Autonomic Nervous System

The portion of the nervous system that regulates the activity of smooth muscle, cardiac muscle, and glands is the autonomic nervous system (ANS). Structurally, the system consists of visceral efferent neurons organized into nerves, ganglia, and plexuses. Functionally, the system usually operates without conscious control. The autonomic system is neither structurally nor functionally independent of the central nervous system. It is regulated by centers in the brain, in particular by the cerebral cortex, hypothalamus, and medulla oblongata.

Somatic Efferent and Autonomic Nervous System

Whereas the somatic efferent nervous system produces conscious movement in the skeletal muscle, the autonomic nervous system (visceral efferent nervous system) regulates visceral activities, and in general does so involuntarily and automatically. Examples of visceral activities regulated by the autonomic nervous system are changes in the size of the pupil, accommodation for near vision, dilation and constriction of blood vessels, adjustment of the rate and force of the heart beat, movements of the gastrointestinal tract, and secretion by most glands.

The autonomic nervous system is generally considered to be entirely motor. All its axons are efferent fibers, which transmit impulses from the central nervous system to visceral effectors. In the motor portion of the neural pathway of the somatic efferent system, an efferent neuron runs from the central nervous system and synapse directly on the skeletal muscle. In the neural pathway of the autonomic nervous system, there are two efferent neurons and a ganglion between them. The first neuron runs from the central nervous system to a ganglion, where it synapses with the second efferent neuron. It is this neuron that ultimately synapses on a visceral effector. Also, whereas fibers of somatic efferent neurons release acetylcholine (ACh) as their neurotransmitter, fibers of autonomic efferent neurons release either ACh or norepinephrine (NE).

The autonomic nervous system consists of two principal divisions: the sympathetic and the parasympathetic. Many organs innervated by the autonomic nervous system receive visceral efferent neurons from both components of the autonomic nervous system, one set from the sympathetic division, another from the parasympathetic division. In general, nerve impulses

transmitted by the fibers of one division stimulate the organ to start or increase activity, whereas nerve impulses from the other division decrease the organ's activity. Thus autonomic innervation may be excitatory or inhibitory. In the somatic efferent nervous system, only one kind of motor neuron innervates an organ, which is always a skeletal muscle. Moreover, innervation is always excitatory. When a somatic neuron stimulates a skeletal muscle, the muscle becomes active. When the neuron ceases to stimulate the muscle, contraction stops together.

A summary of the principal differences between the somatic efferent and the autonomic nervous system is as follows:

	Somatic Efferent	**Autonomic**
Effectors	**Skeletal muscle**	**Cardiac muscle, smooth muscle, glandular epithelium**
Type of control	**Voluntary**	**Involuntary**
Neural pathway	**One efferent neuron extends from the CNS and synapses directly on a skeletal muscle**	**One efferent neuron extends from the CNS and synapses with another efferent neuron in a ganglion; the second neuron synapses on a visceral effector**
Action on effector	**Always excitatory**	**May be excitatory or inhibitory, depending on whether stimulation is sympathetic or parasympathetic**
Neurotransmitters	**ACh**	**ACh or NE**

Structure of the Autonomic Nervous System

Autonomic visceral efferent pathways always consist of two neurons. One extends from the CNS to a ganglion. The other extends directly from the ganglion to the effector (muscle or gland).

The first of the visceral efferent neurons in an autonomic pathway is called a preganglionic neuron. Its cell body is in the brain or spinal cord. Its myelinated axons, called a preganglionic fiber, passes out of the CNS as part of a cranial or spinal nerve. At some point, the fiber separates from the nerve and travels to an autonomic ganglion, where it synapses with the dendrites or cell body of the postganglionic neuron, the second neuron in the visceral efferent pathway.

The postganglionic neuron lies entirely outside the CNS. Its cell body and dendrites are located in the autonomic ganglion, where the synapse with one or more preganglionic fibers occurs. The axon of a postganglionic neuron, called a postganglionic fiber, is unmyelinated and terminates in a visceral effector.

Preganglionic Neuron

In the sympathetic division, the preganglionic neurons have their cell bodies in the lateral gray horns of the twelve thoracic segments and first two or three lumbar segments of the spinal cord. It is for this reason that the sympathetic division is also called the thoracolumbar division.

The cell bodies of the preganglionic neurons of the parasympathetic division are located in the nuclei of the cranial nerves III, VII, IX, and X in the brain stem and in the lateral gray horns of the second through fourth sacral segments of the spinal cord. Thus, the parasympathetic division is also called craniosacral division.

Autonomic Ganglia

Autonomic pathways always include autonomic ganglia, where synapses between visceral efferent neurons occur. The autonomic ganglia differ from posterior root ganglia, the latter contain cell bodies of sensory neurons and no synapses occur in them.

The autonomic ganglia may be divided into three general groups. The sympathetic trunk (vertebral chain) ganglia are a series of ganglia that lie in a vertical row on either side of the vertebral column, extending from the base of the skull to the coccyx. They are also known as paravertebral (lateral) ganglia.

They receive preganglionic fibers only from the sympathetic division. Because of this, sympathetic preganglionic fibers tend to be short.

The second type of autonomic ganglion also belongs to the sympathetic division. It is called a prevertebral (collateral) ganglion. The ganglia of this group lie anterior to the spinal column and close to the large abdominal arteries from which their names are derived. Examples of the prevertebral ganglia are the celiac, the superior mesenteric, and the inferior mesenteric ganglia. Prevertebral ganglia receive preganglionic fibers from the sympathetic division.

The third type of autonomic ganglion belongs to the parasympathetic division and is called a terminal (intramural) ganglion. The ganglia of this group are located at the end of a visceral efferent pathway very close to visceral effector or actually within the walls of visceral effectors. Terminal ganglia receive preganglionic fibers from the parasympathetic division. The preganglionic fibers do not pass through sympathetic trunk ganglia. Because of this, parasympathetic preganglionic fibers tend to be long.

In addition to autonomic ganglia, the autonomic nervous system contains autonomic plexuses. Slender nerve fibers from ganglia containing postganglionic nerve cell bodies arranged in a branching network constitute an autonomic plexus.

Postganglionic Neurons

Axons from preganglionic neurons of the sympathetic division pass to ganglia of the sympathetic trunk. They can either synapse in the sympathetic chain ganglia with postganglionic neurons or they can continue, without synapsing, through the chain ganglia to end at a prevertebral ganglion where synapses with postganglionic neurons can take place. Each sympathetic preganglionic fiber synapses with several postganglionic fibers in the ganglia, and the postganglionic fibers pass to several visceral effectors.

Axons from preganglionic neurons of the parasympathetic division pass to terminal ganglia near or within visceral effectors. In the ganglion, the preganglionic neuron usually synapses with only four or five postganglionic neurons to a single visceral effector.

Sympathetic Division

The preganglionic fibers of the sympathetic division have their cell bodies located in the lateral gray horns of all thoracic segments and first two or three lumbar segments of the spinal cord. The preganglionic fibers are myelinated and leave the spinal cord through the ventral root of a spinal nerve along with the somatic efferent fibers at the same segmental levels. After exiting through the intervertebral foramina, the preganglionic sympathetic fibers enter a white ramus to pass to the nearest sympathetic trunk ganglion on the same side. Collectively, the white rami are called the white rami communicantes. Their name indicates that they contain myelinated fibers. Only thoracic and upper lumbar nerves have white rami communicantes. The white rami communicantes connect the ventral ramus of the spinal nerve with the ganglia of the sympathetic trunk.

The paired sympathetic trunks are situated anterolaterally to the spinal cord, one on either side. Each consists of a series of ganglia arranged more or less segmentally. Typically, there are 22 ganglia in each chain: 3 cervical, 11 thoracic, 4 lumbar, and 4 sacral. Although the trunk extends downward from the neck, thorax, and abdomen to the coccyx, it receives preganglionic fibers only from the thoracic and lumbar segments of the spinal cord.

The cervical portion of the sympathetic trunk is located in the neck anterior to the prevertebral muscles. It subdivided into a superior, middle, inferior ganglion. The superior cervical ganglion is posterior to the internal carotid artery and anterior to the transverse processes of the second cervical vertebra. Postganglionic fibers leaving the ganglion serve the head, where they are distributed to the sweat glands, the smooth muscle of the eye and blood vessels of the face, the nasal mucosa, and parotid salivary glands. The middle cervical ganglion is situated near the sixth cervical vertebra at the level of the cricoid cartilage. Postganglionic fibers from it innervate the heart. The inferior cervical ganglion is located near the first rib, anterior to the transverse processes of the seventh cervical vertebra. Its postganglionic fibers supply the heart.

When a preganglionic fiber of a white rami communicans enters the sympathetic trunk it may terminates in several ways. Some fibers synapse in the first ganglion at the level of entry. Others pass up or down the sympathetic trunk for a variable distance to form the fibers on which the ganglia are strung. These fibers may not synapse until they reach a ganglion in the cervical or sacral area.

Some preganglionic fibers pass through the sympathetic trunk without terminating in the trunk. Beyond the trunk, they form nerves known as splanchnic nerves. After passing through the trunk of the ganglia, the splanchnic nerve from the thoracic area terminate in the celiac plexus. The greater splanchnic nerve passes to the celiac ganglion of the celiac plexus. From here the postganglionic fibers are distributed to the stomach, spleen, liver, kidney, and small intestine. The lesser splanchnic nerve passes through the celiac plexus to the superior mesenteric ganglion of the superior mesenteric plexus. Postganglionic fibers from this ganglion innervate the small intestine and colon. The lumbar splanchnic nerve enters the inferior mesenteric plexus. In the plexus, the preganglionic fibers synapse with postganglionic fibers in the inferior mesenteric ganglion. These fibers pass through the hypogastric plexus and supply the distal colon and rectum, urinary bladder, and genital organs.

Parasympathetic Division

The preganglionic cell bodies of the parasympathetic division are found in the nuclei in the brain stem and the lateral gray horn of the second through the fourth sacral segments of the spinal cord. Their fibers emerge as part of a cranial nerve or as part of the ventral root of a spinal nerve. The cranial parasympathetic preganglionic fibers leave the brain stem by way of the oculomotor (III) nerve, facial (VII) nerve, glossopharyngeal (IX) nerve, and vagus (X) nerve. The sacral parasympathetic preganglionic fibers leave through the ventral roots of the second through fourth sacral nerves. The preganglionic fibers of both cranial and sacral parts end in terminal ganglia, where they synapse with postganglionic neurons.

The cranial part has five components: four pairs of ganglia and the plexuses associated with the vagus nerve. The four pairs of cranial parasympathetic ganglia innervate structures in the head and are located close to the organs they innervate.

The ciliary ganglion is near the back of an orbit lateral to the optic (II) nerve. Preganglionic fibers pass with the oculomotor (III) nerve to the ciliary ganglion. Postganglionic fibers from the ganglion innervate the smooth muscle cells in the eyeball.

Each pterygopalatine ganglion is located lateral to a sphenopalatine foramen. It receives preganglionic fibers from the facial (VII) nerve and transmits postganglionic fibers to the nasal mucosa, palate, pharynx, and lacrimal gland.

Each submandibular ganglion is found near the duct of the submandibular salivary gland. It receives preganglionic fibers from the facial (VII) nerve and transmits postganglionic fibers that innervate the submandibular and sublingual salivary gland.

The otic ganglion is situated just below each foramen ovale. The otic ganglion receives the preganglionic fibers from the glossopharyngeal (IX) nerve and transmits postganglionic fibers that innervate the parotid salivary gland.

Ganglia associated with the cranial fibers are classified as terminal ganglia. Since the terminal ganglia are close to their visceral effectors, postganglionic parasympathetic fibers are short. Postganglionic sympathetic fibers are relatively long.

The last component of the cranial outflow consists of the preganglionic fibers that leave the brain via the vagus (X) nerve. This component has the most extensive distribution of the parasympathetic fibers. Each vagus (X) nerve enters into the formation of several plexuses in the thorax and abdomen. As it passes through thorax, it sends fibers to the superficial cardiac plexus in the arch of the aorta and the deep cardiac plexus anterior to the branching of the trachea. These plexuses contain terminal ganglia, and the postganglionic parasympathetic fibers emerging from them and supply the heart. Also in the thorax is the pulmonary plexus, anterior and posterior to the root of the lungs and within the lungs themselves. It receives preganglionic parasympathetic fibers from the vagus and transmits postganglionic parasympathetic fibers to the long and bronchi. Other plexuses associated with the vagus are described with appropriate thoracic, abdomen, and pelvic viscera. Postganglionic fibers from these plexuses innervate viscera such as the liver, pancreas, stomach, kidney, small intestine, and part of the colon.

The sacral parasympathetic outflow consists of preganglionic fibers from the ventral roots of the second through the fourth sacral nerves. Collectively they form the pelvic splanchnic nerves. They pass into the hypogastric plexus. From the ganglia in the plexus, parasympathetic postganglionic fibers are distributed to the colon, ureters, urinary bladder, and reproductive organs.

In summary the structural features of the sympathetic and parasympathetic division

Sympathetic	Parasympathetic
Forms thoracolumbar outflow. **Contains sympathetic trunk and prevertebral ganglia.** **Ganglia are close to the CNS and distant from visceral effectors.** **Each preganglionic fiber synapses with many postganglionic neurons that pass to many visceral effectors.** **Distributed throughout the body, including the skin.**	**Forms cranioscacral outflow.** **Contains terminal ganglia.** **Ganglia are near or with visceral effectors.** **Each preganglionic fiber usually synapses with four or five postganglionic neurons that pass to a single visceral effectors.** **Distribution limited primarily to head and viscera of thorax, abdomen, and pelvis.**