Essentials of Human Anatomy & Physiology

Seventh Edition

Elaine N. Marieb

Chapter 7

The Nervous System

Slides 7.1 – 7.22

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

Functions of the Nervous System

- Motor output
  - A response to integrated stimuli
  - The response activates muscles or glands

Structural Classification of the Nervous System

- Central nervous system (CNS)
  - Brain
  - Spinal cord
- Peripheral nervous system (PNS)
  - Nerve outside the brain and spinal cord

Functional Classification of the Peripheral Nervous System

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

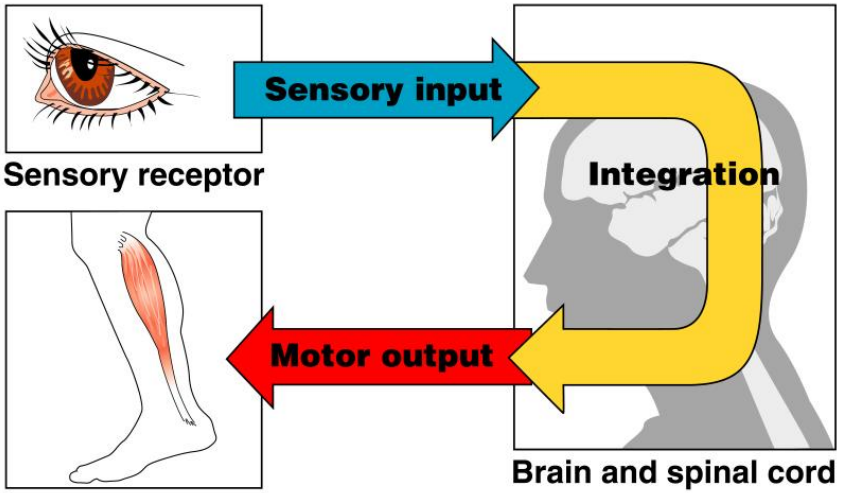


Figure 7.1

Functional Classification of the Peripheral Nervous System

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

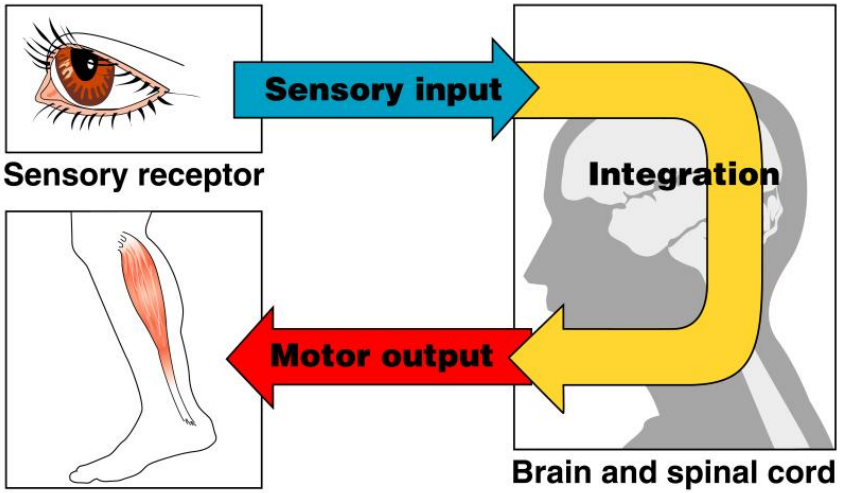


Figure 7.1

Functional Classification of the Peripheral Nervous System

- Motor (efferent) division
  - Two subdivisions
    - Somatic nervous system = voluntary
    - Autonomic nervous system = involuntary

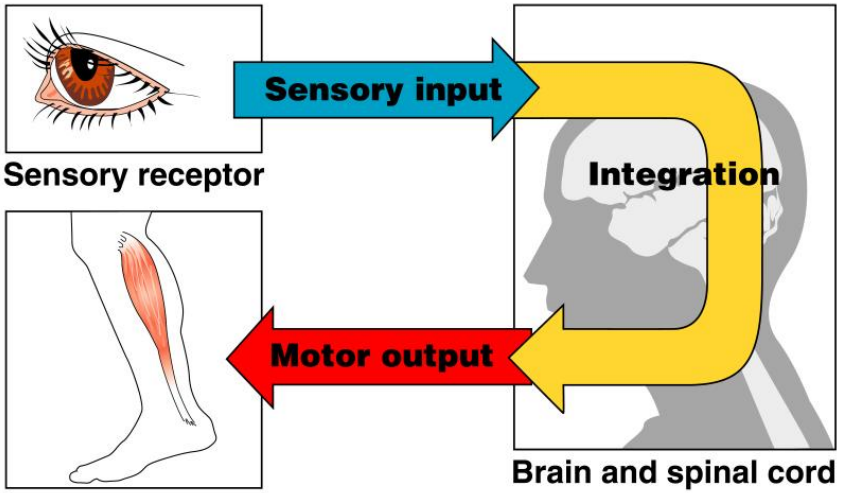


Figure 7.1

Organization of the Nervous System

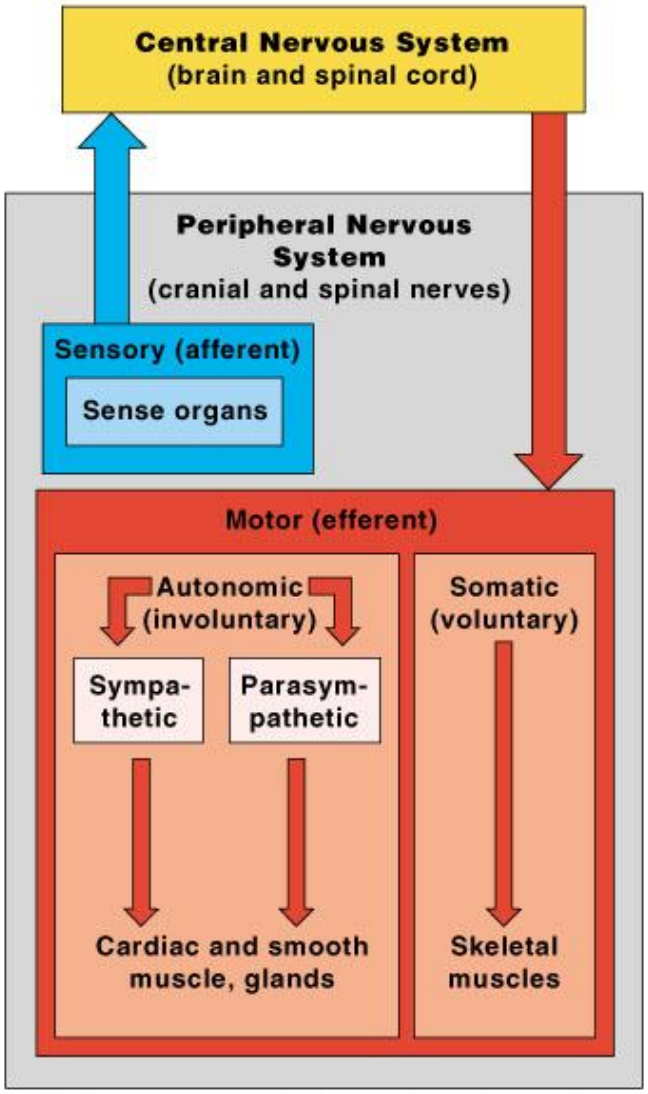


Figure 7.2

Nervous Tissue: Support Cells (Neuroglia)

- Astrocytes
  - Abundant, star-shaped cells
  - Brace neurons
  - Form barrier between capillaries and neurons
  - Control the chemical environment of the brain

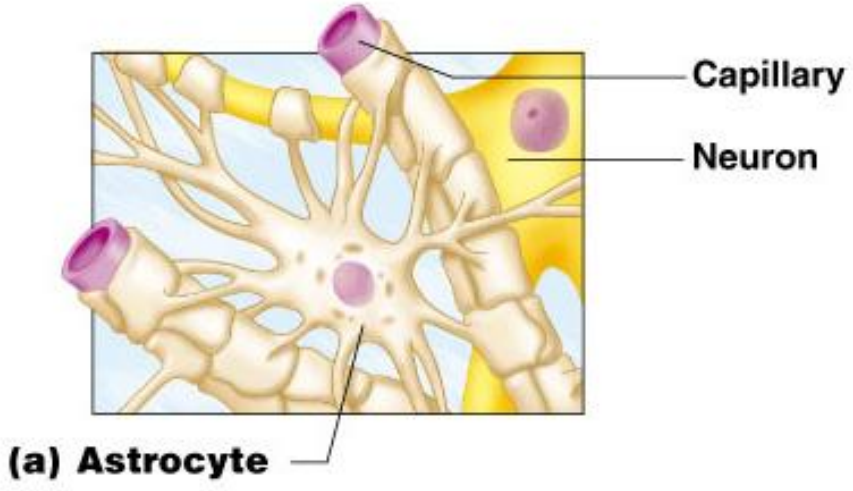
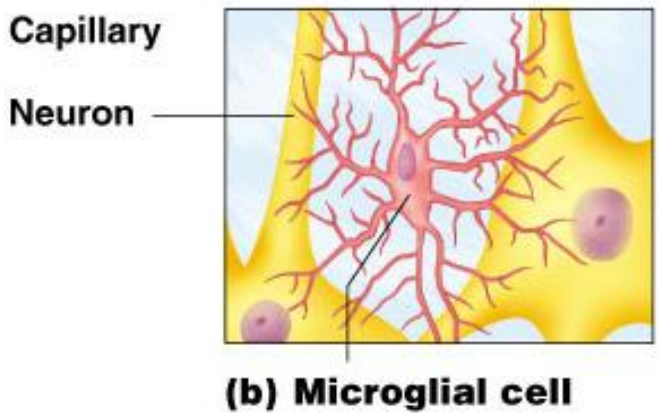


Figure 7.3a

Nervous Tissue: Support Cells

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



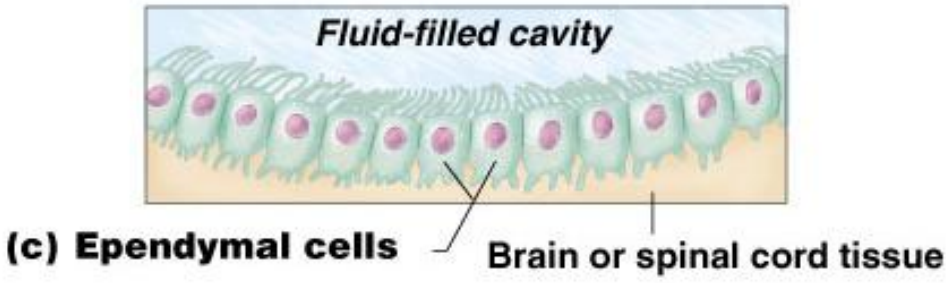


Figure 7.3b, c

Nervous Tissue: Support Cells

- Oligodendrocytes
  - Produce myelin sheath around nerve fibers in the central nervous system

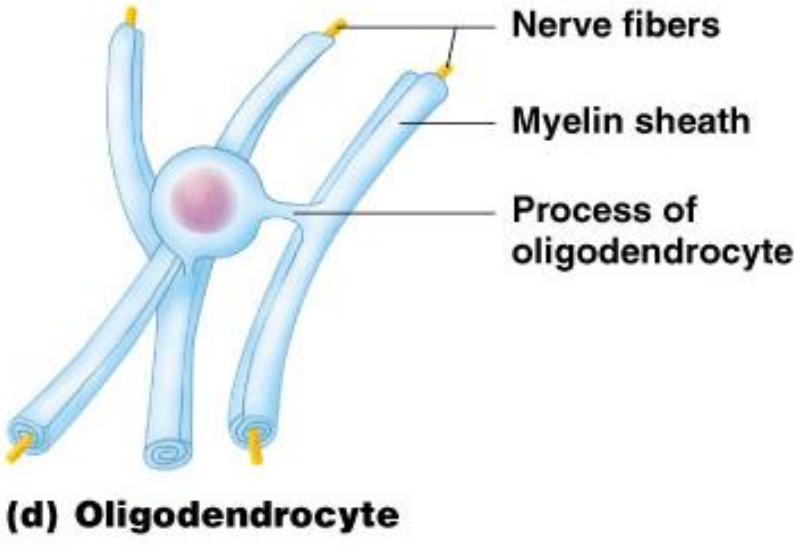


Figure 7.3d

Nervous Tissue: Support Cells

- Satellite cells
  - Protect neuron cell bodies
- Schwann cells
  - Form myelin sheath in the peripheral nervous system

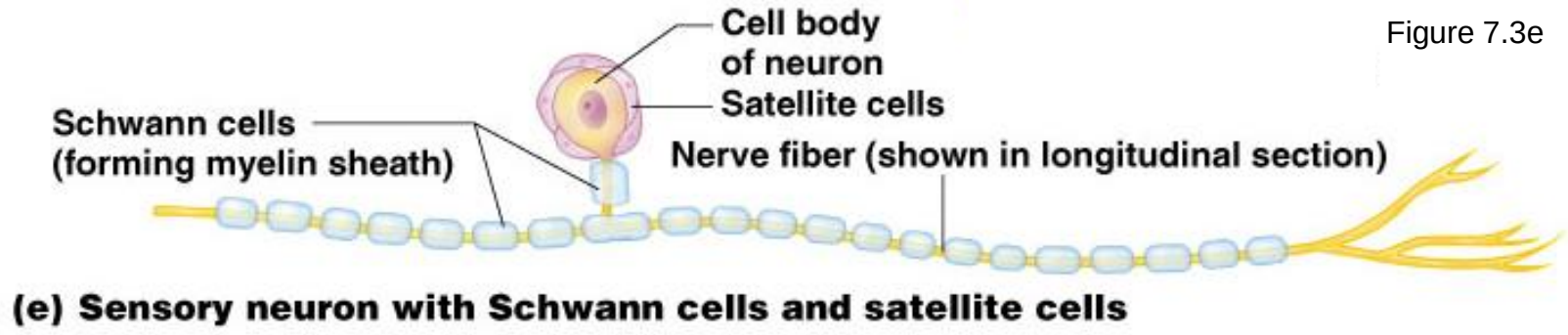


Figure 7.3e

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

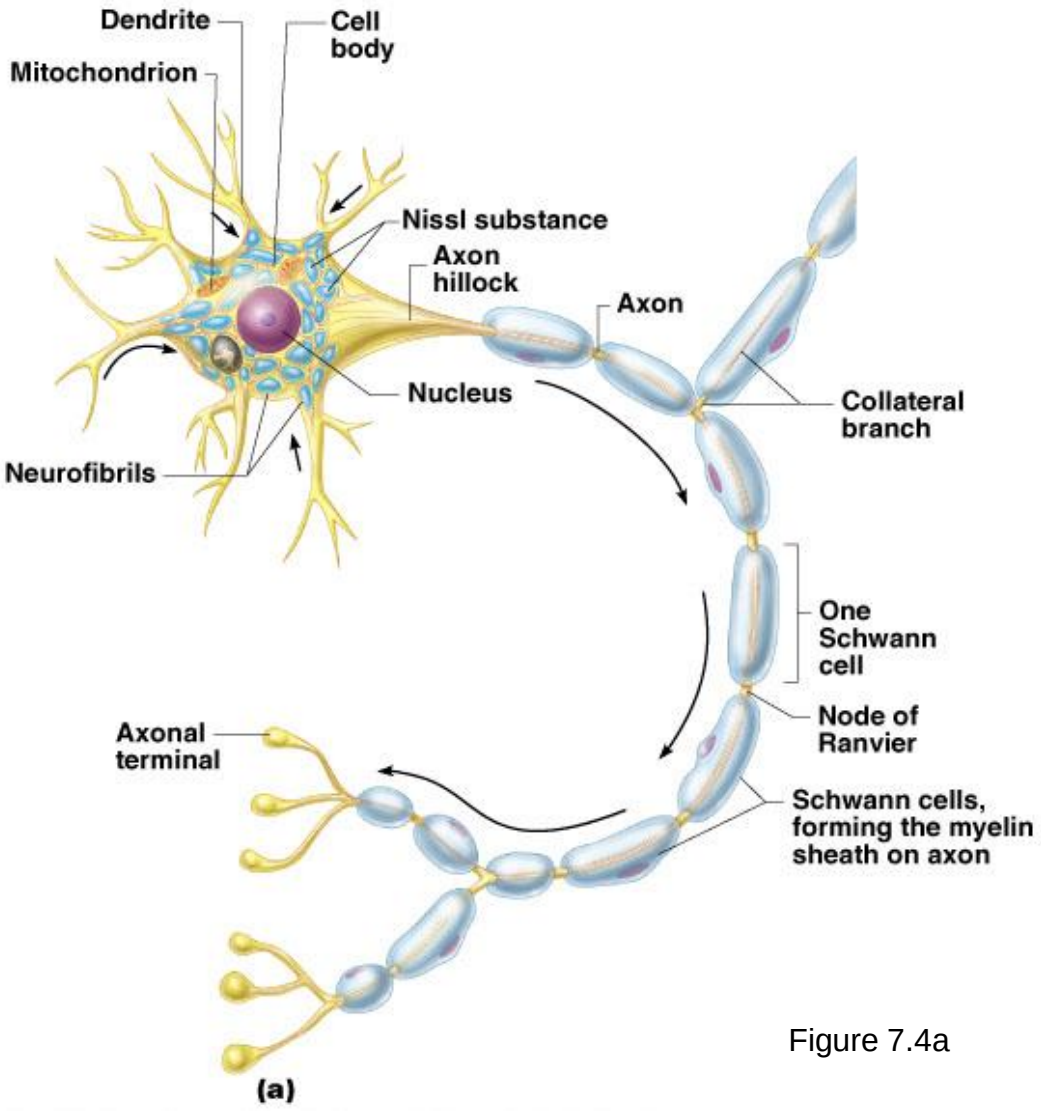


Figure 7.4a

Neuron Anatomy

- Cell body
  - Nucleus
  - Large nucleolus

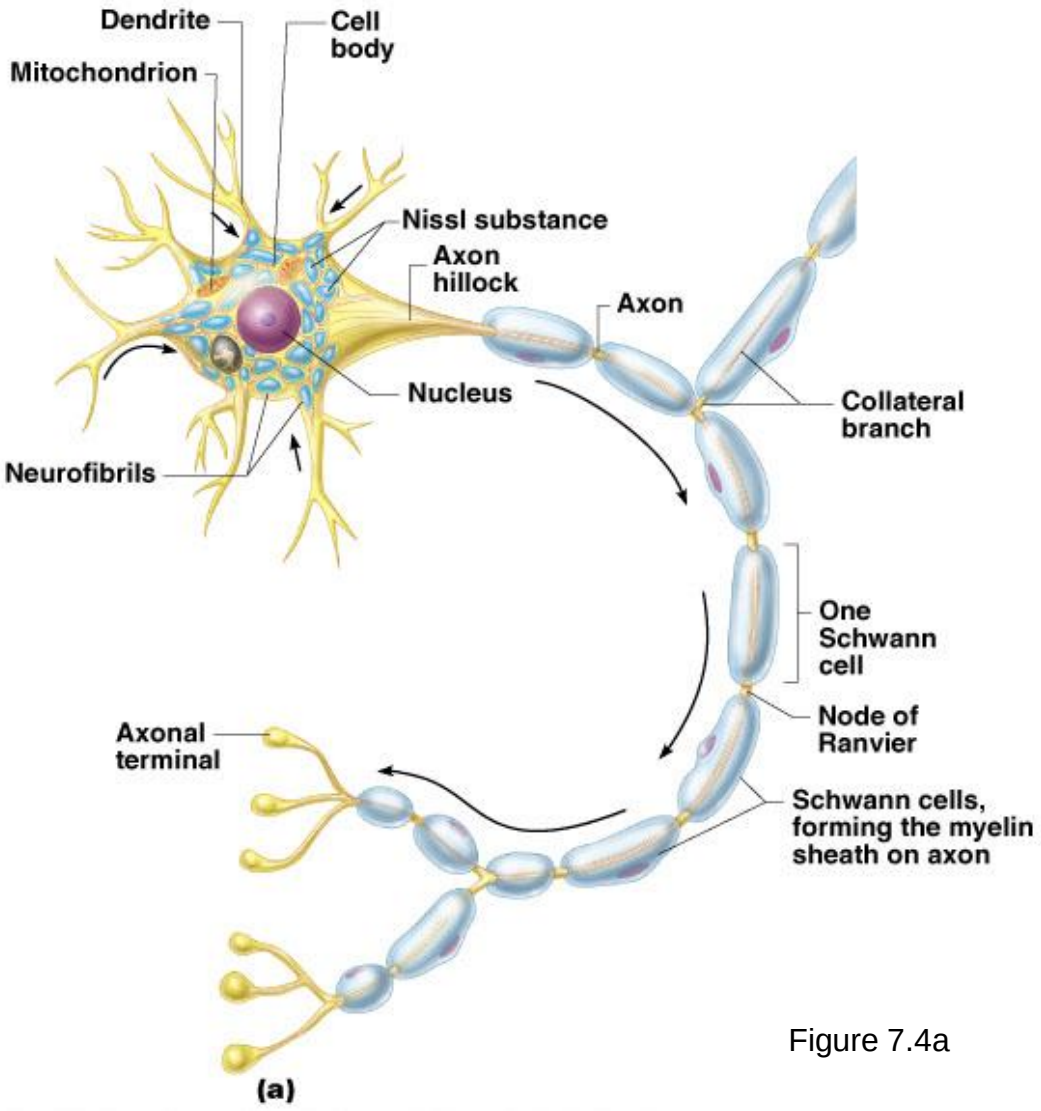


Figure 7.4a

Neuron Anatomy

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

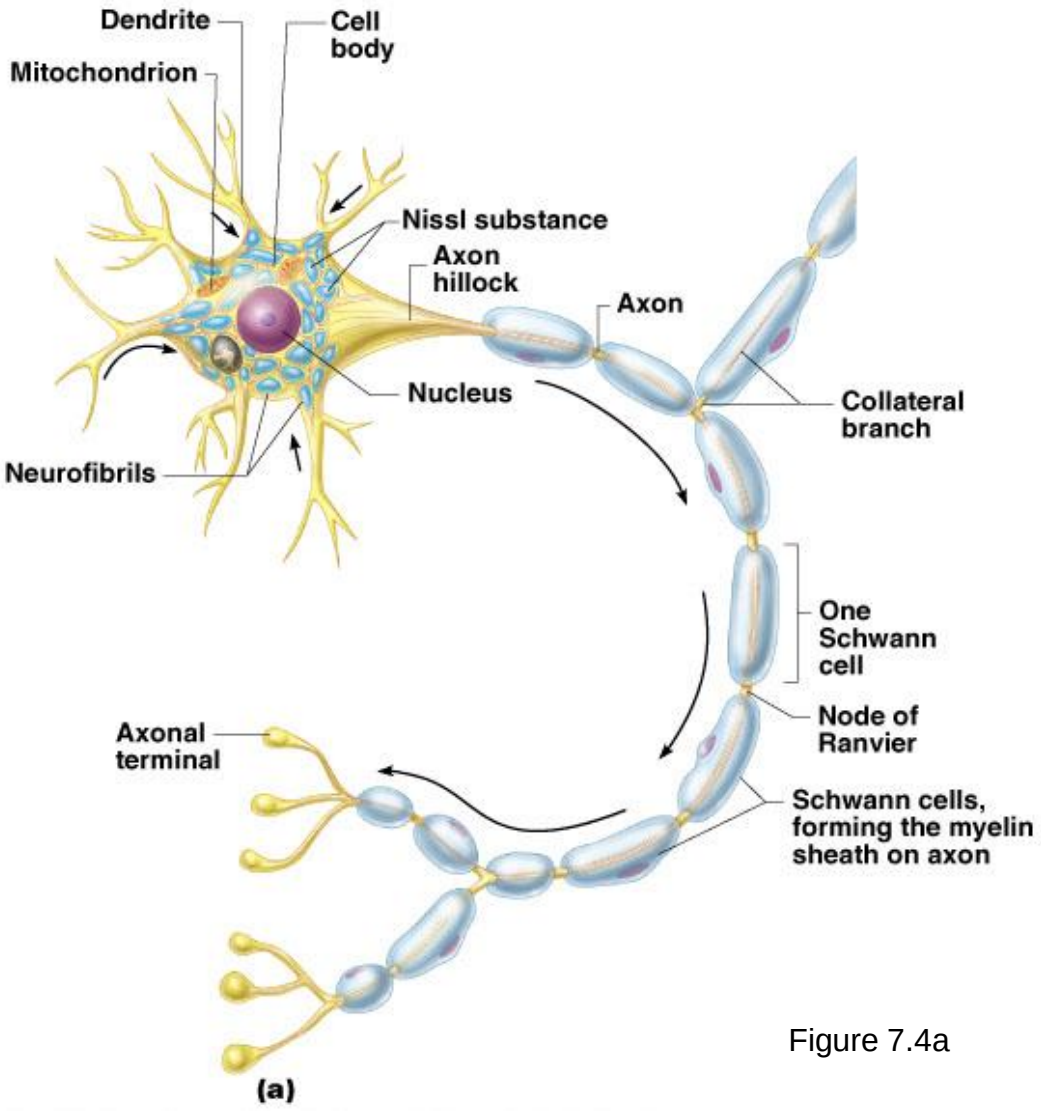


Figure 7.4a

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

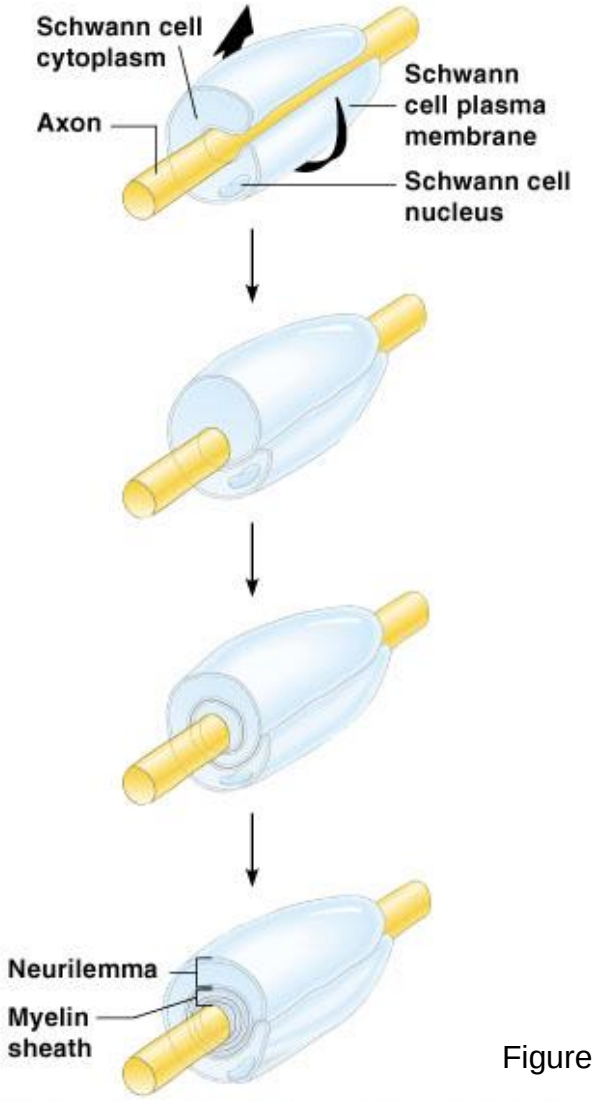


Figure 7.5

Neuron Cell Body Location

- Most are found in the central nervous system
  - Gray matter – cell bodies and unmylenated fibers
  - Nuclei – clusters of cell bodies within the white matter of the central nervous system
- Ganglia – collections of cell bodies outside the central nervous system

Functional Classification of Neurons

- Sensory (afferent) neurons
  - Carry impulses from the sensory receptors
    - Cutaneous sense organs
    - Proprioceptors – detect stretch or tension
- Motor (efferent) neurons
  - Carry impulses from the central nervous system

Functional Classification of Neurons

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

Neuron Classification

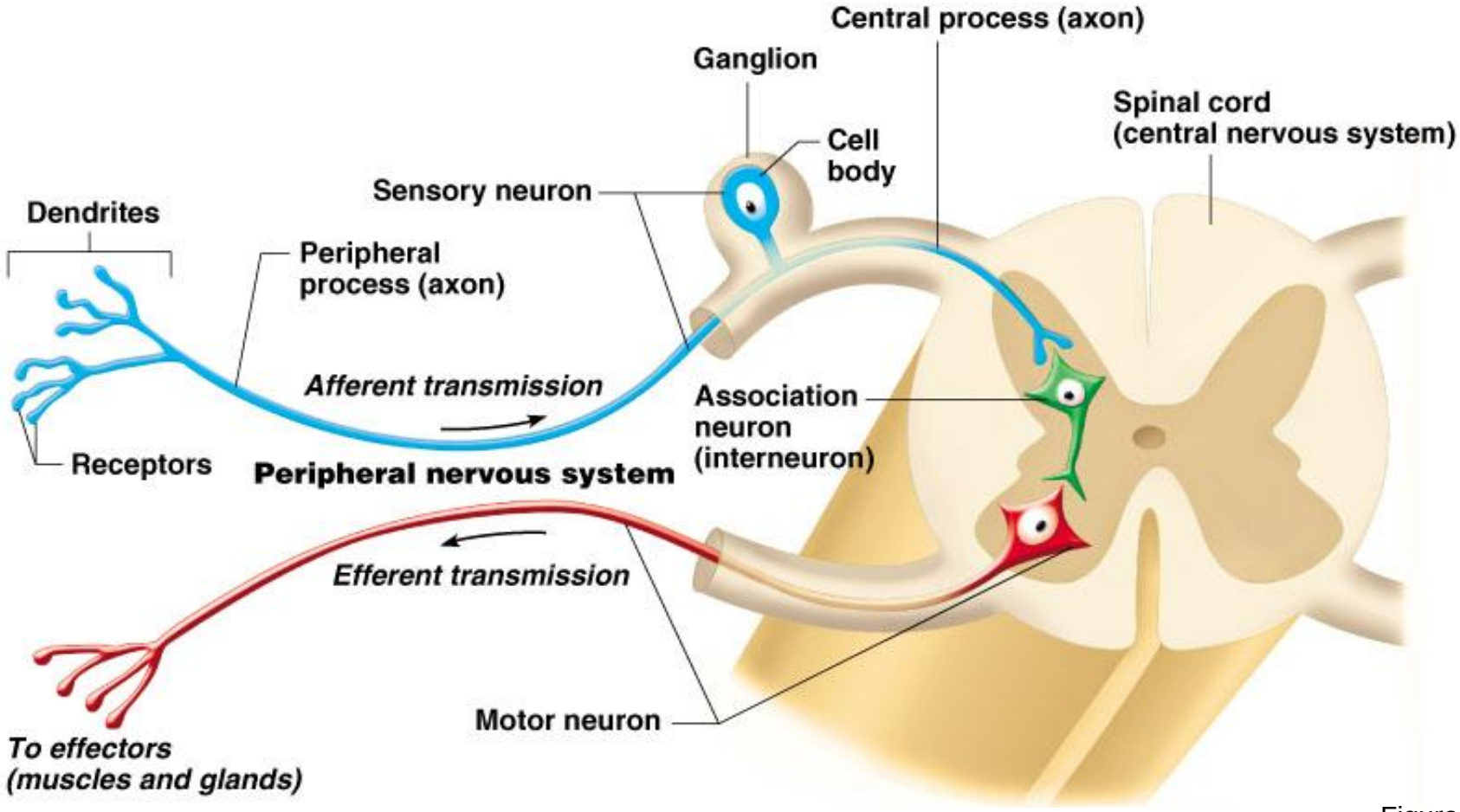
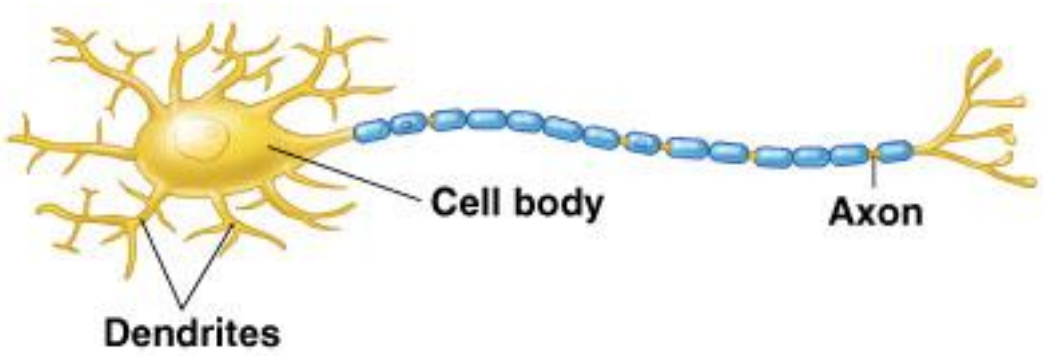


Figure 7.6

Structural Classification of Neurons

- Multipolar neurons – many extensions from the cell body



(a) Multipolar neuron

Figure 7.8a

Structural Classification of Neurons

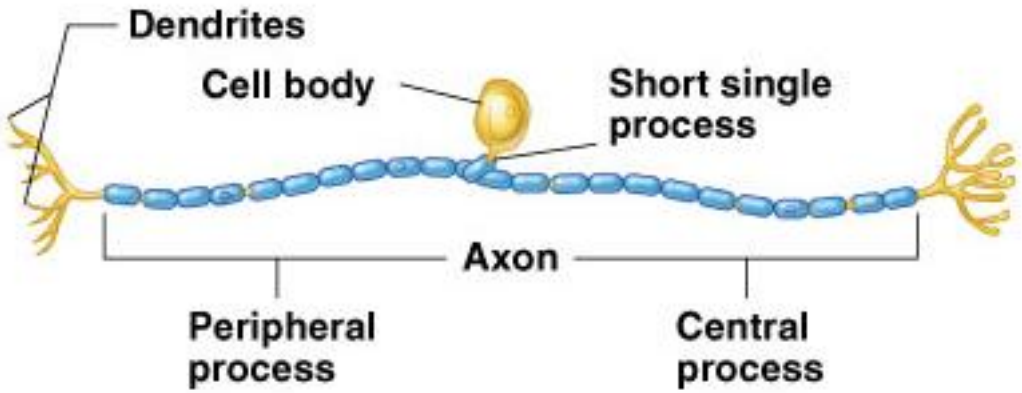
- Bipolar neurons – one axon and one dendrite

(b) Bipolar neuron

Figure 7.8b

Structural Classification of Neurons

- Unipolar neurons – have a short single process leaving the cell body



(c) Unipolar neuron

Figure 7.8c

Functional Properties of Neurons

- Irritability – ability to respond to stimuli
- Conductivity – ability to transmit an impulse
- The plasma membrane at rest is polarized
  - Fewer positive ions are inside the cell than outside the cell

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 in the neuron

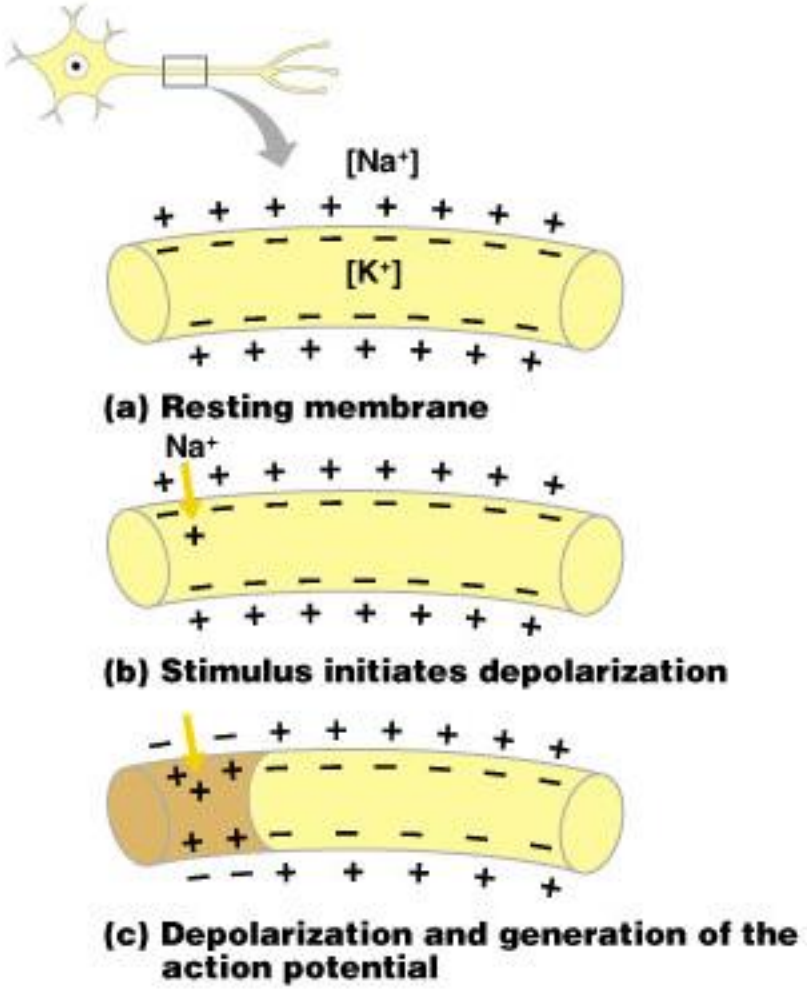


Figure 7.9a–c

The Action Potential

- If the action potential (nerve impulse) starts, it is propagated over the entire axon
- 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

Nerve Impulse Propagation

- The impulse continues to move toward the cell body
- Impulses travel faster when fibers have a myelin sheath

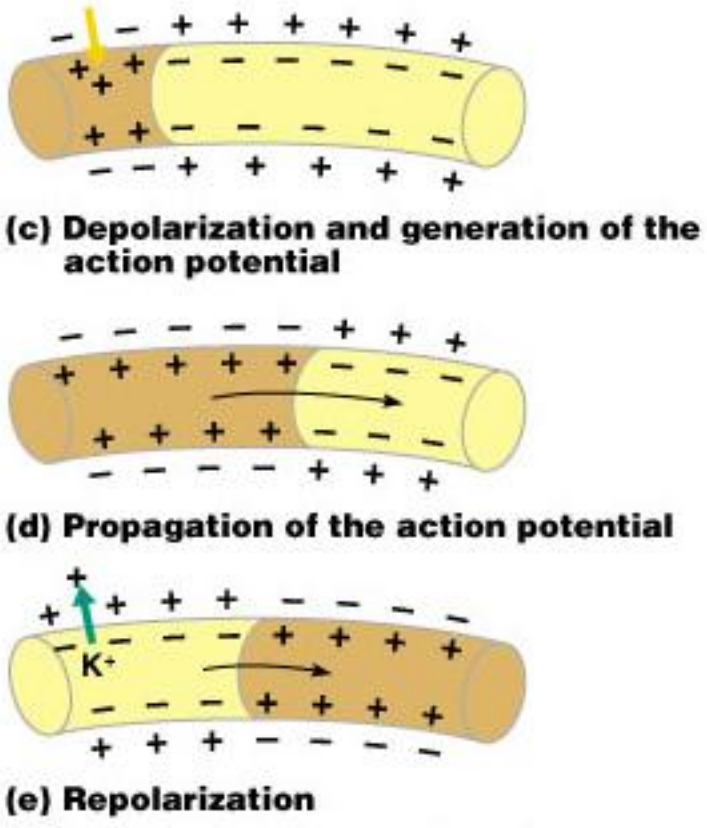


Figure 7.9c–e

Continuation of the Nerve Impulse between Neurons

- Impulses are able 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 dendrite

How Neurons Communicate at Synapses

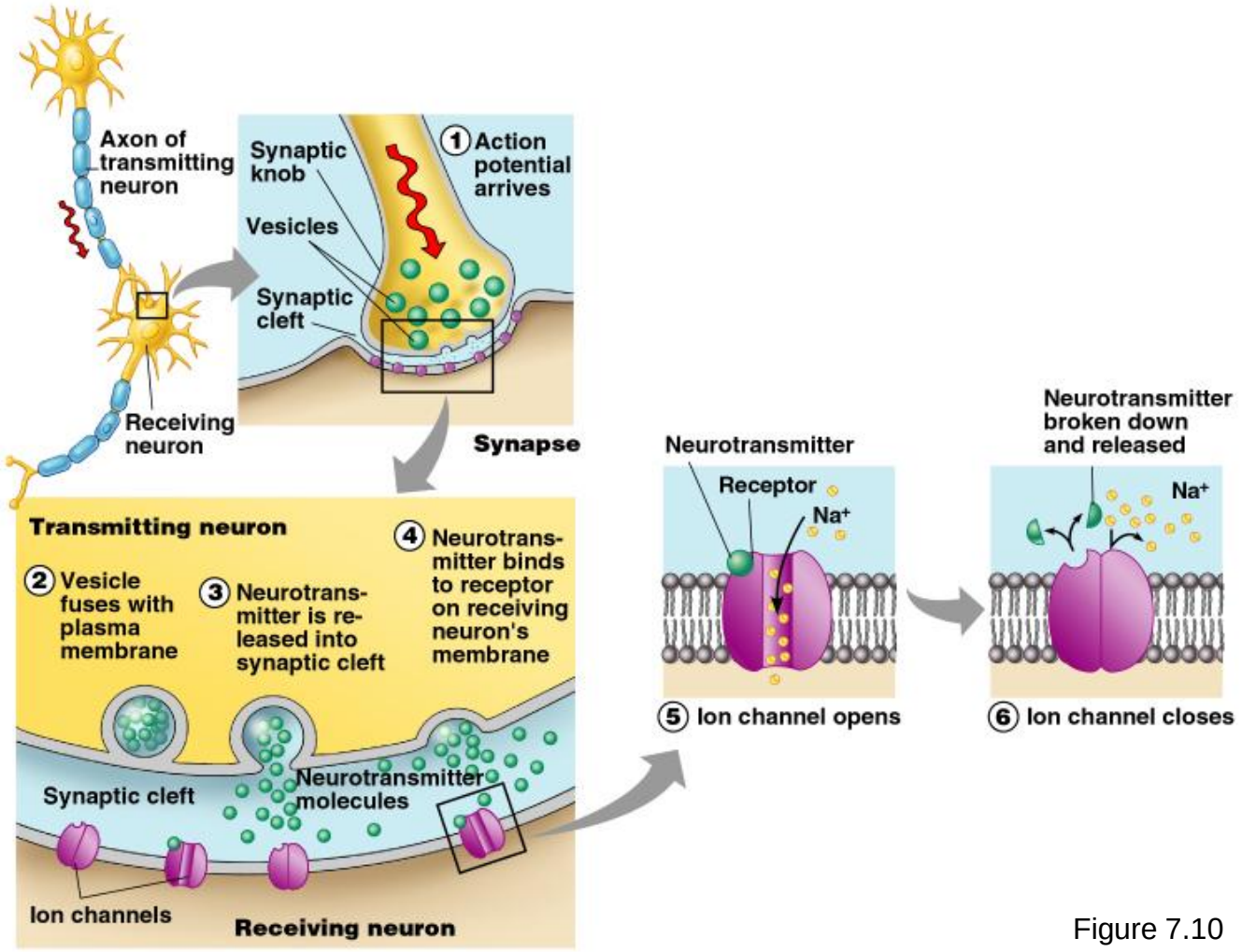


Figure 7.10

Essentials of Human Anatomy & Physiology

Seventh Edition

Elaine N. Marieb

Chapter 7

The Nervous System

Slides 7.23 – 7.42

Lecture Slides in PowerPoint by Jerry L. Cook

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

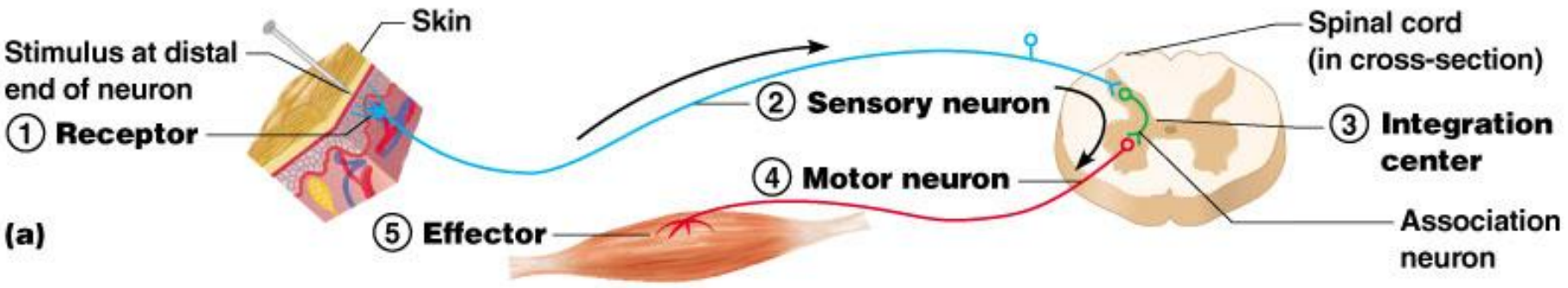


Figure 7.11a

Simple Reflex Arc

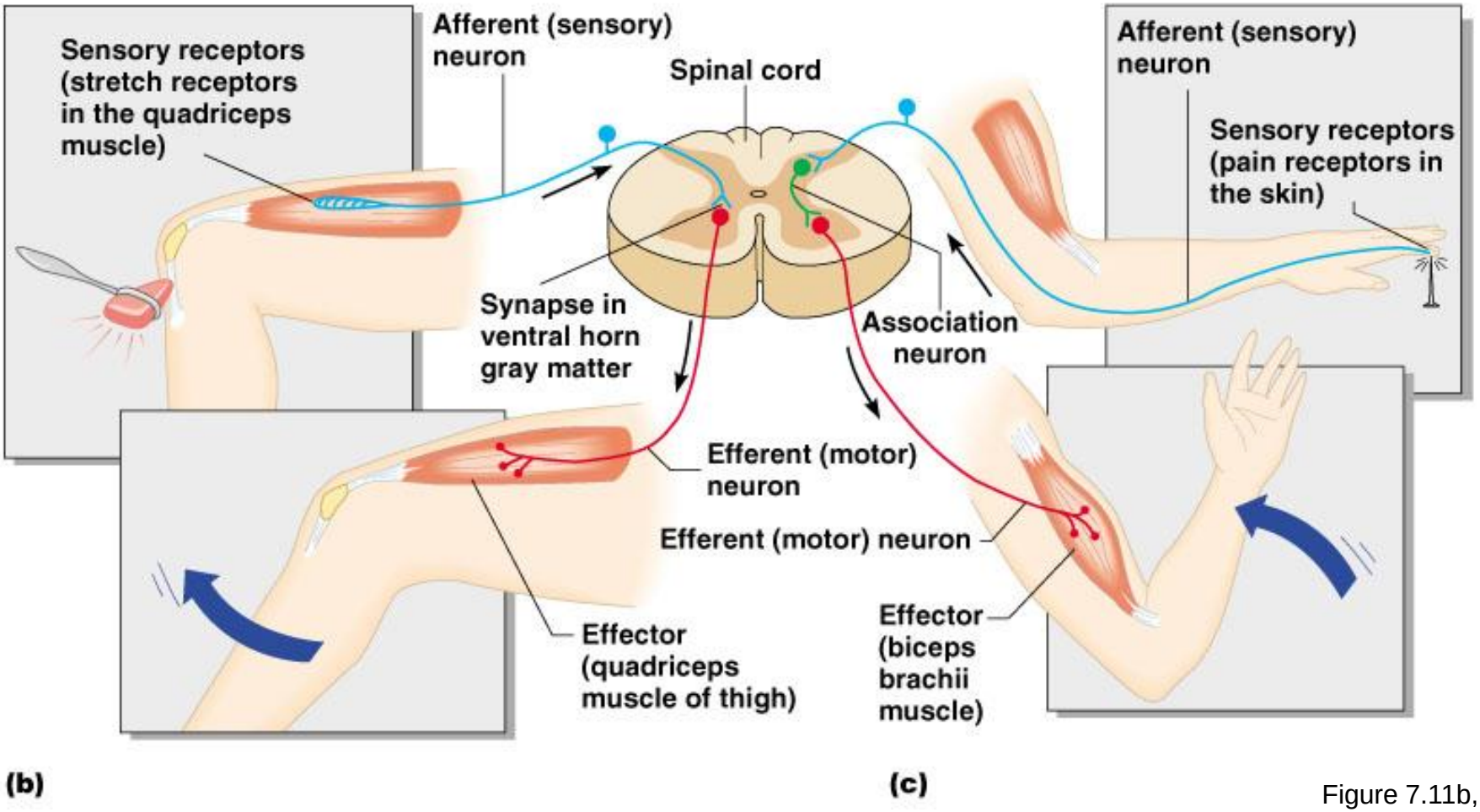


Figure 7.11b, c

Types of Reflexes and Regulation

- Autonomic reflexes
  - Smooth muscle regulation
  - Heart and blood pressure regulation
  - Regulation of glands
  - Digestive system regulation
- Somatic reflexes
  - Activation of skeletal muscles

Central Nervous System (CNS)

- CNS develops from the embryonic neural 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

Cerebral Hemispheres (Cerebrum)

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

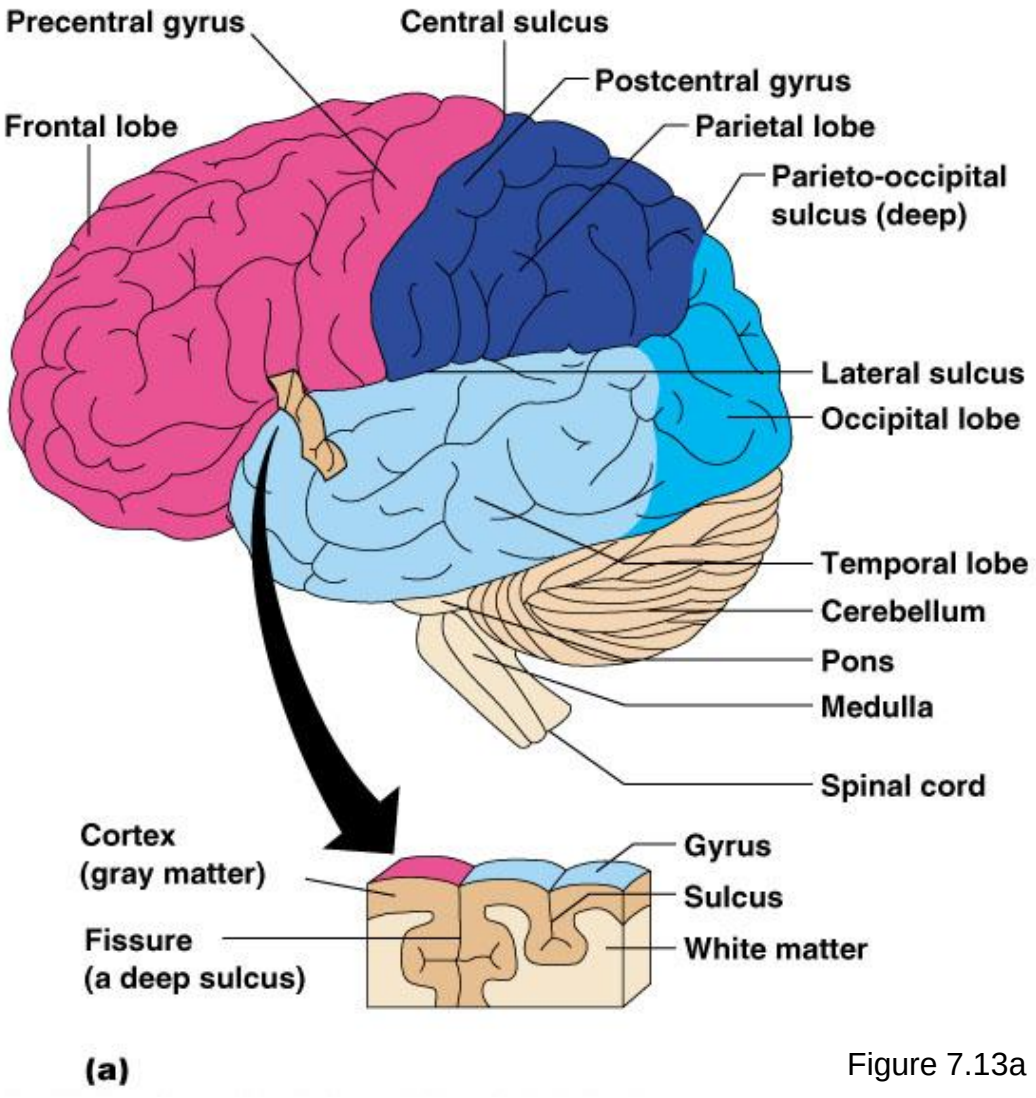


Figure 7.13a

Regions of the Brain

- Cerebral hemispheres
- Diencephalon
- Brain stem
- Cerebellum

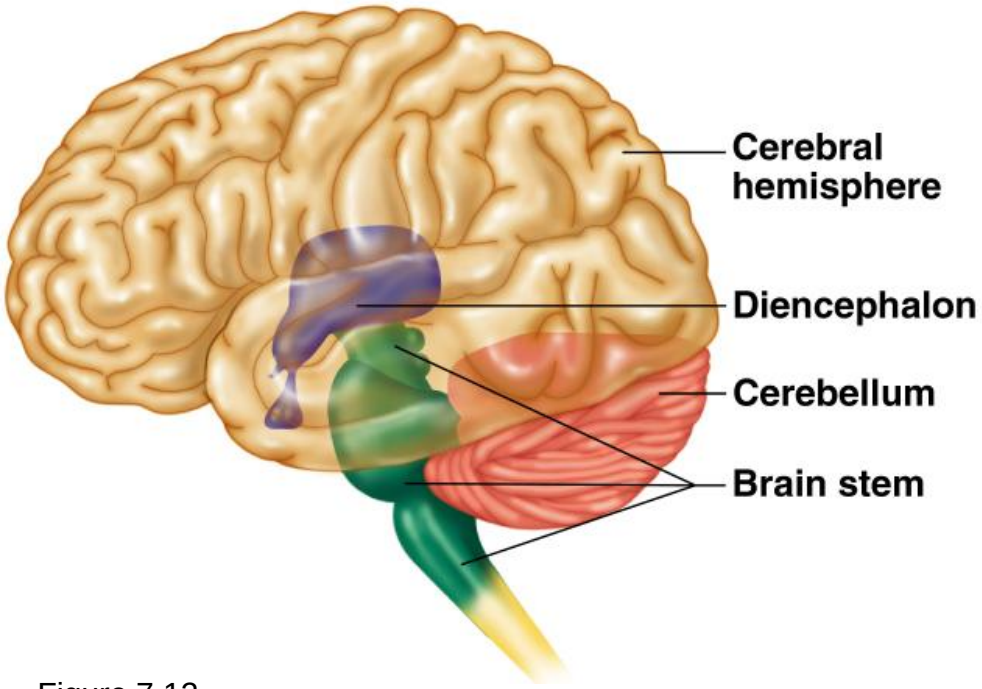


Figure 7.12

Cerebral Hemispheres (Cerebrum)

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

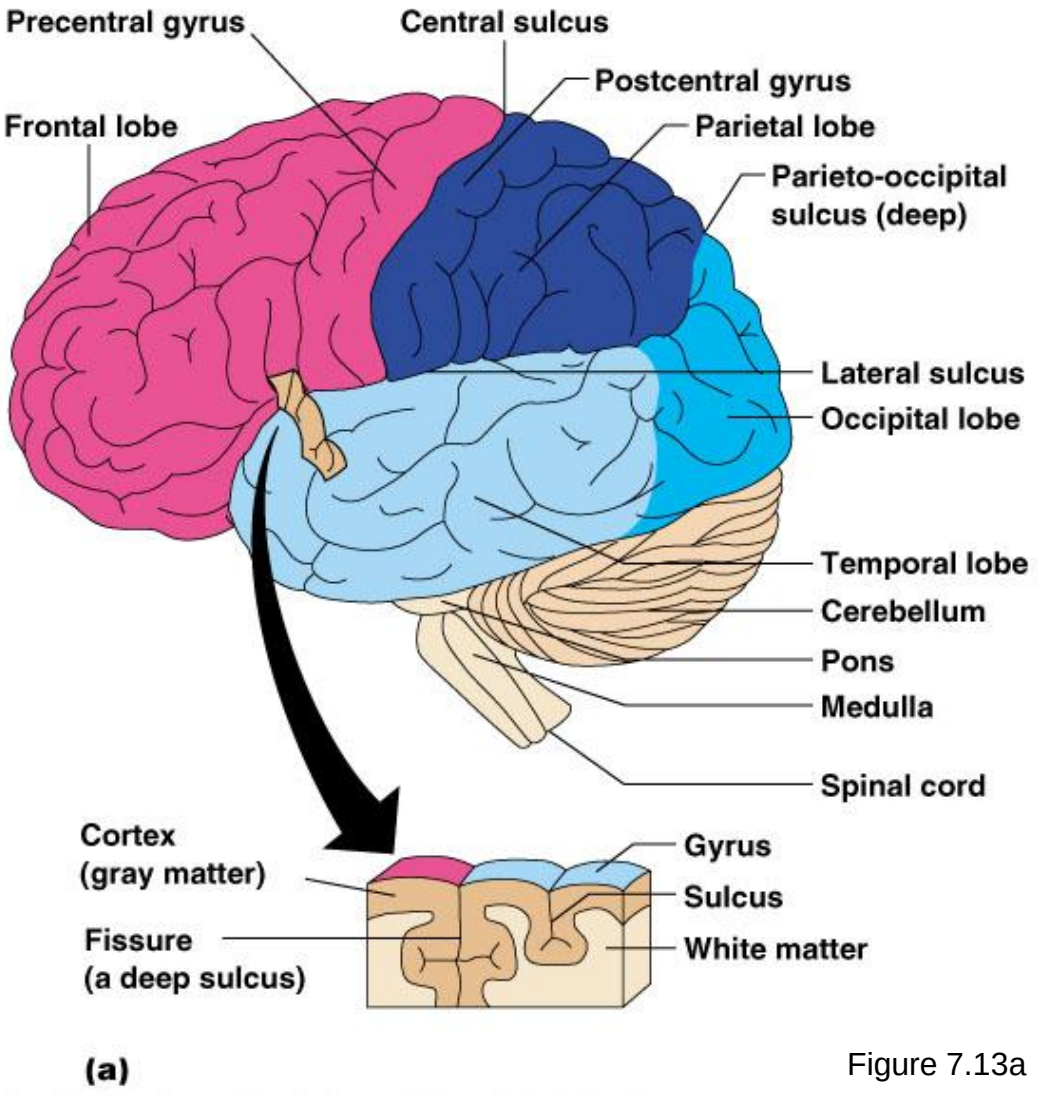


Figure 7.13a

Lobes of the Cerebrum

- Fissures (deep grooves) divide the cerebrum into lobes
- Surface lobes of the cerebrum
  - Frontal lobe
  - Parietal lobe
  - Occipital lobe
  - Temporal lobe

Lobes of the Cerebrum

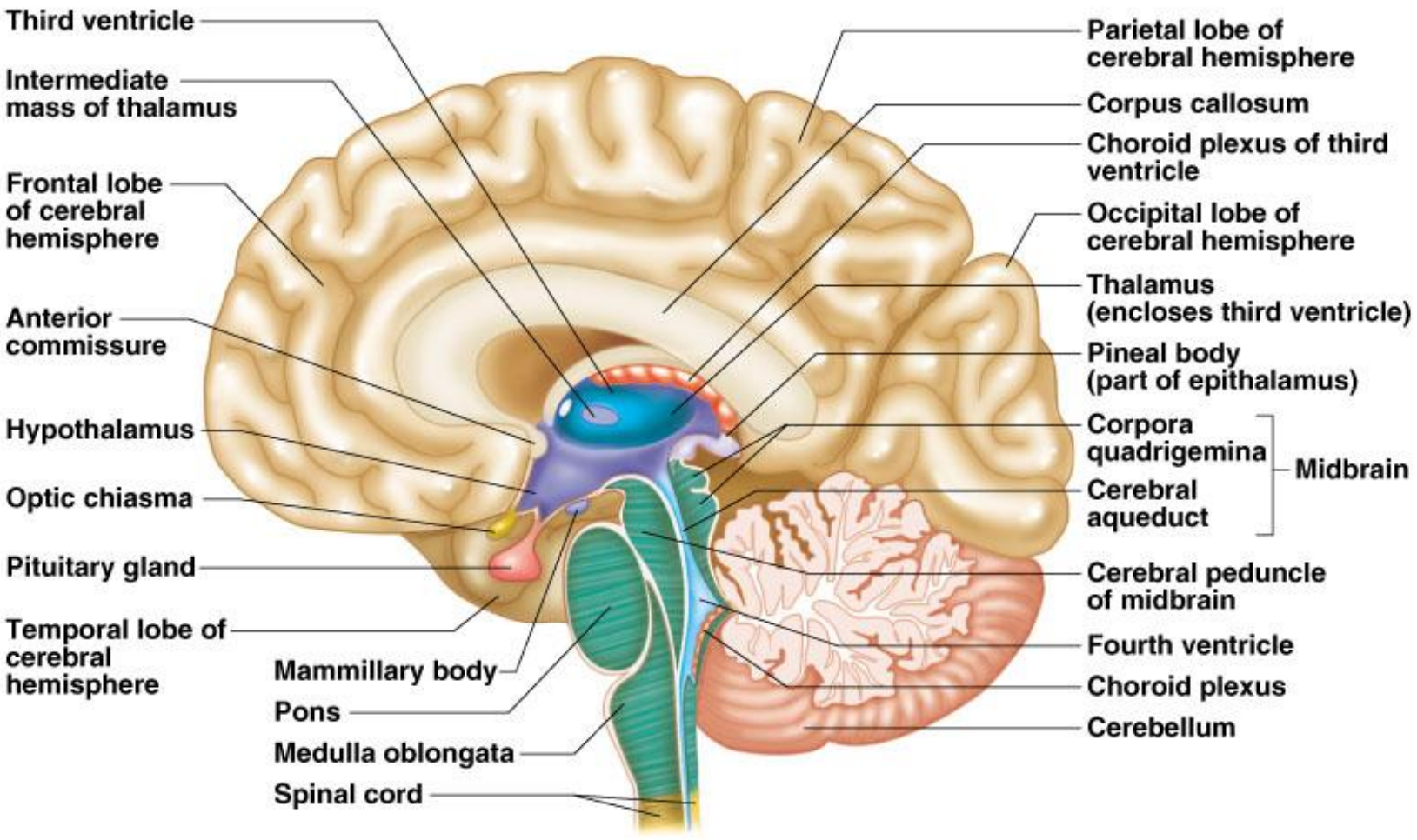


Figure 7.15a

Specialized Areas of the Cerebrum

- Somatic sensory area – receives impulses from the body's sensory receptors
- Primary motor area – sends impulses to skeletal muscles
- Broca's area – involved in our ability to speak

Sensory and Motor Areas of the Cerebral Cortex

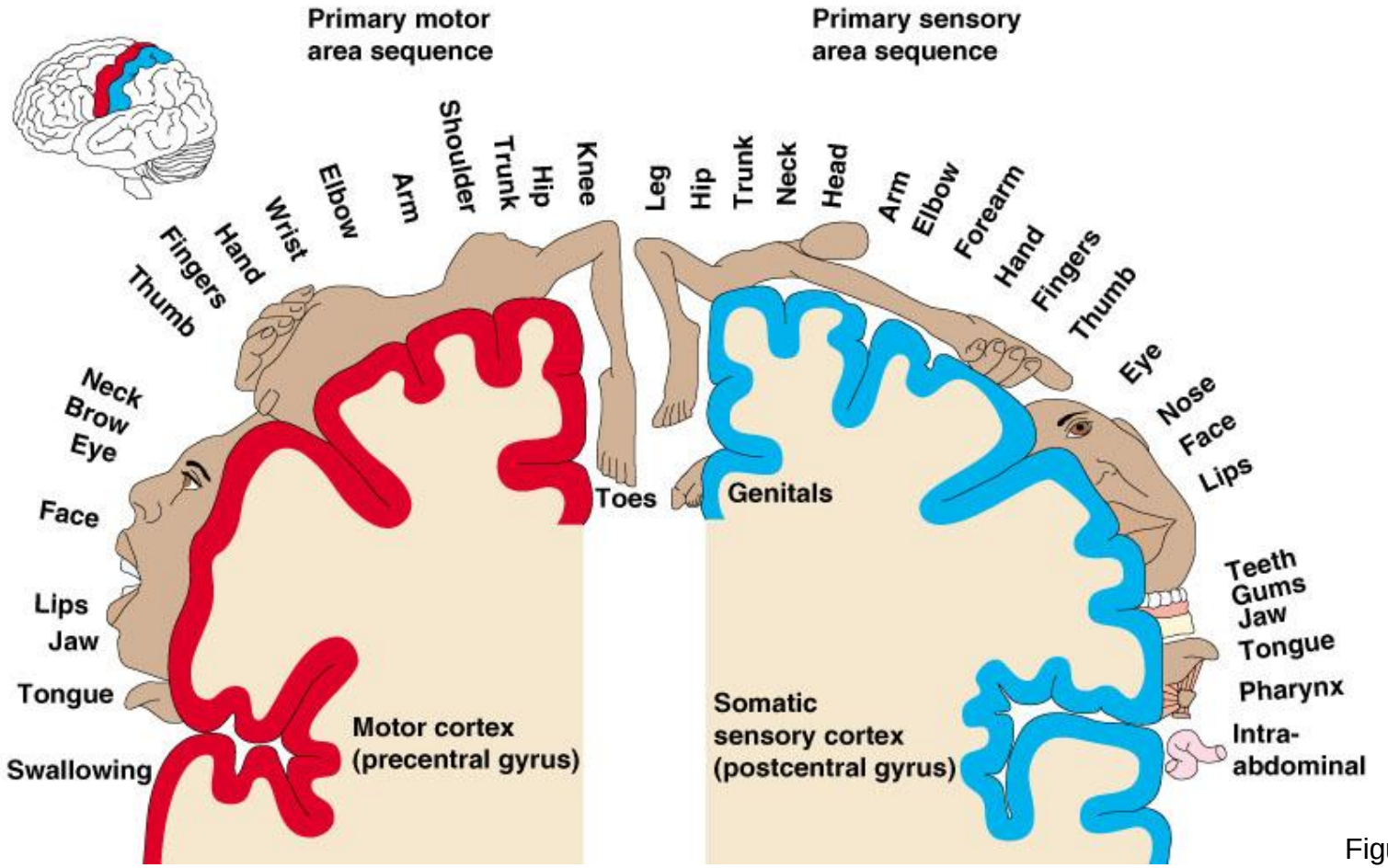


Figure 7.14

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

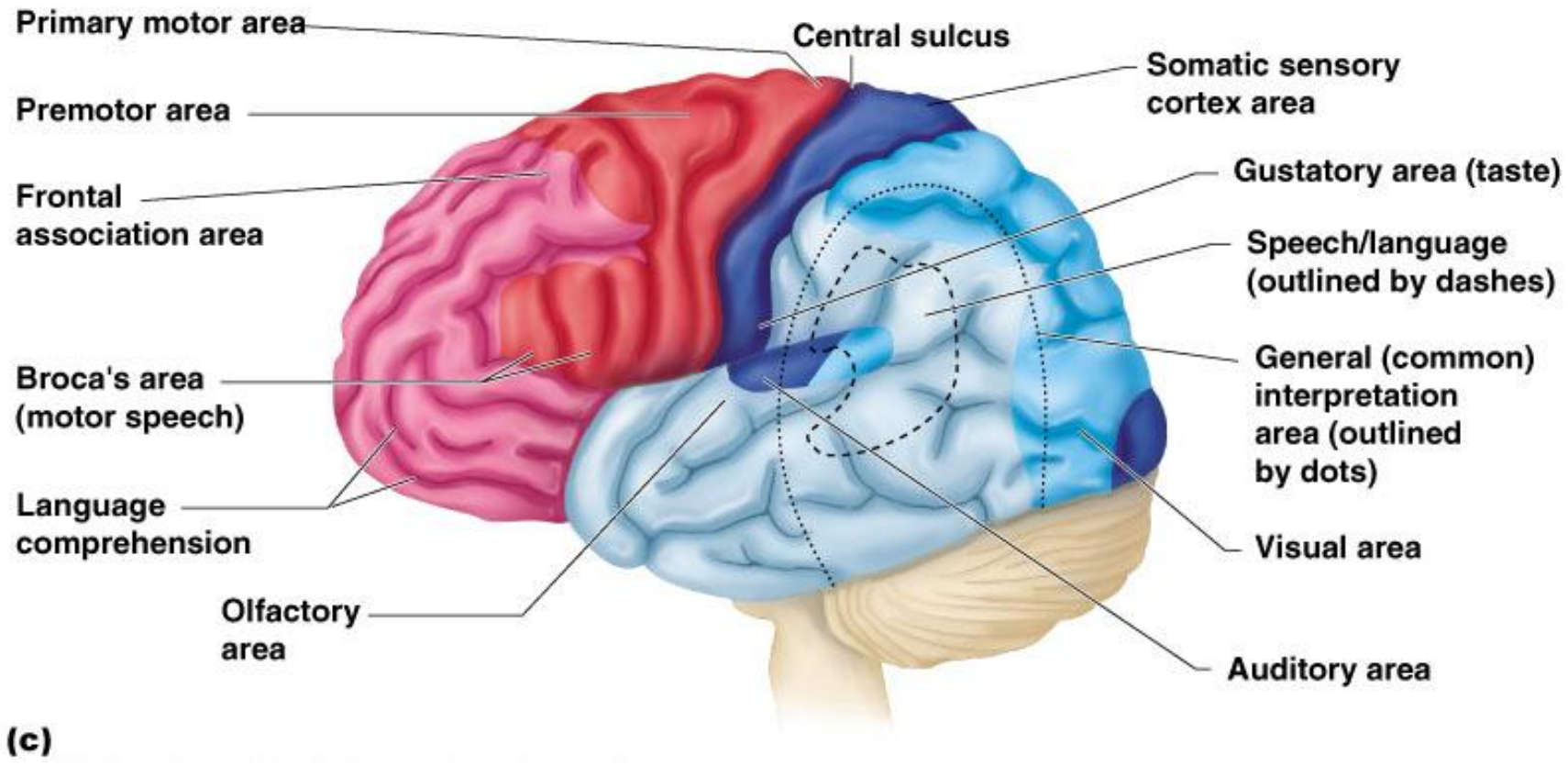


Figure 7.13c

Layers of the Cerebrum

- Gray matter
  - Outer layer
  - Composed mostly of neuron cell bodies

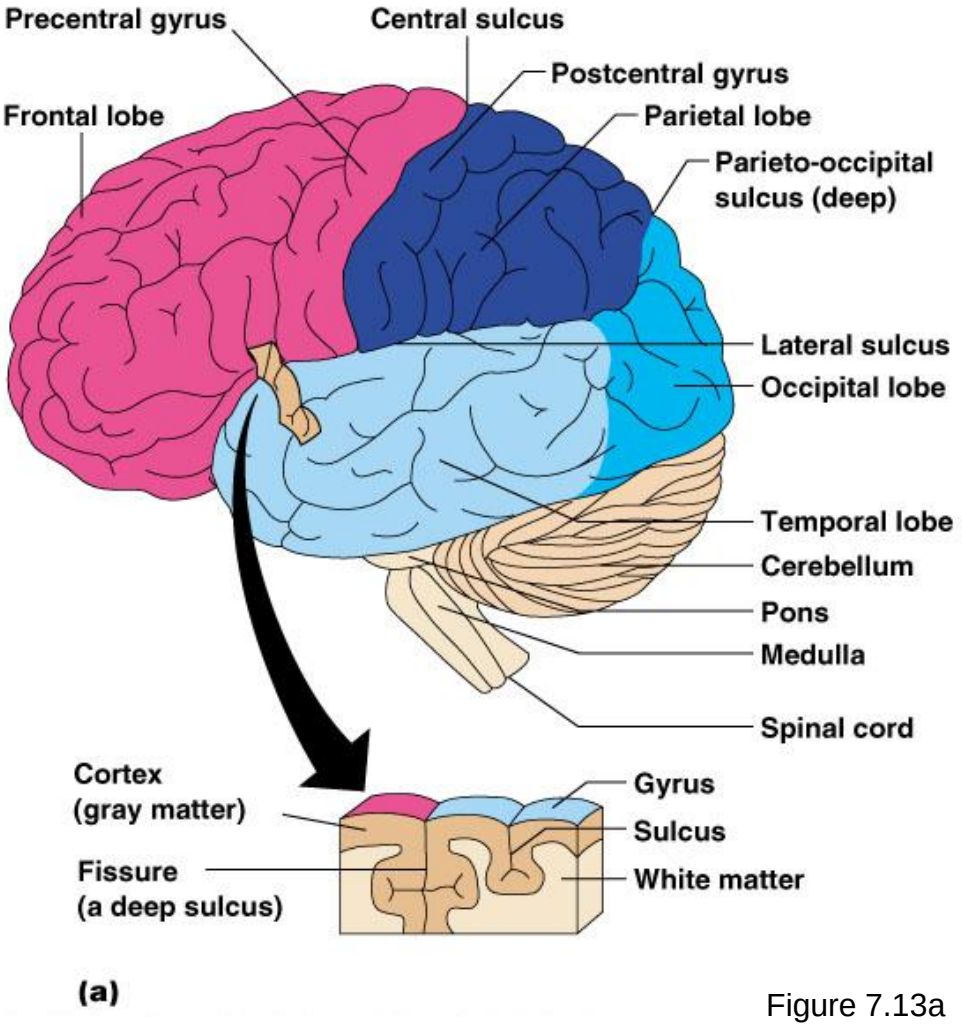


Figure 7.13a

Layers of the Cerebrum

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

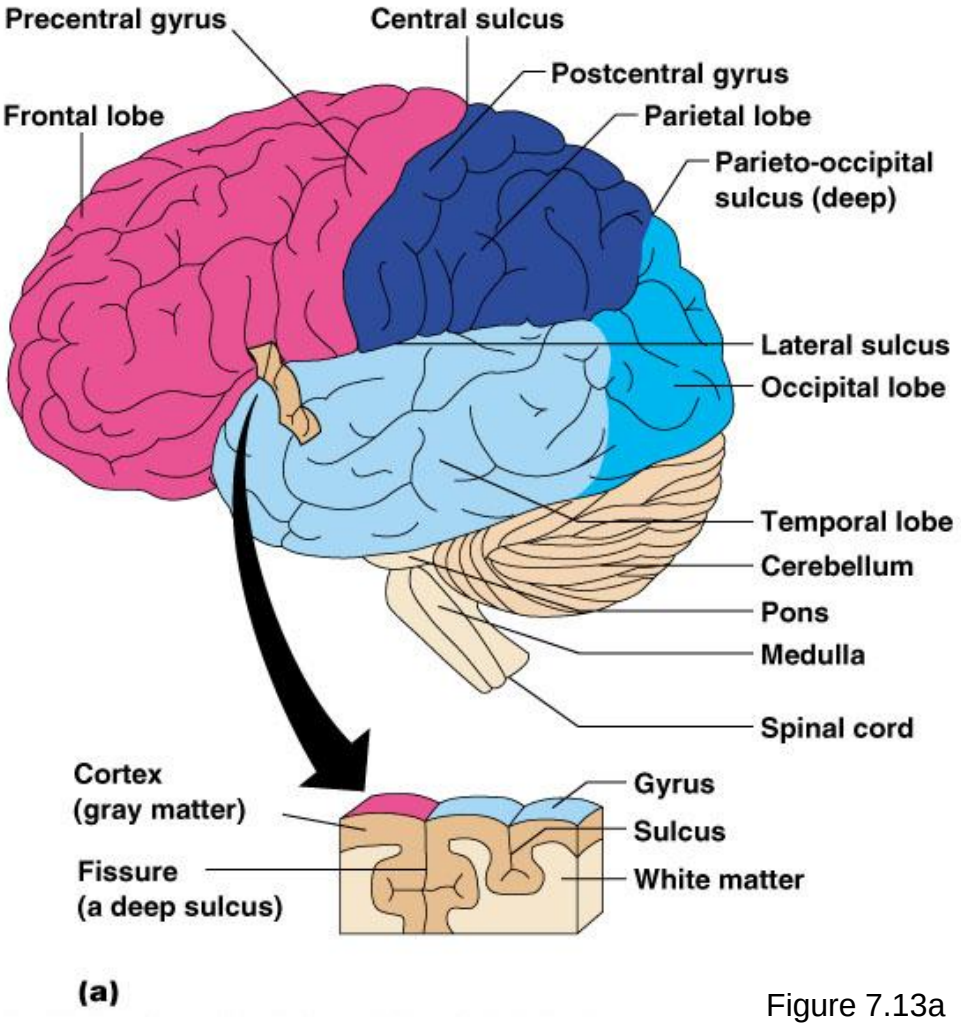


Figure 7.13a

Layers of the Cerebrum

- Basal nuclei – internal islands of gray matter

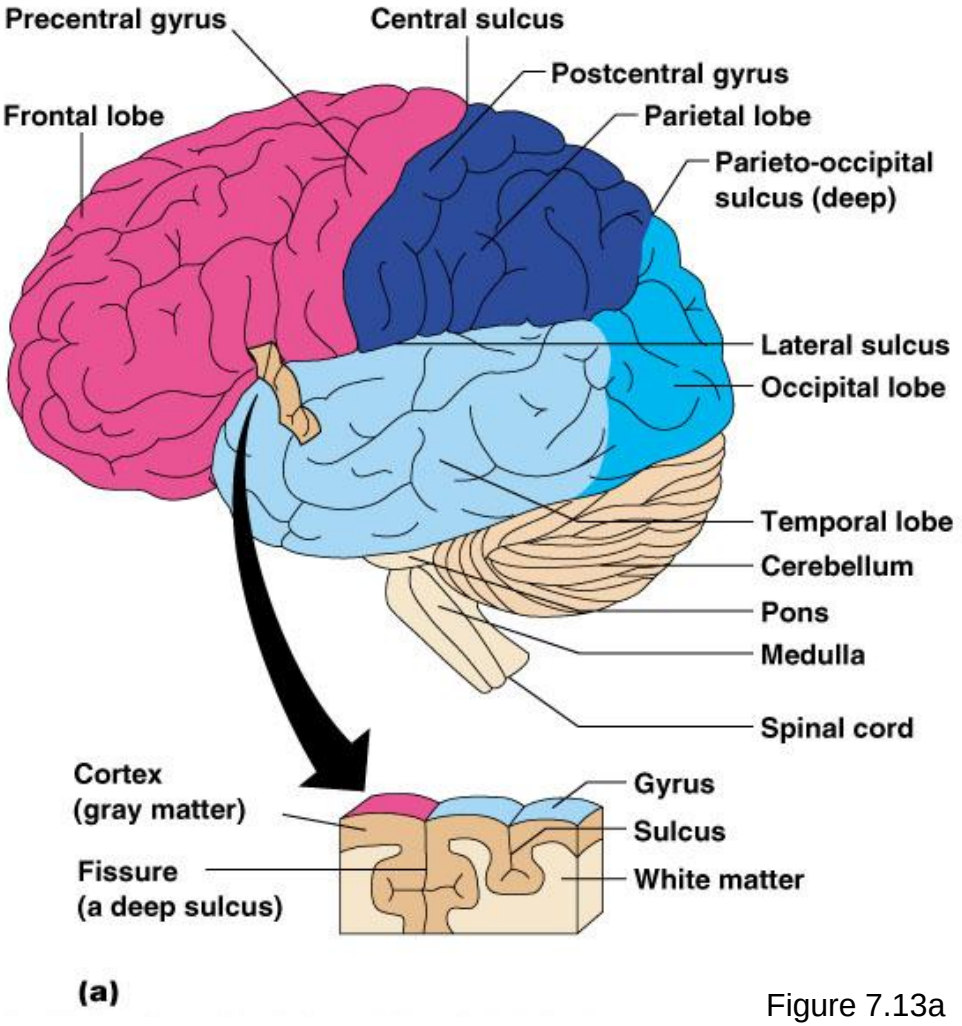


Figure 7.13a

Diencephalon

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

Diencephalon

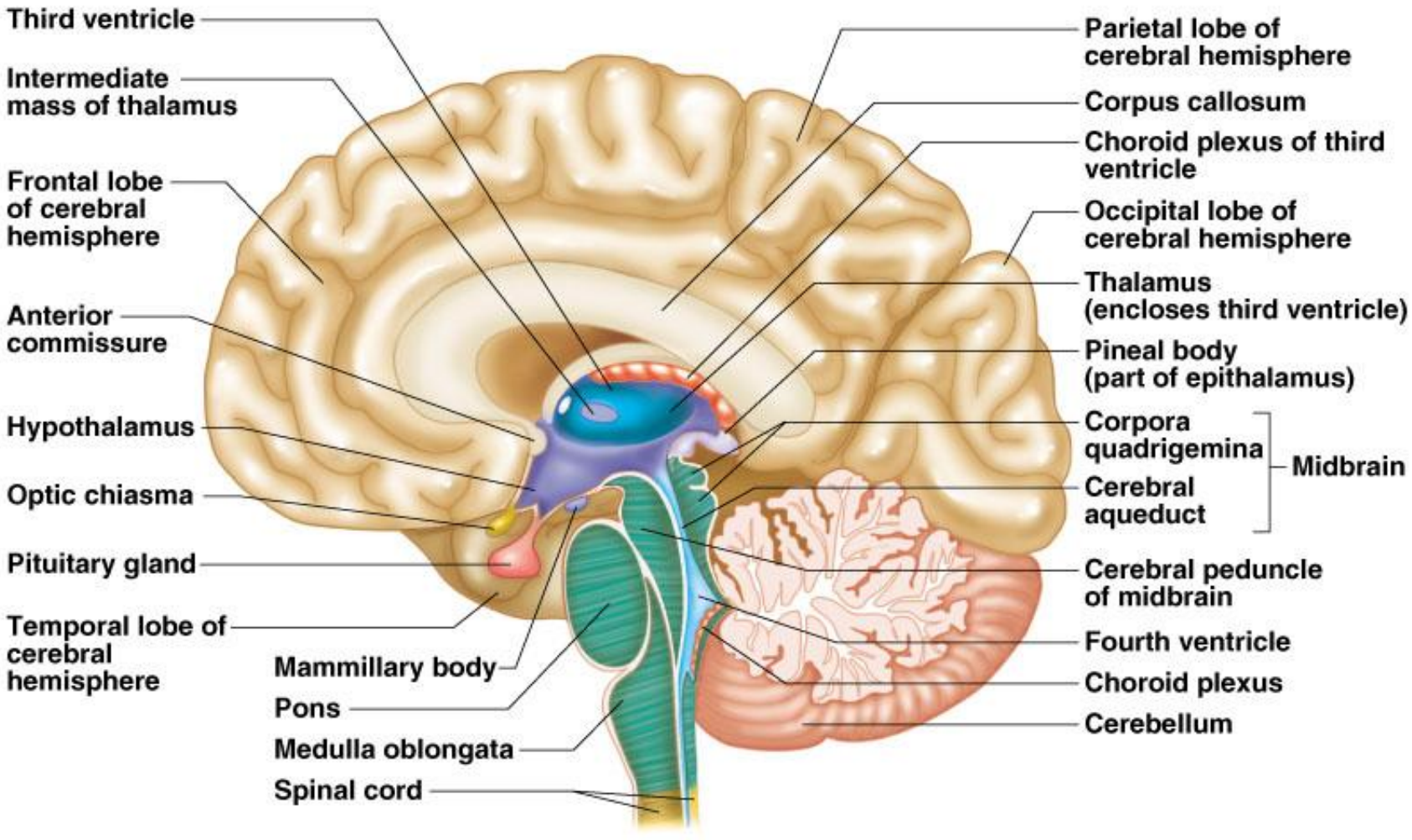


Figure 7.15

Thalamus

- Surrounds the third ventricle
- The relay station for sensory impulses
- 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)
- The pituitary gland is attached to 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

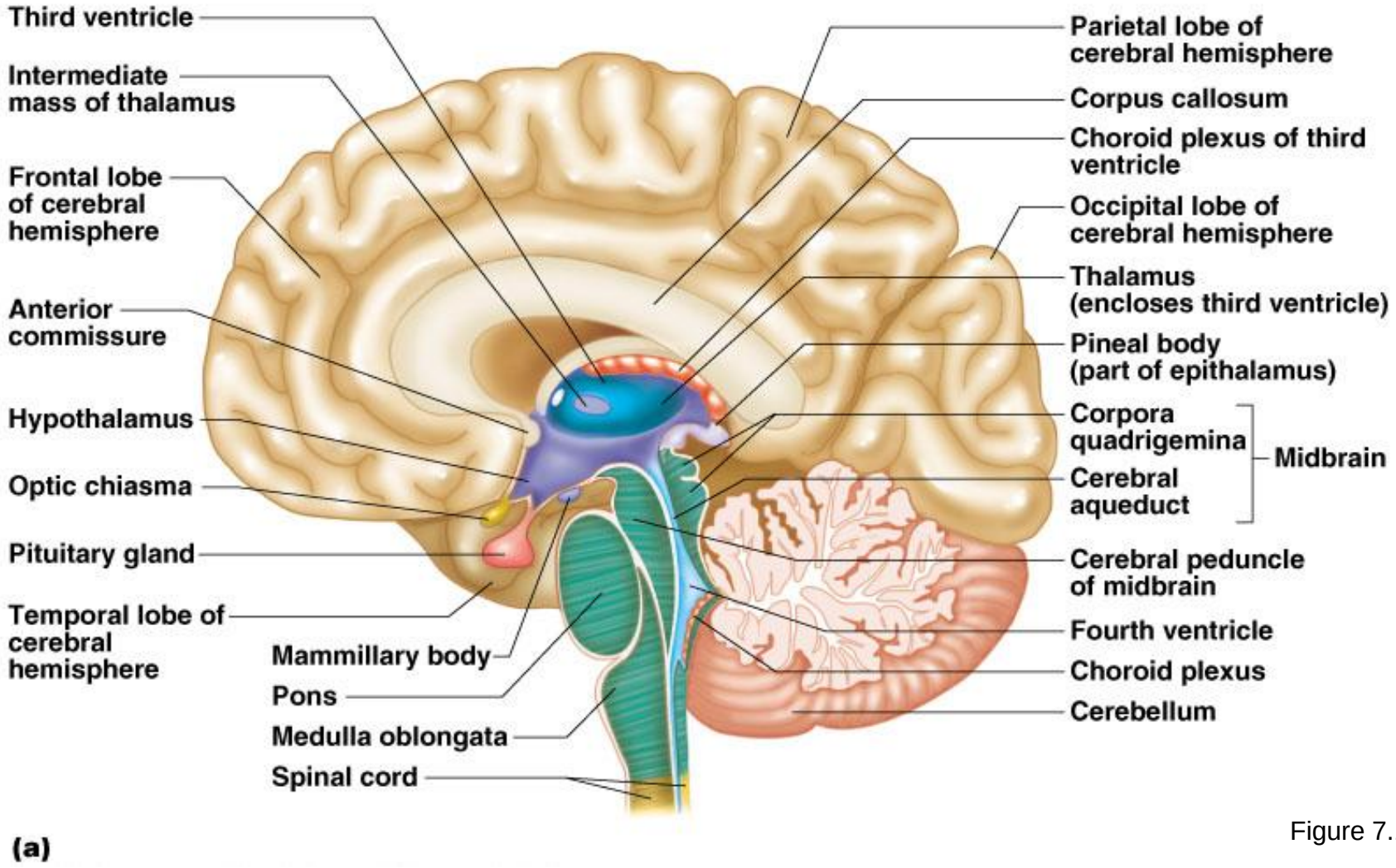


Figure 7.15a

Midbrain

- Mostly composed of tracts of nerve fibers
- Has two bulging fiber tracts – cerebral peduncles
- 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

Reticular Formation

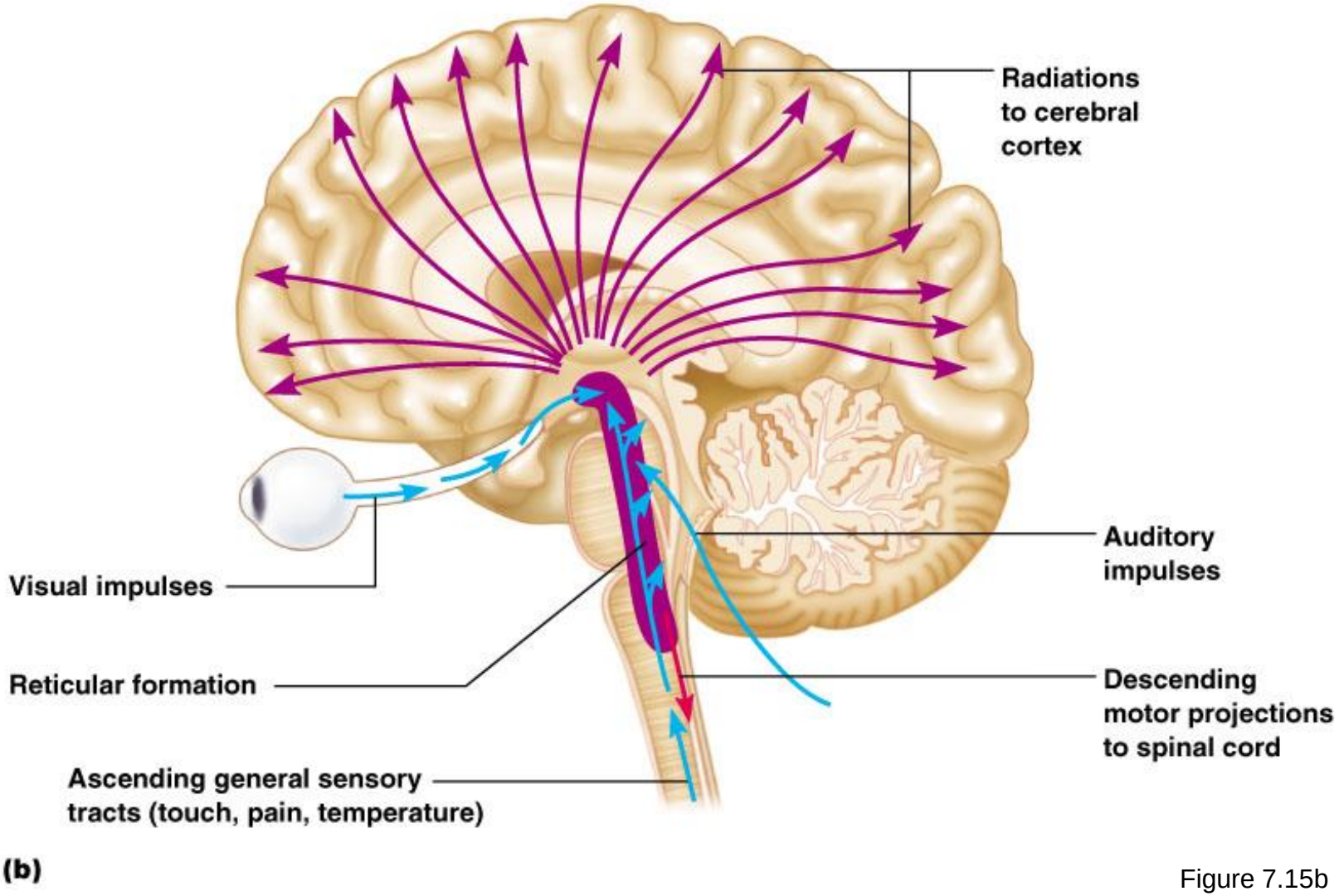


Figure 7.15b

Essentials of Human Anatomy & Physiology

Seventh Edition

Elaine N. Marieb

Chapter 7

The Nervous System

Slides 7.43 – 7.62

Lecture Slides in PowerPoint by Jerry L. Cook

Cerebellum

- Two hemispheres with convoluted surfaces
- Provides involuntary coordination of body movements

Cerebellum

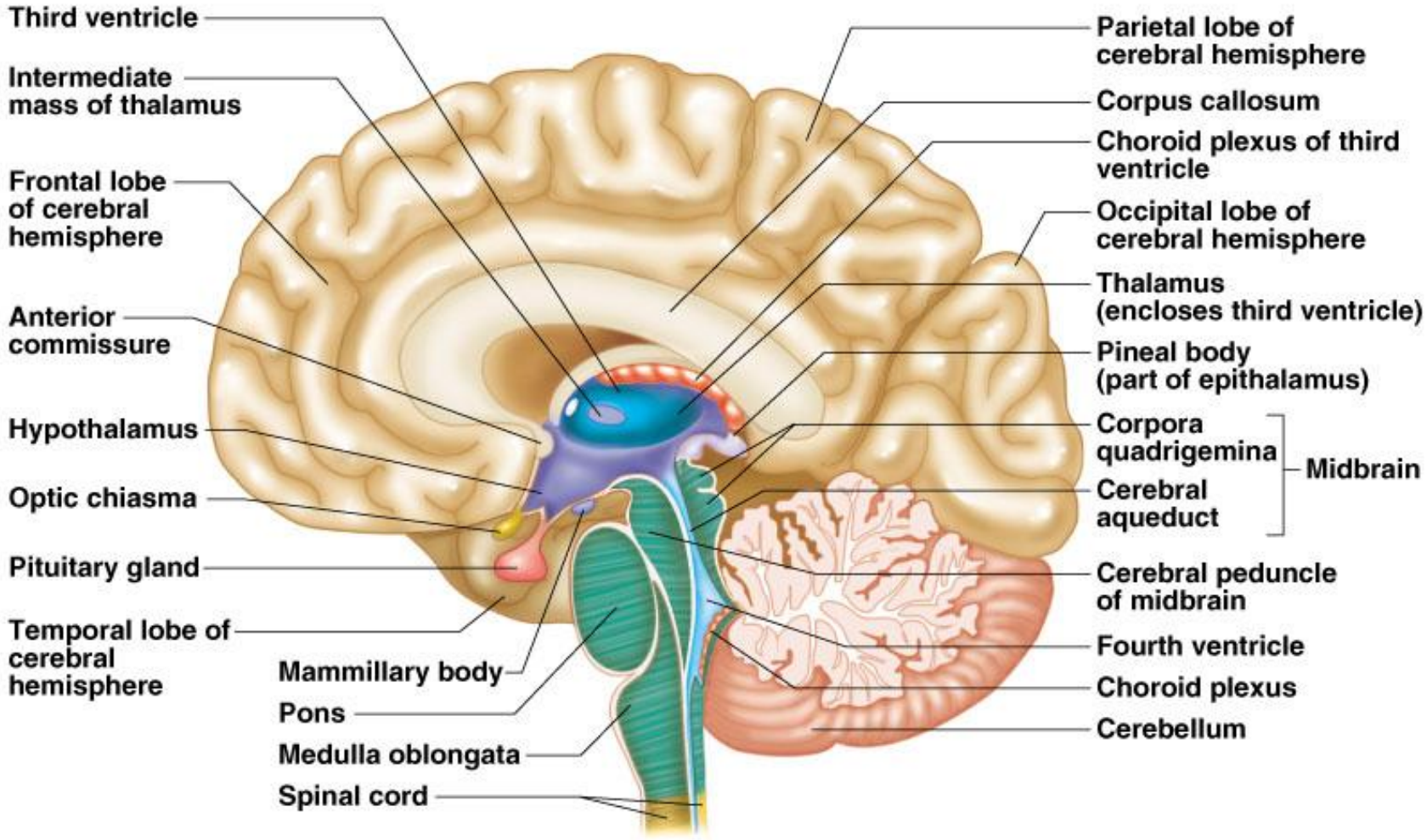


Figure 7.15a

Protection of the Central Nervous System

- Scalp and skin
- Skull and vertebral column
- Meninges

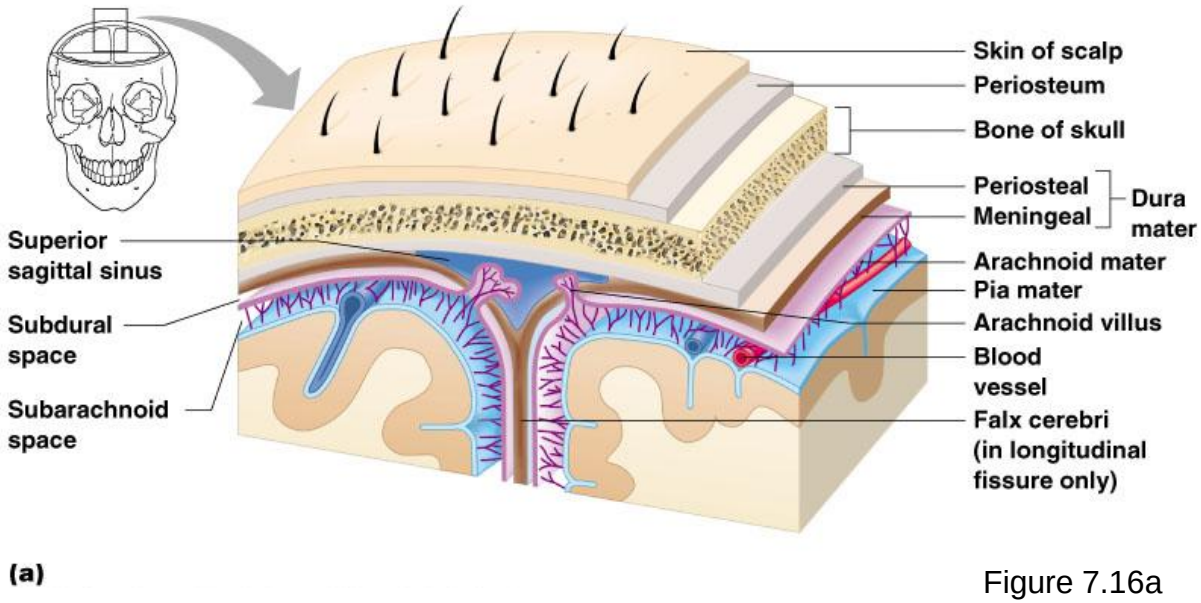


Figure 7.16a

Protection of the Central Nervous System

- Cerebrospinal fluid
- Blood brain barrier

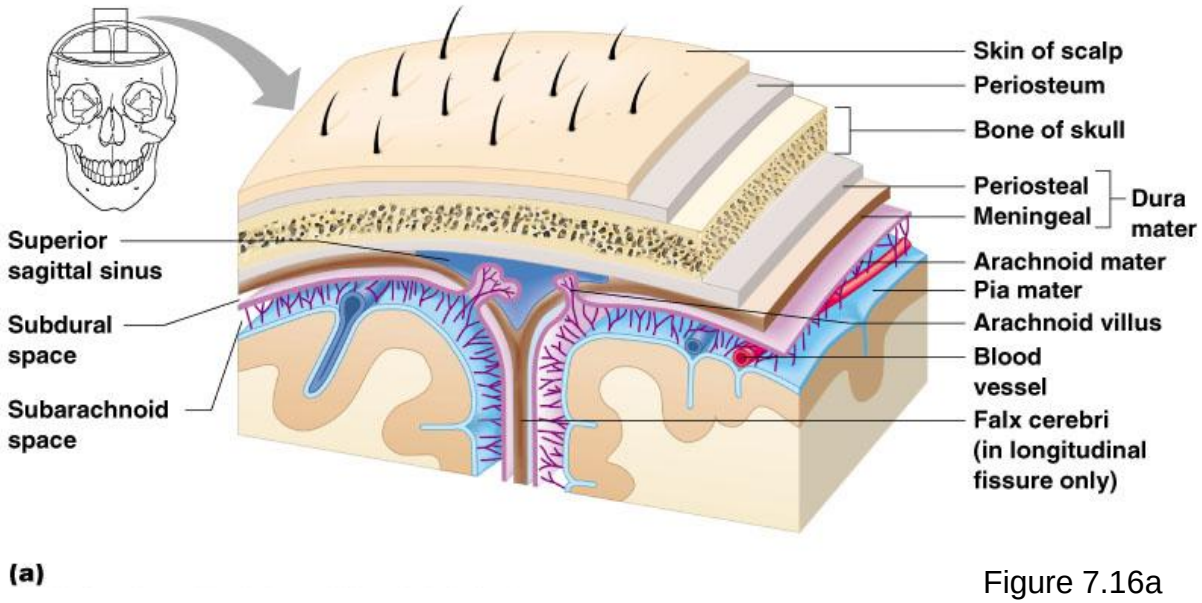


Figure 7.16a

Meninges

- Dura mater
  - Double-layered external covering
    - Periosteum – attached to surface of the skull
    - Meningeal layer – outer covering of the brain
  - Folds inward in several areas

Meninges

- Arachnoid layer
  - Middle layer
  - Web-like
- Pia mater
  - Internal layer
  - Clings to the surface of the brain

Cerebrospinal Fluid

- Similar to blood plasma composition
- 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

Blood Brain Barrier

- Includes the least permeable capillaries of the body
- Excludes many potentially harmful substances
- Useless against some substances
  - Fats and fat soluble molecules
  - Respiratory gases
  - Alcohol
  - Nicotine
  - Anesthesia

Ventricles and Location of the Cerebrospinal Fluid

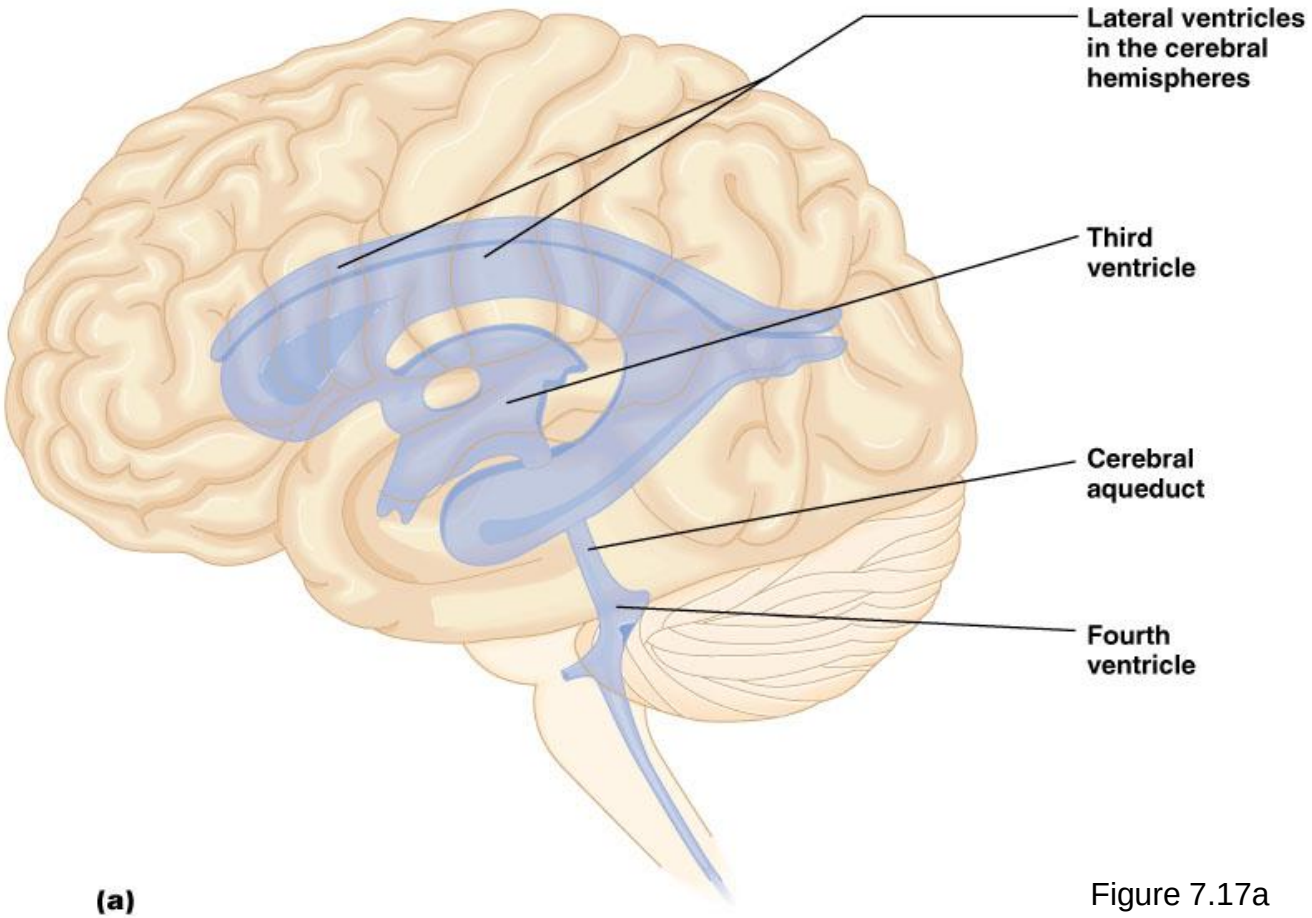


Figure 7.17a

Ventricles and Location of the Cerebrospinal Fluid

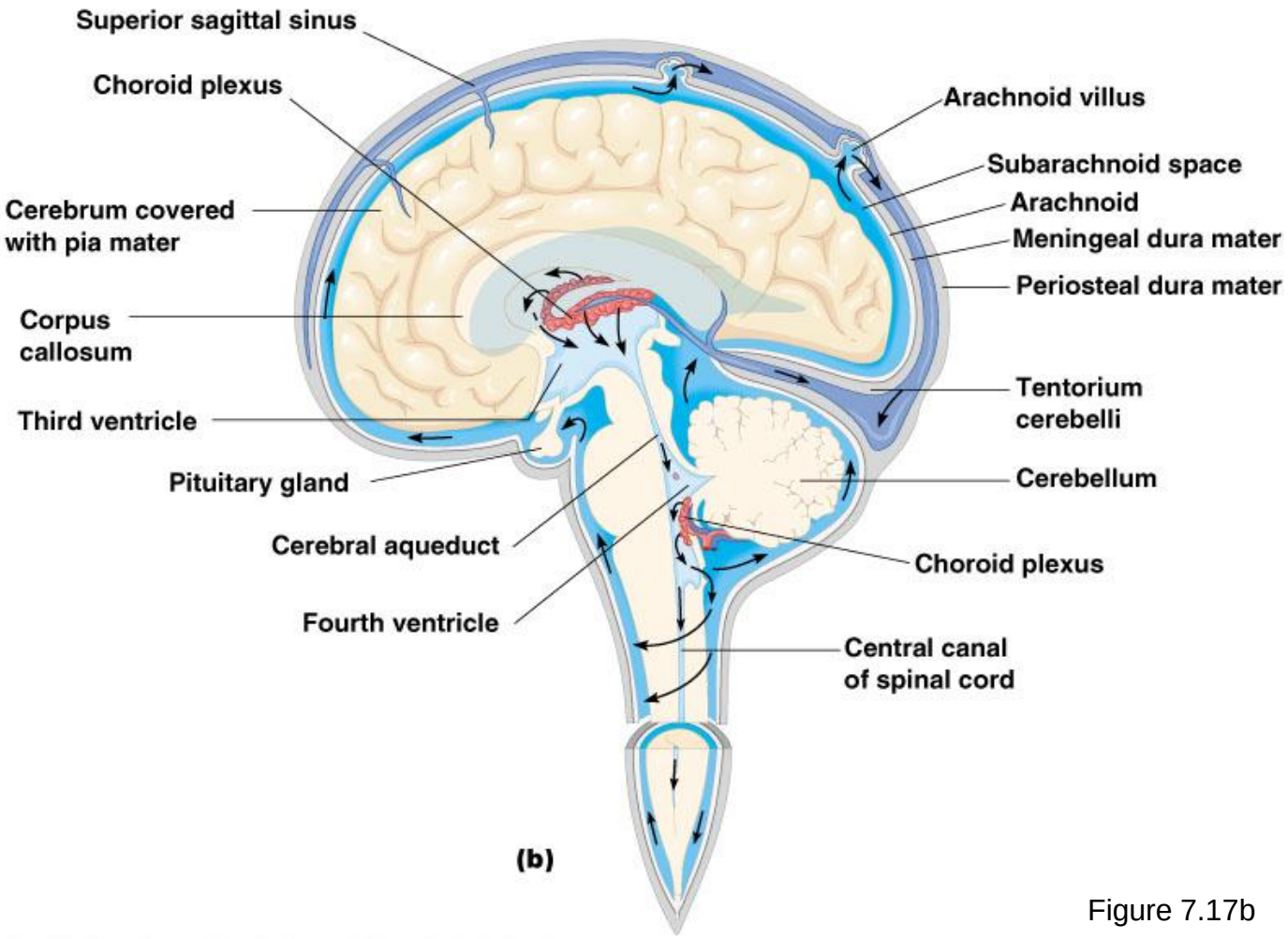


Figure 7.17b

Traumatic Brain Injuries

- Concussion
  - Slight brain injury
  - No permanent brain damage
- Contusion
  - Nervous tissue destruction occurs
  - Nervous tissue does not regenerate
- Cerebral edema
  - Swelling from the inflammatory response
  - May compress and kill brain tissue

Cerebrovascular Accident (CVA)

- Commonly called a stroke
- The result of 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

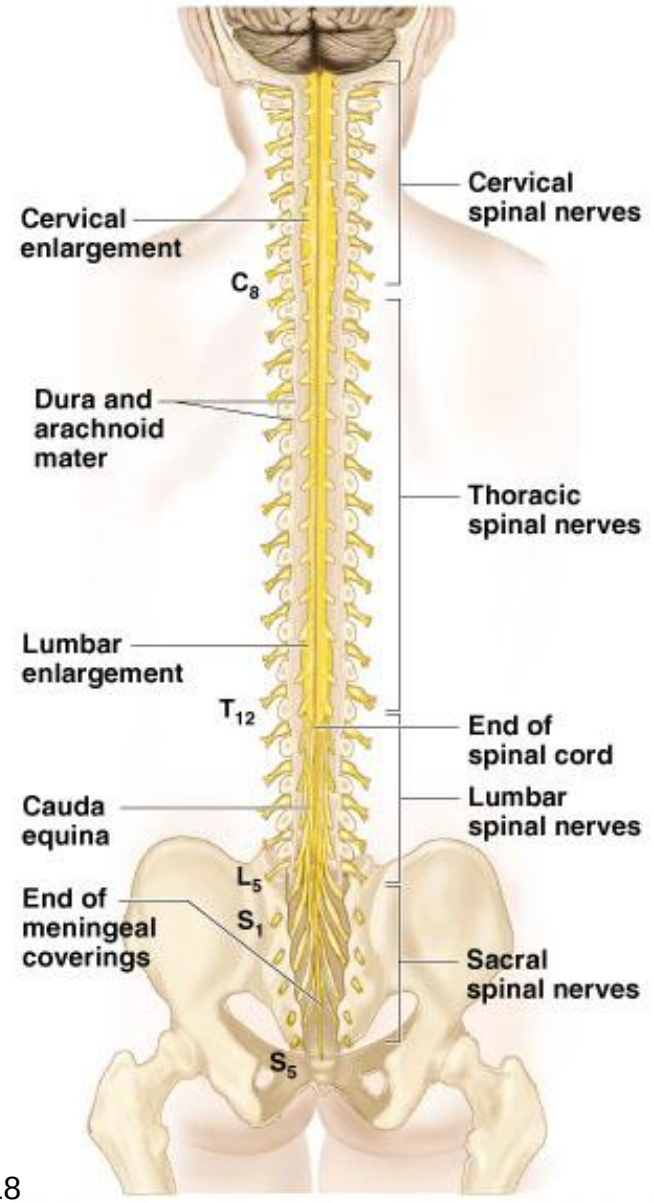


Figure 7.18

Spinal Cord Anatomy

- Exterior white mater – conduction tracts

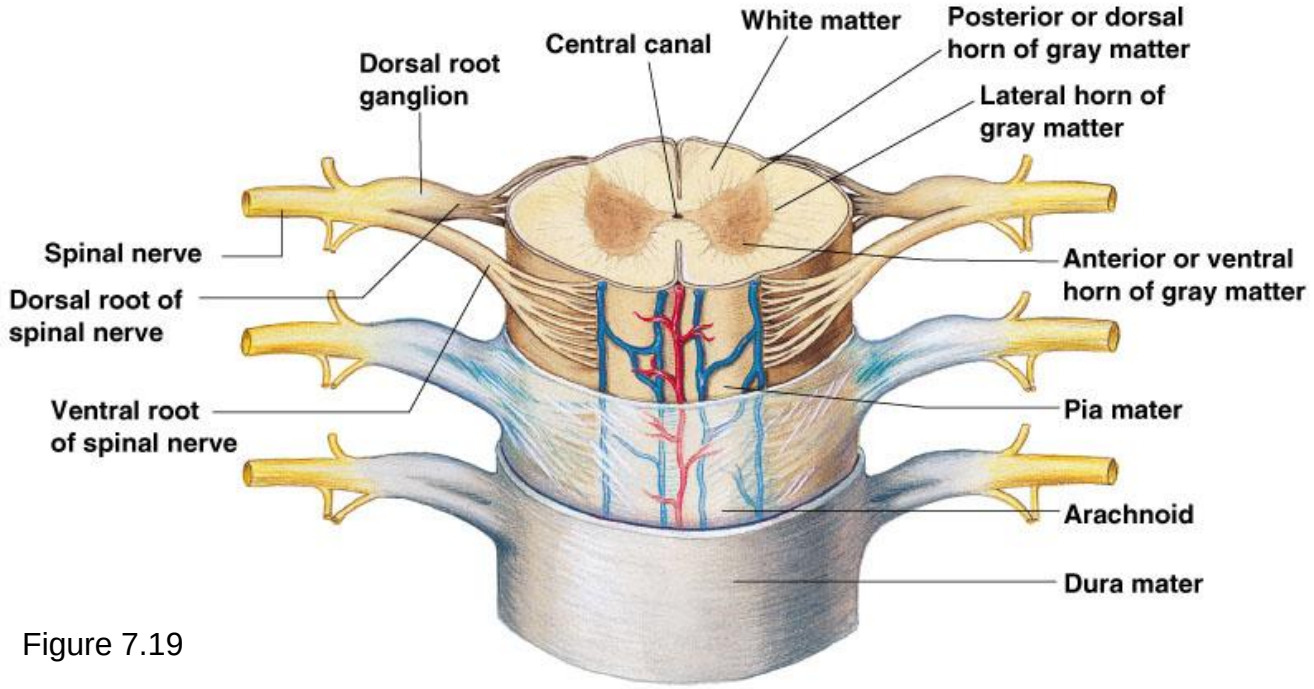


Figure 7.19

Spinal Cord Anatomy

- Internal gray matter - mostly cell bodies
  - Dorsal (posterior) horns
  - Anterior (ventral) horns

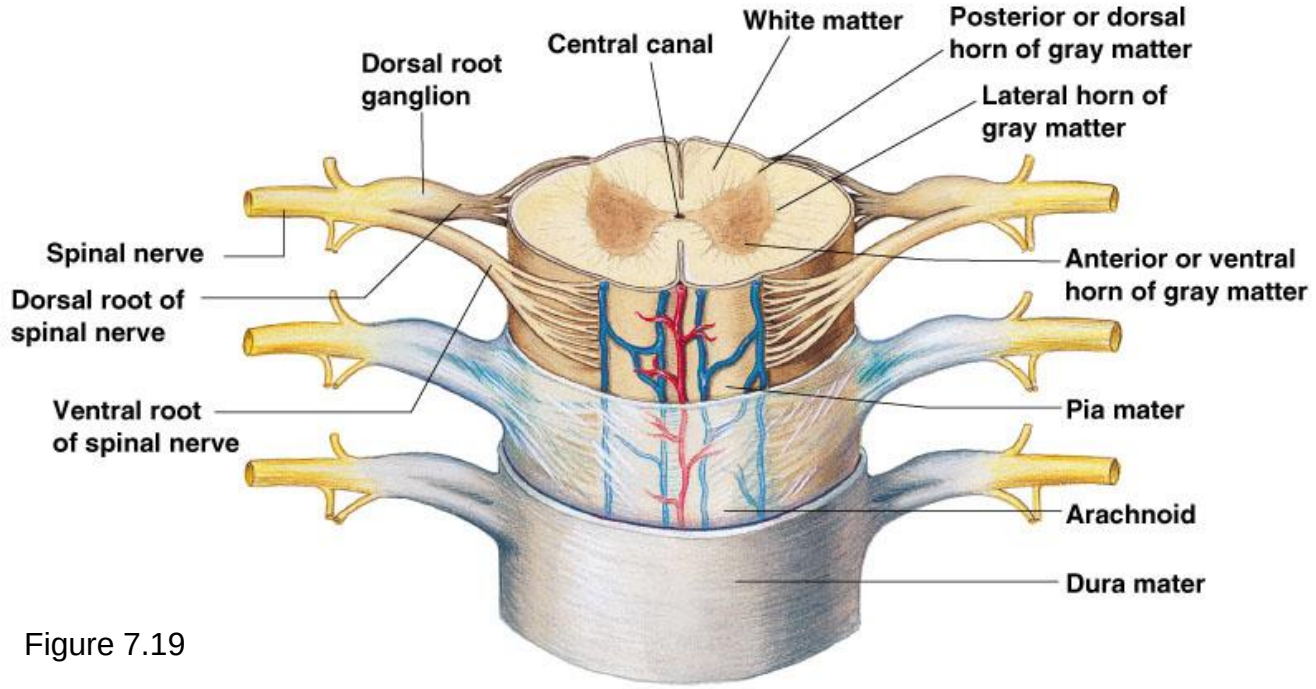


Figure 7.19

Spinal Cord Anatomy

- Central canal filled with cerebrospinal fluid

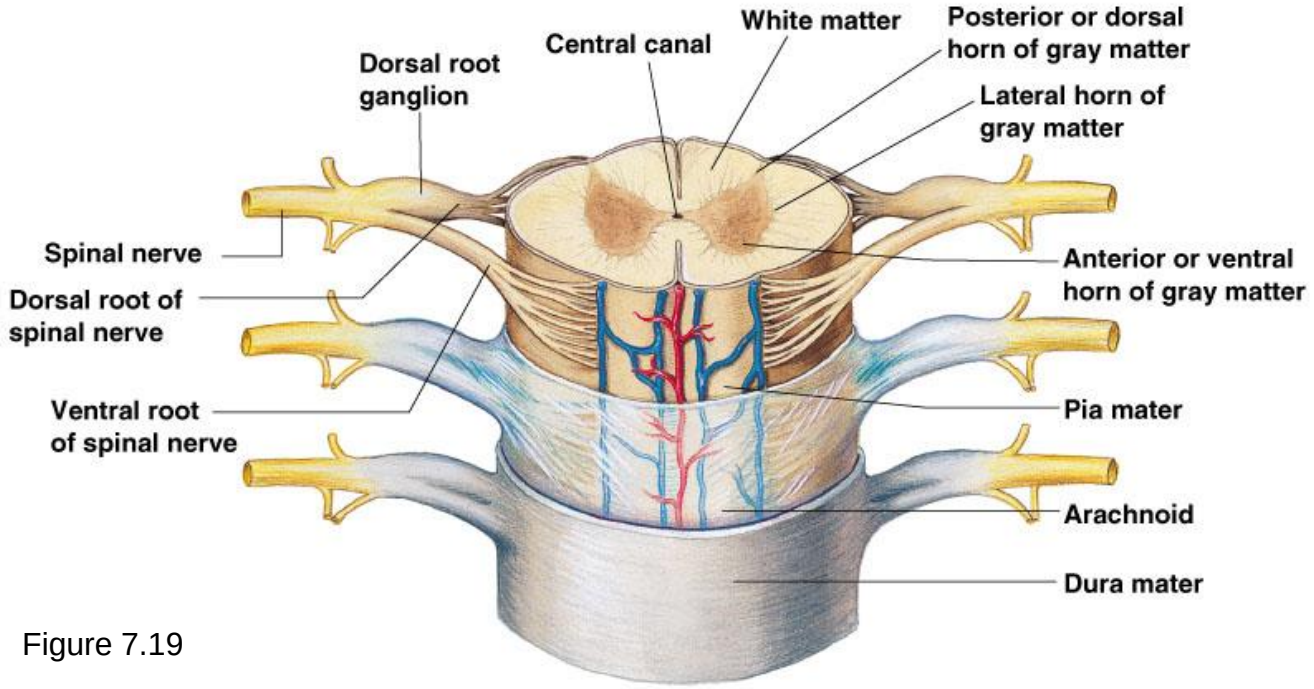


Figure 7.19

Spinal Cord Anatomy

- Meninges cover the spinal cord
- Nerves leave at the level of each vertebrae
  - Dorsal root
    - Associated with the dorsal root ganglia – collections of cell bodies outside the central nervous system
  - Ventral root

Peripheral Nervous System

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

Structure of a Nerve

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

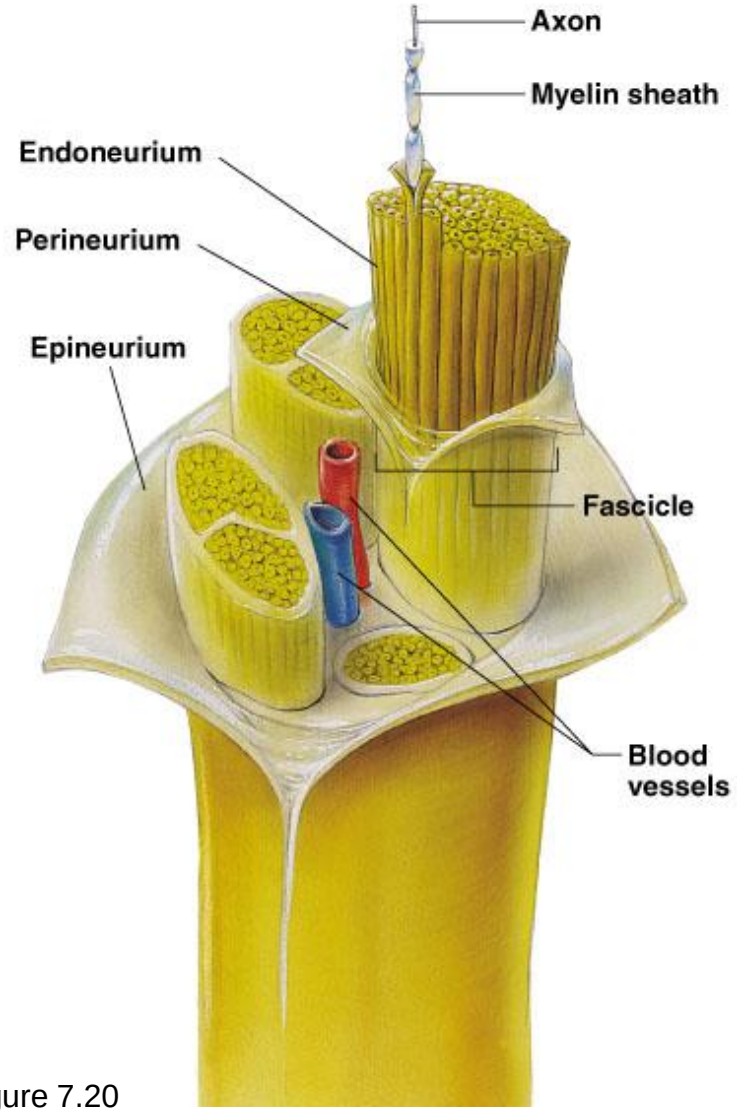


Figure 7.20

Classification of Nerves

- Mixed nerves – both sensory and motor fibers
- 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
- Most are mixed nerves, but three are sensory only

Distribution of Cranial Nerves

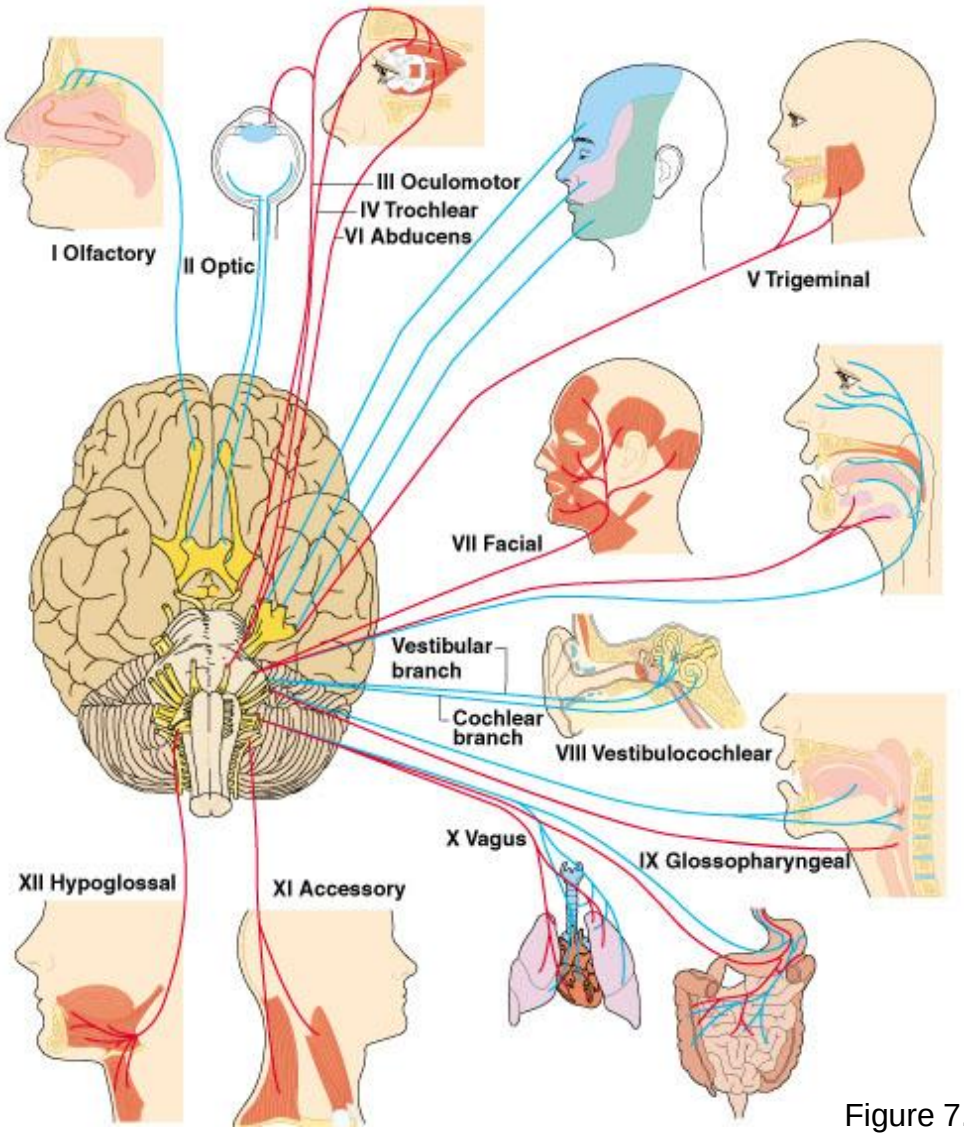


Figure 7.21

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

Essentials of Human Anatomy & Physiology

Seventh Edition

Elaine N. Marieb

Chapter 7

The Nervous System

Slides 7.63 – 7.75

Lecture Slides in PowerPoint by Jerry L. Cook

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

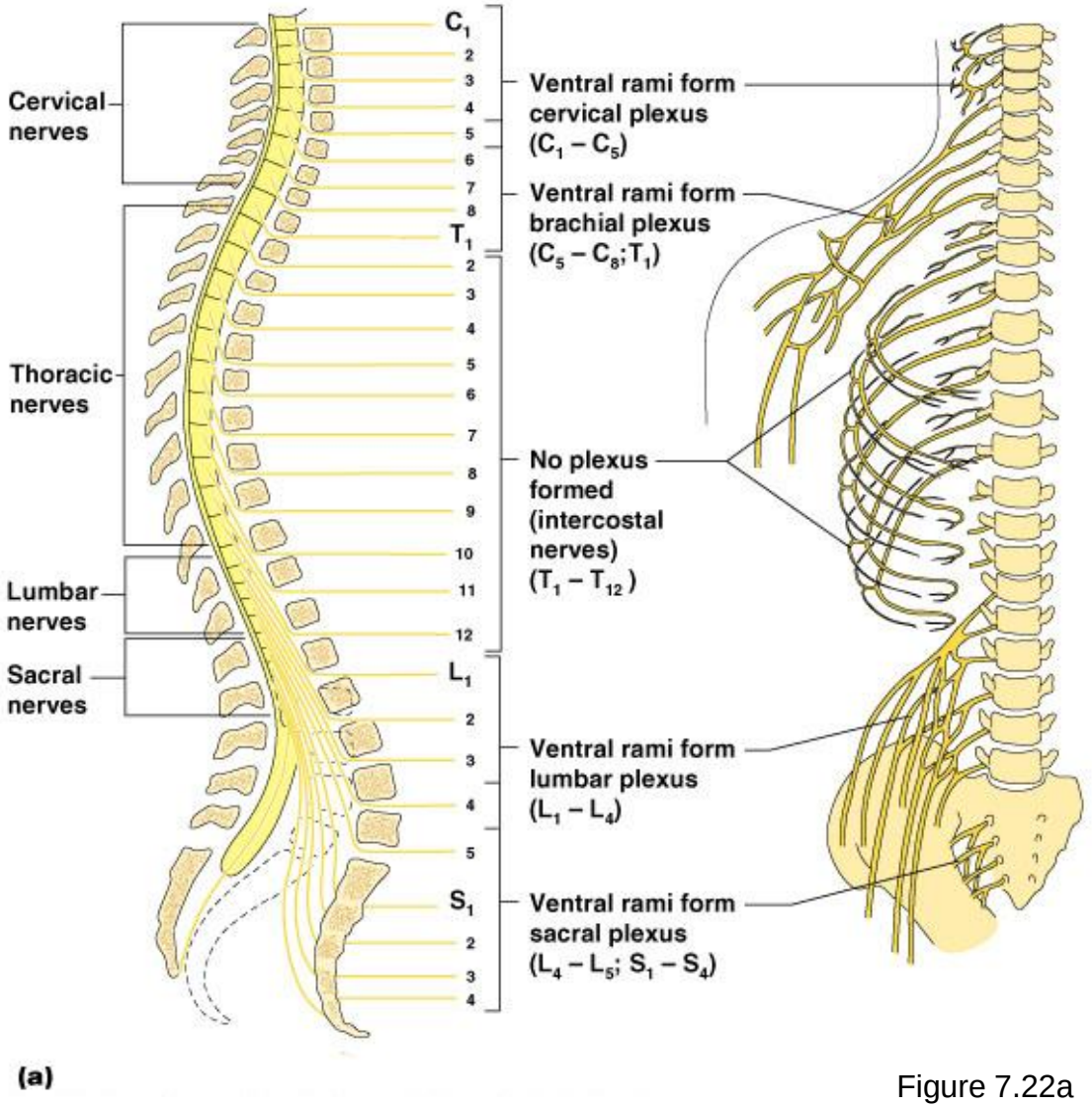


Figure 7.22a

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

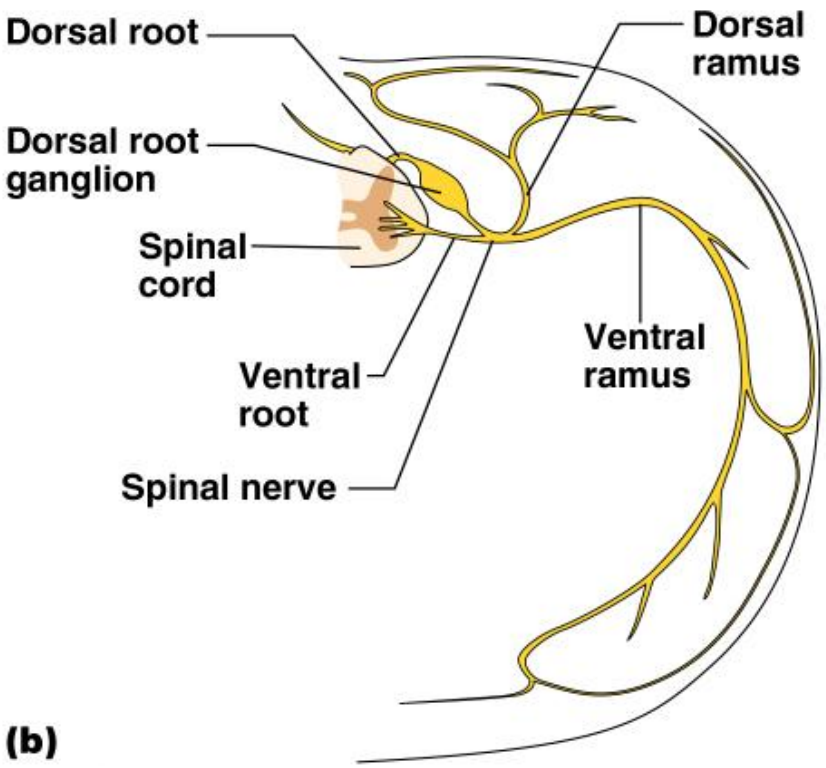
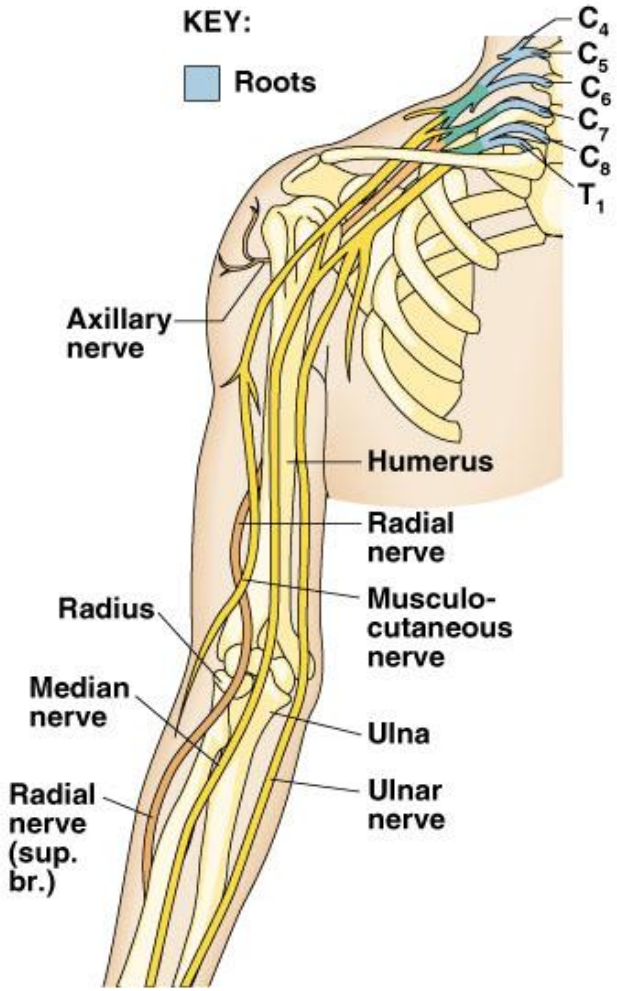
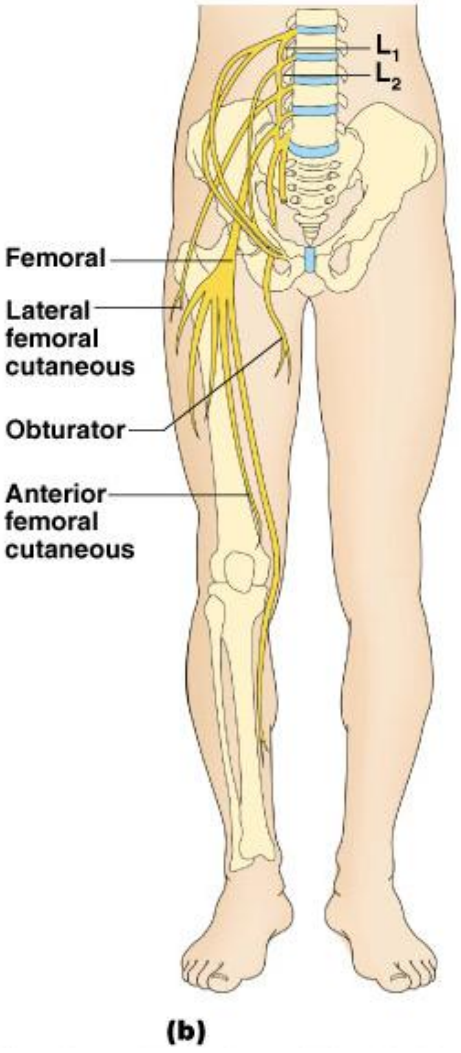


Figure 7.22b

Examples of Nerve Distribution





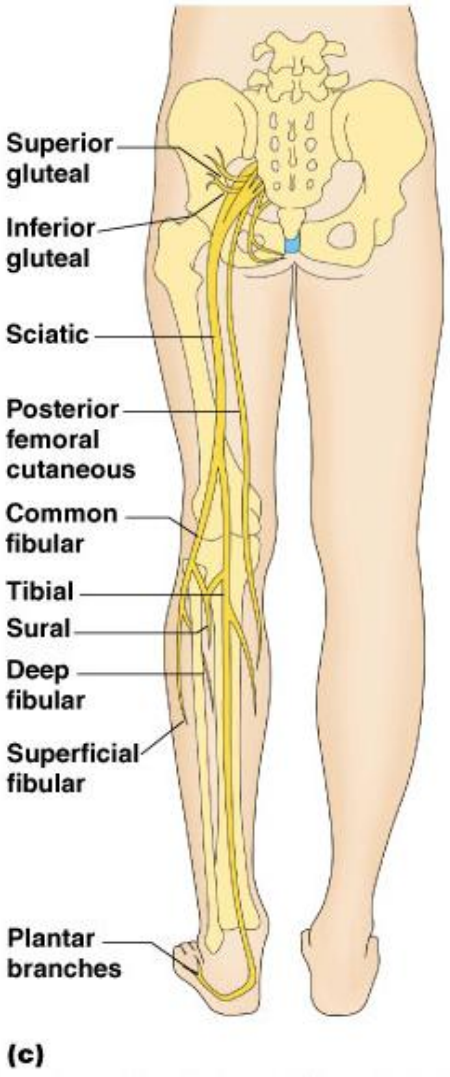


Figure 7.23

Autonomic Nervous System

- The involuntary branch of the nervous system
- Consists of only motor nerves
- Divided into two divisions
  - Sympathetic division
  - Parasympathetic division

Differences Between Somatic and Autonomic Nervous Systems

- Nerves
  - Somatic – one motor neuron
  - 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

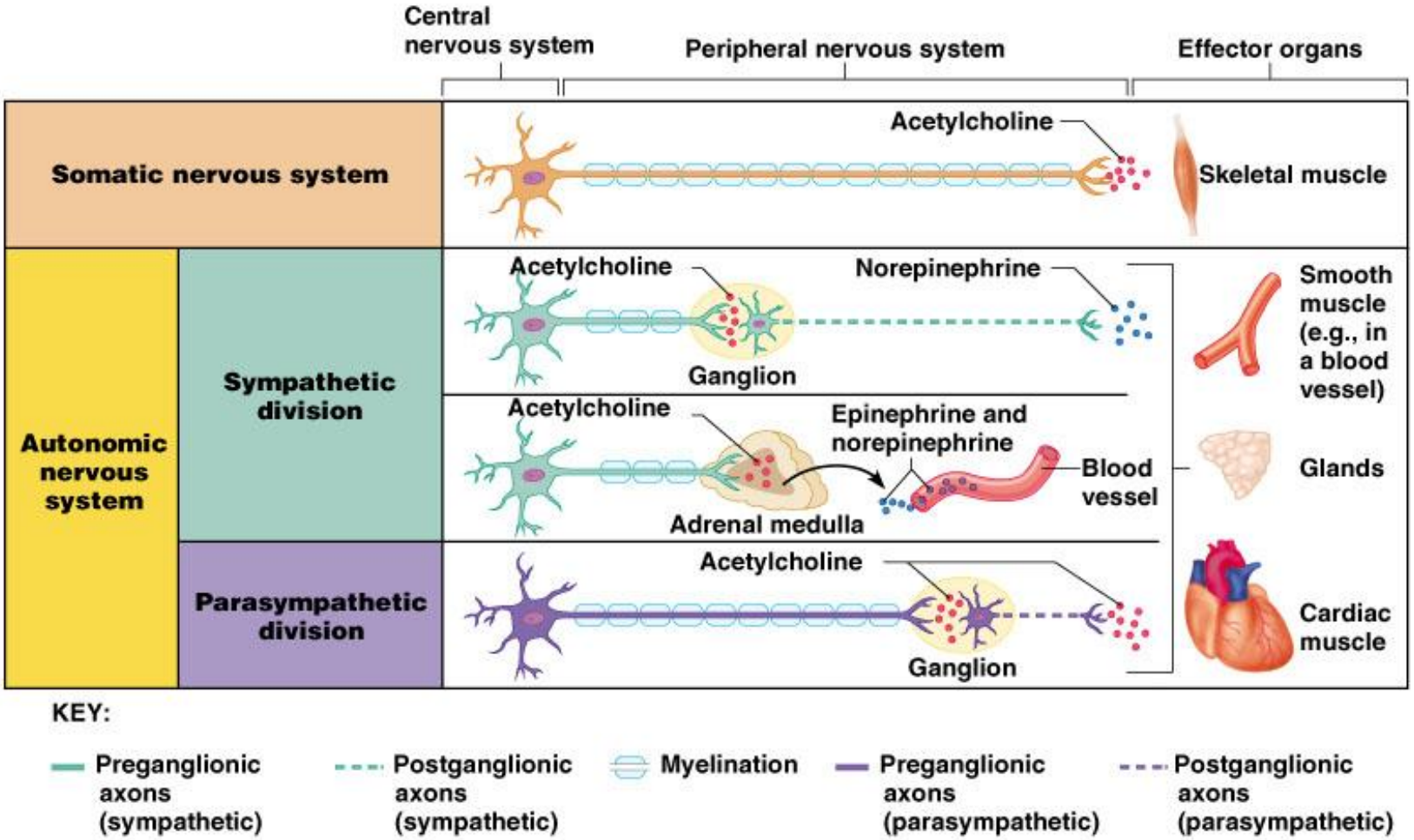


Figure 7.24

Anatomy of the Sympathetic Division

- Originates from T_1 through L_2
- Ganglia are at the sympathetic 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

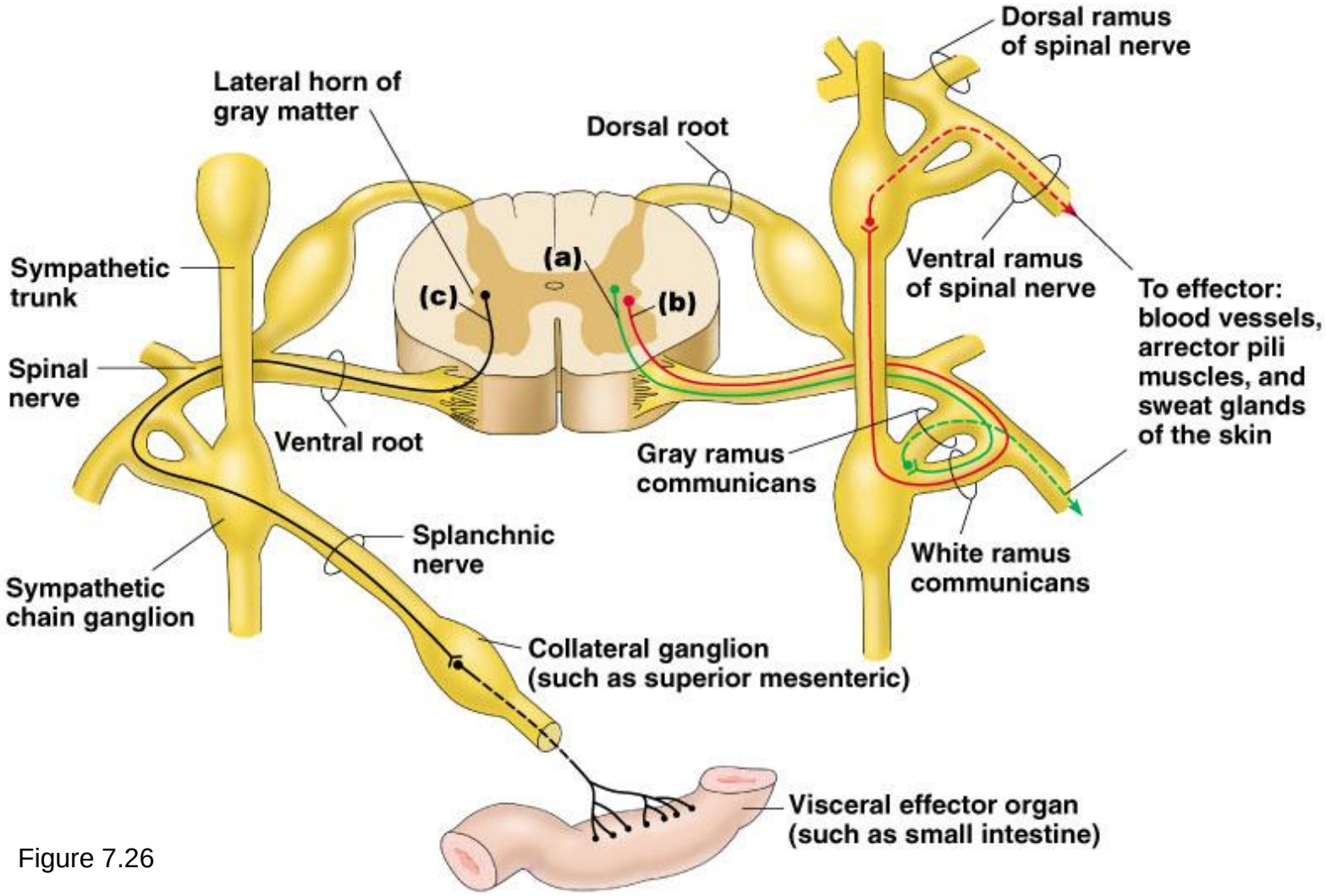


Figure 7.26

Anatomy of the Parasympathetic Division

- Originates from the brain stem and S_1 through S_4
- Terminal ganglia are at the effector organs
- Always uses acetylcholine as a neurotransmitter

Anatomy of the Autonomic Nervous System

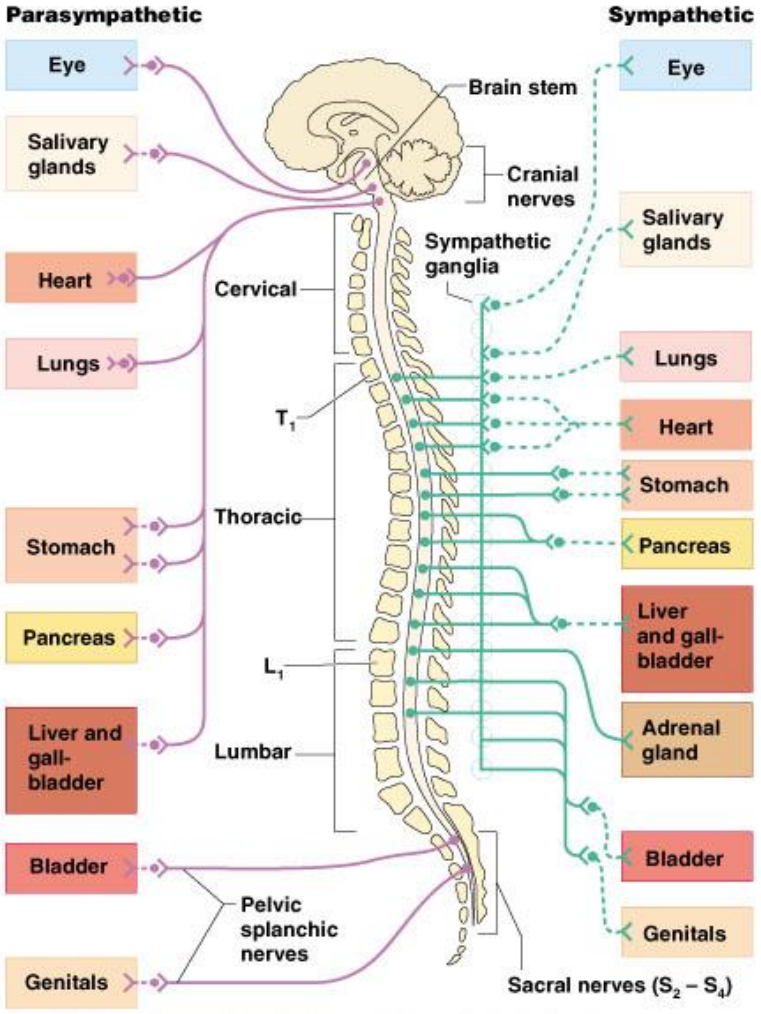


Figure 7.25

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

Development Aspects of the Nervous System

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