Chapter 14 The Autonomic Nervous System

Chapter Outline

Module 14.1 Overview of the Autonomic Nervous System (Figures 14.1–14.3)

A. The **autonomic nervous system (ANS)** is the involuntary arm of the peripheral nervous system (PNS), also known as the _____ division.

1. The ANS is divided into two separate divisions, the _____ and _____ nervous systems, which work together constantly to maintain homeostasis.
2. The ANS oversees most vital functions including: _____, _____, and _____.

E. **Functions of the ANS and Visceral Reflex Arcs**: the ANS manages vital process through a series of events called **visceral reflex arcs**, in which a sensory stimulus leads to a predictable motor response. **Summarize the visceral reflex arc in the ANS (Figure 14.1)**:

1. _____
2. _____
3. _____

Comparison of Somatic and Autonomic Nervous Systems: the following summarizes the main differences between motor divisions of the PNS **(Figure 14.2)**:

1. Somatic motor division neurons innervate _____ muscle, which leads to _____ muscle contractions, initiated consciously **(Figure 14.2a)**.
2. Autonomic motor neurons innervate _____ muscle cells, _____ muscle cells, and glands, and produce _____ actions. ANS motor neurons do not directly innervate their target like somatic motors

neurons; instead, they require the following two neuron circuit **(Figure 14.2b)**:

a. The first neuron is the _____ **neuron**, which is the initial efferent neuron whose cell body resides within the CNS. All of these axons release the neurotransmitter _____.
b. The second is the _____ **neuron**, whose cell body resides in the autonomic ganglion in the PNS. The axons of these neurons travel to the target cells where they trigger specific changes, either inhibitory or excitatory responses, by releasing specific neurotransmitters, either _____ or _____.

B. **Divisions of the ANS** include the sympathetic and parasympathetic nervous systems. The following highlights the main structural and functional differences between these two systems **(Figure 14.3)**:

1. **The sympathetic nervous system**: preganglionic axons are usually _____ and postganglionic axons are usually _____. This system exhibits the following characteristics:
   a. Preganglionic cell bodies originate in the thoracic and upper lumbar spinal cord giving rise to the name, _____ **division**.
   b. Sympathetic ganglia are generally located near the _____ _____, which where preganglionic axons synapse with postganglionic neuron cell bodies. Postganglionic axons proceed to the target.
   c. This is the "_____ or _____" division of the ANS because it prepares the body for emergency situations.
   d. **What activities prompt this division to be in control? _____**
      _____
      _____
2. **The parasympathetic nervous system**: preganglionic parasympathetic axons are long while postganglionic axons are short. This system exhibits the following characteristics:

a. Preganglionic cell bodies are located within the nuclei of several cranial nerves in the brainstem and the sacral region of the spinal cord giving rise to the name,_____**division**.

b. **What do the cranial nerves of this division innervate? _____**

_____

_____

c. **What do the sacral nerves of this division innervate?** _____

_____

d. Cell bodies of postganglionic neurons are usually located near the target organ, which requires only a short axon to make the connection.

e. This is the "_____and_____" division because of its role in digestion and in maintaining the body's homeostasis at rest.

3. **The balance between the parasympathetic and sympathetic nervous systems**: actions of the parasympathetic division directly antagonize those of the_____division. Together, these two divisions maintain a delicate balance to ensure that homeostasis is preserved.

Module 14.2 The Sympathetic Nervous System (Figures 14.4–14.8)

A. The **sympathetic nervous system**, or "the fight or flight system", is adapted to maintain homeostasis during certain situations. **Name some situations when the sympathetic nervous system is adapted to maintain homeostasis: _____**

_____,_____, or_____.

B. **Gross and Microscopic Anatomy of the Sympathetic Nervous System**: the anatomical features are summarized as follows **(Figures 14.4, 14.5)**:

1. The **sympathetic chain ganglia** are where most of the postganglionic cell bodies are found, running down both sides in parallel with the vertebral column **(Figure 14.4)**.

a. This feature has a "chainlike" appearance, hence the name.

b. The section of chain that extends above the thoracic spinal cord terminates in the_____**ganglion**.

c. The section of chain that extends below the lumbar spinal cord terminates in the_____ganglion.

2. Preganglionic neurons originate in the lateral horns of thoracic and lumbar spinal cord and exit with the axons of lower motor neurons via the anterior root.
    a. Preganglionic axons quickly separate from the spinal nerve anterior ramus to form a small nerve called the **white (myelinated) rami communicantes**, which leads to the postganglionic cell bodies found in the_____chain ganglion.
    b. Some preganglionic axons pass through the chain ganglia without forming synapses. These may form synapses with _____ **ganglia** located near the target organ.
    c. Preganglionic axons that synapse with collateral ganglia near the organs of the abdominopelvic cavity are components of the _____ **nerves**.
3. The following three synapse options are possible between the pre and postganglionic neuron **(Figure 14.5)**:
    a. Preganglionic axons can synapse with: _____
    _____
    b. Preganglionic axons can ascend or descend to synapse with: _____
    _____
    _____
    c. Preganglionic axons can pass through the chain ganglia and travel to collateral ganglia where they synapse.
4. Postganglionic axons exit the ganglia as small **gray (unmyelinated) rami communicantes**, which reunite to travel with spinal nerves until they reach their target cells.

C. **Sympathetic Neurotransmitters and Receptors**: neurotransmitters bind to specific protein-based receptors embedded in the plasma membrane of a target cell. The following summarizes the sympathetic nervous system neurotransmitters and target cell receptors with which they bind **(Figure 14.6)**:
1. **Classes of sympathetic neurotransmitters** include the following:

a. **Acetylcholine (ACh)** is the neurotransmitter used in excitatory synapses between sympathetic_____axons and _____ neurons. Postganglionic axons then transmit action potentials to the target cell. ACh is one of three neurotransmitters that can be released in the synapse with target cells.

b. **Norepinephrine** (noradrenalin) is the most frequently utilized neurotransmitter released into the synapses between _____ axons and target cells.

c. **Epinephrine** (adrenalin) is the third neurotransmitter that can be released into synapses between_____axons and target cells.

2. **Classes of sympathetic receptors**: **Adrenergic receptors** bind to _____ and_____. The two major types of adrenergic receptors,_____and_____, are further classified into the following subtypes:

a. **Where are alpha-1 receptors located?** _____

b. **Where are alpha-2 receptors located?** _____

c. **Where are beta-1 receptors located?** _____

d. **Where are beta-2 receptors located?** _____

e. **Where are beta-3 receptors located?** _____

_____

_____

3. **Classes of sympathetic receptors**: **Cholinergic receptors** bind to _____ and include the following two types: _____ and _____.

   a. **Where are muscarinic receptors located?** _____

   _____

   b. **Where are nicotinic receptors located?** _____

   _____

   _____

4. **Explain how alpha-2 receptors differ from the other adrenergic receptor subtypes**. _____

   _____

   (Figure 14.6a) _____

   _____

   _____

   _____

5. **Pharmacology and sympathetic nervous system receptors**: different subtypes of sympathetic nervous system receptors have provided targets for medication therapy for many different disease states, including asthma and hypertension.

D. **Effects of the Sympathetic Nervous System on Target Cells**: the effects of the sympathetic nervous system on its target cells are directed at ensuring survival and maintenance of homeostasis during time of physical or emotional stress **(Figures 14.7, 14.8)**:

1. **Summarize the effects of norepinephrine on cardiac muscle cells when it binds b-1 receptors (Figure 14.7)**:

   a. _____

   _____

b. _____

_____

c. _____

_____

_____

2. **Effects on smooth muscle cells**: when norepinephrine binds to specific receptors it mediates the following changes **(Figure 14.7)**:
    a. **Constriction of blood vessels serving the digestive**, **urinary**, **and integumentary system** occurs when norepinephrine binds to _____ receptors, which decreases blood flow to these organs.
    b. **Dilation of the bronchioles** occurs when norepinephrine binds to _____ receptors, which increases the amount of oxygen that can be inhaled with each breath.
    c. **Dilation of blood vessels serving the skeletal and cardiac muscle** occurs when norepinephrine binds to b-2 receptors, which _____ the blood flow, allowing for an increase in physical activity.
    d. **Contraction of urinary and digestive sphincters** occurs when norepinephrine binds to b-2 and b-3 receptors respectively, which makes emptying the bladder and bowel more difficult during increased physical activity.
    e. **Relaxation of the smooth muscle of the digestive tract** occurs when norepinephrine binds to b-2, which_____digestion during increased physical activity.
    f. **Dilation of the pupils** occurs when norepinephrine binds to a-1 receptors that cause the dilator papillae muscles to contract, which causes the pupil to allow_____.
    g. **Constriction of blood vessels serving most exocrine glands** occurs when norepinephrine binds to beta receptors on the blood vessels

serving various salivary glands, which_____the secretion of saliva, with the exception of sweat glands.

3. **Effects on cellular metabolism**: during times of sympathetic nervous activation, nearly all cells, especially skeletal muscle, require higher amounts of ATP. **To assist with this higher energy demand norepinephrine has the following three effects**:
    a. _____
    _____
    b. _____
    _____
    c. _____
    _____
    _____
4. **Effects on secretion from sweat glands**: the sympathetic nervous system attempts to maintain body temperature homeostasis during periods of increased physical activity. **Summarize the process**:
    a. _____
    _____
    b. _____
    _____
    c. _____
    _____
5. **Effects on cells of the adrenal medulla**: the adrenal medulla sits on top of each kidney. It is in direct contact with preganglionic sympathetic neurons. The medulla of this multifunctional endocrine gland is composed of modified sympathetic postganglionic neurons with the following functions **(Figure 14.8)**:
    a. ACh is released from preganglionic neurons that then bind to _____ receptors on the adrenal medulla cells.

b. ACh stimulates the medullary cells to release _____ and _____ into the bloodstream. In this case these are considered hormones rather than neurotransmitters.

c. These hormones act as long-distance chemical messengers and act as an interface between the endocrine and sympathetic nervous systems.

6. **Effects on other cells**: the sympathetic nervous system influences many other target cells all with the mission of maintaining homeostasis during increased physical or emotional stress.

Module 14.3 The Parasympathetic Nervous System (Figures 14.9, 14.10)

A. The **parasympathetic nervous system** is considered the "rest and digest" division of the ANS because of its role in the body's maintenance functions. **What are some of the functions the parasympathetic nervous system maintains?** _____.

B. **Gross and Microscopic Anatomy of the Parasympathetic Nervous System**: this division is known as the craniosacral system based on its association with the following cranial nerves and the pelvic nerves from the sacral plexus **(Figure 14.9)**:

1. **Parasympathetic cranial nerves** are associated with the _____ (CN III), _____ (CN VII), _____ (CN IX), and _____ (CN X) nerve.

a. The two _____ nerves are the main parasympathetic nerves that innervate most thoracic and abdominal viscera.

b. Branches of the vagus nerves contribute to the _____, _____, and _____ plexuses.

2. The **parasympathetic sacral nerves** make up the pelvic nerve-component of this division. This subdivision supplies the last segment of the large intestine, the urinary bladder, and the reproductive organs.

a. Sacral nerve branches form the **pelvic _____ nerves**, which form plexuses in the pelvic floor.

b. Some preganglionic neurons synapse with terminal ganglia in associated plexuses, but most synapse in terminal ganglia within the walls of the target organs.

C. **Parasympathetic Neurotransmitters and Receptors**: both pre and postganglionic parasympathetic neurons release_____at their synapses, and the effect is generally_____. The following two cholinergic receptors are components of this ANS division:

1. _____ receptors are located in the membranes of all postganglionic neurons.
2. _____ receptors are located in the membranes of all parasympathetic target cells.

D. **Effects of the Parasympathetic Nervous System on Target Cells**: the main function of this division is to maintain homeostasis when the body is at rest. The following effects can be seen under the influence of this system **(Figure 14.10)**:

1. **Effects on cardiac muscle cells**: parasympathetic activity _____ heart rate and blood pressure.
    a. Preganglionic parasympathetic neurons travel to the heart with the vagus nerve (CN X).
    b. Postganglionic neurons_____the heart rate, which reduces the blood pressure.
2. **Effects on smooth muscle cells**: postganglionic neurons innervate smooth muscle cells in many organs with the following effects:
    a. **Constriction of the pupil** involves the_____nerves, CN III, the ciliary ganglion, and the sphincter papillae muscle, which reduces the amount of light allowed into the eye.
    b. **Accommodation of the lens for near vision** involves the _____ nerves, CN III, and the contraction of the _____ muscle, which changes the lens to a more rounded shaped.
    c. **Constriction of the bronchioles** or bronchoconstriction involves the _____ nerves, CN X.

d. **Contraction of the smooth muscle lining the digestive tract** involves the_____nerves, CN X, which produces rhythmic contractions called peristalsis that propels food through the digestive tract.

e. **Relaxation of digestive and urinary sphincters** involves the _____ nerves, CN X, and sacral nerves, which promotes _____ and_____.

f. **Engorgement of the penis or clitoris** occurs when stimulated by the sacral nerves in the male or female respectively.

g. Although the parasympathetic division only innervates specific blood vessels, many blood vessels dilate when the system is activated, due to a reduction in sympathetic activity.

3. **Effects on glandular epithelial cells**: the parasympathetic division has little effect on sweat glands but does increase secretion production from other glands:
    a. CN VII stimulation stimulates tear production from _____ glands and mucus production from glands in the nasal mucosa.
    b. CN VII and IX stimulation leads to increased production of _____ from the salivary glands.
    c. CN X stimulates secretion of enzymes and other products from _____ tract cells.
4. **Effects on other cells**: the parasympathetic division has no direct effect on cells that mediate metabolic rate, mental alertness, the force generated by skeletal muscle contractions, blood clotting, adipocytes, or most endocrine secretions.
    a. Each of the above bodily functions returns to a "resting" state during periods of parasympathetic activity, which allows for replenishment of glucose storage and other fuels.
    b. Fuel replenishment is critical for allowing the sympathetic nervous system to function properly when needed.

Module 14.4 Homeostasis Part II: PNS Maintenance of Homeostasis (Figures 14.11, 14.12)

A. **Interactions of Autonomic Divisions**: the sympathetic and parasympathetic divisions work together to keep many of the body's functions within their normal homeostatic ranges **(Figure 14.11)**.
   1. Both divisions innervate many of the same organs where their actions antagonize one another, a condition called_____.
   2. Dual innervation allows the sympathetic division to become dominant and trigger effects that maintain homeostasis during _____ periods.
   3. The parasympathetic division, on the other hand, regulates the same organs, preserving homeostasis between periods of increased physical activity.

B. **Autonomic tone** refers to the fact that neither division is ever completely shut down. The constant amount of activity from each division can be divided into sympathetic and parasympathetic tone**.**
   1. _____ tone dominates in blood vessels, which keeps them partially constricted.
   2. _____ tone dominates in the heart, which keeps the heart rate at an average of_____beats per minute.

C. **Summary of Nervous System Control of Homeostasis**: maintenance of homeostasis is one of the body's most essential functions, in which the ANS plays a critical role **(Figure 14.12)**.
   1. Homeostasis is controlled centrally by the_____, brainstem reticular formation, and the actions carried out by the two divisions of the ANS.
   2. **Autonomic centers** are regions found in the_____formation that the hypothalamus is in contact with, which contains neurons that control the activity of preganglionic sympathetic and parasympathetic neurons.