Chapter 14
Lecture Outline

See separate PowerPoint slides for all figures and tables pre-inserted into PowerPoint without notes.
Nervous System
Points to ponder

• What are the three types of neurons?
• What are neuroglia?
• What is the structure of a neuron?
• What is the myelin sheath? Saltatory conduction? Schwann cell? Node of Ranvier?
• Explain the resting and action potential as they relate to a nerve impulse.
• How does the nerve impulse traverse the synapse?
• What are the two parts of the nervous system?
• What three things protect the CNS?
• What are the four parts of the brain and their functions?
• What is the reticular activating system and the limbic system?
• What are some higher mental functions of the brain?
• What are the two parts of the peripheral nervous system?
• How do abused drugs work?
The nervous divisions

• Two divisions
  – **Central nervous system (CNS)**: Brain and spinal cord
  – **Peripheral nervous system (PNS)**: Nerves and ganglia (collections of cell bodies)
14.1 Overview of the Nervous System

The nervous divisions

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**Figure 14.1** The two divisions of the nervous system.
The nervous system

• The nervous system allows for communication between cells through sensory input, integration of data, and motor output.

• Two cell types: neurons and neuroglia
Expanding on neurons

• Three types of neurons
  • **Sensory** – takes impulses from sensory receptor to CNS
  • **Interneuron** – receives information in the CNS and sends it to a motor neuron
  • **Motor** – takes impulses from the CNS to an effector (i.e., gland or muscle fiber)
Expanding on neurons

• Neuron structure (Ch. 4 review)
  • **Cell body** – main cell where nucleus and most organelles reside

• **Dendrites** – many short extensions that carry impulses to a cell body

• **Axon** (nerve fiber) – single, long extension that carries impulses away from the cell body
14.1 Overview of the Nervous System

Types of neurons

Figure 14.2 The structure of sensory neurons, interneurons, and motor neurons.
The myelin sheath

- A lipid covering on long axons that acts to increase the speed of nerve impulse conduction, insulation, and regeneration in the PNS

- Schwann cells – neuroglia that make up the myelin sheath in the PNS

- **Nodes of Ranvier** – gaps between myelination on the axons

- **Saltatory conduction** – conduction of the nerve impulse from node to node
Neuron structure

Figure 14.2 The structure of sensory neurons, interneurons, and motor neurons.
The nerve impulse: Resting potential (RP)

- **Resting potential** – when the axon is not conducting a nerve impulse

  - More positive ions outside than inside the membrane
  
  - Negative charge of -70 mV inside the axon
  
  - More Na$^+$ outside than inside
  
  - More K$^+$ inside than outside
The nerve impulse: Resting potential (RP)

a. Resting potential: Na⁺ outside the axon, K⁺ and large anions inside the axon. Separation of charges polarizes the cell and causes the resting potential.

Figure 14.3a  Generation of an action potential.
The nerve impulse: Action potential

- **Action potential** – rapid change in the axon membrane that allows a nerve impulse to occur.

- Sodium gates open, letting Na\(^+\) in.
  - **Depolarization** occurs.
  - Interior of axon loses negative charge (-55 mV, then +35 mV).
14.1 Overview of the Nervous System

The nerve impulse: Action potential

- Potassium gates open, letting $K^+$ out.
  - Repolarization occurs.
  - Interior of axon regains negative charge (-70 mV).
  - Wave of depolarization/repolarization travels down the axon.

- Resting potential is restored by moving potassium inside and sodium outside.
The nerve impulse: Stimulus causes the axon to reach its threshold

Figure 14.3b  Generation of an action potential.

b. Stimulus causes the axon to reach its threshold; the axon potential increases from −70 to −55. The action potential has begun.
The nerve impulse: Action potential

c. Depolarization continues as Na$^+$ gates open and Na$^+$ moves inside the axon.

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Figure 14.3c  Generation of an action potential.
The synapse

• The **synapse** is a small gap between the sending neuron (presynaptic membrane) and the receiving neuron (postsynaptic membrane).

• Transmission is accomplished across this gap by a **neurotransmitter** (e.g., ACh, dopamine, or serotonin).

• Neurotransmitters are stored in synaptic vesicles in the **axon terminals**.
How does transmission across the synapse occur?

- Nerve impulse reaches the axon terminal.
- Calcium ions enter the axon terminal and stimulate the synaptic vesicles to fuse with the presynaptic membrane.
- Neurotransmitters are released and diffuse across the synapse, where they bind with the postsynaptic membrane to inhibit or excite the neuron.
A synapse and how it functions

1. After an action potential arrives at an axon terminal (arrow), Ca$^{2+}$ enters, and synaptic vesicles fuse with the plasma membrane of the sending neuron.

2. Neurotransmitter molecules are released and bind to receptors on the membrane of the receiving neuron.

3. When an excitatory neurotransmitter binds to a receptor, Na$^+$ diffuses into the receiving neuron, and an action potential begins.

Figure 14.4 Signal transmission at the synapse.
Synaptic integration

- **Integration** is the summation of the inhibitory and excitatory signals received by a postsynaptic neuron.

- This occurs because a neuron receives many signals.
14.1 Overview of the Nervous System

Synaptic integration

Figure 14.5 Integration of excitatory and inhibitory signals at the synapse.
The central nervous system

- The CNS consists of the brain and spinal cord.

- Both are protected by
  - Bones – skull and vertebral column
  - **Meninges** – 3 protective membranes that wrap around CNS
  - **Cerebral spinal fluid (CSF)** – space between meninges is filled with this fluid that cushions and protects the CNS
The central nervous system

• Both the brain and spinal cord are made up of two types of nervous tissue.
  • **Gray matter** – contains cell bodies and nonmyelinated fibers
  • **White matter** – contains myelinated axons
The CNS: Spinal cord

- It extends from the base of the brain and along the length of the vertebral canal formed by the vertebrae.

- The spinal cord functions to provide communication between the brain and most of the body.

- It is the center for reflex arcs.

- Gray matter in the center is a butterfly shape.

- White matter surrounds the gray matter.
What does the spinal cord look like?

**Figure 14.7** The organization of white and gray matter in the spinal cord and the spinal nerves.
The CNS: Brain

Four major parts

1. Cerebrum
2. Diencephalon
3. Cerebellum
4. Brain stem
14.2 The Central Nervous System

The CNS: Overview of the brain

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Figure 14.8 The human brain.
The brain: Cerebrum

- Cerebral hemispheres
- Cerebral cortex
- Primary motor and sensory areas of the cortex
- Association areas
- Processing centers
- Central white matter
1. The brain: Cerebrum — The lobes

- **Cerebrum** — largest portion of the brain

- Divided into four lobes
  1. Frontal lobe: primary motor area and conscious thought
  2. Temporal lobe: primary auditory, smell, and speech area
  3. Parietal lobe: primary somatosensory and taste area
  4. Occipital lobe: primary visual area
1. The brain: Cerebrum – The cerebral lobes

Figure 14.9 The lobes of the cerebral hemispheres.
1. The brain: Cerebrum – The cerebral cortex

- **Cerebral cortex** – thin, outer layer of gray matter
  - **Primary motor area** – voluntary control of skeletal muscle
  - **Primary somatosensory area** – for sensory information from skeletal muscle and skin
  - **Association areas** – integration occurs here
  - **Processing centers** – perform higher level analytical functions including Wernicke’s and Broca’s areas, both involved in speech
1. The brain: Cerebrum – The cerebral cortex

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Figure 14.10 The primary motor and primary somatosensory areas of the brain.
2. The brain: Diencephalon

- Includes the
  - **Hypothalamus** – helps maintain homeostasis (hunger, sleep, thirst, body temperature, and water balance) and controls pituitary gland

- **Thalamus** – Two masses of gray matter that receive all sensory input except smell; involved in memory and emotions

- **Pineal gland** – secretes melatonin that controls our daily rhythms
14.2 The Central Nervous System

2. The brain: Diencephalon

Figure 14.8 The human brain.
3. The brain: Cerebellum

- Receives and integrates sensory input from the eyes, ears, joints, and muscles about the current position of the body

- Functions
  - Maintains posture
  - Coordinates voluntary movement
  - Allows learning of new motor skills (i.e., playing the piano or hitting a baseball)
4. The brain: The brain stem

- Includes
  - **Midbrain** – relay station between the cerebrum and spinal cord or cerebellum; reflex center
  - **Pons** – a bridge between cerebellum and the CNS; regulates breathing rate; reflex center for head movements
  - **Medulla oblongata** – contains reflex centers for regulating breathing, heartbeat, and blood pressure
  - **Reticular formation** – major component of the reticular activating system (RAS) that regulates alertness
The reticular formation

RAS radiates to cerebral cortex.

Figure 14.11  The reticular formation of the brain.
The limbic system

• It joins primitive emotions (i.e., fear, pleasure) with higher functions such as reasoning.

• The **limbic system** can cause strong emotional reactions to situations but conscious thought can override and direct our behavior.

• Includes
  • **Amygdala** – imparts emotional overtones
  • **Hippocampus** – important to learning and memory
The limbic system

Figure 14.12 The regions of the brain associated with the limbic system.
Higher mental functions

- **Learning** – what happens when we recall and use past memories

- **Memory** – ability to hold a thought or to recall past events

- **Short-term memory** – retention of information for only a few minutes
Higher mental functions

- **Long-term memory** – retention of information for more than a few minutes and includes the following:
  - Episodic memory – people and events
  - Semantic memory – numbers and words

- **Skill memory** – performing skilled motor activities (i.e., riding a bike)

- **Language** – depends on semantic memory
What parts of the brain are active in reading and speaking?

1. The word is seen in the visual cortex.
2. Information concerning the word is interpreted in Wernicke’s area.
3. Information from Wernicke’s area is transferred to Broca’s area.
4. Information is transferred from Broca’s area to the primary motor area.

Figure 14.13 The areas of the brain involved in reading.
The peripheral nervous system (PNS)

- It includes cranial nerves (12 pairs), spinal nerves (31 pairs), and ganglia outside the CNS.
  - Spinal nerves conduct impulses to and from the spinal cord.
  - Cranial nerves conduct impulses to and from the brain.

- The PNS is divided into two systems.
  - Somatic division
  - Autonomic division
The peripheral nervous system

Figure 14.14 The structure of a nerve.

14.4 The Peripheral Nervous System
14.4 The Peripheral Nervous System

The peripheral nervous system

Cranial Nerves

I  from olfactory receptors
II from retina of eyes
III to eye muscles
IV to eye muscles
V from mouth and to jaw muscles
VI to eye muscles
VII from taste buds and to facial muscles and glands
VIII from inner ear
IX from pharynx and to pharyngeal muscles
XII to tongue muscles
X from and to internal organs
XI to neck and back muscles

Figure 14.15 The cranial nerves.
The PNS: Somatic division

• The **somatic system** serves the skin, skeletal muscles and tendons.

• Automatic responses are called **reflexes**.
Figure 14.16 The events in a spinal reflex.
The PNS: Autonomic division

- The autonomic system regulates the activity of involuntary muscles (cardiac and smooth) and glands.
The PNS: Autonomic division

• Two divisions
  1. **Sympathetic division**: coordinates the body for the “fight or flight” response by speeding up metabolism, heart rate, and breathing while slowing down and regulating other functions.

  2. **Parasympathetic division**: counters the sympathetic system by bringing up a relaxed state by slowing down metabolism, heart rate, and breathing, and returning other functions to normal.
14.4 The Peripheral Nervous System

The PNS: Autonomic division

Figure 14.17 The two divisions of the autonomic nervous system.
Drugs and drug abuse

• Both legal pharmaceuticals and illegal drugs of abuse have certain basic modes of action.

They:

– promote the action of a neurotransmitter.

– interfere with or decrease the action of a neurotransmitter.

– replace or mimic a neurotransmitter or neuromodulator.
Drugs and drug abuse

• Most drug abusers take drugs that affect dopamine and thus artificially affect this reward circuit to the point that they ignore basic physical needs in favor of the drug.

• Drug abusers tend to show a physiological and psychological effect.

• Once a person is physically dependent, they usually need more of the drug for the same effect because their body has become tolerant.
Drug abuse: Alcohol

- **Alcohol** – a depressant directly absorbed from the stomach and small intestine.

- Alcohol is the most socially accepted form of drug use.

- About 80% of college-aged people drink.

- Alcohol denatures proteins and causes damage to tissues such as the brain and liver; chronic consumption can damage the frontal lobe.

- High blood alcohol levels can lead to poor judgment, loss of coordination, or even coma and death.
Drug abuse: Nicotine

- **Nicotine** – stimulant derived from tobacco plant
- Nicotine stimulates neurons to release dopamine that reinforces dependence on the drug.
- It adversely affects a developing embryo or fetus.
- Smoking increases heart rate and blood pressure.
- Nicotine causes psychological and physiological dependency.
Drug abuse: Cocaine

- **Cocaine** – stimulant derived from a shrub

- Cocaine causes a rush sensation that lasts from 5-30 minutes.

- A cocaine binge occurs when a user takes the drug at ever-higher doses, resulting in hyperactivity, little desire for food and sleep, and an increased sex drive.

- There is extreme physical dependence with this drug.

- "Crack" is the street name for cocaine that is processed to a free-base form for smoking.
Drug abuse: Methamphetamine

• Powder form is called speed and crystal form is called meth or ice.

• It is a stimulant that reverses the effects of fatigue and is a mood elevator.

• High agitation is common after the rush and can lead to violent behavior.

• Methamphetamine causes psychological dependency and hallucinations.

• “Ecstasy” is the street name for a drug that has the same effects as meth without the hallucinations.
Drug abuse: Heroin

- Heroin – depressant from the sap of the opium poppy plant

- It leads to a feeling of euphoria and no pain because it is delivered to the brain and converted into morphine.

- Side effects are nausea, vomiting, and depression of the respiratory and circulatory systems.

- Heroin use can lead to HIV, hepatitis, and other infections due to shared needles.

- Extreme dependency is common.
Drug abuse: Marijuana

• Marijuana – psychoactive drug derived from a hemp plant called *Cannabis*

• It is most often smoked as a “joint.”

• Occasional users experience mild euphoria, alterations to vision and judgment, as well as impaired motor coordination with slurred speech.

• Heavy users may experience depression, anxiety, hallucinations, paranoia, and psychotic symptoms.

• Long term use may lead to brain damage.

• K2 ("Spice") is a synthetic drug with higher potency than the active chemical in marijuana.