Anatomy, Physiology, & Disease

An Interactive Journey for Health Professionals

Chapter 9

The Nervous System:

The Body's Control Center

PEARSON

Anatomy, Physiology, and Disease: An Interactive Journey for Health Professionals
Bruce J. Colbert, Jeff E. Ankney, and Karen T. Lee

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Introduction

- Nervous system is complex and important to body's control system
- Nervous system monitors conditions and takes corrective action, when necessary, to keep everything running smoothly
- Control systems of body are nervous and endocrine systems which receive help from special senses

Introduction (cont'd)

- Like any control system, they have large, complex job that is sometimes difficult to understand; they must keep track of everything that is happening in your body; thus, systems themselves are perhaps most complex and vital systems

Learning Objectives

- List and describe the components and basic operation of the nervous system
- Contrast the central and peripheral nervous systems
- Explain the relationship of the sensory system to the nervous system
- Define the parts and functions of the nervous tissue
- Discuss the anatomy and physiology of the spinal cord

Learning Objectives (cont'd)

- List and describe various disorders of the nerves and spinal cord
- Organize the hierarchy of the nervous system
- Locate and define the external structures of the brain and their corresponding functions
- Locate and define the internal structures of the brain and their corresponding functions
- Describe the sensory functions of the brain with related structures

Learning Objectives (cont'd)

- Describe the motor functions of the brain with related structures
- Contrast the parasympathetic and sympathetic branches of the autonomic nervous system
- Discuss some representative diseases of the nervous system

Pronunciation Guide

Click on the megaphone icon before each item to hear the pronunciation.

Acetylcholine	(AHS eh till KOH leen)
Acetylcholinesterase	(AHS eh till KOH lin ehs tur ace)
Amyotrophic	(AA mee o TROF ic)
Anterior commissure	(an TEE ree or KAH mih sure)
Arachoid mater	(ah RAK noyd MAY ter)
Astrocytes	(ASS troh SITES)
Axon	(AK son)
Basal nuclei	(BAY sal noo KLEE ie)
Cerebellum	(ser eh BELL um)
Cerebrospinal fluid	(ser eh broh SPY nal FLOO id)
Cerebrum	(ser EE brum)

Pronunciation Guide (cont'd)

Click on the megaphone icon before each item to hear the pronunciation.

Chemical synapse	(KEH mih cull SIH naps)
Commissures	(KAH mih sures)
Corpus callosum	(KOR pus kah LOH sum)
Corticobulbar tract	(KOR ti coe BUL bar)
Corticospinal tract	(KOR ti coe SPY nal)
Dendrites	(DEN drights)
Diencephalon	(dye en SEFF ah lon)
Dorsal root ganglion	(DOR sal ROOT GANG lee on)
Dura mater	(DOO ra MAY ter)
Ependymal cells	(ep PEN deh mall)
Epidural space	(ep pih DURE all)

Pronunciation Guide (cont'd)

Click on the megaphone icon before each item to hear the pronunciation.

Fornix	(FOR niks)
Ganglia	(GANG lee ah)
Glial cells	(GLEE all sells)
Guillain Barré	(gee YAH bar RAY)
Gyri	(JIE rie)
Hydrocephalus	(high droh SEF ah lus)
Hypothalamus	(high poh THAL ah mus)
Limbic system	(LIM bick)
Medulla oblongata	(meh DULL lah ob long GA ta)
Meninges	(men IN jeez)

Pronunciation Guide (cont'd)

Click on the megaphone icon before each item to hear the pronunciation.

Microglia	(mie crow GLEE ah)
Myelin	(MY eh lin)
Neuroglia (glial cells)	(noo ROH glee ah)
Nodes of Ranvier	(ron vee AYE)
Occipital lobe	(ok SIP eh tal)
Oligodendrocytes	(AH li go DEN droe site)
Parietal lobe	(pah RYE eh tal)
Pia mater	(PEE ah MAY ter)
Pineal body	(pih NEE al)
Plexus	(PLECK sus)

Pronunciation Guide (cont'd)

Click on the megaphone icon before each item to hear the pronunciation.

Schwann cells	(SHWAN sells)
Somatic nervous system	(so MAT ick)
Spinocerebellar tract	(SPY no ser eh BELL ar)
Spinothalamic tract	(SPY no thol AH mic)
Subarachnoid space	(SUB ah RACK noyd)
Subdural space	(sub DOO ral)
Sulcus	(SULL cuss)
Vesicles	(VESS ih klz)

Basic Operations

- Brain and spinal cord are central nervous system (CNS) which controls total nervous system
- Everything outside brain and spinal cord is part of peripheral nervous system (PNS)
- Input side of nervous system is sensory system

Basic Operations (cont'd)

- Output side of nervous system is motor system
- Somatic nervous system controls skeletal muscle and mostly voluntary movements

Basic Operation (cont'd)

- Autonomic nervous system controls smooth muscle and cardiac muscle, along with several glands
- Autonomic system is divided into parasympathetic system that deals with normal body functioning and maintenance of homeostasis while sympathetic nervous system controls "fight or flight" response system

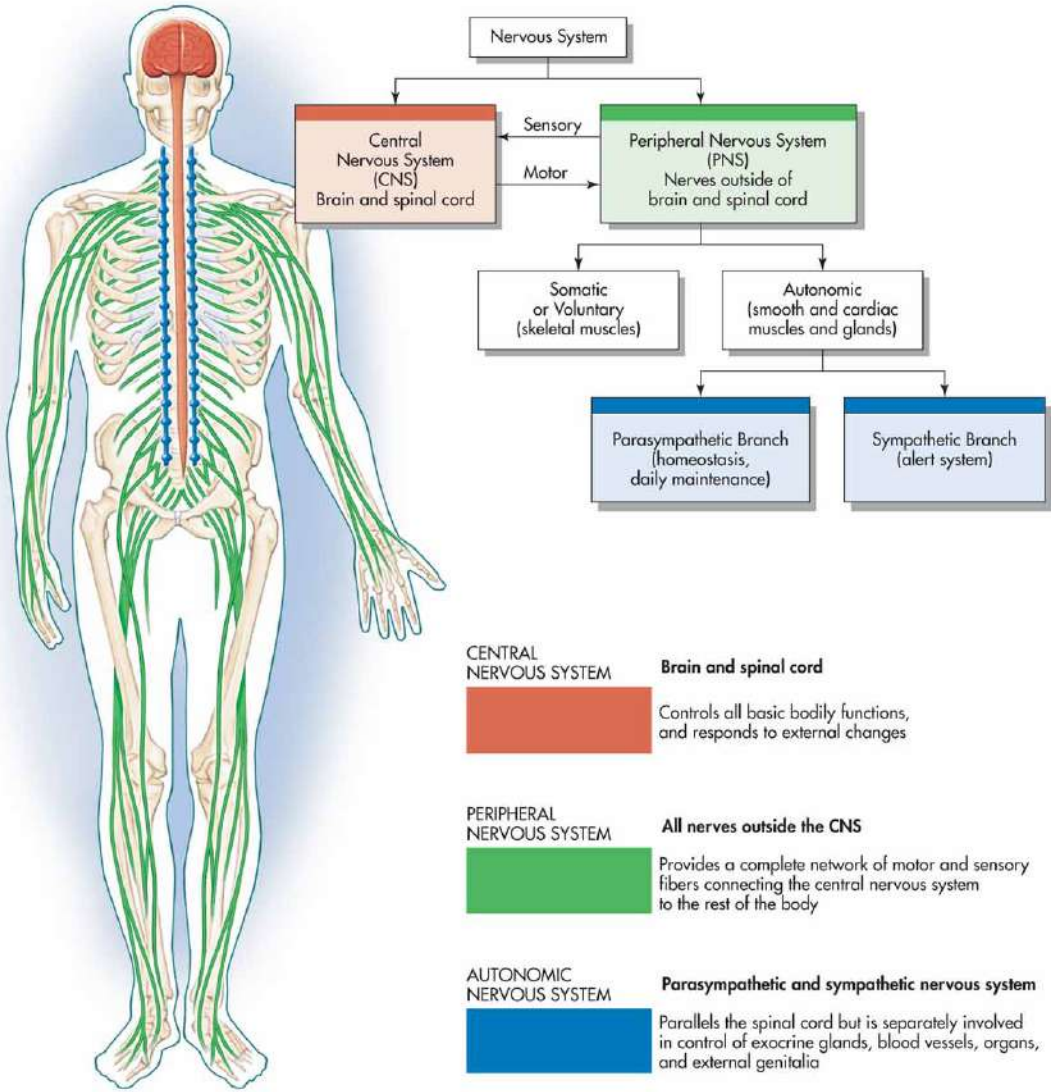


Figure 9-1 Organization of the nervous system.

Basic Operation (cont'd)

- Real life example
  - You park your car and get out to visit a friend; as you step on the walk a large dog bounds down steps barking and snarling at you
  - Your sensory system gathers information including large unfriendly dog, you are far from protection of your car, and no one around for help

Basic Operation (cont'd)

- Real life example
  - Information goes into spinal cord and brain and you process information to make decisions; you are in danger, something must be done!

Basic Operation (cont'd)

- Real life example
  - CNS sends directions to organs to gear up for action via autonomic nervous system
  - Heart rate, blood pressure, and respiration rate increase; you begin to sweat; more blood is delivered to skeletal muscles and heart in order to get fully ready to respond; this is all involuntary, meaning you cannot consciously control it

Basic Operation (cont'd)

- Real life example
  - Somatic nervous system readies skeletal muscles to get you out of there; often called "fight or flight" response and will be discussed later in further depth; if you can control your fear, you back slowly away from situation; if you are scared witless, you run from yard as fast as possible; either way, you can hopefully escape danger, with skin and pride intact

Nervous Tissue

- Specialized cells in nervous system called neuroglia, or glial cells, perform specialized functions
  - CNS has four types of glial cells:
    - Astrocytes: metabolic and structural support cells
    - Microglia: remove debris
    - Ependymal cells: cover and line cavities of nervous system
    - Oligodendrocytes: make lipid insulation called myelin

Nervous Tissue (cont'd)

- Specialized cells in nervous system called neuroglia, or glial cells, perform specialized functions
  - PNS has two types of glial cells:
    - Schwann cells: make myelin for the PNS
    - Satellite cells: support cells

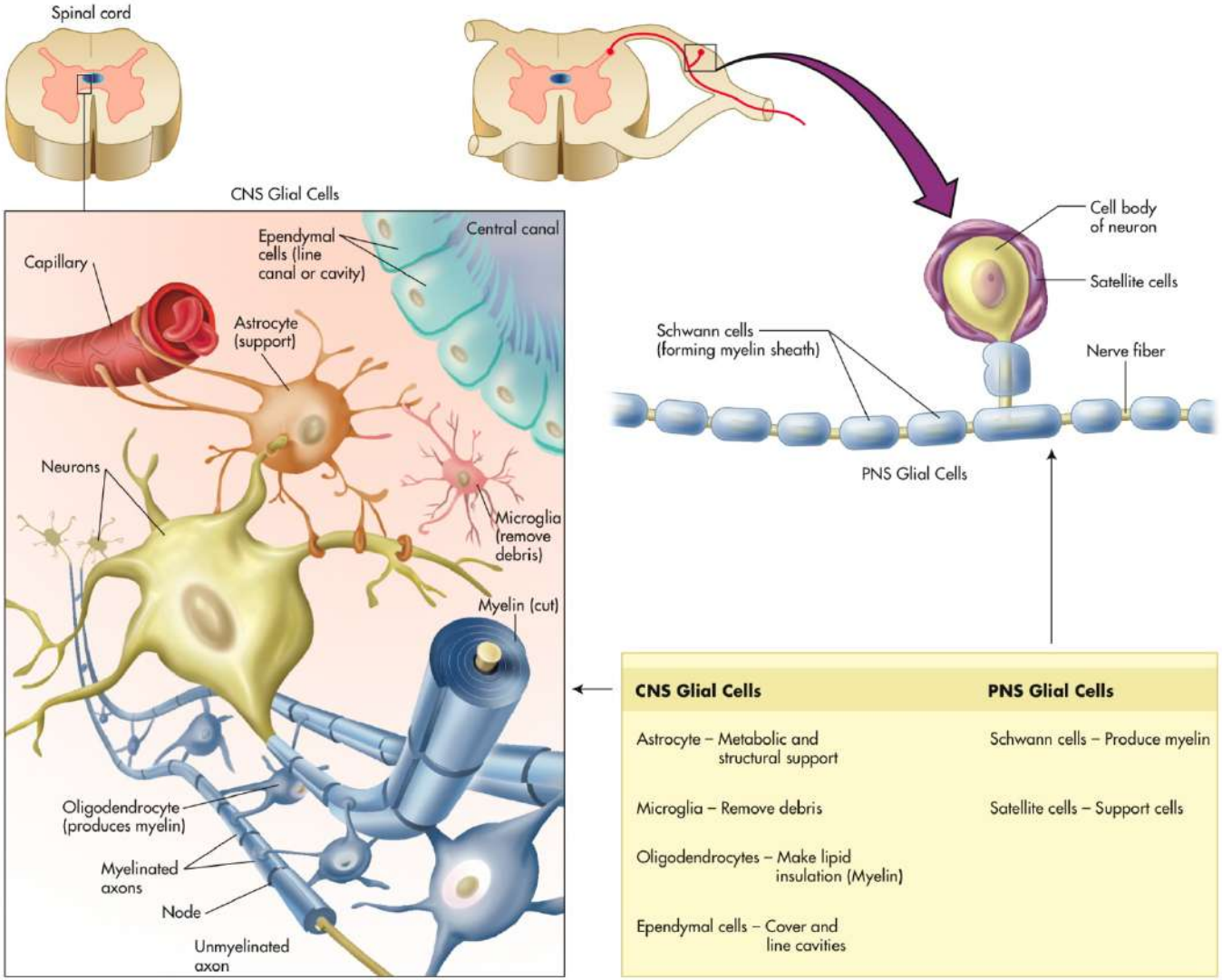


Figure 9-2 Glial cells and their functions.

Nervous Tissue (cont'd)

- All of control functions of nervous system must be carried out by group of cells called neurons
- Neurons are bizarre looking cells, often with many branches and even what appears to be a tail

Nervous Tissue (cont'd)

- Each part of neuron has specific function:
  - Body: cell metabolism
  - Dendrites: receive information from the environment
  - Axon: generates and sends signals to other cells
  - Axon terminal: where signal leaves cell
  - Synapse: where axon terminal and receiving cell combine

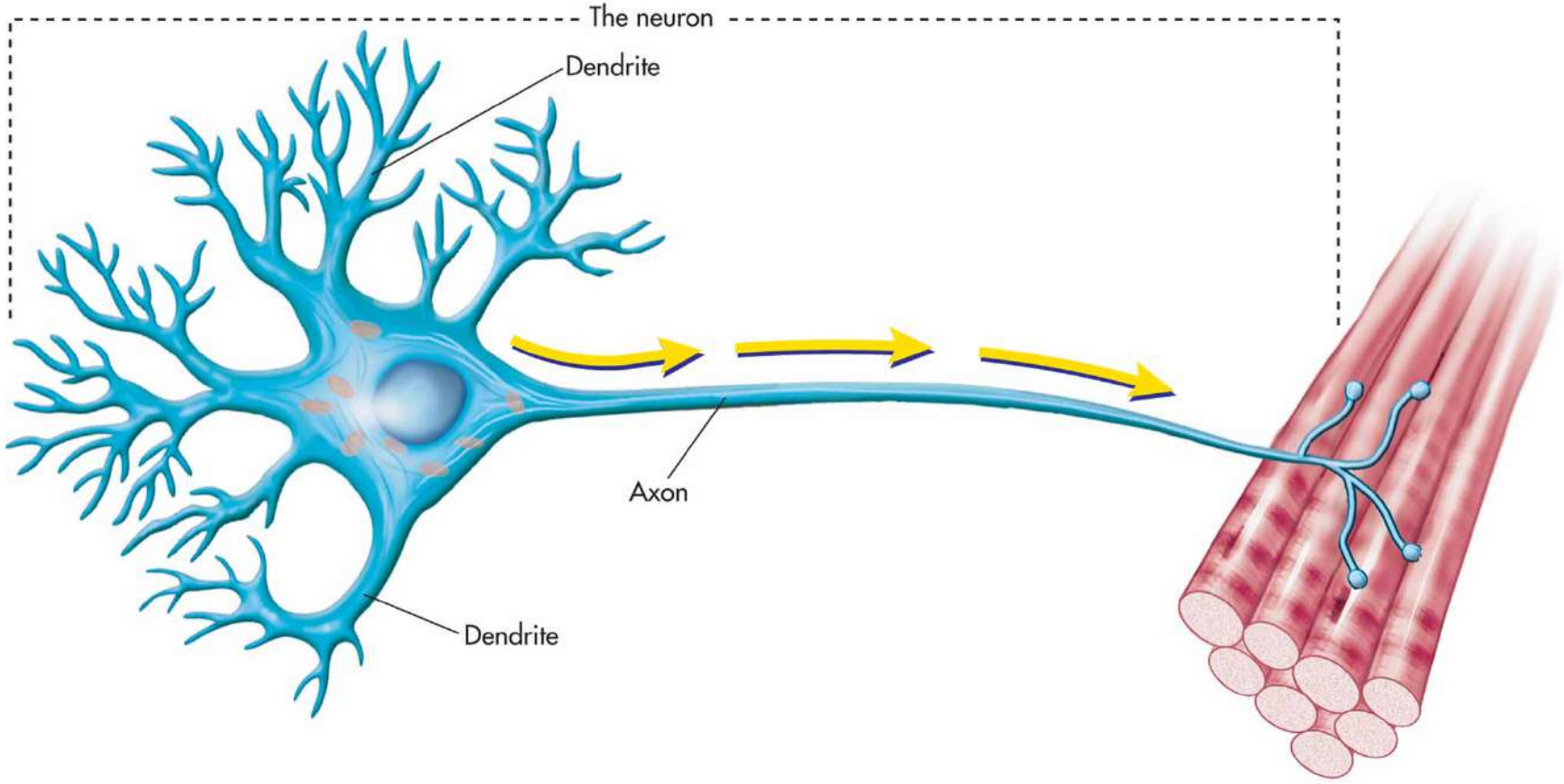


Figure 9-3 A neuron connecting to a skeletal muscle.

Nervous Tissue (cont'd)

- Neurons can be classified by how they look (structure) or what they do (function)
- Input neurons are known as sensory neurons while output neurons are known as motor neurons
- Neurons which carry information between neurons are called interneurons (inter – between) or association neurons

How Neurons Work

- Neurons are called excitable cells; this simply means that if cell is stimulated it can carry small electrical charge
- Each time charged particles flow across cell membrane, there is tiny charge generated

How Neurons Work (cont'd)

- All three muscle types are excitable cells, as are many gland cells
- Cells are like miniature batteries, able to generate tiny currents simply by changing permeability of their membranes

How Neurons Work (cont'd)

- A cell that is not stimulated or excited is called a resting cell; it is said to be polarized
- It has difference in charge across membrane, being more negative inside than outside cell

How Neurons Work (cont'd)

- When cell is stimulated, sodium gates in cell membrane spring open, allowing sodium to travel across membrane
- Sodium bits are positively charged, so cell becomes more positive as they enter

How Neurons Work (cont'd)

- A cell that is more positive is called depolarized
- Sodium gates close after a few minutes and potassium gates open; potassium leaves cell, taking its positive charge with it
- This is called repolarization

How Neurons Work (cont'd)

- If cell becomes more negative than resting it is called hyperpolarized
- Action potential (AP) is cell moving through depolarization, repolarization, and hyperpolarization
- Cell cannot accept another stimulus until it returns to its resting state, and this time period when it cannot accept another stimulus is called refractory period

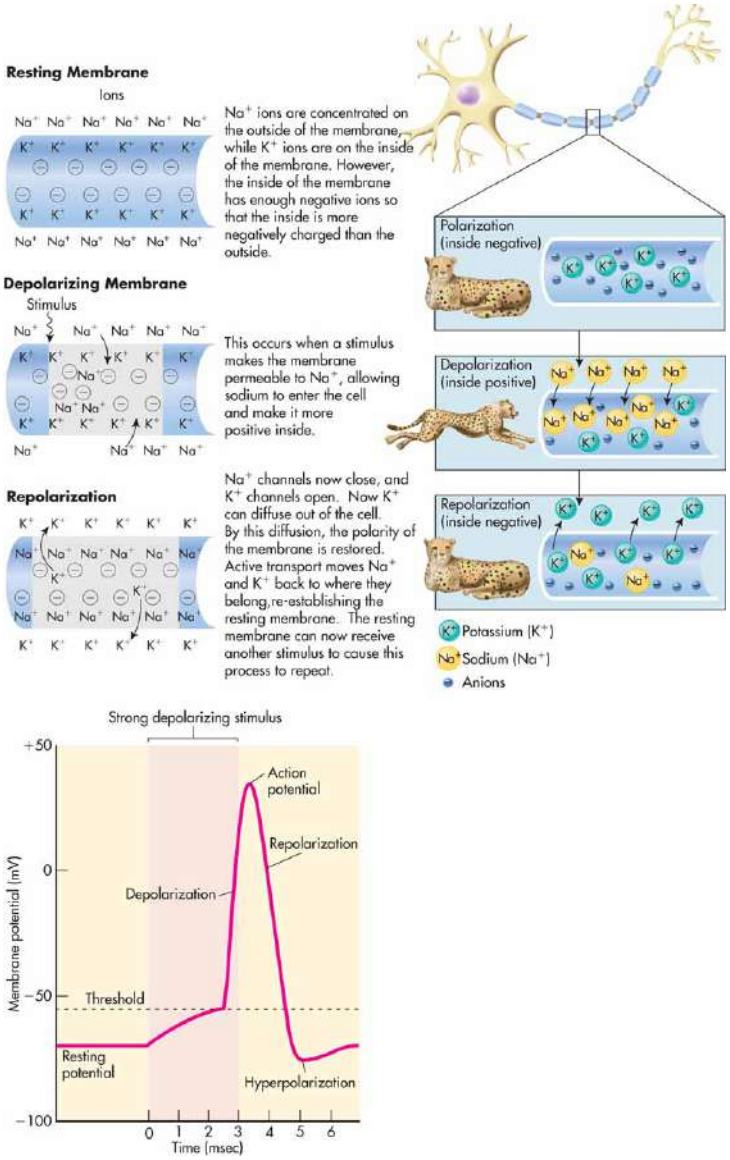


Figure 9-4 Depolarization, repolarization, and action potential.

How Neurons Work (cont'd)

- Neurons can use their ability to generate electricity to send, receive, and interpret signals
- If you hit your thumb with a hammer, dendrites in thumb are stimulated by blow and sodium gates open, sodium flows into dendrites and they become depolarized; number of cells affected depend on how hard you hit your thumb

How Neurons Work (cont'd)

- Local potential
  - Size of stimulus determines excitement of cell; many sensory cells work via local potentials, which is how CNS determines size of environmental change
- Action potential
  - "All-or-none;" either the cell has one or it doesn't
  - Once it starts, will always finish and will always be same size

How Neurons Work (cont'd)

- Dendrites carry depolarization to sensory neuron cell body, which takes information and generates action potential if stimulus is large enough
- Speed of impulse conduction is determined by amount of myelin and diameter of axon
- Myelin is lipid insulation or sheath formed by oligodendrocytes in CNS and Schwann cells in PNS

How Neurons Work (cont'd)

- Myelinated nerves are white; unmyelinated nerves are gray

How Neurons Work (cont'd)

- Myelin is essential for speedy flow of AP's down axons; in unmyelinated axon, AP can only flow down axon by depolarizing each and every centimeter of axon (relatively slow process); in myelinated axons there are nodes located periodically, and only nodes must depolarize, allowing impulse to travel quickly as it skips from node to node

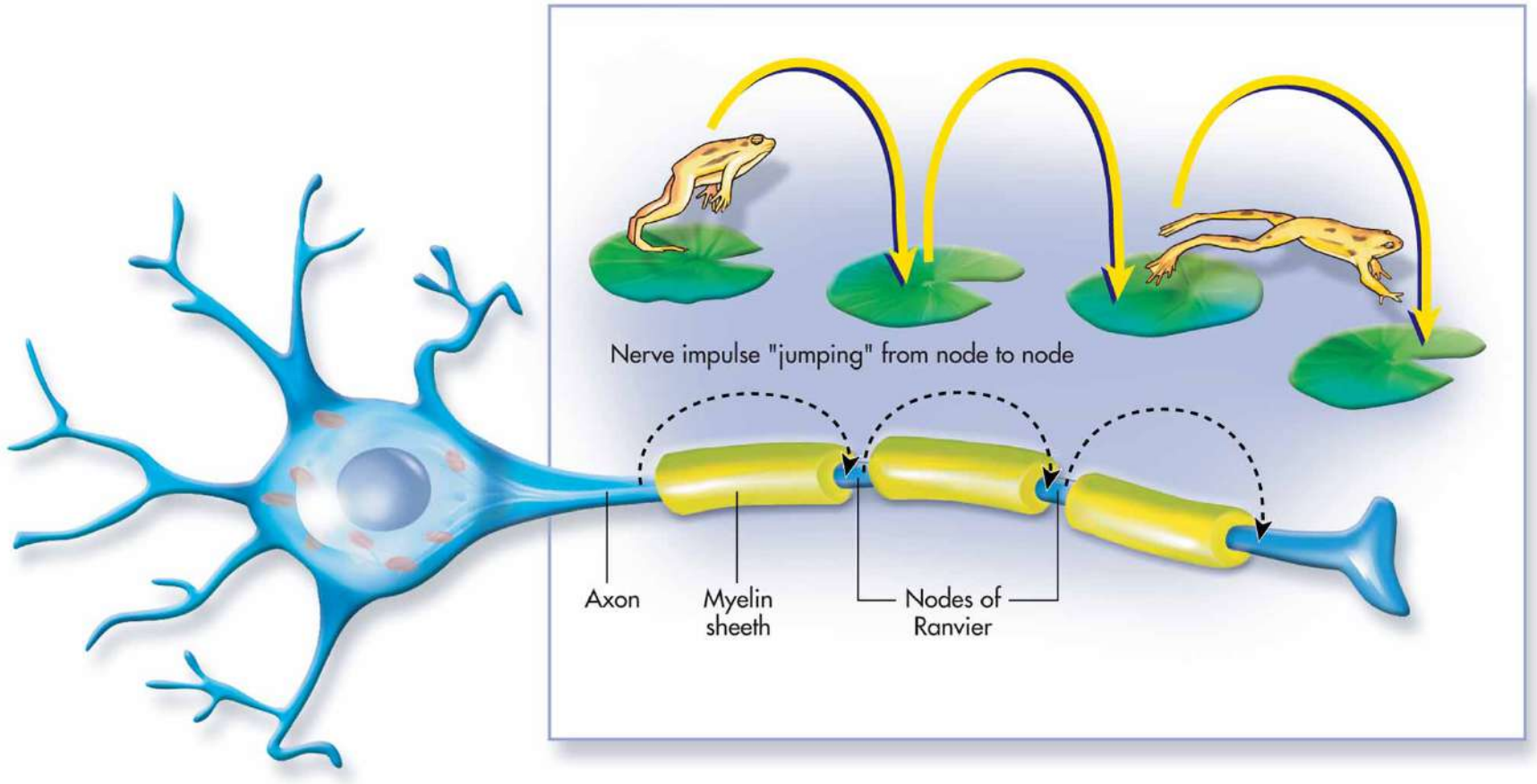


Figure 9-5 Impulse conduction via myelinated axon.

How Neurons Work (cont'd)

- Diameter of axon also affects speed of AP flow; wider the diameter of axon, faster the flow of ions
- Myelination and larger diameters allow for huge difference in speed

How Neurons Work (cont'd)

- Small unmyelinated axons have speeds as low as 0.5 meters/second, whereas large diameter myelinated axons may be as fast as 100 meters/second; that's 200 times faster!

Pathology Connection: Myelin Disorders

- Multiple Sclerosis (MS): disorder where myelin in CNS is destroyed
  - In areas without myelin, impulse conduction is slow or impossible
  - These areas of damaged myelin often have plaques or scarred areas
  - Cause is probably auto-immune attack
  - Symptoms vary depending on where patient's myelin has been damaged; possible symptoms include disturbances in vision, balance, speech, and movement

Pathology Connection: Myelin Disorders (cont'd)

- Types of MS
  - Relapsing-remitting: characterized by symptomatic flare-ups (called relapses), followed by periods of time where patient has no symptoms (called remissions)
  - Chronic progressive: has no remission periods; patients become steadily more disabled
  - Most patients initially diagnosed with relapsing-remitting, but at least 50% will progress to chronic progressive form

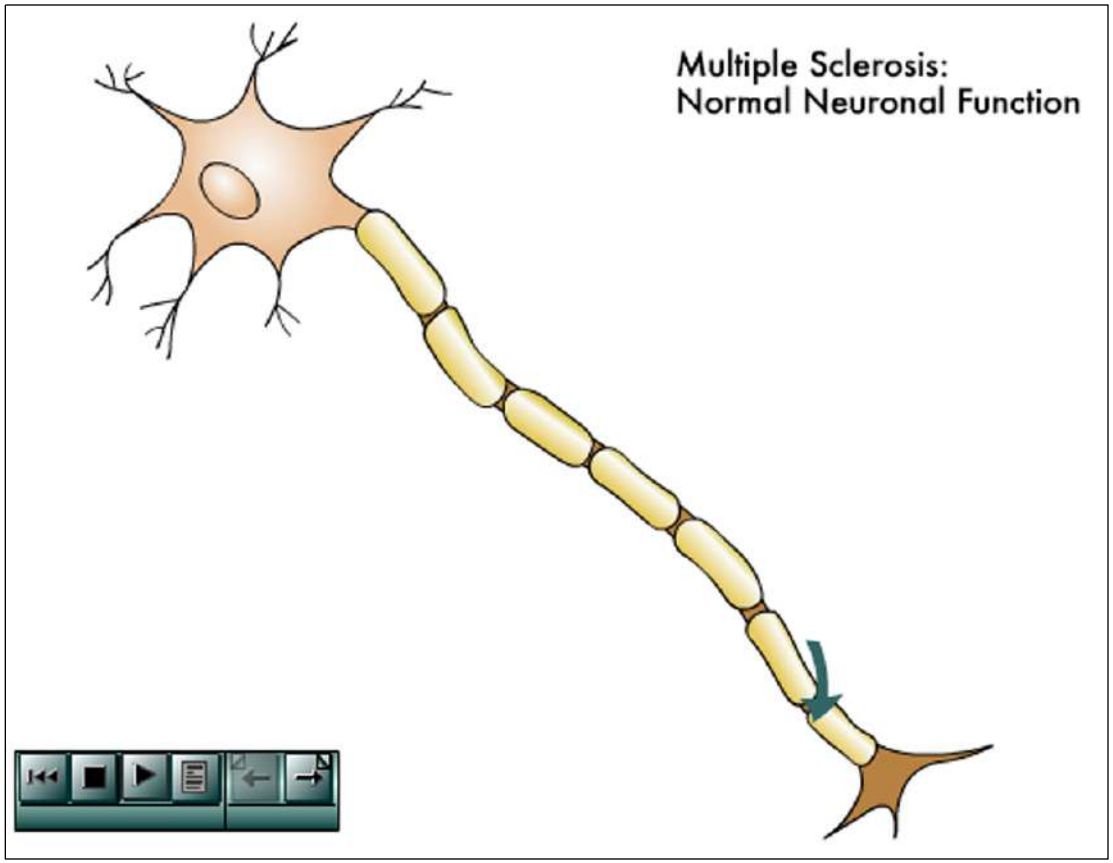
Pathology Connection: Myelin Disorders (cont'd)

- Epidemiology: more common in women; diagnosed most often in people under age 50
- Diagnosis: based upon history of symptoms flare-ups, and presence of plaques on MRI; no definitive diagnosis

Pathology Connection: Myelin Disorders (cont'd)

- Treatment: no cure; in acute flare, symptoms may be treated with steroid medication, plasma exchange, or intravenous immunoglobulin G; immunosuppressant drugs can also be used to decrease frequency of relapses, prevent or slow conversion from relapsing-remitting to chronic-progressive

Multiple Sclerosis Animation



Click here to view a video on the topic of multiple sclerosis.

Pathology Connection: Myelin Disorders (cont'd)

- Guillain-Barré Syndrome
  - Disorder caused by autoimmune attack on myelin and/or axons in peripheral nervous system
  - Symptoms: weakness and ascending paralysis of limbs, face and diaphragm
  - Cause is unknown, although many patients develop Guillain-Barré syndrome after viral infection

Pathology Connection: Myelin Disorders (cont'd)

- Guillain-Barré Syndrome
  - Course of disease has three phases
    - Acute phase: initial onset of disease, in which patient becomes steadily worse
    - Plateau phase: period of days to weeks, in which patient's condition is stable
    - Recovery phase: period of time during which patients recover function
      - Some recover full function, over a period of up to 2 years
      - Significant portion of patients with severe cases have measurable disability two years after recovery

Pathology Connection: Myelin Disorders (cont'd)

- Guillain-Barré Syndrome
  - Diagnosis: based mostly on history of ascending paralysis after viral infection
  - Tests that may also be helpful include EMG and cerebrospinal fluid analysis showing high protein but no white blood cells
  - Treatment: consists of supportive care until symptoms improve/resolve; care may include ventilation support, prevention of blood clots and bed sores, pain medication; many patients need rehabilitation after their PNS recovers

How Synapses Work

- When AP arrives at axon terminal, terminal depolarizes and calcium gates open; calcium flows into cell; when calcium flows in, it triggers change in terminal
- There are tiny sacs in terminal called vesicles that release their contents from cell when calcium flows in;
- Vesicles are filled with molecules called neurotransmitters that send signal from neuron across synapse to next cell in line

How Synapses Work (cont'd)

- Neurotransmitters bind to cell receiving signal, opening or closing gates; some excite receiving cell and some calm it down
- Last step in transfer of information is to clean up, removing neurotransmitter from synapse to prevent it from binding to receiving cell
- Use of neurotransmitters is called chemical synapse because chemicals carry information from one cell to another

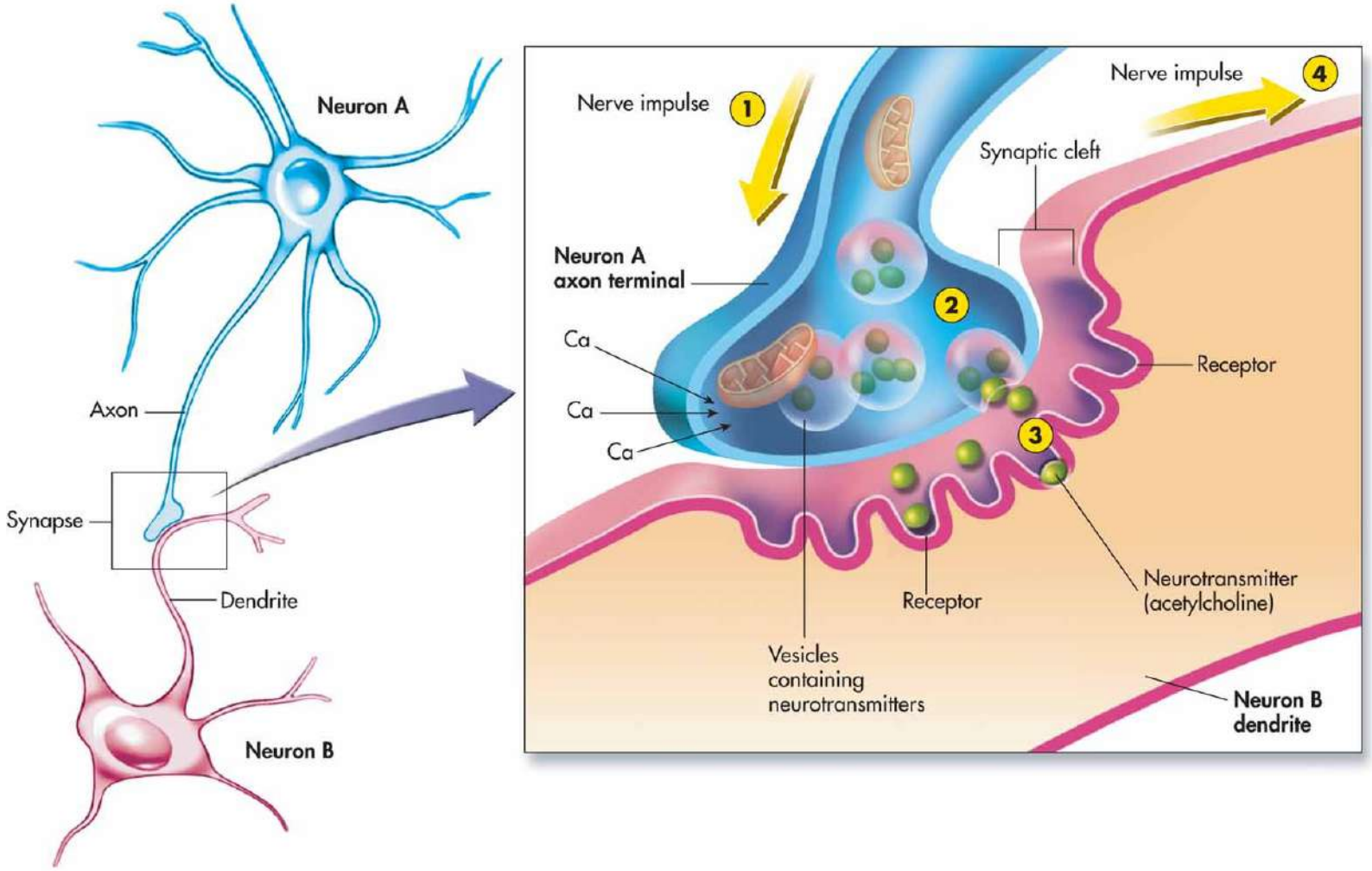


Figure 9-6 The chemical synapse. Step 1: the impulse travels down the axon. Step 2: vesicles are stimulated to release neurotransmitter (exocytosis). Step 3: the neurotransmitter travels across the synapse and binds with the receptor site of post synaptic cell. Step 4: the impulse continues down the dendrite.

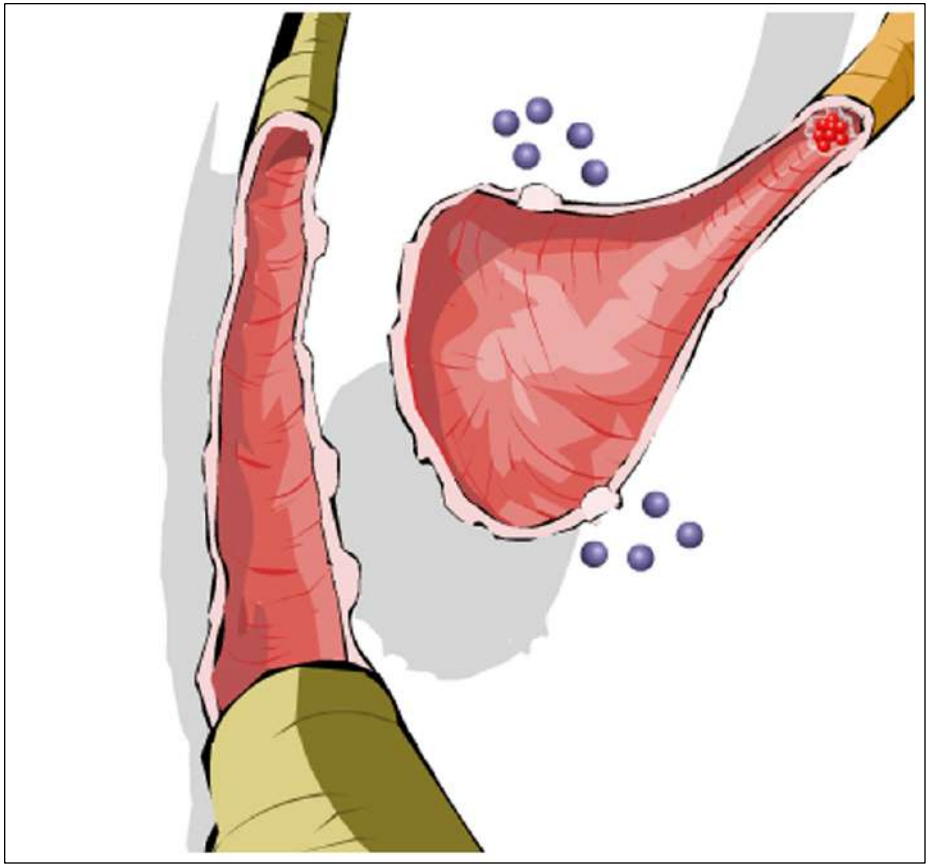
How Synapses Work (cont'd)

- Our understanding of chemical synapses has led to several breakthroughs for treating mental illness
- Many medications on market today are designed to modify synapses

How Synapses Work (cont'd)

- Selective serotonin reuptake inhibitors (SSRI) are good examples; these medications prevent cleanup of neurotransmitter serotonin from synapses, thus increasing effects of serotonin on receiving cell
- Many antidepressants and anti-anxiety drugs are SSRIs

Neurosynapses Animation



Click here to view an animation on the topic of neurosynapses.

TABLE 9-1 Selected Common Neurotransmitters

NEUROTRANSMITTER	LOCATION	FUNCTION	COMMENTS
Acetylcholine	CNS* and PNS*	Generally excitatory but is inhibitory to some organs and glands	Found in skeletal neuromuscular junctions and in many ANS* synapses
Norepinephrine	CNS and PNS	May be excitatory or inhibitory depending on the receptors	Found at visceral and cardiac muscle synapses, ANS
Epinephrine	CNS and PNS	May be excitatory or inhibitory depending on the receptors	Found in pathways concerned with behavior and mood
Serotonin	CNS	Generally inhibitory	Found in pathways that regulate temperature, sensory perception, mood, onset of sleep
Endorphins	CNS	Generally inhibitory	Inhibit release of pain neurotransmitters

*CNS = central nervous system; PNS = peripheral nervous system; ANS = autonomic nervous system.

Table 9-1 Selected Common Neurotransmitters

How Synapses Work (cont'd)

- Some cells do not need chemicals to transmit information from one cell to another
- These synapses are electrical synapses, transferring information freely because they have special connections called gap junctions
- These kinds of connections can exist between any types of excitable cells
- They are found in intercalated disks between cardiac muscle fibers

Spinal Cord and Spinal Nerves

- Spinal cord is hollow tube running inside vertebral column, from foramen magnum to the second lumbar vertebrae
- Spinal cord is like sophisticated neural information superhighway
- There are 31 segments, each with pair of spinal nerves, named for corresponding vertebrae

Spinal Cord and Spinal Nerves (cont'd)

- Spinal cord ends at L2 in pointed structure called conus medullaris; hanging from conus medullaris is cauda equine (horses tail), which dangles loosely and floats in bath of cerebral spinal fluid (CSF)
- Spinal cord has two widened areas, cervical and lumbar enlargements, that contain neurons for upper and lower limbs respectively

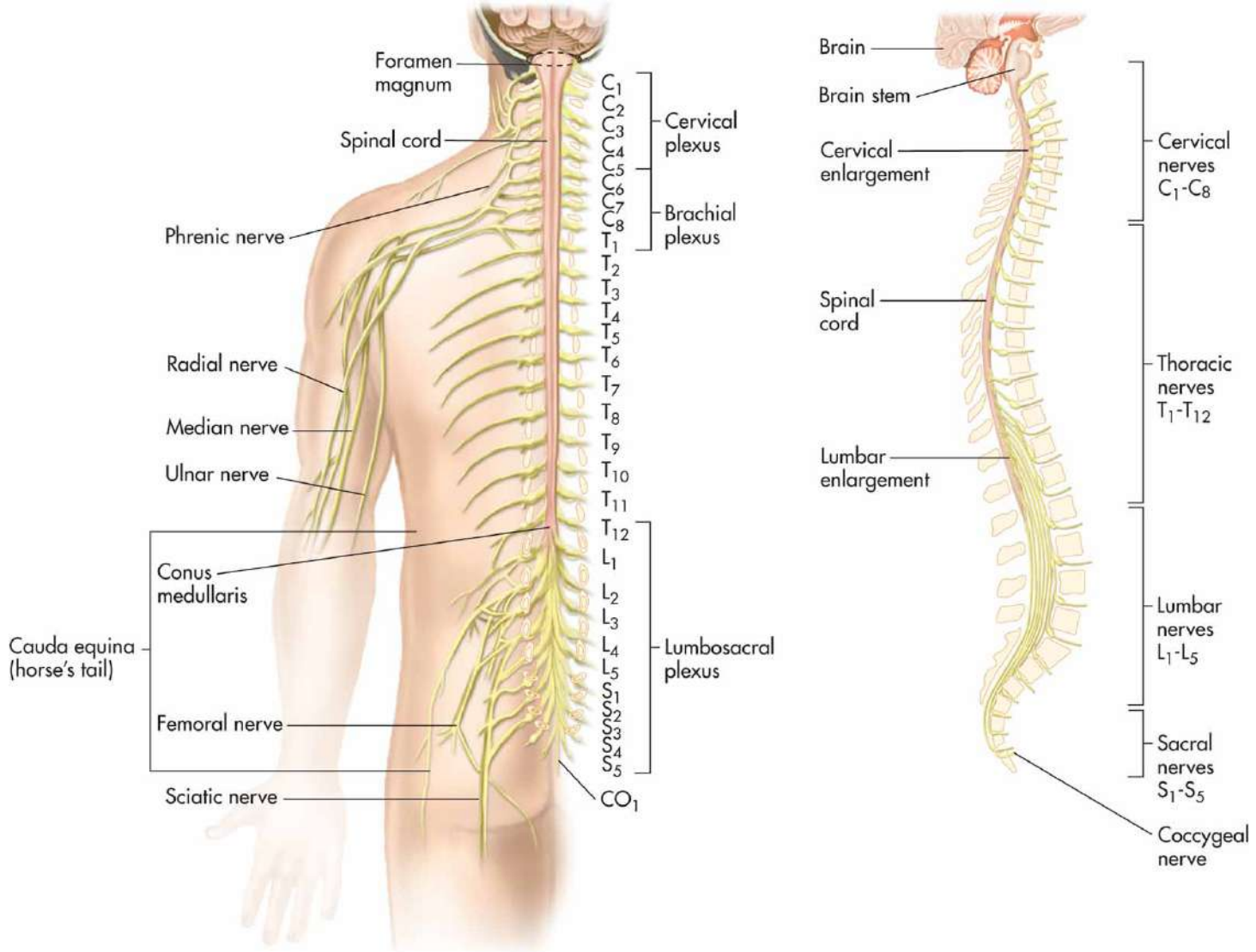


Figure 9-7 The spinal cord. Please note that while there are seven cervical vertebrae, there are eight pairs of cervical spinal nerves.

Spinal Cord and Spinal Nerves (cont'd)

- Meninges are protective covering of both brain and spinal cord
- Meninges help to set up layers that act as cushioning and shock absorbers

Spinal Cord and Spinal Nerves (cont'd)

- There are three distinct layers of meninges
  - Outer layer is thick fibrous tissue called dura mater
  - Middle layer is wispy delicate layer resembling spider web called arachnoid mater, composed of collagen and elastic fibers acting as shock absorber, and transporting dissolved gases and nutrients as well as chemical messengers and waste products
  - Third, innermost layer, fused to neural tissue, is pia mater, containing blood vessels that serve brain and spinal cord

Spinal Cord and Spinal Nerves (cont'd)

- Series of spaces associated with meninges
  - Between dura mater and vertebral column is space filled with fat and blood vessels called epidural space
  - Between dura mater and arachnoid mater is subdural space filled with tiny bit of fluid
  - Between arachnoid mater and pia mater is large subarachnoid space filled with CSF that acts as fluid cushion

Spinal Cord and Spinal Nerves (cont'd)

- These three membranes and their fluid filled spaces, together with bones of skull and vertebral column, form strong protective system against CNS injury

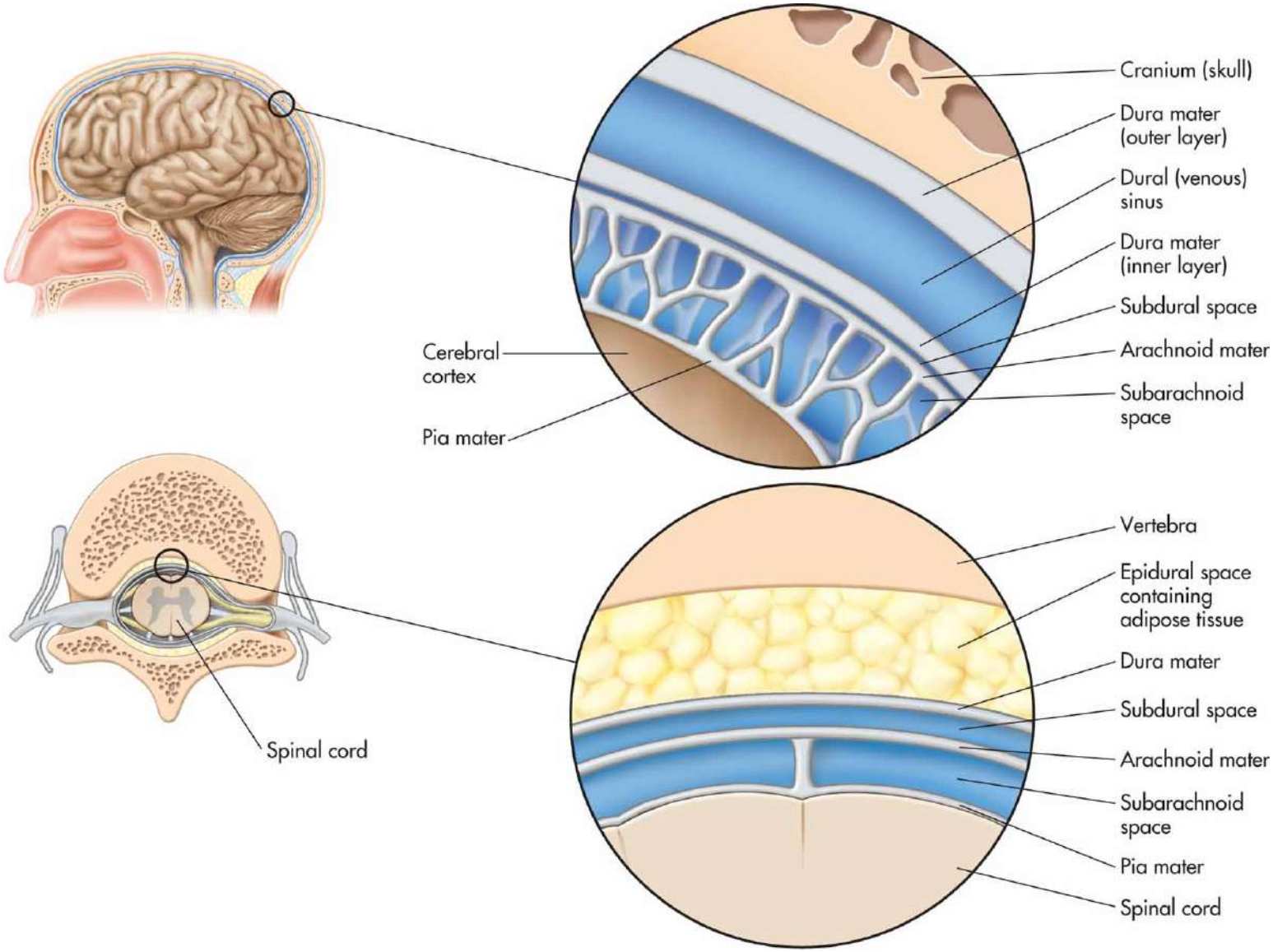


Figure 9-8 The meninges of the brain and spinal cord.

Epidural Placement Video

Click here to view a video on the topic of epidural placement.

Internal Anatomy of the Spinal Cord

- Spinal cord is divided in half by anterior median fissure (deep groove) and posterior median sulcus (shallow groove)
- Interior of spinal cord is then divided into series of sections of white matter columns and gray matter horns

Internal Anatomy of the Spinal Cord (cont'd)

- Three types of horns; regions where neuron's cell bodies reside
  - Dorsal horn: involved in sensory functions
  - Ventral horn: involved in motor function
  - Lateral horn: dealing with autonomic functions

Internal Anatomy of the Spinal Cord (cont'd)

- Columns: areas of white matter (which contain axons running up and down spinal cord, to and from brain)
  - Ascending pathways: carry sensory information up to brain
    - Dorsal column tract: carries fine-touch and vibration information to cerebral cortex
    - Spinothalamic tract: carries temperature, pain, and crude touch information to cerebral cortex
    - Spinocerebellar tract: carries information about posture and position to cerebellum

Internal Anatomy of the Spinal Cord (cont'd)

- Descending pathways: carry motor information down from brain
  - Corticospinal tract: carries orders from brain to motor neurons in ventral horn of spinal cord
  - Corticobulbar tract: carries orders from brain to motor neurons in brain stem
  - Reticulospinal and rubrospinal tracts (and others): carry information which helps coordinate movement from brain to brainstem and ventral horn of spinal cord

Internal Anatomy of the Spinal Cord (cont'd)

- Left and right halves of spinal cord connected by commissures (gray and white); allows two sides of CNS to communicate
- In center of spinal cord is CSF-filled cavity called central canal

Internal Anatomy of the Spinal Cord (cont'd)

- Spinal roots project from both sides of spinal cord in pairs, and fuse to form spinal nerves
- Dorsal root, with embedded dorsal root ganglion, collection of sensory neurons, carries sensory information while ventral root is motor

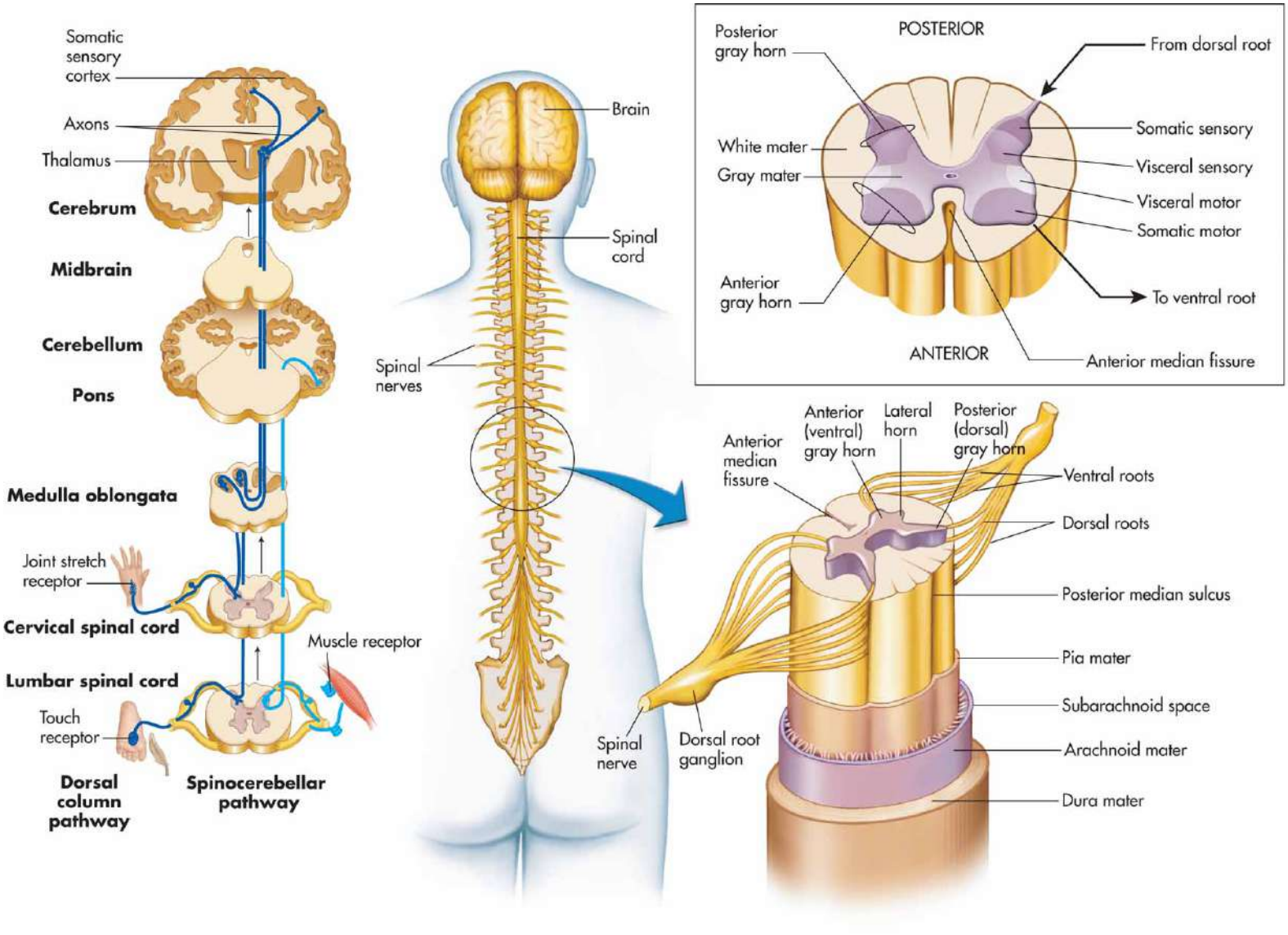


Figure 9-9 Internal anatomy of the spinal cord.

Pathology Connection: Polio and Post-Polio Syndrome

- Polio: paralysis caused by poliomyelitis virus
  - Epidemiology: common prior to start of large-scale vaccinations in 1950s; now extremely rare
  - Symptoms
    - 99% of patients suffer only mild upper respiratory or digestive illness (which lasts only a few days)
    - 1% of patients develop paralytic form; virus kills motor neurons in ventral horn of spinal cord; cell death results in paralysis; sensation, however, remains intact (since sensory neurons are unaffected)

Pathology Connection: Polio and Post-Polio Syndrome (cont'd)

- Treatment/Prognosis
  - There is no cure; patients are kept alive during acute phase, and if they survive, they need extensive rehabilitation
  - 25% of patients with paralytic polio suffer permanent disability

Pathology Connection: Polio and Post-Polio Syndrome (cont'd)

- Post-polio syndrome (PPS): progressive weakness that appears several decades after polio infection
  - Affects 25-40% of patients with paralytic polio
  - Cause may be related to damage left by polio virus
    - In parts of spinal cord damaged by original polio infection, neurons are actually destroyed
    - Patients recover function by using few surviving motor neurons to power all muscles
    - Current thinking is that surviving neurons become severely overworked and eventually begin to die themselves

Pathology Connection: Polio and Post-Polio Syndrome (cont'd)

- Diagnosis consists of ruling out other causes of progressive muscle weakness in polio survivors
- Treatment
  - There are no treatments to stop progression of PPS
  - Exercise has been shown to improve muscle function in some patients

Spinal Nerves

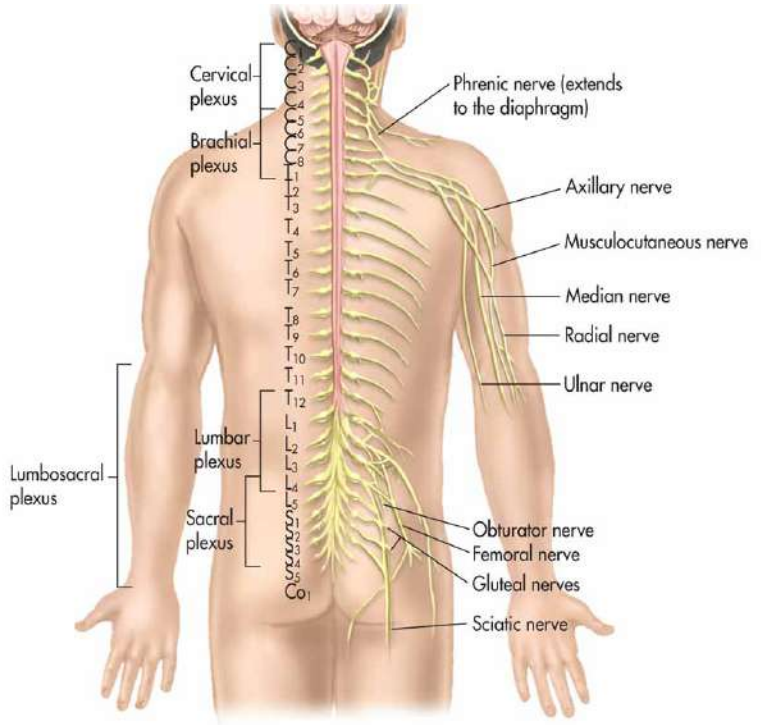
- Nerves are connection between CNS and world outside CNS
- Nerves are, therefore, part of PNS
- All nerves consist of bundles of axon, blood vessels, and connective tissue
- Nerves run between CNS and organs or tissues, carrying information into and out of CNS

Spinal Nerves (cont'd)

- Nerves connected to spinal cord are called spinal nerves, each named for spinal cord segment to which they are attached
- All spinal nerves are mixed nerves, which means they carry both sensory and motor information

Spinal Nerves (cont'd)

- Spinal nerves from thoracic spinal column project directly to thoracic body wall without branching
- All other spinal nerves branch extensively, recombining with nerves from other spinal cord segments before projecting to peripheral structures; these complex branching patterns are called plexuses

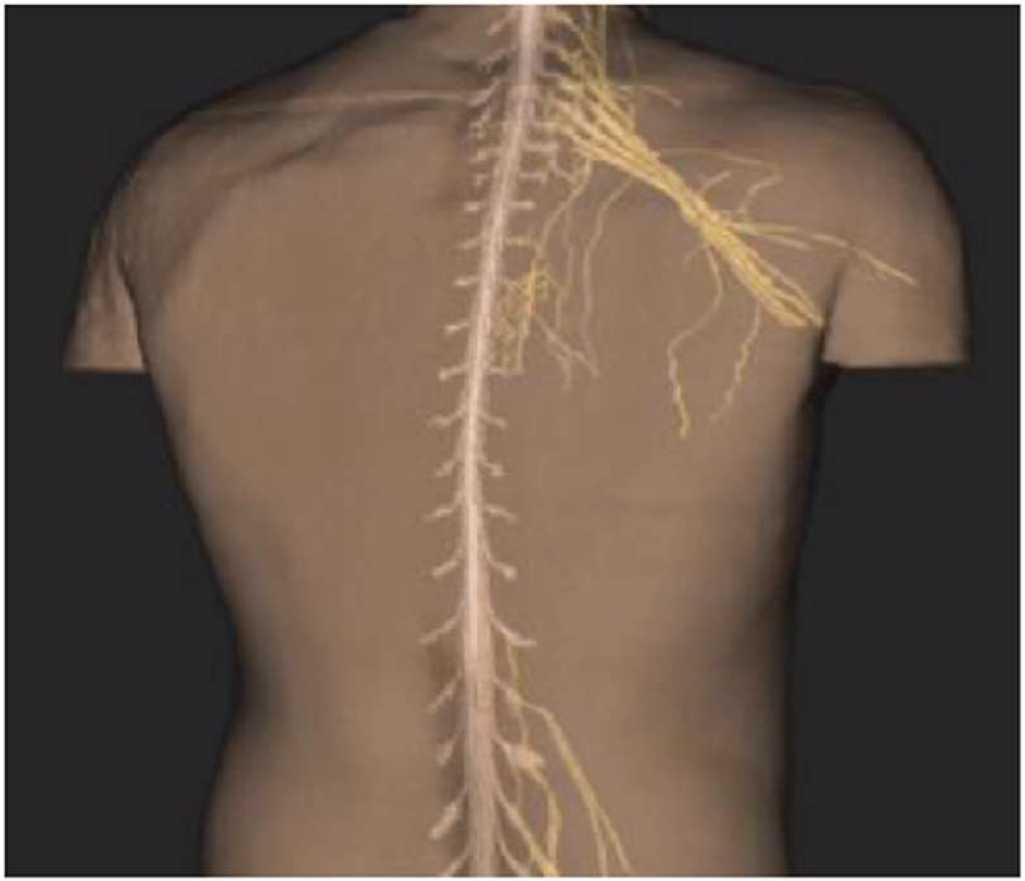


SPINAL NERVE PLEXUSES

PLEXUS	LOCATION	SPINAL NERVES INVOLVED	REGION SUPPLIED	MAJOR NERVES LEAVING PLEXUS
Cervical	Deep in the neck, under the sternocleidomastoid muscle	C_1-C_4	Skin and muscles of neck and shoulder; diaphragm	Phrenic (Diaphragm)
Brachial	Deep to the clavicle, between the neck and the axilla	C_5-C_8, T_1	Skin and muscles of upper extremity	Musculocutaneous Ulnar Median Radial Axillary
Lumbosacral	Lumbar region of the back	T_{12}, L_1-L_5, S_1-S_4	Skin and muscles of lower abdominal wall, lower extremity, buttocks, external genitalia	Obturator Femoral Sciatic Pudendal

Figure 9-10 Spinal cord plexuses.

Spinal Cord Animation



Click here to view an animation on the spinal cord.

Brachial Plexus Animation

Click here to view an animation on the brachial plexus.

Lumbosacral Plexus Animation

Click here to view an animation on the lumbosacral plexus.

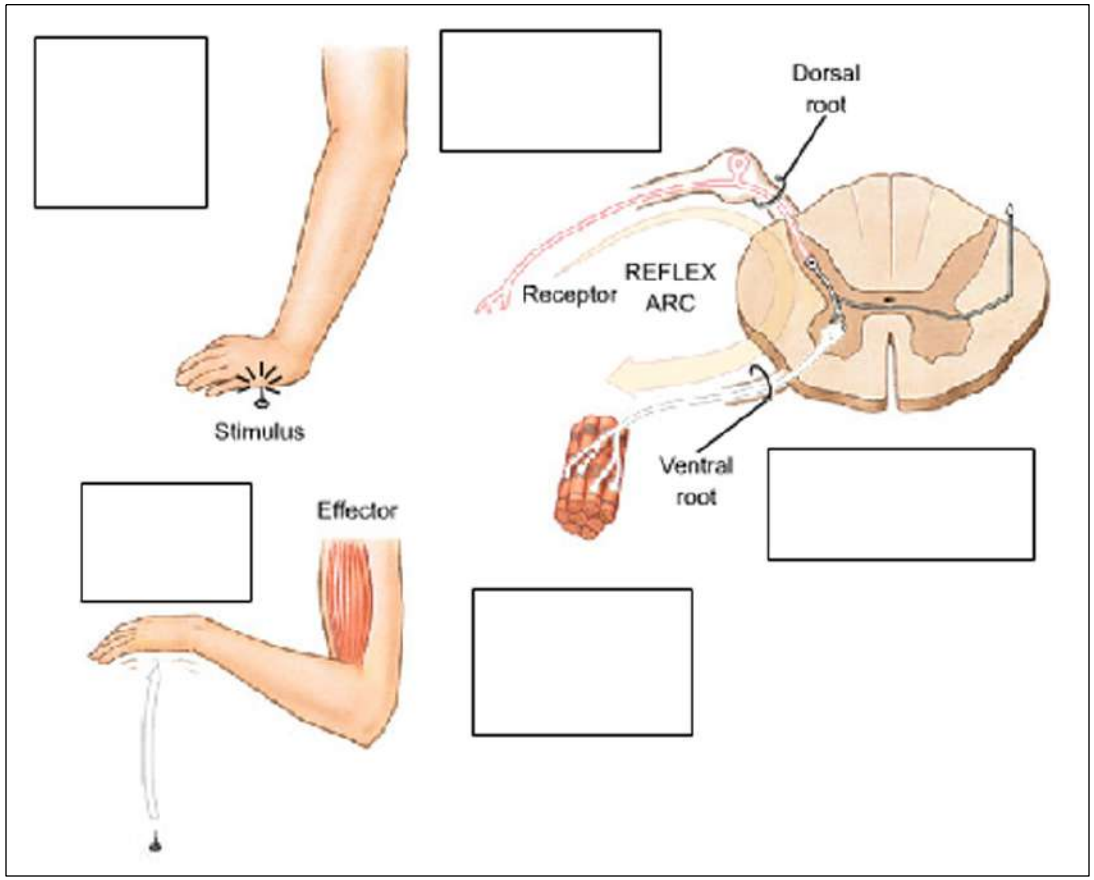
Reflexes

- Simplest form of motor output you can make
- Generally protective, keeping you from harm
- Involuntary and usually response gets bigger as stimulus gets bigger

Reflexes (cont'd)

- Some familiar reflexes are patellar reflex, which keeps you vertical, and startle reflex, which causes you to jump at loud sounds
- Amazing thing about reflexes is that they can often occur without brain being involved, involving only spinal cord

Reflex Arc Animation



Click here to view an animation on the topic of the reflex arc.

Common Disorders of the Nervous System: Part I

- Peripheral neuropathy
- Spinal trauma
- Guillain-Barré syndrome
- Myasthenia gravis
- Botulism
- Meningitis
- Carpal tunnel syndrome

Pathology Connection: Peripheral Neuropathy

- Family of disorders involving damage to peripheral nerves
- Symptoms
  - Because peripheral nerves are involved in sensory, motor, and autonomic functions, symptoms can vary greatly among patients
  - Possible symptoms include: muscle weakness, decreased reflexes, numbness, tingling, paralysis, pain, difficulty controlling blood pressure, abnormal sweating, digestive abnormalities

Pathology Connection: Peripheral Neuropathy (cont'd)

- Causes
  - Trauma
    - Most common overall cause of peripheral neuropathy
    - Anything that causes mechanical injury to nerves, such as falls, car accidents

Pathology Connection: Peripheral Neuropathy (cont'd)

- Causes
  - Systemic disease
    - Diabetes (most common systemic cause of peripheral neuropathy)
    - Kidney disorders
    - Hormonal imbalance
    - Alcoholism
    - Vascular damage
    - Repetitive stress
    - Chronic inflammation
    - Toxins
    - Tumors

Pathology Connection: Peripheral Neuropathy (cont'd)

- Infection & autoimmune causes
  - Shingles
  - Epstein-Barr virus
  - Herpes
  - HIV
  - Lyme disease
  - Polio
- Genetic: Charcot Marie Tooth

Pathology Connection: Peripheral Neuropathy (cont'd)

- Diagnosis: based on history of symptoms and presence of other conditions that can cause neuropathy
  - Diagnostic testing may include CT, MRI, electromyogram (EMG), biolspy
- Treatment: underlying cause is treated; symptoms are managed with medication and therapy

Pathology Connection: Spinal Cord Injury

- Most common causes
  - Car accidents
  - Violence
  - Falls
  - Work injuries
  - Disease

Pathology Connection: Spinal Cord Injury (cont'd)

- Epidemiology
  - Half of all spinal cord injuries occur in people between ages16 and 30
  - Most injuries are in males
  - 10,000 spinal cord injuries occur in U.S. per year

Pathology Connection: Spinal Cord Injury (cont'd)

- Types of injury to spinal cord
  - Severing of spinal cord (partial or complete)
  - Crushing
  - Bruising
- Expected outcome
  - Bruises to spinal cord may resolve with time and rehabilitation
  - Severed or crushed spinal cord usually results in permanent injury

Pathology Connection: Spinal Cord Injury (cont'd)

- Mechanism of tissue injury
  - Initial injury traumatizes spinal cord
  - Body's response to injury causes further tissue damage
    - Spinal cord swells, decreasing its blood flow
    - Immune system removes and demyelinates some of surviving tissue
    - Excess neurotransmitter release kills cells
    - Damaged neurons self-destruct

Pathology Connection: Spinal Cord Injury (cont'd)

- Symptoms of spinal cord injury
  - Paralysis and sensory loss below injury
  - Extent of body affected depends on location of injury
    - Cervical injuries: patients become quadriplegic (paralyzed in all four limbs); some patients have paralysis of diaphragm, and require assistance to breathe; sensory perception is also lost below injury
    - Thoracic and lumbar injuries: patients become paraplegic (paralyzed in legs); patients who experience paralysis of abdominal muscles may have difficulty coughing or taking deep breaths; sensory information is lost below injury

Pathology Connection: Spinal Cord Injury (cont'd)

- Sexual function is usually preserved
  - Men
    - Penile erection is a reflex, so it can still occur
    - Ejaculation may be impaired, but sperm are normal and can be used for conception with medical intervention
  - Women
    - Menstrual cycle may be abnormal due to hormonal changes post injury
    - However, many women remain fertile, and may be able to carry a child with adequate medical supervision

Pathology Connection: Spinal Cord Injury (cont'd)

- Diagnosis of spinal cord injury
  - Neurological exam testing sensory and motor function
  - Imaging studies
    - MRI
    - X-ray
    - CT scan
    - Myelography (X-ray of spinal cord using dye)

Pathology Connection: Spinal Cord Injury (cont'd)

- Treatment of spinal cord injury
  - Acute stage: clinicians attempt to prevent further damage
    - Injury is immobilized
    - Respiration is aided
    - Low blood pressure or cardiac problems are treated
    - Steroids are given to reduce damage caused by inflammation and cell death
    - Injury is permanently stabilized using surgical techniques

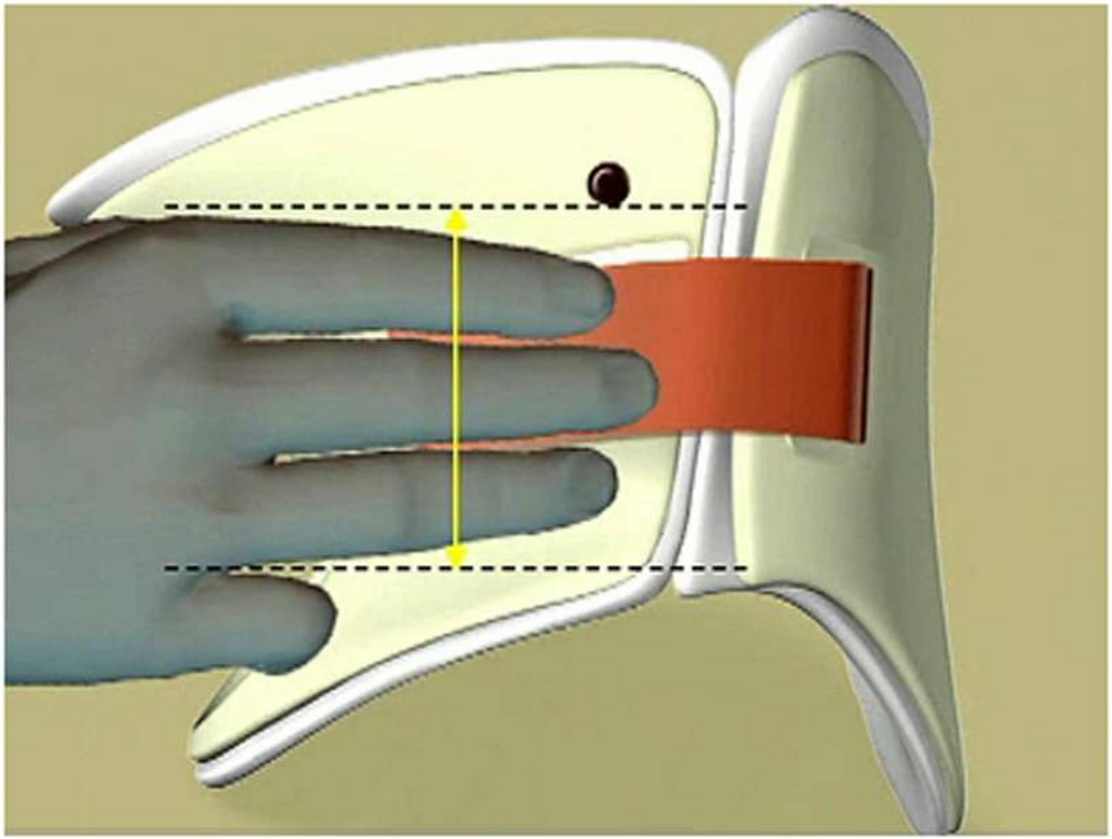
Pathology Connection: Spinal Cord Injury (cont'd)

- Treatment of spinal cord injury
  - After acute stage: clinicians try to treat or prevent long term problems such as:
    - Respiratory difficulties
    - Blood pressure abnormalities
    - Pneumonia
    - Blood clots
    - Organ dysfunction
    - Pressure sores
    - Pain
    - Bladder and bowel dysfunction

Pathology Connection: Spinal Cord Injury (cont'd)

- Rehabilitation
  - Extensive and vigorous rehabilitation exercises can help spinal cord injury patients recover some function
  - Other aspects of rehab include learning to cope with the injury

Spinal Injury Video



Click here to view a video on spinal injuries.

The Brain and Cranial Nerves

- Brain acts as main processor and director of nervous system
- Cranial nerves leave brain and go mainly to head, where they receive information and send it back to brain (sensory); brain sends back instructions to move (motor)

The Brain and Cranial Nerves (cont'd)

- At top of spinal cord, beginning at level of foramen magnum and filling skull, is brain
- Brain can be divided into several anatomical and functional sections
- Brain consists of:
  - Cerebrum
  - Cerebellum
  - Brain stem

The Brain and Cranial Nerves (cont'd)

- Cerebrum is largest part of brain
  - Divided into right and left hemispheres by longitudinal fissure and divided from cerebellum by transverse fissure
  - Surface is not smooth, but broken by ridges (gyri) and grooves (sulci) collectively known as convolutions

The Brain and Cranial Nerves (cont'd)

- Cerebrum is largest part of brain
  - Convolutions serve very important purpose by increasing surface area of brain, so you can pack more brain in smaller space
  - Most of sulci are extremely variable in their locations among humans, but a few are in basically same place in every brain; these divide brain into lobes

The Brain and Cranial Nerves (cont'd)

- Lobes named for skull bones that cover them and occur in pairs, one in each hemisphere
  - The most anterior lobes, separated from the rest of brain by central sulci, are frontal lobes; frontal lobes are responsible for motor activities, conscious thought, and speech
  - Posterior to frontal lobes are parietal lobes; parietal lobes are involved with body sense perception, primary taste, and speech
  - Posterior to parietal lobes are occipital lobes, which are responsible for vision

The Brain and Cranial Nerves (cont'd)

- Most inferior lobes, separated by lateral sulci, are temporal lobes, which are involved in hearing and integration of emotions
- There is a section of brain, insula, deep inside temporal lobes, often listed as fifth lobe, but is not visible on surface of cerebrum

The Brain and Cranial Nerves (cont'd)

- Much of information coming into brain is contralateral, meaning the right side of body is controlled by left side of cerebral cortex and left side of body is controlled by right side of cerebral cortex

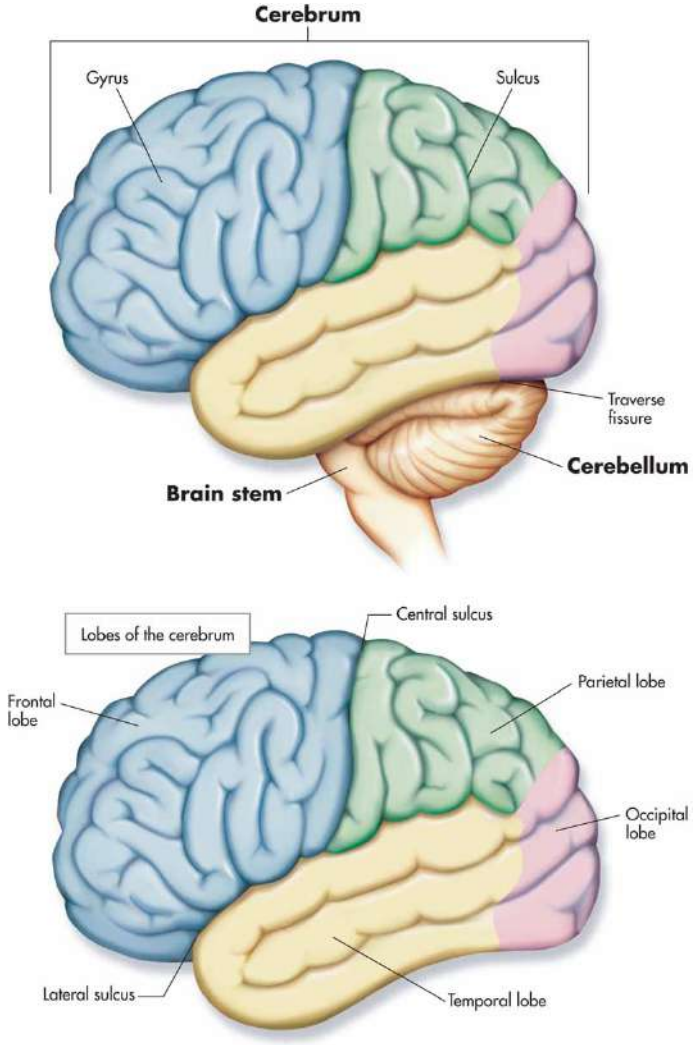


Figure 9-11 External brain anatomy and lobes.

The Brain and Cranial Nerves (cont'd)

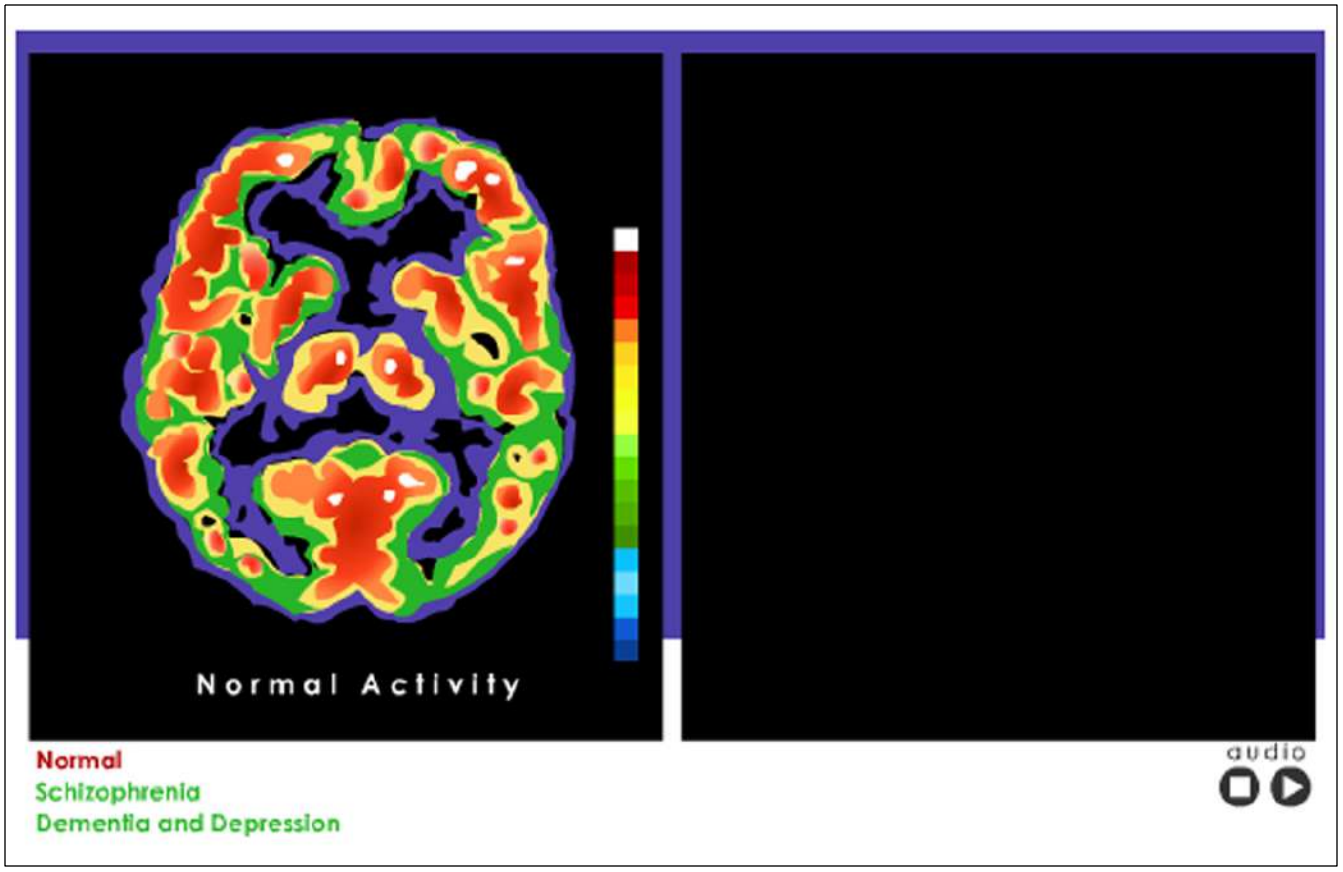
- Cerebellum is posterior to cerebrum
  - Divided into hemispheres by raised ridge called vermis
  - Surface is convoluted like that of cerebrum
  - From external appearance it is easy to see why cerebellum is called little brain
  - Involved in sensory collection, motor coordination, and balance

TABLE 9-2 Cerebral Lobes and Cerebellum

STRUCTURE	MAJOR FUNCTIONS
Cerebral Lobes	
Frontal lobe	Motor function, behavior and emotions, memory storage, thinking, smell
Parietal lobe	Body sense, perception, and speech
Occipital lobe	Vision
Temporal lobe	Hearing, taste, language comprehension, integration of emotions
Insula	Autonomic functions
Cerebellum	Sensory and motor coordination and balance

Table 9-2 Cerebral Lobes and Cerebellum

PET Scan Animation



Click here to view an animation on the topic of PET scans.

The Brain and Cranial Nerves (cont'd)

- Brain stem is stalk-like structure inferior to, and partially covered by, cerebrum
  - Divided into three sections
    - Medulla oblongata: continuous with spinal cord, responsible for impulses that control heartbeat, respirations, and blood vessel diameter
    - Pons: just superior to medulla oblongata
    - Midbrain: most superior portion of brain stem and is completely covered by cerebrum

TABLE 9-3 The Brain Stem

STRUCTURE	FUNCTION
Midbrain	Relays sensory and motor information
Pons	Relays sensory and motor information; role in breathing
Medulla oblongata	Regulates vital functions of heart rate, blood pressure, breathing, and reflex center for coughing, sneezing, swallowing and vomiting

Table 9-3 The Brain Stem

The Brain and Cranial Nerves (cont'd)

- The brainstem contains reticular system, diffuse network of brain stem neurons responsible for "waking up" cerebral cortex
  - General anesthesia inhibits reticular system, causing unconsciousness
  - Injury to reticular system can lead to coma
- Brain stem receives sensory information and contains control systems for vital processes such as blood pressure, heart rate, and ventilation

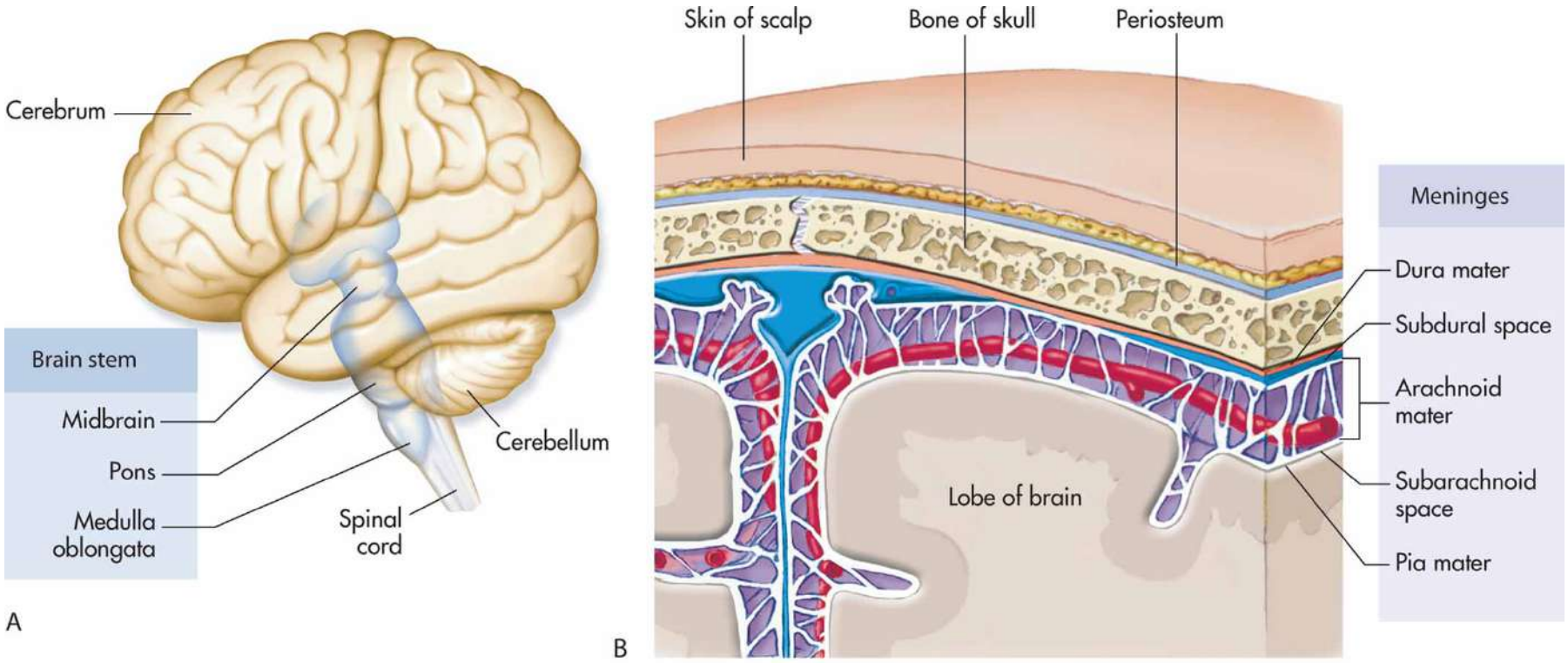
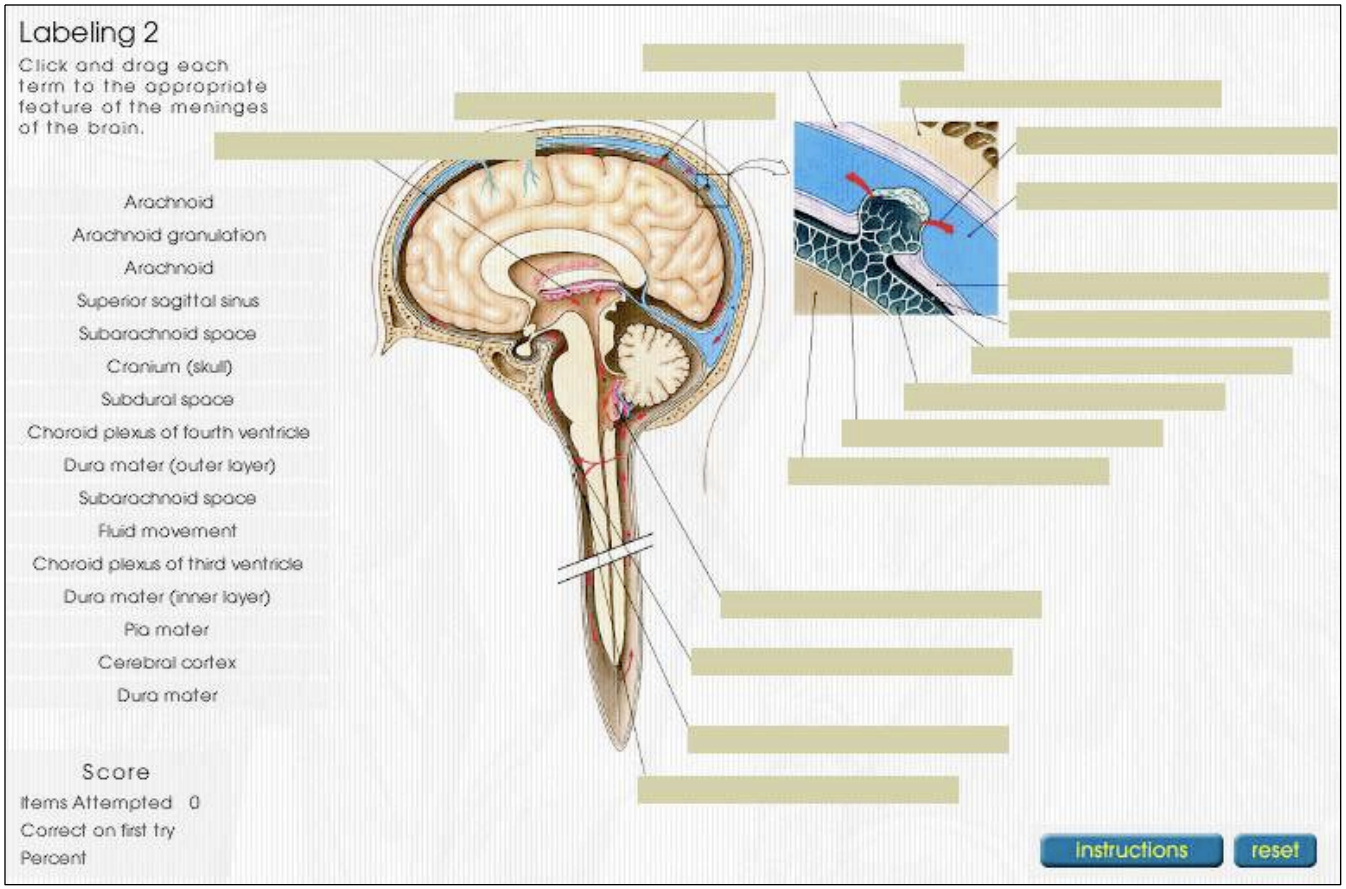


Figure 9-12 (A) The brain stem and (B) meninges.

Brain Anatomy Exercise



Click here to view an interactive labeling exercise of the features of the brain.

The Brain and Cranial Nerves (cont'd)

- Brain, like spinal cord, is covered with protective membranes called *meninges*
- Meninges of brain are continuous with spinal cord meninges
- Meningitis is infection of meninges, a possibly fatal condition that can rapidly spread and affect brain and spinal cord through this common covering

Pathology Connection: Brain Injury

- Traumatic Brain Injury (TBI)
  - Occurs when force is applied to skull, causing damage to brain tissue
  - Common causes
    - Vehicle accidents (most common cause)
    - Falls
    - Violence
    - Sports injuries
  - Damage similar to TBI can also be caused by lack of oxygen to brain, strokes, or hemorrhage

Pathology Connection: Brain Injury (cont'd)

- Epidemiology
  - There are 100 cases per 100,000 people in U.S. each year
  - 50% of accident or violence related TBIs involve alcohol
  - Riskiest ages for TBI are under age 5, 15-24 (males), over age 75
  - Types of TBI
    - Closed: skull is not open
    - Penetrating: skull is punctured by an object

Pathology Connection: Brain Injury (cont'd)

- Stroke
  - Caused by disruption of blood flow to portion of brain
  - If oxygen disrupted for long enough, brain tissue will die
  - Symptoms of stroke occur suddenly, and vary depending on location involved; can include sensory, language, motor, and memory difficulties

Pathology Connection: Brain Injury (cont'd)

- Stroke
  - Cerebrovascular accident (CVA)
    - Major stroke
    - Brain tissue dies due to insufficient blood supply
    - Symptoms largely permanent

Pathology Connection: Brain Injury (cont'd)

- Transient Ischemic Attack (TIA)
  - Also known as "mini-stroke"
  - Patients have stroke-like symptoms that are temporary
  - Can be precursor to major stroke

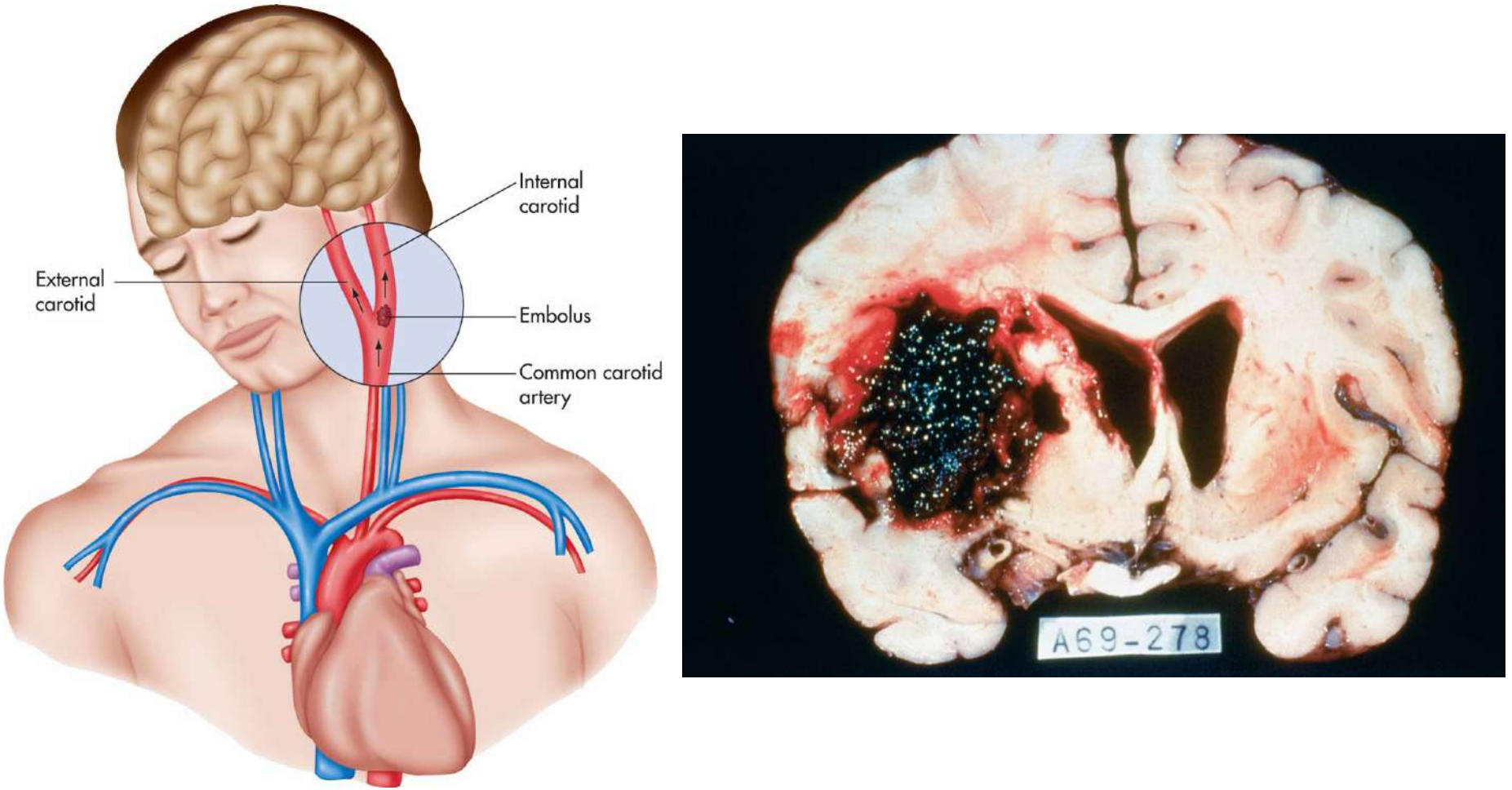


Figure 9-13 (A) Embolus traveling to the brain and (B) cross-section of brain showing cerebrovascular accident (CVA).

Pathology Connection: Brain Injury (cont'd)

- Hematoma
  - Pool of blood between any of layers of meninges and skull
  - Common locations are epidural (between dura mater and skull), subdural (between dura mater and arachnoid mater) and subarachnoid (in subarachnoid space)
  - Blow to head can rupture tiny blood vessels in skull, causing them to bleed into space
  - Stoke or ruptured aneurysm (weak spot in blood vessel inside skull) can also cause hematoma

Pathology Connection: Brain Injury (cont'd)

- Several techniques used to diagnose brain injury
  - Glascow Coma Scale: scale from 3-15 based on patient's ability to open their eyes on command, respond verbally to questions, and to move limbs when requested; lower number indicates more severe injury
  - Imaging, CT, MRI and PET scanning: used to pinpoint location and severity of injury and to monitor its progression

Pathology Connection: Brain Injury (cont'd)

- Treatment of head injury, like treatment of spinal cord injury, involves both prevention of further injury and treatment of existing injury
- Like spinal cord, injured brain will self-destruct due to increased swelling and cell death caused by tissue's attempt to repair damage

Pathology Connection: Brain Injury (cont'd)

- Acute care of head injury
  - Immobilization of head
  - Stabilization of cardiovascular and respiratory functions
  - Monitoring of intracranial pressure
  - Medication to decrease intracranial pressure
  - Surgery to remove clots, blood or foreign objects (for example, bullet or bone fragments) from brain

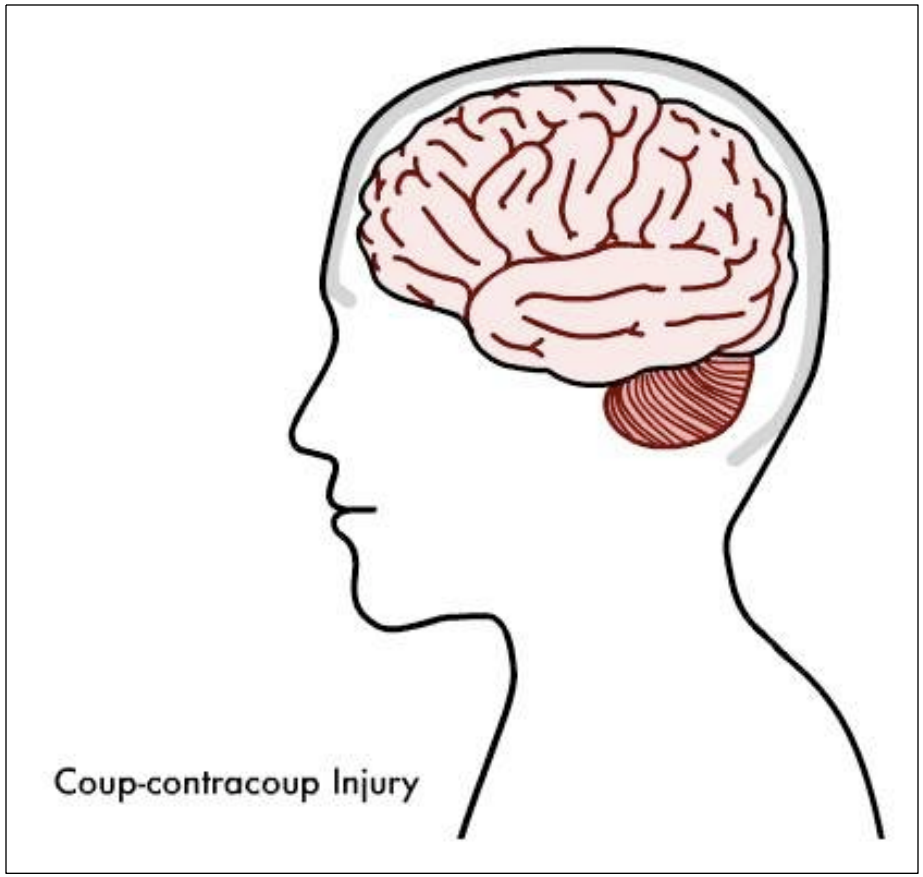
Pathology Connection: Brain Injury (cont'd)

- Approximately 40% of brain injured people, even with mild injuries, will experience post-concussion syndrome
- Several days or weeks after injury, patients experience dizziness, headache, memory and concentration problems, irritability, disordered sleep, and anxiety and depression; these conditions are usually temporary

Glasgow Coma Scale Video

Click here to view a video on the topic of the Glasgow coma scale.

Contracoup Injury Animation



Click here to view an animation on the topic of the contracoup injury.

Internal Anatomy of the Brain

- Inside of brain has white and gray matter, along with hollow cavities containing CSF
- White matter of brain surrounded by gray matter
- Layer of gray matter surrounding white matter is called cortex
  - In cerebrum it is called cerebral cortex
  - In cerebellum it is called cerebellar cortex

Internal Anatomy of the Brain

- There are also “islands” of grey matter deep inside brain; islands are called nuclei; examples of nuclei
  - Basal nuclei: motor coordination system
  - Limbic system: controls emotion, mood, and memory

Internal Anatomy of the Brain (cont'd)

- Inside of cerebrum reflects external anatomy; lobes (frontal, parietal, temporal, and occipital) are clearly visible
- On either side of central sulcus are two gyri
  - Precentral gyrus anterior to central sulcus
  - Postcentral gyrus posterior to central sulcus

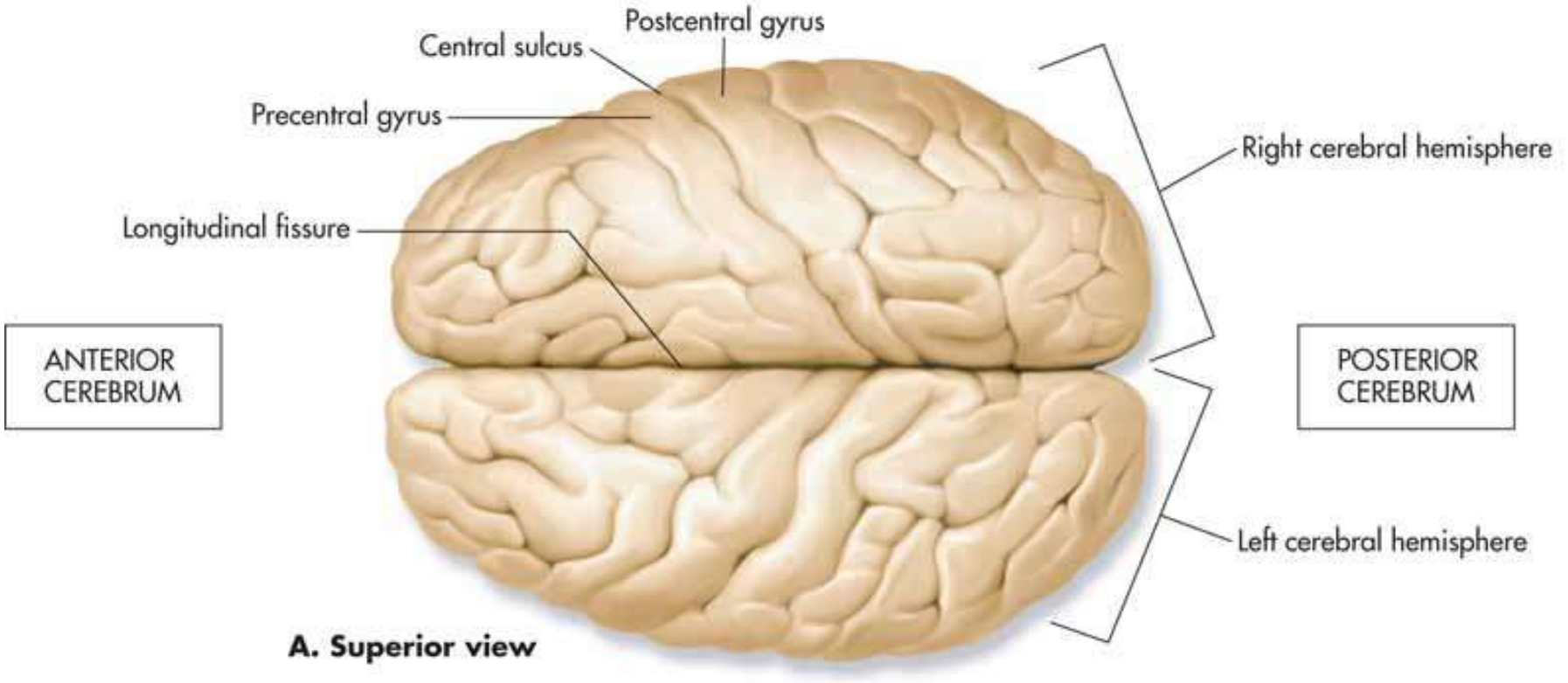


Figure 9-14 Superior (a) and sagittal (b) and sagittal (c) views of the brain.

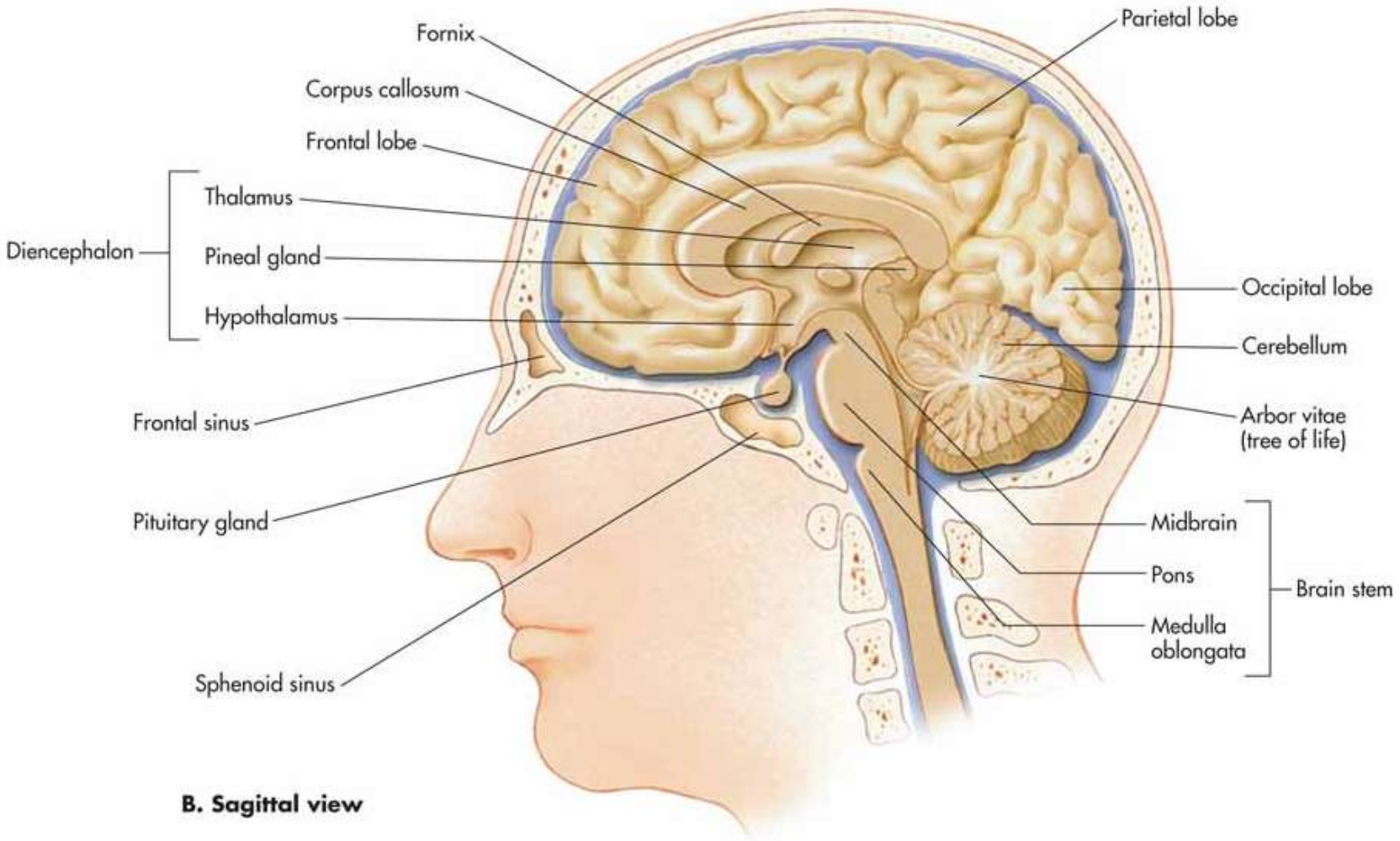


Figure 9-14 (continued) Superior (a) and sagittal (b) and sagittal (c) views of the brain.

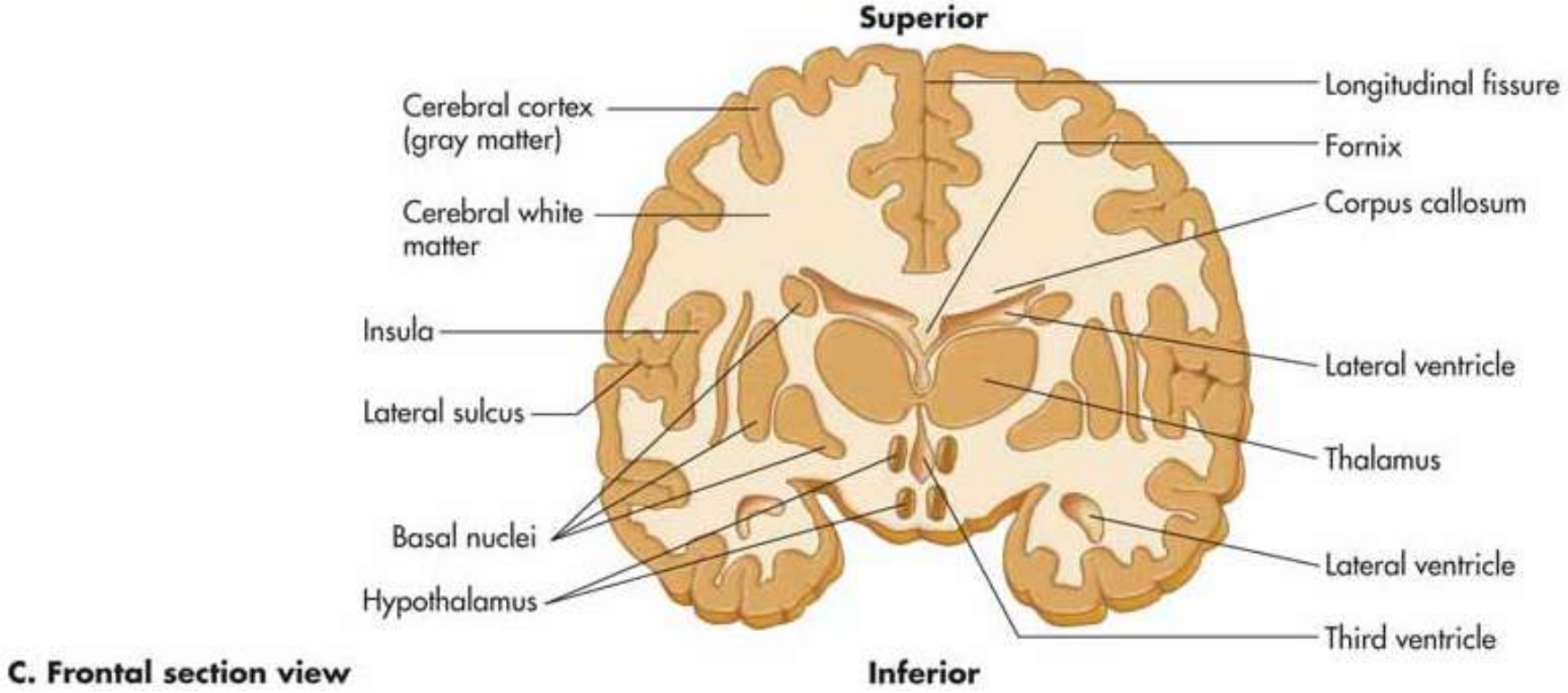


Figure 9-14 (continued) Superior (a) and sagittal (b) and sagittal (c) views of the brain.

Internal Anatomy of the Brain (cont'd)

- Precentral gyrus
  - Location: just anterior to central sulcus (in frontal lobe)
  - Function: contains primary motor cortex (region that controls body movements)
    - Each portion of primary motor cortex controls specific area of body
    - This creates "map" of body on brain sometimes called motor "homunculus" (little man)
    - Body parts that perform more finely coordinated movements (like hands and lips) require larger area on "map"

Internal Anatomy of the Brain (cont'd)

- Other frontal lobe structures
  - Premotor and prefrontal areas: areas that plan movements (before movement occurs)
  - Broca's area: area of brain that controls movements associated with speech

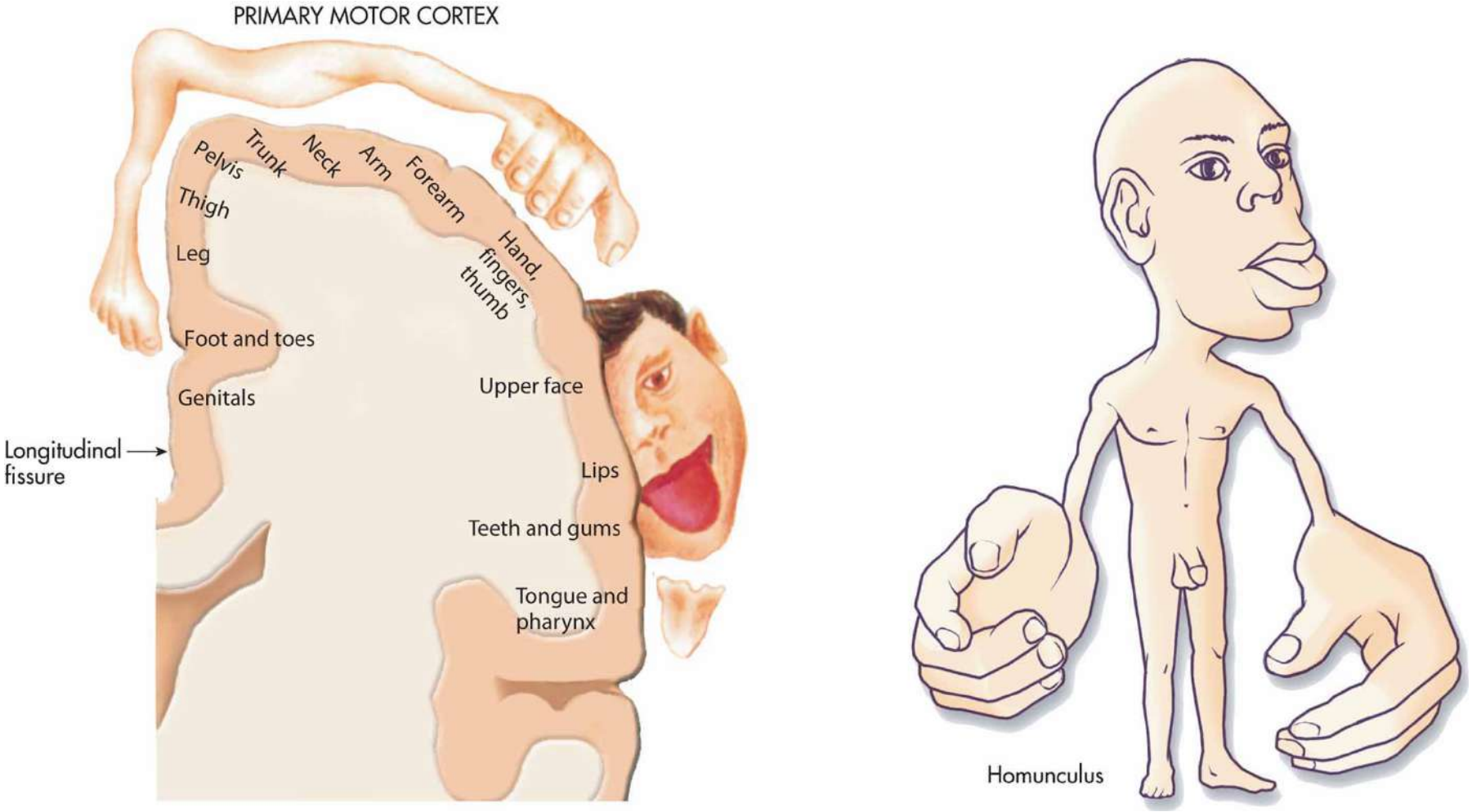


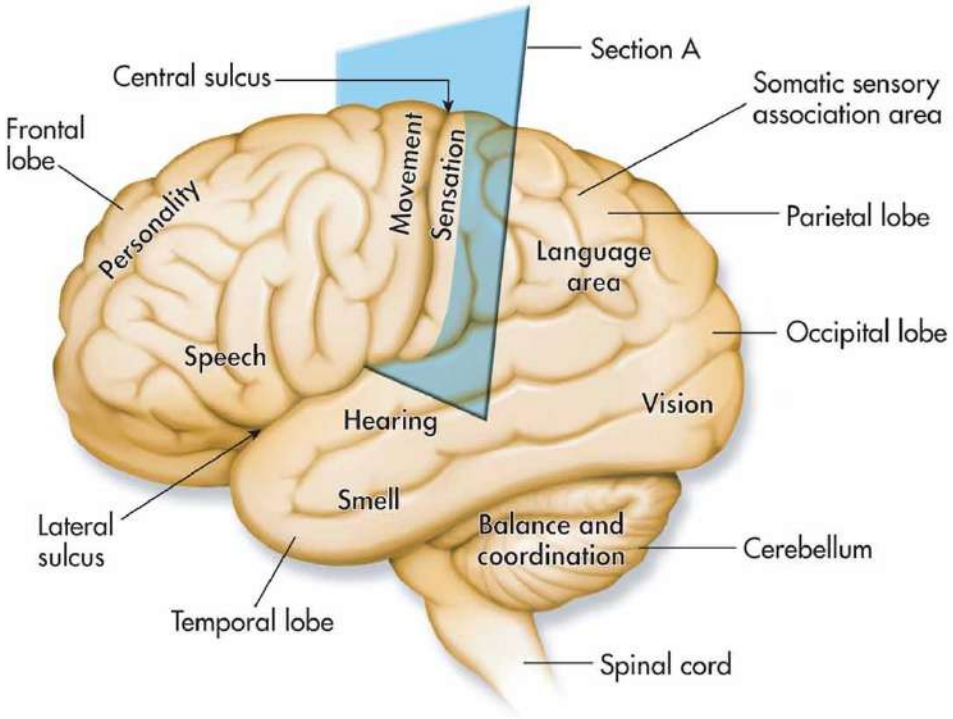
Figure 9-15 Motor areas of the brain, with homunculus.

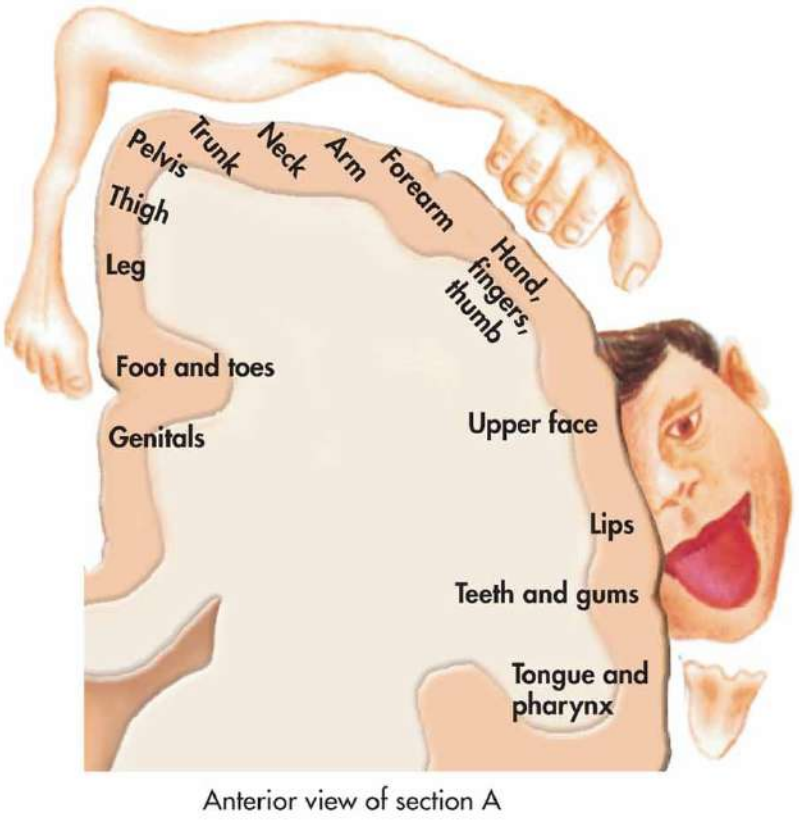
Internal Anatomy of the Brain (cont'd)

- Postcentral gyrus
  - Location: just posterior to central sulcus in parietal lobe
  - Function: contains primary somatosensory cortex (center for processing sensory information)
    - Each portion of somatosensory cortex gets sensory input from specific area of body
    - Also creates "map" of body on brain
    - Size of body parts on "map" is proportional to amount of sensory input provided

Internal Anatomy of the Brain (cont'd)

- Other areas of parietal lobe
  - Somatic sensory association area: allows understanding and interpretation of sensory information
  - Wernicke's area: controls understanding of speech





Anterior view of section A

Figure 9-16 Primary somatic sensory area. Notice the size of the body parts are proportional to the amount of the sensory input provided. For example, the hands provide much more sensory input due to touch than your neck would and as a result the area devoted to the neck is much smaller.

Pain Assessment Video

Click here to view a video on assessing pain and pain management.

Internal Anatomy of the Brain (cont'd)

- Corpus callosum
  - Collection of white matter that connects left and right hemispheres
  - Connection allows for cross-communication between right and left sides of brain
  - Many day-to-day activities, like walking or driving, require both sides of body, and therefore both sides of brain, to be well coordinated

Internal Anatomy of the Brain (cont'd)

- Inferior to cerebrum is section of brain not visible from exterior, called diencephalon
  - Consists of several parts including thalamus, hypothalamus, pineal body, and pituitary gland
  - Glands represent interface with endocrine system
  - Contains a number of nuclei that are part of basal nuclei and limbic system

TABLE 9-4 Diencephalon

STRUCTURE	FUNCTION
Thalamus	Relays and processes information going to the cerebrum
Hypothalamus	Regulates hormone levels, temperature, water-balance, thirst, appetite, and some emotions (pleasure and fear); regulates the pituitary gland and controls the endocrine system
Pineal body	Responsible for secretion of melatonin (body clock)
Pituitary gland	Secretes hormones for various functions (explained in Chapter 10)

Table 9-4 Diencephalon

Internal Anatomy of the Brain (cont'd)

- External similarities between cerebellum and cerebrum are also obvious internally
- Cerebellum has gray matter cortex and white matter center, known as arbor vitae (tree of life)
- Cerebellum also has nuclei that coordinate motor and sensory activity
- Essentially, cerebellum fine tunes voluntary skeletal muscle activity and helps in maintenance of balance

Pathology Connection: Alzheimer's Disease

- Progressive degenerative disease of brain, causing memory loss and diminishing cognitive function (dementia)
- Etiology unknown, age is most important risk factor

Pathology Connection: Alzheimer's Disease (cont'd)

- Symptoms begin gradually with mild forgetfulness; gradually progress to include severe forgetfulness (such as getting lost in familiar location), and difficulty speaking, reading, writing, and maintaining personal hygiene; as condition worsens, patient may experience personality changes, anxiety, and aggressiveness

Pathology Connection: Alzheimer's Disease (cont'd)

- Treatment, no cure; some medications may help to slow progression of early and middle stages of disease

Cerebrospinal Fluid and Ventricles

- Ventricles
  - Cavities inside of brain that are filled with CSF; continuous with central canal of spinal cord, and subarachnoid space
  - There are four ventricles
    - Lateral ventricles (ventricles 1 and 2) in cerebrum
    - Third ventricle is in diencephalon
    - Fourth ventricle is in inferior part of brain between medulla oblongata and cerebellum

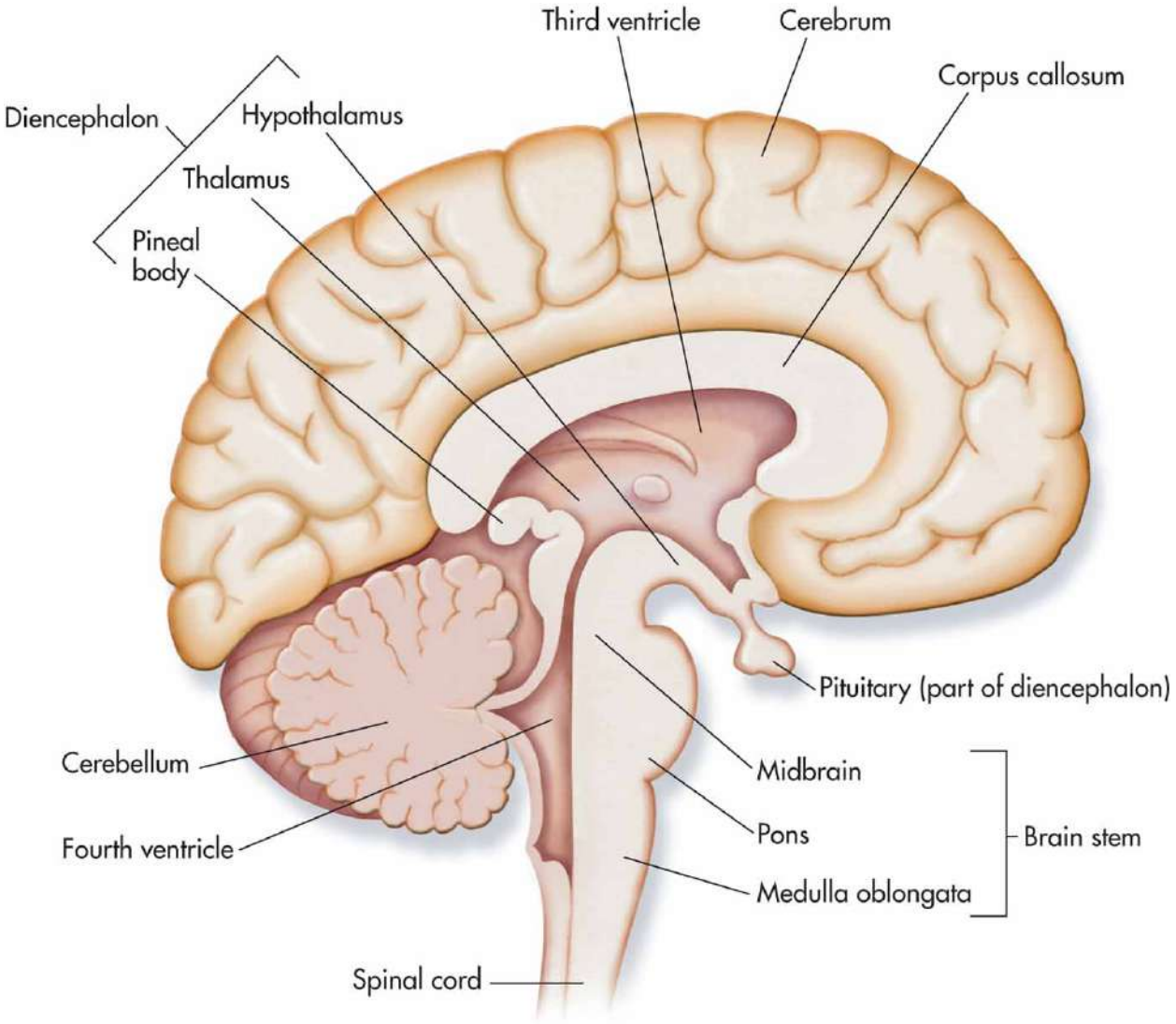


Figure 9-17 Internal anatomy of the brain.

Cerebrospinal Fluid and Ventricles (cont'd)

- CSF circulation
  - CSF is filtered from blood in ventricles by tissue called choroid plexus
  - CSF, made in lateral ventricles, flows through tiny opening into third ventricle and then through another opening into fourth ventricle
  - CSF flows into central canal of spinal cord and subarachnoid space
  - CSF is returned to blood via special "ports" between subarachnoid space and blood spaces in dura mater

Pathology Connection: Hydrocephalus

- Condition where there is too much CSF in skull
- Causes include blockage of narrow passages due to trauma, birth defect, tumor, or decreased reabsorption of CSF
- Can cause changes in intracranial pressure
  - Some cases increased pressure inside skull (and can eventually crush brain tissue)
  - Other cases may have no obvious rise in pressure (normal pressure hydrocephalus)

Pathology Connection: Hydrocephalus (cont'd)

- Symptoms may include
  - Expansion of skull (in infants whose skulls have not fully hardened)
  - Nausea/vomiting
  - Irritability
  - Seizures
  - Headache

Pathology Connection: Hydrocephalus (cont'd)

- Symptoms may include
  - Blurred vision
  - Balance and coordination problems
  - Sleepiness
  - Personality changes
  - Dementia

Pathology Connection: Hydrocephalus (cont'd)

- Diagnosis
  - CT or MRI imaging showing enlarged ventricles
  - Monitoring of intracranial pressure
- Treatment
  - Can be treated with medications
  - More commonly treated with surgical placement of shunt to drain fluid to heart or abdominal cavity

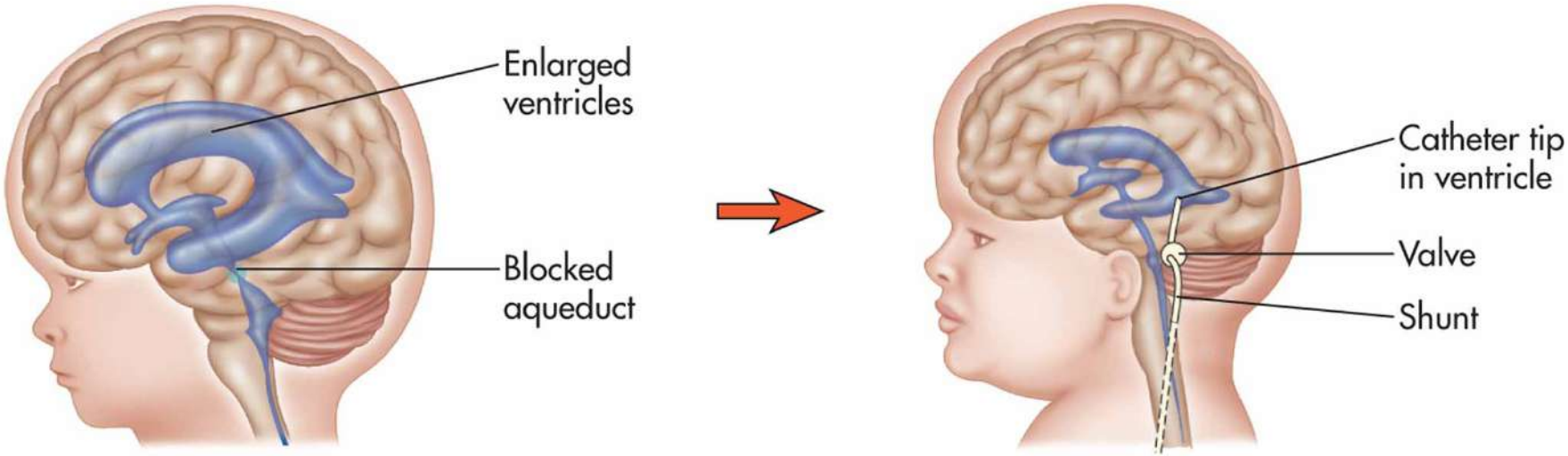


Figure 9-18 Hydrocephalus.

Cranial Nerves

- In order for CNS to function, it must be connected to outside world via nerves of PNS
- Like spinal cord has spinal nerves, likewise, brain has nerves called cranial nerves
- Cranial nerves are like spinal nerves in that they are input and output pathways for brain
- There are only 12 pairs of cranial nerves, all but two of which arise from brain stem

Cranial Nerves (cont'd)

- Not all mixed nerves like spinal nerves; some are mainly sensory and others are mainly motor, and some are mixed nerves
- Much more specialized than spinal nerves
- Carry sensory and motor information for head, face, and neck, as well as visual, auditory, smell, or taste sensations

Cranial Nerves (cont'd)

- Peripheral neuropathy: damage to peripheral nerves
  - Not just about spinal nerves; cranial nerves are also subject to peripheral neuropathy
  - Symptoms would be seen on face and head or in special senses (vision, hearing, taste, smell)

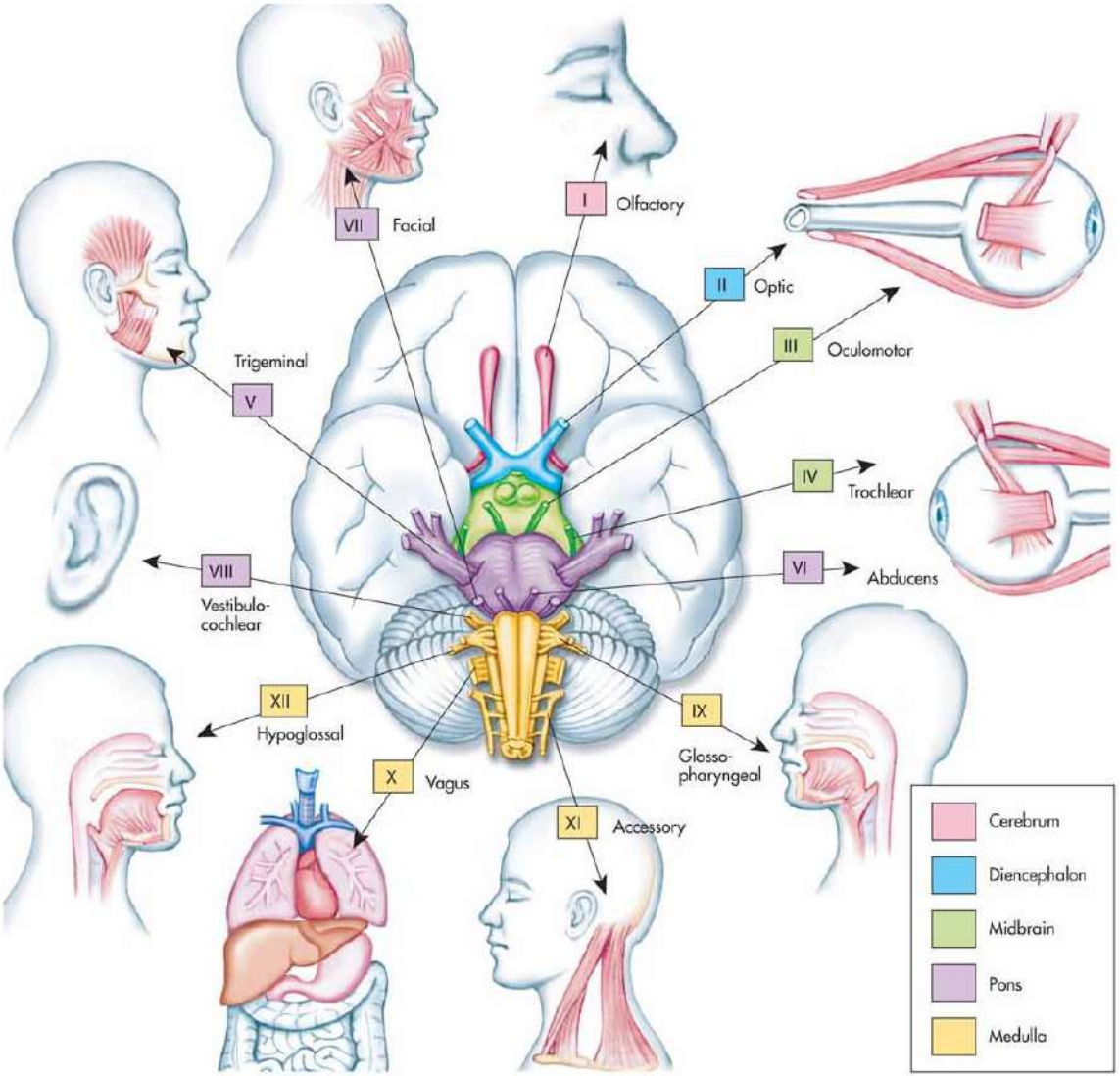


Figure 9-19 Cranial nerves.

TABLE 9-5 Cranial Nerves and Functions

NERVE	FUNCTION
Olfactory (I)	Sensory (smell)
Optic (II)	Sensory (vision)
Oculomotor (III)	Mixed, chiefly motor for eye movements
Trochlear (IV)	Mixed, chiefly motor for eye movements
Trigeminal (V)	Mixed, sensory for face, motor for chewing
Abducens (VI)	Mixed, chiefly motor for eye movements
Facial (VII)	Motor for facial expression
Vestibulocochlear (VIII)	Sensory, hearing, and balance
Glossopharyngeal (IX)	Mixed, motor for throat muscles; sensory for taste
Vagus (X)	Mixed, motor for autonomic heart, lungs, viscera; sensory for viscera, taste buds, and so on
Accessory (XI)	Mixed, chiefly motor; motor and sensory for larynx, soft palate, trapezius, and sternocleidomastoid muscles
Hypoglossal (XII)	Chiefly motor for tongue muscles

Table 9-5 Cranial Nerves and Functions

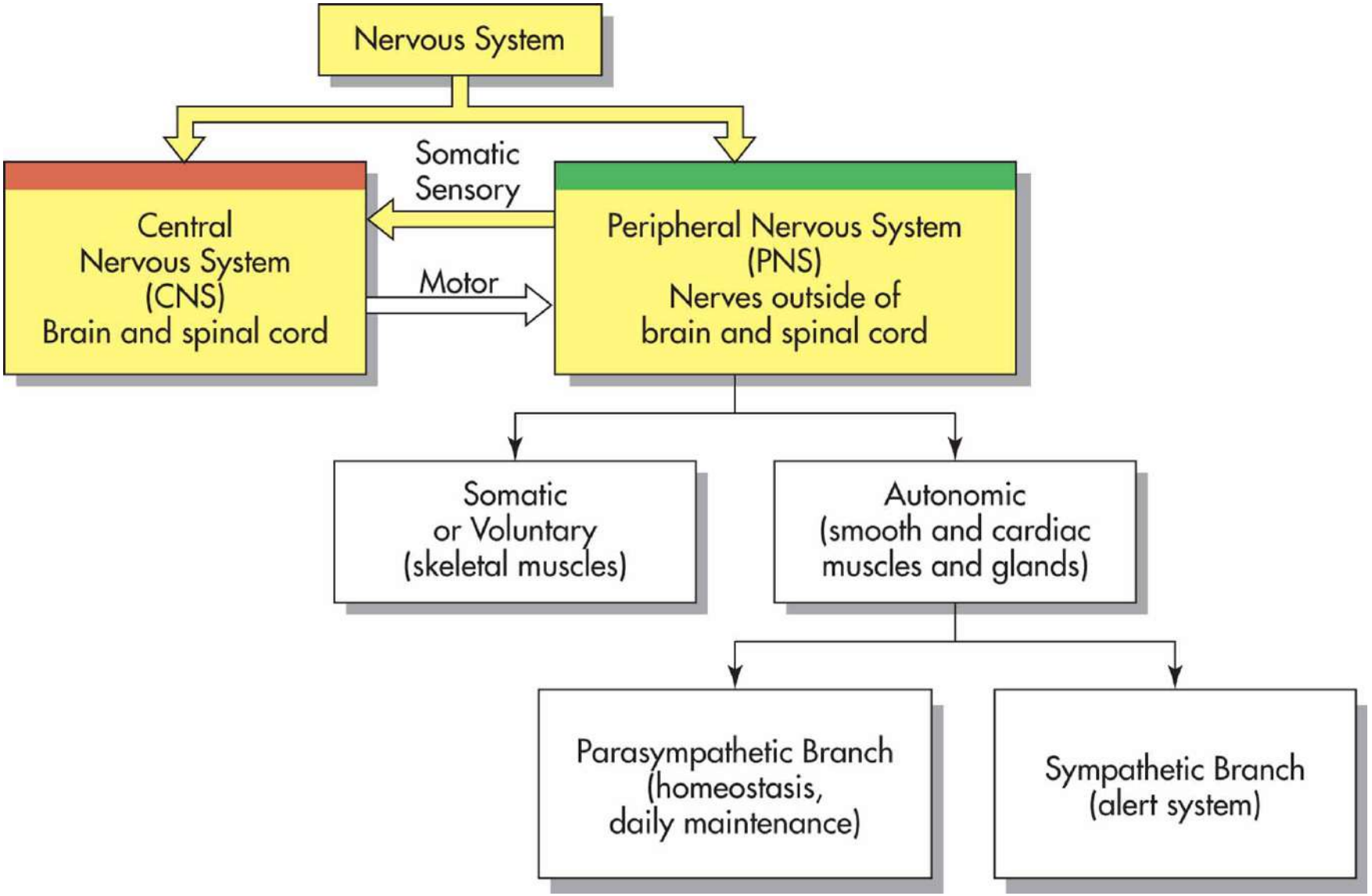


Figure 9-20 Nervous system flowchart highlighting the area thus far explained.

The Somatic Sensory System

- Provides sensory input for your nervous system
- Allows you to feel the world around you
- Includes fine touch, crude touch, vibration, pain, temperature, and body position

The Somatic Sensory System (cont'd)

- Other special senses are carried on cranial nerves, but information for somatic sensation comes into both brain and spinal cord
- To attach meaning to sensation, it must get to brain for interpretation

The Somatic Sensory System (cont'd)

- Somatic sensory information comes into spinal cord via dorsal root and synapse with motor neuron in ventral horn
- Same axon that carries information to motor neuron further carries sensory information to brain via tracts in white matter of spinal cord, so you feel pain

TABLE 9-6 Spinal Cord Pathways for Sensory Information

PATHWAY	INFORMATION	FROM	TO
Spinothalamic		skin	somatic sensory cortex
Lateral	pain; temperature	skin	somatic sensory cortex
Anterior	itch; pressure; tickle	skin	somatic sensory cortex
Dorsal column	fine touch; limb position	skin; joints	somatic sensory cortex; cerebellum
Spinocerebellar	posture	joints; tendons	cerebellum

Table 9-6 Spinal Cord Pathways for Sensory Information

The Somatic Sensory System (cont'd)

- Sensory information coming into brain from dorsal column and spinothalamic tracts both provide sensory information from skin and joints to portion of cerebrum known as primary somatic sensory cortex
- This is located in postcentral gyrus of parietal lobe

The Somatic Sensory System (cont'd)

- Axons transport information to specific parts of SS cortex that correspond to parts of body
- Neurons in SS cortex are neurons that allow you to have conscious sensation

The Somatic Sensory System (cont'd)

- Another area of cerebral cortex that allows understanding and interpretation of somatic sensory information is located just posterior to SS cortex in parietal lobe and is known as somatic sensory association area

The Somatic Sensory System (cont'd)

- Somatic sensory system works on kind of hierarchy, with sensory neurons in spinal cord and brain stem collecting information and passing it to areas in thalamus, cerebellum, and cerebral cortex for processing

The Somatic Sensory System (cont'd)

- Your actual understanding of complex sensory input happens only after information is passed to somatic sensory cortex and somatic sensory association area

The Big Picture: The Motor System

- Motor system also a hierarchy, working in parallel with SS system, with two obvious differences
- Information moves in opposite direction from brain to spinal cord
- Second, motor system has two divisions, somatic motor system and autonomic nervous system

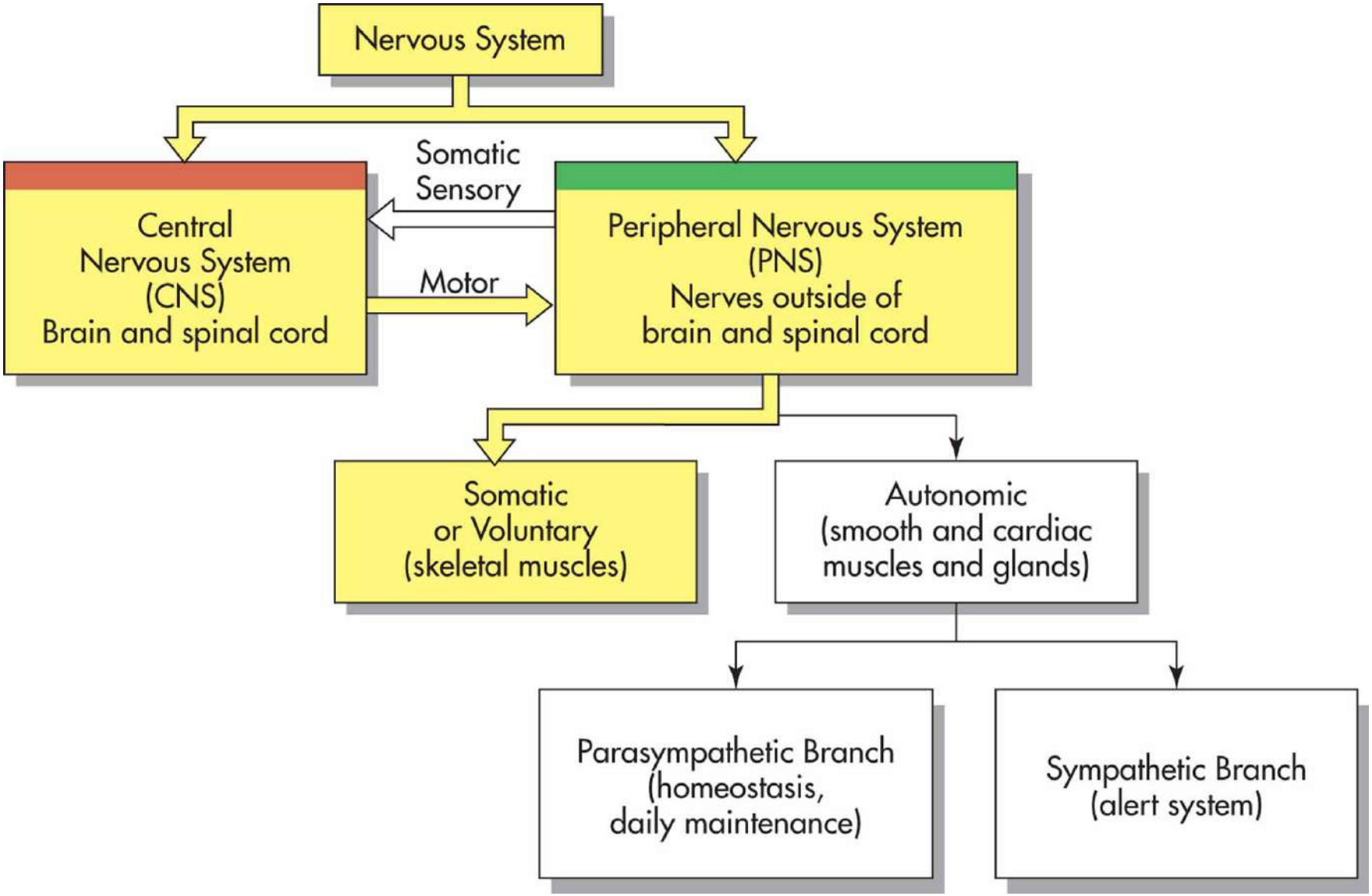


Figure 9-21 Progress thus far on the nervous system flow chart.

The Big Picture: The Motor System (cont'd)

- Somatic motor system controls voluntary movements under orders from cerebral cortex
- In frontal lobe are premotor and prefrontal areas, which plan movements
- Plan from these two areas is sent to primary motor cortex, located in prefrontal gyrus

The Big Picture: The Motor System (cont'd)

- Orders are then sent to spinal cord directly and also to number of coordination centers, including thalamus, basal nuclei, and cerebellum

The Big Picture: The Motor System (cont'd)

- Plan for movement leaves motor cortex and connects with neurons in thalamus, located in diencephalon
- Thalamus, basal nuclei, and cerebellum are part of complicated motor coordination loop

The Big Picture: The Motor System (cont'd)

- Here, movement must be fine tuned, posture and limb position are judged, other movements are turned off, and movement and sensation are integrated
- Without this loop, movement would be, at best, jerky and inaccurate, and some impossible

The Big Picture: The Motor System (cont'd)

- Cerebellum has both motor and sensory inputs and outputs from cerebral cortex, thalamus, basal nuclei, and spinal cord
- Cerebellum gets information about planned movement and actual movement and compares plan to actual; if plan and actual don't match, cerebellum can adjust actual movement to fit plan
- Function of cerebellum is subtle and still a bit of a mystery, but without cerebellum movements would be inaccurate at best

The Big Picture: The Motor System (cont'd)

- After movement information is processed by thalamus and basal nuclei, it moves to spinal cord and brain stem via corticospinal and corticobulbar tracts

The Big Picture: The Motor System (cont'd)

- Corticospinal and corticobulbar tracts from motor cortex are *direct* pathways, carrying orders to neurons in brainstem and ventral horn of spinal cord; pathways coming from subcortical structures are considered *indirect* pathways, which help coordinate movement

The Big Picture: The Motor System (cont'd)

- Function of spinal cord pathways is to send orders from brain to motor neurons in spinal cord and brainstem
- Motor neurons in spinal cord connect to skeletal muscles via cranial nerves (in brain stem) or spinal nerves (spinal cord), sending orders to skeletal muscles to carry out planned movement or coordinate ongoing movements

The Big Picture: The Motor System (cont'd)

- Second function of corticospinal and corticobulbar tracts is fine tuning of reflexes; tracts inhibit reflexes, making them softer than they would be if they had no influence from brain

Pathology Connection: Motor Pathologies

- Cerebral palsy (CP)
  - Permanent, non-progressive set of motor deficits diagnosed in infants and young children
  - Generally thought to be due to damage to motor cortex
  - Risk factors: low birth weight, premature birth, multiple births, infection during pregnancy, developmental abnormalities, brain hemorrhage, perinatal brain injury, lack of oxygen, childhood illness

Pathology Connection: Motor Pathologies (cont'd)

- Cerebral palsy (CP)
  - Symptoms may vary and can include
    - Increased muscle tone
    - Overactive reflexes
    - Lack of coordination of voluntary movements
    - Foot drag
    - Drooling
    - Speech difficulties
    - Fine motor problems
    - Tremor or other uncontrollable movements
  - Many patients with cerebral palsy are of normal or above normal intelligence

Pathology Connection: Motor Pathologies (cont'd)

- Cerebral palsy (CP)
  - Diagnosis may consist of
    - Observing childhood motor skills and developmental milestones
    - Imaging (such as CT or MRI)
    - Ruling out other causes of motor deficits
  - Treatment
    - Physical and occupational therapy
    - Assistive devices
    - Drugs to control symptoms
    - There is no cure for CP

Pathology Connection: Motor Pathologies (cont'd)

- Parkinson's disease (PD)
  - Chronic progressive motor disorder characterized by resting tremor, slow movement, impaired balance, rigidity, and number of emotional and cognitive disturbances

Pathology Connection: Motor Pathologies (cont'd)

- Parkinson's disease (PD)
  - Caused by disappearance of dopamine neurons in one of basal nuclei, which later spreads to cerebral cortex; why these neurons disappear is unknown, though toxins, mitochondrial malfunctions, viruses, and genetics have been suggested

Pathology Connection: Motor Pathologies (cont'd)

- Diagnosis based on history and physical exam
  - Specific physical exam findings in Parkinson's
    - Shuffling gate
    - Cogwheel rigidity (muscles that seem to catch and release when moved)
    - Tremors
  - Imaging is not helpful, since most early-stage cases of PD will have perfectly normal scans

Pathology Connection: Motor Pathologies (cont'd)

- Treatment
  - Dopamine-enhancing drugs (like L-dopa)
    - Side effects may include hallucinations and excessive uncontrollable movements
    - L-dopa treated patients may have "on" and "off" periods that are unpredictable
  - Deep brain stimulation

Parkinson's Disease Video

Click here to view a video on the topic of Parkinson's disease.

Pathology Connection: Motor Pathologies (cont'd)

- Amyotrophic lateral sclerosis (ALS)
  - Rapidly progressive, fatal degeneration of motor system
  - Occurs when motor neurons in cerebral cortex, brainstem, and spinal cord self-destruct; also called Lou Gehrig's disease
  - On average, patients die within 5 years of diagnosis; usually due to respiratory failure

Pathology Connection: Motor Pathologies (cont'd)

- Amyotrophic lateral sclerosis (ALS)
  - Usually begins between ages 40 and 60; first symptoms are muscle weakness, twitching, and cramping; progress to complete paralysis including difficultly speaking and swallowing
  - Eventually diaphragm becomes paralyzed, forcing patient to become ventilator-dependant; eye movements, bladder, and bowel control usually retained

Pathology Connection: Motor Pathologies (cont'd)

- Amyotrophic lateral sclerosis (ALS)
  - Cause is unknown, but toxins, damage from free radicals, and mitochondrial problems may be involved

Pathology Connection: Motor Pathologies (cont'd)

- Amyotrophic lateral sclerosis (ALS)
  - In most cases there seems to be excess activity of neuroglia and excess production of neurotransmitter glutamate, both of which increase neuron death

Pathology Connection: Motor Pathologies (cont'd)

- Amyotrophic lateral sclerosis (ALS)
  - Diagnosis
    - No definitive test
    - One unique feature that can aid in diagnosis is that patients have both spastic and flaccid paralysis
    - Imaging, EMG, and blood and urine tests can help rule out other disorders
    - Neural biopsy may also be helpful

Pathology Connection: Motor Pathologies (cont'd)

- Treatment
  - No cure
  - The medication riluzole can be used to slow progression of disease; drug decreases neurotransmitter glutamate, thereby decreasing cell death
  - Other treatments can be used to improve symptoms and quality of life

Autonomic Nervous System

- Peripheral nervous system is divided into two systems:
  - Somatic system controls skeletal muscles
  - Autonomic system controls physiological characteristics such as blood pressure, heart rate, respiratory rate, digestion, and sweating

Autonomic Nervous System (cont'd)

- Neurons for autonomic system, like somatic motor neurons, are located in spinal cord and brain stem, and release neurotransmitter acetylcholine; this is where similarities end
- Autonomic motor neurons are located in lateral horn rather than ventral horns and unlike somatic motor neurons, autonomic neurons do not project directly to muscles

Autonomic Nervous System (cont'd)

- They make synapse in ganglion outside CNS called pre-synaptic junction
- Then second motor neuron, called postganglionic neuron, projects to muscle

Autonomic Nervous System (cont'd)

- There are no autonomic neurons in cervical spinal cord
- Autonomic nervous system is divided into two subdivisions:
  - Sympathetic division
  - Parasympathetic division

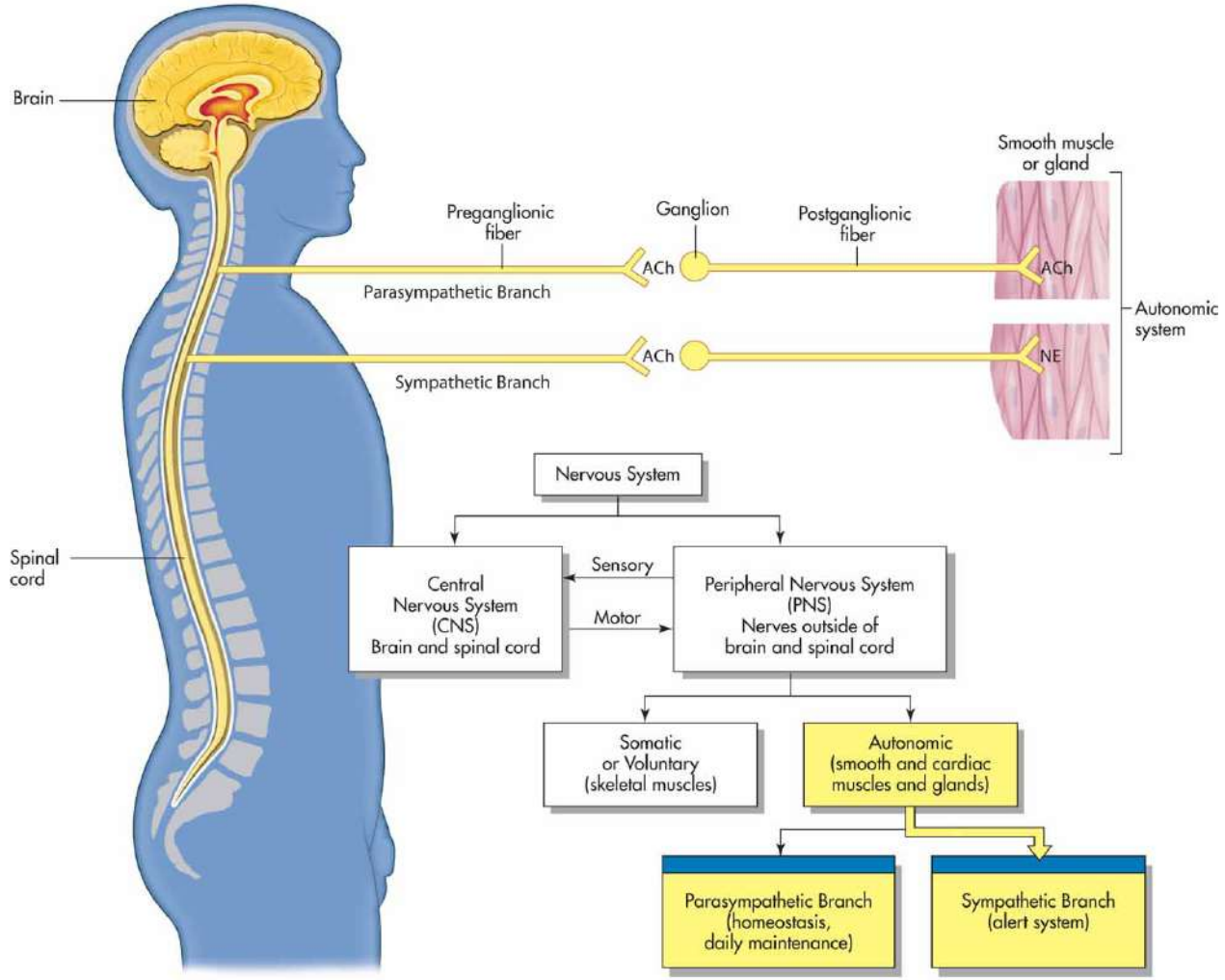


Figure 9-22 General representation of autonomic nervous system. ACh = acetylcholine and NE = norepinephrine.

The Sympathetic Branch

- Controls “flight or fight” response; it is charged with responding to emergencies
- Effects increase heart rate, BP, and sweating, also causing dry mouth, symptoms of adrenaline rush
- Postganglionic neurons are located in thoracic and first two lumbar segments of spinal cord; preganglionic neurons, which secrete acetylcholine, synapse with postganglionic neurons in sympathetic ganglia

The Sympathetic Branch (cont'd)

- Ganglia form pair of chain-like structures that run parallel to spinal cord (paravertebral ganglia), where neurons in ganglia release neurotransmitter norepinephrine
- Most importantly, sympathetic system stimulates adrenal glands to release hormone epinephrine that causes adrenaline rush

The Parasympathetic Branch

- Often called “resting and digesting” as it has opposite effect of sympathetic division
- Responsible for everyday activities, as well as reversing sympathetic effects

The Parasympathetic Branch (cont'd)

- Effects include decreased heart rate, respiration, and blood pressure, and increased digestive activity including salivation and stomach activity
- Neurons of parasympathetic system are in brain stem and sacral spinal cord; neurotransmitter acetylcholine is released by postganglionic neurons

Diseases of the Nervous System

- Multiple Sclerosis
  - Etiology: autoimmune attack on myelin in CNS
  - Symptoms: varies depending on location of plaques, may be sensory, motor or cognitive
  - Diagnosis: patient history, imaging
  - Treatments: steroids, plasma exchange, immunosuppressant drugs, symptom management

Diseases of the Nervous System (cont'd)

- Guillain-Barré Syndrome
  - Etiology: autoimmune destruction of PNS myelin, often after virus
  - Symptoms: rapid onset of ascending paralysis
  - Diagnosis: history, EMG, spinal tap
  - Treatments: no real treatment available, supportive care, sometimes plasma exchange; symptoms are typically temporary

Diseases of the Nervous System (cont'd)

- Charcot Marie Tooth Disorder
  - Etiology: genetic destruction of PNS myelin and/or axons
  - Symptoms: ascending muscle weakness and atrophy, decreased sensation in affected limbs
  - Diagnosis: history, EMG, biopsy, genetic testing
  - Treatments: PT, OT, surgery, pain medication, symptom management, no treatment to stop deterioration

Diseases of the Nervous System (cont'd)

- Myasthenia Gravis
  - Etiology: autoimmune attack of acetylcholine receptor at neuromuscular junction
  - Symptoms: progressive fluctuating muscle weakness, often starting with facial or eye muscles
  - Diagnosis: blood tests, EMG
  - Treatments: steroids, immunosuppressant drugs, plasma exchange, acetylchoinesterase inhibitors

Diseases of the Nervous System (cont'd)

- Polio
  - Etiology: destruction of ventral horn motor neurons by poliomyelitis virus
  - Symptoms: muscle weakness
  - Diagnosis: sudden onset of paralysis after flu-like symptoms (rare in US since widespread vaccination began in 1950s)
  - Treatments: supportive care until virus runs its course; therapy to regain strength in damaged muscles

Diseases of the Nervous System (cont'd)

- Post-polio syndrome
  - Etiology: late onset fatigue of motor neurons originally affected by polio
  - Symptoms: muscle weakness (in patient with a past history of paralytic polio)
  - Diagnosis: rule out other causes of weakness
  - Treatments: no treatment, although exercise may help

Diseases of the Nervous System (cont'd)

- Spinal cord injury
  - Etiology: usually mechanical injury to spinal cord tissue
  - Symptoms: loss of sensory and motor function, depends on location of injury
  - Diagnosis: neurological exam, imaging
  - Treatments
    - Acute treatment to prevent further injury: immobilization, steroids
    - Long term care: PT, OT, supportive care and symptom management

Diseases of the Nervous System (cont'd)

- Peripheral neuropathy
  - Etiology: damage to peripheral nerves due to injury or illness
  - Symptoms: motor and sensory abnormalities; including weakness, pain, numbness, and tingling
  - Diagnosis: imaging, biopsy, patient history
  - Treatments: management, treatment of underlying disorder causing nerve damage

Diseases of the Nervous System (cont'd)

- Traumatic brain injury
  - Etiology: damage to brain tissue due to mechanical injury, lack of oxygen or brain hemorrhage
  - Symptoms: depends on injury severity and location; ranges from dizziness and nausea, to severe cognitive disturbances, memory loss, seizures and unconsciousness

Diseases of the Nervous System (cont'd)

- Traumatic brain injury
  - Diagnosis: Glasgow coma scale, imaging
  - Treatments
    - Acute treatment to prevent further injury: immobilization, stabilization of physiology, surgery, medication to relieve pressure
    - Long term care: PT, OT, supportive care and symptom management

Diseases of the Nervous System (cont'd)

- Hydrocephalus
  - Etiology: excess CSF in brain due to trauma, birth defects, tumors, etc.
  - Symptoms, vary with age: skull expansion and irritability in babies, irritability, vomiting, seizures, sleepiness and dementia in older patients
  - Diagnosis: imaging, pressure monitoring
  - Treatments: shunt insertion

Diseases of the Nervous System (cont'd)

- Cerebral Palsy
  - Etiology: risk factors include premature birth, low birthweight, developmental abnormalities, perinatal brain injury
  - Symptoms: non-progressive motor deficits in young children
  - Diagnosis, difficult: observation of childhood motor skills, rule out other disorders
  - Treatments, no cure: PT, OT, assistive devises, symptom management

Diseases of the Nervous System (cont'd)

- Parkinson's Disease
  - Etiology: progressive loss of dopamine neurons in substantia nigra
  - Symptoms: resting tremor, slow movement, rigidity, cognitive and emotional disturbance
  - Diagnosis: history, imaging, neurological exam
  - Treatments, no cure: dopamine enhancing drugs, symptom management, deep brain stimulation

Diseases of the Nervous System (cont'd)

- Huntington's disease
  - Etiology: genetic; progressive loss of neurons from basal nuclei and cerebral cortex
  - Symptoms: mid-life onset of chorea, mood swings and memory loss, progressing to dementia and paralysis
  - Diagnosis: family history will show pattern of disease, imaging, genetic testing
  - Treatments, no cure: medication to control emotional and motor symptoms, no drug treatment for dementia

Diseases of the Nervous System (cont'd)

- Amyotrophic Lateral Sclerosis (ALS)
  - Etiology: progressive loss of motor neurons in CNS and PNS, cause unknown
  - Symptoms: progressive muscle weakness, twitching and cramping, eventually leading to complete paralysis; sensation is normal
  - Diagnosis: no definitive diagnosis, but presence of both flaccid and spastic paralysis indicates ALS; rule out other disorders
  - Treatments, no cure: drug treatment may slow progression, symptom management

Diseases of the Nervous System (cont'd)

- Alzheimer's disease
  - Etiology: not fully known; believed to be buildup of plaque in brain and/or a defect in neurotransmitter system in brain
  - Symptoms; varying degrees of confusion, memory loss, cognitive defects, personality changes.

Diseases of the Nervous System (cont'd)

- Alzheimer's disease
  - Diagnosis: history and physical exam; interview of family members and various cognitive testing
  - Treatments, no cure: drug therapy can prevent or decrease some symptoms in early to middle stages of disease

Alzheimer's Disease Video

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Absence Seizures Video

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Autism Video

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Bipolar Disorder Video

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Dissociative Identity Disorder Video

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Epilepsy Video

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Schizophrenia Disorder Video

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Complex Partial Seizures Video

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Generalized Toni-clonic Seizures Video

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Panic Attacks Video

Click here to view a video on the topic of panic attacks.

Pharmacology Corner

- Blood brain barrier: barrier that prevents or slows down passage of chemicals and pathogens from blood into central nervous system
  - Believed to consist of walls of capillaries in CNS and surrounding glial membranes
  - Important to remember because some beneficial drugs cannot pass easily through this barrier

Pharmacology Corner (cont'd)

- Medications can affect chemical synaptic transmission in many ways
  - Some medicines bind to neurotransmitter receptors and mimic effects of that neurotransmitter, such as:
    - Nicotine (in tobacco)
    - Opiates (like the pain-reliever morphine)
    - L-dopa (for Parkinson's)
    - Benzodiazepines (tranquilizers like Valium)

Pharmacology Corner (cont'd)

- Some medicines stop removal of neurotransmitters from synapse (thereby prolonging neurotransmitter activity), such as:
  - Monoamine Oxide (MAO) inhibitors (like Selegiline for Parkinson's)
  - Selective Serotonin Reuptake Inhibitors (SSRIs, like Prozac for depression)
  - Acetylcholinesterase inhibitors (like Neostigmine for Myasthenia gravis or Aricept for Alzheimer's)

Pharmacology Corner (cont'd)

- Some medications block neurotransmitter receptors, preventing neurotransmitter effect, such as:
  - Acetlycholine receptor blockers (like Scopolamine for motion sickness and succinylcholine, a muscle relaxant)
  - Beta blockers, which block norepinephrine receptors (like Lopressor for cardiac problems)

Pharmacy Video

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Carpal Tunnel Syndrome

- Carpal tunnel syndrome is an inflammation and swelling of the tendon sheathe surrounding the flexor tendon of the palm
- This is a result of repetitive motion, such as typing on a keyboard
- As a result of the inflammation, the median nerve is compressed, producing tingling sensations or numbness of the palm and first 3 fingers.

Carpal Tunnel Syndrome Video

Click here to view a video on the topic of carpal tunnel syndrome.

Electroneurodiagnosticians Video

Click here to view a video on the topic of electroneurodiagnosticians.

Snapshots from the Journey

- Nervous system is body's computer, its information superhighway; it has sensory (input) system, integration center, CNS, and motor (output) system; input and output nerves are in PNS, and brain and spinal cord are CNS

Snapshots from the Journey (cont'd)

- Tissue of nervous system made up of two types of cells:
  - Neurons, which send, receive, and process information
  - Neuroglia, which support neurons

Snapshots from the Journey (cont'd)

- Neurons are excitable cells, carry tiny electrical currents caused by changes in cell permeability to certain ions; tiny electrical currents can:
  - Be all-or-none (action potentials)
  - Change depending on size of stimulus (local potentials)
  - Travel down axons (impulse conduction),
  - Be used to transmit information from one cell to another (synapses)

Snapshots from the Journey (cont'd)

- CNS composed of brain and spinal cord
- CNS surrounded by three-layered membrane system: dura mater, arachnoid mater, and pia mater, collectively known as meninges; cerebrospinal fluid (CSF) is also contained in space between arachnoid and pia maters

Snapshots from the Journey (cont'd)

- Spinal cord has 31 segments, each a pair of spinal nerves
- Spinal nerves are part of peripheral nervous system and made of pair of spinal roots:
  - Ventral root is integral to motor function
  - Dorsal root is integral to sensory function
- Spinal nerves are mixed: they carry both sensory and motor information

Snapshots from the Journey (cont'd)

- Series of tracts run up and down spinal cord to and from brain; tracts going toward brain carry sensory information to brain; tracts coming from brain toward the spinal cord carry motor information from brain

Snapshots from the Journey (cont'd)

- Brain is hierarchical organ; divided into compartments (lobes), each with very specific functions; nerves attached to brain are called cranial nerves, which occur in 12 pairs, can be sensory, motor, or mixed

Snapshots from the Journey (cont'd)

- Cerebrum controls conscious movement and sensation
- Beneath cerebrum are diencephalon, brain stem, and cerebellum; each part plays important role in coordinating sensory and motor information for cerebrum

Snapshots from the Journey (cont'd)

- Cerebral cortex contains motor and sensory maps of body
  - Orders for voluntary movements originate in primary motor cortex, located in precentral gyrus of frontal lobe, and travel down spinal cord via direct spinal cord tracts
  - Subcortical structures coordinate this information via indirect tracts

Snapshots from the Journey (cont'd)

- Somatic sensory cortex is in postcentral gyrus of parietal lobe
- Sensory information from spinal cord tracts eventually ends up in this part of cortex; when information arrives there, you become aware of your sense of touch
- Other parts of brain, called association areas, allow you to make connections between different types of sensory information and to compare current experience to memories

Snapshots from the Journey (cont'd)

- Ventricles are cavities in brain; spinal cord cavity (ventricle) is central canal; these cavities are part of elaborate protection system for CNS and are filled with cerebrospinal fluid

Snapshots from the Journey (cont'd)

- Nervous system also controls involuntary movement via part of system known as autonomic nervous system; sympathetic division controls "flight-or-fight" response, and parasympathetic division controls day-to-day activities

Snapshots from the Journey (cont'd)

- Nervous system can have many disorders; most are chronic, progressive, and incurable
- Symptoms vary depending on location of damage
- Symptoms typically do not vary depending on whether the disorder is central or peripheral, genetic or caused by disease or trauma

Snapshots from the Journey (cont'd)

- Muscle weakness, loss of sensation and respiratory difficulty often accompany problems in nervous system
- Subtle differences between symptoms are key to making difficult diagnoses and finding appropriate treatment
- Treatment generally consists of symptom management and prevention of further deterioration

Case Study – Ray's Story

- Let's visit with Ray again. This is the young man who hit his chin on the bottom of the swimming pool doing a back flip. He had struck the bottom of the pool on the point of his chin, jamming and twisting his neck. His neck is broken, the first two vertebrae shattered, and his spinal cord irreversibly damaged.

Case Study – Ray's Story

- He is paralyzed from the neck down and is ventilator dependent. Muscle weakness, loss of sensation and respiratory difficulty often accompany problems in nervous system

Case Study – Ray's Story

- Subtle differences between symptoms are key to making difficult diagnoses and finding appropriate treatment
- Treatment generally consists of symptom management and prevention of further deterioration

Case Study – Ray's Story (cont'd)

- What is the level of Ray's injury? (Is it cervical, thoracic, lumbar, or sacral?)
- Why can't he breathe? (be specific)
- What do you call the paralysis of all four limbs?
- What complications might be a problem for Ray?
- Does Ray have spastic or flaccid paralysis?