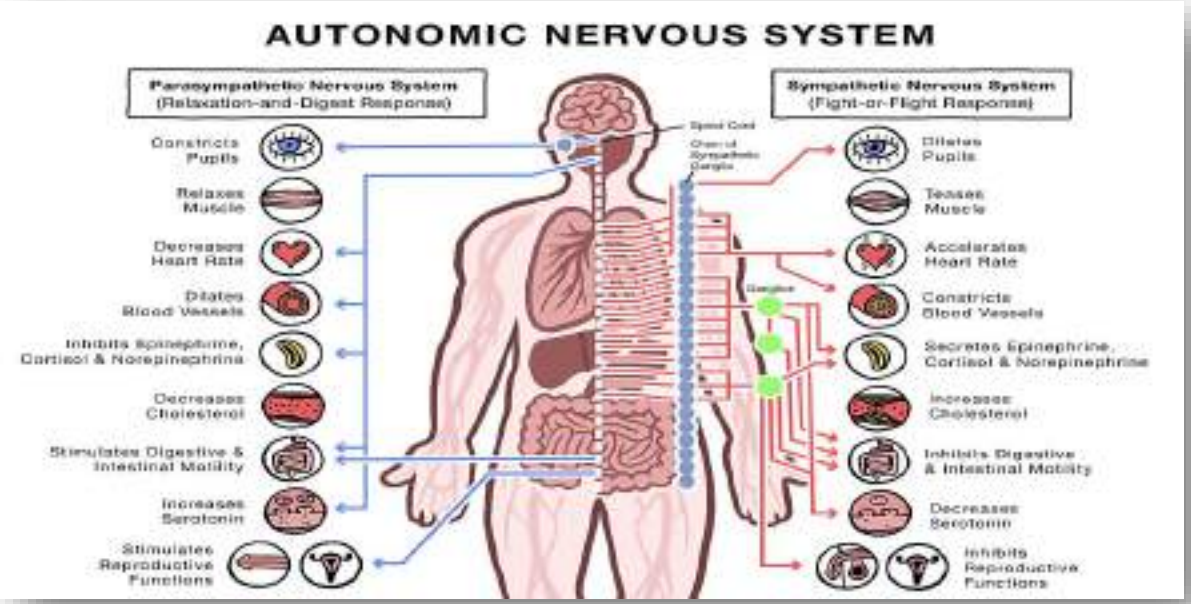
PNS MODULE
PHYSIOLOGY LECTURE (4)
(Function of Autonomic Nervous System I)

By
Dr. Fatma Farrag Ali
Associate Prof. of Medical Physiology
Faculty of Medicine-Mutah University
2025-2026



Autonomic Nervous System (ANS)

Autonomic nervous system

- **The autonomic nervous system (ANS) is:**
  - **The part of the peripheral nervous system (PNS) that controls the involuntary motor functions (cardiac and smooth muscle contractions and secretion of glands).**
  - **It is the efferent innervation of tissues other than skeletal muscle.**
- **The two divisions of the autonomic nervous system are:**
  - ✓The sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS).
  - ✓The enteric nervous system of the gastrointestinal tract is sometimes considered a subdivision of the autonomic efferent nervous system as well although it also includes sensory neurons and interneurons.

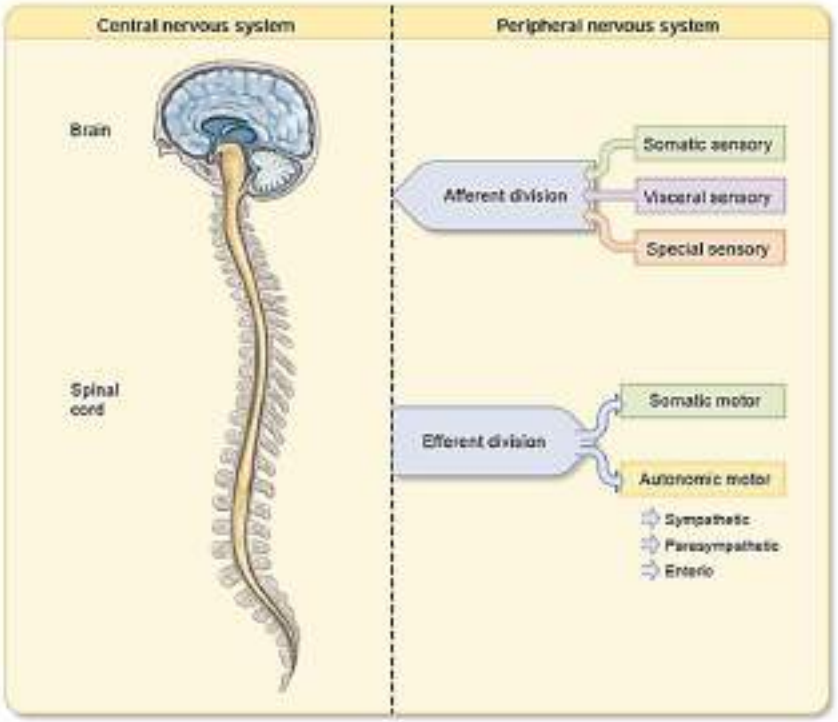
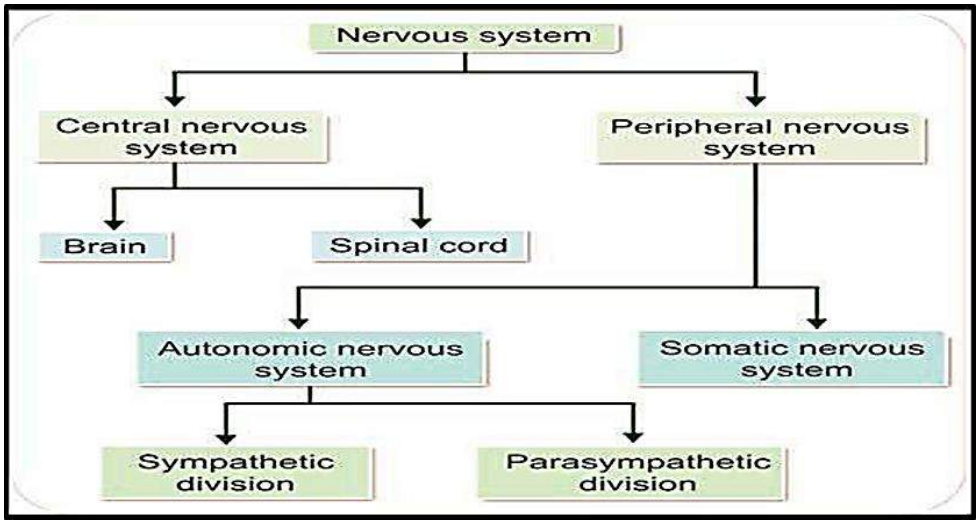
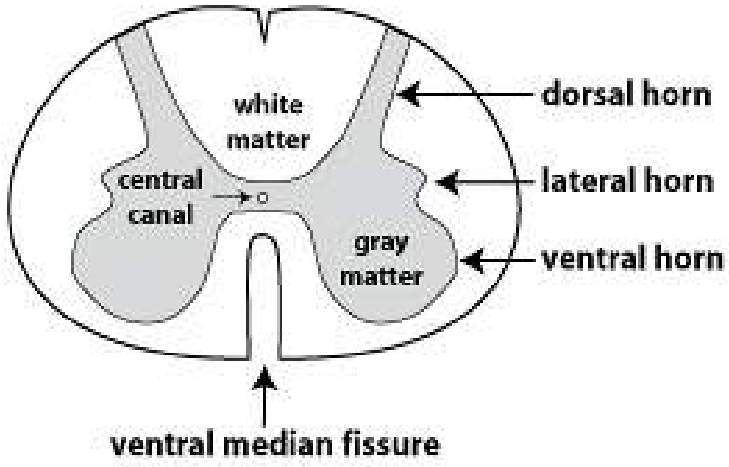


Figure 6.37 Overview of the structural and functional organization of the nervous system.





Anatomic organization of autonomic outflow

- ✓ In contrast to the somatic nervous system, the autonomic nervous system is made up of **two neurons (preganglionic and postganglionic neurons)** in series that connect the CNS and the effector cells.
- ✓ The first neuron has its cell body in the CNS (in the spinal cord and in motor nuclei of some cranial nerves). The **synapse** between the two neurons is outside the CNS in a cell cluster called an **autonomic ganglion**.
- ✓ The neurons passing between the CNS and the ganglia are called preganglionic neurons; those passing between the ganglia and the effector cells are postganglionic neurons.
- ✓ In contrast to the large diameter and rapidly conducting α-motor neurons, preganglionic axons are small-diameter, myelinated, relatively slowly conducting B fibers. The axons of the postganglionic neurons are mostly unmyelinated C fibers and terminate on the visceral effectors.

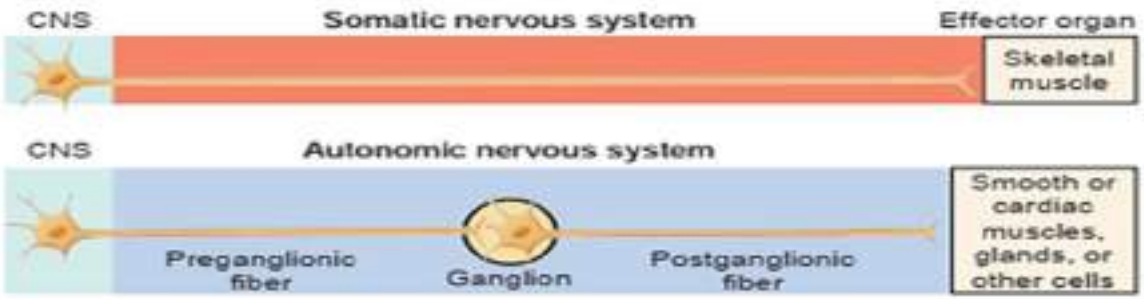


Figure 6.43 Efferent division of the PNS, including an overall plan of the somatic and autonomic nervous systems.

ORGANIZATION AND GENERAL FUNCTIONS OF THE AUTONOMIC NERVOUS SYSTEM (ANS)

- The autonomic nervous system has as its central components: the hypothalamus, the brainstem, and the spinal cord. Peripherally, it consists of sympathetic and parasympathetic nerves.
- Areas within the hypothalamus and brainstem regulate and coordinate various processes through the autonomic nervous system, including, for example, temperature regulation, micturition, respiration, and cardiovascular function.
- This regulation is in response to sensory input and occurs through the reciprocal regulation of the sympathetic nervous system and parasympathetic nervous system.

Anatomical and physiological differences within the autonomic nervous system are the basis for its further subdivision into sympathetic and parasympathetic divisions.

1- The Sympathetic Nervous System:

It arises from:

The **lateral horn cells (L.H.Cs)** of **all thoracic and upper 2-4 lumber segments of the spinal cord.** So, it is called the **thoraco-lumbar outflow**.

2- The Parasympathetic Nervous System:

It arises from :

The **nuclei of 3rd (III) , 7th (VII), 9th (IX) and 10th (X) cranial nerves and from the lateral horn cells of the 2nd, 3rd and 4th sacral segments (S2,3,4) of the spinal cord**. So, it is called the **cranio-sacral outflow**.

The two divisions also differ in the location of autonomic ganglia:

- Most of the sympathetic ganglia lie close to the spinal cord and form the two chains of ganglia—one on each side of the cord—known as the **sympathetic trunks or chains (paravertebral or lateral)**.
- Other ganglia, called **collateral (prevertebral) ganglia**—the celiac, superior mesenteric, and inferior mesenteric ganglia—are in the abdominal cavity, closer to the innervated organ. They mostly the site for relay of sympathetic preganglionic neuron.
- In contrast, the **parasympathetic ganglia** lie within, or very close to, the organs that the postganglionic neurons innervate **(terminal ganglia)**.

AUTONOMIC GANGLIA:

Definition:

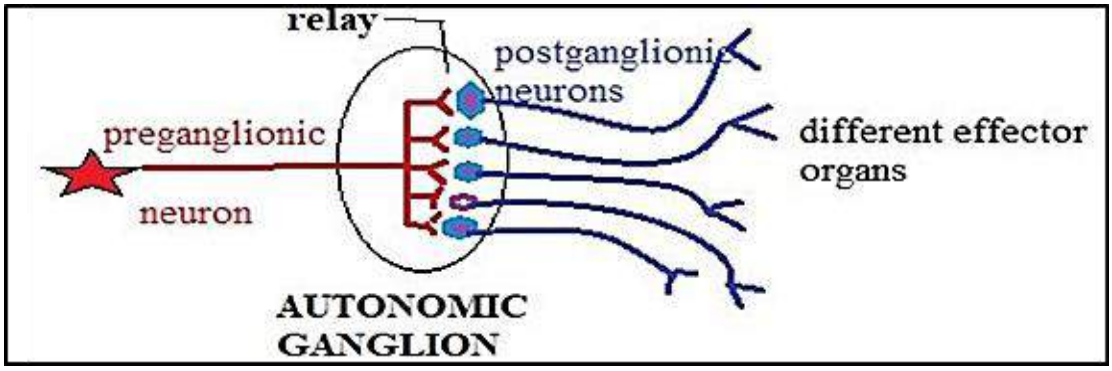
- They are collection of nerve cells present outside the CNS.
- Autonomic ganglia are the site of relay (synapse) of preganglionic fibers over the postganglionic fibers.

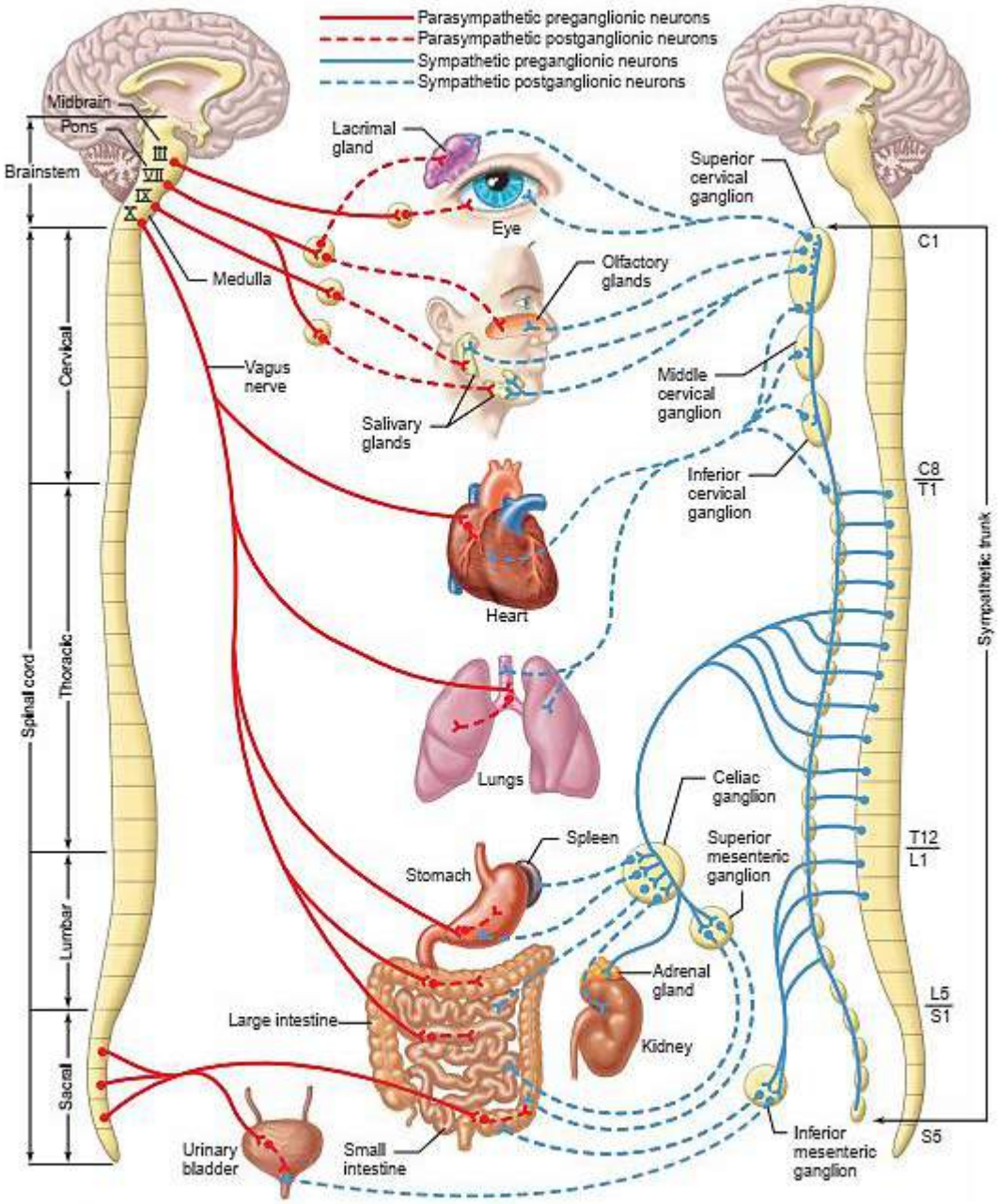
Function of the Autonomic Ganglia:

Act as distributing centers.

The preganglionic fibers are few and arise from limited CNS regions. So, inside the ganglion one preganglionic neuron can relay on large number of postganglionic neurons and through them it controls many effector organs.

Synapse: is the site of contact but not continuity between preganglionic nerve terminals and cell bodies of postganglionic neurons inside autonomic ganglia.





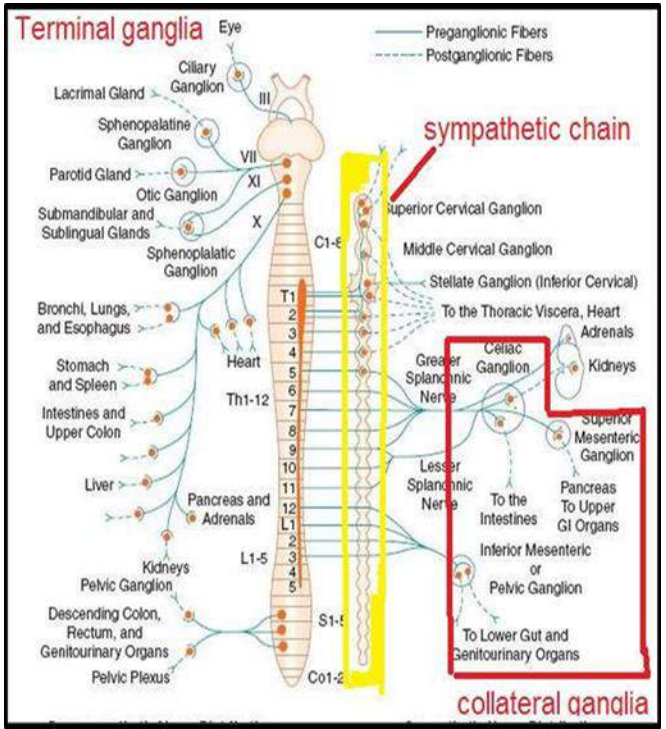


Figure 6.44 AP|R The parasympathetic (at left) and sympathetic (at right) divisions of the autonomic nervous system. Although single nerves are shown exiting the brainstem and spinal cord, all represent paired (left and right) nerves. Only one sympathetic trunk is indicated, although there are two, one on each side of the spinal cord. The celiac, superior mesenteric, and inferior mesenteric ganglia are collateral ganglia. Not shown are the fibers passing to the liver, blood vessels, genitalia, and skin glands.

General Characteristics of the Parasympathetic and Sympathetic Nervous Systems

General Characteristics of the Parasympathetic and Sympathetic Nervous Systems		
Characteristic	**Parasympathetic Nervous System (SNS)**	**Sympathetic Nervous System (PNS)**
Location of preganglionic nerve cell bodies	Brainstem (nuclei of cranial nerves III, VII, IX, and X) or sacral spinal cord (S2–S4; sacral parasympathetic nucleus)	Thoracolumbar spinal cord (T1–L3)
Location of ganglia	In or adjacent to target organs (terminal ganglia)	Paravertebral (sympathetic chain) and prevertebral (collateral)
Neurotransmitter of preganglionic neurons	Acetylcholine (acts at nicotinic receptors)	Acetylcholine (acts at nicotinic receptors)
Major neurotransmitter released by postganglionic neuron	Acetylcholine (acts at muscarinic receptors)	Norepinephrine (acts at α and β adrenergic receptors)

GENERAL CHARACTERISTICS OF PARASYMPATHETIC AND SYMPATHETIC NERVOUS SYSTEMS

- **The heart, many glands and smooth muscles are innervated by both sympathetic and parasympathetic fibers; that is, they receive dual (double) innervation.** Whatever effect one division has on the effector cells, the other division usually has the opposite effect. Moreover, **the two divisions are usually activated reciprocally; that is, as the activity of one division increases, the activity of the other decreases**. For example, heart rate is elevated by SNS activity and decreased by PNS activity.
- **The sympathetic division discharges as a unit in emergency situations and can be called the catabolic nervous system or the "flight or fight" division of the ANS, and the PNS mediates "vegetative" responses, such as digestion.**
- **The fight-or flight response is a generalized reaction to extreme fear, stress, exercise, hemorrhage, and other challenges to homeostasis and results in a patterned response in many organ systems.**

- **During fight-or flight, all resources for physical exertion are activated:** heart rate, cardiac output and blood pressure increase; blood flow increases to the skeletal muscles, heart, and brain; the liver releases glucose; bronchodilation occurs and the pupils dilate (mydriasis). Simultaneously, the activity of the gastrointestinal tract and blood flow to it are inhibited by sympathetic firing. In contrast, when **the parasympathetic system is activated, a person is in a rest-or-digest state** in which homeostatic functions are predominant.
- The emphasis on mass discharge in stressful situations should not obscure the fact that the sympathetic fibers also subserve other functions and, in fact, **there is activity in sympathetic nerves even under resting conditions**.
- For example, tonic sympathetic discharge to the arterioles maintains arterial pressure, and variations in this tonic discharge are the mechanism by which carotid sinus feedback regulation of blood pressure occurs.

- **Although the sympathetic nervous system often responds in such patterned manners, the parasympathetic may produce more selective effects.**
- Due in part to differences in their anatomy, the overall activation pattern within the sympathetic and parasympathetic systems tends to be different.
- **The close anatomical association of the sympathetic ganglia and the marked divergence of presynaptic sympathetic neurons make that division tend to respond as a single unit**. **It is more typical for increased sympathetic activity to occur body-wide** when circumstances warrant activation.
- The **parasympathetic system**, in contrast, **exhibits less divergence**; thus, it **tends to activate specific organs** in a pattern finely tailored to each given physiological situation.
- **In other cases, the effects of sympathetic and parasympathetic activation can be considered complementary**. **An example is the innervation of salivary glands. Parasympathetic activation causes release of watery saliva, while sympathetic activation causes the production of thick, viscous saliva.**

- **The two divisions of the ANS can also act in a synergistic or cooperative manner in the control of some functions. One example is the control of pupil diameter in the eye. Both sympathetic and parasympathetic innervations are excitatory, but the former contracts the radial (or dilator) muscle to cause mydriasis (widening of the pupil) and the latter contracts the sphincter (or constrictor) muscle to cause miosis (narrowing of the pupil).**
- **Another example is the synergistic actions of these nerves on sexual function. Activation of parasympathetic nerves to the penis increases penile blood flow and leads to erection while activation of sympathetic nerves to the male reproductive tract causes ejaculation.**
- **There are also several organs that are innervated by only one division of the ANS. In addition to the adrenal gland, most blood vessels, the pilomotor muscles in the skin (hair follicles), and sweat glands are innervated exclusively by sympathetic nerves.**
- **The lacrimal gland, ciliary muscle (for accommodation for near vision), and the nasopharyngeal gland are innervated exclusively by parasympathetic nerves.**

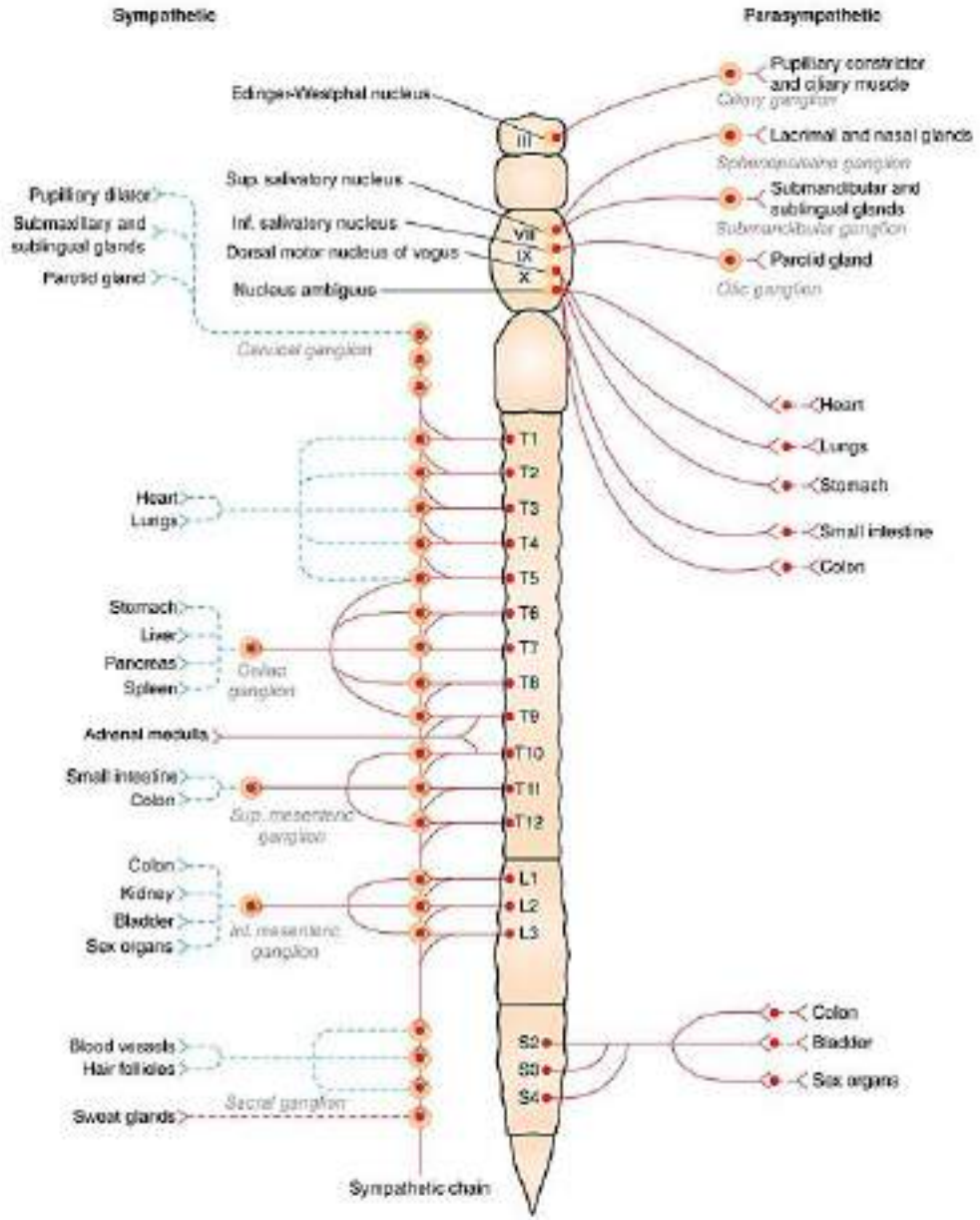


FIGURE 13–3 Organization of sympathetic (left) and parasympathetic (right) nervous systems. Cholinergic nerves are shown in red and noradrenergic nerves are shown in blue. Preganglionic nerves are solid lines; postganglionic nerves are dashed lines.

Distribution and Functions of Sympathetic Nervous System

I- Sympathetic Supply to Head and Neck (Cervical Division):

A- On the Eye:

- Motor to the dilator pupillae muscle to produce **dilation of the pupil (mydriasis).**
- Motor to the eyelid muscles (superior & inferior tarsal muscle) → **widening of the palpebral fissure.**
- Motor to the Muller's muscle to cause forward protrusion of the eye ball (**exophthalmos**).

All these changes increase the field of vision.

B- On Salivary glands:

Motor to myoepithelial cells around salivary acini → **release of trophic secretion (concentrated small viscous saliva)**.

C- On Skin of the head & neck:

- **Blood vessels:** **Vasoconstriction (VC)** of all blood vessels of head and neck including cerebral blood vessels, however, cerebral blood flow increases secondary to increased arterial blood pressure.

- **Sweat glands:** **increase sweat secretion**.

- **Erector pilae (pilomotor) muscle** → **erection of hairs**.

II- Sympathetic Supply to the Thorax (Cardio-Pulmonary division):

1- Heart:

- **↑ all properties of cardiac muscle:**

*** ↑ heart rate * ↑ excitability * ↑ conductivity * ↑ contractility → (↑ H.R, ↑ C.O.& ↑A.B.P).**

- **↑ cardiac metabolism and oxygen consumption→ ↑metabolites→ coronary vasodilation →↑ coronary blood flow.**
  - **Coronary vessels: vasodilation (V.D.).** Direct effect is V.C. (vasoconstriction) but coronary vessels dilate (vasodilation) due to increased metabolism of the heart).

2- Lungs:

- **Bronchodilation** due to relaxation of the circular smooth muscles of bronchi **→↑ air entry**.
- **V.C. of the pulmonary vessels (pulmonary V.C.)** to allow lungs to expand.

III- Sympathetic Supply to Abdomen (Greater Splanchnic Nerve):

- **Both vasoconstrictor and vasodilator to splanchnic vessels (vasoconstriction > vasodilation).**

- V.C. of blood vessels of stomach, small intestine and kidney - V.D. of hepatic blood vessels.

- **Inhibits GIT secretion.**

- Delay GIT emptying (food retention) by inhibiting smooth muscles of the wall (relaxation) + contraction of the sphincters e.g., the pyloric sphincter.

- **Liver: Increase the hepatic glycogenolysis** to increase the blood glucose which is used as fuel for heart, brain and muscles.

- **Spleen: Contraction of the spleen capsule to squeeze out blood (add about 200-250 ml), which is rich in red blood cells to the general circulation → ↑ O_2 carriage**.

- **Suprarenal (adrenal) medulla:** Secretory fibers to the suprarenal medulla (modified sympathetic ganglia). **It secretes 80% adrenaline and 20% noradrenaline which circulate in blood and produce generalized sympathetic action all over the body (augments the sympathetic response).**

IV- Sympathetic Supply to Pelvis (Lesser Splanchnic Nerve):

- Inhibition of the smooth muscles of rectum wall and anal canal and motor to the internal anal sphincter → **retention of stool**.
- Inhibition of the smooth muscles of urinary bladder wall and motor to the internal urethral sphincter → **retention of urine**.
- **Ejaculation of semen** due to contraction of the smooth muscles of epididymis, vas deferens and seminal vesicles.

V- Sympathetic Supply to limbs, thoracic and abdominal walls (somatic division):

Functions:

Skin:

- V.C. of skin blood vessels.
- Stimulates sweat secretion.
- Erection of hair.

Skeletal muscle (Orbelli phenomenon):

- V.D. of skeletal blood vessels to increase blood supply to skeletal muscle.
- ↑ force of contraction and delays onset of skeletal muscles fatigue.
- ↑ muscle glycogenolysis.

N.B.

Sympathetic nervous system causes V.C. of all blood vessels except coronary blood vessels and skeletal muscle blood vessels.

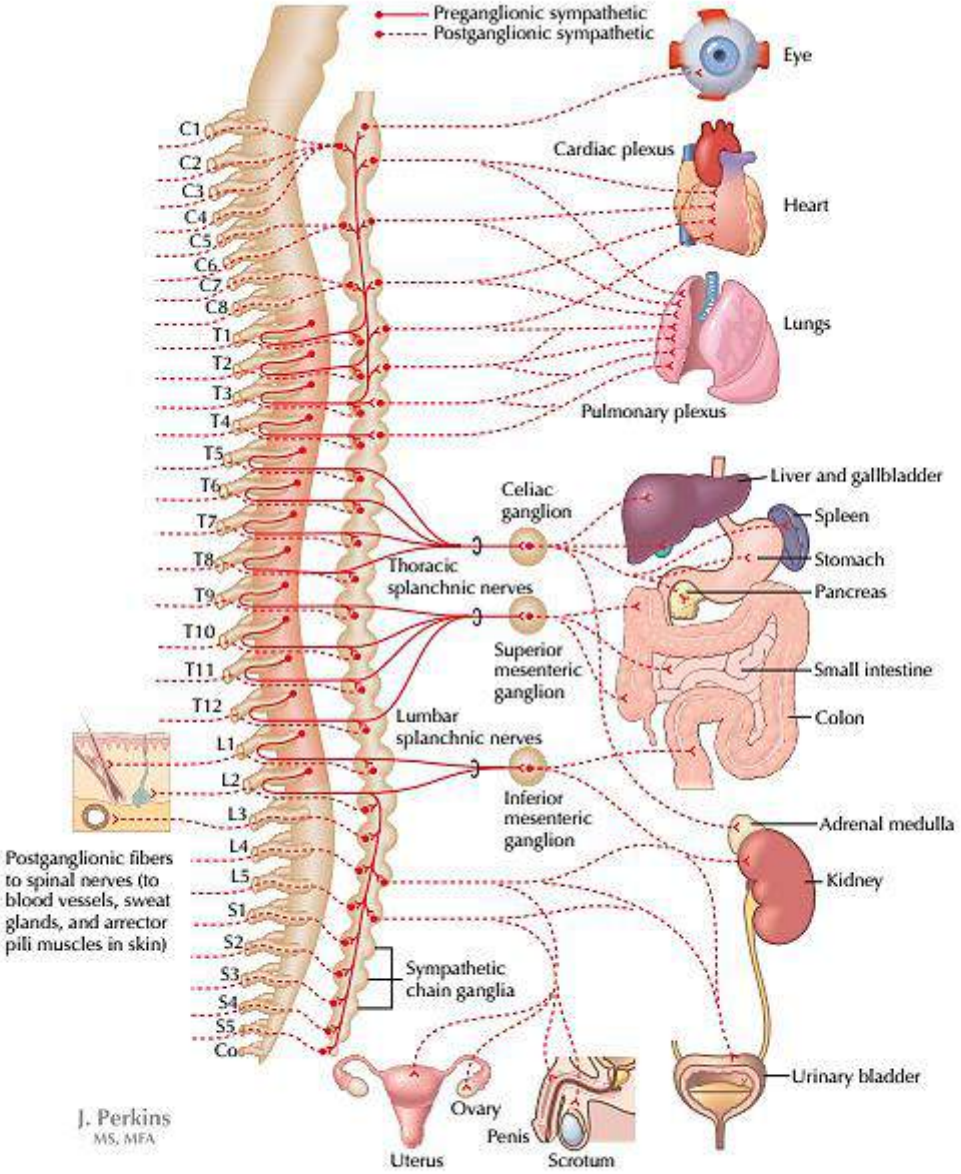


Figure 7.2 **Autonomic Nervous System: Sympathetic Division** The two divisions of the autonomic nervous system are the sympathetic nervous system and the parasympathetic nervous system. Preganglionic fibers of the SNS emerge from the spinal cord at levels T1–T2. The SNS is involved in "fight-or-flight" responses, as well as responses to exercise, hemorrhage, and other challenges to homeostasis. Both SNS and PNS innervate smooth and cardiac muscle and glands; in general, they work together in reciprocal fashion to regulate bodily function.

- ✓ Sweat gland secretion is stimulated by activation of the sympathetic nervous system.
- ✓ Most of the postganglionic sympathetic neurons innervating these glands are atypical, releasing the neurotransmitter acetylcholine instead of norepinephrine.
- ✓ Acetylcholine acts on muscarinic receptors, inducing sweat secretion.

Horner's Syndrome

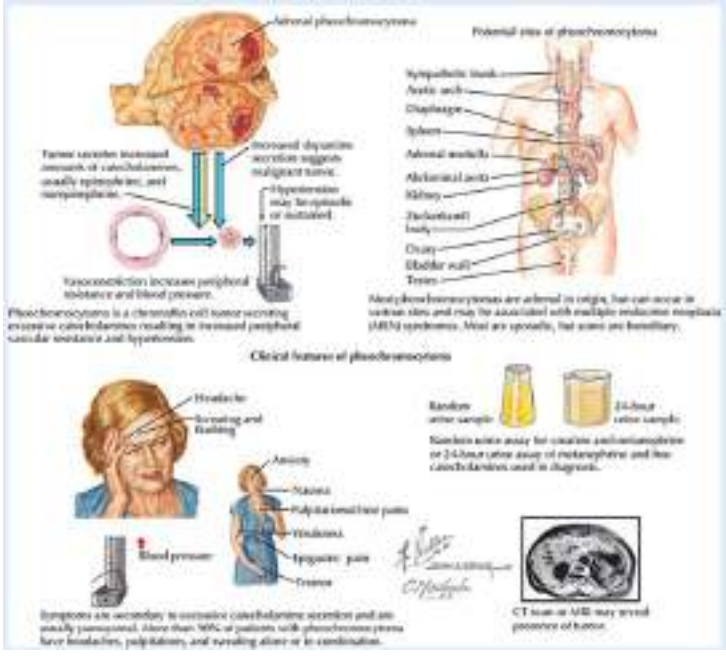
- Horner syndrome is a rare disorder resulting from interruption of preganglionic or postganglionic sympathetic innervation to the face. The problem can result from injury to the nerves, injury to the carotid artery, a stroke or lesion in the brainstem, or a tumor in the lung.
- In most cases the problem is unilateral, with symptoms occurring only on the side of the damage.
- The hallmark of Horner syndrome is the **triad of anhidrosis (reduced sweating), ptosis (drooping eyelid), and miosis (constricted pupil)**. Symptoms also include enophthalmos (sunken eyeball) and vasodilation.

CLINICAL CORRELATE
Pheochromocytoma

Tumors of the adrenal medulla that secrete epinephrine and norepinephrine are known as pheochromocytomas; catecholamine secreting tumors in extraadrenal tissue may also occur.

In either case, signs and symptoms are consistent with increased sympathetic activity. Catecholamines in plasma and 24-hour urine collections are elevated, and unlike catecholamines released by normal adrenal medulla, are not suppressed by clonidine administration (clonidine acts centrally to suppress sympathetic activity).

Treatment is by surgical resection of the tumor.



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