

## CHAPTER 15

### LECTURE OUTLINE

#### I. INTRODUCTION

- A. The autonomic nervous system (ANS) regulates the activity of smooth muscle, cardiac muscle, and certain glands.
- B. Operation of the ANS to maintain homeostasis, however, depends on a continual flow of sensory afferent input, from receptors in organs, and efferent motor output to the same effector organs.
  - 1. Structurally, the ANS includes autonomic sensory neurons, integrating centers in the CNS, and autonomic motor neurons.
  - 2. Functionally, the ANS usually operates without conscious control.
- C. The ANS is regulated by centers in the brain, mainly the hypothalamus and medulla oblongata, which receive input from the limbic system and other regions of the cerebrum.

#### II. COMPARISON OF SOMATIC AND AUTONOMIC NERVOUS SYSTEMS

- A. The somatic nervous system contains both sensory and motor neurons.
- B. The somatic sensory neurons receive input from receptors of the special and somatic senses.
  - 1. These sensations are consciously perceived.
- C. Somatic motor neurons innervate skeletal muscle to produce conscious, voluntary movements.
  - 1. The effect of a motor neuron is always excitation.
- D. The autonomic nervous system contains both autonomic sensory and motor neurons.
  - 1. Autonomic sensory neurons are associated with interoceptors.
    - a. Autonomic sensory input is not consciously perceived.
  - 2. The ANS also receives sensory input from somatic senses and special sensory neurons.
- E. The autonomic motor neurons regulate visceral activities by either increasing (exciting) or decreasing (inhibiting) ongoing activities of cardiac muscle, smooth muscle, and glands.
- F. Most autonomic responses can not be consciously altered or suppressed.
- G. All autonomic motor pathways consists of two motor neurons in series (Figure 15.1).
  - 1. The axon of the first motor neuron of the ANS extends from the CNS and synapses in a ganglion with the second neuron.

2. The second neuron synapses on an effector. Preganglionic fibers release acetylcholine and postganglionic fibers release acetylcholine or norepinephrine.
3. The output (efferent) part of the ANS is divided into two principal parts: the sympathetic and the parasympathetic divisions. Organs that receive impulses from both sympathetic and parasympathetic fibers are said to have dual innervation.
4. Table 15.1 summarizes the similarities and differences between the somatic and autonomic nervous systems.

### **III. ANATOMY OF AUTONOMIC MOTOR PATHWAYS**

#### **A. Anatomical Components**

1. The first of two autonomic motor neurons is called a preganglionic neuron (Figure 15.1b)
  - a. Its cell body is in the brain or spinal cord.
  - b. Its myelinated axon, called a preganglionic fiber, passes out of the CNS as part of a cranial or spinal nerve, later separating from the nerve and extending to an autonomic ganglion where it synapses with the postganglionic neuron.
2. The postganglionic neuron, the second neuron in the autonomic motor pathway, lies entirely outside the CNS (Figure 15.1)
  - a. Its cell body and dendrites are located in an autonomic ganglion, where it makes synapses with one or more preganglionic fibers.
  - b. The axon of a postganglionic neuron, the postganglionic fiber, is unmyelinated and terminates in a visceral effector.

#### **B. Preganglionic Neurons**

1. The cell bodies of sympathetic preganglionic neurons are in the lateral gray horns of the 12 thoracic and first 2 or 3 lumbar segments (Figure 15.2).
  - a. This division is called the thoracolumbar division.
2. The axons of the sympathetic preganglionic neurons are known as the thoracolumbar outflow.
3. The cell bodies of parasympathetic preganglionic neurons are in cranial nerve nuclei (III, VII, IX, and X) in the brain stem and lateral gray horns of the second through fourth sacral segments of the cord (Figure 15.3).
4. The parasympathetic division is known as the craniosacral division.

- a. The axons of the parasympathetic preganglionic neurons are referred to as the craniosacral outflow.

### **C. Autonomic Ganglia**

#### **1. Sympathetic Ganglia**

- a. These ganglia include the sympathetic trunk or vertebral chain or paravertebral ganglia that lie in a vertical row on either side of the vertebral column (Figures 15.2).
- b. Other sympathetic ganglia are the prevertebral or collateral ganglia that lie anterior to the spinal column and close to large abdominal arteries. They include the celiac, superior mesenteric, and inferior mesenteric ganglia. (Figures 15.2 and 17.5).
- c. Sympathetic preganglionic neurons synapse with postganglionic neurons in ganglia of the sympathetic trunk or prevertebral ganglia (Figure 15.2).

#### **2. Parasympathetic Ganglia**

- a. Parasympathetic ganglia are the terminal or intramural ganglia that are located very close to or actually within the wall of a visceral organ.
  - 1. Examples include the ciliary, pterygopalatine, submandibular, and otic ganglia (Figure 15.3)
  - 2. Parasympathetic preganglionic neurons synapse with postganglionic neurons in terminal ganglia (Figure 15.3).

#### **3. Postganglionic Neurons**

- a. Connect with preganglionic neurons through the following ways
  - 1. Within the ganglia
  - 2. From sympathetic chains
  - 3. Within the prevertebral ganglion
  - 4. Within the adrenal medulla

### **D. Autonomic Plexuses**

- 1. These are tangled networks of sympathetic and parasympathetic neurons (Figure 15.5).
- 2. Major autonomic plexuses include the cardiac, pulmonary, celiac, and hypogastric.

### **E. Structure of the Sympathetic Division**

#### **1. Organization of Sympathetic Ganglia**

- a. White rami communicans (plural - the white rami communicantes) connect the anterior ramus of the thoracic and first 2 or 3 lumbar spinal nerves with the ganglia of the sympathetic trunk.
  - b. The gray ramus communicans is the structure containing the postganglionic fibers that connect the ganglion of the sympathetic trunk to the spinal nerve (Figure 15.4).
  - c. Preganglionic fibers that pass through the sympathetic trunk without terminating in the trunk form nerves beyond the trunk known as splanchnic nerves (Figure 15.6).
  - d. Developmentally, the adrenal medulla is a modified sympathetic ganglion and its cells are similar to sympathetic postganglionic neurons.
2. Pathways from the Sympathetic Trunk Ganglia to Visceral Effectors
    - a. Spinal Nerves (Figure 15.4)
    - b. Cephalic Periarterial Nerves (Figure 15.4)
    - c. Sympathetic Nerves (Figure 15.4)
    - d. Splanchnic Nerves (Figure 15.2 and 15.4)
  3. **Clinical Connection:** In Horner's syndrome, the sympathetic innervation to one side of the face is lost.

#### **F. Structure of the Parasympathetic Division**

1. The cranial outflow consists of preganglionic axons that extend from the brain stem in four cranial nerves. The cranial outflow components are four pairs of ganglia and the plexuses associated with the vagus nerve (Figure 15.3).
2. The sacral outflow consists of preganglionic axons in anterior roots of the second through fourth sacral nerves.
3. Anatomical features of the sympathetic and parasympathetic divisions are compared in Table 15.3.

#### **G. Structure of the Enteric Division**

1. The division of the gastrointestinal tract
2. Specialized collection of nerves and ganglia within the wall of the gastrointestinal tract, pancreas and gallbladder.
3. Contains over 100 million neurons, the same number as the spinal cord
  - a. Myenteric plexus – between the outer longitudinal and circular muscle layers
  - b. Submucosal plexus – between the circular muscle and the muscularis mucosae

## **IV. ANS NEUROTRANSMITTERS AND RECEPTORS**

### **A. Cholinergic Neurons and Cholinergic Receptors**

1. Cholinergic neurons release the neurotransmitter acetylcholine and include all sympathetic and parasympathetic preganglionic neurons, all parasympathetic postganglionic neurons, and sympathetic postganglionic neurons that innervate most sweat glands (Figure 15.7).
  - a. Cholinergic receptors are integral membrane proteins in the postsynaptic plasma membrane. The two types of cholinergic receptors are nicotinic and muscarinic receptors (Figure 15.7).
  - b. Activation of nicotinic receptors causes excitation of the postsynaptic cell.
  - c. Activation of muscarinic receptors can cause either excitation or inhibition depending on the cell that bears the receptors.

### **B. Adrenergic Neurons and Adrenergic Receptors**

1. The adrenergic neurons release norepinephrine (Figure 15.7) and include most sympathetic postganglionic neurons.
2. The main types of adrenergic receptors are alpha and beta receptors.
  - a. These receptors are further classified into subtypes.
    1. Depending on the subtype, activation of the receptor can result in either excitation or inhibition.
3. Effects triggered by adrenergic neurons typically are longer lasting than those triggered by cholinergic neurons.
4. Table 15.2 describes the location of the subtypes of cholinergic and adrenergic receptors and summarizes the responses that occur when each type of receptor is activated.

### **C. Receptor Agonists and Antagonists**

1. An agonist is a substance that binds to and activates a receptor, mimicking the effect of a natural neurotransmitter or hormone; an antagonist is a substance that binds to and blocks a receptor, preventing a natural neurotransmitter or hormone from exerting its effect.
2. Different drugs can serve as agonists or antagonists to selectively activate or block ANS receptors.

## **V. PHYSIOLOGICAL OF THE ANS**

- A. Most body structures receive dual innervation, that is, fibers from both the sympathetic and parasympathetic divisions. Usually one division causes excitation and one causes inhibition resulting in autonomic tone.
- B. The sympathetic responses prepare the body for emergency situations (the fight-or-flight responses).
  - 1. Sympathetic responses are stimulated by the four E's (Emergency, Embarrassment, Exercise, Excitement)
  - 2. The effects of sympathetic stimulation are longer-lasting and more widespread than those of the parasympathetic stimulation.
    - a. Norepinephrine is degraded more slowly than Ach.
    - b. There are more postganglionic neurons in this division.
  - 3. Specific sympathetic responses include:
    - a. Pupils dilate
    - b. heart rate and blood pressure increase.
    - c. Blood flow to the kidneys and gastrointestinal tract diminishes
    - d. Blood flow to the skeletal muscles, liver, heart and adipose tissue increases
    - e. Liver cells release glucose and adipose cells break down fat to increase available energy
    - f. The parasympathetic division regulates activities that conserve and restore body energy (energy conservation-restorative system).
- C. Parasympathetic responses are stimulated during periods of rest and relaxation.
  - 1. The effects of parasympathetic stimulation are last for a shorter time and are less widespread than those of the sympathetic stimulation.
    - a. Acetylcholine is degraded more rapidly than NE.
    - b. There are more postganglionic neurons in this division.
  - 2. Parasympathetic responses include
    - a. Salivation
    - b. Lacrimation
    - c. Urination
    - d. Digestion
    - e. defecation ( collectively known as "SLUDD").
    - f. also decreased heart rate
    - g. decreased airway diameter
    - h. decreased pupil diameter.

- D. table 15.4 summarizes the responses of glands, cardiac muscle, and smooth muscle to stimulation by the ANS.

## **VI. INTEGRATION AND CONTROL OF AUTONOMIC FUNCTIONS**

### **A. Autonomic Reflexes**

1. A visceral autonomic reflex adjusts the activity of a visceral effector, often unconsciously.
2. A visceral autonomic reflex arc consists of a receptor, sensory neuron, association neuron, autonomic motor neurons, and visceral effector.

### **B. Autonomic Control by Higher Centers**

1. The hypothalamus controls and integrates the autonomic nervous system. It is connected to both the sympathetic and the parasympathetic divisions.
2. Control of the ANS by the cerebral cortex occurs primarily during emotional stress.

## **VII. FOCUS ON HOMEOSTASIS: THE NERVOUS SYSTEM**

- A. This section depicts relationships between the nervous system and other systems.

## **VIII. HOMEOSTATIC DISORDERS**

- A. Raynaud's disease is due to excessive sympathetic stimulation of arterioles within the fingers and toes resulting in diminished blood flow to the digits.
- B. Autonomic dysreflexia is an exaggerated response of the sympathetic division of the ANS that occurs in about 80% of individuals with spinal cord injury at or above the level of T6. It occurs due to interruption of the control of the ANS by higher centers.