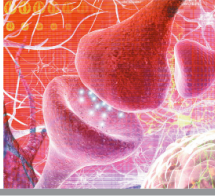


**11**

## Introduction to the Nervous System and Nervous Tissue

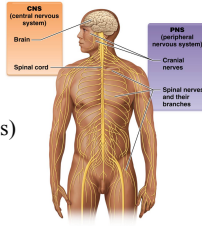


**Nervous system** – controls our *perception* and *experience* of world  
 Directs \_\_\_\_\_  
 Seat of *consciousness, personality, learning*, and \_\_\_\_\_  
 Regulates \_\_\_\_\_

## Anatomical Divisions of the Nervous System

**[2 Anatomical Div. = CNS, PNS]**

- CNS – includes \_\_\_\_\_ and \_\_\_\_\_
- PNS – consists of all nerves in body outside protection of skull and vertebral column (\_\_\_\_\_ nerves, \_\_\_\_\_ nerves)



## Functional Divisions of the Nervous System

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

- Sensory functions**
  - \_\_\_\_\_ gather information about internal and external environments
  - **afferent division** carries information toward CNS

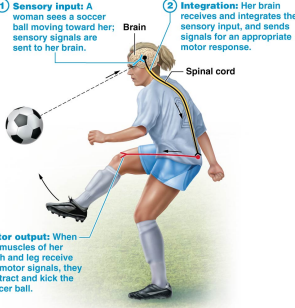
- Somatic sensory division**
  - signals from skeletal muscles, bones, joints, and skin;
  - **special sensory div.** (vision, hearing, taste, smell, and balance)
- Visceral sensory division**
  - signals from \_\_\_\_\_ (organs)

## Functional Divisions of the Nervous System

- Integrative functions** – *analyze* and *interpret* incoming \_\_\_\_\_ and determine *response*
- Motor functions**
  - actions performed in response to integration
  - \_\_\_\_\_ carries information away from CNS

- somatic** nervous system – information to skeletal muscle
- autonomic** nervous system (ANS) – information to smooth muscle, cardiac muscle, glands

## Functional Divisions of the Nervous System



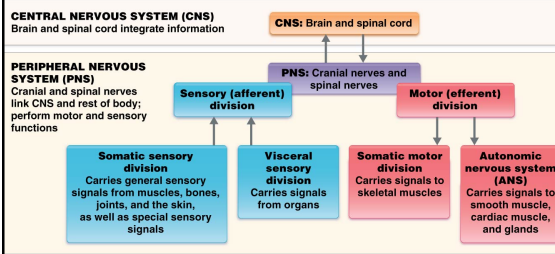
① **Sensory input:** A woman sees a soccer ball moving toward her; sensory signals are sent to her brain.

② **Integration:** Her brain receives and integrates the sensory input, and sends signals for an appropriate motor response.

③ **Motor output:** When the muscles of her thigh and leg receive the motor signals, they contract and kick the soccer ball.

**Figure 11.2** Functions of the nervous system.

## Functional Divisions of the Nervous System



**CENTRAL NERVOUS SYSTEM (CNS)**  
Brain and spinal cord integrate information

**CNS:** Brain and spinal cord

**PERIPHERAL NERVOUS SYSTEM (PNS)**  
Cranial and spinal nerves link CNS and rest of body; perform motor and sensory functions

**PNS:** Cranial nerves and spinal nerves

**Sensory (afferent) division**

- Somatic sensory division**  
Carries general sensory signals from muscles, bones, joints, and the skin, as well as special sensory signals
- Visceral sensory division**  
Carries signals from organs

**Motor (efferent) division**

- Somatic motor division**  
Carries signals to skeletal muscles
- Autonomic nervous system (ANS)**  
Carries signals to smooth muscle, cardiac muscle, and glands

**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)

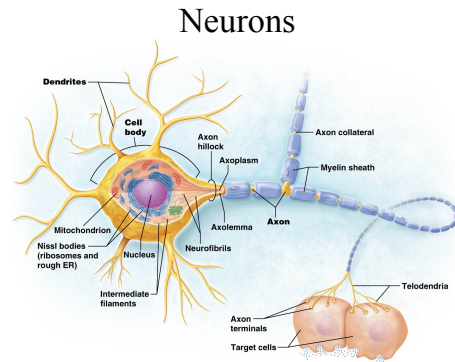
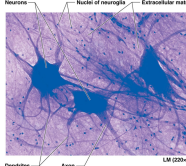


Figure 11.5 Neuron structure.



## 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

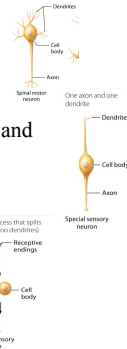
## Classification of Neurons

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 dendrites (see diagram) | One axon and one dendrite (see diagram)                                      | Single short process that splits into two axons (no dendrites) (see diagram)     |
| 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

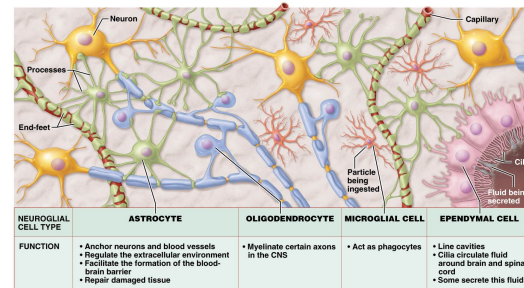
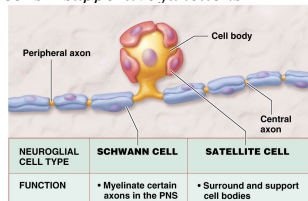


Figure 11.6 Neuroglial cells of the CNS.

## Neuroglia

- **PNS:**
  - **Schwann cells** – produce \_\_\_\_\_
  - **Satellite cells** – *supportive functions*



## The Myelin Sheath

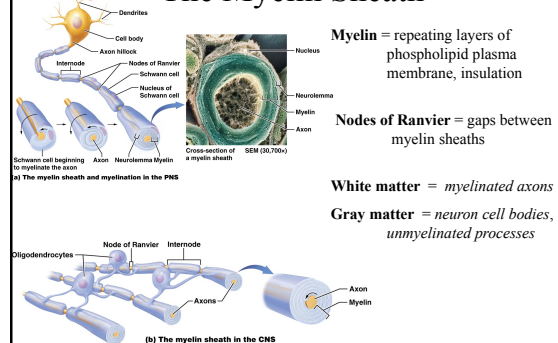


Figure 11.8a The myelin sheath in the PNS and CNS.

### Regeneration of Nervous Tissue

Regeneration nearly *nonexistent* in CNS and is limited in PNS

- Regeneration steps:
  1. Degeneration of axon and myelin sheath \_\_\_\_\_ to injury (**Wallerian degeneration**)
  2. Growth processes from proximal 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

| Type of Channel    | Structure                     | Stimulus for Opening/Closing                                       |
|--------------------|-------------------------------|--------------------------------------------------------------------|
| Leak Channel       | ECF, Plasma membrane, Cytosol | None; always open                                                  |
| Ligand-Gated       | ECF, Plasma membrane, Cytosol | Binding of a ligand to a receptor associated with the channel      |
| Voltage-Gated      | ECF, Plasma membrane, Cytosol | Voltage changes across the plasma membrane                         |
| Mechanically-Gated | ECF, Plasma membrane, Cytosol | Mechanical deformation of the channel (by stretch, pressure, etc.) |

Open in response to specific chemical binding

Open or close due to changes in voltage across PM

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)

ECF

Plasma membrane (PM)

Cytosol

Voltmeter

-70 mV

**Figure 11.11** Measurement of the voltage across a plasma membrane.

### Principles of Electrophysiology

ECF

Plasma membrane

Cytosol

Na<sup>+</sup>

K<sup>+</sup>

Na<sup>+</sup>/K<sup>+</sup> pump

K<sup>+</sup> leak channel

Na<sup>+</sup> leak channel

Voltmeter

-70 mV

Ion concentration gradients (due to the activity of the Na<sup>+</sup>/K<sup>+</sup> pump) favor diffusion of K<sup>+</sup> out of the cell and Na<sup>+</sup> into the cell.

Favored direction of K<sup>+</sup> diffusion

Favored direction of Na<sup>+</sup> diffusion

These two factors cause the cytosol to lose more positive charges than it gains, leading to the negative resting membrane potential.

K<sup>+</sup> diffuse through leak channels more easily than do Na<sup>+</sup>.

**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<sup>+</sup> outside > Na<sup>+</sup> inside

K<sup>+</sup> inside > K<sup>+</sup> outside

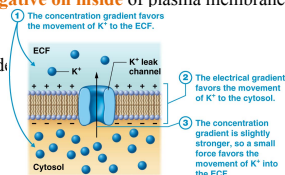
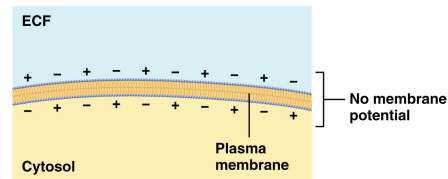


Figure 11.13 The electrochemical gradient for potassium ions.

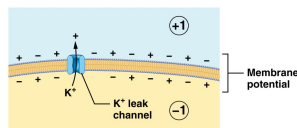
## How Do Positive Ions Create a Negative Resting Membrane Potential

- 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

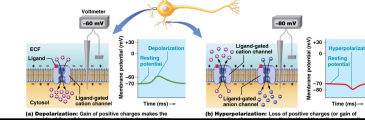


- Six positive charges are now outside membrane and four positive charges inside; makes overall charge inside **cytosol -1** and in **extracellular fluid +1**—a *membrane potential* has been created
- Imagine that *many thousands* of potassium ions exit through leak channels; causes membrane potential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

## Principles of Electrophysiology

Changes in Resting Membrane Potential: Ion Movements:

- Depolarization** — Na<sup>+</sup> channels open, \_\_\_\_\_; membrane potential becomes *more positive*
- Repolarization** — K<sup>+</sup> ion channels open; \_\_\_\_\_; cell becomes *more negative*, returning to RMP
- Hyperpolarization** — cell becomes *more negative* than normal RMP due to efflux of K<sup>+</sup> plus influx of Cl<sup>-</sup>



## Review

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

- Sodium rushes into the neuron
- Cell becomes less polarized
- Cell depolarizes
- Interior of cell becomes more negative

## Review

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

- Potassium rushes into the neuron
- Cell becomes more polarized
- Cell repolarizes
- Interior of cell becomes more negative

### Review

Which of the following is TRUE regarding membrane hyperpolarization?

- Potassium rushes into the neuron
- Cell becomes less polarized than at rest
- May result from chloride ion influx
- Interior of cell becomes more positive

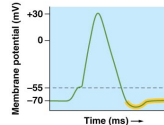
### Local Potentials

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

- May cause:
  - Depolarization** – *positive charges* enter cytosol & make membrane potential less negative \_\_\_\_\_
  - Hyperpolarization** – either *positive charges* exit or *negative charges* enter cytosol; makes membrane potential more negative \_\_\_\_\_
- Sometimes called **graded potentials** because *vary in size*

### Action Potentials

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



### Review

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

- Repolarization
- Hypopolarization
- Depolarization
- Hyperpolarization

### Review

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

- Repolarization, depolarization, hyperpolarization
- Depolarization, hyperpolarization, repolarization
- Depolarization, repolarization, hyperpolarization
- Hyperpolarization, depolarization, repolarization

### Review

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

- Gradients
- Cell to cell communication
- Structure vs function
- 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



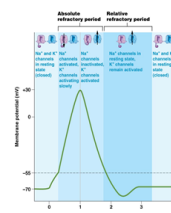
## Local Anesthetic Drugs (p. 400)

- **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

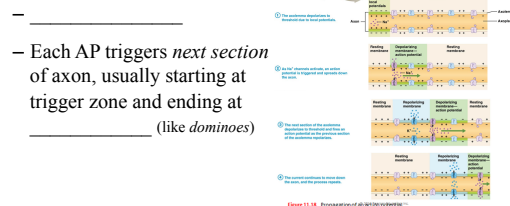
**Graded local potentials** produce *variable changes* in membrane potentials

**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 **not dependent on strength, frequency, or length of stimulus** like local potentials

## Propagation of Action Potentials

APs **conducted (propagated)** along **entire** length of axon = **nerve impulse**



### 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 self-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** – \_\_\_\_\_ increase speed of conduction; AP only depolarize *nodes of Ranvier* and “jump over” *internodes*

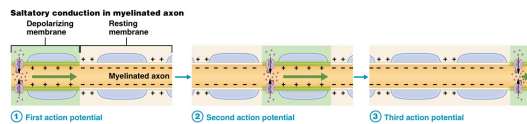


Figure 11.19 Comparison of saltatory and continuous conduction.

## Propagation of Action Potentials

- **Continuous conduction** – in **unmyelinated axons** every section of axolemma from trigger zone to axon terminal \_\_\_\_\_ propagate AP; slower conduction speed

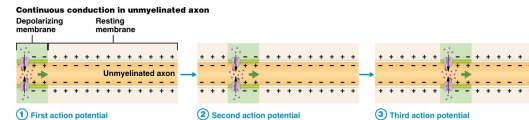


Figure 11.19 Comparison of saltatory and continuous conduction.

## Propagation of Action Potentials

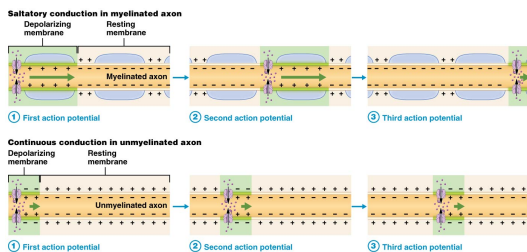


Figure 11.19 Comparison of saltatory and continuous conduction.

## Propagation of Action Potentials

- **Classification of Axons by Conduction Speed:**
  - **Type A fibers** – largest diameter (120 m/sec or **250 mi/h**); (5–20  $\mu\text{m}$ ) 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  $\mu\text{m}$ ); 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  $\mu\text{m}$ ); \_\_\_\_\_ ANS efferent fibers and sensory axons (transmit pain, temperature, and pressure)

## Putting It All Together: The Big Picture of Action Potentials

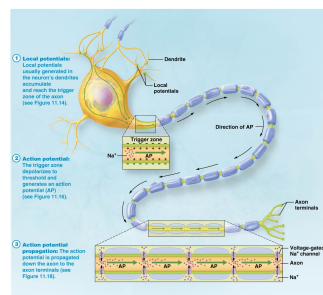


Figure 11.20 The Big Picture of Action Potentials.

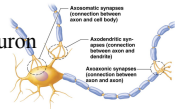


## Multiple Sclerosis (p. 406)

- **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

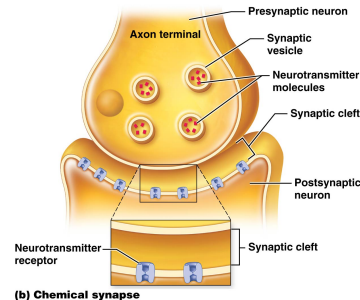


Figure 11.22b The structure chemical synapse.

## Chemical Synapses

- **Events at a Chemical Synapse:**
    - multiple neurons secreting many different types of *excitatory* or *inhibitory* neurotransmitters (Fig. 11.23):
1. AP in presynaptic neuron triggers **calcium ion channels** in axon terminal to open
  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 possibly an *AP* if threshold is reached

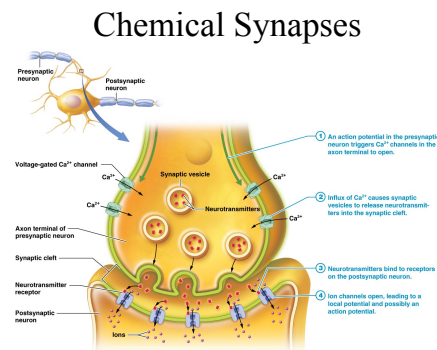


Figure 11.23 Events at a chemical synapse.

## Review

The correct order for events at a chemical synapse:

**Action potential arrives at axon terminal**

**Neurotransmitter is released**

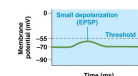
**Neurotransmitter binds to receptors**

**Local potential occurs in postsynaptic cell**

## Chemical Synapses

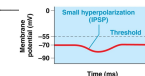
- **Postsynaptic potentials** – can be *Excitatory* or *Inhibitory*:

– **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

- Are always inhibitory
- Always move the postsynaptic membrane toward threshold
- Depend on which membrane channels open
- Only involve sodium channel opening and closing

## Review

### EPSPs

- Are inhibitory
- Move the postsynaptic membrane toward threshold
- Result from potassium channels opening
- Are usually large local potentials

## Review

### IPSPs

- Are inhibitory
- Move the postsynaptic membrane toward threshold
- Result from sodium channels opening
- Are usually large local potentials

## Chemical Synapses

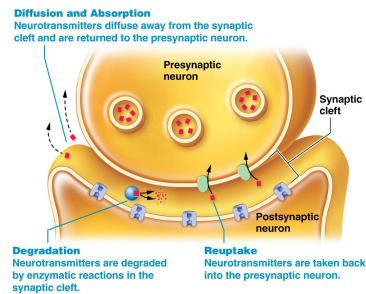


Figure 11.25 Methods of termination of synaptic transmission.



## 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 different but result is similar; 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

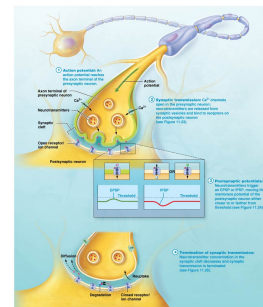


Figure 11.26 The Big Picture of Chemical Synaptic Transmission.

## Review

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

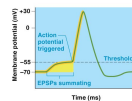
- Action potential
- Synaptic transmission
- Postsynaptic potentials
- Synaptic transmission termination

## Neural Integration

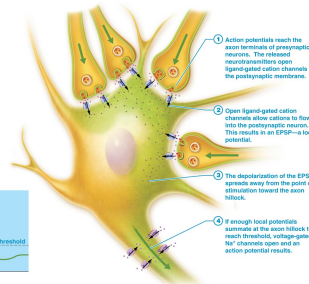
- Neurons receive input, both *inhibitory* and *excitatory*, from multiple neurons, each of which influences whether an *action potential is generated*
- **Neural integration** – process in which postsynaptic neuron *integrates* all *incoming information* into a single effect

## 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 summing and leading to an action potential



## Neurotransmitters

- Over 100 known neurotransmitters
- 4 groups:**
  1. ACh (acetylcholine)- 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

| Neurotransmitter                                       | Precursor Molecule(s)  | Predominant Postsynaptic Effect | Location(s)                                                                                                                             | Type of Receptor(s)         |
|--------------------------------------------------------|------------------------|---------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|
| <b>Acetylcholine</b>                                   | Acetyl-CoA and choline | Excitatory                      | CNS: brain and spinal cord<br>PNS: neuromuscular junction and ANS                                                                       | Ionotropic and metabotropic |
| <b>Biogenic Amines</b>                                 |                        |                                 |                                                                                                                                         |                             |
| Catecholamines (norepinephrine, epinephrine, dopamine) | Tyrosine               | Excitatory                      | CNS: brain and spinal cord<br>PNS: ANS (sympathetic division)                                                                           | Metabotropic                |
| Serotonin                                              | Tryptophan             | Excitatory                      | CNS: brain                                                                                                                              | Metabotropic                |
| Histamine                                              | Histidine              | Excitatory                      | CNS: brain                                                                                                                              | Metabotropic                |
| <b>Amino Acids</b>                                     |                        |                                 |                                                                                                                                         |                             |
| 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                  |
| <b>Neuropeptides</b>                                   |                        |                                 |                                                                                                                                         |                             |
| Substance P                                            | Amino acids            | Excitatory and inhibitory       | CNS: brain and spinal cord (major neurotransmitter for pain perception)<br>PNS: enteric nervous system (neurons in the digestive tract) | Metabotropic                |
| Opioids (enkephalins, endorphins, dynorphin-A)         | Amino acids            | Excitatory and inhibitory       | CNS: brain and spinal cord (major neurotransmitters for pain control)                                                                   | Metabotropic                |
| Neuropeptide Y                                         | —                      | Excitatory and inhibitory       | CNS: brain<br>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

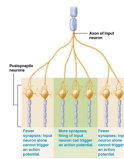


Figure 11.30 A neuronal pool © 2010 Pearson Education, Inc.

## Neuronal Circuits

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

### → Diverging circuits

- one neuron sends impulses to multiple 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*

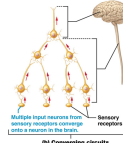
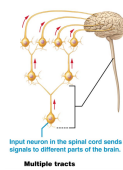
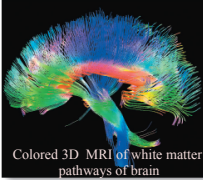


Fig. 11.31 Neural Circuits





12

**The Central Nervous System**

Colored 3D MRI of white matter pathways of brain

**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

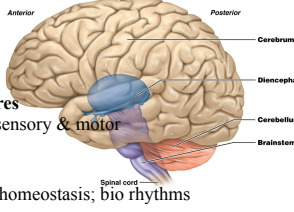
- **Brain** – soft, whitish-gray organ in cranial cavity, continuous with SC
  - mostly *nervous tissue*; some *epithelial* and *CT*
  - \_\_\_\_\_ filled with **cerebrospinal fluid (CSF)**
  - ~20% of *cardiac output*; requires large amounts of  $O_2$ , *glucose*, and *nutrients*

### Basic Structure of the Brain

Anterior      Posterior

*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, \_\_\_\_\_

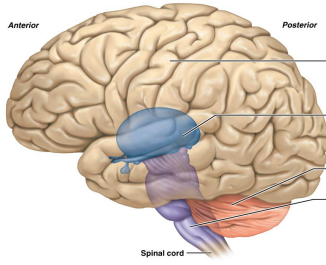


Cerebrum  
Diencephalon  
Cerebellum  
Brainstem  
Spinal cord

**Figure 12.1** Divisions of the brain (lateral view).

### Basic Structure of the Brain and Spinal Cord

Anterior      Posterior



| BRAIN DIVISION      | FUNCTION                                                                                                                                                                                 |
|---------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Cerebrum</b>     | <ul style="list-style-type: none"> <li>• Performs higher mental functions</li> <li>• Interprets sensory stimuli</li> <li>• Plans and initiates movement</li> </ul>                       |
| <b>Diencephalon</b> | <ul style="list-style-type: none"> <li>• Processes, integrates, and relays information</li> <li>• Maintains homeostasis</li> <li>• Regulates biological rhythms</li> </ul>               |
| <b>Cerebellum</b>   | <ul style="list-style-type: none"> <li>• Monitors and coordinates movement</li> </ul>                                                                                                    |
| <b>Brainstem</b>    | <ul style="list-style-type: none"> <li>• Maintains homeostasis</li> <li>• Controls certain reflexes</li> <li>• Monitors movement</li> <li>• Integrates and relays information</li> </ul> |

Spinal cord

**Figure 12.1** Divisions of the brain (lateral view).

### Basic Structure of Spinal Cord

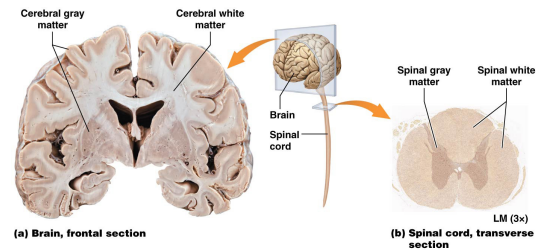
- **Spinal cord** – located in **vertebral cavity**
  - *Extends from foramen magnum to* \_\_\_\_\_
  - Length ~ 45 cm (17–18 inches)
  - Diameter 0.65–1.25 cm (0.25–0.5 inches)
  - \_\_\_\_\_ – CSF filled cavity within SC, *continuous with brain's ventricles*



## Basic Structure of the Brain and SC

- **White matter** – found in both 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 both brain and SC;  
(*cell bodies, dendrites, and*                      *axons*)
  - Cerebral cortex is gray matter
  - Center H (butterfly)-shape of SC

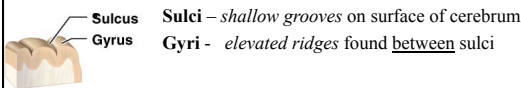
## Basic Structure of the Brain and SC



**Figure 12.2** White and gray matter in the CNS.

## The Cerebrum

### • Cerebrum

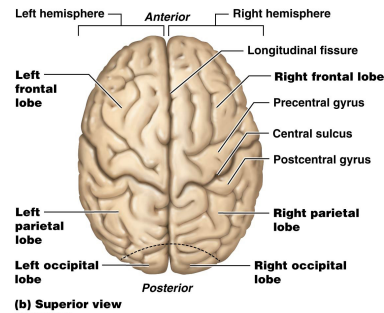


**Corpus callosum** – connects                       
**Longitudinal fissure** – deep groove that separates *left and right cerebral hemispheres*

**Transverse fissure** – *separates occipital lobe from cerebellum*

**Ventricles** –                      *cavities, one in each hemisphere*  
**Figure 12.4** Structure of the cerebrum.

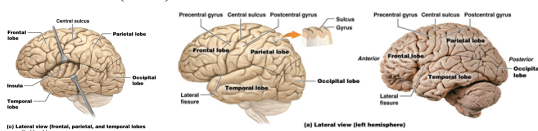
## The Cerebrum



**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)



## The Cerebrum-Gray Matter

- **Cerebral Cortex** = gray matter, covers cerebral hemispheres
  - All 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** – \_\_\_\_\_

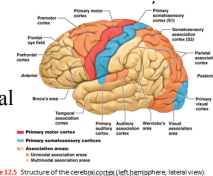


Figure 12.5 Structure of the cerebral cortex (left hemisphere, lateral view).

## 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

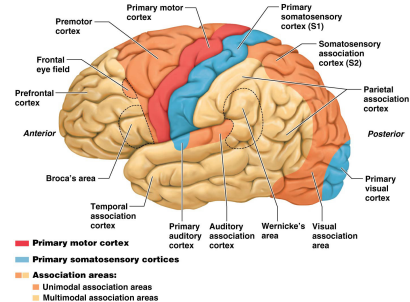


Figure 12.5 Structure of the cerebral cortex (left hemisphere, lateral view).

## The Cerebrum-Gray Matter

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

| Area Name                        | Type of Cortex                            | Location                                                           | Function                                              |
|----------------------------------|-------------------------------------------|--------------------------------------------------------------------|-------------------------------------------------------|
| Primary motor cortex             | Motor                                     | Precentral gyrus of frontal lobe                                   | Plans and executes movement                           |
| Premotor cortex                  | Unimodal association                      | Widely spread 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                    | Widely spread in the parietal lobe                                 | Spatial awareness and attention                       |
| Temporal association cortex      | Multimodal association                    | Widely spread 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**

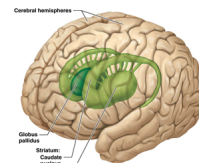
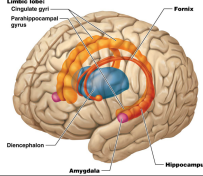


Figure 12.6 Structure of the basal nuclei (anterior view).

## 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*



## 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*

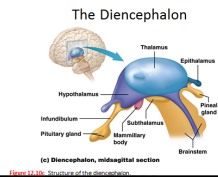
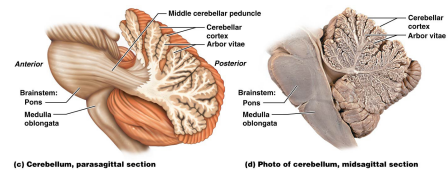


Figure 12.10b Structures of the diencephalon

## Cerebellum

### Cerebellum

- located inferior to occipital lobe
- *coordinate* \_\_\_\_\_
- *arbor vitae*



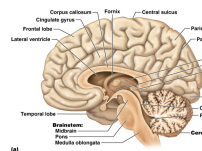
(c) Cerebellum, parasagittal section

(d) Photo of cerebellum, midsagittal section

## The Brainstem

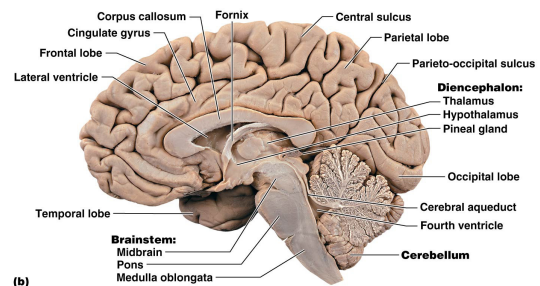
### Brainstem

- one of oldest components of brain
- vital to our immediate survival
- Includes *midbrain*, *pons*, *medulla oblongata*



(a)

## The Brainstem



(b)

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* reflexes 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

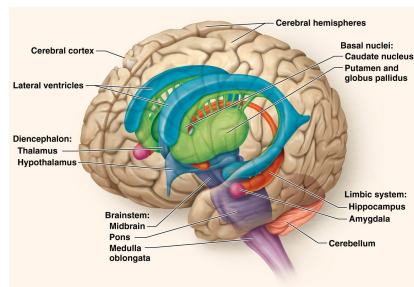


Figure 12.16 The Big Picture of Major Brain Structures and Their Functions.

## The Big Picture of Major Brain Structures and Their Functions

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

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

## The Big Picture of Major Brain Structures and Their Functions

| DIVISION   | STRUCTURES | 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                | Medulla oblongata | Regulates breathing                                                |
|                     |                   | Regulates reflexes                                                 |
|                     |                   | Regulates the sleep/wake cycle                                     |
|                     |                   |                                                                    |
| Reticular formation |                   | Contains tracts of white matter involved in movement and sensation |
|                     |                   | Regulates many homeostatic functions                               |
|                     |                   | Involved in sleep and arousal                                      |
|                     |                   | Involved in pain transmission                                      |

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

## Brain Protection

Three features protect delicate brain tissue:

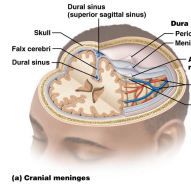
1. **Cranial meninges** – three layers of *membranes* that surround brain
2. **Cerebrospinal fluid (CSF)** – *fluid* that bathes brain and fills cavities
3. **Blood-brain barrier** – prevents many substances from *entering brain* and its cells *from blood*

## Brain Protection

- **Cranial meninges**

– composed of three layers:  
*superficial to deep:*

- a. **dura mater**  
epidural 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 (1<sup>st</sup> & 2<sup>nd</sup> = lateral ventricles, 3<sup>rd</sup> and 4<sup>th</sup> 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

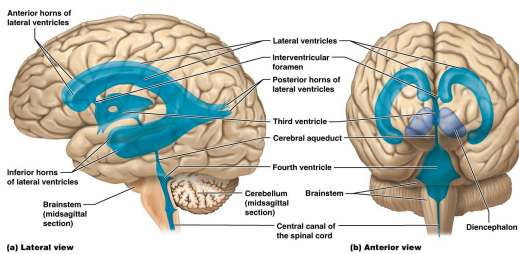


Figure 12.19 Ventricles of the brain.

## The Ventricles and Cerebrospinal Fluid

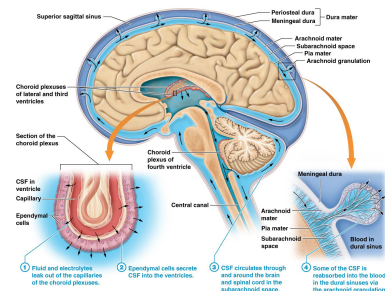


Figure 12.20 Formation and flow of cerebrospinal fluid (CSF).

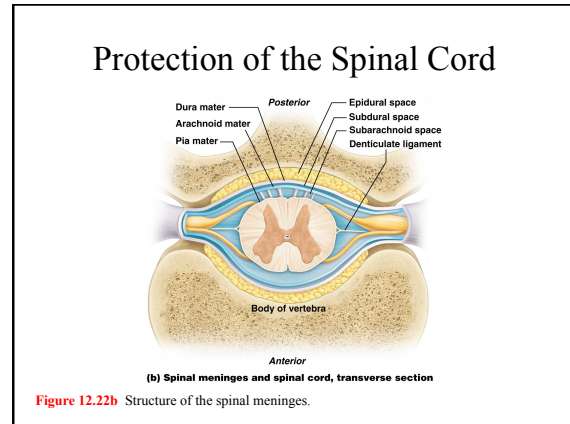
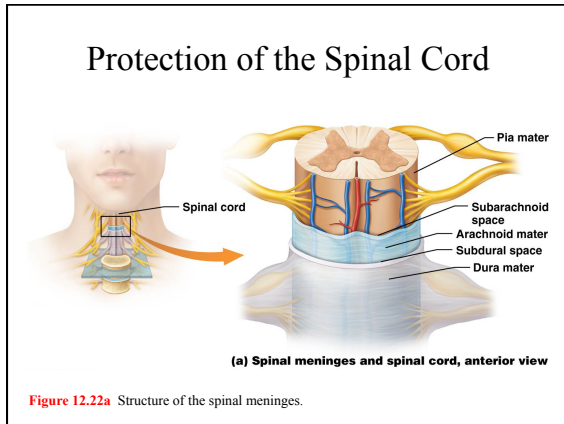


## Infectious Meningitis (p. 448)

- 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



### 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

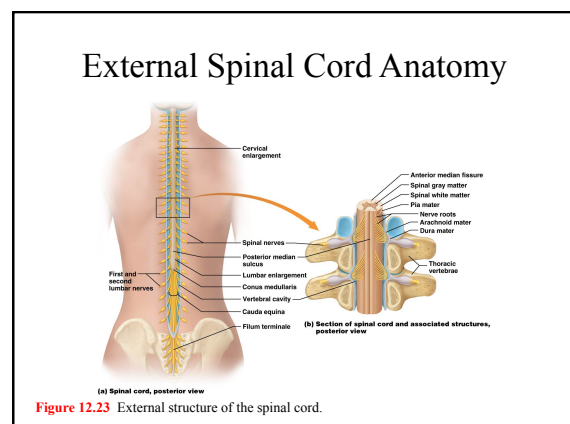
- **Filum terminale** – extends from between L1 and L2 to coccyx  
- composed of *spinal pia mater*
- **Cauda Equina** = bundle of spinal nerves contained in \_\_\_\_\_

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





## Internal Spinal Cord Anatomy

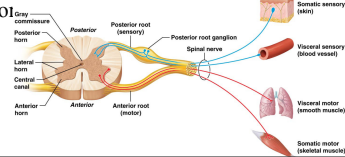
Butterfly (H)-shaped spinal gray matter is surrounded by tracts of white matter

**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)

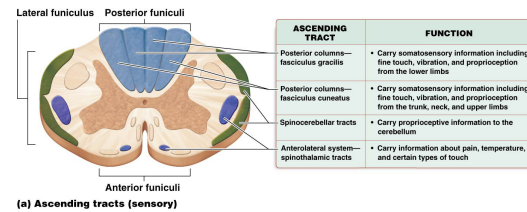


Figure 12.25a Ascending and descending tracts of the spinal cord.

## Internal Spinal Cord Anatomy

### Descending tracts (motor)

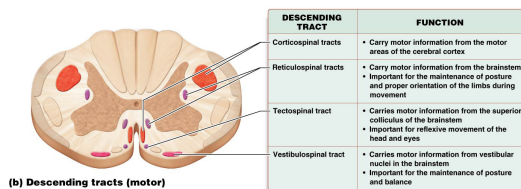
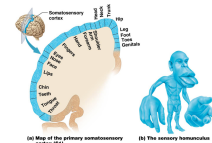


Figure 12.25b Ascending and descending tracts of the spinal cord.

## 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 **specific region of S1**, a type of organization called **somatotopy** (Figure 12.28)
  - **More** S1 space is dedicated to hands and face; represents importance of **manual dexterity**, **facial expression**, and **speech** to human existence

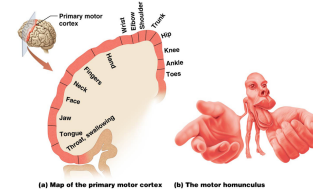


## Phantom Limb Pain (p. 456)

- 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

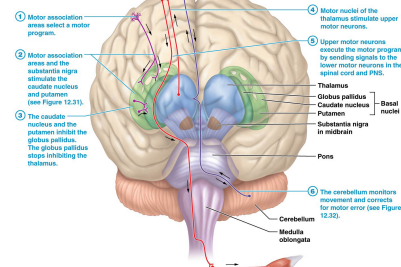




### Parkinson's Disease (p. 461)

- 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 increase 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<sub>2</sub>]; 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 *vital functions* (\_\_\_\_\_)
  - Although ANS is a *component of PNS*, mainly controlled by \_\_\_\_\_
- **Respiration** is one of few vital functions not 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

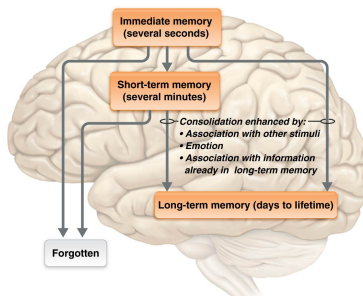


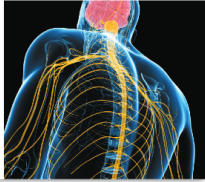
Figure 12.37 Pathways for consolidation of memories.

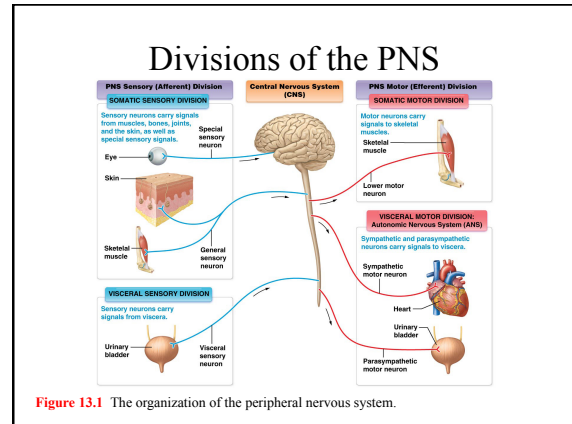
**13**

**The Peripheral Nervous System**

**PNS =**

- Sensory** ( )
  - Somatic Sensory Div. (special senses, skin, skeletal muscle)
  - Visceral Sensory Div. (viscera)
- Motor** ( )
  - Somatic Motor Div. (to skeletal muscle)
  - Visceral Motor Div. (ANS)





### Overview of Peripheral Nerves and Associated Ganglia

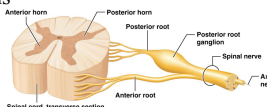
- Peripheral nerves**  
= *axons* of many neurons bound together by CT
- Mixed nerves** – contain both \_\_\_\_\_ neurons
- Sensory nerves** – contain only \_\_\_\_\_ neurons
- Motor nerves** – contain mostly \_\_\_\_\_ neurons

*2 types of nerves:*

- Spinal nerves (31 pairs)
- Cranial nerves (12 pairs)

### Overview of Peripheral Nerves

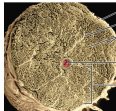
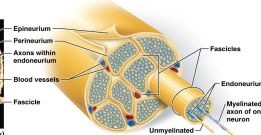
- Spinal nerves**
  - Anterior** ( ) root
    - *motor neurons* from anterior horn
  - Posterior** ( ) root
    - *sensory neurons* from posterior horn
  - Dorsal root ganglion** - collection of cell bodies of sensory neurons



(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 (SEM, 20x)      (c) Detailed structure of spinal nerve

### Structure of Spinal Nerves and Spinal Nerve Plexuses

**Cervical Plexus**

- Phrenic Nerve

**Brachial Plexus**

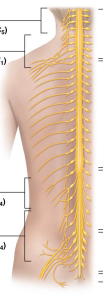
- Axillary n.
- Musculocutaneous n.
- Median n.
- Ulnar n.

**Lumbar Plexus**

- Obturator n.
- Femoral n.

**Sacral Plexus**

- Sciatic n.



Cervical nerves (C<sub>1</sub>-C<sub>8</sub>)      *Cervical = 8 pr.*

Thoracic nerves (T<sub>1</sub>-T<sub>12</sub>)      *Thoracic = 12 pr.*

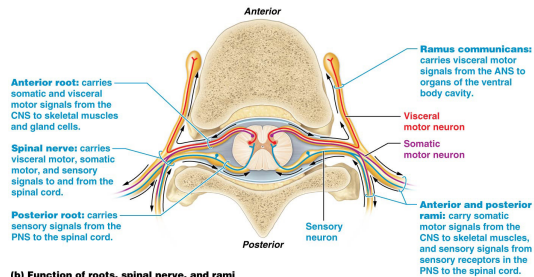
Lumbar nerves (L<sub>1</sub>-L<sub>5</sub>)      *Lumbar = 5 pr.*

Sacral nerves (S<sub>1</sub>-S<sub>5</sub>)      *Sacral = 5 pr.*

Coccygeal nerve (Co.)      *Coccygeal = 1 pr.*

**Figure 13.5** Overview of spinal nerves.

## Structure of Spinal Nerves and Spinal Nerve Plexuses



(b) Function of roots, spinal nerve, and rami

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)**

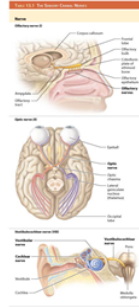


Table 13.1 The Sensory Cranial Nerves

## The Sensory Cranial Nerves

| Nerve                           | Origin and Destination                                                               | Function                                                                                                   |
|---------------------------------|--------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------|
| <b>Olfactory (I)</b>            | Origin: Olfactory bulb. Destination: Olfactory cortex.                               | Carries sensory information from the olfactory bulb to the olfactory cortex.                               |
| <b>Optic (II)</b>               | Origin: Optic chiasm. Destination: Optic tract, optic tectum, and optic chiasm.      | Carries sensory information from the optic chiasm to the optic tract, optic tectum, and optic chiasm.      |
| <b>Vestibulocochlear (VIII)</b> | Origin: Vestibular and cochlear nuclei. Destination: Vestibular and cochlear nuclei. | Carries sensory information from the vestibular and cochlear nuclei to the vestibular and cochlear nuclei. |

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

| Nerve                   | Origin and Destination                                     | Function                                                                       |
|-------------------------|------------------------------------------------------------|--------------------------------------------------------------------------------|
| <b>Oculomotor (III)</b> | Origin: Oculomotor nucleus. Destination: Oculomotor nerve. | Carries motor information from the oculomotor nucleus to the oculomotor nerve. |
| <b>Trochlear (IV)</b>   | Origin: Trochlear nucleus. Destination: Trochlear nerve.   | Carries motor information from the trochlear nucleus to the trochlear nerve.   |
| <b>Abducens (VI)</b>    | Origin: Abducens nucleus. Destination: Abducens nerve.     | Carries motor information from the abducens nucleus to the abducens nerve.     |

Table 13.2 The Motor Cranial Nerves.

## The Motor Cranial Nerves

| Nerve                    | Origin and Destination                                       | Function                                                                         |
|--------------------------|--------------------------------------------------------------|----------------------------------------------------------------------------------|
| <b>Accessory (XI)</b>    | Origin: Accessory nucleus. Destination: Accessory nerve.     | Carries motor information from the accessory nucleus to the accessory nerve.     |
| <b>Hypoglossal (XII)</b> | Origin: Hypoglossal nucleus. Destination: Hypoglossal nerve. | Carries motor information from the hypoglossal nucleus to the hypoglossal nerve. |

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

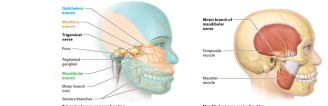
**Glossopharyngeal (IX)** – taste post. 1/3 tongue, BP changes, swallowing, salivary glands

**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**

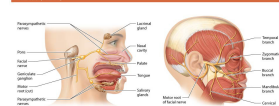


| Nerve                        | Origin, Course, and Distribution                                                                                                                                                                                                                                                                                          | Sensory Function                                                                                       | Motor Function                                                                           |
|------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|
| <b>Trigeminal (V)</b>        | Origin: The trigeminal ganglion is located in the middle cranial fossa. The nerve divides into three branches: ophthalmic (V1), maxillary (V2), and mandibular (V3). V1 supplies the face and scalp; V2 supplies the face and upper lip; V3 supplies the face, lower lip, and jaw.                                        | General somatic afferent (GSA) – touch, pain, temperature, and proprioception from the face and scalp. | General somatic efferent (GSE) – motor control of the muscles of mastication.            |
| <b>Facial (VII)</b>          | Origin: The facial nerve originates in the pons and travels through the facial canal. It divides into two main branches: the greater petrosal nerve and the lesser petrosal nerve. The greater petrosal nerve supplies the parotid gland, and the lesser petrosal nerve supplies the submandibular and sublingual glands. | General somatic afferent (GSA) – taste from the anterior two-thirds of the tongue.                     | General somatic efferent (GSE) – motor control of the muscles of facial expression.      |
| <b>Glossopharyngeal (IX)</b> | Origin: The glossopharyngeal nerve originates in the medulla and travels through the jugular foramen. It divides into two main branches: the tonsillar nerve and the pharyngeal nerve. The tonsillar nerve supplies the tonsils, and the pharyngeal nerve supplies the pharynx.                                           | General somatic afferent (GSA) – taste from the posterior one-third of the tongue.                     | General somatic efferent (GSE) – motor control of the muscles of the pharynx and larynx. |

Table 13.3 The Mixed Cranial Nerves.

## The Mixed Cranial Nerves

**Table 13.3 The Mixed Cranial Nerves**

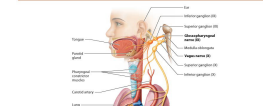


| Nerve                        | Origin, Course, and Distribution                                                                                                                                                                                                                                                                                          | Sensory Function                                                                                       | Motor Function                                                                           |
|------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|
| <b>Trigeminal (V)</b>        | Origin: The trigeminal ganglion is located in the middle cranial fossa. The nerve divides into three branches: ophthalmic (V1), maxillary (V2), and mandibular (V3). V1 supplies the face and scalp; V2 supplies the face and upper lip; V3 supplies the face, lower lip, and jaw.                                        | General somatic afferent (GSA) – touch, pain, temperature, and proprioception from the face and scalp. | General somatic efferent (GSE) – motor control of the muscles of mastication.            |
| <b>Facial (VII)</b>          | Origin: The facial nerve originates in the pons and travels through the facial canal. It divides into two main branches: the greater petrosal nerve and the lesser petrosal nerve. The greater petrosal nerve supplies the parotid gland, and the lesser petrosal nerve supplies the submandibular and sublingual glands. | General somatic afferent (GSA) – taste from the anterior two-thirds of the tongue.                     | General somatic efferent (GSE) – motor control of the muscles of facial expression.      |
| <b>Glossopharyngeal (IX)</b> | Origin: The glossopharyngeal nerve originates in the medulla and travels through the jugular foramen. It divides into two main branches: the tonsillar nerve and the pharyngeal nerve. The tonsillar nerve supplies the tonsils, and the pharyngeal nerve supplies the pharynx.                                           | General somatic afferent (GSA) – taste from the posterior one-third of the tongue.                     | General somatic efferent (GSE) – motor control of the muscles of the pharynx and larynx. |

Table 13.3 The Mixed Cranial Nerves.

## The Mixed Cranial Nerves

**Table 13.3 The Mixed Cranial Nerves**



| Nerve                        | Origin, Course, and Distribution                                                                                                                                                                                                                                                                                          | Sensory Function                                                                                       | Motor Function                                                                           |
|------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|
| <b>Trigeminal (V)</b>        | Origin: The trigeminal ganglion is located in the middle cranial fossa. The nerve divides into three branches: ophthalmic (V1), maxillary (V2), and mandibular (V3). V1 supplies the face and scalp; V2 supplies the face and upper lip; V3 supplies the face, lower lip, and jaw.                                        | General somatic afferent (GSA) – touch, pain, temperature, and proprioception from the face and scalp. | General somatic efferent (GSE) – motor control of the muscles of mastication.            |
| <b>Facial (VII)</b>          | Origin: The facial nerve originates in the pons and travels through the facial canal. It divides into two main branches: the greater petrosal nerve and the lesser petrosal nerve. The greater petrosal nerve supplies the parotid gland, and the lesser petrosal nerve supplies the submandibular and sublingual glands. | General somatic afferent (GSA) – taste from the anterior two-thirds of the tongue.                     | General somatic efferent (GSE) – motor control of the muscles of facial expression.      |
| <b>Glossopharyngeal (IX)</b> | Origin: The glossopharyngeal nerve originates in the medulla and travels through the jugular foramen. It divides into two main branches: the tonsillar nerve and the pharyngeal nerve. The tonsillar nerve supplies the tonsils, and the pharyngeal nerve supplies the pharynx.                                           | General somatic afferent (GSA) – taste from the posterior one-third of the tongue.                     | General somatic efferent (GSE) – motor control of the muscles of the pharynx and larynx. |

Table 13.3 The Mixed Cranial Nerves.

## Overview of Cranial Nerves

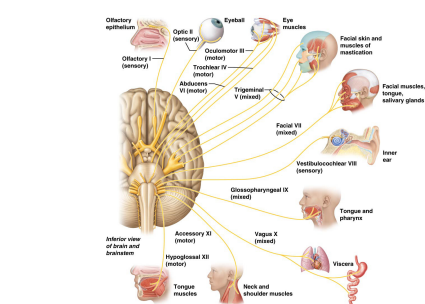


Figure 13.3 Overview of cranial nerves.



## 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**

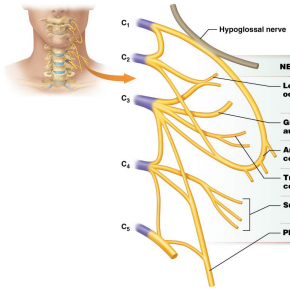
- Oh (I, Olfactory) Once (II, Optic) One (III, Oculomotor) Takes (IV, Trochlear) The (V, Trigeminal) Anatomy (VI, Abducens) Final (VII, Facial) Very (VIII, Vestibulocochlear) Good (IX, Glossopharyngeal) Vacations (X, Vagus) Are (XI, Accessory) Happening (XII, Hypoglossal)
- Remember that you have one 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—Sensory) Say (II, Optic—Sensory) Money (III, Oculomotor—Motor) Matters (IV, Trochlear—Motor) But (V, Trigeminal—Both) My (VI, Abducens—Motor) Brother (VII, Facial—Both) Says (VIII, Vestibulocochlear—Sensory) Big (IX, Glossopharyngeal—Both) Brains (X, Vagus—Both) Matter (XI, Accessory—Motor) More (XII, Hypoglossal—Motor)
- 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 <sub>2</sub>                 | Sensory to the skin on the scalp and posterior part of the ear |
| Greater auricular   | C <sub>2</sub> -C <sub>3</sub> | Sensory to the skin on the ear                                 |
| Ansa cervicalis     | C <sub>1</sub> -C <sub>3</sub> | Motor to the geniohyoid and infrahyoid muscles                 |
| Transverse cervical | C <sub>2</sub> -C <sub>3</sub> | Sensory to the skin on the superior chest and shoulder         |
| Suprascapular       | C <sub>3</sub> -C <sub>4</sub> | Sensory to the skin on the superior chest and shoulder         |
| Phrenic             | C <sub>3</sub> -C <sub>5</sub> | Motor to the diaphragm                                         |

**Figure 13.6** The cervical plexus.

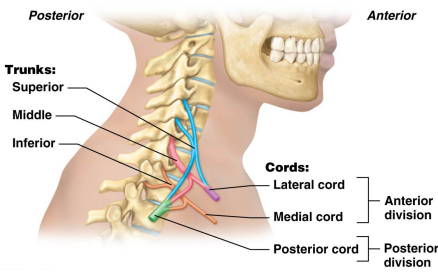


### A Hiccup Cure That Really Works (p. 498)



- **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



**Trunks:** Superior, Middle, Inferior

**Cords:** Lateral cord, Medial cord, Posterior cord

**Anterior division:** Lateral cord, Medial cord

**Posterior division:** Medial cord, Posterior cord

## Brachial Plexuses

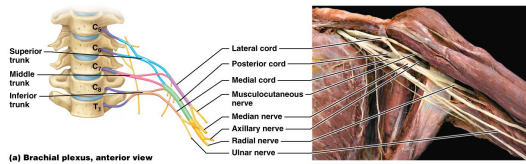


Figure 13.7a The brachial plexus.

## Brachial Plexuses

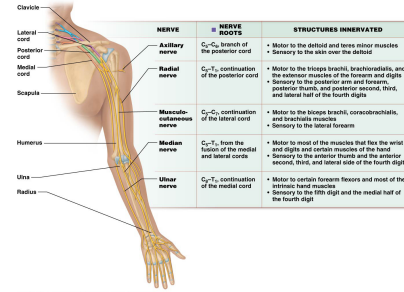


Figure 13.7b The brachial plexus.

## Lumbar Plexuses

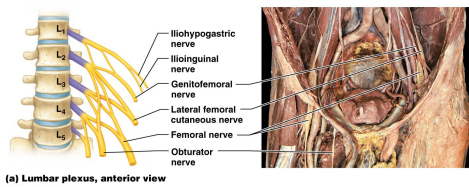


Figure 13.8a The lumbar plexus.

## Lumbar Plexuses

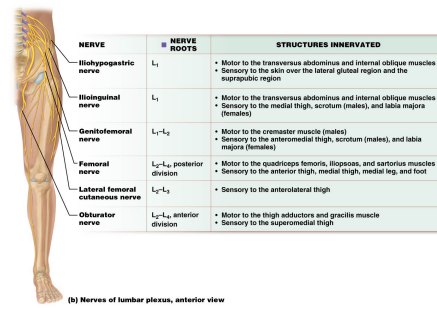


Figure 13.8b The lumbar plexus.

## Sacral Plexuses

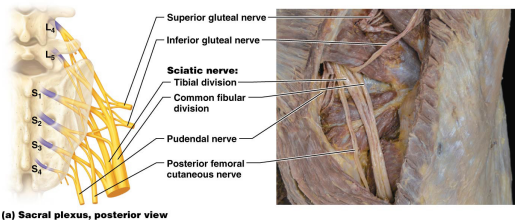


Figure 13.9a The sacral plexus.

## Sacral Plexuses

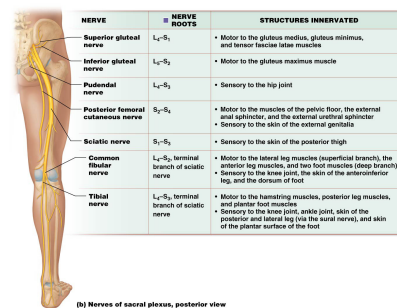


Figure 13.9b The sacral plexus.



### 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

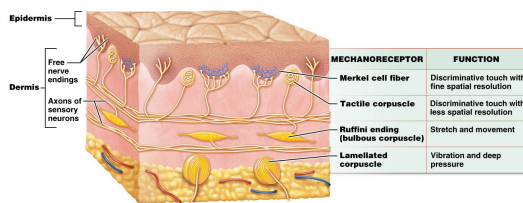
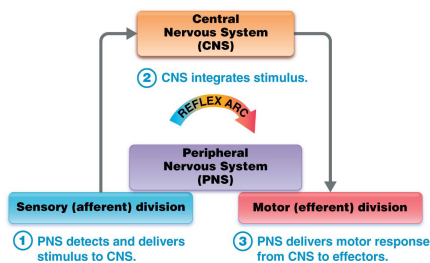


Figure 13.12 Mechanoreceptors in the skin.

### 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**

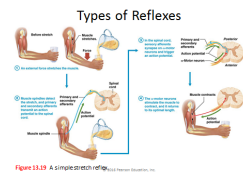
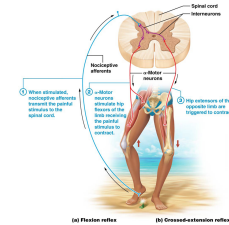


Figure 13.19 A simple stretch reflex

## Types of Reflexes

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

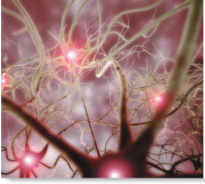


## Amyotrophic Lateral Sclerosis (p. 513)

### (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



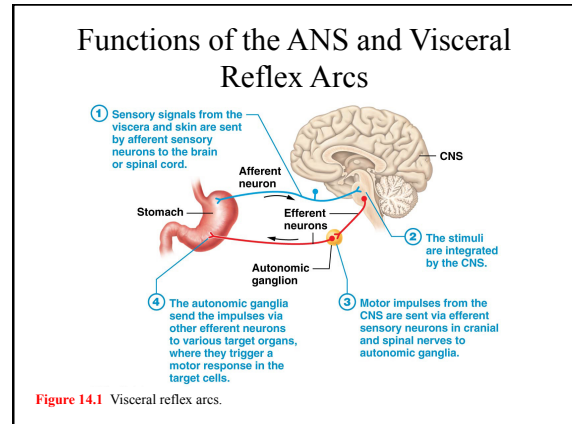


### 14

## The Autonomic Nervous System and Homeostasis

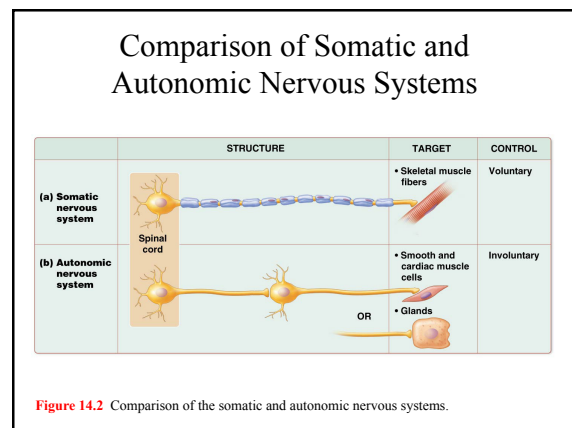
ANS = involuntary arm of PNS

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



### Comparison of Somatic and Autonomic Nervous Systems

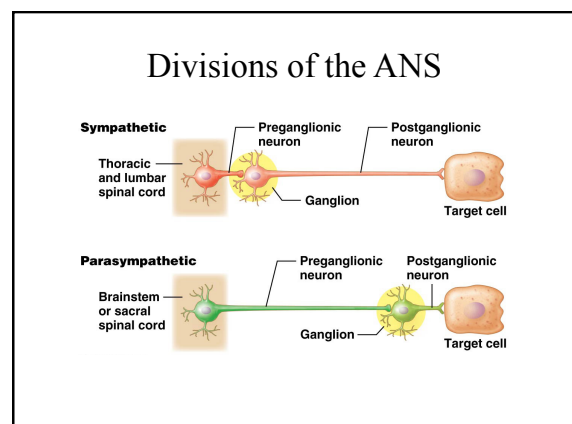
- Motor divisions of PNS (**Figure 14.2**):
  - Somatic motor division** → \_\_\_\_\_ (conscious control)
  - Autonomic motor division** → \_\_\_\_\_ muscle, \_\_\_\_\_ muscle, and glands (*involuntary*)
- ANS motor neurons require a two-neuron circuit:
  - Preganglionic neuron** – release *ACh*
  - Postganglionic neuron** – release *ACh* or *NEpi*



### 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

- **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 most 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 short axon to connect

### Divisions of the ANS

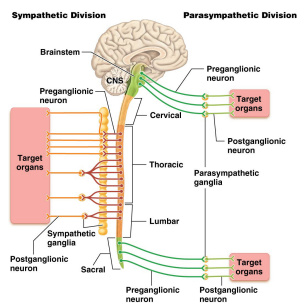
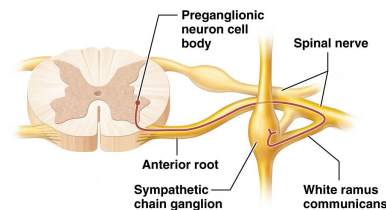


Figure 14.3 Overview of the structure of ANS divisions.

### Gross and Microscopic Anatomy of Sympathetic Nervous System



### Gross and Microscopic Anatomy of Sympathetic Nervous System

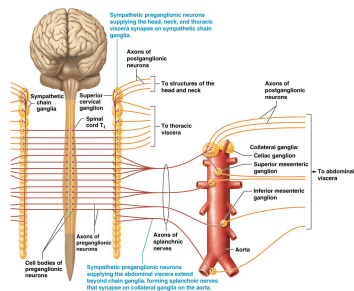


Figure 14.4 Organization of the sympathetic nervous system.

### Gross and Microscopic Anatomy of Sympathetic Nervous System

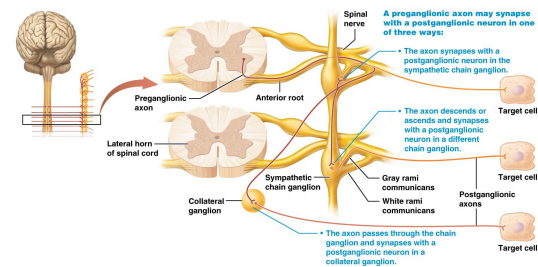


Figure 14.5 Three possible pathways of sympathetic preganglionic and postganglionic neurons.

## 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

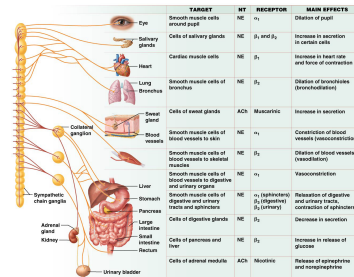


Figure 14.7 The main effects of the sympathetic nervous system on target cells.

## 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

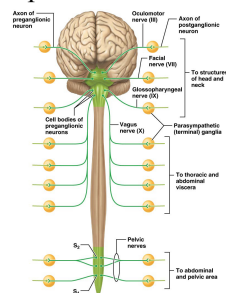


Figure 14.9 Organization of the parasympathetic nervous system.

## 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

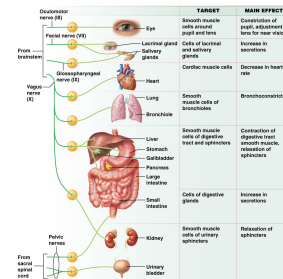
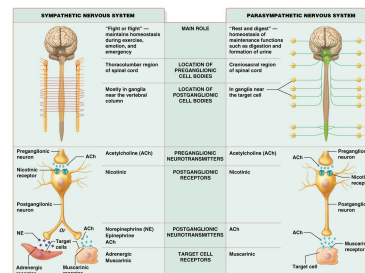


Figure 14.10 The main effects of parasympathetic nervous system on target cells.

## Interactions of Autonomic Divisions

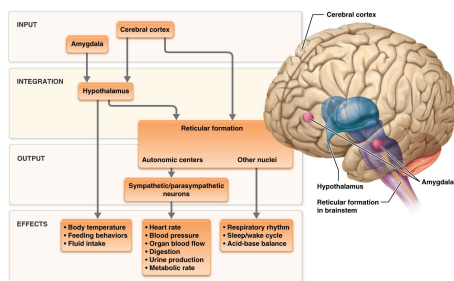
- Sympathetic and parasympathetic divisions work *together* to keep many of body's functions within their normal homeostatic ranges (**Figure 14.11**)
  - **dual innervation**
  - Dual innervation allows SNS to become dominant and trigger effects that maintain homeostasis during *physically demanding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



## Postural Orthostatic 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