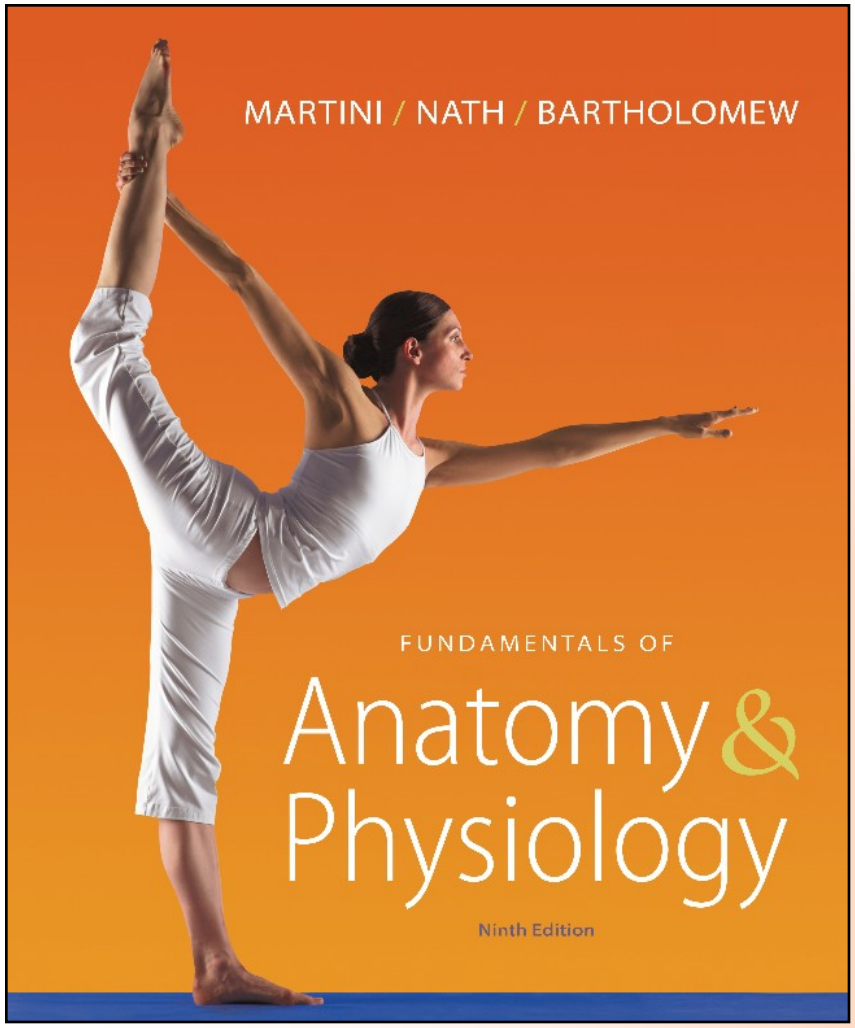


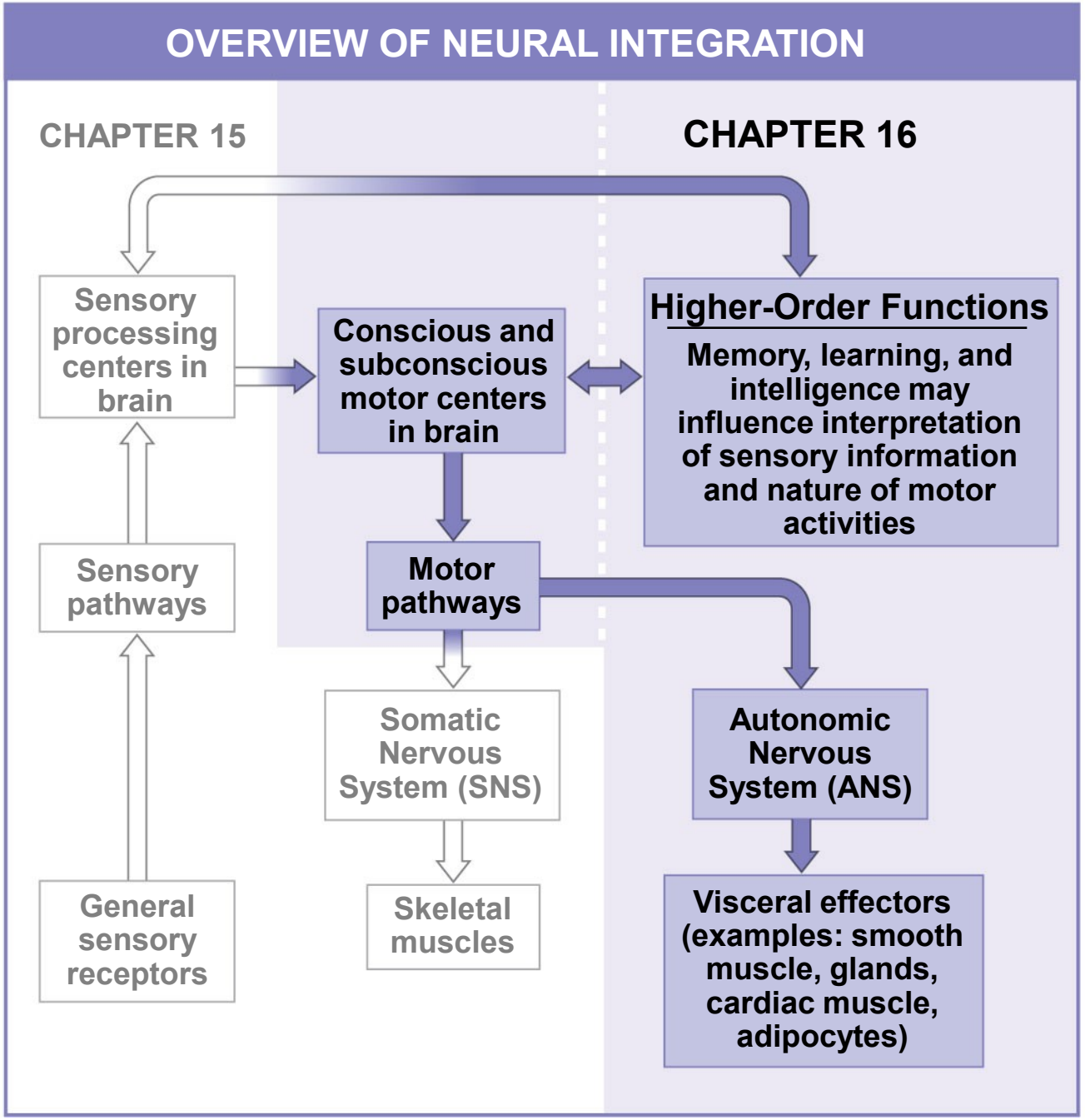

# 16

# Neural Integration II: The Autonomic Nervous System and Higher-Order Functions

*PowerPoint® Lecture Presentations prepared by Jason LaPres*

*Lone Star College—North Harris*

**Figure 16-1 An Overview of Neural Integration**



# 16-1 Autonomic Nervous System

- Organization of the ANS
  - Integrative centers
    - For autonomic activity in hypothalamus
    - Neurons comparable to upper motor neurons in SNS

# 16-1 Autonomic Nervous System

- Organization of the ANS
  - Visceral motor neurons
    - In brain stem and spinal cord, are known as **preganglionic neurons**
    - **Preganglionic fibers**
      - Axons of preganglionic neurons
      - Leave CNS and synapse on **ganglionic neurons**

# 16-1 Autonomic Nervous System

- Visceral Motor Neurons
  - **Autonomic ganglia**
    - Contain many ganglionic neurons
    - Ganglionic neurons innervate visceral effectors
      - Such as cardiac muscle, smooth muscle, glands, and adipose tissue
    - **Postganglionic fibers**
      - Axons of ganglionic neurons

**Figure 16-2a The Organization of the Somatic and Autonomic Nervous Systems**

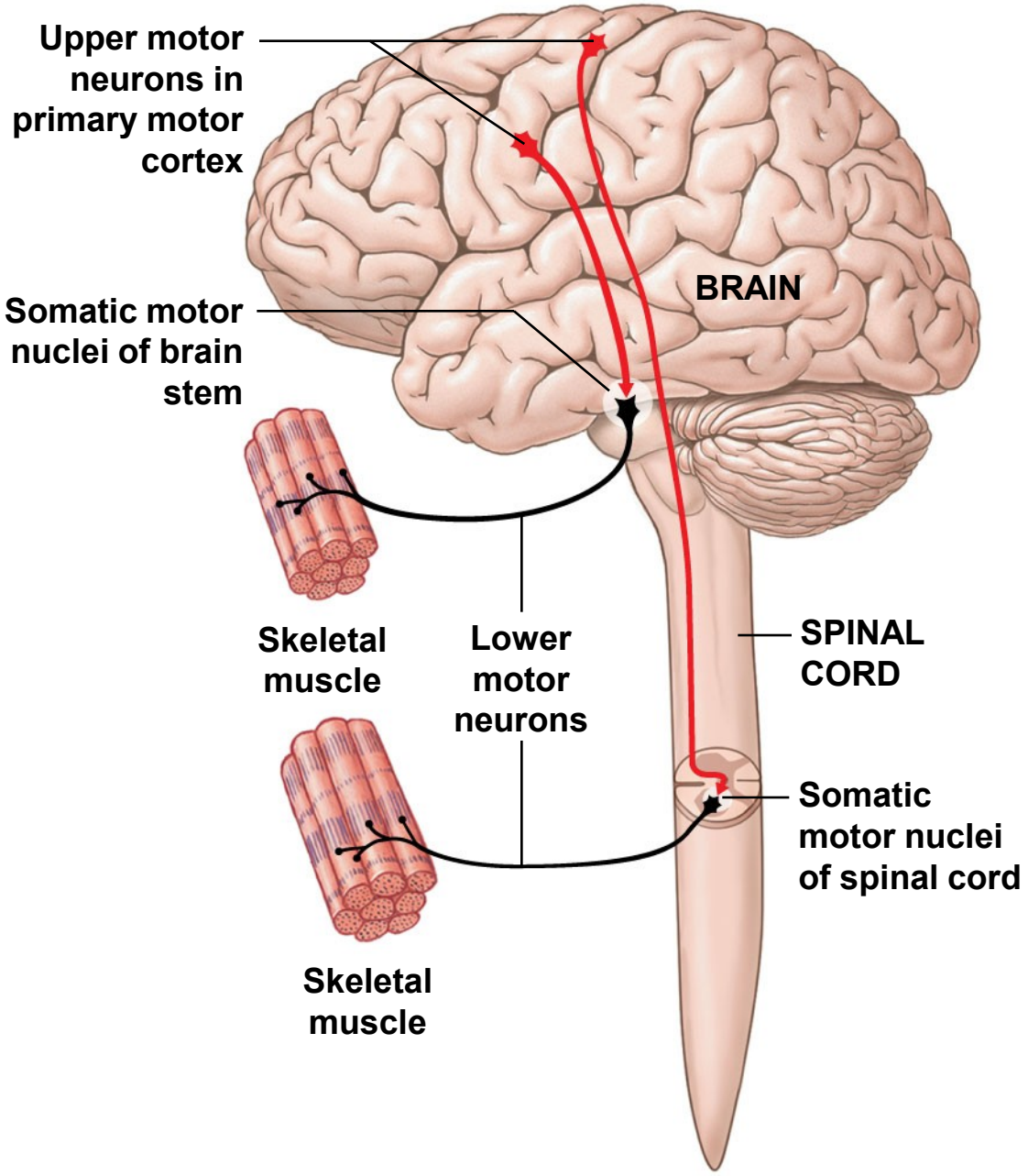
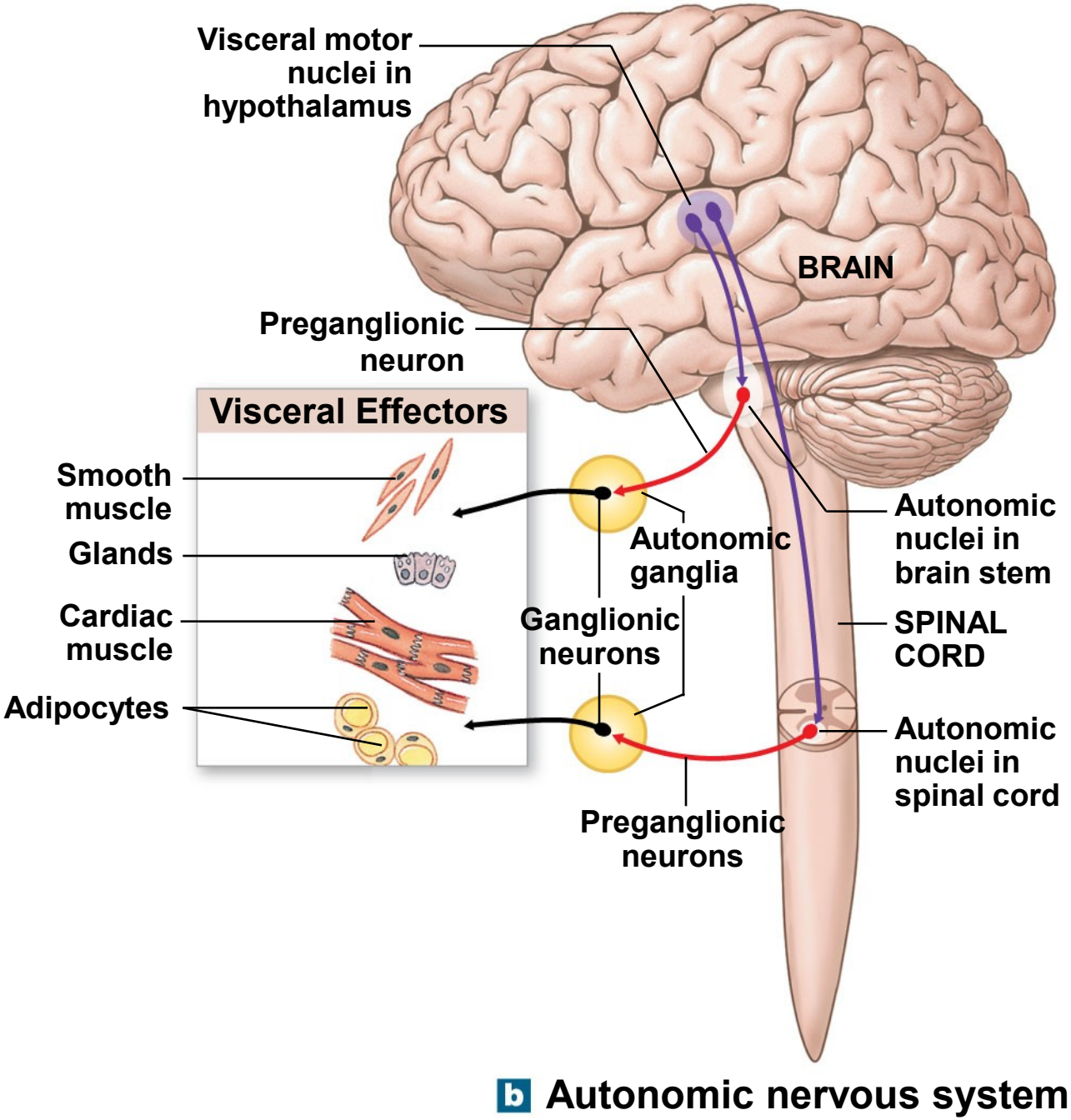


**Figure 16-2b The Organization of the Somatic and Autonomic Nervous Systems**



# 16-1 Divisions of the ANS

- The Autonomic Nervous System
  - Operates largely outside our awareness
  - Has two divisions
    1. **Sympathetic division**
       - Increases alertness, metabolic rate, and muscular abilities
    2. **Parasympathetic division**
       - Reduces metabolic rate and promotes digestion

# 16-1 Divisions of the ANS

- **Sympathetic Division**
  - "Kicks in" only during exertion, stress, or emergency
  - "Fight or flight"
- **Parasympathetic Division**
  - Controls during resting conditions
  - "Rest and digest"

# 16-1 Divisions of the ANS

- Sympathetic and Parasympathetic Division
  1. Most often, these two divisions have opposing effects
     - If the sympathetic division causes excitation, the parasympathetic causes inhibition
  2. The two divisions may also work independently
     - Only one division innervates some structures

# 16-1 Divisions of the ANS

- Sympathetic Division
  - Preganglionic fibers (thoracic and superior lumbar; thoracolumbar) synapse in ganglia near spinal cord
  - Preganglionic fibers are short
  - Postganglionic fibers are long

# 16-1 Divisions of the ANS

- Seven Responses to Increased Sympathetic Activity
  1. Heightened mental alertness
  2. Increased metabolic rate
  3. Reduced digestive and urinary functions
  4. Energy reserves activated
  5. Increased respiratory rate and respiratory passageways dilate
  6. Increased heart rate and blood pressure
  7. Sweat glands activated

# 16-1 Divisions of the ANS

- Parasympathetic Division
  - Preganglionic fibers originate in brain stem and sacral segments of spinal cord; craniosacral
  - Synapse in ganglia close to (or within) target organs
  - Preganglionic fibers are long
  - Postganglionic fibers are short
  - Parasympathetic division stimulates visceral activity
  - Conserves energy and promotes sedentary activities

# 16-1 Divisions of the ANS

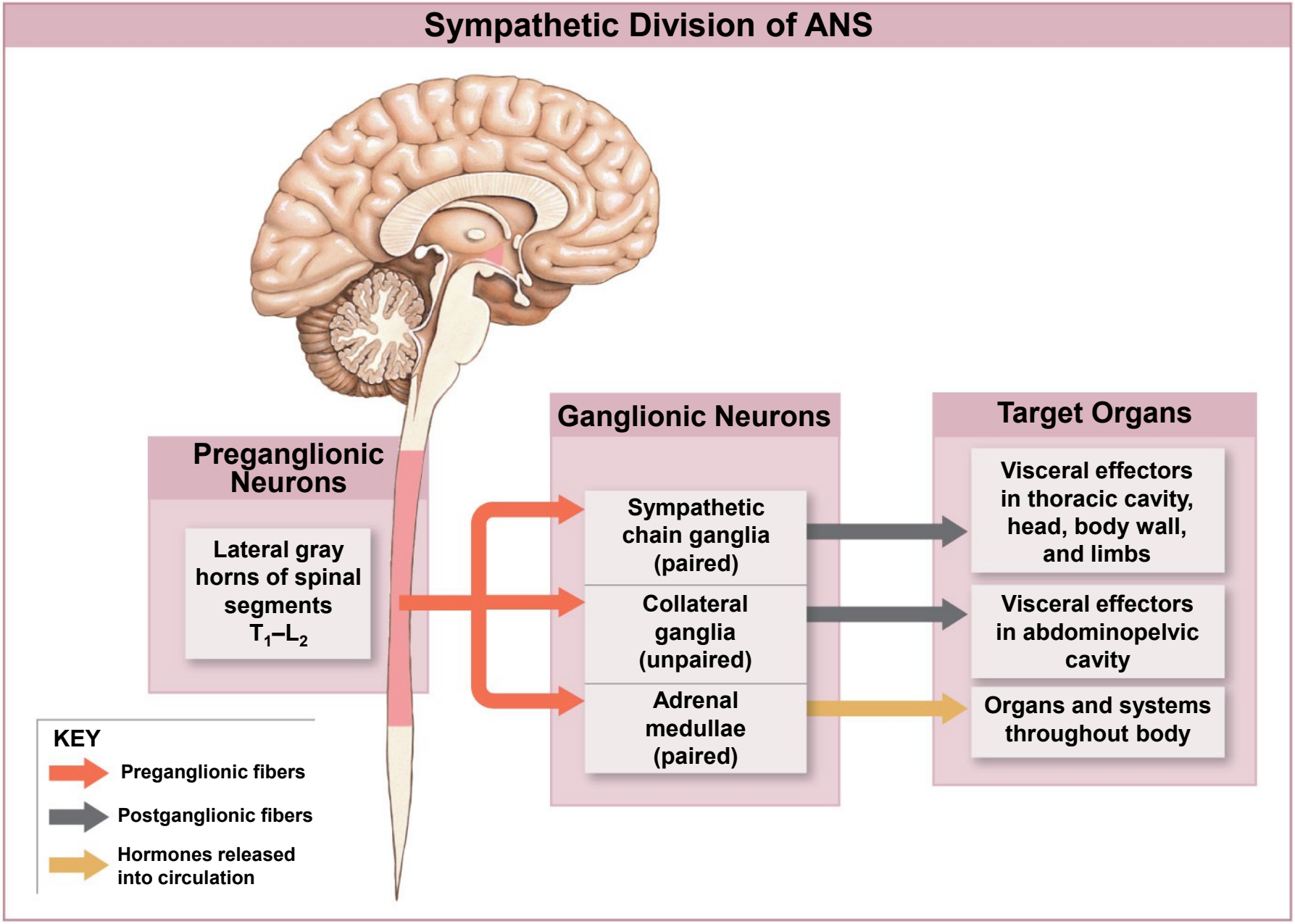
- Five Responses to Increased Parasympathetic Activity

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 in digestive tract
5. Urination and defecation stimulation

# 16-2 The Sympathetic Division

- The Sympathetic Division
  - Preganglionic neurons located between segments $T_1$ and $L_2$ of spinal cord
  - Ganglionic neurons in ganglia near vertebral column
  - Cell bodies of preganglionic neurons in lateral gray horns

**Figure 16-3 The Organization of the Sympathetic Division of the ANS**



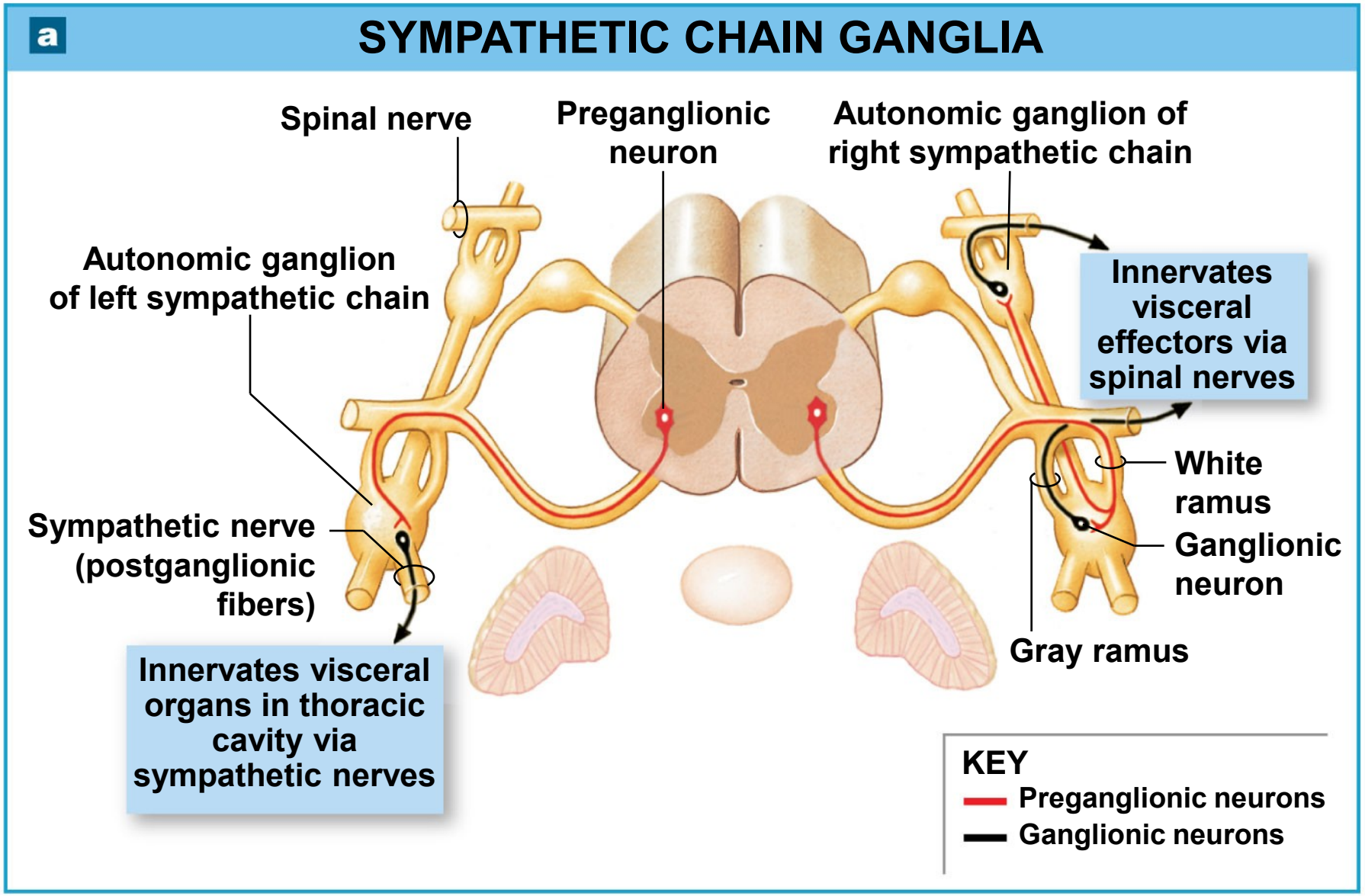
# 16-2 The Sympathetic Division

- Ganglionic Neurons
  - Occur in three locations
    1. *Sympathetic chain ganglia*
    2. *Collateral ganglia*
    3. *Suprarenal medullae*

# 16-2 The Sympathetic Division

- **Sympathetic Chain Ganglia**
  - Are on both sides of vertebral column
  - Control effectors:
    - In body wall
    - Inside thoracic cavity
    - In head
    - In limbs

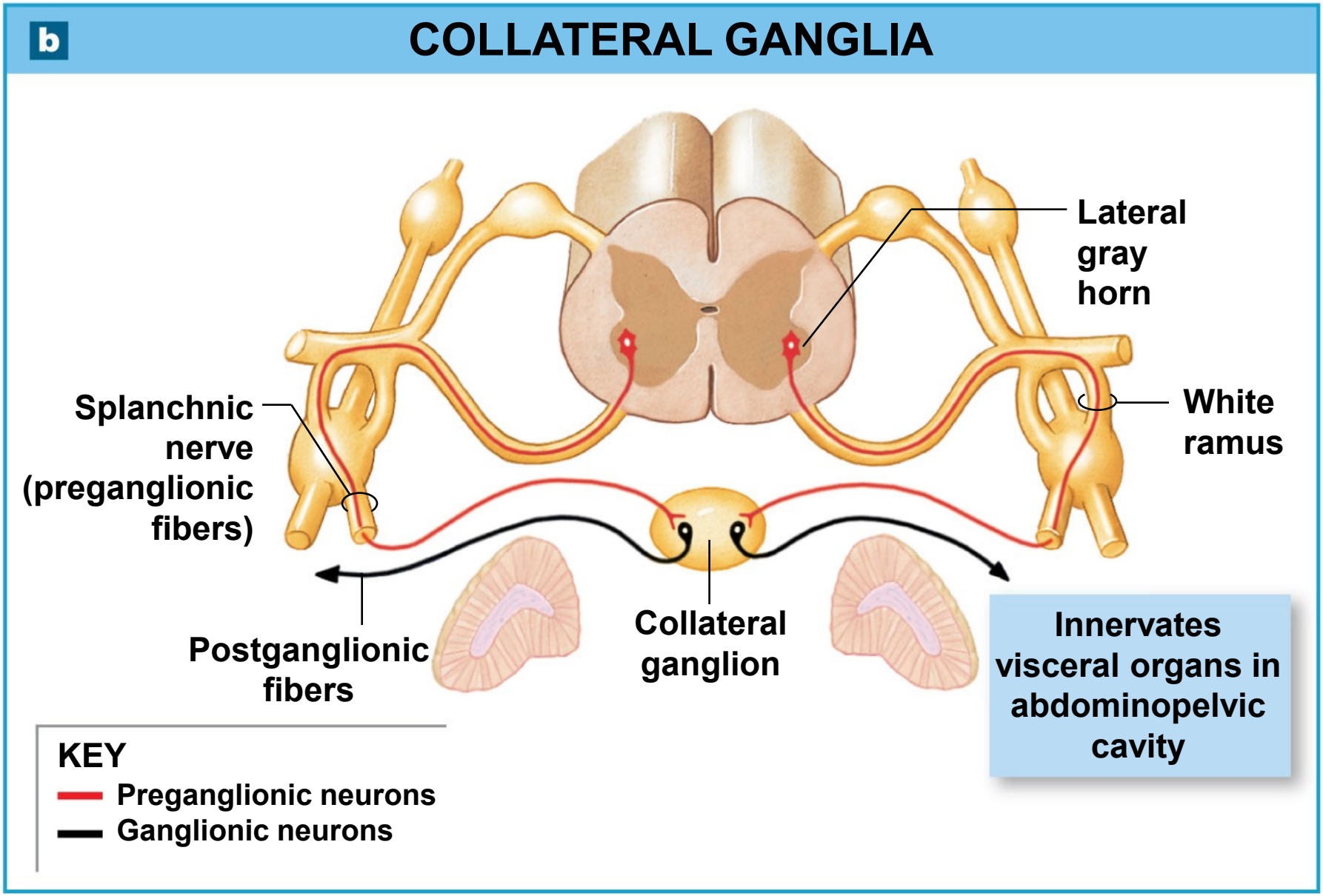
Figure 16-4a Sites of Ganglia in Sympathetic Pathways



# 16-2 The Sympathetic Division

- **Collateral Ganglia**
  - Are anterior to vertebral bodies
  - Contain ganglionic neurons that innervate tissues and organs in abdominopelvic cavity

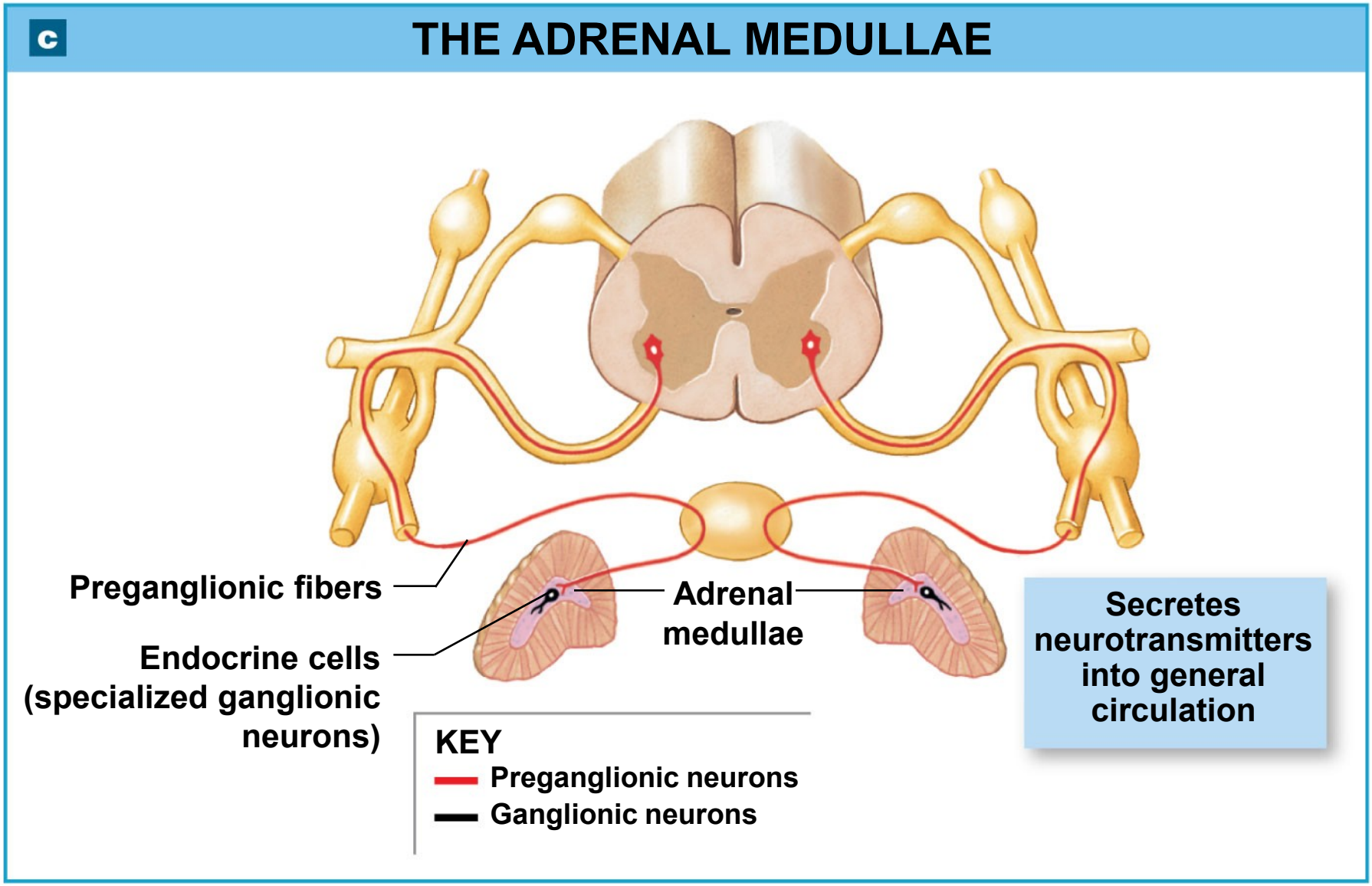
Figure 16-4b Sites of Ganglia in Sympathetic Pathways



# 16-2 The Sympathetic Division

- **Adrenal Medullae** (*Suprarenal Medullae*)
  - Very short axons
  - When stimulated, release neurotransmitters into bloodstream (not at synapse)
  - Function as hormones to affect target cells throughout body

Figure 16-4c Sites of Ganglia in Sympathetic Pathways



# 16-2 The Sympathetic Division

- Sympathetic Chain Ganglia
  - Postganglionic fibers control visceral effectors
    - In body wall, head, neck, or limbs
    - Enter *gray ramus*
    - Return to spinal nerve for distribution
  - Postganglionic fibers innervate effectors
    - Sweat glands of skin
    - Smooth muscles in superficial blood vessels

# 16-2 The Sympathetic Division

- Sympathetic Chain Ganglia
  - Postganglionic fibers innervating structures in thoracic cavity form bundles
    - **Sympathetic nerves**

# 16-2 The Sympathetic Division

- Sympathetic Chain Ganglia
  - Each sympathetic chain ganglia contains:
    - 3 cervical ganglia
    - 10–12 thoracic ganglia
    - 4–5 lumbar ganglia
    - 4–5 sacral ganglia
    - 1 coccygeal ganglion

# 16-2 The Sympathetic Division

- Sympathetic Chain Ganglia
  - Preganglionic neurons
    - Limited to spinal cord segments $T_1$–$L_2$
    - White rami (myelinated preganglionic fibers)
    - Innervate neurons in:
      - Cervical, inferior lumbar, and sacral sympathetic chain ganglia

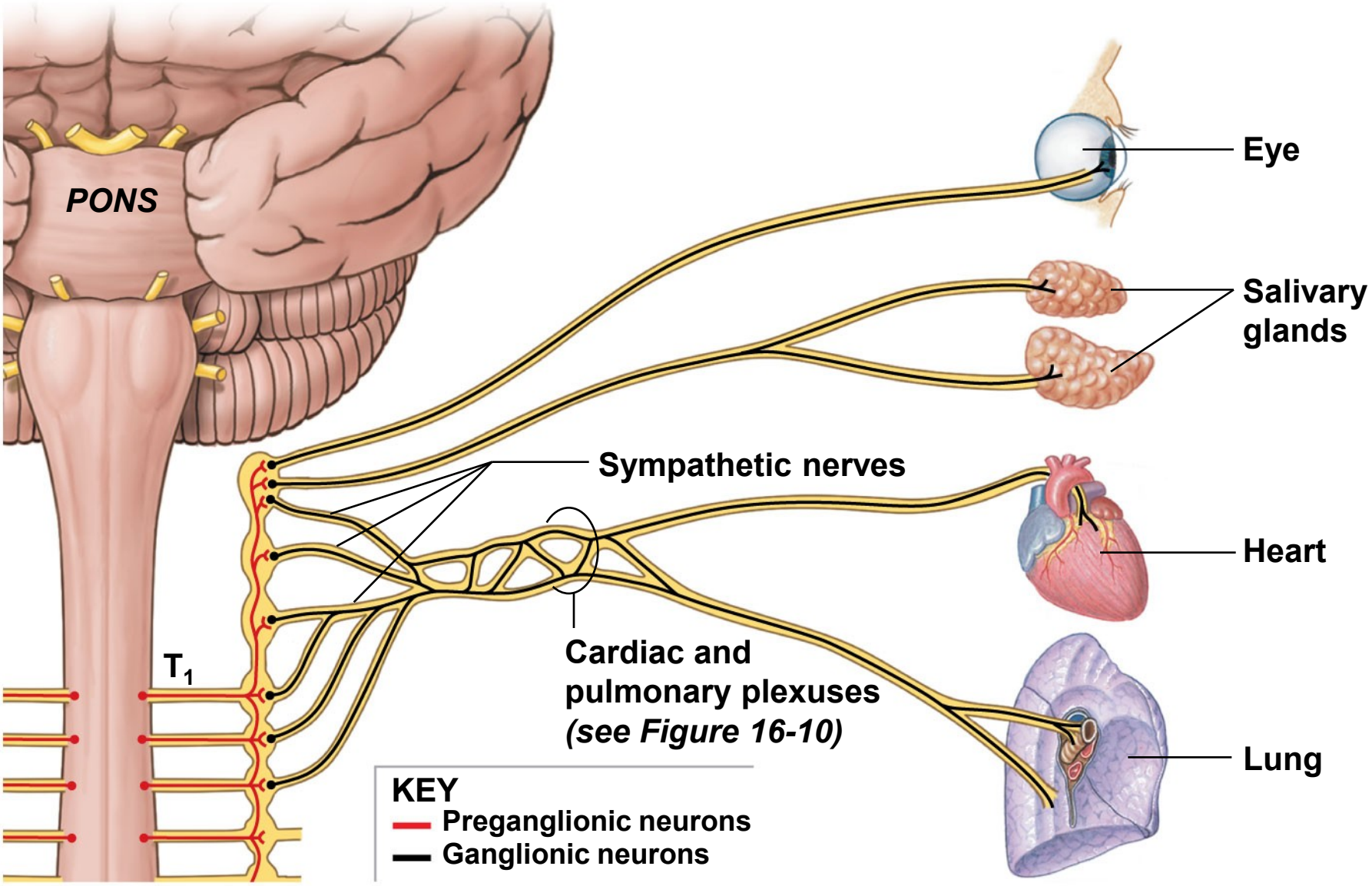
# 16-2 The Sympathetic Division

- Sympathetic Chain Ganglia
  - Chain ganglia provide postganglionic fibers
    - Through gray rami (unmyelinated postganglionic fibers)
    - To cervical, lumbar, and sacral spinal nerves

# 16-2 The Sympathetic Division

- Sympathetic Chain Ganglia
  - Only spinal nerves $T_1$–$L_2$ have white rami
  - Every spinal nerve has gray ramus
    - That carries sympathetic postganglionic fibers for distribution in body wall

**Figure 16-5 The Distribution of Sympathetic Innervation**



# 16-2 The Sympathetic Division

- **Collateral Ganglia**
  - Receive sympathetic innervation via sympathetic preganglionic fibers
  - **Splanchnic nerves**
    - Formed by preganglionic fibers that innervate collateral ganglia
    - In dorsal wall of abdominal cavity

# 16-2 The Sympathetic Division

- Collateral Ganglia
  - Postganglionic fibers
    - Leave collateral ganglia
    - Extend throughout abdominopelvic cavity
    - Innervate variety of visceral tissues and organs

Figure 16-5 The Distribution of Sympathetic Innervation

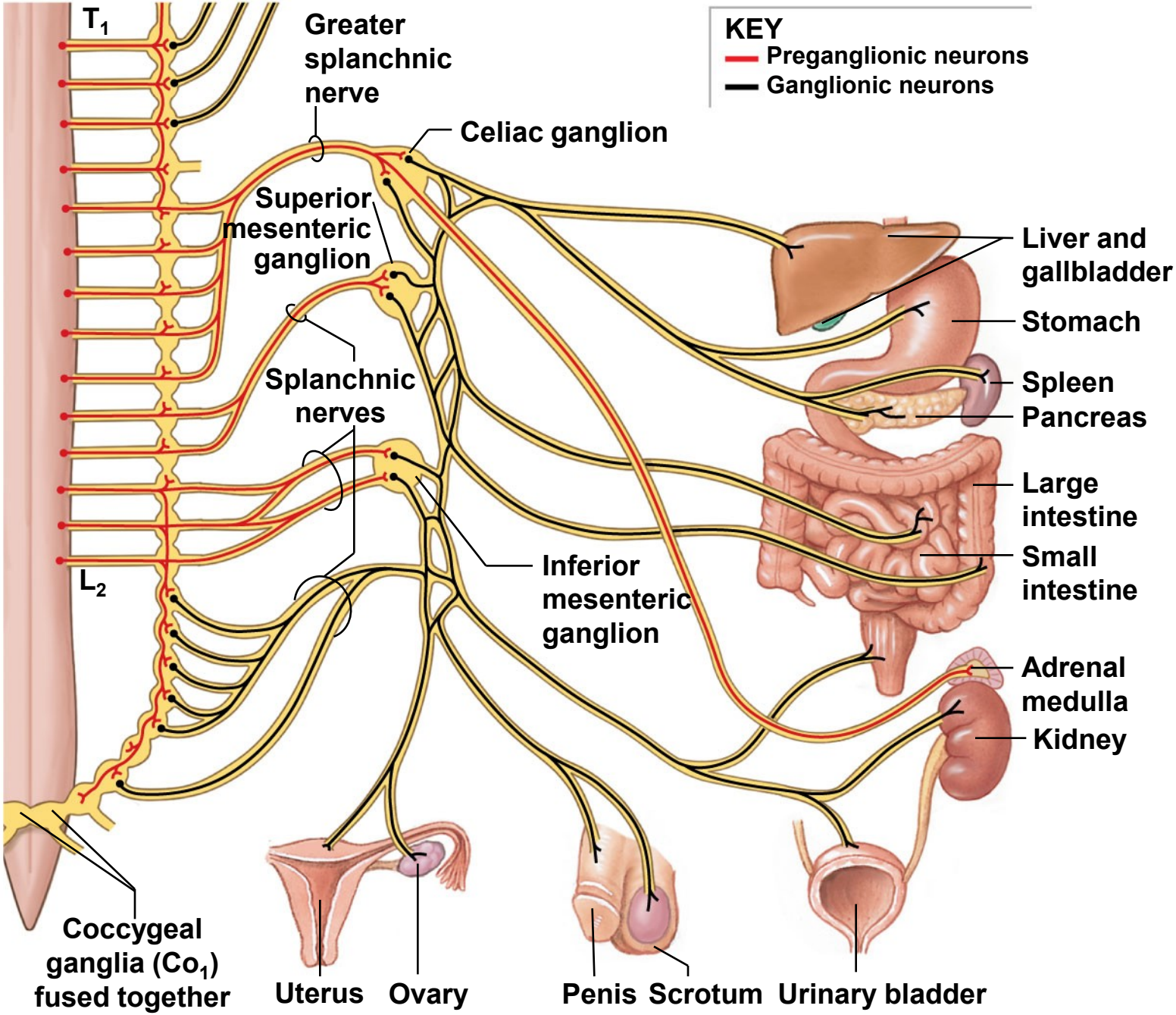
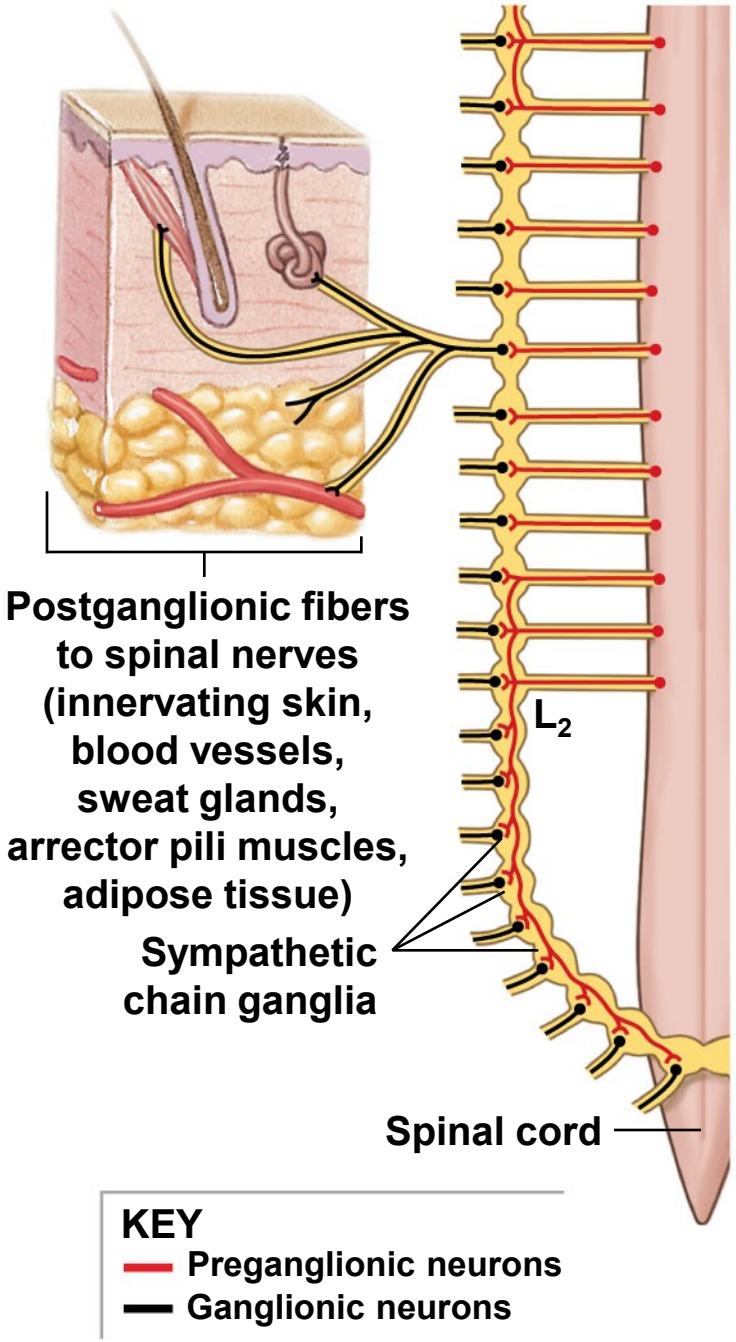


**Figure 16-5 The Distribution of Sympathetic Innervation**



# 16-2 The Sympathetic Division

- Adrenal Medullae
  - Preganglionic fibers entering adrenal gland proceed to center (adrenal medulla)
  - Modified sympathetic ganglion
  - Preganglionic fibers synapse on *neuroendocrine cells*
  - Specialized neurons secrete hormones into bloodstream

# 16-2 The Sympathetic Division

- Adrenal Medullae
  - Neuroendocrine cells
    - Secrete neurotransmitters *epinephrine* (E) and *norepinephrine* (NE)
    - Epinephrine
      - Also called *adrenaline*
      - Is 75–80% of secretory output
    - Remaining is norepinephrine (NE)
      - *Noradrenaline*

# 16-2 The Sympathetic Division

- Adrenal Medullae
  - Bloodstream carries neurotransmitters through body
  - Causing changes in metabolic activities of different cells including cells not innervated by sympathetic postganglionic fibers
  - Effects last longer
    - Hormones continue to diffuse out of bloodstream

# 16-2 The Sympathetic Division

- **Sympathetic Activation**
  - Change activities of tissues and organs by:
    - Releasing NE at peripheral synapses
      - Target specific effectors, smooth muscle fibers in blood vessels of skin
      - Are activated in reflexes

# 16-2 The Sympathetic Division

- Sympathetic Activation
  - Changes activities of tissues and organs by:
    - Distributing E and NE throughout body in bloodstream
      - Entire division responds (sympathetic activation)
      - Are controlled by sympathetic centers in hypothalamus
      - Effects are not limited to peripheral tissues
      - Alters CNS activity

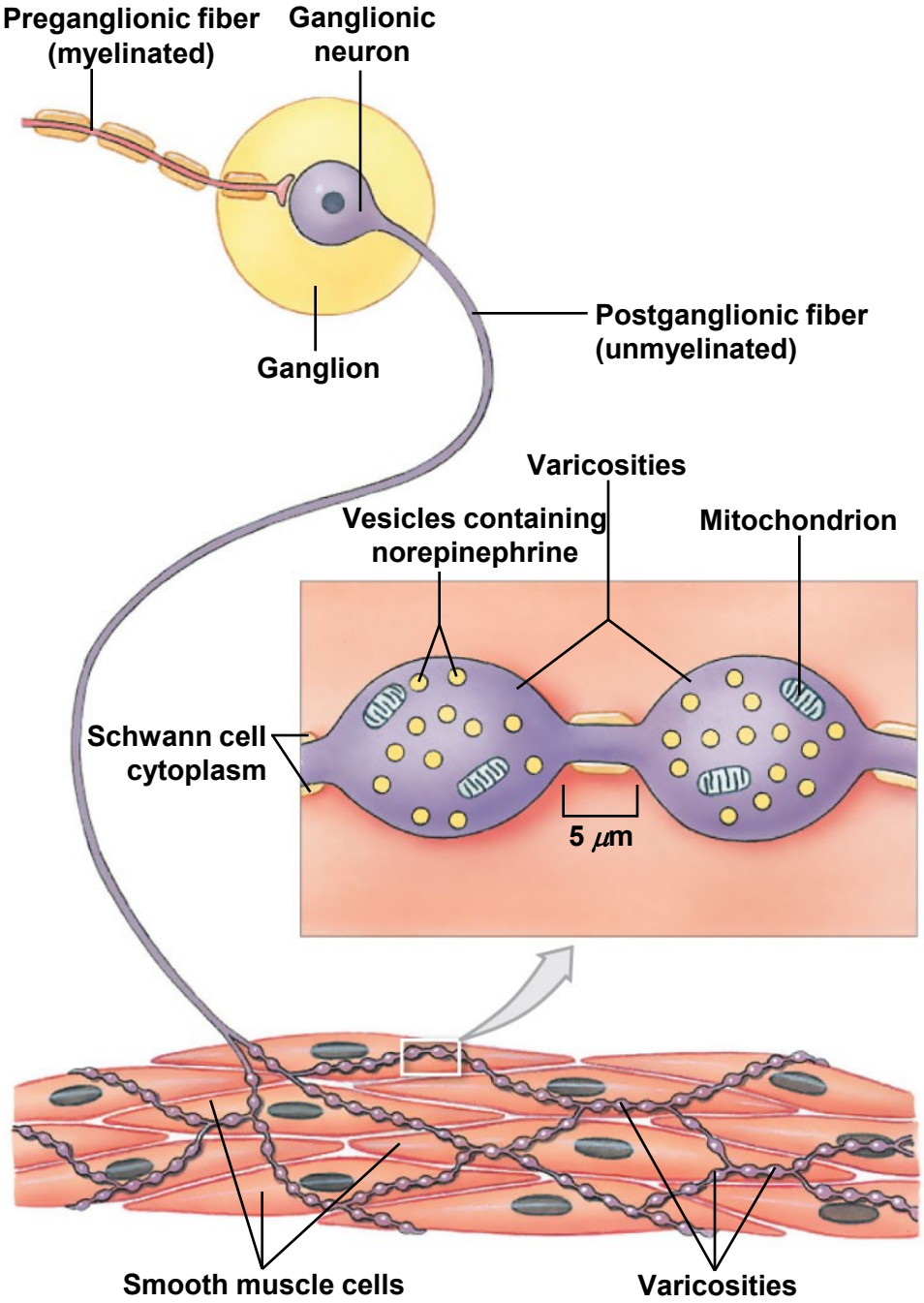
# 16-2 The Sympathetic Division

- Changes Caused by Sympathetic Activation
  - Increased alertness
  - Feelings of energy and euphoria
  - Change in breathing
  - Elevation in muscle tone
  - Mobilization of energy reserves

# 16-3 Various Sympathetic Neurotransmitters

- Stimulation of Sympathetic Preganglionic Neurons
  - Releases ACh at synapses with ganglionic neurons
  - Excitatory effect on ganglionic neurons
- Ganglionic Neurons
  - Release neurotransmitters at specific target organs

**Figure 16-6 Sympathetic Varicosities**



# 16-3 Various Sympathetic Neurotransmitters

- Ganglionic Neurons
  - Axon terminals
    - Release NE at most varicosities
      - Called *adrenergic* neuron
    - Some ganglionic neurons release ACh instead
      - Are located in body wall, skin, brain, and skeletal muscles
      - Called *cholinergic* neurons

# 16-3 Various Sympathetic Neurotransmitters

- Sympathetic Stimulation and the Release of ACh
  - Cholinergic (ACh) sympathetic terminals
    - Innervate sweat glands of skin and blood vessels of skeletal muscles and brain
    - Stimulate sweat gland secretion and dilate blood vessels

# 16-4 The Parasympathetic Division

- Autonomic Nuclei
  - Are contained in the mesencephalon, pons, and medulla oblongata
    - Associated with cranial nerves III, VII, IX, X
  - In lateral gray horns of spinal segments $S_2$–$S_4$

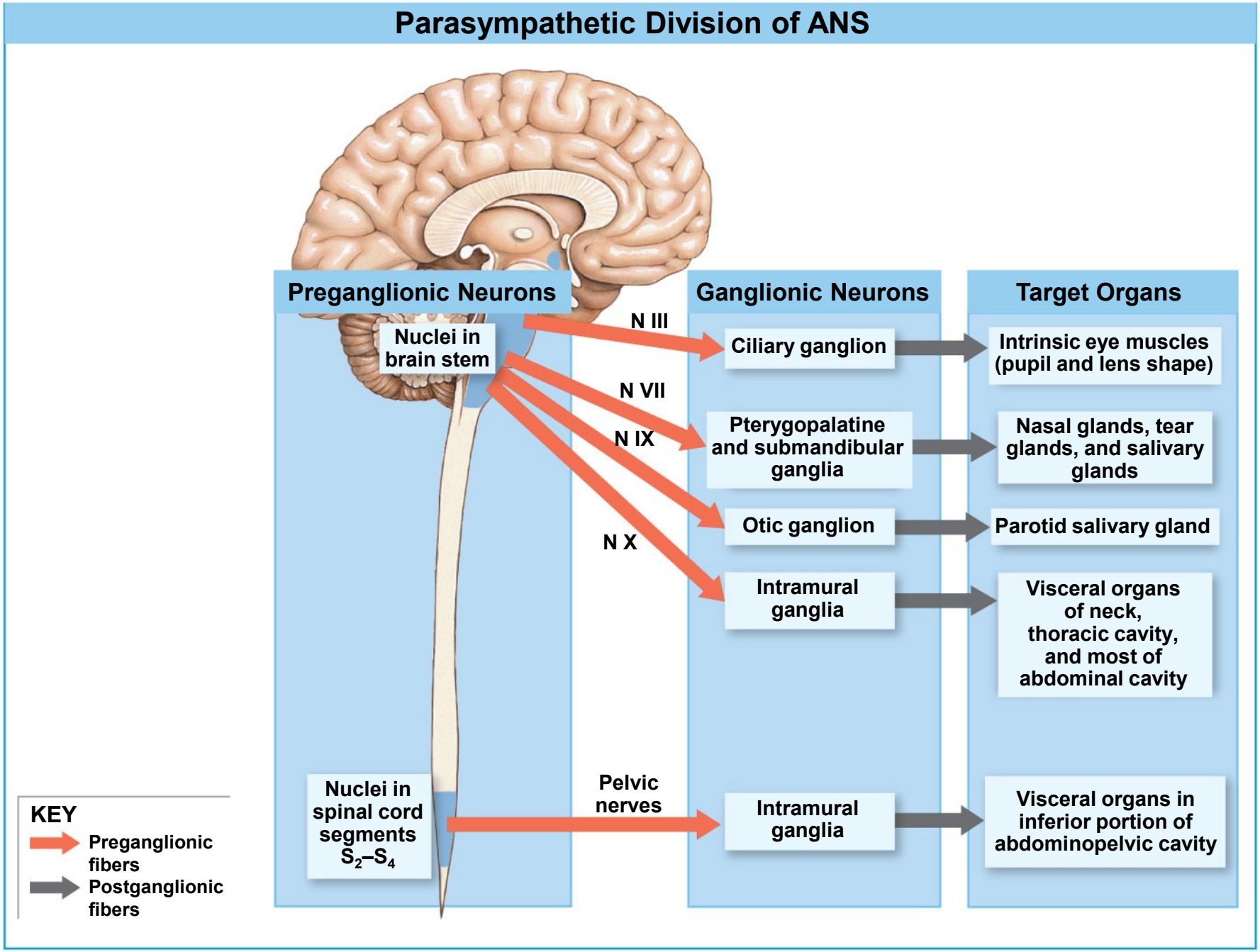
# 16-4 The Parasympathetic Division

- Ganglionic Neurons in Peripheral Ganglia
  - **Terminal ganglion**
    - Near target organ
    - Usually paired
  - **Intramural ganglion**
    - Embedded in tissues of target organ
    - Interconnected masses
    - Clusters of ganglion cells

# 16-4 The Parasympathetic Division

- Organization and Anatomy of the Parasympathetic Division
  - Parasympathetic preganglionic fibers leave brain as components of cranial nerves
    - III (oculomotor)
    - VII (facial)
    - IX (glossopharyngeal)
    - X (vagus)
  - Parasympathetic preganglionic fibers leave spinal cord at sacral level

**Figure 16-7 The Organization of the Parasympathetic Division of the ANS**



# 16-4 The Parasympathetic Division

- Oculomotor, Facial, and Glossopharyngeal Nerves
  - Control visceral structures in head

# 16-4 The Parasympathetic Division

- Vagus Nerve
  - Provides preganglionic parasympathetic innervation to structures in:
    - Neck
    - Thoracic and abdominopelvic cavity as distant as a distal portion of large intestine
  - Provides 75% of all parasympathetic outflow

# 16-4 The Parasympathetic Division

- Sacral Segments of Spinal Cord
  - Preganglionic fibers carry sacral parasympathetic output
    - **Pelvic nerves** innervate intramural ganglia in walls of kidneys, urinary bladder, portions of large intestine, and the sex organs

**Figure 16-8 The Distribution of Parasympathetic Innervation**

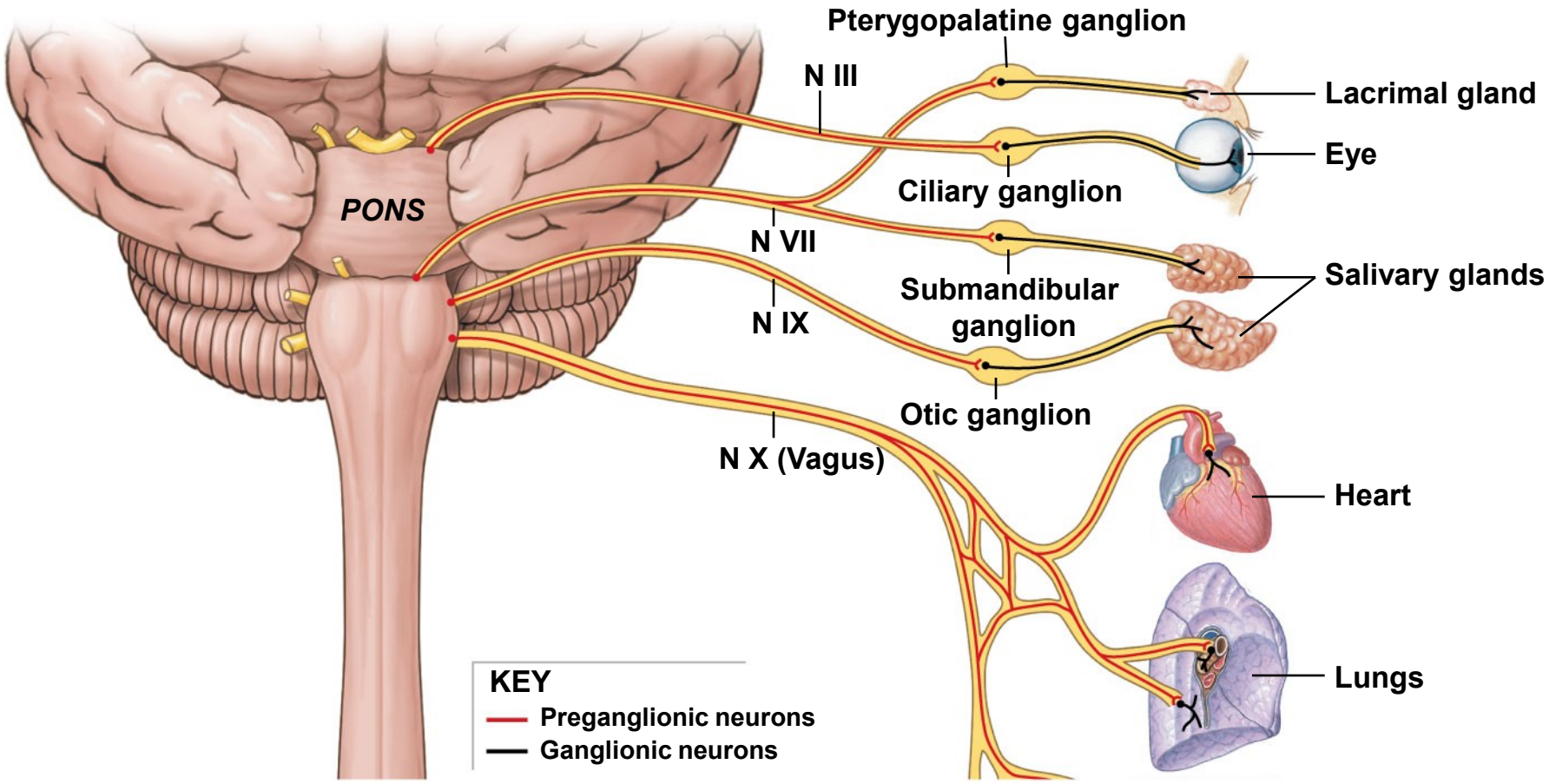
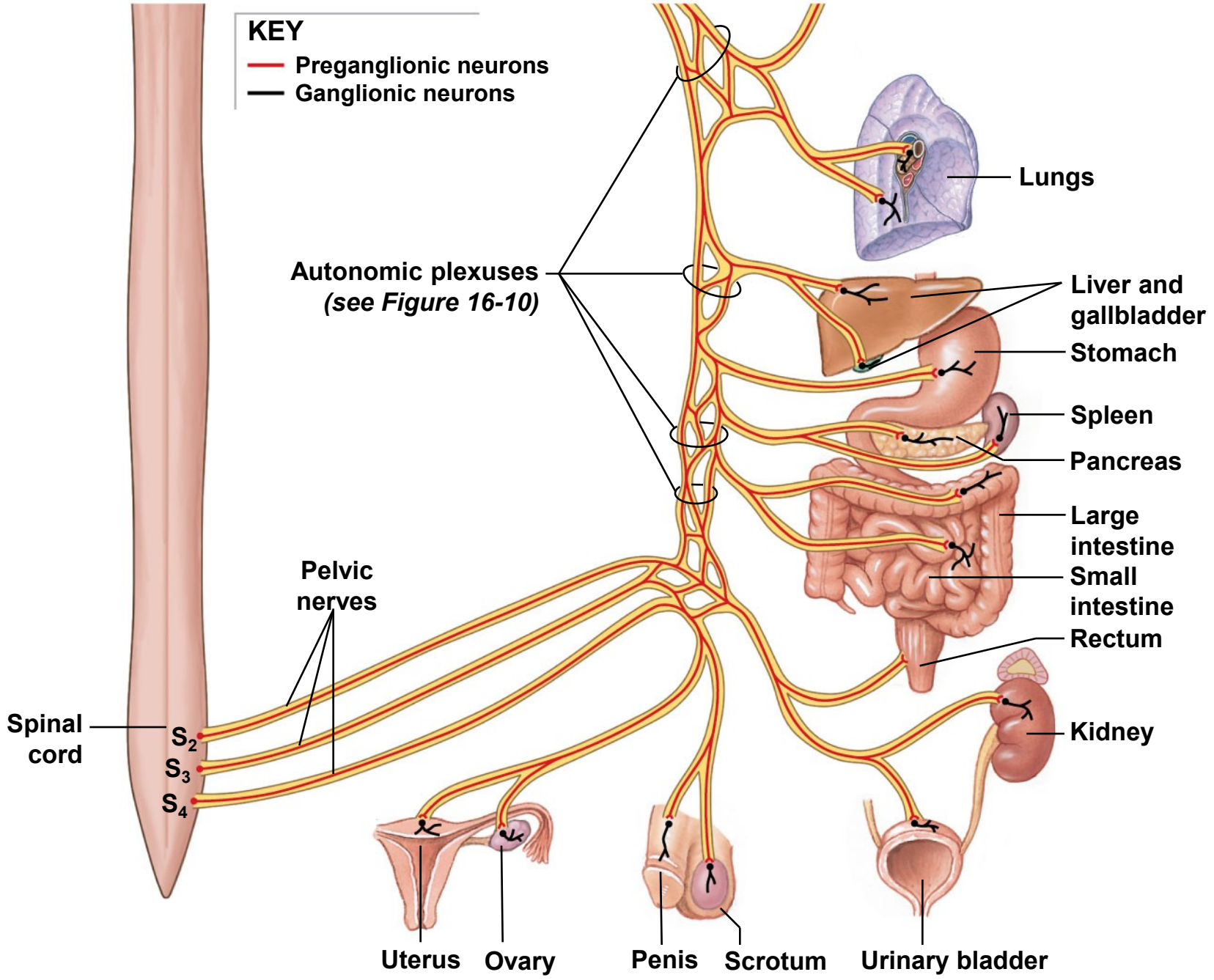


**Figure 16-8 The Distribution of Parasympathetic Innervation**



# 16-4 The Parasympathetic Division

- Parasympathetic Activation
  - Centers on relaxation, food processing, and energy absorption
  - Localized effects, last a few seconds at most

# 16-4 The Parasympathetic Division

- Major Effects of Parasympathetic Division
  - 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

# 16-4 The Parasympathetic Division

- Major Effects of Parasympathetic Division
  - 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
  - Increase in smooth muscle activity
    - Along the digestive tract

# 16-4 The Parasympathetic Division

- Major Effects of Parasympathetic Division
  - Stimulation and coordination of defecation
  - Contraction of the urinary bladder during urination
  - Constriction of the respiratory passageways
  - Reduction in heart rate and in the force of contraction

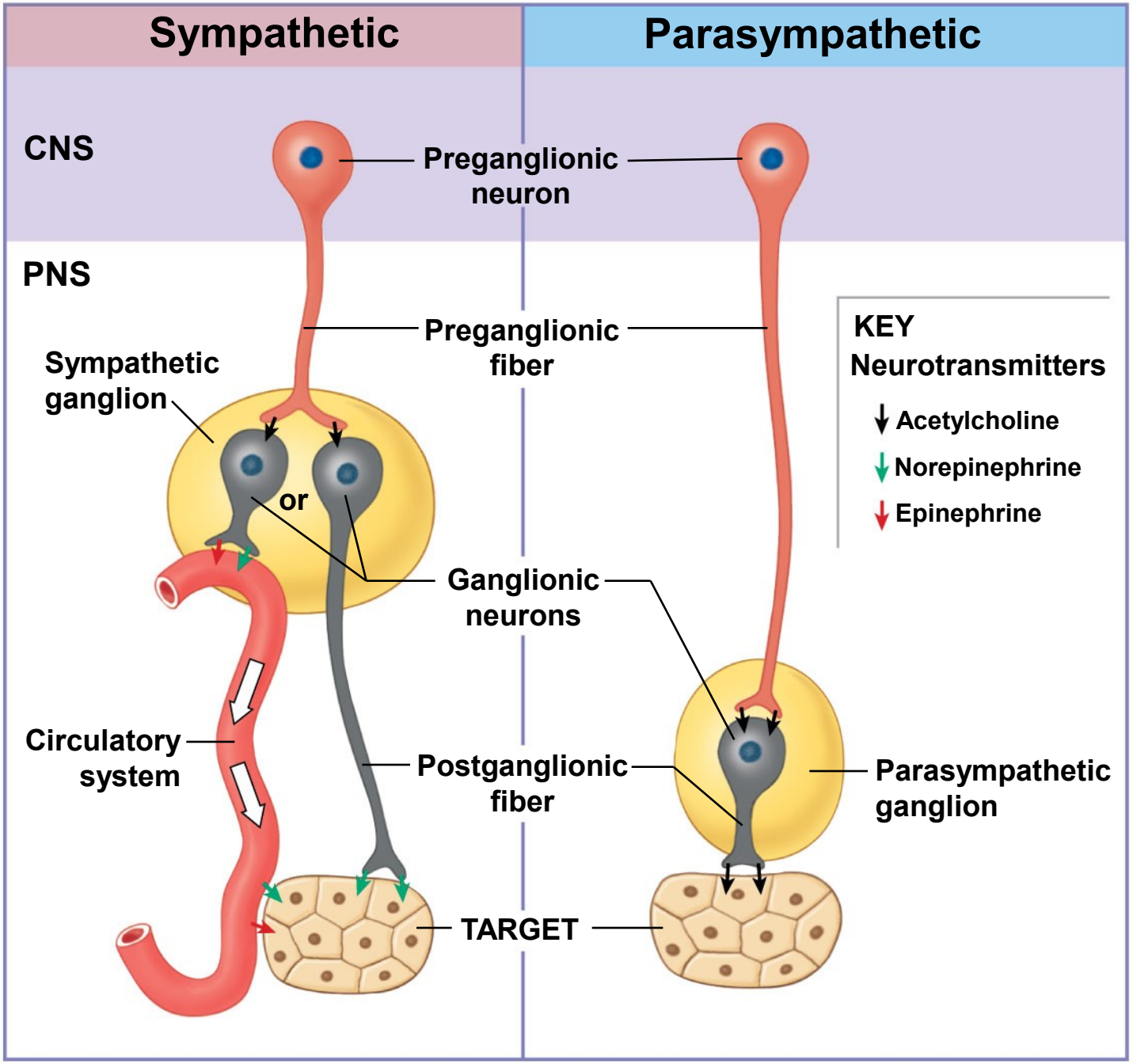
# 16-5 Parasympathetic Neurons Release ACh

- Neuromuscular and Neuroglandular Junctions
  - All release ACh as neurotransmitter

# 16-6 Dual Innervation

- Sympathetic Division
  - Widespread impact
  - Reaches organs and tissues throughout body
- Parasympathetic Division
  - Innervates only specific visceral structures
- Sympathetic and Parasympathetic Division
  - Most vital organs receive instructions from both sympathetic and parasympathetic divisions
  - Two divisions commonly have opposing effects

**Figure 16-9 Summary: The Anatomical Differences between the Sympathetic and Parasympathetic Divisions**



# 16-6 Dual Innervation

- Anatomy of Dual Innervation
  - *Autonomic plexuses*
    - Nerve networks in the thoracic and abdominopelvic cavities
      - Are formed by mingled sympathetic postganglionic fibers and parasympathetic preganglionic fibers
    - Travel with blood and lymphatic vessels that supply visceral organs

# 16-6 Dual Innervation

- **Autonomic Tone**
  - Is an important aspect of ANS function
    - If nerve is inactive under normal conditions, can only increase activity
    - If nerve maintains background level of activity, can increase or decrease activity

# 16-6 Dual Innervation

- The Heart Receives Dual Innervation
  - Two divisions have opposing effects on heart function
    1. Parasympathetic division
       - Acetylcholine released by postganglionic fibers slows heart rate
    2. Sympathetic division
       - NE released by varicosities accelerates heart rate
  - Balance between two divisions
    - Autonomic tone is present
    - Releases small amounts of both neurotransmitters continuously

# 16-6 Dual Innervation

- The Heart Receives Dual Innervation
  - Parasympathetic innervation dominates under resting conditions
    - Crisis accelerates heart rate by:
      - Stimulation of sympathetic innervation
      - Inhibition of parasympathetic innervation

# 16-6 Dual Innervation

- Autonomic Tone
  - Blood vessel dilates and blood flow increases
  - Blood vessel constricts and blood flow is reduced
  - Sympathetic postganglionic fibers release NE
    - Innervate smooth muscle cells in walls of peripheral vessels

# 16-6 Dual Innervation

- Autonomic Tone
  - Background sympathetic tone keeps muscles partially contracted
  - To increase blood flow:
    - Rate of NE release decreases
    - Vessels dilate and blood flow increases

# 16-7 Visceral Reflexes Regulate the ANS

- Somatic Motor Control
  - Centers in all portions of CNS
  - Lowest level regulatory control
    - Lower motor neurons of cranial and spinal visceral reflex arcs
  - Highest level
    - Pyramidal motor neurons of primary motor cortex
    - Operating with feedback from cerebellum and basal nuclei

# 16-7 Visceral Reflexes Regulate the ANS

- **Visceral Reflexes**
  - Provide automatic motor responses
  - Can be modified, facilitated, or inhibited by higher centers, especially hypothalamus
  - **Visceral reflex arc**
    - Receptor
    - Sensory neuron
    - Processing center (one or more interneurons)
      - All polysynaptic
    - Two visceral motor neurons

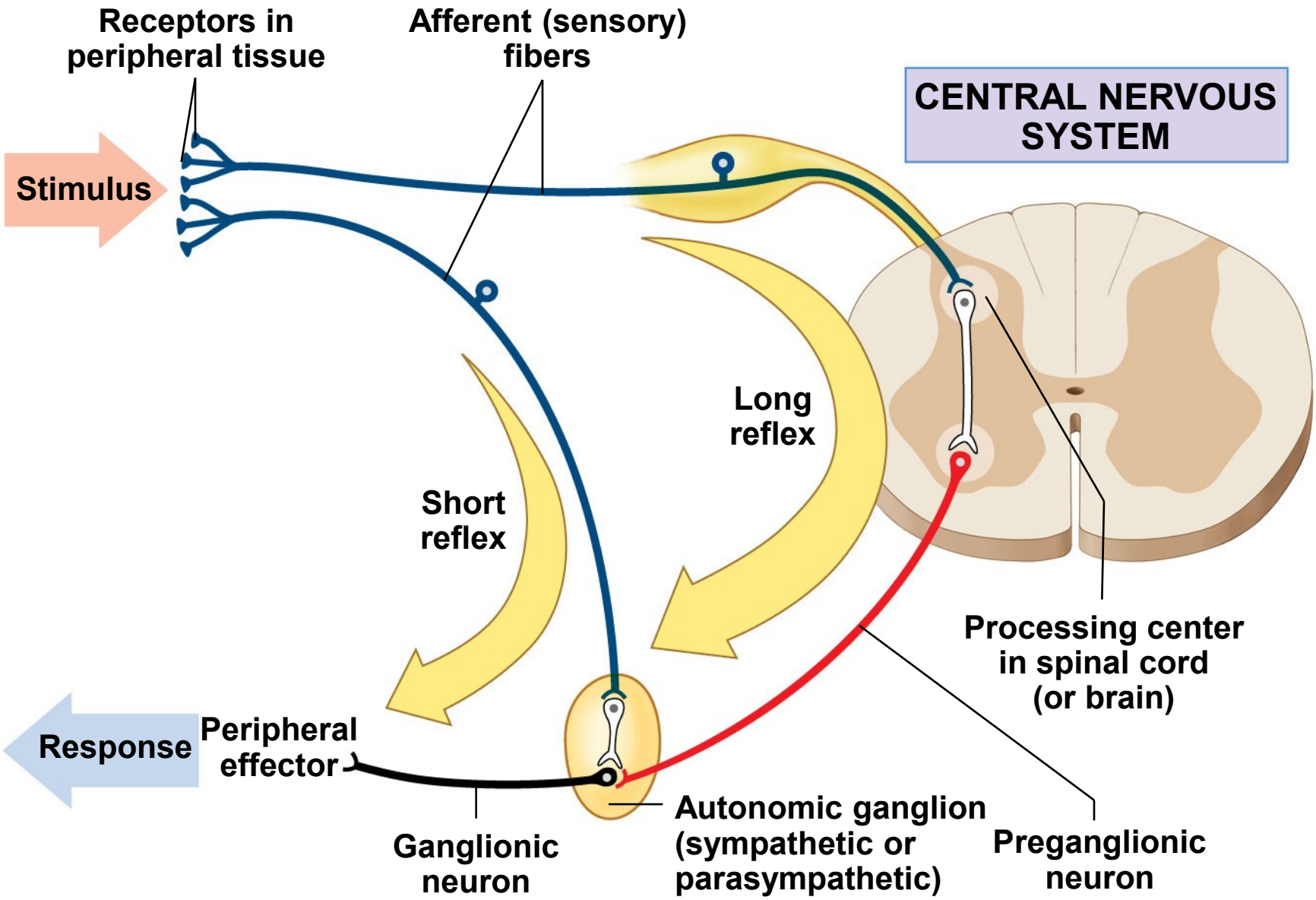
# 16-7 Visceral Reflexes Regulate the ANS

- Visceral Reflexes
  - **Long reflexes**
    - Autonomic equivalents of polysynaptic reflexes
    - Visceral sensory neurons deliver information to CNS along dorsal roots of spinal nerves
      - Within sensory branches of cranial nerves
      - Within autonomic nerves that innervate visceral effectors
    - ANS carries motor commands to visceral effectors
    - Coordinate activities of entire organ

# 16-7 Visceral Reflexes Regulate the ANS

- Visceral Reflexes
  - **Short reflexes**
    - Bypass CNS
    - Involve sensory neurons and interneurons located within autonomic ganglia
    - Interneurons synapse on ganglionic neurons
    - Motor commands distributed by postganglionic fibers
    - Control simple motor responses with localized effects
    - One small part of target organ

Figure 16-11 Visceral Reflexes



# 16-7 Visceral Reflexes Regulate the ANS

- Visceral Reflexes
  - Regulating visceral activity
    - Most organs
      - Long reflexes most important
    - Digestive tract
      - Short reflexes provide most control and coordination

# 16-7 Visceral Reflexes Regulate the ANS

- Visceral Reflexes
  - *Enteric nervous system*
    - Ganglia in the walls of digestive tract contain cell bodies of:
    - Axons form extensive nerve nets
    - Control digestive functions independent of CNS

**Table 16-4 Representative Visceral Reflexes**

**Table 16–4 Representative Visceral Reflexes**

| Reflex | Stimulus | Response | Comments |
|---|---|---|---|
| **PARASYMPATHETIC REFLEXES** | | | |
| **Gastric and intestinal reflexes** *(Chapter 24)* | Pressure and physical contact | Smooth muscle contractions that propel food materials and mix with secretions | Via vagus nerve |
| **Defecation** *(Chapter 24)* | Distention of rectum | Relaxation of internal anal sphincter | Requires voluntary relaxation of external anal sphincter |
| **Urination** *(Chapter 26)* | Distention of urinary bladder | Contraction of walls of urinary bladder; relaxation of internal urethral sphincter | Requires voluntary relaxation of external urethral sphincter |
| **Direct light and consensual light reflexes** *(Chapter 14)* | Bright light shining in eye(s) | Constriction of pupils of both eyes | |
| **Swallowing reflex** *(Chapter 24)* | Movement of food and liquids into pharynx | Smooth muscle and skeletal muscle contractions | Coordinated by medullary swallowing center |
| **Coughing reflex** *(Chapter 23)* | Irritation of respiratory tract | Sudden explosive ejection of air | Coordinated by medullary coughing center |
| **Baroreceptor reflex** *(Chapters 17, 20, 21)* | Sudden rise in carotid blood pressure | Reduction in heart rate and force of contraction | Coordinated in cardiac centers of medulla oblongata |
| **Sexual arousal** *(Chapter 28)* | Erotic stimuli (visual or tactile) | Increased glandular secretions, sensitivity, erection | |

**Table 16-4 Representative Visceral Reflexes**

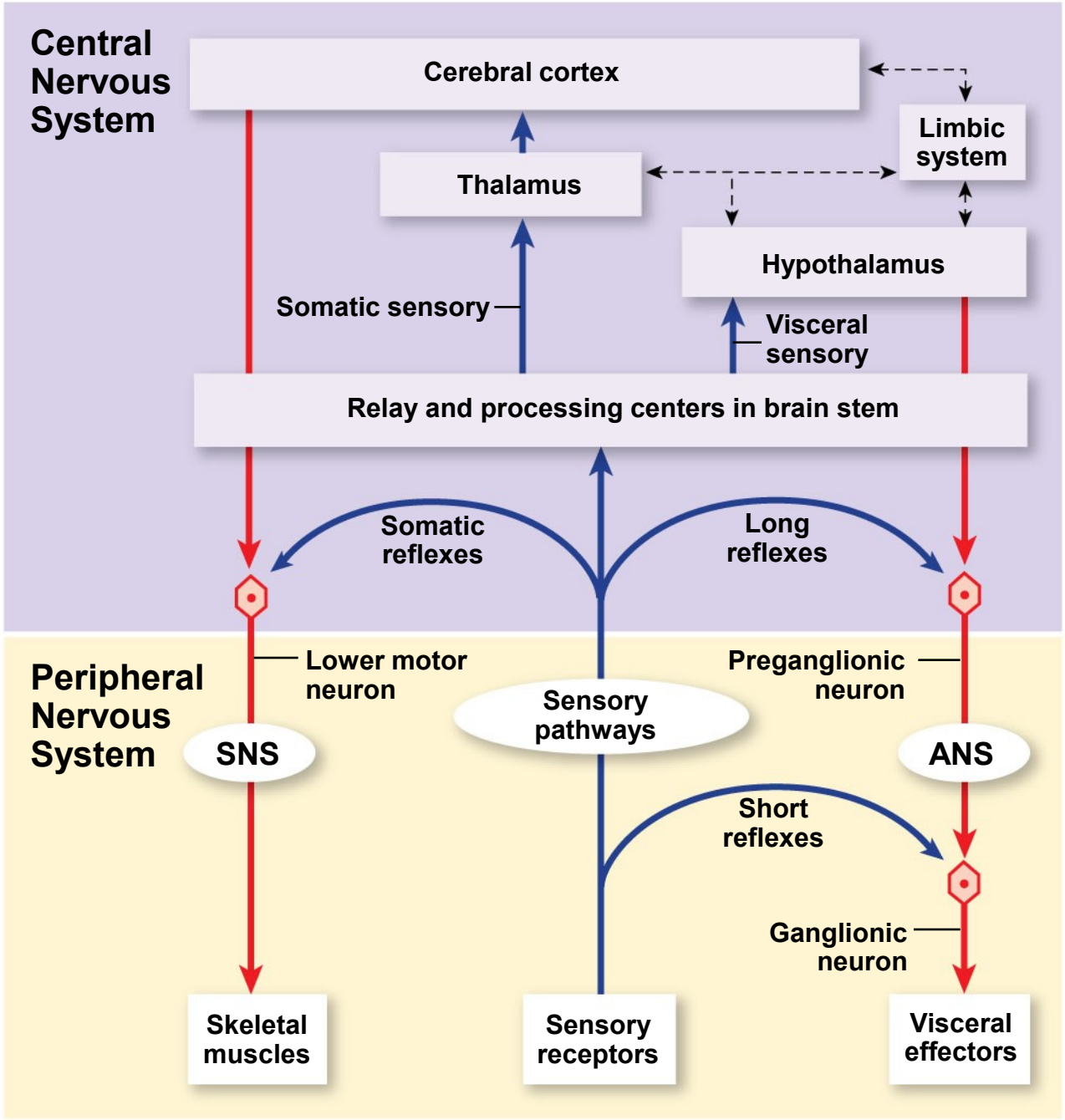
**Table 16–4** Representative Visceral Reflexes

| Reflex | Stimulus | Response | Comments |
|---|---|---|---|
| **SYMPATHETIC REFLEXES** | | | |
| **Cardioacceleratory reflex** *(Chapter 21)* | Sudden decline in blood pressure in carotid artery | Increase in heart rate and force of contraction | Coordinated in cardiac centers of medulla oblongata |
| **Vasomotor reflexes** *(Chapter 21)* | Changes in blood pressure in major arteries | Changes in diameter of peripheral vessels | Coordinated in vasomotor center in medulla oblongata |
| **Pupillary reflex** *(Chapter 17)* | Low light level reaching visual receptors | Dilation of pupil | |
| **Ejaculation (in males)** *(Chapter 28)* | Erotic stimuli (tactile) | Skeletal muscle contractions ejecting semen | |

# 16-7 Visceral Reflexes Regulate the ANS

- Higher Levels of Autonomic Control
  - Simple reflexes from spinal cord provide rapid and automatic responses
  - Complex reflexes coordinated in medulla oblongata
    - Contains centers and nuclei involved in:
      - Salivation
      - Swallowing
      - Digestive secretions
      - Peristalsis
      - Urinary function
    - Regulated by hypothalamus

**Figure 16-12 A Comparison of Somatic and Autonomic Function**



# 16-8 Higher-Order Functions

- Memory
  - **Fact memories**
    - Are specific bits of information
  - **Skill memories**
    - Learned motor behaviors
    - Incorporated at unconscious level with repetition
    - Programmed behaviors stored in appropriate area of brain stem
    - Complex are stored and involve motor patterns in the basal nuclei, cerebral cortex, and cerebellum

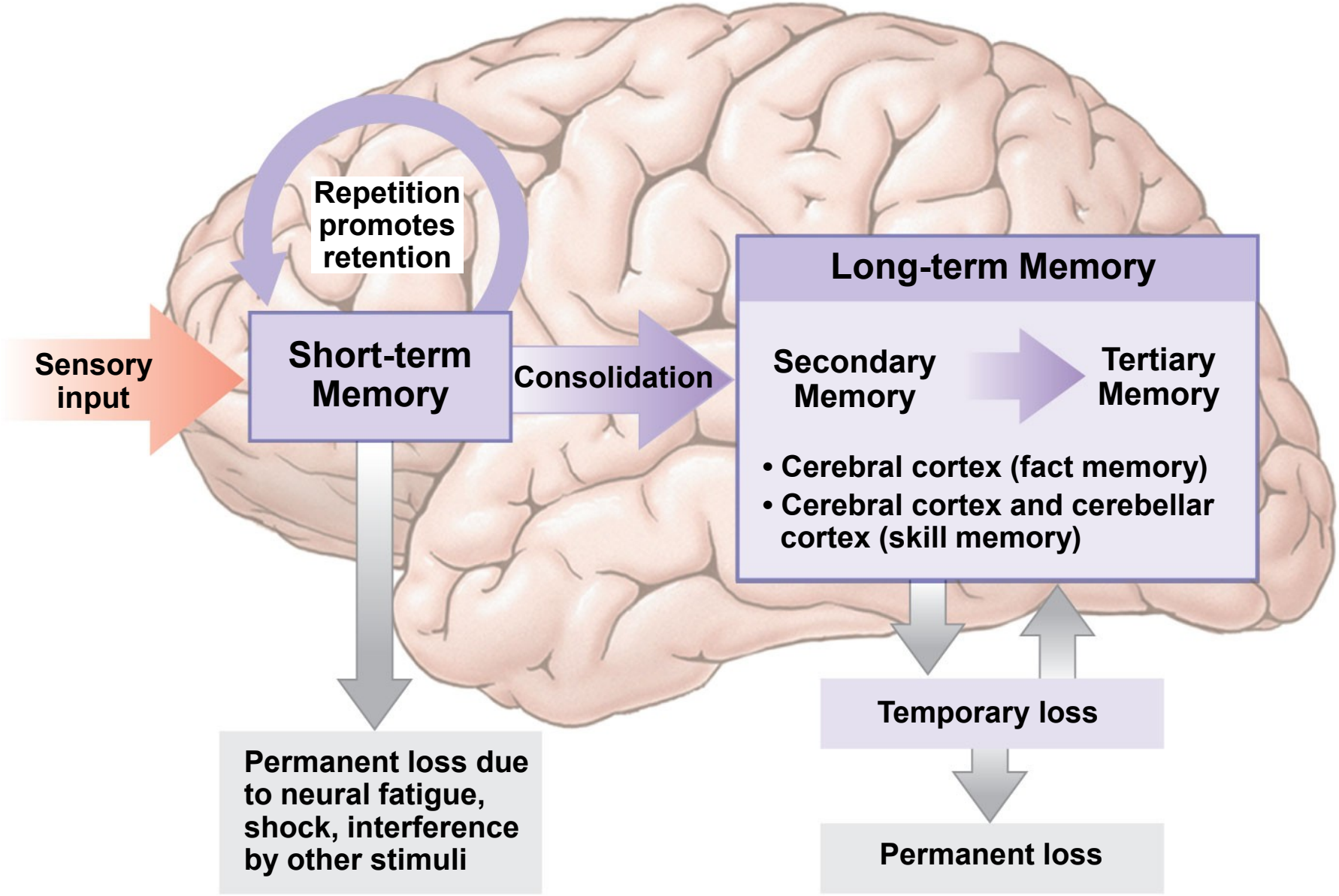
# 16-8 Higher-Order Functions

- Memory
  - **Short-term memories**
    - Information that can be recalled immediately
    - Contain small bits of information
    - *Primary memories*

# 16-8 Higher-Order Functions

- Memory
  - **Long-term memories**
    - **Memory consolidation** – conversion from short-term to long-term memory
    - Two types of long-term memory
      1. *Secondary memories* fade and require effort to recall
      2. *Tertiary memories* are with you for life

**Figure 16-13 Memory Storage**



# 16-8 Higher-Order Functions

- Brain Regions Involved in Memory Consolidation and Access
  - Amygdaloid body and hippocampus
  - Nucleus basalis
  - Cerebral cortex

# 16-8 Higher-Order Functions

- Amygdaloid Body and Hippocampus
  - Are essential to memory consolidation
  - Damage may cause:
    - Inability to convert short-term memories to new long-term memories
    - Existing long-term memories remain intact and accessible

# 16-8 Higher-Order Functions

- **Nucleus Basalis**
  - Cerebral nucleus near diencephalon
  - Plays uncertain role in memory storage and retrieval
  - Tracts connect with hippocampus, amygdaloid body, and cerebral cortex
  - Damage changes emotional states, memory, and intellectual functions

# 16-8 Higher-Order Functions

- Cerebral Cortex
  - Stores long-term memories
  - Conscious motor and sensory memories referred to association areas
  - Occipital and temporal lobes

# 16-8 Higher-Order Functions

- Cerebral Cortex
  - Visual association area
  - Auditory association area
  - Speech center
  - Frontal lobes
  - Related information stored in other locations
    - If storage area is damaged, memory will be incomplete

# 16-8 Higher-Order Functions

- Cellular Mechanisms of Memory Formation and Storage
  - Involves anatomical and physiological changes in neurons and synapses
    - *Increased neurotransmitter release*
    - *Facilitation at synapses*
    - *Formation of additional synaptic connections*

# 16-8 Higher-Order Functions

- Cellular Mechanisms of Memory Formation and Storage
  - Basis of memory storage
    - Processes create anatomical changes
    - Facilitate communication along specific neural circuit

# 16-8 Higher-Order Functions

- Cellular Mechanisms of Memory Formation and Storage
  - Efficient conversion of short-term memory
    - Takes at least 1 hour
    - Repetition crucial
  - Factors of conversion
    - Nature, intensity, and frequency of original stimulus
    - Strong, repeated, and exceedingly pleasant or unpleasant events likely converted to long-term memories

# 16-8 Higher-Order Functions

- Cellular Mechanisms of Memory Formation and Storage
  - Drugs stimulate CNS
    - Caffeine
      - Enhance memory consolidation through facilitation

# 16-8 Higher-Order Functions

- States of Consciousness
  - **Deep sleep**
    - Also called *slow-wave or Non-REM (NREM)* sleep
    - Entire body relaxes
    - Cerebral cortex activity minimal
    - Heart rate, blood pressure, respiratory rate, and energy utilization decline up to 30%

# 16-8 Higher-Order Functions

- States of Consciousness
  - **Rapid eye movement (REM) sleep**
    - Active dreaming occurs
    - Changes in blood pressure and respiratory rate
    - Less receptive to outside stimuli than in deep sleep
    - Muscle tone decreases markedly
    - Intense inhibition of somatic motor neurons
    - Eyes move rapidly as dream events unfold

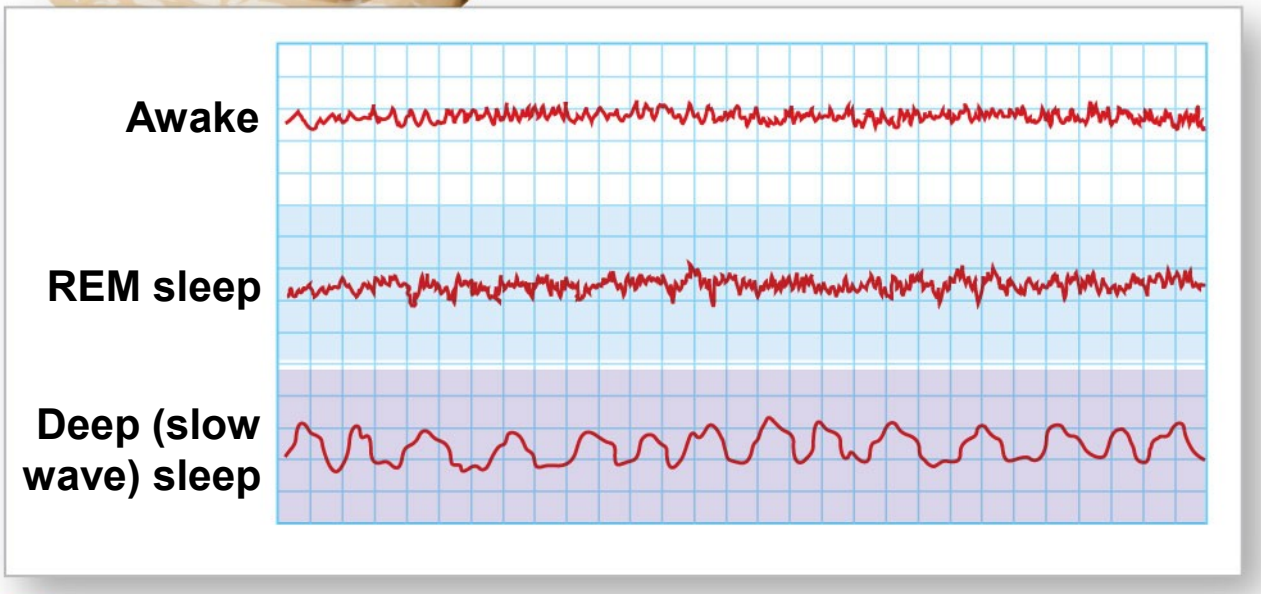
# 16-8 Higher-Order Functions

- States of Consciousness
  - Nighttime sleep pattern
    - Alternates between levels
    - Begins in deep sleep
    - REM periods average 5 minutes in length; increase to 20 minutes over 8 hours

# 16-8 Higher-Order Functions

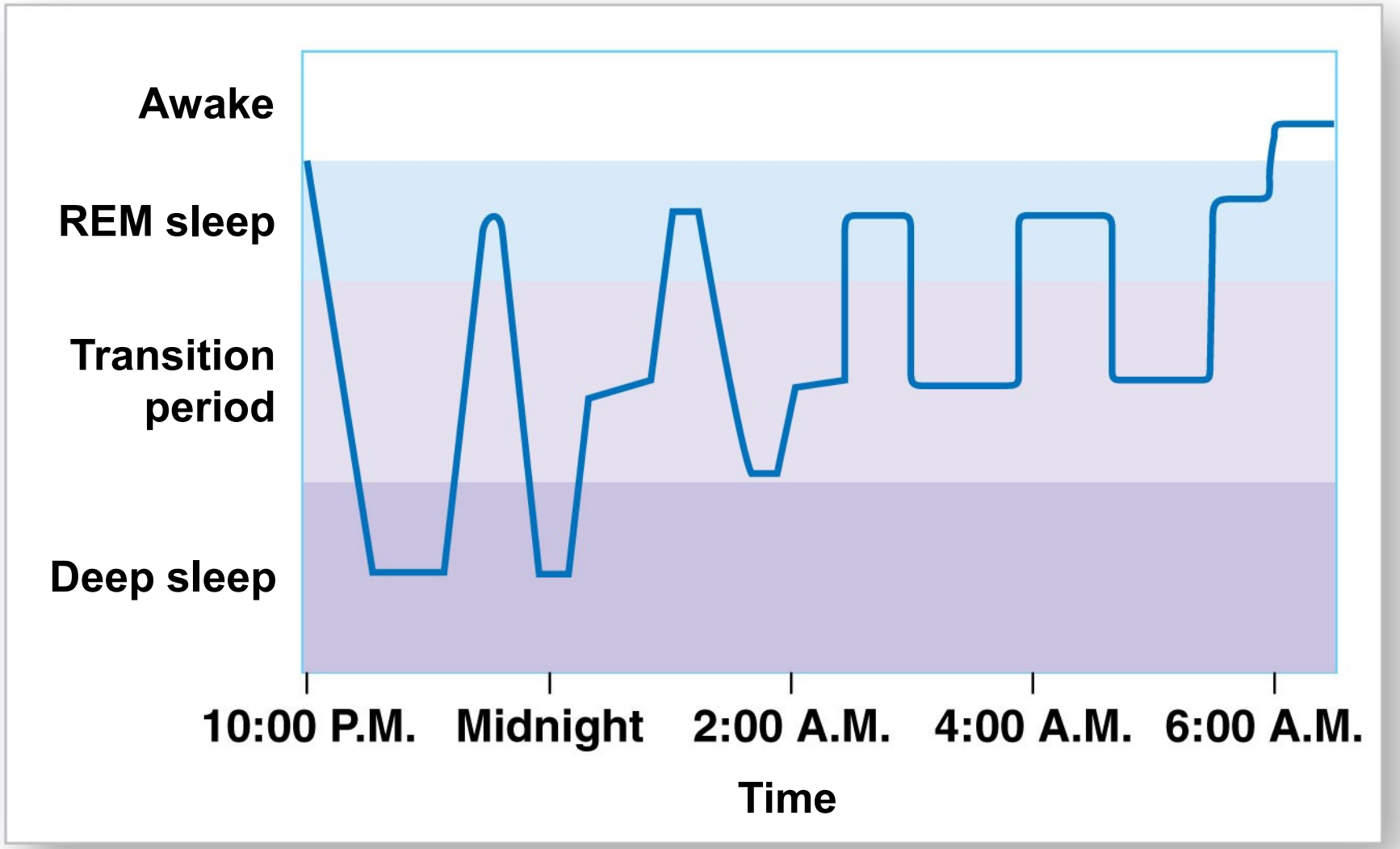
- Sleep
  - Has important impact on CNS
  - Produces only minor changes in physiological activities of organs and systems
  - Extended periods without sleep lead to disturbances in mental function

Figure 16-14a Levels of Sleep




**a** EEG from the awake, REM, and deep (slow wave) sleep states. The EEG pattern during REM sleep resembles the alpha waves typical of awake adults.

Figure 16-14b Levels of Sleep




**b** Typical pattern of sleep stages in a healthy young adult during a single night's sleep.