Essentials of Human Anatomy & Physiology

Seventh Edition

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Chapter 7

The Nervous System

Slides 7.1 – 7.102

Lecture Slides in PowerPoint by Jerry L. Cook

Functions of the Nervous System

- Sensory input – gathering information
  - To monitor changes occurring inside and outside the body
  - Changes = stimuli
- Integration
  - To process and interpret sensory input and decide if action is needed
- Motor output
  - A response to integrated stimuli
  - The response activates muscles or glands

Structural Classification of the Nervous System

- Central nervous system (CNS)
  - Brain and Spinal cord
  - Acts as integrating and command center – interpret incoming sensory information and issue instructions based on past experiences and current conditions
- Peripheral nervous system (PNS)
  - Nerves outside the brain and spinal cord
  - Link all parts of the body by carrying impulses to the CNS and back

Functional Classification of the Peripheral Nervous System

- Sensory (afferent) division
  - Nerve fibers that carry information *to* the central nervous system

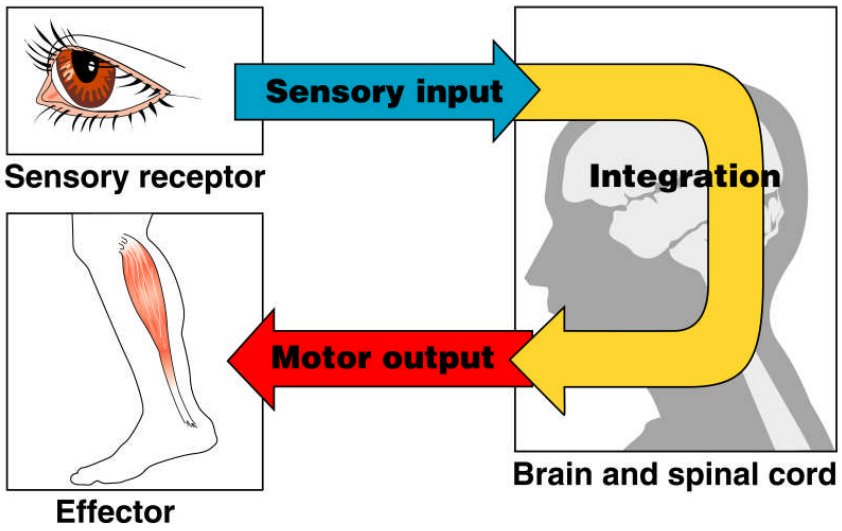


Figure 7.1

Functional Classification of the Peripheral Nervous System

- Motor (efferent) division
  - Nerve fibers that carry impulses *away from* the central nervous system

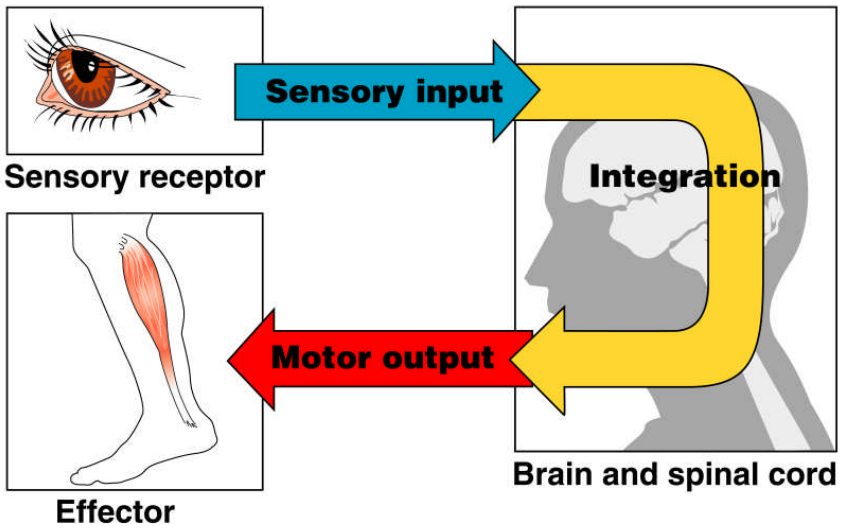


Figure 7.1

Functional Classification of the Peripheral Nervous System

- Motor (efferent) division
  - Two subdivisions
    - Somatic nervous system = voluntary nervous system
      - Skeletal muscle reflexes such as stretch reflex are initiated involuntarily by same fibers
    - Autonomic nervous system = involuntary nervous system
      - Sympathetic and parasympathetic divisions

Organization of the Nervous System

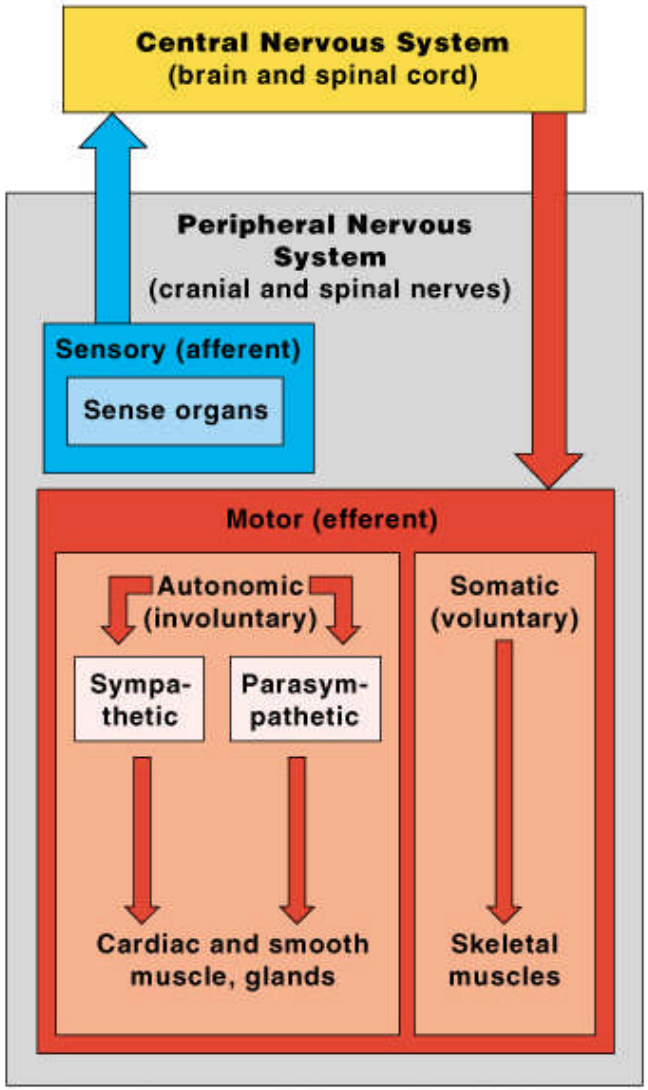


Figure 7.2

Nervous Tissue: Support Cells (Neuroglia) - glia

- Astrocytes
  - Abundant, star-shaped cells
  - Brace neurons
  - Form barrier between capillaries and neurons and make exchanges between the two
  - Control the chemical environment of the brain by capturing ions and neurotransmitters

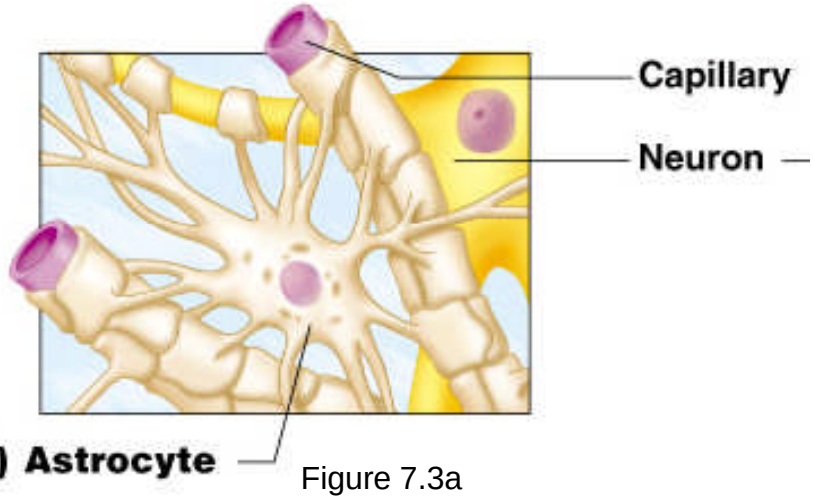
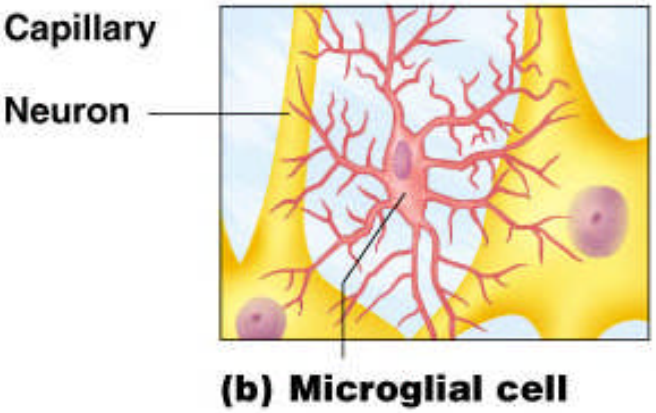


Figure 7.3a

Nervous Tissue: Support Cells

- Microglia
  - Spider-like phagocytes
  - Dispose of debris – dead cells and bacteria
- Ependymal cells
  - Line cavities of the brain and spinal cord
  - Circulate cerebrospinal fluid with cilia



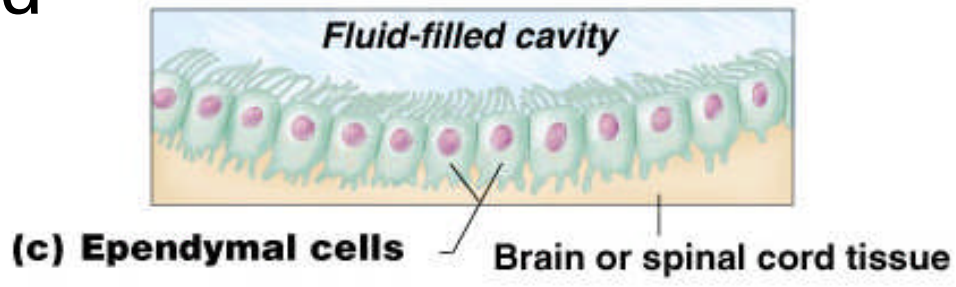


Figure 7.3b, c

Nervous Tissue: Support Cells

- Oligodendrocytes
  - Wrap their flat extensions tightly around the nerve fibers
  - Produce myelin sheath around nerve fibers in the central nervous system

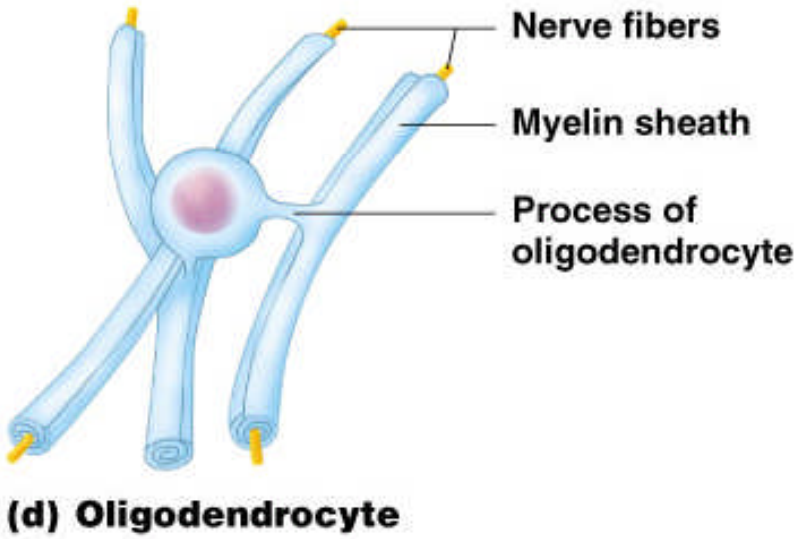
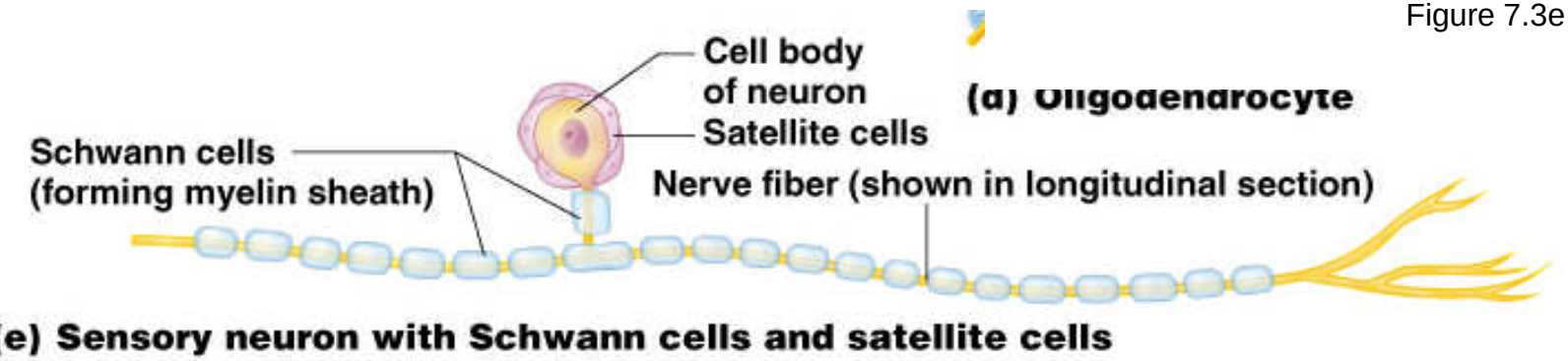


Figure 7.3d

Nervous Tissue: Support Cells

- Satellite cells
  - Protect neuron cell bodies
- Schwann cells
  - Form myelin sheath in the peripheral nervous system
- Neuroglia are not able to transmit nerve impulses but do not lose their ability to divide, unlike neurons

Figure 7.3e



Nervous Tissue: Neurons

- Neurons = nerve cells
  - Cells specialized to transmit messages
  - Major regions of neurons
    - Cell body – nucleus and metabolic center of the cell
    - Processes – fibers that extend from the cell body

Neuron Anatomy

- Cell body
  - Nissl substance – specialized rough endoplasmic reticulum
  - Neurofibrils – intermediate cytoskeleton that maintains cell shape

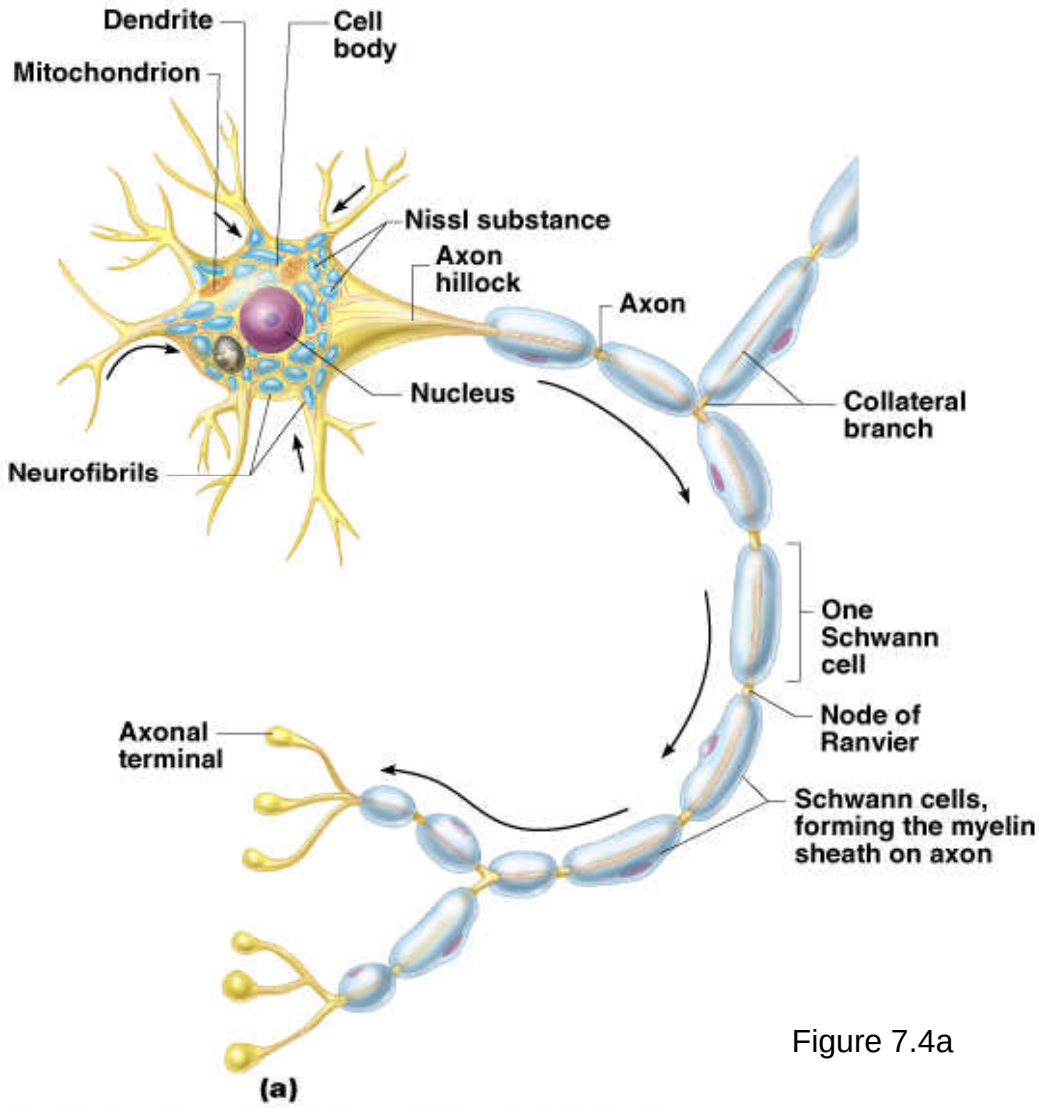


Figure 7.4a

Neuron Anatomy

- Cell body
  - Nucleus
  - Large nucleolus

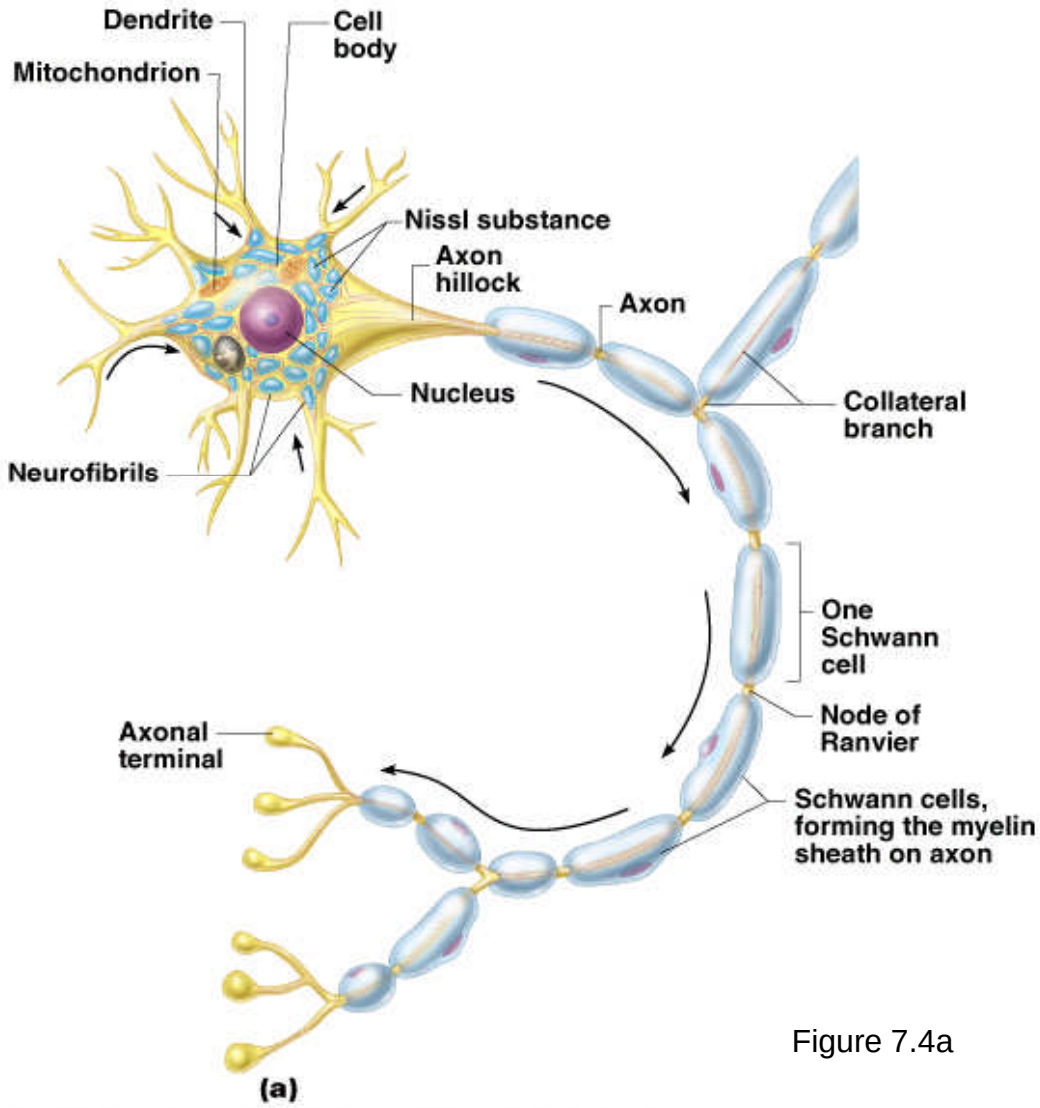


Figure 7.4a

Neuron Anatomy

- Extensions outside the cell body
  - Dendrites – conduct impulses toward the cell body
  - Axons – conduct impulses away from the cell body

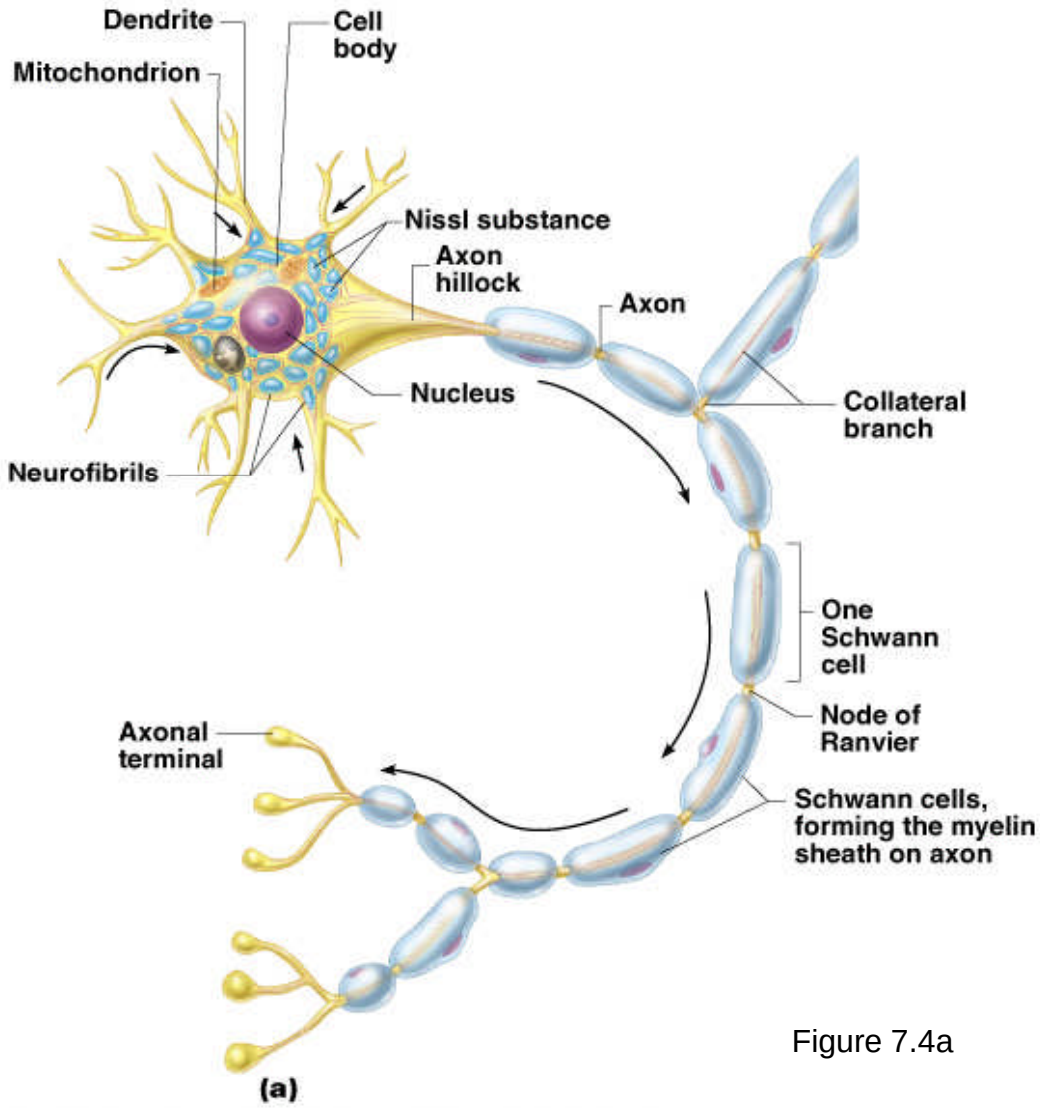


Figure 7.4a

Axons and Nerve Impulses

- Axons end in axonal terminals
- Axonal terminals contain vesicles with neurotransmitters
- Axonal terminals are separated from the next neuron by a gap
  - Synaptic cleft – gap between adjacent neurons
  - Synapse – junction between nerves

Nerve Fiber Coverings

- Schwann cells – produce myelin sheaths in jelly-roll like fashion
- Nodes of Ranvier – gaps in myelin sheath along the axon

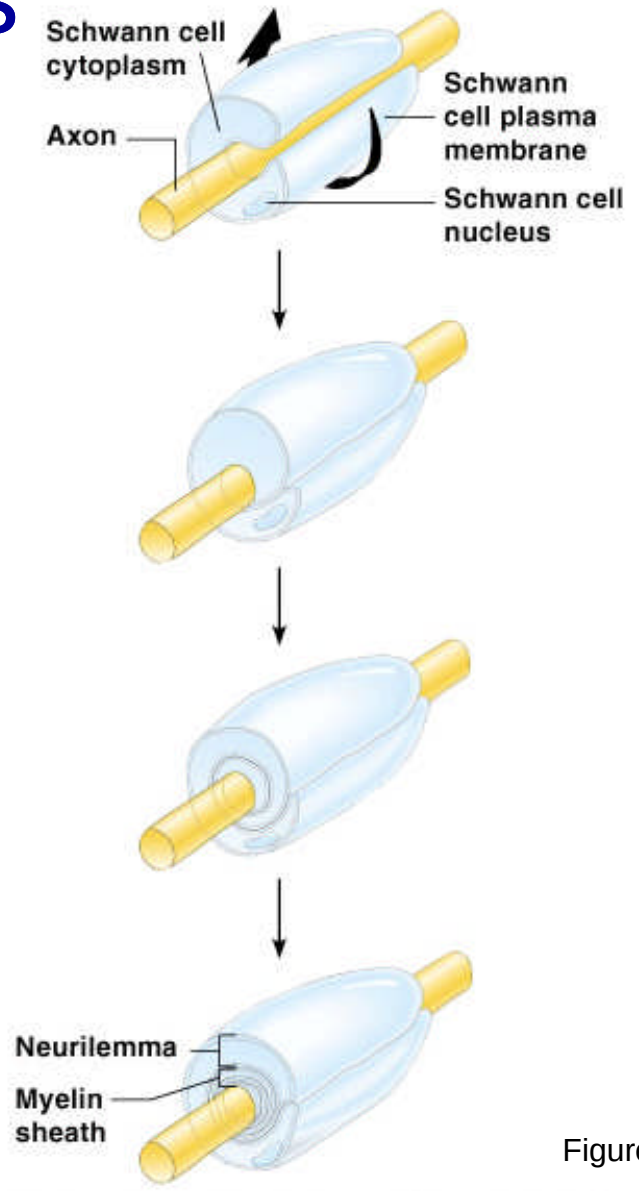


Figure 7.5

Neuron Cell Body Location

- Most are found in the central nervous system in clusters called nuclei
  - Bundles of nerve fibers in CNS = tracts
    - Gray matter – cell bodies and unmyelinated fibers
    - White matter – myelinated fibers
  - Bundles of nerve fibers in PNS = nerves
- Ganglia – collections of cell bodies outside the central nervous system

Functional Classification of Neurons

- Sensory (afferent) neurons
  - Cell bodies in a ganglion outside the CNS
  - Carry impulses from the sensory receptors to CNS
    - Cutaneous (skin) sense organs
    - Proprioceptors – detect stretch or tension in muscles, tendons, joints
- Motor (efferent) neurons
  - Cell bodies found in the CNS
  - Carry impulses from the central nervous system

Functional Classification of Neurons

- Interneurons (association neurons)
  - Found in neural pathways in the central nervous system
    - Cell bodies in the CNS
  - Connect sensory and motor neurons

Neuron Classification

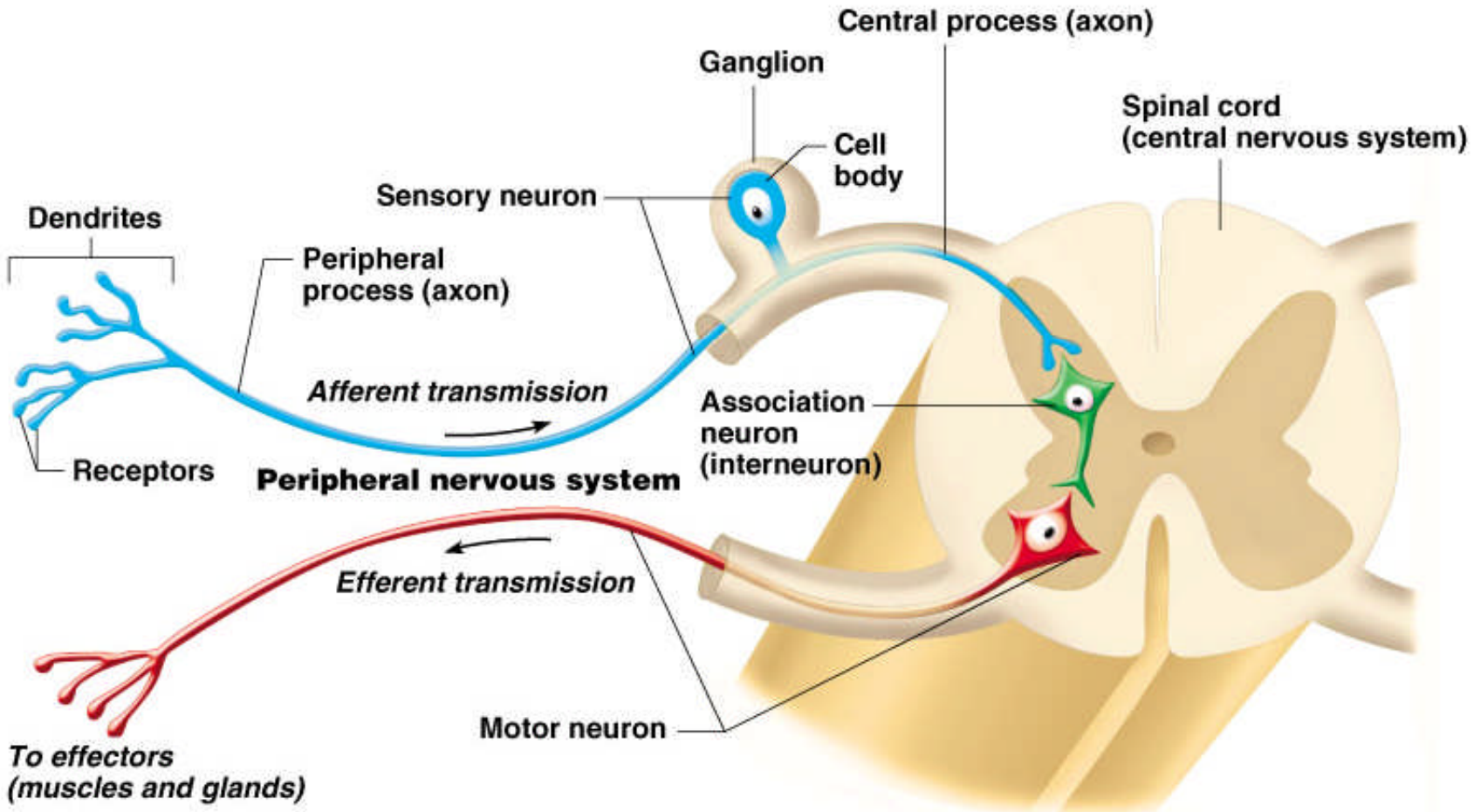


Figure 7.6

Structural Classification of Neurons

- Multipolar neurons – many extensions from the cell body

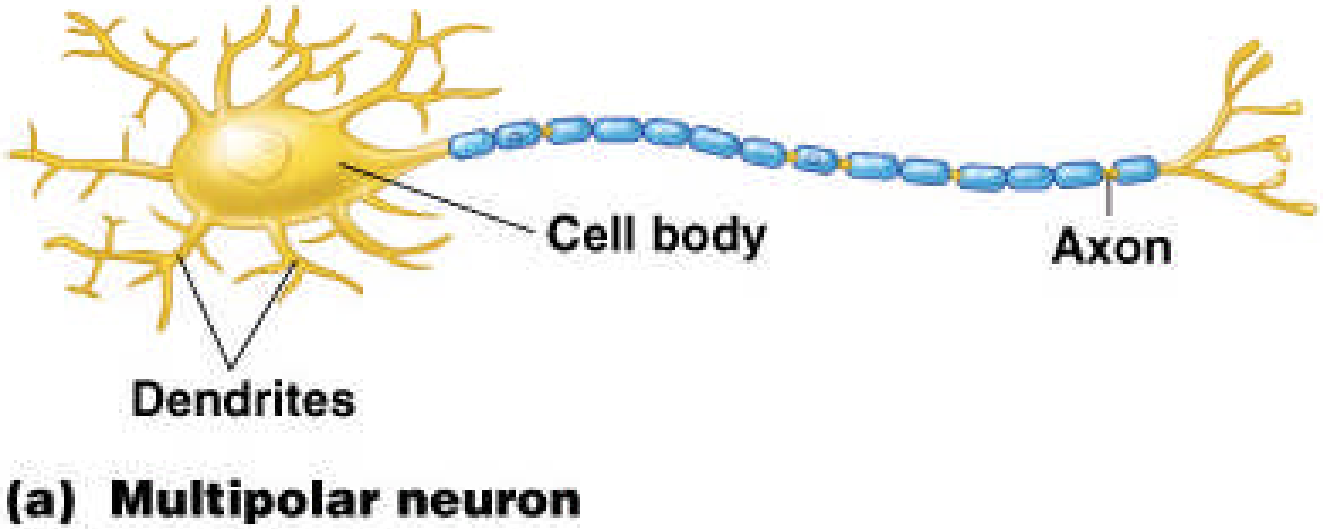


Figure 7.8a

Structural Classification of Neurons

- Bipolar neurons – one axon and one dendrite
  - Rare in adults – in eye and ear only

(b) Bipolar neuron

Figure 7.8b

Structural Classification of Neurons

- Unipolar neurons – have a short, single process leaving the cell body
  - Axon conducts nerve impulses both to and from the cell body

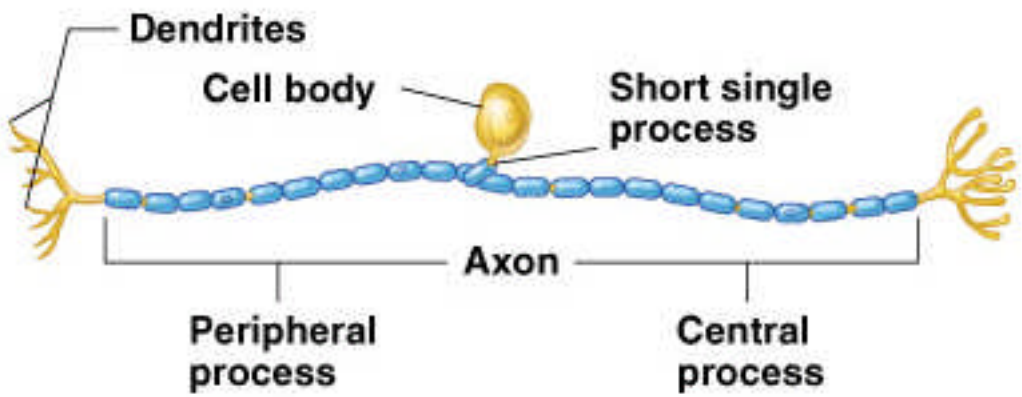


Figure 7.8c

Functional Properties of Neurons

- Two main functions
  - Irritability – ability to respond to stimuli
  - Conductivity – ability to transmit an impulse
- The plasma membrane at rest is polarized
  - Fewer positive ions (usually K^+) are inside the cell than outside the cell (usually Na^+)

Starting a Nerve Impulse

- Depolarization – a stimulus depolarizes the neuron's membrane
- A deploarized membrane allows sodium (Na^+) to flow inside the membrane
- The exchange of ions initiates an action potential (nerve impulse) in the neuron

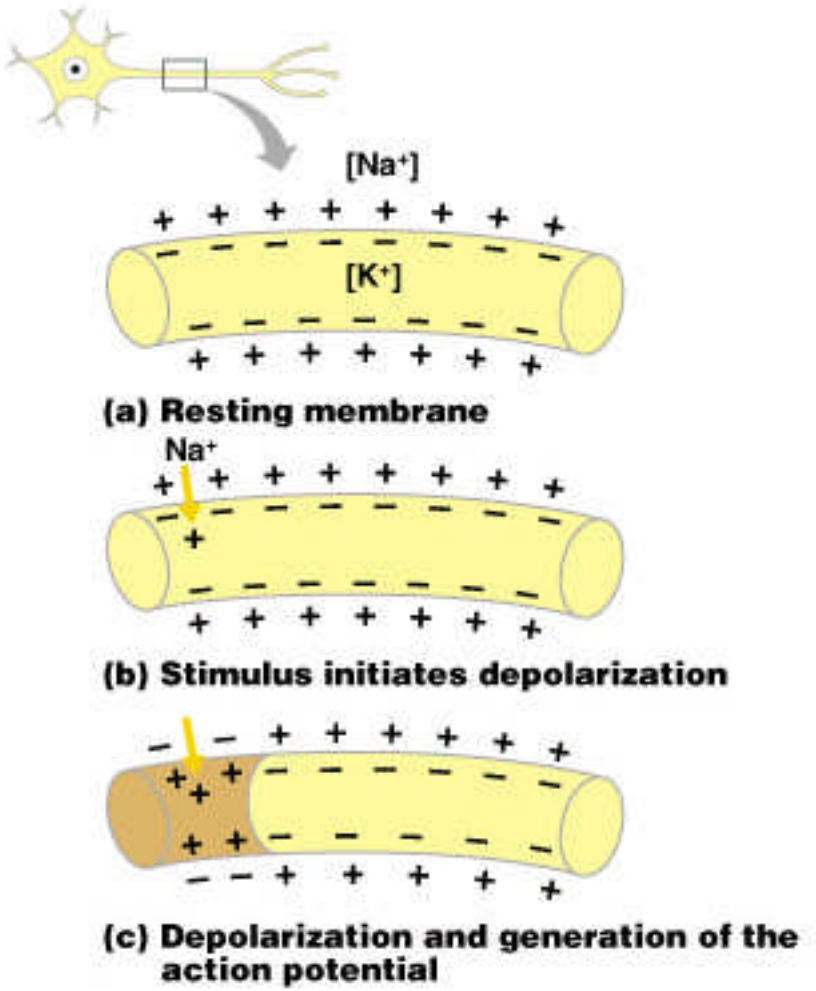


Figure 7.9a–c

Slide 7.26

The Action Potential

- If the action potential (nerve impulse) starts, it is propagated over the entire axon – all-or-none response
- Potassium ions rush out of the neuron after sodium ions rush in, which repolarizes the membrane
- The sodium-potassium pump restores the original configuration
  - This action requires ATP
- Until repolarization occurs, a neuron cannot conduct another impulse

Nerve Impulse Propagation

- The impulse continues to move toward the cell body
- Impulses travel faster when fibers have a myelin sheath
  - Nerve impulse literally jumps from node to node because it cannot cross myelin insulation

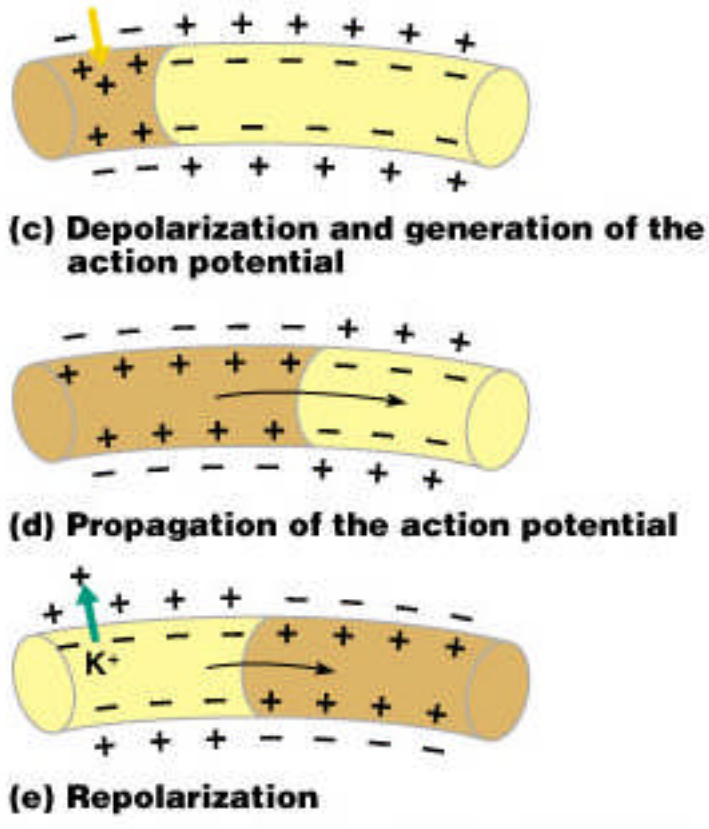


Figure 7.9c–e

Continuation of the Nerve Impulse between Neurons

- Impulses are unable to cross the synapse to another nerve
  - Neurotransmitter is released from a nerve's axon terminal
  - The dendrite of the next neuron has receptors that are stimulated by the neurotransmitter
  - An action potential is started in the dendrites of the next neuron
- Transmission of an impulse is an electrochemical event

How Neurons Communicate at Synapses

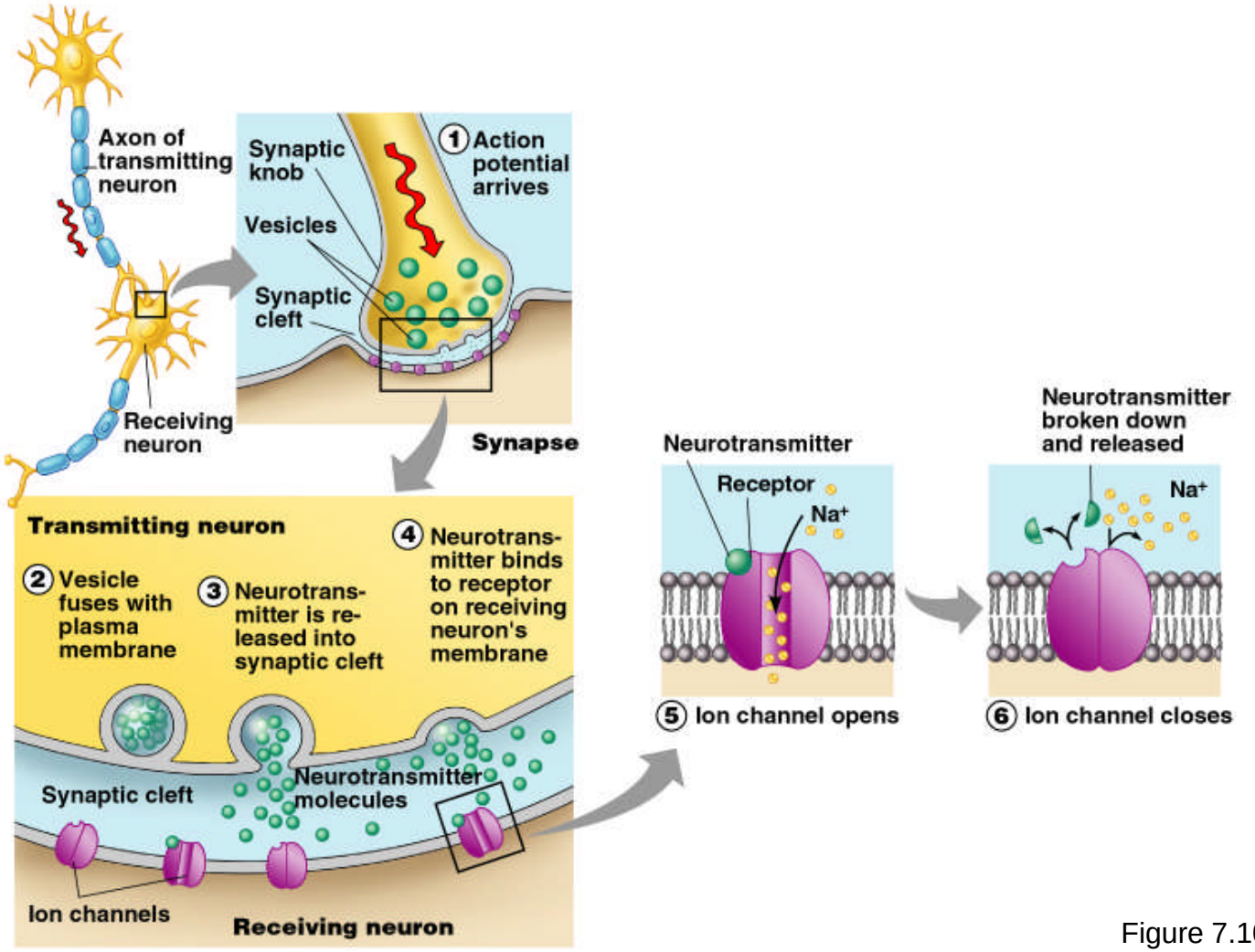


Figure 7.10

The Reflex Arc

- Reflex – rapid, predictable, and involuntary responses to stimuli
- Reflex arc – direct route from a sensory neuron, to an interneuron, to an effector

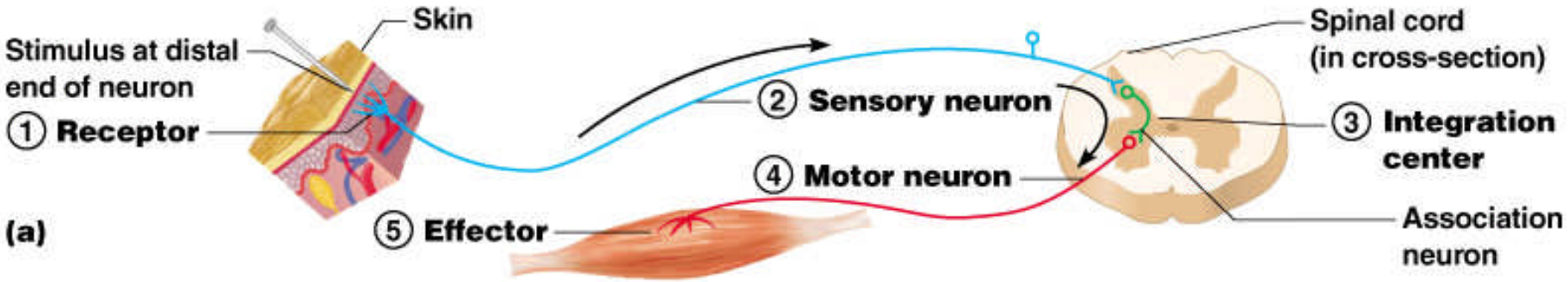


Figure 7.11a

Simple Reflex Arc

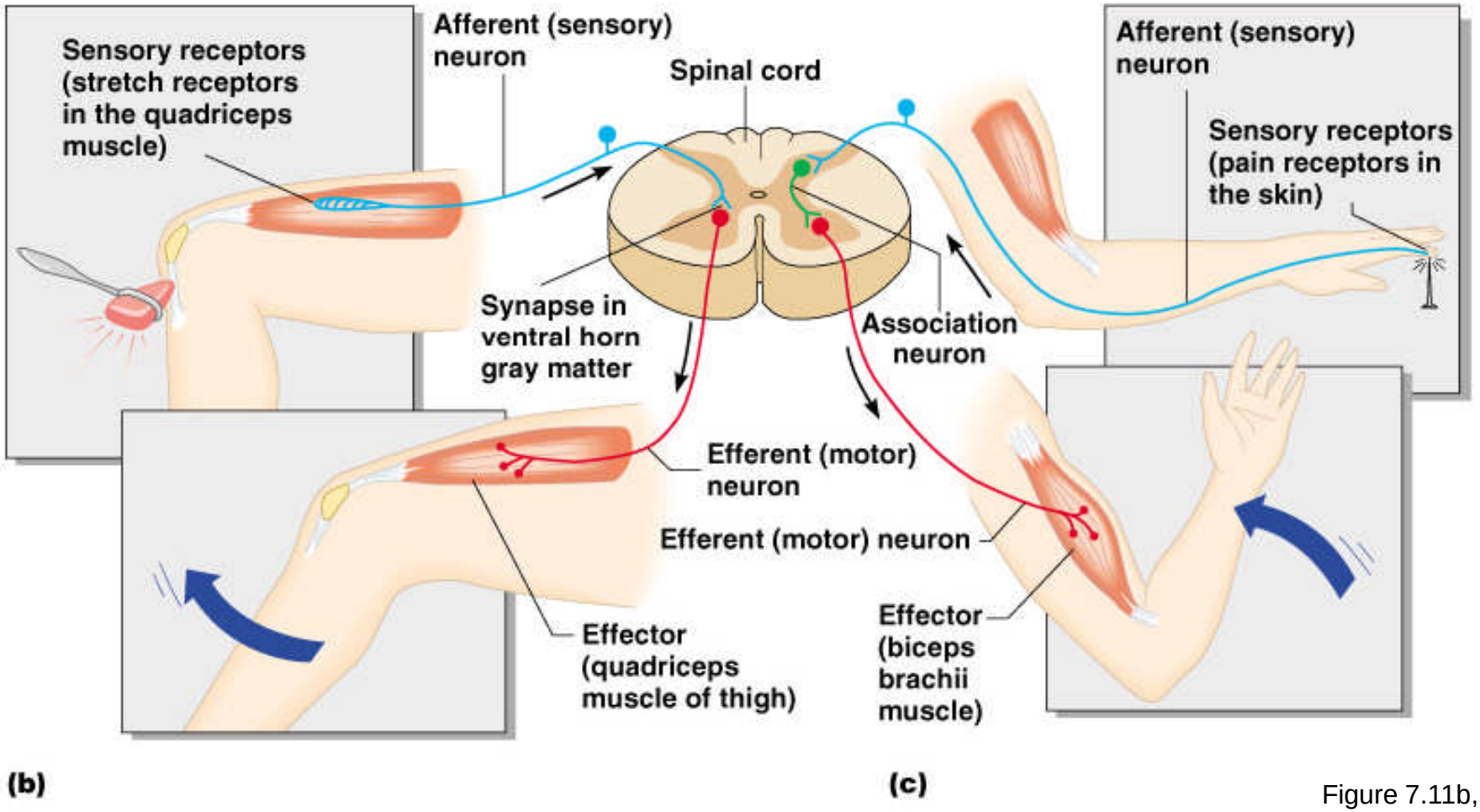


Figure 7.11b, c

Types of Reflexes and Regulation

- Autonomic reflexes
  - Smooth muscle regulation
  - Size of eye pupils
  - Heart and blood pressure regulation
  - Regulation of glands and sweating
  - Digestive system and elimination regulation
- Somatic reflexes
  - Activation of skeletal muscles

Types of Reflexes and Regulation

- Reflex arcs have a minimum five elements
  - A sensory receptor – reacts to stimuli
  - An effector receptor – muscle or gland stimulated
  - Afferent and efferent neurons connecting the two
  - The CNS integration center

Central Nervous System (CNS)

- CNS develops from the embryonic neural tube – a simple tube
  - The neural tube becomes the brain and spinal cord
  - The opening of the neural tube becomes the ventricles
    - Four chambers within the brain
    - Filled with cerebrospinal fluid

Regions of the Brain

- Cerebral hemispheres
- Diencephalon
- Brain stem
- Cerebellum

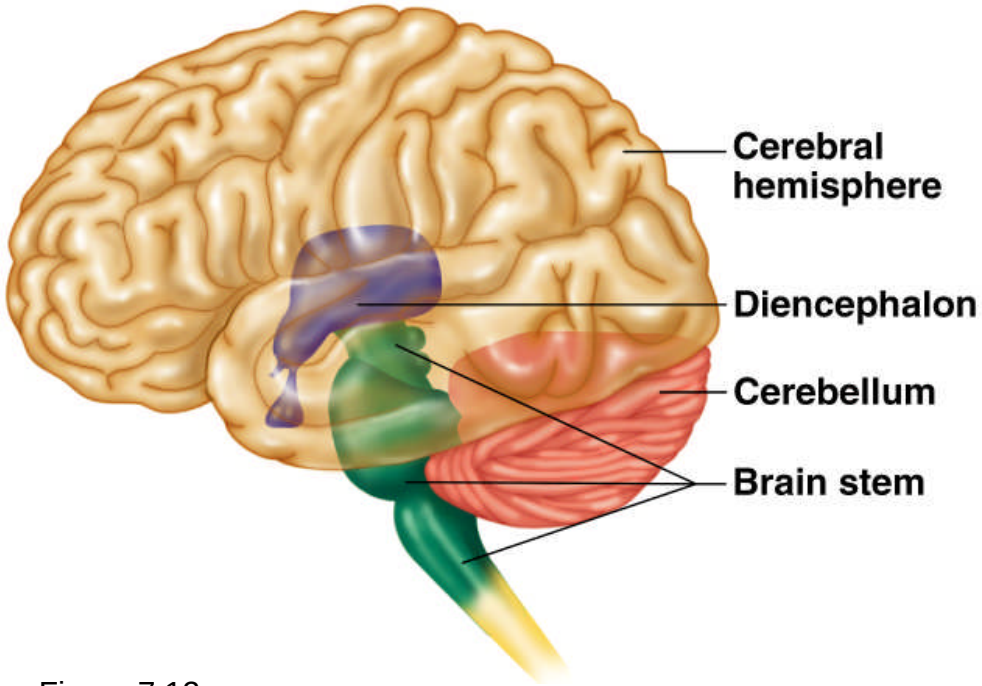


Figure 7.12

Cerebral Hemispheres (Cerebrum)

- Paired (left and right) superior parts of the brain
- Include more than half of the brain mass

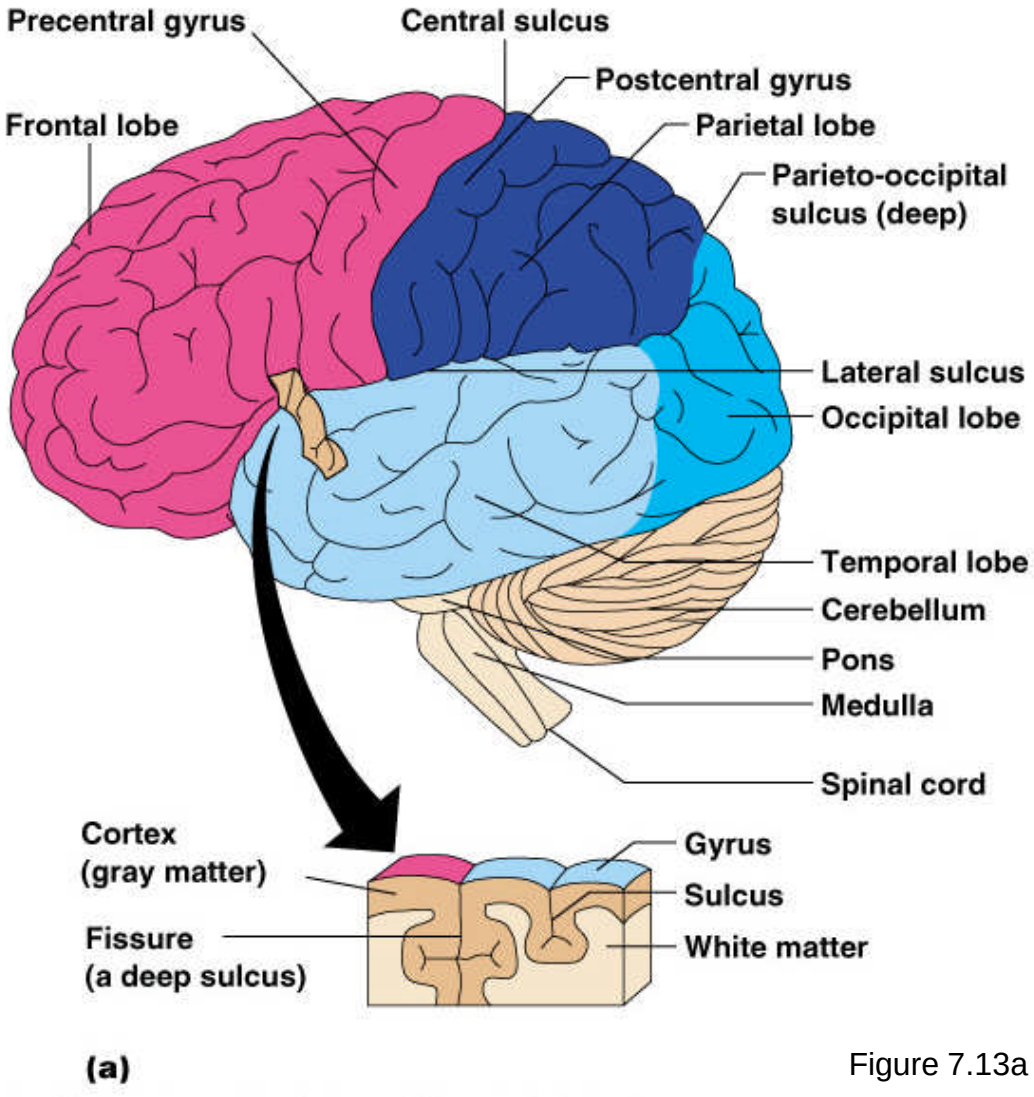


Figure 7.13a

Cerebral Hemispheres (Cerebrum)

- The surface is made of elevated ridges (gyri) and shallow grooves (sulci)

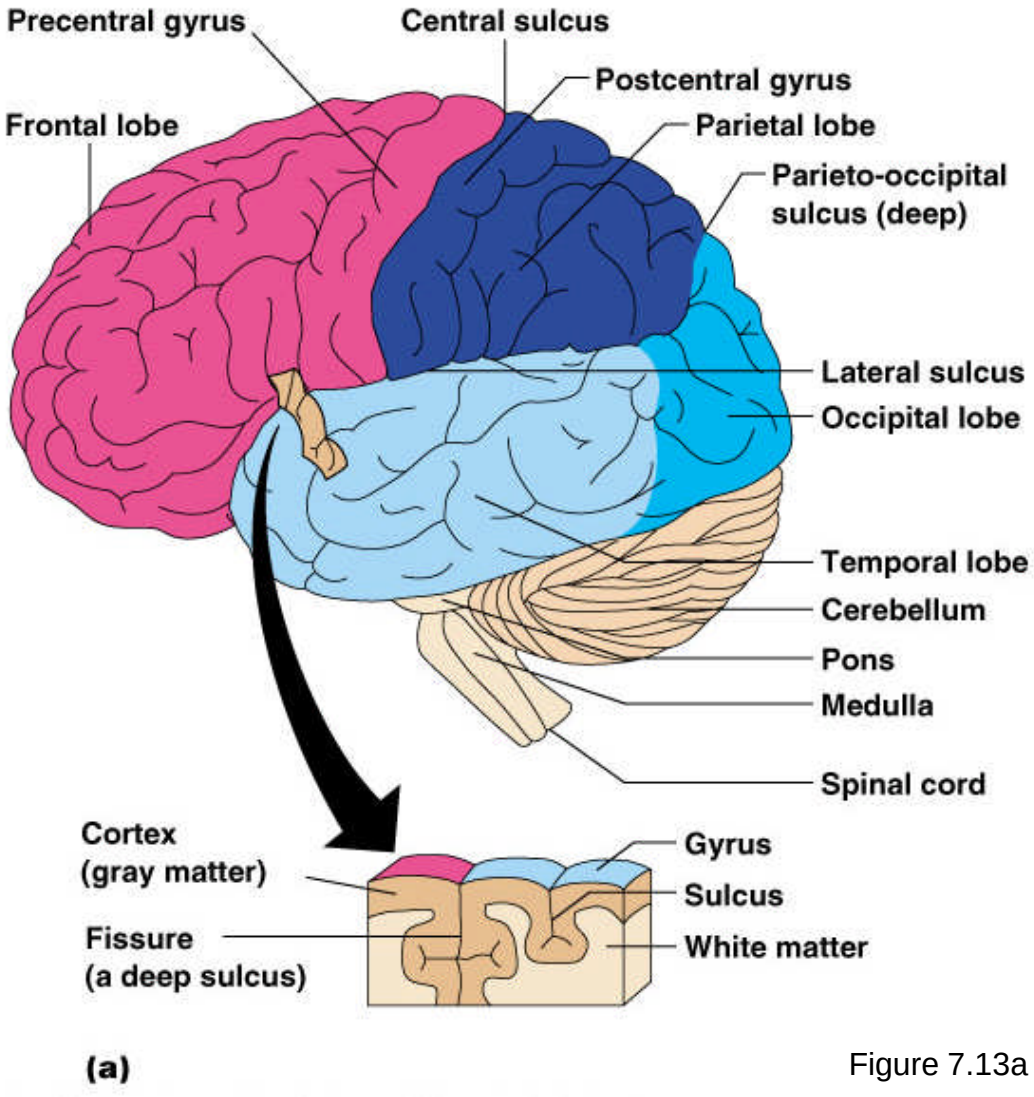


Figure 7.13a

Lobes of the Cerebrum

- Fissures (deep grooves) divide the cerebrum into lobes
- Surface lobes of the cerebrum – named for cranial bone over them
  - Frontal lobe
  - Parietal lobe
  - Occipital lobe
  - Temporal lobe

Lobes of the Cerebrum

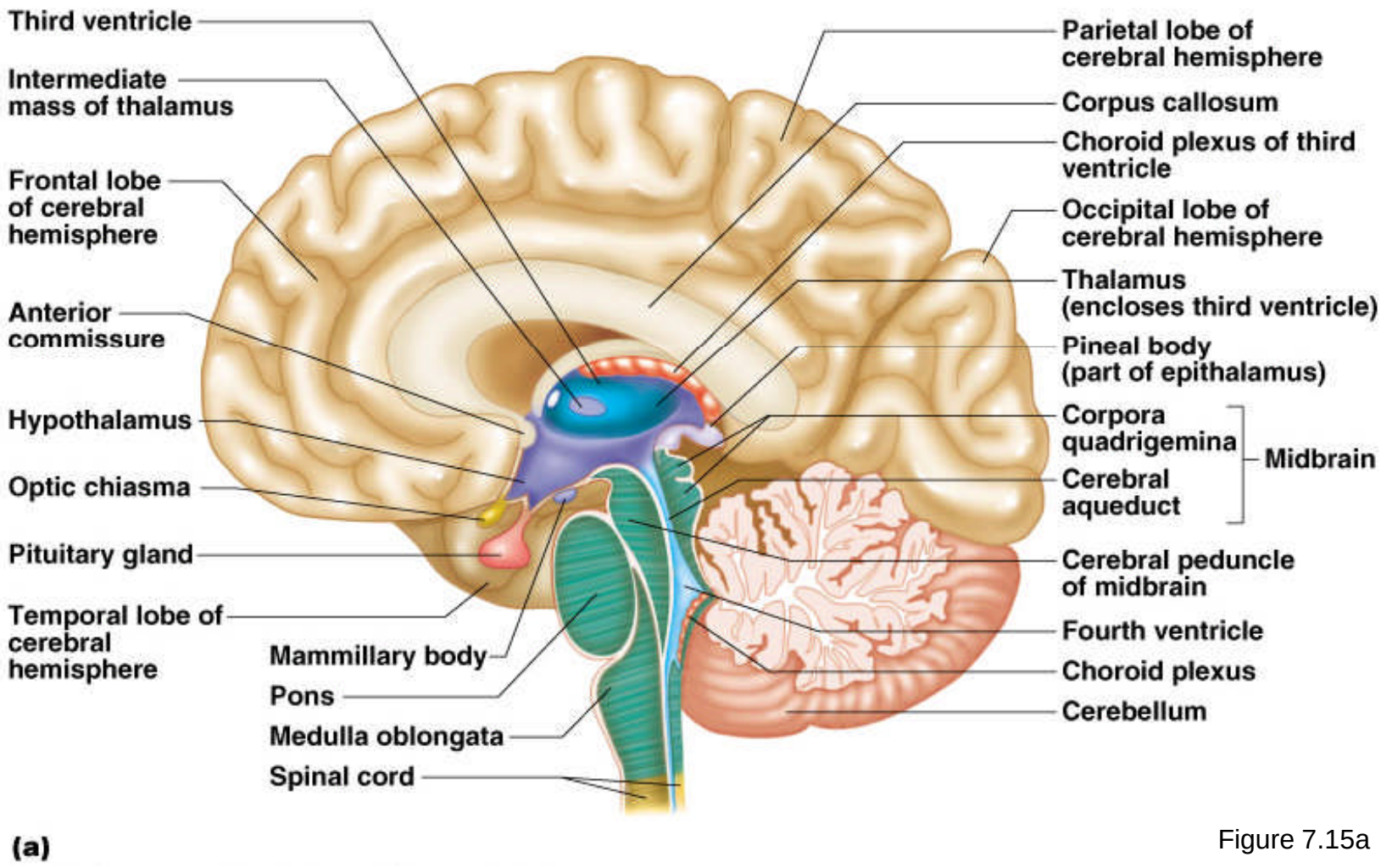


Figure 7.15a

Specialized Areas of the Cerebrum

- Somatic sensory area in parietal lobe – receives impulses from the body's sensory receptors (except special senses)
  - Occipital lobe – vision and temporal lobe – auditory
- Primary motor area – sends impulses to skeletal muscles – frontal lobe
- Broca's area – involved in our ability to speak – base of the precentral gyrus

Sensory and Motor Areas of the Cerebral Cortex

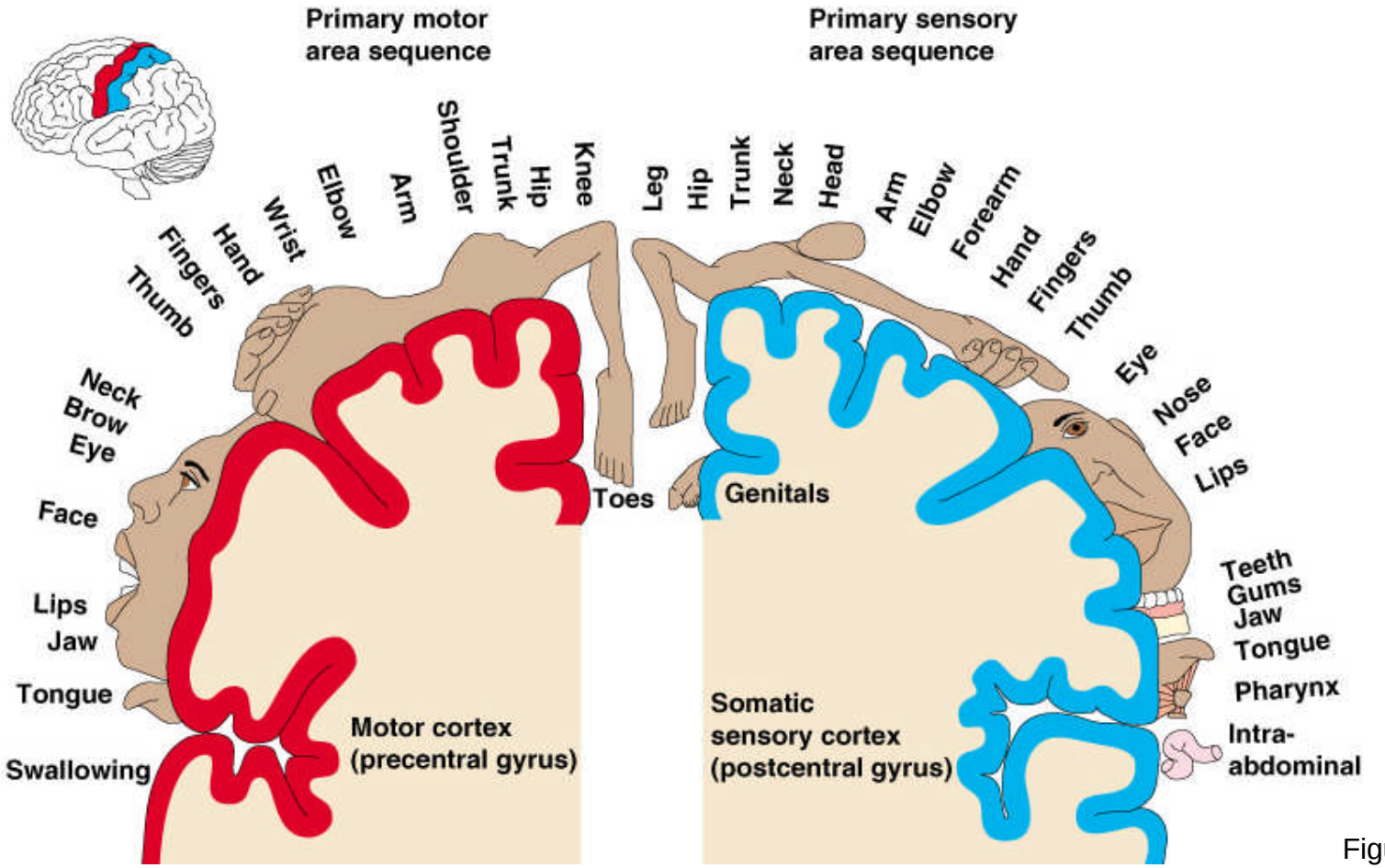


Figure 7.14

Specialized Area of the Cerebrum

- Cerebral areas involved in special senses
  - Gustatory area (taste)
  - Visual area
  - Auditory area
  - Olfactory area

Specialized Area of the Cerebrum

- Interpretation areas of the cerebrum
  - Speech/language region
  - Language comprehension region
  - General interpretation area

Specialized Area of the Cerebrum

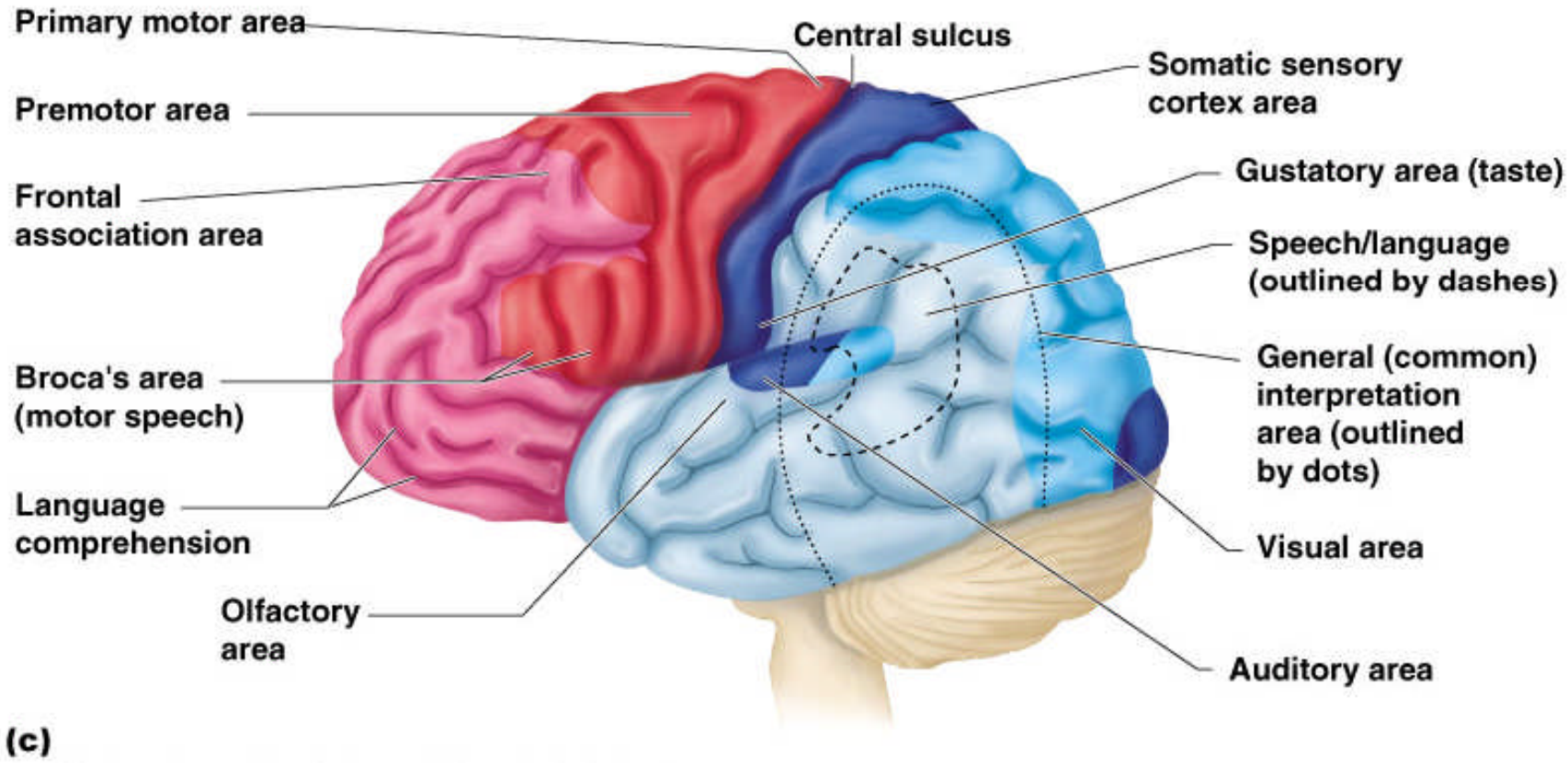


Figure 7.13c

Layers of the Cerebrum

- Gray matter
  - Outermost layer
  - Composed mostly of neuron cell bodies
  - Cerebral cortex

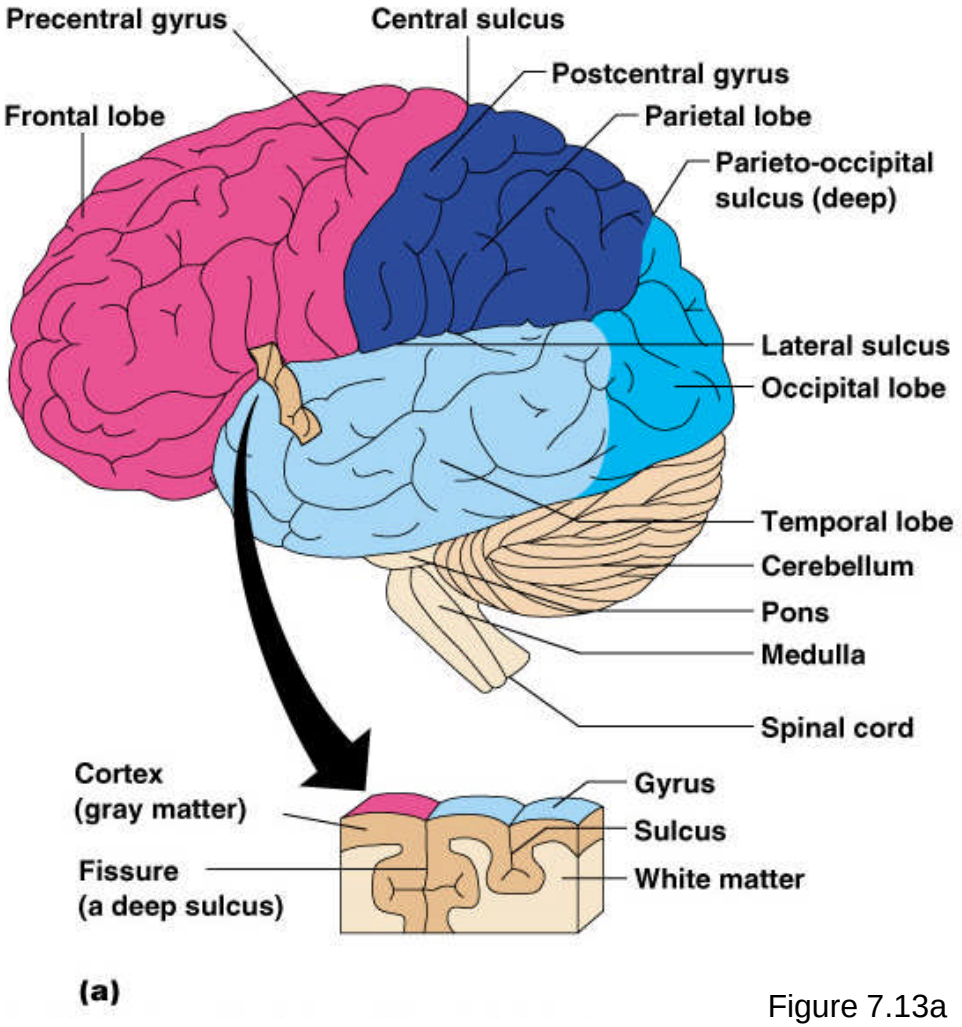


Figure 7.13a

Layers of the Cerebrum

- White matter
  - Fiber tracts inside the gray matter
  - Example: corpus callosum connects hemispheres

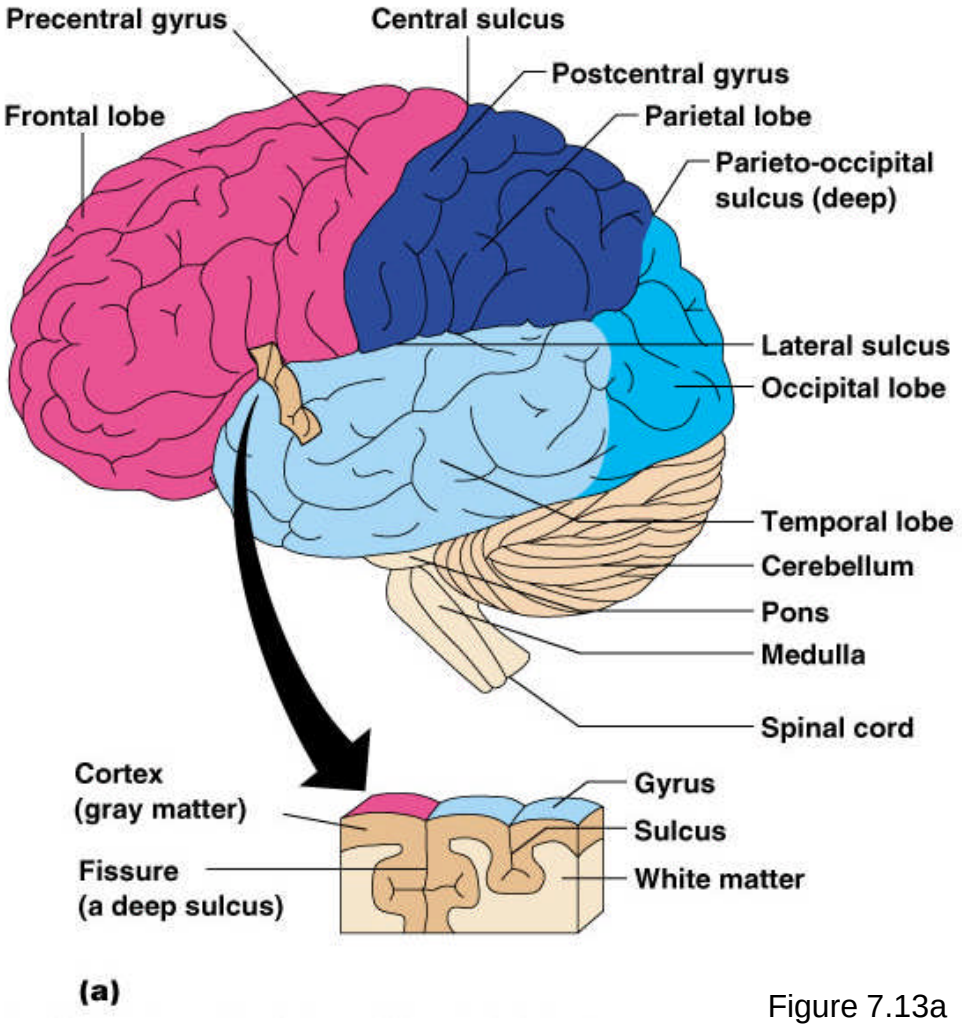


Figure 7.13a

Layers of the Cerebrum

- Basal nuclei – internal islands of gray matter
- Helps regulate voluntary motor activities by modifying instructions sent to the skeletal muscles

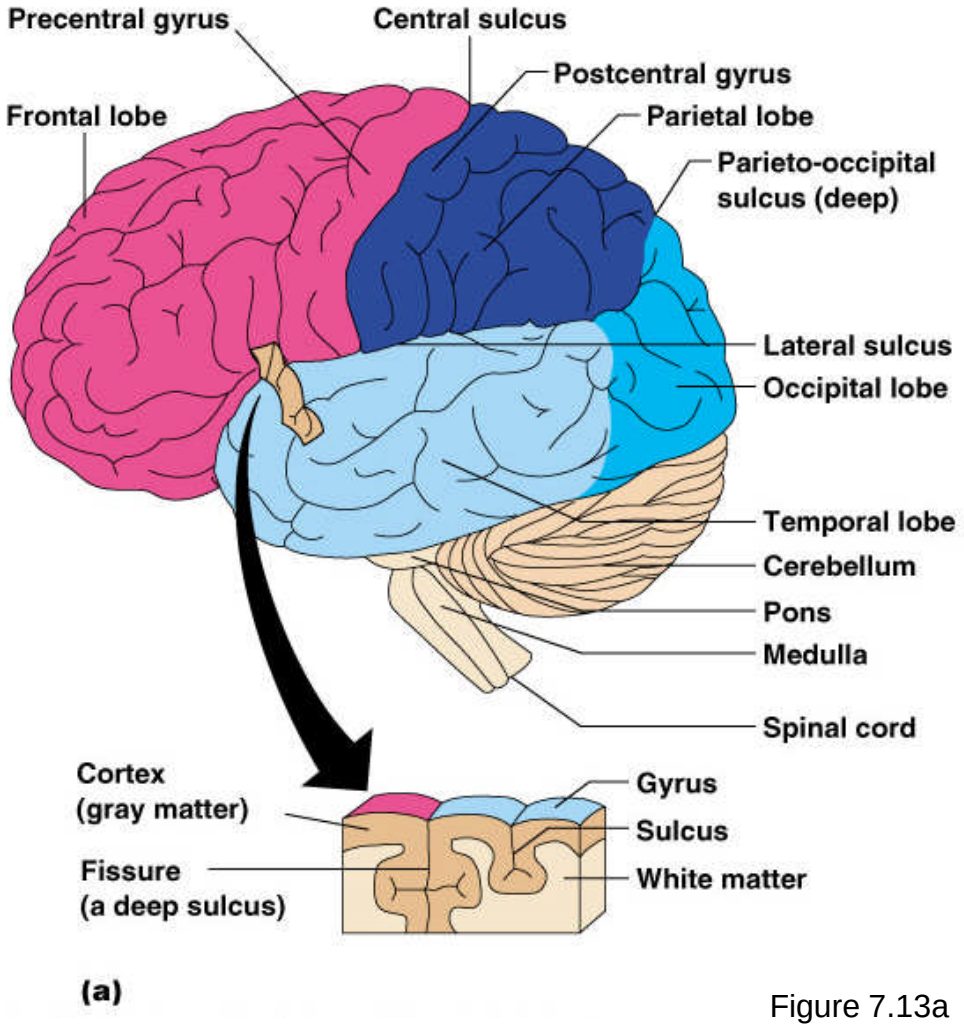


Figure 7.13a

Diencephalon - interbrain

- Sits on top of the brain stem
- Enclosed by the cerebral hemispheres
- Made of three parts
  - Thalamus
  - Hypothalamus
  - Epithalamus

Diencephalon

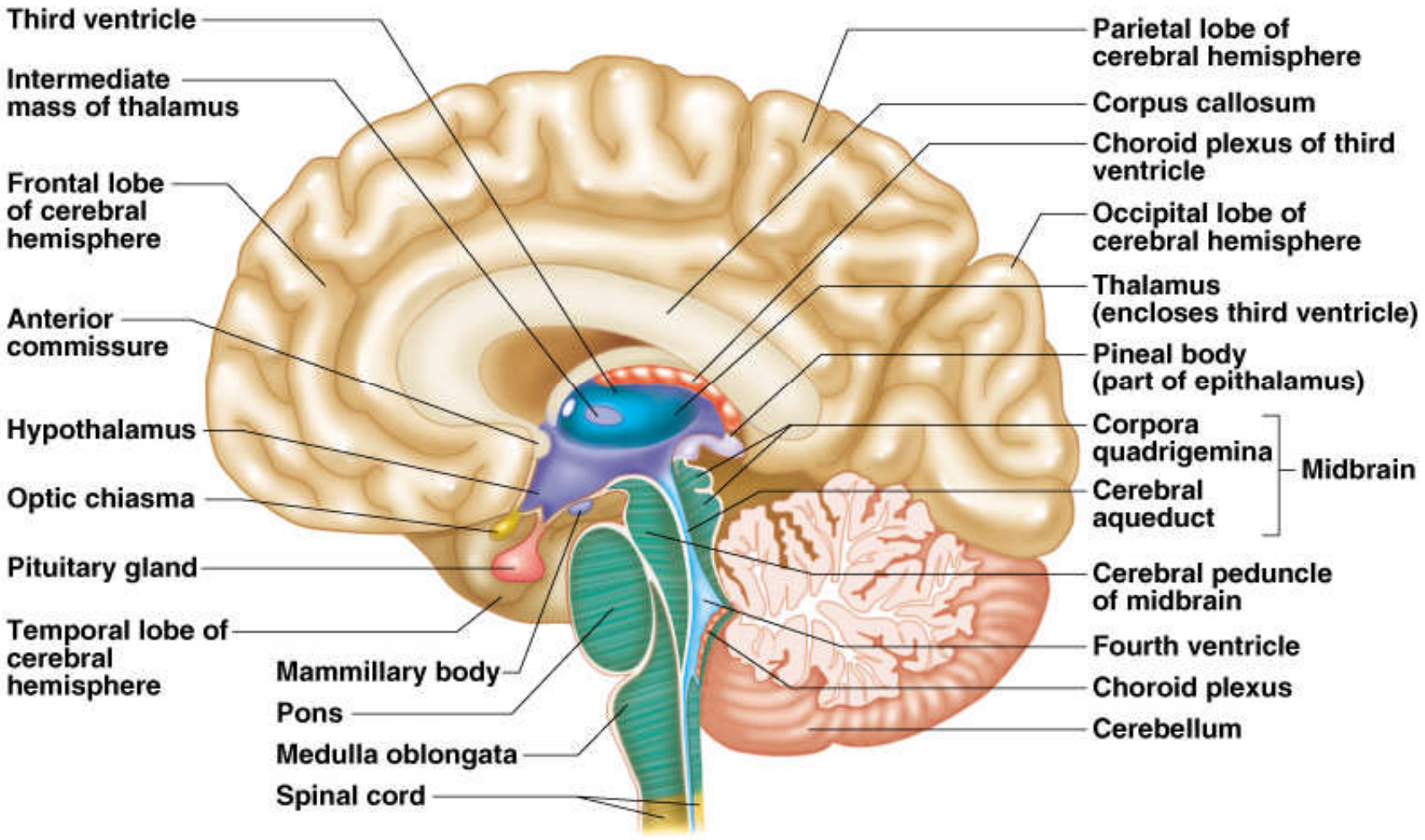


Figure 7.15

Thalamus

- Surrounds the third ventricle of the brain
- The relay station for sensory impulses passing upward to the sensory cortex
- Transfers impulses to the correct part of the cortex for localization and interpretation

Hypothalamus

- Under the thalamus
- Important autonomic nervous system center
  - Helps regulate body temperature
  - Controls water balance
  - Regulates metabolism

Hypothalamus

- An important part of the limbic system (emotions) – emotional-visceral brain
- The pituitary gland is attached to and regulated by the hypothalamus

Epithalamus

- Forms the roof of the third ventricle
- Houses the pineal body (an endocrine gland)
- Includes the choroid plexus – forms cerebrospinal fluid

Brain Stem

- Attaches to the spinal cord
- Parts of the brain stem
  - Midbrain
  - Pons
  - Medulla oblongata

Brain Stem

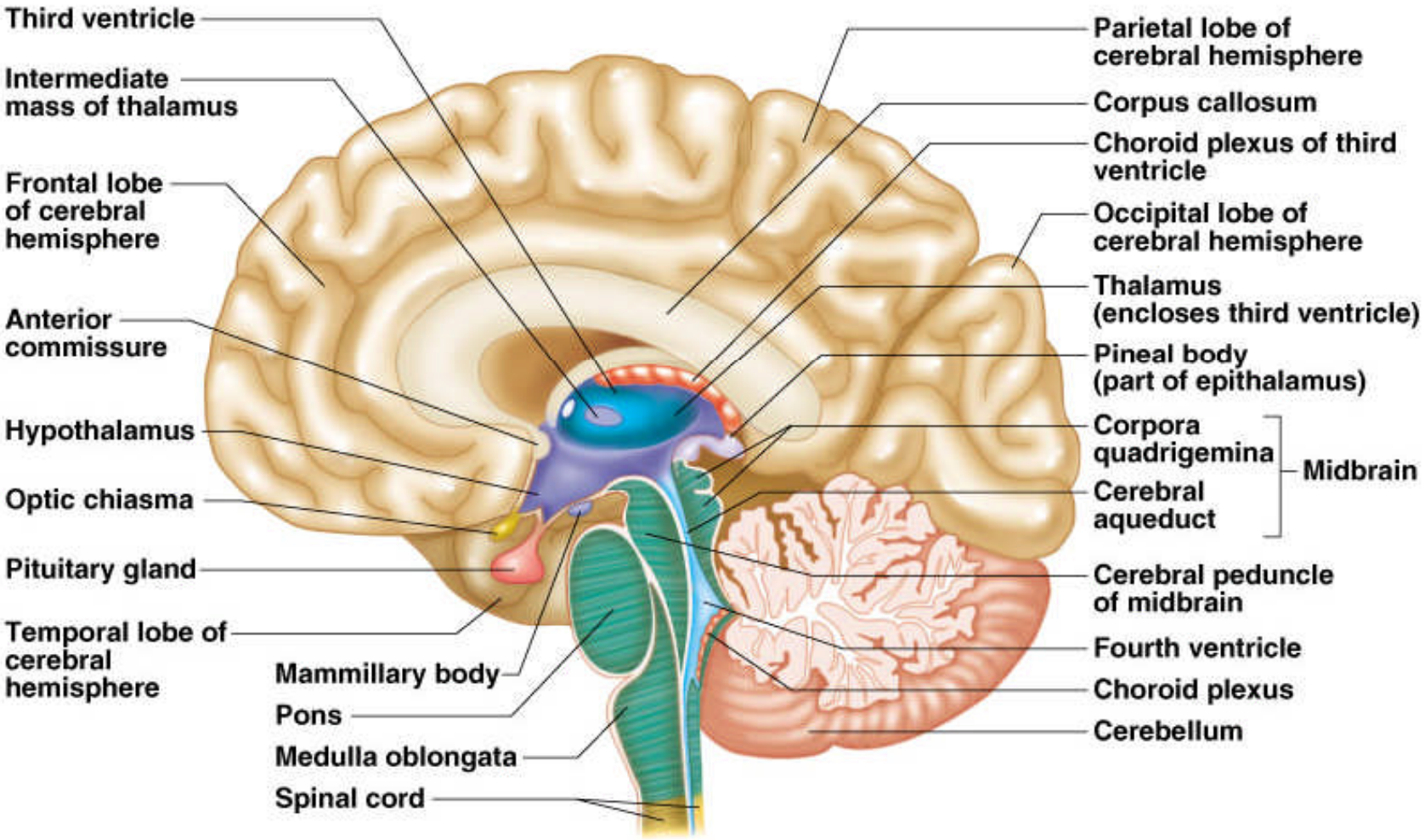


Figure 7.15a

Midbrain

- Mostly composed of tracts of nerve fibers
- The cerebral aqueduct – canal that connects the 3rd ventricle of the diencephalon to the 4th ventricle
- Has two bulging fiber tracts – cerebral peduncles – convey ascending and descending impulses
- Has four rounded protrusions – corpora quadrigemina – Reflex centers for vision and hearing

Pons

- The bulging center part of the brain stem
- Mostly composed of fiber tracts
- Includes nuclei involved in the control of breathing

Medulla Oblongata

- The lowest part of the brain stem
- Merges into the spinal cord
- Includes important fiber tracts
- Contains important control centers
  - Heart rate control
  - Blood pressure regulation
  - Breathing
  - Swallowing
  - Vomiting

Reticular Formation

- Diffuse mass of gray matter along the brain stem
- Involved in motor control of visceral organs
- Reticular activating system plays a role in awake/sleep cycles and consciousness
- Damage here results in a permanent coma

Reticular Formation

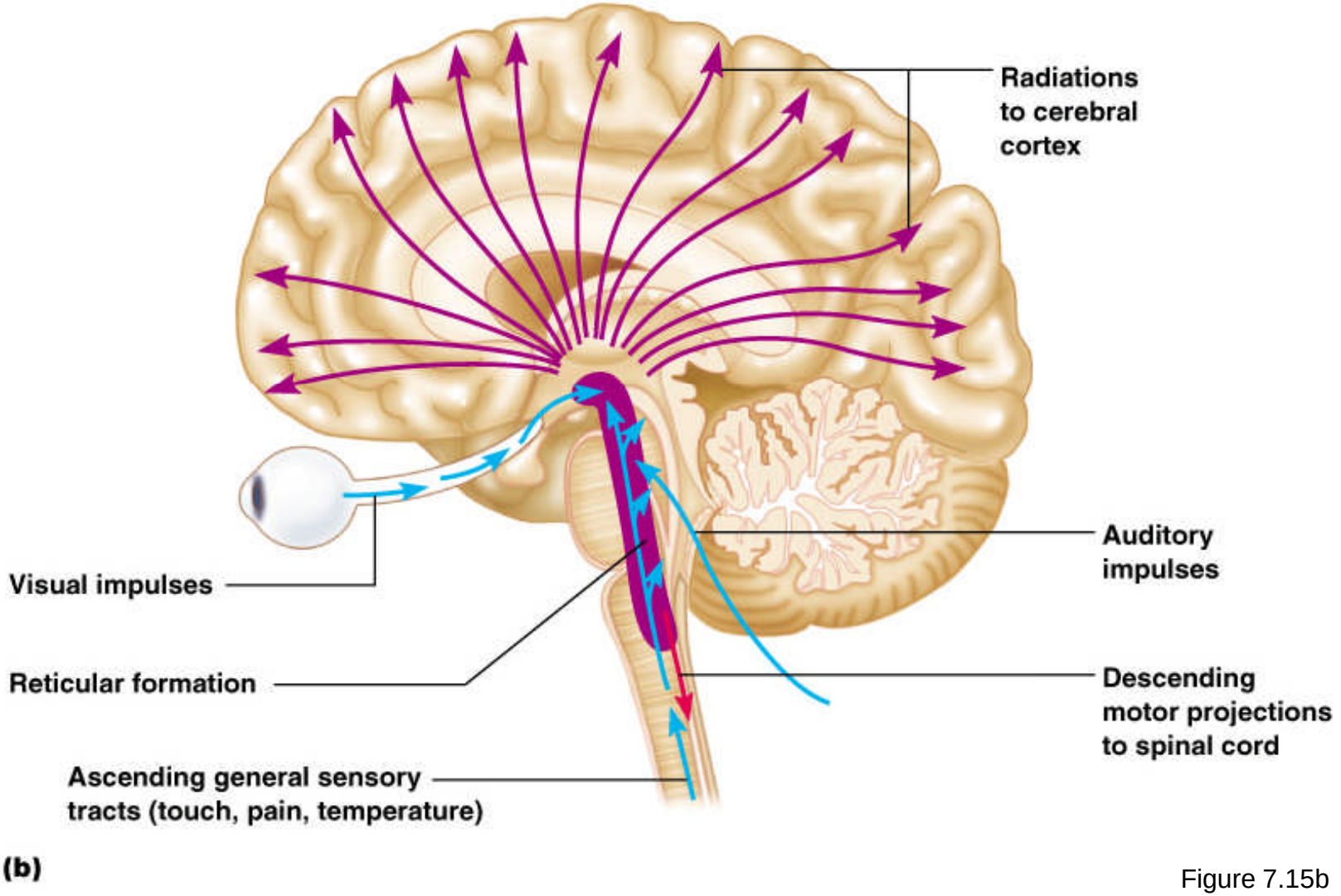


Figure 7.15b

Cerebellum

- Two hemispheres with convoluted surfaces
- Provides involuntary coordination of body movements – of skeletal muscles, balance and equilibrium
- Automatic pilot – continually comparing brain's intentions with actual body performance

Cerebellum

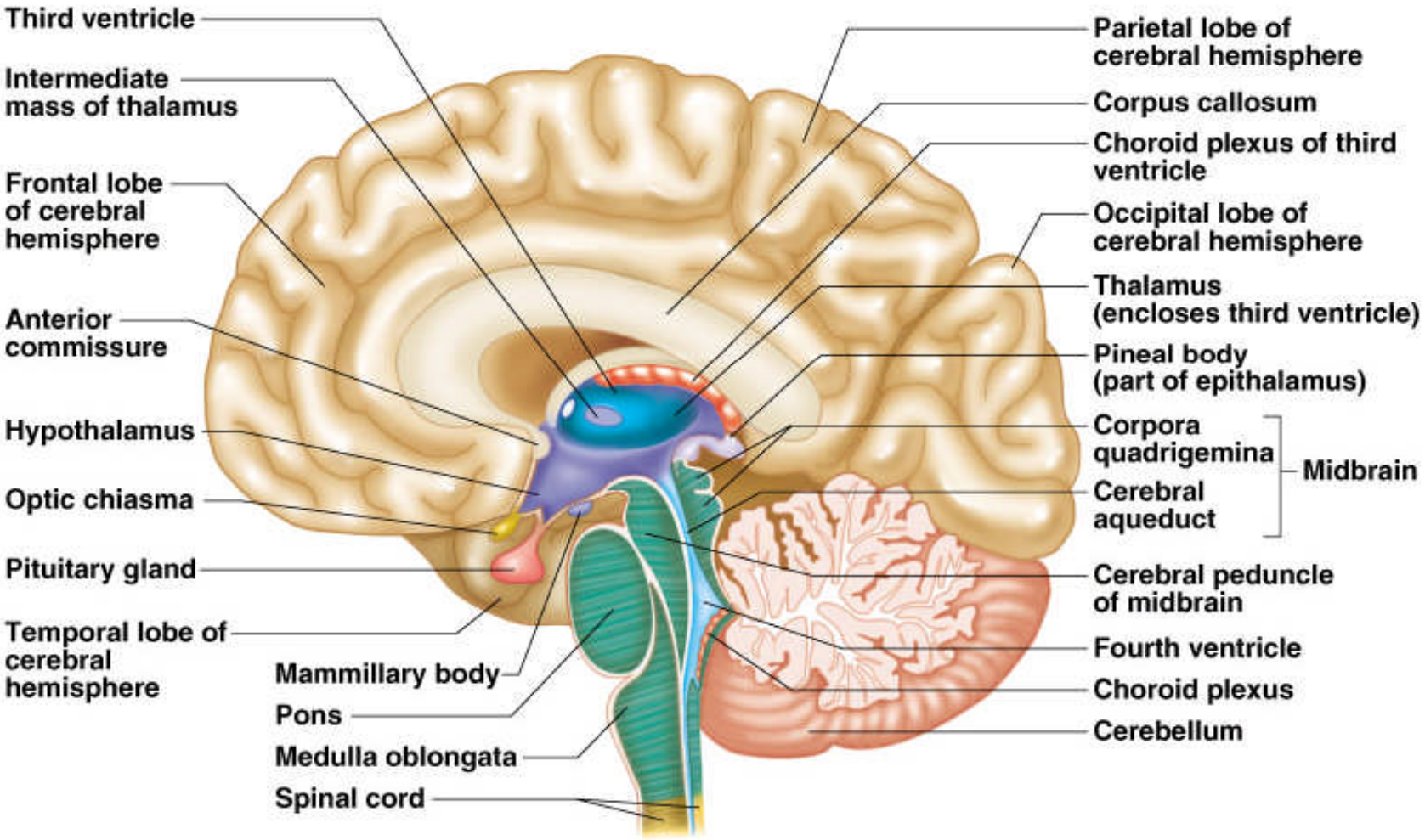


Figure 7.15a

Protection of the Central Nervous System

- Scalp and skin
- Skull and vertebral column
- Meninges
- Cerebrospinal fluid
- Blood brain barrier

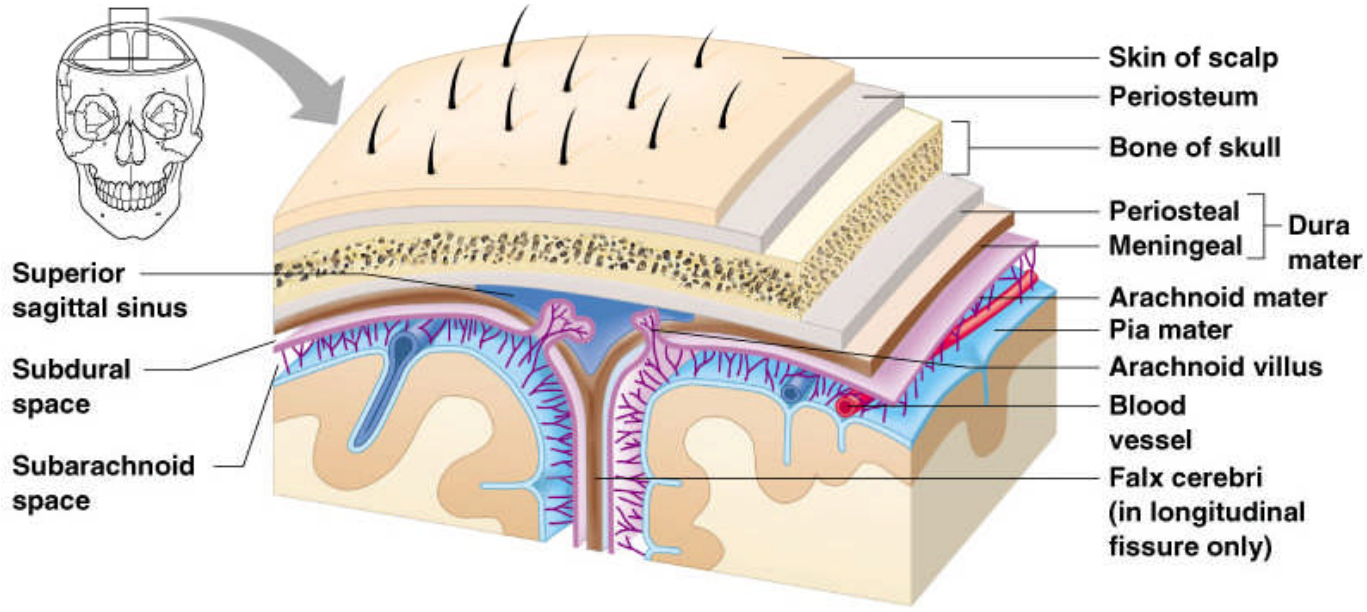


Figure 7.16a

Meninges

- Dura mater
  - Double-layered external covering the brain
    - Periosteum – attached to surface of the skull
    - Meningeal layer – outer covering of the brain and continues as the dura matter of the spinal cord
  - Folds inward in several areas that attaches the brain to cranial cavity

Meninges

- Arachnoid layer
  - Middle layer that is web-like
- Pia mater
  - Internal layer that clings to the surface of the brain following every fold
- Subarachnoid space filled with cerebrospinal fluid
  - Arachnoid villi – projections of arachnoid membrane protruding through the dura matter

Cerebrospinal Fluid

- Similar to blood plasma composition
  - Less protein, more vitamin C, different ions
- Formed by the choroid plexus
- Forms a watery cushion to protect the brain
- Circulated in arachnoid space, ventricles, and central canal of the spinal cord

Ventricles and Location of the Cerebrospinal Fluid

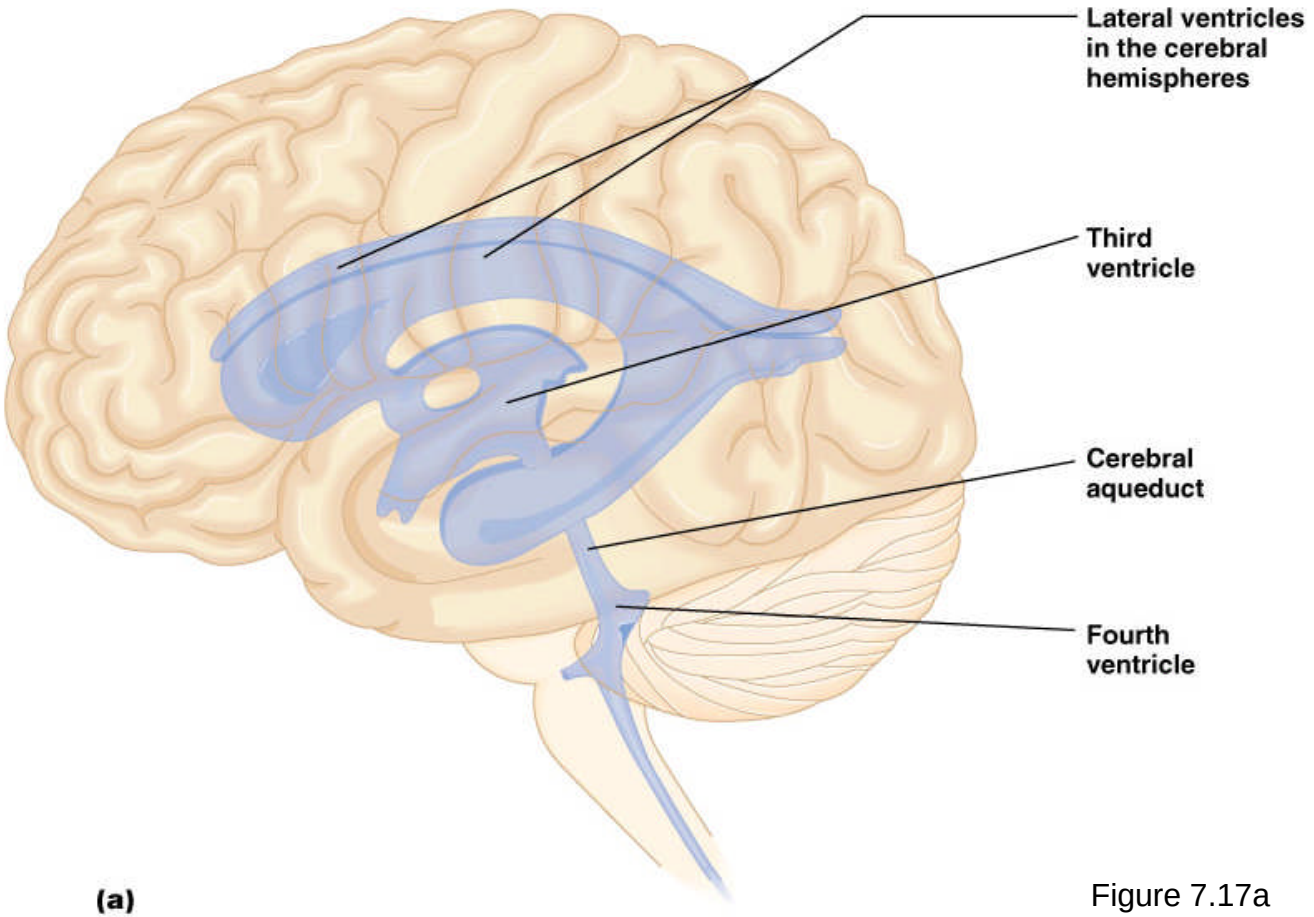


Figure 7.17a

Ventricles and Location of the Cerebrospinal Fluid

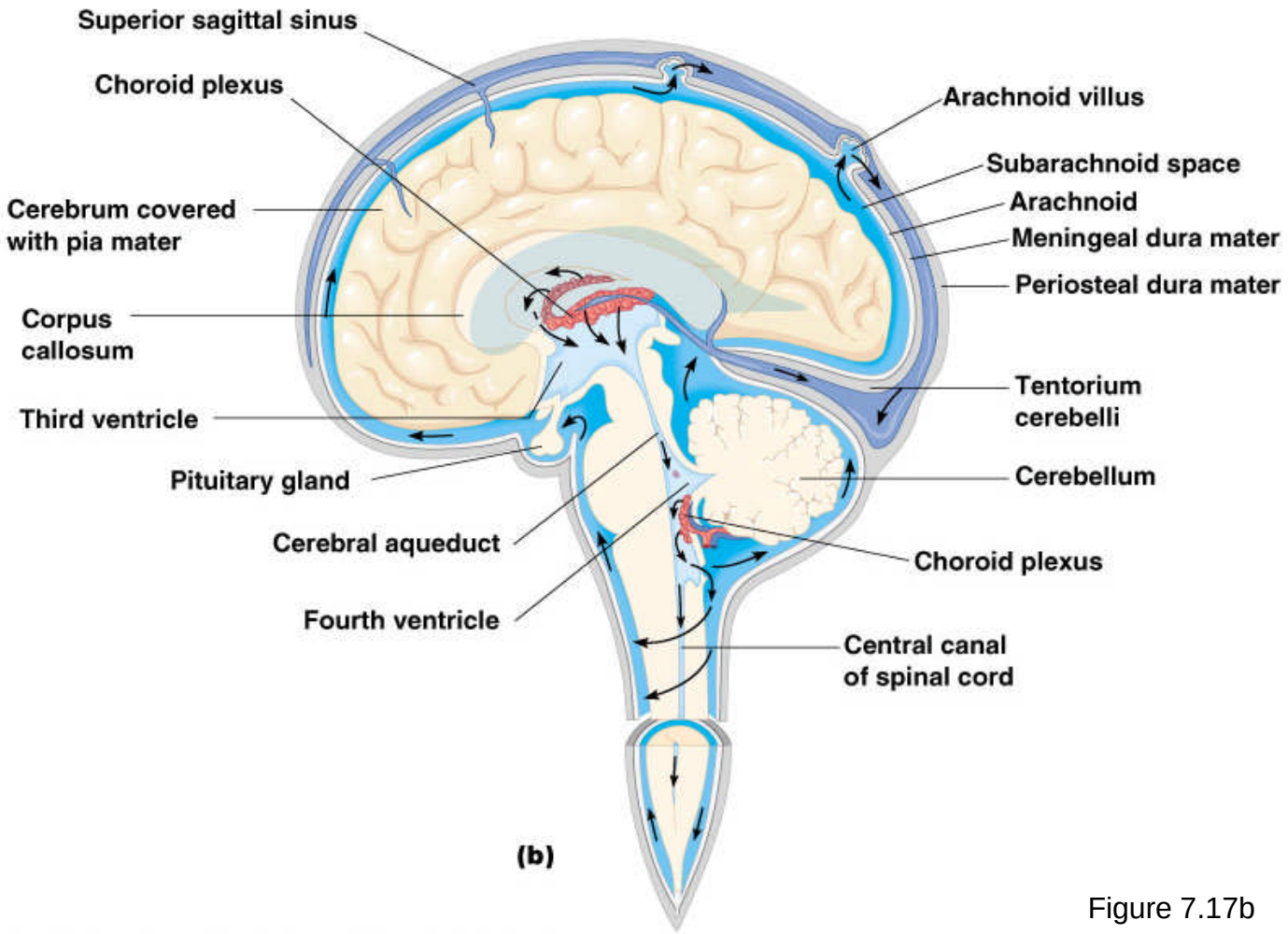


Figure 7.17b

Blood Brain Barrier

- Includes the least permeable capillaries of the body – only H2O, glucose, and essential amino acids get through
- Excludes many potentially harmful substances
- Useless against some substances
  - Fats and fat soluble molecules
  - Respiratory gases
  - Alcohol
  - Nicotine
  - Anesthesia

Traumatic Brain Injuries

- Concussion
  - Slight brain injury – dizzy or lose consciousness briefly
  - No permanent brain damage
- Contusion
  - Nervous tissue destruction occurs - does not regenerate
  - If cortex is damaged, coma for hours or life
- Cerebral edema
  - Swelling from the inflammatory response
  - May compress and kill brain tissue

Cerebrovascular Accident (CVA)

- Commonly called a stroke
- The result of a clot or a ruptured blood vessel supplying a region of the brain
- Brain tissue supplied with oxygen from that blood source dies
- Loss of some functions or death may result

Alzheimer's Disease

- Progressive degenerative brain disease
- Mostly seen in the elderly, but may begin in middle age
- Structural changes in the brain include abnormal protein deposits and twisted fibers within neurons
- Victims experience memory loss, irritability, confusion and ultimately, hallucinations and death

Spinal Cord

- Extends from the medulla oblongata to the region of T12
- Below T12 is the cauda equina (a collection of spinal nerves)
- Enlargements occur in the cervical and lumbar regions

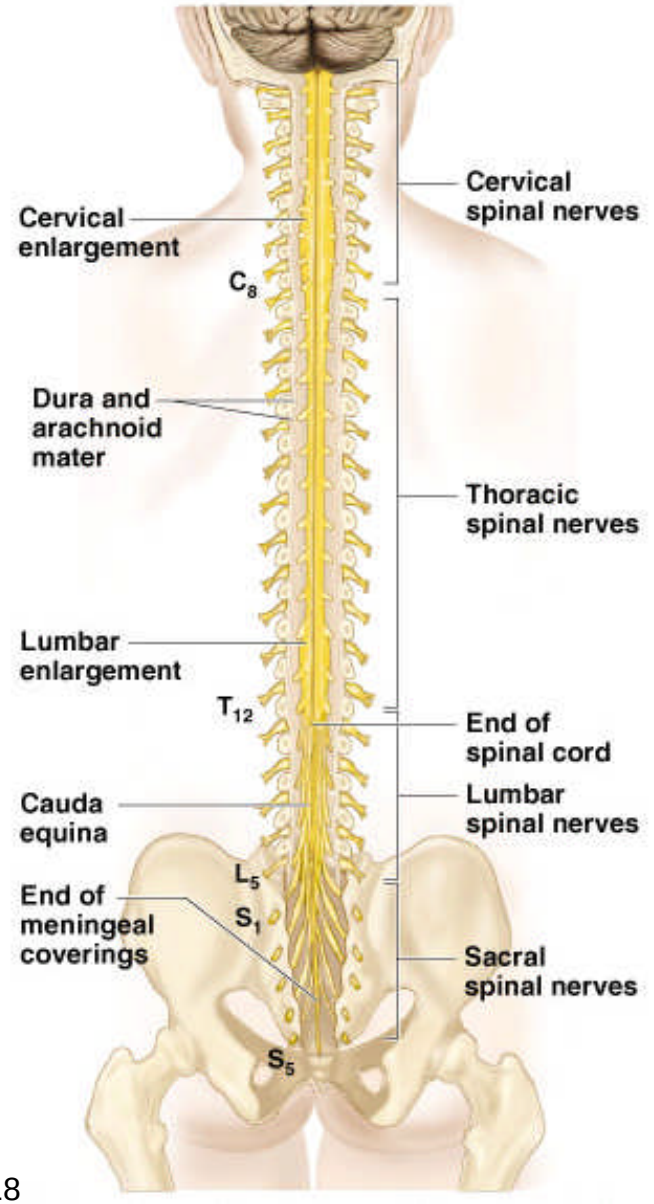


Figure 7.18

Spinal Cord Anatomy

- Internal gray matter - mostly cell bodies that surround the central canal of the cord
  - Dorsal (posterior) horns
  - Anterior (ventral) horns
    - Contains motor neurons of the somatic nervous system, which send their axons out the ventral root
  - Together they fuse to form the spinal nerves
  - Nerves leave at the level of each vertebrae

Spinal Cord Anatomy

- Cell bodies of sensory neurons, whose fibers enter the cord by the dorsal root, are found in an enlarged area called the dorsal root ganglion
- Damage to this area causes sensation from the body area served to be lost

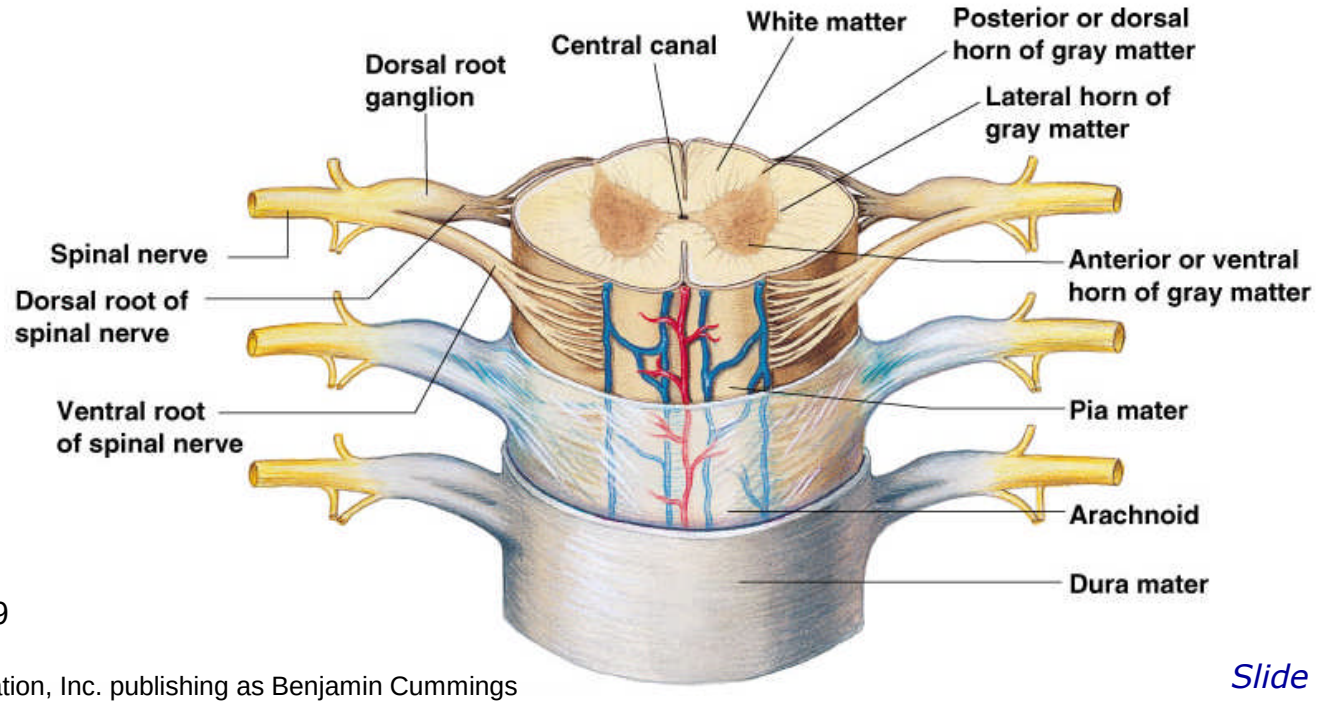


Figure 7.19

Spinal Cord Anatomy

- Exterior white mater – conduction tracts
  - Posterior, lateral, and anterior columns
    - Each contains a number of fiber tracts make up of axons with the same destination and function

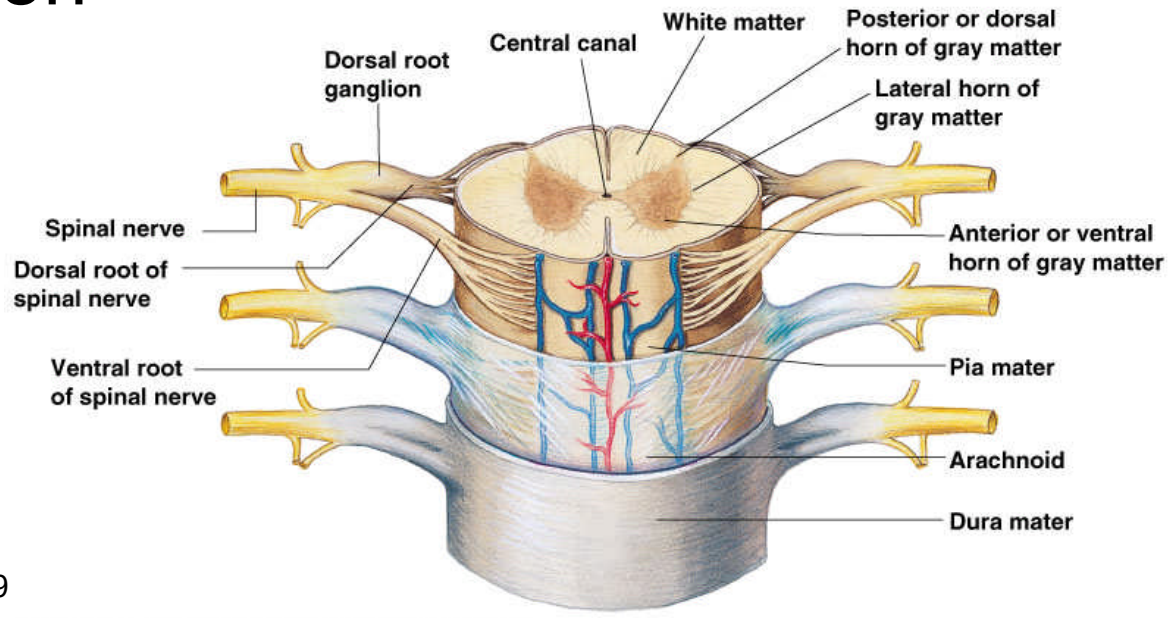


Figure 7.19

Spinal Cord Anatomy

- Central canal filled with cerebrospinal fluid

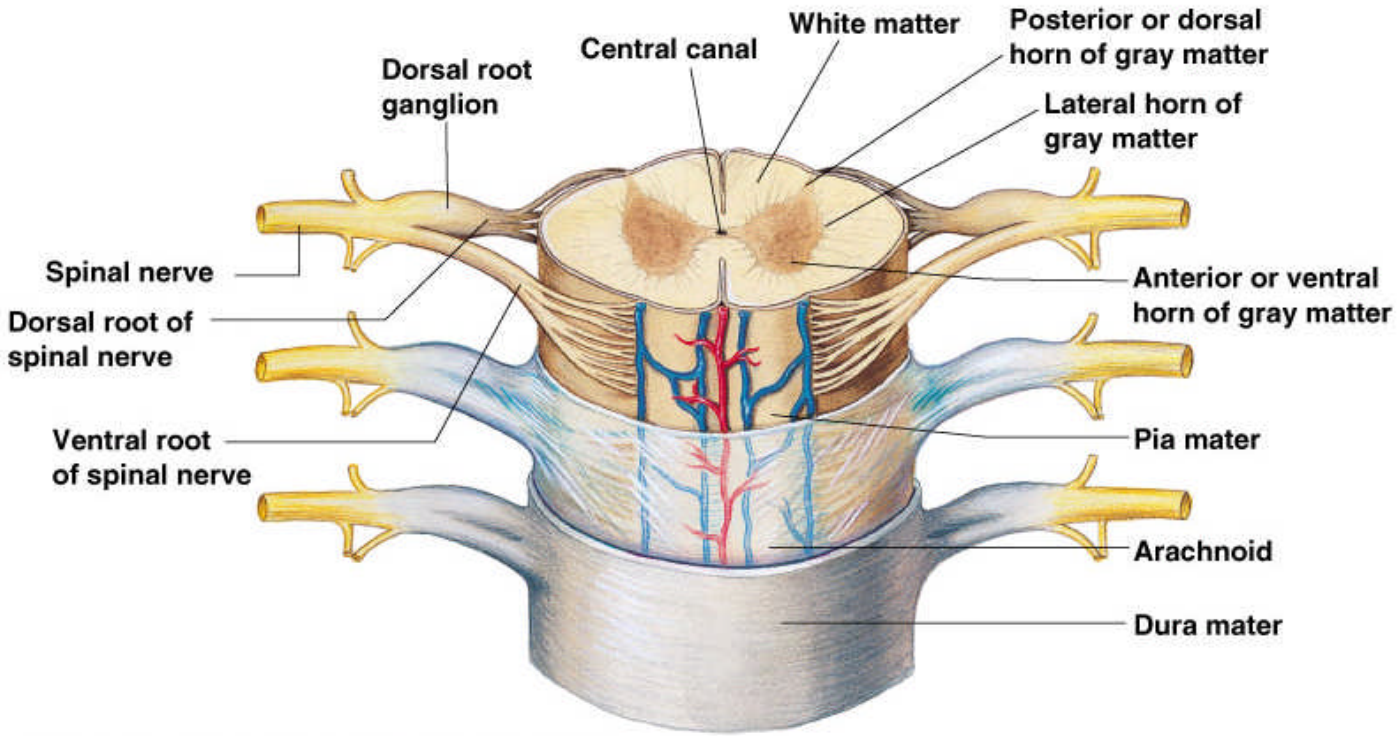


Figure 7.19

Peripheral Nervous System

- Nerves and ganglia outside the central nervous system
- Nerve = bundle of neuron fibers
- Neuron fibers are bundled by a connective tissue sheath

Structure of a Nerve

- Endoneurium surrounds each fiber
- Groups of fibers are bound into fascicles by perineurium
- Fascicles are bound together by epineurium

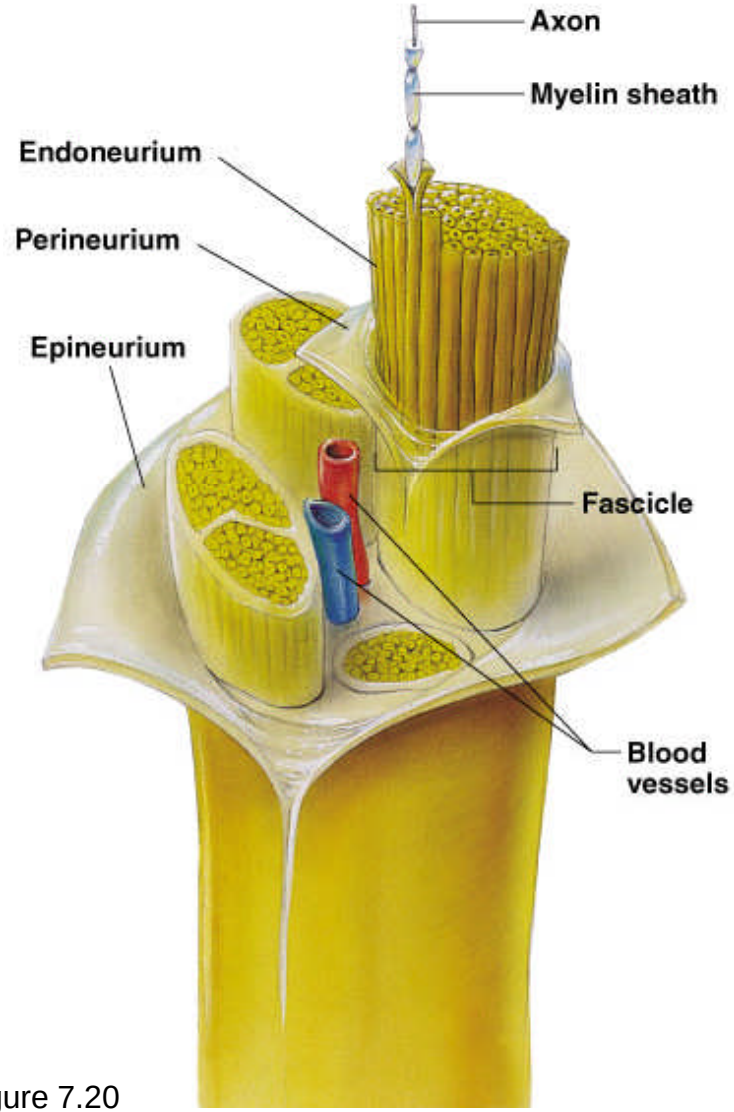


Figure 7.20

Classification of Nerves

- Classified according to the direction in which they transmit impulses
- Mixed nerves – carry both sensory and motor fibers – spinal nerves
- Afferent (sensory) nerves – carry impulses toward the CNS
- Efferent (motor) nerves – carry impulses away from the CNS

Cranial Nerves

- 12 pairs of nerves that mostly serve the head and neck
- Numbered in order, front to back – names reveal structures they control
- Most are mixed nerves, but three are sensory only
  - Optic, olfactory, and vestibulocochlear

Distribution of Cranial Nerves

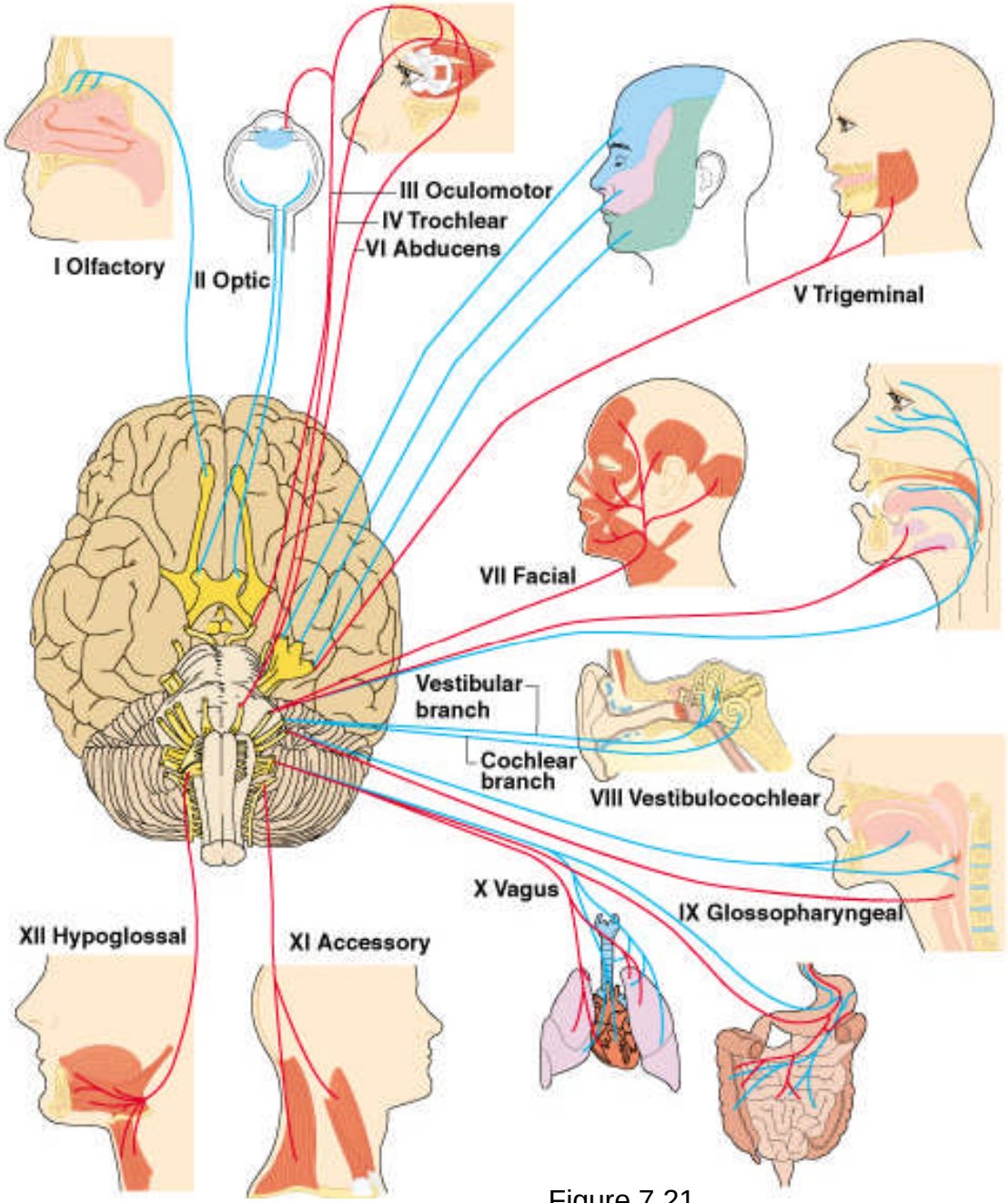


Figure 7.21

Cranial Nerves

- **I** Olfactory nerve – sensory for smell
- **II** Optic nerve – sensory for vision
- **III** Oculomotor nerve – motor fibers to eye muscles
- **IV** Trochlear – motor fiber to eye muscles

Cranial Nerves

- **V** Trigeminal nerve – sensory for the face; motor fibers to chewing muscles
- **VI** Abducens nerve – motor fibers to eye muscles
- **VII** Facial nerve – sensory for taste; motor fibers to the face
- **VIII** Vestibulocochlear nerve – sensory for balance and hearing

Cranial Nerves

- **IX** Glossopharyngeal nerve – sensory for taste; motor fibers to the pharynx
- **X** Vagus nerves – sensory and motor fibers for pharynx, larynx, and viscera
- **XI** Accessory nerve – motor fibers to neck and upper back
- **XII** Hypoglossal nerve – motor fibers to tongue

Spinal Nerves

- There is a pair of spinal nerves at the level of each vertebrae for a total of 31 pairs
- Spinal nerves are formed by the combination of the ventral and dorsal roots of the spinal cord
- Spinal nerves are named for the region from which they arise

Spinal Nerves

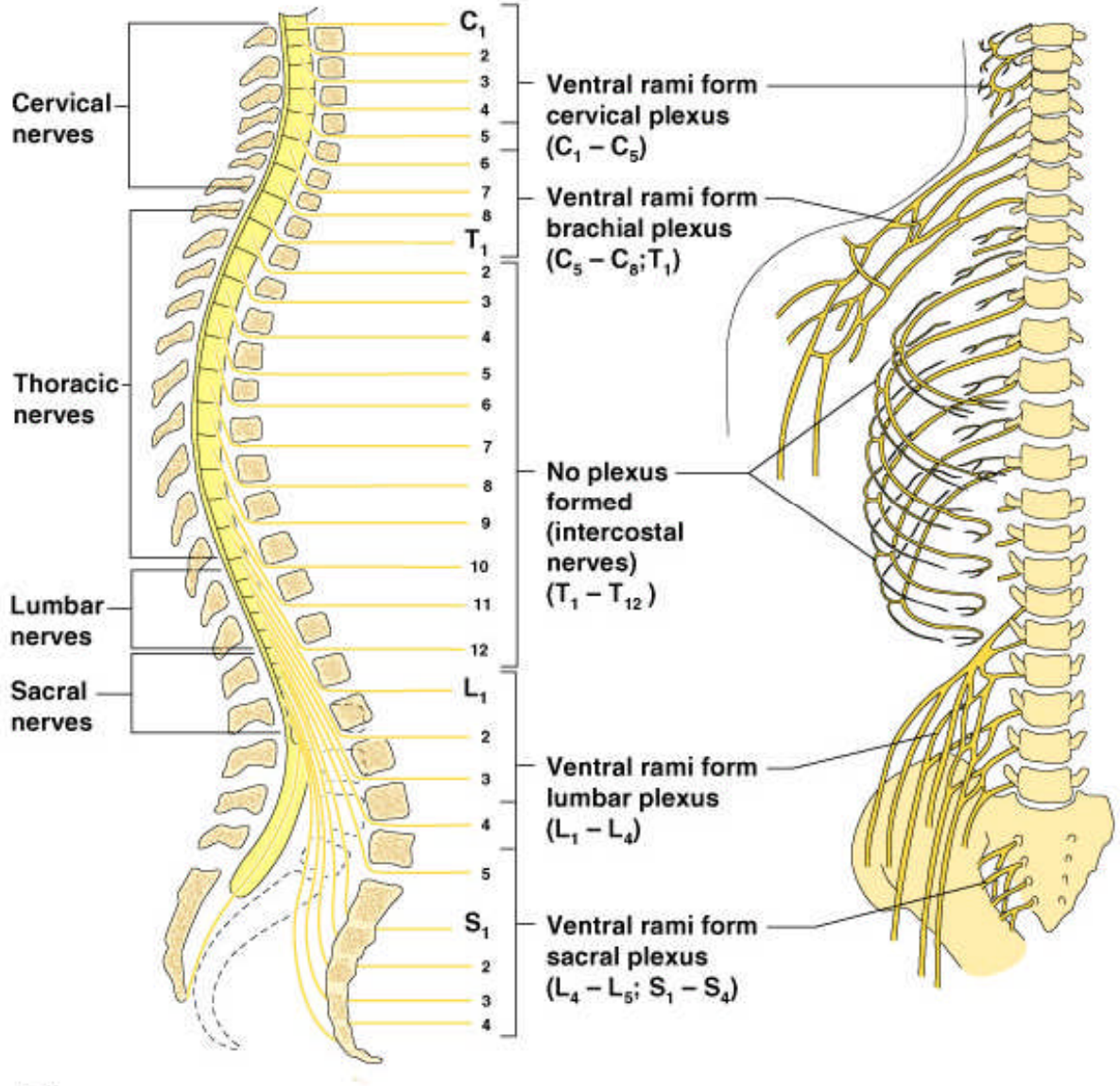


Figure 7.22a

Anatomy of Spinal Nerves

- Spinal nerves divide soon after leaving the spinal cord
  - Dorsal rami – serve the skin and muscles of the posterior trunk
  - Ventral rami – forms a complex of networks (plexus) for the anterior, which serve the motor and sensory needs of the limbs

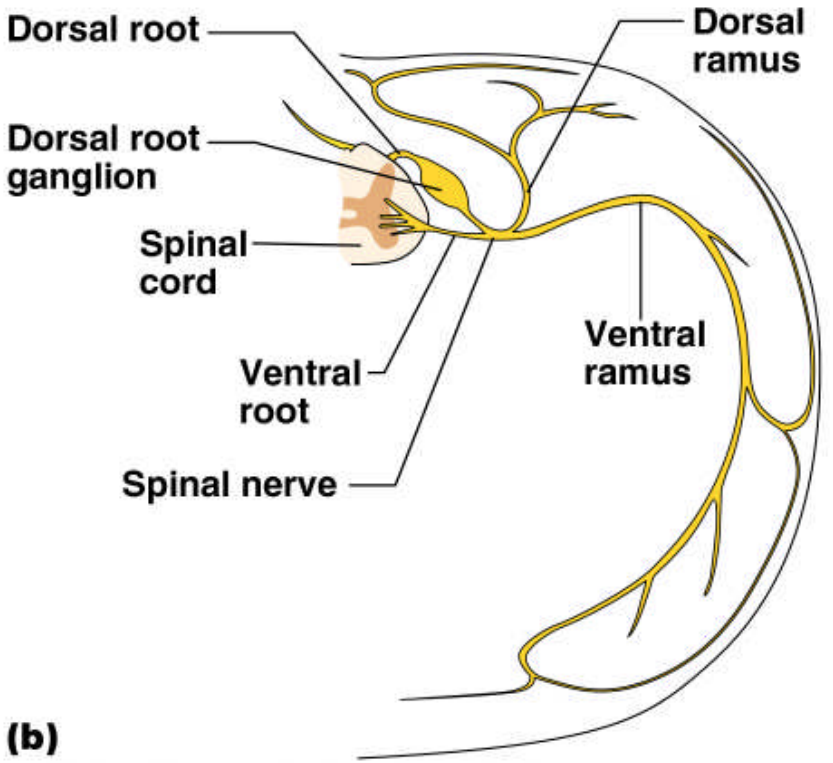


Figure 7.22b

Examples of Nerve Distribution

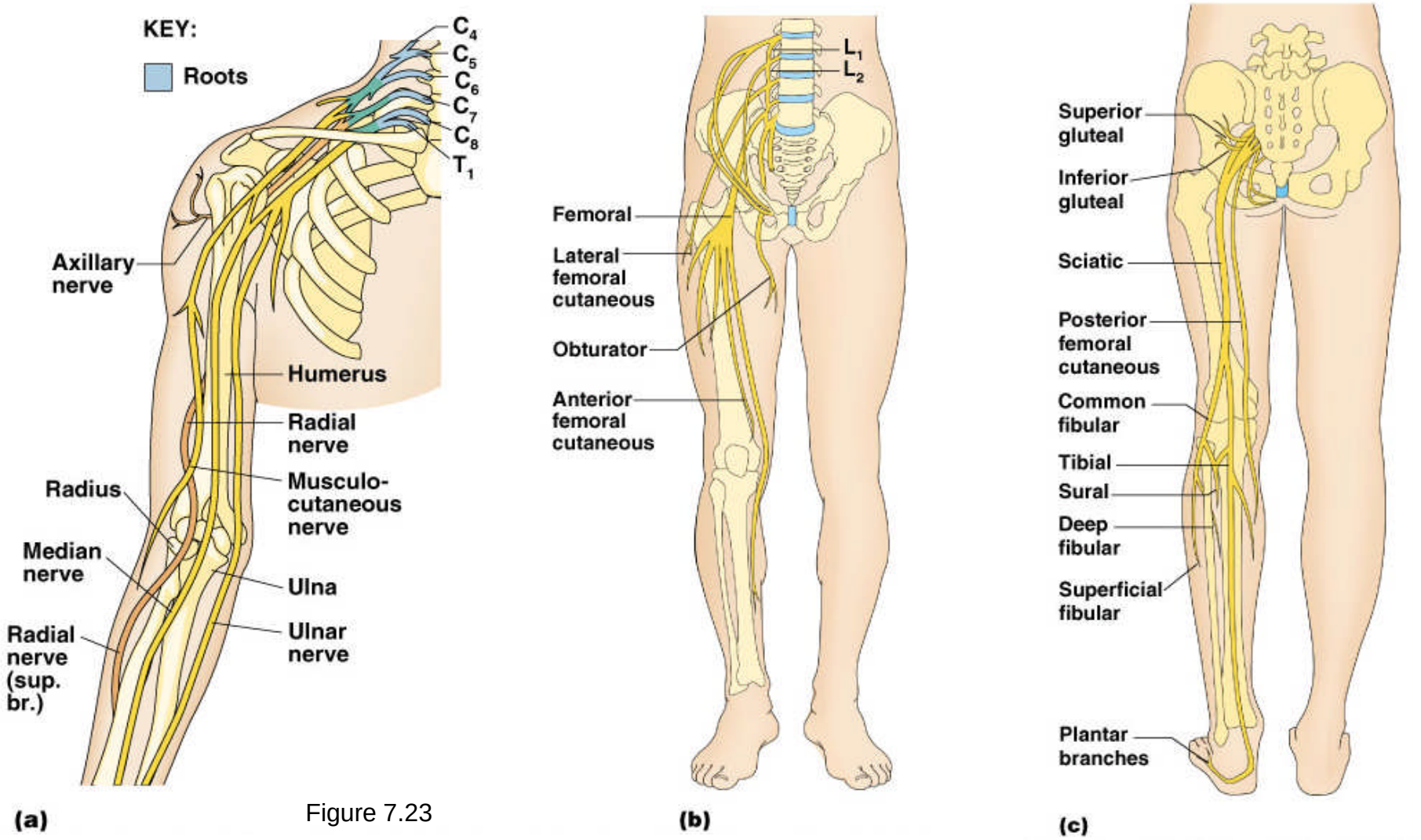


Figure 7.23

Autonomic Nervous System

- The involuntary branch of the nervous system
- Consists of only motor nerves
- Divided into two divisions
  - Sympathetic division – mobilizes the body
  - Parasympathetic division – allows body to unwind

Differences Between Somatic and Autonomic Nervous Systems

- Nerves
  - Somatic – one motor neuron – axons extend all the way to the skeletal muscle they serve
  - Autonomic – preganglionic and postganglionic nerves
- Effector organs
  - Somatic – skeletal muscle
  - Autonomic – smooth muscle, cardiac muscle, and glands

Differences Between Somatic and Autonomic Nervous Systems

- Nerurotransmitters
  - Somatic – always use acetylcholine
  - Autominic – use acetylcholine, epinephrine, or norepinephrine

Comparison of Somatic and Autonomic Nervous Systems

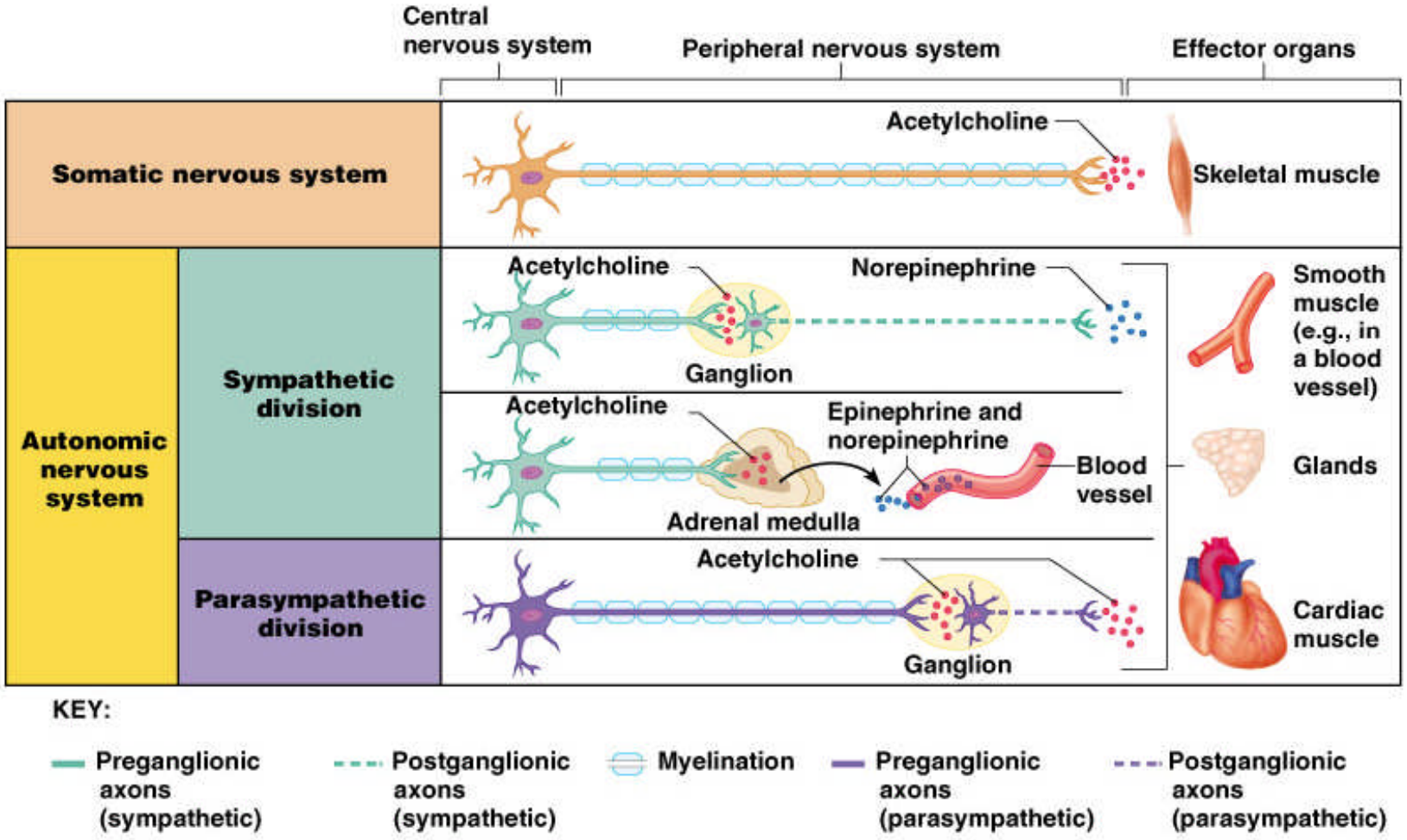


Figure 7.24

Anatomy of the Parasympathetic Division

- Originates from the brain stem and $S_2 – S_4$
- Neurons in the cranial region send axons out in cranial nerves to the head and neck organs
- They synapse with the second motor neuron in a terminal ganglion
- Terminal ganglia are at the effector organs
- Always uses acetylcholine as a neurotransmitter

Anatomy of the Sympathetic Division – thoracolumbar division

- Originates from T_1 through L_2
- Preganglionic axons leave the cord in the ventral root, enter the spinal nerve, then pass through a ramus communications, to enter a sympathetic chain ganglion at the sympathetic chain (trunk) (near the spinal cord)
- Short pre-ganglionic neuron and long postganglionic neuron transmit impulse from CNS to the effector
- Norepinephrine and epinephrine are neurotransmitters to the effector organs

Sympathetic Pathways

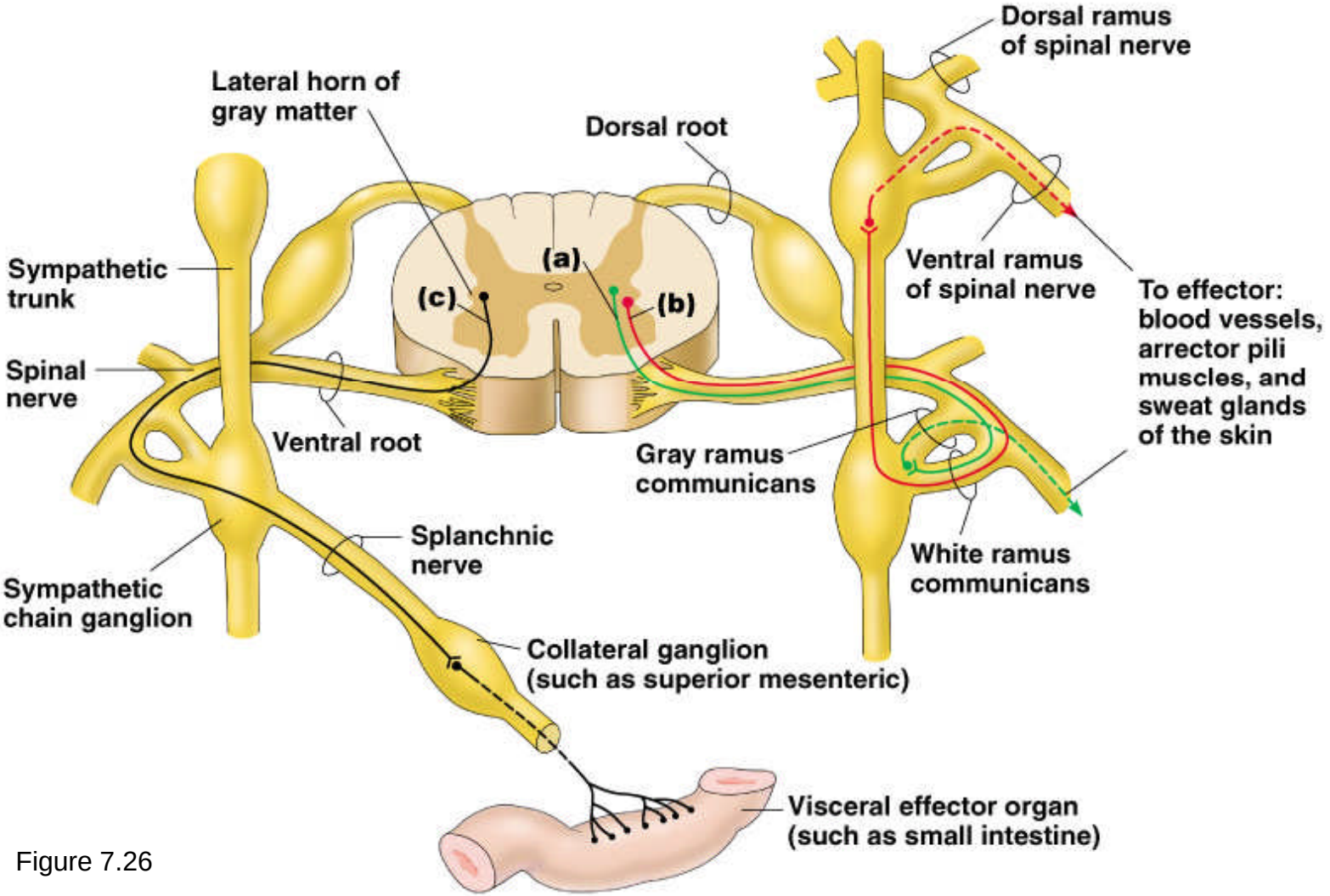


Figure 7.26

Anatomy of the Autonomic Nervous System

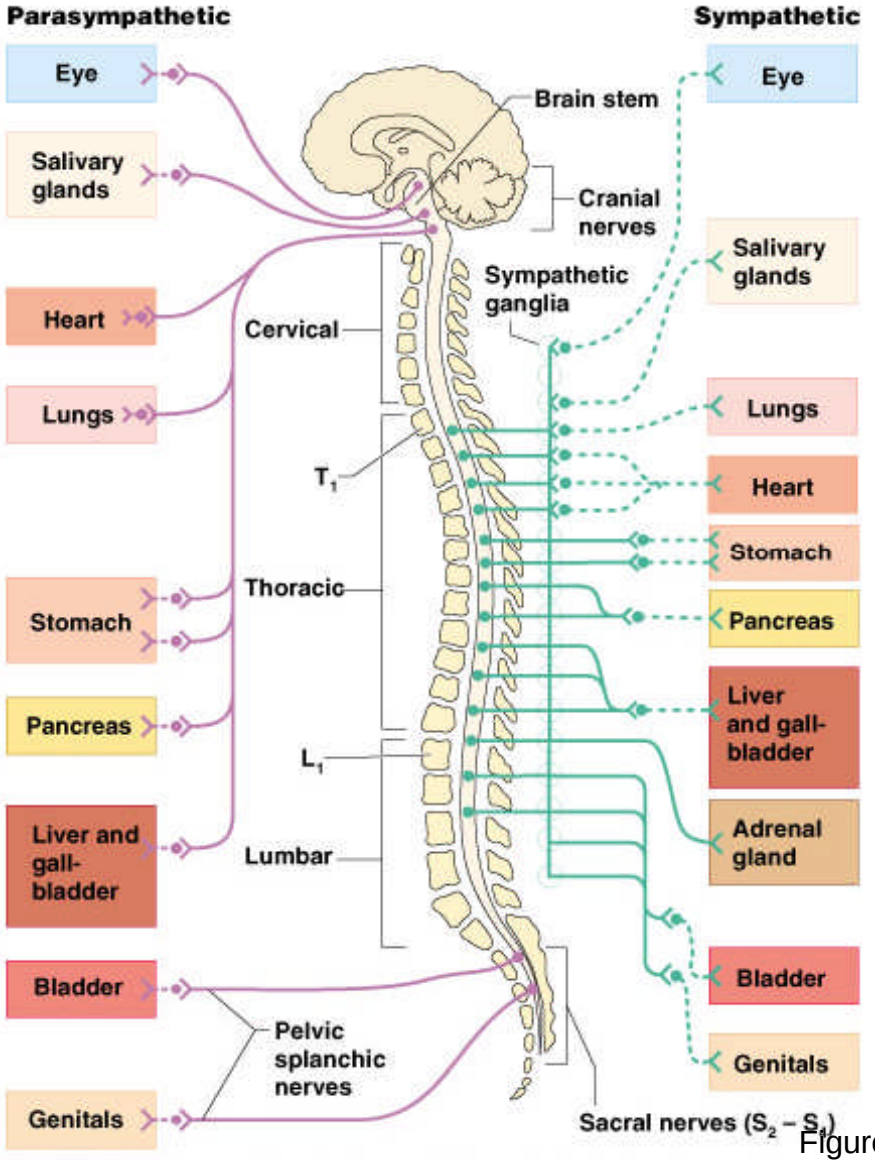


Figure 7.25

Autonomic Functioning

- Sympathetic – “fight-or-flight”
  - Response to unusual stimulus
  - Takes over to increase activities
  - Remember as the “E” division = exercise, excitement, emergency, and embarrassment

Autonomic Functioning

- Parasympathetic – housekeeping activites
  - Conserves energy
  - Maintains daily necessary body functions
  - Remember as the “D” division - digestion, defecation, and diuresis

Development Aspects of the Nervous System

- The nervous system is formed during the first month of embryonic development
- Any maternal infection can have extremely harmful effects
- The hypothalamus is one of the last areas of the brain to develop – contains centers for regulating body temperature

Development Aspects of the Nervous System

- No more neurons are formed after birth, but growth and maturation continues for several years largely due to myelination
- The brain reaches maximum weight as a young adult