جامعة الملك سعود
King Saud University

MED437

2nd Lecture |The Physiology Team

The Autonomic Nervous System

Objectives :

- The anatomy of somatic and autonomic nervous system.
- Sympathetic and parasympathetic nerves.
- Pre and postganglionic neurons.
- Functions of sympathetic and parasympathetic nerves in head & neck, chest, abdomen and pelvis.
- Neurotransmitters release at pre and postganglionic sympathetic / parasympathetic nerves endings.
- Various responses due to stimulation of the sympathetic / parasympathetic nervous system.

Done by:

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Colour index :
important
Numbers
Extra

وَأَن لَّيْسَ لِلْإِنسَانِ إِلَّا مَا سَعَىٰ

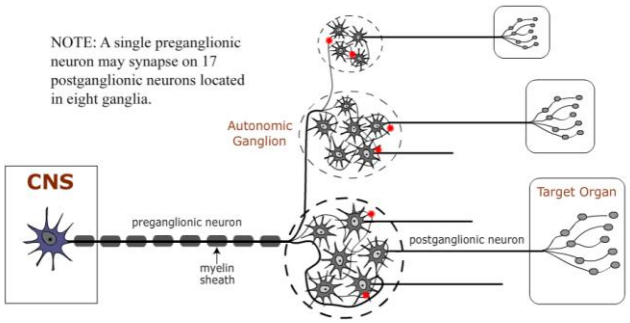
The Nervous system monitors and controls almost every organ / system through a series of positive and negative feedback loops.

- **The Central Nervous System (CNS):** .droc lanips dna niarb eht sedulcnI
- **The Peripheral Nervous System (PNS):** Formed by neurons & their process present in all the regions of the body .
  - It consists of cranial nerves arising from the brain & spinal nerves arising from the spinal cord .
  - The peripheral NS is divided into
    - Somatic Nervous system
    - Autonomic nervous system

Autonomic Nervous system

Visceral Efferent Two-Neuron Pathway

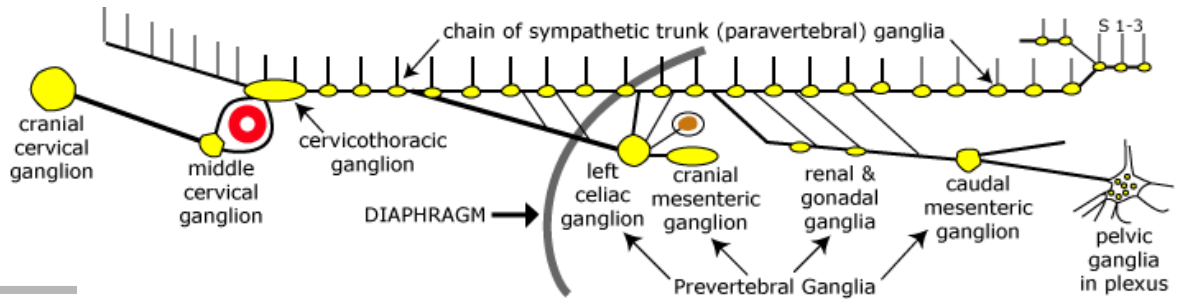
Visceral efferent (VE) pathways that innervate smooth muscle, cardiac muscle, and glands involve two neurons and a synapse within an autonomic ganglion. The cell bodies of the preganglionic neurons are in the brainstem or spinal cord of the central nervous system (CNS). The cell bodies of the postganglionic neurons are in autonomic ganglia located peripherally. Axon terminal of preganglionic neurons synapse on dendrites and cell bodies of postganglionic neurons. **ylno sevlovni elcsum lateleks fo noitavrenni (ES) tnereffe citamos ,tsartnoc nI) (.SNC eht ni ydob llec sti ;noruen elgnis a**



The advantage of two neurons is conservation of space in the CNSeht otni snoruen gnitfihs yb , spacious periphery .
The small number of CNS neurons utilize divergent circuits to drive the numerous peripheral neurons .)This strategy has succeeded, in just gut wall alone there are more neurons than in the entire spinal cord (**The disadvantage of moving neurons out of the CNS is reduced brain control,** but decreased brain control is not a problem in the case of visceral organs which have a limited repertoire of actions .

Preganglionic axons are **myelinated** od naht yldipar erom tcudnoc yeht taht snaem hcihw , suoremun eht**non-myelinated** era snoxa detanileym-non ,revewoH .snoxa cinoilgnagtsop fo sesac ni melborp a ton si deeps noitcudnoc decuder dna tneiciffe erom yllacilobatem .noiterces dnalg dna noitcartnoc elcsum htooms

The following schematic image shows locations of a number of autonomic ganglia (yellow ovals) in the periphery. A bilateral chain of paravertebral ganglia is located beside vertebral bodies in thoracic and abdominal cavities. Prevertebral ganglia are located around major vessels within the abdomen. Cervical ganglia are located in the vicinity of the neck.



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

- Somatic division:

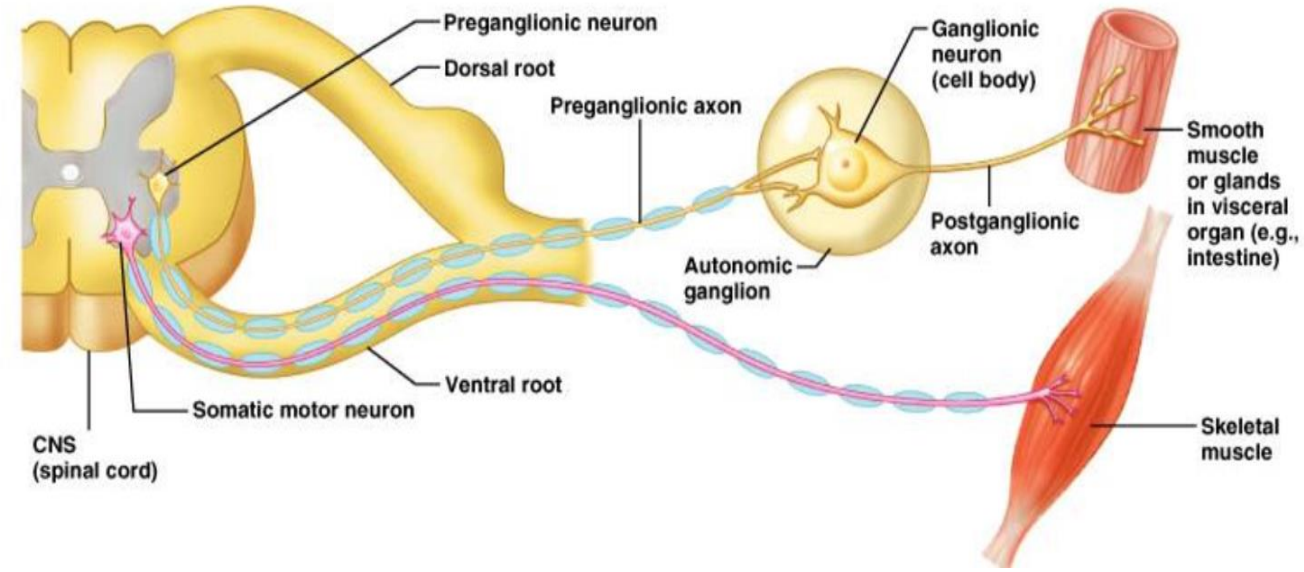
1. Cell bodies of motor neurons reside in CNS (brain or spinal cord).
2. Their axons (sheathed in spinal nerves) extend all the way to their skeletal muscles.

Note : somatic signaling is faster because it is **heavily myelinated**

- Autonomic system:
  chains of two motor neurons

1. 1st neuron: preganglionic neuron (in brain or spinal cord).
2. 2nd neuron: ganglionic neuron (cell body in ganglion outside the CNS).

Note : autonomic signaling is slower because it is **lightly or unmyelinated**



Basic concept: larehpirep eht fo noisividbus eht si metsys suovren cimonotuA **rednu ton** yllareneg era taht seitivitca ydob setaluger taht metsys suovren **.lortnoc suoicsnoc**

Subdivisions of the Autonomic nervous system:

A. Sympathetic
B. Parasympathetic
C. Enteric "Second Brain"

Visceral motor innervates non-skeletal (non-somatic) muscles:

1. Cardiac muscle
2. Smooth muscle (walls of viscera and blood vessels)
3. Internal organs
4. Skin

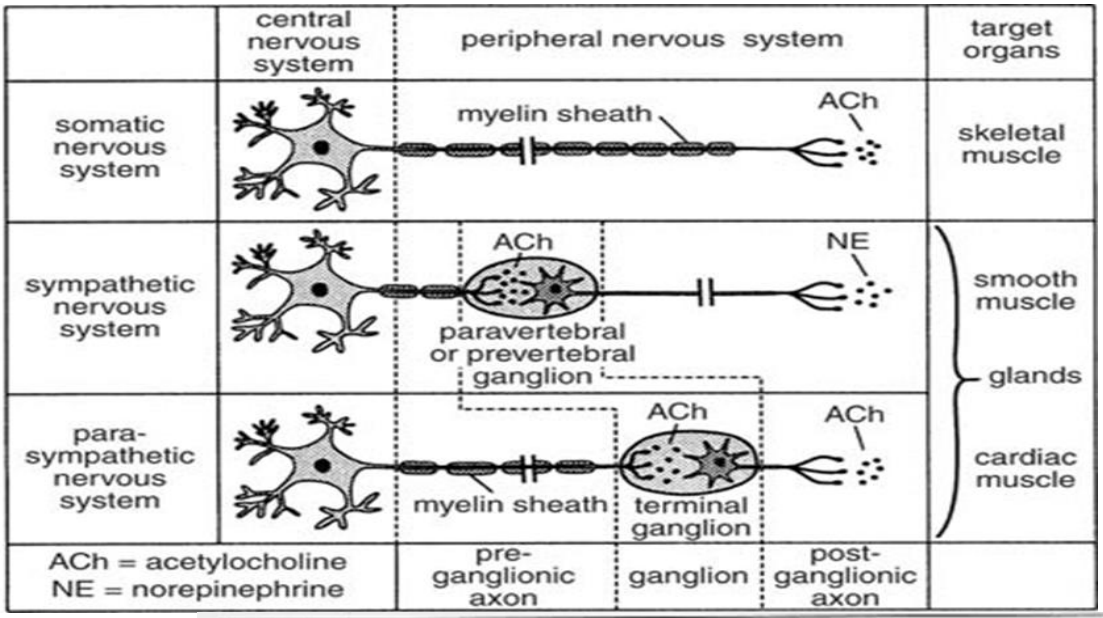
ANS activated by

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 .

DIFFERENCES IN SYMPATHETIC AND PARASYMPATHETIC DIVISIONS



organization of the autonomic nervous system

Characteristics	Sympathetic Division	Parasympathetic Division	Somatic Nervous System*
Origin of preganglionic neurons	Spinal cord segments T1–L3 (thoracolumbar)	Nuclei of CN III, VII, IX, and X; spinal cord segments S2–S4 (craniosacral)	—
Location of autonomic ganglia	Paravertebral and prevertebral	In or near effector organs	—
Length of preganglionic axons	Short	Long	—
Length of postganglionic axons	Long	Short	—
Effector organs	Smooth muscle; cardiac muscle; glands	Smooth muscle; cardiac muscle; glands	Skeletal muscle
Neurotransmitter and receptor type in ganglion	ACh/nicotinic receptor	ACh/nicotinic receptor	—
Neurotransmitter in effector organs	Norepinephrine (except sweat glands)	ACh	ACh
Receptor types in effector organs	α_1, α_2, β_1, β_2	Muscarinic	Nicotinic

ACh, Acetylcholine; CN, cranial nerve.

Pre and post ganglionic neurons

Axon of 1st (preganglionic2 eht htiw espanys ot SNC sevael noruen (nd (ganglionic (noruen

↓

Axon of 2nd (ganglionicsevres ti nagro eht ot sdnetxe noruen (

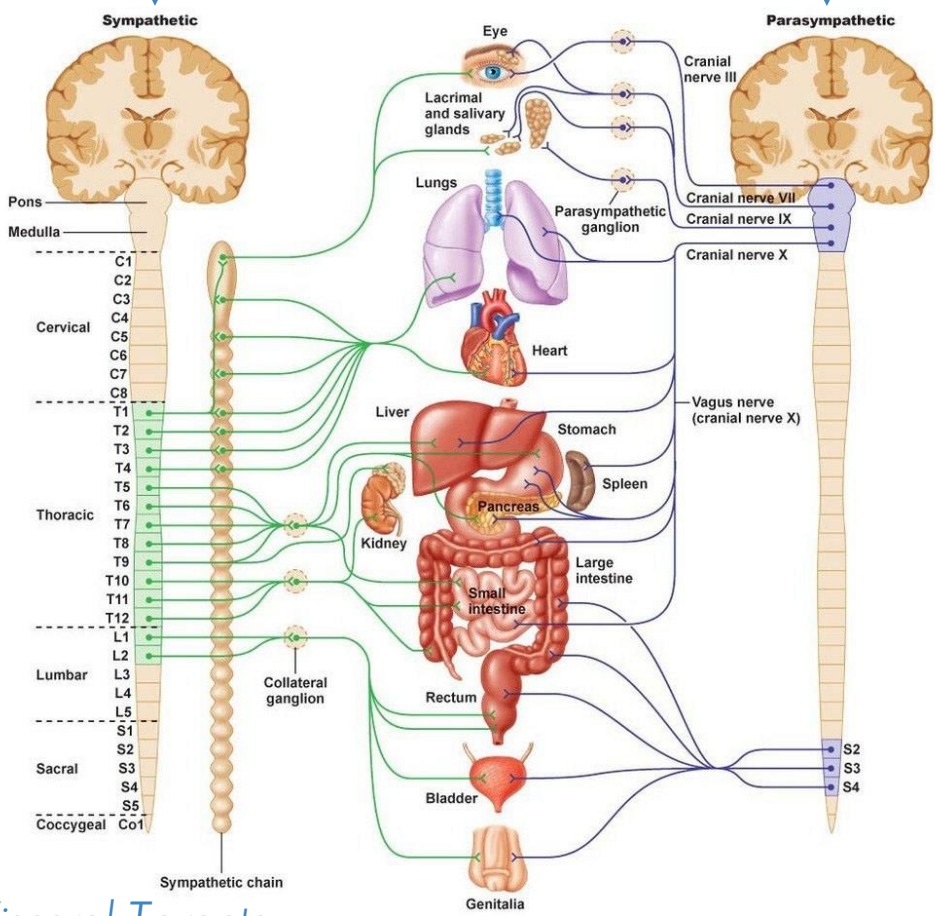
❑ *Locations Of Autonomic Ganglia*

- **Sympathetic Ganglia:**

1. Trunk (chain) ganglia near vertebral bodies.
2. Prevertebral ganglia near large blood vessel in the gut: celiac, superior mesenteric & inferior mesenteric.

- **Parasympathetic Ganglia:**

1. Terminal ganglia
2. In the wall of organ



❑ *Innervation Of Visceral Targets*

- **Sympathetic:**
  - Short, **lightly myelinated** preganglionic neurons
  - Long, **unmyelinated** postganglionic neurons
  - The sympathetic axons are Highly branched

See the **Introduction** to know why

note: Ganglia close to spinal cord

- **Parasympathetic:**
  - Preganglionic neurons - long, & myelinated.
  - Postganglionic neurons - short & unmyelinated
  - The parasympathetic axons contain few branches

note: Ganglia close to or on target organs

Sympathetic & parasympathetic nervous system origin:

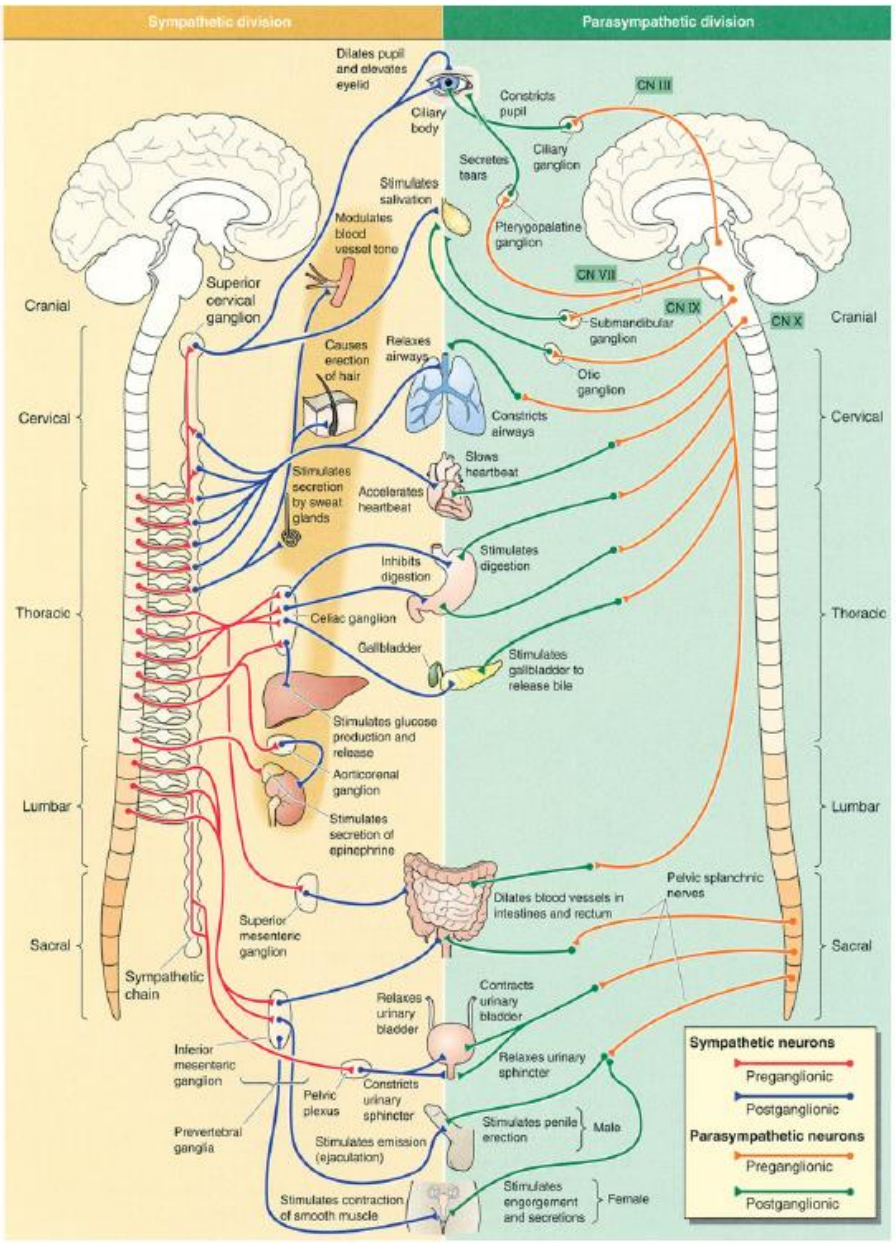


FIGURE 17–3 **Organization of sympathetic (left) and parasympathetic (right) nervous systems.** Preganglionic sympathetic and parasympathetic neurons are shown in red and orange, respectively; postganglionic sympathetic and parasympathetic neurons in blue and green, respectively. (Reproduced with permission from Boron WF, Boulpaep EL: *Medical Physiology*. Elsevier, 2005.)

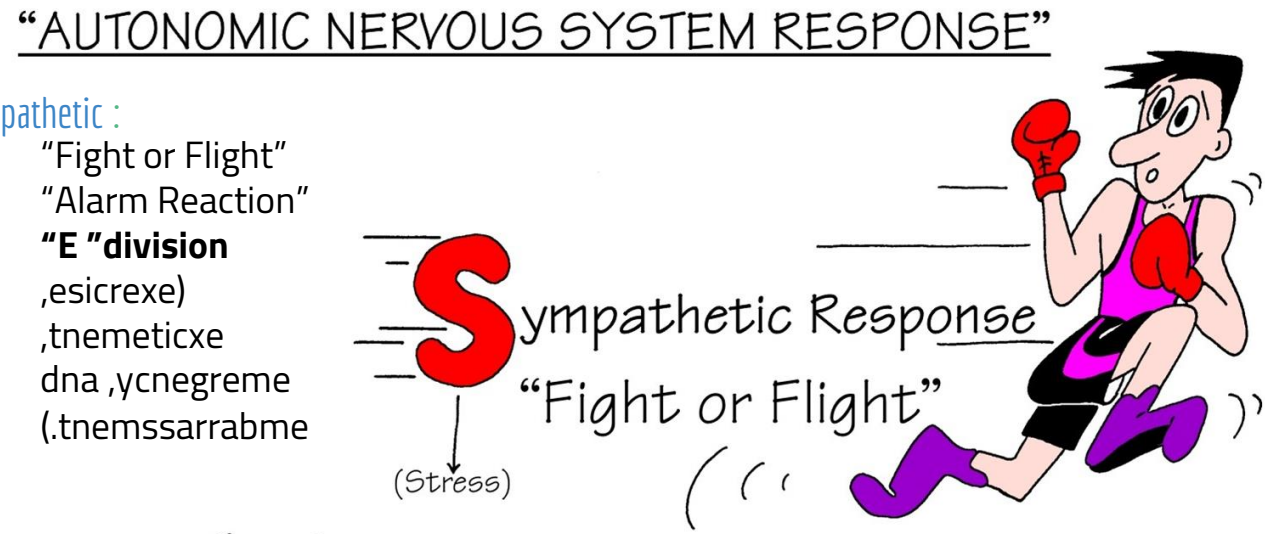
- Sympathetic - Origin :
  - Thoracolumbar **lateral horns of the spinal segment T.2L -1**
  - Nerve fibers originate between T.2L &1

- Parasympathetic - Origin:
  - Craniosacral cell bodies of the motor nuclei of the **cranial nerves III, VII, IX and X** in the brain stem.
  - **Second, third and fourth [S** lanips eht fo **stnemges larcas [4S-2** .droc
  - Nerve fibers emerge from brain & sacrum forming craniosacral outflow.

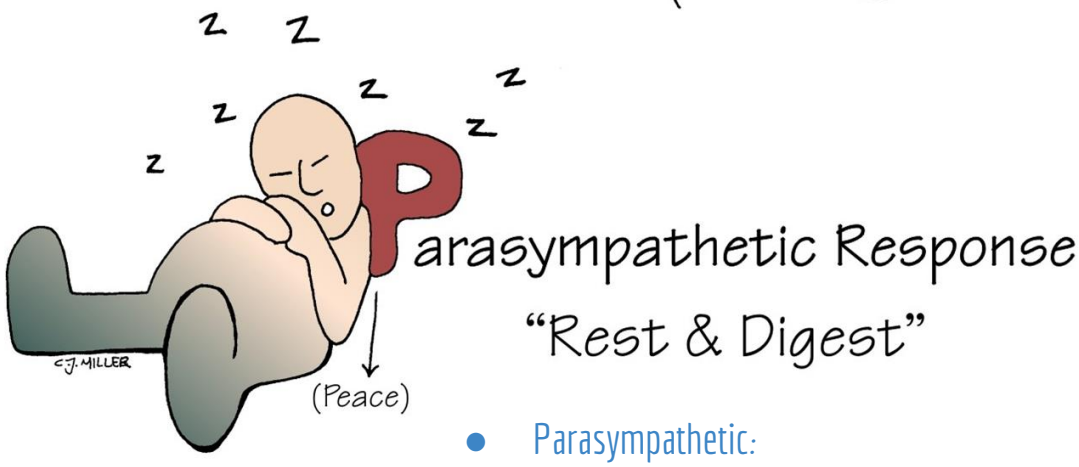
Parasympathetic Nervous system:

- The **cranial nerves III, VII and IX** dnalg yravilas dna lipup eht tceffa .noiterces
- **Vagus nerve (X)** reppu ,hcamots ,sgnul ,traeh eht ot serbif seirrac .reteru dna enitsetni
- **The sacral fibres** latsid eht etavrenni hcihw sesuxelp civlep mrof .snagro evitcudorper dna reddalb ,mutcer ,noloc

Autonomic nervous system divisions:



- Sympathetic :
  - "Fight or Flight"
  - "Alarm Reaction"
  - **"E "division** ,esicrexe) ,tnemeticxe dna ,ycnegreme (.tnemssarrabme



- Parasympathetic:
  - "Rest and digest"
  - **"SLUDD "**responses:
    - salivation, lacrimation, urination, digestion & defecation.
  - **"D "division**
    - Digestion, defecation, and diuresis

Paradoxical fear: when there is no escape route or no way to win causes massive activation of parasympathetic division

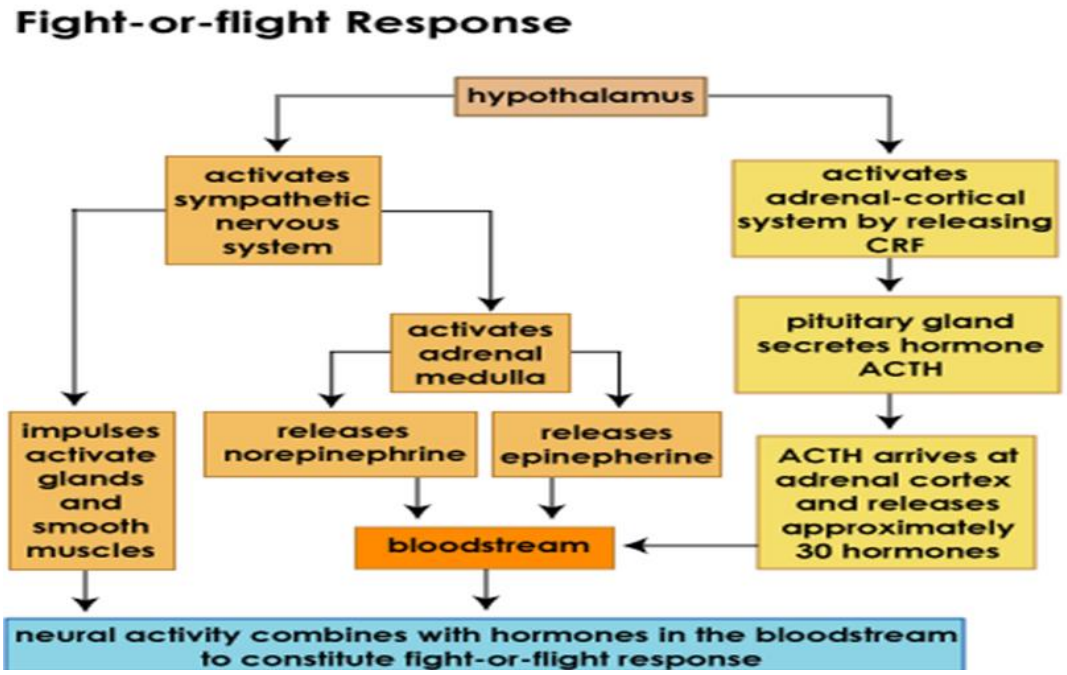
- ★ loss of control over urination and defecation

Functions of Sympathetic nervous system

Fear - Flight - Fight:

- The sympathetic nervous system allows the the body to be prepared for the Fear-Flight-Fight situations.
- Sympathetic responses also contribute to Increase in heart rate , blood pressure , and cardiac output.
- It diverts blood flow away from the GIT "splanchnic vessels "and skin via **vasoconstriction** .
    - Blood flow to skeletal muscles, lungs is not only maintained, but enhanced (by as much as .selcsum lateleks fo esac ni ,(1200%
- Increase pupil size , bronchial dilatation , and contraction of sphincters and metabolic changes **such as the mobilisation of fat and glycogen.**

1. Bronchioles dilate ⟶ Increase alveolar oxygen exchange.
2. Increases heart rate and contractility of skeletal muscles (Myocytes) ⟶ Will increase blood flow to skeletal muscles.
3. Dilation of the pupil and relaxation of lens ⟶ Allow MORE light to enter through the eye.



Functions of Parasympathetic nervous system

Rest and Digest:

- 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* fo noitprosba dna noitsegid setatilicaf dna , .stcudorp etsaw fo noitercxe eht yltneuqesnoc dna ,stneirtun
- The chemical transmitter at both pre and postganglionic synapses in the parasympathetic system is **Acetylcholine (Ach).**

Autonomic nervous system

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

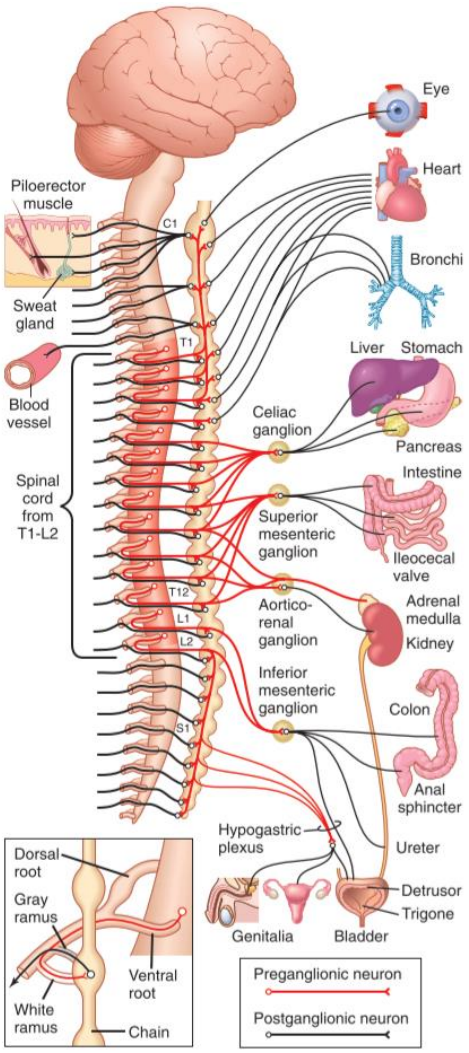


Figure 61-1. Sympathetic nervous system. The black lines represent postganglionic fibers, and the red lines show preganglionic fibers.

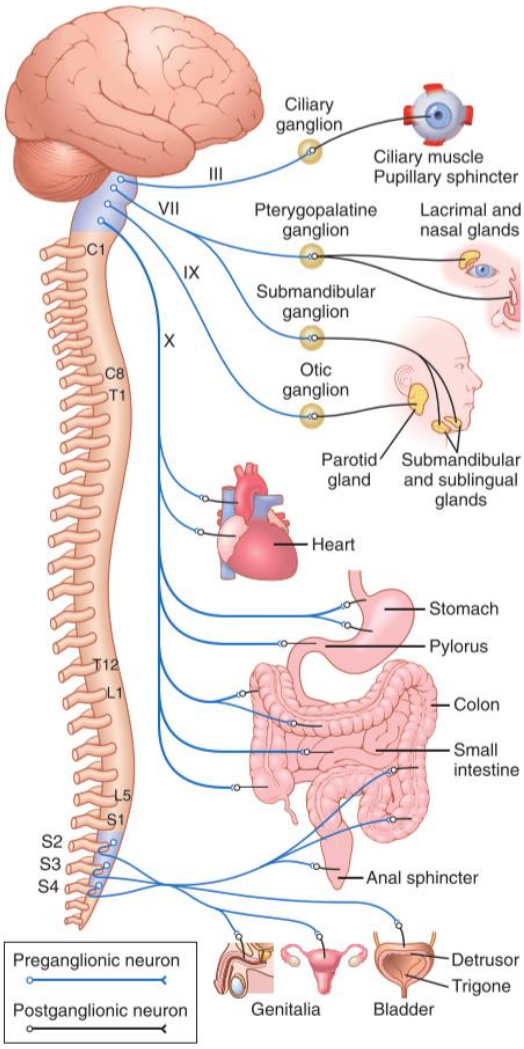


Figure 61-3. The parasympathetic nervous system. The blue lines represent preganglionic fibers and the black lines show postganglionic fibers.

Structure	Sympathetic Stimulation	Parasympathetic Stimulation
Iris (eye muscle)	Pupil dilation	Pupil constriction
Salivary Glands	Saliva production reduced	Saliva production increased
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
Stomach	Peristalsis reduced	Gastric juice secreted; motility increased
Small Intes	Motility reduced	Digestion increased
Large Intes	Motility reduced "Constipation"	Motility reduced
Liver	Increased conversion of glycogen to glucose	No effect
Kidney	Decreased urine secretion	Increased urine secretion
Adrenal medulla	Norepinephrine and epinephrine secreted	No effect
Bladder	Wall relaxed Sphincter closed	Wall contracted Sphincter relaxed

Doctor's Notes:

- ★ Sympathetic overstimulation in liver =increased conversion of glycogen to glucose that lead to **diabetes**
- ★ Sympathetic overstimulation in large intes. leads to **constipation**
- ★ Notice that both E 20% EN +80% released from adrenal medulla, while in neuromuscular junction only NE is released.

Neurotransmitters release at pre and post ganglionic sympathetic / parasympathetic nerves endings

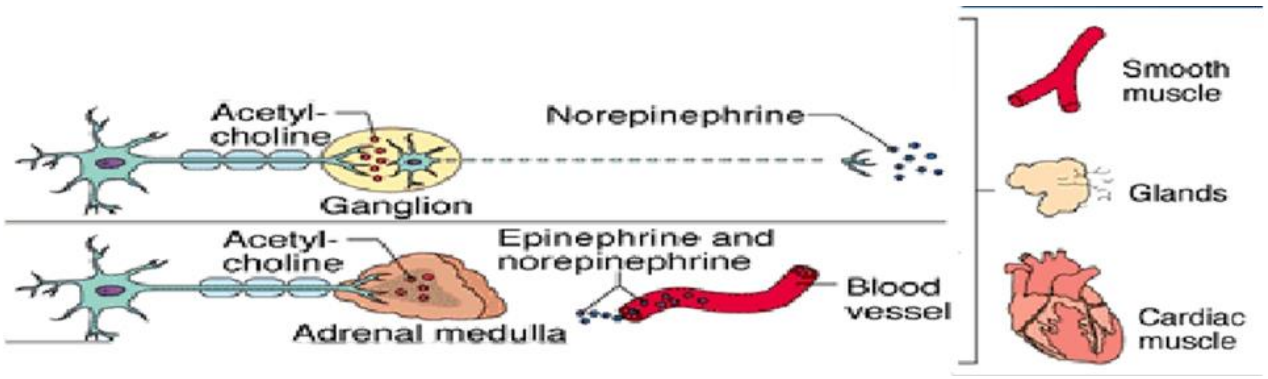
-1Sympathetic neurons Neurotransmitters

A- Preganglionic neurons

Cholinergic:. enilohclyteca esaeler

B-Postganglionic neurons:

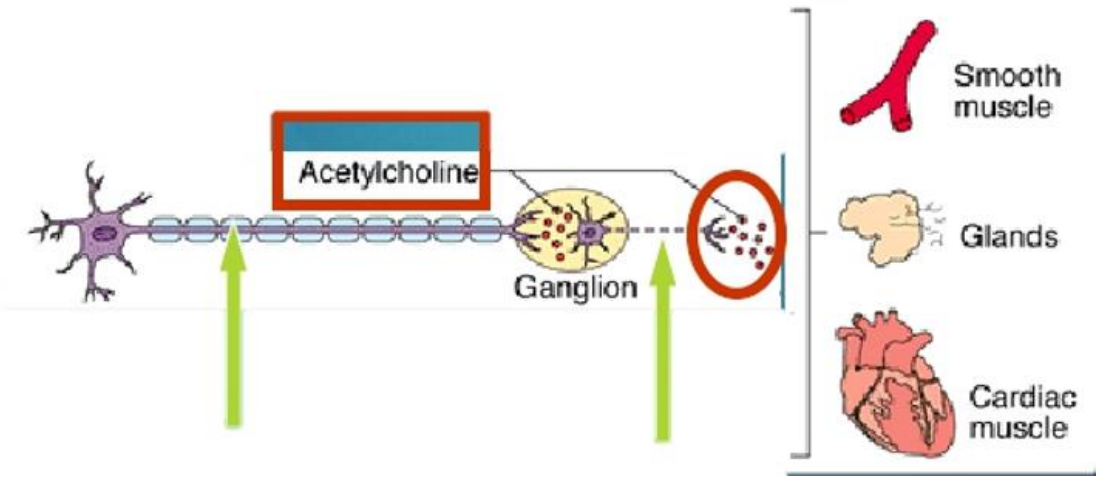
Adrenergic: release norepinephrine at target organs. except Sweat glands and blood vessels to skeletal muscles where they release Ach



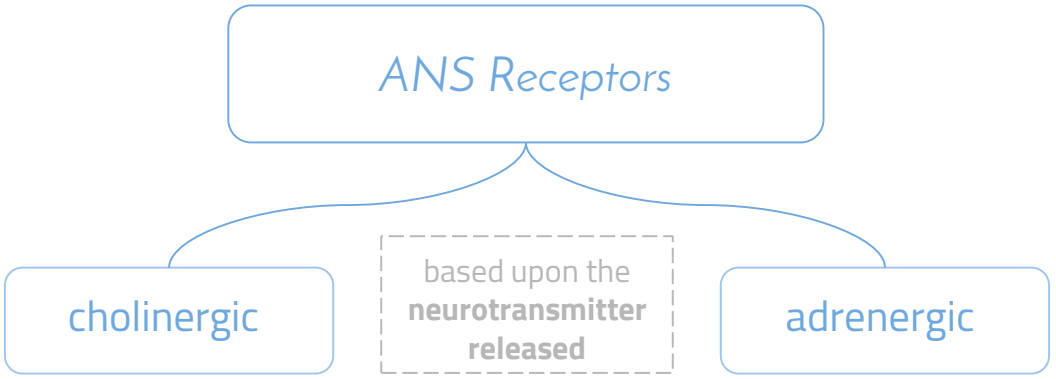
-2Parasympathetic Neurotransmitters

Pre & Postganglionic neurons:

Cholinergic: release acetylcholine



Neurotransmitters release at pre and post ganglionic sympathetic / parasympathetic nerves endings

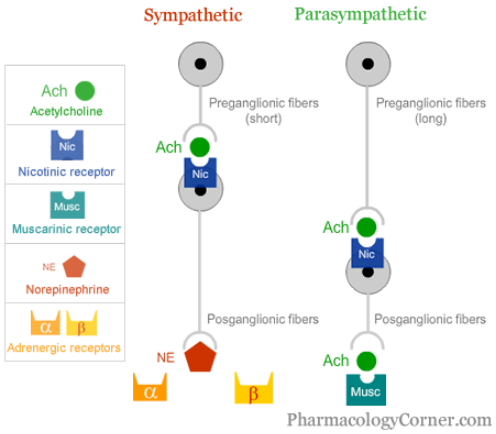


Chemical or neural transmitter

- All preganglionic fibers release acetylcholine (Ach).
- All parasympathetic postganglionic release Ach.
- All sympathetic postganglionic release noradrenaline except sweat glands & blood vessels to skeletal muscles

Receptors

- **The parasympathetic nervous system** sti sa (hCA) enilohclyteca ylno sesu .rettimsnartoruen
  The ACh acts on two types of receptors, the muscarinic and nicotonic receptors.
  - **Note:** nicotine is agonist to nicotinic receptor , and antagonist to muscarinic receptor , and vise versa.
  - **Muscarinic receptors** eht yb detalumits era taht sllec rotceffe lla no dnuof era metsys suovren citehtapmysarap eht rehtie fo snoruen cigrenilohc cinoilgnagtsop .metsys citehtapmys eht ro
  - **Nicotinic receptors** neewteb sespanys eht ta ailgnag cimonotua eht ni dnuof era dna citehtapmys eht htob fo snoruen cinoilgnagtsop dna cinoilgnagerp eht .smetsys citehtapmysarap
- 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.

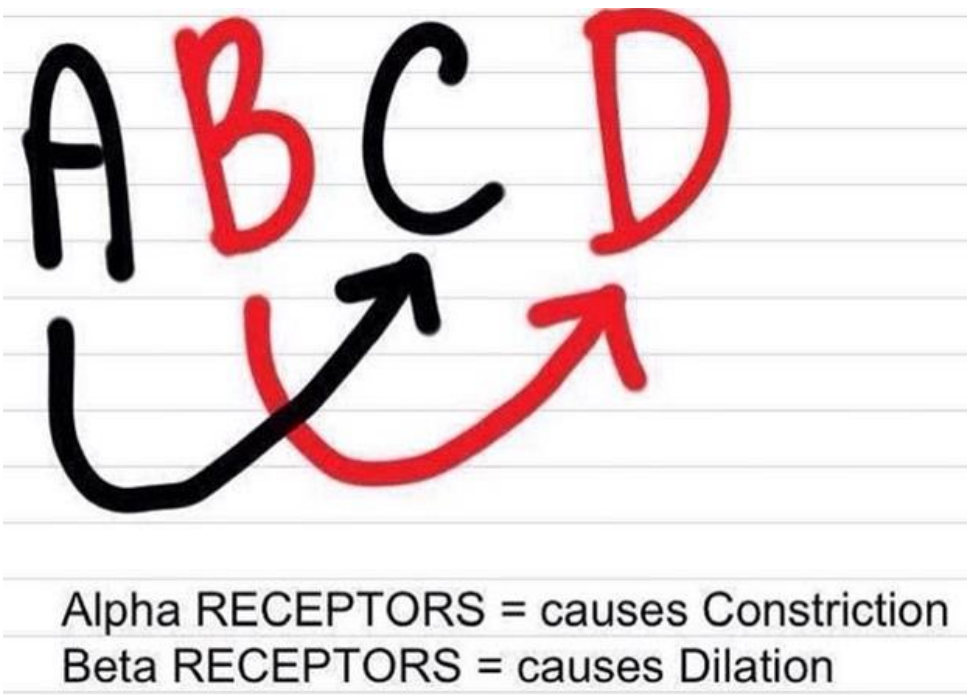


Neurotransmitters release at pre and post ganglionic sympathetic / parasympathetic nerves endings

The Sympathetic NS Acts on two types of receptors

What do the receptors do?

- α
  - smooth muscle **contraction**
- β
  - 1β
    - smooth muscle **contraction** ni yllaicepse) (traeh
  - 2β
    - smooth muscle **relaxation**



Neurotransmitters release at pre and post ganglionic sympathetic / parasympathetic nerves endings

sympathetic adrenergic

parasympathetic muscarinic

circulatory system

- cardiac output
- SA node: heart rate (chronotropic)
- cardiac muscle: contractility (inotropic)*
- conduction at AV node
- vascular smooth muscle **
- platelets
- mast cells-histamine

2α
- increases → SA node: heart rate (chronotropic)
- increases → cardiac muscle: contractility (inotropic)*
- aggregates → platelets

1β
- increases → conduction at AV node
- inhibits → mast cells-histamine

M1
- decreases → cardiac output

M2
- decreases → SA node: heart rate (chronotropic)
- decreases → cardiac muscle: contractility (inotropic)*
- decreases → conduction at AV node

respiratory system

- smooth muscles of bronchioles

2β
- relaxes (major contribution) → smooth muscles of bronchioles
- contracts (minor contribution) → smooth muscles of bronchioles

M3
- contracts → smooth muscles of bronchioles
- contracts → pupil of eye
- contracts → ciliary muscle

nervous system

1α
- relaxes → pupil of eye
- relaxes → ciliary muscle

)*atria only(

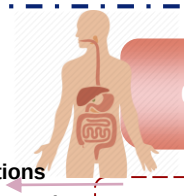
**has only sympathetic activity with the following receptors

Msexaler =2 β ;stcartnoc = α ;stcartnoc :3

Neurotransmitters release at pre and post ganglionic sympathetic / parasympathetic nerves endings

sympathetic adrenergic

parasympathetic muscarinic



digestive system

stimulates viscous, amylase secretions

stimulates potassium cation

salivary glands: secretions

stimulates watery secretions

decreases

lacrimal glands (tears)

increases

1α

secretes

kidney (renin)

secration

M1

parietal cells

glycogenolysis, gluconeogenesis

liver

contracts

decreases

GI tract motility

increases

increases

2α

sexaler:α

smooth muscles of GI tract

M2

relaxes

sphincters of GI tract

relaxes

endocrine system

contracts

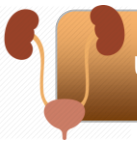
1β

decreases secretion

pancreas (islets)

N: secretes epinephrine

adrenal medulla



urinary system

relaxes

bladder wall

contracts

2β

M3

contracts

ureter

relaxes

relaxes

sphincter

contracts

1α

stimulates(minor contribution)

sweat gland secretions

stimulates

arrector pili

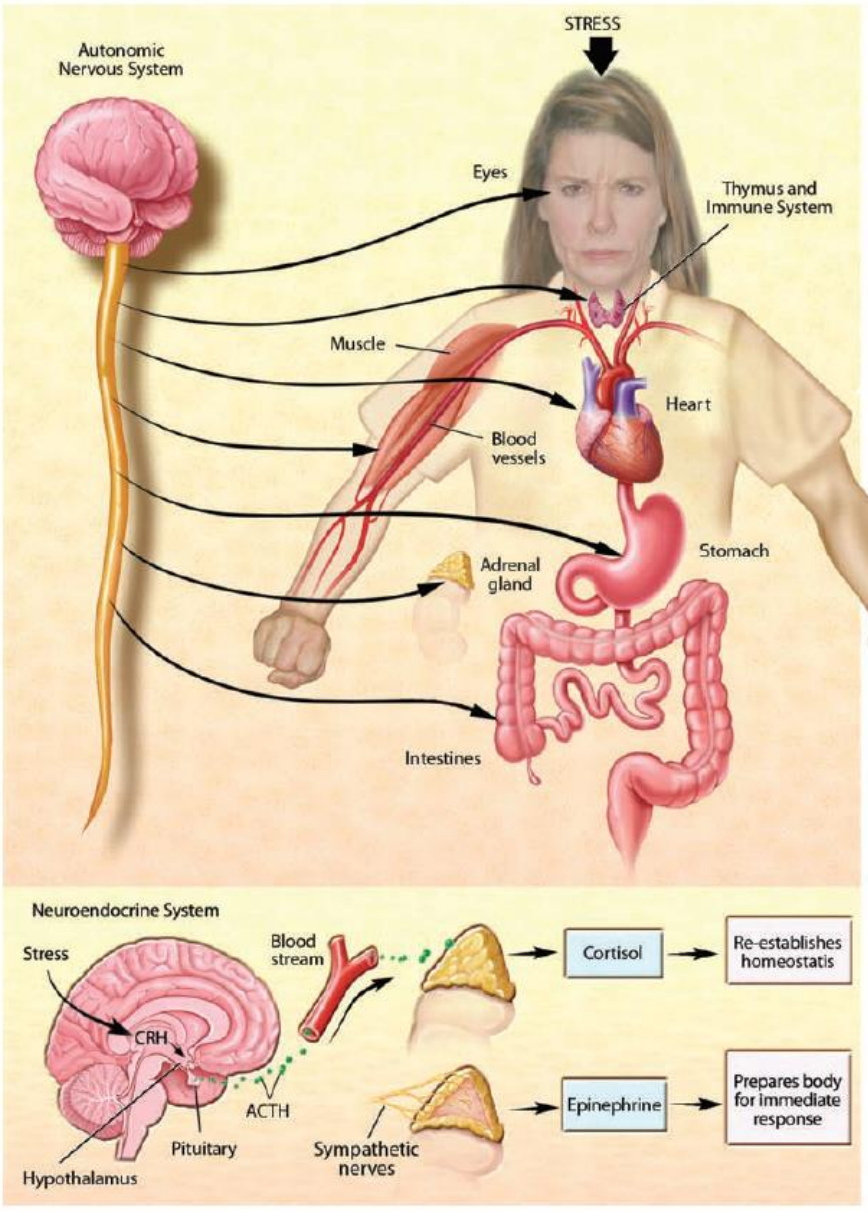
note: if there is only an arrow that means the effect has no specific receptor mentioned in the lecture

Postural orthostatic tachycardia syndrome:

Postural orthostatic tachycardia syndrome (POTS) is a condition characterized by too little blood returning to the heart when moving from a lying down to a standing up position (orthostatic intolerance). Orthostatic Intolerance causes lightheadedness or fainting that can be eased by lying back down. In people with POTS, these symptoms are also accompanied by a rapid increase in heart rate.

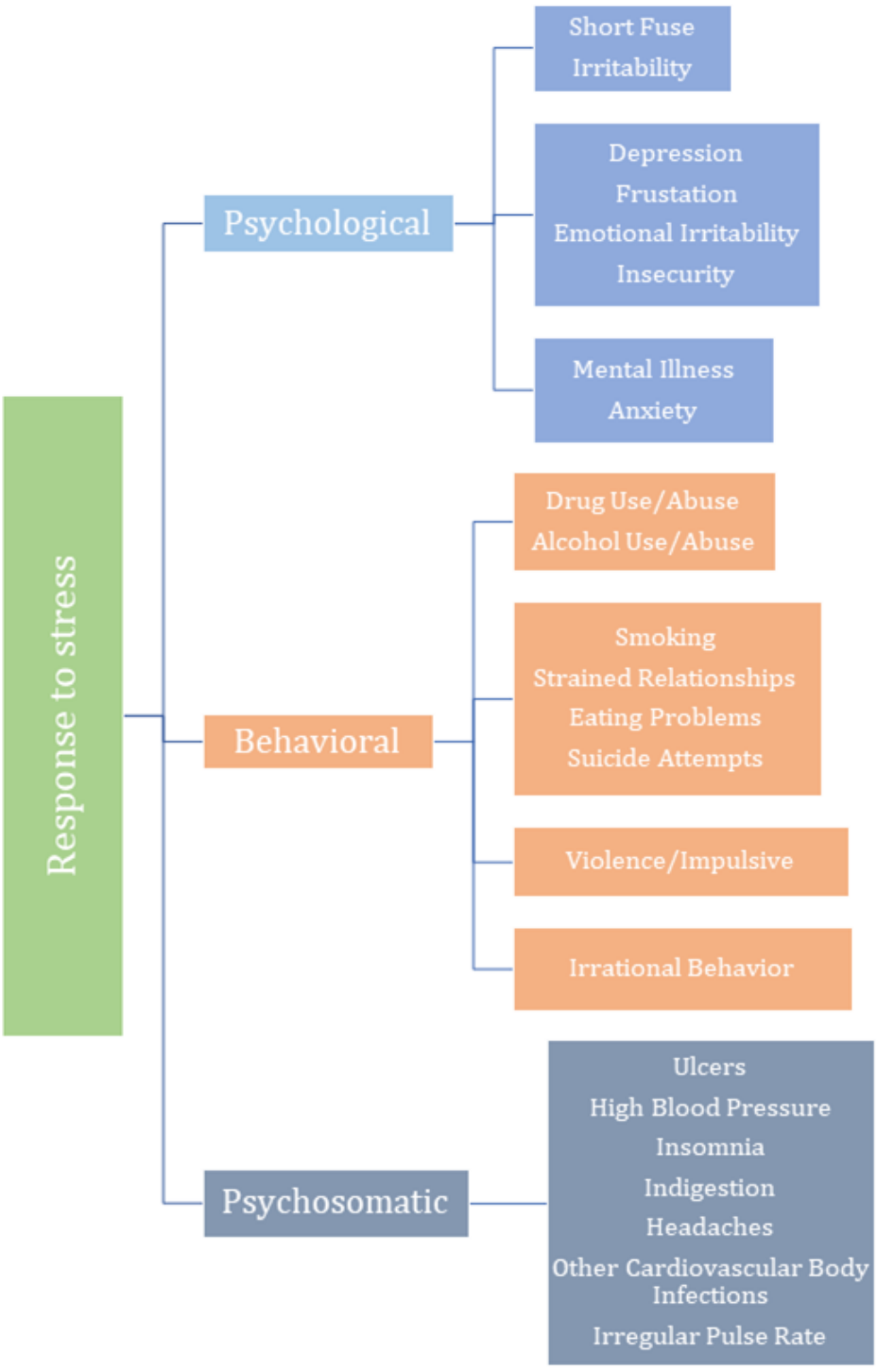
The stress reaction:

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.



1. Release of epinephrine from the adrenal medulla would initially cause
   A. hepatic glycogen synthesis
   B. decreased strength of heart contraction
   C. contraction of ciliary muscle
   D. decreased salivation

.2Targets of the autonomic nervous system include all of the following except
   A. endocrine system
   B. exocrine system
   C. skeletal muscle
   D. cardiac muscle

.3which of the following cranial nerves doesn't contain preganglionic parasympathetic fibers?
   A. II
   B. III
   C. VII
   D. IX

.4somatic motor neurons have cell bodies located _ _ the CNS that project axons only to _ _; and are usually under _ _ control
   A. inside, skeletal muscle, voluntary
   B. outside. skeletal muscle, involuntary
   C. inside, the viscera, involuntary
   D. inside, the viscera, voluntary

.5Vagus nerve carries fibers to all the following except
   A. Stomach
   B. Ureter
   C. Bladder
   D. Heart

Answers:
.1D
.2C
.3A
.4A
.5C