The Autonomic Nervous System (ANS)

The portion of the nervous system that controls most visceral functions of the body is called the autonomic nervous system. This system helps to control arterial pressure, gastrointestinal motility, gastrointestinal secretion, urinary bladder emptying, sweating, body temperature, and many other activities, some of which are controlled almost entirely and some only partially by the autonomic.

The autonomic nervous system is activated mainly by centers located in the spinal cord, brain stem, and hypothalamus can transmit signals to the lower centers and in this way influence autonomic control. The autonomic nervous system also often operates by means of visceral reflexes. That is, subconscious sensory signals from a visceral organ can enter the autonomic ganglia, the brain stem, or the hypothalamus and then return subconscious reflex responses directly back to the visceral organ to control its activities.

The efferent autonomic signals are transmitted to the various organs of the body through two major subdivisions called the sympathetic nervous system and the parasympathetic nervous system.

Physiologic Anatomy of the Sympathetic Nervous System

The sympathetic nerve fibers originate in the spinal cord along with spinal nerves and pass first into the sympathetic chain and then to the tissues and organs that are stimulated by the sympathetic nerves.

The sympathetic nerves are different from skeletal motor nerves in the following way: Each sympathetic pathway from the cord to the stimulated tissue is composed of two neurons, a preganglionic neuron and a postganglionic neuron, in contrast to only a single neuron in the skeletal motor pathway.

Immediately after the spinal nerve leaves the spinal canal, the preganglionic sympathetic fibers leave the spinal nerve. The postganglionic sympathetic neuron thus originates either in one of the sympathetic chain ganglia or in one of the peripheral sympathetic ganglia. From either of these two sources, the postganglionic fibers then travel to their destinations in the various organs.

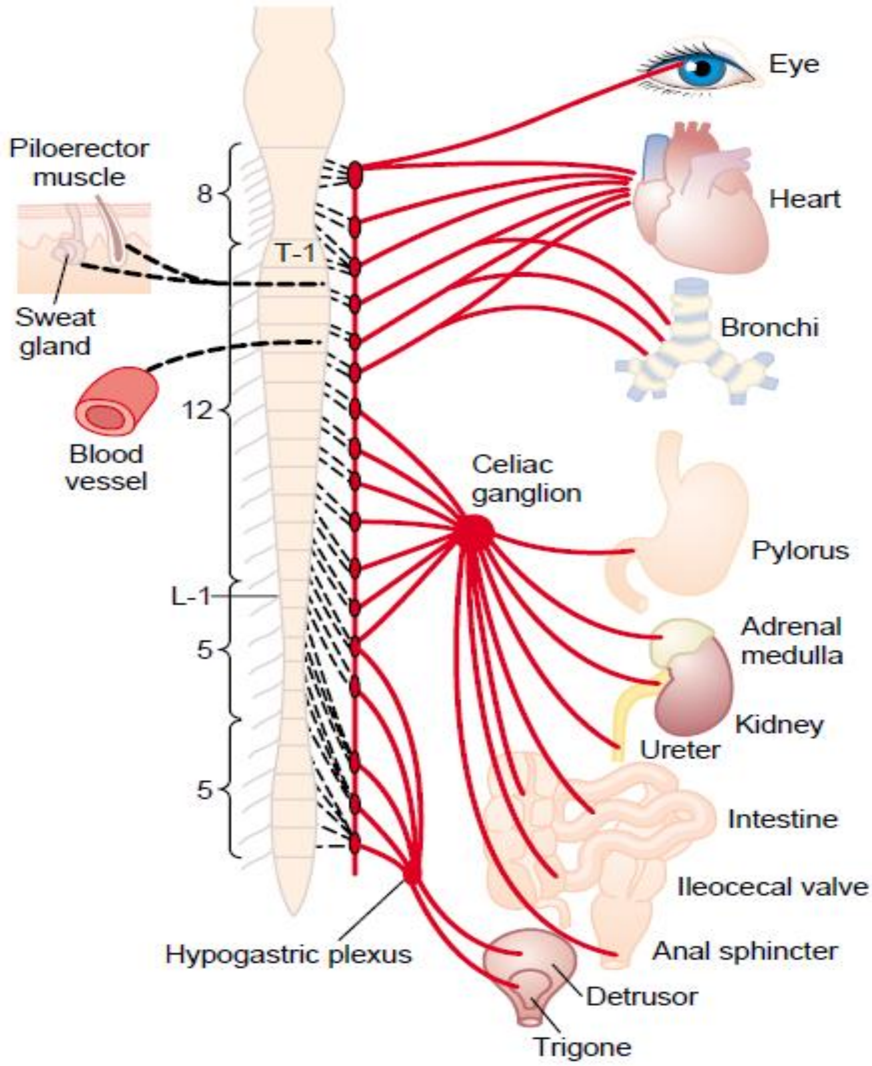


Figure 60–1

Sympathetic nervous system. The black dashed lines represent postganglionic fibers in the gray rami leading from the sympathetic chains into spinal nerves for distribution to blood vessels, sweat glands, and piloerector muscles.

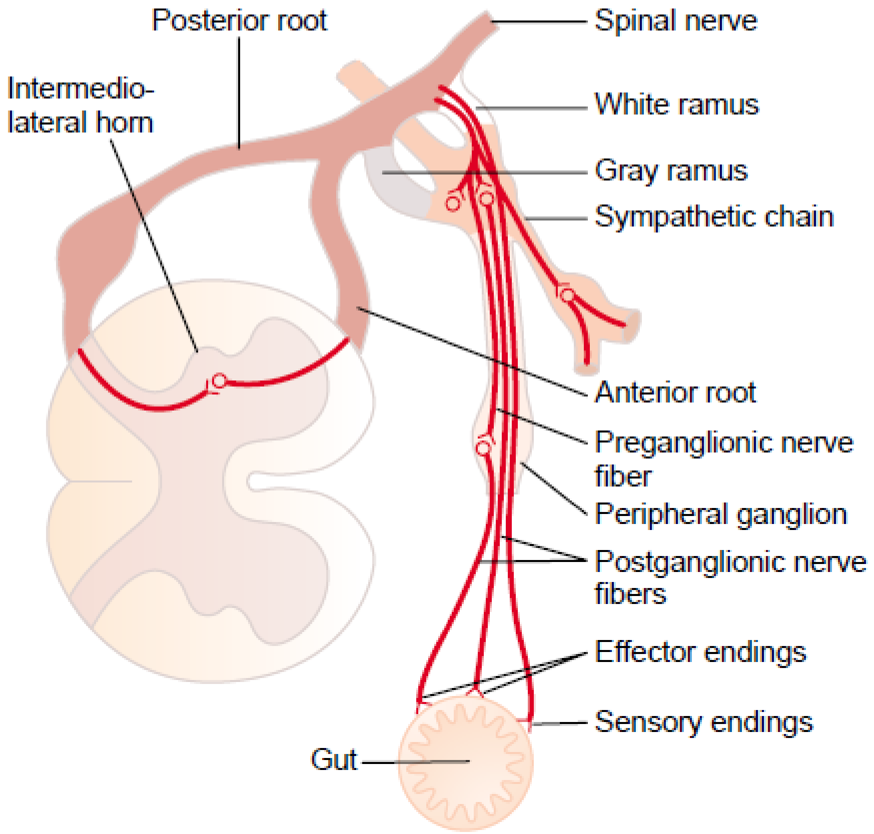


Figure 60–2

Nerve connections between the spinal cord, spinal nerves, sympathetic chain, and peripheral sympathetic nerves.

Physiologic Anatomy of the Parasympathetic Nervous System

The parasympathetic nervous system is shown in Figure, demonstrating that parasympathetic fibers leave the central nervous system through cranial nerves III, VII, IX, and X. The vagus nerves supply parasympathetic nerves to the heart, lungs, esophagus, stomach, entire small intestine, proximal half of the colon, liver, gallbladder, pancreas, kidneys, and upper portions of the ureters, The parasympathetic system, like the sympathetic, has both preganglionic and postganglionic neurons.

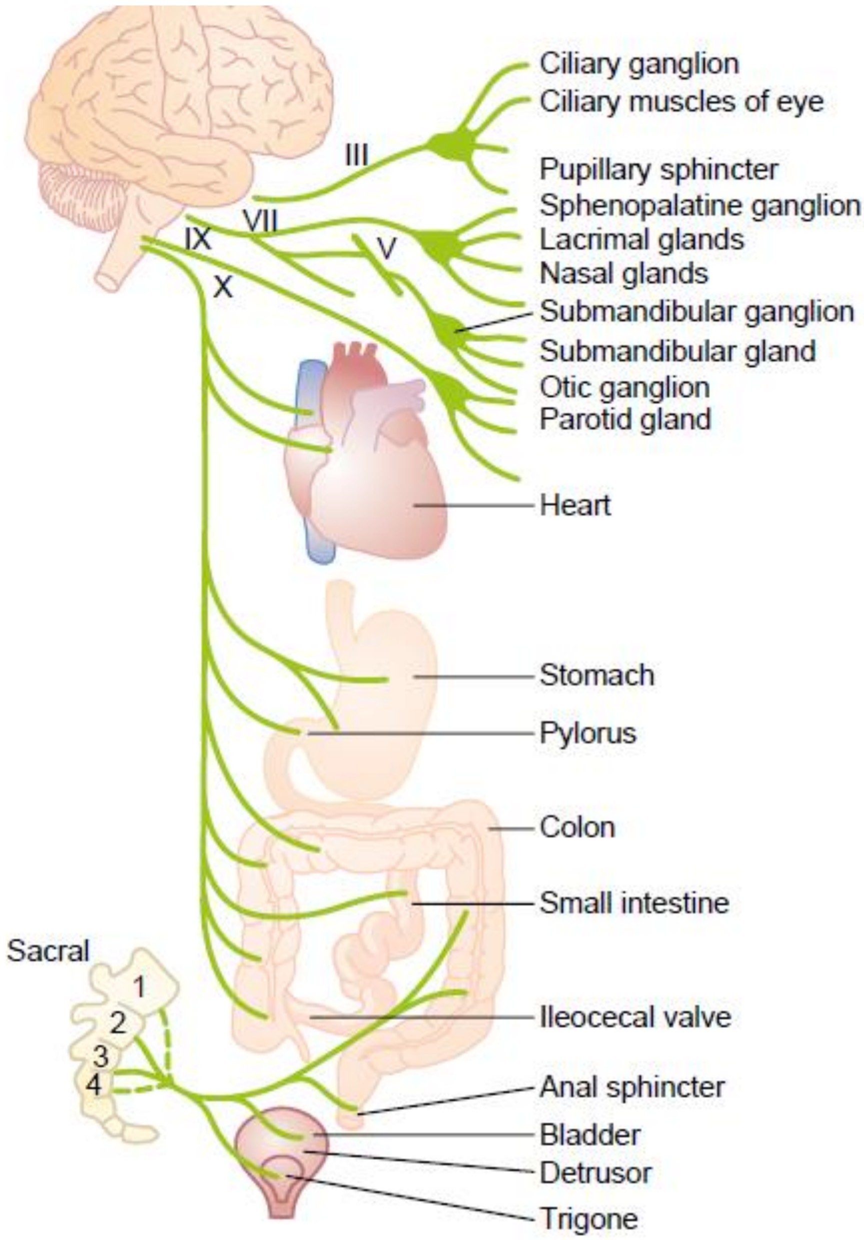


Figure 60–3

Parasympathetic nervous system.

Basic Characteristics of Sympathetic and Parasympathetic Function

Cholinergic and Adrenergic Fibers—Secretion of Acetylcholine or Norepinephrine

The sympathetic and parasympathetic nerve fibers secrete mainly one or the other of two synaptic transmitter substances, acetylcholine or norepinephrine. Those fibers that secrete acetylcholine are said to be cholinergic.

Those that secrete norepinephrine are said to be adrenergic, a term derived from adrenalin, which is an alternate name for epinephrine. All preganglionic neurons are cholinergic in both the sympathetic and the parasympathetic nervous systems. when applied to the ganglia, will excite both sympathetic and parasympathetic postganglionic neurons. Either all or almost all of the postganglionic neurons of the parasympathetic system are also cholinergic. Conversely, most of the postganglionic sympathetic neurons are adrenergic. However, the postganglionic sympathetic nerve fibers to the sweat glands, to the piloerector muscles of the hairs, and to a very few blood vessels are cholinergic.

Thus, the terminal nerve endings of the parasympathetic system all or virtually all secrete acetylcholine. Almost all of the sympathetic nerve endings secrete norepinephrine, but a few secrete acetylcholine. These hormones in turn act on the different organs to cause respective parasympathetic or sympathetic effects. Therefore, acetylcholine is called a parasympathetic transmitter and norepinephrine is called a sympathetic transmitter.

Synthesis of Acetylcholine, Its Destruction After Secretion, and
Its Duration of Action.

Acetylcholine is synthesized in the terminal endings and varicosities of the cholinergic nerve fibers where it is stored in vesicles in highly concentrated form until it is released. The basic chemical reaction of this synthesis is the following:
Once acetylcholine is secreted into a tissue by a cholinergic nerve ending, it persists in the tissue for a few seconds while it performs its nerve signal transmitter function. Then it is split into an acetate ion and choline, catalyzed by the enzyme acetylcholinesterase.

$$\text{Acetyl-CoA} + \text{Choline} \xrightarrow[\text{transferase}]{\text{choline acetyl-}} \text{Acetylcholine}$$

Synthesis of Norepinephrine, Its Removal, and Its Duration of Action.

Synthesis of norepinephrine begins in the axoplasm of the terminal nerve endings of adrenergic nerve fibers but is completed inside the secretory vesicles. The basic steps are the following

1. $\text{Tyrosine} \xrightarrow{\text{hydroxylation}} \text{Dopa}$
2. $\text{Dopa} \xrightarrow{\text{decarboxylation}} \text{Dopamine}$
3. Transport of dopamine into the vesicles
4. $\text{Dopamine} \xrightarrow{\text{hydroxylation}} \text{Norepinephrine}$

In the adrenal medulla, this reaction goes still one step further to transform about 80 per cent of the norepinephrine into epinephrine, as follows:

5. $\text{Norepinephrine} \xrightarrow{\text{methylation}} \text{Epinephrine}$

After secretion of norepinephrine by the terminal nerve endings, it is removed from the secretory site in three ways: (1) reuptake into the adrenergic nerve endings themselves by an active transport process—
accounting for removal of 50 to 80 per cent of the secreted norepinephrine; (2) diffusion away from the nerve endings into the surrounding body fluids and then into the blood—accounting for removal of most of the remaining norepinephrine; and (3) destruction
of small amounts by tissue enzymes (one of these enzymes is monoamine oxidase, which is found in the nerve endings, and another is catechol-O-methyl transferase, which is present diffusely in all tissues).

Before an acetylcholine, norepinephrine, or epinephrine secreted at an autonomic nerve ending can stimulate an effector organ, it must first bind with specific receptors on the effector cells, When the transmitter substance binds with the receptor, this causes a conformational change in the structure of the protein molecule. In turn, the altered protein molecule excites or inhibits the cell, most often by (1) causing a change
in cell membrane permeability to one or more ions or (2) activating or inactivating an enzyme attached to the other end of the receptor protein where it protrudes into the interior of the cell.

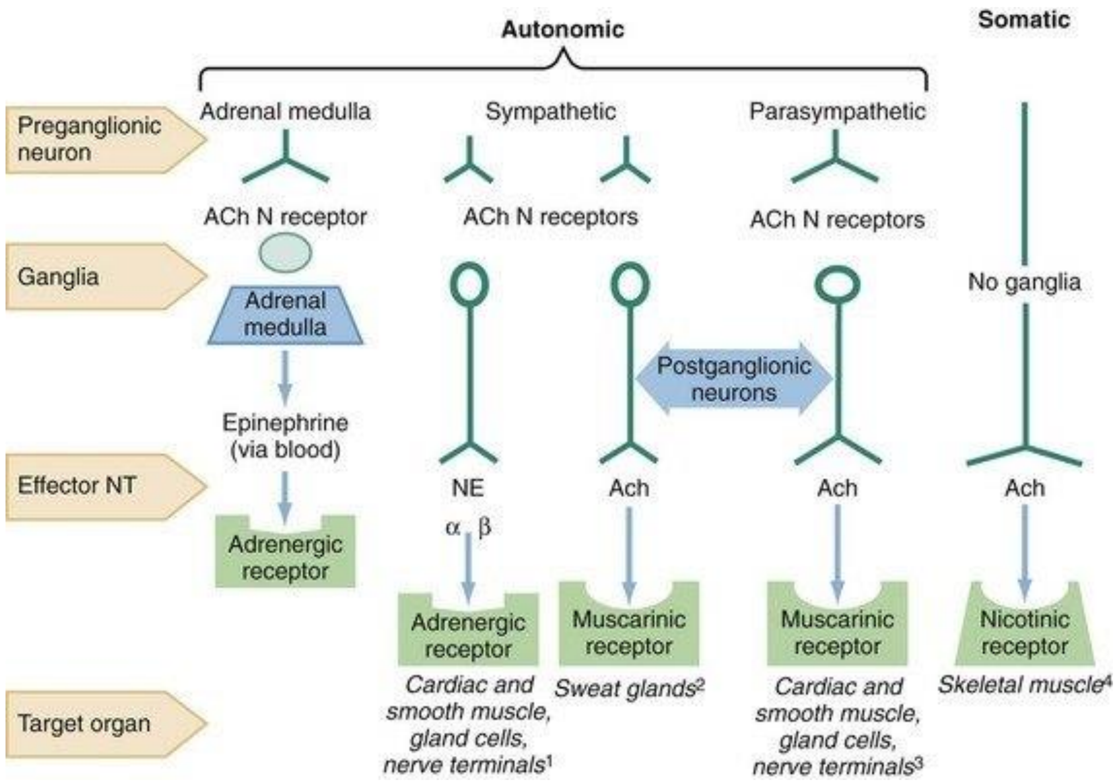
Two Principal Types of Acetylcholine Receptors—Muscarinic and Nicotinic Receptors

Acetylcholine activates mainly two types of receptors. They are called muscarinic and nicotinic receptors, muscarine activates only muscarinic receptors and will not activate nicotinic receptors(N1,N2) whereas nicotine activates only nicotinic receptors; acetylcholine activates both of them.

Nicotinic receptors are ionotropic, meaning that when acetylcholine binds to it, ions flow through it. It acts as a channel for positively charged ions, mainly sodium. This depolarizes the cell. You can find N1 nicotinic receptors at neuromuscular junctions. They play an integral part in allowing your muscles to move. N2 nicotinic receptors are found in the brain, plus the autonomic and parasympathetic nervous systems. Different subunits make up these two types of nicotinic receptor, which is why we consider them separately. Collectively, nicotinic receptors can be found in both the sympathetic and parasympathetic nervous systems on post-ganglionic neurons.

Muscarinic receptors have a different mechanism of action. Instead of becoming an ion channel for sodium, they use a G-protein. When ACh binds to the receptor, this special protein changes shape, which then allows it to phosphorylate various second messengers.
There are five different types of muscarinic receptors. M1, M3 & M5 are excitatory receptors. The two others, M2 and M4, are inhibitory. You can find muscarinic receptors in the brain, heart and smooth muscle. Like nicotinic receptors, they are found in both the parasympathetic and sympathetic nervous systems.

Muscarinic receptors are found on all effectors cells that are stimulated by the postganglionic cholinergic neurons of either the parasympathetic nervous system or the sympathetic system. Nicotinic receptors are found in the autonomic ganglia at the synapses between the preganglionic and postganglionic neurons of both the sympathetic and parasympathetic systems. (Nicotinic receptors are also present at many nonautonomic at the neuromuscular junctions in skeletal muscle).



the main difference between them is their mechanism of action: one uses ions and the other uses G-proteins. Nicotinic receptors are all excitatory, but muscarinic receptors can be both excitatory and inhibitory depending on the subtype. They also differ in the locations they are found in the body.

Adrenergic Receptors—Alpha and Beta Receptors

There are also two major types of adrenergic receptors, alpha receptors and beta receptors. (The beta receptors in turn are divided into beta1 and beta2 receptors because certain chemicals affect only certain beta receptors. Also, there is a division of alpha receptors into alpha1 and alpha2 receptors.) Norepinephrine and epinephrine, both of which are secreted into the blood by the adrenal medulla, have slightly different effects in exciting the alpha and beta receptors. Norepinephrine excites mainly alpha receptors but excites the beta receptors to a lesser extent as well. Conversely, epinephrine excites both types of receptors approximately equally. Therefore, the relative effects of norepinephrine and epinephrine on different effector organs are determined by the types of receptors in the organs. If they are all beta receptors, epinephrine will be the more effective excitant.

Adrenergic Receptors and Function

Alpha Receptor	Beta Receptor
Vasoconstriction	Vasodilation (β_2)
Iris dilation	Cardioacceleration (β_1)
Intestinal relaxation	Increased myocardial strength (β_1)
Intestinal sphincter contraction	Intestinal relaxation (β_2)
	Uterus relaxation (β_2)
Pilomotor contraction	Bronchodilation (β_2)
Bladder sphincter contraction	Calorigenesis (β_2)
	Glycogenolysis (β_2)
	Lipolysis (β_1)
	Bladder wall relaxation (β_2)

Autonomic Effects on Various Organs of the Body

Organ	Effect of Sympathetic Stimulation	Effect of Parasympathetic Stimulation
Eye		
Pupil	Dilated	Constricted
Ciliary muscle	Slight relaxation (far vision)	Constricted (near vision)
Glands	Vasoconstriction and slight secretion	Stimulation of copious secretion (containing many enzymes for enzyme-secreting glands)
Nasal		
Lacrimal		
Parotid		
Submandibular		
Gastric		
Pancreatic		
Sweat glands	Copious sweating (cholinergic)	Sweating on palms of hands
Apocrine glands	Thick, odoriferous secretion	None
Blood vessels	Most often constricted	Most often little or no effect
Heart		
Muscle	Increased rate Increased force of contraction	Slowed rate Decreased force of contraction (especially of atria)
Coronaries	Dilated (β_2); constricted (α)	Dilated
Lungs		
Bronchi	Dilated	Constricted
Blood vessels	Mildly constricted	? Dilated
Gut		
Lumen	Decreased peristalsis and tone	Increased peristalsis and tone
Sphincter	Increased tone (most times)	Relaxed (most times)
Liver	Glucose released	Slight glycogen synthesis
Gallbladder and bile ducts	Relaxed	Contracted
Kidney	Decreased output and renin secretion	None
Bladder		
Detrusor	Relaxed (slight)	Contracted
Trigone	Contracted	Relaxed
Penis	Ejaculation	Erection
Systemic arterioles		
Abdominal viscera	Constricted	None
Muscle	Constricted (adrenergic α) Dilated (adrenergic β_2) Dilated (cholinergic)	None
Skin	Constricted	None
Blood		
Coagulation	Increased	None
Glucose	Increased	None
Lipids	Increased	None
Basal metabolism	Increased up to 100%	None
Adrenal medullary secretion	Increased	None
Mental activity	Increased	None
Piloerector muscles	Contracted	None
Skeletal muscle	Increased glycogenolysis Increased strength	None
Fat cells	Lipolysis	None

Autonomic Reflexes

Many visceral functions of the body are regulated by autonomic reflexes. Throughout this text, the functions of these reflexes are discussed in relation to individual organ systems.

Cardiovascular Autonomic Reflexes.

Several reflexes in the cardiovascular system help to control especially the arterial blood pressure and the heart rate. One of these is the baroreceptor reflex. Briefly, stretch receptors called baroreceptors are located in the walls of several major arteries, including especially the internal carotid arteries and the arch of the aorta. When these become stretched by high pressure, signals are transmitted to the brain stem, where they inhibit the sympathetic impulses to the heart and blood vessels and excite the parasympathetics; this allows the arterial pressure to fall back toward normal.

Gastrointestinal Autonomic Reflexes.

The uppermost part of the gastrointestinal tract and the rectum are controlled principally by autonomic reflexes. For instance, the smell of appetizing food or the presence of food in the mouth initiates signals from the nose and mouth to the vagal, glossopharyngeal, and salivatory nuclei of the brain stem. These in turn transmit signals through the parasympathetic nerves to the secretory glands of the mouth and stomach, causing secretion of digestive juices sometimes even before food enters the mouth.