University of Baghdad
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Lecture in :

Physiology of The Autonomic Nervous System (ANS)

For Class-Two

By

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Physiology of The Autonomic Nervous System (ANS)

The nervous system is generally organized as follows:

I-Central nervous system (CNS) which is composed of :

1-Brain . **2-**Spinal cord.

II-Peripheral nervous system (PNS) which is composed of :

A- Efferent nerves: these are motor nerves , exiting from CNS to periphery (take information from CNS). These are composed of :

1-Somatic nerves ,which is supply skeletal muscles (motor nerve).

2-Autonomic nerves.

B- Afferent nerves, these are sensory nerves, entering the CNS(bring information from CNS). These are composed of :

1-Somatic sensory nerves, that transmit sensory information from skin, to the CNS.

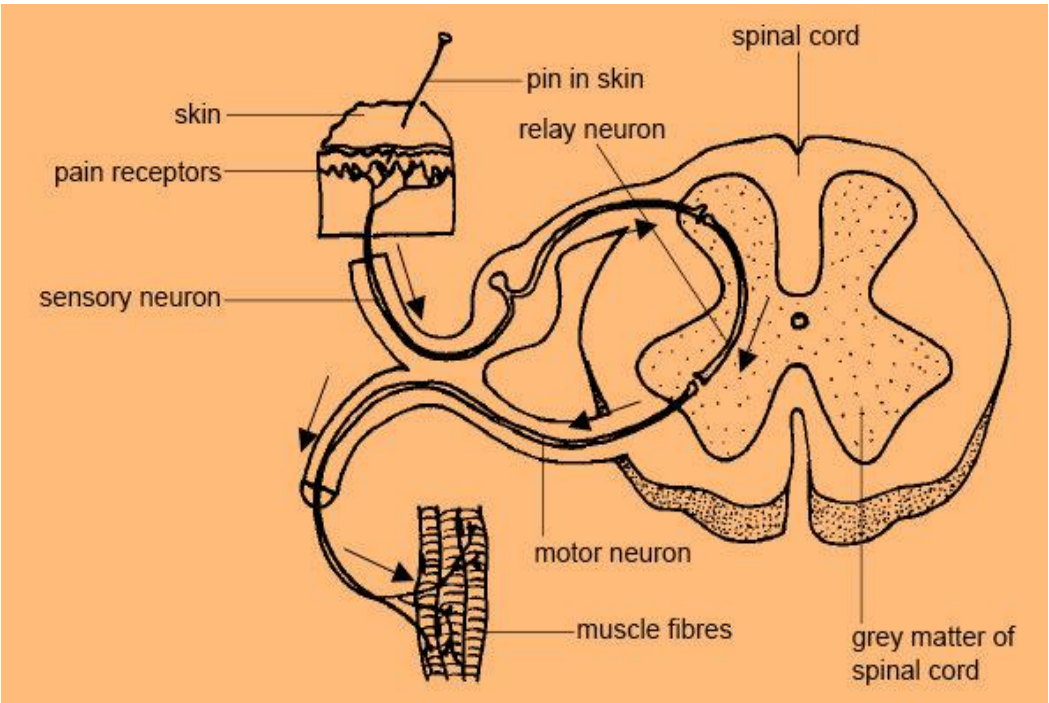
2- Visceral **sensory nerves**, that transmit sensory information from visceral organ such as blood vessels, stomach, intestine, liver, kidneys, bladder, genitals, lungs, pupils, heart, and sweat, salivary, and digestive glands to the CNS.

The sensory-somatic system consists of

- 12 pairs of **cranial nerves** and
- 31 pairs of **spinal nerves**.

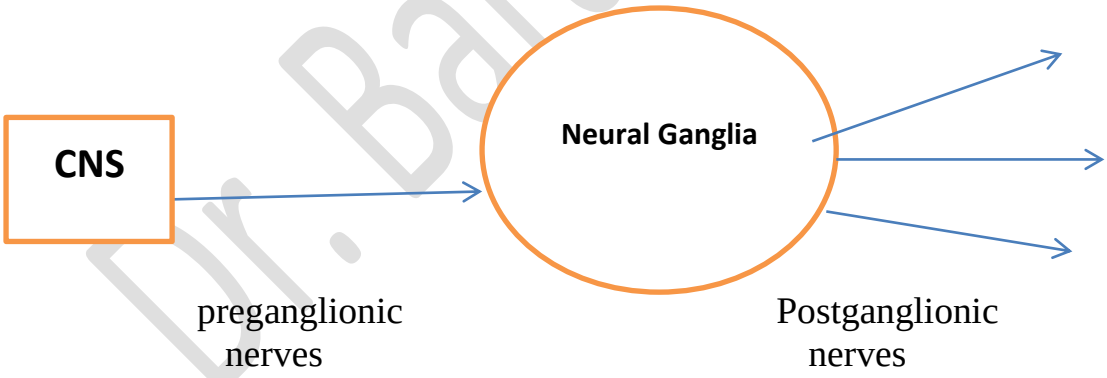
Note : The ANS works automatically in persons without any effort.

Disorders of the autonomic nervous system can affect any body part or process. Autonomic disorders may result from other disorders that damage autonomic nerves (such as diabetes).



Physiological anatomy of the reflex.

Sensory neuron = Afferent nerve
Motor neuron = Efferent nerve
Muscle fibers = Effector organ



Structure of Synapse.

The autonomic nervous system has two main divisions:

1-Sympathetic autonomic nervous system :

Sympathetic autonomic nervous system also called Thoracolumbar division (anatomically) and Sympathetic Division (physiologically).

2-Parasympathetic autonomic nervous system :

Parasympathetic autonomic nervous system also called Craniosacral division (anatomically) and Parasympathetic Division (physiologically).

After the autonomic nervous system receives information about the body and external environment, it responds by stimulating body processes usually through the sympathetic division, or inhibiting them usually through the parasympathetic division.

I- The Sympathetic autonomic nervous system :

The cell bodies of nerves of this division are located at the thoracic and lumbar positions of spinal cord { starting from first thoracic to the 3rd ((in human)) or 4th ((in animals)) of lumbar vertebrates}. So that this division is named THORACOLUMBAR.

Characters of this division (Sympathetic):

A- The axons of preganglionic nerves end on the cell bodies of postganglionic nerves at the paravertebral sympathetic ganglionic chain { Two Chains, one on each side of the vertebral column}.

B- The axons of postganglionic nerves terminate on the effector organs.

C- The axons of preganglionic nerves are short, while those of postganglionic nerves are long.

II- The Parasympathetic autonomic nervous system :

The cell bodies of preganglionic parasympathetic nerves of this division are located at the cranial in CNS and several sacral spinal nerves. So that this division is named CRANIOSACRAL.

The parasympathetic nervous system control the relaxation, or "rest-and-digest" .
This division response through **4 cranial and 2-4 sacral nerves** .

Cranial Nerves:

1- The **Oculomotor** nerve III : The oculomotor nerve controls several muscles of the eye.

2- The **Facial** nerve VII : The facial nerve has both sensory and motor nerve endings throughout the face, which are responsible for sensation and muscle movement.

3- The **Glossopharyngeal** nerve IX : The glossopharyngeal nerve has a number of functions related to taste and eating. Example this nerve control the parotid glands, the largest of the salivary glands.

4- The **Vagus** nerve X: The vagus nerve, which contains about 80 percent of all parasympathetic fibers in the body, is the most important. Fibers from the vagus nerve pass all over the body, influencing almost every organ below the neck -- including the heart, lungs, esophagus, trachea, stomach, small intestine, first part of the colon, liver, gallbladder, pancreas and ureters.

Sacral Nerves:

The sacral nerves are three spinal nerves in the sacrum **(S2-4),** commonly referred to as the pelvic splanchnic nerves, also act as parasympathetic nerves.

- **Characters of this division (parasympathetic) :**

1- The axons of preganglionic nerves are long and synapse with the cell bodies of postganglionic nerves (with short axon) at four (4) ganglia:

a) Ciliary ganglion (to the eye).

b) Sphenopalatine ganglion (to the lacrimal and nasal glands).

c) Submaxillary ganglion (to the submaxillary and sublingual glands).

d) Otic ganglion (to parotid gland).

2- The axons of postganglionic nerves terminate a very near on the effector organs.

Chemical Transmission in ANS:
Types of neurotransmitters (NT) in the ANS:

1) All preganglionic autonomic nerves (sympathetic and parasympathetic) release acetylcholine (**Ach**) at their nerve endings at the ganglia. Therefore, they are named ***Cholinergic*** nerves that release Ach to excite the postganglionic nerves.

2) All parasympathetic postganglionic nerves release Ach to the effector organ, so that they are also named ***Cholinergic*** nerves.

3) Most of the sympathetic postganglionic nerves release ***Norepinephrine*** (also named noradrenalin) to the effector organ, so that are named ***adrenergic*** nerves.

4) Some of the sympathetic postganglionic nerves release Ach to the effector organs. Therefore, they are named ***Sympathetic Cholinergic*** nerves.

The ***Sympathetic Cholinergic*** nerves anatomically they belong to the sympathetic division but physiologically they release **(Ach)** i.e. cholinergic.

Theses nerves supply the following effector organs :

A- Sweet gland.
B- Blood vessels of skeletal muscles.
C- Blood vessels of external genitalia.
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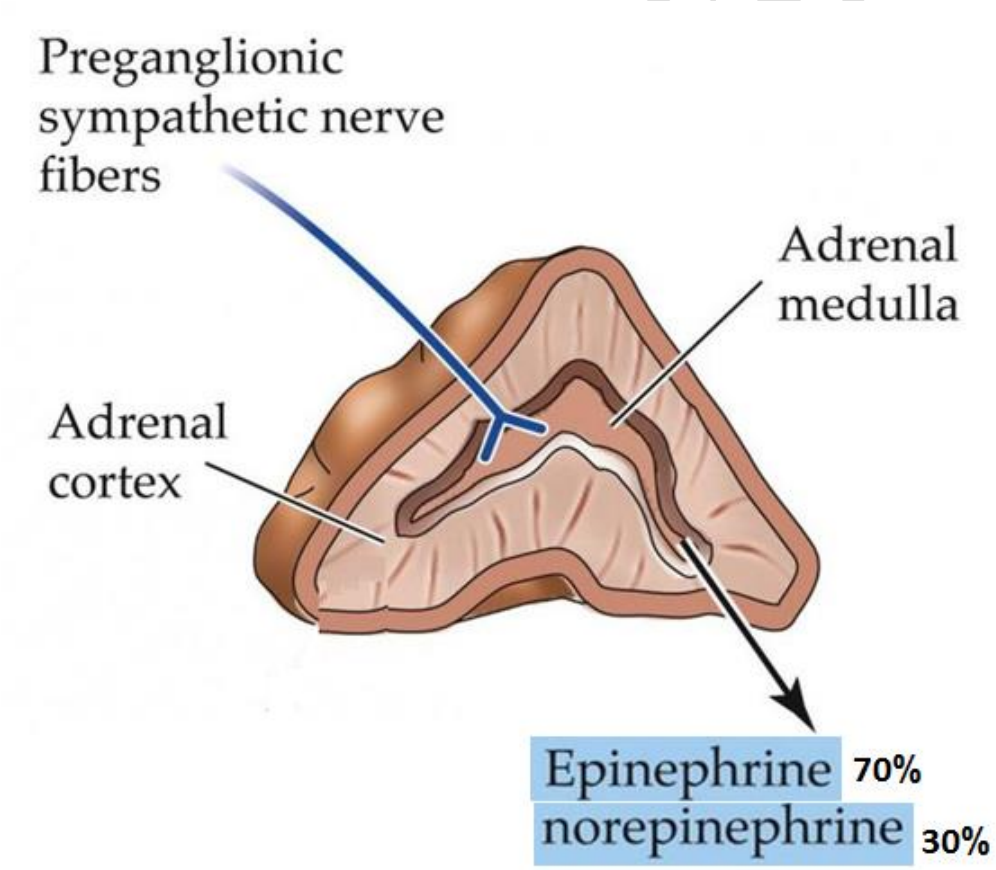
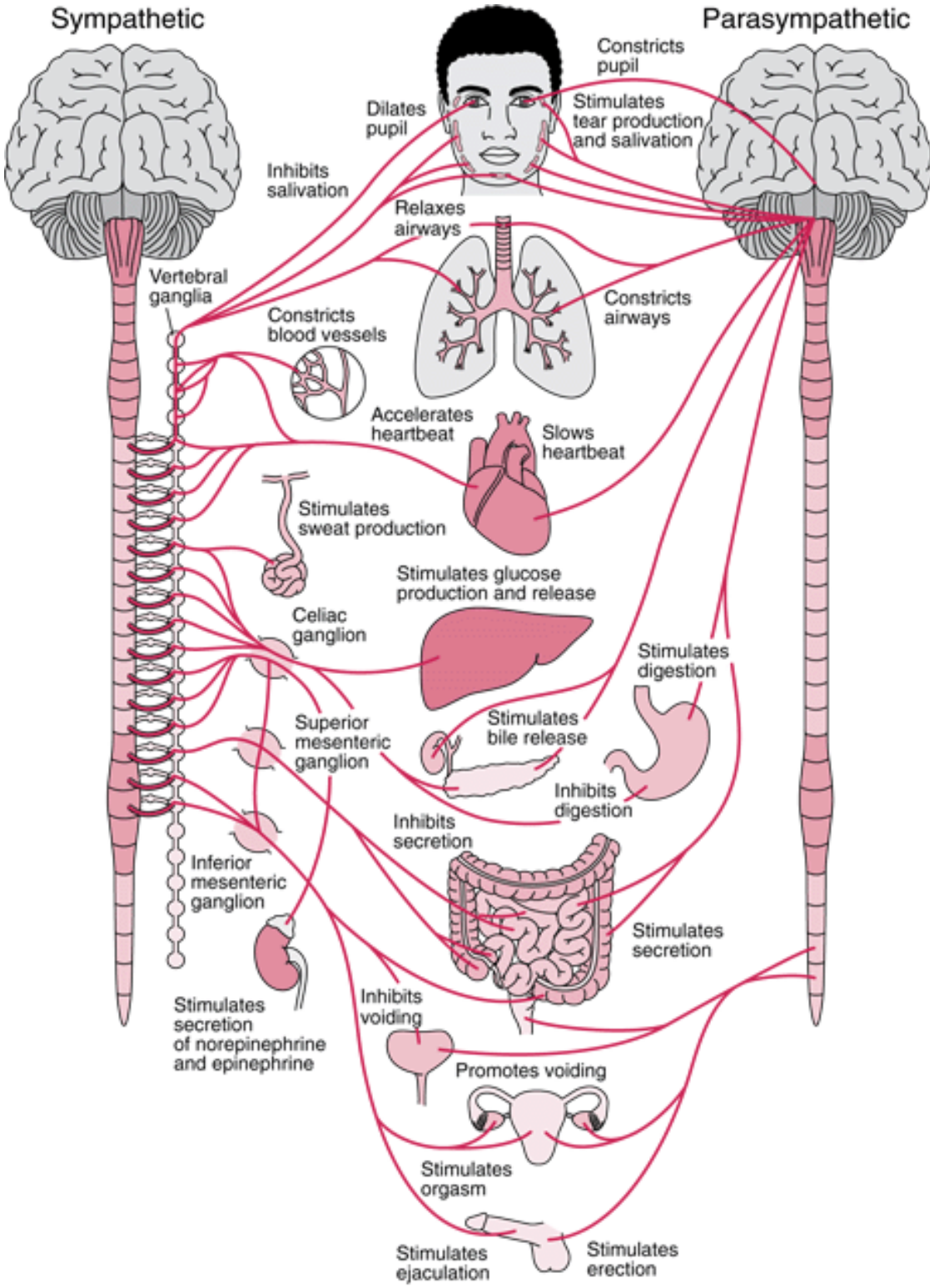
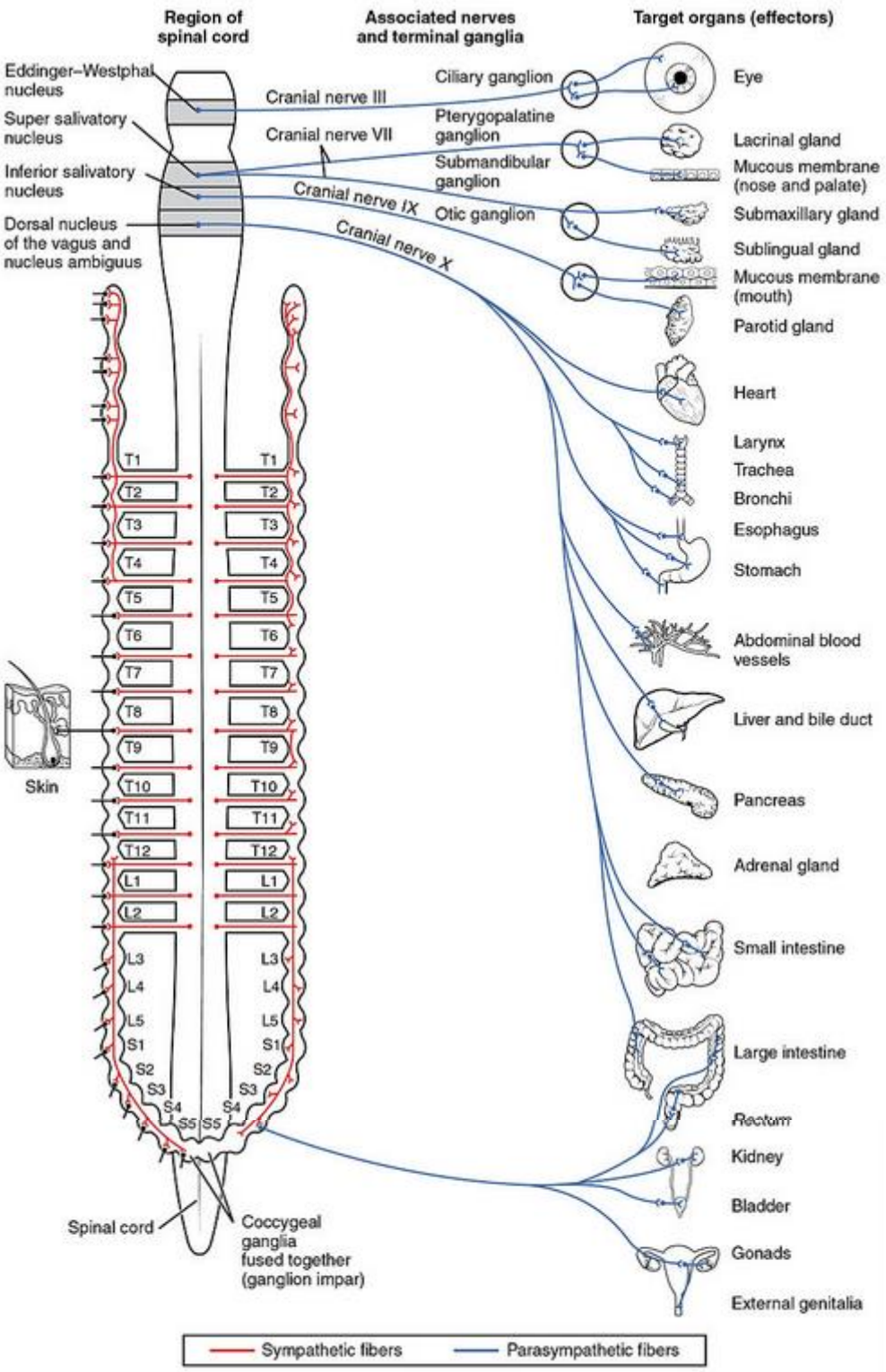
Note: The adrenal gland belongs to the sympathetic division anatomically. The preganglionic axon of sympathetic nerves ends up directly on the adrenal medulla (**without ganglion**) and release **Ach.** In response to this, the adrenal medulla release primary Epinephrine **(EP)** and some **norepinephrine (NE)** into the circulating blood as shown in the following diagram:





Anatomy of autonomic nervous system.



Parasympathetic autonomic nervous system.

Types of Receptors of ANS :

The postganglionic autonomic nerves release their NTs that bind to various types of autonomic receptors on the effector organs. The response depends on the type of receptor that is stimulated.

There are two major classes of receptors:

I- Cholinergic Receptors (which is respond to **Ach**): These are 2 subtypes of their receptors:

a- Muscarinic Cholinergic receptors :

- These receptors are stimulation by **Ach** and **muscarine.**
- They are found on vascular smooth muscles, visceral smooth muscles and cardiac muscle.
- These receptors are blocked by ***Atropin***.

b- Nicotinic Cholinergic receptors:

- These receptors are stimulation by **Ach** and **Nicotine.**
- They are found in skeletal muscles, CNS and cell bodies of postganglionic nerves.
- These receptors are blocked by **Curare**.

II- Adrenergic receptors :

- These receptors are stimulated by NE and EP and include 2 subtypes :

I- Alpha (α) adrenergic receptors , have 2 types :

a- **α_1 receptors :** found on smooth muscles of visceral organs and vascular smooth muscles.

b- **α_2 receptors :**found on the nerve endings of the postganglionic fibers.

II- Beta (β) adrenergic receptors , have 2 types :

a- **β_1** (beta one) receptors : found on cardiac muscle.

b- **β_2** (beta two)receptors : found on vascular smooth muscles and visceral smooth muscles.

Effect of sympathetic and parasympathetic stimulation on various organs :

Usually the response of each branch is opposite to the response of the other. e.g. the effect of sympathetic stimulation to the heart can increase heart rate, while the effect of parasympathetic stimulation causes decreased heart rate. Therefore, this opposite effect is to cause a balance in the function of heart.

Also this opposite effect must apply to the other organs as shown in the following **table-1:**

Table-1: Response of Effector Organs to Autonomic Nerve Stimulation.

Effector organs	**Sympathetic Stimulation (Noradrenergic impulse)**	**Parasympathetic Stimulation (muscarinic impulse)**
Circulatory System		
cardiac output	increases	decreases
SA node	β1, β2: increases in heart rate	Decreases in heart rate (vagal arrest)
atria	β1, β2: increases in contractility and conduction velocity	Decreases in contractility and increase in conduction velocity
AV node	β1, B2 : increases conduction velocity	Decreases conduction velocity
His-Purkinje system	β1, B2 : increases conduction velocity	Decreases conduction velocity
ventricles	β1, B2 : increases contractility	Decreases contractility
ARTERIES		
coronary	α : vasoconstriction	Dilation
Skin	α1,α2 : vasoconstriction	Dilation
Skeletal muscles	α1: vasoconstriction. β2: vasodilation.	Dilation
Respiratory System (Lung)		
bronchioles muscles (smooth muscles)	β2: relaxation	contraction
Bronchial gland	α 1 : inhibition	stimulation
EYE		
pupil of eye	α1: relaxes	contracts
ciliary muscle	β2: relaxation for far vision	Contraction for near vision
Digestive System		
salivary glands:	Stimulates thick, viscous secretion (localized).	stimulates profuse watery secretions (Generalized secretion) .
lacrimal glands (tears)	Decreases secretion	M3: increases secretion
Kidney		
Renin (juxtaglomerular cells)	B1 :increased renin secretion	---

liver	α1, β2: glycogenolysis,	---
Gastrointestinal tract (GIT)		
Motility and tone	decreases	increases
sphincters	contraction	relaxation
secretion	inhibition	secretion
gallbladder	relaxation	contraction
Urinary system		
Urinary bladder (Detrusor muscle)	β2: relaxation	contraction
ureter	α1: contraction	relaxation
sphincters	contraction	relaxation
Male sex organ	Ejaculation (contracts).	Erection
Uterine muscles	The effect is a variable depending on the stage of female cycle.	

The Fight and Flight Response :

OR: ALARM REFLEX. OR: EMERGENCY REFLEX

This is a cause of generalize increase in sympathetic effect and decrease parasympathetic effect . It happens upon sudden exposure to an emergency .

The increased sympathetic activity causes (release of Norepinephrine)

1. Stimulates heart beat lead to increased heart rate (Tachycardia).
2. Increased blood pressure (due to vasoconstriction).
3. Dilates the pupil of the eye (let more light enter the eyes and leading to increase vision ability).
4. Dilate the trachea and bronchi.
5. Cutaneous vasoconstriction and decrease blood flow to the skin and visceral organs.
6. Shunt blood away skeletal muscles, brain and heart.
7. Inhibits peristalsis in the gastrointestinal (GI) tract.
8. Inhibits contraction of bladder and rectum.
9. Increase glycogenolysis (causing conversion of liver glycogen into glucose to increase blood glucose concentration leading to increase metabolism of skeletal muscles).
10. Increase alertness.

The effects of the all of the above make the animal / human ready and alert to face an emergency condition and can be FIGHE or FLIGHT.

GOOD LUCK