Introduction

- Spinal cord injuries disrupt communication between
  - the central nervous system (brain and spinal cord) and
  - the rest of the body.

- Over 250,000 Americans are living with spinal cord injuries.

- Spinal cord injuries
  - happen more often to men,
  - happen mostly to people in their teens and 20s,
  - are caused by vehicle accidents, gunshots, and falls, and
  - are usually permanent because the spinal cord cannot be repaired.
28.1 Nervous systems receive sensory input, interpret it, and send out appropriate commands

- The **nervous system**
  - obtains sensory information, **sensory input**.
  - processes sensory information, **integration**, and
  - sends commands to effector cells (muscles) that carry out appropriate responses, **motor output**.

- The **central nervous system** (CNS) consists of the
  - brain and
  - spinal cord (vertebrates).
- The **peripheral nervous system** (PNS)
  - is located outside the CNS and
  - consists of
    - **nerves** (bundles of neurons wrapped in connective tissue) and
    - **ganglia** (clusters of neuron cell bodies).

28.2 Neurons are the functional units of nervous systems

- **Neurons** are
  - cells specialized for carrying signals and
  - the functional units of the nervous system.
- A neuron consists of
  - a **cell body** and
  - two types of extensions (fibers) that conduct signals,
    - **dendrites** and
    - **axons**.
28.2 Neurons are the functional units of nervous systems

- Myelin sheaths
  - enclose axons,
  - form a cellular insulation, and
  - speed up signal transmission.

28.3 Nerve function depends on charge differences across neuron membranes

- The resting potential exists because of differences in ion concentration of the fluids inside and outside the neuron.
  - Inside the neuron
    - K⁺ is high and
    - Na⁺ is low.
  - Outside the neuron
    - K⁺ is low and
    - Na⁺ is high.

- At rest, a neuron’s plasma membrane has potential energy—the **membrane potential**, in which
  - just inside the cell is slightly negative and
  - just outside the cell is slightly positive.

- The **resting potential** is the voltage across the plasma membrane of a resting neuron.
28.4 A nerve signal begins as a change in the membrane potential

- A **stimulus** is any factor that causes a nerve signal to be generated. A stimulus
  - alters the permeability of a portion of the membrane,
  - allows ions to pass through, and
  - changes the membrane's voltage.

- A nerve signal, called an **action potential**, is
  - a change in the membrane voltage,
  - from the resting potential,
  - to a maximum level, and
  - back to the resting potential.

28.5 The action potential propagates itself along the axon

- Action potentials are
  - self-propagated in a one-way chain reaction along a neuron and
  - all-or-none events.

- The frequency of action potentials (but not their strength) changes with the strength of the stimulus.
28.6 Neurons communicate at synapses

- **Synapses** are junctions where signals are transmitted between
  - two neurons or
  - between neurons and effector cells.

- Electrical signals pass between cells at electrical synapses.
- At chemical synapses
  - the ending (presynaptic) cell secretes a chemical signal, a neurotransmitter,
  - the neurotransmitter crosses the synaptic cleft, and
  - the neurotransmitter binds to a specific receptor on the surface of the receiving (postsynaptic) cell.

28.7 Chemical synapses enable complex information to be processed

- Some neurotransmitters
  - excite a receiving cell, and
  - others inhibit a receiving cell’s activity by decreasing its ability to develop action potentials.

- A receiving neuron’s membrane may receive signals
  - that are both excitatory and inhibitory and
  - from many different sending neurons.

- The summation of excitation and inhibition determines if a neuron will transmit a nerve signal.
28.8 A variety of small molecules function as neurotransmitters

- Many small, nitrogen-containing molecules are neurotransmitters.
  - Acetylcholine is a neurotransmitter
    - in the brain and
    - at synapses between motor neurons and muscle cells.
- Biogenic amines
  - are important neurotransmitters in the CNS and
  - include serotonin and dopamine, which affect sleep, mood, and attention.

28.8 A variety of small molecules function as neurotransmitters

- Many neuropeptides
  - consist of relatively short chains of amino acids important in the CNS and
  - include endorphins, decreasing our perception of pain.
- Nitric oxide
  - is a dissolved gas and
  - triggers erections during sexual arousal in men.

28.9 CONNECTION: Many drugs act at chemical synapses

- Many psychoactive drugs
  - act at synapses and
  - affect neurotransmitter action.
- Caffeine counters the effect of inhibitory neurotransmitters.
- Nicotine acts as a stimulant by binding to acetylcholine receptors.
- Alcohol is a depressant.

28.10 EVOLUTION CONNECTION: The evolution of animal nervous systems reflects changes in body symmetry

- Radially symmetrical animals have a nervous system arranged in a weblike system of neurons called a nerve net.
Most bilaterally symmetrical animals evolved
- **cephalization**, the concentration of the nervous system at the head end, and
- **centralization**, the presence of a central nervous system distinct from a peripheral nervous system.
28.11 Vertebrate nervous systems are highly centralized

- In the vertebrates, the central nervous system (CNS) consists of the brain and spinal cord and includes spaces filled with cerebrospinal fluid forming ventricles of the brain, forming the central canal of the spinal cord, and surrounding the brain.
- The vertebrate peripheral nervous system (PNS) consists of cranial nerves, spinal nerves, and ganglia.

28.12 The peripheral nervous system of vertebrates is a functional hierarchy

- The PNS can be divided into two functional components:
  1. the motor system, mostly voluntary, and
  2. the autonomic nervous system, mostly involuntary.

- The motor nervous system carries signals to and from skeletal muscles and mainly responds to external stimuli.
- The autonomic nervous system regulates the internal environment and controls smooth and cardiac muscle and organs and glands of the digestive, cardiovascular, excretory, and endocrine systems.
28.12 The peripheral nervous system of vertebrates is a functional hierarchy

- The autonomic nervous system is composed of three divisions.
  1. The **parasympathetic division** primes the body for activities that gain and conserve energy for the body.
  2. The **sympathetic division** prepares the body for intense, energy-consuming activities.
  3. The **enteric division** consists of networks of neurons in the digestive tract, pancreas, and gallbladder that control secretion and peristalsis.

28.13 The vertebrate brain develops from three anterior bulges of the neural tube

- The vertebrate brain evolved by the enlargement and subdivision of the
  - forebrain,
  - midbrain, and
  - hindbrain.

- In the course of vertebrate evolution, the forebrain and hindbrain gradually became subdivided
  - structurally and
  - functionally.
In birds and mammals the cerebrum
- is much larger and
- correlates with their sophisticated behavior.

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The structure of a living supercomputer: The human brain

28.14 The structure of a living supercomputer: The human brain
- The human brain is
  - more powerful than the most sophisticated computer and
  - composed of three main parts:
    1. forebrain,
    2. midbrain, and
    3. hindbrain.

28.14 The structure of a living supercomputer: The human brain
- The midbrain, subdivisions of the hindbrain, the thalamus, and the hypothalamus
  - conduct information to and from higher brain centers,
  - regulate homeostatic functions,
  - keep track of body position, and
  - sort sensory information.
28.14 The structure of a living supercomputer: The human brain

- The cerebrum is
  - part of the forebrain and
  - the largest and most complex part of the brain.
  - Most of the cerebrum’s integrative power resides in the cerebral cortex of the two cerebral hemispheres.

28.15 The cerebral cortex is a mosaic of specialized, interactive regions

- The cerebral cortex
  - is less than 5 mm thick and
  - accounts for 80% of the total human brain mass.
- Specialized integrative regions of the cerebral cortex include
  - the somatosensory cortex and
  - centers for vision, hearing, taste, and smell.

28.16 CONNECTION: Injuries and brain operations provide insight into brain function

- Brain injuries and surgeries reveal brain functions.
  - After a 13-pound steel rod pierced his skull, Phineas Gage appeared to have an intact intellect but his associates noted negative changes to his personality.
  - Stimulation of the cerebral cortex during surgeries caused patients to recall sensations and memories.
  - Cutting the corpus callosum revealed information about brain lateralization.
28.17 CONNECTION: fMRI scans provide insight into brain structure and function

- Functional magnetic resonance imaging (fMRI) is
  - a scanning and imaging technology used to study brain functions,
  - used on conscious patients,
  - monitors changes in blood oxygen usage in the brain, and
  - correlates to regions of intense brain function.

28.18 Several parts of the brain regulate sleep and arousal

- Sleep and arousal involve activity by the
  - hypothalamus,
  - medulla oblongata,
  - pons, and
  - neurons of the reticular formation.

- Sleep
  - is essential for survival,
  - is an active state, and
  - may be involved in consolidating learning and memory.
28.19 The limbic system is involved in emotions, memory, and learning

- The **limbic system** is
  - a functional group of integrating centers in the
    - cerebral cortex,
    - thalamus,
    - hypothalamus, and
  - involved in
    - emotions, such as nurturing infants and bonding emotionally to other people,
    - memory, and
    - learning.

28.20 CONNECTION: Changes in brain physiology can produce neurological disorders

- Many neurological disorders can be linked to changes in brain physiology, including
  - schizophrenia,
  - major depression,
  - Alzheimer’s disease, and
  - Parkinson’s disease.

28.20 CONNECTION: Changes in brain physiology can produce neurological disorders

- **Schizophrenia** is
  - a severe mental disturbance and
  - characterized by psychotic episodes in which patients lose the ability to distinguish reality.

28.20 CONNECTION: Changes in brain physiology can produce neurological disorders

- **Depression**
  - Two broad forms of depressive illness have been identified:
    1. major depression and
    2. bipolar disorder, manic-depressive disorder.
  - Treatments may include selective serotonin reuptake inhibitors (SSRIs), which increase the amount of time serotonin is available to stimulate certain neurons in the brain.
Alzheimer’s disease is characterized by confusion, memory loss, and personality changes and difficult to diagnose.

Parkinson’s disease is a motor disorder and characterized by difficulty in initiating movements, slowness of movement, and rigidity.

You should now be able to

1. Describe the structural and functional subdivisions of the nervous system.
2. Describe the three parts of a reflex, distinguishing the three types of neurons that may be involved in the reaction.
3. Describe the structures and functions of neurons and myelin sheaths.
4. Define a resting potential and explain how it is created.
5. Explain how an action potential is produced and the resting membrane potential restored.
6. Explain how an action potential propagates itself along a neuron.
7. Compare the structures, functions, and locations of electrical and chemical synapses.
8. Compare excitatory and inhibitory neurotransmitters.
9. Describe the types and functions of neurotransmitters known in humans.
10. Explain how drugs can alter chemical synapses.
11. Describe the diversity of animal nervous systems and provide examples.
12. Describe the general structure of the brain, spinal cord, and associated nerves of vertebrates.
13. Compare the functions of the motor nervous system and autonomic nervous system.
14. Compare the structures, functions, and interrelationships of the parasympathetic, sympathetic, and enteric divisions of the peripheral nervous system.
15. Explain how the vertebrate brain develops from an embryonic tube.
16. Describe the main parts and functions of the human brain.
17. Explain how injuries, illness, and surgery provide insight into the functions of the brain.
18. Explain how fMRI scans help us understand brain functions.
19. Explain how the brain regulates sleep and arousal.
20. Describe the structure and functions of the limbic system.
21. Describe the causes, symptoms, and treatments of schizophrenia, depression, Alzheimer’s disease, and Parkinson’s disease.