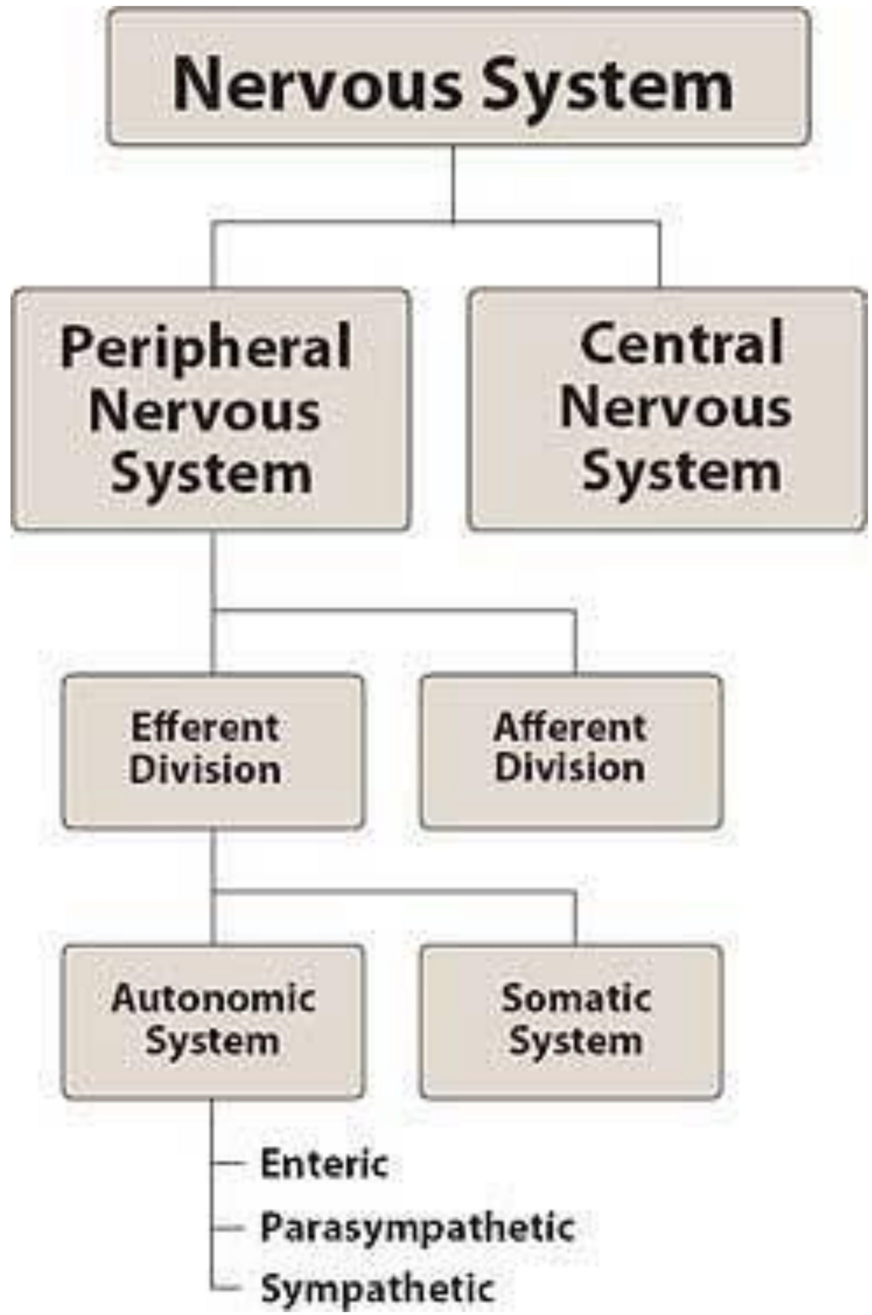
Autonomic Nervous System

The autonomic nervous system, along with the endocrine system, coordinates the regulation and integration of bodily functions.

The endocrine system sends signals to target tissues by varying the levels of blood-borne hormones.

Drugs that produce their primary therapeutic effect by altering the functions of the autonomic nervous system are called autonomic drugs.

These autonomic agents act either by stimulating portions of the autonomic nervous system or by blocking the action of the autonomic nerves.


Nervous System
Peripheral Nervous System
Central Nervous System
Efferent Division
Afferent Division
Autonomic System
Somatic System
Enteric
Parasympathetic
Sympathetic

The nervous system is divided into two anatomical divisions: the central nervous system (CNS), which is composed of the brain and spinal cord, and the peripheral nervous system, which includes neurons located outside the brain and spinal cord.

The efferent division, the neurons of which carry signals away from the brain and spinal cord to the peripheral tissues.

The afferent division, the neurons of which bring information from the periphery to the CNS.

The somatic efferent neurons are involved in the voluntary control of functions such as contraction of the skeletal muscles essential for locomotion.

The autonomic system regulates the everyday requirements of vital bodily functions without the conscious participation of the mind (digestion, cardiac output, blood flow, and glandular secretions).

Efferent neurons: The autonomic nervous system carries nerve impulses from the CNS to the effector organs by way of two types of efferent neurons.

The first nerve cell is called a preganglionic neuron, and its cell body is located within the CNS.

Preganglionic neurons emerge from the brainstem or spinal cord and make a synaptic connection in ganglia (an aggregation of nerve cell bodies located in the peripheral nervous system).

These ganglia function as relay stations between a preganglionic neuron and a second nerve cell, the postganglionic neuron.

The latter neuron has a cell body originating in the ganglion, it terminates on effector organs, such as smooth muscles of the viscera, cardiac muscle, and the exocrine glands.

Afferent neurons: The afferent neurons of the autonomic nervous system are important in the reflex regulation of this system and signaling the CNS to influence the efferent branch of the system to respond.

The efferent autonomic nervous system is divided into the sympathetic and the parasympathetic nervous systems, as well as the enteric nervous system.

Anatomically, they originate in the CNS and emerge from the spinal cord.

The preganglionic neurons of the sympathetic system come from thoracic and lumbar regions of the spinal cord.

The preganglionic neurons are short in comparison to the postganglionic ones.

The parasympathetic preganglionic fibers arise from the cranium and from the sacral region of the spinal cord and synapse in ganglia near or on the effector organs.

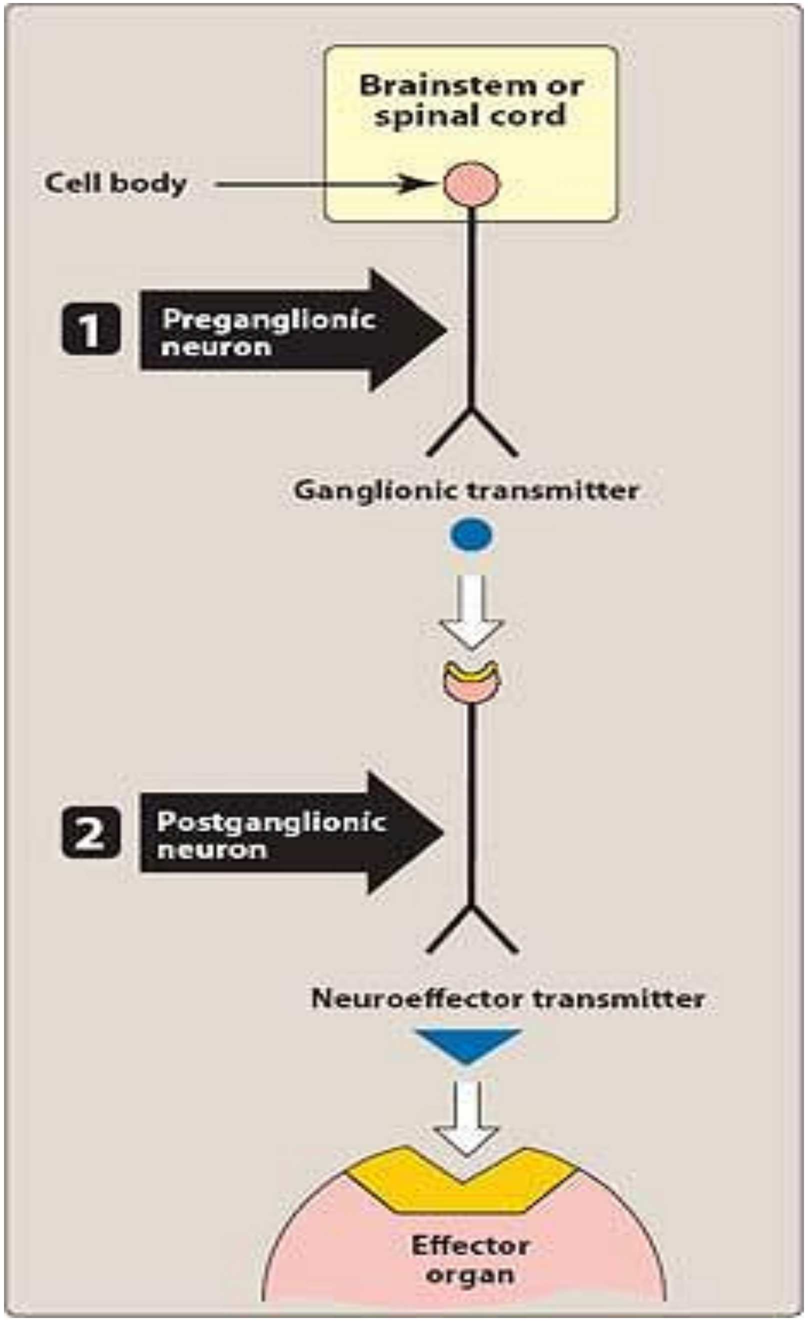
The preganglionic fibers are long, and the postganglionic ones are short, with the ganglia close to or within the organ innervated.

The enteric nervous system is the third division of the autonomic nervous system.

It is a collection of nerve fibers that innervate the gastrointestinal tract, pancreas, and gallbladder.

This system functions independently of the CNS and controls the motility, exocrine and endocrine secretions, and microcirculation of the gastrointestinal tract.

It is modulated by both the sympathetic and parasympathetic nervous systems.



Efferent neurons of the autonomic nervous system

Functions of the sympathetic nervous system

Although continually active to some degree, the sympathetic division has the property of adjusting in response to stressful situations, such as trauma, fear, hypoglycemia, cold, or exercise.

Effects of stimulation of the sympathetic division: The effect of sympathetic output is to increase heart rate and blood pressure, to mobilize energy stores of the body, and to increase blood flow to skeletal muscles and the heart while diverting flow from the skin and internal organs.

Sympathetic stimulation results in dilation of the pupils and the bronchioles.

It also affects gastrointestinal motility and the function of the bladder and sexual organs.

Fight or flight response: The changes experienced by the body during emergencies have been referred to as the fight or flight response.

These reactions are triggered both by direct sympathetic activation of the effector organs and by stimulation of the adrenal medulla to release epinephrine and lesser amounts of norepinephrine.

These hormones enter the bloodstream and promote responses in effector organs that contain adrenergic receptors.

The sympathetic nervous system tends to function as a unit, and it often discharges as a complete system.

This system is involved in a wide array of physiologic activities, but it is not essential for life.

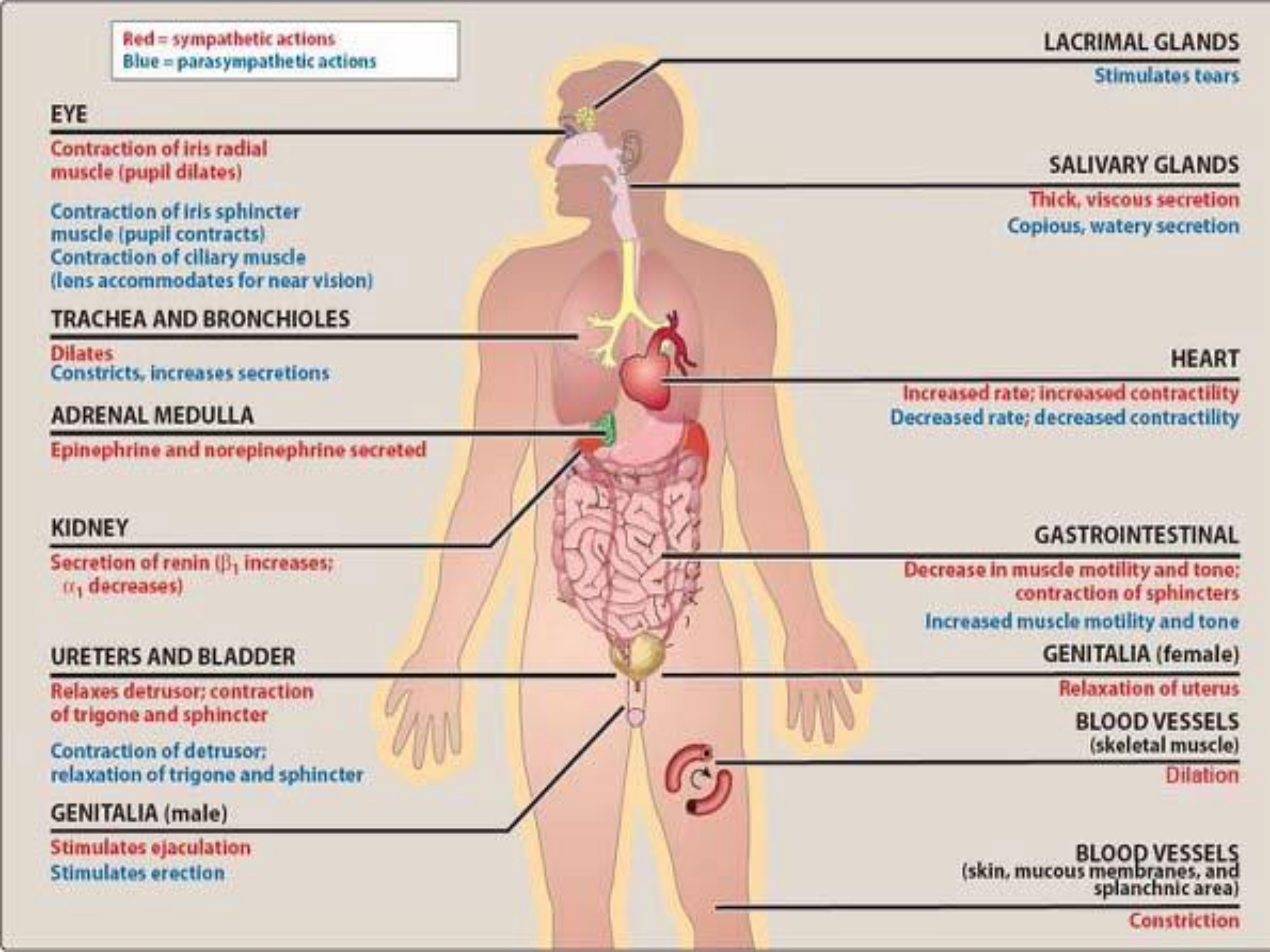
Functions of the parasympathetic nervous system

The parasympathetic division maintains essential bodily functions, such as digestive processes and elimination of wastes, that is required for life.

It usually acts to oppose or balance the actions of the sympathetic division and is generally dominant over the sympathetic system in rest and digest situations.

The parasympathetic system is not a functional entity, and it never discharges as a complete system.

Parasympathetic fibers are activated separately, and the system functions to affect specific organs, such as the stomach or eye.


Red = sympathetic actions
Blue = parasympathetic actions
EYE
Contraction of iris radial muscle (pupil dilates)
Contraction of iris sphincter muscle (pupil contracts)
Contraction of ciliary muscle (lens accommodates for near vision)
TRACHEA AND BRONCHIOLES
Dilates
Constricts, increases secretions
ADRENAL MEDULLA
Epinephrine and norepinephrine secreted
KIDNEY
Secretion of renin (β_1 increases; α_1 decreases)
URETERS AND BLADDER
Relaxes detrusor; contraction of trigone and sphincter
Contraction of detrusor; relaxation of trigone and sphincter
GENITALIA (male)
Stimulates ejaculation
Stimulates erection
LACRIMAL GLANDS
Stimulates tears
SALIVARY GLANDS
Thick, viscous secretion
Copious, watery secretion
HEART
Increased rate; increased contractility
Decreased rate; decreased contractility
GASTROINTESTINAL
Decrease in muscle motility and tone; contraction of sphincters
Increased muscle motility and tone
GENITALIA (female)
Relaxation of uterus
BLOOD VESSELS (skeletal muscle)
Dilation
BLOOD VESSELS (skin, mucous membranes, and splanchnic area)
Constriction

Role of the CNS in autonomic control functions

Although the autonomic nervous system is a motor system, it does require sensory input from peripheral structures to provide information on the state of affairs in the body.

This feedback is provided by streams of afferent impulses, originating in the viscera and other autonomically innervated structures, that travel to integrating centers in the CNS.

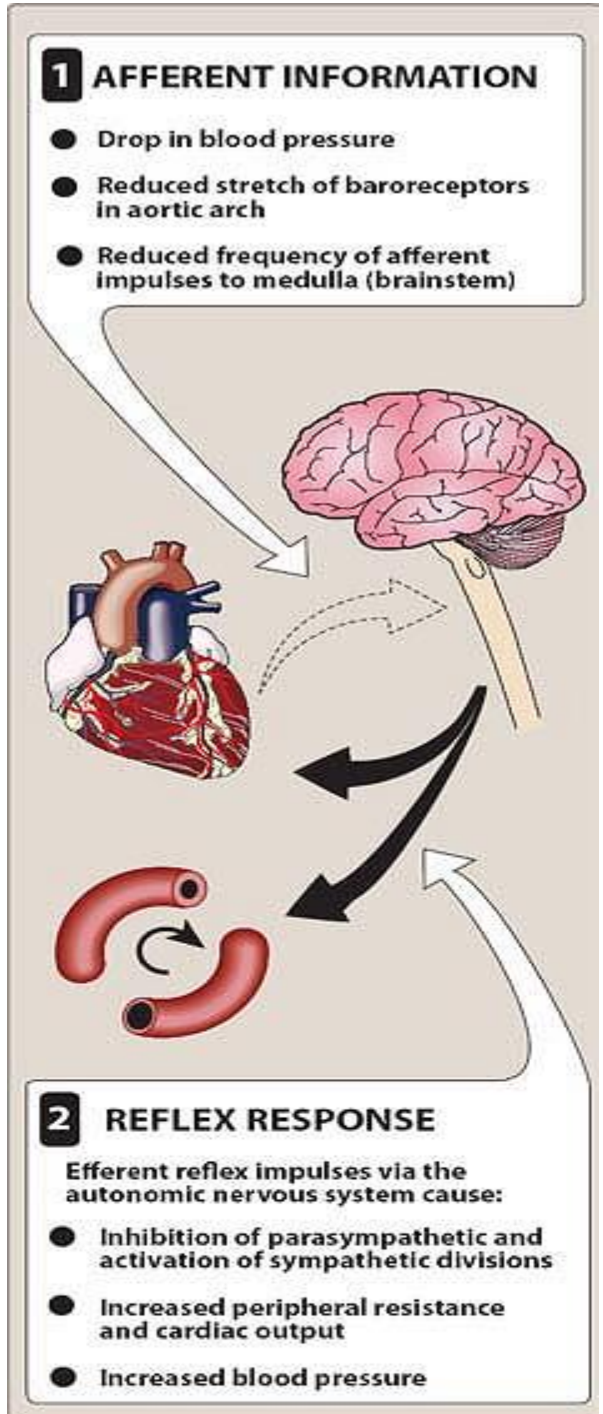
These centers respond to the stimuli by sending out efferent reflex impulses via the autonomic nervous system.

Reflex arcs: Most of the afferent impulses are translated into reflex responses without involving consciousness.

For example, a fall in blood pressure causes pressure-sensitive neurons to send fewer impulses to cardiovascular centers in the brain.

This prompts a reflex response of increased sympathetic output to the heart and vasculature and decreased parasympathetic output to the heart, which results in a compensatory rise in blood pressure and tachycardia.

In each case, the reflex arcs of the autonomic nervous system comprise a sensory (or afferent) arm, and a motor (or efferent, or effector) arm.


1 AFFERENT INFORMATION
Drop in blood pressure
Reduced stretch of baroreceptors in aortic arch
Reduced frequency of afferent impulses to medulla (brainstem)
2 REFLEX RESPONSE
Efferent reflex impulses via the autonomic nervous system cause:
Inhibition of parasympathetic and activation of sympathetic divisions
Increased peripheral resistance and cardiac output
Increased blood pressure

Innervation by the autonomic nervous system

Dual innervation: Most organs in the body are innervated by both divisions of the autonomic nervous system.

Thus, vagal parasympathetic innervation slows the heart rate, and sympathetic innervation increases the heart rate.

Despite this dual innervation, one system usually predominates in controlling the activity of a given organ.

For example, in the heart, the vagus nerve is the predominant factor for controlling rate.

This type of antagonism is considered to be dynamic and is fine-tuned at any given time to control homeostatic organ functions.

Organs receiving only sympathetic innervation: Although most tissues receive dual innervation, some effector organs, such as the adrenal medulla, kidney, and sweat glands, receive innervation only from the sympathetic system.

The control of blood pressure is also mainly a sympathetic activity, with essentially no participation by the parasympathetic system.

Somatic nervous system

The efferent somatic nervous system differs from the autonomic system in that a single myelinated motor neuron, originating in the CNS, travels directly to skeletal muscle without the mediation of ganglia. As noted earlier, the somatic nervous system is under voluntary control, whereas the autonomic is an involuntary system.

Chemical Signalling Between Cells

A. Local mediators

Most cells in the body secrete chemicals that act locally, that is, on cells in their immediate environment.

These chemical signals are rapidly destroyed or removed; therefore, they do not enter the blood and are not distributed throughout the body.

Histamine and the prostaglandins are examples of local mediators.

B. Hormones

Specialized endocrine cells secrete hormones into the bloodstream, where they travel throughout the body exerting effects on broadly distributed target cells in the body.

C. Neurotransmitters

All neurons are distinct anatomic units, and no structural continuity exists between most neurons.

Communication between nerve cells and between nerve cells and effector organs occurs through the release of specific chemical signals, called neurotransmitters, from the nerve terminals.

This release is triggered by the arrival of the action potential at the nerve ending, leading to depolarization.

Uptake of Ca^{2+} initiates fusion of the synaptic vesicles with the presynaptic membrane and release of their contents.

The neurotransmitters rapidly diffuse across the synaptic space (synapse) between neurons and combine with specific receptors on the postsynaptic (target) cell.

Membrane receptors: All neurotransmitters and most hormones and local mediators are too hydrophilic to penetrate the lipid bilayer of target-cell plasma membranes.

Their signal is mediated by binding to specific receptors on the cell surface of target organs.

It has a binding specificity, and it is coupled to processes that eventually evoke a response.

Most receptors are proteins.

Types of neurotransmitters: Although over fifty signal molecules in the nervous system have been identified, six signal compounds norepinephrine (and the closely related epinephrine), acetylcholine, dopamine, serotonin, histamine, and GABA are most commonly involved in the actions of therapeutically useful drugs.

Each of these chemical signals binds to a specific family of receptors.

Acetylcholine and norepinephrine are the primary chemical signals in the autonomic nervous system, whereas a wide variety of neurotransmitters function in the CNS.

Not only these neurotransmitters released on nerve stimulation, cotransmitters, such as adenosine, often accompany them and modulate the transmission process.

Acetylcholine: The autonomic nerve fibers can be divided into two groups based on the chemical nature of the neurotransmitter released.

If transmission is mediated by acetylcholine, the neuron is termed cholinergic.

Acetylcholine mediates the transmission of nerve impulses across autonomic ganglia in both the sympathetic and parasympathetic nervous systems.

It is the neurotransmitter at the adrenal medulla.

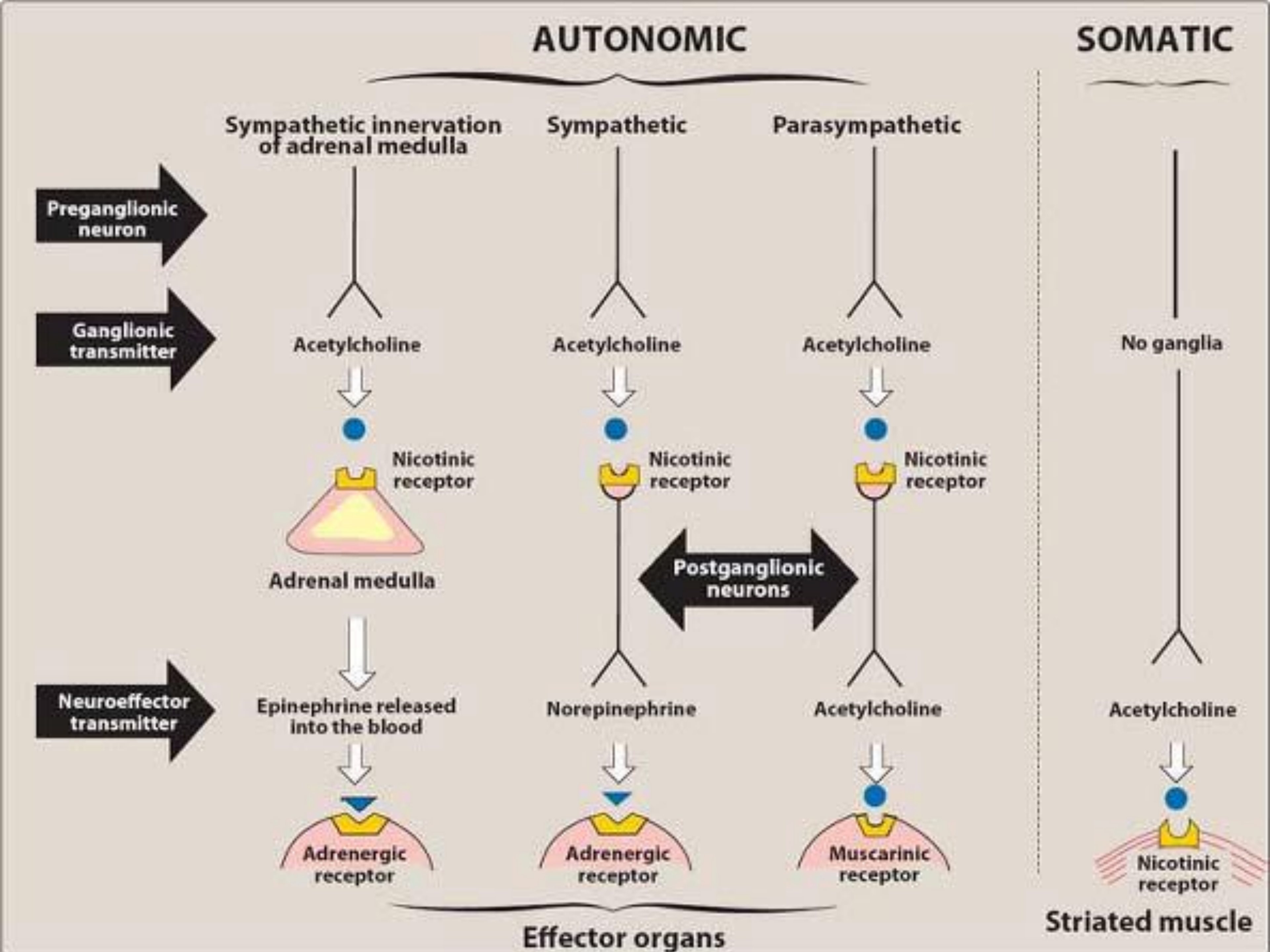
Transmission from the autonomic postganglionic nerves to the effector organs in the parasympathetic system and a few sympathetic system organs also involves the release of acetylcholine.

In the somatic nervous system, transmission at the neuromuscular junction (that is, between nerve fibers and voluntary muscles) is also cholinergic.

Norepinephrine and epinephrine: When norepinephrine or epinephrine is the transmitter, the fiber is termed adrenergic (adrenaline being another name for epinephrine).

In the sympathetic system, norepinephrine mediates the transmission of nerve impulses from autonomic postganglionic nerves to effector organs.

A few sympathetic fibers, such as those involved in sweating, are cholinergic.


AUTONOMIC
SOMATIC
Sympathetic innervation of adrenal medulla
Sympathetic
Parasympathetic
Preganglionic neuron
Ganglionic transmitter
Acetylcholine
Acetylcholine
Acetylcholine
No ganglia
Nicotinic receptor
Nicotinic receptor
Nicotinic receptor
Adrenal medulla
Postganglionic neurons
Neuroeffector transmitter
Epinephrine released into the blood
Norepinephrine
Acetylcholine
Acetylcholine
Adrenergic receptor
Adrenergic receptor
Muscarinic receptor
Nicotinic receptor
Effector organs
Striated muscle