MEDICINE
KING SAUD UNIVERSITY

تمت المراجعة
شوق الأحمري & عبدالعزيز العنقري

Physiology Team 436

CNS PHYSIOLOGY

- Text
- Important
- Formulas
- Numbers
- Doctor notes
- Notes and explanation

Lecture No.3

"Failure Is Simply The Opportunity To Begin Again, This Time More Intelligently"

Physiology of the autonomic nervous system

Objectives:

1. The anatomy of somatic and autonomic nervous system.
2. Sympathetic and parasympathetic nerves.
3. Pre and post ganglionic neurons.
4. Functions of sympathetic and parasympathetic nerves in head & neck, chest, abdomen and pelvis.
5. Neurotransmitters release at pre and post ganglionic sympathetic / parasympathetic nerve endings.
6. Various responses due to stimulation of the sympathetic / parasympathetic nervous system.

Introduction

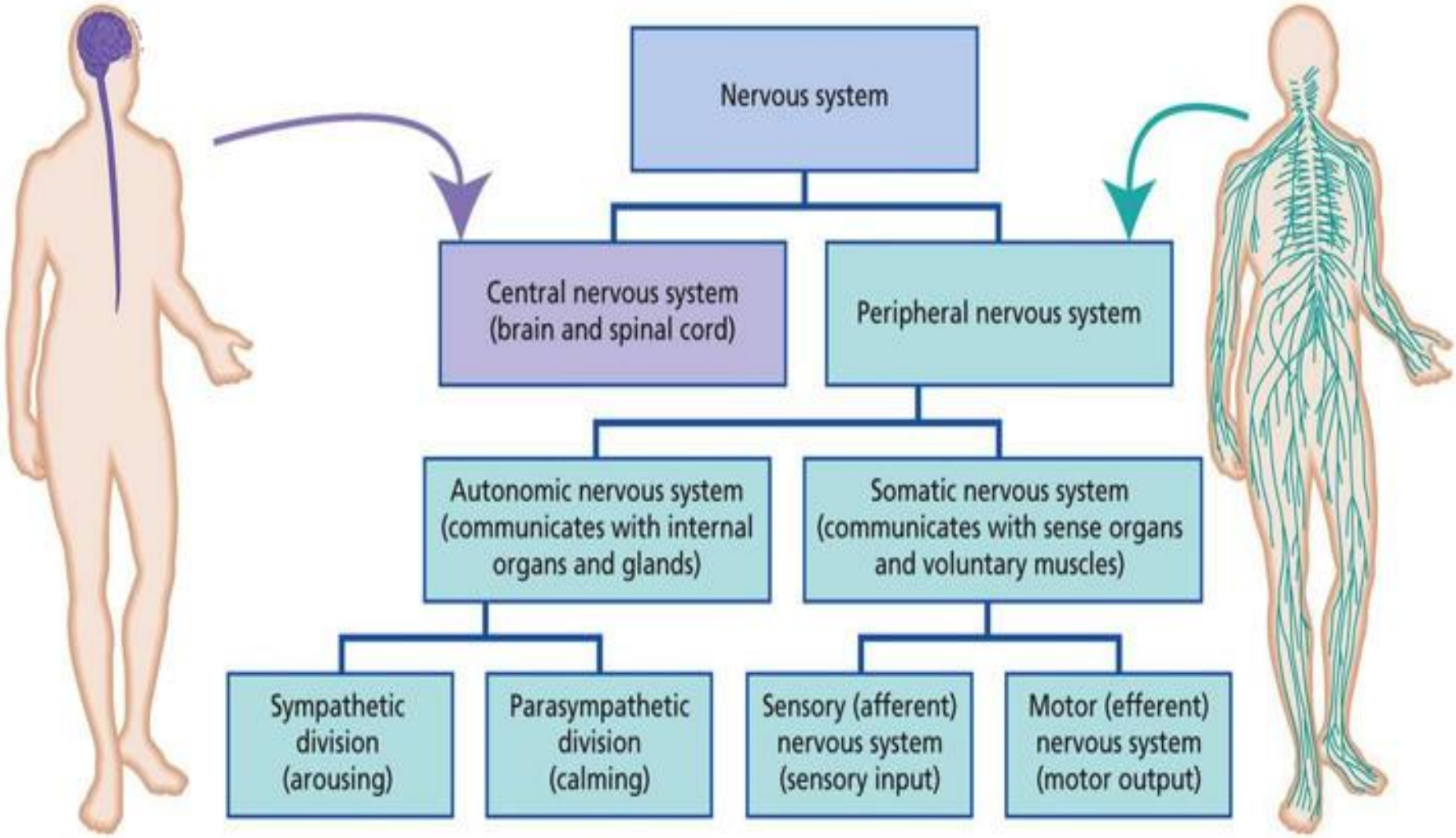
- The autonomic nervous system is a subdivision of the Efferent nervous system and then the autonomic nervous system has 2 subdivisions, sympathetic and parasympathetic.

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

- The Central Nervous System (CNS): Includes the brain and spinal cord.

- The Peripheral Nervous System (PNS): Formed by neurons & their process present in all the regions of the body.
  - It consists of :
    I. cranial nerves arises from the brain
    II. spinal nerves arising from the spinal cord.
  - The peripheral NS is divided into:
    I. Somatic Nervous system
    II. Autonomic nervous system

THE NERVOUS SYSTEM



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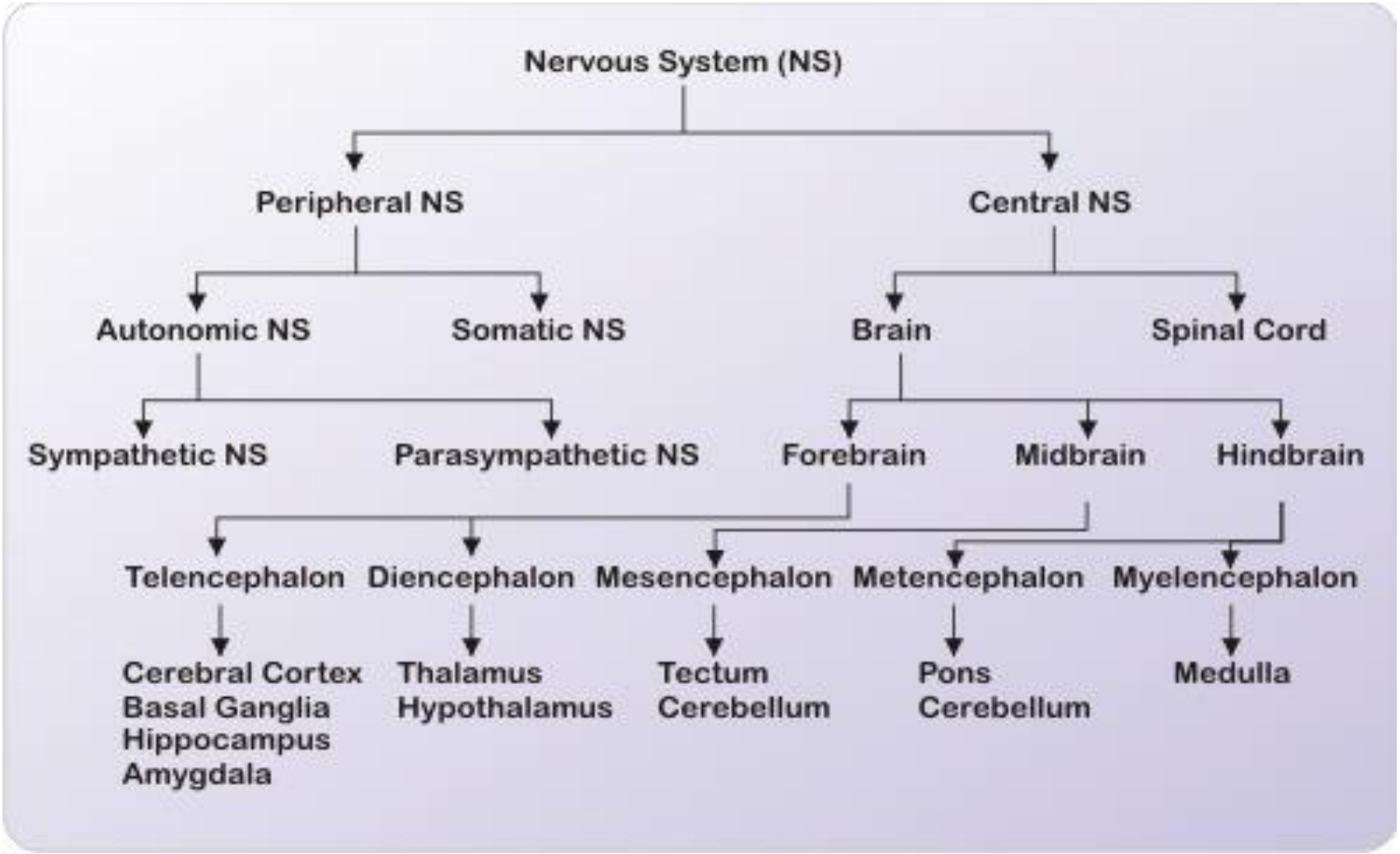

Nervous System (NS)
Peripheral NS
Central NS
Autonomic NS
Somatic NS
Brain
Spinal Cord
Sympathetic NS
Parasympathetic NS
Forebrain
Midbrain
Hindbrain
Telencephalon
Diencephalon
Mesencephalon
Metencephalon
Myelencephalon
Cerebral Cortex
Basal Ganglia
Hippocampus
Amygdala
Thalamus
Hypothalamus
Tectum
Cerebellum
Pons
Cerebellum
Medulla

Anatomical Divisions of the Nervous System

Nervous system

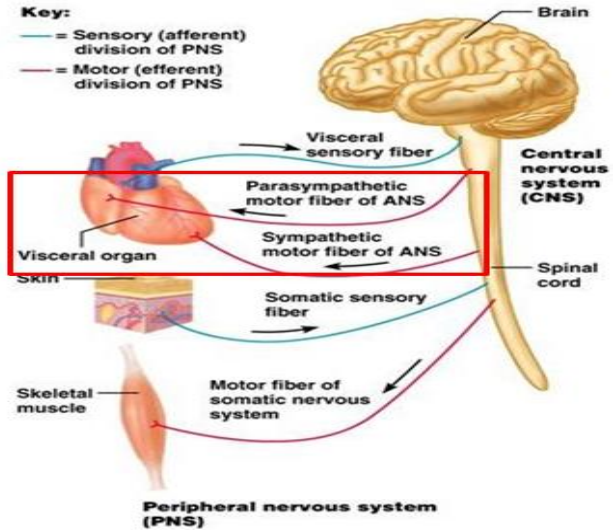
CNS: brain and spinal cord

PNS: cranial and spinal nerves.

Sensory (Afferent) division		Motor (Efferent) division	
Somatic	Visceral	Somatic	Visceral (Autonomic)
General: -Touch and pain - Temperature - Proprioception **Special:** Hearing, vision, and smell.	**General:** - Temperature - Pain -Chemical changes **Special:** Taste.	Innervation of all skeletal muscles.	Innervation of smooth and cardiac muscles (non-skeletal/non-somatic) and glands ,Ex: cardiac/smooth muscle ,Internal organs and skin.
			Sympathetic division / Parasympathetic division

What is Autonomic Nervous System?

- ANS is the **Efferent** portion of the peripheral nervous system that controls **involuntary** (subconsciously) to adapt the changes in environment by regulating individual organ, homeostasis and visceral functions such as:
  I. Control of heart rate and force of contraction
  II. Constriction and dilatation of blood vessels
  III. Contraction and relaxation of smooth muscle
  IV. Visual accommodation
  V. Secretions from exocrine and endocrine glands.



- Divisions of ANS:
  I. Sympathetic
  II. Parasympathetic
  III. Enteric Nervous System : neurons that control the function of the gastrointestinal tract.

ONLY IN MALES' SLIDES

- 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.
- 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.

- Subconsciously = not under conscious control.

THE AUTONOMIC NERVOUS SYSTEM

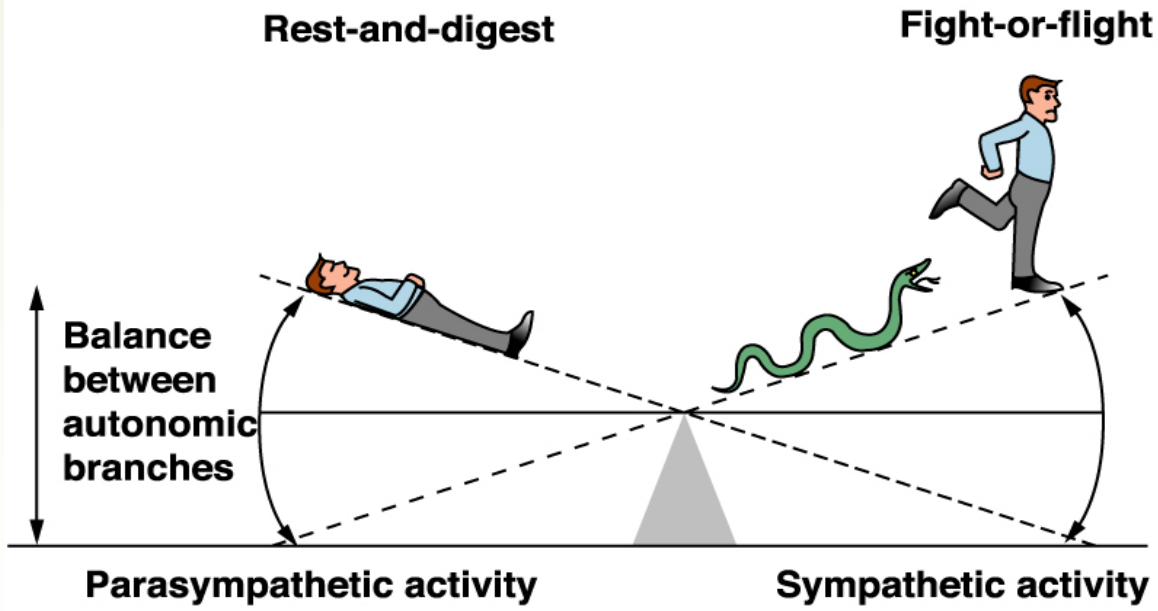
- The striking characteristics of ANS is the rapidity and intensity with which it can change visceral functions:

I. Heart rate can be doubled within 3-5 sec.

II. Blood pressure can be doubled or decreased low enough to cause fainting within 10-15 sec.

III. Sweating can begin within seconds.

IV. The urinary bladder may empty involuntarily, also within seconds.



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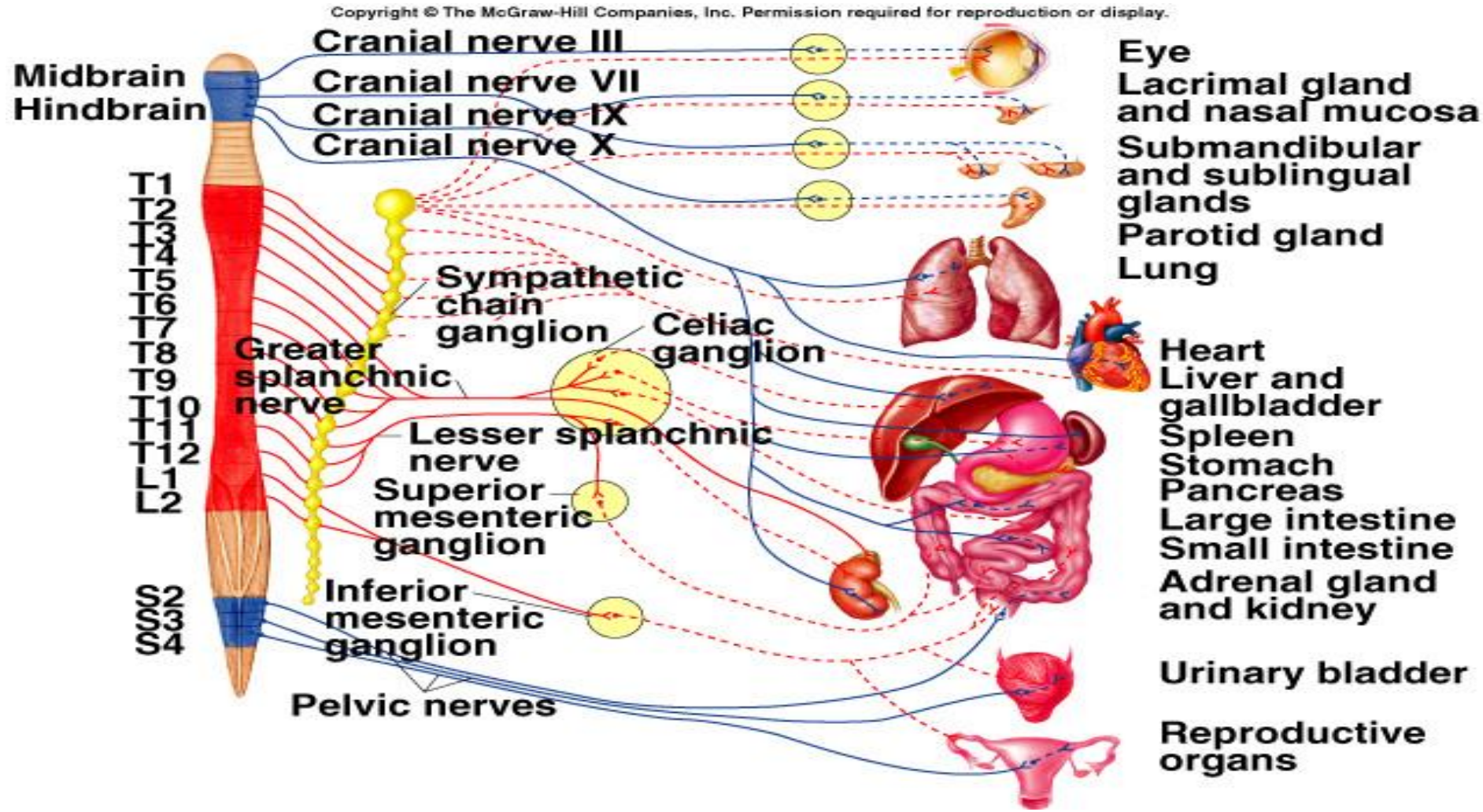
Distribution of the sympathetic and parasympathetic nervous system

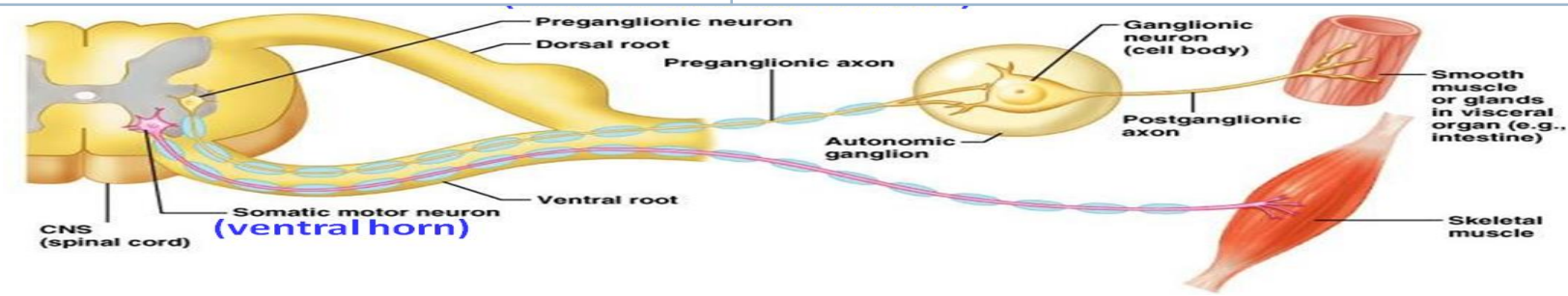


9 Blue= parasympathetic.
Red: sympathetic

Comparison Between Autonomic and Somatic motor systems

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

Somatic motor system	Autonomic nervous system (Not under voluntary control)
• One motor neuron extends from CNS to skeletal muscle. • Cell bodies of motor neurons reside in CNS (brain or spinal cord). • Their axons (sheathed in spinal nerves) extend all the way to their skeletal muscles.	Chain of two motor neuron: 1st: Preganglionic neuron (in brain or cord). 2nd: Postganglionic neuron (Cell body in ganglion outside CNS).
Axons are thickly myelinated, conduct impulses rapidly.	Conduction is slower due to lightly/thinly or unmyelinated axons.
No autonomic ganglion, only one neuron inside the Nervous system.	Myelin sheath and node of Ranvier play a major rule is increasing the conduction of impulses. The conduction is slower because the preganglionic neuron is myelinated and postganglionic neuron is unmyelinated.



Basic anatomy of the ANS

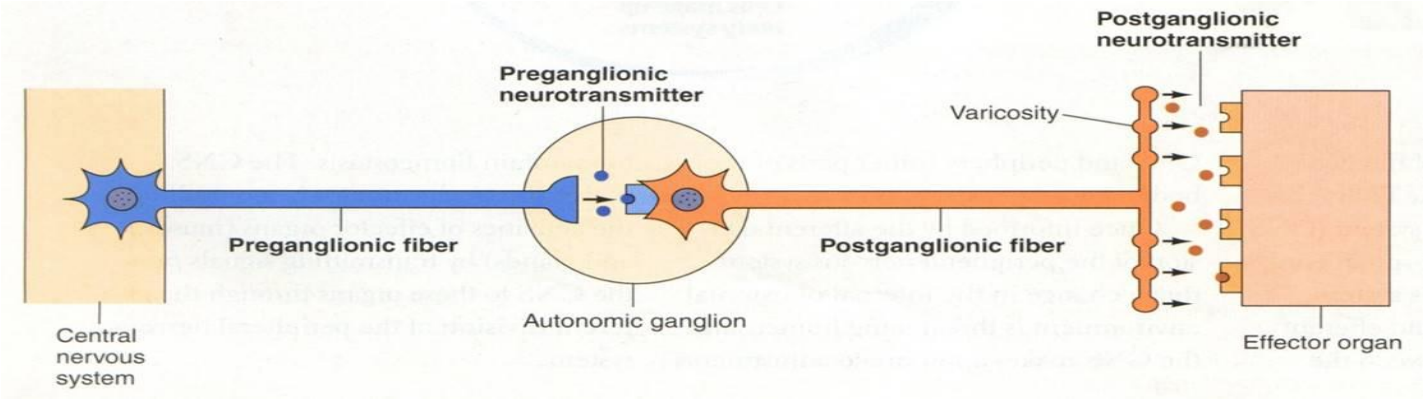
Preganglionic neuron:

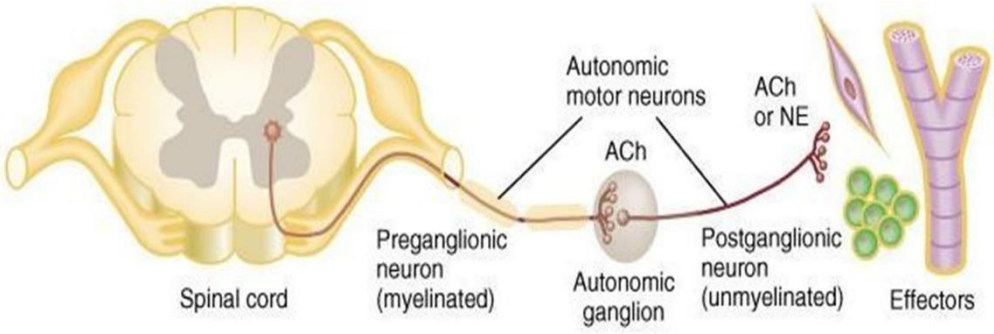
- Cell body in brain or spinal cord
- Axon is myelinated (Aβ-type) that extends to autonomic ganglion

Postganglionic neuron:

- Cell body is outside in CNS in an autonomic ganglion
- Axon is unmyelinated (C-type) that terminates on an effector cell (organ)

- A single preganglionic neuron synapses with 8-9 postganglionic neurons
- Process :
  - Axon of 1st (preganglionic) neuron leaves CNS to synapse with the 2nd (ganglionic) neuron.
  - Axon of 2nd (ganglionic) neuron extends to the organ it serves.
- 2 ganglion, preganglionic inside the nervous system but postganglionic is outside the nervous system



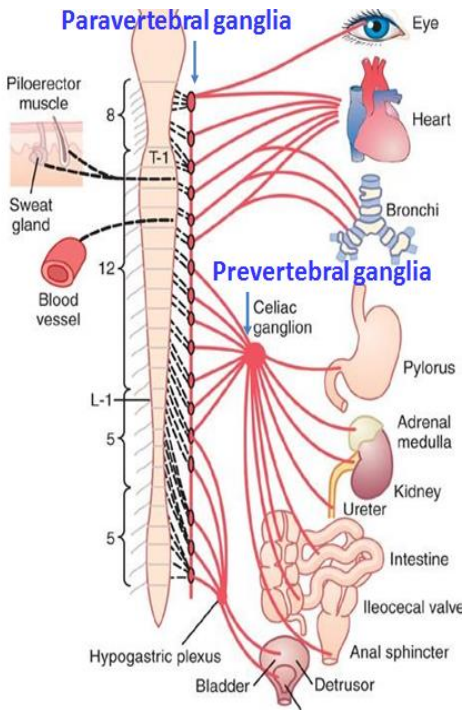


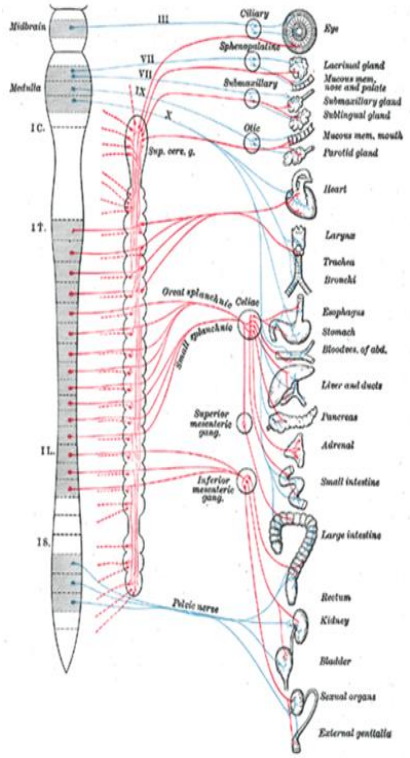
Locations of autonomic ganglia

Sympathetic and parasympathetic systems are consists of myelinated pre-ganglionic fibers which make synaptic connections with un-myelinated postganglionic fibers and then innervate the effector organ. These synapses usually occur in clusters called ganglia.

Sympathetic ganglia location:

- Paravertebral ganglia: Two (bilateral) Trunk (chain) ganglia near vertebral bodies.
- Prevertebral ganglia near large blood vessel in gut, celiac, superior mesenteric & inferior mesenteric.
- All the red lines are outside the CNS (Ganglia trunk).

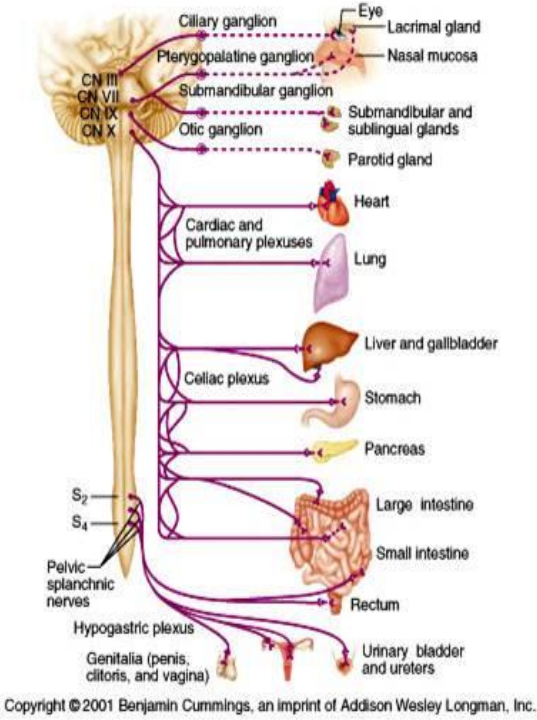




Parasympathetic ganglia location:

- Has only :

Terminal ganglia: in the wall of organ (or close to it)



Blue= Parasympathetic Red= Sympathetic

characteristics

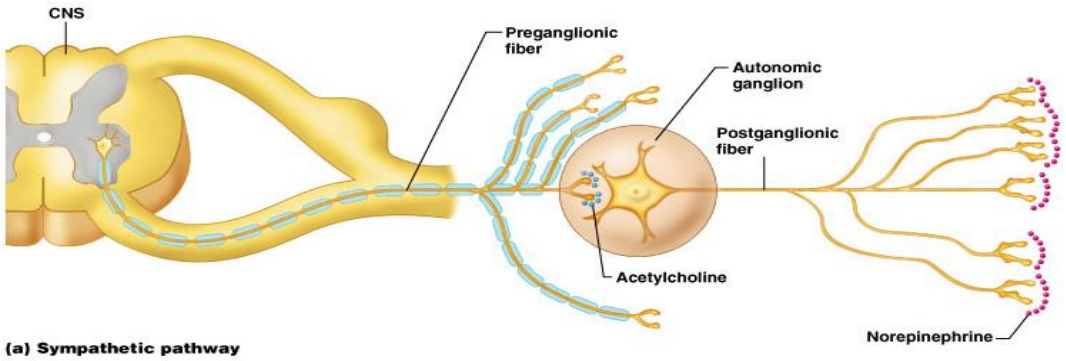
Sympathetic:

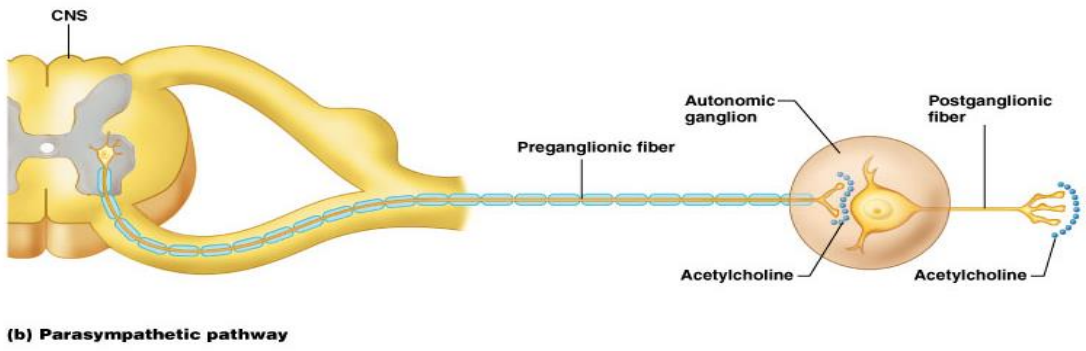
- Preganglionic: Short, lightly myelinated fibers to ST.
- Postganglionic: Long, unmyelinated fibers, terminating at effectors.
- Sympathetic axons – highly branched.
- Ganglia as we said is close to spinal cord.

Parasympathetic:

- Preganglionic: Long preganglionic fibers.
- Postganglionic: Short postganglionic fibers.
- Parasympathetic axons – few branches.
- terminal ganglia on or near effectors (target organs).

All preganglionic, (sympathetic or parasympathetic are myelinated) originate from lateral horn of spinal cord, but motor system from anterior and sensory from dorsal





Sympathetic division of the ANS

- The 2 divisions originate from different regions of the CNS.
- A. Sympathetic division originates from thoracic & lumbar levels of spinal cord. (Thoracolumbar lateral horns, T1- L2).
- Nerve fibers originate between T1 & L2.

- Sympathetic fibers from cord segment T-1 **ONLY IN MALES' SLIDES**

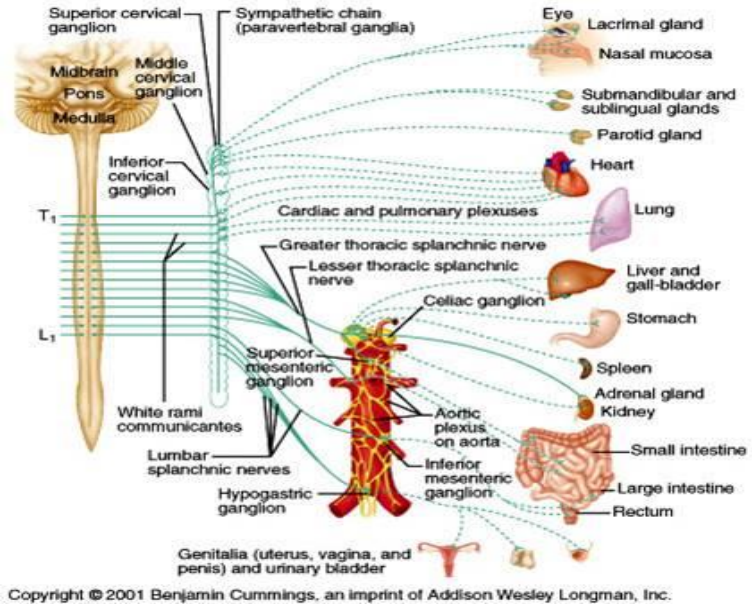
  generally pass up the sympathetic chain to terminate in the head;

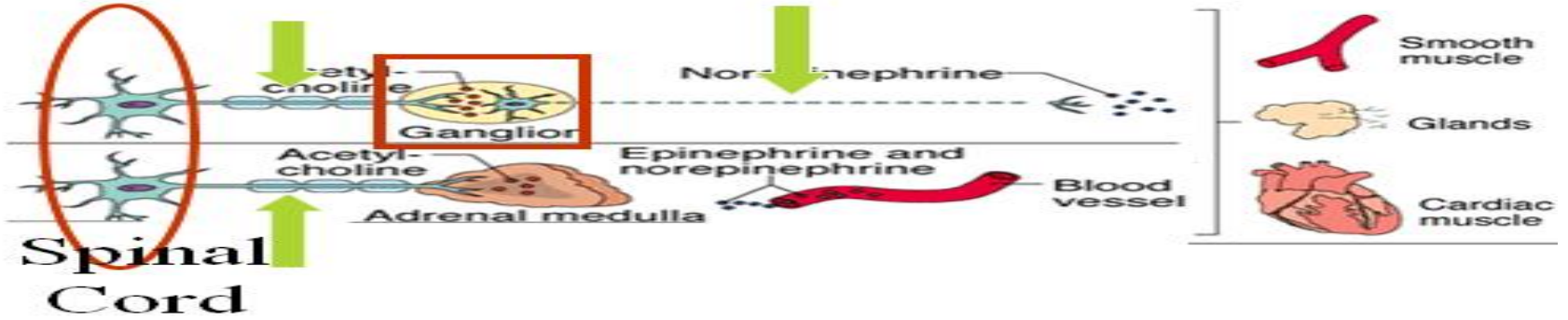
  T-2 to terminate in the neck

  T-3, T-4, T-5, and T-6 into the thorax

  T-7, T-8, T-9, T-10, and T-11 into the abdomen

  T-12, L-1, and L-2 into the legs.

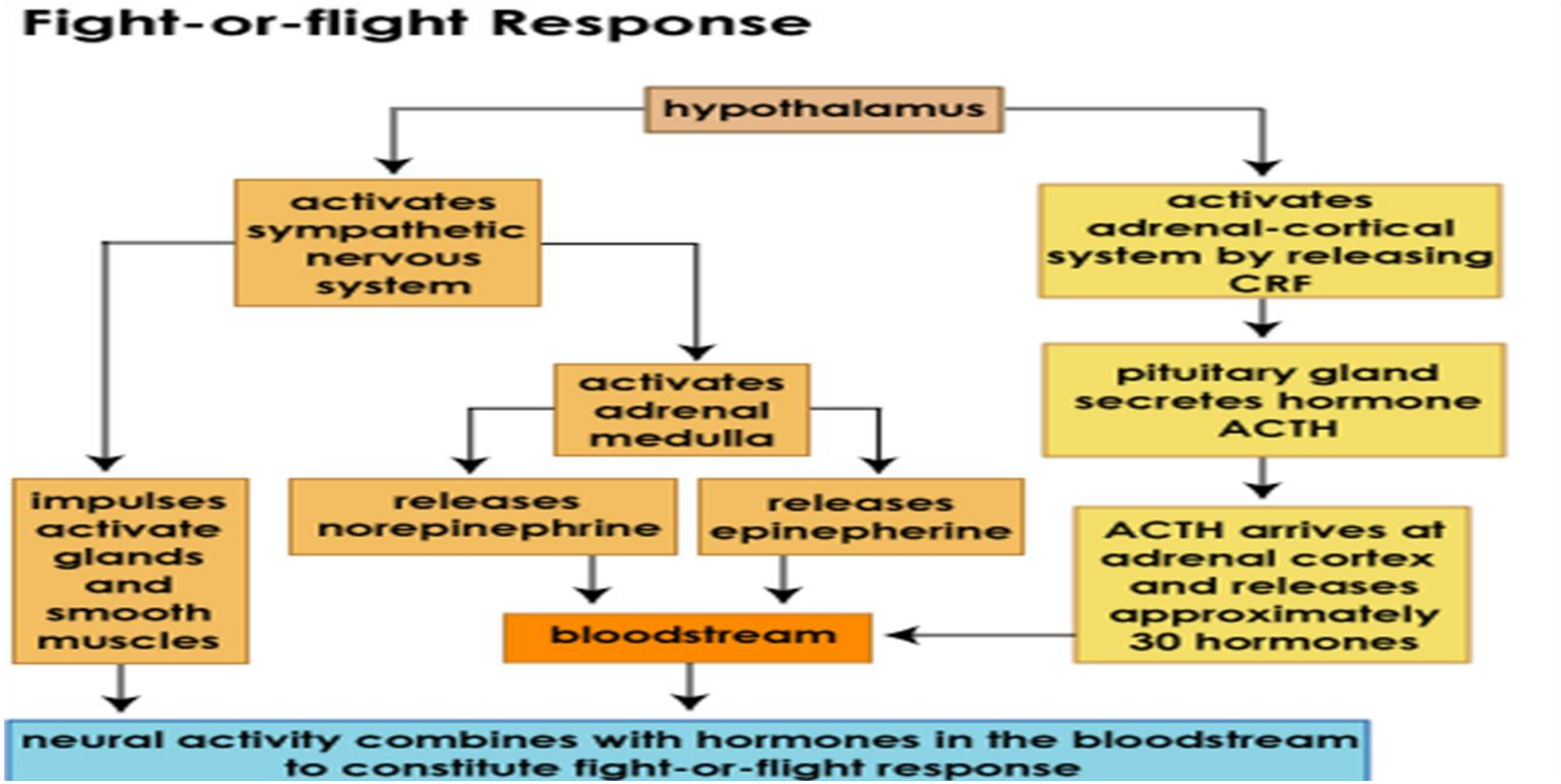




Function of Sympathetic nervous system

- The sympathetic system enables the body to be prepared for fear, flight or fight.
- Under stress condition
- Sympathetic responses include an increase in heart rate, blood pressure and cardiac output.
- Diversion of blood flow from the skin and splanchnic vessels to those supplying skeletal muscle. (No need for a lot of blood in the skin under stress so there will be vasoconstriction, so the blood will go to the brain, decrease blood supply to skin and GIT)
- Bronchioles dilate, which allows for greater alveolar oxygen exchange.
- Blood flow to skeletal muscles, lungs is not only maintained, but enhanced (by as much as 1200%), in case of skeletal muscles.
- Decrease saliva, في حالة الخوف يكون الريق ناشف
- Increased (Far vision) pupil size, contraction of sphincters (No time to go the bathroom even if you feel full) and metabolic changes such as the mobilization of fat and glycogen
- increases heart rate and the contractility of cardiac cells (myocytes), thereby providing a mechanism for the enhanced blood flow to skeletal muscles.
- Sympathetic nerves dilate the pupil and relax the lens, allowing more light to enter the eye.
- Also known as the "E" division:
- Exercise.
- Excitement.
- Emergency.
- Embarrassment

The sympathetic nervous system



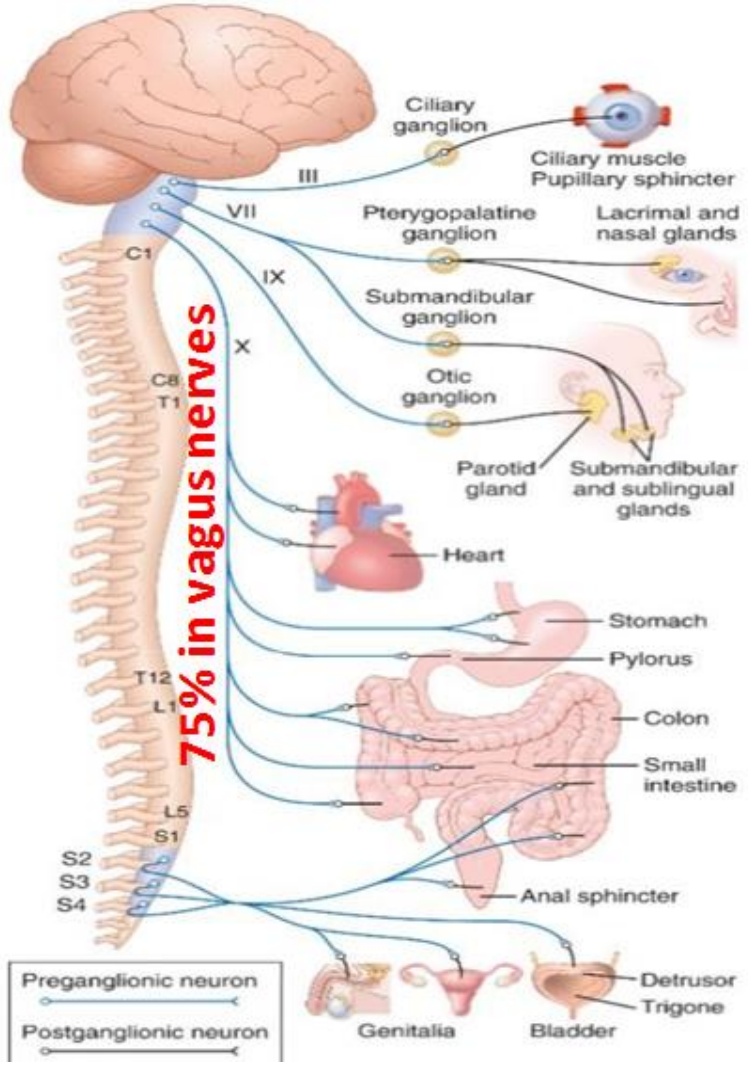
Parasympathetic ANS Dominates During Relaxed Situations

Parasympathetic division originates from:

I. motor nuclei of the cranial nerves (III, VII, IX and X) in the brain stem.

II. 2nd, 3rd, & 4th [S2-S4] sacral levels of CNS. (**craniosacral)**

The Parasympathetic division of the ANS is sometimes referred to as the "craniosacral outflow " division **because** its nerve fibers arise from the Central Nervous System directly from the brain in the cranium and from spinal chord between the sacral vertebrae.

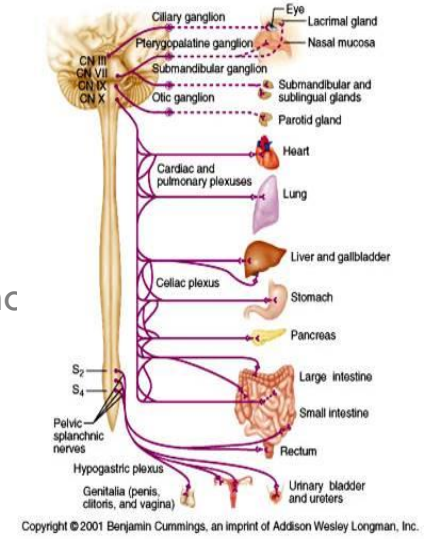


Dual innervation allows the precise control over the activity of a visceral organ.

- The cranial nerves III, VII, IX and X is classified as Parasympathetic nerves.

Parasympathetic nervous system

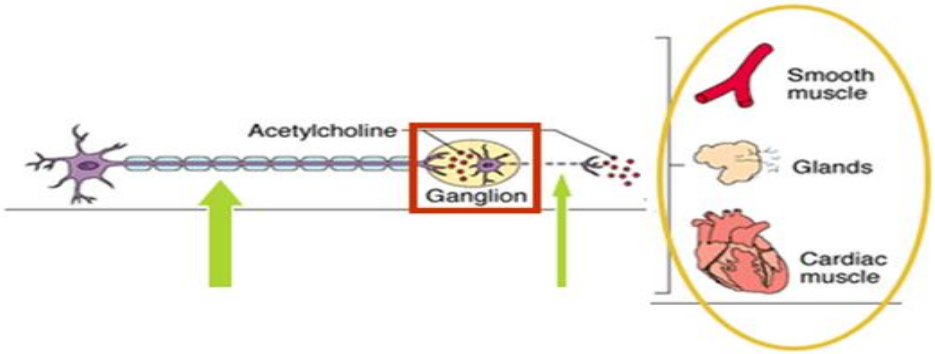
- The cranial nerves III, VII and IX affect the pupil and salivary gland secretion.
- Vagus nerve (X) carries fibres to the heart, lungs, stomach, upper intestine, ureter.
- The sacral fibres form pelvic plexuses which innervate the distal colon, rectum, bladder and reproductive organs.
- Responsible for stimulation of "Rest & Digest" or "Feed & Breed" activities
- Also known as the "D" division:
  i. Digestion.
  ii. Defecation.
  iii. Diuresis.
- Elicits responses that are usually (but nc those caused by sympathetic division.
- Conservation of body energy.



- 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.

ONLY IN MALES' SLIDES

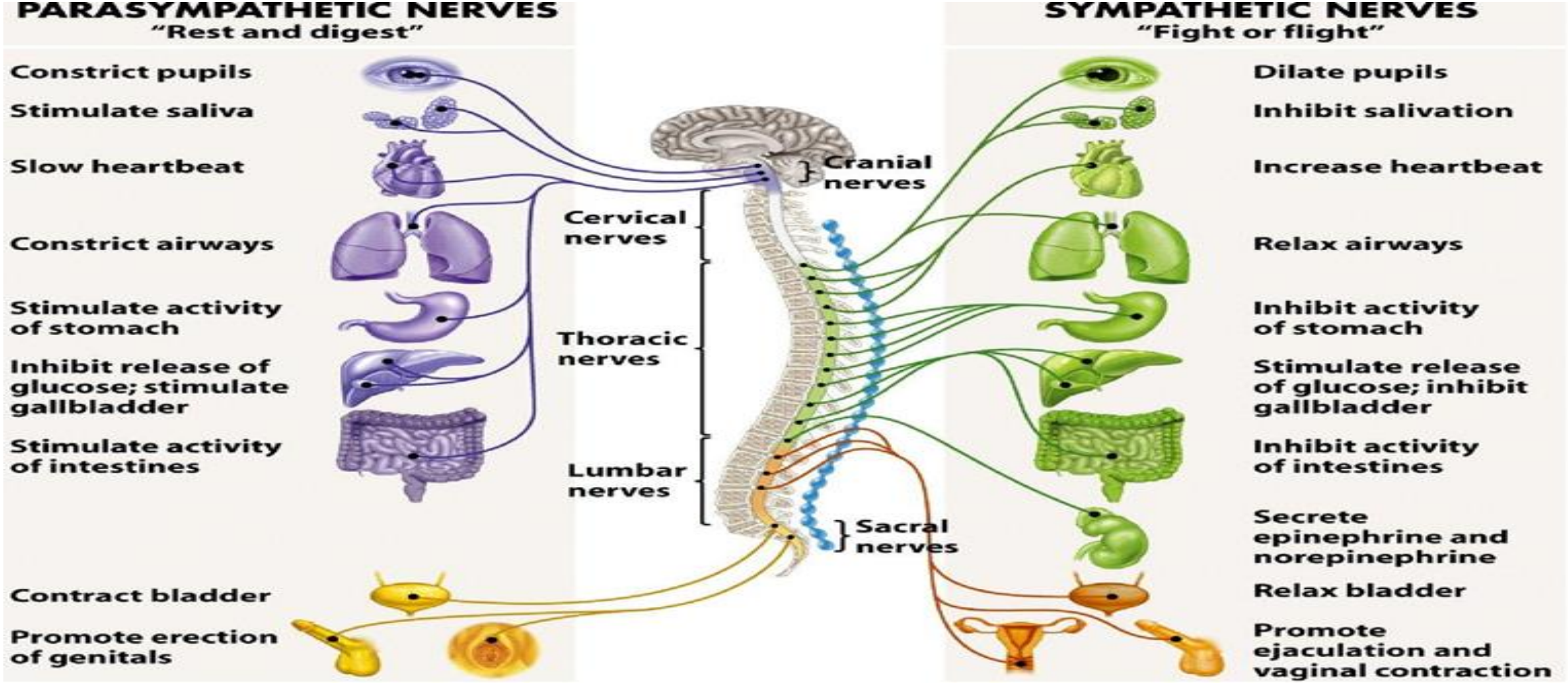
- Normally dominate over sympathetic impulses.
- SLUDD type responses: salivation, lacrimation, urination, digestion & defecation.
- 3 "Decreases" decreased HR, diameter of airways and diameter of pupil.
- Paradoxical fear when there is no escape route or no way to win causes massive activation of parasympathetic division loss of control over urination and defecation



The autonomic nervous system

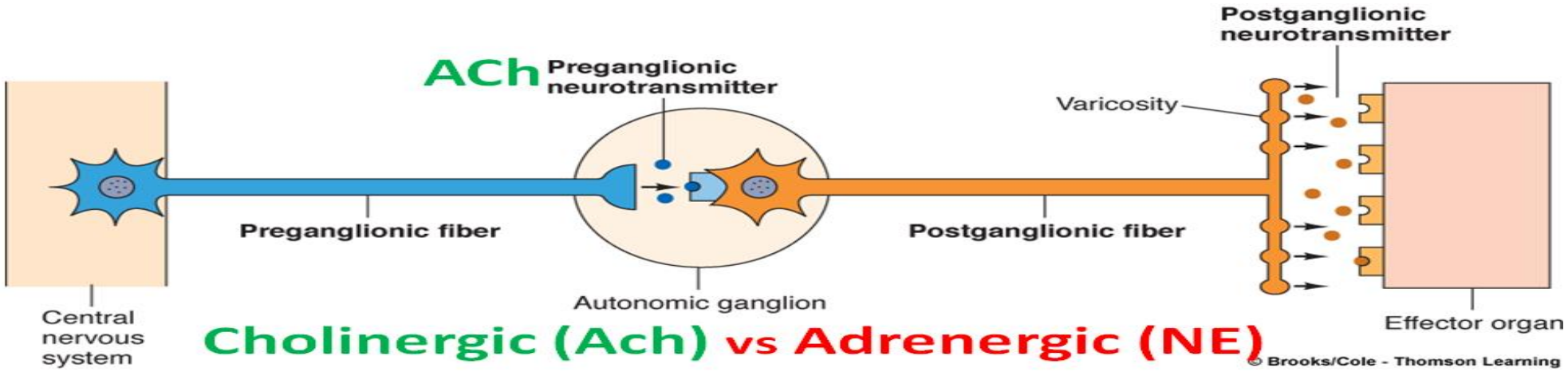
Subdivision	Nerves Employed	Location of Ganglia	Chemical Messenger	General Function
Sympathetic	Thoracolumbar	Alongside vertebral column	Norepinephrine	Fight or flight
Parasympathetic	Craniosacral	On or near an effector organ	Acetylcholine	Conservation of body energy

Summary of main functions of ANS

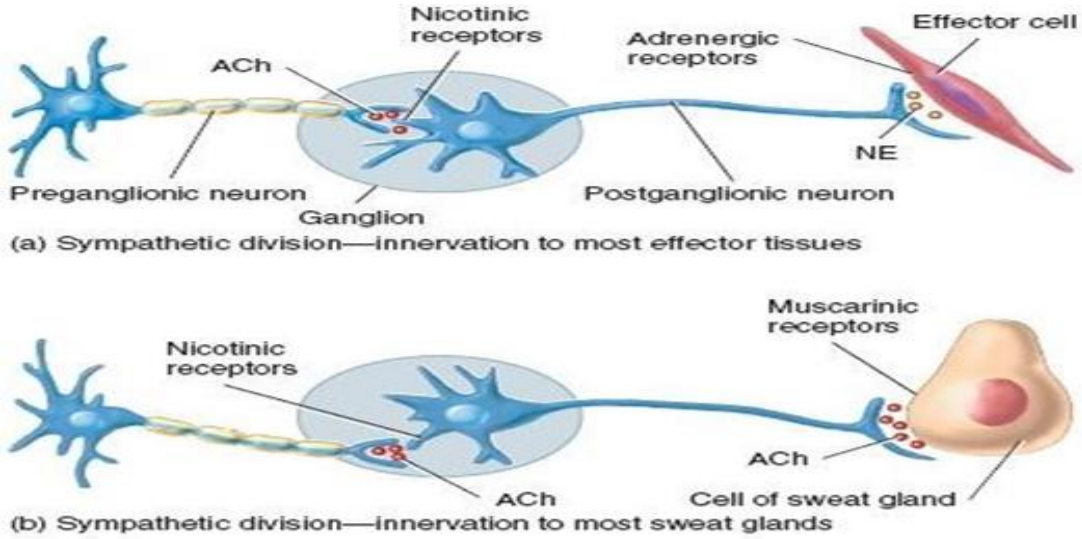
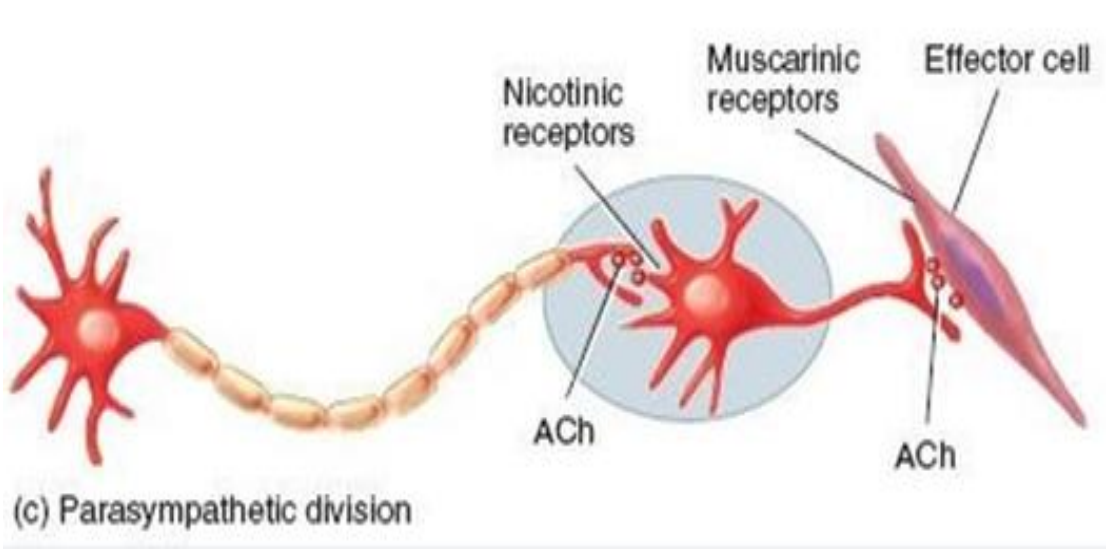


Neurotransmitters & Receptors of the ANS

- ANS Neurotransmitters: Classified as either cholinergic or adrenergic neurons based upon the neurotransmitter released.
- Adrenergic= release norepinephrine\epinephrine (NE).
- Cholinergic= release acetylcholine (ACh).
- The ACh acts on two types of receptors, the muscarinic and nicotinic cholinergic receptors.
- All cholinergic receptors on the postganglionic neurons of sympathetic and parasympathetic systems and on the adrenal gland are nicotinic.
- All cholinergic receptors on effector cells are muscarinic.

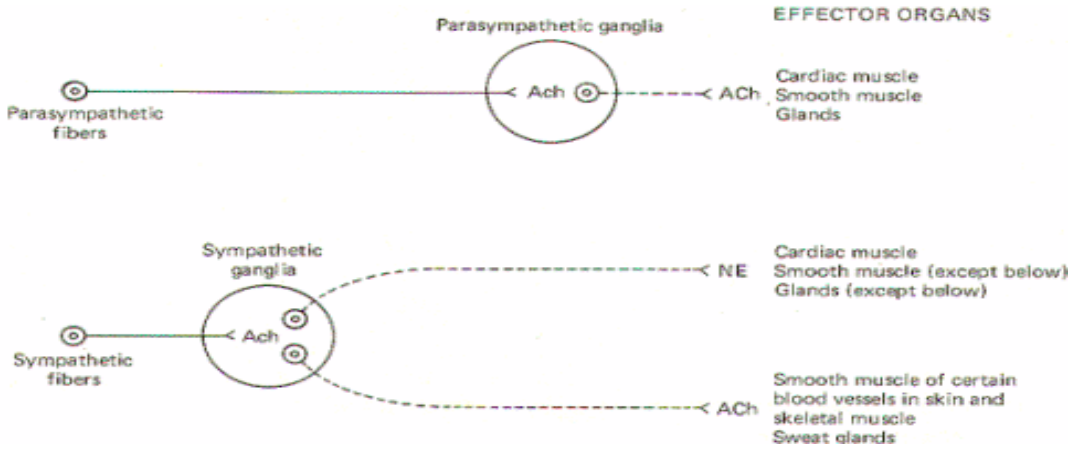


Cholinergic & Adrenergic Receptors

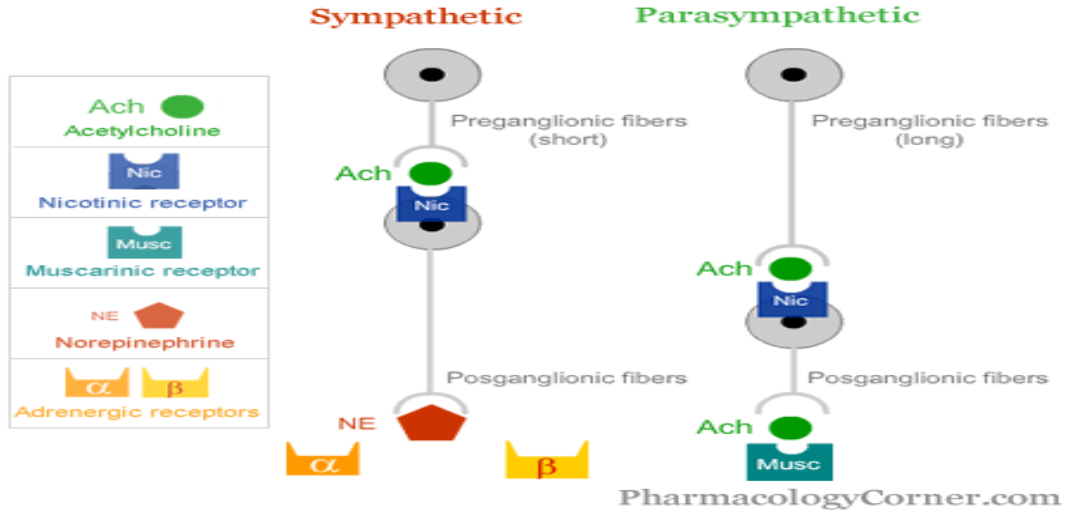
Cholinergic & adrenergic receptors	
Sympathetic	Parasympathetic
All preganglionic fibers of ANS release acetylcholine (ach) (cholinergic).	
MOST postganglionic sympathetic fibers release norepinephrine (adrenergic), except at sweat glands and some blood vessels in skeletal muscles where they release ach.	All parasympathetic postganglionic fiber release acetylcholine (ach) (cholinergic).
	

Neurotransmitters of autonomic nervous system

- Neurotransmitter released by pre-ganglionic axons:
  - Acetylcholine for both branches (cholinergic).
- Neurotransmitter released by postganglionic axons:
  - Sympathetic – most release norepinephrine (adrenergic).
  - Parasympathetic – release acetylcholine.



Feature	Sympathetic	Parasympathetic
Origin of pre-ganglionic fibers	Thoracolumbar nerves	Craniosacral nerves
Location of ganglia	Far from visceral effector organs; in sympathetic chain or collateral ganglia	Near or within viscera effector organs
Neurotransmitter	In ganglia, acetylcholine; in effector organs, norepinephrine	In ganglia, acetylcholine; in effector organs, acetylcholine



The autonomic nervous system

- Acetylcholine activates mainly two types of receptors. They are called muscarinic and nicotinic receptors.
- Muscarine activates only muscarinic receptors whereas nicotine activates only nicotinic receptors; acetylcholine activates both of them.
- Muscarinic receptors are found on all effector cells that are stimulated by the postganglionic cholinergic neurons of either the parasympathetic nervous system or the sympathetic system.
- Nicotinic receptors are found in the autonomic ganglia at the synapses between the preganglionic and postganglionic neurons of both the sympathetic and parasympathetic systems.

Receptors

Extra

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Cholinergic receptors:

- They are named after the drugs that bind to them:

I. Muscarinic (G-ptotein coupled) Receptors (bind muscarine)

II. Nicotinic (ligand-gated) Receptors (bind nicotine)

Muscarinic Receptors

M1
M2
M3
M4
M5

Muscarine (Mushroom)

Nicotinic Receptors

Nicotine (Tobacco)

Adrenergic receptors:

- The Sympathetic NS Acts on two types of receptors α and β :
- α1-receptors: their activation usually produces excitation (most target tissues).
- α2-receptors: their activation usually produce inhibition (digestive organs)
- β1-receptors:. They cause an excitatory response (mainly in heart).
- β2-receptors: their activation in general causes inhibition (blood vessels and airways).
- β3-receptors:

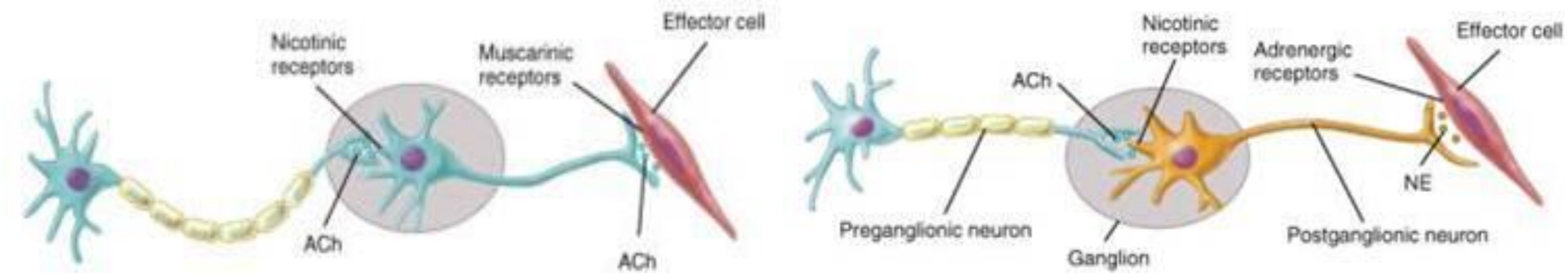
- Blocker: Aatropine blocks M receptors and is used to inhibit salivary and bronchial secretion before surgery.

Receptors

- The parasympathetic nervous system uses only acetylcholine (ACh) as its neurotransmitter.
- The ACh acts on two types of receptors, the muscarinic and nicotinic cholinergic receptors.
- 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.
- The Sympathetic NS Acts on two types of receptors : α and β.

- What do the receptors do?

I. Activation of α receptors leads to smooth muscle contraction e.g.blood vessel.
II. Activation of β_2 receptors leads to smooth muscle relaxation.
III. Activation of β_1 receptors leads to smooth muscle contraction (especially in heart).



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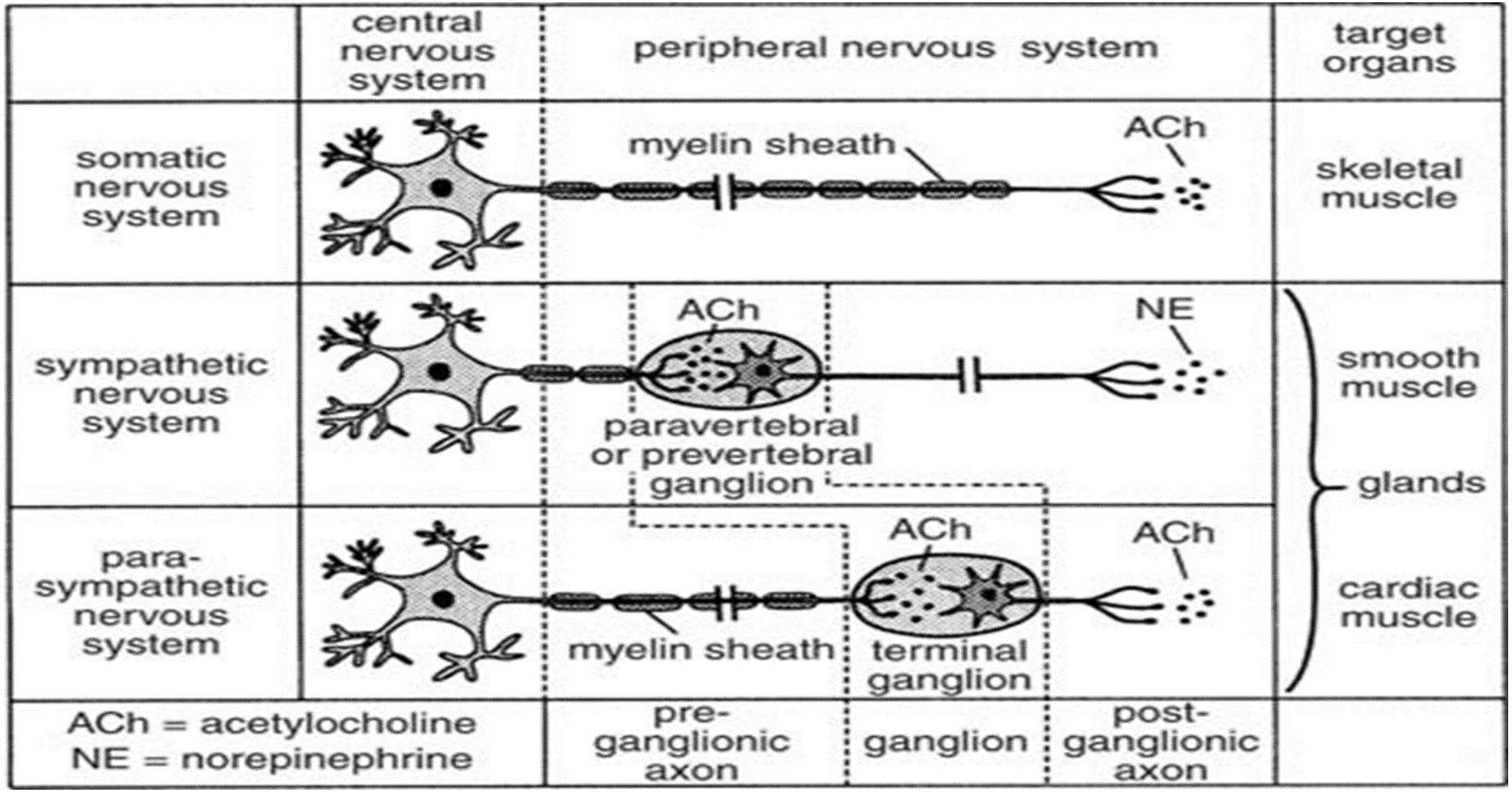

central nervous system
peripheral nervous system
target organs
somatic nervous system
myelin sheath
ACh
skeletal muscle
sympathetic nervous system
ACh
NE
paravertebral or prevertebral ganglion
smooth muscle
glands
para-sympathetic nervous system
ACh
ACh
myelin sheath
terminal ganglion
cardiac muscle
ACh = acetylocholine
NE = norepinephrine
pre-ganglionic axon
ganglion
post-ganglionic axon

ONLY IN MALES' SLIDES

Physiological functions of the autonomic nervous system

Physiological functions of the autonomic nervous system					
Structure	Sympathetic (adrenergic)	Parasympathetic (muscarinic)	Structure	Sympathetic (adrenergic)	Parasympathetic (muscarinic)
Endocrine	-	-	circulatory system	-	-
Pancreas (islets)	A2: decreases secretion	-	cardiac output	increases	M2: decreases
Adrenal medulla	N: secretes epinephrine	-	SA node: heart rate (chronotropic)	β, β2: increases	M2: decreases
Urinary system	-	-	cardiac muscle: contractility (inotropic)	β, β2: increases	M2: decreases (atria only)
Bladder wall	B2: relaxes	Contracts	conduction at AV node	β1: increases	M2: decreases
Ureter	A1: contracts	Relaxes	vascular smooth muscle	M3: contracts A= contracts β2 = relaxes	-
Sphincter	A1: contracts; β2 relaxes	Relaxes	platelets	α2: aggregates	-
Sweat gland secretions	M: stimulates (major contribution) α1: stimulates (minor contribution)	-	mast cells - histamine	β2: inhibits	-
Arrector pili	A1: stimulates	-	circulatory system	-	-

ONLY IN MALES' SLIDES

Physiological functions of the autonomic nervous system

Physiological functions of the autonomic nervous system					
Structure	Sympathetic (adrenergic)	Parasympathetic (muscarinic)	Structure	Sympathetic (adrenergic)	Parasympathetic (muscarinic)
respiratory system	-	-	lacrimal glands (tears)	decreases	M3: increases
smooth muscles of bronchioles	β2: relaxes (major contribution) α1: contracts (minor contribution)	M3: contracts	kidney (renin)	secretes	-
nervous system	-	-	parietal cells	-	M1: secretion
pupil of eye	α1: relaxes	M3: contracts	liver	α1, β2: glycogenolysis, gluconeogenesis	-
ciliary muscle	β2: relaxes	M3: contracts	GI tract motility	decreases	M1, M3: increases
digestive system	-	-	smooth muscles of GI tract	α, β2: relaxes	M3: contracts
salivary glands: secretions	β: stimulates viscous, amylase secretions α1= stimulates potassium cation	stimulates watery secretions	sphincters of GI tract	α1: contracts	M3: relaxes

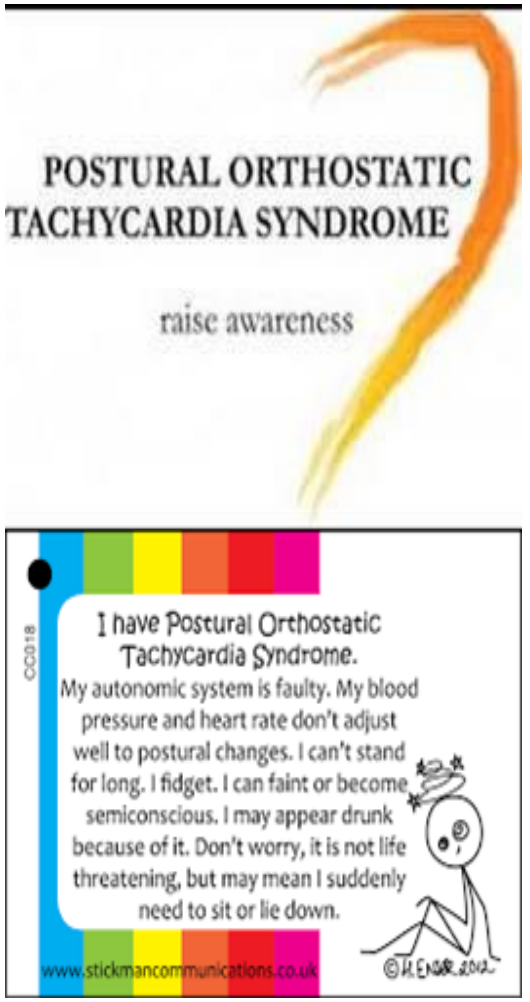
The stress reaction

- 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 traffc 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	Drug/Use Abuse	Ulcers
Irritability	Alcohol Use/Abuse	High Blood Pressure
Depression	Smoking	Insomnia
Frustration	Strained Relationships	Indigestion
Emotional Irritability	Eating Problems	Headaches
Insecurity	Suicide Attempts	Other Cardiovascular
Mental Illness	Violence	Body Infections
Anxiety	Impulsive/ Irrational Behavior	Irregular Pulse rate



Summary

The autonomic nervous system				
Subdivision	Nerves Employed	Location of Ganglia	Chemical Messenger	General Function
Sympathetic	Thoracolumbar	Alongside vertebral column	Norepinephrine	Fight or flight
Parasympathetic	Craniosacral	On or near an effector organ	Acetylcholine	Conservation of body energy

Physiological functions of the autonomic nervous system

Structure	Sympathetic	Parasympathetic
Iris (eye muscle)	Pupil dilation	Pupil constriction
Salivary glands	Saliva prod. reduces	Saliva prod. induced
Oral/Nasal mucosa	Mucus prod. reduced	Mucus prod. induced
Heart	Heart rate and force increased	Heart rate and force decreased.

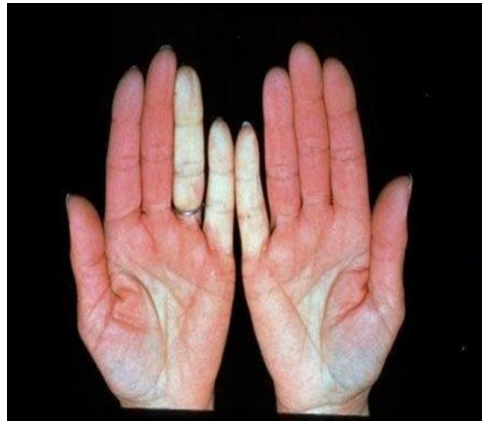
Structure	Sympathetic	Parasympathetic
Lung	Bronchial muscle relaxed (Because we need more oxygen)	Bronchial muscle contracted
Stomach	Peristalsis reduced	Gastric juice secreted; motility increased
Small intestine	Motility reduced	Digestion increased
Large intestine	Motility reduced	Secretions and motility increased

Structure	Sympathetic	Parasympathetic
Liver	Increased conversion of glycogen to glucose (Because we need more energy)	
Kidney	Decreased urine secretion	Increased urine secretion
Adrenal medulla	Norepinephrine and epinephrine secreted	
Bladder	Wall relaxed Sphincter closed	Wall contracted Sphincter relaxed

- Blood sample of stimulated adrenal medulla will have more noradrenaline and adrenaline

Disorders of the ANS

Raynaud's disease:



- Characterized by constriction of blood vessels
- It is an exaggeration of vasomotor responses to cold or emotional stress
- During an attack, the fingers and toes can change colors from white to blue to red.

Hypertension – high blood pressure

- Can result from overactive sympathetic vasoconstriction.

Thank you!

اعمل لترسم بسمة، اعمل لتمسح دمعة، اعمل و أنت تعلم أن الله لا يضيع أجر من أحسن عملا.

The Physiology 436 Team:

Females Members:
Aseel Alsulimani
Lina alwakeel
Hayfaa Alshaalan

Males Members:
Hassan Alshammari

Team Leaders:

Lulwah Alshiha
Laila Mathkour
Mohammad Alayed

Contact us:




QUIZ

اقتراحات وشكاوي

References:

- Females and Males slides.
- Guyton and Hall Textbook of Medical Physiology (Thirteenth Edition.)