#### Essentials of Human Anatomy & Physiology

# **The Nervous System**

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## Functions of the Nervous System

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

Structural Classification of the Nervous System

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

Functional Classification of the Peripheral Nervous System

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



#### Functional Classification of the Peripheral Nervous System

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



#### Functional Classification of the Peripheral Nervous System

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



# Organization of the Nervous System





### Nervous Tissue: Support Cells (Neuroglia or Glia)

#### Astrocytes

Abundant, star-shaped cells

- Brace neurons
- Form barrier between capillaries and neurons
- Control the chemical environment of the brain (CNS)





## Nervous Tissue: Support Cells

- Microglia (CNS)
  - Spider-like phagocytes
  - Dispose of debris
- Ependymal cells (CNS)
  - Line cavities of the brain and spinal cor
  - Circulate cerebrospinal fluid



(b) Microglial cell



#### Nervous Tissue: Support Cells

#### Oligodendrocytes (CNS)

 Produce myelin sheath around nerve fibers in the central nervous system



## Neuroglia vs. Neurons

- Neuroglia divide.
- Neurons do not.
- Most brain tumors are "gliomas."
- Most brain tumors involve the neuroglia cells, not the neurons.
- Consider the role of cell division in cancer!

### Support Cells of the PNS

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



(e) Sensory neuron with Schwann cells and satellite cells

#### Nervous Tissue: Neurons

#### Neurons = nerve cells

- Cells specialized to transmit messages
- Major regions of neurons
  - Cell body nucleus and metabolic center of the cell
  - Processes fibers that extend from the cell body (dendrites and axons)



Slide 7.9b

#### **Neuron Anatomy**

- Extensions outside the cell body
  - Dendrites conduct impulses toward the cell body
  - Axons conduct impulses away from the cell body (only 1!)



Slide 7.10

#### **Axons and Nerve Impulses**

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



#### **Nerve Fiber Coverings**

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



Slide 7.12

# Application

- In Multiple Scleroses the myelin sheath is destroyed.
- The myelin sheath hardens to a tissue called the scleroses.
- This is considered an autoimmune disease.
- Why does MS appear to affect the muscles?

### **Neuron Cell Body Location**

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

# Functional Classification of Neurons

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

# Functional Classification of Neurons

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

#### **Neuron Classification**



#### **Structural Classification of Neurons**

#### Multipolar neurons – many extensions from the cell body



Figure 7.8a

#### **Structural Classification of Neurons**

 Bipolar neurons – one axon and one dendrite



Figure 7.8b

#### **Structural Classification of Neurons**

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



Figure 7.8c

# How Neurons Function (Physiology)

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

#### Starting a Nerve Impulse

- Depolarization a stimulus depolarizes the neuron's membrane
- A deploarized membrane allows sodium (Na<sup>+</sup>) to flow inside the membrane
- The exchange of ions initiates an action potential in the neuron



Figure 7.9a–c *Slide 7.18* 

#### **The Action Potential**

- If the action potential (nerve impulse) starts, it is propagated over the entire axon
- Potassium ions rush out of the neuron after sodium ions rush in, which repolarizes the membrane
- The sodium-potassium pump restores the original configuration
  - This action requires ATP

#### **Nerve Impulse Propagation**

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



(c) Depolarization and generation of the action potential



(d) Propagation of the action potential



(e) Repolarization

Figure 7.9c-e

Slide 7.20

# Continuation of the Nerve Impulse between Neurons

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

#### How Neurons Communicate at Synapses



Slide 7.22

#### The Reflex Arc

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



Figure 7.11a

*Slide* 7.23

#### Simple Reflex Arc



## Types of Reflexes and Regulation

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

## Central Nervous System (CNS)

- CNS develops from the embryonic neural tube
  - The neural tube becomes the brain and spinal cord
  - The opening of the neural tube becomes the ventricles
    - Four chambers within the brain
    - Filled with cerebrospinal fluid
### **Regions of the Brain**

- Cerebral hemispheres
- Diencephalon
- Brain stem
- Cerebellum



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# **Cerebral Hemispheres (Cerebrum)**

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



Slide 7 28a

### **Cerebral Hemispheres (Cerebrum)**



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

> Slide 7 28h

#### Lobes of the Cerebrum

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

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#### Lobes of the Cerebrum



#### Specialized Areas of the Cerebrum

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



# Sensory and Motor Areas of the Cerebral Cortex



Slide 7.31

#### Specialized Area of the Cerebrum

#### Cerebral areas involved in special senses

- Gustatory area (taste)
- Visual area
- Auditory area
- Olfactory area

#### Specialized Area of the Cerebrum

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

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#### Specialized Area of the Cerebrum



Figure 7.13c

#### Layers of the Cerebrum

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



Figure 7.13a

### Layers of the Cerebrum

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



#### Layers of the Cerebrum

- Basal nuclei internal islands of gray matter
- Regulates voluntary motor activities by modifying info sent to the motor cortex
- Problems = ie unable to control muscles, spastic, jerky
- Involved in Huntington's and Parkinson's Disease



### Diencephalon

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

Slide

#### Diencephalon



Figure 7.15

Slide 7 31h

#### Thalamus

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

### Hypothalamus

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



- An important part of the limbic system (emotions)
- The pituitary gland is attached to the hypothalamus

#### **Epithalamus**

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

#### **Brain Stem**

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

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#### **Brain Stem**

(a)



Figure 7.15a

#### Midbrain

- Mostly composed of tracts of nerve fibers
  - Reflex centers for vision and hearing
  - Cerebral aquaduct 3<sup>rd</sup>-4<sup>th</sup> ventricles

#### Pons

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

# Medulla Oblongata

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

#### Cerebellum

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

#### Cerebellum



Figure 7.15a

# Protection of the Central Nervous System

- Scalp and skin
- Skull and vertebral column
- Meninges



#### Protection of the Central Nervous System

- Cerebrospinal fluid
- Blood brain barrier



# Meninges

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

# Meninges

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

#### **Cerebrospinal Fluid**

Similar to blood plasma composition

- Formed by the choroid plexus
- Forms a watery cushion to protect the brain
- Circulated in arachnoid space, ventricles, and central canal of the spinal cord

# Ventricles and Location of the Cerebrospinal Fluid



Slide 7 47a

# Ventricles and Location of the Cerebrospinal Fluid



#### **Blood Brain Barrier**

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

# Traumatic Brain Injuries (TBI)

- Concussion
  - Slight or mild brain injury
  - Bleeding & tearing of nerve fibers happened
  - Recovery likely with some memory loss
- Contusion
  - A more severe TBI
  - Nervous tissue destruction occurs
  - Nervous tissue does not regenerate
- Cerebral edema
  - Curalling from the inflormatory roomano

Slide 7.49
- Cerebral edema
  - Swelling from the inflammatory response
  - May compress and kill brain tissue
- Subdural hematoma
  - Collection of blood below the dura
- Standards for these conditions were revised in 2004. Please check out TBIs at Mayoclinic.com for more current information on diagnostic terminology.

## Cerebrovascular Accident (CVA)

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

#### **Alzheimer's Disease**

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

# **Spinal Cord**

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



Exterior white mater – conduction tracts



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



 Central canal filled with cerebrospinal fluid



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

#### **Peripheral Nervous System**

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

#### Structure of a Nerve

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



### **Classification of Nerves**

- Mixed nerves both sensory and motor fibers
- Afferent (sensory) nerves carry impulses toward the CNS
- Efferent (motor) nerves carry impulses away from the CNS

#### **Spinal Nerves**

 There is a pair of spinal nerves at the level of each vertebrae.

# **Spinal Nerves**



# Autonomic Nervous System

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

# Comparison of Somatic and Autonomic Nervous Systems



# Anatomy of the Autonomic Nervous System



Figure 7.25

# **Autonomic Functioning**

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

# **Autonomic Functioning**

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

Slide 7 74h Development Aspects of the Nervous System

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

## Development Aspects of the Nervous System

- No more neurons are formed after birth, but growth and maturation continues for several years (new evidence!)
- The brain reaches maximum weight as a young adult
- However, we can always grow dendrites!