## Chapter 11 Introduction to the Nervous System and Nervous Tissue

## Chapter Outline

### Module 11.1 Overview of the Nervous System (Figures 11.1-11.3)

A. The **nervous system** controls our perception and experience of the world.

1. It directs voluntary movement, and is the seat of our consciousness, personality, and learning and memory.
2. It regulates many aspects of homeostasis along with the ______ system, including respiratory rate, blood pressure, body temperature, the sleep-wake cycle, and blood pH.

B. **Anatomical Divisions of the Nervous System (Figure 11.1)**: The nervous system is divided anatomically into the _____________ **nervous system (CNS)** and the______________**nervous system (PNS)**.

1. The **CNS** includes the__________, protected by the bones of the skull, and______________, which begins at the foramen magnum and continues through the vertebral foramina of the first cervical to the first or second lumbar vertebra.
2. The **PNS** consists of all the_____________, which are bundles of axons, blood vessels, and connective tissue, in the body outside the protection of the skull and vertebral column.
   a. **How many pairs of cranial nerves travel back to or from the brain?** ________
   b. **How many pairs of spinal nerves travel back to or from the spinal cord?** ________

C. **Functional Divisions of the Nervous System (Figure 11.2; Table 11.1)**: The tasks the nervous system performs fall into three functional categories: 1.___________, 2.____________, or 3.___________.

1. **Sensory functions** involve ____________________________________

   ____________________________________________________________

   Sensory input is gathered by the **sensory or afferent division of the**

**PNS**, which is further divided into___________and ____________ sensory divisions.

a. The somatic sensory division consists of neurons that carry signals from__________________,____________,____________, and __________. The somatic sensory division also transmits signals from the organs of vision, hearing, taste, smell, and balance, so it is sometimes called the_____________________________.

b. The visceral sensory division consists of neurons that transmit signals from viscera (organs) such as the_____________,______________, ______________,______________, and________________.

c. Sensory input from both divisions is carried from sensory receptors to the spinal cord and/or brain by spinal and cranial nerves.

2. **Integrative functions** analyze and interpret incoming ______________ information and determine an appropriate response.

3. **Motor functions** are the actions performed in response to ____________. Motor output is performed by the **motor**, or **efferent**, **division** of the PNS, which can be further subdivided into ____________ and _______________divisions, based on the organs that the neurons contact.

a. Organs that carry out the effects of the nervous system are commonly called_______________.

**Module 11.2 Nervous Tissue (Figures 11.4-11.10; Table 11.1)**

A. **Neurons** are the excitable cells responsible for sending and receiving signals in the form of action potentials. Most neurons consist of the following three parts **(Figures 11.4, 11.5)**:

1. The______________(soma) is the most metabolically active region of the neuron. It manufactures all the proteins needed for the neuron and houses many organelles.

2. ____________ are short, branched processes that receive input from other neurons which they transmit to toward the cell body in the form of electrical impulses. Each neuron may have multiple dendrites.

3. Each neuron has only one___________or nerve fiber that can generate and conduct______________. The axon may have these distinct regions: axon hillock, telodendria, axon terminals or synaptic bulbs, and axolemma.
4. The neuron has three main functional regions:  receptive region, conducting region, and secretory region.
5. Neurons can be classified according to their structural features into the following 3 groups **(Table 11.1)**:
    a. ________________ neurons  have a single axon and multiple dendrites.
    b. ________________ neurons,  with one axon and one dendrite with a cell body between them, are found in the eye and the olfactory epithelium in the nasal cavity.
    c. _________________ neurons  eventually have only one fused axon that extends from the cell body that divides into two processes. These are sensory neurons that carry information related to pain, touch, and pressure.
6. Neurons can also be classified into to the following three functional groups **(Table 11.1)**:
    a. Sensory, or afferent neurons, in the PNS carry information from sensory receptors____________the central nervous system (brain or spinal cord).
    b. Interneurons, or association neurons, relay information ___________ the CNS between sensory and motor neurons and make up most of the neurons in the body.
    c. Motor, or efferent neurons, carry information___________the cell body in the CNS to muscles and glands.
7. Structural groups of neuron components in the CNS (nuclei, tracts) and the PNS (ganglia, nerves) group together.

B. **Neuroglia**, or **neuroglial cells**, not only provide structural support and protection for neurons but also maintain their environment. Astrocytes, oligodendrocytes, microglia, and ependymal cells reside within the ___________, while the Schwann cells and satellite cells reside in the ___________ **(Figures 11.6, 11.7)**.

C. **The Myelin Sheath** is composed of repeating layers of the plasma membrane of the______________(PNS) or_________________(CNS) **(Figures 11.8, 11.9)**

1. How does myelination occur? ________________________________________
   ________________________________________________________________
   ________________________________________________________________
2. What are the gaps in the myelin sheath called? ________________________
   ____________________________________________________ (Figure 11.9)
3. What effect does myelin have on the speed of action potential conduction?
   ________________________________________________________________
4. What is the difference between white matter and gray matter? ____________
   ________________________________________________________________
   ________________________________________________________________
   ________________________________________________________________
   ________________________________________________________________

Regeneration of Nervous Tissue: regeneration or the replacement of damaged tissue is nearly non-existent in the CNS and is limited in the PNS. Neural tissue can regenerate only if the____________remains intact.

**Module 11.3 Electrophysiology of Neurons (Figures 11.11-11.20; Table 11.2)**

A. **Introduction to Electrophysiology of Neurons**:

1. All neurons are excitable or responsive in the presence of various stimuli: chemical signals, local electrical signals, and mechanical deformation.
2. Stimuli generate electrical changes across the neuron plasma membrane that is rapidly conducted (conductivity) along the entire length of the membrane.
3. What are the two forms of electrical changes that occur in neurons? 1) ________________________________ and 2) _____________________ ____________________________.

B. **Principles of Electrophysiology (Figures 11.11, 11.12, 11.13; Table 11.2)**: Electrical changes across neuron plasma membranes rely on ion channels and a resting membrane potential.

1. Ion channels and gradients: ions must rely on specific protein channels such as leak channels, gated channels, ligand-gated channels, voltage-gated channels, and mechanically-gated channels.
2. The resting membrane potential is the negatively charged voltage that is present when a cell is at rest (Figure 11.11).
   a. **What is voltage and how is it established?** ______________

   ____________________________________________________

   ____________________________________________________

   b. **Define membrane potential**. ____________________________

   ____________________________________________________

   c. **When is a cell polarized?** ____________________________

   ____________________________________________________

   d. **What charge does the typical neuron have as resting membrane potential?** _____________

1. Generation of the resting membrane potential relies on the following factors that work together:
   a. Ion concentration gradients favor the diffusion of potassium ions_____________of the cell through leak channels and sodium ions_____________the cell.
   b. The cytosol loses more positive charges than it gains and the membrane potential becomes more______________until it reaches the resting membrane potential.
2. Diffusion of an ion across the plasma membrane is determined by both its concentration and electrical gradients collectively called the ______________________________ **(Figure 11.13)**.
3. **Changes in the Resting Membrane Potential: Ion Movements (Figure 11.14)**:

a. **How is resting membrane potential generated?** __________

______________________________________________________

______________________________________________________

b. Opening a gated channel in the plasma membrane alters the membrane potential as it changes the ion's ability to move across the plasma membrane.

c. **Depolarization** is where the membrane potential becomes more______________due to the influx of positive charges across the plasma membrane. **How is depolarization accomplished?** _______________________________________

______________________________________________________

______________________________________________________

_______________________________________ **(Figure 11.14a)**

d. **Repolarization** is where the cell returns to ________________

________________________________. **How is repolarization accomplished?** _______________________________________

______________________________________________________

______________________________________________________

e. **How is hyperpolarization accomplished?** _______________

______________________________________________________

_______________________________________ **(Figure 11.14b)**

C. **Local potentials**, sometimes called graded potentials, are small changes in the membrane potential of a neuron's plasma membrane that may have caused either_________________or____________________**(Figures 11.14)**. Local potentials can trigger long distance action potentials.

D. An **action potential** is a uniform, rapid depolarization and repolarization of the membrane potential of a cell. Action potentials are only generated in trigger zones that include the________________,_______________and the initial segment of the____________. **(Figures 11.15, 11.16)**

1. **States of voltage-gated channels** allow ions to move and change the membrane potential of the neuron. The movement of ____________ ions is responsible for repolarization **(Figure 11.15a)**.
   a. Voltage-gated potassium channels have two possible states: __________ (closed) and______________(open) **(Figure 11.15a)**.
   b. Voltage-gated sodium channels have two gates, an activation gate and an inactivation gate, with three states: resting, activated, and inactivated **(Figure 15.15b)**.
2. The neuronal action potential has three general phases and lasts only a few milliseconds **(Figure 11.16)**.
   a. **What happens to the membrane potential during the depolarization phase? ________________________________**

      ________________________________________________________

      ________________________________________________________

   b. **What happens to the membrane potential during the repolarization phase? _________________________________**

      ________________________________________________________

      ________________________________________________________

   c. The membrane potential temporarily becomes more __________ than the resting membrane potential during the **hyperpolarization phase.**
3. The action potential proceeds through its three phases because of the opening and closing of specific ion channels. The action potential can be broken down into the following steps:
   a. A local potential must be able to depolarize the axon strongly enough to reach a level called **threshold,** usually________mV.
   b. Once threshold is reached, voltage-gated sodium channels activate and sodium ions are able to flow into the axon causing it to____________________.

c. Sodium ion channels inactivate and voltage-gated potassium ion channels activate:___________ions stop flowing into the axon and_______________begins exiting the axon as repolarization begins.

d. The axolemma may hyperpolarize before potassium ion channels return to the resting state; after this, the axolemma returns to its resting membrane potential.

E. **The Refractory Period** is the period of time, after a neuron has already generated an action potential, when the neuron ______________________ __________________________________________________ **(Figure 11.17)**.

F. **Local and action potentials** compared: graded local potentials produce variable changes in membrane potentials while actions potentials cause a maximum depolarization to_______mV.

1. **Describe the all-or-none principle**. _____________________________

_____________________________________________________________

_____________________________________________________________

Local potentials are reversible. When the stimulus ends, the neuron returns to________________________________________. Action potentials are irreversible once threshold is reached: all-or-none.

2. The signal distance traveled is greater for action potentials versus "local" potentials.

G. **The Propagation of Action Potentials**. An action potential must be conducted or **propagated** along the entire length of the axon to serve as a long-distance signaling service **(Figures 11.18, 11.19)**:

1. An action potential is self-propagating and travels in _______________ direction.

2. **Describe the events of propagation of an action potential down the axon (Figure 11.16)**:

a. _______________________________________________________

_______________________________________________________

b. ________________________________________________

________________________________________________

c. ________________________________________________

________________________________________________

d. ________________________________________________

________________________________________________

3. **Conduction Speed** is the rate of propagation that is influenced by both axon diameter and the presence or absence of myelination. **(Figure 11.18)**:
   a. **Describe saltatory conduction**. ________________________

   ________________________________________________

   ________________________________________________

   ________________________________________________

   ________________________________________________

   ________________________________________ **(Figure 11.19)**
   b. **Describe continuous conduction**. ________________________

   ________________________________________________

   ________________________________________________

   ________________________________________________

   ________________________________________________

   ________________________________________________

**Module 11.4 Neuronal Synapses (Figures 11.21-11.28)**

A. **Overview of Neuronal Synapses**. **Define synapse**. __________________

________________________________________________

________________________________________________ **(Figure 11.21)**

1. Neuronal synapses can occur between the axon of one neuron and another part of another neuron.
2. The following terms are used to describe which neuron is sending and which is receiving the message, regardless of the type of synapse.
   a. **What is the function of the presynaptic neuron? ____**

   ________________________________________________

_______________________________________________________

_______________________________________________________

b. **What is the function of the postsynaptic neuron?** _________

_______________________________________________________

_______________________________________________________

_______________________________________________________

_______________________________________________________

c. **Where is the synaptic cleft located?** ______________________

_______________________________________________________

_______________________________________________________

_______________________________________________________

3. **Synaptic transmission** is the transfer of chemical or electrical signals between neurons at a synapse.

B. **Electrical Synapses.** An electrical synapse occurs between cells that are electrically coupled via gap junctions **(Figure 11.22a)**.

C. **Chemical synapses** make up the majority of synapses in the nervous system. These synapses convert electrical signals into chemical signals so no signal strength is lost as is the case at electrical synapses **(Figures 11.22, 11.23, 11.24, 11.25)**.

1. **Events at a chemical synapse**. Neuronal synapses are more complicated than the neuromuscular junction. There are multiple neurons secreting many different types of excitatory or inhibitory neurotransmitters. The following are the events at the chemical synapse **(Figure 11.23)**:

   a. An action potential in the presynaptic neuron triggers ___________ ion channels in the axon terminal to open.

   b. Influx of calcium ions causes _____________________________

   _______________________________________________________

   _______________________________________________________

   c. Neurotransmitters bind to receptors on the _________________ neuron.

d. Ion channels open, leading to a local potential and possibly an action potential if_______________is reached.

2. **Postsynaptic potentials** are the local potentials found in the membranes of the postsynaptic neuron, which can move the membrane either closer to or further away from threshold. The two following events are possible depending on which channels are opened **(Figure 11.24)**:

   a. ________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________

   b. ________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________________

3. **Termination of Synaptic Transmission** may occur by ending the effects of the neurotransmitter **(Figure 11.25)**.

D. **Neural Integration**: **Summation of Stimuli**:

1. **Define neural integration**. __________________________________________________________________________________________________________________________________________________________________________________

2. **Describe summation**. _________________________________________________________________________________________________________________________________________________________________________________________

   a. An action potential will only be generated if threshold is reached, which means that the sum of the______________must be enough to overcome the sum of the_____________.

b. If the sum of IPSPs is greater than EPSPs, then threshold will not be reached. **Will an action potential be generated?** ____

_______________________________________________

3. **Describe how temporal summation and spatial summation are created**. ______________________________________________

______________________________________________________

______________________________________________________

______________________________________________________

__________________________________________ **(Figure 11.28)**

**Module 11.5 Neurotransmitters (11.29; Table 11.3)**

A. **Neurotransmitter Receptors**. The type of receptor a neurotransmitter binds to on the postsynaptic membrane determines the response.

1. Ionotropic receptors are found as components of a ligand-gated ion channels. These receptors directly control the movement of ions into or of the neuron when they bind to neurotransmitter **(Figure 11.29a)**.
2. Metabotropic receptors are found within the plasma membrane associated with a separate ion channel. These receptors are directly connected to metabolic processes that are initiated when neurotransmitter binds **(Figure 11.29b)**. G-proteins, intracellular enzymes associated with many metabotropic receptors, activate a cascade of reactions that ultimately form second messengers such as cAMP (cyclic adenosine monophosphate).

B. **Major neurotransmitters**. Regardless of the receptor-type that it binds, neurotransmitters lead to either an EPSP and have_____________effects or an IPSP and have___________effects. Most neurotransmitters can have both effects depending on which postsynaptic neuron receptors they bind **(Table 11.3)**:

1. **Acetylcholine (ACh)** is a neurotransmitter widely used by the nervous system. It is largely excitatory but does exhibit some inhibitory effects in the PNS. ACh is quickly degraded by ______ (AChE), an enzyme in the synaptic cleft.

2. **The biogenic amines** (monoamines) are a class of five neurotransmitters synthesized from amino acids. They are used throughout the CNS and PNS for functions such as regulation of homeostasis and cognition.________________,_______________, and________________form the **catecholamine** subgroup and are mostly excitatory. Serotonin and histamine are involved in brain functions.
3. **Amino acid neurotransmitters**. The three main amino acid neurotransmitters are:_______________,________________________, and__________________.
4. The **neuropeptides** are a group of neurotransmitters that have a wide variety of functions within the nervous system, such as substance P, opioids, and neuropeptide Y.

**Module 11.6 Functional Groups of Neurons (Figures 11.30-11.31)**

A. **Neuronal Pools** are groups of interneurons within the CNS **(Figure 11.30)**.

B. **Neural circuits** are the patterns of synaptic connection between neural pools **(Figure 11.31)**.