AUTONOMIC NERVOUS SYSTEM (1+2)

Red: very important.
Green: only found in males' slides.
Purple: only found in females' slides.
Gray: notes.

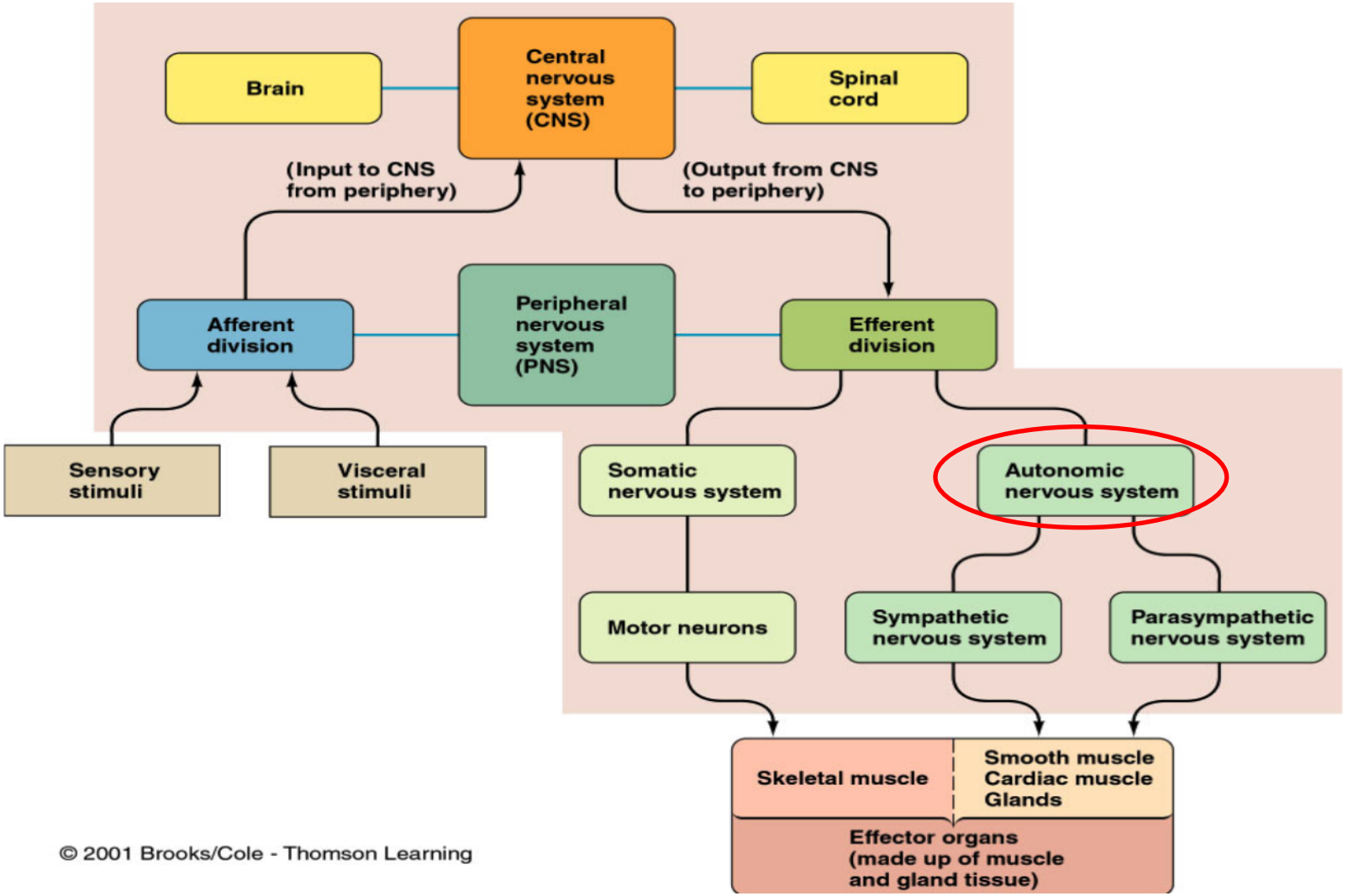
Physiology Team 436 – Foundation block – Lectures 6+7

Lecture: If work is intended for initial studying.
Review: If work is intended for revision.

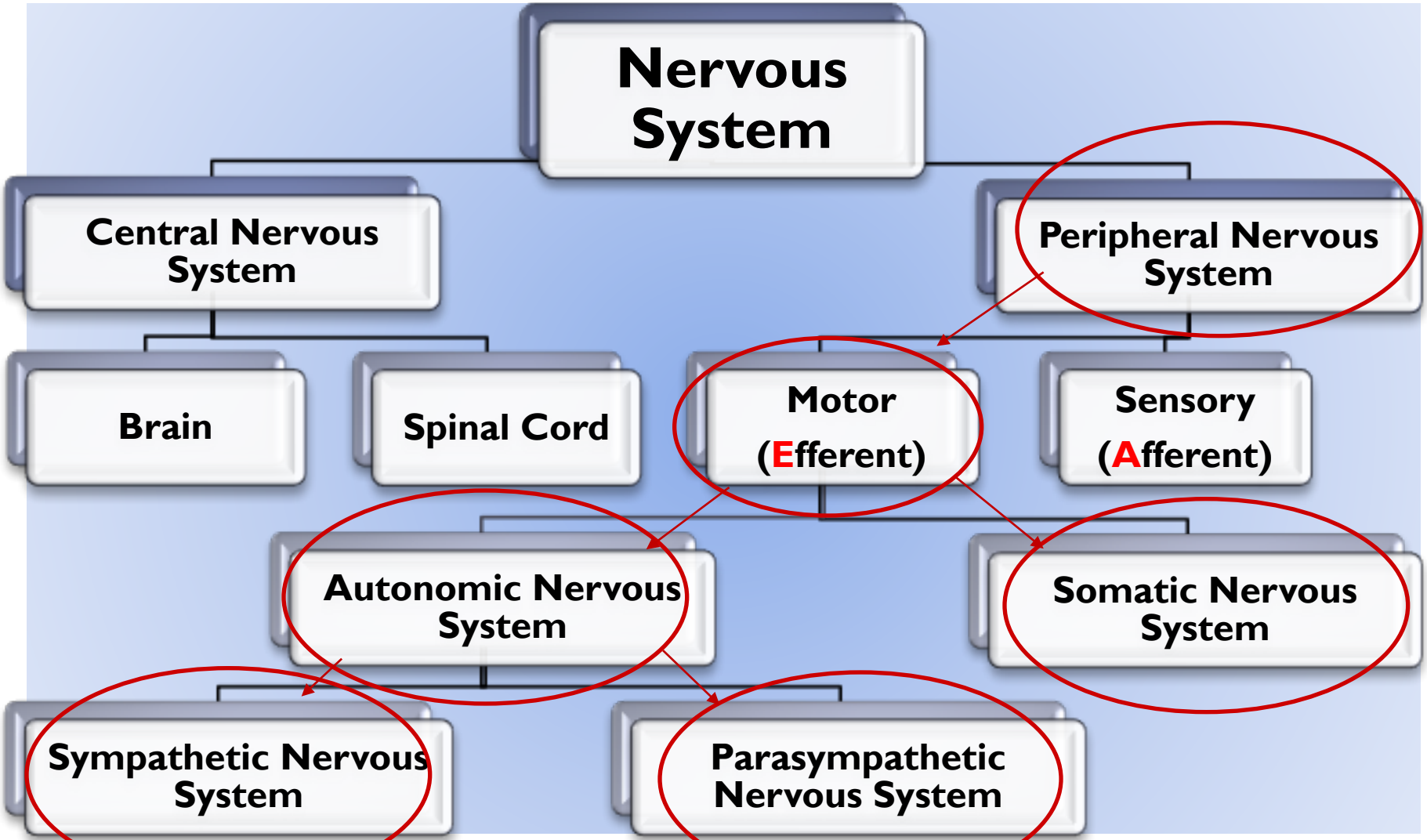
Objectives

- Organization of the Autonomic Nervous System.
- Terminology.
- Sympathetic Nervous System (SNS).
- Neurotransmitters and Types of Receptors.
- Parasympathetic Nervous System.
- Autonomic Receptors.
- a. Adrenoreceptors.
- b. Cholinorecptors.
- Prototypes of Agonists and Antagonists to Autonomic Receptors.
- Sympathetic and Parasympathetic Tone.
- Function of Adrenal Gland.
- Examples of The Effects of Sympathetic and Parasympathetic.

Overview


Brain
Central nervous system (CNS)
Spinal cord
(Input to CNS from periphery)
(Output from CNS to periphery)
Afferent division
Peripheral nervous system (PNS)
Efferent division
Sensory stimuli
Visceral stimuli
Somatic nervous system
Autonomic nervous system
Motor neurons
Sympathetic nervous system
Parasympathetic nervous system
Skeletal muscle
Smooth muscle
Cardiac muscle
Glands
Effector organs (made up of muscle and gland tissue)
© 2001 Brooks/Cole - Thomson Learning

Efferent : **E**xit = output.
To help you memorize: (You need to **M**ove to **E**xit → **M**otor.)
Afferent : input.
To help you memorize: (**A**ffection (sensed feeling) → **A**fferent →**S**ensory.)



Definitions

- **Afferent Nerve:** sensory nerve that carries nerve impulses from receptors or sense organs toward the central nervous system.
- **Efferent Nerve:** a nerve that conveys impulses toward or to muscles or glands.
- (للربط : E: Exit Central Nervous System)
- **Neurotransmitters:** A chemical substance, such as acetylcholine or dopamine, that transmits nerve impulses across a synapse.
- **Synapse:** The junction across which a nerve impulse passes. (The process by which information/orders are transmitted)

From: an axon terminal

To :a neuron, muscle cell, or gland cell.

- **Ganglia** : an encapsulated collection of nerve-cell bodies outside the CNS .
- **Neuron:**

a specialized cell transmitting nerve impulses.

- **Sensory axon:**

sensory nerve cell process, conducting impulses from the periphery toward the nerve cell body.

- **Motor axon :**

single nerve cell process, conducting impulses from the nerve cell body toward a muse.

Note : Differentiate between

Afferent: إلى الجهاز العصبي المركزي من الأعضاء

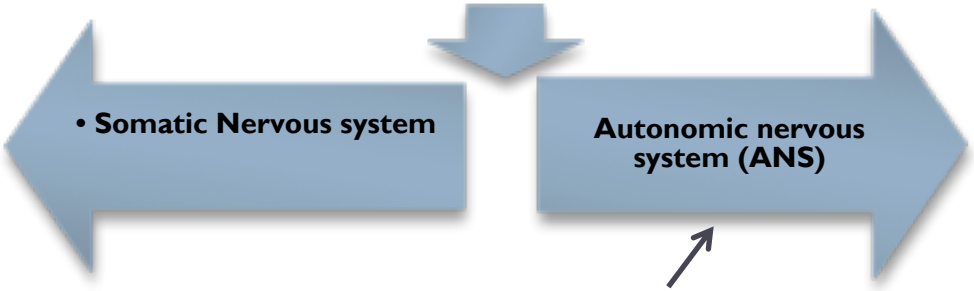
Efferent: من الجهاز العصبي المركزي إلى الأعضاء

Introduction

- The Central Nervous System (CNS) include of :
The brain and spinal cord.

-The Peripheral Nervous System (PNS) Formed by:
neurons & their processes present in all the regions of the body.

- The Peripheral Nervous System (PNS):



-ANS is subdivision of the peripheral nervous system.

-PNS is consists of:
1- **cranial nerves** arising from the brain
2- spinal nerves arising from the spinal cord.
(الأعصاب مع إنهم يجون من المخ والسباينل كورد بس جزء من الطرفي)

Central Vs. Peripheral
Is a structural division of the nervous system
*Somatic vs. autonomic is a functional division of the nervous system.

Q) How does the Nervous System **monitor and control** almost every organ / system?
A) through: a series **of positive and negative feedback loops.**

Difference between Motor (Efferent) Pathways of Somatic vs. Autonomic

Somatic NS

- Voluntary: Controls skeletal muscles.
- NO ganglia
- **ONE** motor-neuron (one axon) Sheathed in spinal nerves, extend all the way to their skeletal muscles. (نوع واحد من الخلايا العصبية يصل مباشرة إلى العضلات الهيكلية)
- **Cell bodies of motor reside in CNS** (brain & spinal cord)

Autonomic NS

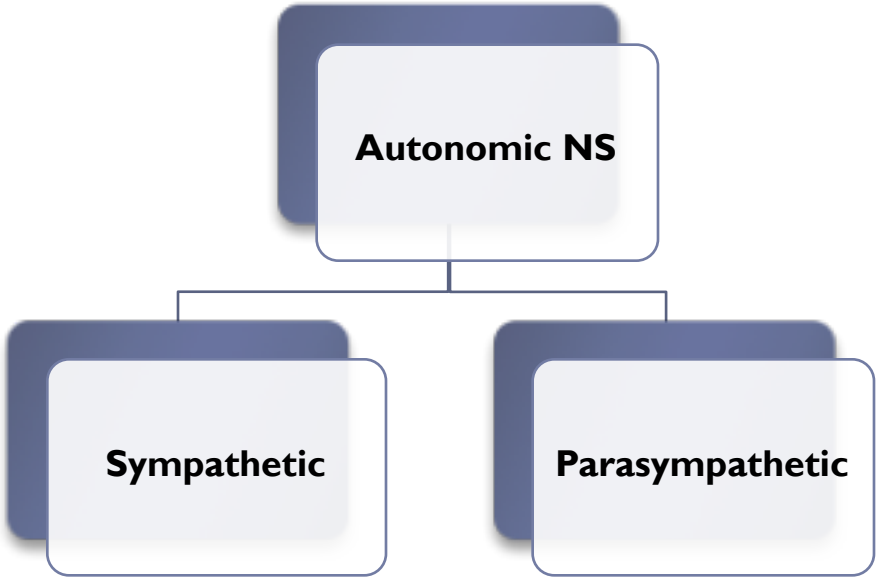
Composed of a special group of neurons serving:

- Cardiac muscle (the heart)
- Smooth muscle (walls of viscera and blood vessels)
- Internal organs
- Skin

- **Control** : Involuntary visceral organs (organs generally not under conscious control)
- Has ganglia (Ganglia: a cluster of interconnecting nerve cells in the ANS)
- **Chains of Two moto-neurons:**
  - **1-** Pre-ganglionic (from CNS to the ganglion)
  - **2-** Post-ganglionic (cell body in ganglion outside CNS)
- **Slower** because its nerve fibers are either lightly-myelinated or unmyelinated.(

(Myelination: a mixture of proteins and phospholipids forming a whitish sheath around nerve fibers)

Sympathetic ANS vs. Parasympathetic



- Sympathetic and parasympathetic : anatomic terms.
- Their anatomic **origin** is : **preganglionic** neurons in the central nervous system (CNS)

Parasympathetic = **P**eace.
Sympathetic = **S**tress.

Sympathetic & Parasympathetic both have Preganglionic fibers and Postganglionic fibers

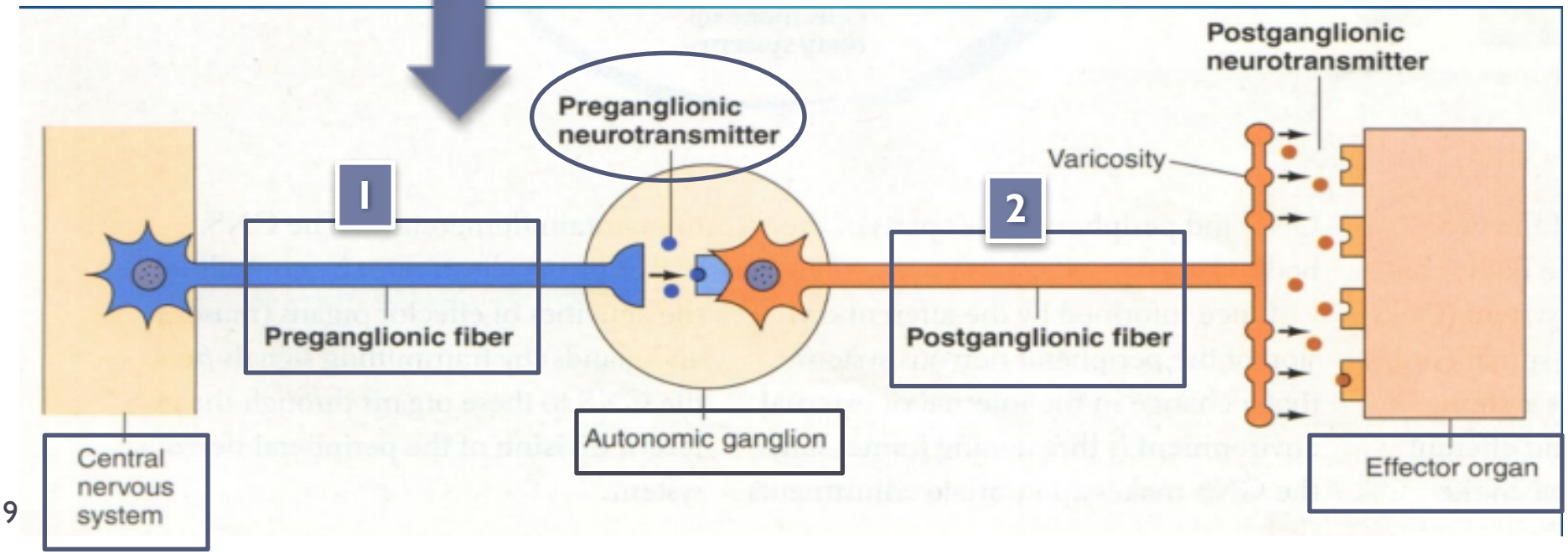
1- (PREganglionic) : Axon of 1st neuron leaves CNS synapse with the 2nd neuron (POSTganglionic) , myelinated nerve fiber

2- (POSTganglionic) : Axon of 2nd neuron extends to the organ it serves , unmyelinated nerve fibers

ANS

- **activated** by:
  - Center in spinal cord
  - Brain stem
  - Hypothalamus
- **operated** by: **visceral reflex**

reflexes that occur in the soft tissue organs of the body. Example coughing, sneezing, swallowing and vomiting.



1- Sympathetic Nervous System (SNS)

- • **Operates continuously** to modulate (adjust) the functions of many organ systems
- e.g; heart, blood vessels, gastrointestinal tract, bronchi and sweat glands

- • **Activated by**: Stressful stimulation Which leads to a response called:
  - "fight or flight" /"E" division
  - **(Exercise, Excitement, Emergency, and Embarrassment)**
  - increased arterial pressure, blood flow, blood glucose, metabolic rate and mental activity

1- SNS location : Originate from **thoracolumbar lateral horns** of the spinal cord segments (T1-L2~L3)

من T1-L2 لكن بعض المراجع مكتوب الى L3

T1 = Thoracic
L2~L3 = Lumber

2- (SNS nerve fiber):

Preganglionic neurons: **short , lightly myelinated**

Postganglionic neurons: **long , unmyelinated**

3- SNS ganglia:

According to location:

1. paravertebral ganglia (sympathetic chain)
2. prevertebral ganglia

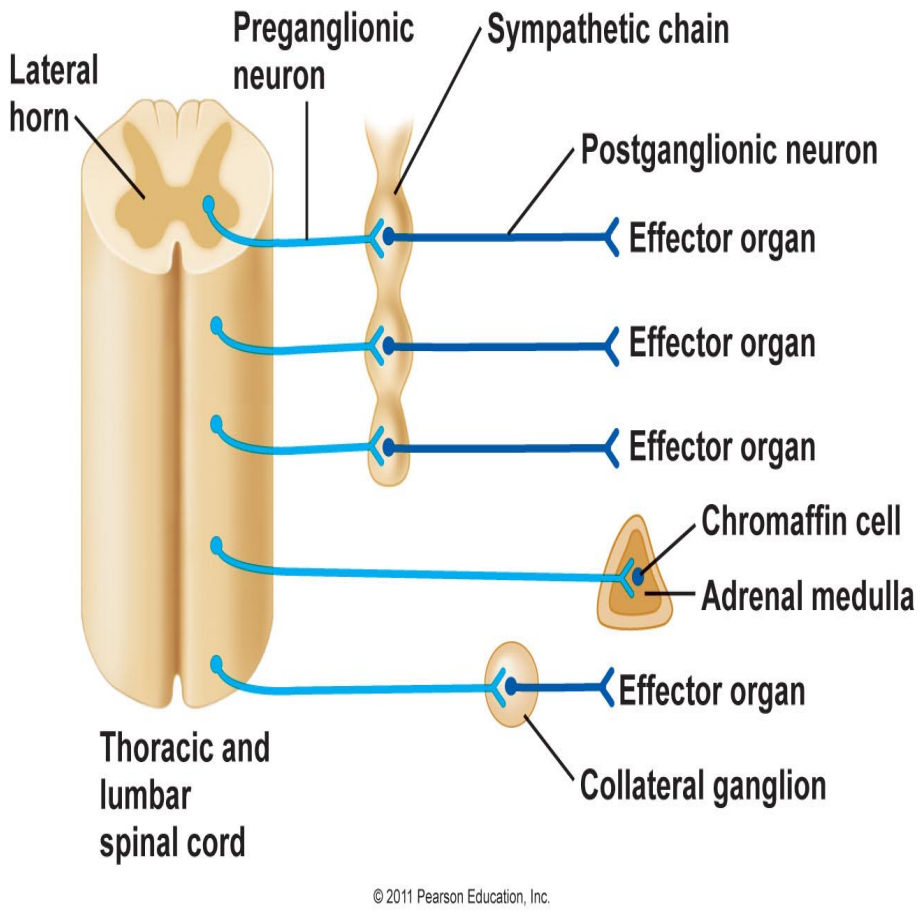
Paravertebral Ganglia: (sympathetic chain): near vertebral body

على امتداد العمود الفقري. (جنب العمود الفقري من الجهتين)

Prevertebral Ganglia: Ganglia between Paravertebral Ganglia and the target organ

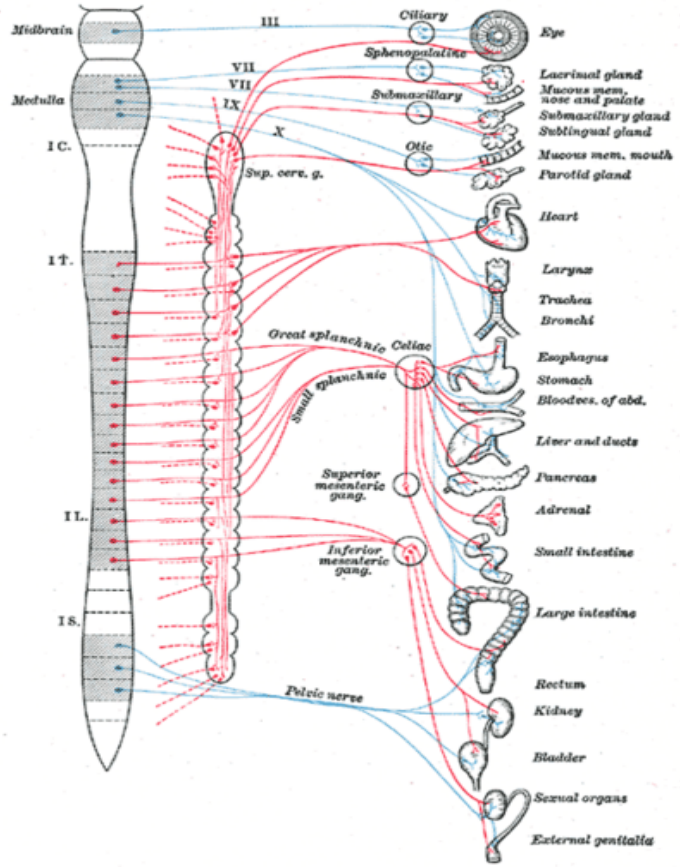
near large blood vessel in gut :celiac ,superior mesenteric & inferior mesenteric

Thoracic and Lumbar Spinal Cord



لتوضيح الشريحة السابقة

Locations of Autonomic Ganglia



The picture is for clarification of location and origin only.
(Red: Symp – Blue: Parasymp)

2- Parasympathetic Nervous System

- Responsible for activities that occur when the body is at rest "rest and digest"/ "D" division

  (Digestion, Defecation, and Diuresis)

2-(SNS nerve fiber):

1- preganglionic neurons

has long axon

2- Postganglionic neurons

short axon

(Length of Pre and Post is Parasympathetic is the opposite of the sympathetic NS)

3- Ganglia :

- in or on the affected organ:
  - Terminal ganglia
  - in the wall of organ

1- Location : Their fibers originate from

brain & sacrum (Craniosacral)

1. **cranial nuclei** Cell bodies of the motor nuclei of the cranial nerves III, VII, IX and X (3^{rd},7^{th}.9^{th}.10^{th}) in brain stem (mid brain, pons, medulla)
2. **sacral segments of the spinal cord** (S2 -S4)

Gives: (cranio-sacral outflow)

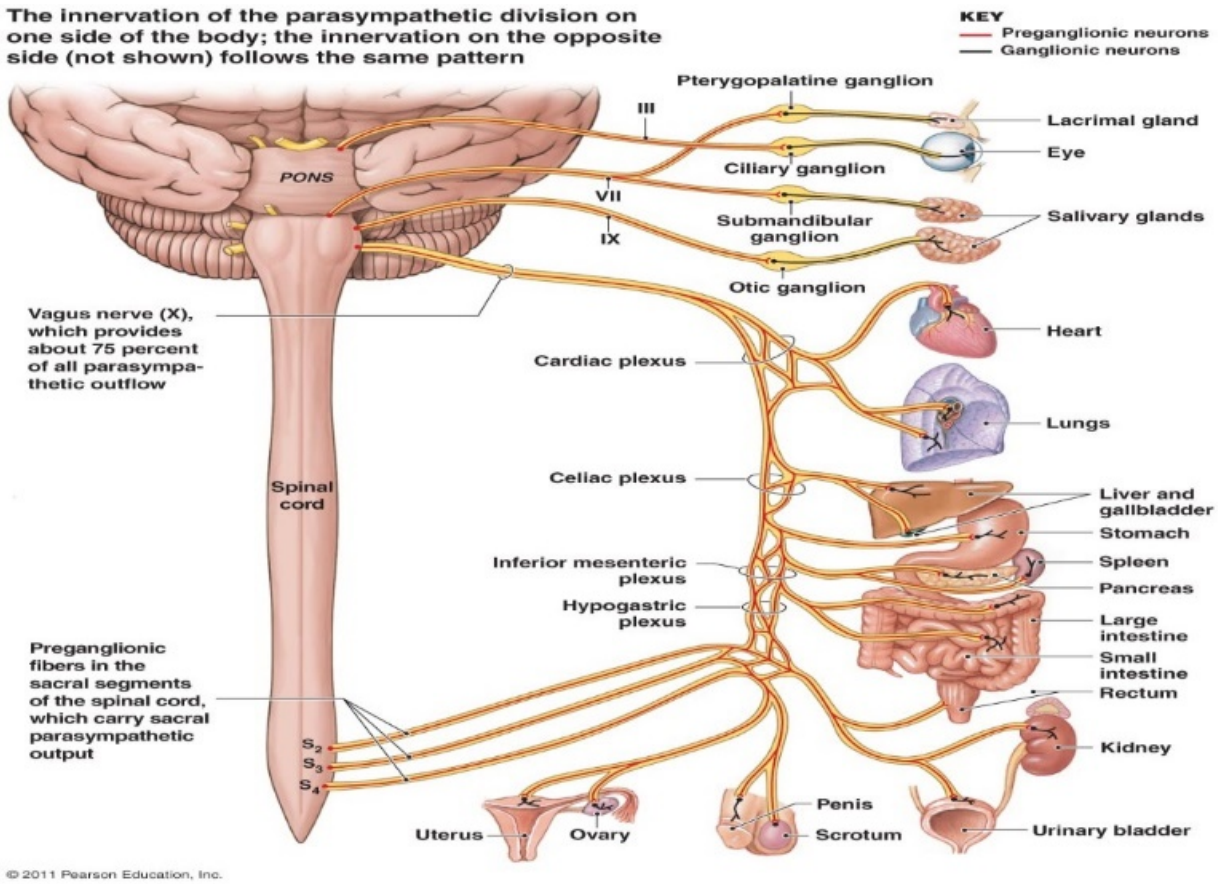
(compare origin to Sympathetic)

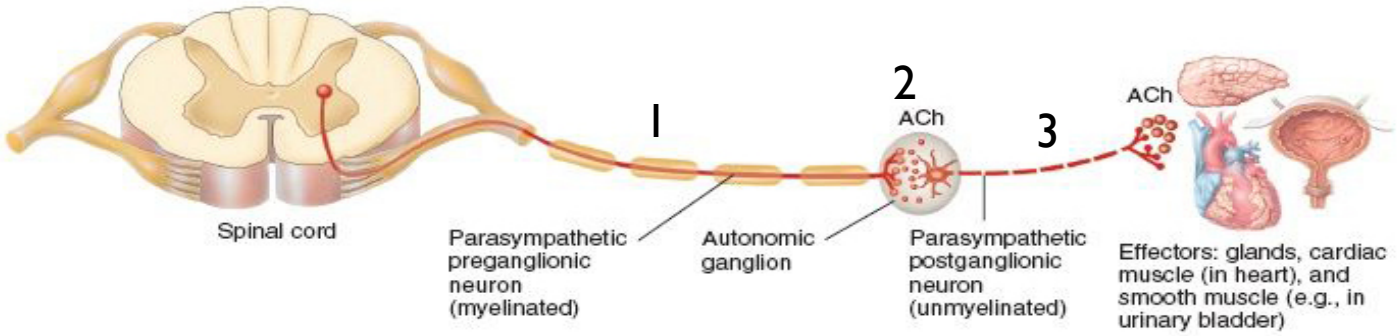
	neurons	axon
Inside CNS	Nucleus	track
Outside CNS	Ganglion	Nerves

Parasympathetic NS Cont.

- **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 and ureter
- **The sacral fibres form pelvic plexuses which innervate the** distal colon, rectum, bladder and reproductive organs.

Parasympathetic origin





1- pre
2- ganglion
3- Post

The Autonomic Nervous System Functions I

Structure	Sympathetic Stimulation	Parasympathetic Stimulation
Iris (eye muscle)	contracts the meridional fibers of the iris to dilate the pupil Lens relax and allow more light to enter the eye (بالظلام) **Meridional Fibers :** longitudinal fibers of Ciliary muscle **Ciliary muscles :** ring of smooth muscles in eye's middle layer	contracts the circular muscle (ciliary muscle) of the iris to constrict the pupil بالنور القوي (الساطع). **Iris :** القزحية **Dilate :** يتوسع **contract** = constrict: يضيق
Salivary Glands	vasoconstriction of the blood vessels to the glands which causes reduction in their secretion.	• It is Controlled by parasympathetic • Increase their secretion
Oral/Nasal Mucosa	Mucus production reduced	Mucus production increased
Heart	Heart rate and force increased	Heart rate and force decreased
Lung	Bronchial muscle relaxed	Bronchial muscle contracted
Systemic Blood Vessels: & Arterial pressure :	Constricted (Increase the cardiac output and resistance to the blood flow and increase blood pressure)	No effect except in certain areas, such as blushing of the face. (by Decrease cardiac output)

The Autonomic Nervous System Functions 2

Structure	Sympathetic Stimulation	Parasympathetic Stimulation
Stomach	Peristalsis reduced	Gastric juice secreted; motility increased
Small Intes	Motility reduced	Digestion increased
Large Intes	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 عضلة دائرية مسؤولة عن حماية أو فتح أو إغلاق أنبوب (مثل الشرج)	Wall contracted (increases peristaltic contraction)(حركة الأمعاء) Sphincter relaxed
Sweat glands secretion:	increased by sympathetic stimulation.	No affect

decreases the activity of GI.

increases the activity of GI .

(Enteric nervous system: (it is the division of the nervous system that controls the function of the gastrointestinal system)

Autonomic Nervous System (ANS): Neurotransmitters & Receptors

#Adrenergic Neuron Vs. #Cholinergic Neuron

- **Neurotransmitter:** norepinephrine
- **Adreno-receptors:**
  - alpha 1
  - alpha 2
  - Beta 1
  - Beta 2

-Neurotransmitter:
Ach

-Cholinergic-Receptors:
1. Nicotinic
2. Muscarinic

Note: they're named after drugs they're sensitive to

*** Remmber: ANS motor pathway consists of two neurons:**

- **Pre**ganglionic neuron : inside CNS (in brain or spinal cord)
- **Post**ganglionic neuron : outside CNS (cell body in ganglion outside CNS)

Cholinergic: Relating to nerve cells or fibers that use acetylcholine as their neurotransmitter

Sympathetic vs. Parasympathetic Receptors

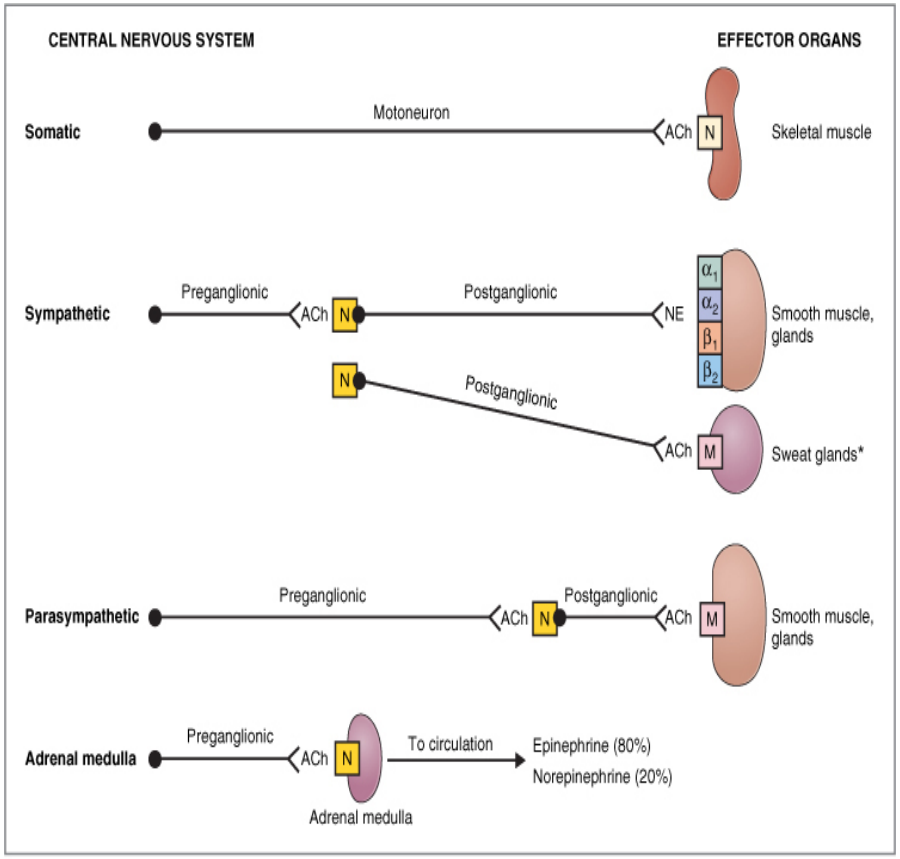
In Sympathetic Nervous System

- **Pre** receptor: Nicotinic
- **Post** receptor: Adrenoreceptor **except in** sweat glands where it is **Muscarinic**

In Parasympathetic Nervous System:

- **Pre receptor:** Nicotinic
- **Post receptor:** Muscarinic

Because the ONLY neurotransmitter in parasympathetic: acetylcholine (Ach)



- Sympathetic postganglionic neurons are "adrenergic" except in thermoregulatory sweat glands where they're cholinergic and the receptor is Muscarinic

Autonomic Nervous System (ANS): Neurotransmitters & Receptors

All preganglionic neurons: release Acetylcholine (Ach)

Therefore they're ***ALWAYS*** **Cholinergic neurons**

PRE: Releases Ach which interacts with nicotinic receptors on the (cell body) of POST neurons

***During stressful conditions there is secretion of ?** Epinephrine & norepinephrine .

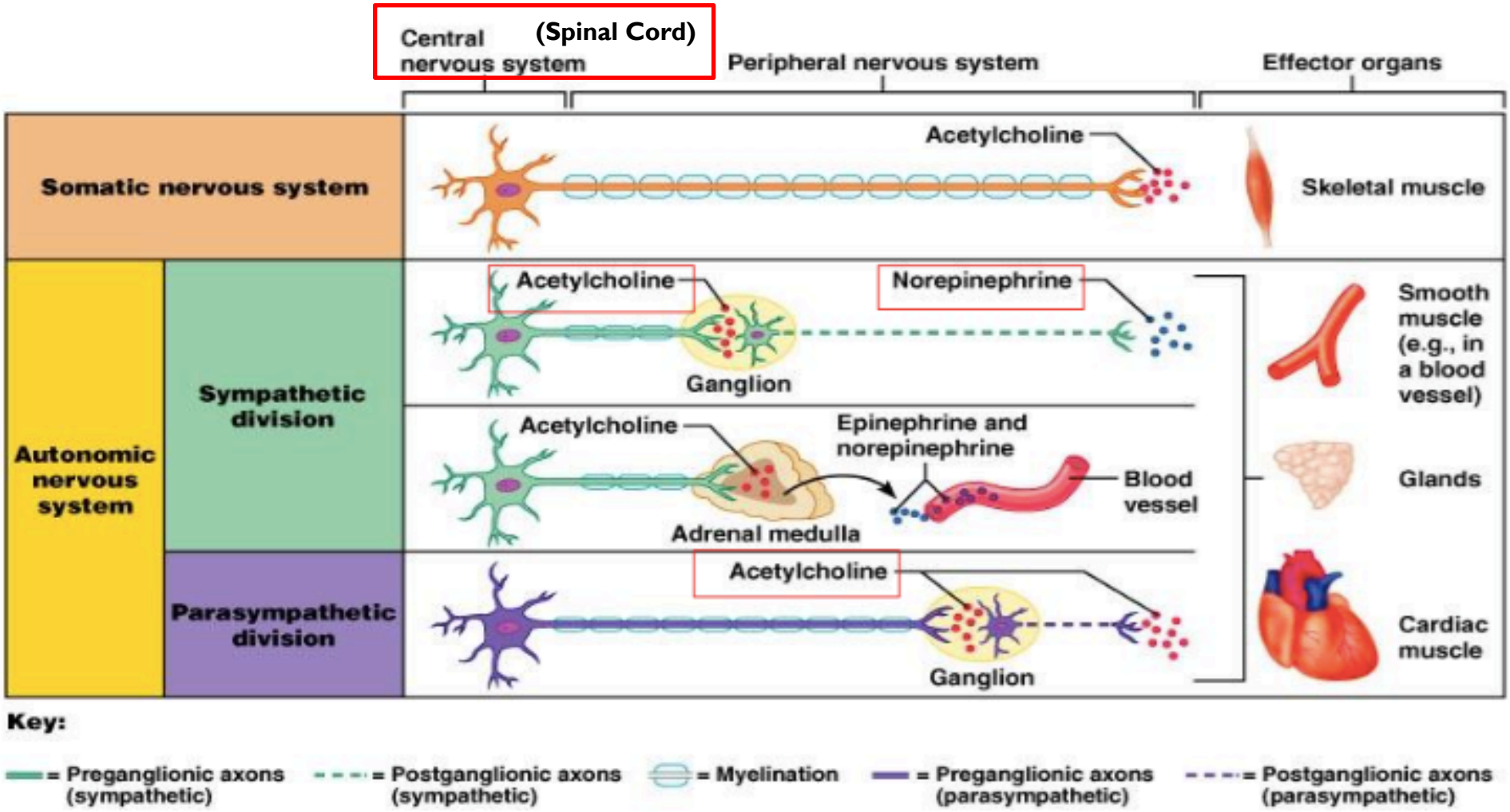
Postganglionic neurons: (norepinephrine) Or (Acetylcholine),

either **Cholinergic** Or **Adrenergic**

Post: Adrenergic **EXCEPT IN** thermoregulatory **sweat glands** where they're **Cholinergic** and the receptor is **Muscarinic**

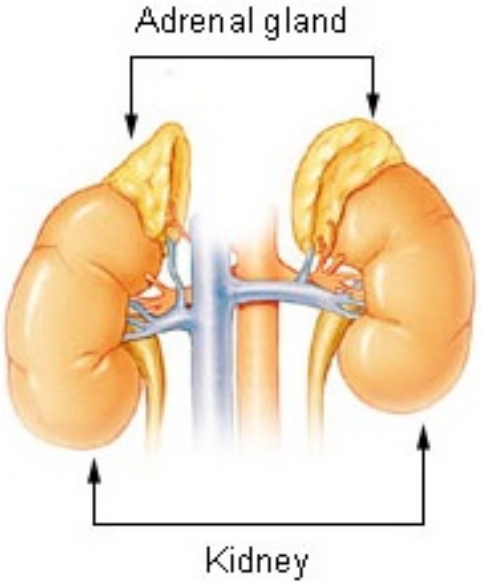
Because sweat gland release Ach in both pre&postganglionic

Neurotransmitters



Function of Adrenal Gland

- Adrenal gland triggers the Adrenal Medulla to release Epinephrine & Norepinephrine.
- Stimulation of sympathetic nerves causes large quantities of Epinephrine and Nor-epinephrine to be secreted in blood by the Adrenal gland.
- Adrenal medulla will stimulated during Sympathetic only
- The effect of Epinephrine & Nor-epinephrine lasts 5-10 times more than the ones which are secreted from sympathetic.



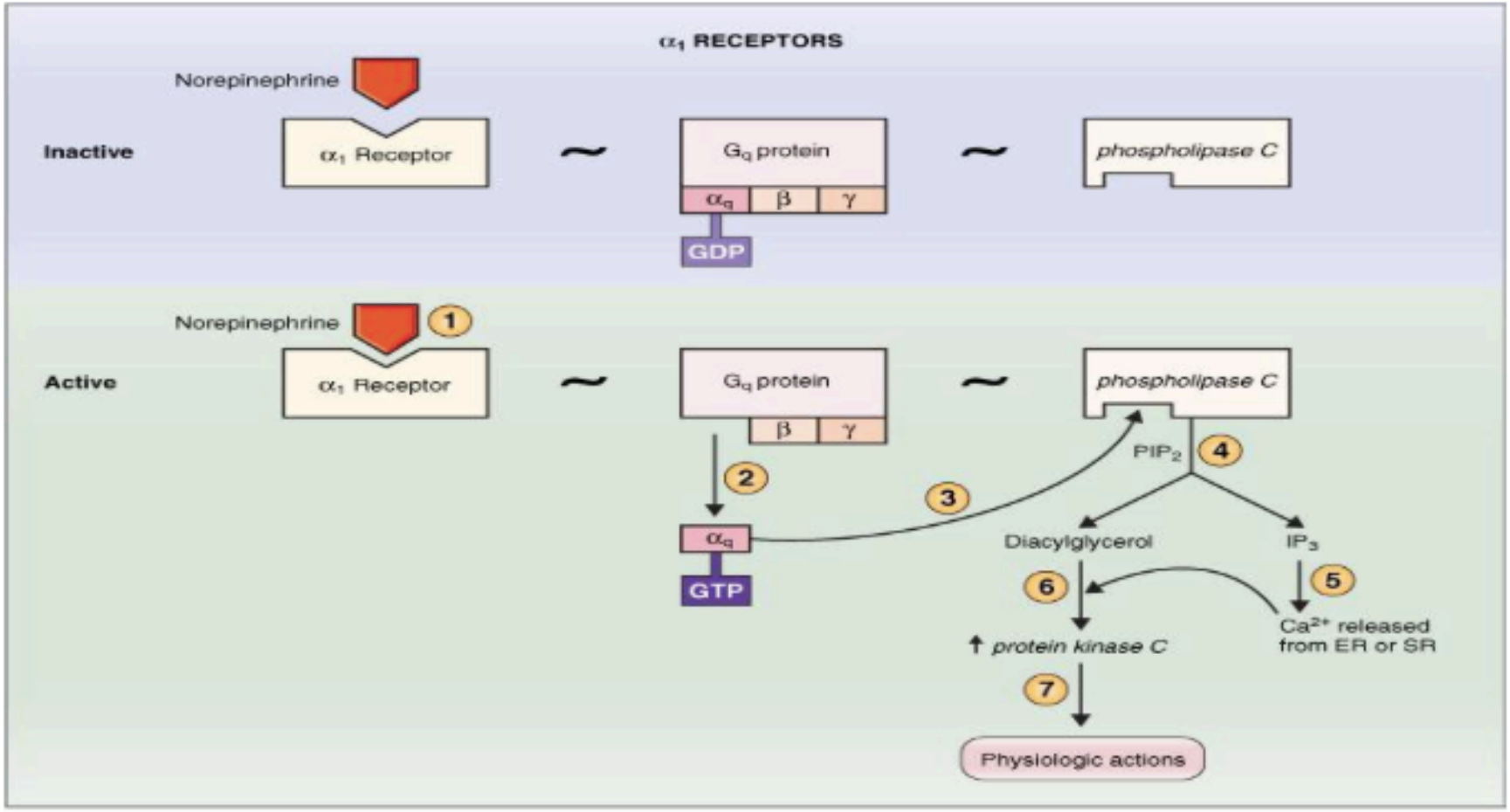
Epinephrine = Adrenaline
Nor-Epinephrine = Nor-Adrenaline
Adrenal gland = الغدة الكظرية

Adrenoreceptors

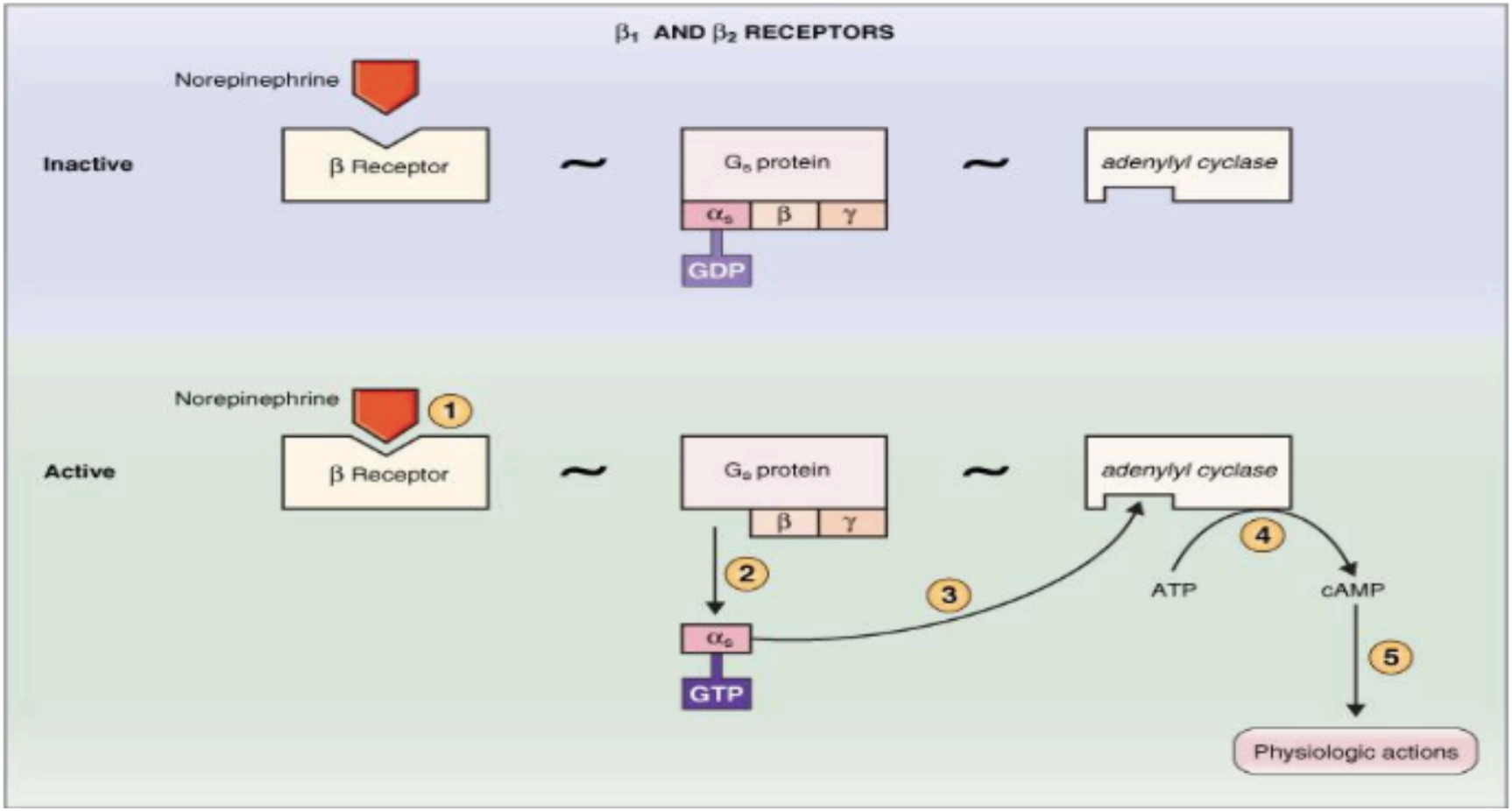
alpha I	Found in **vascular smooth muscle**, **gastrointestinal sphincters** and **bladder**, **radial muscle of iris** Function: **contraction** of all these organs "leads to smooth muscle contraction "
beta I	Existing in : 1) **sinoatrial node**(S.A node)**:** increases heart rate 2) **Atrioventricular node**(A.V node) increases conduction velocity 3) **Ventricular muscles**: increases contractility 4) **Salivary gland**: increases secretion (but enzymes production) "leads to smooth muscle contraction (especially in heart)
beta 2	found in vascular smooth muscle **wall of bladder**, and **wall of GI**. Activation of β2 is *relaxation* β2 is more sensitive to Epinephrine than Nor-epinephrine " leads to smooth muscle relaxation "

alpha 2 has the same function as alpha 1 and is rarely found in the human body.

Alpha 1


α1 RECEPTORS
Norepinephrine
Inactive
α1 Receptor
Gq protein
αq
β
γ
GDP
phospholipase C
Norepinephrine
1
Active
α1 Receptor
Gq protein
β
γ
phospholipase C
PIP2
4
2
3
αq
GTP
Diacylglycerol
IP3
6
5
Ca2+ released from ER or SR
↑ protein kinase C
7
Physiologic actions

Beta 1-2


β1 AND β2 RECEPTORS
Norepinephrine
Inactive
β Receptor
Gs protein
αs
β
γ
GDP
adenylyl cyclase
Norepinephrine
1
Active
β Receptor
Gs protein
β
γ
adenylyl cyclase
2
3
4
ATP
cAMP
αs
GTP
5
Physiologic actions

Cholinoreceptors

Nicotinic	**Function**: • an ion channel for Na+ and K+ • on all postganglionic neurons motor end plate at skeletal muscle and chromaffin cells .
Muscarinic	Works either like a1 adrenoceptors via **PKC, DAG and IP3** Or via **G protein** (which has a1 subunit that binds K+ channel and open it)

DE-POLARIZATION :
A change in a cell's membrane potential that makes it more positive (allowing Na+ to enter the cell or closing K+ pump)
Excites action potential

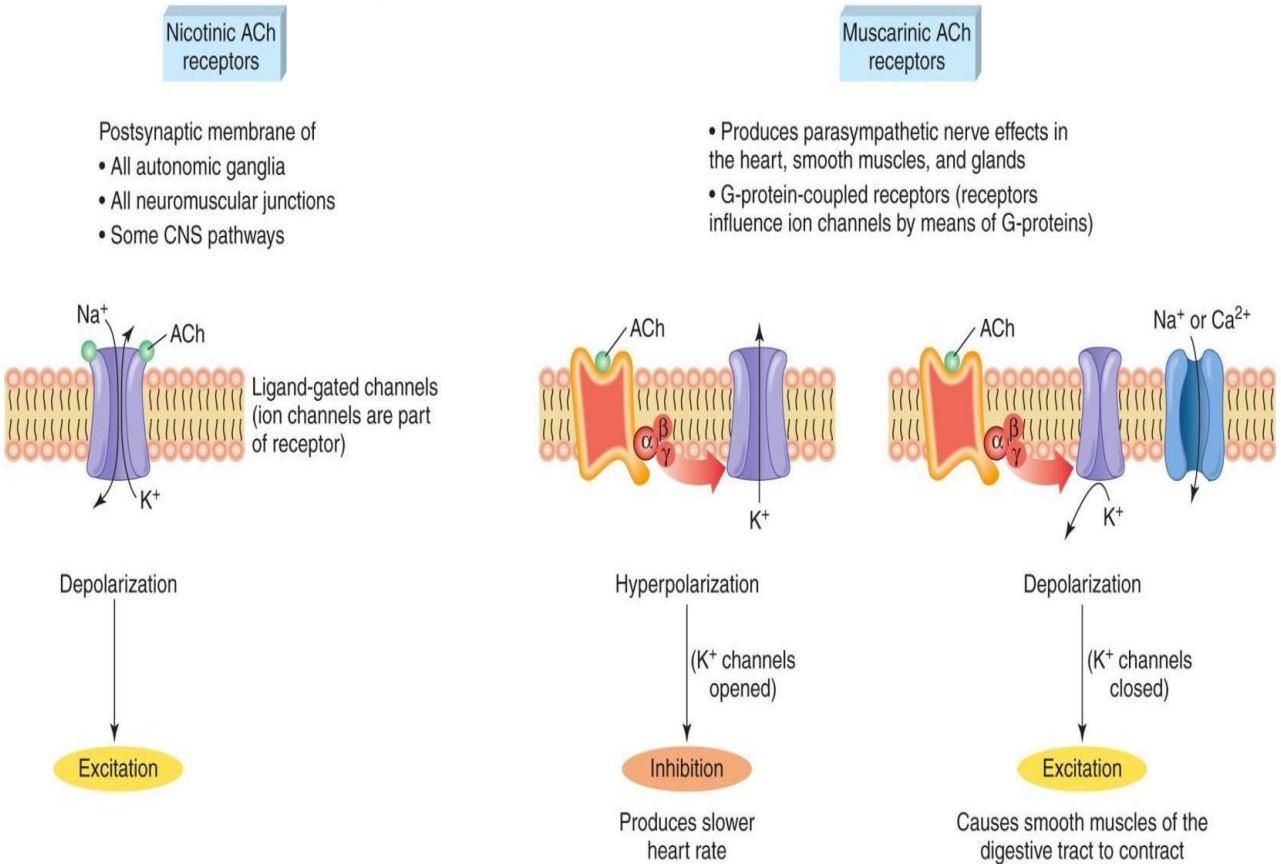
Hyper-polarization:
is a change in a cell's membrane potential that makes it more negative. (opening K+ channels for it to leave) It inhibits action potentials.

Nicotinic receptors work as activators (cause depolarization = excitation) by allowing Na+ to enter the cell.

Muscarinic receptors can cause
-Hyperpolarization= inhibition by opening K+ pump
-Or Depolarization= excitation by closing K+ pump

IP3 (Inositol trisphosphate) / DAG (Diacylglycerol) / PKC (Protein kinase C)

Cholinorecepters



#Remember: concentration of Na+ is higher out of the cell and the concentration of K+ is higher in the cell

To help you memorize:
The cell asks more Sodium (Na) to come in but it says "**Na**h" then Potassium (K) says "o**K**" and enters!

Summary of ANS

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

Prototypes of Agonists and Antagonists to Autonomic Receptors

Receptor	Agonists	Antagonists
Adrenoceptors		
α_1	Norepinephrine	Phenoxybenzamine
	Phenylephrine	Prazosin
α_2	Clonidine	Yohimbine
β_1	Norepinephrine	Propranolol
	Isoproterenol	Metoprolol
β_2	Epinephrine	Propranolol
	Isoproterenol	Butoxamine
	Albuterol	
Cholinoreceptors		
Nicotinic	ACh	Curare
	Nicotine Carbachol	Hexamethonium (blocks ganglionic receptor but not neuromuscular junction)
Muscarinic	ACh	Atropine
	Muscarine	

NOTES

- **Agonist** : A drug (or other chemical substance) that combines with a receptor on a cell **to produce a physiologic reaction.**

- Antagonist : is a chemical substance **that interferes with the physiological action of another**, especially by combining with its nerve receptor and blocking it.

- ملاحظة عن الجدول السابق: الدكتور لمح لنا إن الأساسيات من الأقونست والأنتاقونست هي بس للحفظ. حطيناها باللون الأحمر
- ملاحظة ثانية: الجدول مب جاي بالترتيب يعني مثلا نورابينيفرن مب بس الاقنست حق الفا ١. يمديه يشتغل مع كل الريسيبتورز

Sympathetic and Parasympathetic Tone

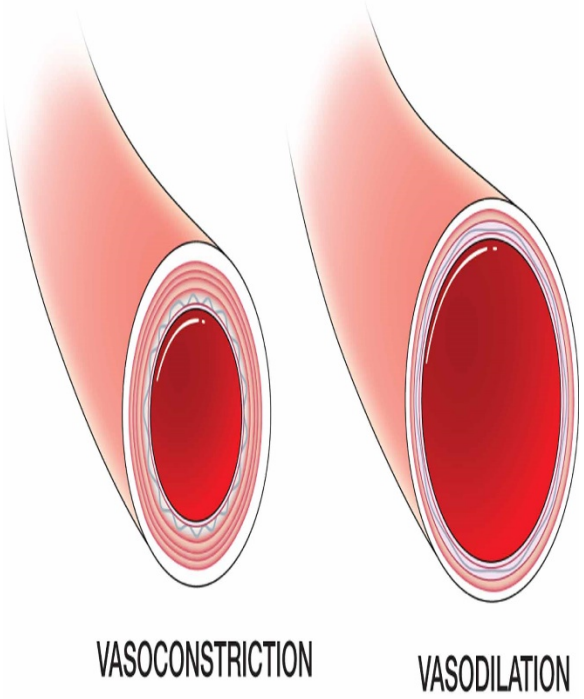
- Their role is <u>to keep the stimulated organs in normal stage.</u>
- **Examples**:

1. Sympathetic always keeps the blood vessel constricted ½ of its normal diameter.
2. removal of vagus nerve → atony → loss of peristalsis (contraction of small intestine) → constipation.

Atony: loss of tone

Effect of loss of sympathetic and parasympathetic tone after denervation

- Loss of sympathetic tone in blood vessel causes severe vasodilatation but after sometime, intrinsic tone increases by chemical adaptation.



Severe vasodilation: توسع حاد بالأوعية
Intrinsic: منتمي إلى هذا العضو- (هنا نقصد منتمي إلى الأوعية الدموية)

Autonomic Reflexes

- Most of the visceral functions of the body are regulated by autonomic reflexes.

Cardiovascular	Gastrointestinal (GI)	Urinary Bladder	Sexual Reflexes
Baro-receptor reflex: - It is a stretch reflex in the main arteries (such as carotid artery) to detect the blood pressure.	The receptors in the nose and mouth send a signal to parasympathetic -to notify the glands of mouth & stomach to secrete the digestive juices.	Initiate the micturition (urination) by parasympathetic innervations.	- erection by parasympathetic. - ejaculation by sympathetic.

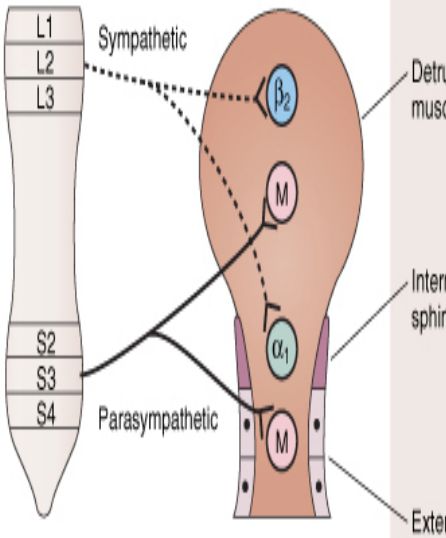
Autonomic Reflexes. Example: Urinary Bladder

❑ Filling the bladder:

- **Detrusor muscle:**
- **B2** is activated: **relaxed** (increase filling)
- **Internal sphincter**:
- **A1** is activated : **contracted**
- **External sphincter** (voluntary): **contacted**

❑ Emptying of the bladder:

- **Detrusor muscle:** Muscarinic receptor is activated: **contraction**
- **Internal sphincter**: Muscarinic receptor is activated: **relaxation**
- **External sphincter** (voluntary): **relaxed**



Muscle	Filling of Bladder: State	Filling of Bladder: Control Mechanism	Emptying of Bladder: State	Emptying of Bladder: Control Mechanism
Detrusor muscle	Relaxed	Sympathetic β2	Contracted	Parasympathetic M
Internal sphincter	Contracted	Sympathetic α1	Relaxed	Parasympathetic M
External sphincter	Contracted	Voluntary	Relaxed	Voluntary

Filling the bladder is controlled by **Sympathetic Nervous System**. Emptying the bladder is controlled by Parasympathetic Nervous System

Autonomic Reflexes

Sympathetic activation:

- Occurs in isolated portions such as:
- **heart regulation**.
- many sympathetic reflexes that regulate **G.I. functions**.

Parasympathetic:

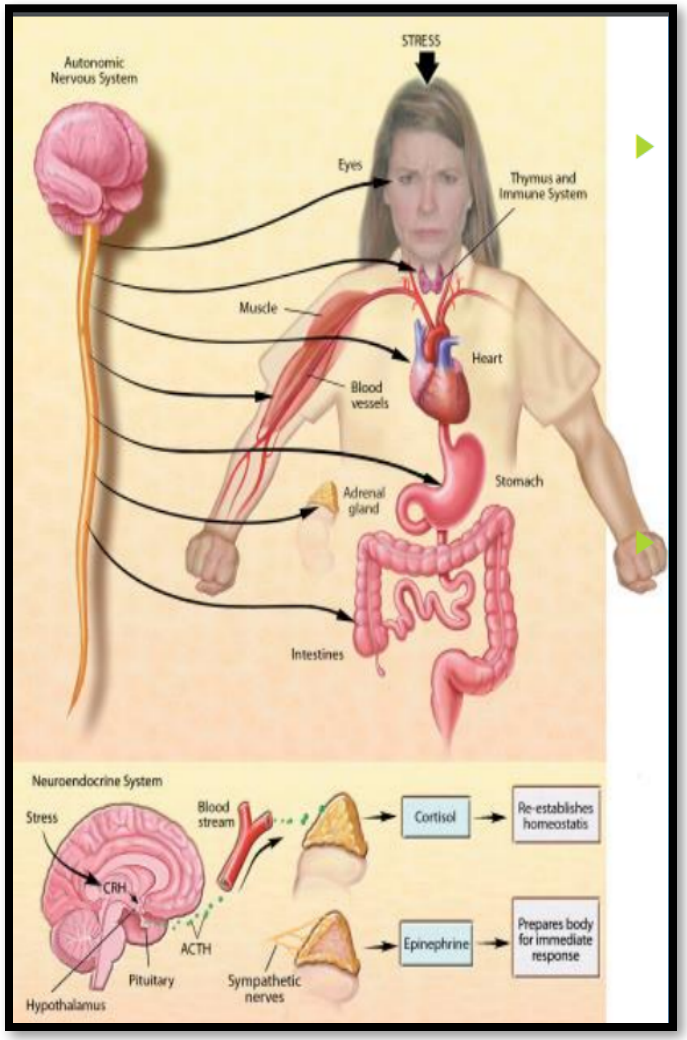
- **Usually:** The effect of parasympathetic is specific to a certain organ. (specific localized responses)
- **But sometimes** parasympathetic activity has a common effect: affects the functions of some organs together.
- **Example**: rectal emptying and bladder emptying, salivary secretion and gastric secretion.

- **Sympathetic** can deal with every single organ alone. - **Parasympathetic** can do that, but sometimes not, should be two processes together.

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 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	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

Important question (team 435)

- **What is the Neurotransmitter of the sympathetic NS ?**

(in general) Norepinephrine (Noradrenaline)

- **What are the Neurotransmitters that released during sympathetic stimulation?**

Norepinephrine & Epinephrine.

- **What is the Neurotransmitter that released at the Preganglionic fiber during sympathetic stimulation ?**

Acetylcholine (Ach).

- **What is the Neurotransmitter of the parasympathetic stimulation ?**

Acetylcholine (Ach).

- **What are is Neurotransmitter of the Preganglionic fiber during parasympathetic stimulation ?**

Acetylcholine (Ach).

Quiz : https://www.onlineexambuilder.com/autonomic-nervous-system-physiology/exam-37006

Thank you!

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

The Physiology 436 Team:

Lina Alwakeel
Rana Barassain
Heba Alnasser
Munira Aldofayan
Sara Alshamrani
Sundus Alhawamda
Ruba Ali
Rehab Alanazi
Norah Alshabib
Nouf Alaqeeli
Buthaina Almajed
Alaa Alaqeel

Fahad Al Fayez
Ibrahim Al Deeri
Hassan Al Shammari
Abdullah Al Otaibi
Abdullah Al Subhi
Ali Al Subaei
Omar Al Babteen
Foad Fathi
Faisal Al Fawaz
Muhammad Al Aayed
Muhammad Al Mutlaq
Nasser Abu Dujeen
Waleed Al Asqah

Team Leaders:

Qaiss Almuhaideb
Lulwah Alshiha

Contact us:

Physiology436@gmail.com
@Physiology436