GENERAL PHYSIOLOGY
(Lecture 18)
(Overview of Autonomic nervous system I)

By
Associate Prof. Dr. Fatma Farrag Ali
Faculty of Medicine-Mutah University

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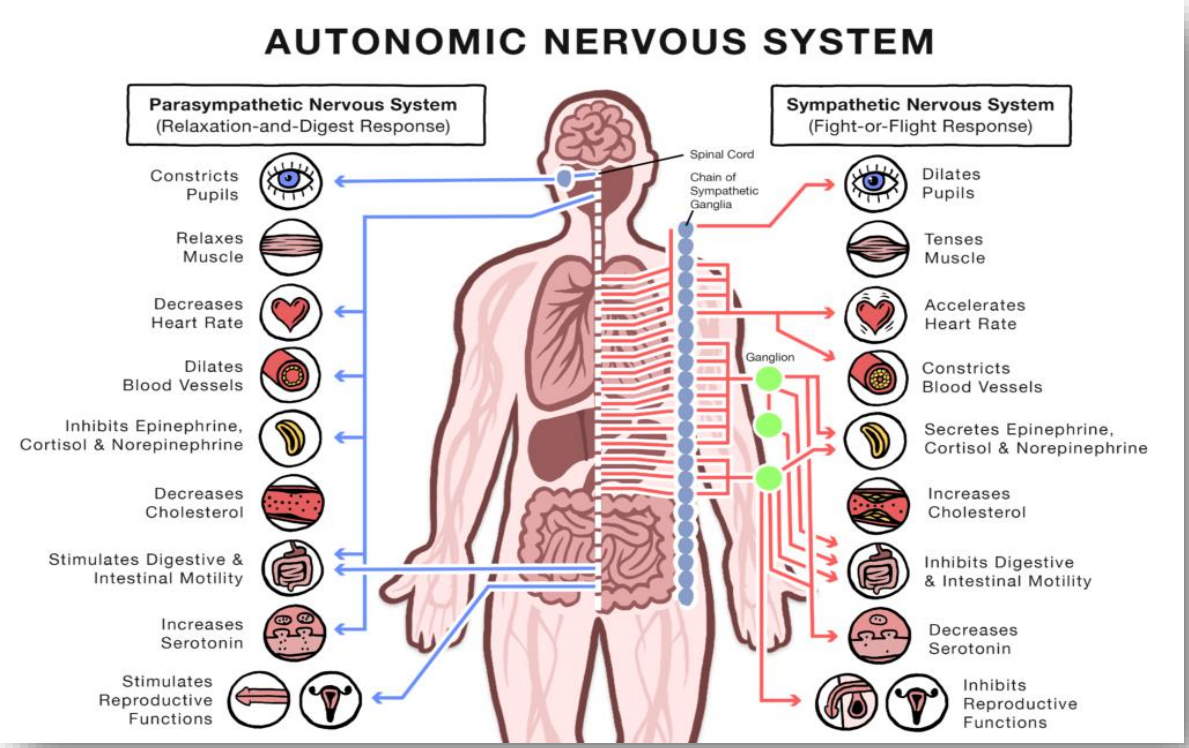


The body functions are regulated by two systems:

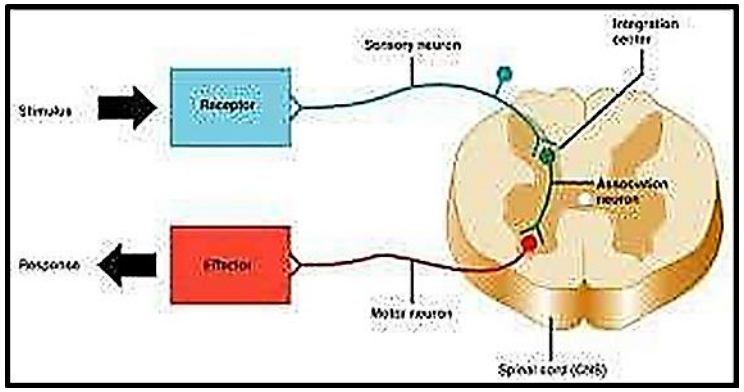
1) The nervous system, which is rapid and controls rapid motor functions as skeletal muscle contraction.

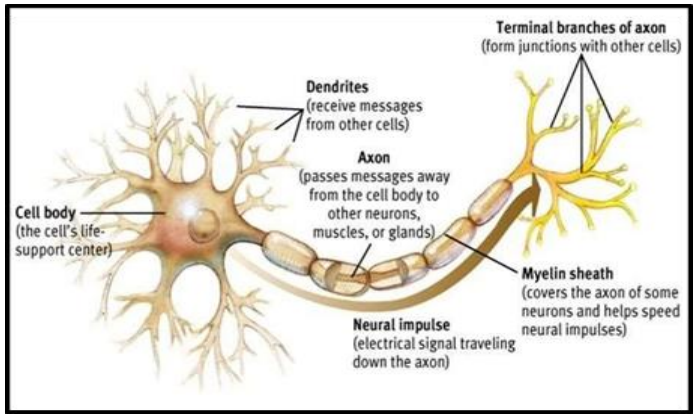
2) The endocrine system, is slow and controls slow metabolic functions.

The Nervous system:

The structural unit of the nervous system is the nerve cell (neuron).

The functional unit of the nervous system is the reflex arc.





The nervous system is 2 divisions:

1- **Central nervous system; CNS:**

It is formed of brain and spinal cord.

Brain: Cerebral cortex, cerebellum and brain stem.

The spinal cord: It is formed of 31 segments: (8 cervical, 12 thoracic, 5 lumbar, 5 sacral and one coccygeal).

2- Peripheral nervous system; PNS

It is formed of peripheral nerves that arise from CNS.

These peripheral nerves are:

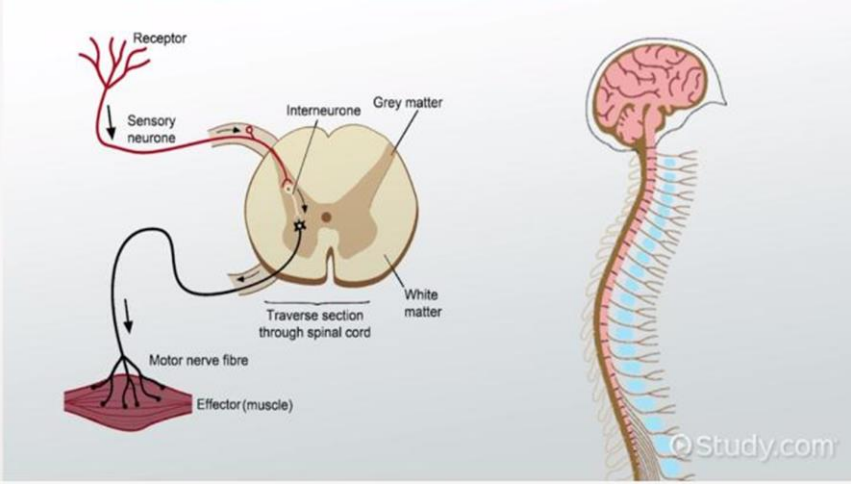
- Cranial (12 pairs) attached to brain and brain stem (mostly).
- Spinal (31 pairs), one pair attached to each spinal cord segment.

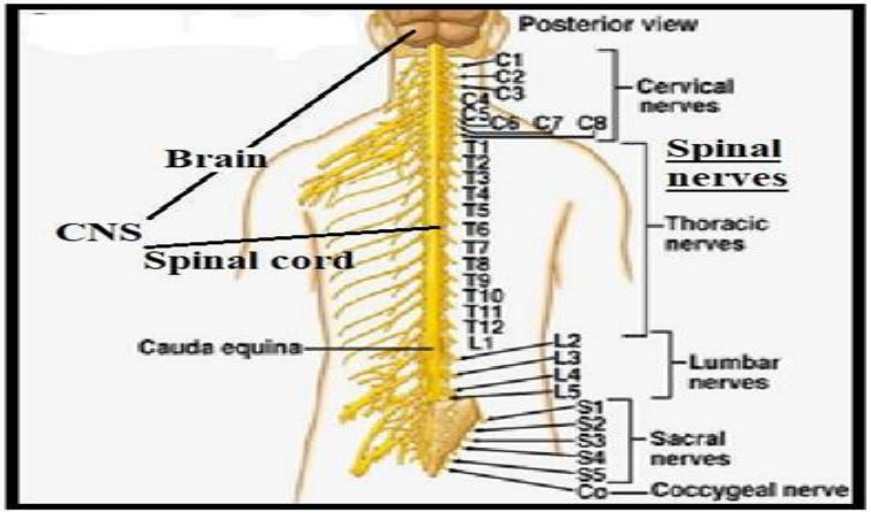
- **Peripheral nerves may be:**

1- Sensory: conduct impulses towards the CNS.

2- Motor: conduct the impulses from CNS to peripheral organs.

3- Mixed: containing both sensory and motor nerve fibers.

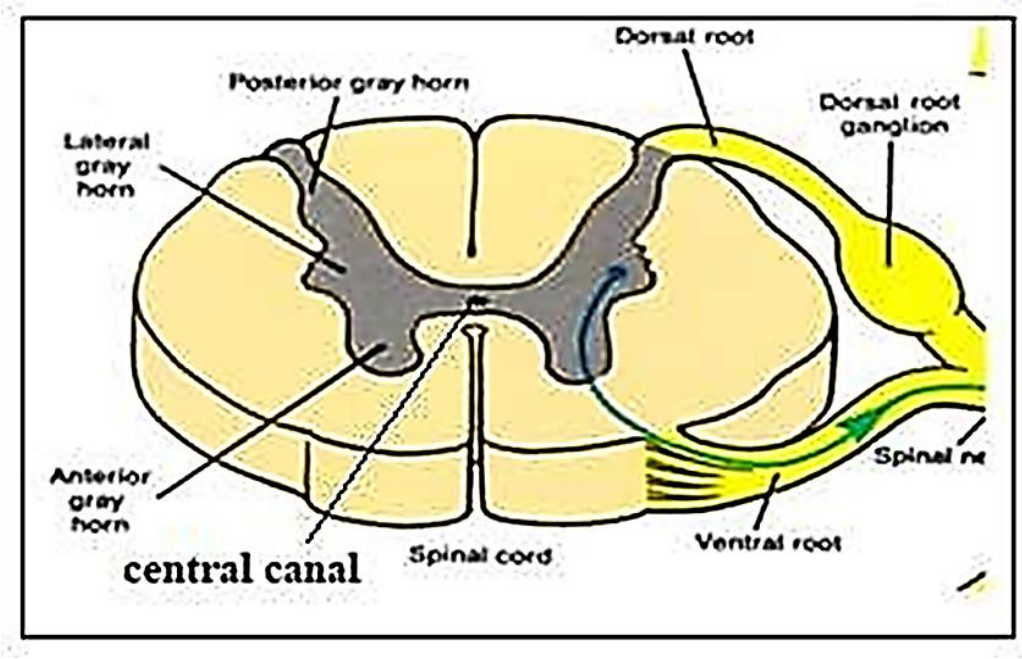




- Cranial nerves are either pure sensory, pure motor, or mixed.
- All spinal nerves are mixed.

Each spinal nerve is attached to the spinal cord segment by 2 roots:

- Ventral (anterior) motor root.
- Dorsal (posterior) sensory root.



Motor Fibers May Be:

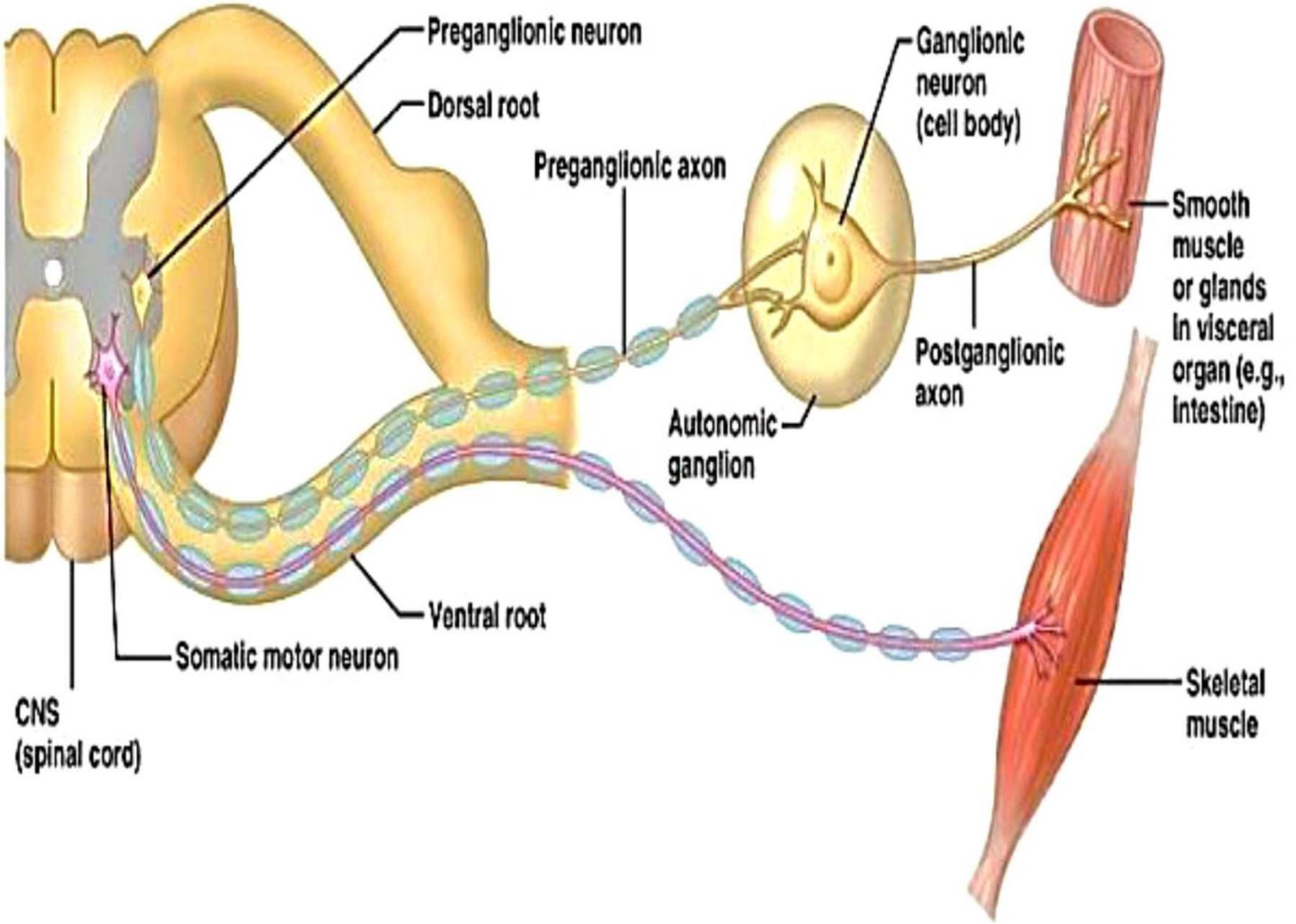
A- **Somatic** to **skeletal muscles**.

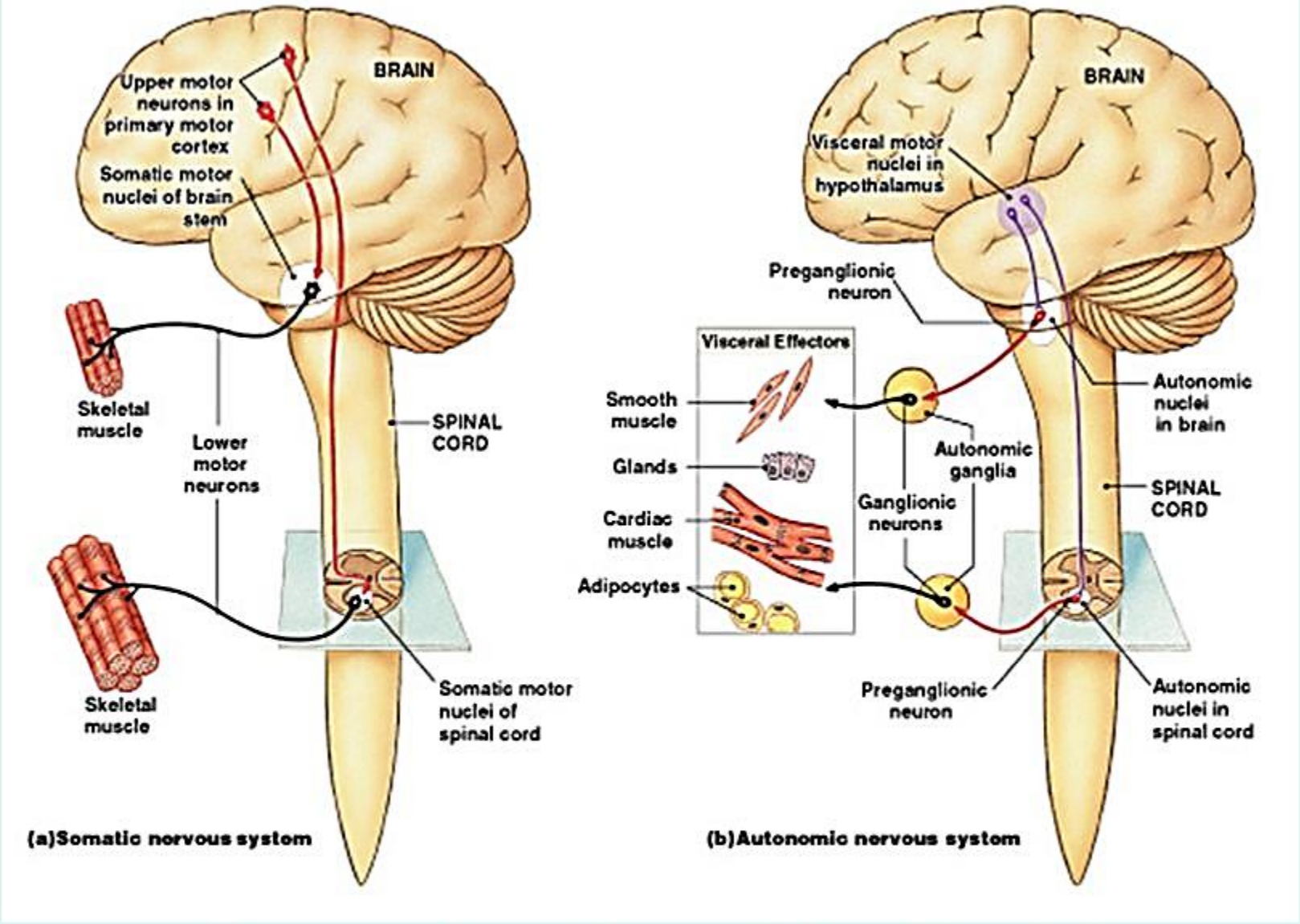
B- **Autonomic** to **involuntary** controlled organs:

(1) Smooth muscles (2) Cardiac muscle (3) glands.

1. **The somatic nerves (Somatic Nervous System; SNS)** that arise from **anterior horn cells (AHCs)** of all spinal cord segments and **somatic motor nuclei of cranial nerves**. It is responsible for voluntary control of body movements via **skeletal muscles**.

2. **The autonomic nerves (Autonomic Nervous System; ANS)** that arise from **lateral horn cells (LHCs)** of some spinal cord segments and **autonomic nuclei of cranial nerves**. It controls **cardiac and smooth muscle contractions and secretion of glands**.


Preganglionic neuron
Dorsal root
Preganglionic axon
Ganglionic neuron (cell body)
Smooth muscle or glands in visceral organ (e.g., intestine)
Postganglionic axon
Autonomic ganglion
Ventral root
Somatic motor neuron
CNS (spinal cord)
Skeletal muscle



Organization Similarities of SNS and ANS

Figure 16-2

Origin and Distribution of 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).
- The peripheral nervous system includes 12 pairs of cranial nerves and 31 pairs of spinal nerves.
- The ANS has two major and anatomically distinct divisions: **the sympathetic and parasympathetic nervous systems**.

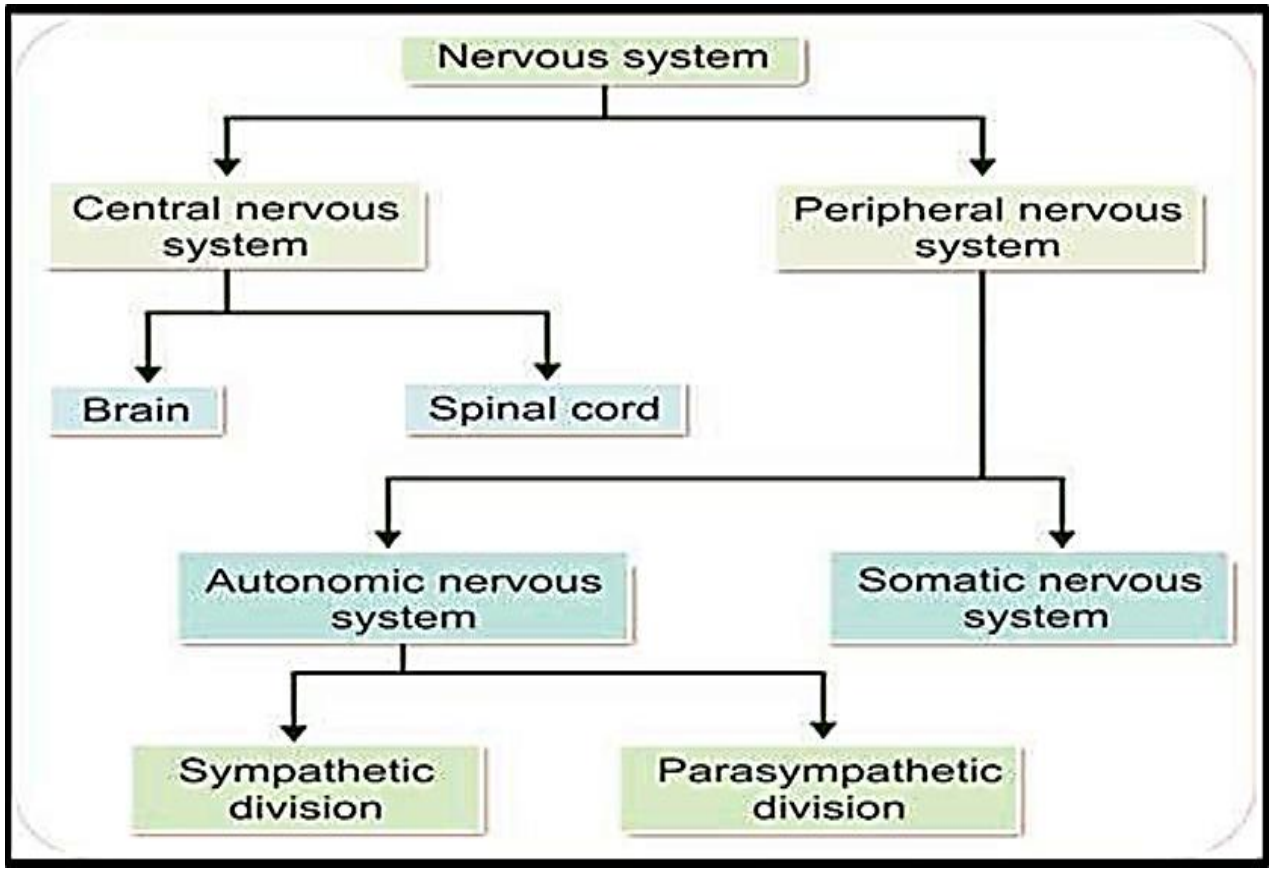
1- The Sympathetic Nervous System:

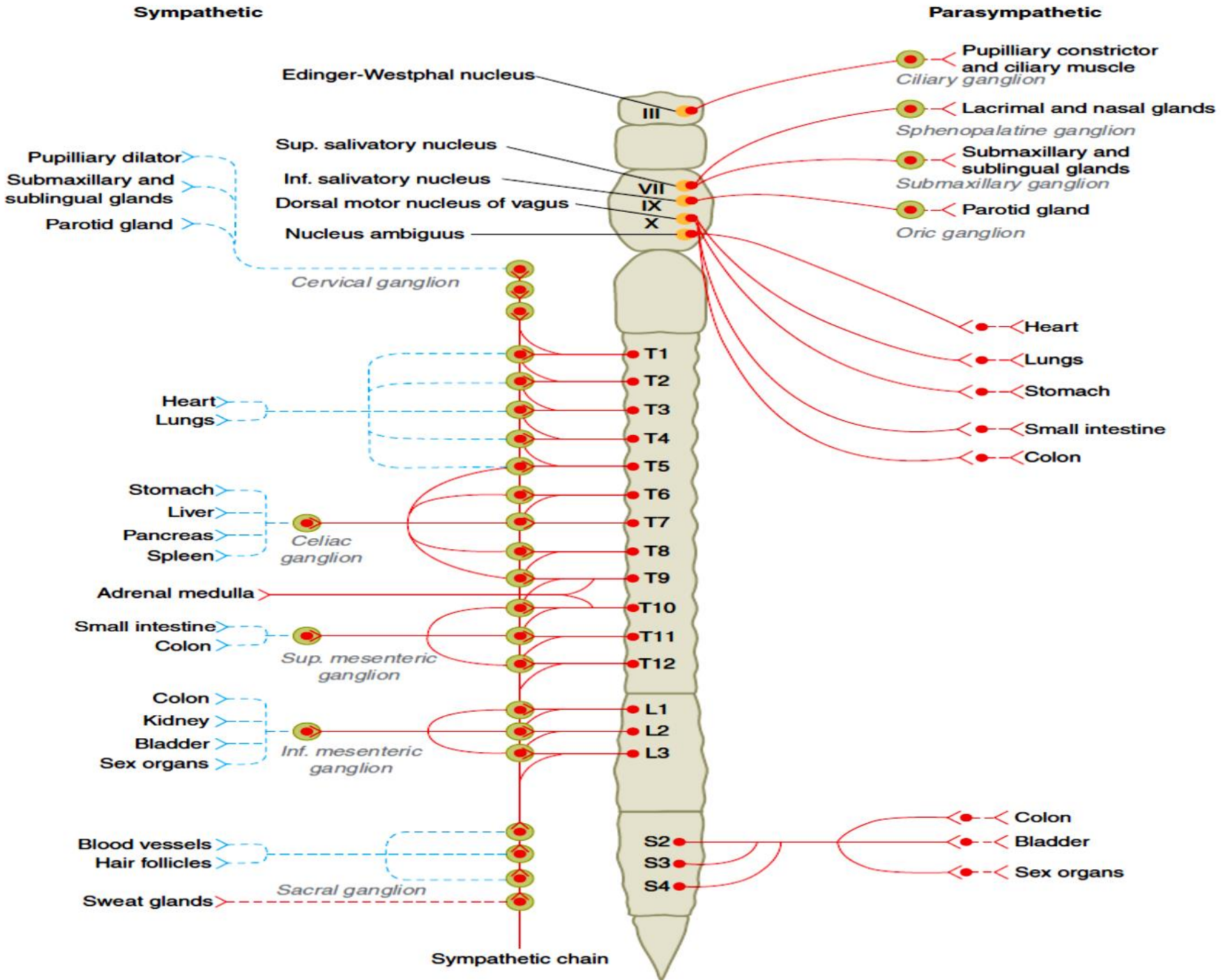
It arises from the **lateral horn cells (L.H.Cs)** of **all thoracic and upper 2-4 lumber segments of the spinal cord.** So, it is called the **thoraco-lumbar outflow**.

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**.


Nervous system
Central nervous system
Peripheral nervous system
Brain
Spinal cord
Autonomic nervous system
Somatic nervous system
Sympathetic division
Parasympathetic division


Sympathetic
Parasympathetic
Edinger-Westphal nucleus
III
Pupilliary constrictor and ciliary muscle
Ciliary ganglion
Lacrimal and nasal glands
Sphenopalatine ganglion
Sup. salivatory nucleus
Inf. salivatory nucleus
Dorsal motor nucleus of vagus
Nucleus ambiguus
VII
IX
X
Submaxillary and sublingual glands
Submaxillary ganglion
Parotid gland
Oric ganglion
Pupilliary dilator
Submaxillary and sublingual glands
Parotid gland
Cervical ganglion
Heart
Lungs
Stomach
Small intestine
Colon
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
T12
L1
L2
L3
Heart
Lungs
Stomach
Liver
Pancreas
Spleen
Celiac ganglion
Adrenal medulla
Small intestine
Colon
Sup. mesenteric ganglion
Colon
Kidney
Bladder
Sex organs
Inf. mesenteric ganglion
S2
S3
S4
Colon
Bladder
Sex organs
Blood vessels
Hair follicles
Sweat glands
Sacral ganglion
Sympathetic chain

Characters of the autonomic nervous system:

1. Most of organs supplied by the ANS have double autonomic supply; impulses in one nerve produce stimulation, while in the other produce inhibition (antagonistic effects). While in the salivary gland, sympathetic (rich in enzymes) and parasympathetic (large in volume) functions are complementary to each other. Functions of sympathetic and parasympathetic are synergistic (co-operative) during sexual intercourse (Erection by parasympathetic and Ejaculation by sympathetic).

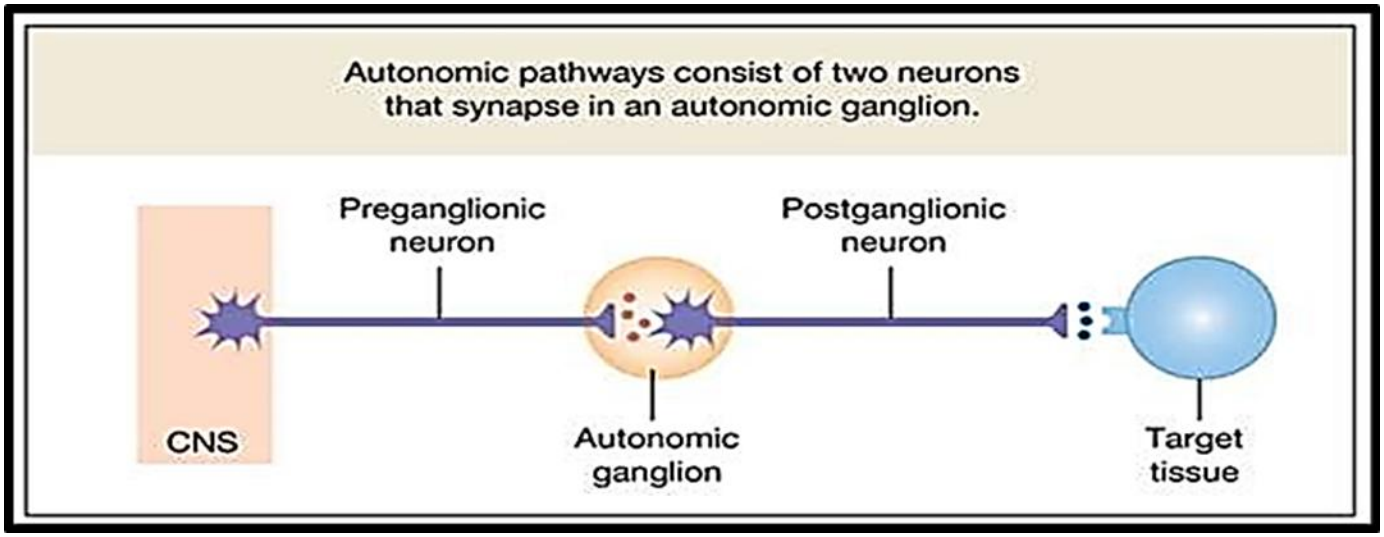
2. The sympathetic nervous system has wider distribution in the body than the parasympathetic nervous system. No parasympathetic fibers supply the skin, skeletal muscle blood vessels, ventricles of the heart, adrenal medulla and spleen while sympathetic fibers do.

3. The sympathetic system prepares the body for the process of fight or flight under conditions of stress.

4. Parasympathetic system is **anabolic** in function (helps digestion, absorption and metabolism of food with energy saving).
5. Sympathetic system is **catabolic** in function.
6. Any autonomic fiber that arise from the CNS must relay (synapse) inside autonomic ganglion on a second neuron that will transmit the impulse to the effector organ.

Autonomic pathway:

Preganglionic neuron from the CNS to → autonomic ganglion → postganglionic neuron → effector organ.



AUTONOMIC GANGLIA:

Definition:

They are collection of nerve cells present outside the CNS.

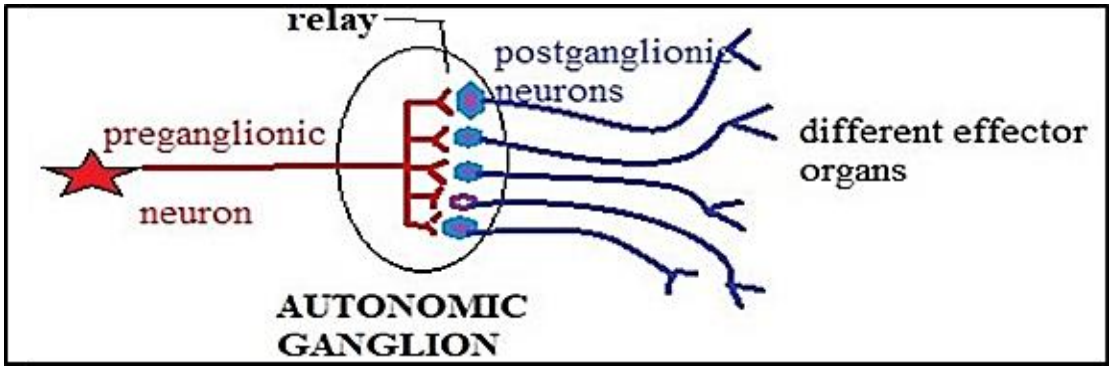
Autonomic ganglia are the site of relay (synapse) of preganglionic fibers over the postganglionic fibers.

Functions of the Autonomic Ganglia:

Act as **distributing centers**.

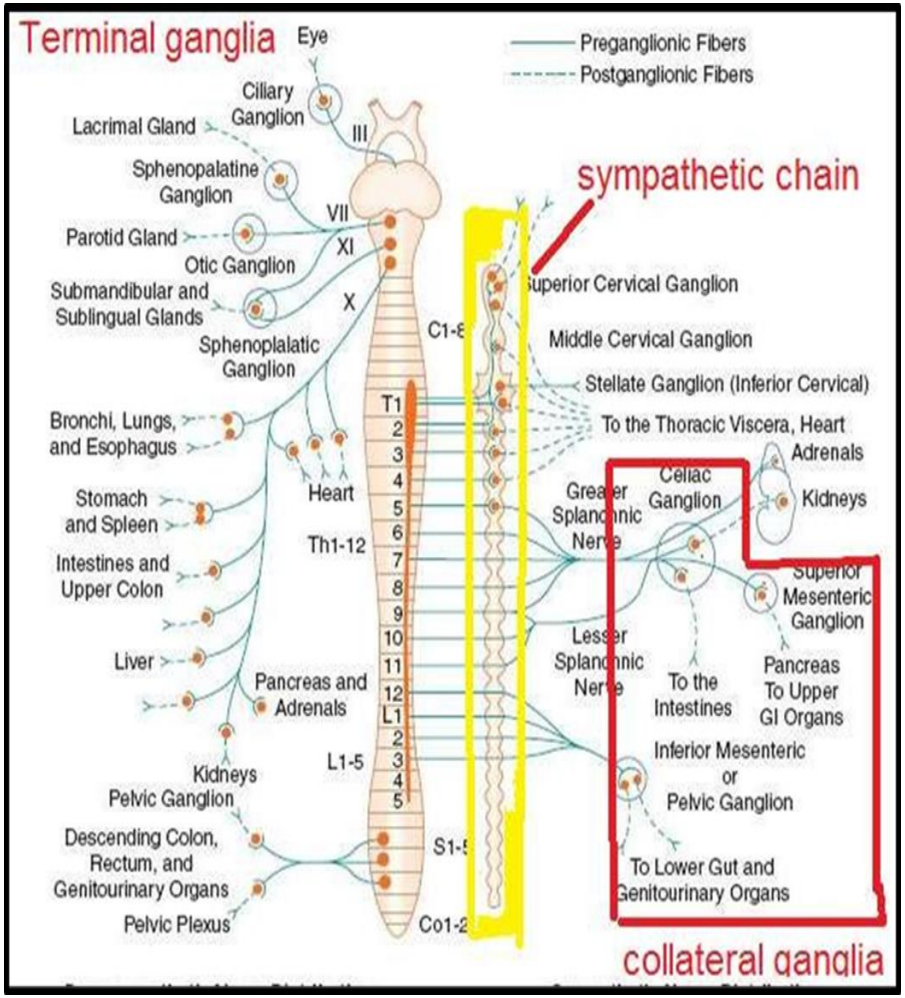
The preganglionic fibers are few and arise from limited CNS regions. So, inside the ganglion one preganglionic neuron can relay on large number of postganglionic neurons and through them it controls many effector organs.

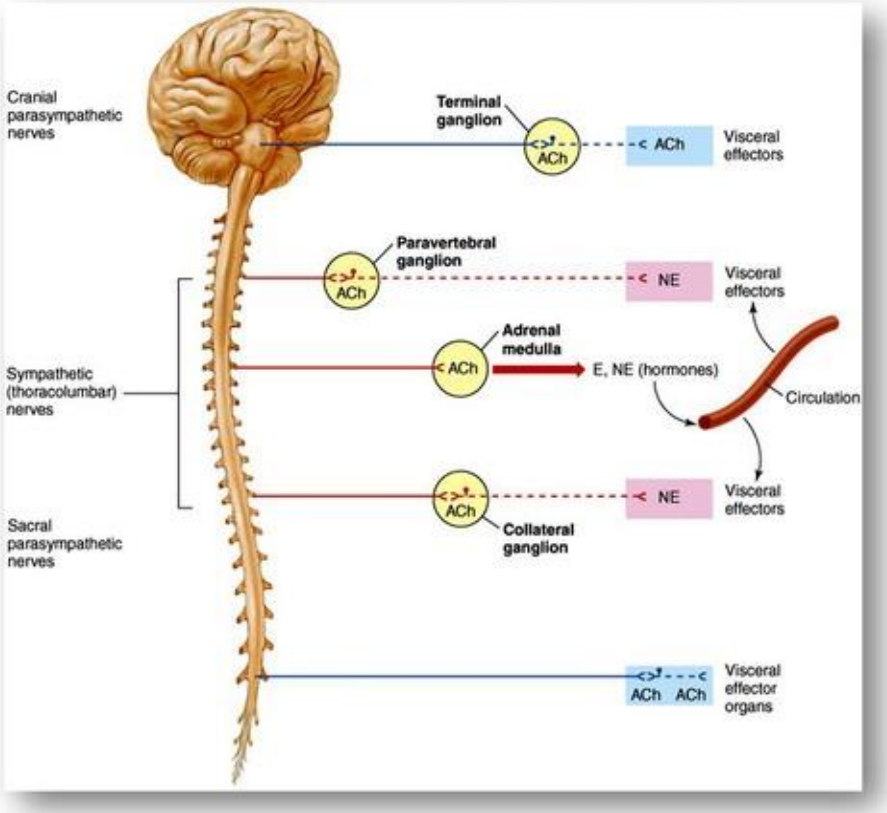
Synapse: is the site of contact but not continuity between preganglionic nerve terminals and cell bodies of postganglionic neurons inside autonomic ganglia.



Types of autonomic ganglia:

1. **Lateral or Paravertebral ganglia (sympathetic chain):** present on either side and lateral to the vertebral column. They are divided into 3 cervical (i.e., superior, middle, and inferior); 12 thoracic; 4 lumbar; 4 sacral and 1 coccygeal. They are the main site for sympathetic preganglionic neuron relay (only sympathetic).
2. **Collateral ganglia: present near the origin of big arterial branches from the aorta in the abdomen and pelvis** and they carry the name of their corresponding arteries as celiac, superior and inferior mesenteric. They are mostly the site for relay of preganglionic sympathetic neuron.
3. **Terminal (peripheral) ganglia :** situated near or in the wall of the effector organs. They are the sites of relay for preganglionic parasympathetic neuron only.


Terminal ganglia
Eye
Preganglionic Fibers
Postganglionic Fibers
Ciliary Ganglion
Lacrimal Gland
III
Sphenopalatine Ganglion
VII
Parotid Gland
XI
Otic Ganglion
Submandibular and Sublingual Glands
X
Sphenoplalatic Ganglion
sympathetic chain
Superior Cervical Ganglion
C1-8
Middle Cervical Ganglion
Stellate Ganglion (Inferior Cervical)
T1
2
3
4
5
6
7
8
9
10
11
12
L1
2
3
4
5
To the Thoracic Viscera, Heart
Adrenals
Kidneys
Celiac Ganglion
Greater Splanchnic Nerve
Superior Mesenteric Ganglion
Lesser Splanchnic Nerve
To the Intestines
Pancreas To Upper GI Organs
Inferior Mesenteric or Pelvic Ganglion
To Lower Gut and Genitourinary Organs
Bronchi, Lungs, and Esophagus
Heart
Th1-12
Stomach and Spleen
Intestines and Upper Colon
Liver
Pancreas and Adrenals
L1-5
Kidneys
Pelvic Ganglion
Descending Colon, Rectum, and Genitourinary Organs
Pelvic Plexus
S1-5
Co1-2
collateral ganglia


Cranial parasympathetic nerves
Terminal ganglion
ACh
ACh
Visceral effectors
Paravertebral ganglion
ACh
NE
Visceral effectors
Adrenal medulla
ACh
E, NE (hormones)
Circulation
Sympathetic (thoracolumbar) nerves
ACh
NE
Visceral effectors
Collateral ganglion
Sacral parasympathetic nerves
ACh ACh
Visceral effector organs

Distribution & Functions of Sympathetic Nervous System

The Sympathetic nervous system:

- The SNS prepares the body for the process of **fight and flight under stress conditions**. It acts on the whole body to produce:
  1. Increases visual fields: dilatation of the pupil, elevation of upper eye lid and exophthalmos.
  2. Increases the blood glucose level (liver glycogenolysis).
  3. Increases oxygenation of the blood in the lungs (bronchodilatation) and oxygen supply to the tissues.
  4. Increases pumping function of the heart and arterial blood pressure →↑blood flow and tissue perfusion→↑O2 and glucose supply to tissues.
  5. Increases skeletal muscle blood flow, decreases the onset of fatigue and accelerates recovery.
  6. Shift of blood from areas of less activity e.g. the splanchnic area and skin to areas of maximum activity e.g. brain, heart and skeletal muscles.
  7. Increases the heat loss from the body through sweating.
  8. ↑ brain alertness and arousal.

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 **pupillodiltation (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 rich in enzymes).

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 muscle** → erection of hairs.

Horner's Syndrome:

Causes:

This syndrome is due to cutting of the sympathetic supply to head and neck or damage of the superior cervical sympathetic ganglion on one side (unilateral).

Manifestations (on the same affected side):

1. Miosis: constriction of the pupil (opposite of mydriasis).
2. Ptosis: drooping of the upper eye lid.
3. Enophthalmos: inward displacement of the eye (sunken eye).
4. Red warm skin or flushing of the face (loss of vasoconstriction) due to persistent vasodilatation.
5. Anhydrosis: dryness of the face skin due to absence of sweat secretion.

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.P & ↑A.B.P).

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

2- Lungs:

- Bronchodilatation 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 > vasodilatation).

- 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 400 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 → delay empty → **retention of stool**.
- Inhibition of the smooth muscles of urinary bladder wall and motor to the internal urethral sphincter → delay empty → **retention of urine**.
- **V.C of the pelvic viscera** including erectile tissue of penis and clitoris leading to their shrinkage (inhibits erection).
- **Ejaculation of semen** due to contraction of the smooth muscles of epididymis, vas deferens and seminal vesicles.
- Variable effects (inhibitory or excitatory) on the uterus depending on the stage of menstrual cycle and the level of ovarian hormones.

V- Sympathetic Supply to limbs, thoracic and abdominal walls:

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.

THANK YOU