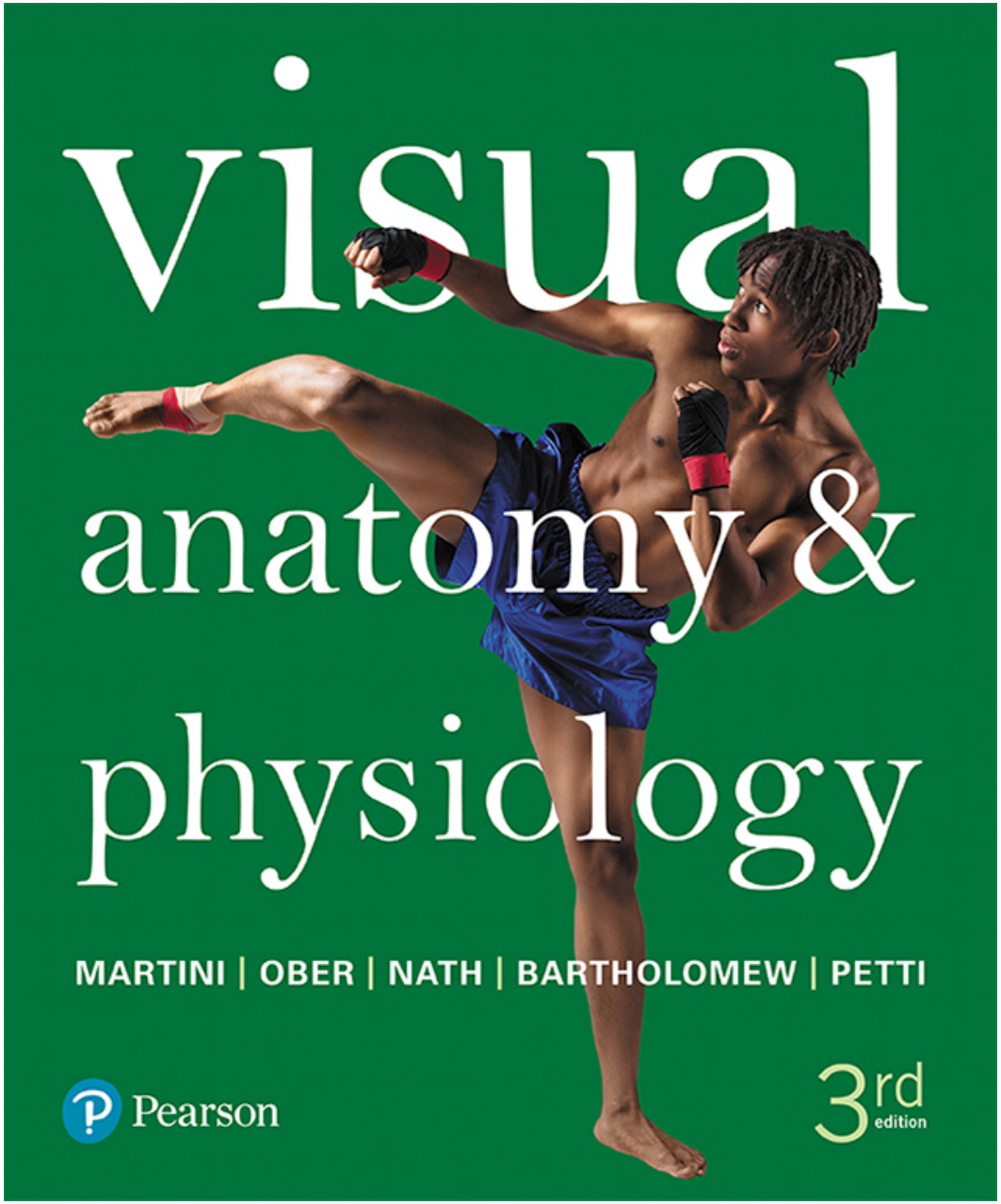

14

The Autonomic Nervous System

Lecture Presentation by
Lori Garrett

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Section 1: Functional Anatomy of the Autonomic Nervous System

Learning Outcomes

14.1 Describe the control of skeletal muscles by the SNS and the control of visceral effectors by the ANS.

14.2 List the divisions of the ANS and the general functions of each.

14.3 Describe the structures and functions of the sympathetic and parasympathetic divisions of the ANS.

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Section 1: Functional Anatomy of the Autonomic Nervous System

Learning Outcomes (continued)

14.4 Describe the innervation patterns of the sympathetic and parasympathetic divisions of the ANS.

14.5 Describe the mechanisms of neurotransmitter release in the ANS, and explain the effects of neurotransmitters on target organs and tissues.

14.6 Describe the types of sympathetic and parasympathetic receptors and their associated neurotransmitters.

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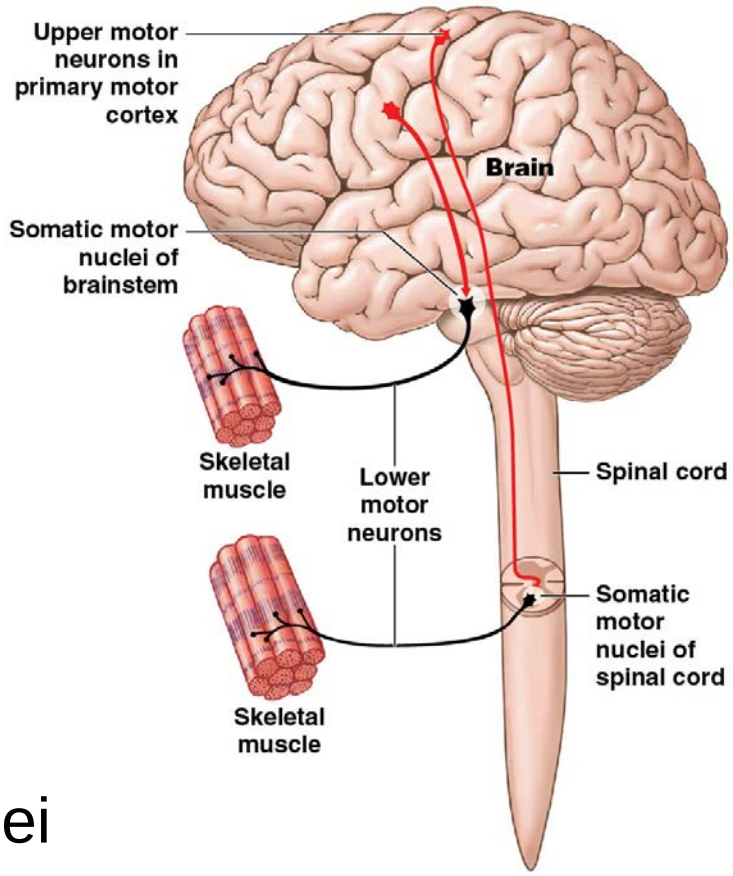
Module 14.1: Ganglionic neurons of the ANS control visceral effectors

Somatic nervous system (SNS)

- Conscious and subconscious control of skeletal muscles
- Pathway—an upper motor neuron and a lower motor neuron
- Lower motor neurons may be controlled by:
  1. Reflexes based in the spinal cord or brain
  2. Upper motor neurons in nuclei of brain or primary motor cortex



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Module 14.1: Ganglionic neurons

Autonomic nervous system (ANS)

- Controls visceral function, mostly outside our awareness
- Motor neurons of CNS synapse on visceral motor neurons on autonomic ganglia
- Integrative centers located in hypothalamus
- Two motor neurons in sequence; control **visceral effectors**
  1. **Preganglionic neurons**
  2. **Ganglionic neurons**

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Module 14.1: Ganglionic neurons

1. **Preganglionic neurons**
   - Cell bodies in brainstem and spinal cord
   - Part of visceral reflex arcs
   - Most activities represent direct reflex responses
   - Leave CNS and synapse with **ganglionic neurons**
2. **Ganglionic neurons**
   - Visceral motor neurons
   - Cell bodies in peripheral **autonomic ganglia**
   - Innervate **visceral effectors—**cardiac muscle, smooth muscle, glands, adipose tissue

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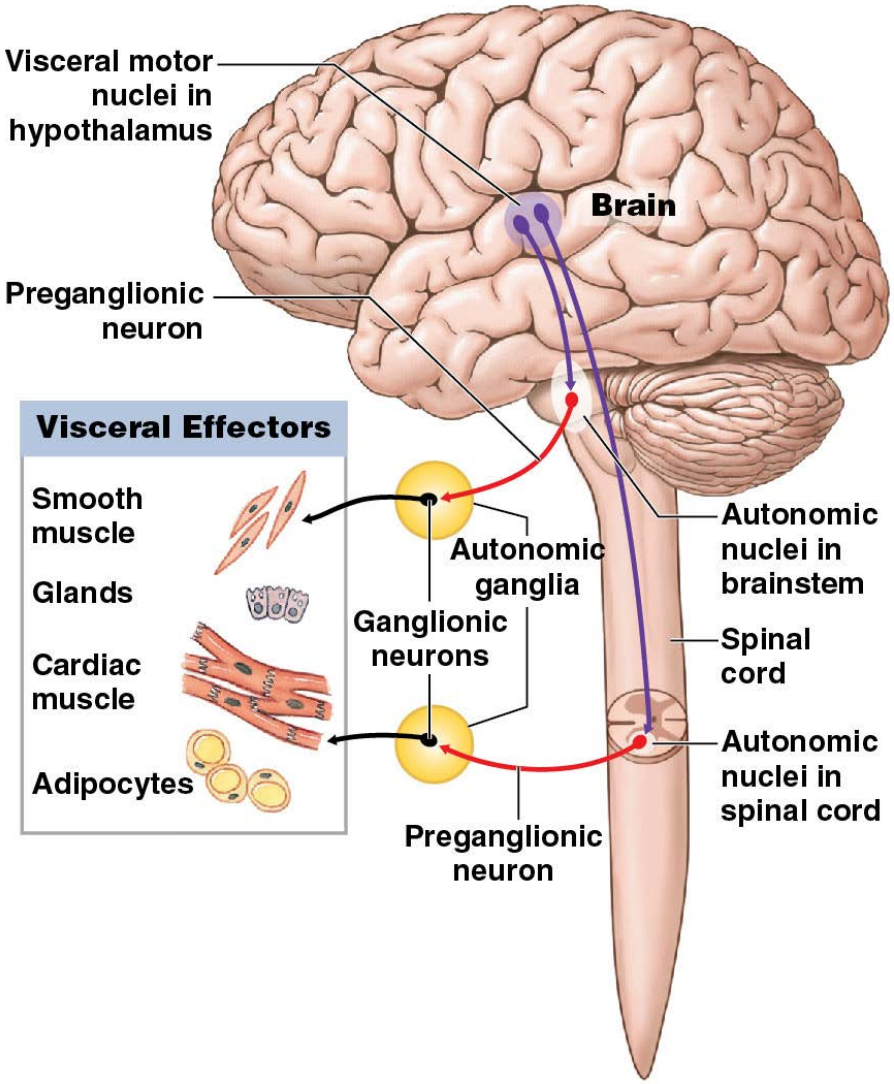
Preganglionic and ganglionic neurons of the autonomic nervous system



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Module 14.1: Review

A. Compare the SNS with the ANS.
B. Describe the role of preganglionic neurons.
C. Explain the function of autonomic ganglia.

Learning Outcome: Describe the control of skeletal muscles by the SNS and the control of visceral effectors by the ANS.

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Module 14.2: The ANS consists of sympathetic and parasympathetic divisions

Autonomic nervous system

- Two major divisions
  - **Sympathetic division**
  - **Parasympathetic division**
- Usually have opposing effects
  - May also work independently
  - Some structures innervated by only one division
  - Sometimes work together in complex processes
- Both divisions influence third autonomic division, called the **enteric nervous system (ENS)**

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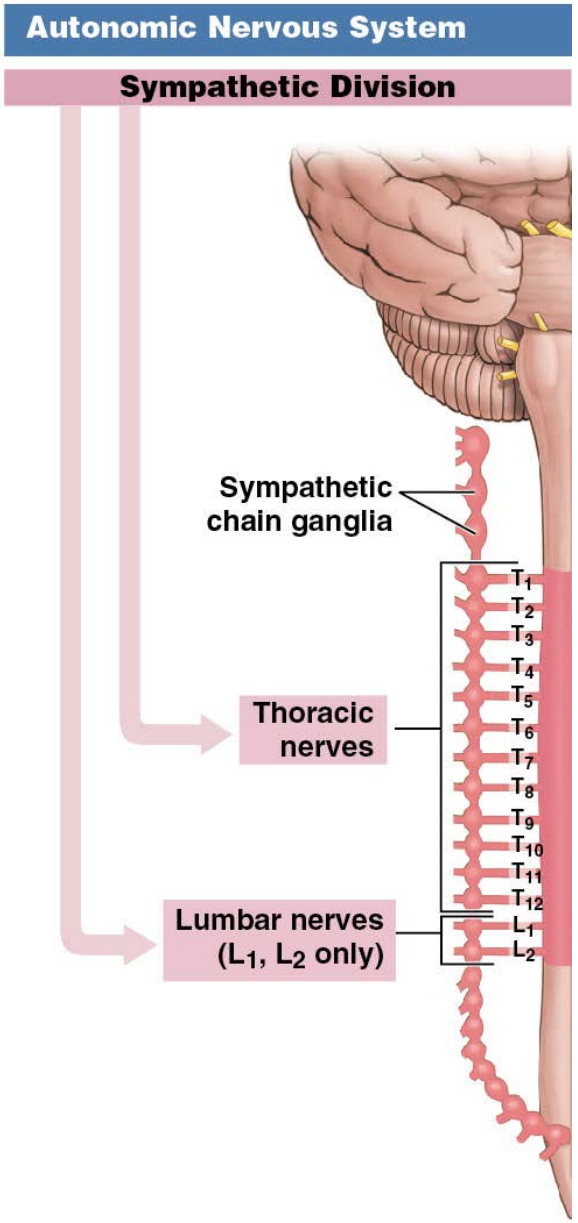
Module 14.2: ANS divisions

Sympathetic division

- In general, active during exertion, stress, or emergency
- Also called **thoracolumbar division**
  - Axons emerge from cell bodies in lateral gray horns of thoracic and superior lumbar segments of spinal cord (T_1–L_2)
- Axons innervate ganglia close to spinal cord (sympathetic chain ganglia)



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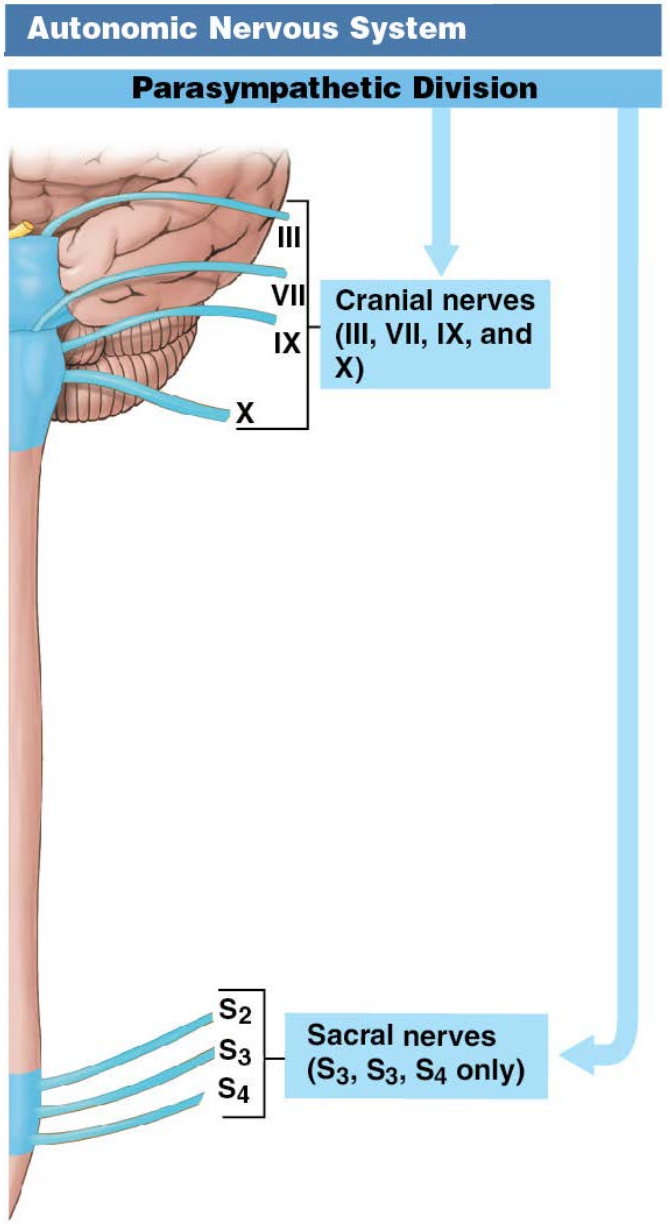
Module 14.2: ANS divisions

Parasympathetic division

- Predominates under resting conditions
- Also called **craniosacral division**
  - Axons emerge from brainstem nuclei and lateral gray horns of sacral segments of spinal cord
- Axons innervate ganglia close to or within target organs
- Parasympathetic fibers carried in cranial nerves III, VII, IX, and X and sacral nerves S_2, S_3, and S_4



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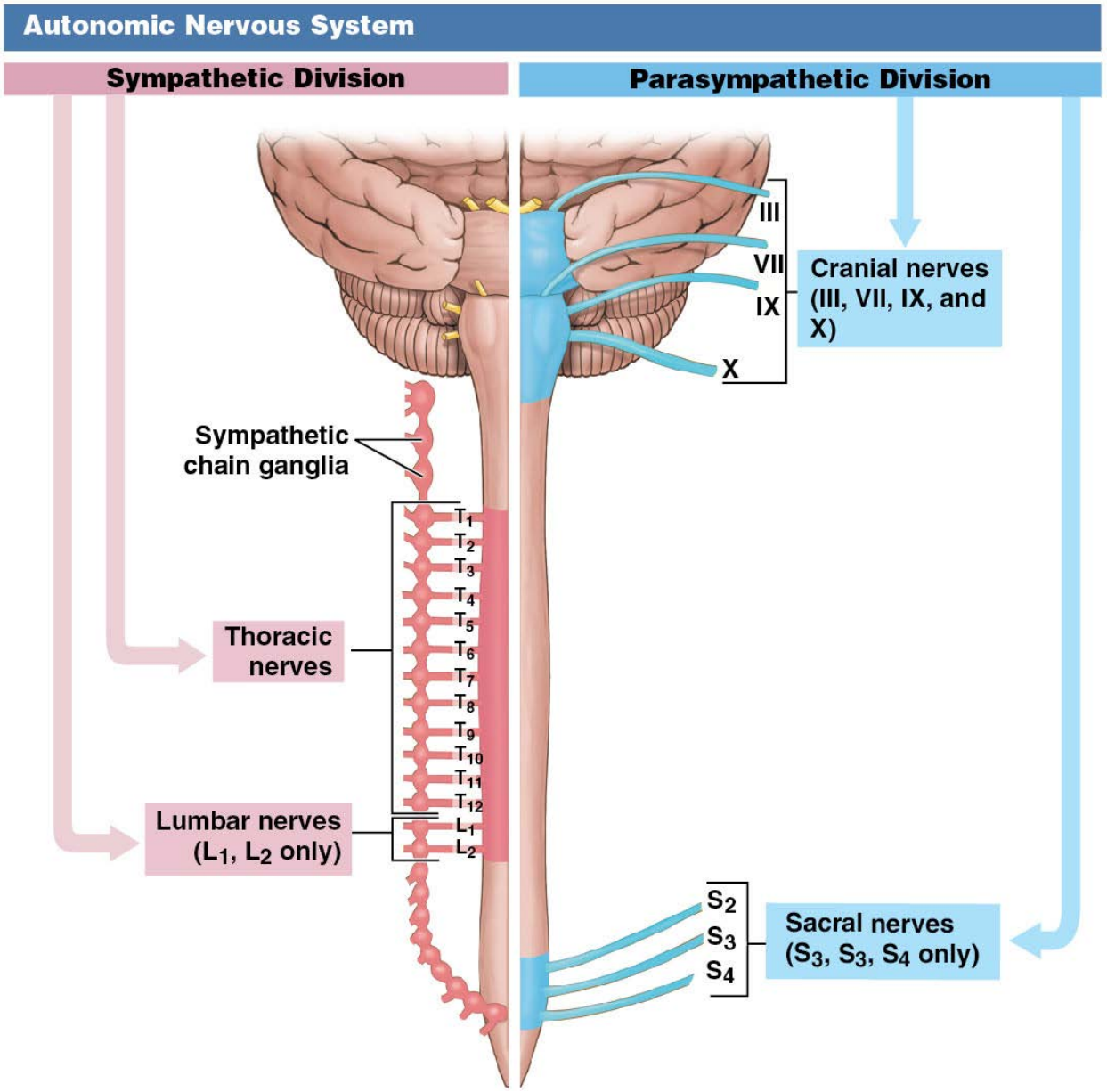
Module 14.2: ANS divisions



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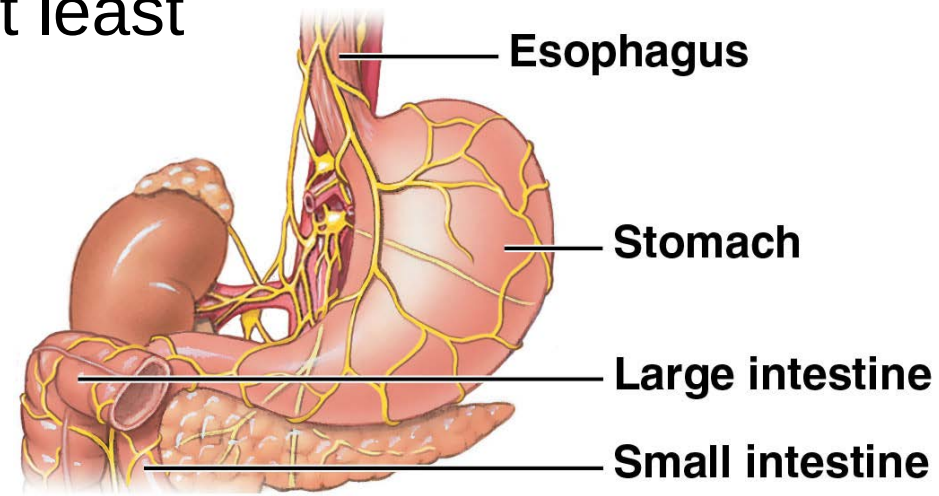
Module 14.2: ANS divisions

Enteric nervous system (ENS)

- Extensive network of neurons and nerve networks in walls of digestive tract
- Initiates/coordinates many complex local visceral reflexes with no CNS input
- Influenced by sympathetic and parasympathetic divisions
- ~100 million neurons—at least as many as spinal cord
- Same neurotransmitters as brain
- See Chapter 22



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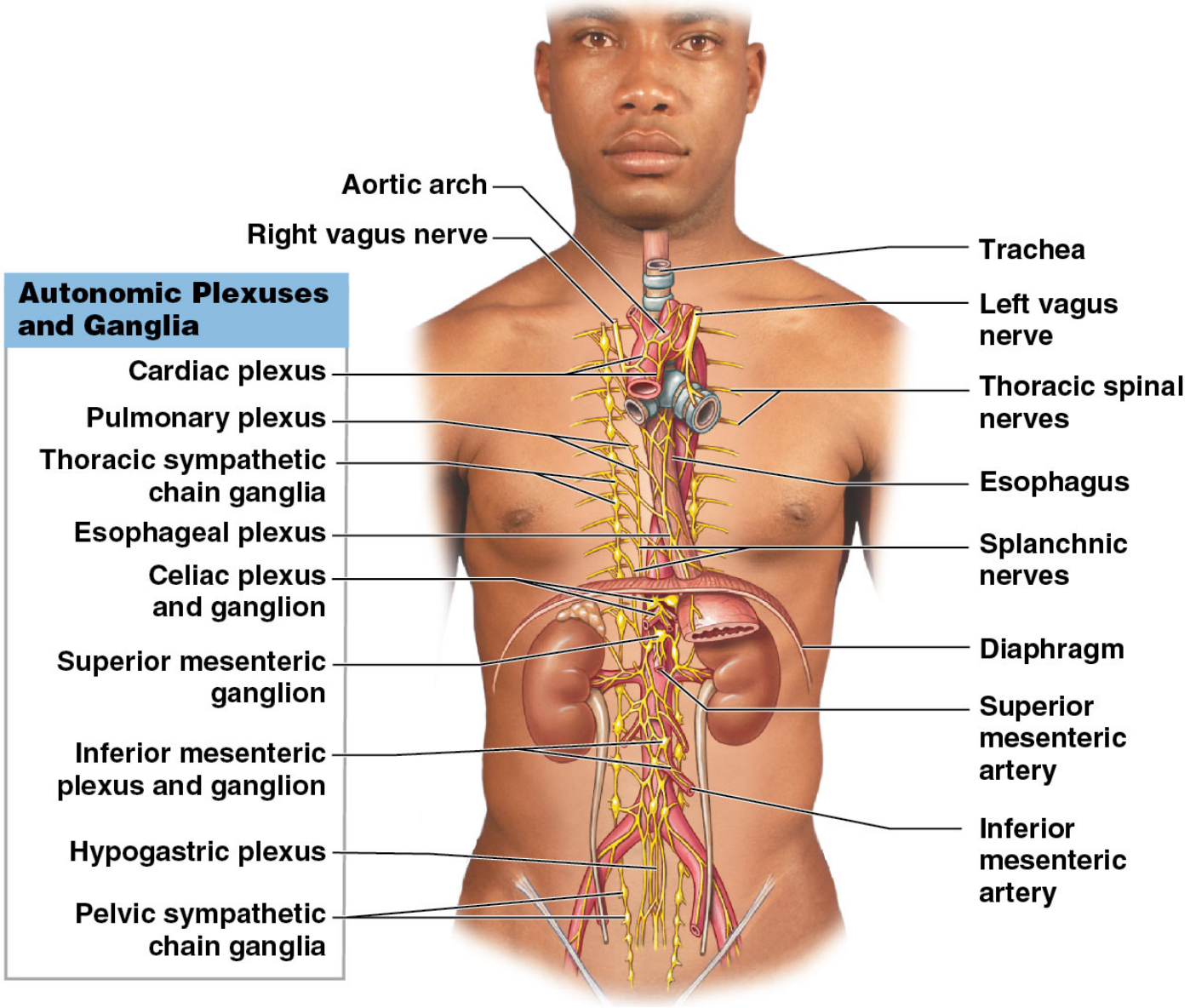
Module 14.2: ANS divisions



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Module 14.2: Review

A. Identify two major divisions of the ANS.
B. Compare the anatomy of the sympathetic division with that of the parasympathetic division.
C. Describe the ENS.
D. Which division of the ANS is responsible for the physiological changes you experience when startled by a loud noise?

Learning Outcome: List the divisions of the ANS and the general functions of each.

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Module 14.3: The sympathetic division has chain ganglia, collateral ganglia, and the adrenal medullae…

Organization of the sympathetic division

- Preganglionic neurons synapse on **ganglionic neurons**
  1. **Sympathetic chain ganglia—**interconnected ganglia on each side of vertebral column
  2. **Collateral ganglia** innervate abdominopelvic tissues
     - Include **celiac ganglia**, **superior mesenteric ganglia**, and **inferior mesenteric ganglia**

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Module 14.3: The sympathetic division has chain ganglia, collateral ganglia, and the adrenal medullae…

Organization of the sympathetic division (continued)

- Preganglionic neurons synapse on **ganglionic neurons** (continued)
  3. **Adrenal medullae**—modified sympathetic ganglia; secrete neurotransmitters into bloodstream that act as hormones
  - Have short **preganglionic fibers** and long **postganglionic fibers**

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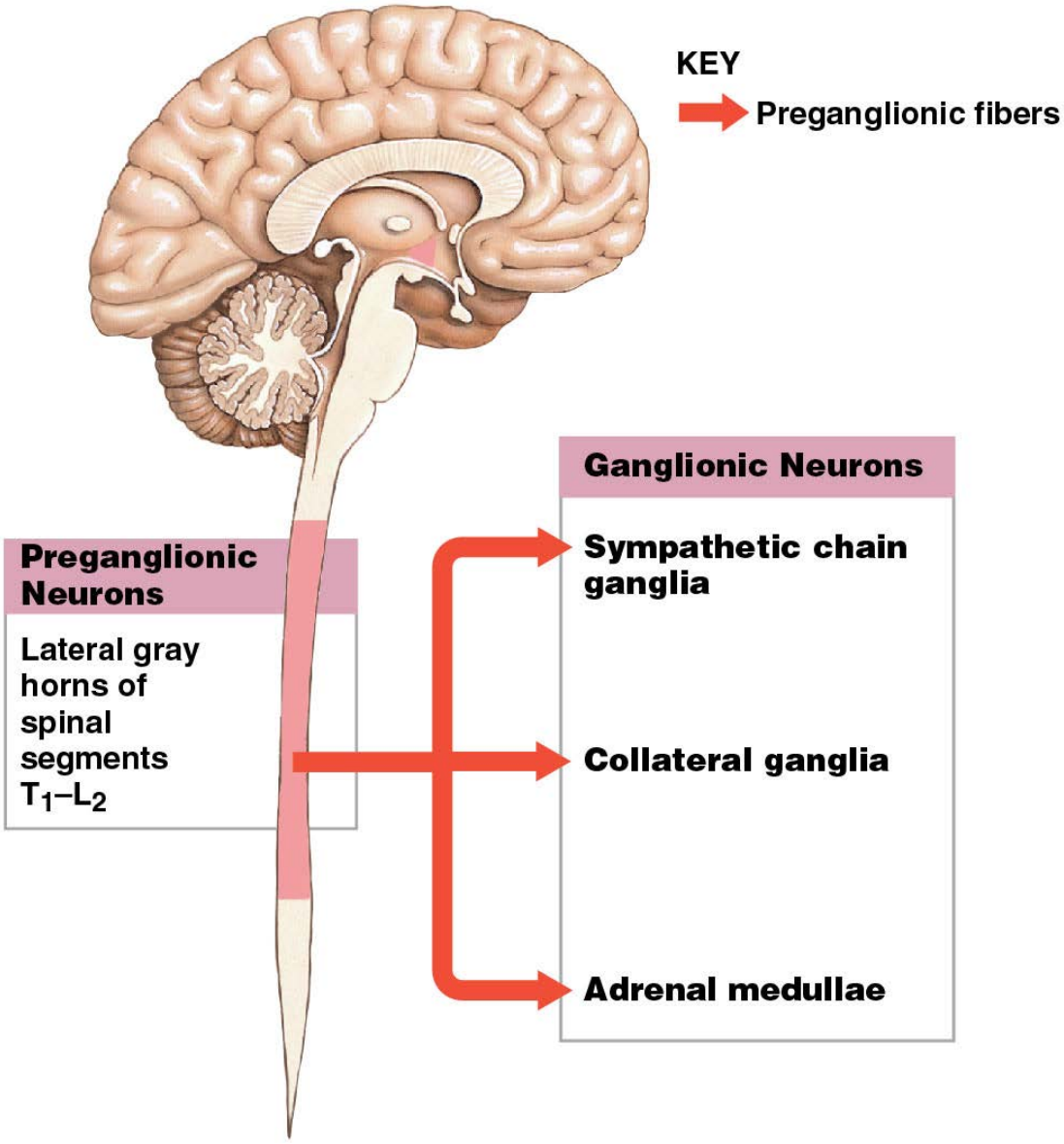
The sympathetic nervous system



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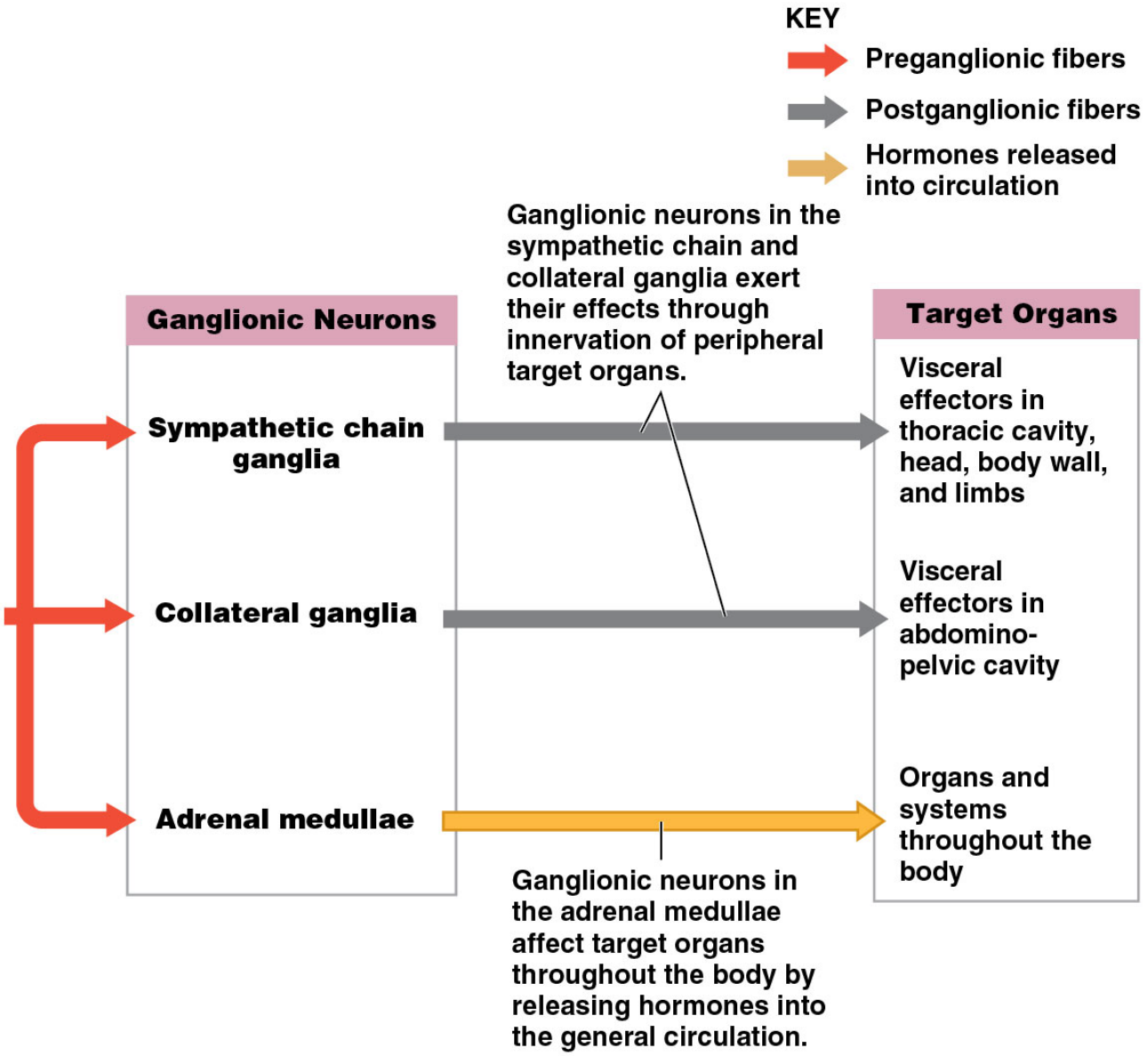
The sympathetic nervous system



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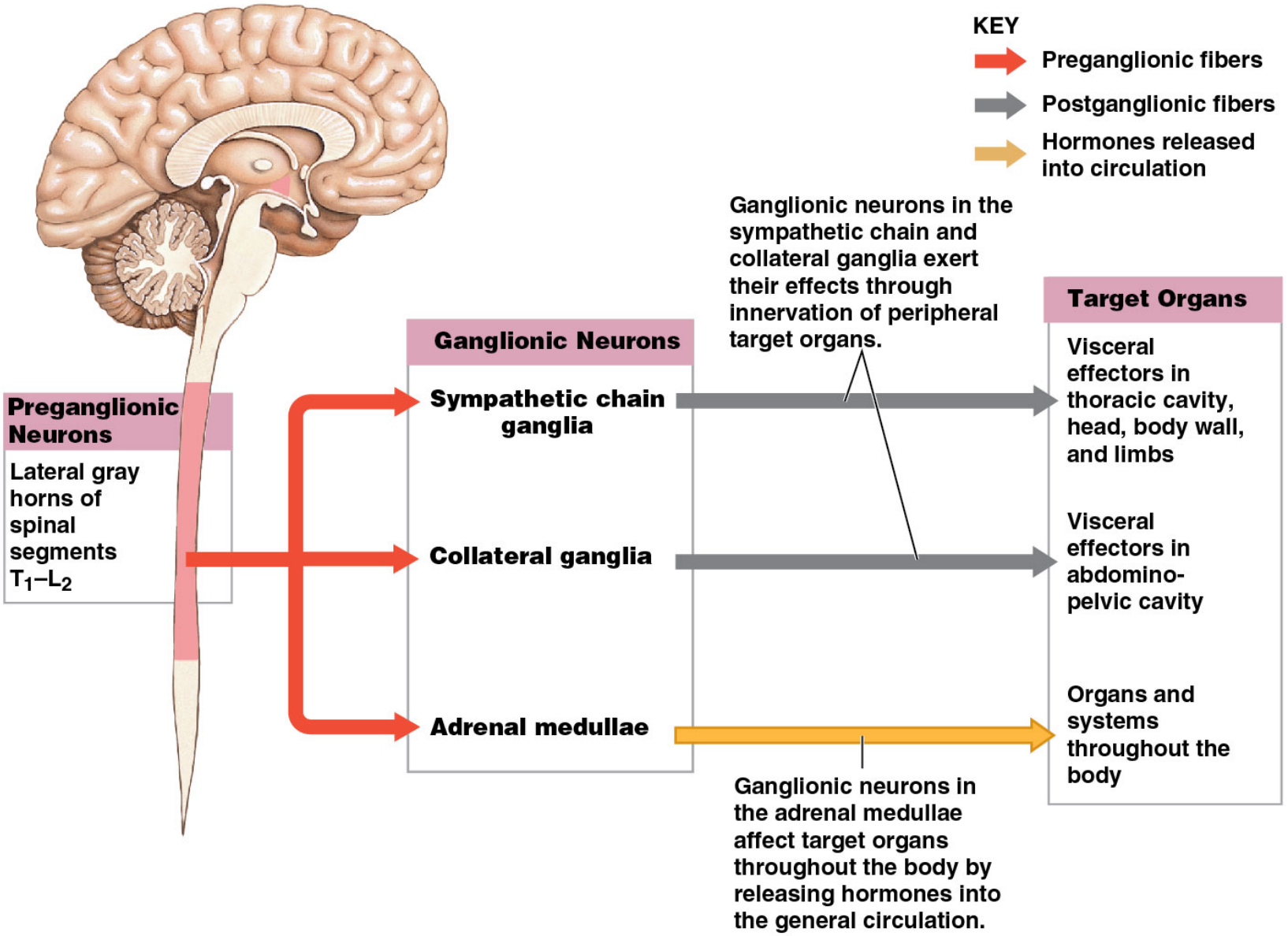
The sympathetic nervous system



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Module 14.3: Sympathetic and parasympathetic divisions

Responses to increased sympathetic activity

- "Fight or flight" responses, which include:
  1. Heightened mental alertness
  2. Increased metabolic rate
  3. Decreased digestive and urinary functions
  4. Activation of energy reserves
  5. Dilation of respiratory passageways; increased respiratory rate
  6. Increased heart rate and blood pressure
  7. Activation of sweat glands

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. . . whereas the parasympathetic division has terminal or intramural ganglia

Organization of the parasympathetic division

- Typical preganglionic fiber synapses on six to eight ganglionic neurons
  1. **Terminal ganglia**
     - Located near target organ
     - Usually paired
     - *Examples:* parasympathetic ganglia associated with cranial nerves
  2. **Intramural ganglia** (*murus*, wall)
     - Embedded in tissues of target organ
     - Typically consist of interconnected masses and clusters of ganglion cells

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. . . whereas the parasympathetic division has terminal or intramural ganglia

Organization of the parasympathetic division (continued)

- Typical preganglionic fiber synapses on six to eight ganglionic neurons (continued)
  - Others: **ciliary ganglion**, **pterygopalatine** and **submandibular ganglia**, **otic ganglia**

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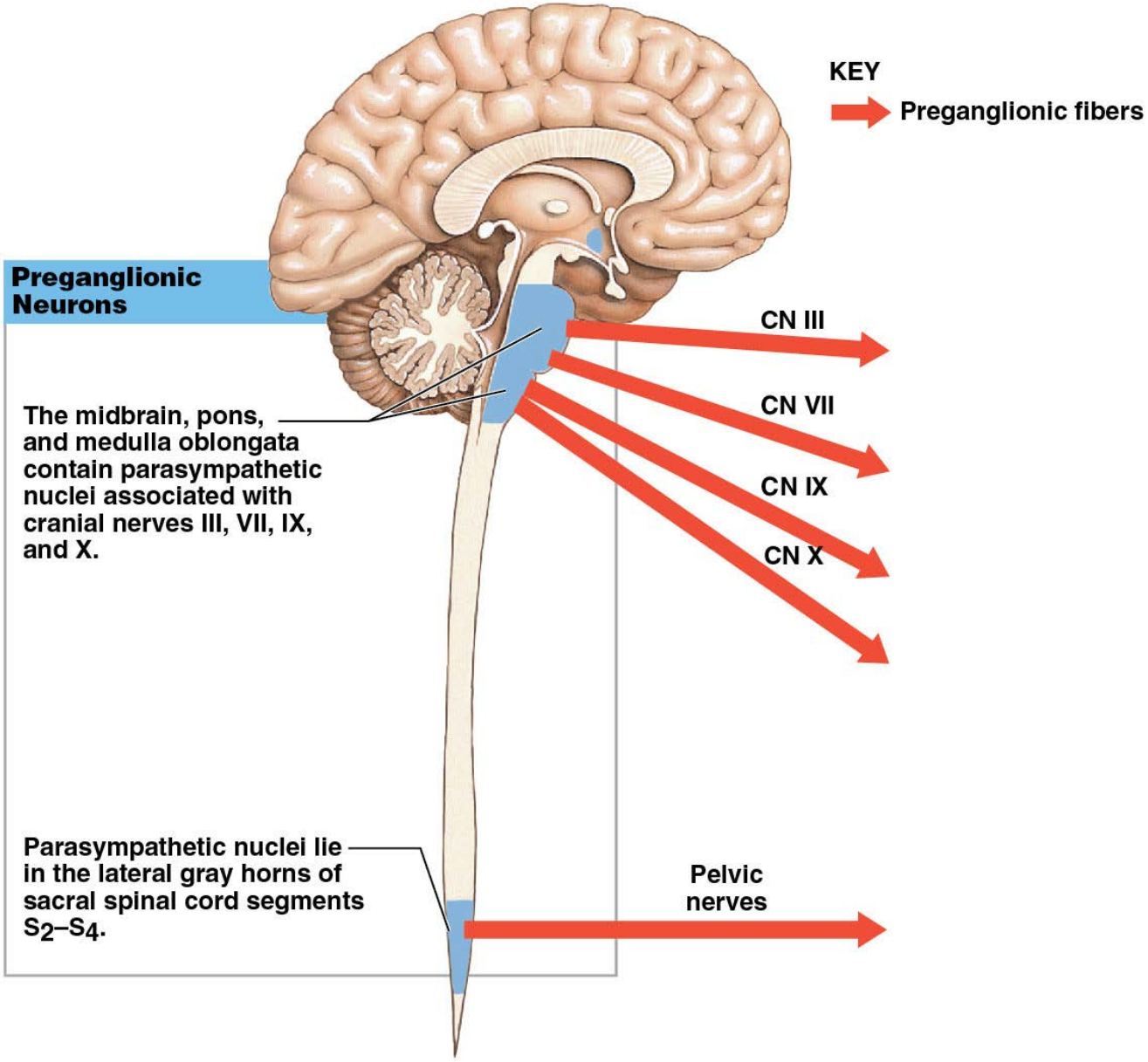
The parasympathetic nervous system



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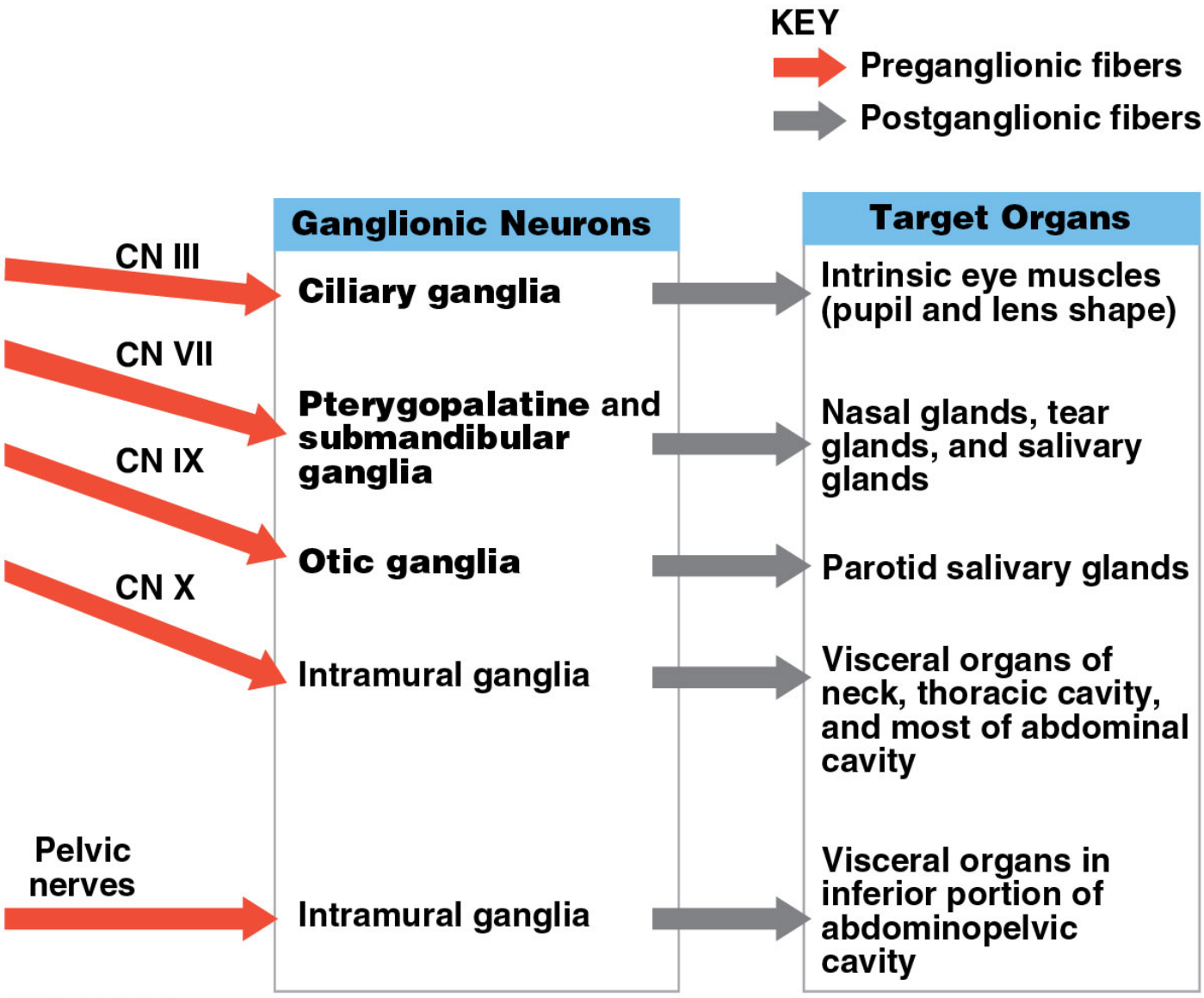
The parasympathetic nervous system



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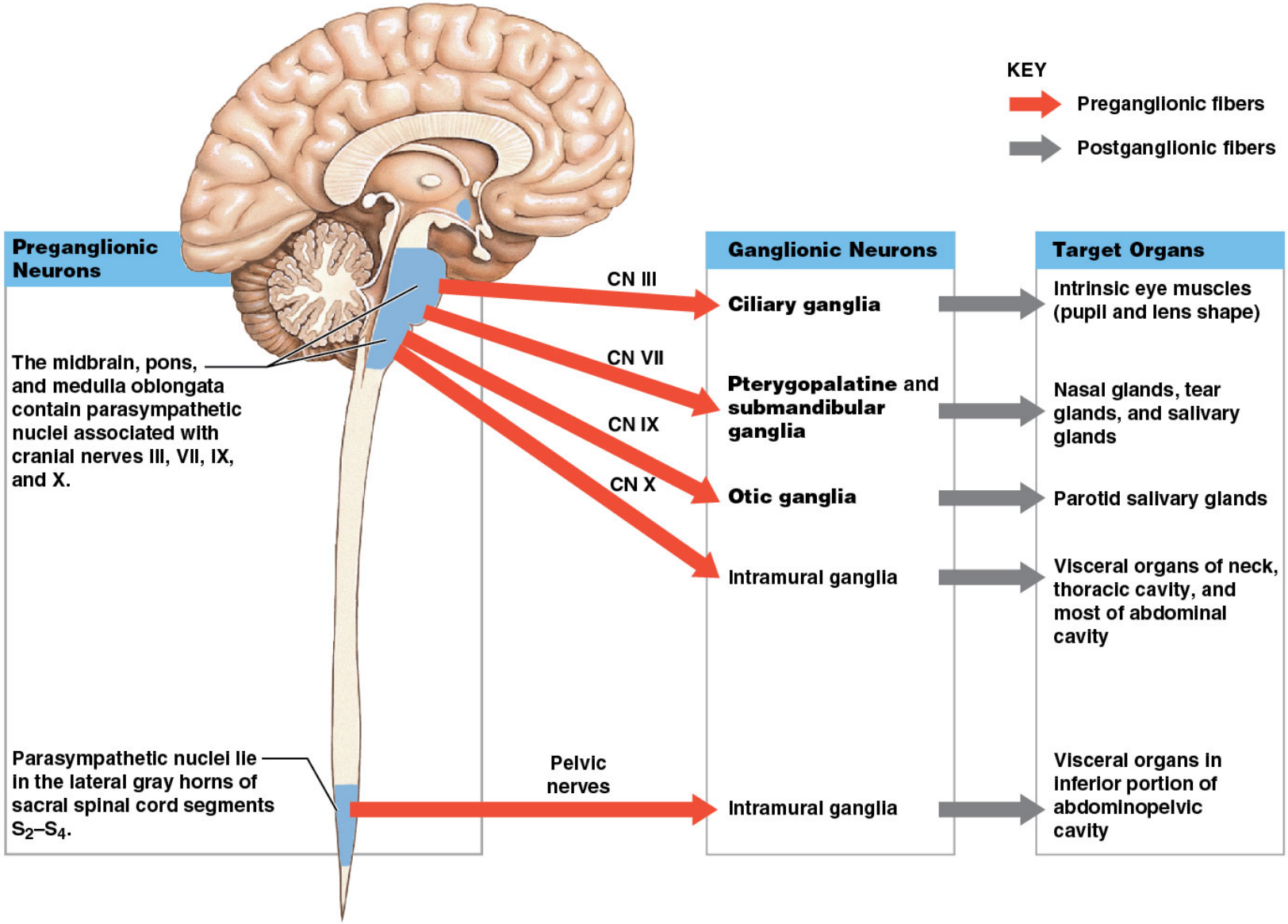
The parasympathetic nervous system



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Module 14.3: Sympathetic and parasympathetic divisions

Responses to increased parasympathetic activity

- "Rest and digest" responses, which include:
  1. Decreased metabolic rate
  2. Decreased heart rate and blood pressure
  3. Increased secretion by salivary and digestive glands
  4. Increased motility and blood flow to the digestive tract
  5. Stimulation of urination and defecation

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Module 14.3: Review

A. Starting in the spinal cord, trace the path of a nerve impulse through the sympathetic ANS to its target organ in the abdominopelvic cavity.
B. Describe an intramural ganglion.
C. List general responses to increased sympathetic activity and to parasympathetic activity.

Learning Outcome: Describe the structures and functions of the sympathetic and parasympathetic divisions of the ANS.

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Module 14.4: The two ANS divisions innervate many of the same structures, but the innervation patterns are different

Innervation in the sympathetic division

- Same on both sides of body
- Gray ramus communicans of each spinal nerve carries postganglionic sympathetic fibers to body wall and limbs
- Head and neck—postganglionic sympathetic fibers from superior cervical sympathetic ganglia go to areas supplied by cranial nerves III, VII, IX, and X

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Module 14.4: Innervation patterns of the sympathetic and parasympathetic divisions

Three groups of **splanchnic nerves** supply the viscera

1. Cardiopulmonary—postganglionic fibers to heart/lungs
2. Abdominopelvic
   - Preganglionic fibers synapse on collateral ganglia (celiac, superior, and inferior mesenteric)
   - Postganglionic fibers to abdominopelvic viscera
3. Pelvic—postganglionic fibers below L_2 go to pelvic structures

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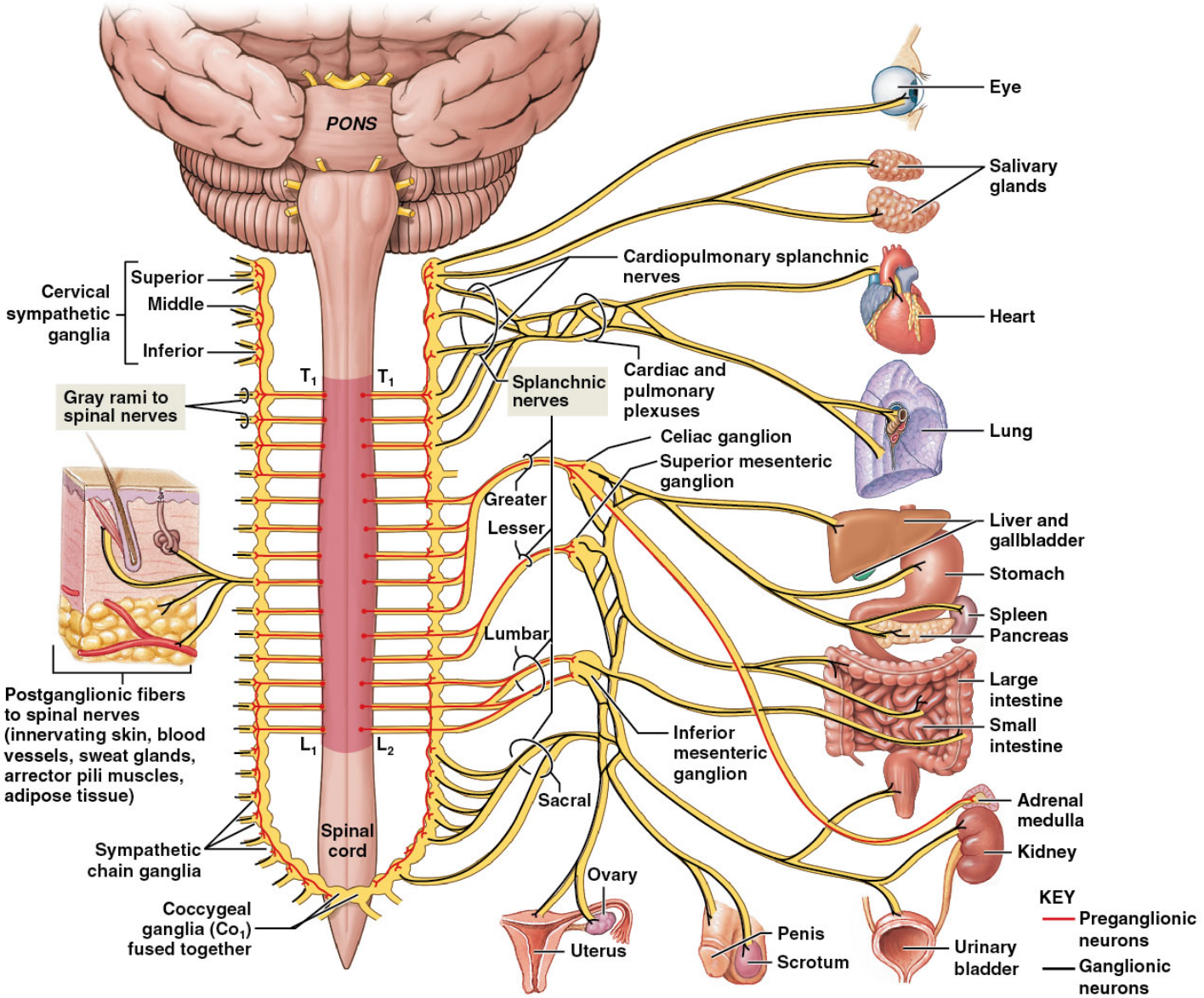
Sympathetic nervous system distribution



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Module 14.4: Innervation patterns of the sympathetic and parasympathetic divisions

Innervation in the parasympathetic division

- Vagus nerve (cranial nerve X) provides ~75 percent of all parasympathetic outflow
  - Vagal branches intermingle sympathetic fibers, forming nerve plexuses
- Sacral preganglionic fibers carry sacral parasympathetic output directly—do not join spinal nerves
  - Form distinct **pelvic nerves**
    - Innervate intramural ganglia in kidneys, bladder, distal large intestine, and sex organs

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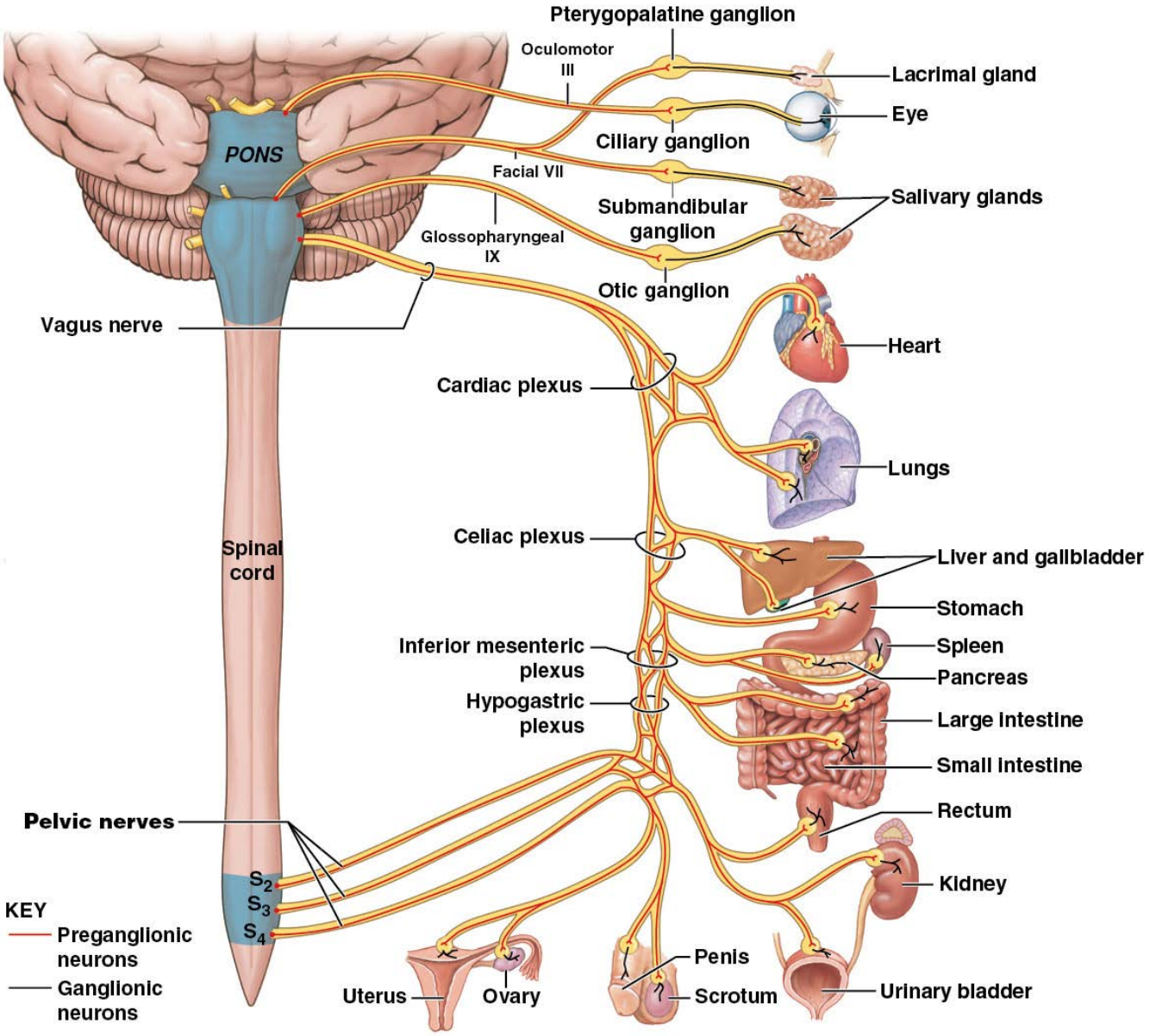
Parasympathetic nervous system distribution



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Module 14.4: Review

A. Define *splanchnic nerves*.
B. Name the plexuses innervated by the vagus nerve.
C. Which nerve carries most of the parasympathetic outflow?

Learning Outcome: Describe the innervation patterns of the sympathetic and parasympathetic divisions of the ANS.

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Module 14.5: The functional differences between the two ANS divisions reflect their divergent anatomical and physiological characteristics

Sympathetic division

- Can trigger local reflexes with specific effectors
- Can be activated in its entirety (**sympathetic activation**) by:
  - Releasing norepinephrine (NE) at peripheral synapses
  - Distributing NE and epinephrine (E) throughout body

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Module 14.5: Functional differences in ANS divisions

Sympathetic activation controlled by centers in hypothalamus

- Occurs during crisis
- Effects not limited to peripheral tissues
- Also alters CNS activity

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Module 14.5: Functional differences in ANS divisions

Effects of Sympathetic Activation

- Increased alertness by stimulation of the reticular activating system, causing the person to feel "on edge."
- A feeling of energy and euphoria, often associated with a disregard for danger and a temporary insensitivity to painful stimuli.
- Increased activity in the cardiovascular and respiratory centers of the pons and medulla oblongata, which increases blood pressure, heart rate, breathing rate, and depth of respiration.
- A general increase in muscle tone through stimulation of the medial and lateral pathways, so the person *looks* tense and may begin to shiver.
- Mobilization of energy reserves, through the accelerated breakdown of glycogen in muscle and liver cells and the release of lipids by adipose tissues.

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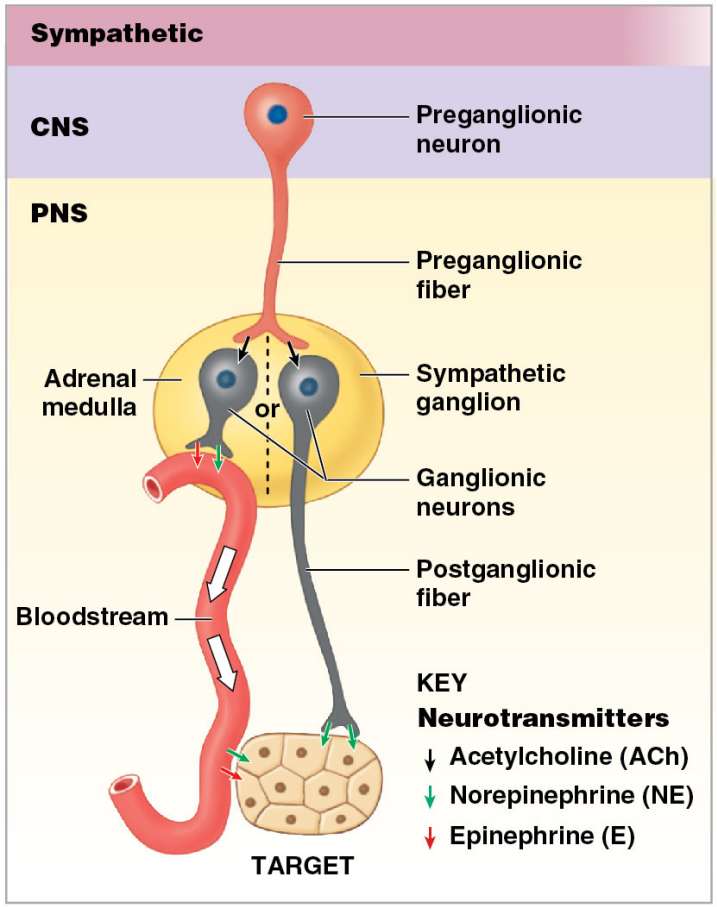
Organization of the sympathetic division



Characteristic	Sympathetic Division
Location of CNS visceral motor neurons	Lateral gray horns of spinal segments T_1–L_2
Location of PNS ganglia	Near vertebral column
Preganglionic fibers Neurotransmitter	Short ACh
Postganglionic fibers Neurotransmitter	Long Normally NE, less commonly ACh or NO (nitric oxide)
General functions	Stimulates metabolism; increases alertness; prepares for emergency ("fight or flight")

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Module 14.5: Functional differences in ANS divisions

Parasympathetic division

- Does not release neurotransmitters into bloodstream, so does not do division-wide system activation.
- Parts are active continuously
- Activities are reflex responses to conditions within specific structures or regions
- Effects center on relaxation, food processing, and energy absorption

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Module 14.5: Functional differences in ANS divisions

Parasympathetic division (continued)

- Also called the **anabolic system**—increases nutrients in blood
  - Growth and development
  - Excess stored as lipids or glycogen for energy reserve

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Module 14.5: Functional differences in ANS divisions

Effects of Parasympathetic Activation

- Constriction of the pupils (to restrict the amount of light that enters the eyes) and focusing of the lenses of the eyes on nearby objects.
- Secretion by digestive glands, including salivary glands, gastric glands, duodenal glands, intestinal glands, the pancreas (exocrine and endocrine), and the liver.
- Secretion of hormones that promote the absorption and utilization of nutrients by peripheral cells.
- Changes in blood flow and glandular activity associated with sexual arousal.
- Increased smooth muscle activity along the digestive tract.
- Stimulation and coordination of defecation.
- Contraction of the urinary bladder during urination.
- Constriction of the respiratory passageways.
- Reduction in heart rate and force of contraction.

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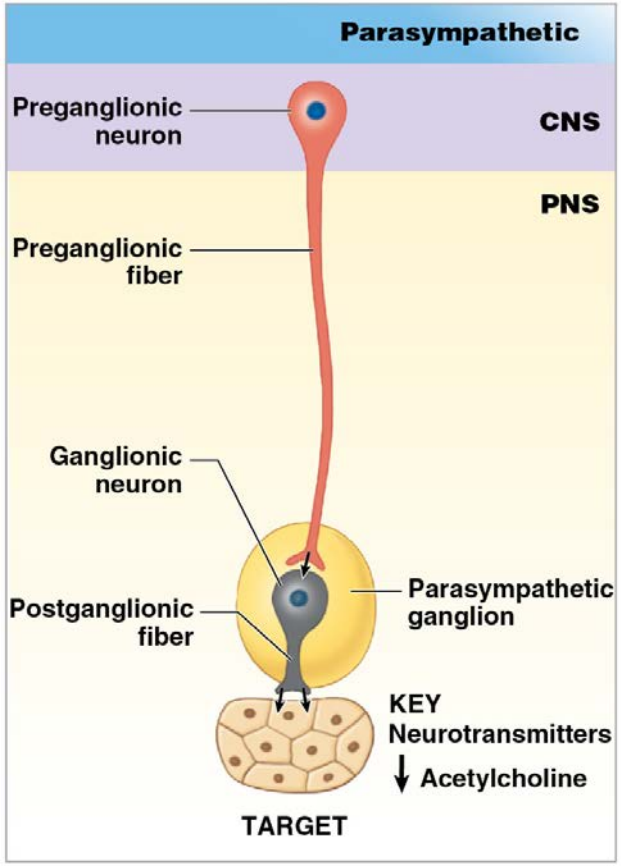
Organization of the parasympathetic division



Characteristic	Parasympathetic Division
Location of CNS visceral motor neurons	Brainstem and spinal segments S_2–S_4
Location of PNS ganglia	Typically intramural
Preganglionic fibers Neurotransmitter	Relatively long ACh
Postganglionic fibers Neurotransmitter	Relatively short ACh
General functions	Promotes relaxation, nutrient uptake, energy storage ("rest and digest")

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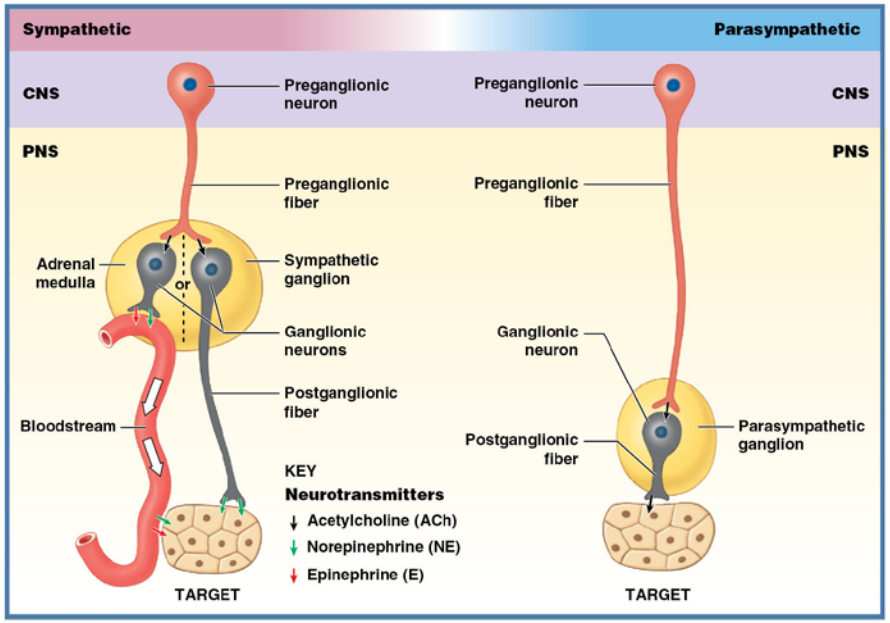
Summary comparison of sympathetic and parasympathetic divisions



Characteristic	Sympathetic Division	Parasympathetic Division
Location of CNS visceral motor neurons	Lateral gray horns of spinal segments T_1–L_2	Brainstem and spinal segments S_2–S_4
Location of PNS ganglia	Near vertebral column	Typically intramural
Preganglionic fibers Neurotransmitter	Short ACh	Relatively long ACh
Postganglionic fibers Neurotransmitter	Long Normally NE, less commonly ACh or NO (nitric oxide)	Relatively short ACh
General functions	Stimulates metabolism; increases alertness; prepares for emergency ("fight or flight")	Promotes relaxation, nutrient uptake, energy storage ("rest and digest")

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Module 14.5: Review

A. What physiological changes are typical in a tense or anxious person?
B. What neurotransmitter is released by all parasympathetic neurons?
C. Why is the parasympathetic division called the *anabolic system*?

Learning Outcome: Describe the mechanisms of neurotransmitter release in the ANS, and explain the effects of neurotransmitters on target organs and tissues.

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Module 14.6: Membrane receptors at target organs mediate the effects of sympathetic and parasympathetic stimulation

Neurotransmitter release in sympathetic division

- Effects result from norepinephrine (NE) and epinephrine (E) binding to **adrenergic receptors** in target cell plasma membrane
- Two types of adrenergic receptors: **alpha receptors** and **beta receptors**
  - NE stimulates alpha receptors more than beta receptors
  - E stimulates both types

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Module 14.6: Membrane receptors at target organs mediate the effects of sympathetic and parasympathetic stimulation

- Generalized sympathetic activation and release of NE/E from adrenal medulla stimulates both types of receptors; effect lasts longer.
- Adrenals release three times more E than NE, so during sympathetic activation, beta receptor effects predominate

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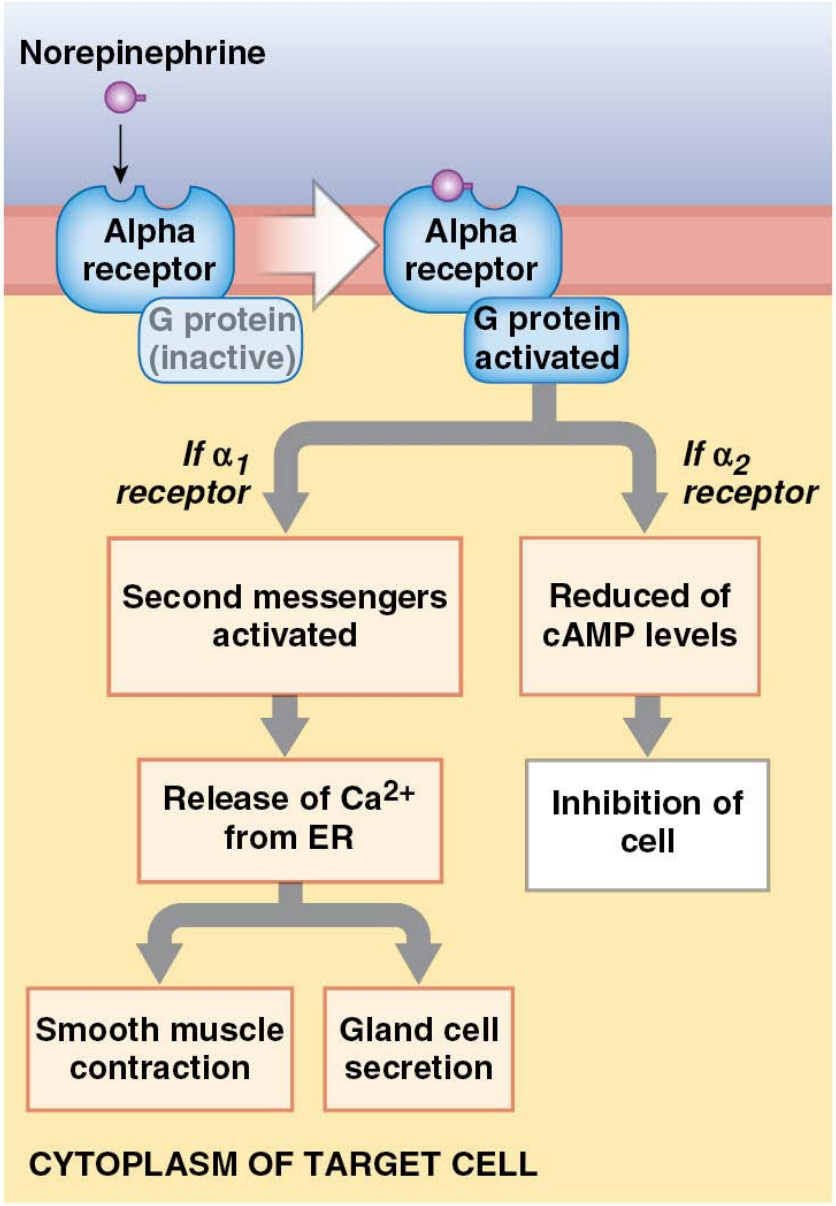
Module 14.6: Neurotransmitter release in ANS divisions

Alpha (α) receptors

- Generally stimulated by NE and E
- Activates G proteins of plasma membrane
- Activation triggers different activities in cell
  - Alpha-1 receptors—excitatory
  - Alpha-2 receptors—inhibitory



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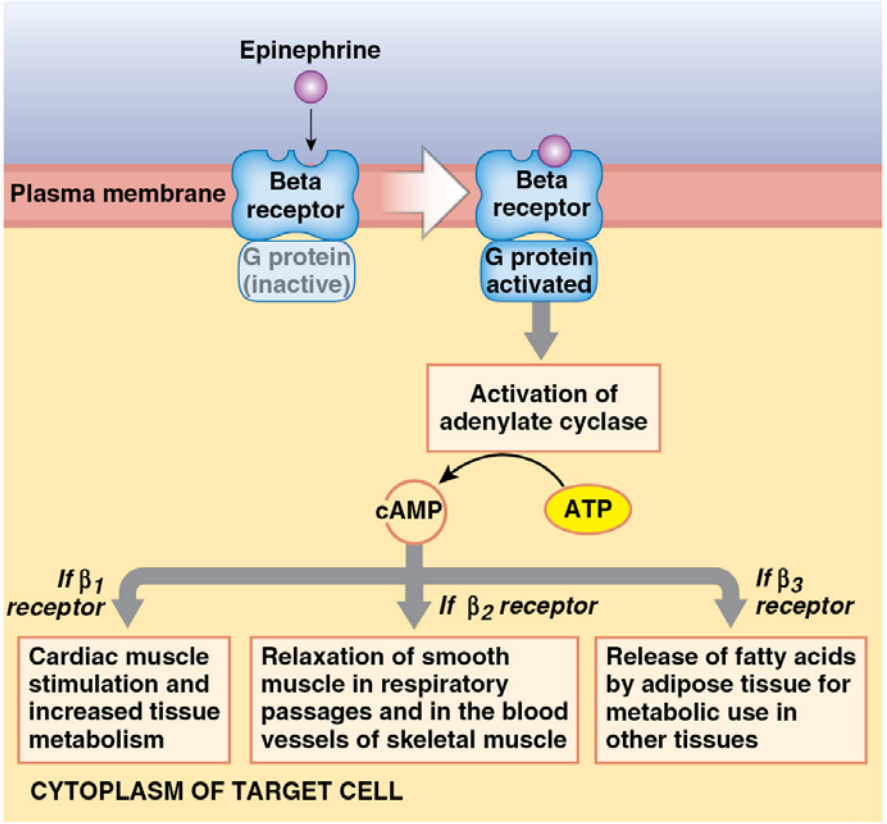
Module 14.6: Neurotransmitter release in ANS divisions

Beta (β) receptors

- Generally stimulated by E
- In many organs (skeletal muscles, lungs, heart, liver)
- Stimulation of beta receptors and G protein activation change target cell's metabolic activity
- Three types: beta-1 (β_1), beta-2 (β_2), beta-3 (β_3)



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Module 14.6: Neurotransmitter release in ANS divisions

Neurotransmitter release in the parasympathetic division

- All parasympathetic fibers release acetylcholine (ACh)
- Two types of **cholinergic receptors**—nicotinic and muscarinic

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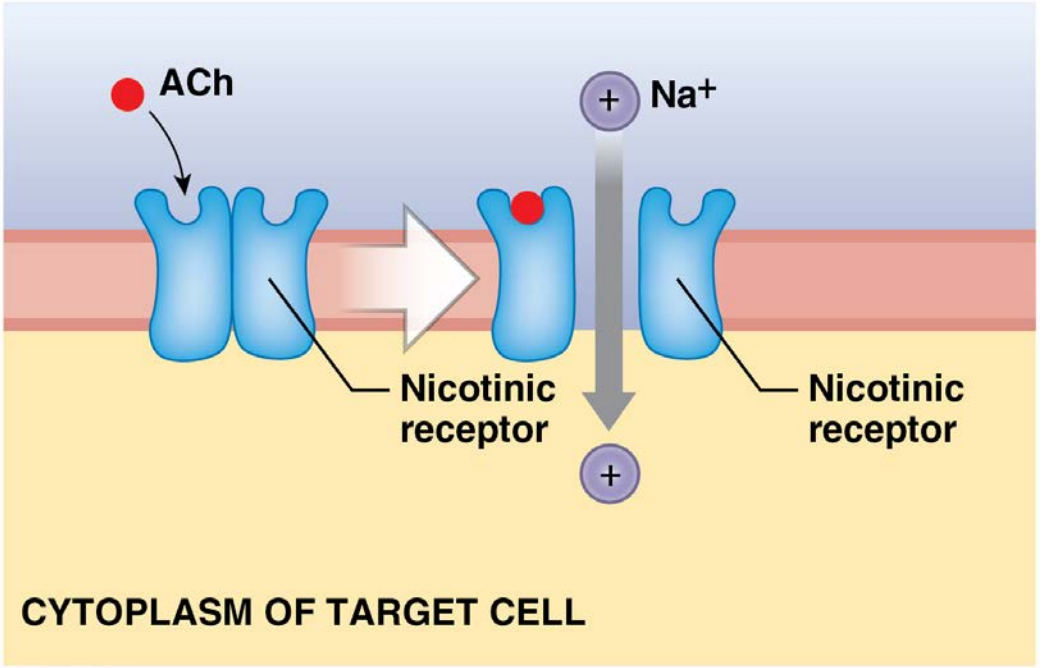
Module 14.6: Neurotransmitter release in ANS divisions

1. **Nicotinic receptors**
   - On all postganglionic neurons, on adrenal medullae cells, and at neuromuscular junctions of skeletal muscle fibers
     - Excitatory
     - Stimulated by nicotine



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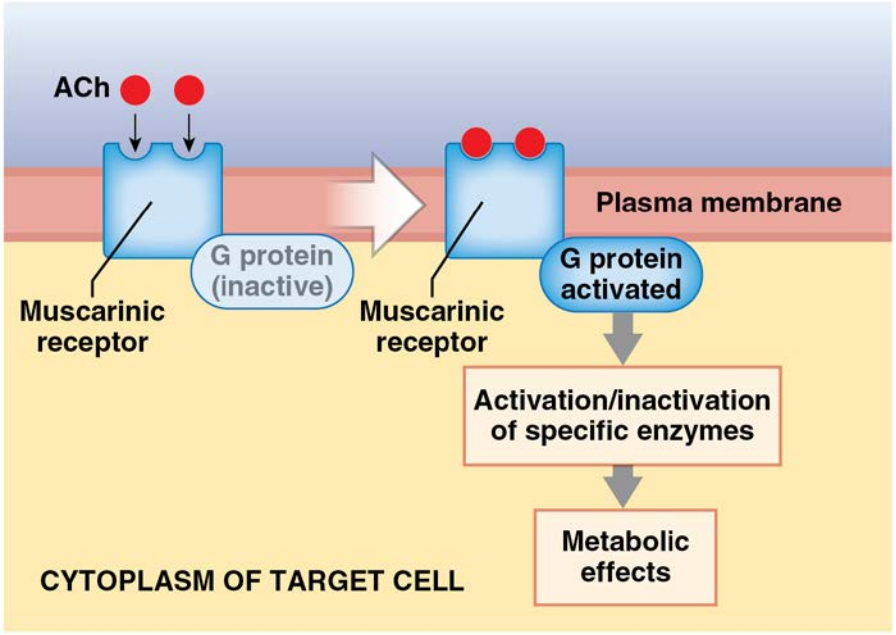
Module 14.6: Neurotransmitter release in ANS divisions

2. Muscarinic receptors

- G protein–coupled receptors
- At cholinergic neuromuscular or neuroglandular junctions in parasympathetic division and few cholinergic junctions in sympathetic division
- Longer-lasting effects than nicotinic receptors
- Excitatory or inhibitory
- Stimulated by muscarine (toxin produced by poisonous mushrooms)



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Module 14.6: Review

A. Compare and contrast alpha and beta receptors.
B. Compare nicotinic receptors with muscarinic receptors.
C. A person with high blood pressure (hypertension) is prescribed a drug that blocks beta receptors. How could this medication alleviate hypertension?

Learning Outcome: Describe the types of sympathetic and parasympathetic receptors and their associated neurotransmitters.

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Section 2: Autonomic Regulation and Control Mechanisms

Learning Outcomes

14.7 Describe the role of the ANS in maintaining homeostasis during unconsciousness.

14.8 Discuss the relationship between the two divisions of the ANS and the significance of dual innervation.

14.9 Define a visceral reflex, and explain the significance of such reflexes.

14.10 Explain the roles of baroreceptors and chemoreceptors in homeostasis.

14.11 Describe the hierarchy of interacting levels of control in the ANS, beginning with the hypothalamus.

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Module 14.7: The ANS adjusts visceral motor responses to maintain homeostasis

Maintaining homeostasis

- Vital physiological processes continue even if person is unconscious
- Person can survive in a coma for decades
- ANS adjusts activities of digestive, cardiovascular, respiratory, and reproductive systems without input from conscious mind
- ANS output impacts virtually every body system

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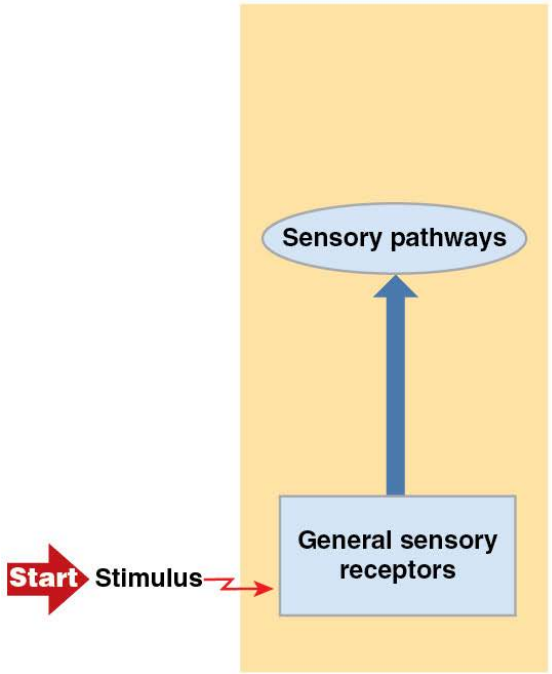
CNS processing



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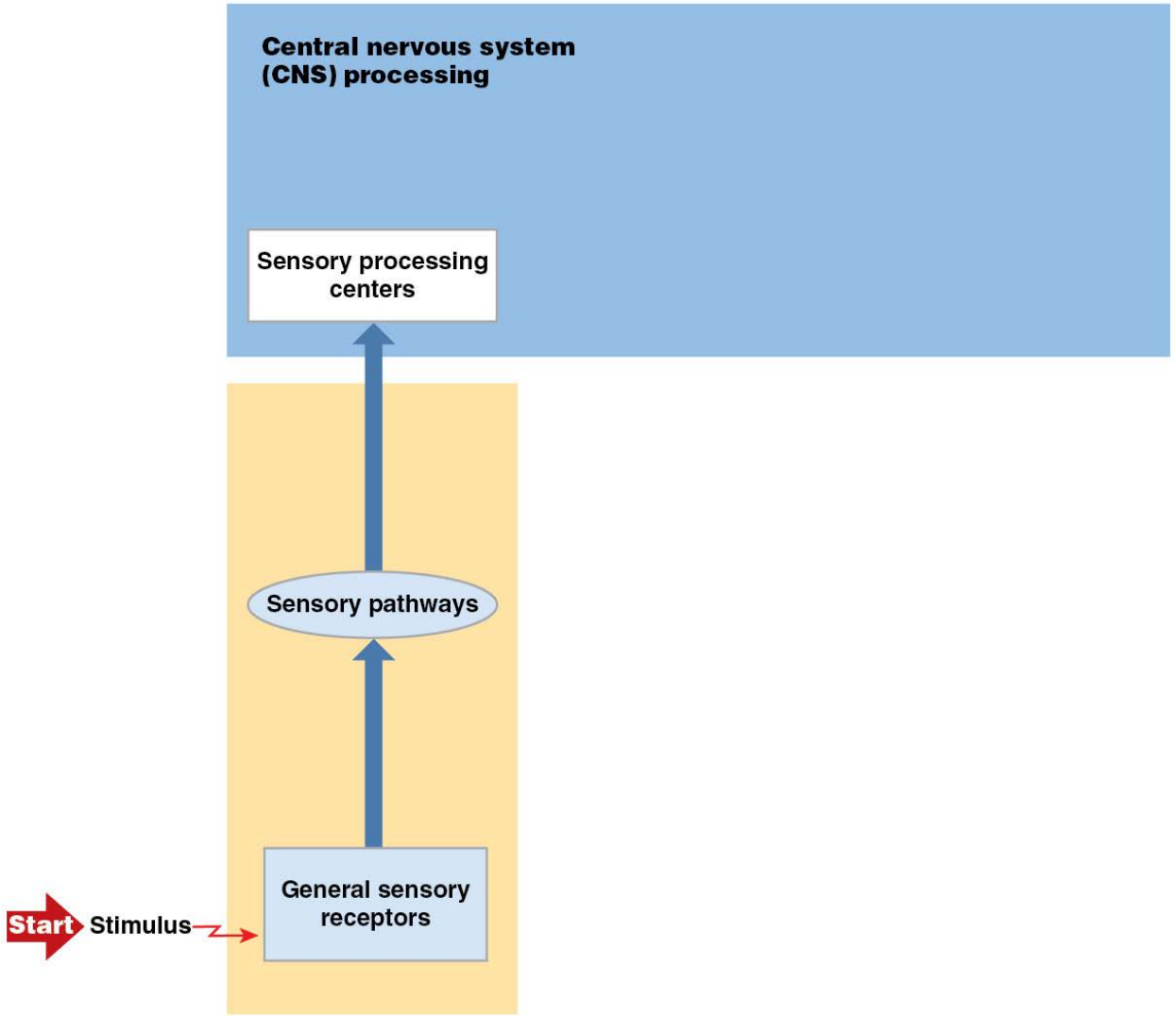

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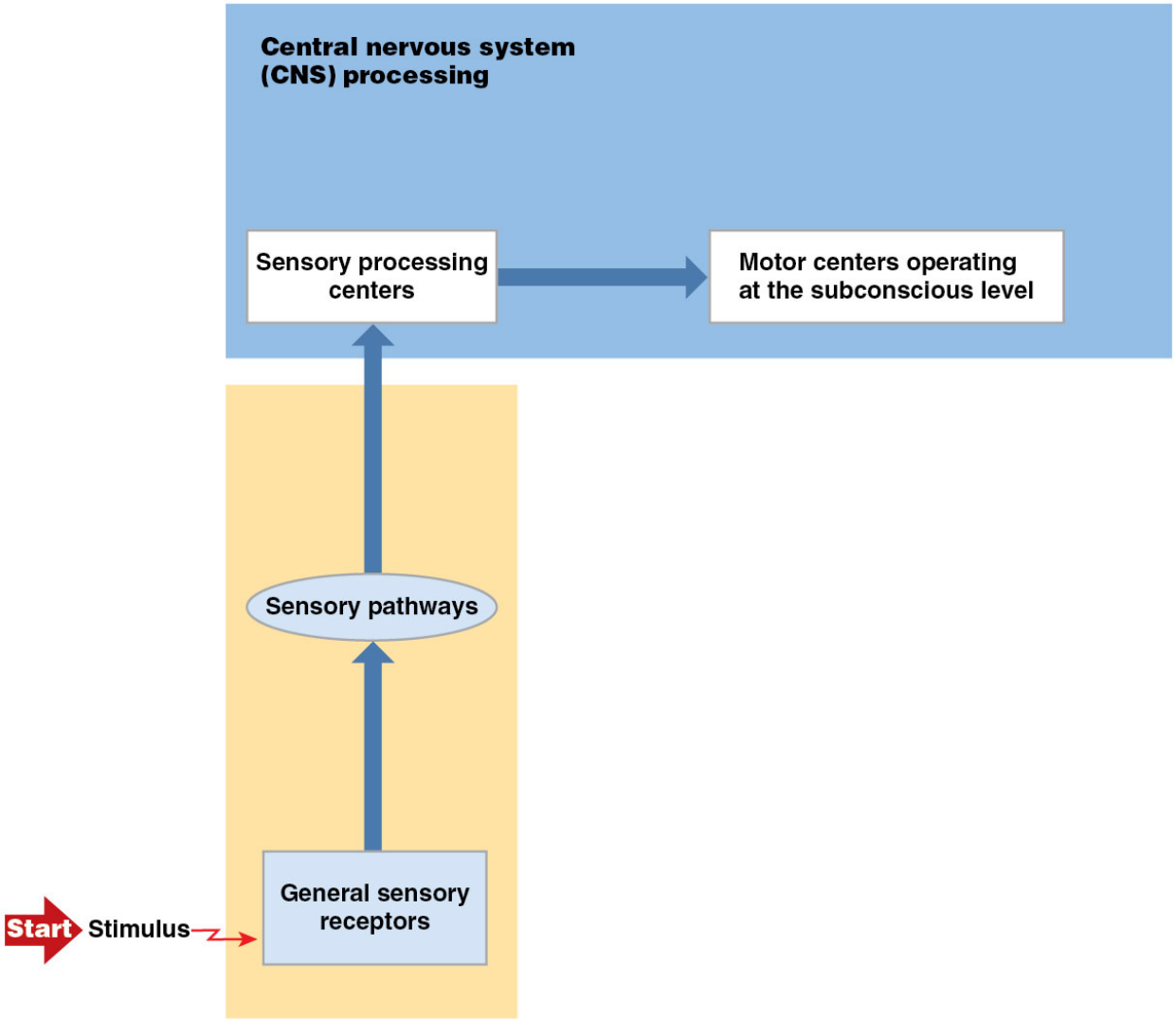

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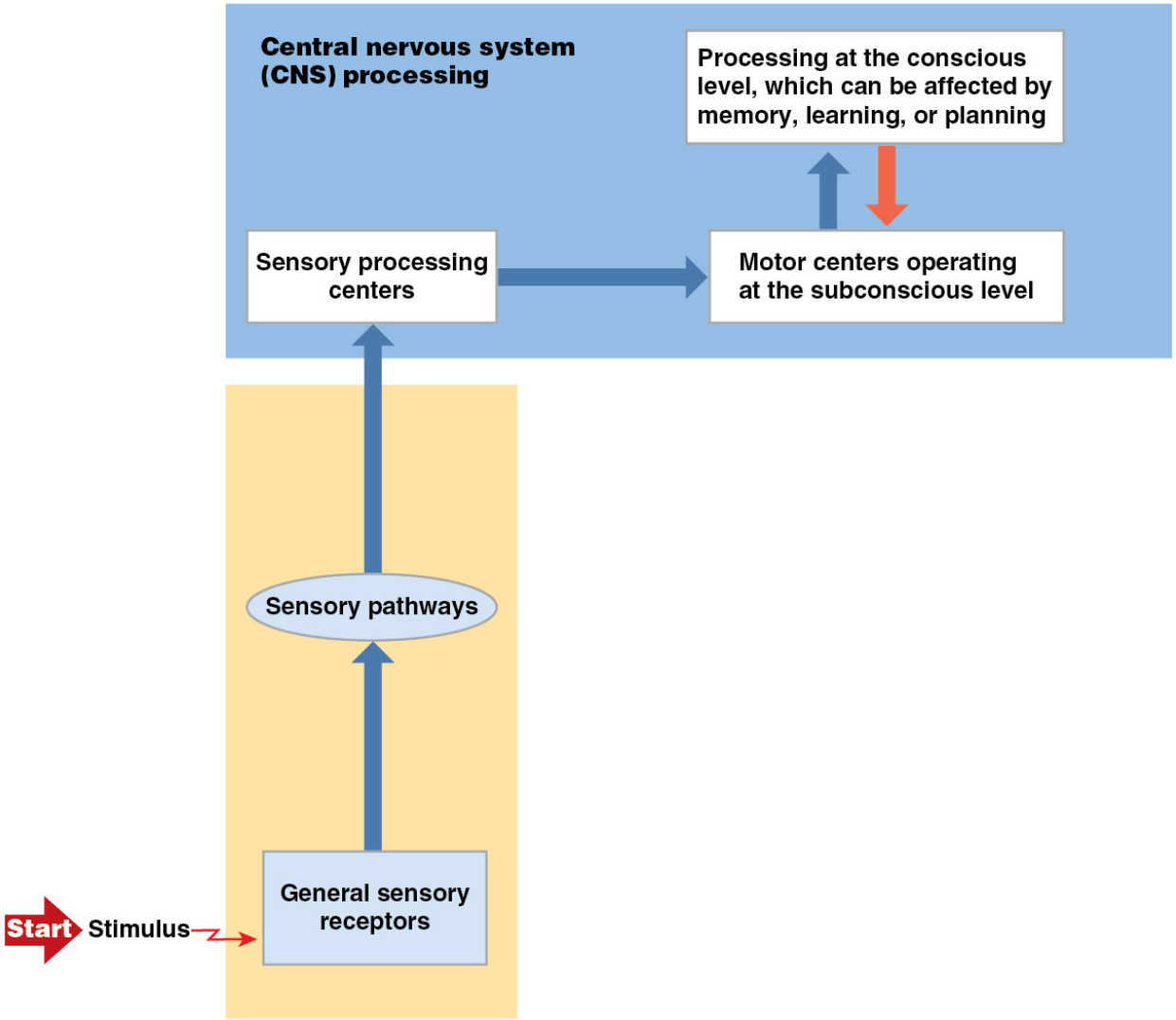

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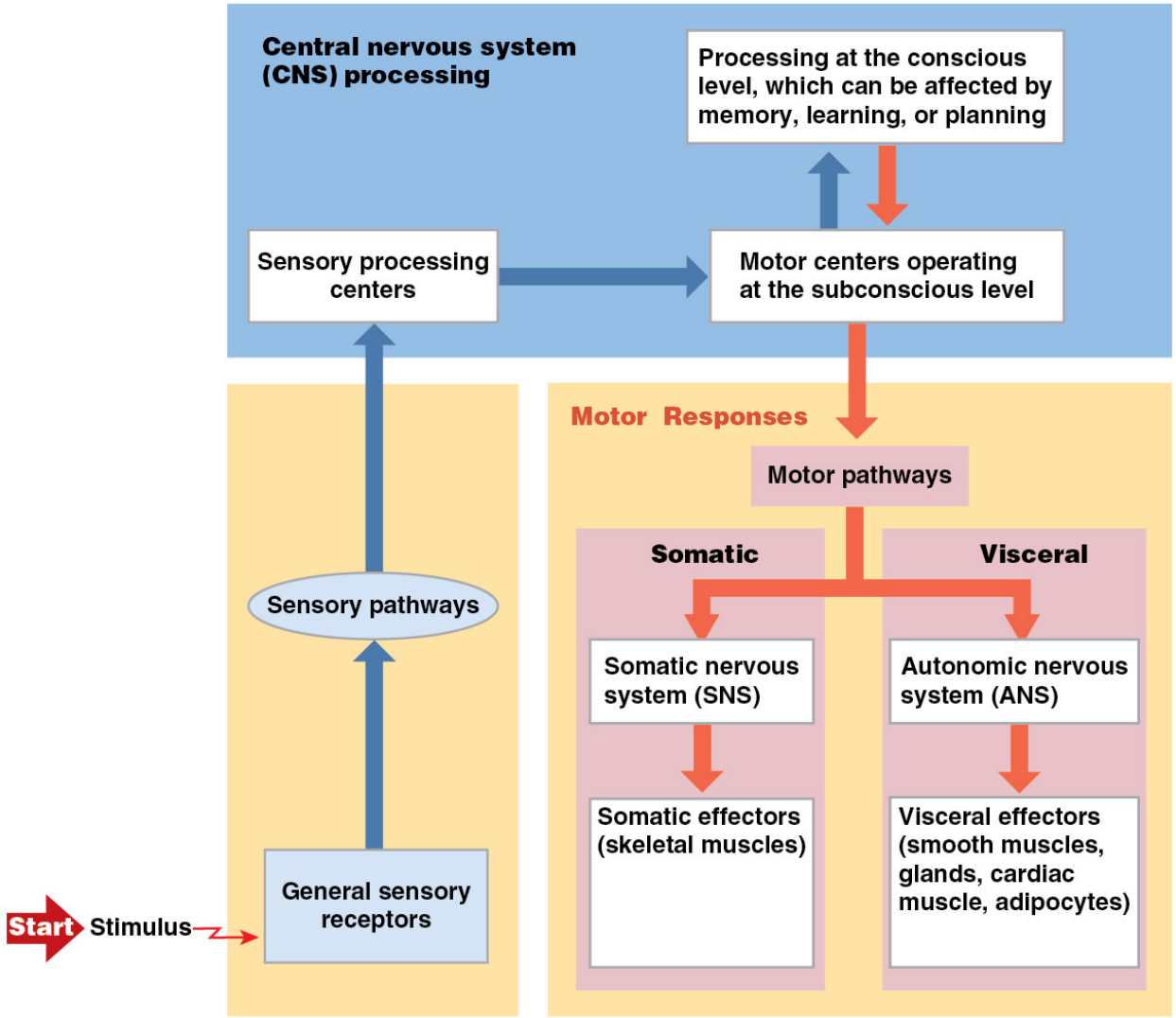

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Module 14.7: Review

A. Explain the significance of the ANS to homeostasis.
B. Name the two types of motor pathways.
C. Identify somatic effectors and visceral effectors.

Learning Outcome: Describe the role of the ANS in maintaining homeostasis during unconsciousness.

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Module 14.8: The ANS provides precise control over visceral functions

ANS control over visceral functions

- **Autonomic tone**
  - Continuous level of spontaneous ANS activity; maintained even without stimuli
- **Dual innervation**
  - Receiving instructions from both ANS divisions
  - Effects may be complementary or opposite
- In organs with only sympathetic innervation, responses vary depending on receptor type stimulated

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Dual innervation

A Functional Comparison of the Sympathetic and Parasympathetic Divisions of the ANS		
Structure	**Sympathetic Effects** (receptor or synapse type)	**Parasympathetic Effects** (all muscarinic)
Eye		
	Dilation of pupil (α_1); accommodation for distance vision (β_2)	Constriction of pupil; accommodation for close vision
Lacrimal glands	None (not innervated)	Secretion
Skin		
Sweat glands	Increased secretion, palms and soles (α_1); generalized increase in secretion (cholinergic)	None (not innervated)
Arrector pili muscles	Contraction; erection of hairs (α_1)	None (not innervated)
Cardiovascular System		
Blood vessels		
To skin	Dilation (β_2 and cholinergic); constriction (α_1)	None (not innervated)
To skeletal muscles	Dilation (β_2 and cholinergic)	None (not innervated)
To heart	Dilation (β_2); constriction (α_1, α_2)	None (not innervated)
To lungs	Dilation (β_2); constriction (α_2)	None (not innervated)
To digestive viscera	Constriction (β_2); dilation (α_2)	None (not innervated)
To kidneys	Constriction, decreased urine production (α_1, α_2); dilation, increased urine production (β_1, β_2)	None (not innervated)
To brain	Dilation (cholinergic and nitroxidergic)	None (not innervated)
Veins	Constriction (α_1, β_2)	None (not innervated)
Heart	Increased heart rate, force of contraction, and blood pressure (α_1, β_1)	Decreased heart rate, force of contraction, and blood pressure

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Dual innervation

A Functional Comparison of the Sympathetic and Parasympathetic Divisions of the ANS		
Structure	**Sympathetic Effects** (receptor or synapse type)	**Parasympathetic Effects** (all muscarinic)
Endocrine System		
Adrenal gland	Secretion of epinephrine, norepinephrine by adrenal medulla	None (not innervated)
Neurohypophysis	Secretion of ADH (β_1)	None (not innervated)
Pancreas	Decreased insulin secretion (α_2)	Increased insulin secretion
Pineal gland	Increased melatonin secretion (β_1, β_2)	Inhibition of melatonin synthesis
Respiratory System		
Airways	Increased airway diameter (β_2)	Decreased airway diameter
Secretory glands	Mucous secretion (α_1)	None (not innervated)
Digestive System		
Salivary glands	Production of viscous secretion (α_1, β_1) containing mucins and enzymes	Production of copious, watery secretion
Sphincters	Constriction (α_1)	Dilation
General level of activity	Decreased (α_2, β_2)	Increased
Secretory glands	Inhibition (α_2)	Stimulation
Liver	Glycogen breakdown, glucose synthesis and release (α_1, β_2)	Glycogen synthesis
Pancreas	Decreased exocrine secretion (α_1)	Increased exocrine secretion

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Dual innervation

A Functional Comparison of the Sympathetic and Parasympathetic Divisions of the ANS (Continued)

Structure	**Sympathetic Effects** (receptor type)	**Parasympathetic Effects** (all muscarinic)
Muscular System		
	Increased force of contraction, glycogen breakdown (β_2)	None (not innervated)
	Facilitation of ACh release at neuromuscular junction (α_2)	None (not innervated)
Adipose Tissue		
	Lipolysis, fatty acid release (α_1, β_1, β_3)	None (not innervated)
Urinary System		
Kidneys	Secretion of renin (β_1)	Uncertain effects on urine production
Urinary bladder	Constriction of internal sphincter; relaxation of urinary bladder (α_1, β_2)	Tensing of urinary bladder, relaxation of internal sphincter to eliminate urine
Male Reproductive System		
	Increased glandular secretion and ejaculation (α_1)	Erection
Female Reproductive System		
	Increased glandular secretion; contraction of pregnant uterus (α_1)	Variable (depending on hormones present)
	Relaxation of nonpregnant uterus (β_2)	Variable (depending on hormones present)

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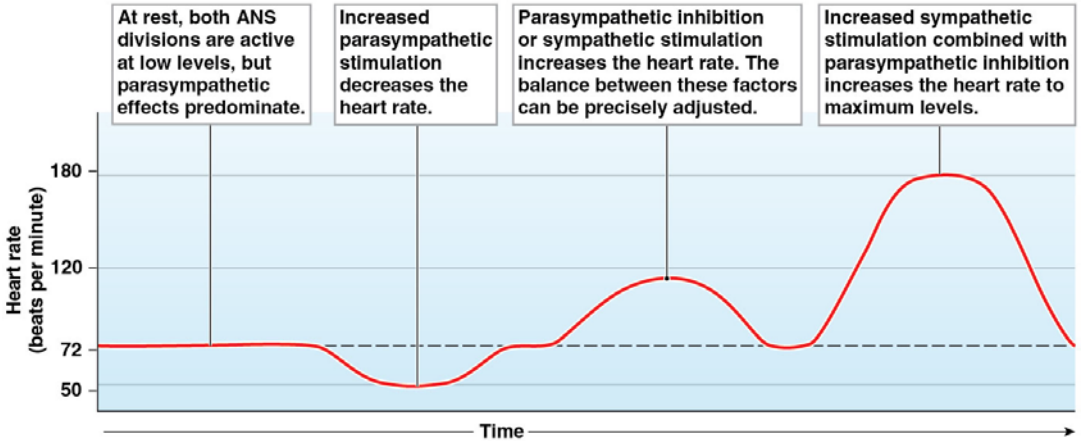
Module 14.8: Dual innervation

Dual innervation of the heart

- Cardiac muscle tissue—contractions triggered by pacemaker cells
  - ANS divisions—opposing effects on pacemaker function
    - ACh (parasympathetic) reduces heart rate
    - NE (sympathetic) accelerates heart rate
    - Small amounts of both released continuously
  - At rest, parasympathetic effects dominate



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Module 14.8: Review

A. Define *dual innervation*.
B. Explain autonomic tone and its significance in controlling visceral function.
C. You go outside on a cold day, and blood flow to your skin is reduced, conserving body heat. You become angry, and your face turns red. Explain these changes.

Learning Outcome: Discuss the relationship between the two divisions of the ANS and the significance of dual innervation.

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Module 14.9: Most visceral functions are controlled by visceral reflexes

Visceral reflexes = autonomic reflexes initiated in viscera

- Automatic motor responses that can be modified, facilitated, or inhibited by higher centers (especially hypothalamus)
- Polysynaptic

Two types of visceral reflexes

1. **Short reflexes**
2. **Long reflexes**

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Module 14.9: Visceral reflexes

Short reflexes

- Bypass CNS
  - Cell bodies of sensory neurons and interneurons are in autonomic ganglia
  - Interneurons synapse on ganglionic neurons
  - Motor commands are sent to effectors by postganglionic fibers
- Control simple motor responses with localized effects
  - Usually activity in one small part of a target organ
- Predominate in enteric nervous system; works largely out of awareness/control of CNS

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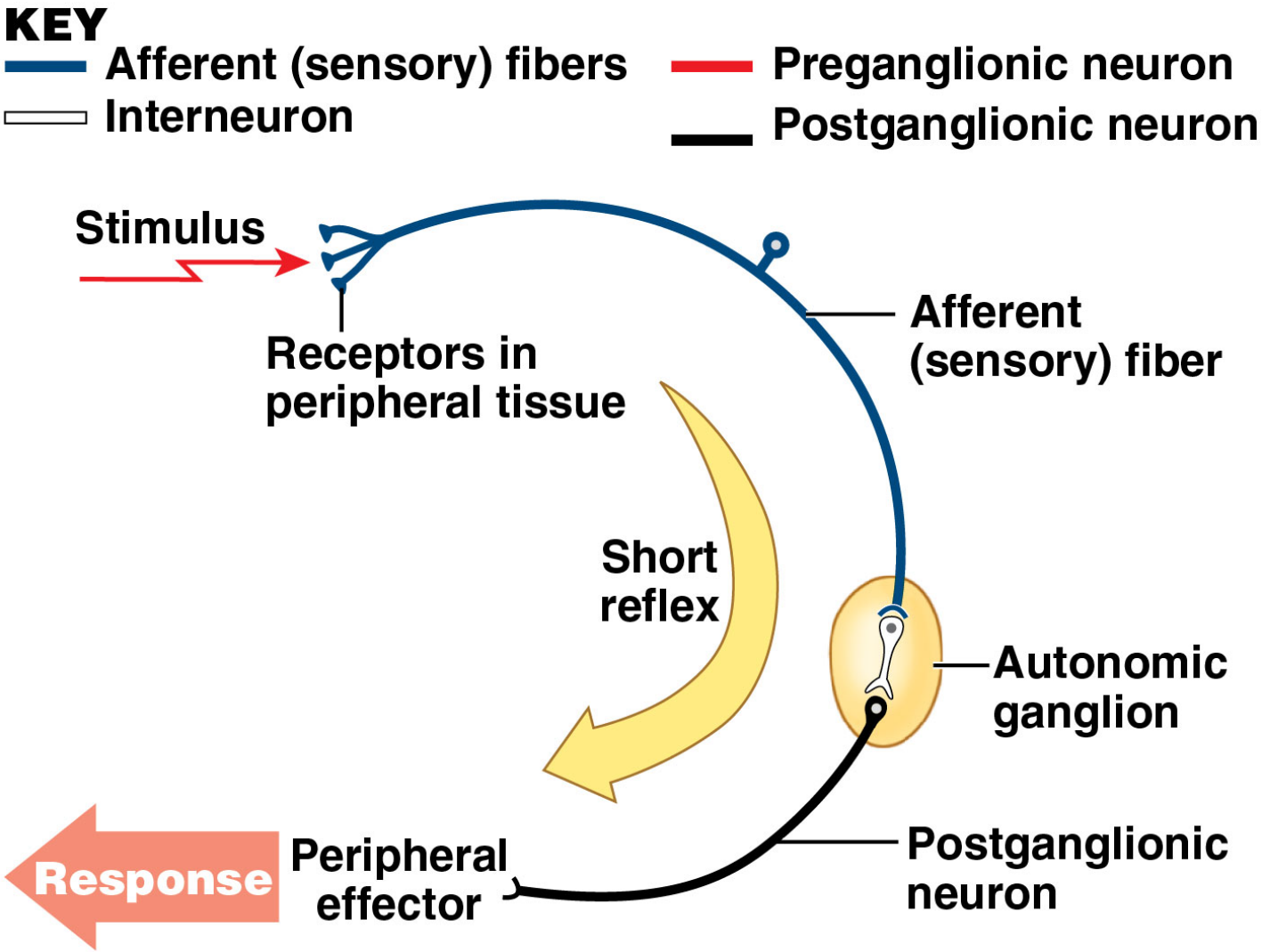
Short reflexes



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Module 14.9: Visceral reflexes

Long reflexes

- Visceral sensory neurons send information to CNS via:
  - Dorsal roots of spinal nerves
  - Sensory branches of cranial nerves
  - Autonomic nerves to visceral effectors
- Interneurons process information within CNS
- ANS carries motor commands to visceral effectors
- Predominate over short reflexes
- Coordinate activities of whole organs and responses involving multiple organ systems

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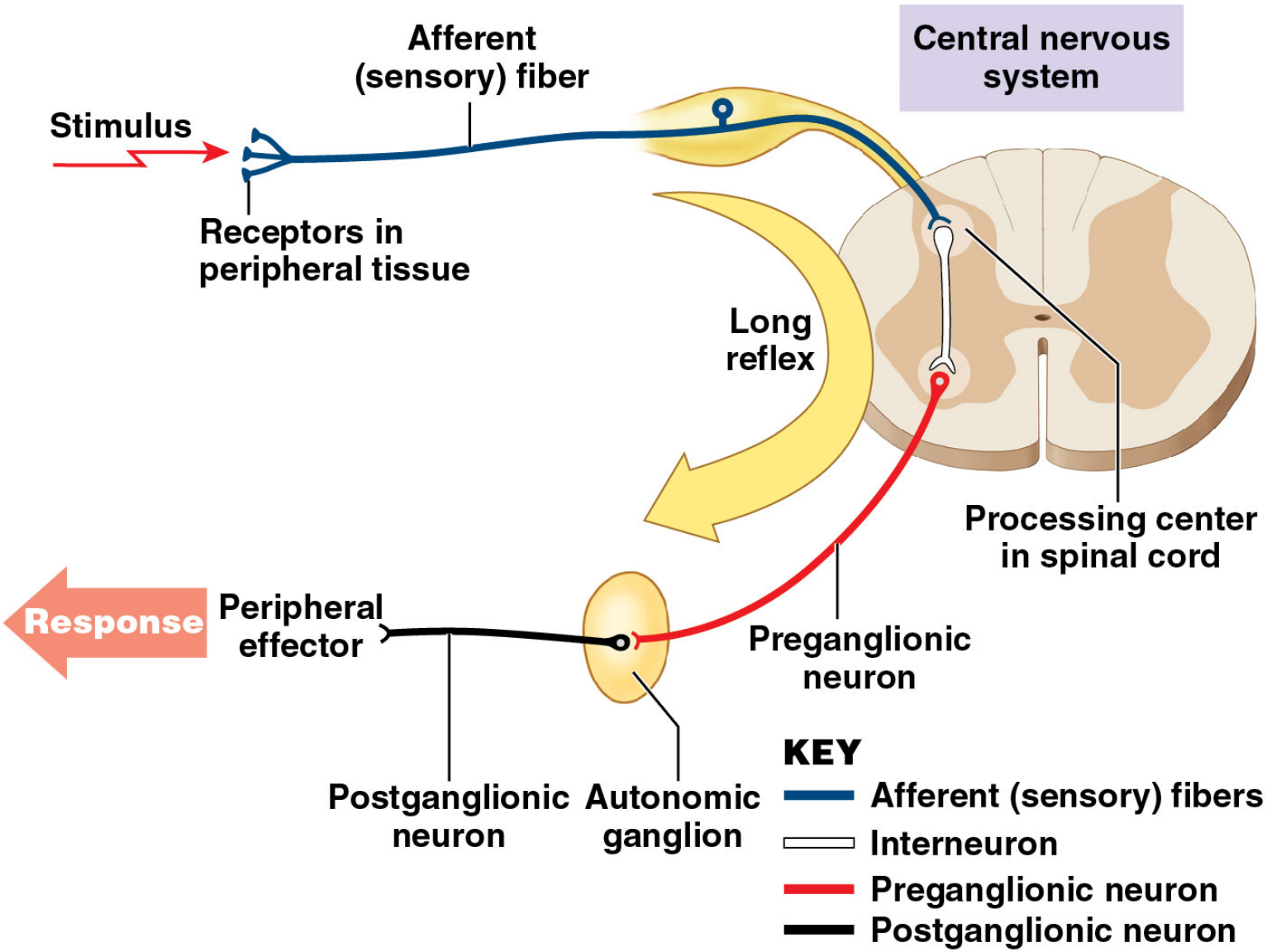
Long reflexes



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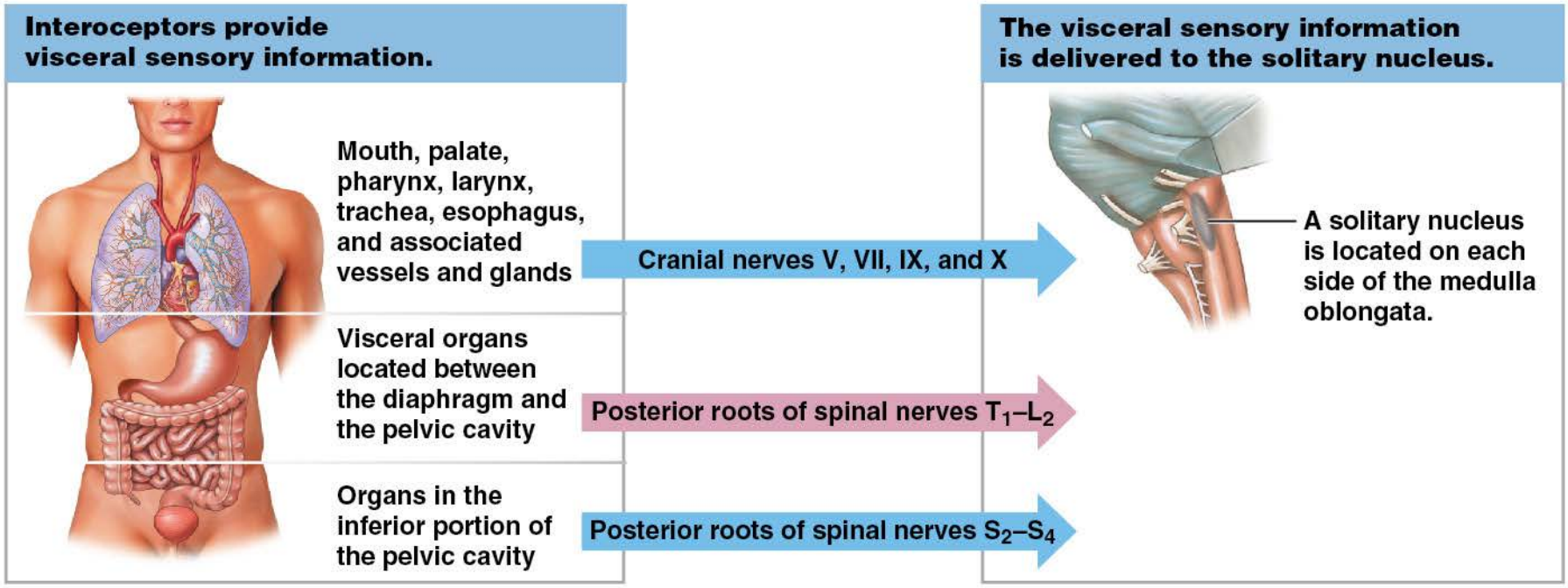
Module 14.9: Visceral reflexes

Interoceptors monitor visceral tissues and organs

- Include nociceptors, thermoreceptors, tactile receptors, baroreceptors, chemoreceptors
- Most processing is subconscious—occurs in nuclei of spinal nerves and **solitary nuclei** in brainstem



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Module 14.9: Visceral reflexes

Common Visceral Reflexes

	Reflex	Stimulus	Response	Comments
SYMPATHETIC	**Cardioacceleratory reflex**	Sudden decrease in carotid blood pressure	Increase in heart rate and force of contraction	Coordinated in cardiac centers of medulla oblongata
	Vasomotor reflexes	Changes in blood pressure in major arteries	Changes in diameter of peripheral vessels	Coordinated in vasomotor center in medulla oblongata
	Pupillary light reflex	Light reaches visual receptors	Changes in pupil diameter	Allows eye to adjust to light; lack of light inhibits reflex
	Ejaculation (in males)	Erotic stimuli (primarily tactile)	Skeletal muscle contractions ejecting semen	Process results in propulsion of semen
PARASYMPATHETIC	**Gastric and intestinal reflexes**	Pressure and physical contact	Smooth muscle contractions that propel food materials and mix them with secretions	Initiated by vagus nerve and controlled locally by ENS
	Defecation	Distention of rectum	Relaxation of internal anal sphincter	Requires voluntary relaxation of external anal sphincter
	Urination	Distention of urinary bladder	Contraction of walls of urinary bladder; relaxation of internal urethral sphincter	Requires voluntary relaxation of external urethral sphincter
	Consensual light response	Bright light shining in eye(s)	Constriction of pupils of both eyes	Reflex observed on one side of the body when the other side is stimulated
	Swallowing reflex	Movement of food and liquids into pharynx	Smooth muscle and skeletal muscle contractions	Coordinated by medullary swallowing center
	Coughing reflex	Irritation of respiratory tract	Sudden explosive ejection of air	Coordinated by medullary coughing center
	Baroreceptor reflex	Sudden increase in carotid blood pressure	Reduction in heart rate and force of contraction	Coordinated in cardiac centers of medulla oblongata
	Sexual arousal	Erotic stimuli (visual or tactile)	Increased glandular secretions, sensitivity, erection	Heightened sensitivity and blood flow to sexual organs

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Module 14.9: Review

A. Define *visceral reflex*.
B. Compare short reflexes with long reflexes.
C. Describe the solitary nuclei.

Learning Outcome: Define a visceral reflex, and explain the significance of such reflexes.

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Module 14.10: Baroreceptors and chemoreceptors initiate important autonomic reflexes involving visceral sensory pathways

Baroreceptors

- Stretch receptors that monitor pressure changes
- Free nerve endings branching into elastic tissues in:
  - Hollow organs
  - Blood vessels
  - Tubes of respiratory, digestive, urinary tracts
- Changes in pressure distort dendritic branches; alter rate of action potential generation

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Module 14.10: Roles of baroreceptors and chemoreceptors

Baroreceptors (continued)

- Monitor blood pressure in walls of major vessels
  - Carotid artery (at the **carotid sinus**)
  - Aorta (at the **aortic sinus**)
  - Regulates cardiac function; adjusts blood flow to vital tissues
- Monitor degree of lung expansion
  - Relayed to respiratory rhythmicity centers in medulla oblongata (sets the pace of respiration)
- Trigger visceral reflexes in digestive and urinary tracts
  - *Example*: urination/defecation

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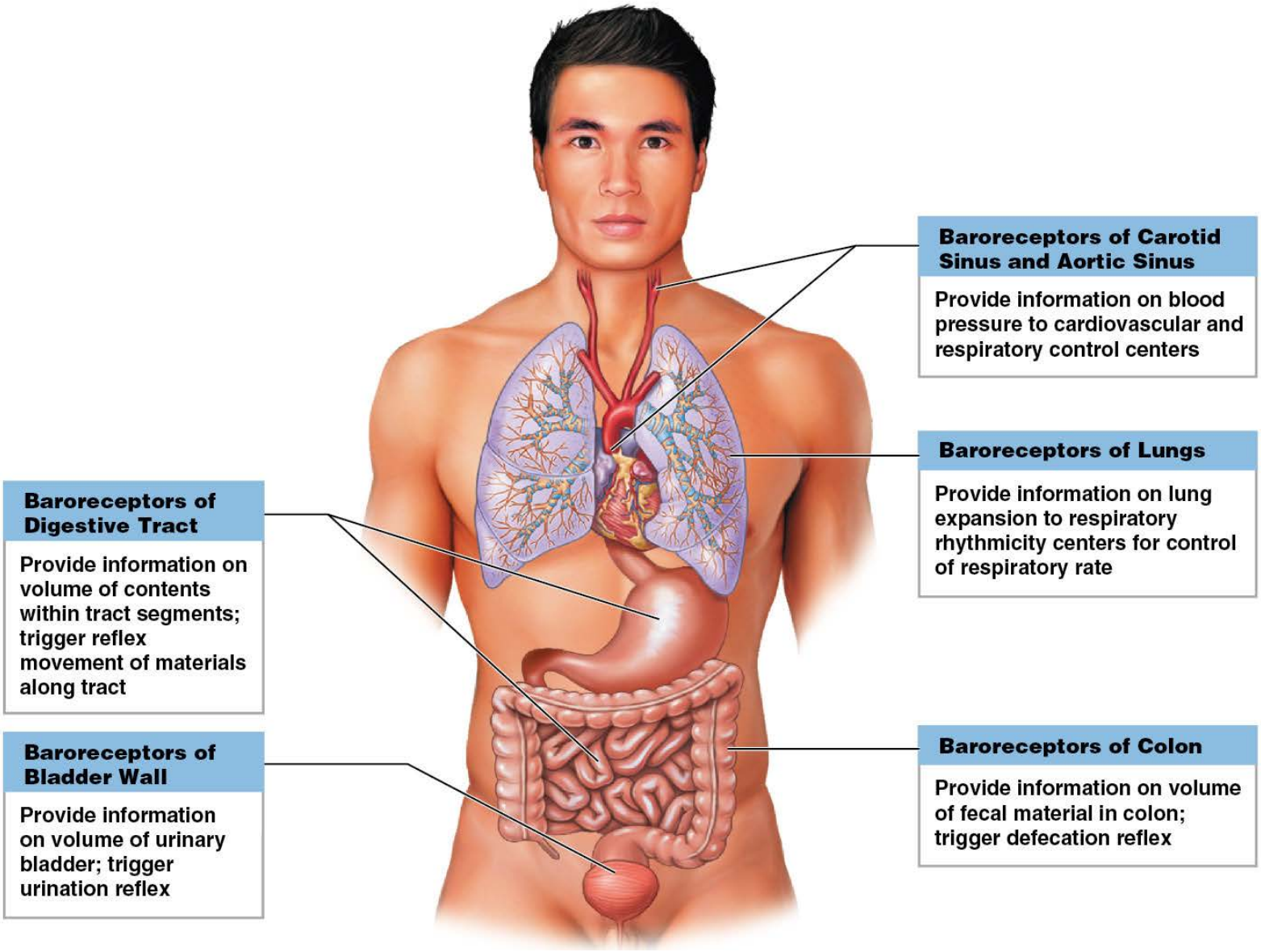
Baroreceptors



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Module 14.10: Roles of baroreceptors and chemoreceptors

Chemoreceptors

- Specialized neurons that detect changes in concentrations of specific chemicals or compounds
  - Role in reflexive control of respiration/cardiovascular function

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Module 14.10: Roles of baroreceptors and chemoreceptors

Locations of chemoreceptors

1. Medulla oblongata and elsewhere in the brain
   - Monitor pH and P_{CO_2} in CSF
2. **Carotid bodies**
   - Near the origin of internal carotid arteries
   - Monitor pH, P_{CO_2}, and P_{O_2} in arterial blood
3. **Aortic bodies**
   - Between branches of the aortic arch
   - Monitor pH, P_{CO_2}, and P_{O_2} in arterial blood

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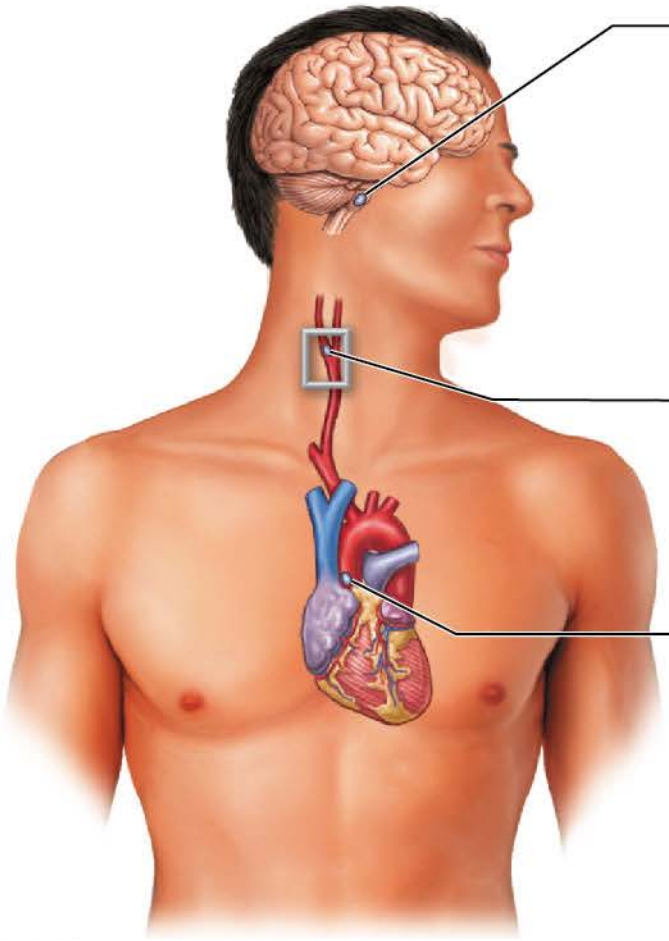
Chemoreceptors



Chemoreceptors in Respiratory Centers in the Medulla Oblongata

Chemoreceptors within the respiratory centers of the medulla oblongata respond to the concentration of hydrogen ions (pH) and carbon dioxide (P_{CO_2}) in cerebrospinal fluid.

→ Trigger reflexive adjustments in depth and rate of respiration

Chemoreceptors of Carotid Bodies

Sensitive to changes in the pH, P_{CO_2}, and P_{O_2} in arterial blood

→ By cranial nerve IX

Chemoreceptors of Aortic Bodies

Sensitive to changes in the pH, P_{CO_2}, and P_{O_2} in arterial blood

→ By cranial nerve X

→ Trigger reflexive adjustments in respiratory and cardiovascular activity

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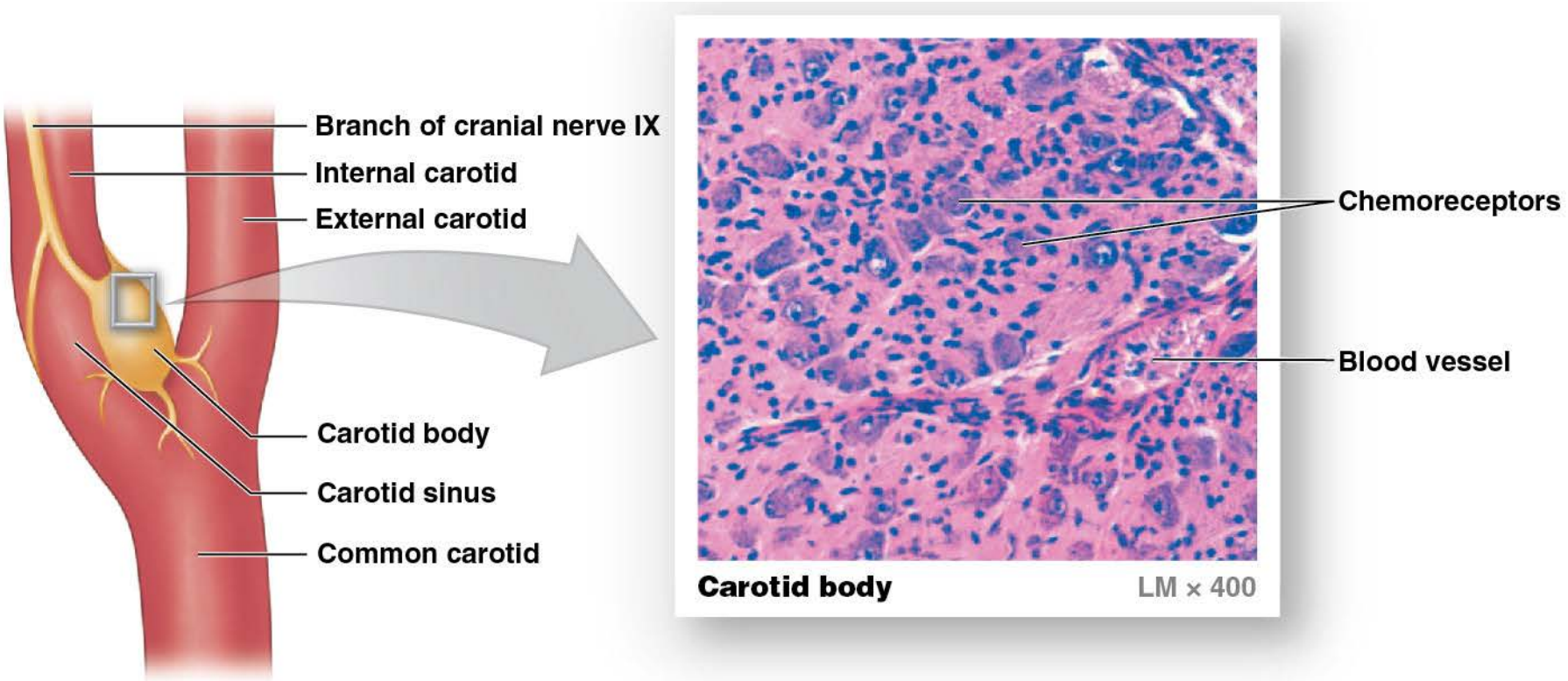
The carotid sinus and carotid body



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Module 14.10: Review

A. Define *baroreceptors.* Where are baroreceptors located within the body?
B. Which type of receptor is sensitive to changes in blood pH?

Learning Outcome: Explain the roles of baroreceptors and chemoreceptors in homeostasis.

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Module 14.11: The autonomic nervous system has multiple levels of motor control

ANS activity is controlled by nuclei in brainstem

- Relatively rapid, automatic responses to stimuli
- More complex reflexes coordinated by centers in medulla oblongata
  - Cardiovascular and respiratory centers
  - Centers/nuclei for salivating, swallowing, digestive secretions, peristalsis, urinary function
- Medullary centers regulated by hypothalamus—ANS headquarters

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Module 14.11: The autonomic nervous system has multiple levels of motor control

- Hypothalamus interacts with other areas of brain (limbic system, thalamus, cerebral cortex)—links brain activity/autonomic functions
  - *Example*: heart rate acceleration with anger
- Continual feedback between higher brain centers, hypothalamus, and brainstem

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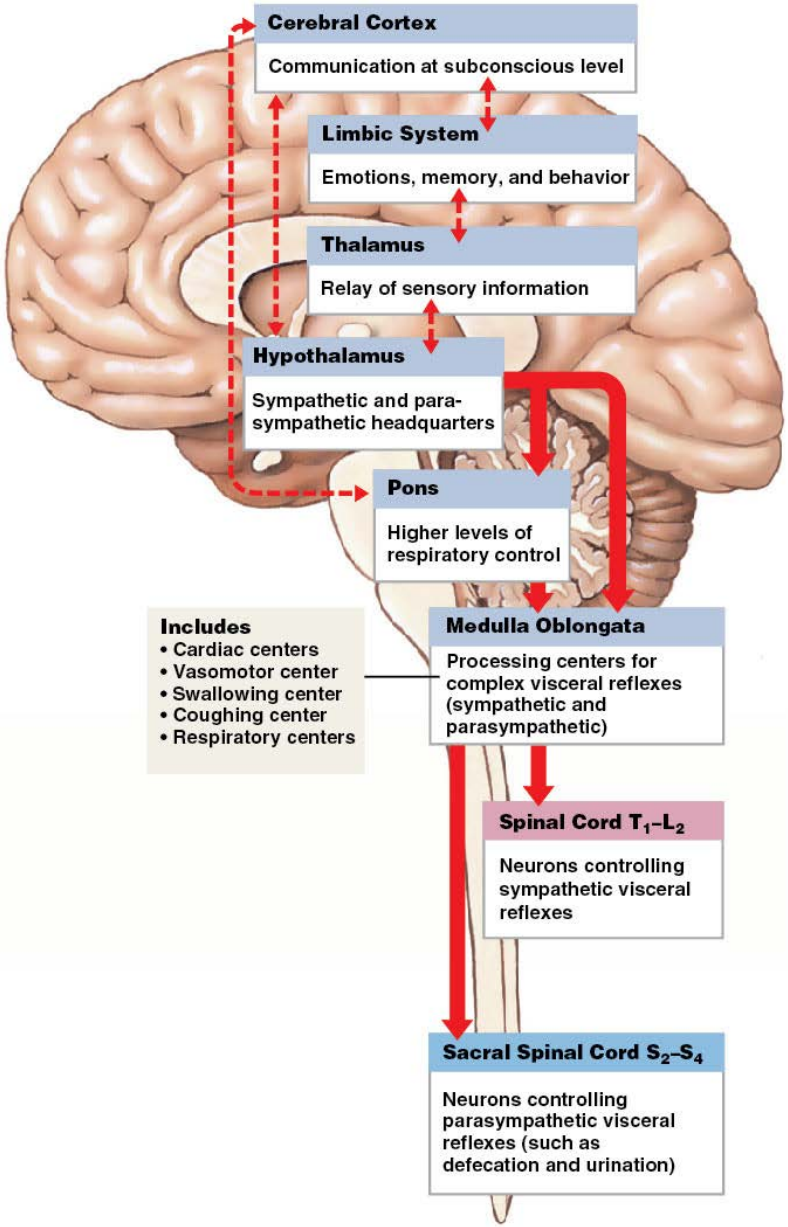
Module 14.11: Levels of control in the ANS



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Module 14.11: Levels of control in the ANS

Patterns of organization

- Both SNS and ANS have parallel organization
- Integrated at many levels
- Sensory pathways may carry information distributed to both SNS and ANS
  - Triggers integrated and compatible reflexes
- Higher levels of integration involve brainstem
- Both systems influenced, maybe controlled, by higher brain centers

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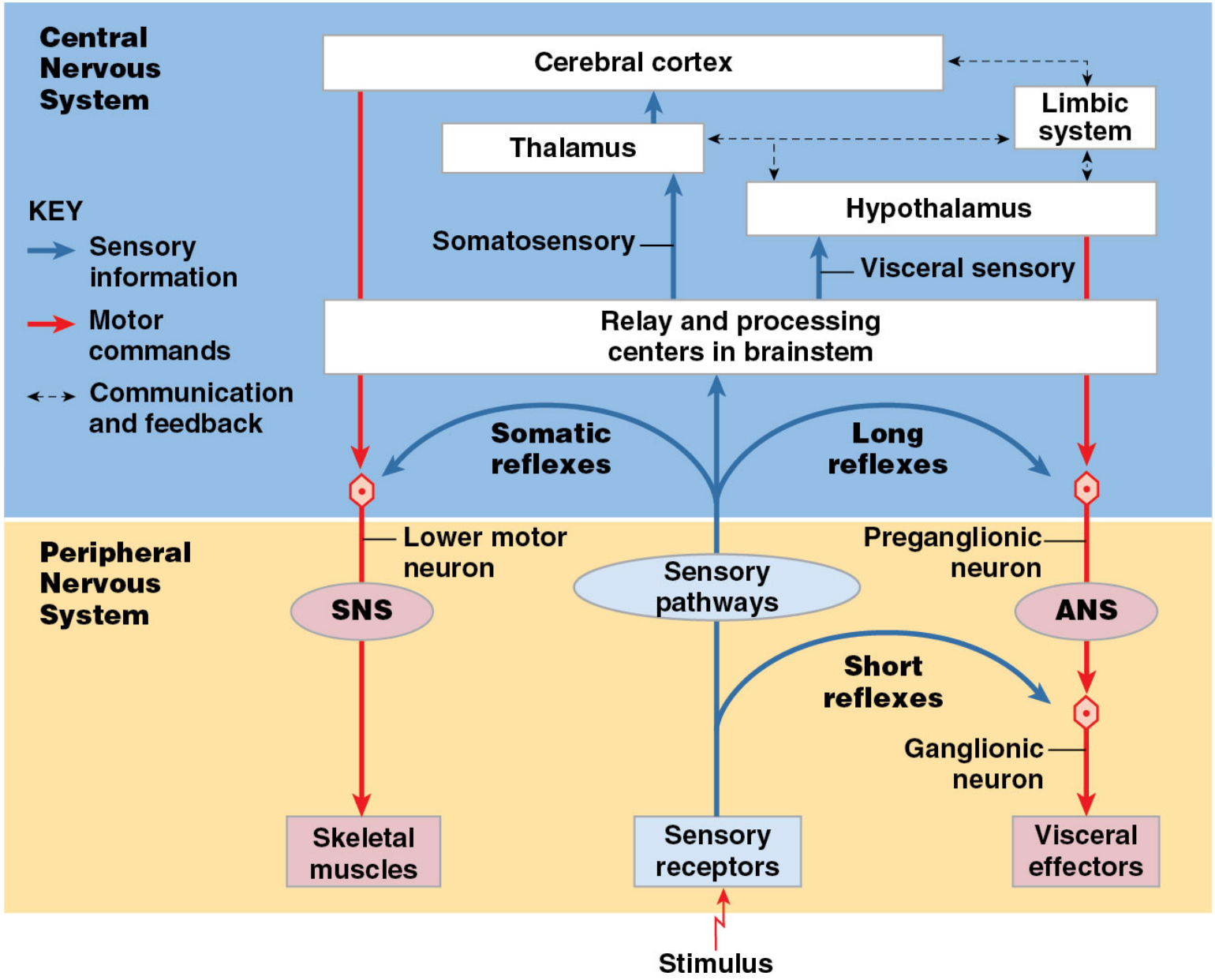
Integration of SNS and ANS pathways



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Module 14.11: Review

A. What brain structure is considered to be the headquarters for the ANS?
B. What brain structure relays somatosensory information?
C. Harry has a brain tumor that is pressing against his hypothalamus. Explain the effect on autonomic function.

Learning Outcome: Describe the hierarchy of interacting levels of control in the ANS, beginning with the hypothalamus.

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