neurons to the postganglionic neurons, are known as ganglionic blockers. Tetraethyl ammonium ion, hexamethonium ion and pentolinium are some of the ganglionic blockers. These drugs block both sympathetic and parasympathetic ganglia. However, the ganglionic blockers are commonly used to block the sympathetic ganglia rather than the parasympathetic ganglia because; the sympathetic blockade overshadows the parasympathetic blockade.

Visceral Sensory Neurons

- General visceral sensory neurons monitor:
  - Stretch, temperature, chemical changes, and irritation
- Cell bodies are located in the dorsal root ganglia
- Visceral pain – perceived to be somatic in origin
  - Referred pain

A Map of Referred Pain

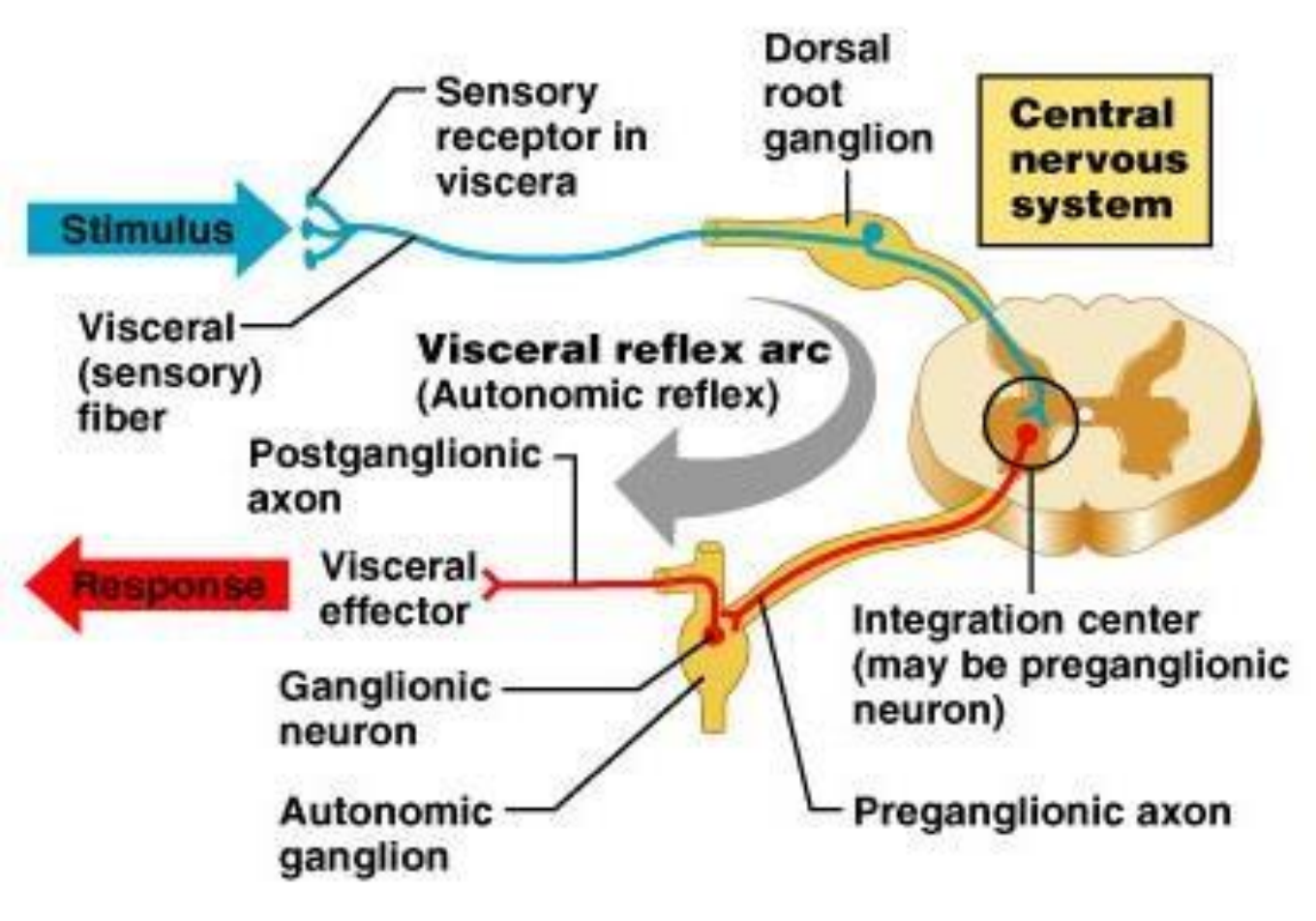


- Increasing of tactile (hyperesthesy) and noceoceptive (hyperalgy) sensitivity occurs at inner organs diseases in skin limited areas. This is reflected pain. They are called as Zahar`in-Ged`s zones on skin.

Visceral Reflexes

- Visceral sensory and autonomic neurons
  - Participate in visceral reflex arcs
    - Defecation reflex
    - Micturition reflex

Visceral Reflex Arc



VEGETATIVE FUNCTIONS INVESTIGATIVE METHODS

- **VEGETATIVE FUNCTIONS INVESTIGATIVE METHODS**
- **Vegetative reactivity investigation:**
  - pharmacological probes (tests):
    - 0,1% adrenalin (epinephrine) 0,3 mm injection under physiological conditions leads to arterial pressure increasing on 10 mm Hg, heart beatings rate increasing on 8-10 beatings per 1 min;
    - insulin 0,15 units/kg injection leads to arterial pressure decreasing on 10 mm Hg and heart beatings rate decreasing on 8-10 beatings per 1 min;
    - pressure on reflectory zones:
      - oculo-cardiac reflex of Danjini-Ashner: pressure to eyelids during 15-20 sec leads to heart beatings rate retardation on 6-12 per 1 min;
      - sino-carotid reflex of Chermac: pressure to carotid artery area on the right leads to heart beatings rate retardation on 10-15 per 1 min;
      - solar (epigastral) reflex during 20-30 sec inhibits heart beatings rate.

Vegetative provision investigation:

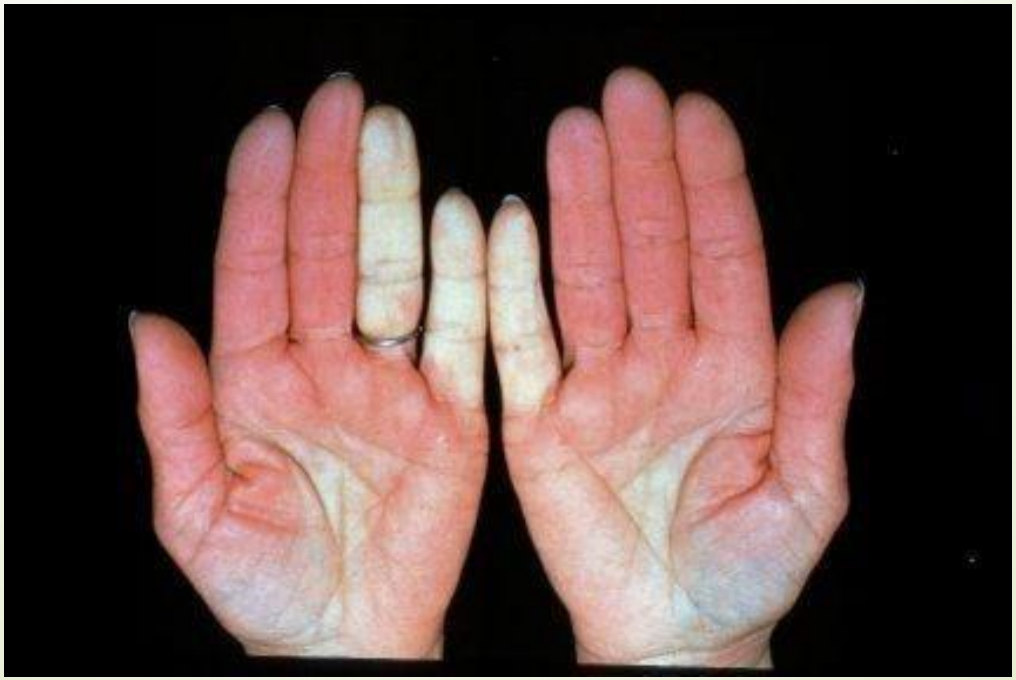
- ortho-static (ortho-clinic) probe - transition from horizontal state to the vertical one leads on heart beatings rate increasing on 12 beatings per 1 min, arterial pressure increasing on 20 mm Hg; there numerals increasing indicates to sympathetic influencings dominance;
- clino-stathic probe – transition from vertical state to horizontal one (opposite reaction) inhibits heart beatings rate and decreases arterial pressure.
- **Dermographism –** is skin vascular reaction to its mechanic irritation with acute subject. Red stripe occurs at an irritation place. Very thick red stripes testify to parasympathetic part tone increasing. White stripes occur at sympathetic part tone dominance. Dermographism is absent in vegetative segments injuries zones.

Central Control of the ANS

- Control by the brain stem and spinal cord
  - Reticular formation exerts most direct influence
    - Medulla oblongata
    - Periaqueductal gray matter
  - Control by the hypothalamus and amygdala
    - Hypothalamus – the main integration center of the ANS
    - Amygdala – main limbic region for emotions
  - Control by the cerebral cortex

Disorders of the Autonomic Nervous System: Raynaud's Disease

- Raynaud's disease – characterized by constriction of blood vessels
  - Provoked by exposure to cold or by emotional stress



Disorders of the Autonomic Nervous System: Hypertension

- Hypertension – high blood pressure
  - Can result vasoconstrictio

Disorders of the Autonomic Nervous System: Mass Reflex Reaction

- Mass reflex reaction
  - Uncontrolled activation of autonomic and somatic motor neurons
  - Affects quadriplegics and paraplegics

Disorders of the Autonomic Nervous System: Achalasia of the Cardia

- Achalasia of the cardia
- Defect in the autonomic innervation of the esophagus