Physiology Team 439

MED439
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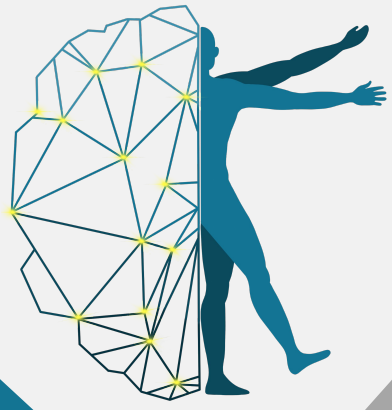


The Autonomic Nervous System

Objectives:

- Appreciate the anatomy of sympathetic & parasympathetic nervous system.
- Explain physiological functions of Sympathetic & parasympathetic nerves in head & neck, chest, abdomen and pelvis.
- Describe neurotransmitters that can release at pre and postganglionic of Autonomic NS.
- Describe Autonomic NS receptors.

Color index:

- Important.
- Girls slide only.
- Boys slide only.
- Dr's note.
- Extra information.

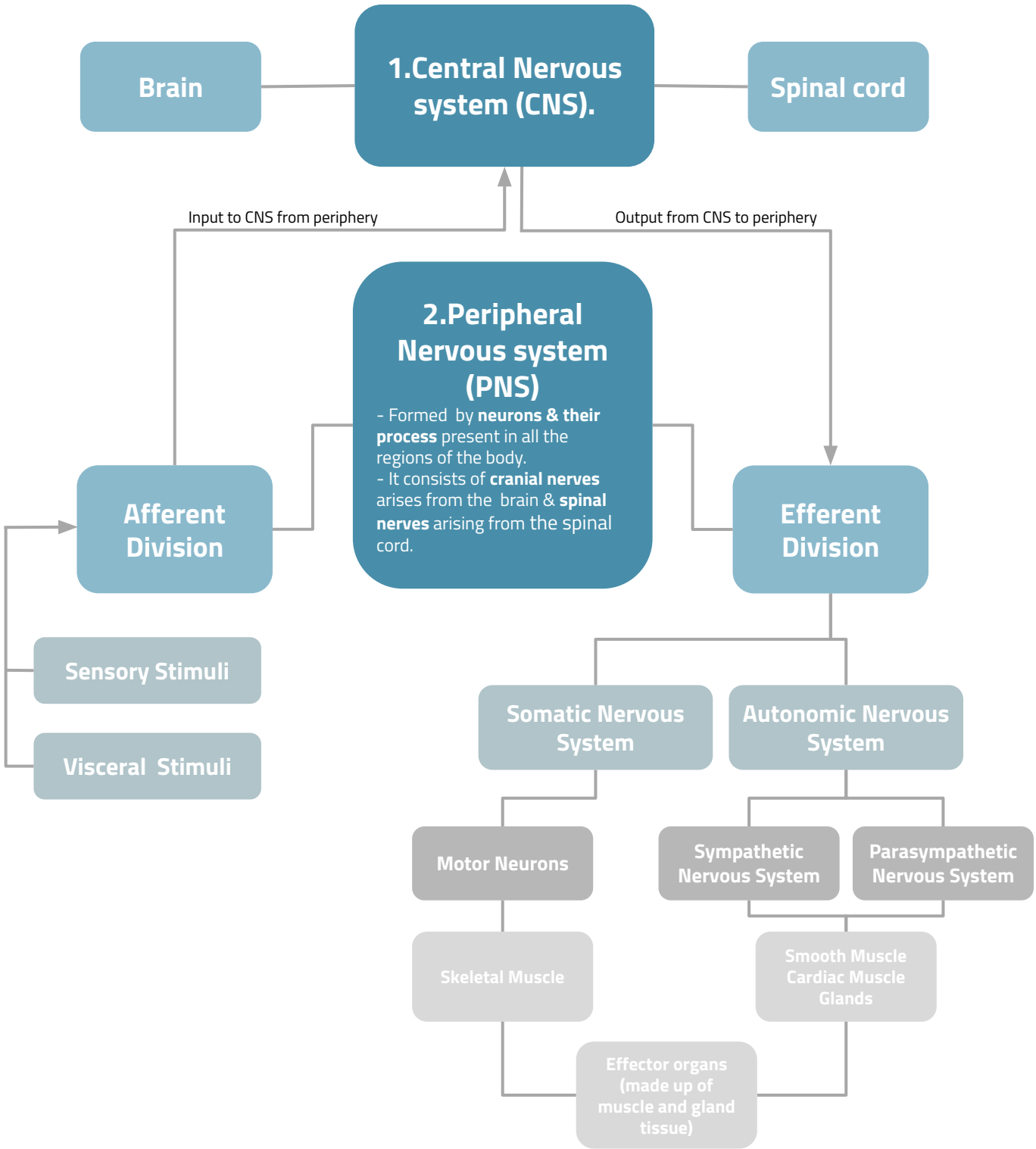
Editing File

Introduction..

Nervous system:

The nervous system monitors and controls almost every organ /system through a series of positive and negative feedback loops

And divided into:

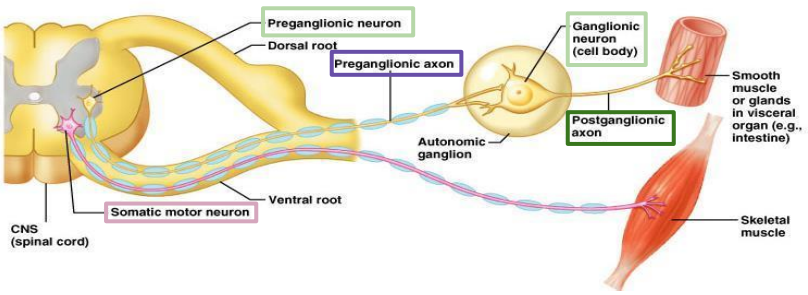


Efferent Division of The peripheral NS is divided into:

- Somatic Nervous system.
- Autonomic nervous system.

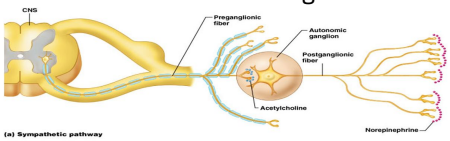
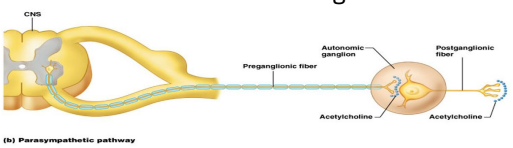
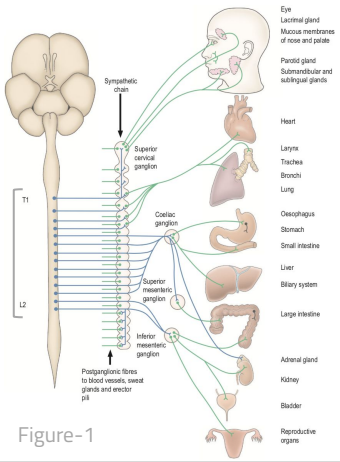
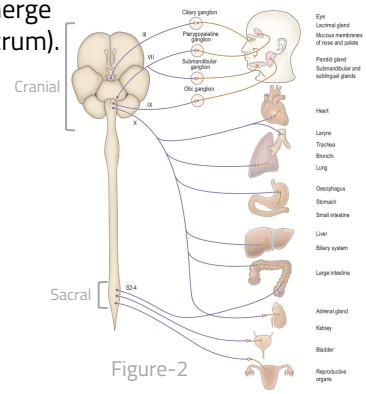
Somatic Division	System	Autonomic System
Cell bodies of **motor neurons** reside in CNS (brain or spinal cord). **One neuron**	**No. Of Neuron**	chains of **two motor neurons**: - 1st = **preganglionic neuron** (in brain or cord). - 2nd = **gangionic neuron** (cell body in ganglion outside CNS).
- Their axons (sheathed in spinal nerves) extend all the way to their skeletal muscles. - **One motor neuron** extends from the CNS to skeletal muscle. - Axons are **well myelinated**. - Conduct impulses **rapidly**.	**Axons**	- **Axon of 1st (preganglionic) neuron** leaves CNS to synapse with the 2nd (ganglionic) neuron/ autonomic ganglion. - **Axon of 2nd (ganglionic) neuron** extends to the organ it serves. Conduction is **slower** due to thin or **unmyelinated** axons.
Controls organs under voluntary control (mainly skeletal muscles)	**Innervation**	- ANS is the subdivision of the peripheral nervous system that **regulates body activities** that are generally **not under conscious control**. - **Visceral motor innervates** non-skeletal (non-somatic) muscles. - Composed of a special group of neurons serving: ❖ Cardiac muscle (the heart). ❖ Smooth muscle (walls of viscera and blood vessels). ❖ Internal organs. ❖ Skin.

- Basic anatomical difference between the motor pathways of the voluntary **somatic nervous system** (to skeletal muscles) and those of the **autonomic nervous system**.



The Autonomic Nervous System ANS

- The ANS is predominantly an **efferent system** transmitting impulses from the Central Nervous System (CNS) to peripheral organ systems.
- It regulates individual organ, **visceral functions** and homeostasis, known as the visceral or automatic system. Effectors includes cardiac, smooth muscles and glands.
- Helps to **adapt the changes in environment.** Adjusts or modifies functions in response to stress such as blood pressure, sweating body temperature, sweating etc. It **fully response in 3-5 seconds**.
- **Subdivisions** of the Autonomic nervous system:
  A. Sympathetic **B.** Parasympathetic.

	Sympathetic	Parasympathetic
Location of ganglia	1- Trunk (chain) ganglia near vertebral bodies. Ganglia close to spinal cord. 2- Prevertebral ganglia near large blood vessel in gut: ❖ celiac. ❖ superior mesenteric. ❖ inferior mesenteric. Figure-1	1- Terminal ganglia. 2- In the wall of organ. (Ganglia close to or on target organs). Figure-2
Pre-ganglionic neuron	- Short, lightly myelinated preganglionic neurons/ fibers which make synaptic connections with postganglionic fibers. These synapses usually occur in clusters called ganglia. - highly branched Axons.	- Long, myelinated preganglionic neurons/ fibers which make synaptic connections with postganglionic fibers. These synapses usually occur in clusters called ganglia. - few branches.
Post-ganglionic neuron	Long unmyelinated postganglionic neurons/ fibers innervate the effector organ. 	Short, Unmyelinated postganglionic neurons/ fibers innervate the effector organ. 
Origin	**Thoracolumbar** Nerve fibers originate From: - lateral horns of the spinal segments T1-L2.  Figure-1	**Craniosacral** cell bodies of the motor nuclei of the: cranial nerves III, VII, IX and X in the brain stem. [S2- S3- S4] sacral segments of the spinal cord. (Nerve fibers emerge from brain & sacrum).  Figure-2
Function	Fight or flight ("E" division). ❖ Exercise. ❖ Excitement. ❖ Emergency. ❖ Embarrassment.	Rest and digest ("D" division). Conservation of body energy ❖ Digestion. ❖ Defecation. ❖ Diuresis.

CAUSES OF DEMYELINATION:

Boys slide only

- Inflammatory processes.
- Viral demyelination.
- Metabolic derangements.
- Hypoxic–ischemic demyelination.
- Focal compression.
- Multiple sclerosis.
- Acute encephalomyelitis.

PARASYMPATHETIC NERVOUS SYSTEM Origin:

Girls slide only

The cranial nerves III, VII and IX	pupil and salivary gland secretion
Vagus nerve (X) carries fibres to the	heart, lungs, stomach, upper intestine and ureter
The sacral fibres form pelvic plexuses which innervate the	distal colon, rectum, bladder and reproductive organs.

The Autonomic Nervous System

Boys slide only

1 THE ANS IS ACTIVATED BY:

Centers located in the **spinal cord, brain stem, hypothalamus and also cerebral cortex especially the limbic cortex** can transmit signals to the lower centers, influence autonomic control..

2 THE ANS OPERATES BY:

visceral reflexes. Subconscious sensory signals from a **visceral organ enter the autonomic ganglia, brain stem or hypothalamus** and then return subconscious reflex responses directly back to the visceral organ to control its activities.

SYMPATHETIC NERVOUS SYSTEM FUNCTIONS

- The whole page is mixed between Boy's and girl's slide.
- Summary on the next page.

- Dominance by the sympathetic system is caused by **physical or emotional stress** "E situations".
- It has a **stimulatory effect** on organs and physiological systems, responsible for rapid sensory activity (pupils in the eye) and movement (skeletal muscle).

01

It diverts blood flow away from the GIT and skin via vasoconstriction.
Diversion of blood flow from the skin pale skin and splanchnic vessels to those supplying skeletal muscle. Blood flow to skeletal muscles, lungs is not only maintained, but enhanced (by as much as 1200%), in case of skeletal muscles.

02

Sympathetic responses include an **increase in heart rate, blood pressure and cardiac output.** It increases heart rate and the contractility of cardiac cells (myocytes), thereby providing a mechanism for the **enhanced blood flow to skeletal muscles and cardiac muscle.**

03

Increased pupil size, bronchial dilation, contraction of sphincters and metabolic changes such as the mobilisation of fat and glycogen. Blood glucose level increase.

04

Bronchioles dilate, which allows for **greater alveolar oxygen exchange.** Airways dilate & respiratory rate increases.

05

Sympathetic nerves **dilate the pupil and relax the lens**, allowing **more light to enter the eye.**

PARASYMPATHETIC NERVOUS SYSTEM FUNCTIONS

- Normally **dominate** over sympathetic impulses.
- Paradoxical fear when there is no escape route or no way to win causes massive activation of parasympathetic division loss of control over urination and defecation.
- **SLUDD type responses:** salivation, lacrimation, urination, digestion and defecation.
- **3 "Decreases"**: decreased HR, diameter of airways and diameter of pupil.
- In physiological terms, the parasympathetic system is concerned with **conservation and restoration of energy**, as it causes a reduction in heart rate and blood pressure, and facilitates digestion and absorption of nutrients, and consequently the excretion of waste products

PHYSIOLOGICAL FUNCTIONS OF THE AUTONOMIC NERVOUS SYSTEM

Structure	Sympathetic stimulation	parasympathetic stimulation
Iris (eye muscle)	Pupil dilation allow more light to come in to enhance the vision	Pupil constriction
Salivary Glands	Saliva production decreased	Saliva Production Increased
Oral/Nasal Mucosa	Mucus production decreased	Mucus production increased
Heart	Heart rate and force increased	Heart rate and force decreased
Lungs	Bronchial muscle relaxed to accomodate more oxygen	Bronchial muscle Contracted
Stomach	Peristalsis reduced	Gastric juice secreted; motility increased
Small intestine	Motility reduced	Digestion increased
Large intestine	Motility reduced	Secretions and motility increased
Liver	Increased conversion of glycogen to glucose	-
Kidney	Decreased urine secretion	Increased urine secretion
Adrenal medulla	Norepinephrine and epinephrine secreted	-
Bladder	Wall relaxed Sphincter closed	Wall contracted Sphincter relaxed

ANS Neurotransmitters:

Classified as either cholinergic or adrenergic neurons based upon the neurotransmitter released.

Acetylcholine (Ach)

The ACh acts on two types of receptors, the **muscarinic** and **nicotinic cholinergic** receptors.

Boys slide only

Nicotinic receptors are found in the **autonomic ganglia** at the synapses between the preganglionic and postganglionic neurons of both the sympathetic and parasympathetic systems.

Muscarinic receptors are found on all **effector cells** that are stimulated by the postganglionic cholinergic neurons of either the parasympathetic or the sympathetic system.

Muscarine activates only muscarinic receptors whereas nicotine activates only nicotinic receptors; **acetylcholine activates both of them.**

Norepinephrine

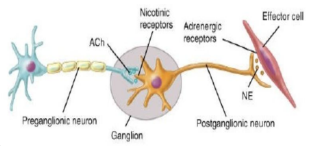
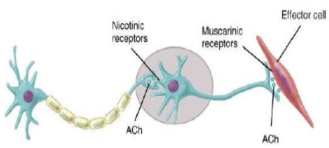
Guyton: The norepinephrine acts on two classes of receptors,

- Alpha (α).
- Beta (β)

alpha receptors divided into α1 and α2 which are linked to different G proteins beta receptors divided into β1,β2, and β3, because certain chemicals affect certain β receptors

The neurotransmitters & receptors of Autonomic

L4

	Sympathetic	Parasympathetic
Neurotransmitters	- **Cholinergic** = (release acetylcholine). - Postganglionic neurons: release **norepinephrine** at target ie. organs Adrenergic.	Pre & Postganglionic neurons release acetylcholine = **Cholinergic**
Preganglionic Axons	All preganglionic release **Acetylcholine (Ach)**	
Postganglionic Axons	All sympathetic postganglionic release Noradrenaline **except sweat glands & blood vessels to skeletal muscles**	All parasympathetic postganglionic release **Acetylcholine** (Ach)
Receptors Girls slide only	The Sympathetic NS Acts on two types of receptors : **α and β.** What do the receptors do? - **Activation of α** receptors leads to **smooth muscle contraction.** - **Activation of β2** receptors leads to **smooth muscle relaxation.** - **Activation of β1** receptors leads to **smooth muscle contraction (especially in heart).**	Most transmissions occur in two stages: - When stimulated, the **preganglionic nerve** releases ACh at the ganglion, which acts on **nicotinic receptors** of the postganglionic nerve. - The **postganglionic nerve** then releases ACh to stimulate the **muscarinic receptors** of the target organ.
Picture		

All sympathetic postganglionic release Noradrenaline **except sweat glands & blood vessels to skeletal muscles**, why ?

- Skeletal muscle has one motor neuron extends from the CNS to skeletal muscle. the cholinergic receptors Are located in skeletal muscle at the neuromuscular junction.
- Blood vessel: the adrenal medulla work as ganglia, which has a cholinergic receptors that activated by Acetylcholine, activates postsynaptic cholinergic receptors (on adrenal glands) triggers the secretion of medullary hormones (epinephrine and norepinephrine) in the blood vessels.
- Sweat glands: its ganglion release Acetylcholine. **Guyton:** The sweat glands secrete large quantities of sweat when the sympathetic nerves are stimulated, but no effect is caused by stimulating the parasympathetic nerves. However, the sympathetic fibers to most sweat glands are cholinergic (except for a few adrenergic fibers to the palms and soles), in contrast to almost all other sympathetic fibers, which are adrenergic. Furthermore, the sweat glands are stimulated primarily by centers in the hypothalamus that are usually considered to be parasympathetic centers. Therefore, sweating could be called a parasympathetic function, even though it is controlled by nerve fibers that anatomically are distributed through the sympathetic nervous system. **Guyton:** These glands can also be stimulated to some extent by epinephrine or norepinephrine circulating in the blood, even though the glands themselves do not have adrenergic innervation.

THE AUTONOMIC NERVOUS SYSTEM

Boys slide only.

	Sympathetic (adrenergic with exceptions)	Parasympathetic (muscarinic)
Circulatory System		
Cardiac Output	Increases	M2: decreases
SA node: heart rate (chronotropic)	β1,β2: increases	M2: decreases
Cardiac muscle: contractility (inotropic)	β1,β2 increases	M2: decreases (atria only)
Conduction at AV node	β1: increases	M2: decreases
vascular smooth muscle	M3: contracts; α = contracts; β2 = relaxes	---
platelets	α2: aggregates	---
Mast cells - histamine	β2: inhibits	---
Respiratory system		
Smooth muscles or bronchioles	β2: relaxes (major contribution); α1: contracts (minor contribution)	M3: contracts
Nervous system		
Pupil of eye	α1: relaxes	M3: contracts
ciliary muscle	β2: relaxes	M3: contracts
Endocrine system		
Pancreas (islets)	α2: decreases secretion	---
Adrenal medulla	N: secretes epinephrine	---

THE AUTONOMIC NERVOUS SYSTEM

Boys slide only.

	Sympathetic (adrenergic with exceptions)	Parasympathetic (muscarinic)
Digestive system		
Salivary Glands: secretions	β: stimulates viscous, amylase secretions; α = stimulates potassium cation	stimulates watery secretions
Lacrimal Glands (tears)	decreases	M3: increases
Kidney (renin)	secretes	---
parietal cells	---	M1: secretion
liver	α1, β2: glycogenolysis, gluconeogenesis	---
GI tract motility	decreases	M1,M3: increases
Smooth muscles of GI tract	α,β2: relaxes	M3: contracts
Sphincters of GI tract	α1: contracts	M3: relaxes
Urinary system		
Bladder wall	β2: relaxes	contracts
ureter	α1: contracts	relaxes
Sphincter	α1: contracts, β2 relaxes	relaxes
Sweat gland secretion	M: stimulates (major contribution) α1: stimulates (minor contribution)	---
Arrector pili	α1: stimulates	---

The Stress Reaction

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When stress occurs, the sympathetic nervous system is triggered. **Norepinephrine is released** by nerves, and **epinephrine** is secreted by the adrenal glands. By activating receptors in blood vessels and other structures, these substances ready the heart and working muscles for action.

Acetylcholine is released in the parasympathetic nervous system, producing **calming effects**. The digestive tract is stimulated to digest a meal, the heart rate slows, and the pupils of the eyes become smaller. The **neuroendocrine system also maintains the body's normal internal functioning.**

Chronic Stress

When **glucocorticoids or adrenaline are secreted in response** to the **prolonged psychological stress** commonly encountered by humans, the results are not ideal. Normally, bodily systems gear up under stress and **release hormones to improve memory**, **increase immune function**, **enhance muscular activity**, and **restore homeostasis.** If you are not fighting or fleeing, but standing frustrated in a supermarket checkout line or sitting in a traffic jam, you are not engaging in muscular exercise.

Yet these systems continue to be stimulated, and **when they are stimulated chronically,** there are different consequences: **Memory is impaired, immune function is suppressed,** and **energy is stored as fat.**

Response to stress

Psychological	Behavioral	Psychosomatic
Short fuse irritability depression frustration emotional irritability insecurity mental illness anxiety	Drug use/abuse alcohol use/abuse smoking strained relationships eating problems suicide attempts violence impulsive irrational behavior	Ulcers High blood pressure Insomnia Indigestion Headaches Other cardiovascular body infections Irregular Pulse rate

Enteric Nervous System.

Guyton: The gastrointestinal tract has a nervous system all its own called the enteric nervous system. It lies entirely in the wall of the gut, beginning in the esophagus and extending all the way to the anus. The enteric nervous system is composed mainly of two plexuses:

Myenteric plexus

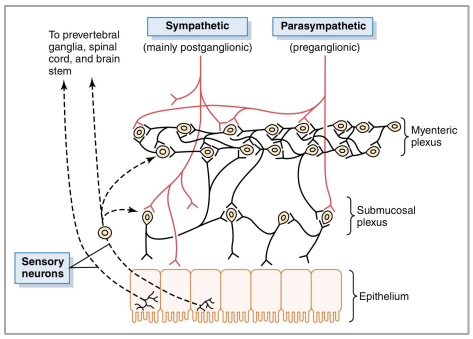
Outer plexus

- is located between longitudinal and circular layers of muscle.
- it's **involve in control of digestive tract motility.**

Submucosal plexus

Inner plexus

- is located between the circular muscle and luminal mucosa.
- it senses the environment of the lumen and **regulates gastrointestinal blood flow** and **epithelial cell function**.



Guyton: Neural control of the gut wall, showing (1) the **myenteric** and **submucosal** plexuses (black fibers); (2) **extrinsic control of these plexuses by the sympathetic and parasympathetic** nervous systems (red fibers); and (3) **sensory fibers** passing from the luminal epithelium and gut wall to the enteric plexuses, then to the prevertebral ganglia of the spinal cord and directly to the spinal cord and brainstem (dashed fibers).

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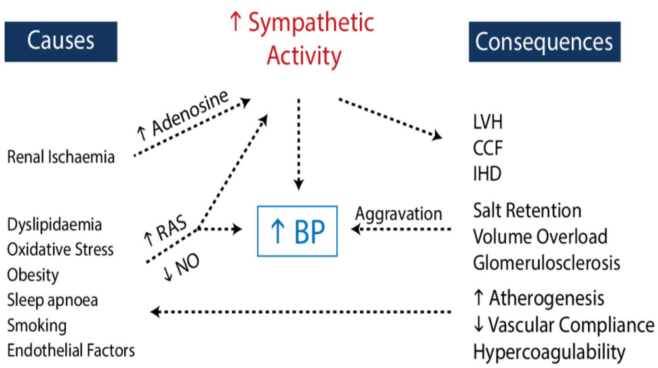

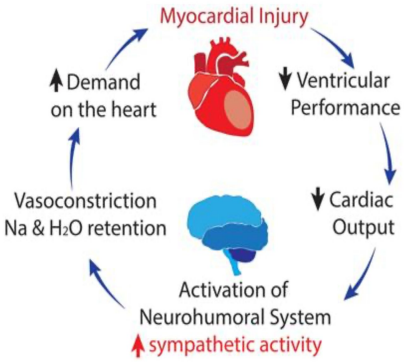

❖ Tests for sympathetic function:

1) Cardiac:
   - tachycardia during standing or head-up tilt.
   - tachycardia during valsalva strain (phase II).

2) Peripheral:
   - Blood pressure overshoot after valsalva release.
   - BP increase when cold pressure test.
   - Diastolic BP rise with isometric handgrip.
   - Systolic and diastolic BP response to Upright position.

❖ Tests for cardiac vagal function:

- respiratory sinus arrhythmia.
- valsalva ratio (phase IV/II).
- Bradycardia during phenylephrine challenge.
- Absence of tachycardia with atropine.

MCQ & SAQ:

Q1: which one of the following is true about autonomic division of PNS

A. Innervate skeletal muscle.
B. Unmyelinated axon.
C. Signaling faster than somatic.
D. voluntary control.

Q2: which of the following is innervated by somatic neurons?

A. Cardiac muscle.
B. Smooth muscle.
C. Skin.
D. Skeletal muscle.

Q3: Vagus nerve carries fibers to all of the following except

A. Stomach.
B. Ureter.
C. Bladder.
D. Heart.

Q4: Sympathetic preganglionic neuron is

A. Long, unmyelinated.
B. Long, myelinated.
C. Short, unmyelinated.
D. Short, myelinated.

Q5: During parasympathetic stimulation

A. Pupil dilates.
B. Urine secretion increase.
C. Bronchial muscle relaxed.
D. Stomach peristalsis reduced.

Q6: Norepinephrine is released during

A. Sympathetic, postganglionic.
B. Sympathetic, preganglionic.
C. Parasympathetic, postganglionic.
D. Parasympathetic, preganglionic.

answer key:
1: B
2: D
3: C
4: D
5: B
6: A

1- mentions two differences between autonomic and somatic nervous systems ?

2- mention the origin of sympathetic and parasympathetic nerve fibers?

3- mention the ans neurotransmitters and what receptors do they act on

4- mention 5 behavioral responses to stress

A1: 1) somatic axons is myelinated 2) autonomic has two neurons (preganglionic and postganglionic)

A2: Sympathetic: Thoracolumbar lateral horns of the spinal segment T1-L2.
Parasympathetic: Craniosacral. Cranial nerves III, VII, IX and X in the brain stem.
[S2-S4] sacral segments of the spinal cord.

A3: Acetylcholine and norepinephrine, they act on nicotinic and muscarinic receptors

A4: Drug use/abuse, alcohol use/abuse, smoking, eating problems, suicide attempts

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