CHAPTER 7
THE NERVOUS SYSTEM: NEURONS AND SYNAPSES

CHAPTER SCOPE

This chapter begins a four-chapter unit (chapters 7 through 10) on the basic structure and function of **neurons** and **synapses** in the nervous system. The electrical membrane potential of a neuron at rest that was introduced in the last chapter, now "comes to life" as appropriate stimuli alter the permeability of the plasma membrane to ions. The carefully synchronized opening and closing of Na^+ and K^+ gates or "channels" result in the movement of electrical charges that generates a nerve impulse, or **action potential**.

Action potentials reach the end of each neuron where these electrical signals are either transmitted directly to the next cell in the sequence via electrical synapses or *gap junctions*, or indirectly are responsible for activating the release of specialized **neurotransmitter** chemicals. Released from vesicles into the synaptic space, these neurotransmitters diffuse a short distance, bind to specialized receptors integrated in the membrane of the next effector cell in the conduction pathway and promote the formation of new action potentials. Effector cells such as another neuron, a muscle fiber (chapters 12, 13), or a gland cell (chapters 11, 20), will then respond.

The release and action of specific neurotransmitters, especially *acetylcholine* (ACh), is carefully detailed in this chapter. Others, such as the **catecholamines** (*dopamine*, *norepinephrine*, and *epinephrine*) and a growing number of less well-known neurochemicals (*amino acids*, *polypeptides*, *nitric oxide*, or *endocannabinoid*) are particularly active in the CNS.

It is important to have a solid understanding of the nervous system's structure and function presented in these four chapters for a successful (and enjoyable) comprehension of the organ system chapters that follow. The nervous system forms the basic communication network linking all tissues of the body to the brain and to each other. As will be featured in chapter 11, the nervous system's fast electrical signals (action potentials) often work together with slower-responding chemical messengers (*hormones*). Both messenger systems, however, must cooperate effectively in the maintenance of overall body homeostasis.

I. NEURONS AND SUPPORTING CELLS

The nervous system is composed of neurons, which produce and conduct electrochemical impulses, and supporting cells, which assist the functions of neurons. Neurons are classified functionally and structurally; the various types of supporting cells perform specialized functions.

A. Multiple Choice

___ 1. Which of the following is *not* a function of neurons?
   a. respond to physical and chemical stimuli
   b. conduct electrical impulses
   c. release specific chemical regulators
   d. All of these are neuron functions.

___ 2. Nissl bodies located only in the cell body are composed of
   a. mitochondria.
   b. rough endoplasmic reticulum.
   c. Golgi apparatus.
   d. lysosomes.

___ 3. A grouping of cell bodies located within the CNS is known as a
   a. tract.
   b. nerve.
   c. nucleus.
   d. ganglion.

___ 4. Involuntary effectors (glands, smooth or cardiac muscle) are innervated (stimulated) by
   a. autonomic nerves.
   b. efferent nerves.
   c. motor nerves.
   d. All of these nerves innervate involuntary effectors.

___ 5. The most common type of neuron (motor neuron, for example) is
   a. bipolar.
   b. multipolar.
   c. pseudounipolar.

___ 6. Myelin sheaths around axons within the CNS are formed by
   a. Schwann cells.
   b. microglia.
   c. astrocytes.
   d. oligodendrocytes.

___ 7. The most abundant supporting (glial) cell in the CNS, which forms end-feet around capillaries associated with the blood-brain barrier, is the
   a. astrocyte.
   b. oligodendrocyte.
   c. satellite cell.
   d. microglia.

___ 8. The supporting cells of the nervous system that line the ventricles (cavities) of the brain, that form choroid plexuses producing cerebrospinal fluid (CSF); and more recently that seem to function as stem cells (able to divide and differentiate into new neurons and neuroglial cells), best describes the
   a. Astrocyte.
   b. Oligodendrocyte.
   c. satellite cell.
   d. Microglia.
   e. ependymal cell.

___ 9. Which statement about **Schwann cells** is *not* true?
   a. They remain alive as their cytoplasm is forced to the outside of the myelin sheath.
   b. They have extensions, like tentacles of an octopus that form myelin sheaths around several axons simultaneously.
   c. Adjacent cells form gaps exposing nodes of Ranvier along an axon.
   d. They are only found in the peripheral nervous system (PNS).
   e. They can form a regeneration tube; helping to reconnect and reestablish nerve function after an axon has been cut.

___ 10. Which part of neurons is progressively destroyed in those people with the chronic disease, *multiple sclerosis* (MS)?
   a. cell body
   b. axons
   c. dendrites
   d. axon hillock
   e. myelin sheath

___ 11. *Neurotrophins*, are important chemicals secreted by neurons that
   a. help make the blood-brain barrier.
   b. promote neuron growth, especially in the developing fetal brain.
   c. make myelin for neuron axons.
   d. keep the CNS tissue clear of debris and foreign particles.
   f. relay impulses from one neuron to the next.

___ 12. Which of the following is *not* a function of glial cells known as astrocytes?
   a. absorb released K^+ from the extracellular fluid
   b. absorb certain neurotransmitters such as glutamate for reuse
   c. absorb energy molecules such as glucose for production of ATP
   d. regulate the differentiation (specialization) of glial cells and neurons in the adult brain from stem cells
   e. All of these are functions of astrocytes.

B. True or False/Edit

___ 13. The nervous system is composed of two principal types of cells — neurons and supporting cells (neuroglia or glial cells).

___ 14. Neurons cannot divide by mitosis, although some neurons can regenerate severed portions or sprout new branches under some conditions.

___ 15. In the brain, neurons outnumber glial cells five to one.

___ 16. Orthograde (forward flow) and retrograde (reverse flow) transport in neurons is characteristic of rapid axonal transport.

___ 17. Association neurons (interneurons) are located entirely within the central nervous system (CNS).

___ 18. A continuous, living sheath of Schwann cells surrounds all axons in the central nervous system (CNS) but not in the peripheral nervous system (PNS).

___ 19. The myelin sheaths surrounding CNS axons are formed by glial cells known as *oligodendrocytes* after birth.

___ 20. The myelin sheaths around axons of the CNS give this tissue a gray color and thus form gray matter.

___ 21. Myelinated axons conduct impulses more rapidly than those that are unmyelinated..

___ 22. Regeneration of CNS axons is inhibited by many factors including growth-inhibiting proteins in the membranes of myelin sheaths and from oligodendrocytes as well as glial scars formed from astrocytes.

___ 23. *Astrocytes* are glial cells that surround capillaries of the CNS using their end-feet to uptake glucose molecules from the blood; and can also take up such substances as K^+ and glutamate neurotransmitters from the extracellular fluid.

___ 24. Spaces (pores) are found between endothelial cells lining the capillaries of the brain, and thus form the *blood-brain barrier*.

C. Label the Figure — Neuron Structure

Study figure 7.1 and notice the differences in structure between sensory neurons and motor neurons. Then correctly label each neuron type using the term “sensory” or “motor.” Complete the exercise by labeling the various parts of each neuron in the spaces provided. (When finished, check your work with figure 7.1 in your textbook.)

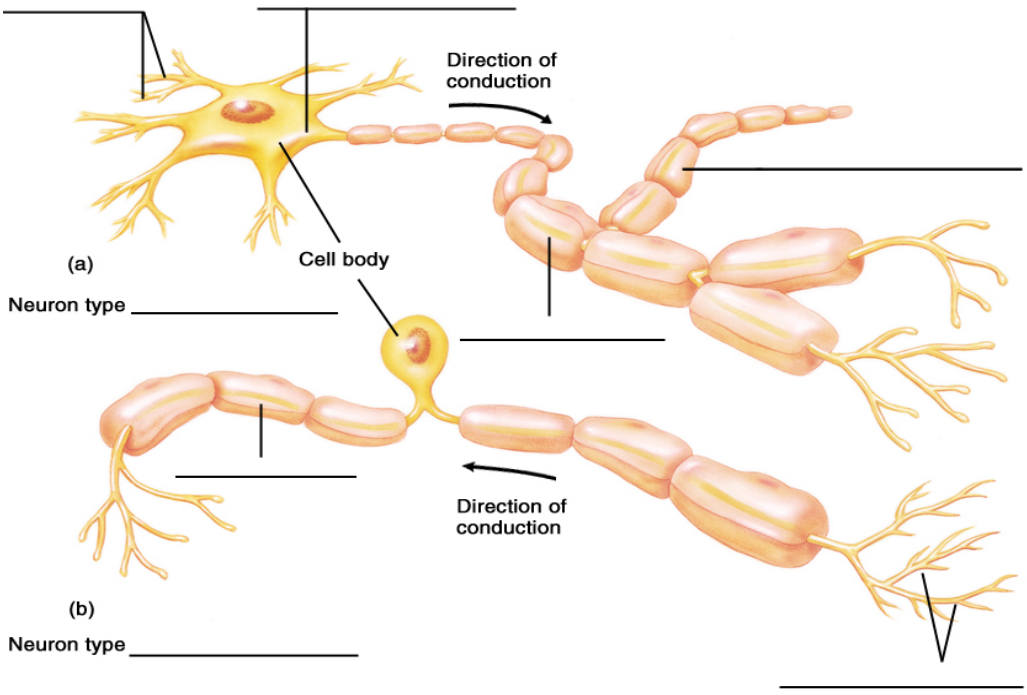

Figure 7.1 The structure of two kinds of neurons.

II. ELECTRICAL ACTIVITY IN AXONS

The permeability of the axon membrane to Na^+ and K^+ is regulated by gates, which open in response to stimulation. Net diffusion of these ions occurs in two stages: first Na^+ moves into the axon, then K^+ moves out. This flow of ions, and the changes in the membrane potential that result, constitute an event called an action potential.

A. Multiple Choice

___ 25. When a cell is stimulated and more negative charges flow into the cell so that the cell becomes more negative than the resting membrane potential, describes
   a. depolarization.
   b. repolarization.
   c. hyperpolarization.

___ 26. The term "voltage regulated" means that the membrane
   a. gates open and close with changes in the membrane potential.
   b. potential is controlled by the Na^+/K^+ pumps.
   c. will not respond unless electrically stimulated.
   d. potential can only be seen with an oscilloscope.

___ 27. Arrange these **action potential** events in proper sequence:
   1. Membrane depolarization begins. 2. K^+ gates begin to open. 3. K^+ gates begin to close; hyperpolarization occurs. 4. Na^+ gates open rapidly. 5. Na^+ gates begin to close. 6. Membrane repolarization begins.
   a. 1, 2, 4, 3, 5, 6
   b. 2, 6, 3, 4, 1, 5
   c. 4, 6, 2, 1, 5, 3
   d. 1, 4, 2, 5, 6, 3

___ 28. Which statement about the action potential or nerve impulse is *false*?
   a. Only a relatively small number of Na^+ and K^+ ions actually diffuse across the axon membrane.
   b. Each action potential includes both positive and negative feedback loops.
   c. The Na^+/K^+ pumps are directly involved in creating the action potential.
   d. During the action potential, Na^+ and K^+ total concentrations are not significantly changed.
   e. Repolarization requires the outward diffusion of K^+ ions.

___ 29. When a stimulus of greater strength is applied to a neuron
   a. identical action potentials are produced more frequently (more are produced per minute).
   b. the total amplitude (height) of each action potential increases also.
   c. the neuron fires a steady barrage of action potentials for a longer duration of time.

___ 30. Action potentials conducted without *decrement* means conducted without.
   a. decreasing its velocity.
   b. altering the threshold potential.
   c. decreasing its amplitude.
   d. altering the Na^+ or K^+ concentrations in the neuron.

___ 31. Which of the following statements about the conduction velocity of action potentials along myelinated axons when compared to that along unmyelinated axons, is *false*?
   a. Conduction velocity in the myelinated axon is very fast, approaching 225 miles per hour.
   b. Cable properties within the myelinated axon increase the conduction velocity.
   c. Nodes of Ranvier increase the conduction velocity.
   d. Saltatory conduction increases the conduction velocity.

B. True or False/Edit

___ 32. Although all cells have a membrane potential only a few types of cells, such as neurons and muscle cells, demonstrate the ability to respond to stimulation – a property called excitability or irritability.

___ 33. Following stimulation of a neuron, positive charges flow into the cell causing depolarization (excitation), whereas the return to resting is known as hyperpolarization (inhibition).

___ 34. There may be two types of neuron membrane channels for Na^+; one type is always open because it lacks gates (*leakage channels*) whereas the other type has gates that are closed in the resting cell.

___ 35. The Na^+/K^+ pumps are not directly involved in the formation of an action potential; rather they are required to maintain the proper, opposing concentration gradients of these two ions.

___ 36. Within a collection of axons (or nerves), a low-intensity stimulus will only activate those few fibers with low thresholds, whereas high-intensity stimuli can activate fibers with higher thresholds.

___ 37. The *absolute* refractory period occurs at a time when the Na^+ channel is inactivated either by a molecular ball attached to a polypeptide chain or, in a different type of ion channel, the channel's molecular structure is rearranged thereby resulting in the inactivation.

___ 38. An axon membrane in its *relative* refractory period can respond only if a sufficiently strong stimulus is applied because during this time the Na^+ channels are recovering from inactivation and the K^+ channels are still open.

___ 39. Compared to metal wires, the axon is a very poor electrical conductor.

___ 40. High-speed conduction of neural impulses is made possible due to the *cable properties* of the axon.

___ 41. The entry of Na^+ into a stimulated axon during depolarization is followed by Na^+ conduction by cable properties to the adjacent unstimulated region of the axon, leading to depolarization of this region to threshold and production of a new action potential.

___ 42. The action potential produced at the end of the axon looks different from that formed at the axon nearest the cell body.

___ 43. Action potentials conducted along thicker, unmyelinated fibers are conducted faster than those along thin, unmyelinated fibers; and are conducted *substantially* faster if the axon is myelinated.

___ 44. Thick, myelinated fibers would be expected to mediate (to come in the middle of or to control) slower responses in the viscera (to and from internal organs and smooth muscle).

___ 45. Fast saltatory conduction of action potentials is made possible by the interruptions in the myelin sheath along axons, known as nodes of Ranvier.

III. THE SYNAPSE

Axons end close to, or in some cases at the point of contact with, another cell. Once action potentials reach the end of an axon, they directly or indirectly stimulate (or inhibit) the other cell. In specialized cases, action potentials can directly pass from one cell to another. In most cases, however, the action potentials stop at the axon ending where they stimulate the release of a chemical neurotransmitter that affects the next cell.

A. Multiple Choice

___ 46. The only synapse that should *not* conduct impulses in one direction only is called
- a. axodendritic.
- b. axosomatic.
- c. axoaxonic.
- d. dendrodentritic.
- e. All are one-directional only.

___ 47. Electrical synapses (for example, smooth and cardiac muscle fibers) are characterized by having two adjoining cells that
- a. are about equal in size.
- b. have contact areas with low electrical resistance.
- c. have gap junctions present between them.
- d. All of these characterize electrical synapses.
- e. None of these characterize electrical synapses.

___ 48. As the intensity of the stimulus in a presynaptic neuron increases, the number of vesicles undergoing exocytosis _____, and the number of released neurotransmitter molecules _____.
- a. increases; increases
- b. increases; decreases
- c. decreases; increases
- d. decreases; decreases

___ 49. The ion that must flow into the presynaptic neuron ending to activate the release of neurotransmitter chemicals from synaptic vesicles is
a. sodium.
b. potassium.
c. calcium.
d. iron.
e. hydrogen.

___ 50. Which of the following events is *not* involved in the release of neurotransmitter chemicals from the presynaptic terminal boutons?
a. opening of voltage-regulated calcium channels
b. turning off the Na^+/K^+ membrane pumps
c. activation of intracellular enzymes known as protein kinases
d. pores form in membrane-bound vesicles causing exocytosis
e. phosphorylation of synapsin proteins in the membrane of the synaptic vesicles.

B. True or False/Edit

___ 51. Myoneural and neuromuscular junctions mean the same thing – that is, they refer to a neuron-to-muscle synapse.

___ 52. Synaptic transmission is electrical rather than chemical.

___ 53. Gap junctions are characteristic features of smooth and cardiac muscle cells (fibers), brain neurons, and even many embryonic tissues.

___ 54. The synaptic cleft refers to the swollen ending of the presynaptic axon terminal.

___ 55. Voltage-regulated channels are found in the postsynaptic membrane and open in response to electrical depolarization.

___ 56. Depolarization of the postsynaptic membrane results in an EPSP and excitation, whereas hyperpolarization of the postsynaptic membrane results in an IPSP and inhibition.

IV. ACETYLCHOLINE AS A NEUROTRANSMITTER

When acetylcholine (ACh) binds to its receptor, it directly or indirectly causes the opening of chemically regulated gates. In many cases, this produces a depolarization called an excitatory postsynaptic potential, or EPSP. In some cases, however, ACh causes a hyperpolarization known as an inhibitory postsynaptic potential, or IPSP.

A. Multiple Choice

___ 57. **Acetylcholine** (ACh) is a neurotransmitter released from all of the following areas, *except*
a. specific CNS neuron endings.
b. somatic motor neurons at the neuromuscular junction.
c. specific autonomic neuron endings.
d. All of these neurons release ACh.

___ 58. Which of the following is *not* a property of *chemically regulated* gated channels?
a. They respond best to electrical membrane potential changes.
b. They are located on the postsynaptic membrane.
c. They can allow Na^+ and K^+ diffusion simultaneously through opened ion channels .
d. They are activated by neurotransmitters binding to specific receptor molecules.

___ 59. Which of the following statements describes ***nicotinic*** ACh receptor subtypes (as opposed to *muscarinic* ACh receptor subtypes)?
a. These receptors are formed from only a single membrane polypeptide subunit.
b. Once activated, they release G-proteins that move laterally through the plasma membrane.
c. These receptors are activated by binding with a single ACh neurotransmitter molecule.
d. These receptors are found in smooth muscle, cardiac muscle, and certain gland cells.
e. Once opened, result in the direct inward diffusion of Na^+; and depolarization.

___ 60. *Acetylcholinesterase* (AChE) is an enzyme located on or immediately outside the
a. presynaptic membrane.
b. postsynaptic membrane.
c. axon terminal cytoplasm.
d. vesicles released by exocytosis.

___ 61. The drug *curare* reduces the size of end plate potentials on the membrane of muscle fibers by
a. competing with ACh for attachment to the receptor proteins.
b. blocking the release of ACh from presynaptic vesicles.
c. enhancing the breakdown of ACh by the enzyme, AChE.
d. blocking the flow of Na^+ through open ion channels.

___ 62. *Myasthenia gravis* is a muscle weakness disease caused by
a. antibodies blocking and destroying ACh receptors.
b. blocking the release of ACh from presynaptic vesicles.
c. enhancing the breakdown of ACh by AChE.
d. blocking the flow of Na^+ through open ion channels.

___ 63. Which statement about the *muscarinic type* of G-protein-operated channel is *false?*
a. Muscarinic receptors are formed from only a single protein subunit that binds to only one ACh molecule.
b. Muscarinic receptors do not contain ion channels.
c. Opening muscarinic channels cause the simultaneous movement of Na^+ and K^+ down their respective concentration gradients.
d. In some receptors, the beta-gamma complex is activated whereas in other receptors the alpha subunit is the effector molecule initiating receptor response.
e. Muscarinic receptors can be found various regions of the body, including cardiac muscle cells (heart) and smooth muscle cells (stomach).

___ 64. EPSPs produced by ACh acting on the postsynaptic membrane of skeletal muscle cells (muscle fibers) during voluntary muscle stimulation formally known as
a. end-plate potentials (EPPs).
b. depolarizations.
c. repolarizations.
d. action potentials (APs).
e. inhibitory potentials (IPSPs).

___ 65. The first voltage-regulated gates encountered along the neuron membrane, which initiate the formation of action potentials, are located on the
a. dendrite.
b. cell body.
c. axon hillock portion of the axon.
d. axon terminal.
e. postsynaptic membrane.

B. True or False/Edit

___ 66. The effects of acetylcholine (ACh) can be either excitatory or inhibitory.

___ 67. ACh is transported into the postsynaptic cell cytoplasm, where it produces its effects.

___ 68. Neurotransmitters operating chemically regulated gates, do *not* directly result in action potentials, but rather initially produce EPSPs and IPSPs.

___ 69. Acetylcholinesterase (AChE) is an enzyme that inactivates ACh, thus serves to uncouple the electrochemical conduction of the nerve impulse.

___ 70. The bond between ACh and its receptor protein is exceptionally strong.

___ 71. Unlike action potentials, excitatory postsynaptic potentials (EPSPs) can summate and have no refractory period.

___ 72. Curare, a drug first used on poison darts by South American Indians, interrupts neuromuscular transmission and results in a spastic form of paralysis.

___ 73. EPSPs become action potentials at the initial segment portion of the axon.
___ 74. *Somatic* motor neurons always make synapses with skeletal muscle fibers releasing ACh molecules that bind to *nicotinic* receptors on the motor end plate, resulting in end plate potentials (EPPs) and contraction of the muscle.
___ 75. It is believed that Alzheimer's disease is caused by a loss of CNS neurons that release the neurotransmitter, serotonin.

V. MONOAMINES AS NEUROTRANSMITTERS

A variety of chemicals in the CNS function as neurotransmitters. Among these are the monoamines, a chemical family that includes dopamine, norepinephrine, and serotonin. Although these molecules have similar mechanisms of action, they are used by different neurons for different functions.

A. Multiple Choice

___ 76. All of the following regulatory molecules are in the chemical family known as **monoamines**, *except:*
a. acetylcholine.
b. epinephrine.
c. dopamine.
d. serotonin.
e. norepinephrine.

___ 77. Which of the following is *not* used to inhibit or to inactivate the stimulatory effects of monoamines that are released as neurotransmitters from presynaptic vesicles?
a. reuptake (pump) into the presynaptic neuron ending
b. enzyme degradation(breakdown) by monoamine oxidase (MAO) enzymes
c. receptor blockade and inhibition by specific receptor antibodies
d. enzyme degradation by catecholamine-O-methyltransferase (COMT) enzymes
e. All of these inhibit the effects of released monamines.

___ 78. *Adenylate cyclase* is an important enzyme that
a. inhibits cAMP by converting it into inactive metabolites.
b. phosphorylates other proteins to open postsynaptic membrane channels.
c. converts ATP to cAMP and pyrophosphate in the postsynaptic cell cytoplasm.
d. catalyzes the conversion of ADP and phosphate to active ATP.

___ 79. *Cocaine* stimulates the synapses of specific neurons that release dopamine, by
a. inhibiting enzyme inactivation of dopamine.
b. blocking dopamine reuptake into the presynaptic axons.
c. mimicking the effects of dopamine on the postsynaptic cell.
d. facilitating the release of dopamine from the presynaptic cell terminal.

___ 80. *Parkinson's disease* is caused by loss of neurons that secrete the neurotransmitter
a. acetylcholine (ACh).
b. norepinephrine.
c. serotonin.
d. GABA.
e. dopamine.

___ 81. Amphetamines are in a class of drugs that cause general arousal in behavior by stimulating specific pathways that use _____ as a neurotransmitter.
a. ACh
b. norepinephrine
c. serotonin
d. GABA
e. dopamine

B. True or False/Edit

___ 82. Serotonin is a neurotransmitter derived from the amino acid, tryptophan.
___ 83. Norepinephrine is also known as adrenalin, a hormone secreted by the adrenal cortex.
___ 84. Epinephrine is both a hormone and a neurotransmitter molecule.
___ 85. Dopamine is only a neurotransmitter molecule and not a hormone.
___ 86. Drugs that inhibit MAO (and COMT) known as monoamine oxidase inhibitors ultimately promote the effects of monoamine neurotransmitter action.
___ 87. Instead of opening ionic channels directly in the postsynaptic membrane, monoamine neurotransmitters act through a second messenger molecule, such as cyclic adenosine monophosphate (cAMP).
___ 88. Schizophrenia may be caused, in part, by overactivity of the specific mesolimbic dopaminergic (activated by dopamine) pathways.
___ 89. Sympathetic neurons of the PNS use norepinephrine as the neurotransmitter at their terminal synapses with smooth muscle cells, cardiac muscle cells, and gland cells.

VI. OTHER NEUROTRANSMITTERS

A surprisingly large number of diverse molecules appear to function as neurotransmitters. These include some amino acids and their derivatives, many polypeptides, and even the gas nitric oxide.

A. Multiple Choice

___ 90. Which of the following neurotransmitters is *inhibitory*?
a. glycine
b. aspartic acid
c. norepinephrine
d. glutamic acid

___ 91. The most prevalent brain neurotransmitter is
a. ACh.
b. norepinephrine.
c. serotonin.
d. GABA.
e. dopamine.

___ 92. The neurotransmitter that appears to be involved in such clinical problems as *Huntington's chorea, status epilepticus* (seizures), and severe alterations in mood and emotions, is
a. ACh.
b. norepinephrine.
c. serotonin.
d. GABA.
e. dopamine.

___ 93. The group of brain neurotransmitters that may have *opioid* (pain relieving) properties are the
a. enkaphalin peptides.
b. dynorphin polypeptides.
c. ß-endorphins.
d. All of these are endogenous opiods.
e. None of these are endogenous opiods.

___ 94. Which of the following statements about **nitric oxide** (NO) is *false*?
a. NO acts locally to relax the smooth muscles of blood vessel walls, resulting in vessel dilation.
b. Dentists occasionally use NO as an analgesic (painkiller).
c. NO acts as a neurotransmitter of certain neurons in both the PNS and the CNS; and in the immune system, helps to kill bacteria.
d. NO stimulates the production of cyclic guanosine monophosphate (cGMP) that can act as a second messenger in the cytoplasm.
e. NO appears to be involved in such processes as erection of the penis, dilation of respiratory passageways, and learning and memory.

B. True or False/Edit

___ 95. Certain amino acids neurotransmitters excite effectors by forming EPSPs, and others inhibit CNS neurons by producing IPSPs.

___ 96. Similar to the arrangement seen in the *nicotinic* ACh receptors, the receptor for glutamate (glutamic acid) encloses an ion channel that produces excitatory postsynaptic potentials (EPSPs).

___ 97. Two important excitatory amino acid neurotransmitters found in the CNS are glutamic acid (glutamate) and to a lesser degree, aspartic acid.

___ 98. Both GABA (gamma-aminobutyric acid) and glycine are excitatory CNS neurotransmitters.

___ 99. Inhibitory neurotransmitters may cause inhibition by hyperpolarizing the postsynaptic membranes of their target cells.

___ 100. Synaptic plasticity means that neurons may release either classical neurotransmitters or polypeptides known as neuromodulators; and that synapses are formed and reformed continuously even in the mature brain.

___ 101. Naloxone is a drug that mimics (imitates) the analgesic action of the endogenous opioids produced naturally by the brain.

___ 102. Recently, the human brain appears to produce a new class of lipid (fatty acid) neurotransmitters that are similar to THC, a cannabinoid and active ingredient of marijuana.

___ 103. Neuropeptide Y, the most abundant neuropeptide in the brain, is a powerful stimulator of appetite and perhaps, is involved in overeating.

___ 104. Through its relaxing action on the smooth muscle of blood vessels, nitric oxide (NO) gas can be used to treat pulmonary hypertension and respiratory distress syndrome.

VII. SYNAPTIC INTEGRATION

The summation of numerous EPSPs may be needed to produce a depolarization of sufficient magnitude to stimulate the postsynaptic cell. The net effect of EPSPs on the postsynaptic neuron is reduced by hyperpolarization (IPSPs), which is produced by inhibitory neurotransmitters. The activity of neurons within the central nervous system is thus the net result of both excitatory and inhibitory effects.

A. Multiple Choice

___ 105. EPSPs produced by many different presynaptic fibers converging on a single postsynaptic neuron, causing summation on the postsynaptic dendrites and cell body, best describes
  a. synaptic plasticity.
  b. temporal summation.
  c. synaptic inhibition.
  d. spatial summation.

___ 106. *Inhibitory postsynaptic potentials* (IPSPs)
  a. result in hyperpolarization of the postsynaptic membrane.
  b. may be caused by opening postsynaptic K^+ gates.
  c. may be caused by opening postsynaptic Cl^- gates.
  d. lower the membrane potential; more negative than resting.
  e. All of these statements regarding IPSPs are correct.

___ 107. Which of the following is *not* characteristic of the term, *presynaptic inhibition*?
  a. The axon of the first neuron synapses with the axon (rather than the dendrite) of the second neuron.
  b. It can result from the opening Cl^- gates, producing hyperpolarization and forming IPSPs.
  c. The first neuron is partially depolarized by the neurotransmitter from the second neuron.
  d. Lesser amounts of neurotransmitter is released by the first neuron due to fewer action potentials arriving at the axon terminal.
  e. All of these are characteristic of presynaptic inhibition.

B. True or False/Edit

___ 108. *Temporal summation* of EPSPs in the postsynaptic neuron is caused by the combined effect of successive waves of transmitter released from presynaptic neurons.

___ 109. ***Long-term potentiation (LTP)*** refers to the enhancement of synaptic transmission that may last for hours or weeks along frequently used pathways, perhaps representing a mechanism of neural "learning" or memory.

___ 110. In the spinal cord (CNS), postsynaptic inhibition is mainly produced by the neurotransmitter GABA, while in the brain it is mainly produced by glycine.

___ 111. The algebraic balance created by hundreds or thousands of incoming EPSPs and IPSPs determines the ultimate response of a given postsynaptic neuron.

CHAPTER REVIEW

A. Completion

112. The nervous system is divided into two parts — the central nervous system and the _____ nervous system. The CNS includes the _____ and _____ _____, featuring collections of cell bodies called _____ and bundles of axons called _____. The PNS collections of cell bodies are _____and axons are _____. 113. Neurons contain _____ which receive stimuli, whereas the _____ conducts impulses away from the _____. 114. Sensory or_____ neurons are _____ in structure, conducting impulses _____ (toward/away from) the CNS — whereas a _____or efferent neuron is _____ in structure and conducts impulses _____ (toward/away from) the CNS. There are _____ (#) different categories of supportive cells. (Do you remember *why* each is significant? See *table 7.3* in the text.) 115. A depolarizing stimulus opens _____-regulated Na^+ and K^+ gates, causing the all-or-none _____ potential — which is separated from the next by a period of time called a _____ period. This time period is first _____, during which the neuron will never respond, and then _____, during which supramaximal stimuli are required. Stronger stimuli increase the _____ of action potentials. 116. Electrical synapses called _____ junctions are found in _____ muscle, _____ muscle, and sometimes in the brain. 117. By the process of _____, chemical synapses release vesicles containing _____ molecules, which open _____ regulated gates. The resulting depolarizations are _____, meaning they can be added, or _____ as EPSPs at the initial segment of the axon _____, reach threshold, and fire action potentials. 118. CNS neurotransmitters that have short-term and long-term effects include the catecholamines _____ and _____ that ultimately form second messengers called _____. Two known inhibitory neurotransmitters in the CNS are _____ and _____. They _____-polarize (de/re/hyper) the postsynaptic membrane forming IPSPs by opening chemically regulated gates to _____ or _____ ions. 119. Neuron inhibition can be pre- or postsynaptic, preventing the formation of _____ potentials, whereas EPSPs are excitatory and are often summated both _____ and _____, thus facilitating the formation of nerve impulses.

B. Sequencer — The Action Potential

120. In sequence, number the following events that take place along the membrane of an activated neuron axon leading to the formation and completion of an action potential. If this is fuzzy to you, see the second section in your text chapter that describes the electrical activity in axons. *Note*: The last event (8) has been marked for you.

____ K^+ gates begin to open while Na^+ gates begin to close.

____ Outward diffusion of K^+ may result in an overshoot in the membrane potential below -60 mV (hyperpolarization).

____ Na^+ diffuses through open gates into the axon, further depolarizing the axon (example of positive feedback!), as the membrane potential rapidly approaches +40 mV.

____ Neuron membrane at rest (-65 mV), voltage-regulated gates are closed.

____ Na^+ gates open, the membrane potential reaches its threshold potential level.

8 Refractory periods along the axon membrane prevent subsequent action potentials from running together.

____ Depolarizing stimulus begins to open voltage-regulated Na^+ gates (followed later by K^+ gates opening).

____ Membrane potential at around +40 mV sharply reverses its direction and returns toward resting (repolarization).

C. Essay

Essay Tutorial

This essay tutorial will answer the first essay question found in the "**Review Activities**" section of your *Human Physiology* textbook. Please read *Essay Question* 1 in the "**Test Your Understanding of Concepts and Principles**" section located at the end of chapter 7 and let me guide you through one possible answer. Watch for key terms in boldface type, helpful tips and general suggestions on writing the essay or short-answer questions. Enjoy!

121. Compare the **characteristics** of **action potentials** with those of **synaptic** potentials.

Answer. Study table 7.5 in the text, and note that the three column headings are *similar* to the boldfaced key terms in the question. As an example of graded synaptic potentials, the text has chosen to feature excitatory postsynaptic potentials (EPSPs). Read this table carefully. Notice that this *EPSPs* column could just as easily have been written to describe inhibitory postsynaptic potentials (IPSPs). Could you do this? Try it, by making the appropriate changes in the wording already present in the table. Good luck.

Now, try the following essay questions — and remember, tables are acceptable formats for answering physiology essay questions.

122. During the formation of an action potential (nerve impulse), the membrane potential *never* reaches the Na^+ equilibrium potential at +60 mV. Use the flow of Na^+ and K^+ through gates in the living neuron to explain why this does not happen.

123. Distinguish between the absolute and relative refractory periods of an axon. Include the role of ion gates and the physiologic significance of these periods *in vivo* (in the body).

124. Describe those features of the action potential that represent both positive and negative feedback loops.

125. Compare voltage-regulated gates with chemically regulated gates on the neuron membrane. Include differences in their location and their function.

Answers — Chapter 7

I. Neurons and Supporting Cells
   A. 1. d, 2. b, 3. c, 4. d, 5. b, 6. d, 7. a, 8. e, 9. b, 10. e, 11. b, 12. e
   B. 13. T, 14. T, 15. F—Switch “neurons” with “glial cells,” 16. T, 17. T, 18. F—Switch “CNS” with “PNS,” 19. T, 20. F—Replace “gray” with “white,” 21. T, 22. T, 23. T, 24. F—Brain endothelial cells have no spaces but do form a blood — brain barrier
   C. Label the Figure — Neuron Structure; See figure 7.1 in the text

II. Electrical Activity in Axons
   A. 25. c, 26. a, 27. d, 28. c, 29. a, 30. c, 31. b
   B. 32. T, 33. F—Replace “hyperpolarization” with “repolarization,” 34. F—Replace “Na” with “K,” 35. T, 36. T, 37. T, 38 T, 39. T, 40. F—Cable properties in unmyelinated axons result in very slow conduction of impulses, 41. T, 42. F—All action potentials look the same—“all or none,” 43. T, 44. F—Replace “thick myelinated” with “thin unmyelinated,” 45. T

III. The Synapse
   A. 46. d, 47. d, 48. a, 49. c, 50. b
   B. 51. T, 52. F—Switch “electrical” for “chemical,” 53. T, 54. F—Replace “synaptic cleft” with “terminal boutons,” 55. F—Replace “postsynaptic membrane” with “axon,” 56. T

IV. Acetylcholine as a Neurotransmitter
   A. 57. d, 58. a, 59. e, 60. b, 61. a, 62. a, 63. c, 64. a, 65. c
   B. 66. T, 67. F—ACh cannot cross the membrane, so it binds and opens ion channel gates for Na^+ and K^+, 68. T, 69. T, 70. F—Replace “strong” with “weak,” 71. T, 72. F—Replace “spastic” with “flaccid,” 73. T, 74. T, 75. F—Replace “serotonin” with “ACh”

V. Monoamines and Neurotransmitters
   A. 76. a, 77. c, 78. c, 79. b, 80. e, 81.e
   B. 82. T, 83. F—Delete “Nor” to make “Epinephrine,” and replace “cortex” with “medulla,” 84. F—Epinephrine is only a hormone, 85. T, 86. T, 87. T, 88. T, 89. T

VI. Other Neurotransmitters
   A. 90. a, 91. d, 92. d, 93. d, 94. b
   B. 95. T, 96. T, 97. T, 98. F—Replace “excitatory” with “inhibitory,” 99. T, 100. T, 101. F—Replace “mimics (imitates)” with “blocks,” 102. T, 103. T, 104. T

VII. Synaptic Integration
   A. 105. d, 106. e, 107. b
   B. 108. T, 109. T, 110. F—Switch “GABA” with “glycine,” 111. T

Chapter Review
   A. 112. peripheral; brain, spinal cord, nuclei, tracts; ganglia, nerves, 113. dendrites, axon, cell body, 114. afferent, pseudounipolar, to, motor, multipolar, from; six, 115. voltage, action, refractory; absolute, relative; frequency, 116. gap, smooth, cardiac, 117. exocytosis, neurotransmitter, chemically; graded, summated, hillock, 118. dopamine, norepinephrine, cAMP; glycine, GABA; hyper, K^+, Cl^-, 119. action, temporally; spatially
   B. 120. 5, 7, 4, 1, 3, 8, 2, 6