The Nervous System
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

Figure 7.1

*Slide 7.3a*
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

Figure 7.1
Organization of the Nervous System

Figure 7.2

Central Nervous System (brain and spinal cord)

Peripheral Nervous System (cranial and spinal nerves)

Sensory (afferent)
- Sense organs

Motor (efferent)
- Autonomic (involuntary)
  - Sympathetic
  - Parasympathetic
- Somatic (voluntary)
  - Cardiac and smooth muscle, glands
  - Skeletal muscles

Slide 7.4
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)

Figure 7.3a
Nervous Tissue: Support Cells

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

Figure 7.3b, c
Slide 7.6
Nervous Tissue: Support Cells

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

Figure 7.3d

(d) Oligodendrocyte

Nerve fibers
Myelin sheath
Process of oligodendrocyte
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
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)
Neuron Anatomy

- Cell body
- Nucleus
- Large nucleolus
Neuron Anatomy

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

[Diagram of a neuron with labels for dendrites, cell body, axon, and nodes of Ranvier]
Axons and Nerve Impulses

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

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

Figure 7.5

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

![Neuron Classification Diagram](image)

- **Peripheral nervous system**
  - Dendrites
  - Receptors
  - Sensory neuron
  - Peripheral process (axon)
  - Afferent transmission
  - To effectors (muscles and glands)
- **Central nervous system**
  - Ganglion
  - Cell body
  - Association neuron (interneuron)
  - Efferent transmission
  - Motor neuron
  - Spinal cord (central nervous system)

**Figure 7.6**

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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 depolarized membrane allows sodium ($Na^+$) to flow inside the membrane
- The exchange of ions initiates an action potential in the neuron

*Figure 7.9a–c*
The Action Potential

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

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

1. Action potential arrives
2. Vesicle fuses with plasma membrane
3. Neurotransmitter is released into synaptic cleft
4. Neurotransmitter binds to receptor on receiving neuron's membrane
5. Ion channel opens
6. Ion channel closes

Figure 7.10

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
Simple Reflex Arc

Figure 7.11b, c

Slide 7.24
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
Cerebral Hemispheres (Cerebrum)

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

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

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

Slide 7.15a

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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
Figure 8. Components of the Wernicke-Geschwind Model.
Sensory and Motor Areas of the Cerebral Cortex

Figure 7.14

Motor cortex (precentral gyrus)

Somatic sensory cortex (postcentral gyrus)

Primary motor area sequence

Primary sensory area sequence

Neck
Brow
Eye
Face
Lips
Jaw
Tongue
Swallowing

Toes
Genitals

Teeth
Gums
Jaw
Tongue
Pharynx
Intra-abdominal

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
Specialized Area of the Cerebrum

- Primary motor area
- Premotor area
- Frontal association area
- Broca's area (motor speech)
- Language comprehension
- Olfactory area
- Central sulcus
- Somatic sensory cortex area
- Gustatory area (taste)
- Speech/language (outlined by dashes)
- General (common) interpretation area (outlined by dots)
- Visual area
- Auditory area

Figure 7.13c
Layers of the Cerebrum

- Gray matter
- Outer layer
- Composed mostly of neuron cell bodies
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 hemispheres
- Made of three parts
  - Thalamus
  - Hypothalamus
  - Epithalamus
Figure 7.15

Diencephalon

- Third ventricle
- Intermediate mass of thalamus
- Frontal lobe of cerebral hemisphere
- Anterior commissure
- Hypothalamus
- Optic chiasma
- Pituitary gland
- Temporal lobe of cerebral hemisphere
- Mammillary body
- Pons
- Medulla oblongata
- Spinal cord
- Parietal lobe of cerebral hemisphere
- Corpus callosum
- Choroid plexus of third ventricle
- Occipital lobe of cerebral hemisphere
- Thalamus (encloses third ventricle)
- Pineal body (part of epithalamus)
- Corpora quadrigemina
- Cerebral aqueduct
- Midbrain
- Cerebral peduncle of midbrain
- Fourth ventricle
- Choroid plexus
- Cerebellum
Thalamus

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

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

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

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

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

- Third ventricle
- Intermediate mass of thalamus
- Frontal lobe of cerebral hemisphere
- Anterior commissure
- Hypothalamus
- Optic chiasma
- Pituitary gland
- Temporal lobe of cerebral hemisphere
- Mammillary body
- Pons
- Medulla oblongata
- Spinal cord
- Parietal lobe of cerebral hemisphere
- Corpus callosum
- Choroid plexus of third ventricle
- Occipital lobe of cerebral hemisphere
- Thalamus (encloses third ventricle)
- Pineal body (part of epithalamus)
- Corpora quadrigemina
- Cerebral aqueduct
- Cerebral peduncle of midbrain
- Fourth ventricle
- Choroid plexus
- Cerebellum

Figure 7.15a
Midbrain

- Mostly composed of tracts of nerve fibers
  - Reflex centers for vision and hearing
  - Cerebral aquaduct – 3rd-4th 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

Third ventricle
Intermediate mass of thalamus
Frontal lobe of cerebral hemisphere
Anterior commissure
Hypothalamus
Optic chiasma
Pituitary gland
Temporal lobe of cerebral hemisphere
Mammillary body
Pons
Medulla oblongata
Spinal cord
Parietal lobe of cerebral hemisphere
Corpus callosum
Choroid plexus of third ventricle
Occipital lobe of cerebral hemisphere
Thalamus (encloses third ventricle)
Pineal body (part of epithalamus)
Corpora quadrigemina
Cerebral aqueduct
Cerebral peduncle of midbrain
Fourth ventricle
Choroid plexus
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
Ventricles and Location of the Cerebrospinal Fluid

Figure 7.17b
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
  - Swelling from the inflammatory response
• 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

Figure 7.18
Spinal Cord Anatomy

- Exterior white mater – conduction tracts
Spinal Cord Anatomy

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

- Central canal filled with cerebrospinal fluid
Spinal Cord Anatomy

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

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

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

Figure 7.22a

Ventral rami form cervical plexus (C₁ – C₈)

Ventral rami form brachial plexus (C₉ – C₁₂; T₁)

No plexus formed (intercostal nerves) (T₁ – T₁₂)

Ventral rami form lumbar plexus (L₁ – L₄)

Ventral rami form sacral plexus (L₄ – L₅; S₁ – S₄)
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

- **Somatic nervous system**
  - Central nervous system
  - Peripheral nervous system
  - Effector organs

- **Autonomic nervous system**
  - Sympathetic division
    - Acetylcholine
    - Norepinephrine
    - Ganglion
    - Smooth muscle (e.g., in a blood vessel)
  - Parasympathetic division
    - Acetylcholine
    - Blood vessel
    - Glands
    - Cardiac muscle

**KEY:**
- Preganglionic axons (sympathetic)
- Postganglionic axons (sympathetic)
- Myelination
- Preganglionic axons (parasympathetic)
- Postganglionic axons (parasympathetic)

Figure 7.24 Slide 7.69
Anatomy of the Autonomic Nervous System

Figure 7.25

Slide 7.73
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 activities
  - Conserves energy
  - Maintains daily necessary body functions
  - Remember as the “D” division - digestion, defecation, and diuresis
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!