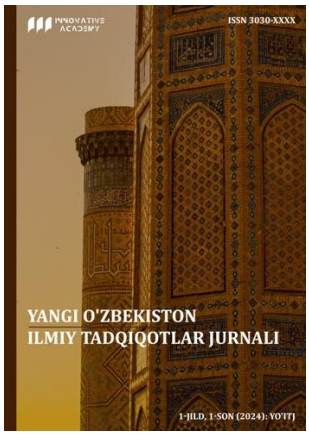


THE SYMPATHETIC PART OF THE AUTONOMIC NERVOUS SYSTEM. THE PARASYMPATHETIC PART OF THE AUTONOMIC NERVOUS SYSTEM

Khamidjonov Abdulaziz
Tashkent State Dental Institute Faculty of Dentistry
https://doi.org/10.5281/zenodo.11093601

ARTICLE INFO

Qabul qilindi: 26-aprel 2024 yil
Ma'qullandi: 28-aprel 2024 yil
Nashr qilindi: 30-aprel 2024 yil

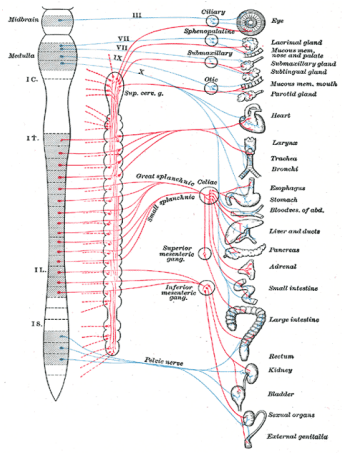
KEY WORDS

autonomic nervous system, sympathetic, parasympathetic, adrenergic, cholinergic, physiology

ABSTRACT

This article is about the sympathetic part of the autonomic nervous system. This manuscript discusses the physiology of the autonomic nervous system (ANS). The following topics are presented: regulation of activity; efferent pathways; sympathetic and parasympathetic divisions; neurotransmitters, their receptors and the termination of their activity; functions of the ANS; and the adrenal medullae. In addition, the application of this material to the practice of pharmacy is of special interest. Two case studies regarding insecticide poisoning and pheochromocytoma are included.

The vegetative nervous system (Latin: vegetatio - growth, development, stimulation) is a part of the nervous system of humans and vertebrates; The fibers of the nervous system spread to the smooth muscles of all internal organs and control their activity without a person's will (autonomously). But V.n.s. Like animal (spreading to skeletal muscles) nerves, it operates under the control of the cortex of the large hemispheres of the brain. This term was introduced to science for the first time by the French doctor M. Bisha (1801) and scientifically justified its difference from the activity of the somatic nervous system.



The English physiologist J. Langley (1903) called the nervous system the "autonomic nervous system", because the activity of the nervous system is not controlled by consciousness, so it is also called the "autonomic" or involuntary nervous system.

Regulation of Autonomic Nervous System Activity

The efferent nervous activity of the ANS is largely regulated by autonomic reflexes. In many of these reflexes, sensory information is transmitted to homeostatic control centers, in particular, those located in the hypothalamus and brainstem. Much of the sensory input from the thoracic and abdominal viscera is transmitted to the brainstem by afferent fibers of cranial nerve X, the vagus nerve. Other cranial nerves also contribute sensory input to the hypothalamus and the brainstem. This input is integrated and a response is carried out by the transmission of nerve signals that modify the activity of preganglionic autonomic neurons. Many important variables in the body are monitored and regulated in the hypothalamus and the brainstem including heart rate, blood pressure, gastrointestinal peristalsis and glandular secretion, body temperature, hunger, thirst, plasma volume, and plasma osmolarity.

An example of this type of autonomic reflex is the baroreceptor reflex. Baroreceptors located in some of the major systemic arteries are sensory receptors that monitor blood pressure. If blood pressure decreases, the number of sensory impulses transmitted from the baroreceptors to the vasomotor center in the brainstem also decreases. As a result of this change in baroreceptor stimulation and sensory input to the brainstem, ANS activity to the heart and blood vessels is adjusted to increase heart rate and vascular resistance so that blood pressure increases to its normal value.

These neural control centers in the hypothalamus and the brainstem may also be influenced by higher brain areas. Specifically, the cerebral cortex and the limbic system influence ANS activities associated with emotional responses by way of hypothalamic-brainstem pathways. For example, blushing during an embarrassing moment, a response most likely originating in the frontal association cortex, involves vasodilation of blood vessels to the face. Other emotional responses influenced by these higher brain areas include fainting, breaking out in a cold sweat, and a racing heart rate.

Some autonomic reflexes may be processed at the level of the spinal cord. These include the micturition reflex (urination) and the defecation reflex. Although these reflexes are subject to influence from higher nervous centers, they may occur without input from the brain.

Efferent Pathways of the Autonomic Nervous System

The efferent pathways of the ANS consist of 2 neurons that transmit impulses from the CNS to the effector tissue. The preganglionic neuron originates in the CNS with its cell body in the lateral horn of the gray matter of the spinal cord or in the brainstem. The axon of this neuron travels to an autonomic ganglion located outside the CNS, where it synapses with a postganglionic neuron. This neuron innervates the effector tissue.

Synapses between the autonomic postganglionic neuron and effector tissue—the neuroeffector junction—differ greatly from neuron-to-neuron synapses. The postganglionic fibers in the ANS do not terminate in a single swelling like the synaptic knob, nor do they synapse directly with

the cells of a tissue. Instead, where the axons of these fibers enter a given tissue, they contain multiple swellings called varicosities. When the neuron is stimulated, these varicosities release neurotransmitters along a significant length of the axon and, therefore, over a large surface area of the effector tissue. The neurotransmitter diffuses through the interstitial fluid to wherever its receptors are located in the tissue. This diffuse release of the neurotransmitter affects many tissue cells simultaneously. Furthermore, cardiac muscle and most smooth muscle have gap junctions between cells. These specialized intercellular communications allow for the spread of electrical activity from one cell to the next. As a result, the discharge of a single autonomic nerve fiber to an effector tissue may alter the activity of the entire tissue.

Divisions of the Autonomic Nervous System

The ANS is composed of 2 anatomically and functionally distinct divisions, the sympathetic system and the parasympathetic system. Both systems are tonically active. In other words, they provide some degree of nervous input to a given tissue at all times. Therefore, the frequency of discharge of neurons in both systems can either increase or decrease. As a result, tissue activity may be either enhanced or inhibited. This characteristic of the ANS improves its ability to more precisely regulate a tissue's function. Without tonic activity, nervous input to a tissue could only increase.

Many tissues are innervated by both systems. Because the sympathetic system and the parasympathetic system typically have opposing effects on a given tissue, increasing the activity of one system while simultaneously decreasing the activity of the other results in very rapid and precise control of a tissue's function.

Sympathetic Division of the Autonomic Nervous System

To respond to a threat—to fight or to run away—the sympathetic system causes divergent effects as many different effector organs are activated together for a common purpose. More oxygen needs to be inhaled and delivered to skeletal muscle. The respiratory, cardiovascular, and musculoskeletal systems are all activated together. itionally, sweating keeps the excess heat that comes from muscle contraction from causing the body to overheat. The digestive system shuts down so that blood is not absorbing nutrients when it should be delivering oxygen to skeletal muscles. To coordinate all these responses, the connections in the sympathetic system diverge from a limited region of the central nervous system (CNS) to a wide array of ganglia that project to the many effector organs simultaneously. The complex set of structures that compose the output of the sympathetic system make it possible for these disparate effectors to come together in a coordinated, systemic change.

The sympathetic division of the autonomic nervous system influences the various organ systems of the body through connections emerging from the thoracic and upper lumbar spinal cord. It is referred to as the thoracolumbar system to reflect this anatomical basis. A central neuron in the lateral horn of any of these spinal regions projects to ganglia adjacent to the vertebral column through the ventral spinal roots.

The majority of ganglia of the sympathetic system belong to a network of sympathetic chain ganglia that runs alongside the vertebral column. The ganglia appear as a series of clusters of neurons linked by axonal bridges. There are typically 23 ganglia in the chain on either side of

the spinal column. Three correspond to the cervical region, 12 are in the thoracic region, four are in the lumbar region, and four correspond to the sacral region. The cervical and sacral levels are not connected to the spinal cord directly through the spinal roots, but through ascending or descending connections through the bridges within the chain.

A diagram that shows the connections of the sympathetic system is somewhat like a circuit diagram that shows the electrical connections between different receptacles and devices. In Figure 1, the “circuits” of the sympathetic system are intentionally simplified.

An example of this type is spinal nerve T1 that synapses with the T1 chain ganglion to innervate the trachea. The fibers of this branch are called white rami communicantes (singular = ramus communicans); they are myelinated and therefore referred to as white (see Figure 2a). The axon from the central neuron (the preganglionic fiber shown as a solid line) synapses with the ganglionic neuron (with the postganglionic fiber shown as a dashed line). This neuron then projects to a target effector—in this case, the trachea—via gray rami communicantes, which are unmyelinated axons.

In some cases, the target effectors are located superior or inferior to the spinal segment at which the preganglionic fiber emerges. With respect to the “wiring” involved, the synapse with the ganglionic neuron occurs at chain ganglia superior or inferior to the location of the central neuron. An example of this is spinal nerve T1 that innervates the eye. The spinal nerve tracks up through the chain until it reaches the superior cervical ganglion, where it synapses with the postganglionic neuron (see Figure 2b). The cervical ganglia are referred to as paravertebral ganglia, given their location adjacent to prevertebral ganglia in the sympathetic chain.

Not all axons from the central neurons terminate in the chain ganglia. itional branches from the ventral nerve root continue through the chain and on to one of the collateral ganglia as the greater splanchnic nerve or lesser splanchnic nerve. For example, the greater splanchnic nerve at the level of T5 synapses with a collateral ganglion outside the chain before making the connection to the postganglionic nerves that innervate the stomach (see Figure 2c).

Collateral ganglia, also called prevertebral ganglia, are situated anterior to the vertebral column and receive inputs from splanchnic nerves as well as central sympathetic neurons. They are associated with controlling organs in the abdominal cavity, and are also considered part of the enteric nervous system. The three collateral ganglia are the celiac ganglion, the superior mesenteric ganglion, and the inferior mesenteric ganglion (see Figure 1). The word celiac is derived from the Latin word “coelom,” which refers to a body cavity (in this case, the abdominal cavity), and the word mesenteric refers to the digestive system.

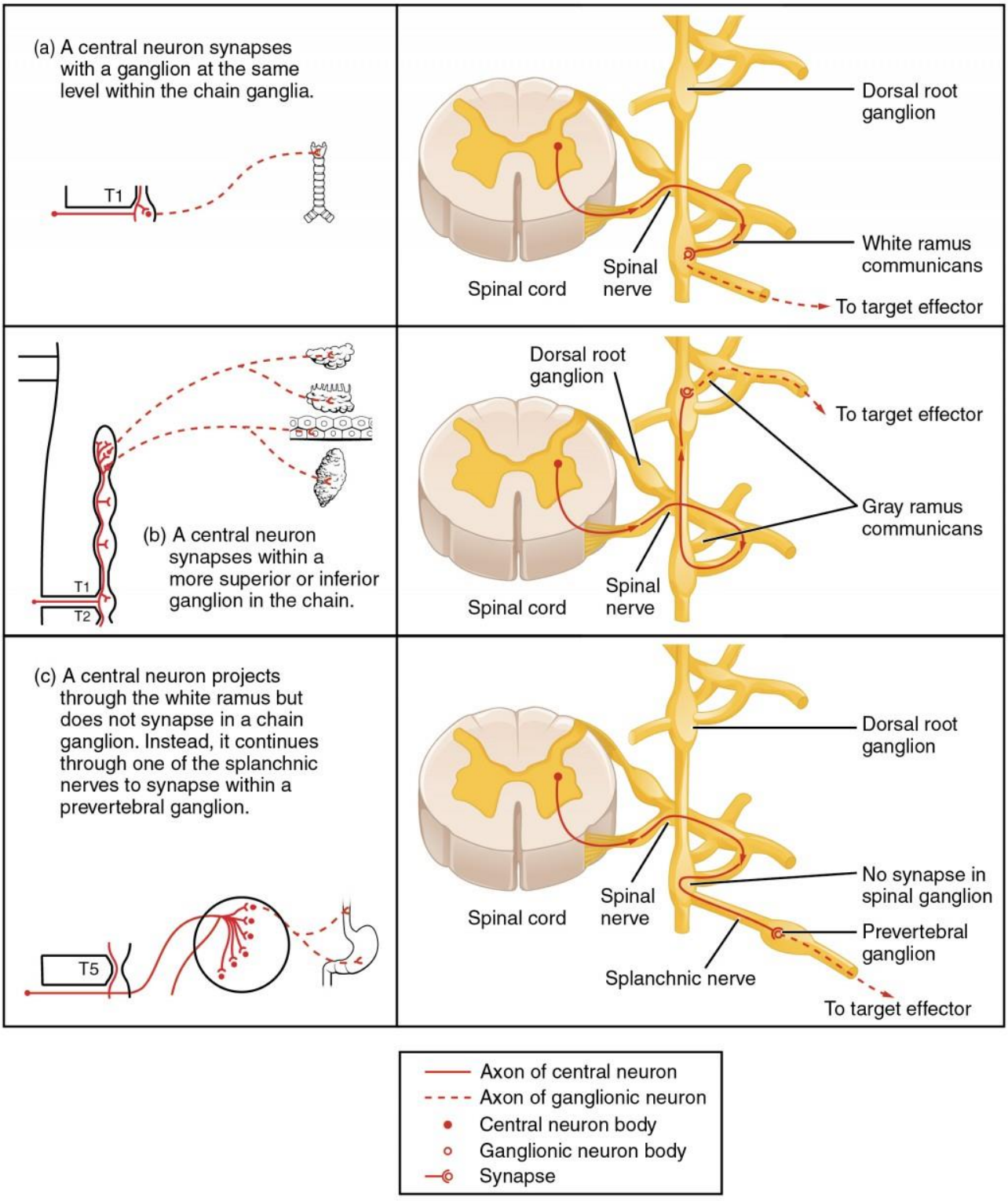


Figure 2. Sympathetic Connections and Chain Ganglia. The axon from a central sympathetic neuron in the spinal cord can project to the periphery in a number of different ways. (a) The fiber can project out to the ganglion at the same level and synapse on a ganglionic neuron. (b) A branch can project to more superior or inferior ganglion in the chain. (c) A branch can project through the white ramus communicans, but not terminate on a ganglionic neuron in the chain. Instead, it projects through one of the splanchnic nerves to a collateral ganglion or the adrenal medulla (not pictured).

An axon from the central neuron that projects to a sympathetic ganglion is referred to as a preganglionic fiber or neuron, and represents the output from the CNS to the ganglion. Because the sympathetic ganglia are adjacent to the vertebral column, preganglionic sympathetic fibers are relatively short, and they are myelinated. A postganglionic fiber—the axon from a ganglionic neuron that projects to the target effector—represents the output of a ganglion that directly influences the organ.

Compared with the preganglionic fibers, postganglionic sympathetic fibers are long because of the relatively greater distance from the ganglion to the target effector. These fibers are unmyelinated. (Note that the term “postganglionic neuron” may be used to describe the projection from a ganglion to the target. The problem with that usage is that the cell body is in the ganglion, and only the fiber is postganglionic. Typically, the term neuron applies to the entire cell.)

One type of preganglionic sympathetic fiber does not terminate in a ganglion. These are the axons from central sympathetic neurons that project to the adrenal medulla, the interior portion of the adrenal gland. These axons are still referred to as preganglionic fibers, but the target is not a ganglion. The adrenal medulla releases signaling molecules into the bloodstream, rather than using axons to communicate with target structures. The cells in the adrenal medulla that are contacted by the preganglionic fibers are called chromaffin cells. These cells are neurosecretory cells that develop from the neural crest along with the sympathetic ganglia, reinforcing the idea that the gland is, functionally, a sympathetic ganglion.

The projections of the sympathetic division of the autonomic nervous system diverge widely, resulting in a broad influence of the system throughout the body. As a response to a threat, the sympathetic system would increase heart rate and breathing rate and cause blood flow to the skeletal muscle to increase and blood flow to the digestive system to decrease. Sweat gland secretion should also increase as part of an integrated response.

All of those physiological changes are going to be required to occur together to run away from the hunting lioness, or the modern equivalent. This divergence is seen in the branching patterns of preganglionic sympathetic neurons—a single preganglionic sympathetic neuron may have 10–20 targets. An axon that leaves a central neuron of the lateral horn in the thoracolumbar spinal cord will pass through the white ramus communicans and enter the sympathetic chain, where it will branch toward a variety of targets. At the level of the spinal cord at which the preganglionic sympathetic fiber exits the spinal cord, a branch will synapse on a neuron in the adjacent chain ganglion.

Some branches will extend up or down to a different level of the chain ganglia. Other branches will pass through the chain ganglia and project through one of the splanchnic nerves to a collateral ganglion. Finally, some branches may project through the splanchnic nerves to the adrenal medulla. All of these branches mean that one preganglionic neuron can influence different regions of the sympathetic system very broadly, by acting on widely distributed organs.

Parasympathetic Division of the Autonomic Nervous System

The parasympathetic division of the autonomic nervous system is named because its central neurons are located on either side of the thoracolumbar region of the spinal cord (para– = “beside” or “near”). The parasympathetic system can also be referred to as the craniosacral system (or outflow) because the preganglionic neurons are located in nuclei of the brain stem and the lateral horn of the sacral spinal cord.

The connections, or “circuits,” of the parasympathetic division are similar to the general layout of the sympathetic division with a few specific differences (Figure 3). The preganglionic fibers from the cranial region travel in cranial nerves, whereas preganglionic fibers from the sacral region travel in spinal nerves. The targets of these fibers are terminal ganglia, which are located near—or even within—the target effector. These ganglia are often referred to as intramural ganglia when they are found within the walls of the target organ. The postganglionic fiber projects from the terminal ganglia a short distance to the target effector, or to the specific target tissue within the organ. Comparing the relative lengths of axons in the parasympathetic system, the preganglionic fibers are long and the postganglionic fibers are short because the ganglia are close to—and sometimes within—the target effectors.

The cranial component of the parasympathetic system is based in particular nuclei of the brain stem. In the midbrain, the Eddinger–Westphal nucleus is part of the oculomotor complex, and axons from those neurons travel with the fibers in the oculomotor nerve (cranial nerve III) that innervate the extraocular muscles. The preganglionic parasympathetic fibers within cranial nerve III terminate in the ciliary ganglion, which is located in the posterior orbit. The postganglionic parasympathetic fibers then project to the smooth muscle of the iris to control pupillary size. In the upper medulla, the salivatory nuclei contain neurons with axons that project through the facial and glossopharyngeal nerves to ganglia that control salivary glands. Tear production is influenced by parasympathetic fibers in the facial nerve, which activate a ganglion, and ultimately the lacrimal (tear) gland.

REFERENCES:

1. Bear MF, Connors BW, Paradiso MA. Neuroscience, Exploring the Brain. 3rd ed. Philadelphia, Penn: Lippincott Williams & Wilkins; 2007. Chemical control of the brain and behavior. chapter 15. [Google Scholar]

2. Fox SI. Human Physiology. 9th ed. Boston, MA: McGraw Hill; 2006. [Google Scholar]

3. Guyton AC, Hall JE. Textbook of Medical Physiology. 11th ed. Philadelphia, Penn: Elsevier/Saunders; 2006. [Google Scholar]

4. Hoffman BB. Adrenoceptor-activating & other sympathomimetic drugs. In: Katzung BG, editor. Basic and Clinical Pharmacology. 8th ed. Philadelphia, Penn: Lange Medical Books/McGraw Hill; 2001. chapter 9. [Google Scholar]

5. Hoffman BB. Adrenoceptor Antagonist Drugs. In: Katzung BG, editor. Basic and Clinical Pharmacology. 8th ed. Philadelphia, Penn: Lange Medical Books/McGraw Hill; 2001. chapter 10. [Google Scholar]

6. Iversen S, Iversen L, Saper C. The autonomic nervous system and the hypothalamus. In: Kandel ER, Schwartz JH, Jessell TM, editors. Principles of Neuroscience. 4th ed. New York, NY: McGraw Hill; 2000. chapter 49. [Google Scholar]

7. Katzung BG. Introduction to autonomic pharmacology. In: Katzung BG, editor. Basic and Clinical Pharmacology. 8th ed. Philadelphia, Penn: Lange Medical Books/McGraw Hill; 2001. chapter 6. [Google Scholar]

8. Kelly L. Essentials of Human Physiology for Pharmacy. Boca Raton, Fla: CRC Press; 2004. [Google Scholar]

9. McCorry LK. Physiology Case Studies for Pharmacy. Washington, DC: American Pharmacists Association; 2006. [Google Scholar]

10. Naftel JP, Hardy SGP. Visceral motor pathways. In: Haines DE, editor. Fundamental Neuroscience for Basic and Clinical Applications. 3rd ed. Philadelphia, Penn: Churchill Livingstone/Elsevier; 2006. chapter 29. [Google Scholar]