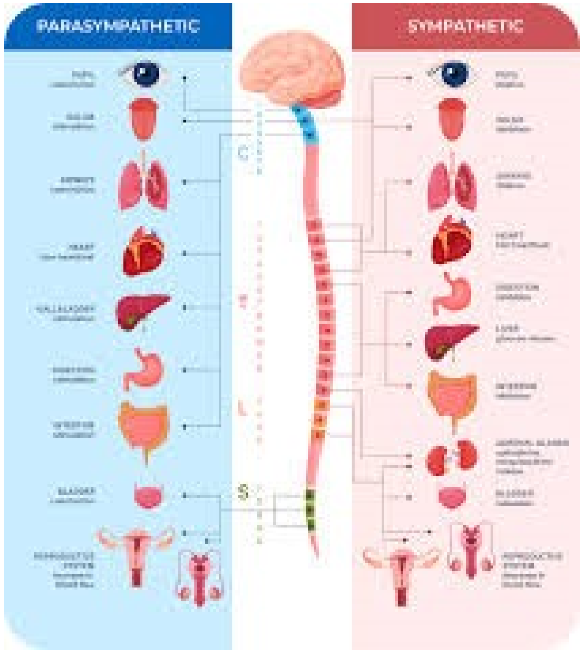
The Autonomic Nervous System



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The Autonomic Nervous System- introduction

THE PERIPHERAL NERVOUS SYSTEM (PNS) includes cranial and spinal nerves.

PNS is divided into:

→ A somatic nervous system (SNS)

→ An autonomic nervous system (ANS)

Like the somatic nervous system, the ***autonomic nervous system (ANS)*** *operates via* ***reflex arcs****.* The ANS usually operates without conscious control.

Structurally, the ANS includes:

1- Autonomic sensory neurons

2- Integrating centers in the central nervous system (CNS)

3- Autonomic motor neurons

4- The enteric division or **enteric nervous system (ENS)**.

Peripheral Nervous System

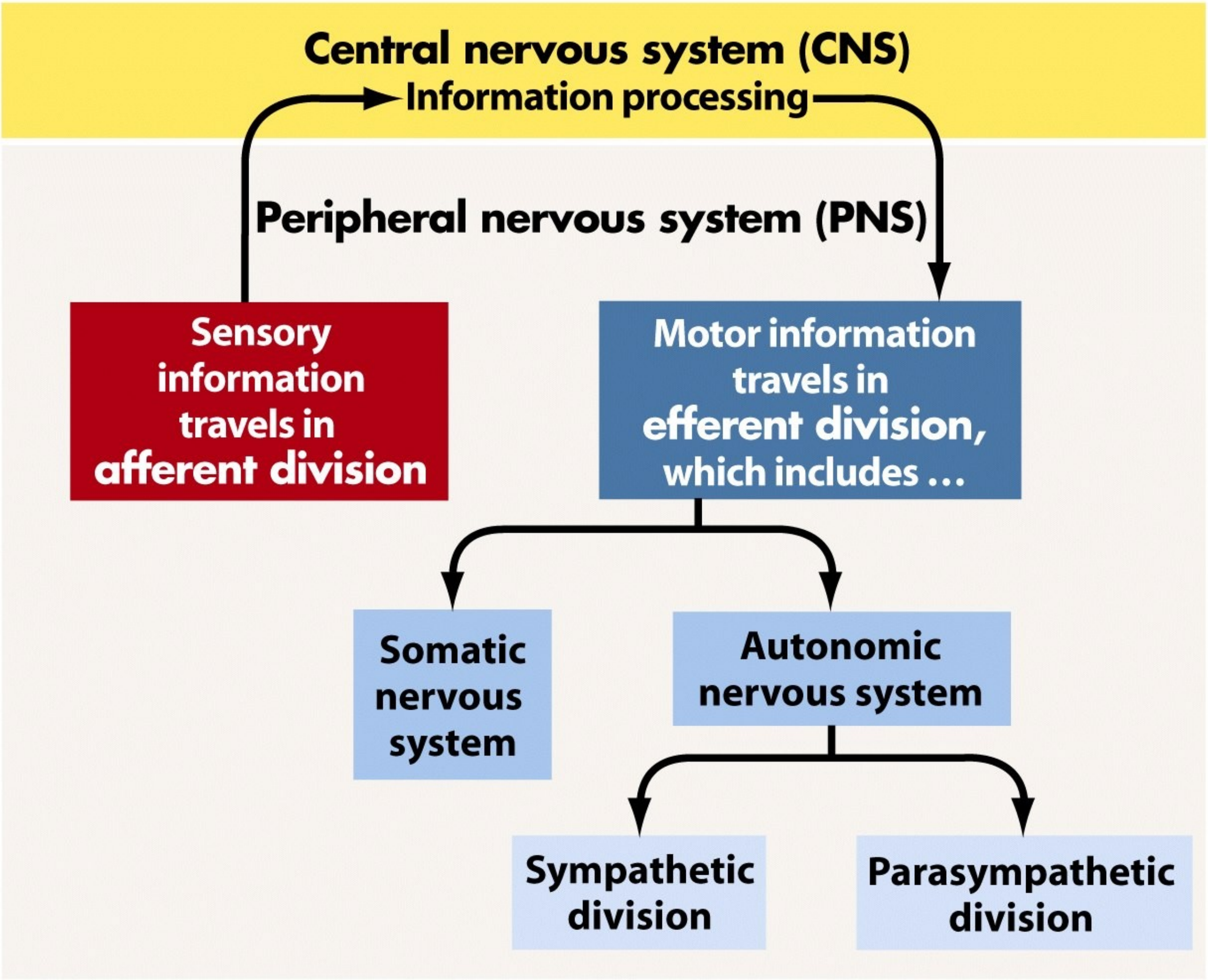
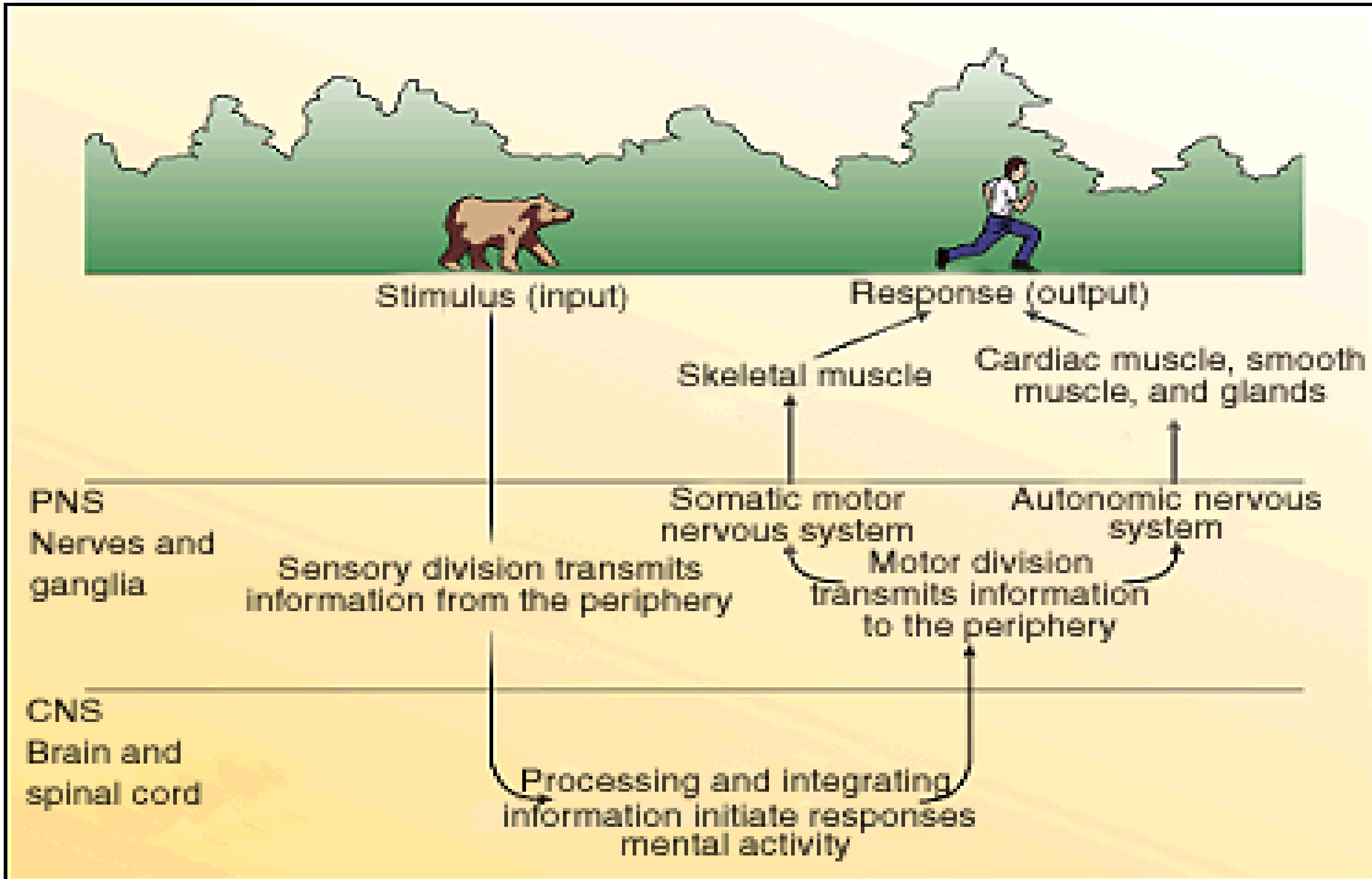


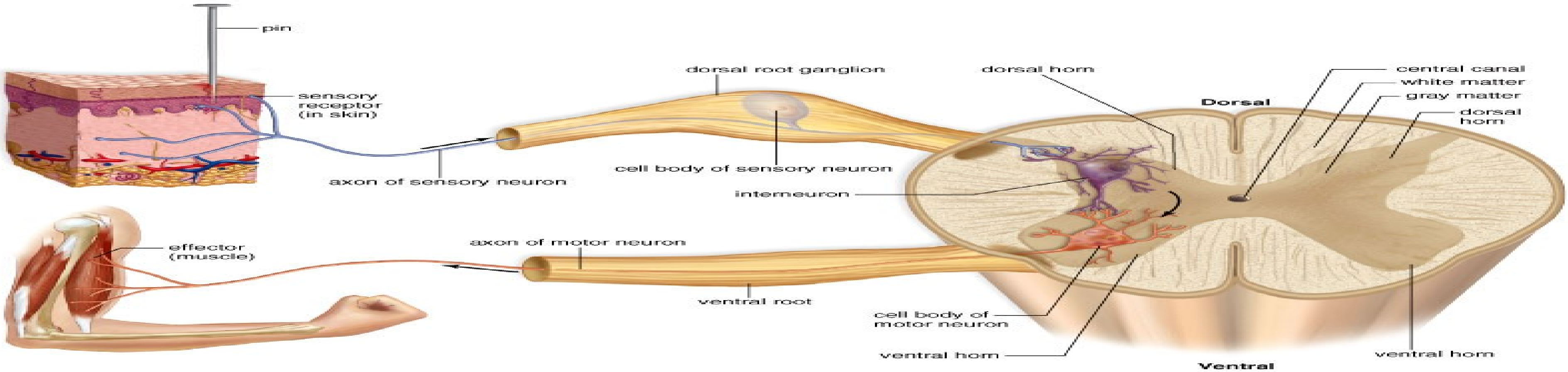
Figure 45-19 Biological Science, 2/e

Nervous System Divisions



Organization of the Nervous System

The afferent division of the PNS detects stimuli and conveys action potentials to the CNS. The CNS integrates incoming information and initiates action potentials that are transmitted through the efferent division to produce a response. The efferent division is divided into the somatic motor nervous system and autonomic nervous system.



Sensory Afferent → Dorsal root → Dorsal root ganglia where cell body of sensory neuron is located → interneuron

Peripheral nervous system (PNS)

Motor Efferent → Ventral root → Somatic Motor → Skeletal muscle

Ventral root → Autonomic Motor → smooth muscles, cardiac muscles, and glands

The Autonomic Nervous System- introduction (continued)

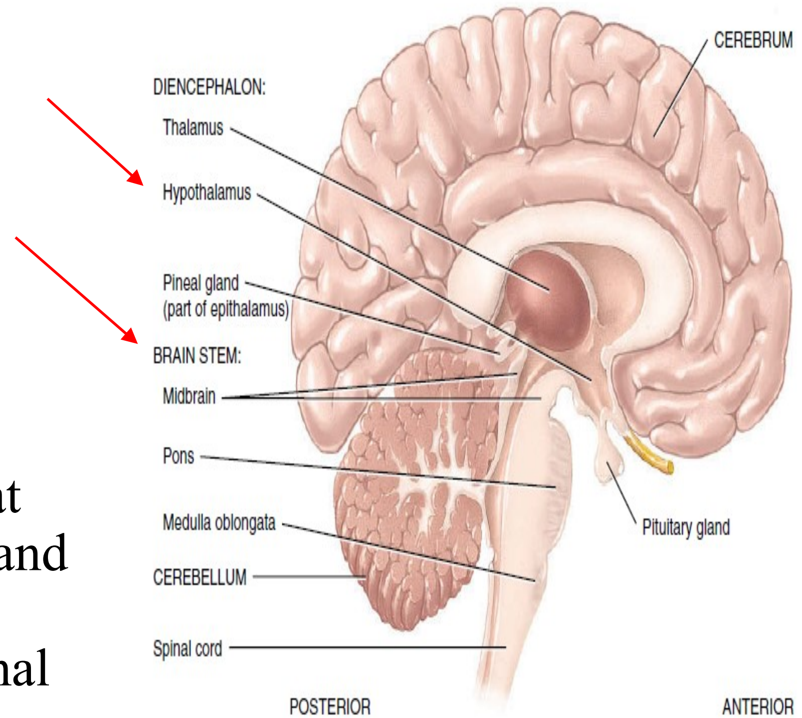
<u>A continual flow of nerve impulses from</u>

(1) *autonomic sensory neurons* in visceral organs and blood vessels propagate into →

(2) *integrating centers* in the <u>CNS</u>. Then, impulses in →

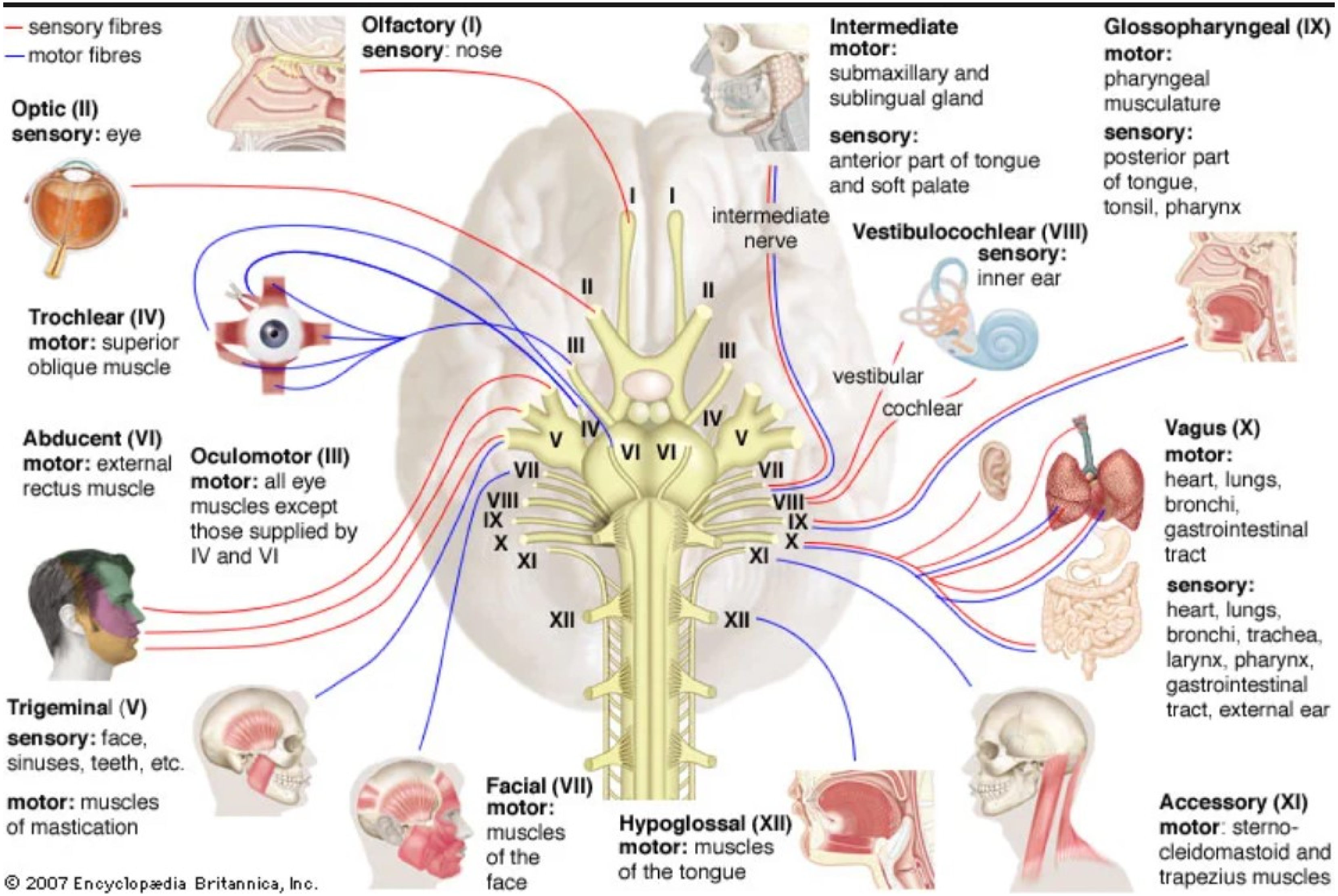
(3) *autonomic motor neurons* propagate to various effector tissues → thereby regulating the activity of smooth muscle, cardiac muscle, and many glands.

- The *enteric division* is a part of the ANS that consists of a <u>specialized</u> network of nerves and ganglia, forming an independent nerve network within the wall of the gastrointestinal (GI) tract.
- However, centers in the hypothalamus and brain stem do regulate ANS reflexes.

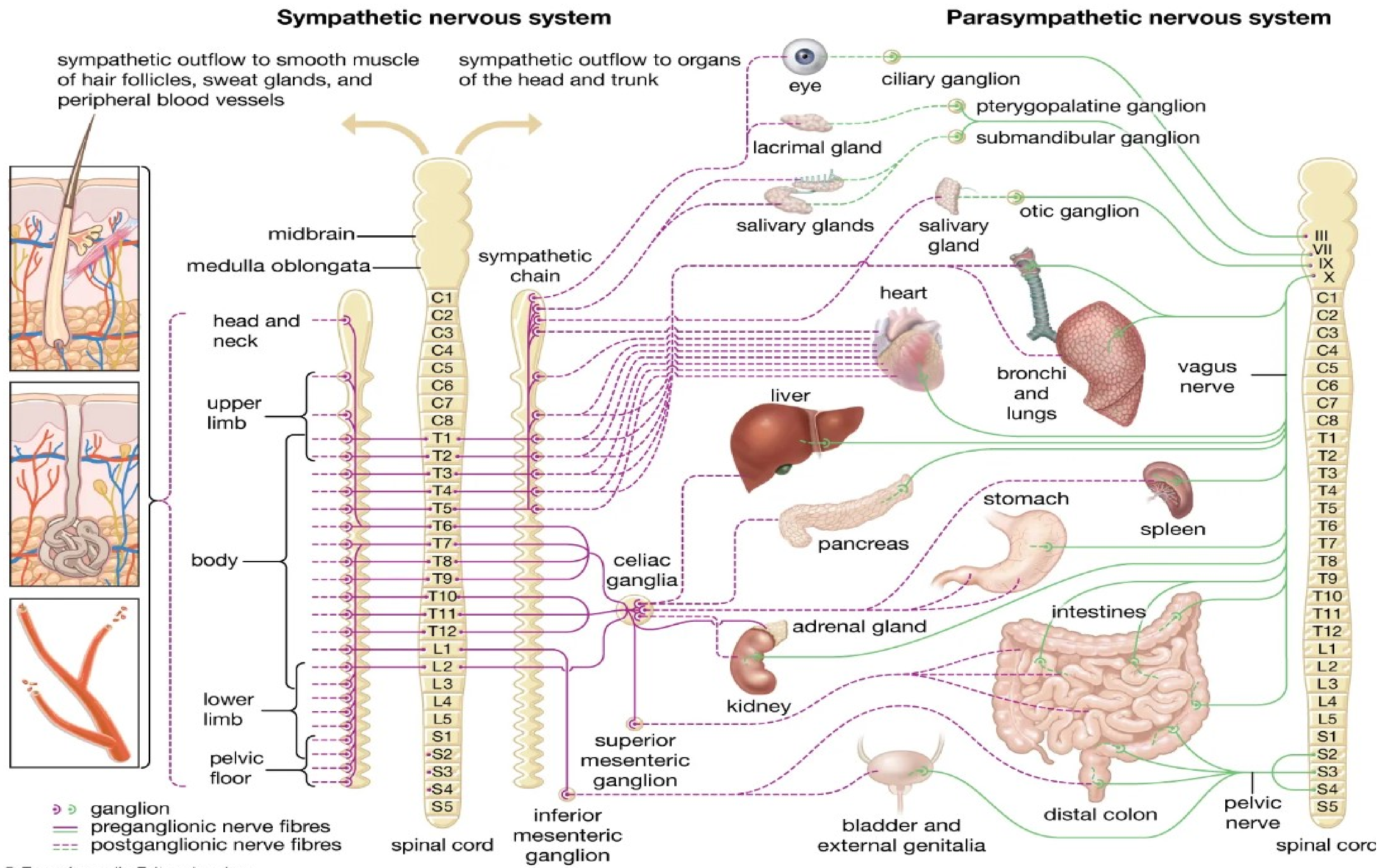


(a) Sagittal section, medial view

Cranial Nerves



Spinal nerves



Comparison of Somatic and Autonomic Nervous Systems

Somatic Nervous System

- Includes both ***sensory*** and ***motor*** neurons.
- **Sensory** neurons convey input from receptors for somatic senses (tactile, thermal, pain, and proprioceptive sensations; and from receptors for the special senses (sight, hearing, taste, smell, and equilibrium. All of these sensations normally are **consciously** perceived.
- In turn, **somatic** motor neurons innervate skeletal muscles—the effectors of the somatic nervous system—and produce both reflexive and voluntary movements.

Autonomic Nervous System

- The main input to the ANS comes from **autonomic** (*visceral*) **sensory neurons**. Mostly, these neurons are associated with **interoceptors**, sensory receptors located in blood vessels, visceral organs, muscles, and the nervous system that monitor conditions in the *internal* environment.

  → Signals from the general somatic and special senses, acting via the **limbic system**, also influence responses of autonomic motor neurons.

- **Autonomic motor neurons** regulate visceral activities by either increasing (exciting) or decreasing (inhibiting) ongoing activities in their effector tissues (cardiac muscle, smooth muscle, and glands).

Autonomic Nervous System→ ***Biofeedback***

BIOFEEDBACK

In which monitoring devices display information about a body function such as heart rate or blood pressure, enhances the ability to learn such conscious control.

→ Most autonomic responses cannot be consciously altered to any great degree. You probably cannot voluntarily slow your heartbeat to half its normal rate. For this reason, some autonomic responses are the basis for polygraph ("lie detector") tests.

→ However, practitioners of yoga or other techniques of meditation ***may learn how to regulate at least some*** of their autonomic activities through long practice.

Comparison of Somatic and Autonomic Motor Neurons → Motor Neurons

- The axon of a single, myelinated **somatic motor** neuron extends from the central nervous system (CNS) all the way to the skeletal muscle fibers in its motor unit other (Figure 15.1a). → Fast-conducting, thick , myelinated axons (A fibers).

- **By contrast, most autonomic motor pathways consist of two motor neurons in series, that is, one following the other (Figure 15.1b).**

→**The first neuron** (preganglionic neuron) has its cell body **in** the CNS; its myelinated axon extends from the CNS to an **autonomic ganglion**. (Recall that a *ganglion* is a collection of neuronal cell bodies in the PNS.)

→The cell body of **the second neuron** (postganglionic neuron) is also in that same autonomic ganglion; its unmyelinated axon extends directly from the ganglion to the effector (smooth muscle, cardiac muscle, or a gland).

→**Alternatively, in some autonomic pathways**, the first motor neuron extends to specialized cells called *chromaffin cells* in the adrenal medullae (inner portions of the adrenal glands) **rather** than an autonomic ganglion. Chromaffin cells secrete the neurotransmitters epinephrine and norepinephrine (NE).

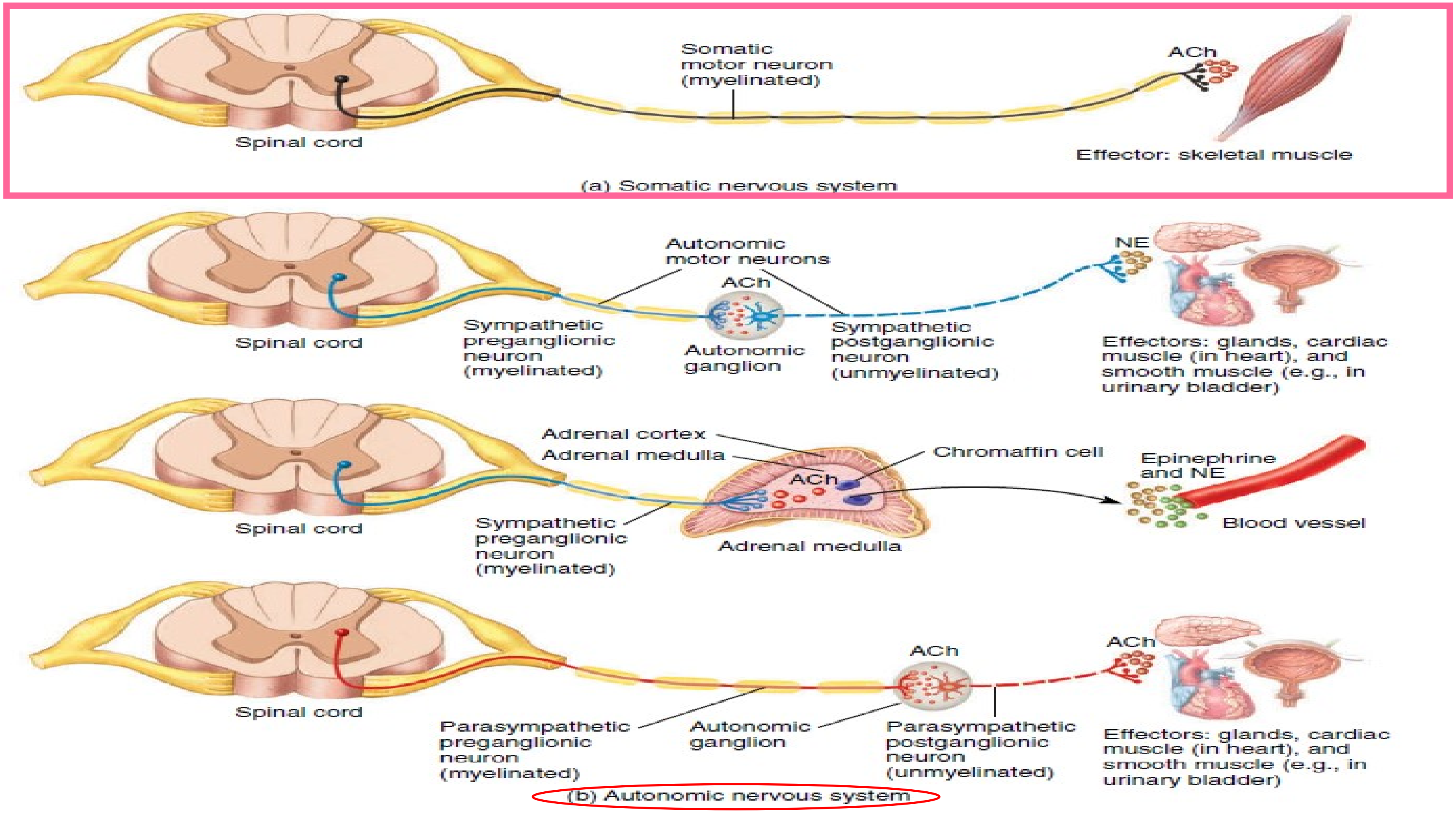
→**All somatic motor neurons release only acetylcholine (ACh) as their neurotransmitter, but autonomic motor neurons release either ACh or norepinephrine (NE).**

Figure 15.1: Motor neuron pathways in the (a) somatic nervous system and (b) autonomic nervous system (ANS).

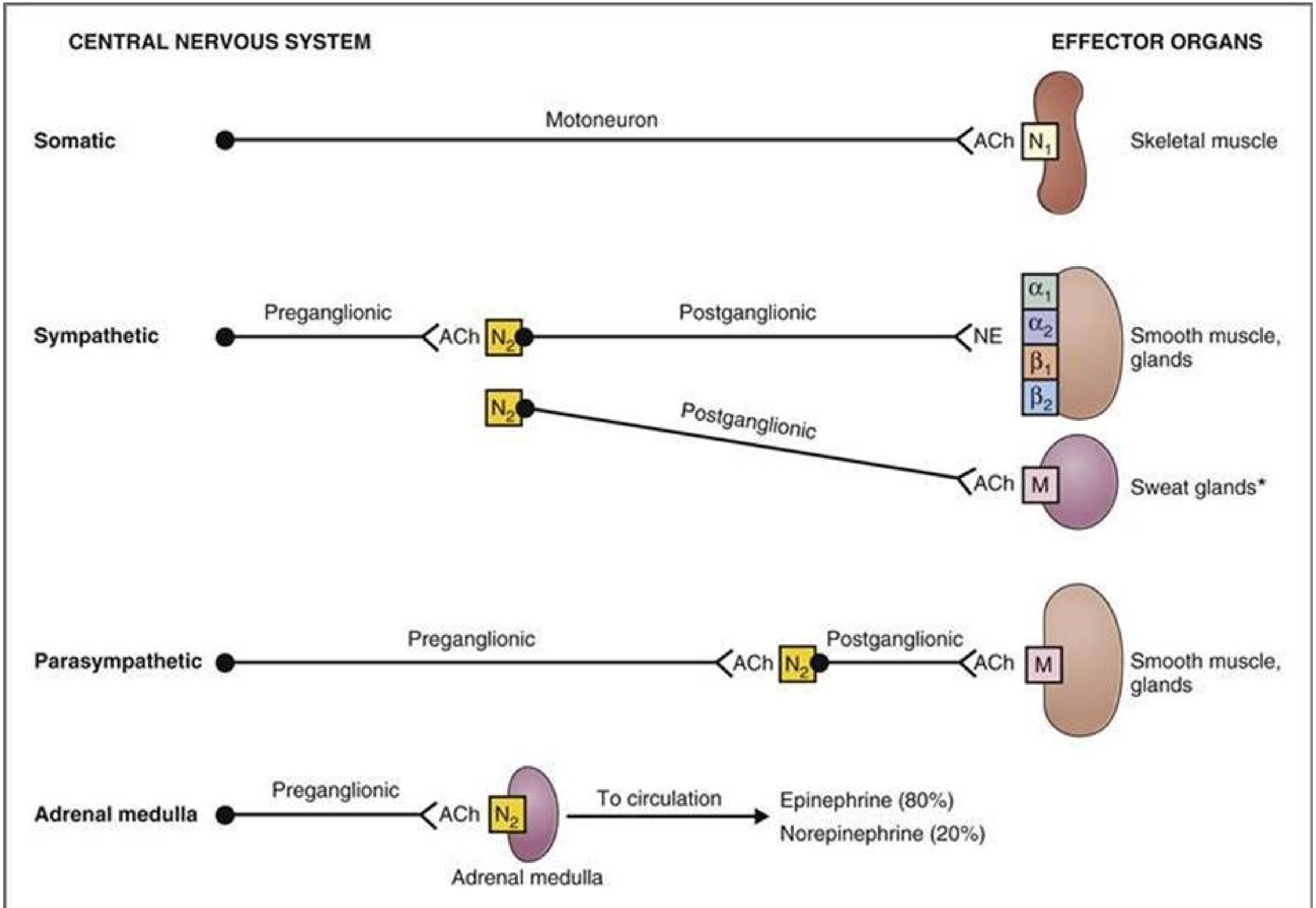
Note that autonomic motor neurons release **either** acetylcholine (ACh) or norepinephrine (NE); somatic motor neurons release only ACh.

→ **Somatic** nervous system stimulation always excites its effectors (**skeletal** muscle fibers);

→ stimulation by the **autonomic** nervous system either excites or inhibits **visceral e**ffectors.



The sympathetic and parasympathetic divisions are included and, for comparison, so is the somatic nervous system



Output part of the ANS

The output part of the ANS has two divisions:

1- the **sympathetic division**

2- the **parasympathetic division**.

- MOST organs have **dual innervation;** that is, they receive impulses from both sympathetic and parasympathetic neurons.
- Although both the sympathetic and parasympathetic divisions are concerned with maintaining homeostasis, they do so in dramatically different ways.
- In some organs, nerve impulses from one division of the ANS stimulate the organ to increase its activity (excitation), and impulses from the other division decrease the organ's activity (inhibition).
- **For example,** an increased rate of nerve impulses from the *sympathetic* division increases heart rate, and an increased rate of nerve impulses from the *parasympathetic* division decreases heart rate.

Output part of the ANS → Sympathetic division

- ***The sympathetic division is often called the fight-or-flight division*** **→** also called the **thoracolumbar division**

- Sympathetic activities result in increased alertness and metabolic activities in order to prepare the body for an **emergency** situation.

- Responses to such situations, which may occur during physical activity or emotional stress, include a rapid heart rate, faster breathing rate, dilation of the pupils, dry mouth, sweaty but cool skin, dilation of blood vessels to organs involved in combating stress (such as the heart and skeletal muscles), constriction of blood vessels to organs not involved in combating stress (for example, the gastrointestinal tract and kidneys), and release of glucose from the liver.

Output part of the ANS → Parasympathetic division

- The parasympathetic division is often referred to as the *rest-and-digest division* because its activities conserve and restore body energy during times of rest or digesting a meal→ also called as the **craniosacral division**

- The majority of its output is directed to the smooth muscle and glandular tissue of the gastrointestinal and respiratory tracts.

Comparison of Somatic and Autonomic Motor Neurons

Comparison of the Somatic and Autonomic Nervous Systems

	SOMATIC NERVOUS SYSTEM	AUTONOMIC NERVOUS SYSTEM
Sensory input	From somatic senses and special senses.	Mainly from interoceptors; some from somatic senses and special senses.
Control of motor output	Voluntary control from cerebral cortex, with contributions from basal ganglia, cerebellum, brain stem, and spinal cord.	Involuntary control from hypothalamus, limbic system, brain stem, and spinal cord; limited control from cerebral cortex.
Motor neuron pathway	One-neuron pathway: Somatic motor neurons extending from CNS synapse directly with effector.	Usually two-neuron pathway: Preganglionic neurons extending from CNS synapse with postganglionic neurons in autonomic ganglion, and postganglionic neurons extending from ganglion synapse with visceral effector. Alternatively, preganglionic neurons may extend from CNS to synapse with chromaffin cells of adrenal medullae.
Neurotransmitters and hormones	All somatic motor neurons release only acetylcholine (ACh).	All sympathetic and parasympathetic preganglionic neurons release ACh. Most sympathetic postganglionic neurons release NE; those to most sweat glands release ACh. All parasympathetic postganglionic neurons release ACh. Chromaffin cells of adrenal medullae release epinephrine and norepinephrine (NE).
Effectors	Skeletal muscle.	Smooth muscle, cardiac muscle, and glands.
Responses	Contraction of skeletal muscle.	Contraction or relaxation of smooth muscle; increased or decreased rate and force of contraction of cardiac muscle; increased or decreased secretions of glands.

Anatomy of Autonomic Motor Pathways
Anatomical Components

- Each division of the ANS has **two** motor neurons.

- The first of the two motor neurons in any autonomic motor pathway is called a **preganglionic neuron** (Figure 15.1b). Its cell body is in the brain or spinal cord; **its axon *EXITS* the CNS as part of a cranial or spinal nerve**.

- The **axon of a preganglionic neuron** is a small-diameter, myelinated type B fiber that usually extends to an autonomic ganglion, where it **synapses with** a **postganglionic neuron**, the second neuron in the autonomic motor pathway.

→Note that the **postganglionic neuron** lies entirely outside the CNS in the PNS. Its cell body and dendrites are located in an **autonomic ganglion**, where it forms **synapses with** one or more preganglionic axons. **The axon of a postganglionic neuron** is a small-diameter, unmyelinated type C fiber that terminates in a visceral effector.

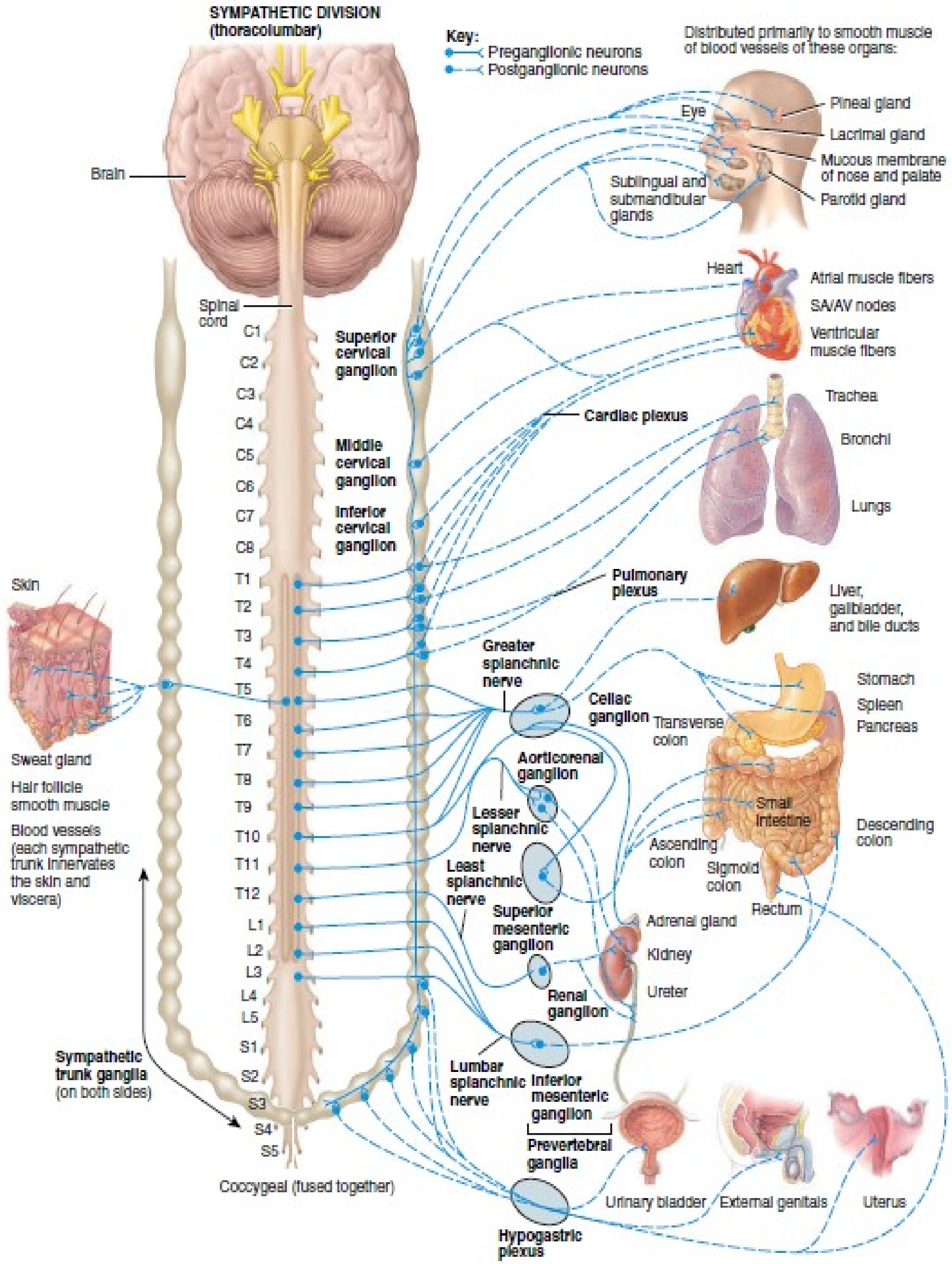
- *Thus, preganglionic neurons convey nerve impulses from the CNS to autonomic ganglia, and postganglionic neurons relay the impulses from autonomic ganglia to visceral effectors.*

Structure of the sympathetic division of the autonomic nervous system.

→ Solid lines represent preganglionic axons; dashed lines represent postganglionic axons.

→ Although the innervated structures are shown for only one side of the body for diagrammatic purposes, the sympathetic division actually innervates tissues and organs on both sides.

→ **<u>Cell bodies</u>** of sympathetic preganglionic neurons are located in the lateral horns of gray matter in the **12 thoracic and first two lumbar segments** of the spinal cord.



Structure of the parasympathetic division of the autonomic nervous system.

→ Solid lines represent preganglionic axons; dashed lines represent postganglionic axons.

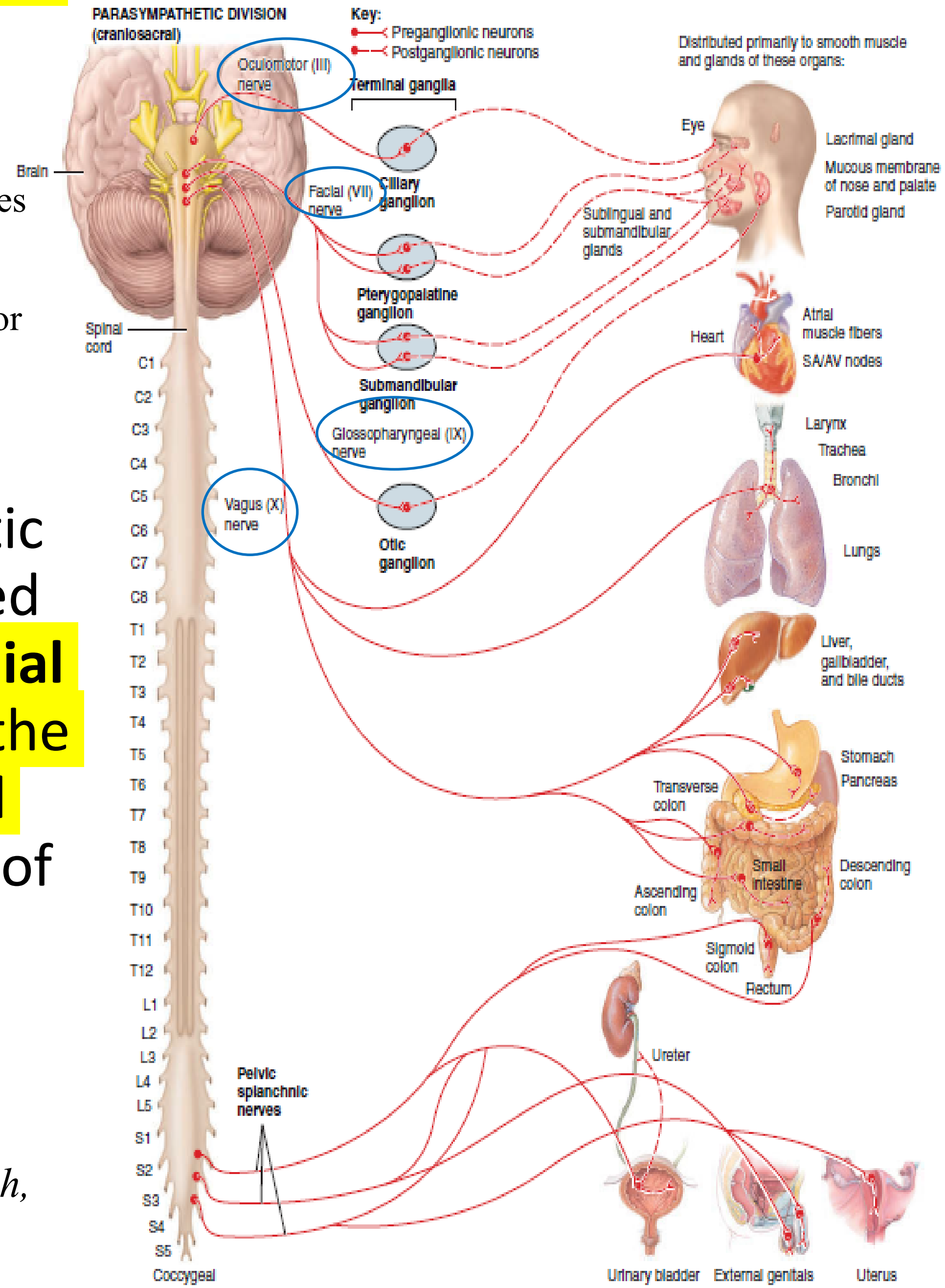
→ Although the innervated structures are shown only for one side of the body for diagrammatic purposes, the parasympathetic division actually innervates tissues and organs on both sides.

→ <u>**Cell bodies**</u> of parasympathetic preganglionic neurons are located in **brain stem nuclei of four cranial nerves (III, VII, IX and X)** and in the lateral gray matter in the **second through fourth sacral** segments of the spinal cord.

III, oculomotor (3)
VII, facial (7)
IX, glossopharyngeal (9)

In the head

X, vagus (10)→*(heart, lungs, esophagus, stomach, liver, small intestine, and upper half of the large intestine)*



Comparison of Sympathetic and Parasympathetic Divisions of the ANS

	SYMPATHETIC (THORACOLUMBAR)	PARASYMPATHETIC (CRANIOSACRAL)
Distribution	Wide regions of body: skin, sweat glands, arrector pili muscles of hair follicles, adipose tissue, smooth muscle of blood vessels.	Limited mainly to head and to viscera of thorax, abdomen, and pelvis; some blood vessels.
Location of preganglionic neuron cell bodies and site of outflow	Lateral gray horns of spinal cord segments T1–L2. Axons of preganglionic neurons constitute thoracolumbar outflow.	Nuclei of cranial nerves III, VII, IX, and X and lateral gray matter of spinal cord segments S2–S4. Axons of preganglionic neurons constitute craniosacral outflow.
Associated ganglia	Sympathetic trunk ganglia and prevertebral ganglia.	Terminal ganglia.
Ganglia locations	Close to CNS and distant from visceral effectors.	Typically near or within wall of visceral effectors.
Axon length and divergence	Preganglionic neurons with short axons synapse with many postganglionic neurons with long axons that pass to many visceral effectors.	Preganglionic neurons with long axons usually synapse with four to five postganglionic neurons with short axons that pass to single visceral effector.
White and gray rami communicantes	Both present; white rami communicantes contain myelinated preganglionic axons; gray rami communicantes contain unmyelinated postganglionic axons.	Neither present.
Neurotransmitters	Preganglionic neurons release acetylcholine (ACh), which is excitatory and stimulates postganglionic neurons; most postganglionic neurons release norepinephrine (NE); postganglionic neurons that innervate most sweat glands and some blood vessels in skeletal muscle release ACh.	Preganglionic neurons release ACh, which is excitatory and stimulates postganglionic neurons; postganglionic neurons release ACh.
Physiological effects	Fight-or-flight responses.	Rest-and-digest activities.

Anatomy of Autonomic Motor Pathways

Autonomic Plexuses (Figure 15.5)

- In the thorax, abdomen, and pelvis, axons of both sympathetic and parasympathetic neurons form tangled networks called **autonomic plexuses**, many of which lie along major arteries.

- The autonomic plexuses also may contain sympathetic ganglia and axons of autonomic sensory neurons.

The major plexuses IN THE THORAX are:

1- The **cardiac plexus**, which supplies the heart,

2- The **pulmonary plexus**, which supplies the bronchial tree

Anatomy of Autonomic Motor Pathways

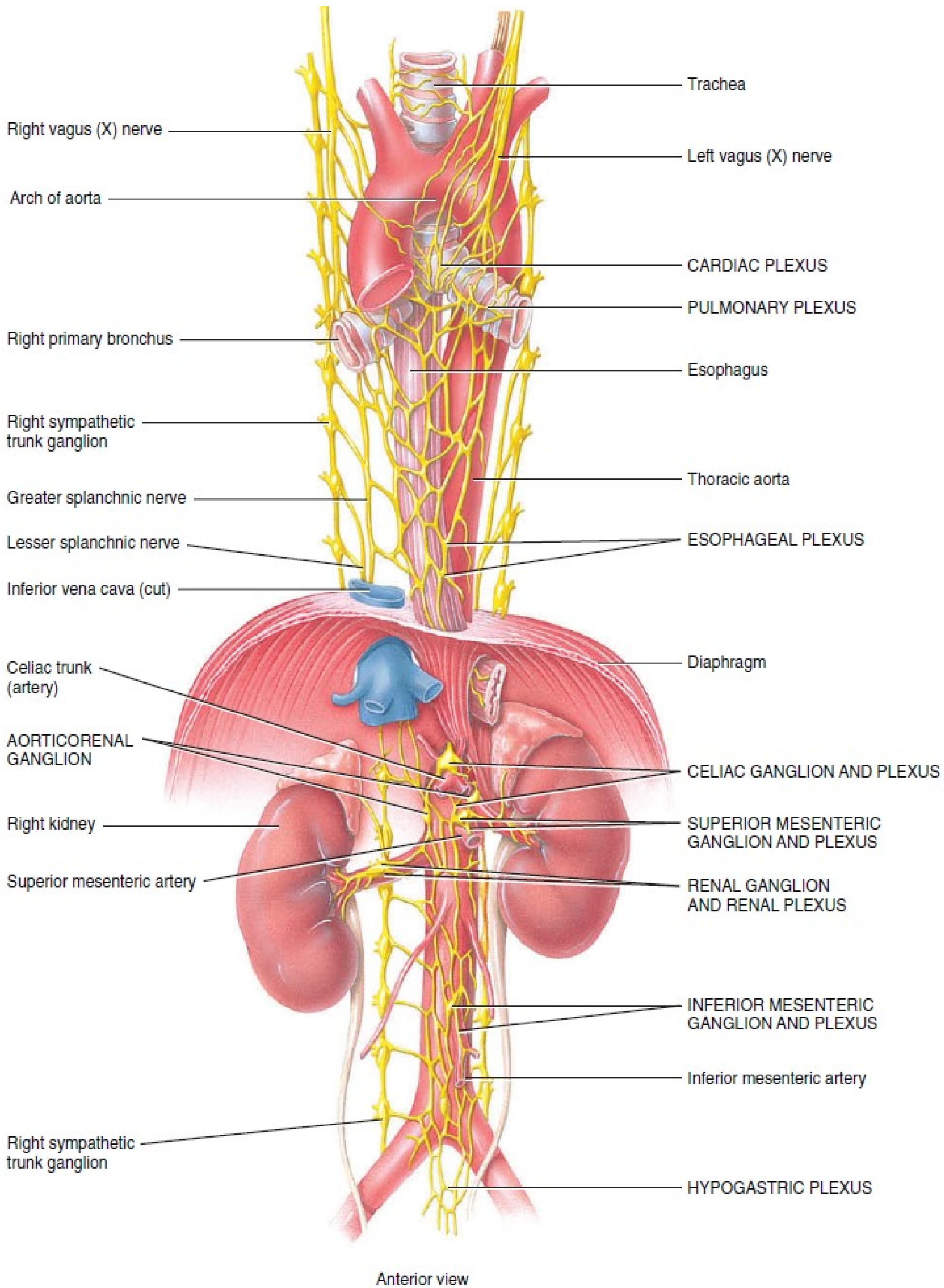
Autonomic Plexuses (Figure 15.5)- continued

The ABDOMEN AND PELVIS also contain major autonomic plexuses:

1. The **celiac** (*solar*) **plexus** is the largest autonomic plexus and surrounds the celiac trunk. **distributed** to the stomach, spleen, pancreas, liver, gallbladder, kidneys, adrenal medullae, testes, and ovaries.
2. The **superior mesenteric plexus** contains the superior mesenteric ganglion and supplies the small and large intestines.
3. The **inferior mesenteric plexus** contains the inferior mesenteric ganglion, which **innervates** the large intestine.
4. The **hypogastric plexus,** Axons of some sympathetic postganglionic neurons from the inferior mesenteric ganglion also extend through, which is anterior to the fifth lumbar vertebra, to **supply** the pelvic viscera.
5. The **renal plexus** contains the renal ganglion and **supplies** the renal arteries within the kidneys and ureters.

Figure 15.5 **Autonomic plexuses in the thorax, abdomen, and pelvis.**

→ An autonomic plexus is a network of sympathetic and parasympathetic axons that sometimes also includes autonomic sensory axons and sympathetic ganglia.



ANS Neurotransmitters and Receptors
1-Cholinergic Neurons and Receptors

Cholinergic neurons release the neurotransmitter **acetylcholine (ACh)**.

In the ANS, the cholinergic neurons include:

(1) **all** sympathetic and parasympathetic preganglionic neurons,

(2) sympathetic postganglionic neurons that innervate most **sweat glands,**

(3) **all** parasympathetic postganglionic neurons (Figure 15.7).

ACETYLCHOLINE (Ach)

- ACh is stored in synaptic vesicles and released by exocytosis.
- It then diffuses across the synaptic cleft and binds with specific **cholinergic receptors** → *integral membrane proteins in the postsynaptic plasma membrane.*
- The two types of cholinergic receptors, both of which bind ACh, are **nicotinic** receptors and **muscarinic** receptors.

ANS Neurotransmitters and Receptors

1-Cholinergic Neurons and Receptors

Nicotinic receptors and Muscarinic receptors (Table 15.2)

Location and Responses of Adrenergic and Cholinergic Receptors

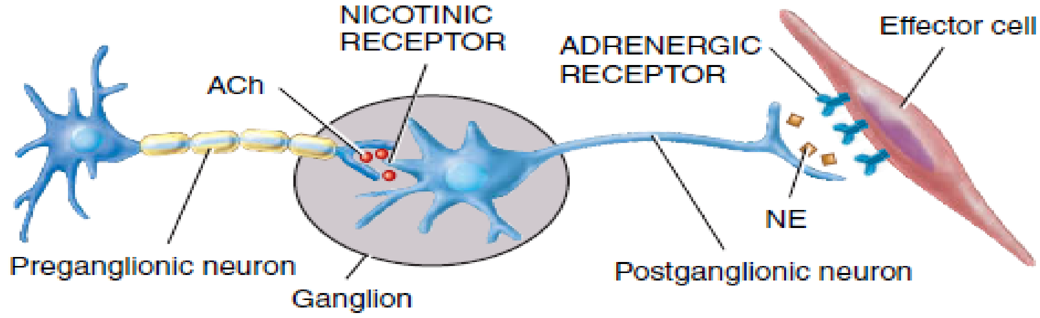
TYPE OF RECEPTOR	MAJOR LOCATIONS	EFFECTS OF RECEPTOR ACTIVATION
CHOLINERGIC	Integral proteins in postsynaptic plasma membranes; activated by the neurotransmitter acetylcholine.	
Nicotinic	Plasma membrane of postganglionic sympathetic and parasympathetic neurons.	Excitation → impulses in postganglionic neurons.
	Chromaffin cells of adrenal medullae.	Epinephrine and norepinephrine secretion.
	Sarcolemma of skeletal muscle fibers (motor end plate).	Excitation → contraction.
Muscarinic	Effectors innervated by parasympathetic postganglionic neurons.	In some receptors, excitation; in others, inhibition.
	Sweat glands innervated by cholinergic sympathetic postganglionic neurons.	Increased sweating.
	Skeletal muscle blood vessels innervated by cholinergic sympathetic postganglionic neurons.	Inhibition → relaxation → vasodilation.

- ACTIVITY TERMINATION: Because acetylcholine is quickly inactivated by the enzyme **acetylcholinesterase (AChE)**, effects triggered by cholinergic neurons are brief.

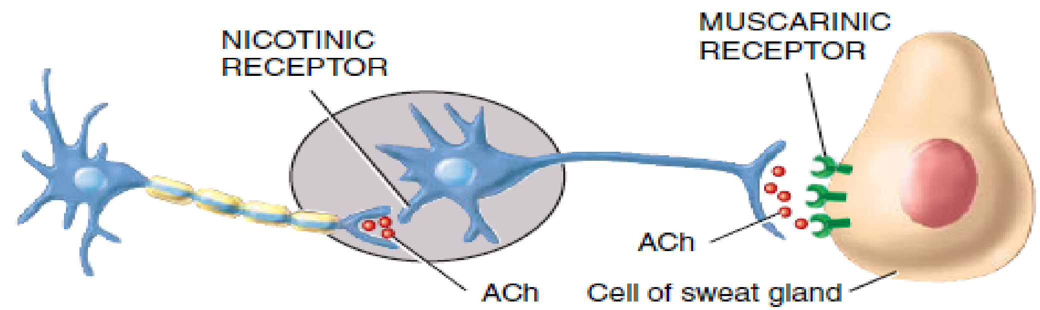
Cholinergic neurons and adrenergic neurons in the sympathetic and parasympathetic divisions.

→ Cholinergic neurons release acetylcholine; adrenergic neurons release norepinephrine.

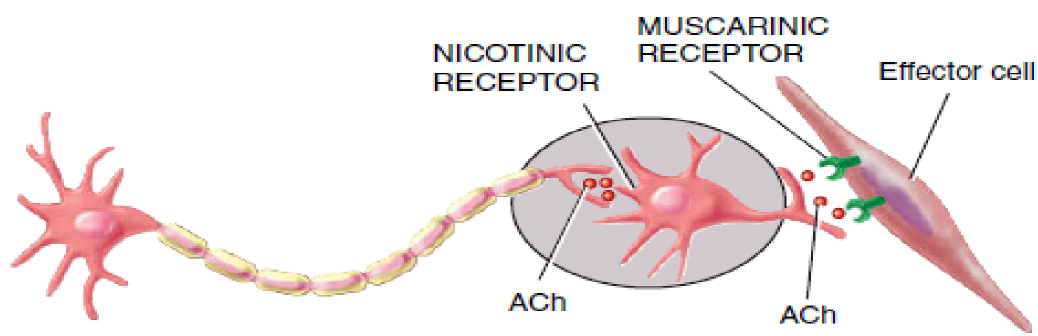
→ Cholinergic <u>receptors</u> (nicotinic or muscarinic) and adrenergic <u>receptors</u> are **integral membrane proteins** located in the plasma membrane of a postsynaptic neuron or an effector cell.



(a) Sympathetic division–innervation to most effector tissues



(b) Sympathetic division–innervation to most sweat glands



(c) Parasympathetic division

ANS Neurotransmitters and Receptors
2-Adrenergic Neurons and Receptors

- In the ANS, **adrenergic neurons** release **norepinephrine (NE)**, also known as **noradrenalin** (Figure 15.7a).
- Most sympathetic postganglionic neurons are adrenergic.

NOREPINEPHRINE (NE)

- NE is stored in synaptic vesicles and released by exocytosis.
- Molecules of NE diffuse across the synaptic cleft and bind to specific adrenergic receptors on the postsynaptic membrane, causing either excitation or inhibition of the effector cell.
- **Adrenergic receptors bind** both norepinephrine and epinephrine.
- The NOREPINEPHRINE can either be released as a neurotransmitter by sympathetic postganglionic neurons or released as a hormone into the blood by chromaffin cells of the adrenal medullae;
- The EPINEPHRINE is released as a hormone.

ANS Neurotransmitters and Receptors
2-Adrenergic Neurons and Receptors
Adrenergic receptors

- The two main types of adrenergic receptors are **alpha (α) receptors** and **beta (β) receptors,** which are found on **visceral** effectors innervated by most sympathetic postganglionic axons.

- These receptors are further classified into subtypes—1, 2, 1, 2, and 3—**based** on the specific responses they elicit and by their selective binding of drugs that activate or block them.

- Although there are some exceptions, activation of 1 and 1 receptors generally produces excitation, and activation of 2 and 2 receptors causes inhibition of effector tissues. 3 receptors are present only on cells of brown adipose tissue, where their activation causes *thermogenesis* (heat production).

- Cells of **MOST effectors** contain **EITHER** alpha or beta receptors
- **Some visceral** effector cells contain **both**.

- ***Norepinephrine*** stimulates **alpha** receptors more strongly than beta receptors;
- ***Epinephrine*** is a potent stimulator of **both** alpha and beta receptors.

ANS Neurotransmitters and Receptors

2-Adrenergic Neurons and Receptors

Adrenergic receptors – activity termination

The activity of norepinephrine at a synapse is terminated either when:

1- The NE is taken up by the axon that released it

OR

2- When the NE is enzymatically inactivated by either **catechol-*O*-methyltransferase (COMT)** or **monoamine oxidase (MAO).**

- Compared to ACh, norepinephrine lingers in the synaptic cleft for a longer time. Thus, effects triggered by adrenergic neurons typically are **longer** lasting than those triggered by cholinergic neurons.

ANS Neurotransmitters and Receptors
2-Adrenergic Neurons and Receptors
Adrenergic receptors (Table 15.2)

Location and Responses of Adrenergic and Cholinergic Receptors

TYPE OF RECEPTOR	MAJOR LOCATIONS	EFFECTS OF RECEPTOR ACTIVATION
ADRENERGIC	Integral proteins in postsynaptic plasma membranes; activated by the neurotransmitter norepinephrine and the hormones norepinephrine and epinephrine.	
α_1	Smooth muscle fibers in blood vessels that serve salivary glands, skin, mucosal membranes, kidneys, and abdominal viscera; radial muscle in iris of eye; sphincter muscles of stomach and urinary bladder.	Excitation → contraction, which causes vasoconstriction, dilation of pupil, and closing of sphincters.
	Salivary gland cells.	Secretion of K^+ and water.
	Sweat glands on palms and soles.	Increased sweating.
α_2	Smooth muscle fibers in some blood vessels.	Inhibition → relaxation → vasodilation.
	Cells of pancreatic islets that secrete the hormone insulin (beta cells).	Decreased insulin secretion.
	Pancreatic acinar cells.	Inhibition of digestive enzyme secretion.
	Platelets in blood.	Aggregation to form platelet plug.
β_1	Cardiac muscle fibers.	Excitation → increased force and rate of contraction.
	Juxtaglomerular cells of kidneys.	Renin secretion.
	Posterior pituitary.	Antidiuretic hormone (ADH) secretion.
	Adipose cells.	Breakdown of triglycerides → release of fatty acids into blood.
β_2	Smooth muscle in walls of airways; in blood vessels that serve heart, skeletal muscle, adipose tissue, and liver; and in walls of visceral organs, such as urinary bladder.	Inhibition → relaxation, which causes dilation of airways, vasodilation, and relaxation of organ walls.
	Ciliary muscle in eye.	Inhibition → relaxation.
	Hepatocytes in liver.	Glycogenolysis (breakdown of glycogen into glucose).
β_3	Brown adipose tissue.	Thermogenesis (heat production).

Receptor Agonists and Antagonists

A large variety of drugs and natural products can selectively activate or block specific cholinergic or adrenergic receptors.

AN **AGONIST** is a substance that binds to and **<u>activates</u>** a receptor, in the process mimicking the effect of a natural neurotransmitter or hormone.

<u>Example:</u> **Phenylephrine**, an adrenergic agonist at 1 receptors, is a common ingredient in cold and sinus medications. Because it constricts blood vessels in the nasal mucosa, phenylephrine reduces production of mucus, thus relieving nasal congestion.

AN **ANTAGONIST** is a substance that binds to and **<u>blocks</u>** a receptor, thereby preventing a natural neurotransmitter or hormone from exerting its effect.

<u>Example:</u> **Atropine** blocks muscarinic ACh receptors, dilates the pupils, reduces glandular secretions, and relaxes smooth muscle in the gastrointestinal tract. As a result, it is used to dilate the pupils during eye examinations, in the treatment of smooth muscle disorders such as iritis and intestinal hypermotility, and as an antidote for chemical warfare agents that inactivate acetylcholinesterase.

Integration and Control of Autonomic Functions
Autonomic Reflexes

A **reflex** is a fast, involuntary, unplanned sequence of actions that occurs in response to a particular stimulus.

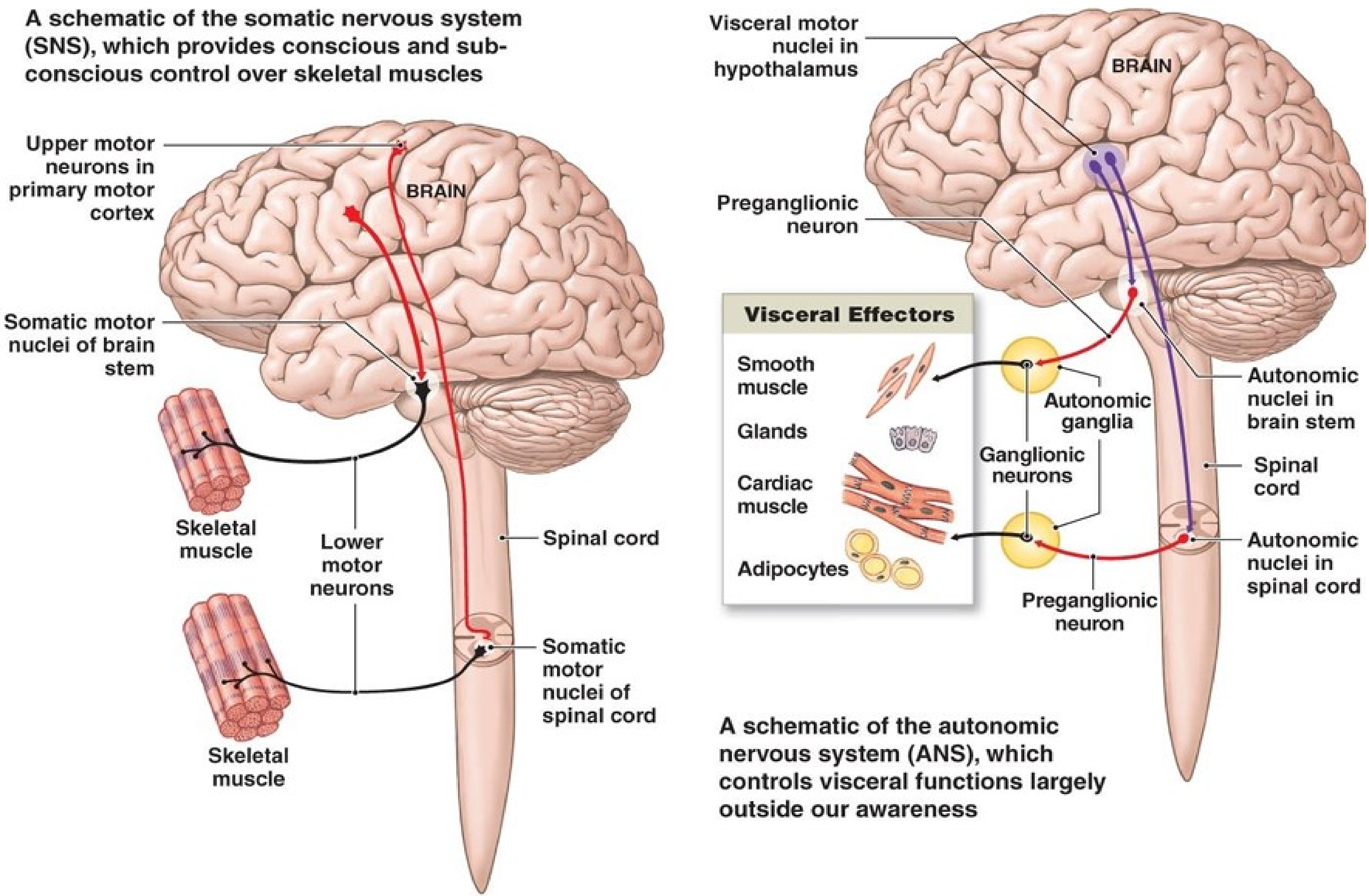
REFLEX ARCS HAVE TWO TYPES: (not consciously perceived)

1-Somatic reflexes, which involve contraction of skeletal muscles.

2- Autonomic (visceral) reflexes They involve responses of smooth muscle, cardiac muscle, and glands. Body functions such as heart rate, digestion, urination, and defecation are controlled by the autonomic nervous system through autonomic reflexes.

Autonomic reflexes are responses that occur when nerve impulses pass through an **autonomic reflex arc**.

Somatic vs Autonomic reflexes



Reflexes and Reflex Arcs (continued)

- Nerve impulses propagating into, through, and out of the CNS follow specific pathways, depending on the kind of information, its origin, and its destination.

- Some reflexes are inborn, such as pulling your hand away from a hot surface before you even feel that it is hot.

- Other reflexes are learned or acquired. For instance, you learn many reflexes while acquiring driving expertise. Slamming on the brakes in an emergency is one example.

- The pathway followed by nerve impulses that produce a reflex is a **reflex arc** (*reflex circuit*).

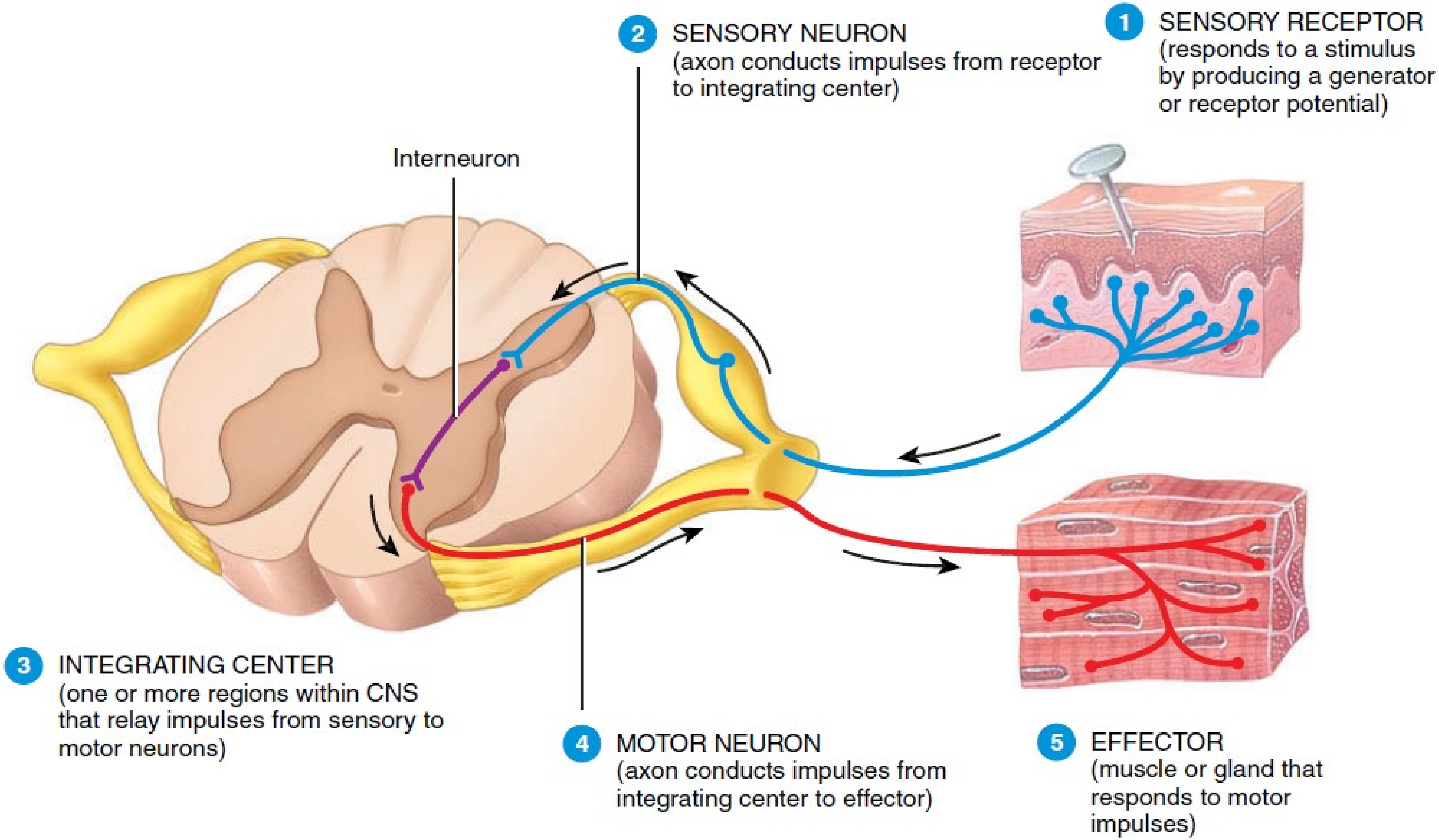
- A reflex arc includes the following five functional components (Figure 13.13)

The components of an autonomic reflex arc are as follows:

1. **Receptor.** Like the receptor in a somatic reflex arc, the receptor in an autonomic reflex arc is the distal end of a sensory neuron, which responds to a stimulus and produces a change that will ultimately trigger nerve impulses. Autonomic sensory receptors are mostly associated with interoceptors.
2. **Sensory neuron.** Conducts nerve impulses from receptors to the CNS.
3. **Integrating center.** Interneurons within the CNS relay signals from sensory neurons to motor neurons. **The main integrating centers for most autonomic reflexes are located in the hypothalamus and brain stem**. **Some** autonomic reflexes, such as those for urination and defecation, have integrating centers in the spinal cord.
4. **Motor neurons.** Nerve impulses triggered by the integrating center propagate out of the CNS along motor neurons to an effector. In an autonomic reflex arc, two motor neurons connect the CNS to an effector: The preganglionic neuron conducts motor impulses from the CNS to an autonomic ganglion, and the postganglionic neuron conducts motor impulses from an autonomic ganglion to an effector (see Figure 15.1).
5. **Effector.** In an autonomic reflex arc, the effectors are smooth muscle, cardiac muscle, and glands, and the reflex is called an autonomic reflex.

Figure 13.13 General components of a reflex arc. Arrows show the direction of nerve impulse propagation.

→ A reflex is a fast, predictable sequence of involuntary actions that occur in response to certain changes in the environment.



Autonomic Control by Higher Centers

- Normally, we are not aware of muscular contractions of our digestive organs, our heartbeat, changes in the diameter of our blood vessels, and pupil dilation and ***constriction because the integrating centers for these autonomic responses are in the spinal cord or the lower regions of the brain.***

- **THE HYPOTHALAMUS** is the major **control** and **integration** center of the ANS.

INPUT:

✓The hypothalamus **receives sensory input related to visceral functions**, olfaction (smell), and gustation (taste), as well as changes in temperature, osmolarity, and levels of various substances in blood.

✓It also receives **input relating to emotions** from the limbic system.

OUTPUT:

✓**Output** from the hypothalamus influences autonomic centers in both the brain stem (such as the cardiovascular, salivation, swallowing, and vomiting centers) and the spinal cord (such as the defecation and urination reflex centers in the sacral spinal cord).

Autonomic Control by Higher Centers (continued)

- Anatomically, the hypothalamus is connected to both the sympathetic and parasympathetic divisions of the ANS by axons of neurons with dendrites and cell bodies in various *hypothalamic nuclei.*
- The axons form **tracts** **from** the hypothalamus **to** parasympathetic and sympathetic nuclei **in** the brain stem and spinal cord **through** relays in the reticular formation.
- **The posterior and lateral parts of the hypothalamus control the sympathetic division**. Stimulation of these areas produces an increase in heart rate and force of contraction, a rise in blood pressure due to constriction of blood vessels, an increase in body temperature, dilation of the pupils, and inhibition of the gastrointestinal tract.
- **The anterior and medial parts of the hypothalamus control the parasympathetic division**. Stimulation of these areas results in a decrease in heart rate, lowering of blood pressure, constriction of the pupils, and increased secretion and motility of the gastrointestinal tract.

Autonomic Control by Higher Centers

Limbic system+ hypothalamus+ medulla