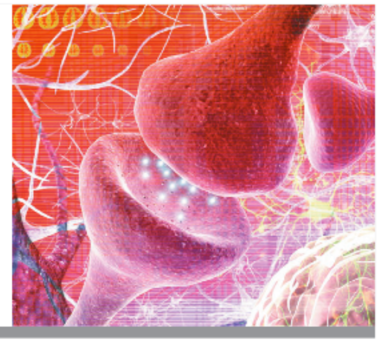
11

Introduction to the Nervous System and Nervous Tissue



Nervous system – controls our *perception* and *experience* of world

Directs ______________

Seat of *consciousness, personality, learning*, and _________

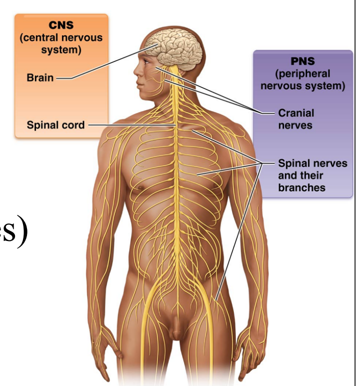
Regulates __________

Anatomical Divisions of the Nervous System

[2 Anatomical Div. = CNS, PNS]

1. **CNS** – includes ______ and ___________

2. **PNS** – consists of all **nerves** in body <u>outside</u> protection of skull and vertebral column (_______ nerves, _______nerves)



Functional Divisions of the Nervous System

[3 Functional Div. = Sensory, Integrative, Motor]

1. **Sensory functions**
   – ____________ gather information about internal and external environments
   - **afferent division** carries information toward CNS

   a. **Somatic sensory division**
      – signals from skeletal muscles, bones, joints, and skin;
      - **special sensory div.** (vision, hearing, taste, smell, and balance)

   b. **Visceral sensory division**
      – signals from __________ (organs)

Functional Divisions of the Nervous System

2. **Integrative functions** – *analyze* and *interpret* incoming ___________________ and determine *response*

3. **Motor functions**
   – actions performed in response to integration
   - _____________ carries information away from CNS

   a. **somatic** nervous system – information to skeletal muscle

   b. **autonomic** nervous system (ANS) – information to smooth muscle, cardiac muscle, glands

Functional Divisions of the Nervous System

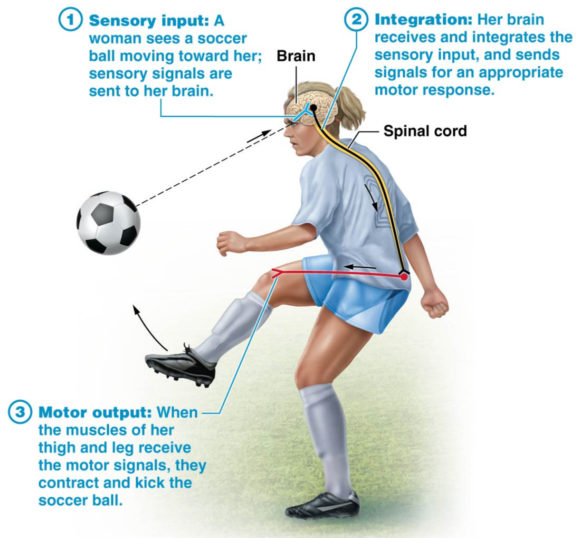


Figure 11.2 Functions of the nervous system.

Functional Divisions of the Nervous System

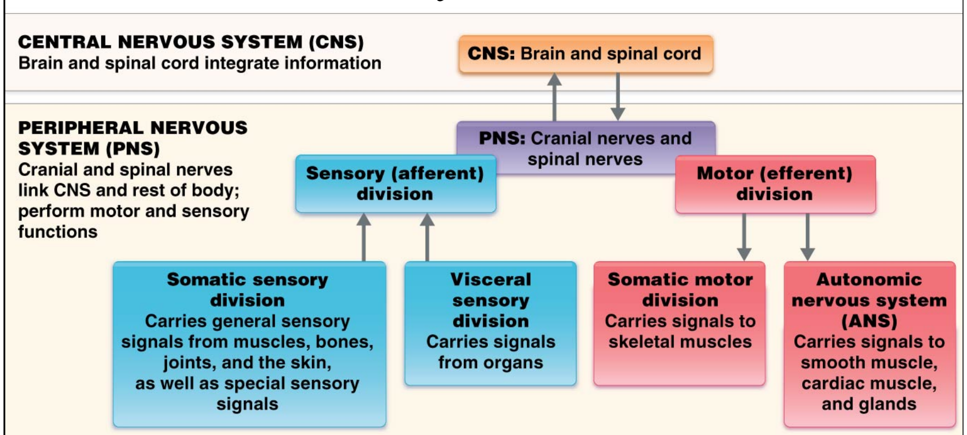
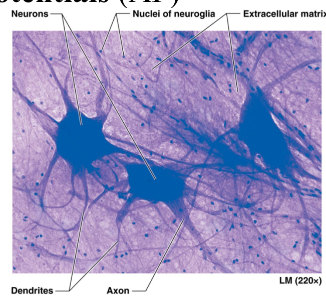


Figure 11.3 Summary of the structural and functional divisions of the nervous system

Neurons

Neurons – *excitable* cell type responsible for sending and receiving signals in form of **action potentials** (AP)



A. Structure of neurons

1. **Cell body** _________
   nucleus, cytoplasm with organelles, **Nissl bodies** (RER, gray color)

Cytoplasmic extensions (processes):

2. **Dendrites** – _________ information from other neurons, conduct impulse toward soma

3. **Axon** (nerve fiber) – conducts impulse ______________, includes axon hillock, axon terminals (synaptic knobs)

Neurons

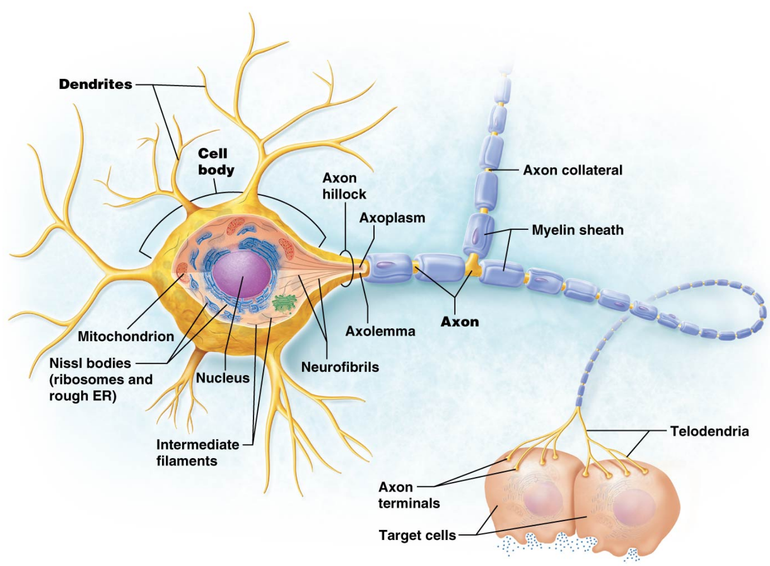


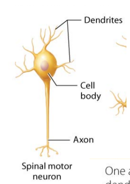
Figure 11.5 Neuron structure.

Poliovirus and Retrograde Axonal Transport *(p. 384)*

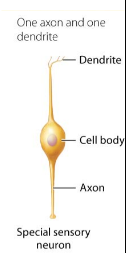
- **Poliomyelitis** – caused by *poliovirus*; infection that impacts CNS (especially SC) → *deformity* and *paralysis*
- No cure exists, but prevented by *vaccination*
- Virus accesses CNS by entering muscle cells →motor neurons at NMJ → **retrograde axonal transport** until reaching SC
- Other viruses (**herpes simplex, rabies**) and toxins (**tetanus**) can to invade via this method

Classification of Neurons

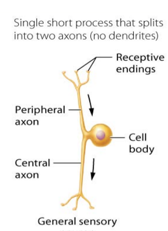
- *Structural* (**Table 11.1**):
  - **Multipolar neurons** – single *axon* and multiple *dendrites*, > 99% of all neurons ___________



  - **Bipolar neurons –** *one* axon, one dendrite, and cell body between them; found in eye and olfactory epithelium ___________



  - **Pseudounipolar neurons –** have only one *fused axon* that extends from cell body and *divides into two processes* ___________



Classification of Neurons

- *Functional* (**Table 11.1**):
  - **Sensory (_______ neurons)** – carry information toward CNS; *pseudounipolar* or *bipolar*
  - **Interneurons (association neurons)** – relay information within CNS between sensory and motor neurons; make up most of neurons in body; *multipolar*
  - **Motor (__________ neurons)** – carry information away from cell body in CNS to *muscles* and glands; *multipolar*

Neurons

TABLE 11.1 NEURON CLASSIFICATION

Structural Class	Multipolar Neurons	Bipolar Neurons	Pseudounipolar Neurons
Structural Features	One axon with two or more dendrites; typically have highly branched dendritic tree	One axon and one dendrite	Single short process that splits into two axons (no dendrites)
Typical Functional Class	Motor (efferent) neurons, interneurons	Sensory (afferent) neurons	Sensory (afferent) neurons
Location	Most neurons in the CNS, motor neurons in the PNS	Special sense organs in the PNS, such as the retina and olfactory epithelium	Sensory neurons in the PNS associated with touch, pain, and vibration sensations

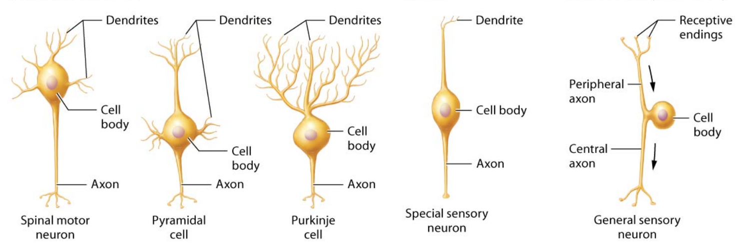


Table 11.1 Neuron Classification.

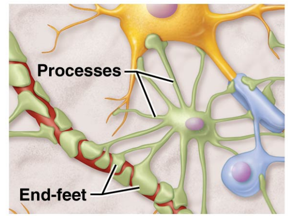
Neurons

- Specific neuron components group together:
  - **CNS**:
    - **Nuclei** – _________________
    - **Tracts** – bundles of axons
  - **PNS**:
    - **Ganglia –** clusters of neuron cell bodies
    - **Nerves –** ______________

Neuroglia

- **Neuroglia** – provide _________________ for neurons, maintain their *environment*, *divide* and *fill space* when a neuron dies
  - CNS:
    - ***Astrocytes***
    - ***Oligodendrocytes***
    - **Microglia**
    - **Ependymal cells**
  - *PNS:*
    - ***Schwann cells***
    - ***Satellite cells***

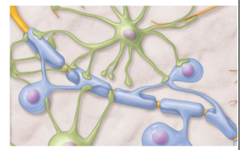
Neuroglia



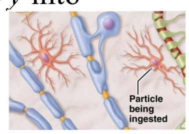
- **CNS:**
  - **Astrocytes** – large *star-shaped* cells

    Facilitate *transport* of nutrients and gases between blood vessels and neurons; form ______________ **(BBB)**

  - **Oligodendrocytes** – form ______________



  - **Microglia –** *activated by injury* into ___________ *cells*



  - **Ependymal cells** – *ciliated cells that manufacture* and *circulate* ________

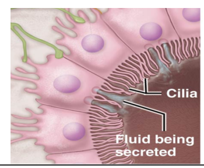
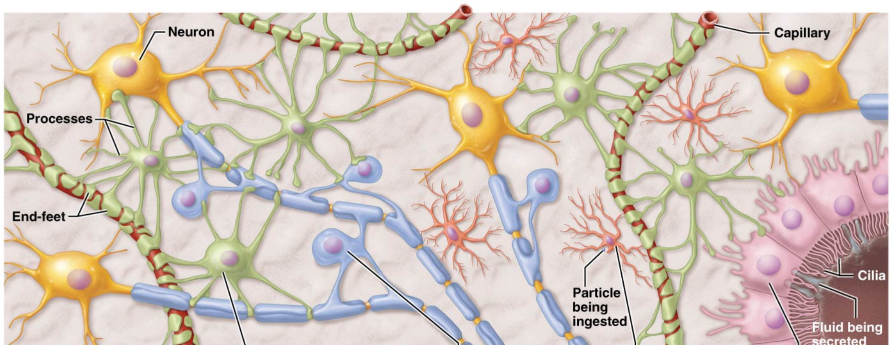


Figure 11.6 Neuroglial cells of the CNS.

Neuroglia

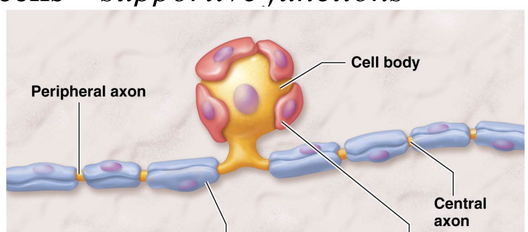


NEUROGLIAL CELL TYPE	ASTROCYTE	OLIGODENDROCYTE	MICROGLIAL CELL	EPENDYMAL CELL
FUNCTION	• Anchor neurons and blood vessels • Regulate the extracellular environment • Facilitate the formation of the blood-brain barrier • Repair damaged tissue	• Myelinate certain axons in the CNS	• Act as phagocytes	• Line cavities • Cilia circulate fluid around brain and spinal cord • Some secrete this fluid

Figure 11.6 Neuroglial cells of the CNS.

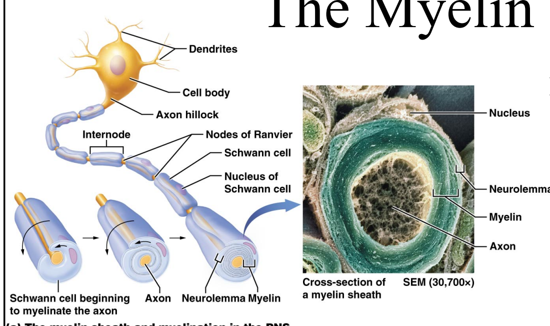
Neuroglia

- **PNS:**
  - **Schwann cells** – produce ________
  - **Satellite cells** – *supportive functions*



NEUROGLIAL CELL TYPE	SCHWANN CELL	SATELLITE CELL
FUNCTION	• Myelinate certain axons in the PNS	• Surround and support cell bodies

The Myelin Sheath



Myelin = repeating layers of phospholipid plasma membrane, insulation

Nodes of Ranvier = gaps between myelin sheaths

White matter = *myelinated axons*

Gray matter = *neuron cell bodies, unmyelinated processes*

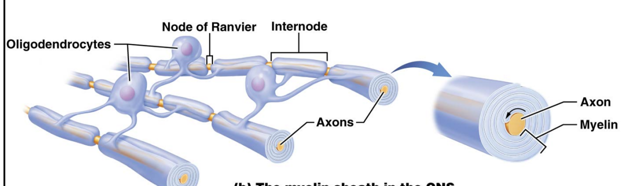
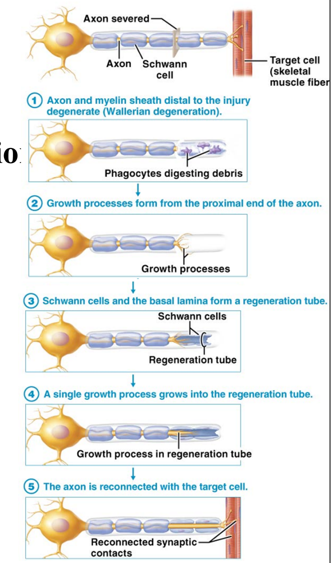


Figure 11.8a The myelin sheath in the PNS and CNS.

Regeneration of Nervous Tissue

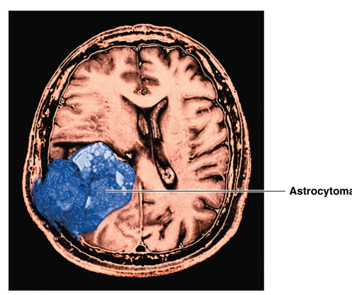
Regeneration nearly *nonexistent* in CNS and is <u>limited</u> in PNS

- **Regeneration** steps:
  1. *Degeneration of axon and myelin sheath* _______ to injury (**Wallerian degeneratio**
  2. **Growth processes** from <u>proximal</u> end of axon
  3. Schwann cells form **regeneration tube**
  4. **Single growth process grows** into regeneration tube
  5. **New axon is *reconnected*** to its target cell



Gliomas and Astrocytomas *(p. 391)*

- **Primary brain tumors** –
  - **Gliomas**
- **Predisposing conditions** – exposure to ionizing *radiation* and certain diseases



- Most commonly affected cell is **astrocyte** → tumor is called ___________
  - Range in severity
  - **Treatment**

Introduction to Electrophysiology of Neurons

- All neurons are *excitable* or responsive to *stimuli*
  (chemical, electrical, and mechanical)
- Stimuli generate *electrical changes* across plasma membrane (PM)
  - **Local potentials** – travel _________distances
  - **Action potentials** – travel ___________of axon; begin at trigger zone → axon terminal
- Ion channels – ions must rely on *specific protein channels for diffusion*
- Resting Membrane Potential **(RMP)** = __________
  - *due to difference in distribution of ions across PM*

Principles of Electrophysiology

Types of Ion Channels

TABLE 11.2 TYPES OF ION CHANNELS IN NEURONS AND OTHER ELECTRICALLY EXCITABLE CELLS

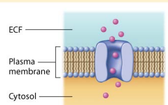
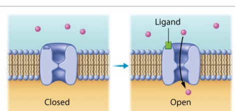
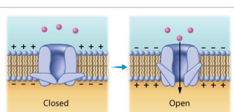
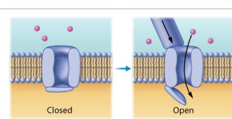
	Type of Channel	Structure	Stimulus for Opening/Closing
Leak	*Leak Channel*		None, always open Ions follow conc. gradient
Ligand-Gated	*Ligand-Gated Channel*		Binding of a ligand to a receptor associated with the channel Open in response to specific chemical binding
Voltage-Gated	*Voltage-Gated Channel*		Voltage changes across the plasma membrane Open or close due to changes in voltage across PM
Mechanically-Gated	*Mechanically Gated Channel*		Mechanical deformations of the channel (by stretch, pressure, etc.) Open or close due to mech. stim. (stretch, press., vibration)

Table 11.2 Types of ion channels in neurons and other electrically excitable cells.

Principles of Electrophysiology

RMP = -70mV
Cell is polarized (positive on outside, negative on inside of PM)

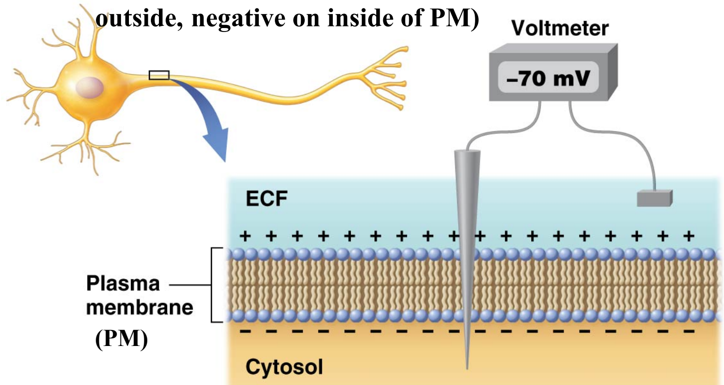


Figure 11.11 Measurement of the voltage across a plasma membrane.

Principles of Electrophysiology

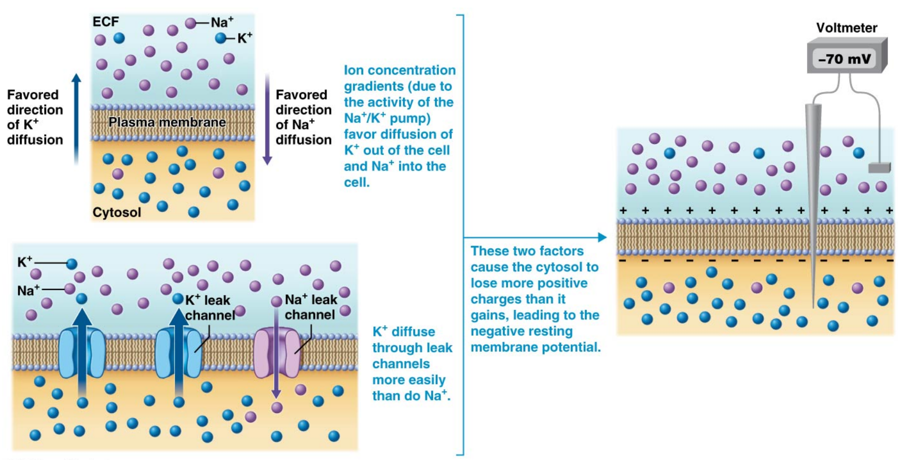


Figure 11.12 Generation of the resting membrane potential.

Principles of Electrophysiology

Diffusion of ions across PM determined by

Electrochemical Gradient:

- Electrical gradient:

  Positive on ________, **negative on inside** of plasma membrane

- Chemical Gradient:

  Na+ outside > Na+ inside

  K+ inside > K+ outside

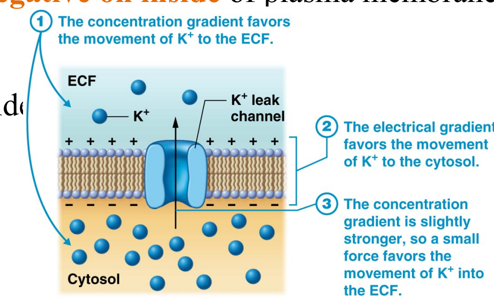
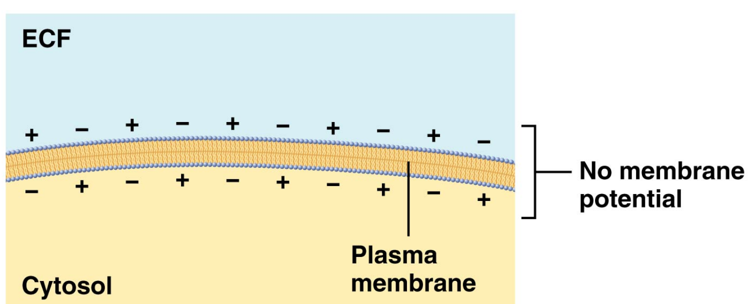


Figure 11.13 The electrochemical gradient for potassium ions.

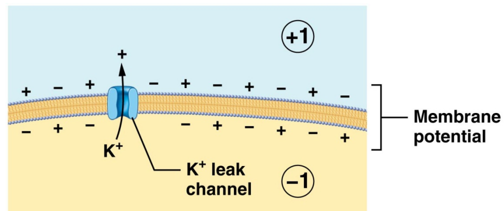
How Do Positive Ions Create a Negative Resting Membrane Potential

- Let's start with a neuron that has *no membrane potential*; charges are distributed equally across plasma membrane



- Now, imagine that a potassium ion *diffuses out of cytosol* down concentration gradient through a leak channel…

How Do Positive Ions Create a Negative Resting Membrane Potential

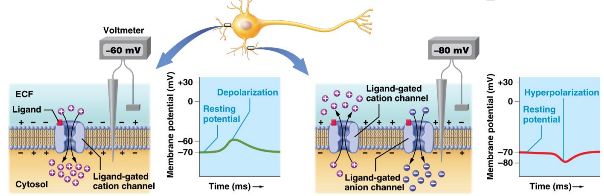


- Six positive charges are now outside membrane and four positive charges inside; makes overall charge inside **cytosol –1** and in **extracellular fluid +1**—a *membrane potential* has been created
- Imagine that *many thousands* of potassium ions exit through leak channels; causes membrane potential to become progressively *more negative*

Principles of Electrophysiology

Changes in Resting Membrane Potential: Ion Movements:

- **Depolarization** –**Na+** channels open, ______________; membrane potential becomes more *positive*
- **Repolarization** – K+ ion channels open; __________________; cell becomes *more negative,* returning to RMP
- **Hyperpolarization** – cell becomes *more negative* than normal *RMP* due to efflux of K+ plus influx of Cl-



(a) **Depolarization:** Gain of positive charges makes the
(b) **Hyperpolarization:** Loss of positive charges (or gain of

Review

Which of the following is NOT related to the opening of sodium ion channels?

a. Sodium rushes into the neuron
b. Cell becomes less polarized
c. Cell depolarizes
d. Interior of cell becomes more negative

Review

Which of the following is NOT related to the opening of potassium ion channels?

a. Potassium rushes into the neuron
b. Cell becomes more polarized
c. Cell repolarizes
d. Interior of cell becomes more negative

Review

Which of the following is TRUE regarding membrane hyperpolarization?

a. Potassium rushes into the neuron
b. Cell becomes less polarized than at rest
c. May result from chloride ion influx
d. Interior of cell becomes more positive

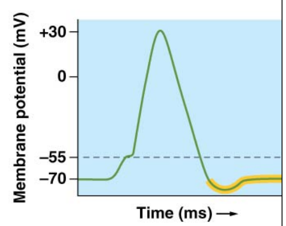
Local **Potentials**

Local potentials – triggers for *long-distance **AP***

- May cause:
  - **Depolarization** – *positive charges* enter cytosol & make membrane potential <u>less</u> *negative* ____________
  - **Hyperpolarization** – either *positive charges* <u>exit</u> or *negative charges* <u>enter</u> cytosol; makes membrane potenti <u>more</u> *negative* _____________
- Sometimes called **graded potentials** because *vary in size*

Action Potentials

- Events in an Action Potential:
  1. *Local potential* must be able to *depolarize axon* strongly enough to reach **threshold** (usually -55 mV)
  2. **Depolarization** – sodium ions rush in ____________ (example of Positive Feedback)
  3. **Repolarization** – potassium ions rush out ____________
  4. **Hyperpolarization** may occur



Review

Which of the following is NOT a general phase of the action potential?

a. Repolarization
b. Hypopolarization
c. Depolarization
d. Hyperpolarization

Review

Which of the following is the correct sequence for phases of the action potential?

a. Repolarization, depolarization, hyperpolarization
b. Depolarization, hyperpolarization, repolarization
c. Depolarization, repolarization, hyperpolarization
d. Hyperpolarization, depolarization, repolarization

Review

An action potential is a good example of which core principle?

a. Gradients
b. Cell to cell communication
c. Structure vs function
d. Feedback loops

Review

The threshold value for neurons is typically

a. -90 mV
b. -70 mV
c. -55 mV
d. +30 mV

Review

The membrane potential at which sodium ion channels CLOSE and potassium channels OPEN during an action potential is

a. -90 mV
b. -70 mV
c. -55 mV
d. +30 mV

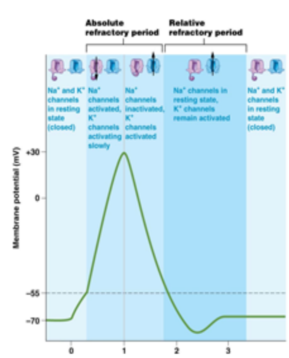
Local Anesthetic Drugs *(p. 400)*

- **Local anesthetics** – (like **lidocaine**) commonly administered agents for *surgical* or *dental* procedures; produce *temporary numbness* in specific area
- Block *voltage-gated sodium channels* of neurons in treated area; prohibits *depolarization* and therefore action potentials relaying pain are not *transmitted to CNS*
- *Nonselective*; also affect sodium channels in muscles of area; causes *temporary paralysis*; reason for crooked smiles and drooling following dental work

Refractory Period

- **Refractory period** – period of time, after neuron has generated an AP, when neuron cannot *be stimulated* to generate another AP (**Figure 11.17**):
- **Absolute refractory period** – when *no additional stimulus* (no matter how strong) is able to produce additional AP
- **Relative refractory period** – immediately after absolute refractory period; only a *strong stimulus* can produce AP

Refractory Period



Local and Action Potentials Compared

Graded local potentials produce *variable changes* in membrane potentials

Actions potentials cause a *maximum depolarization to +30 mV*

- **All-or-none principle** –
  - If a neuron does not depolarize to threshold then *no AP will occur*
  - AP are <u>not</u> *dependent on strength, frequency, or length of stimulus* like local potentials

Propagation of Action Potentials

APs **conducted (propagated)** along <u>entire</u> length of axon = ***nerve impulse***

- ________________
- Each AP triggers *next section* of axon, usually starting at trigger zone and ending at _____________ (like *dominoes*)

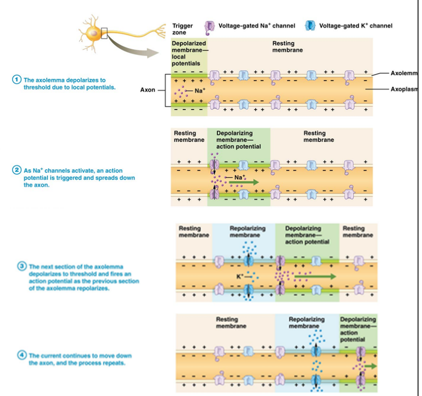


Figure 11.18 Propagation of an action potential.

Review

Action potentials

a. Are short distance signals
b. Spread down dendrites
c. Can be bidirectional
d. Begin at the trigger zone

Review

The threshold potential is best defined as the potential at which

a. Voltage-gated potassium channels open
b. Chemically gated sodium channels open
c. Voltage-gated sodium channels open
d. Voltage-gated potassium channels close

Review

Action potentials propagate

a. Down axon from axon terminus to cell body
b. Across multiple synapses between neurons
c. Across entire surface of neuron cell body
d. Down axon from trigger zone to axon terminus

Review

Action potentials <u>self</u>-propagate because

a. Each action potential triggers another in the next section of axon
b. ATP is always available to drive the action potential
c. Neurotransmitter is released constantly
d. They are a form of negative feedback

Review

The refractory period of an action potential

a. Allows bidirectional flow of the action potential
b. Prevents flow of action potential toward cell body
c. Has no effect on direction of action potential propagation
d. Is not a component of every action potential

Propagation of Action Potentials

- **Conduction speed** – influenced by both *axon diameter* and presence or absence of *myelination*
  - Larger *diameter* have faster *conduction speeds*
  - *Presence* of *absence* of myelination gives rise to 2 types of conduction:
    - **saltatory conduction** – myelinated processes exhibit "jumping" type of conduction, __________
    - **continuous conduction** – unmyelinated processes, ____________ of conduction

Propagation of Action Potentials

– **Saltatory conduction** – _______________ <u>increase</u> *speed* of conduction; AP <u>only</u> depolarize *nodes of Ranvier* and "jump over" *internodes*

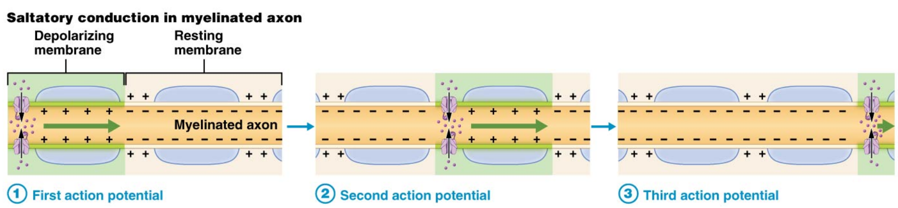


Figure 11.19 Comparison of saltatory and continuous conduction.

Propagation of Action Potentials

– **Continuous conduction** – in **unmyelinated axons** <u>every</u> section of axolemma from trigger zone to axon terminal __________ *propagate AP*; slower conduction speed

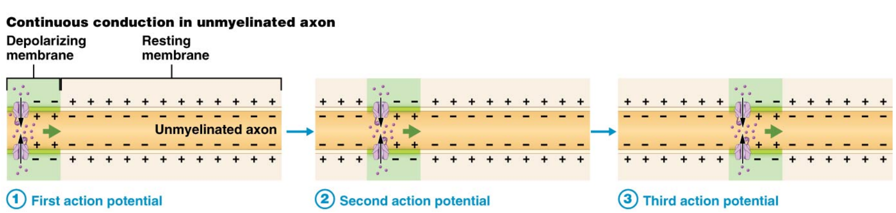


Figure 11.19 Comparison of saltatory and continuous conduction.

Propagation of Action Potentials

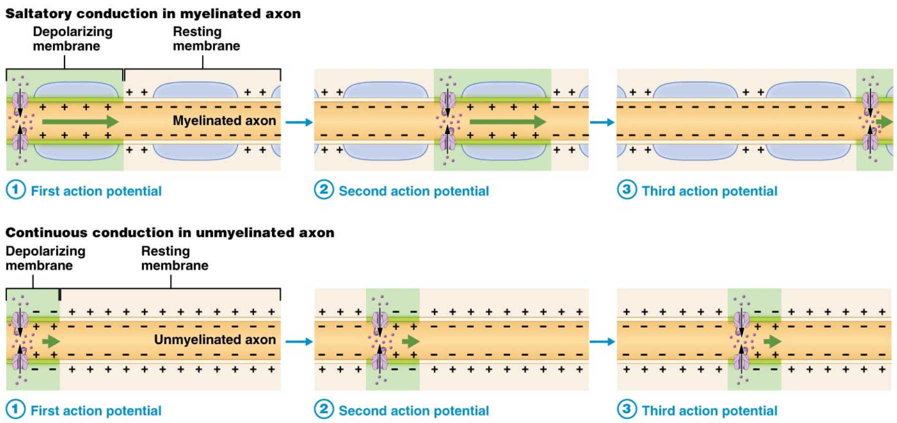


Figure 11.19 Comparison of saltatory and continuous conduction.

Propagation of Action Potentials

- **Classification of Axons by Conduction Speed**:
  - **Type A fibers** – largest diameter (120 m/sec or ***250 mi/h***); (5–20 μm) and ____________; sensory and motor axons associated with skeletal muscle and joints
  - **Type B fibers** – smaller diameter, *slower* conduction speeds (15 m/sec or ***32 mi/hr***); mostly *myelinated* with *intermediate* diameter axons (2–3 μm); ANS efferent fibers, some sensory
  - **Type C fibers** – smallest diameter**,** *slowest* conduction speeds (0.5–2 m/sec or ***1–5 mi/hr***); (0.5–1.5 μm); _____________ ANS efferent fibers and sensory axons (transmit pain, temperature, and pressure)

Putting It All Together: The Big Picture of Action Potentials

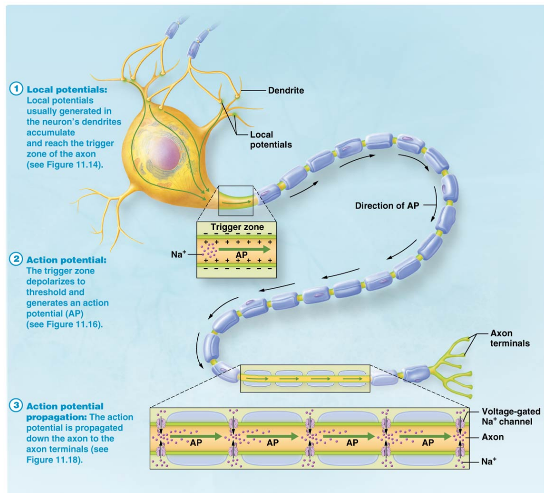


Figure 11.20 The Big Picture of Action Potentials.

Multiple Sclerosis *(p. 406)*

- **Multiple sclerosis (MS)** – certain cells of immune system *attack myelin sheaths* within CNS; type of **autoimmune disorder** (patient's own immune system attacks part of body)
- Causes *progressive loss of myelin sheath*; in turn causes *loss of current* from neurons
- **Symptoms** – result from *progressive slowing of AP propagation*; symptoms depend on region of CNS affected; most exhibit changes in *sensation* (e.g., numbness), alterations in *behavior* and *cognitive abilities*, and *motor dysfunction*, including *paralysis*

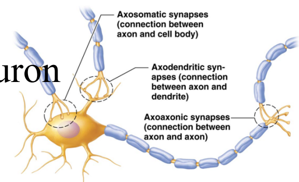
Overview of Neuronal Synapses

- **Synapse** – where a neuron meets its target cell (in this case another neuron) is called a _____________;

  - *electrical (gap junctions) – breathing, cardiac & SMC*

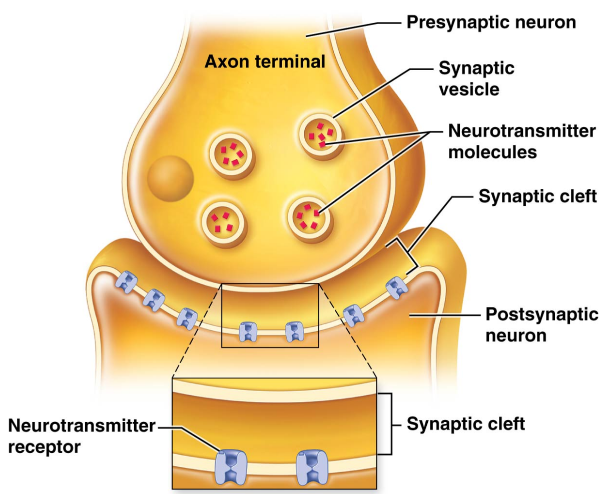
  - *chemical – most synapses*

  – can occur between an *axon* of one neuron and *another part* of another neuron (dendrite, soma, axon)



  – **Presynaptic neuron → synaptic cleft → Postsynaptic neuron**

Chemical Synapses



(b) Chemical synapse

Figure 11.22b The structure chemical synapse.

Chemical Synapses

- **Events at a Chemical Synapse:**
  - <u>multiple</u> neurons secreting many <u>different</u> *types* of *excitatory* or *inhibitory* neurotransmitters **(Fig. 11.23)**:

  1. AP in presynaptic neuron triggers **calcium ion channels** in axon terminal to <u>open</u>
  2. **Influx of calcium ions** causes synaptic vesicles to release neurotransmitter into synaptic cleft
  3. Neurotransmitters ***bind to receptors*** on postsynaptic neuron
  4. **Ion channels open, leading to a *local potential* and <u>possibly</u> an *AP*** if threshold is reached

Chemical Synapses

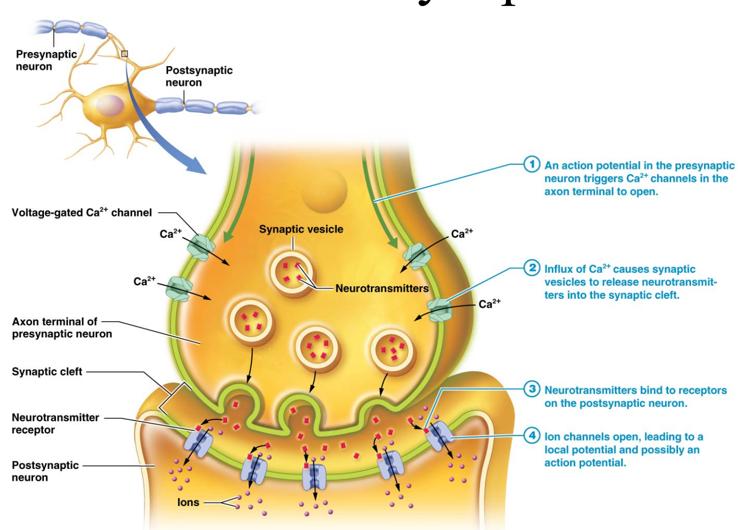


Figure 11.23 Events at a chemical synapse.

Review

The correct order for events at a chemical synapse:

Action potential arrives at axon terminal

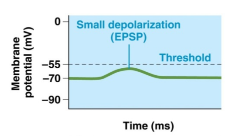
Neurotransmitter is released

Neurotransmitter binds to receptors

Local potential occurs in postsynaptic cell

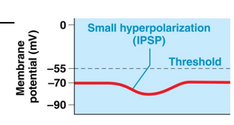
Chemical Synapses

- **Postsynaptic potentials** – *can be* ***E****xcitatory or* ***I****nhibitory*:
  - **Excitatory postsynaptic potential** (**EPSP**) = Membrane potential moves ____________



(a) The membrane potential of the postsynaptic neuron moves closer to threshold.

  - **Inhibitory postsynaptic potential** (**IPSP**) = Membrane potential moves ___ _____________



(b) The membrane potential of the postsynaptic neuron moves away from threshold.

Figure 11.24a Postsynaptic potentials.

Review

Postsynaptic potentials

a. Are always inhibitory
b. Always move the postsynaptic membrane toward threshold
c. Depend on which membrane channels open
d. Only involve sodium channel opening and closing

Review

EPSPs

a. Are inhibitory
b. Move the postsynaptic membrane toward threshold
c. Result from potassium channels opening
d. Are usually large local potentials

Review

IPSPs

a. Are inhibitory
b. Move the postsynaptic membrane toward threshold
c. Result from sodium channels opening
d. Are usually large local potentials

Chemical Synapses

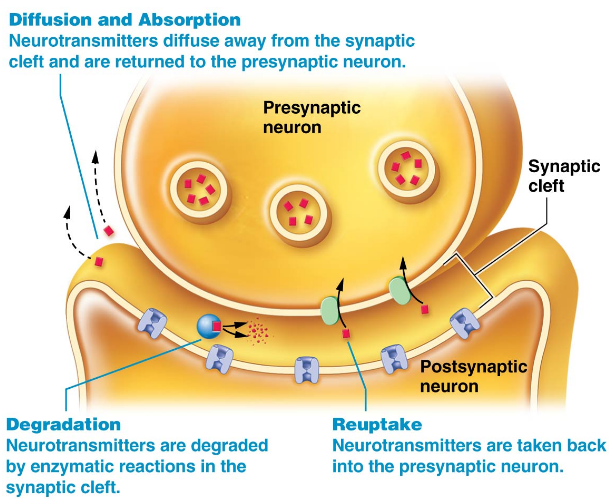


Figure 11.25 Methods of termination of synaptic transmission.

Arthropod Venom *(p. 410)*

- **Venomous arthropods** (in United States) include **spiders** and **scorpions**; many of their venoms affect neuronal synapses; termed **neurotoxins**
  - **Female black widow** (*Latrodectus mactans*) – toxin causes massive *release of neurotransmitter* leading to repetitive stimulation of postsynaptic neuron
  - **Bark scorpion** – most lethal of 40 species in United States; venom *prevents postsynaptic sodium channels from closing*; membrane remains polarized and continues to fire action potentials
- Mechanisms are <u>different</u> but *result* is <u>similar</u>; both lead to *overstimulation of postsynaptic neuron*;
- **Common symptoms** – muscle hyperexcitability, sweating, nausea and vomiting, and difficulty breathing
- **Treatment and prognosis** – depends on amount of venom received and availability of medical care; severe cases usually require **antivenin** to block effects of toxin

Putting It All Together: The Big Picture of Chemical Synaptic Transmission

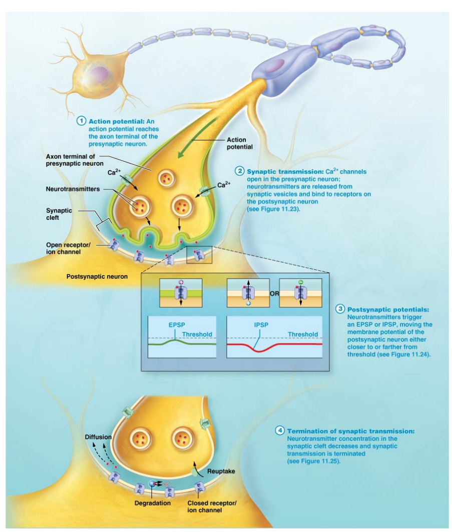


Figure 11.26 The Big Picture of Chemical Synaptic Transmission.

Review

Correct sequence of major events during **chemical synaptic** transmission?

- Action potential

- Synaptic transmission

- Postsynaptic potentials

- Synaptic transmission termination

Neural Integration

- Neurons receive input, both *inhibitory* and *excitatory*, from multiple neurons, each of which influences whether an *action potential is generated*
- **Neural integration** – process in which postsynaptic neuron *integrates* all *incoming information* into a single *effect*

Concept Boost: How Summation Connects Local Potentials and Action Potentials

Link between local potentials and action potentials is **summation**—as excitatory local potentials summate, they depolarize trigger zone to threshold and initiate an action potential

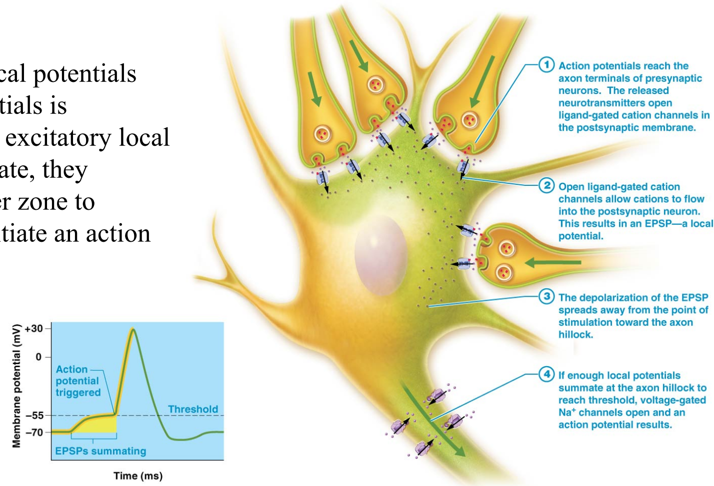


Figure 11.27 Local potentials summating and leading to an action potential

Neurotransmitters

- Over 100 known neurotransmitters

4 groups:

1. ACh (acetylecholine)- E [____________]
2. Biogenic amines: E
   - Catecholamines (NE, Epi (adrenaline), dopamine) [______________]
   - Serotonin
3. Amino acids: (Glutamate – E; GABA- Inhib.)
4. Neuropeptides: E and I (endorphins)

Major Neurotransmitters

Table 11.3 Major Neurotransmitters

Neurotransmitter	Precursor Molecule(s)	Predominant Postsynaptic Effect	Location(s)	Type of Receptor(s)
Acetylcholine	Acetyl-CoA and choline	Excitatory	CNS: brain and spinal cord PNS: neuromuscular junction and ANS	Ionotropic and metabotropic
Biogenic Amines				
Catecholamines (norepinephrine, epinephrine, dopamine)	Tyrosine	Excitatory	CNS: brain and spinal cord PNS: ANS (sympathetic division)	Metabotropic
Serotonin	Tryptophan	Excitatory	CNS: brain	Metabotropic
Histamine	Histidine	Excitatory	CNS: brain	Metabotropic
Amino Acids				
Glutamate	Glutamine	Excitatory	CNS: brain (major neurotransmitter of the brain)	Ionotropic and metabotropic
GABA (γ-aminobutyric acid)	Glutamate	Inhibitory	CNS: brain and spinal cord	Ionotropic and metabotropic
Glycine	Serine	Inhibitory	CNS: brain and spinal cord (most common inhibitory neurotransmitter in the spinal cord)	Ionotropic
Neuropeptides				
Substance P	Amino acids	Excitatory and inhibitory	CNS: brain and spinal cord (major neurotransmitter for pain perception) PNS: enteric nervous system (neurons in the digestive tract)	Metabotropic
Opioids (enkephalin, α-endorphin, dynorphin-A)	Amino acids	Excitatory and inhibitory	CNS: brain and spinal cord (major neurotransmitters for pain control)	Metabotropic
Neuropeptide Y	—	Exhitatory and inhibitory	CNS: brain PNS: ANS	Metabotropic

Psychiatric Disorders and Treatments *(p. 416)*

Psychiatric disorders affect thought processes; generally treated by *modifying synaptic transmission*

- **Psychopharmacology**
- **Schizophrenia**
- **Depressive disorders**
- **Anxiety disorders**
- **Bipolar disorders**

Neuronal Pools

- Groups of *interneurons* within CNS (**Figure 11.30**):
  - Composed of neuroglial cells, dendrites, and axons in one location and cell bodies in another location
  - Connections between pools allow for *complex mental activity* (planned movement, cognition, and personality)

Neuronal Pools

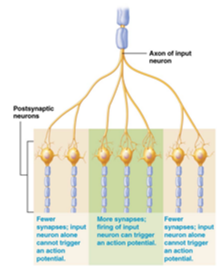
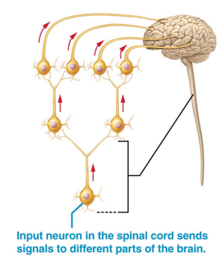


Figure 11.30 A neuronal pool.

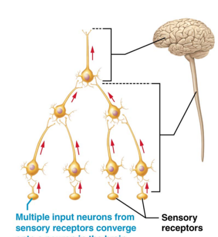
Neuronal Circuits



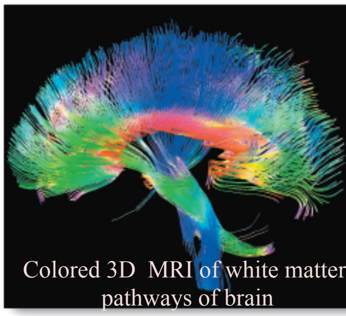
- **Neural circuits**
  – *patterns of synaptic connection* between neural pools

→ **Diverging circuits**
– one neuron sends impulses to <u>multiple</u> postsynaptic neurons
incoming sensory information sent from SC to different neuronal pools in brain for processing

→ **Converging circuits**
- axon terminals from multiple neurons converge onto a single postsynaptic neuron
- *respond to sensory information*



(b) Converging circuits



Colored 3D MRI of white matter pathways of brain

12

The Central Nervous System

CNS = ______________

- involved in __________, interpreting _________, maintaining __________, and functions relating to **mind**

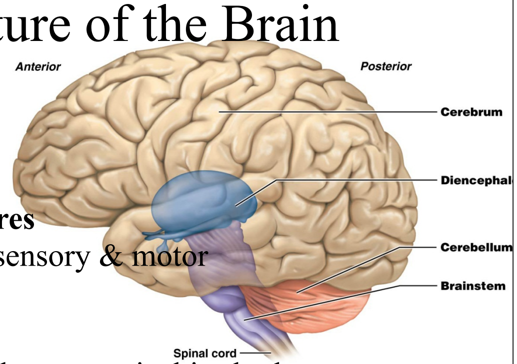
Overview of CNS Functions

- Functions of nervous system:
  - **Motor functions** muscles ________, glands _______ **(PNS)**
  - **Sensory functions** –___________ in and outside body (PNS)
  - ______________– include *decision-making processes* **(CNS)**
    - ***Interpretation*** of **sensory** information
    - *Planning* and monitoring **movement**
    - *Maintenance* of **homeostasis**
    - Higher mental functions such as ***language* and *learning***

Basic Structure of the Brain and SC

- **Brain** – soft, whitish-gray organ in cranial cavity, continuous with SC
  - mostly *nervous tissue*; some *epithelial* and *CT*
  - ________ filled with **cerebrospinal fluid (CSF)**
  - ~20% of *cardiac output*; requires large amounts of O_2, *glucose, and nutrients*

Basic Structure of the Brain

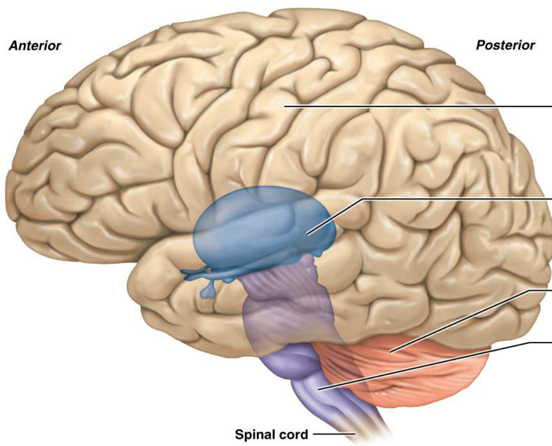


four divisions of brain:

- **Cerebrum**
  -- - left and right **hemispheres**
  - - higher mental functions, sensory & motor
- **Diencephalon**
  - deep to hemispheres
  - process, integrate & relay; homeostasis; bio rhythms
- **-**_____________
  – inferior to occipital lobe
  - voluntary motor activities
- **Brainstem** = midbrain, pons, medulla oblongata
  – reflexes, homeostasis, _____________

Figure 12.1 Divisions of the brain (lateral view).

Basic Structure of the Brain and Spinal Cord



BRAIN DIVISION	FUNCTION
Cerebrum	• Performs higher mental functions • Interprets sensory stimuli • Plans and initiates movement
Diencephalon	• Processes, integrates, and relays information • Maintains homeostasis • Regulates biological rhythms
Cerebellum	• Monitors and coordinates movement
Brainstem	• Maintains homeostasis • Controls certain reflexes • Monitors movement • Integrates and relays information

Figure 12.1 Divisions of the brain (lateral view).

Basic Structure of Spinal Cord

- **Spinal cord** – located in **vertebral cavity**
  - *Extends from foramen magnum to* _______
  - Length ~ 45 cm (17–18 inches)
  - Diameter 0.65–1.25 cm (0.25–0.5 inches)
  - **____________** – CSF filled cavity within SC, *continuous with brain's ventricles*

Basic Structure of the Brain and SC

- **White matter** – found in <u>both</u> brain and SC; (___________)
  - Tracts = *bundles of white matter* (processes in CNS)
  - Nuclei = *clusters of* _________ and dendrites (gray matter) (**Figure 12.2a**)
- **Gray matter** – found in <u>both</u> brain and SC; *(cell bodies, dendrites, and _________ axons)*
  - Cerebral cortex is gray matter
  - Center H (butterfly)-shape of SC

Basic Structure of the Brain and SC

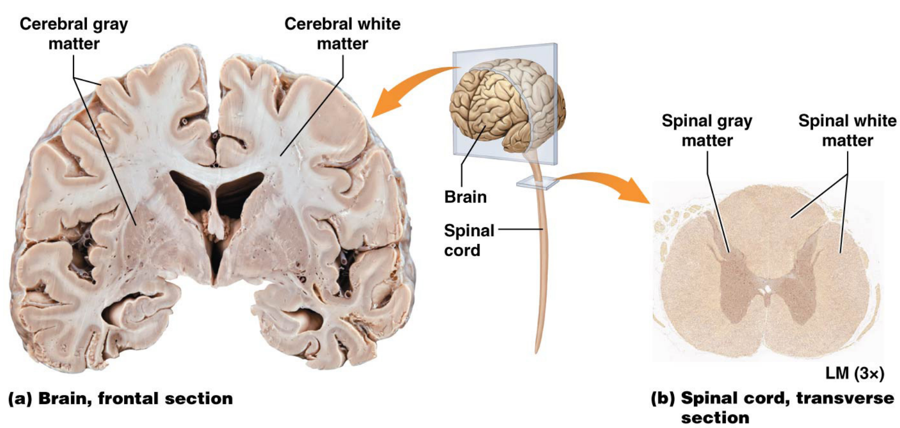
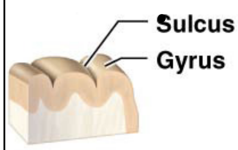


Figure 12.2 White and gray matter in the CNS.

The Cerebrum

- **Cerebrum**



Sulci – *shallow grooves* on surface of cerebrum

Gyri - *elevated ridges* found between sulci

Corpus callosum – connects ___________________

Longitudinal fissure – deep groove that separates *left and right cerebral hemispheres*

Transverse fissure *– separates occipital lobe from cerebellum*

Ventricles – ___________ *cavities, one in each hemisphere*

Figure 12.4 Structure of the cerebrum.

The Cerebrum

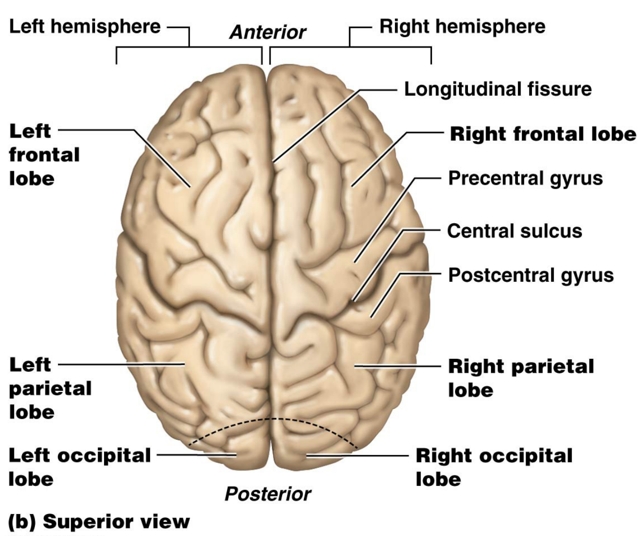
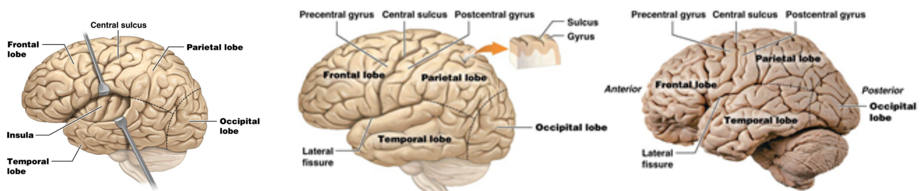


Figure 12.4b Structure of the cerebrum.

The Cerebrum

- *Five lobes* are found in each hemisphere (**Figure 12.4**):
  - **Frontal lobe** (motor, complex mental fcn.)
  - **Parietal lobe** (___________)
  - **Temporal lobe** (hearing)
  - **Occipital lobe** (__________)
  - **Insula** (taste)



(c) Lateral view (frontal, parietal, and temporal lobes pulled back)

(a) Lateral view (left hemisphere)

The Cerebrum-Gray Matter

- **Cerebral Cortex** = gray matter, covers cerebral hemispheres
  - <u>All</u> neurons in cortex are ____________
  - *Functions* of neocortex (most recently evolved part of brain) include *conscious processes* as planning **movement**, interpreting incoming **sensory** information, and **complex higher functions**

The Cerebrum-Gray Matter

- **Gray Matter**: **Cerebral Cortex**:
  - Neocortex is divided into *three areas*:

  [Motor, Sensory, Association]

1. **Primary motor cortex** – plans and executes __________

   - *located in frontal lobe (pre-central gyrus)*

   Premotor cortex – anterior to primary motor cortex, plan and carry out movements

   Frontal eye fields -*back and forth eye movements* as in reading

The Cerebrum-Gray Matter

2. **Primary sensory cortices** – *receive* and *process sensory input*

Somatosensory areas – in postcentral gyrus of parietal lobe; cutaneous (temp. & touch)

Visual areas – ____________ mostly

Auditory areas – temporal lobe

Gustatory cortex – insula and parietal

Olfactory cortex - ____________

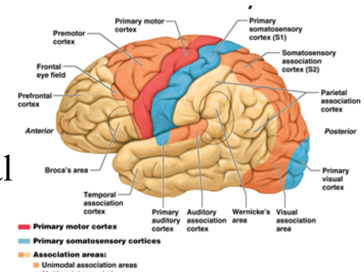


Figure 12.5 Structure of the cerebral cortex (left hemisphere, lateral view).

The Cerebrum-Gray Matter

3. **Association areas** integrate different types of information

   Broca's area – produce _________ sounds

   Prefrontal cortex – most of frontal lobe, fcn. in behavior, personality, learning, memory

   Parietal & temporal association cortices – integrate sensory info., attention

The Cerebrum-Gray Matter

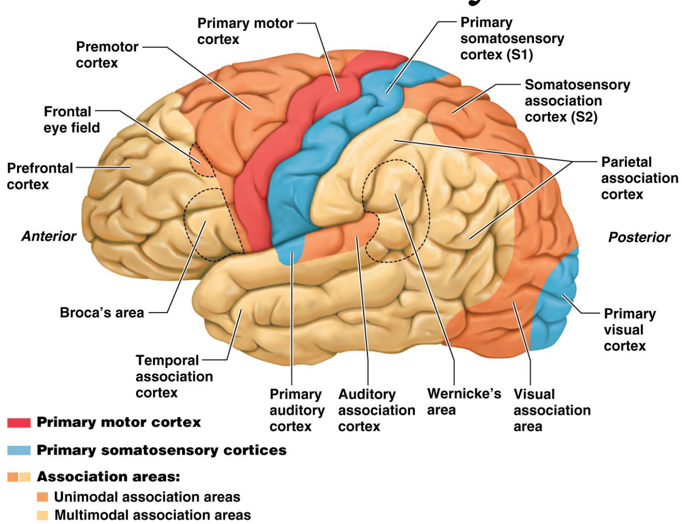


Figure 12.5 Structure of the cerebral cortex (left hemisphere, lateral view).

The Cerebrum-Gray Matter

Area Name	Type of Cortex	Location	Function
Primary motor cortex	Motor	Precentral gyrus of frontal lobe	Plans and executes movement
Premotor cortex	Unimodal association	Widespread throughout lateral and medial frontal lobe	Plans and executes complex movement
Frontal eye fields	Unimodal association; possibly multimodal	Anterior to the premotor cortex	Back-and-forth eye movements
Primary somatosensory cortex	Sensory	Postcentral gyrus of parietal lobe	Interprets incoming somatic sensory information
Somatosensory association cortex	Unimodal association	Posterior to the primary somatosensory cortex in the parietal lobe	Integrates somatic sensory information
Primary visual cortex	Sensory	Posterior occipital lobe	Interprets and processes visual stimuli
Primary auditory cortex	Sensory	Superior temporal lobe	Processes auditory stimuli
Gustatory cortex	Sensory	Insula, parietal lobe	Processes taste stimuli
Vestibular areas	Sensory	Several in both parietal and temporal lobes	Processes stimuli relating to equilibrium and balance
Olfactory cortex	Sensory	Limbic lobe, medial temporal lobe	Processes smell stimuli
Broca's area	Multimodal association	Superolateral frontal lobe	Language production
Wernicke's area	Multimodal association	Superolateral temporal lobe	Language comprehension
Prefrontal cortex	Multimodal association	Anterior frontal lobe	Planning, personality, higher cognitive functions
Parietal association cortex	Multimodal association	Widespread in the parietal lobe	Spatial awareness and attention
Temporal association cortex	Multimodal association	Widespread in the temporal lobe	Recognition and associations

Table 12.1 Motor, Sensory, and Association Areas of the Cerebral Cortex.

The Cerebrum-Gray Matter

- **Basal nuclei**
  - masses of gray matter deep within each hemisphere
  - involved in _____________
- **Caudate nuclei**
- **Putamen**
- **Globus pallidus**

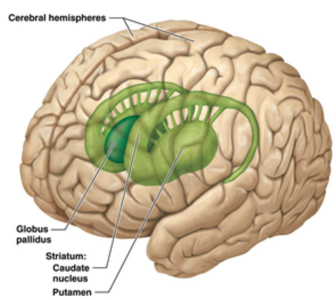
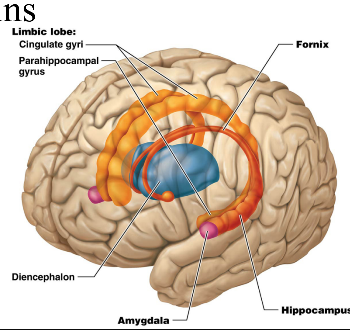


Figure 12.6 Structure of the basal nuclei (anterolateral view).

The Cerebrum-Limbic System

- **Limbic system**
  - includes limbic lobe, hippocampus, amygdala
  - connect these regions of gray matter with rest of brain
  - Found only within *mammalian* brains
  - Involved in __________, *learning*, __________, and *behavior*

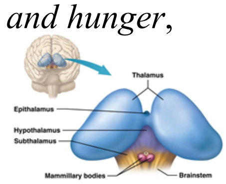


The Diencephalon

Diencephalon – located in center of brain between hemispheres above brainstem

- 4 parts: Thalamus, Hypothalamus, Epithalamus, Subthalamus

- **Thalamus**
  - _____________info. to cerebral cortex
  - Receives all sensory (except smell)
- **Hypothalamus**
  - Regulation of *ANS*, *sleep/wake cycle*, *thirst and hunger*, and *body temperature*
  - *Secretes hormones that reg. pituitary & other glands*



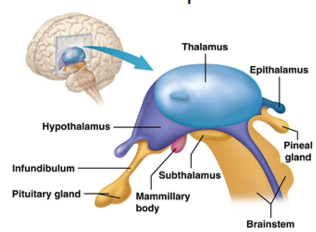
(a) Diencephalon, anterior view

The Diencephalon

- **Epithalamus** – superior to thalamus; includes
  endocrine gland called ______________that secretes **melatonin**; hormone involved in *sleep/wake cycle*

- **Subthalamus** – inferior to thalamus; functionally connected with basal nuclei; together, they *control movement*

The Diencephalon



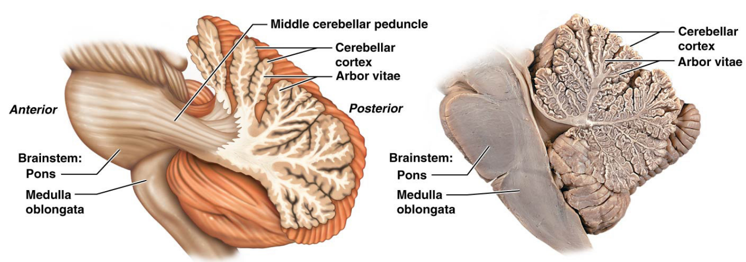
(c) Diencephalon, midsagittal section

Figure 12.10c Structure of the diencephalon.

Cerebellum

Cerebellum

- located inferior to occipital lobe
- *coordinate* ____________
- *arbor vitae*



(c) Cerebellum, parasagittal section

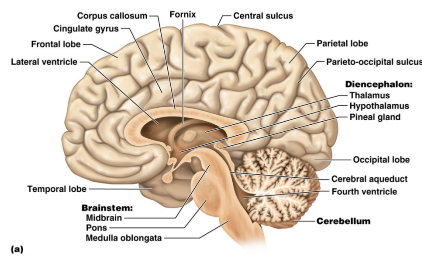
(d) Photo of cerebellum, midsagittal section

The Brainstem

Brainstem

– one of oldest components of brain

- vital to our immediate survival
- *Includes midbrain, pons, medulla oblongata*



The Brainstem

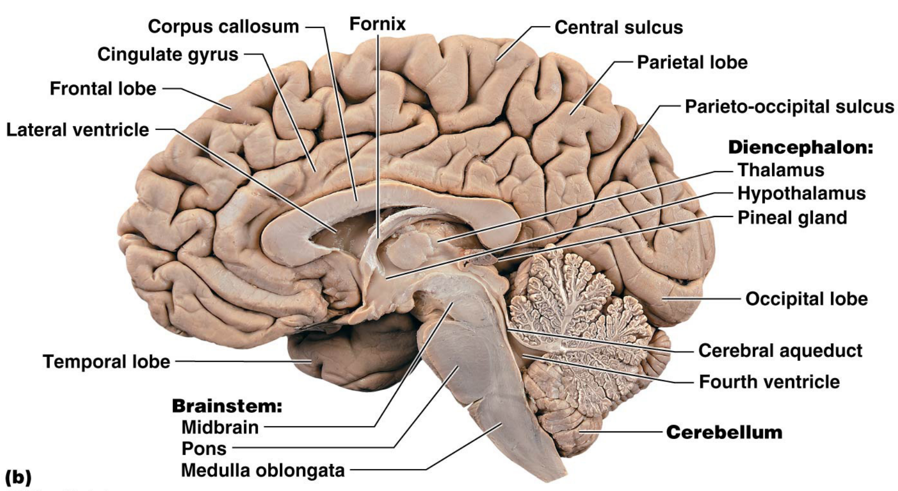


Figure 12.12b Midsagittal section of the brain showing the brainstem.

The Brainstem

- **Midbrain**
  - surrounds **cerebral aqueduct** (connects ________ _________________)
  - **Superior** and **inferior colliculi**: involved in *visual* and *auditory* relexes respectively
  - **Substantia nigra** – works with basal nuclei to *control movement; produces* ____________

The Brainstem

- **Pons** – inferior to midbrain
  - regulation of *movement*, __________, *reflexes*, and complex functions associated with *sleep* and *arousal*
- **Medulla oblongata** – most inferior structure of brainstem
  - regulation of breathing, and other vital activities

The Big Picture of Major Brain Structures and Their Functions

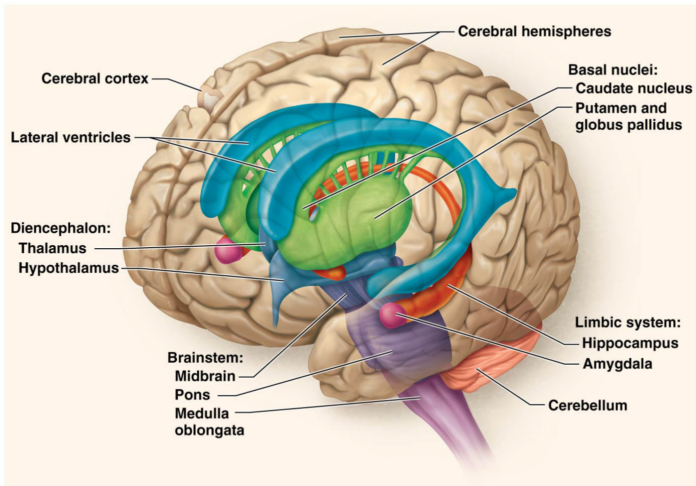
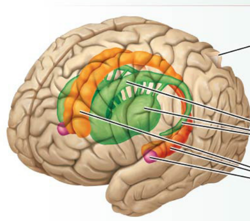


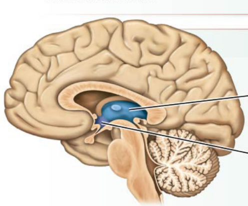
Figure 12.16 The Big Picture of Major Brain Structures and Their Functions.

The Big Picture of Major Brain Structures and Their Functions



Anterolateral view

DIVISION	STRUCTURES	SUBSTRUCTURES	MAIN FUNCTIONS
Cerebrum	Cerebral cortex	Primary motor cortex	• Plans and executes movement
		Primary somatosensory cortices	• Receive and process different types of sensory input
		Multimodal association areas	• Integrate sensory and motor information from a variety of different primary cortices
	Basal nuclei	Caudate nuclei Putamen Globus pallidus	• Regulate movement
	Limbic system	Hippocampus	• Plays a role in memory and learning
		Amygdala	• Plays a role in behavioral expression and emotion

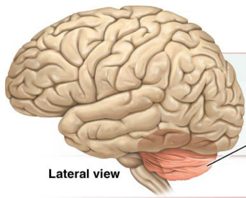


Midsagittal section

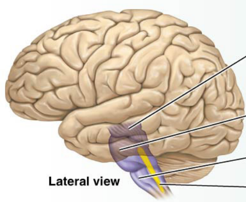
DIVISION	STRUCTURES	MAIN FUNCTIONS
Diencephalon	Thalamus	• Controls information entry into the cerebral cortex • Edits, sorts, and routes stimuli
	Hypothalamus	• Regulates the autonomic nervous system • Regulates the sleep/wake cycle • Regulates thirst and hunger • Regulates body temperature • Produces hormones • Controls secretion from the pituitary gland

Figure 12.17 The Big Picture of Major Brain Structures and Their Functions.

The Big Picture of Major Brain Structures and Their Functions



DIVISION	MAIN FUNCTION
Cerebellum	• Coordinates voluntary movement



DIVISION	STRUCTURES	MAIN FUNCTIONS
Brainstem	Midbrain	• Processes and routes visual and auditory stimuli to the thalamus • Carries motor fibers from the cerebral cortex • Monitors movement with the basal nuclei
	Pons	• Regulates breathing • Regulates reflexes • Regulates the sleep/wake cycle
	Medulla oblongata	• Contains tracts of white matter involved in movement and sensation • Regulates many homeostatic functions
	Reticular formation	• Involved in sleep and arousal • Involved in pain transmission • Plays a role in mood regulation • Involved in many homeostatic functions

Figure 12.17 The Big Picture of Major Brain Structures and Their Functions.

Brain Protection

Three features protect delicate brain tissue:

1. **Cranial meninges** – three layers of *membranes* that surround brain
2. **Cerebrospinal fluid** (**CSF**) – *fluid* that bathes brain and fills cavities
3. **Blood-brain barrier** – prevents many substances from *entering brain* and its cells from *blood*

Brain Protection

- **Cranial meninges**
  – composed of three layers:

superficial to deep:

epidural space

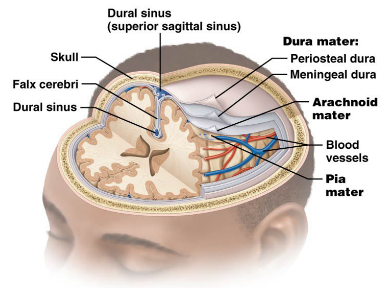
a. **dura mater**

subdural space

b. **arachnoid mater** (weblike)

subarachnoid space (CSF filled)

c. **pia mater** (in contact with brain tissue)



(a) Cranial meninges

The Ventricles and Cerebrospinal Fluid

- **Four ventricles** within brain (1st & 2nd = lateral ventricles, 3rd and 4th ventricle connected via cerebral aqueduct)
  - continuous with *central canal* of spinal cord
  - Lined with **ependymal cells**
  - Filled with **cerebrospinal fluid**

- **CSF** *(similar to ___________)*
  - Produced by ________________
  - Reabsorbed by **arachnoid villi** (granulations)
  - ~800ml produced daily, only 150ml at any time
  - Cushions brain, maintains temp., removes wastes, provides buoyancy

The Ventricles and Cerebrospinal Fluid

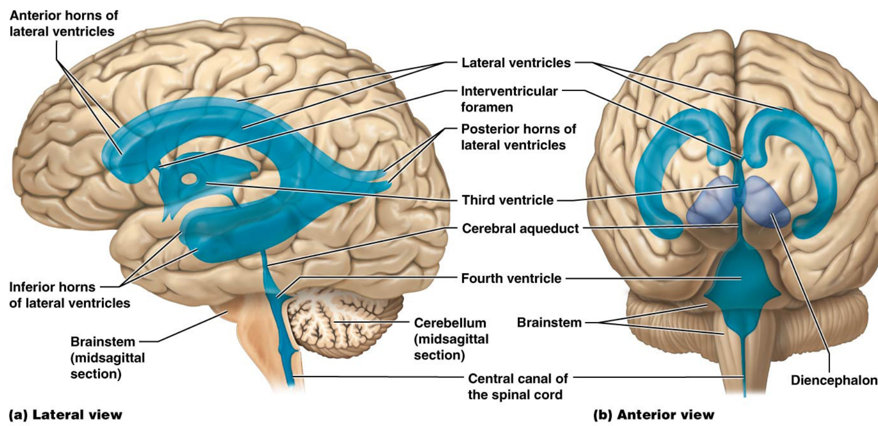


Figure 12.19 Ventricles of the brain.

The Ventricles and Cerebrospinal Fluid

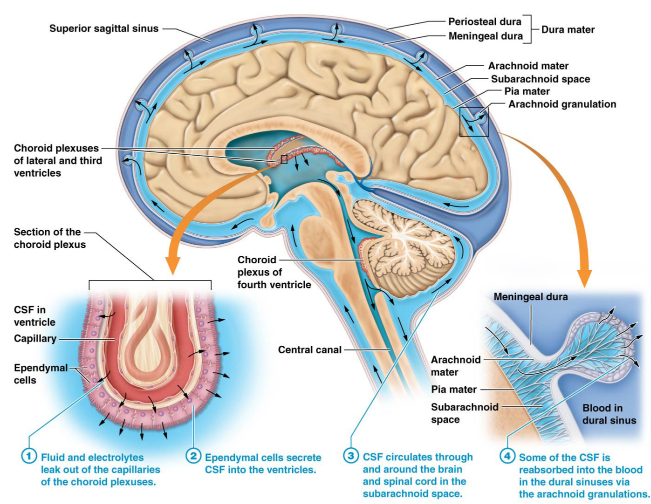


Figure 12.20 Formation and flow of cerebrospinal fluid (CSF).

Infectious Meningitis *(p. 448)*

- Potentially life-threatening *infection of meninges in subarachnoid space*; **inflammation** occurs, causing *classic signs*: headache, lethargy, stiff neck, fever
- **Diagnosis** – examination of CSF for *infectious agents* and *white blood cells* (cells of immune system); bacteria and viruses are most common causative agents:
  - **Viral** – generally mild; resolves in 1–2 weeks
  - **Bacterial** – can rapidly progress to *brain involvement and death*; aggressive *antibiotic treatment* necessary; some most common forms are preventable with *vaccines*

The Spinal Cord

- **Spinal cord** – composed primarily of nervous tissue; responsible for both *relaying* and *processing information (reflexes)*
- *Spinal Meninges (similar to cranial meninges)*
- **Epidural space** – space between meningeal dura and walls of vertebral foramina; filled with veins and adipose tissue; *cushions* and *protects* spinal cord
- **Subarachnoid space** – between arachnoid and pia mater; filled with CSF; base of spinal cord contains a large volume of CSF useful site for *withdrawing samples* laboratory testing

Protection of the Spinal Cord

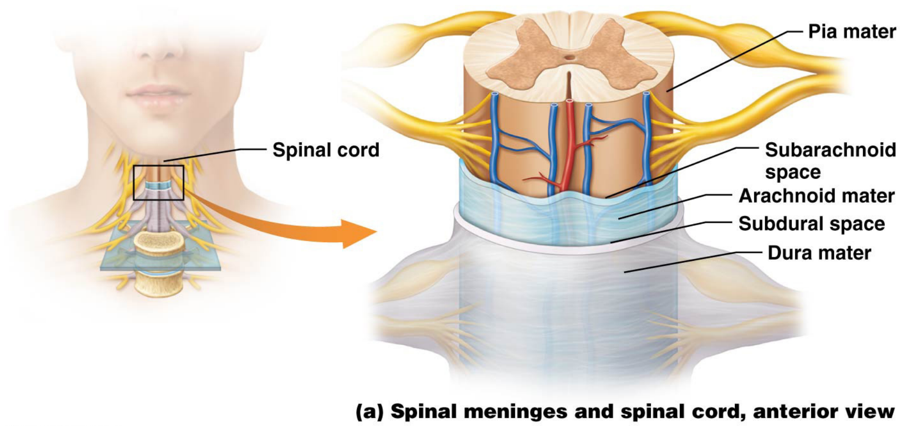


Figure 12.22a Structure of the spinal meninges.

Protection of the Spinal Cord

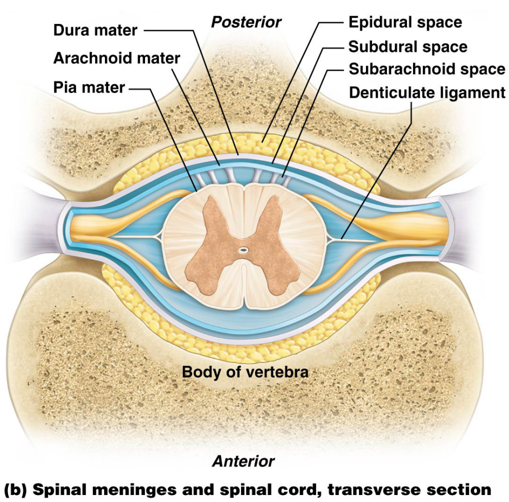
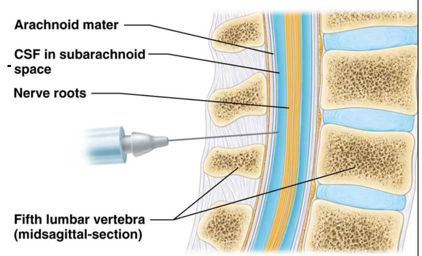


Figure 12.22b Structure of the spinal meninges.

Epidural Anesthesia and Lumbar Punctures

(p. 449)

- **Epidural (spinal) anesthesia**



- Causes "**numbing**"
- Commonly given during *childbirth* and other *surgical procedures*
- **Lumbar puncture (spinal tap)**

External Spinal Cord Anatomy

- **Filum terminale** – extends from between L1 and L2 to coccyx
  - composed of *spinal pia mater*
- ***Cauda Equina*** = bundle of spinal nerves contained in ______________

External Spinal Cord Anatomy

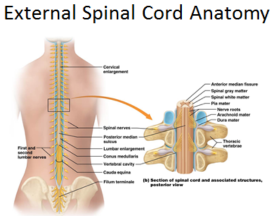


Figure 12.23 External structure of the spinal cord.

External Spinal Cord Anatomy

- **Spinal nerves** (PNS); carry *sensory* and *motor impulses* to and from SC
  - **Posterior (dorsal) nerve root –** ___________
  - **Anterior (ventral) nerve root -** motor

External Spinal Cord Anatomy

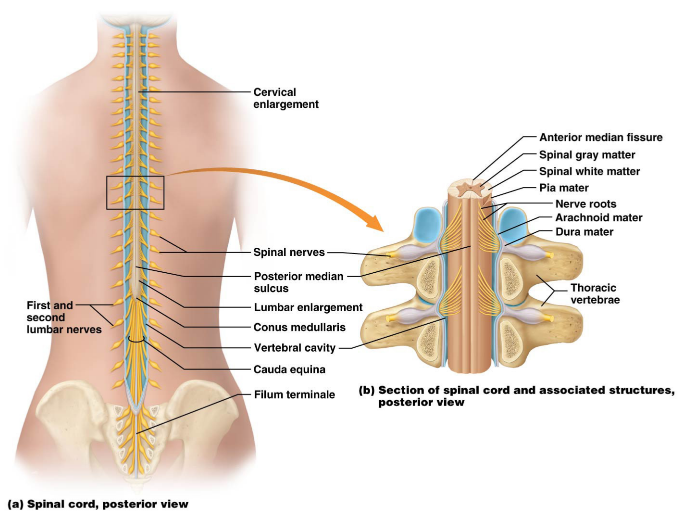


Figure 12.23 External structure of the spinal cord.

Internal Spinal Cord Anatomy

Butterfly (H)-shaped spinal gray matter is surrounded by tracts of white matter

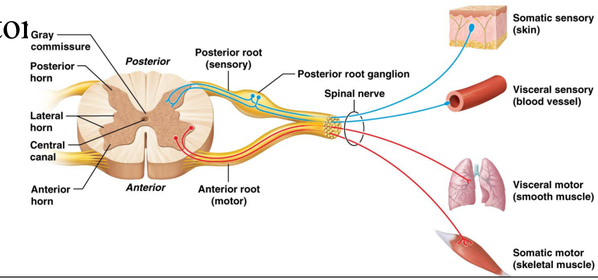
Central canal – filled with CSF; seen in center of SC

Anterior (ventral) horn – motor neurons to

____

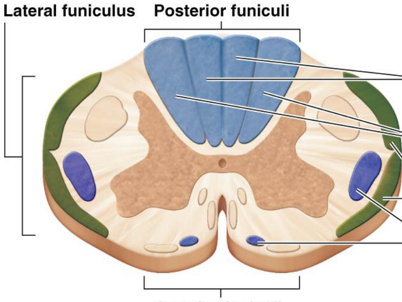
Posterior (dorsal) horn – ___________ information

Lateral horn – motor



Internal Spinal Cord Anatomy

Ascending tracts (sensory)



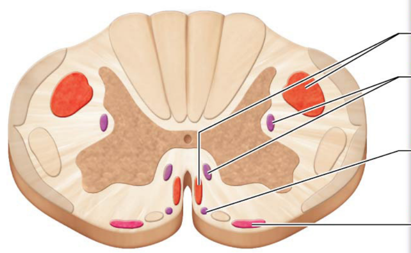
ASCENDING TRACT	FUNCTION
Posterior columns—fasciculus gracilis	• Carry somatosensory information including fine touch, vibration, and proprioception from the lower limbs
Posterior columns—fasciculus cuneatus	• Carry somatosensory information including fine touch, vibration, and proprioception from the trunk, neck, and upper limbs
Spinocerebellar tracts	• Carry proprioceptive information to the cerebellum
Anterolateral system—spinothalamic tracts	• Carry information about pain, temperature, and certain types of touch

(a) Ascending tracts (sensory)

Figure 12.25a Ascending and descending tracts of the spinal cord.

Internal Spinal Cord Anatomy

Descending tracts (motor)



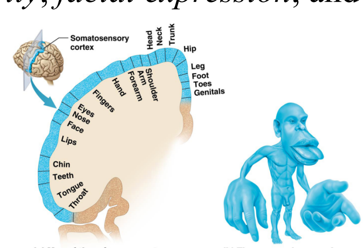
(b) Descending tracts (motor)

DESCENDING TRACT	FUNCTION
Corticospinal tracts	• Carry motor information from the motor areas of the cerebral cortex
Reticulospinal tracts	• Carry motor information from the brainstem • Important for the maintenance of posture and proper orientation of the limbs during movement
Tectospinal tract	• Carries motor information from the superior colliculus of the brainstem • Important for reflexive movement of the head and eyes
Vestibulospinal tract	• Carries motor information from vestibular nuclei in the brainstem • Important for the maintenance of posture and balance

Figure 12.25b Ascending and descending tracts of the spinal cord.

General Somatic Senses

- **Role of Cerebral Cortex in Sensation**, **S1** and **Somatotopy**:
  - Thalamus relays most incoming information to **primary somatosensory cortex** (**S1**) in postcentral gyrus
  - Each part of body is represented by a <u>specific</u> *region of S1*, a type of organization called **somatotopy** (**Figure 12.28**)
  - <u>More</u> S1 space is dedicated to hands and face; represents importance of *manual dexterity*, *facial expression*, and *speech* to human existence



(a) Map of the primary somatosensory cortex (S1) (b) The sensory homunculus

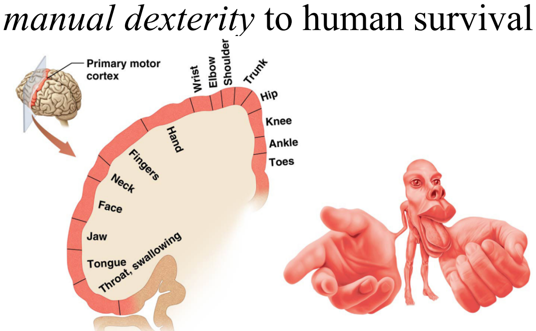
Phantom Limb Pain *(p. 456)*

- **Phantom limb**

- **Phantom pain**

Role of Brain in Voluntary Movement

- **Role of Cerebral Cortex** in Voluntary Movement:
  - Primary motor cortex is organized somatotopically; certain body regions have *disproportionately more cortical area* devoted to them (especially lips, tongue, and hands); signifies importance of *vocalization* and *manual dexterity* to human survival



(a) Map of the primary motor cortex (b) The motor homunculus

Parkinson's Disease *(p. 461)*

- One of most common movement disorders
- **Hypokinetic** = movement is difficult to *initiate* and once started, difficult to *terminate*
- **Symptoms** – minimal facial expression, shuffling gait, no arm swing, resting tremor
- **Cause** – degeneration of *dopamine-secreting neurons of substantia nigra*; *genetics* suspected in ~10% of cases
- **Treatment** – medications that <u>increase</u> *level of dopamine*

The Big Picture of CNS Control of Voluntary Movement

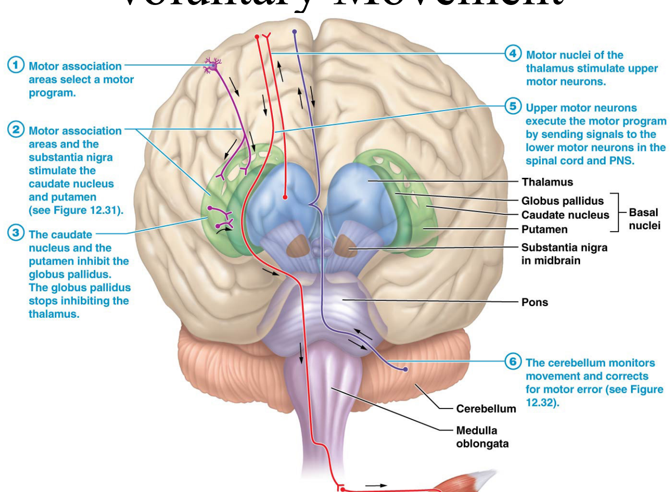


Figure 12.33 The Big Picture of CNS Control of Voluntary Movement.

Role of CNS in Maintenance of Homeostasis

Homeostasis is defined as maintenance of a *relatively* __________________ in face of ever-changing conditions

- **Homeostatic functions** include maintaining fluid, electrolyte, and acid-base balance; BP; BG and [O_2]; biological rhythms; and body temperature
  - Endocrine system secretes ___________ into blood; regulates functions of other cells (long term)
  - Nervous system sends **action potentials**; excite or inhibit target cells (immediate)

Homeostasis of Vital Functions

- **Autonomic nervous system (ANS)**
  - Maintain v*ital functions* (______________)
  - Although ANS is a *component of PNS,* mainly controlled by ______________
- **Respiration** is one of few vital functions <u>not</u> *under ANS control; regulated by Pons and Medulla*
- ***Body Temperature** – reg. by hypothalamus*

Fever *(p. 466)*

- *Elevation of body temperature* can accompany variety of infectious and noninfectious conditions
- Due to **pyrogens** (chemicals) secreted by cells of immune system and by certain bacteria; cross BBB and *interact with hypothalamus* (control temp.)
- Pyrogens increase hypothalamic *set point* to higher temperature; feedback loop triggers *shivering* and *muscle aches* due to increased muscle tone; VC of *blood vessels* to skin
- **Antipyretics** (**acetaminophen** and **aspirin**)- work by blocking *formation of pyrogens*; hypothalamus returns to normal set point

Dementia *(p. 468)*

- Dementia
  - **Alzheimer's disease** (AD)
    - **Neurofibrillary tangles** (aggregates of proteins in neurons), **senile plaques** (extracellular deposits of specific protein around neurons)
  - **Vascular dementia**
  - **Lewy body dementia**
  - **Pick's disease**

Learning and Memory

- Two basic *types of memory*:
  1. **Declarative (fact)** – readily available to consciousness

     ex. – phone number, a quote, or pathway of corticospinal tracts
  2. **Nondeclarative (procedural or skills)** – unconscious association

     ex. – how to enter phone number on a phone, how to move your mouth to speak, and how to read this chapter

Learning and Memory

- Declarative and nondeclarative memory classified by *length of* storage *time*
  - **Immediate memory** – stored only for a *few seconds*; is critical for carrying out normal conversation, reading, and daily tasks
  - **Short-term** (**working**) **memory** – stored for *several minutes*; allows you to remember and manipulate information with a general behavioral goal in mind
  - **Long-term memory** – a more permanent form of storage for *days*, *weeks*, *or even a lifetime*

Learning and Memory

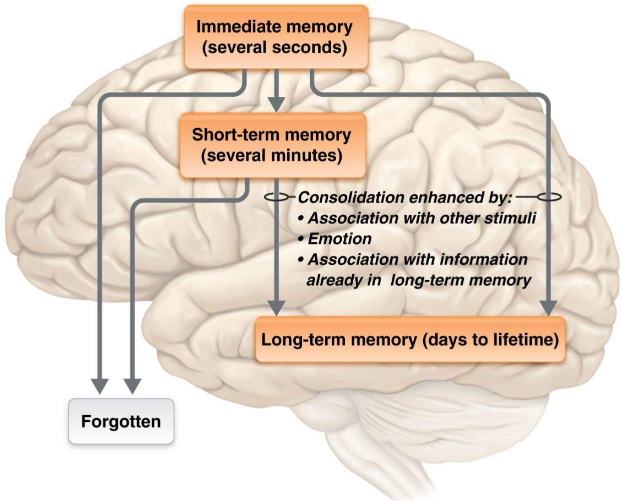
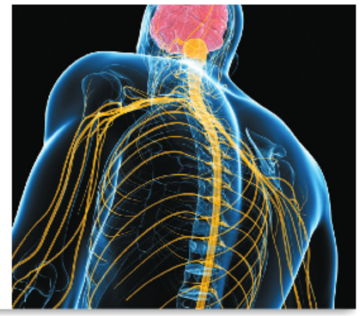


Figure 12.37 Pathways for consolidation of memories.

13

The Peripheral Nervous System



PNS =

1. **Sensory (____________)**
   a. Somatic Sensory Div. (special senses, skin, skeletal muscle)
   b. Visceral Sensory Div. (viscera)
2. **Motor (____________)**
   a. Somatic Motor Div. (to skeletal muscle)
   b. Visceral Motor Div. (ANS)

Divisions of the PNS

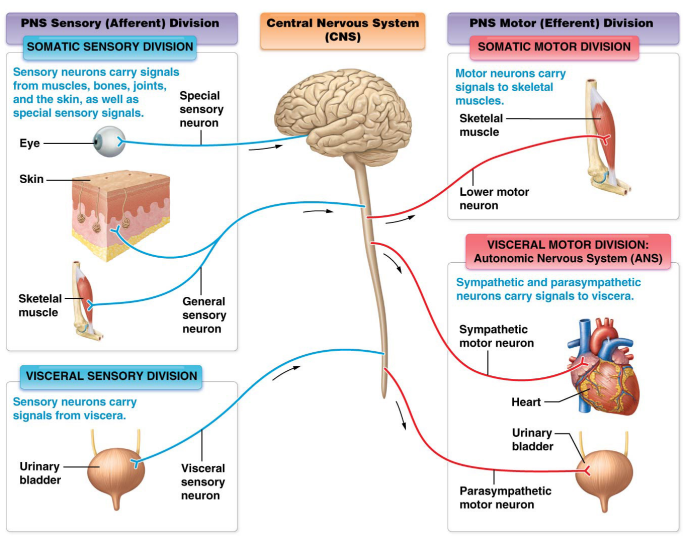


Figure 13.1 The organization of the peripheral nervous system.

Overview of Peripheral Nerves and Associated Ganglia

- **Peripheral nerves**

= *axons* of many neurons bound together by CT

Mixed nerves – contain <u>both</u> _______________ neurons

Sensory nerves – contain <u>only</u> ___________ neurons

Motor nerves - contain <u>mostly</u> __________ neurons

2 types of nerves:

Spinal nerves (31 pairs)

Cranial nerves (12 pairs)

Overview of Peripheral Nerves

- **Spinal nerves**

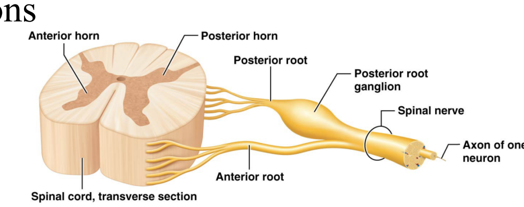
Anterior (__________) root

- *motor neurons* from anterior horn

Posterior (___________) **root**

- *sensory neurons* from posterior horn

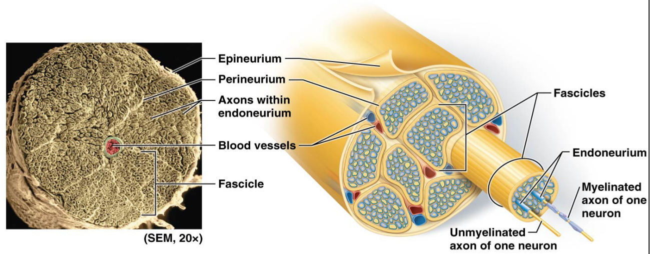
Dorsal root ganglion - collection of cell bodies of sensory neurons



(a) Anterior and posterior roots and spinal nerve

Overview of Peripheral Nerves

- Structures associated with spinal nerves:
  Epineurium – __________ layer of CT, holds motor and sensory axons together
  Perineurium – CT that surrounds **fascicles** (bundles of axons)
  Endoneurium – CT surrounds individual axon



(b) Photomicrograph of dissected spinal nerve
(c) Detailed structure of spinal nerve

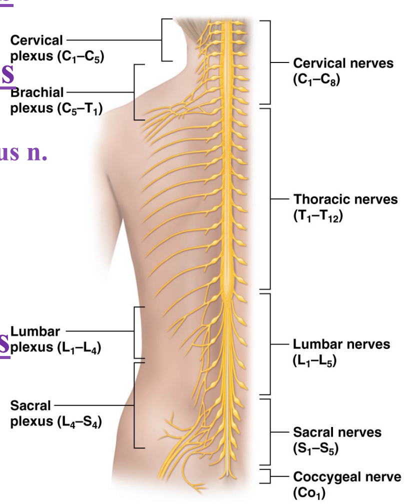
Structure of Spinal Nerves and Spinal Nerve Plexuses

Cervical Plexus
- Phrenic Nerve

Brachial Plexus
- Axillary n.
- Musculocutaneous n.
- Median n.
- Ulnar n.

Lumbar Plexus
- Obturator n.
- Femoral n.

Sacral Plexus
- Sciatic n.



Cervical = 8 pr.
Thoracic = 12 pr.
Lumbar = 5 pr.
Sacral = 5 pr.
Coccygeal = 1 pr.

Figure 13.5 Overview of spinal nerves.

Structure of Spinal Nerves and Spinal Nerve Plexuses

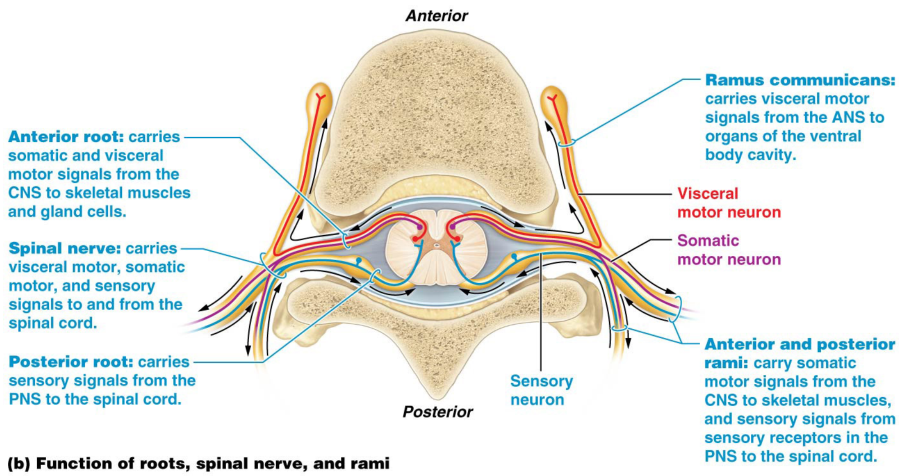


Figure 13.4b Structure and function of roots, spinal nerves, and rami.

The Sensory Cranial Nerves

- *Sensory only cranial nerves*:
  - **Olfactory (I)**
  - **Optic (II)**
  - **Vestibulocochlear (VIII)**

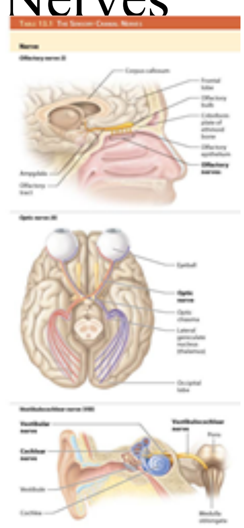


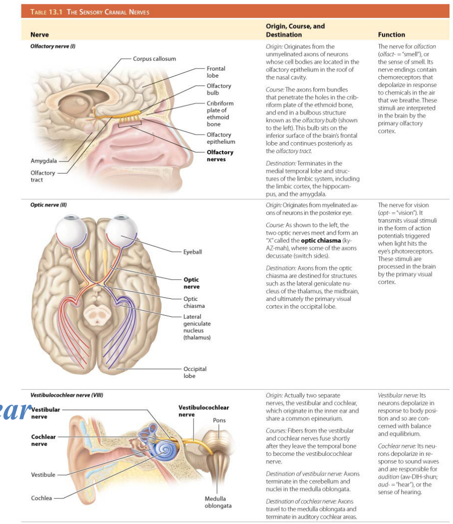
Table 13.1 The Sensory Cranial Nerves.

The Sensory Cranial Nerves

Olfactory (I)

Optic (II)

Vestibulocochlear (VIII)



Nerve	Origin, Course, and Destination	Function
Olfactory nerve (I)	*Origin:* Originates from the unmyelinated axons of neurons whose cell bodies are located in the olfactory epithelium in the roof of the nasal cavity. *Course:* The axons form bundles that penetrate the holes in the cribriform plate of the ethmoid bone, and end in a bulbous structure known as the *olfactory bulb* (shown to the left). This bulb sits on the inferior surface of the brain's frontal lobe and continues posteriorly as the *olfactory tract*. *Destination:* Terminates in the medial temporal lobe and structures of the limbic system, including the limbic cortex, the hippocampus, and the amygdala.	The nerve for *olfaction* (*olfact-* = "smell"), or the sense of smell. Its nerve endings contain chemoreceptors that depolarize in response to chemicals in the air that we breathe. These stimuli are interpreted in the brain by the primary olfactory cortex.
Optic nerve (II)	*Origin:* Originates from myelinated axons of neurons in the posterior eye. *Course:* As shown to the left, the two optic nerves meet and form an "X" called the **optic chiasma** (ky-AZ-mah), where some of the axons decussate (switch sides). *Destination:* Axons from the optic chiasma are destined for structures such as the lateral geniculate nucleus of the thalamus, the midbrain, and ultimately the primary visual cortex in the occipital lobe.	The nerve for vision (*opt-* = "vision"). It transmits visual stimuli in the form of action potentials triggered when light hits the eye's photoreceptors. These stimuli are processed in the brain by the primary visual cortex.
Vestibulocochlear nerve (VIII)	*Origin:* Actually two separate nerves, the vestibular and cochlear, which originate in the inner ear and share a common epineurium. *Courses:* Fibers from the vestibular and cochlear nerves fuse shortly after they leave the temporal bone to become the vestibulocochlear nerve. *Destination of vestibular nerve:* Axons terminate in the cerebellum and nuclei in the medulla oblongata. *Destination of cochlear nerve:* Axons travel to the medulla oblongata and terminate in auditory cochlear areas.	*Vestibular nerve:* Its neurons depolarize in response to body position and so are concerned with balance and equilibrium. *Cochlear nerve:* Its neurons depolarize in response to sound waves and are responsible for *audition* (aw-DIH-shun; *aud-* = "hear"), or the sense of hearing.

Table 13.1 The Sensory Cranial Nerves.

The Motor Cranial Nerves

Oculomotor (III) – 4 of extraocular muscles, pupil constriction, opens eyelid, lens shape

Trochlear (IV) – 1 of extraocular muscles (sup. oblique)

Abducens (VI) – 1 of extraocular muscles (lat. rectus)

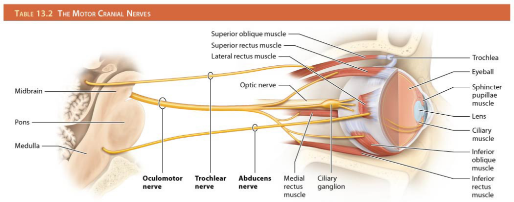
Accessory (XI) – larynx, trapezius, SCM

Hypoglossal (XII) – tongue muscles

- See **Table 13.2** for location and function of these nerves

The Motor Cranial Nerves

TABLE 13.2 THE MOTOR CRANIAL NERVES



Oculomotor (III)

Trochlear (IV)

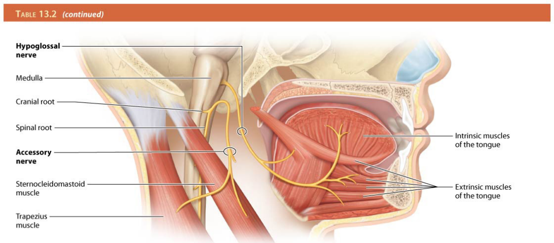
Abducens (VI)

Nerve	Origin and Destination	Function
Oculomotor nerve (III) (ok′-yoo-low-MOW-ter)	*Origin:* Arises from the superior and lateral portion of the midbrain. *Destination:* Extraocular muscles and smooth muscles of the eye (*oculo-* = "eye")	Contains axons of both somatic motor neurons and visceral motor neurons of the parasympathetic nervous system, and has the following four primary functions: • **Moving the eyeball.** As shown above, the somatic motor axons innervate four of the six extraocular muscles that move the eyeball: the medial rectus, superior rectus, inferior rectus, and inferior oblique muscles. It moves our eyes medially, superiorly, inferiorly, and inferolaterally. • **Opening the eye.** Other somatic motor axons innervate the levator palpebrae superioris muscle, which opens the eyelid. • **Constricting the pupil.** The parasympathetic axons innervate a muscle surrounding the pupil called the *sphincter pupillae muscle*. These axons stimulate this muscle to contract, which constricts the pupil and limits the light entering the eye. (Pupil dilation is mediated by a different nerve.) • **Changing the lens shape.** The thickness of the lens (which focuses light on the photoreceptors in the posterior eyeball) is controlled by the ciliary muscle. This muscle is innervated by the parasympathetic axons, which stimulate the ciliary muscle to contract, making the lens rounder for near vision.
Trochlear nerve (IV) (T[illegible]OK-lee-ur)	*Origin:* Originates from the inferior portion of the midbrain. Named for the cartilaginous trochlea through which the tendon of the superior oblique muscle passes. *Destination:* Superior oblique muscle of the eye	As shown above, the somatic motor neurons innervate the superior oblique muscle (a common mnemonic is "SO_4," as it is cranial nerve IV), which moves the eye medially and inferiorly.
Abducens nerve (VI) (a[illegible]DOO-senz)	*Origin:* The cell bodies of the abducens nerve are located in the pons. *Destination:* Lateral rectus muscle of the eye	The somatic motor neurons innervate the lateral rectus muscle. Its name comes from the fact that this muscle abducts the gaze when it turns the eye laterally.

Table 13.2 The Motor Cranial Nerves.

The Motor Cranial Nerves

TABLE 13.2 *(continued)*



Accessary (XI)

Hypoglossal (XII)

Nerve	Origin and Destination	Function
Accessory nerve (XI)	*Origin:* Unique in that its origin has both a cranial component from the medulla and a spinal component from the cervical spinal cord. The somatic motor neurons of the spinal component travel superiorly and enter the cranial cavity through the foramen magnum, after which they merge with the somatic motor neurons of the cranial component. As shown above, the two travel together for only a short distance, after which they diverge. *Cranial Destination:* The cranial component accompanies the vagus nerve (covered in Table 13.3) and innervates certain muscles of the larynx. *Spinal Destination:* The spinal component turns inferiorly and exits the cranial cavity to innervate the trapezius and sternocleidomastoid muscles of the neck and shoulders.	The cranial component of the accessory nerve innervates certain muscles of speech, whereas the spinal component innervates the head and shoulder.
Hypoglossal nerve (XII)	*Origin:* Arises from the inferiormost part of the medulla (see above). *Destination:* As its name suggests, (*hypo-* = "below," *glosso-* = "tongue"), its destination lies inferior to the tongue. It innervates most of the intrinsic and extrinsic muscles of the tongue.	This is a motor nerve that innervates the muscles of the tongue—it plays no role in taste sensation.

Table 13.2 The Motor Cranial Nerves.

The Mixed Cranial Nerves

Trigeminal (V) – supplies skin of face, muscles of mastication

Facial (VII) – facial expressions, taste ant. 2/3 tongue

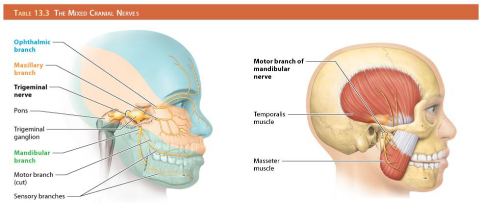
Glossopharyngeal (IX) – taste post. 1/3 tongue, BP changes, swallowing, salivary glands

Vagus (X) – thoracic and abdominal viscera, main nerve of PSN

- See **Table 13.3** for location and function of these nerves

The Mixed Cranial Nerves

TABLE 13.3 THE MIXED CRANIAL NERVES



Trigeminal (V)

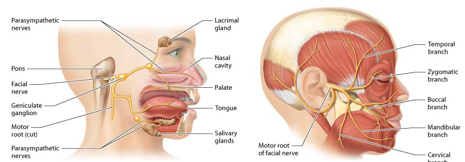
Facial (VII)

Nerve	Origin, Course, and Destination	Sensory Function	Motor Function
Trigeminal (V) (try-JEM-ih-nul)	*Origin:* The motor portion originates at the midbrain and pons junction, and the sensory portion from sensory receptors around the face. *Course:* A short distance from its origin is the large, bulbous **trigeminal ganglion,** which houses the cell bodies of its sensory neurons. Anterior to this ganglion, it splits into three branches (*tri-* = "three"): the *ophthalmic* (off-THAL-mik), *maxillary,* and *mandibular* nerves. *Destinations:* All three branches have sensory fibers that terminate in the primary somatosensory cortex. The mandibular nerve has motor fibers that terminate at the muscles of mastication.	The sensory root detects facial sensation, including stimuli from the oral and nasal cavities. ***Ophthalmic nerve:*** Its somatic sensory axons supply the area shaded blue, shown above, which includes the skin over much of the scalp, the forehead, around the eyes, and over the anterior nose; they also supply the nasal mucosa and structures of the eye. ***Maxillary nerve:*** As shown above, its somatic sensory axons supply the area shaded orange, which includes the skin over the middle of the face. ***Mandibular nerve:*** The sensory axons of the inferior mandibular nerve supply the area shaded green in the illustration above, which includes the skin of the chin and the lateral part of the face.	***Ophthalmic nerve:*** No motor function. ***Maxillary nerve:*** No motor function. ***Mandibular nerve:*** Shown above, its motor axons supply the masseter and temporalis muscles, which elevate the mandible (close the jaw) during mastication (chewing) and swallowing.
Facial nerve (VII)	*Origin:* As shown in the illustrations on the next page, the motor portion (or *motor root*) originates in nuclei in the pons and medulla, and the sensory portion (or *sensory root*) from the tongue, external ear, palate, and nasal cavity. *Course:* Several ganglia house cell bodies of the facial nerve's sensory root; the largest is called the **geniculate ganglion** (jen-IK-yoo-lat).	The sensory root provides the following: • taste sensation from chemoreceptors in specialized receptor cells in the mucosa of the anterior two-thirds of the tongue; and • somatic sensation from the external ear, palate, and nasal cavity.	The somatic motor neurons of the five branches of the motor root supply the muscles of facial expression and other facial muscles.

Table 13.3 The Mixed Cranial Nerves.

The Mixed Cranial Nerves

TABLE 13.3 (continued)



Facial nerve: mixed sensory and visceral motor roots **Facial nerve: motor function**

Facial, con't.

Nerve	Origin, Course, and Destination	Sensory Function	Motor Function
Facial nerve (VII) *(continued)*	*Sensory Destination:* Various somatosensory areas of the cerebral cortex. *Motor Destination:* As shown above, these neurons innervate the muscles of facial expression as well as several other facial and neck muscles. The motor root splits into five branches: the *temporal, zygomatic, buccal, mandibular,* and *cervical nerves* (a common mnemonic is "**T**o **Z**anzibar **B**y **M**otor **C**ar").		In addition, the parasympathetic neurons trigger secretion from certain salivary glands in the mouth, the lacrimal (tear) glands over the eye, and the nasal mucous glands.
Glossopharyngeal nerve (IX) (gloss'-oh-fah-RIN-jee-ul)	*Origin:* The motor neurons originate in nuclei in the medulla; the sensory neurons originate in the tongue, pharynx, around the ear, and in blood vessels of the neck. *Course:* The cell bodies of its sensory neurons are located in two ganglia: the *superior ganglion* and the *inferior ganglion.* *Destination:* Its location and the structures it innervates are reflected in its name—recall that *glosso-* means "tongue" and *pharynx* means "throat."	The sensory portion of this nerve detects sensation as follows: • The chemoreceptors of the posterior one-third of the tongue are associated with special sensory axons of this nerve. The cell bodies of these neurons are in the inferior ganglion. • A small branch of this nerve contains somatic sensory neurons that innervate the external ear alongside the facial nerve. It also contains visceral sensory neurons that provide sensation for the posterior pharynx and surrounding structures. In addition, certain visceral neurons detect changes in blood pressure via receptors in the carotid artery of the neck.	The motor branches of this nerve supply a muscle around the pharynx that is responsible for swallowing movements. Also, parasympathetic neurons trigger salivation from the salivary gland called the *parotid gland.* You can feel this stimulation and subsequent salivation in your cheeks when you eat very salty or acidic foods such as pickles or lemons.

Glossopharyngeal (IX)

(continued)

Table 13.3 The Mixed Cranial Nerves.

The Mixed Cranial Nerves

TABLE 13.3 THE MIXED CRANIAL NERVES (continued)

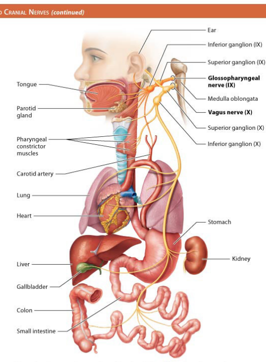


Illustration is not to scale; orange is used simply to distinguish the glossopharyngeal nerve.

Nerve	Origin, Course, and Destination	Sensory Function	Motor Function
Vagus nerve (X)	*Origin:* The motor neurons originate from the brain at the medulla. The sensory neurons originate around the tongue, pharynx, skin of the ear, and certain blood vessels of the neck. *Course:* As shown above, cell bodies of its sensory neurons are housed in the *superior ganglion* and the *inferior ganglion.* *Destination:* It is the main parasympathetic nerve, and the most widely distributed nerve in the body (see above). It innervates both the throat and anterior neck, and nearly all of the thoracic and abdominal viscera.	The somatic sensory neurons serve the skin around the ear. The special sensory neurons convey taste sensation from the pharynx, and the visceral sensory neurons detect sensation in the mucous membranes of the pharynx. This nerve also contains visceral sensory neurons whose chemoreceptors detect the blood CO_2 concentration.	The somatic motor fibers supply the muscles surrounding the pharynx and larynx (the "voice box") that contract during speaking and swallowing. We continue our discussion of the visceral innervation of this nerve in the ANS chapter (see Chapter 14).

Vagus (X)

Table 13.3 The Mixed Cranial Nerves.

Overview of Cranial Nerves

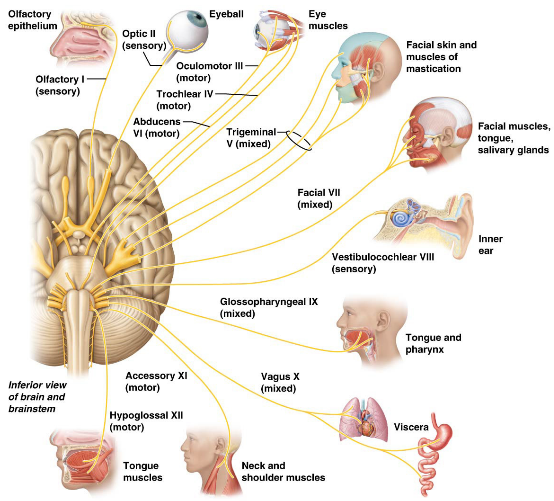


Figure 13.3 Overview of cranial nerves.

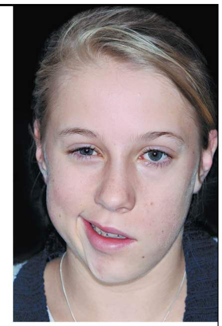
Trigeminal Neuralgia (*p. 489)*

Trigeminal neuralgia (tic douloureux)

– chronic pain syndrome

- involves one or more branches of *trigeminal nerve* ***(CN V)***
- Certain stimuli may *trigger attacks* (chewing, light touch, vibrations
- Cause: idiopathic
- Treatment: pain medications, sever nerve

Bell's Palsy *(p. 489)*



- Facial nerve ***(CN VII)***

Cause: virus, tumor, trauma, or *idiopathic*

Weakness or complete paralysis of facial muscles (unilateral)

Treatment - *anti-inflammatory medication*, *antiviral medication*, *PT*, and *surgery*; even without treatment, many individuals recover function of paralyzed muscles in about 3 weeks

Study Boost: Cranial Nerves

Oh Once One Takes The Anatomy Final Very Good Vacations Are Happening

- **O**h (I, **O**lfactory) **O**nce (II, **O**ptic) **O**ne (III, **O**culomotor) **T**akes (IV, **T**rochlear) **T**he (V, **T**rigeminal) **A**natomy (VI, **A**bducens) **F**inal (VII, **F**acial) **V**ery (VIII, **V**estibulocochlear) **G**ood (IX, **G**lossopharyngeal) **V**acations (X, **V**agus) **A**re (XI, **A**ccessory) **H**appening (XII, **H**ypoglossal)

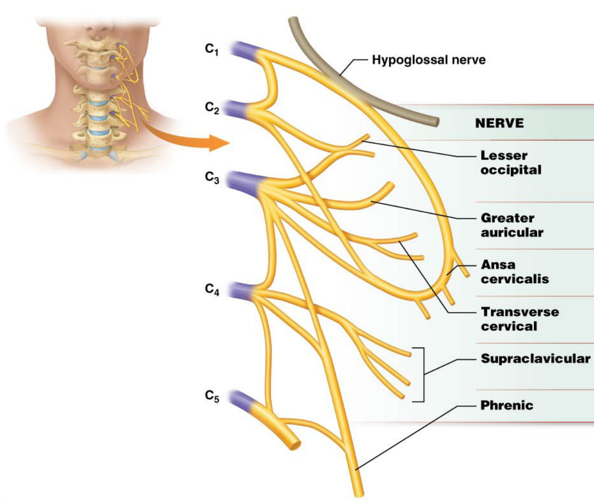
- Remember that you have one nose (I, olfactory) and two eyes (II, optic)

Study Boost: Remembering the Cranial Nerves

Popular mnemonic cranial nerves by their *main function*: ***Some Say Money Matters But My Brother Says Big Brains Matter More***

- Some (I, Olfactory—**S**ensory) **S**ay (II, Optic—**S**ensory) **M**oney (III, Oculomotor—**M**otor) **M**atters (IV, Trochlear—**M**otor) **B**ut (V, Trigeminal—**B**oth) **M**y (VI, Abducens—**M**otor) **B**rother (VII, Facial—**B**oth) **S**ays (VIII, Vestibulocochlear—**S**ensory) Big (IX, Glossopharyngeal—**B**oth) **B**rains (X, Vagus—**B**oth) **M**atter (XI, Accessory—**M**otor) **M**ore (XII, Hypoglossal—**M**otor)
- *Look closely at names: oculomotor, broken into its two components, oculo-, which means "eye," and - motor, which means "movement"*

Cervical Plexuses



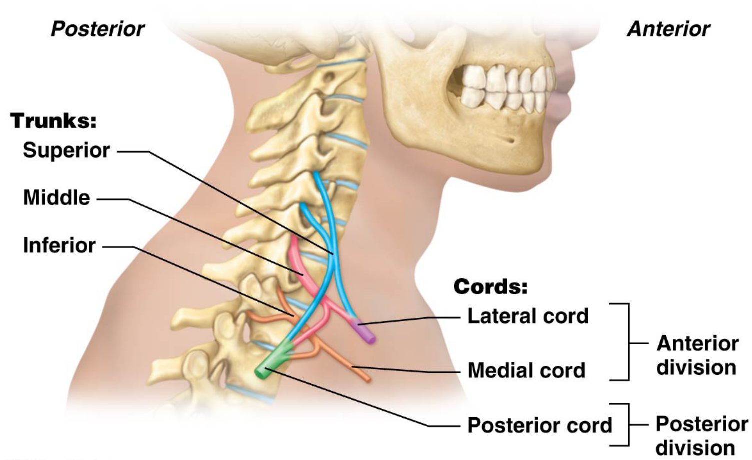
NERVE	NERVE ROOT(S)	STRUCTURES INNERVATED
Lesser occipital	C_2	• Sensory to the skin on the scalp and posterior part of the ear
Greater auricular	C_2–C_3	• Sensory to the skin on the ear
Ansa cervicalis	C_1–C_3	• Motor to the geniohyoid and infrahyoid muscles
Transverse cervical	C_2–C_3	• Sensory to the skin on the superior chest and shoulder
Supraclavicular	C_3–C_4	• Sensory to the skin on the superior chest and shoulder
Phrenic	C_3–C_5	• Motor to the diaphragm

Figure 13.6 The cervical plexus.

A Hiccup Cure That Really Works *(p. 498)*

- **Hiccups** –*spasms* of diaphragm that cause a *forceful inhalation* of air
- **phrenic nerve remedy:**
  Place fingers ~ 1 cm lateral to vertebral column level of C3-C5
  Apply *firm pressure* to muscles of neck that overlie phrenic nerve until hiccups stop, in about 5–10 seconds

Brachial Plexuses



Brachial Plexuses

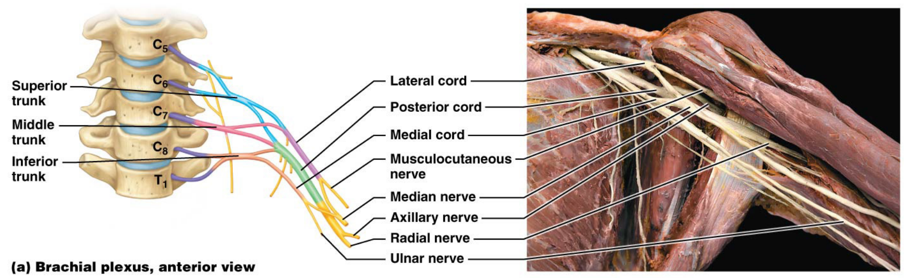
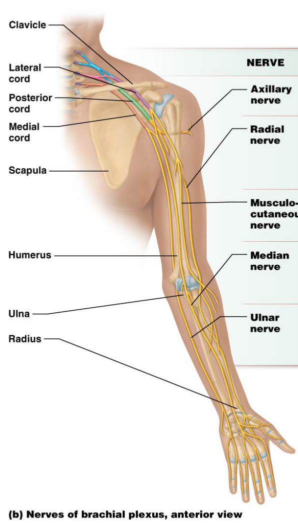


Figure 13.7a The brachial plexus.

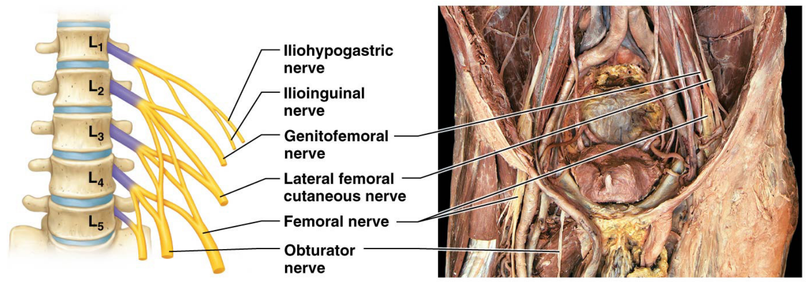
Brachial Plexuses



NERVE	NERVE ROOTS	STRUCTURES INNERVATED
Axillary nerve	C_5–C_6, branch of the posterior cord	• Motor to the deltoid and teres minor muscles • Sensory to the skin over the deltoid
Radial nerve	C_5–T_1, continuation of the posterior cord	• Motor to the triceps brachii, brachioradialis, and the extensor muscles of the forearm and digits • Sensory to the posterior arm and forearm, posterior thumb, and posterior second, third, and lateral half of the fourth digits
Musculo-cutaneous nerve	C_5–C_7, continuation of the lateral cord	• Motor to the biceps brachii, coracobrachialis, and brachialis muscles • Sensory to the lateral forearm
Median nerve	C_5–T_1, from the fusion of the medial and lateral cords	• Motor to most of the muscles that flex the wrist and digits and certain muscles of the hand • Sensory to the anterior thumb and the anterior second, third, and lateral side of the fourth digits
Ulnar nerve	C_8–T_1, continuation of the medial cord	• Motor to certain forearm flexors and most of the intrinsic hand muscles • Sensory to the fifth digit and the medial half of the fourth digit

Figure 13.7b The brachial plexus.

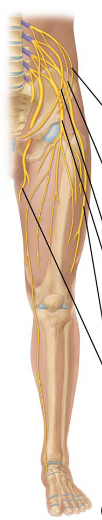
Lumbar Plexuses



(a) Lumbar plexus, anterior view

Figure 13.8a The lumbar plexus.

Lumbar Plexuses

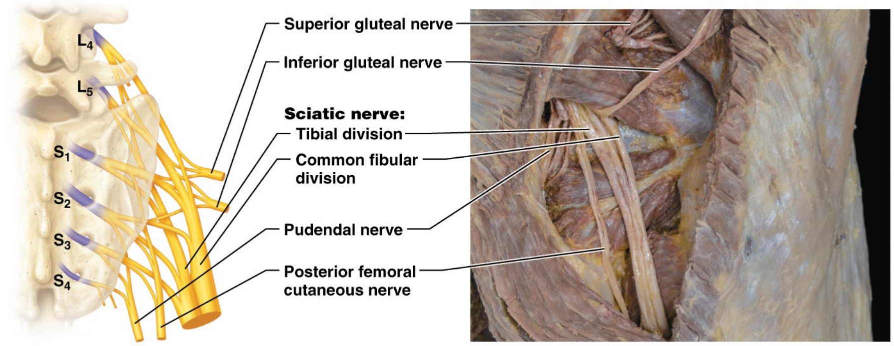


NERVE	NERVE ROOTS	STRUCTURES INNERVATED
Iliohypogastric nerve	L_1	• Motor to the transversus abdominus and internal oblique muscles • Sensory to the skin over the lateral gluteal region and the suprapubic region
Ilioinguinal nerve	L_1	• Motor to the transversus abdominus and internal oblique muscles • Sensory to the medial thigh, scrotum (males), and labia majora (females)
Genitofemoral nerve	L_1–L_2	• Motor to the cremaster muscle (males) • Sensory to the anteromedial thigh, scrotum (males), and labia majora (females)
Femoral nerve	L_2–L_4, posterior division	• Motor to the quadriceps femoris, iliopsoas, and sartorius muscles • Sensory to the anterior thigh, medial thigh, medial leg, and foot
Lateral femoral cutaneous nerve	L_2–L_3	• Sensory to the anterolateral thigh
Obturator nerve	L_2–L_4, anterior division	• Motor to the thigh adductors and gracilis muscle • Sensory to the superomedial thigh

(b) Nerves of lumbar plexus, anterior view

Figure 13.8b The lumbar plexus.

Sacral Plexuses



(a) Sacral plexus, posterior view

Figure 13.9a The sacral plexus.

Sacral Plexuses

NERVE	NERVE ROOTS	STRUCTURES INNERVATED
Superior gluteal nerve	L_4–S_1	• Motor to the gluteus medius, gluteus minimus, and tensor fasciae latae muscles
Inferior gluteal nerve	L_5–S_2	• Motor to the gluteus maximus muscle
Pudendal nerve	L_4–S_3	• Sensory to the hip joint
Posterior femoral cutaneous nerve	S_2–S_4	• Motor to the muscles of the pelvic floor, the external anal sphincter, and the external urethral sphincter • Sensory to the skin of the external genitalia
Sciatic nerve	S_1–S_3	• Sensory to the skin of the posterior thigh
Common fibular nerve	L_4–S_2, terminal branch of sciatic nerve	• Motor to the lateral leg muscles (superficial branch), the anterior leg muscles, and two foot muscles (deep branch) • Sensory to the knee joint, the skin of the anteroinferior leg, and the dorsum of foot
Tibial nerve	L_4–S_3, terminal branch of sciatic nerve	• Motor to the hamstring muscles, posterior leg muscles, and plantar foot muscles • Sensory to the knee joint, ankle joint, skin of the posterior and lateral leg (via the sural nerve), and skin of the plantar surface of the foot

(b) Nerves of sacral plexus, posterior view

Figure 13.9b The sacral plexus.

Classification of Sensory Receptors

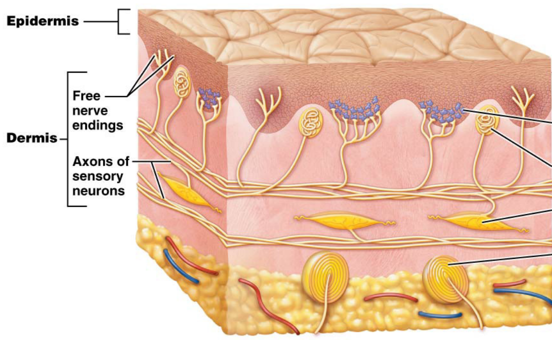
- Based on *location of stimuli* they detect:
  - **Exteroceptors** – detect stimuli originating from *outside* body (thermoreceptors, chemoreceptors, photoreceptors)
  - **Interoceptors** – detect stimuli originating from *within* body itself (chemoreceptors)

  - **Mechanoreceptors** - depolarize in response to anything that *mechanically deforms tissue (vibration*, *light touch*, *stretch*, and *pressure)*

Classification of Sensory Receptors

- **Merkel cell fibers**
  - Found in *epidermal ridges* of especially *fingertips*
  - Detect *discriminative touch stimuli* (object form and texture)
- **Tactile corpuscles (Meissner corpuscles)**
  - Dermal papillae
  - touch
- **Ruffini endings**
  - ________
- **Lamellated corpuscles (Pacinian corpuscles)**
  - __________

Classification of Sensory Receptors



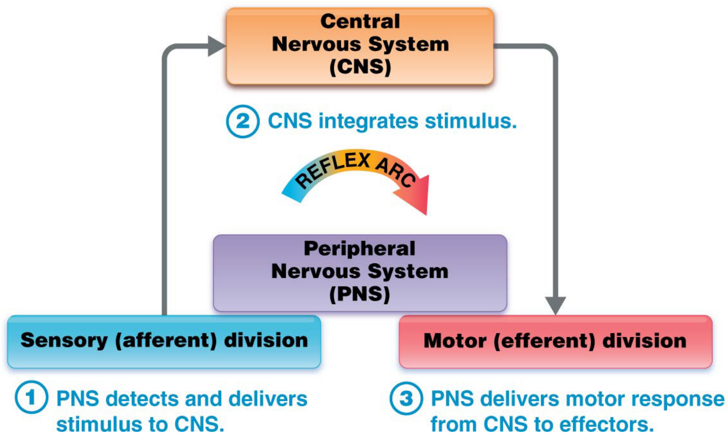
MECHANORECEPTOR	FUNCTION
Merkel cell fiber	Discriminative touch with fine spatial resolution
Tactile corpuscle	Discriminative touch with less spatial resolution
Ruffini ending (bulbous corpuscle)	Stretch and movement
Lamellated corpuscle	Vibration and deep pressure

Figure 13.12 Mechanoreceptors in the skin.

Reflex Arcs

- **Reflexes** – pre-*programmed*, *automatic responses* to stimuli; **reflex arc**
- Reflexes begin with a *sensory stimulus* and finish with a rapid *motor response*
  - *Neural integration* between sensory stimulus and motor response occurs in CNS, at *spinal cord* or *brainstem*

Reflex Arcs

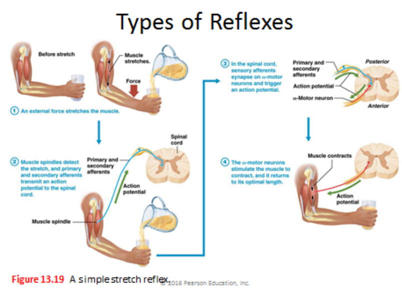


Types of Reflexes

- Reflexes can be classified by at least two criteria (**Figures 13.19, 13.20**):
  - *Number of synapses* that occur between neurons involved in arc
  - *Type of organ* in which reflex takes place, either visceral or somatic
- Simplest reflex arcs (________________) involve only a single synapse within SC between a sensory and motor neuron; more complicated types of reflex arcs (**polysynaptic reflexes**) involve multiple synapses

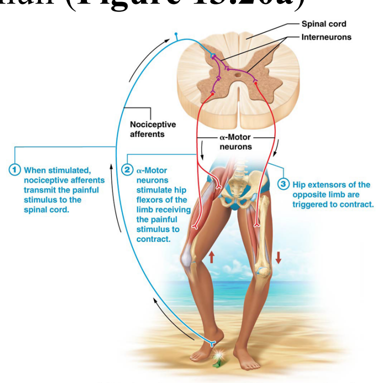
Types of Reflexes

- **Simple stretch reflex**
  - Body's reflexive response to stretching of muscle to shorten it back to within its "*set*" *optimal length*
  - **Patellar (knee-jerk) reflex**



Types of Reflexes

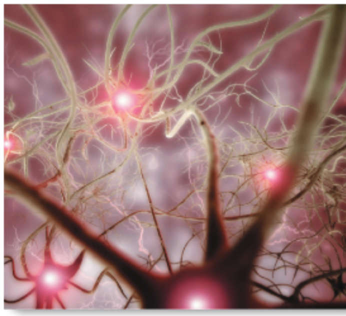
- **Flexion (withdrawal) reflex** (**Figure 13.20**):
  - **Flexion or withdrawal reflex** : act to *withdraw limb* from painful stimuli (**Figure 13.20a**)



Amyotrophic Lateral Sclerosis *(p. 513)*

(**ALS)** aka **Lou Gehrig's disease**

- *degeneration* of cell bodies of *motor neurons* in anterior horn of SC
- Most common early feature of disease is *muscle weakness*
- Death usually in ~5 years of disease's onset
- *No cure or treatment* that prevents disease progression



14 The Autonomic Nervous System and Homeostasis

ANS = involuntary arm of **PNS**

- aka _____________
- two divisions:
  - **sympathetic (SNS)**
  - **parasympathetic** (PSN)
- maintain _____________

Functions of the ANS and Visceral Reflex Arcs

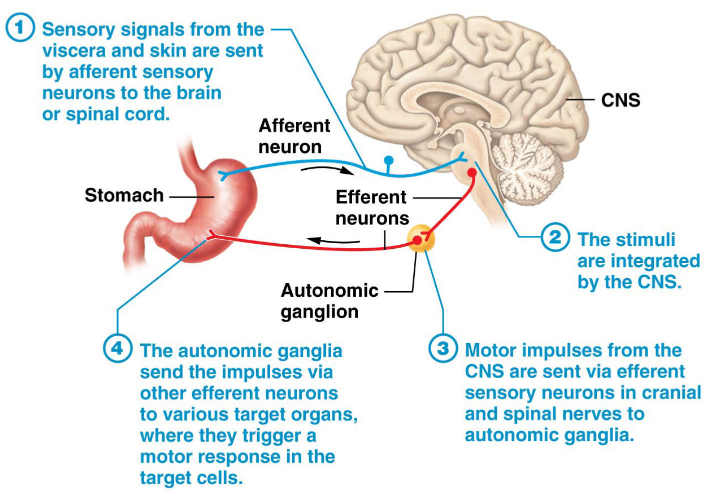


Figure 14.1 Visceral reflex arcs.

Comparison of Somatic and Autonomic Nervous Systems

- Motor divisions of PNS (**Figure 14.2**):
  - **Somatic motor division →** ___________ (conscious control)
  - **Autonomic motor division →** ________ muscle, _________ muscle, and glands (*involuntary)*

- ANS motor neurons require a two-neuron circuit:
Preganglionic neuron – release *ACh*
Postganglionic neuron – release *ACh or NEpi*

Comparison of Somatic and Autonomic Nervous Systems

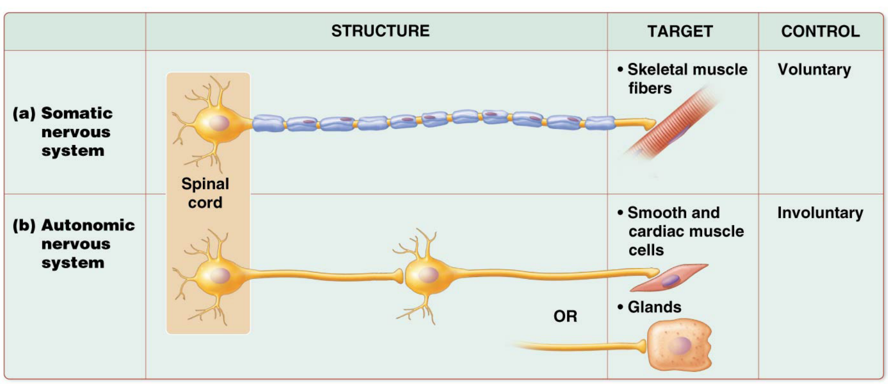


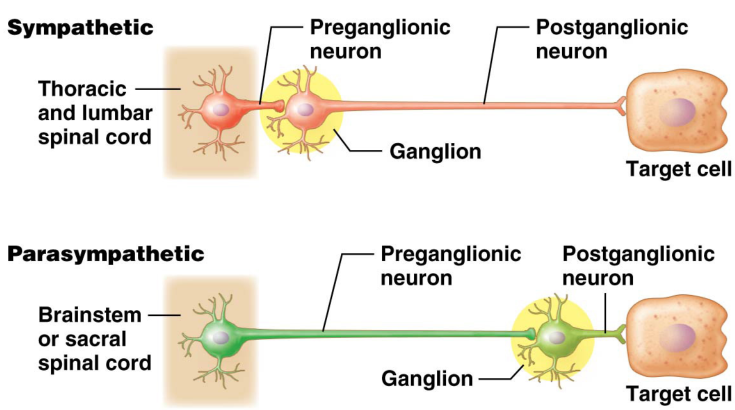
Figure 14.2 Comparison of the somatic and autonomic nervous systems.

Divisions of the ANS

Main *structural* and *functional* differences between SNS and PSN:

- **Sympathetic nervous system** – preganglionic axons are usually *short* and postganglionic axons are usually *long*
- **Parasympathetic nervous system** – preganglionic parasympathetic axons are *long* while postganglionic axons are *short*

Divisions of the ANS



Divisions of the ANS

- **Sympathetic nervous** (SNS)
  - **thoracolumbar division**
  - **Sympathetic ganglia** located *near SC*
  - "**Fight or flight**" division of ANS; prepares body for *emergency situations*

Divisions of the ANS

- **Parasympathetic nervous system**
  - **Craniosacral division**
  - **Cranial nerves** →*head* and *neck*, *thoracic viscera*, and <u>most</u> *abdominal viscera*
  - "**Rest and digest**" division; role in *digestion* and maintain body's homeostasis at *rest*
  - Postganglionic neurons located *near target organ*; requires only a <u>short</u> axon to connect

Divisions of the ANS

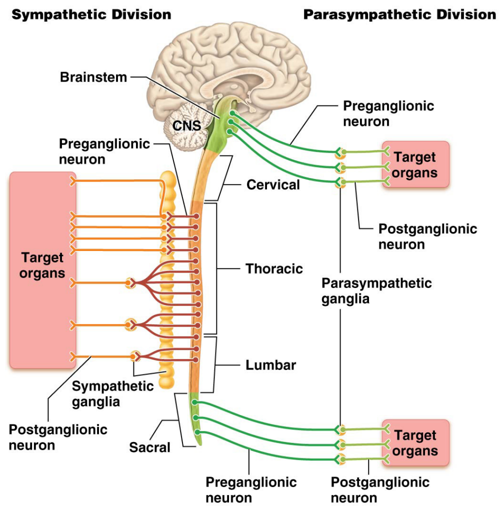
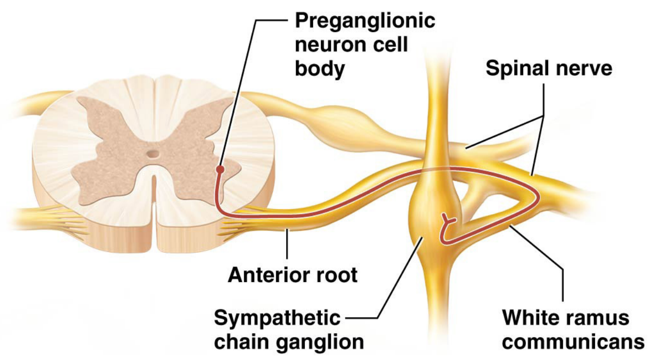


Figure 14.3 Overview of the structure of ANS divisions.

Gross and Microscopic Anatomy of Sympathetic Nervous System



Gross and Microscopic Anatomy of Sympathetic Nervous System

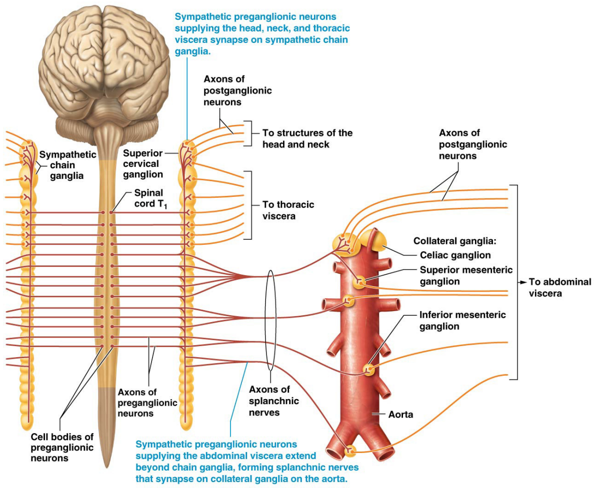


Figure 14.4 Organization of the sympathetic nervous system.

Gross and Microscopic Anatomy of Sympathetic Nervous System

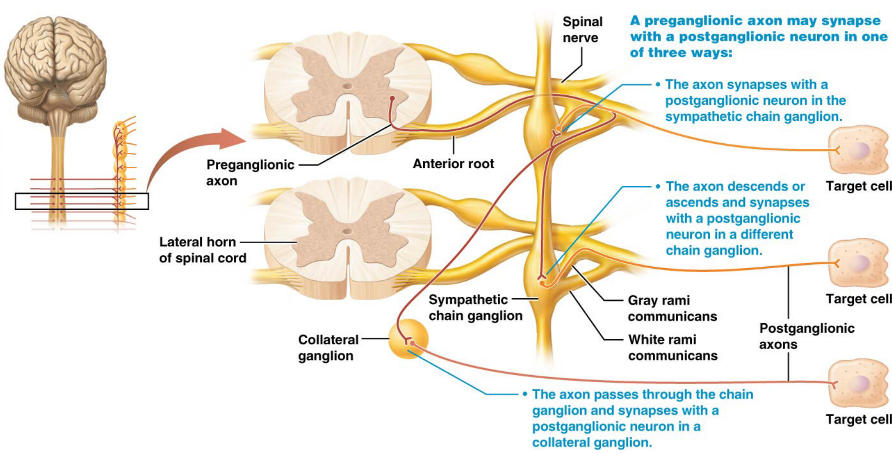


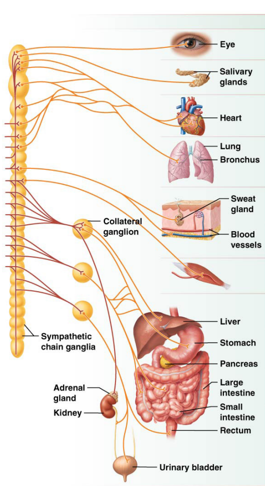
Figure 14.5 Three possible pathways of sympathetic preganglionic and postganglionic neurons.

Effects of SNS on Target Cells

Effects of **SNS** on target cells:
– directed at ensuring *survival* and maintenance of homeostasis during time of *physical* or *emotional stress*

- **Cardiac muscle cells→ _____ HR and** *force* of contraction
- **VC of blood vessels →**digestive, urinary, & integumentary
- **__________ of bronchioles**
- **VD to skeletal & cardiac muscle**
- **Constriction of sphincters →** urinary & digestive
- **___________ of smooth muscle of digestive tract**
- **Dilation of pupils**
- **Increased sweating**

Effects of Sympathetic Nervous System on Target Cells



TARGET	NT	RECEPTOR	MAIN EFFECTS
Smooth muscle cells around pupil	NE	α_1	Dilation of pupil
Cells of salivary glands	NE	β_1 and β_2	Increase in secretion in certain cells
Cardiac muscle cells	NE	β_1	Increase in heart rate and force of contraction
Smooth muscle cells of bronchus	NE	β_2	Dilation of bronchioles (bronchodilation)
Cells of sweat glands	ACh	Muscarinic	Increase in secretion
Smooth muscle cells of blood vessels to skin	NE	α_1	Constriction of blood vessels (vasoconstriction)
Smooth muscle cells of blood vessels to skeletal muscles	NE	β_2	Dilation of blood vessels (vasodilation)
Smooth muscle cells of blood vessels to digestive and urinary organs	NE	α_1	Vasoconstriction
Smooth muscle cells of digestive and urinary tracts and sphincters	NE	α_1 (sphincters) β_3 (digestive) β_2 (urinary)	Relaxation of digestive and urinary tracts, contraction of sphincters
Cells of digestive glands	NE	β_2	Decrease in secretion
Cells of pancreas and liver	NE	β_2	Increase in release of glucose
Cells of adrenal medulla	ACh	Nicotinic	Release of epinephrine and norepinephrine

Figure 14.7 The main effects of the sympathetic nervous system on target cells.

Gross and Microscopic Anatomy PSN

"**Rest and digest**" division of ANS

- Role in *maintenance functions* - digestion and urine formation
- **Craniosacral div.**
- **PSN cranial nerves – oculomotor** (CN III), **facial** (CN VII), **glossopharyngeal** (CN IX), and **vagus** (CN X) nerves

Gross and Microscopic Anatomy of Parasympathetic Nervous System

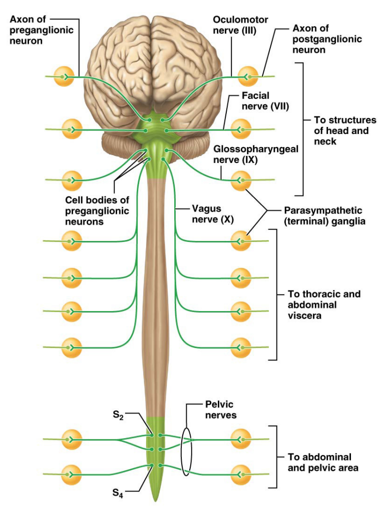


Figure 14.9 Organization of the parasympathetic nervous system.

Effects of PSN on Target Cells

- **Cardiac muscle cells - ___________** *HR* & BP
- **Bronchoconstriction**
- **SMC contraction along digestive tract** –
  _____________ peristalsis
- **Relaxation of digestive and urinary sphincters**
  → promotes *urination* and *defecation*
- **Engorgement of penis or clitoris**
- **Increased salivation, lacrimation, and digestive enz.**

Effects of Parasympathetic Nervous System on Target Cells

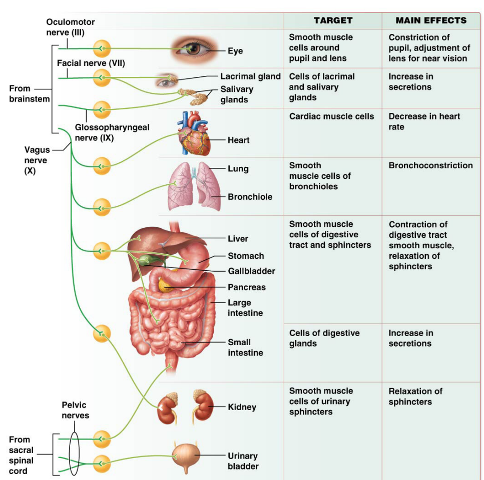


Figure 14.10 The main effects of parasympathetic nervous system on target cells.

Interactions of Autonomic Divisions

- Sympathetic and parasympathetic divisions work *together* to keep many of body's functions within their normal homeostatic ranges (**Figure 14.11**)
  - **dual innervation**
  - Dual innervation allows **SNS** to become dominant and trigger effects that maintain homeostasis during *physically demanding periods*
  - **PSN** division regulates same organs, preserving homeostasis <u>between</u> periods of increased physical activity

Interactions of Autonomic Divisions

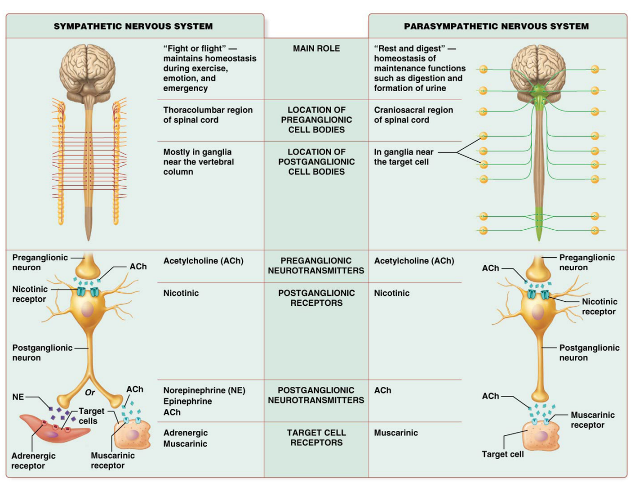


Figure 14.11 Comparison of sympathetic and parasympathetic nervous system structures and effects.

Summary of Nervous System Control of Homeostasis

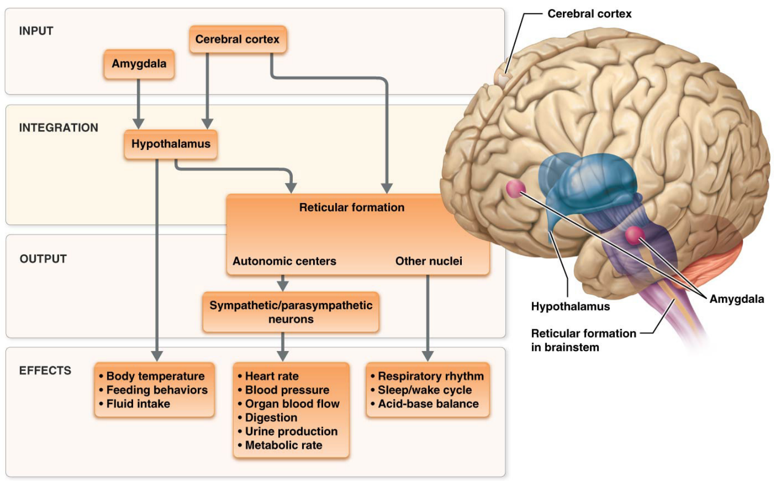


Figure 14.12 Summary of nervous system control of homeostasis.

A&P in the Real World

Postural Orthostatc Tachycardia Syndrome
(p. 534)

- **Postural orthostatic tachycardia syndrome** (**POTS**) –
  - increase in *heart rate* (known as **tachycardia**) when an individual moves from lying or sitting down to *standing up*; VD → BP drop due to drop due to gravity

Symptoms (from low blood pressure)

- include dizziness and lightheadedness
- fatigue, and thirst
- shortness of breath, chest pain, cold extremities, and muscle weakness

Cause: excessive *SNS activity*

Treatment: dietary modifications such as increasing water and salt intake