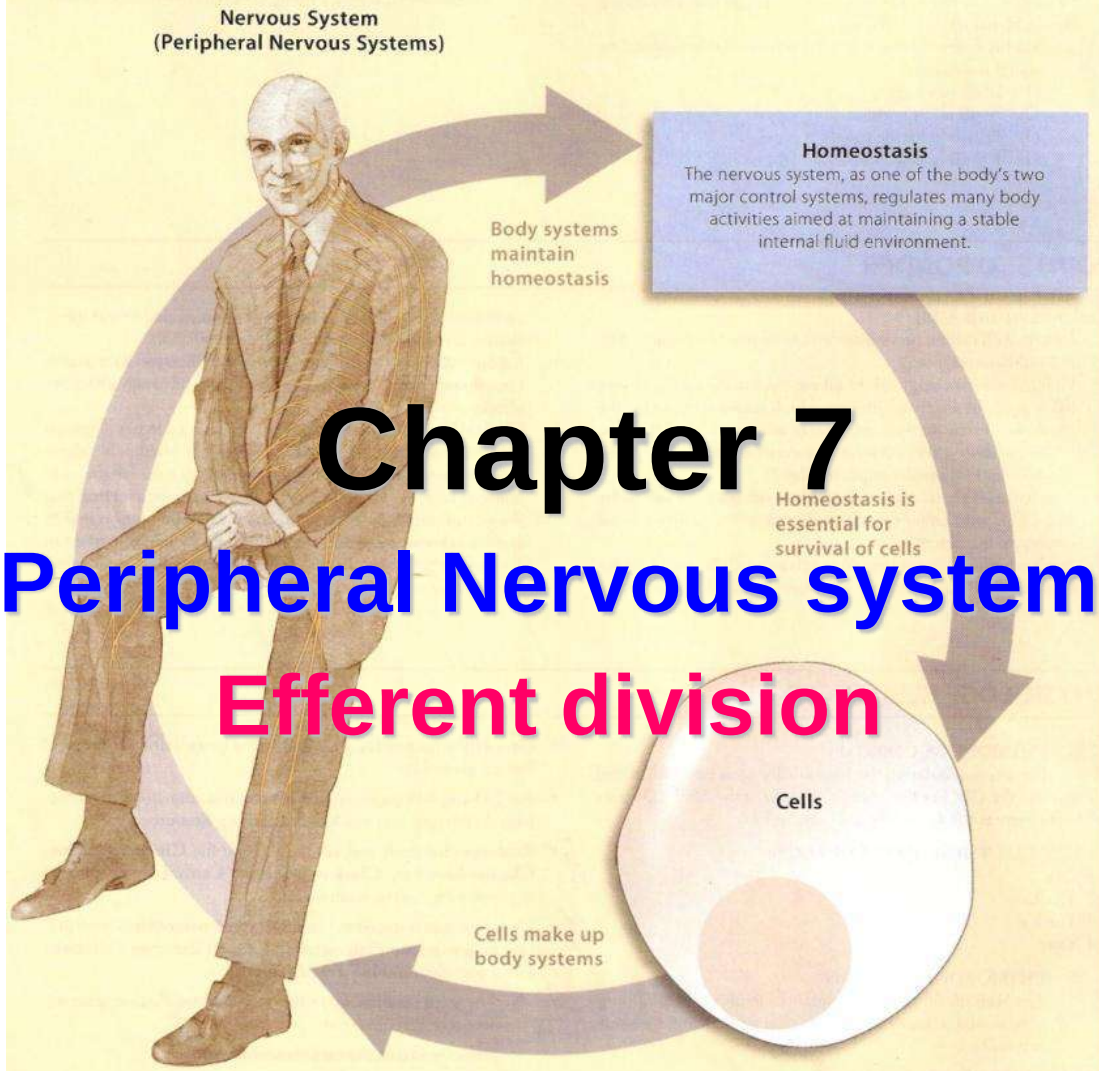


Chapter 7

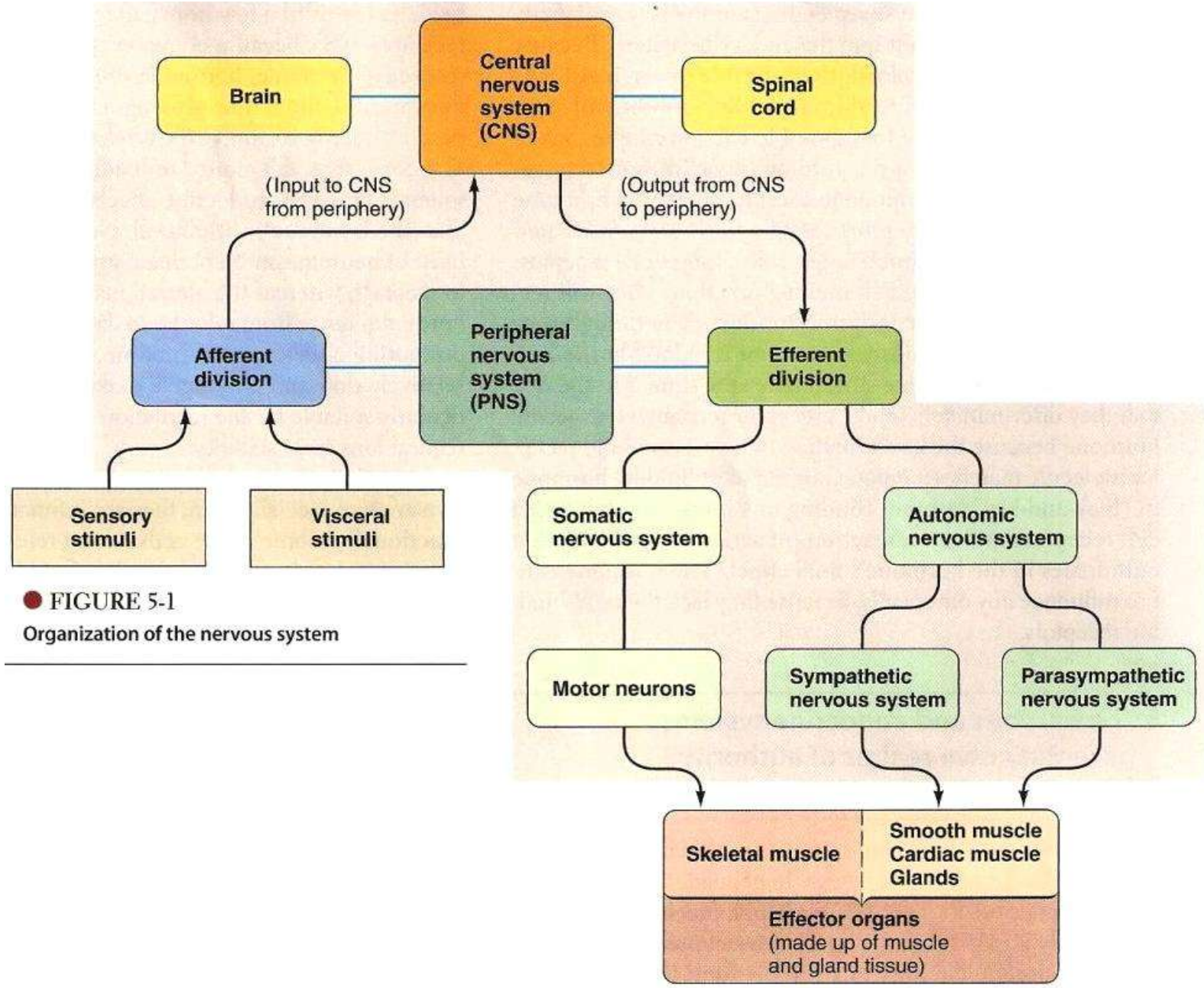
Peripheral Nervous system

Efferent division

The nervous system, one of the two major regulatory systems of the body, consists of the central nervous system (CNS), composed of the brain and spinal cord, and the **peripheral nervous system,** composed of the afferent and efferent fibers that relay signals between the CNS and periphery (other parts of the body).

Once informed by the afferent division of the peripheral nervous system that a change in the internal or external environment is threatening homeostasis, the CNS makes appropriate adjustments to maintain homeostasis. The CNS makes these adjustments by controlling the activities of effector organs (muscles and glands) by transmitting signals *from* the CNS to these organs through the **efferent division** of the peripheral nervous system.

ORGANIZATION OF THE NERVOUS SYSTEM



● FIGURE 5-1
Organization of the nervous system

Introduction

- The efferent division of the peripheral nervous system is the communication link by which the central nervous system controls the activities of muscles and glands, the effector organs that carry out the intended effects or actions.
- By initiating action potentials in the cell bodies of efferent neurons whose axons terminate on these organs.

- **Efferent division classified to:**

1) Autonomic nervous system:

- The involuntary branch that innervate *cardiac muscle, smooth muscles, and some endocrine glands.*

2) Somatic nervous system:

- The voluntary branch that innervate mainly skeletal muscles.

▲ TABLE 7-1
Examples of the Influence of Efferent Output on Movement and Secretion by Effector Organs

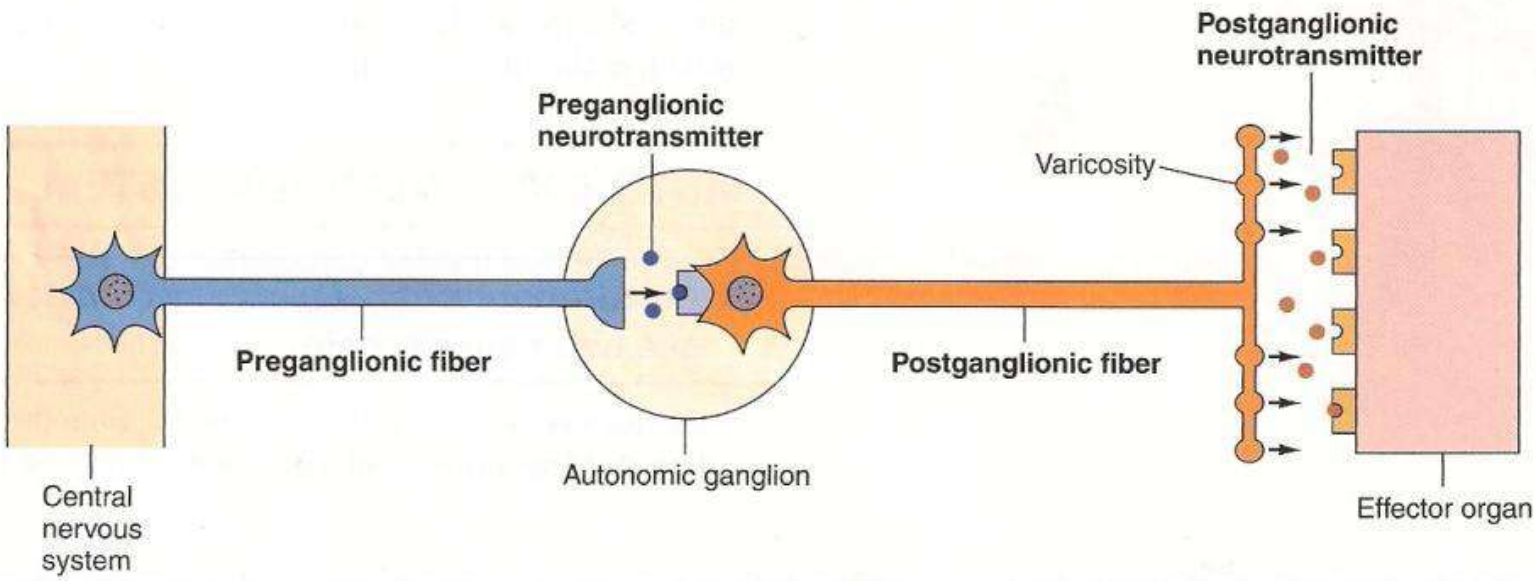
Category of Influence	Examples of Effector Organs with Different Types of Tissues	Sample Outcome in Response to Efferent Output
Influence on Movement	Heart (cardiac muscle)	Increased pumping of blood when the blood pressure falls too low
	Stomach (smooth muscle)	Delayed emptying of the stomach until the intestine is ready to process the food
	Diaphragm—a respiratory muscle (skeletal muscle)	Augmented breathing in response to exercise
Influence on Secretion	Sweat glands (exocrine glands)	Initiation of sweating on exposure to a hot environment
	Endocrine pancreas (endocrine gland)	Increased secretion of insulin, a hormone that puts excess nutrients in storage following a meal

- It is important to realize that many effector organs are also subject to hormonal control and /or intrinsic control mechanisms.
- How many different neurotransmitters would you guess are release from the various efferent neuronal terminals to elicit essentially all the neurally controlled effector organ responses?
- Only two – **Acetyl choline and Norepinephrine !!!**

Autonomic nervous system (ANS)

- An autonomic nerve pathway consists of a two-neuron chain:

FIGURE 7-1
Autonomic nerve pathway



A ganglion is a cluster of neuronal cell bodies located outside the CNS.

The ANS consists of two subdivisions : the sympathetic and parasympathetic nervous system

- Some preganglionic fibers terminate later in sympathetic **collateral ganglia**.
- Parasympathetic preganglionic fibers arise from the cranial and sacral areas of the CNS, it is longer because they do not end until they reach **terminal ganglia**.

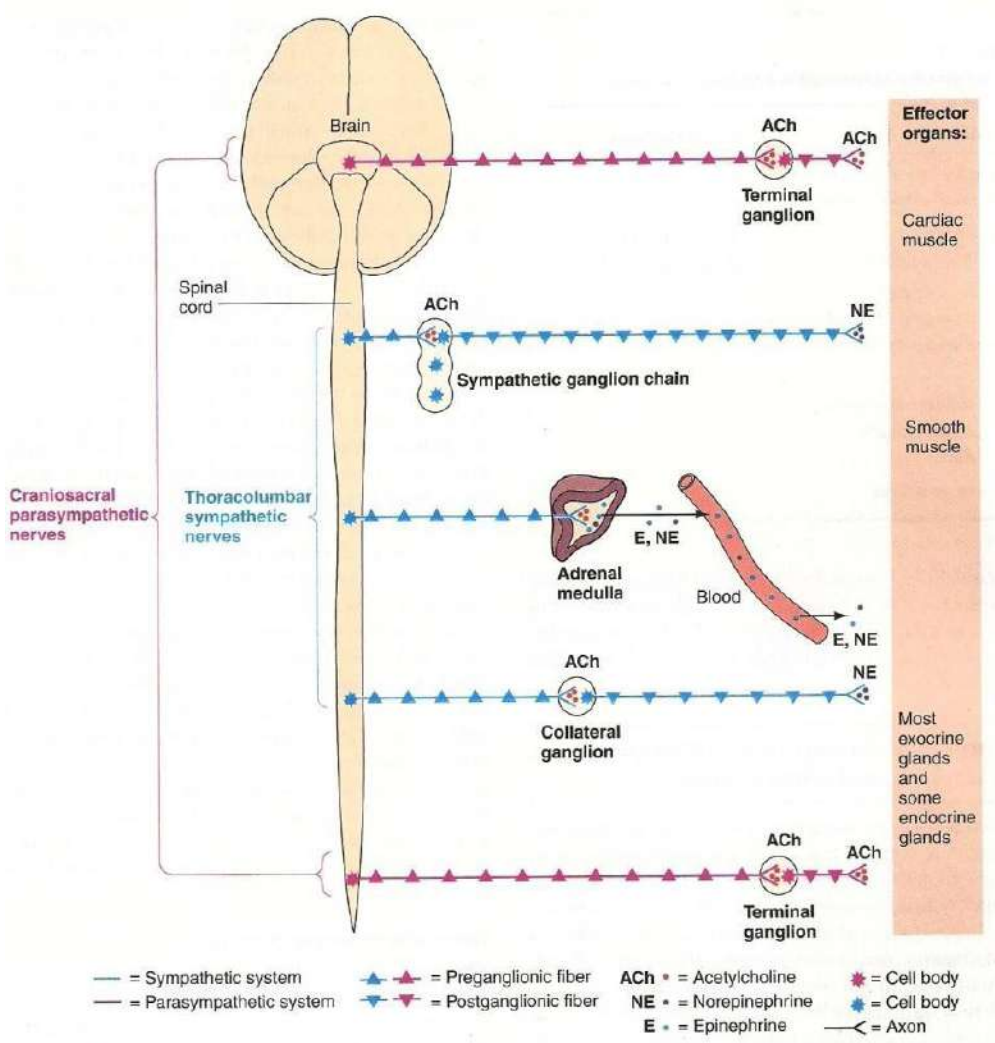


FIGURE 7-2

Autonomic nervous system

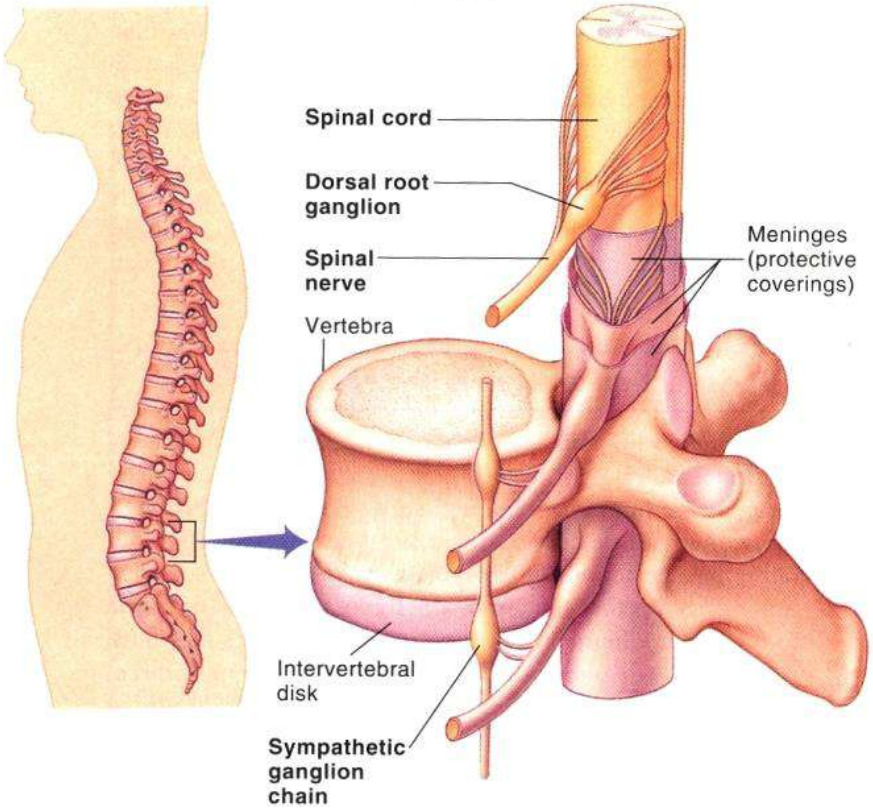
The sympathetic nervous system, which originates in the thoracolumbar regions of the spinal cord, has short cholinergic (acetylcholine-releasing) preganglionic fibers and long adrenergic (norepinephrine-releasing) postganglionic fibers. The parasympathetic nervous system, which originates in the brain and sacral region of the spinal cord, has long cholinergic preganglionic fibers and short cholinergic postganglionic fibers. In most instances, sympathetic and parasympathetic postganglionic fibers both innervate the same effector organs. The adrenal medulla is a modified sympathetic ganglion, which releases epinephrine and norepinephrine into the blood.

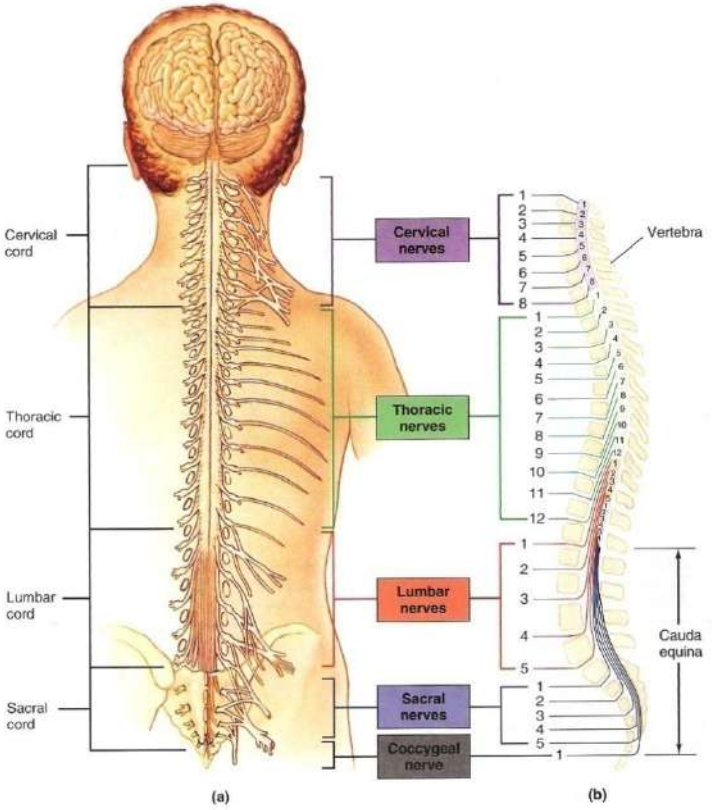
- Sympathetic nerve fibers originate in the thoracic and lumber regions of the spinal cord. Fig. 5-28
- Most sympathetic preganglionic fibers are very short, synapssing with cell bodies of postganglionic neurons within ganglia that lie in a **sympathetic ganglion chain** (**sympathetic trunk**) located along either side of the spinal cord. Fig. 5-27

● FIGURE 5-27

Location of the spinal cord relative to the vertebral column

(SOURCE: Adapted from Cecie Starr and Ralph Taggart, *Biology: The Unity and Diversity of Life*, Eighth Edition, Fig. 35.9a, p. 577. Copyright 1998 Wadsworth Publishing Company.)





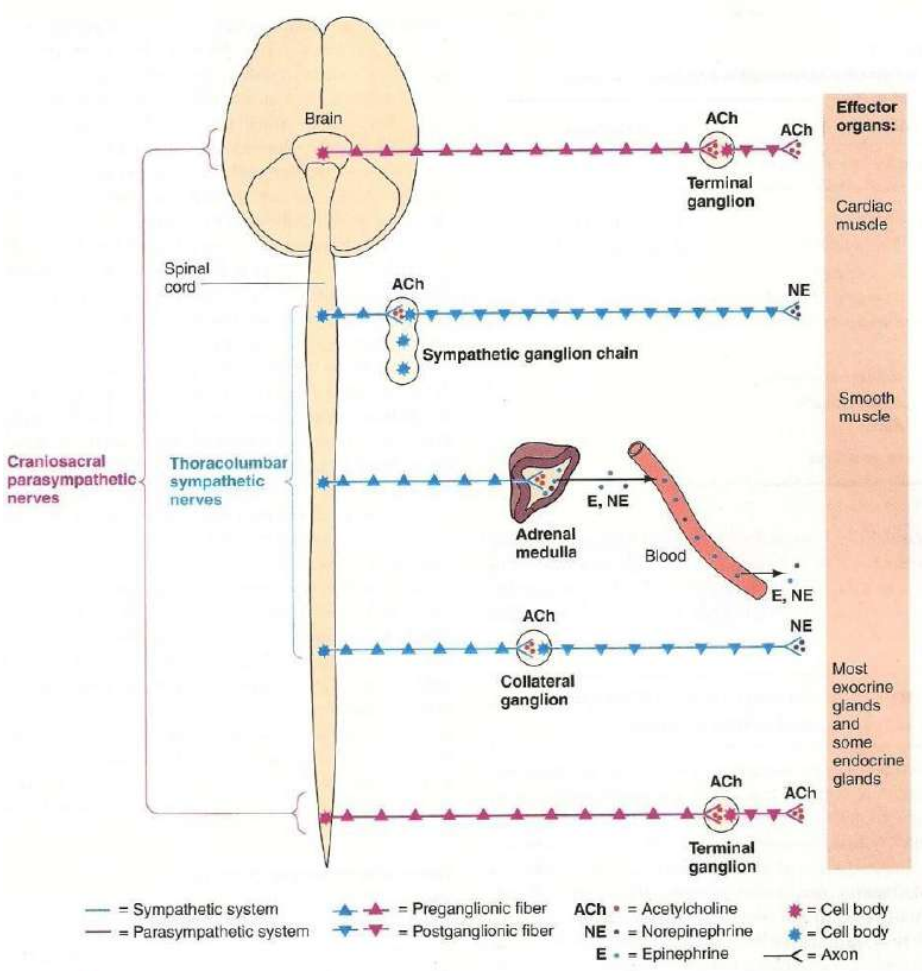
● FIGURE 5-28

Spinal nerves

There are 31 pairs of spinal nerves named according to the region of the vertebral column from which they emerge. Because the spinal cord is shorter than the vertebral column, spinal nerve roots must descend along the cord before emerging from the vertebral column at the corresponding intervertebral space, especially those beyond the level of the first lumbar vertebra (L1). Collectively these rootlets are called the cauda equina, literally "horse's tail." (a) Posterior view of the brain, spinal cord, and spinal nerves (on the right side only). (b) Lateral view of the spinal cord and spinal nerves emerging from the vertebral column.

Parasympathetic postganglionic fibers release Ach; sympathetic ones release NE

- Sympathetic and parasympathetic preganglionic fibers release Ach, but parasympathetic postganglionic fibers release Ach so, its called **cholenergic**, while sympathetic postganglionic fibers that called **adrenergic** fibers release adrenalin (EN).



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Autonomic nervous system

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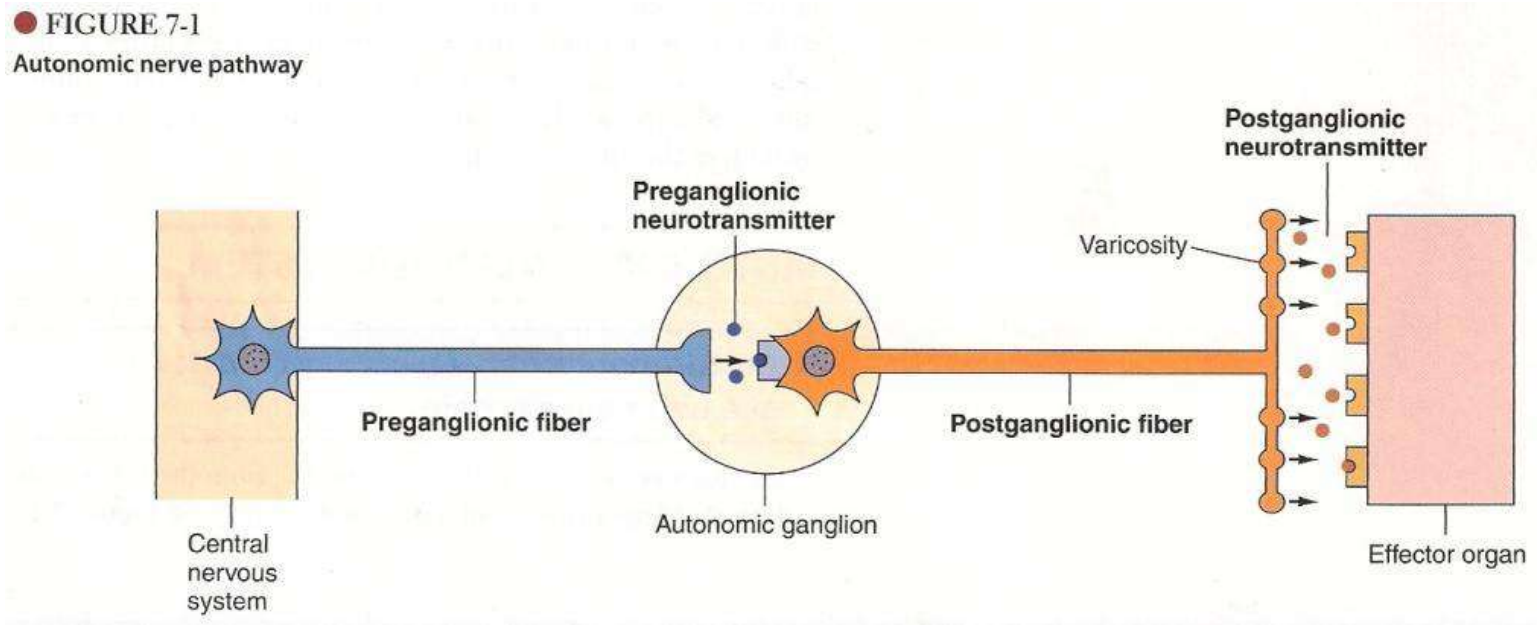
- Both Ach and NE also serve as chemical messengers elsewhere in the body.

▲ TABLE 7-2
Sites of Release for Acetylcholine and Norepinephrine

Acetylcholine	Norepinephrine
All preganglionic terminals of the autonomic nervous system	Most sympathetic postganglionic terminals
All parasympathetic postganglionic terminals	Adrenal medulla
Sympathetic postganglionic terminals at sweat glands and some blood vessels in skeletal muscle	Central nervous system
Terminals of efferent neurons supplying skeletal muscle (motor neurons)	
Central nervous system	

- Postgnaglionic autonomic terminal branches contain numerous swellings (or **varicosities**), that simultaneously release neurotransmitter over a large area of the innervated organ rather than on single cells.
- According to the fact that any resulting change in electrical activity is spread throughout a smooth or cardiac mass via gap junctions.



The ANS controls involuntary visceral organ activities

- Such as, circulation, digestion, sweating and papillary size.
- The technique of ***Biofeedback*** enables individuals to lower their BP consciously.

- **The sympathetic and parasympathetic nervous system dually innervate most visceral organs fig 7-3**

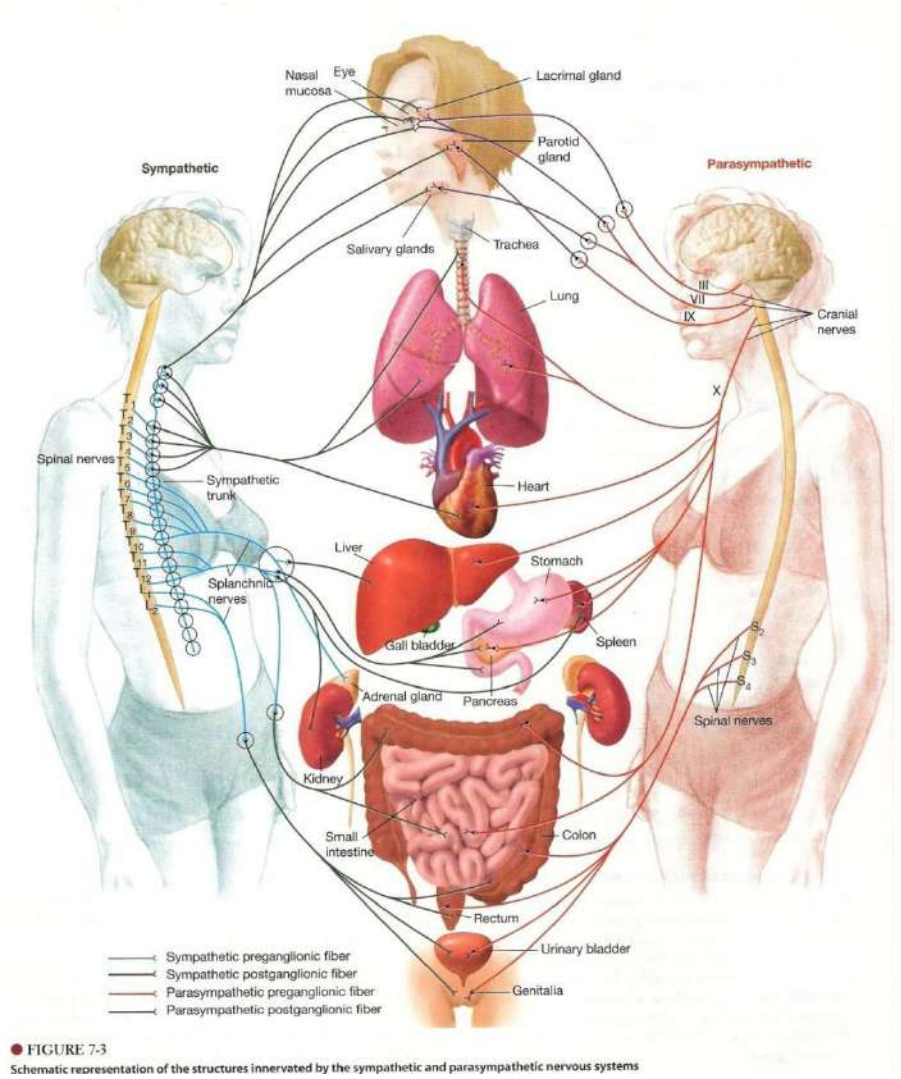


FIGURE 7-3
Schematic representation of the structures innervated by the sympathetic and parasympathetic nervous systems

Table 7-3

summarizes the major effects of these autonomic branches

▲ TABLE 7-3
Effects of the Autonomic Nervous System on Various Organs

Organ	Effect of Sympathetic Stimulation	Effect of Parasympathetic Stimulation
Heart	Increased rate, increased force of contraction (of whole heart)	Decreased rate, decreased force of contraction (of atria only)
Blood Vessels	Constriction	Dilation of vessels supplying the penis and clitoris only
Lungs	Dilation of bronchioles (airways)	Constriction of bronchioles
	Inhibition (?) of mucus secretion	Stimulation of mucus secretion
Digestive Tract	Decreased motility (movement)	Increased motility
	Contraction of sphincters (to prevent forward movement of contents)	Relaxation of sphincters (to permit forward movement of contents)
	Inhibition (?) of digestive secretions	Stimulation of digestive secretions
Gallbladder	Relaxation	Contraction (emptying)
Urinary Bladder	Relaxation	Contraction (emptying)
Eye	Dilation of pupil	Constriction of pupil
	Adjustment of eye for far vision	Adjustment of eye for near vision
Liver (Glycogen Stores)	Glycogenolysis (glucose released)	None
Adipose Cells (Fat Stores)	Lipolysis (fatty acids released)	None
Exocrine Glands		
Exocrine pancreas	Inhibition of pancreatic exocrine secretion	Stimulation of pancreatic exocrine secretion (important for digestion)
Sweat glands	Stimulation of secretion by most sweat glands	Stimulation of secretion by some sweat glands
Salivary glands	Stimulation of small volume of thick saliva rich in mucus	Stimulation of large volume of watery saliva rich in enzymes
Endocrine Glands		
Adrenal medulla	Stimulation of epinephrine and norepinephrine secretion	None
Endocrine pancreas	Inhibition of insulin secretion; stimulation of glucagon secretion	Stimulation of insulin and glucagon secretion
Genitals	Ejaculation and orgasmic contractions (males); orgasmic contractions (females)	Erection (caused by dilation of blood vessels in penis [male] and clitoris [female])
Brain Activity	Increased alertness	None

TABLE 7-1 Effects of Autonomic Nervous System on Various Organs

Organ	Effect of Sympathetic Stimulation (and Types of Adrenergic Receptors)	Effect of Parasympathetic Stimulation
Heart	Increases heart rate and increases force of contraction of the whole heart) (β_1)	Decreases heart rate and decreases force of contraction of the atria only
Most innervated blood vessels	Constricts (α_1)	Dilates vessels supplying the penis and clitoris only
Lungs	Dilates the bronchioles (airways) (β_2)	Constricts the bronchioles
	Inhibits mucus secretion (α)	Stimulates mucus secretion
Digestive tract	Decreases motility (movement) (α_2, β_2)	Increases motility
	Contracts sphincters (to prevent forward movement of contents) (α_1)	Relaxes sphincters (to permit forward movement of contents)
	Inhibits digestive secretions (α_2)	Stimulates digestive secretions
Urinary bladder	Relaxes (β_2)	Contracts (emptying)
Eye	Dilates the pupil (contracts radial muscle) (α_1)	Constricts the pupil (contracts circular muscle)
	Adjusts the eye for far vision (β_2)	Adjusts the eye for near vision
Liver (glycogen stores)	Glycogenolysis (glucose is released) (β_2)	None
Adipose cells (fat stores)	Lipolysis (fatty acids are released) (β_2)	None
Exocrine glands		
Exocrine pancreas	Inhibits pancreatic exocrine secretion (α_2)	Stimulates pancreatic exocrine secretion (important for digestion)
Sweat glands	Stimulates secretion by sweat glands; important in cooling the body (α_1; most are cholinergic)	None
Salivary glands	Stimulates a small volume of thick saliva rich in mucus (α_1)	Stimulates a large volume of watery saliva rich in enzymes
Endocrine glands		
Adrenal medulla	Stimulates epinephrine and norepinephrine secretion (cholinergic)	None
Endocrine pancreas	Inhibits insulin secretion; stimulates glucagon secretion (α_2)	Stimulates insulin and glucagon secretion
Genitals	Controls ejaculation (males) and orgasmic contractions (both sexes) (α_1)	Controls erection (penis in males and clitoris in females)
Brain activity	Increases alertness (receptors unknown)	None

- As you can see from the table, both systems generally exert opposite effects in a particular organ.
- Note that both systems increase the activity of some organs and reduce the activity of others.
- It is better to logically deduce the actions of the two systems based on the understanding of the circumstances under which each system dominate.
- Usually, both systems are partially active (**tonic activity**), thus the activity of one division can dominate the other, and when the *rate of firing* of one system to the organ increases above tonic level, coupled with a simultaneous decrease below tonic level of the other. (to meet specific demands)
- **Time of sympathetic dominance:**

The sympathetic system promotes ***fight – or – flight response***.

- **Time of parasympathetic dominance:**

By which the body can be concerned with its own “general house keeping” activities or ***“Rest and Digest”***.

The advantage of dual autonomic innervations

- It enables **precise control over** an organ's activity, similar to have both an accelerator and a brake to control the speed of a car.
- Indeed, the two divisions of the ANS are usually **reciprocally controlled**, except in:
  - **Innervated blood vessels** (most arterioles and capillaries are not) receive only sympathetic nerve fibers. The only blood vessels to receive both divisions are those supplying the penis and clitoris.
  - **Most sweet glands**: are innervated only by sympathetic nerves.
  - **Salivary glands**: are innervated by both autonomic divisions but they are not antagonistic!!
- Both stimulate salivary secretion, but the saliva's volume and composition differ.
- A wide variety of autonomic malfunctions accompany aging.

The adrenal medulla is a modified part of the sympathetic nervous system

- That dose not give rise to postganglionic fibers, instead on stimulation it secretes hormones into blood (20% NE and 80% EN). Fig 7-4

Several different receptor types are available for each autonomic neurotransmitter

- The particular responses must depend on specialization of the plasma membrane protein.

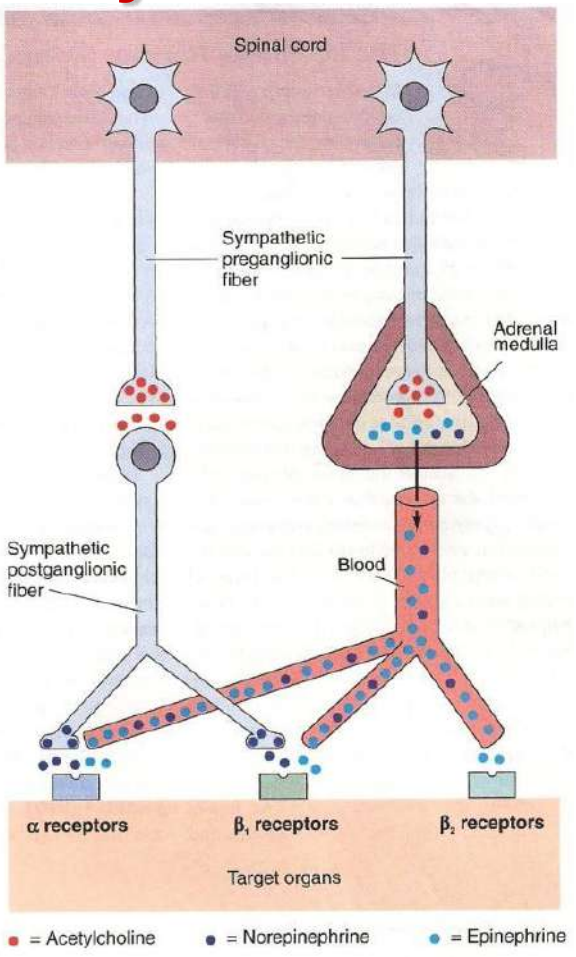


FIGURE 7-4

Comparison of the release and binding to receptors of epinephrine and norepinephrine

Norepinephrine is released both as a neurotransmitter from sympathetic postganglionic fibers and as a hormone from the adrenal medulla. Beta$_1$ (β_1) receptors bind equally with both norepinephrine and epinephrine, whereas beta$_2$ (β_2) receptors bind primarily with epinephrine and alpha (α) receptors of both subtypes have a greater affinity for norepinephrine than for epinephrine.