Autonomic Nervous System

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Nervous System

- Divisions of the nervous system

- The human nervous system consists of the **central nervous System (CNS)** and the **Peripheral Nervous System (PNS)**.

- **CNS** is composed of the **brain** (located in the cranial cavity) and the **spinal cord** (located in the vertebral cavity), which serve as the main control centers for all body activities.

- **PNS** is composed of nerves derived from the brain and spinal cord (12 pairs of **cranial nerves** and 31 pairs of **spinal nerves**) which serve as linkage between the CNS and the body.
ANS Versus SNS

- PNS can be subdivided into sensory (afferent) nerves and motor (efferent) nerves. Sensory nerves send nerve impulse from the body to CNS to effector organs.

- Motor nerves are divided into the somatic nervous system (SNS) which regulates the voluntary contraction of the skeletal muscles, and autonomic nervous system (ANS) which regulates the involuntary control of smooth, cardiac muscles and glands.
Finally, the ANS can be divided into sympathetic and parasympathetic branches where in general **sympathetic nerves** stimulate activities of the effect or organs (except digestive organs) and **parasympathetic nerves** inhibit activities of the effect or organs (except digestive organs).
Comparison of Somatic and Autonomic Systems

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<th>Somatic Nervous System</th>
<th>Autonomic Nervous System</th>
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<td>Cell bodies in central nervous system</td>
<td>Two-neuron chain from CNS to effector organs</td>
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<td>Single neuron from CNS to effector organs</td>
<td>Heavily myelinated axon</td>
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<td>Neuron at effector</td>
<td>Skeletal muscle</td>
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<td>Effect</td>
<td>Stimulatory</td>
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<th>Autonomic Nervous System</th>
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<td>Lightly myelinated preganglionic axon</td>
<td>Lightly myelinated preganglionic axon</td>
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<td>Ganglion</td>
<td>Ganglion</td>
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<tr>
<td>Nonmyelinated postganglionic axon</td>
<td>Nonmyelinated postganglionic axon</td>
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<tr>
<td>Acetylcholine (ACh)</td>
<td>Acetylcholine (ACh)</td>
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<td>Norepinephrine (NE)</td>
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<td>Effect</td>
<td>Stimulatory or inhibitory, depending on neurotransmitter and receptors on effector organs</td>
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ANS together with the endocrine system controls the body's internal organs. It innervates smooth muscles, cardiac muscle, and glands, controlling the circulation of blood, activity of the G.I. Tract and body temp.

**Characteristics:**

1. Innervates smooth muscle, cardiac muscle and glands of internal organs.

2. Involuntary, are reflexes controlled.

3. Two neuron chain

   a. Preganglionic neurons – originate in the brain or spinal cord.

   b. Postganglionic neurons – originate in the ganglion located outside the CNS.
Anatomy of ANS

**Parasympathetic**

1. Fibers originate in the brain stem (cranial fibers) or sacral spinal cord.
2a. Preganglionic fibers are long.
2b. Postganglionic fibers are short.
3. Ganglia are within or near visceral effector organs.

**Sympathetic**

1. Fibers originate in the thoracic and lumbar spinal cord.
2a. Preganglionic fibers are short.
2b. Postganglionic fibers are long.
3. Ganglia are close to spinal cord.
ANS

Two neuron chain:

- a. cell body of first neuron is in CNS.

- b. Axon of first neuron: preganglionic fibers synapse with soma of second neuron.

- c. second neuron is in ganglia outside the CNS (in PNS).

- d. Axon of second neuron: postganglionic fibers innervates effecter organ.

- e. Two divisions

  - sympathetic

  - parasympathetic
Sympathetic Nervous System

- Generally stimulates the effector organ (except in digestive tract)
- It is activated in emergencies, flight– or– fight reaction, in the sense that the body can either quickly flee or "take a stand".

Homeostasis is a dynamic balance between the autonomic branches.

Rest-and-digest: Parasympathetic activity dominates.  
Fight-or-flight: Sympathetic activity dominates.
The pregangionic fibers of the sympathetic nervous system produce Acetylcholine and are called cholinergic fibers.

Most postganglionic fibers produce norepinephrine (noradrenalin) and are called adrenergic fibers (exceptions are the sweat glands and blood vessels in skin).

Location of ganglia is within a few cm of CNS, along the vertebral column (Para vertebral and prevertebral [collateral] ganglia).

Sympathetic fibers originate from the thoracolumbar region of the spinal cord (T₁ – L₂).
Sympathetic Nervous System

- Short preganglionic fibers.
- Long postganglionic fibers.
- Postganglionic fibers are distributed throughout the body.
- Postganglionic fibers run from the ganglion to the organs that they supply.
Parasympathetic division

Generally inhibits the effector organ (except in digestive tract).

All pre and postganglionic fibers product Ach and are cholinergic.

Location of ganglia (terminal ganglia) is in or near effector organ.

Preganglionic fibers arise from the CNS (brain stem) and sacral region of spinal cord ($S_2 - S_4$).

Long preganglionic fibers.

Short postganglionic fibers.

Postganglionic fibers are limited to the head, viscera of chest, abdomen and pelvis.
Parasympathetic Division Outflow
<table>
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<th>Division</th>
<th>Origin of Fibers</th>
<th>Length of Fibers</th>
<th>Location of Ganglia</th>
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<td>Thoracolumbar region of the spinal cord</td>
<td>Short preganglionic and long postganglionic</td>
<td>Close to the spinal cord</td>
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<tr>
<td>Parasympathetic</td>
<td>Brain and sacral spinal cord</td>
<td>Long preganglionic and short postganglionic</td>
<td>In the visceral effector organs</td>
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Adrenergic receptors:

- in General, NE or epinephrine binding to alpha-receptors are stimulatory while their binding to beta-receptors are inhibitory.

- Both and receptors have distinct subtypes (alpha_1, alpha_2, beta_1, beta_2).
Alpha-1 & Alpha-2 Receptors

**Alpha-1 receptors:**

- reflect the "flight or fight" RX.
- cause constriction of blood vessels (control of B.P.).
- Inhibit motility in the gut by contracting sphincter muscles and relaxing non–sphincter tissue.
- Mobilize energy by breaking down liver glycogen to glucose.

**Alpha-2 receptors:**

- found in pre–synaptic membranes and provide feed back control of neurotransmitter secretion (inhibit Ca^{++} influx, decrease neurotransmitter release).
Beta-1 & Beta-2 Receptors:

- **beta-1 receptors:**
  - well known for their effects in the heart (increase rate and force of contraction).
  - induce muscle relaxation in the gut.

- **beta-2 receptors:**
  - Induce bronchiodilation.
  - Induce smooth muscle relaxation in the gut.
  - Induce conversion of glycogen to glucose.
  - Stimulate secretion of insulin from pancreas.
Cholinergic Receptors:

- **Nicotinic receptors:**
  - Are all excitatory.
  - Their response is rapid (milliseconds).

- **Muscarnic receptors:**
  - Either excitatory or inhibitory, depending on the target organ.
  - Have distinct subtypes (M_1, M_2, M_3).
  - Decrease heart activity.
  - Increase motility in G.I. tract.
  - Depolarization of smooth muscle fibers, hyperpolarization of cardiac muscle fibers.
1. Oculomotor nerve (III)
   - Innervates smooth muscles of eye, causing it to constrict.

2. Facial nerve (VII)
   - Stimulates the secretary activity of glands in the head.
   - Ex. Nasal glands, lacrimal gland, submandibular, salivary, & parotid glands.
Cranial Nerves with Parasympathetic outflow

3. Glossopharyngeal never (IX)
   - Activates the parotid, and salivary glands.

4. Vagus nerve (X)
   - Two vagus nerves account for 90% of all preganglionic parasympathetic fibers in the body.
   - Major portion of parasympathetic cranial outflow is via vagus nerve.
   - Mixed nerve containing both sensory and motor fibers.
   - Sensory input from medulla to cardiovascular, pulmonary, urinary, reproductive, and digestive system travels in the afferent fibers of the vagus nerve.
Cranial Nerves with Parasympathetic outflow

- Pons
- Ganglia (inferior and superior)
- Medulla oblongata
- Vagus nerve (X)
- Jugular foramen
- Pharyngeal nerve branches
- Carotid sinus and body
- Laryngeal branches
- Lung
- Heart
- Spleen
- Liver
- Gallbladder
- Stomach
- Kidney
- Small intestine
- Colon (proximal portion)

- Parotid gland
- Parasympathetic fibers
- Glossopharyngeal nerve (IX)
- Jugular foramen
- Superior ganglion
- Inferior ganglion
- Otic ganglion
- Stylopharyngeus
- Carotid sinus
- Pharyngeal muscles
- Common carotid artery
Other Receptors

- **Lungs:**
  a. **Stretch receptors**
  
  b. **Type J receptors**

  a. **Stretch receptors:** Inhibits further inhalation, cardiac rate, and vasodilation.

  b. **Type J receptors:** Increase pulmonary congestion.

  produces feelings of breathlessness and causes a reflex fall in cardiac rate and blood pressure.

- **Aorta:** **chemoreceptors** – stimulated by rise in CO$_2$ and fall in O$_2$, produce increase rate of breathing, rise in heart rate, and vasoconstriction.
Visceral Reflexes

1. Receptor in viscera
2. Visceral sensory neuron
3. Integration center
   - May be preganglionic neuron (as shown)
   - May be a dorsal horn interneuron
   - May be within walls of gastrointestinal tract
4. Motor neuron (two-neuron chain)
   - Preganglionic neuron
   - Postganglionic neuron
5. Visceral effector

Dorsal root ganglion
Spinal cord
Autonomic ganglion
Other Receptors

- a. Baroreceptors
  - Heart:
    - b. Arterial stretch receptors
    - c. Stretch receptors in ventricles

- a. Baroreceptors: stimulated by increased blood pressure – produces a reflex decrease in heart rate.

- b. Arterial stretch receptors:

  Antidiuretic hormone secretion inhibited, thus increase the volume of urine excreted.
Other receptors

- c. stretch receptors in ventricles:
  produces a reflex in Hear rate and vasodilation.

- d. stretch receptors in G.I. tract:
  fleeing of satiety, discomfort and pain.
Pain stimuli arising from the viscera are perceived as somatic in origin. This may be due to the fact that visceral pain afferents travel along the same pathways as somatic pain fibers.
Effects of autonomic Stimulation

- Skin: Apocrine gland (S): secretion
  Eccrine gland (P): no Action

- **Special senses:**

- Iris of eye (S): Dilation
  (P): constriction

- Tear gland (S): Inhibitory
  (P): secretion

- **Endocrine system:**

- Adrenal cortex (S): secretion

- And medulla (P): no Action
Effects of autonomic Stimulation

- Digestive system:
  - Gall bladder: (s): relaxation
    (p): constriction
  - Intestine: (s): decrease peristalsis
    (p): Increase peristalsis
  - Smooth muscle: (s): relaxes
    (p): Contracts
  - Sphincters: (s): constricts
    (p): Relaxes
Effects of autonomic Stimulation

- **Secretion**: (s): increase, (p): decrease
- **pancreas**: (s): decrease, (p): Increase

- **Respiratory System**: (s): dilate bronchioles, (p): constrict bronchioles

- **Heart Muscle**: (s): increase heart rate, (p): decrease heart rate
Effects of autonomic Stimulation

Blood vessels of skin & others:

(S): constriction

(P): no action

Urinary system:

Bladder (S): Relaxation

(P): contraction

Urinary sphincter (S): contraction

(P): relaxation
Effects of autonomic Stimulation

- **penis**: (S): causes erection
  
  (P): causes ejaculation

- **Vagina**: (S): causes erection of clitoris
  
  (P): causes contraction of vagina