

Chapter 11 - Fundamentals of the Nervous System and Nervous Tissue

Objectives

Organization of the Nervous System

1. List the structural and functional divisions of the nervous system, and describe their relationship to each other.

Histology of Nervous Tissue

2. Describe the types of glial cells, their function, and location in the nervous system.
3. Explain the physiological characteristics of mature neurons.
4. Discuss the anatomy of a neuron, and the function of each structure.
5. Describe the anatomy and function of the myelin sheath, and differentiate between myelinated and unmyelinated neurons.
6. Define the structural and functional categories of neurons, and compare how the structural class of a neuron relates to its functional class.

Neurophysiology

7. Define the terms voltage, potential difference, and current, and describe how electrical current travels in the body.
8. Name the various types of membrane channels, and the signals that control each type.
9. Explain the resting membrane potential and how it is generated.
10. Identify how changes in membrane potentials act as signals, and relate each type of signal to the generation of action potentials.
11. Discuss the mechanism of generation of an action potential, and the three phases of an action potential.
12. Describe a threshold stimulus. Discuss how it relates to the graded potentials generated on dendrites, and the all-or-none behavior of axons.
13. Define the absolute and relative refractory periods, and describe the events that occur during each.
14. Identify the effects of axon diameter and myelination on conduction velocity of axons.
15. Define a synapse, name the two types, and describe how synaptic transmission occurs at a chemical synapse.
16. Define EPSP and IPSP. Describe what causes them and how they are summated by the postsynaptic cell.
17. List the chemical and functional classes of neurotransmitters, members of each class, and the types of receptors for neurotransmitters.

Basic Concepts of Neural Integration

18. Describe neuronal pools and their function.
19. Name the various types of circuits.
20. Compare and contrast serial and parallel processing.

Developmental Aspects of Neurons

21. Describe the major events of development, growth, and refinement of the nervous system.

Lecture Outline

I. Organization of the Nervous System (pp. 388–389; Figs. 11.1–11.2)

- A. The central nervous system consists of the brain and spinal cord, and is the integrating and command center of the nervous system (p. 388; Figs. 11.1–11.2).
- B. The peripheral nervous system is outside the central nervous system (pp. 388–389; Fig. 11.2).
 - 1. The sensory, or afferent, division of the peripheral nervous system carries impulses toward the central nervous system from sensory receptors located throughout the body.
 - 2. The motor, or efferent, division of the peripheral nervous system carries impulses from the central nervous system to effector organs, which are muscles and glands.
 - a. The somatic nervous system consists of somatic nerve fibers that conduct impulses from the CNS to skeletal muscles, and allow conscious control of motor activities.
 - b. The autonomic nervous system is an involuntary system consisting of visceral motor nerve fibers that regulate the activity of smooth muscle, cardiac muscle, and glands.

II. Histology of Nervous Tissue (pp. 389–397; Figs. 11.3–11.5; Table 11.1)

- A. Neuroglia, or glial cells, are closely associated with neurons, providing a protective and supportive network (pp. 389–391; Fig. 11.3).
 - 1. Astrocytes are glial cells of the CNS that regulate the chemical environment around neurons and exchange between neurons and capillaries.
 - 2. Microglia are glial cells of the CNS that monitor health and perform defense functions for neurons.
 - 3. Ependymal cells are glial cells of the CNS that line the central cavities of the brain and spinal cord and help circulate cerebrospinal fluid.
 - 4. Oligodendrocytes are glial cells of the CNS that wrap around neuron fibers, forming myelin sheaths.
 - 5. Satellite cells are glial cells of the PNS whose function is largely unknown. They are found surrounding neuron cell bodies within ganglia.
 - 6. Schwann cells, or neurolemmocytes, are glial cells of the PNS that surround nerve fibers, forming the myelin sheath.
- B. Neurons are specialized cells that conduct messages in the form of electrical impulses throughout the body (pp. 391–397; Figs. 11.4–11.5; Table 11.1).
 - 1. Neurons function optimally for a lifetime, are mostly amitotic, and have an exceptionally high metabolic rate requiring oxygen and glucose.
 - a. The neuron cell body, also called the perikaryon or soma, is the major biosynthetic center containing the usual organelles except for centrioles.
 - b. Dendrites are cell processes that are the receptive regions of the cell.
 - c. Each neuron has a single axon that generates and conducts nerve impulses away from the cell body to the axon terminals.
 - d. The myelin sheath is a whitish, fatty, segmented covering that protects, insulates, and increases conduction velocity of axons.
 - 2. There are three structural classes of neurons.
 - a. Multipolar neurons have three or more processes.
 - b. Bipolar neurons have a single axon and dendrite.
 - c. Unipolar neurons have a single process extending from the cell body that is associated with receptors at the distal end.

3. There are three functional classes of neurons.
 - a. Sensory, or afferent, neurons conduct impulses toward the CNS from receptors.
 - b. Motor, or efferent, neurons conduct impulses from the CNS to effectors.
 - c. Interneurons, or association neurons, conduct impulses between sensory and motor neurons, or in CNS integration pathways.

III. Neurophysiology (pp. 397–421; Figs. 11.6–11.22; Tables 11.2–11.3)

- A. Basic Principles of Electricity (pp. 397–398)
 1. Voltage is a measure of the amount of difference in electrical charge between two points, called the potential difference.
 2. The flow of electrical charge from point to point is called current, and is dependent on voltage and resistance (hindrance to current flow).
 3. In the body, electrical currents are due to the movement of ions across cellular membranes.
- B. The Role of Membrane Ion Channels (pp. 393–399; Fig. 11.6)
 1. The cell has many gated ion channels.
 - a. Chemically gated (ligand gated) channels open when the appropriate chemical binds.
 - b. Voltage gated channels open in response to a change in membrane potential.
 - c. Mechanically gated channels open when a membrane receptor is physically deformed.
 2. When ion channels are open, ions diffuse across the membrane, creating electrical currents.
- C. The Resting Membrane Potential (pp. 399–400; Figs. 11.7–11.8)
 1. The neuron cell membrane is polarized, being more negatively charged inside than outside. The degree of this difference in electrical charge is the resting membrane potential.
 2. The resting membrane potential is generated by differences in ionic makeup of intracellular and extracellular fluids, and differential membrane permeability to solutes.
- D. Membrane Potentials That Act as Signals (pp. 400–409; Figs. 11.9–11.17)
 1. Neurons use changes in membrane potential as communication signals. These can be brought on by changes in membrane permeability to any ion, or alteration of ion concentrations on the two sides of the membrane.
 2. Changes in membrane potential relative to resting membrane potential can either be depolarizations, in which the interior of the cell becomes less negative, or hyperpolarizations, in which the interior of the cell becomes more negatively charged.
 3. Graded potentials are short-lived, local changes in membrane potentials. They can either be depolarizations or hyperpolarizations, and are critical to the generation of action potentials.
 4. Action potentials, or nerve impulses, occur on axons and are the principle way neurons communicate.
 - a. Generation of an action potential involves a transient increase in Na^+ permeability, followed by restoration of Na^+ impermeability, and then a short-lived increase in K^+ permeability.
 - b. Propagation, or transmission, of an action potential occurs as the local currents of an area undergoing depolarization cause depolarization of the forward adjacent area.
 - c. Repolarization, which restores resting membrane potential, follows depolarization along the membrane.
 5. A critical minimum, or threshold, depolarization is defined by the amount of influx of Na^+ that at least equals the amount of efflux of K^+ .
 6. Action potentials are an all-or-none phenomena: they either happen completely, in the case of a threshold stimulus, or not at all, in the event of a subthreshold stimulus.

7. Stimulus intensity is coded in the frequency of action potentials.
 8. The refractory period of an axon is related to the period of time required so that a neuron can generate another action potential.
- E. Influence of Axon Diameter and the Myelin Sheath on Conduction Velocity (p. 407; Fig. 11.16)
1. Axons with larger diameters conduct impulses faster than axons with smaller diameters.
 2. Unmyelinated axons conduct impulses relatively slowly, while myelinated axons have a high conduction velocity.
- F. The Synapse (pp. 408–411; Figs. 11.17–11.18)
1. A synapse is a junction that mediates information transfer between neurons or between a neuron and an effector cell.
 2. Neurons conducting impulses toward the synapse are presynaptic cells, and neurons carrying impulses away from the synapse are postsynaptic cells.
 3. Electrical synapses have neurons that are electrically coupled via protein channels and allow direct exchange of ions from cell to cell.
 4. Chemical synapses are specialized for release and reception of chemical neurotransmitters.
 5. Neurotransmitter effects are terminated in three ways: degradation by enzymes from the postsynaptic cell or within the synaptic cleft; reuptake by astrocytes or the presynaptic cell; or diffusion away from the synapse.
 6. Synaptic delay is related to the period of time required for release and binding of neurotransmitters.
- G. Postsynaptic Potentials and Synaptic Integration (pp. 411–413; Figs. 11.19– 11.20; Table 11.2)
1. Neurotransmitters mediate graded potentials on the postsynaptic cell that may be excitatory or inhibitory.
 2. Summation by the postsynaptic neuron is accomplished in two ways: temporal summation, which occurs in response to several successive releases of neurotransmitter, and spatial summation, which occurs when the postsynaptic cell is stimulated at the same time by multiple terminals.
 3. Synaptic potentiation results when a presynaptic cell is stimulated repeatedly or continuously, resulting in an enhanced release of neurotransmitter.
 4. Presynaptic inhibition results when another neuron inhibits the release of excitatory neurotransmitter from a presynaptic cell.
 5. Neuromodulation occurs when a neurotransmitter acts via slow changes in target cell metabolism, or when chemicals other than neurotransmitter modify neuronal activity.
- H. Neurotransmitters and Their Receptors (pp. 413–421; Figs. 11.21–11.22; Table 11.3)
1. Neurotransmitters are one of the ways neurons communicate, and they have several chemical classes.
 2. Functional classifications of neurotransmitters consider whether the effects are excitatory or inhibitory, and whether the effects are direct or indirect.
 3. There are two main types of neurotransmitter receptors: channel-linked receptors mediate direct transmitter action and result in brief, localized changes; and G protein-linked receptors mediate indirect transmitter action resulting in slow, persistent, and often diffuse changes.

IV. Basic Concepts of Neural Integration (pp. 421–423; Figs. 11.23–11.24)

- A. Organization of Neurons: Neuronal Pools (p. 421; Fig. 11.24)
1. Neuronal pools are functional groups of neurons that integrate incoming information from receptors or other neuronal pools and relay the information to other areas.

- B. Types of Circuits (pp. 421–422; Fig. 11.25)
1. Diverging, or amplifying, circuits are common in sensory and motor pathways. They are characterized by an incoming fiber that triggers responses in ever-increasing numbers of fibers along the circuit.
 2. Converging circuits are common in sensory and motor pathways. They are characterized by reception of input from many sources, and a funneling to a given circuit, resulting in strong stimulation or inhibition.
 3. Reverberating, or oscillating, circuits are characterized by feedback by axon collaterals to previous points in the pathway, resulting in ongoing stimulation of the pathway.
 4. Parallel after-discharge circuits may be involved in complex activities, and are characterized by stimulation of several neurons arranged in parallel arrays by the stimulating neuron.
- C. Patterns of Neural Processing (pp. 422–423; Fig. 11.25)
1. Serial processing is exemplified by spinal reflexes, and involves sequential stimulation of the neurons in a circuit.
 2. Parallel processing results in inputs stimulating many pathways simultaneously, and is vital to higher level mental functioning.

V. Developmental Aspects of Neurons (pp. 423–426)

- A. The nervous system originates from a dorsal neural tube and neural crest, which begin as a layer of neuroepithelial cells that ultimately become the CNS.
- B. Differentiation of neuroepithelial cells occurs largely in the second month of development.
- C. Growth of an axon toward its target appears to be guided by older “pathfinding” neurons and glial cells, nerve growth factor and cholesterol from astrocytes, and tropic chemicals from target cells.
- D. The growth cone is a growing tip of an axon. It takes up chemicals from the environment that are used by the cell to evaluate the pathway taken for further growth and synapse formation.
- E. Unsuccessful synapse formation results in cell death, and a certain amount of apoptosis occurs before the final population of neurons is complete.

Cross References

Additional information on topics covered in Chapter 11 can be found in the chapters listed below.

1. Chapter 2: Enzymes and enzyme function
2. Chapter 3: Passive and active membrane transport processes; membrane potential; cytoskeletal elements; cell cycle
3. Chapter 4: Nervous tissue
4. Chapter 9: Synapse (neuromuscular junction)
5. Chapter 13: Membrane potentials; neural integration
6. Chapter 14: Cholinergic and adrenergic receptors and other neurotransmitter effects; autonomic synapses
7. Chapter 15: Receptors for the special senses; synapses involved in the special senses; neurotransmitters in the special senses
8. Chapter 16: Nervous system modulation of endocrine function
9. Chapter 18: Membrane potential and the electrical activity of the heart
10. Chapter 19: Baroreceptors and chemoreceptors in blood pressure and flow regulation
11. Chapter 22: Chemoreceptors and stretch receptors related to respiratory function

12. Chapter 23: Sensory receptors and control of digestive processes
13. Chapter 24: Examples of receptors

Laboratory Correlations

1. Marieb, E. N. *Human Anatomy & Physiology Laboratory Manual: Cat and Fetal Pig Versions*. Eighth Edition Updates. Benjamin Cummings, 2006.
Exercise 17: Histology of Nervous Tissue
Exercise 18: Neurophysiology of Nerve Impulses
 2. Marieb, E. N. *Human Anatomy & Physiology Laboratory Manual: Main Version*. Seventh Edition Update. Benjamin Cummings, 2006.
Exercise 17: Histology of Nervous Tissue
Exercise 18: Neurophysiology of Nerve Impulses
- Stix, Gary. "Saying Yes to NO." *Scientific American* 285 (5) (Nov. 2001): 34.