



PHYSIOLOGY

THE AUTO NERVOUS

The nervous system is one of the most complicated systems in the human body. Along with the endocrine system, it controls many bodily activities. The nervous system senses changes both in the internal and external environments, interprets these changes, and then coordinates appropriate responses in order to maintain homeostasis.¹ In response to changing conditions, the autonomic nervous system (ANS) shunts blood to more needy areas, speeds or slows heart and respiratory rates, adjusts blood pressure and body temperature, and increases or decreases stomach secretions.² Most of this fine-tuning occurs without our conscious awareness or attention, implying a certain amount of functional independence. Hence the term autonomic (auto= self; nom=govern).

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ONOMIC

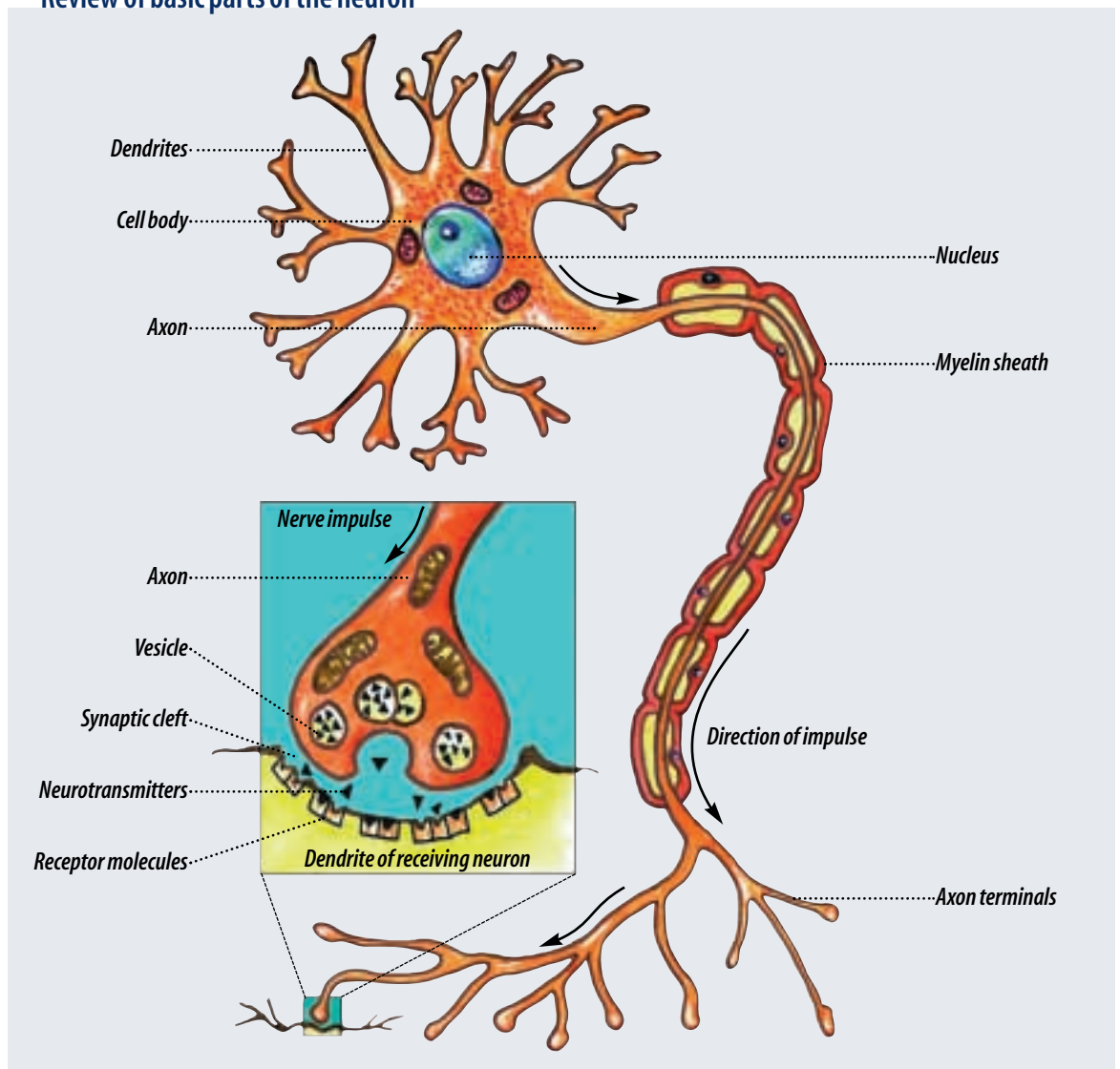
S SYSTEM

General organization

The nervous system includes the central nervous system (CNS), consisting of the brain and spinal cord, and the peripheral nervous system (PNS), consisting of 12 pairs of cranial nerves (which emerge from the base of the skull) and 31 pairs of spinal nerves (which emerge from the spinal cord). All of these nerves consist of fibers that may be sensory or motor or a mixture of both.¹ Nerves composed of both sensory and motor fibers are called mixed nerves. For example, the facial nerve CN VII consists of motor fibers that control facial expressions (eg frowning and smiling) and sensory fibers, which transmit taste sensations from the tongue to the brain.

Functionally, the PNS is subdivided into two specialized systems: the somatic nervous system (SNS) and the autonomic nervous system (ANS).¹ The SNS primarily innervates skeletal muscle, producing consciously controlled, voluntary movement (ie walking and talking). The ANS primarily innervates glands, smooth muscle and cardiac muscle. It's responsible for controlling visceral functions and involuntary muscles in the respiratory, circulatory, digestive and urogenital systems, and in the skin⁶ that are essential for the body to maintain homeostasis. The ANS operates without conscious control. The autonomic nervous system is activated mainly by centers located in the spinal cord, brain stem, and hypo-

Review of basic parts of the neuron



thalamus.³ Often the autonomic nervous system operates by means of autonomic reflexes. Sensory signals from peripheral nerve receptors relay signals into the centers of the cord, brain stem, or hypothalamus, and these in turn transmit appropriate reflex responses back to the peripheral organs or tissues to control their activities.⁴

Divisions of the autonomic nervous system

The autonomic nervous system (ANS) is further divided into two major subdivisions: the parasympathetic nervous system (PaNS) and sympathetic nervous system (SyNS). The two divisions are physiological antagonists and are in equilibrium with each other. Both divisions often innervate the same organ (eg iris of the eye and the heart). Structurally, each division differs in the location of their preganglionic neuron cell bodies within the CNS, the location of their autonomic ganglion, the relative lengths of their preganglionic and postganglionic axons, and the ratio of preganglionic and postganglionic neurons. They both integrate and operate continuously with the rest of the nervous system by responding in varying degrees to information provided by the sensory component of the nervous system.

The SyNS dominates during stressful or physically strenuous situations. It sends impulses that increase blood pressure, speed up rate and force of the heartbeat, dilate bronchioles, increase blood sugar concentration and reroute blood flow to skeletal muscle (fight or flight). Conversely, the PaNS dominates during times of emotional calm and/or physical rest. It sends impulses that decrease blood pressure, decrease heart rate and stimulate gastrointestinal motility (digestion and rest).

Parasympathetic nervous system

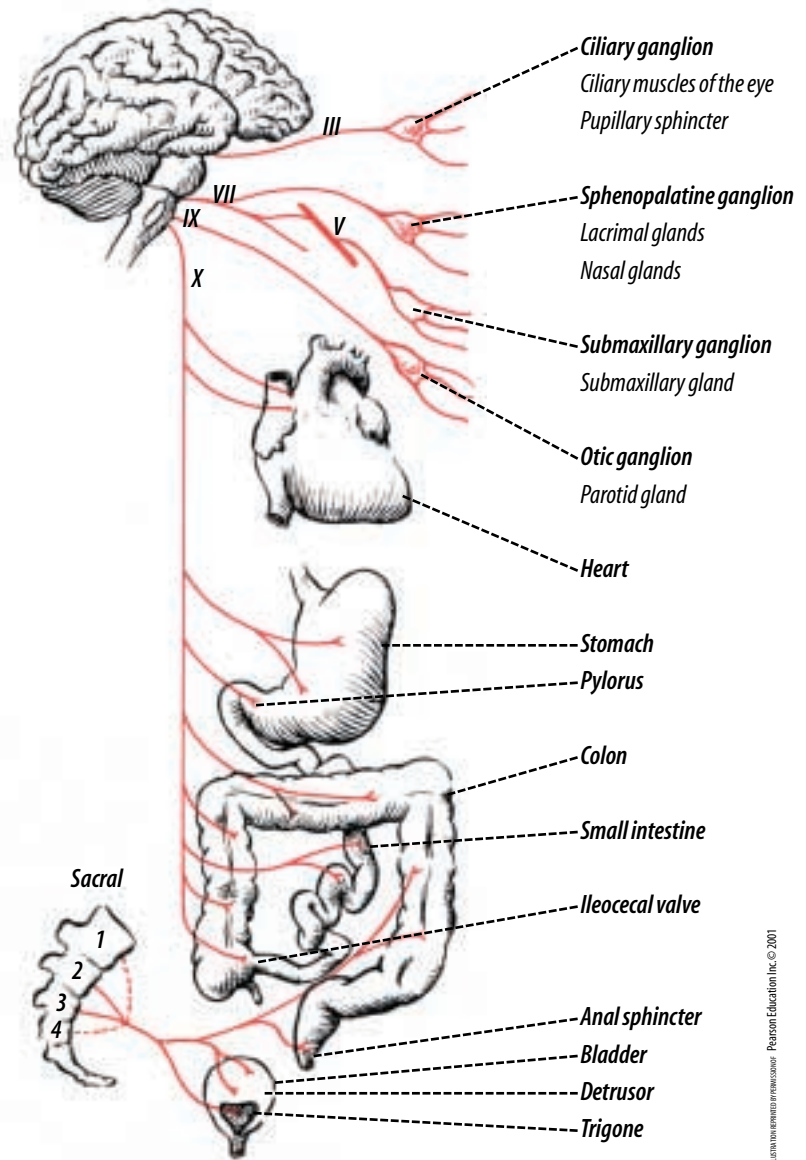
The PaNS is the craniosacral division of the ANS. Preganglionic fibers originate from nuclei in the midbrain, medulla and sacral portion of the spinal cord. Neurons of the PaNS emerge from the brainstem and pass through as part of the III, VII, IX, and X cranial nerves, and 2nd, 3rd, and 4th sacral nerves from the sacral region.⁴ They synapse with postganglionic neurons located in

autonomic (terminal) ganglia that lie near or within the walls of the organs innervated (Figure 1). Since the terminal ganglia are close to the innervated organs/structures, the axons of the postganglionic fibers are short. PaNS preganglionic neurons synapse with only a relatively few postganglionic neurons. For this reason they are much more precise and localized in their effects. Some effects of PaNS stimulation include:

- constriction of pupils
- contraction of smooth muscle of alimentary canal
- constriction of bronchioles
- slowing of heart rate

FIGURE 1

The parasympathetic nervous system.³



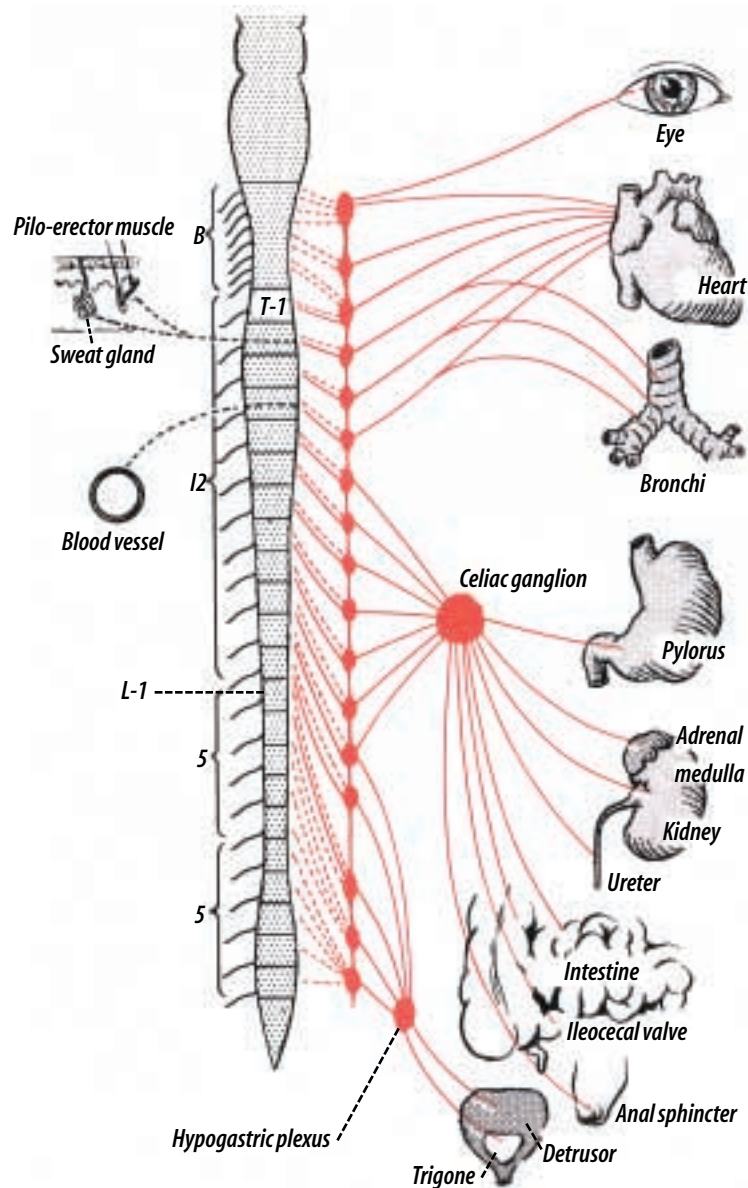


FIGURE 2

The sympathetic nervous system.³

Dashed lines represent post-ganglionic fibers in the gray rami leading into the spinal nerves for distribution to blood vessels, sweat glands, and pilo-erector muscles.

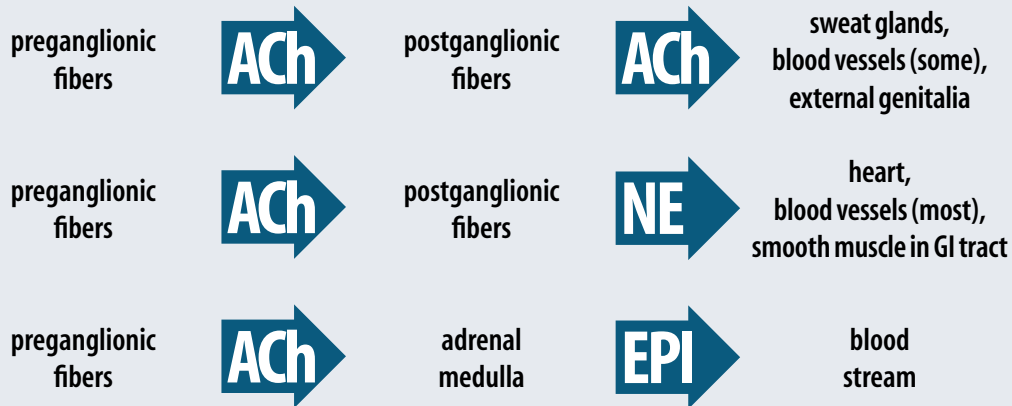
Transmission of an impulse between preganglionic and postganglionic fibers takes place at an electrochemical junction called a synapse. Both pre- and postganglionic neurons of the PaNS are cholinergic and utilize the neurotransmitter acetylcholine (ACh).⁴ When a nerve impulse reaches the terminus of a preganglionic fiber, it causes the release of ACh, which migrates across the synapse. The ACh combines with receptors on the synaptic membrane of the postganglionic fiber, causing depolarization and continuing the impulse down the postganglionic fiber. Once the impulse reaches the postganglionic terminus and depolarizes it, ACh migrates across the synapse and binds to specific

receptor sites in the effector gland, organ or muscle causing the desired effect (eg release of hormones, muscular contraction, etc). (Table 1)

The action of acetylcholine is relatively brief and usually lasts for only a fraction of a second. It is rapidly broken down by the enzyme cholinesterase, which is present both in the terminal nerve ending and on the surface of the receptor organ. Acetylcholine (cholinergic) receptor sites are classified as either nicotinic or muscarinic. Nicotinic receptor sites for ACh occur at the junction between the preganglionic fibers and postganglionic fibers in both the SyNS and the PaNS divisions of the ANS. Muscarinic receptor sites for ACh occur at the junction between the postganglionic fibers and effector sites in the PaNS division of the ANS.

Sympathetic nervous system

The SyNS is the thoracolumbar division of the ANS (Figure 2). Preganglionic fibers originate from cell bodies in the lateral gray horn of all thoracic and the first two or three lumbar segments of the spinal cord and leave the cord by way of the of the anterior (ventral) spinal nerve roots (Figure 3). They pass through the intervertebral foramina, enter a white rami communicans and connect with the ganglia of the paravertebral sympathetic chain, which are situated anterolaterally to the spinal cord. Each of these paired chains is a series of 22 ganglia spanning the length of the vertebral column.⁴ All preganglionic neurons in the SyNS are myelinated, which gives them a white appearance. Most preganglionic neurons end within the paravertebral sympathetic ganglia and synapse with postganglionic efferent neurons. Some of the postganglionic neurons re-enter the spinal nerves via the grey rami communicans. They appear grey because postganglionic neurons are nonmyelinated. These neurons extend with other neurons in the spinal nerves, eventually branch off and form visceral nerves that innervate smooth muscle and sweat glands. Other preganglionic neurons pass through the paravertebral sympathetic ganglia to a second set of ganglia called collateral ganglia located mainly in the

Table 1 ANS parasympathetic**Table 2** ANS sympathetic**Table 3** Cholinergic and adrenergic receptors²

Neurotransmitter	Receptor Type	Major locations	Effect of binding
Acetylcholine	Cholinergic		
	Nicotinic	All postganglionic neurons; adrenal medullary cells (also neuromuscular junctions of skeletal muscle)	Excitation
	Muscarinic	All parasympathetic target organs	Excitation in most cases; inhibition of cardiac muscle
		Selected sympathetic targets:	
		• Sweat glands	Activation
		• Blood vessels in skeletal muscles	Inhibition (causes vasodilation)
Norepinephrine (and epinephrine released by adrenal medulla)	Adrenergic		
	β_1	Heart, adipose tissue	Increases heart rate and strength; stimulates lipolysis
	β_2	Kidneys, lungs, and most other sympathetic target organs; abundant on blood vessels serving skeletal muscles and the heart	Stimulates secretion of renin; other effects mostly inhibitory; dilation of blood vessels and bronchioles; relaxes smooth muscle walls of digestive and urinary visceral organs
	α_1	Most important blood vessels serving the skin, mucosae, abdominal viscera, kidneys, and salivary glands; but virtually all sympathetic target organs except heart	Activation: constricts blood vessels and visceral organ sphincters
	α_2	Membrane of adrenergic axon terminals; blood platelets	Mediates inhibition of NE release from adrenergic terminals; promotes blood clotting

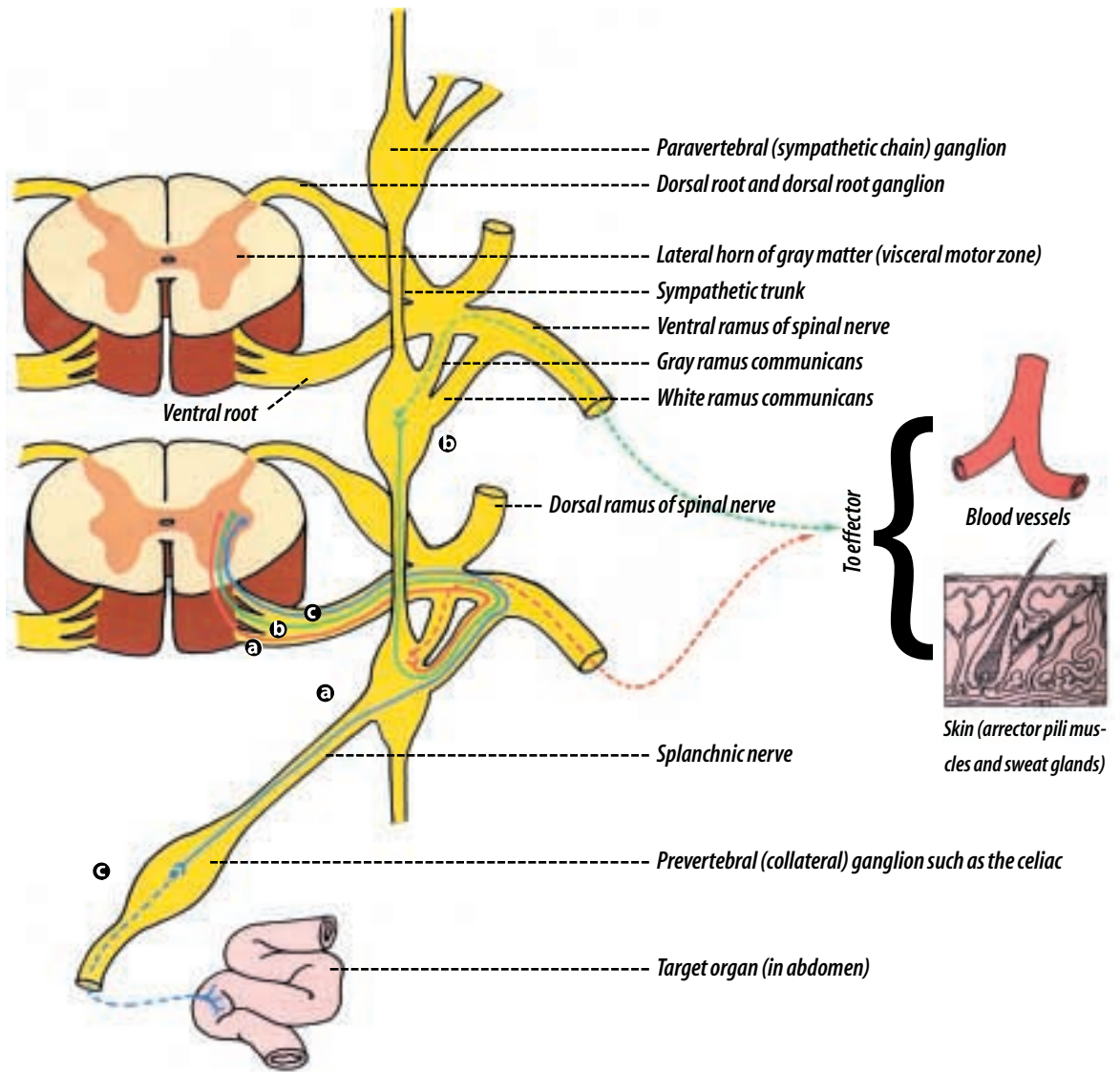


FIGURE 3

Sympathetic pathways.²

- a** synapse in a paravertebral (chain) ganglion at the same level
- b** synapse in a paravertebral ganglion at a different level
- c** synapse in a prevertebral (collateral) ganglion anterior to the vertebral column

abdomen close to the aorta and its major branches (eg celiac, superior mesenteric and inferior mesenteric arteries). These bundles of collateral ganglia are often called plexus.⁴ The preganglionic neurons synapse with nonmyelinated neurons in the collateral ganglion. The postganglionic neurons branch off and innervate the smooth muscles of the abdominal and pelvic viscera and the endocrine glands in that area. The effects of the SyNS are extremely widespread rather than specific to one organ or muscle.

Preganglionic neurons of the SyNS are cholinergic and utilize the neurotransmitter acetylcholine (ACh). A few of the postganglionic neurons of the SyNS are cholinergic and secrete

acetylcholine (ACh). They innervate the sweat glands of the skin, some blood vessels within the skeletal muscles and the external genitalia. But by far, the majority of the sympathetic postganglionic nerves are adrenergic and utilize the neurotransmitter norepinephrine (NE).³ The effect of NE released at the effector site produces different results (excitation or inhibition) depending on the receptor(s) to which it binds. (Table 2)

There are two major classes of adrenergic (NE-binding) receptors: alpha (α) and beta (β). Organs that respond to NE (or epinephrine, EPI) display one or both types of receptors. In general, NE or epinephrine binding to alpha receptors is stimulatory, while their binding to

beta receptors is inhibitory. However, there are notable exceptions. For example, binding of NE to the beta receptors of cardiac muscle prods the heart into more vigorous activity. These differences reflect that both alpha and beta receptors have two receptor subclasses (alpha 1 and alpha 2, beta 1 and beta 2). Each receptor type tends to predominate in certain target organs (Table 3).

Adrenal medulla

Some preganglionic sympathetic (thoracic splanchnic) nerve fibers pass through the celiac ganglion without synapsing and terminate by synapsing with hormone-producing medullary cells (chromaffin cells) of the adrenal gland. When stimulated by the preganglionic fibers, the chromaffin cells release large quantities of epinephrine and norepinephrine directly into the blood stream. These hormones are then carried to tissues throughout the body where they reinforce the effects of the SyNS.⁴

The epinephrine and norepinephrine released by the combined efforts of the SyNS and the adrenal glands is eventually dissipated either by being taken back into the synaptic nerve endings or by action of the enzyme monoamine oxidase.⁴

Sympathetic and parasympathetic tone

The autonomic system generally maintains a 'tone,' a basal level of activity, which then may be either increased or decreased by central control.⁵ The sympathetic and parasympathetic systems are continually active and the basal rates of stimulation are known, respectively, as sympathetic tone and parasympathetic tone.⁵ The value of tone is that it allows a single nervous system to increase or decrease the activity of an organ. For example, sympathetic tone normally keeps almost all the blood vessels of the body constricted to approximately half their maximum diameter. By increasing the degree of sympathetic stimulation, the vessels can be constricted even more; but, on the other hand, by decreasing the level of sympathetic stimulation, the vessels can be dilated.⁵

Another example of tone is that of the parasympathetics in the gastrointestinal tract.

Surgical removal of the parasympathetic supply to the gut by cutting the vagi can cause serious and prolonged gastric and intestinal atony, thus illustrating that in normal function the parasympathetic tone to the gut is strong. This tone can be decreased by the brain, thereby inhibiting gastrointestinal motility, or it can be increased, thereby promoting increased gastrointestinal activity.⁵ The presence of dual innervation and the possibility of either increasing or decreasing the tone permit a wide range of control.⁵

Conclusion

The art and science of medicine has changed very rapidly over the last 10 years. The high cost of hospital care has created an impetus for surgical technologists to master the knowledge and advanced procedural skills necessary to meet the growing demands of an ever more complex surgical environment. It is my hope this article has provided a useful framework upon which surgical technologists can advance their knowledge and understanding of human physiology as it relates to patient care, thus being better prepared to move into the realm of advanced practice.

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- The nervous system along with the _____ system controls many bodily activities.
 - cardiovascular
 - respiratory
 - endocrine
 - urogenital
- The peripheral nervous system consists of _____.
 - 10 pairs of cranial nerves; 28 pairs of spinal nerves
 - 11 pairs of cranial nerves; 29 pairs of spinal nerves
 - 12 pairs of cranial nerves; 31 pairs of spinal nerves
 - 13 pairs of cranial nerves; 32 pairs of cranial nerves
- The autonomic nervous system (ANS) primarily innervates all of the following except _____.
 - glands
 - skeletal muscle
 - smooth muscle
 - cardiac muscle
- The autonomic nervous system (ANS) is activated mainly by centers located in all of the following except _____.
 - Cerebellum
 - Hypothalamus
 - Brain stem
 - Spinal cord
- Which of the following is not a response to sympathetic nervous system (SyNS) impulses?
 - increase blood pressure
 - speed up force/rate of heart beat
 - increase blood sugar concentration
 - constrict bronchioles
- Both pre- and postganglionic neurons of the parasympathetic nervous system (PaNS) utilize the neurotransmitter _____.
 - epinephrine
 - norepinephrine
 - cholinesterase
 - acetylcholine
- When stimulated by preganglionic sympathetic (thoracic splanchnic) nerve fibers, the chromaffin cells of the adrenal glands release large quantities of _____ directly into the blood stream.
 - acetylcholine
 - epinephrine
 - norepinephrine
 - both B and C
- Which of the following branches of the aorta does not have a collateral ganglion (plexus) located next to it?
 - celiac
 - renal
 - superior mesenteric
 - inferior mesenteric
- Preganglionic fibers originate from cell bodies in the _____ gray horn of all the thoracic and first two or three lumbar segments of the spinal cord.
 - anterior
 - lateral
 - medial
 - posterior
- _____ receptor sites for acetylcholine (cholinergic) occur at the junction between preganglionic and postganglionic fibers of both the sympathetic and parasympathetic divisions of the ANS.
 - nicotinic
 - muscarinic
 - adrenergic
 - oxidase

Autonomic nervous system

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