

THE AUTONOMIC NERVOUS SYSTEM

Chapter 15

Anatomy and Physiology Lecture

THE AUTONOMIC NERVOUS SYSTEM

Autonomic Nervous System (ANS) regulates the activity of smooth muscles, cardiac muscles, and certain glands.

-Structurally, the ANS includes two main components:

- (i) General visceral sensory (Afferent) neurons; and
- (ii) General visceral motor (Efferent) neurons.

-Functionally, the ANS usually operates without conscious control.

(The system was originally named autonomic because it was thought to function autonomously or in a self-governing manner, without control by the central nervous system (CNS).

-ANS, however, is regulated by centers in the brain, mainly the hypothalamus and medulla oblongata.

Contrasting the Somatic And Autonomic Nervous Systems

Peripheral Nervous System (PNS) – Is composed of Sensory and Motor Neurons.

Sensory Neurons – Carry action potentials from the peripheral to the central nervous system (CNS).

Motor Neurons – Carry action potentials from the central nervous system (CNS) to the periphery.

Two Subdivisions of the Motor Neurons:

1. **Somatic Motor Neurons** – Innervate skeletal muscles.
2. **Autonomic Motor Neurons** – Innervate smooth muscles, cardiac muscle, and glands.

Organization of Somatic and Autonomic Nervous System Neurons

Somatic Motor Pathway – Cell bodies are in the CNS and their axons extend from the CNS to skeletal muscle.

Autonomic Motor Pathways – Consist of sets of two motor (efferent) neurons in series (one following the other).

- (1) The first (preganglionic neuron) has its cell body in the CNS; its axon extends from the CNS to an autonomic ganglion.

Ganglion is a collection of neuronal cell bodies outside the CNS.

- (2) The second (postganglionic neuron) has its cell body in the Autonomic ganglion; its axon extends directly from the ganglion to the effector (smooth muscle, cardiac muscle, or gland).

*Somatic Motor Neurons release Acetylcholine (ACh) as their neurotransmitter.

*Autonomic Motor Neurons release either Acetylcholine (ACh) or Norepinephrine (NE).

Note: Sensory neurons are not classified as somatic or autonomic. These neurons propagate action potentials from sensory receptors to the CNS and can provide information from reflexes mediated through the somatic nervous system or autonomic nervous system.

Anatomy Of The Autonomic Nervous System

Two Principal Divisions Of Autonomic Nervous System (ANS):

1. Sympathetic Division
2. Parasympathetic Division

Differences Between Sympathetic and Parasympathetic Divisions:

1. Location of their preganglionic neuron cell bodies within the CNS.
2. Location of their autonomic ganglia.

Sympathetic Division

Sympathetic division is sometimes called **Thoracolumbar division** because the cell bodies of sympathetic preganglionic neurons are in the lateral horns of the spinal cord gray matter between the first thoracic (T1) and the second lumbar (L2).

Sympathetic chain ganglia – Because they are connected to one another and form a chain.

Paravertebral ganglia – Because they are located along both sides of the vertebral column.

White ramus communicans – The short connection between a spinal nerve and a sympathetic chain through which the preganglionic axons pass.

Four Routes by which Sympathetic Axons exit the Sympathetic Chain Ganglia :

1. Spinal nerve
2. Sympathetic nerve
3. Splanchnic nerve
4. Innervation to the adrenal gland

Parasympathetic Division

Parasympathetic preganglionic neurons are located both superior and inferior to the thoracic and lumbar regions of the spinal cord where sympathetic preganglionic neurons are found.

Parasympathetic preganglionic is sometimes called the **Craniosacral Division** because the cell bodies of parasympathetic preganglionic neurons are either within cranial nerve nuclei in the brainstem or within the lateral parts of the gray matter in the sacral region of the spinal cord from S2-S4.

Note: Comparison of the Sympathetic and Parasympathetic Divisions

*Organs that receive impulses from both sympathetic and parasympathetic fibers are said to have dual innervation.

Enteric Nervous System

Enteric Nervous System – Consists of nervous plexuses within the wall of the digestive tract.

Three Sources of Plexuses Contribution:

1. Sensory neurons that connect the digestive tract to the CNS.
2. ANS motor neurons that connect the CNS to the digestive tract.
3. Enteric neurons, which are confined to the enteric plexuses.

Several major Types of Enteric Neurons:

1. Enteric sensory neurons can detect changes in the chemical composition of the contents of the digestive tract or detect stretch of the digestive tract wall..
2. Enteric motor neurons can stimulate or inhibit smooth muscle

contraction and gland secretion.

3. Enteric interneurons connect enteric sensory and sensory and motor neurons to each other.

Note: Although the enteric neurons are capable of controlling the activities of the digestive tract completely independently of the CNS, normally the two systems work together.

The Distribution of autonomic nerve Fibers

Sympathetic Division

Sympathetic axons pass from the Sympathetic chain ganglia to their target tissues through spinal, sympathetic, and splanchnic nerves.

Autonomic nerve plexuses – Are complex, interconnected neural networks formed by neurons of the sympathetic and parasympathetic divisions.

- Are named according to organs they supply or to blood vessels along which they are found.

Major Means by Which Sympathetic Axons Reach Organs:

1. Spinal nerve
2. Head Neck Nerve Plexuses
3. Thoracic Nerve Plexuses
4. Abdominopelvic Nerve Plexuses

Parasympathetic Division

Parasympathetic outflow is through cranial and sacral nerves.

Major Means By Which Parasympathetic Axons Reach Organs:

1. Cranial Nerve Supplying the Head and Neck.
 - (a) **Oculomotor (III) Nerve**, through the **Ciliary Ganglion**, supplies the **Ciliary muscles** and **Iris of the eye**.
 - (b) **Facial (VII) Nerve**, through the **Pterygopalatine Ganglion**, supplies the **Lacrimal gland** and **Mucosal glands** of the nasal cavity and palate. **Facial nerve**, through the **Submandibular Ganglion**, also supplies the **Submandibular** and **Sublingual salivary glands**.
 - (c) **Glossopharyngeal (IX) Nerve**, through the **Otic Ganglion**, supplies the **Parotid gland**.
2. The Vagus Nerve and Thoracic Nerve plexuses.
3. Abdominal Nerve Plexuses.
4. Pelvic Nerves and Pelvic Nerve Plexuses.

Physiology Of The Autonomic Nervous System

NEUROTRANSMITTERS

Two Neurotransmitters secreted by the Sympathetic and Parasympathetic Nerve Endings:

1. **Cholinergic Neuron** secretes **Acetylcholine**.
2. **Adrenergic Neuron** secretes **Norepinephrine**.

Note: All Preganglion neurons of the Sympathetic and Parasympathetic divisions and all Postganglionic neurons of the Parasympathetic division are Cholinergic.

Almost all Postganglionic neurons of the Sympathetic division are Adrenergic, but a few Postganglionic neurons that innervate thermoregulatory sweat glands are Cholinergic.

RECEPTORS

Receptors for acetylcholine and norepinephrine are located in the plasma membrane of certain cells.

Cholinergic Receptors

Two Major Structurally Different Receptors:

1. **Nicotinic Receptors** – Bind to nicotine, an alkaloid substance found in tobacco.
2. **Muscarinic Receptors** – Bind to muscarine, and alkaloid extracted from some poisonous mushrooms.

Adrenergic Receptors

Norepinephrine or epinephrine can bind to adrenergic receptors.

Two Major Subdivisions of Adrenergic Receptors:

- 1 **Alpha Receptor**
- 2 **Beta Receptor**

Note:

Effects of the Sympathetic and Parasympathetic Divisions on Various Tissues.

Clinical Focus – The Influence of Drugs on the Autonomic Nervous System.

REGULATION OF THE AUTONOMIC NERVOUS SYSTEM

Much of the regulation of structures by the ANS occurs through autonomic reflexes, but input from the cerebrum, hypothalamus, and other areas of the brain allows conscious thoughts and actions, emotions, and other CNS activities to influence autonomic functions.

Autonomic Reflexes – Like other reflexes, involve sensory receptors; sensory, association, and motor neurons; and effector cells.

Example: **Baroreceptors (stretch receptors)** in the walls of large arteries near the heart detect changes in blood pressure, and sensory neurons transmit information from the baroreceptors through the glossopharyngeal and vagus nerves to the medulla oblongata.

Brainstem and **Spinal Cord** contain important autonomic reflex centers responsible for maintaining homeostasis.

Note: **Hypothalamus** is the overall control of the ANS.

Hypothalamus has connections with the cerebrum and is an important part of the limbic system, which plays an important role in emotions.

Hypothalamus integrates thoughts and emotions to produce ANS responses. Pleasant thoughts of a delicious banquet initiate increased secretion by salivary glands and by glands within the stomach and increased smooth muscle contraction within the digestive system. Enteric Nervous System is involved with autonomic and local reflexes that

regulate the activity of the digestive tract.

Neurons of the Enteric nervous system also operate independently of the CNS to produce local reflexes.

Local reflex does not involve the CNS, but it does produce an involuntary, unconscious, stereotypic response to a stimulus.

FUNCTIONAL GENERALIZATION ABOUT THE AUTONOMIC NERVOUS SYSTEM

Generalizations can be made about the function of the ANS and effector organs, but most of the generalizations have exceptions.

Stimulatory Versus Inhibitory Effects

Both divisions of the ANS produce stimulatory and inhibitory effects.

Example:

Parasympathetic division stimulates contraction of the urinary bladder and inhibits the heart, causing a decrease in heart rate.

Sympathetic division causes vasoconstriction by stimulating smooth muscle contraction in blood vessel walls and produces dilation of lung air passageways by inhibiting smooth muscle contraction in the walls of the passageways.

Note: It is not true that one division of the ANS is always stimulatory and the other is always inhibitory.

Dual Innervation :

Most organs that receive autonomic neurons are innervated by both the parasympathetic and the sympathetic divisions.

Opposite Effects

When a single structure is innervated by both autonomic divisions, the two divisions usually produce opposite effects on the structure.

Cooperative Effects

One autonomic division can coordinate the activities of different structures.

Both divisions of the ANS can act together to coordinate the activity of different structures.

General Versus Localized Effects

The sympathetic division has a more general effect than the parasympathetic division because activation of the sympathetic division often causes secretion of both epinephrine and norepinephrine from the adrenal medulla.

The sympathetic division diverges more than parasympathetic division.

Sympathetic stimulation often activates many different kinds of effector organs at the same time as a result of CNS stimulation or epinephrine and norepinephrine release from the adrenal medulla.

Functions at Rest Versus Activity

Note: In cases in which both sympathetic and parasympathetic neurons innervate a single organ:

(a) **Sympathetic division** has a major influence under conditions of physical activity or stress.

(b) **Parasympathetic division** tends to have a greater influence under resting conditions.

Note: In general, the Sympathetic division decreases the activity of organs not essential for the maintenance of physical activity and shunts blood and nutrients to structures that are active during physical exercise.

Sometimes called the **Fight-or-flight response**.

Typical Responses Produced By the Sympathetic Division During Exercise:

1. Increased heart rate and force of contraction increase blood pressure and the movement of blood.
2. As skeletal or cardiac muscle contracts, oxygen and nutrients are used and waste products are produced. During exercise, a decrease in oxygen and nutrients and an accumulation of waste products are stimuli that cause vasodilation of muscle blood vessels. Vasodilation is beneficial because it increases blood flow, brings needed oxygen and nutrients and removing waste products. Too much vasodilation, however, can cause a decrease in blood pressure that decreases blood flow. Note: Increased stimulation of skeletal muscle blood vessels by sympathetic nerve during exercise causes vasoconstriction that prevents a drop in blood pressure.
3. Increased heart rate and force of contraction potentially increases blood flow through tissues. Vasoconstriction of blood vessels in tissue not involved in exercise, such as abdominopelvic organs, reduce blood flow

through them, thus making more blood available for the exercising tissues.

4. Dilation of air passageways increases air flow into and out of the lung.

5. The availability of energy sources increases. Skeletal muscle cells and liver cell (hepatocytes) are stimulated to break down glucose. Skeletal muscle cells use the glucose and liver cells release it into the blood, which are used as a energy source by skeletal and cardiac muscle.

6. As exercising muscle generate heat, body temperature increases. Vasodilation of blood vessels in the skin brings warm blood close to the surface, where heat is lost to the environment. Sweat glands activity increases, resulting in increased sweat production, and evaporation of the sweat removes additional heat.

7. The activities of organs not essential for exercise decrease. For example, the process of digesting food slow as digestive glands decrease their secretions and the contractions of smooth muscle that mix and move food through the gastrointestinal tract decrease.

Note: Increased activity of the parasympathetic division is generally consistent with resting condition.

The acronym **SLUDD** can be used to remember activities that increase as a result of parasympathetic activity.

S – Salvation

L – Lacrimation (tear production)

U – Urination

D – Digestion

D – Defecation

Activities that decrease as a result of increased parasympathetic activity are:

(a) Heart rate

(b) Diameter of air passageways

(c) Diameter of the pupils

Clinical Focus – Biofeedback, Meditation, and the Fight-or-Flight Response.

Clinical Focus – Disorders of the Autonomic Nervous System.