The NERVOUS SYSTEM

ORGANS AND DIVISIONS OF THE NERVOUS SYSTEM

A. Central nervous system (CNS) – brain and spinal cord
B. Peripheral nervous system (PNS) – all nerves
C. Autonomic Nervous system (ANS)

CELLS OF THE NERVOUS SYSTEM

A. Neurons
    a. Consist of three main parts
        i. Dendrites: conduct impulses to cell body of neuron
        ii. Cell body of neuron
        iii. Axon: conducts impulses away from cell body of neuron
    b. Neurons classified according to function
        i. Sensory: conduct impulse to the spinal cord and brain
        ii. Motor: conduct impulses away from brain and spinal cord to muscles and glands
        iii. Interneuron: conduct impulses from sensory neurons to motor neurons
B. Glia—three main types of connective tissue cells in the CNS
    a. Astrocytes: star shaped cells that anchor small blood vessels to neurons
    b. Microglia: small cells that move in inflamed brain tissue carrying on phagocytosis
    c. Oligodendrocytes (oligodendroglia): form myelin sheaths on axons in the CNS
C. Glia—(PNS)
    a. Schwann cells: invest the axons and insulate them
        i. Produce myelin sheathing in the PNS
        ii. This myelin can assist in the healing of damaged peripheral nerves
        iii. The CNS does not have the ability to heal nervous tissue because the Oligodendrocytes are different than Schwann Cells
D. Disorders of the nervous tissue
    a. Multiple sclerosis: characterized by myelin loss in central nerve fibers and resulting conduction impairment
    b. Tumors
        i. General name for nervous system tumors is neuroma
        ii. Most neuromas are gliomas, glial tumors
        iii. Multiple neurofibromatosis: characterized by numerous benign tumors that can progress to disfiguring, crippling soft tissue tumors

NERVES

A. Nerve-bundle of peripheral axons
    a. Tract-bundle of central axons
    b. White matter-tissue composed primarily of Myelinated axons (nerves or tracts)

c. Gray matter: tissue composed primarily of cell bodies and Unmyelinated fibers

B. Nerve coverings: fibrous connective tissue
   a. Endoneurium: surrounds individual fibers within a nerve
   b. Perineurium: surrounds a group (fascicle) of nerve fibers
   c. Epineurium: surrounds the entire nerve

REFLEX ARCS

A. Nerve impulses are conducted from receptors to effectors over neuron pathways or reflex arcs
   a. Conduction by a reflex arc results in a reflex (that is, contraction by a muscle or secretion by a gland.)

B. Simplest reflex arcs are
   a. two-neuron arcs: Sensory neurons synapsing in the spinal cord with motor neurons
   b. three neuron arcs consist of sensory neurons synapsing in the spinal cord with interneurons that synapse with motor neurons

NERVE IMPULSES

A. definition: self-propagating wave of electrical disturbance that travels along the surface of a neuron membrane

B. mechanism:
   a. a stimulus triggers the opening of Na^+ channels in the plasma membrane of the neuron
   b. inward movement of positive sodium ions leaves a slight excess of negative ions outside at a stimulated point; marks the beginning of a nerve impulse

THE SYNAPSE

A. definition: chemical compounds released from axon terminals (of the presynaptic neuron) into a synaptic cleft

B. neurotransmitters bind to specific receptor molecules in the membrane of a post synaptic neuron, opening ion channels and thereby stimulating impulse conduction by the membrane

C. names of neurotransmitters: acetylcholine, catecholamines (norepinephrine, dopamine and serotonin), and other compounds

D. Parkinson disease: characterized by abnormally low levels of dopamine in motor control areas of the brain; patients usually exhibit involuntary trembling and muscle rigidity

CENTRAL NERVOUS SYSTEM

A. Divisions of the brain
   a. Brainstem
      i. Consists of three parts of brain; named in ascending order, they are the medulla oblongata, pons, and midbrain
      ii. Structure: white matter with bits of gray matter scattered through it
      iii. Function:

1. gray matter in the brainstem functions are reflex centers (for example: heartbeat, respirations, and blood vessel diameter [controlling blood pressure])
2. sensory tracts in the brainstem conduct impulses to the higher parts of the brain;
3. motor tracts conduct from the higher parts of the brain to the spinal cord

b. diencephalon
   i. structure and function of the hypothalamus
      1. consists mainly of the posterior pituitary gland, pituitary stalk, and gray matter
      2. acts as a major center for controlling the ANS;
         a. helps control the functioning of most internal organs
      3. controls hormone secretion by anterior and posterior pituitary glands
         a. indirectly helps control hormone secretion by most other endocrine glands
      4. contains center for controlling appetite, wakefulness, pleasure, etc
   ii. structure and function of the thalamus
      1. dumbbell-shaped mass of gray matter in each cerebral hemisphere
      2. relays sensory impulse to cerebral cortex sensory areas
      3. in some way produces the emotions of pleasantness or unpleasantness associated with sensations

c. cerebellum
   i. second largest part of the human brain
   ii. helps control muscle contractions to produce coordinated movement so that we can maintain balance, move smoothly and sustain normal postures

d. cerebrum
   i. largest part of the brain
   ii. outer layer of gray matter is the cerebral cortex
      1. made up of lobes
      2. composed mainly of dendrites and cell bodies of neurons
   iii. interior of the cerebrum composed of mainly white matter (that is nerve fibers arranged in bundles called **tracts**)
   iv. functions of the cerebrum:
      1. mental processes of all types including
         a. sensations
         b. consciousness
         c. memory
         d. voluntary control of movements

e. brain disorders
   i. destruction of brain tissue

1. **Cerebrovascular accident CVA)**
    a. Type one: Hemorrhage from a cerebral vessel
        i. Causes death of brain tissue from the incompatibility of neural tissue and free blood
        ii. Anoxia beyond the point of rupture
    b. Cessation of blood flow through cerebral blood vessels due to a clot or thrombus
        i. Causes the death of brain tissue from anoxia
    c. Either type is referred to as: A stroke!
2. **Cerebral palsy (CP)**
    a. Condition in which damage to motor control areas of the brain before, during or after birth causes paralysis (usually spastic) of one or more limbs
3. **Dementia**
    a. Syndrome that includes progressive loss of memory, shortened attention span, personality changes, reduced intellectual capacity, and motor control deficit
        i. **Alzheimer disease (AD)** – brain disorder of the middle and late adult years characterized by dementia
        ii. **Huntington disease (HD)** ***(aka: Huntington's Chorea)*** – inherited disorder characterized by chorea (purposeless movement) progressing to severe dementia
        iii. **HIV (aka AIDS)** can infect neurons and thus cause dementia

ii. Seizure disorders

1. **Seizure:** sudden burst of abnormal neuron activity that results in temporary changes in brain function
2. **Epilepsy:** many forms, all characterized by recurring seizures
    a. Most common forms:
        i. Grand Mal—tonic and clonic contractions of the whole body
        ii. Petit mal – disconnect between brain and world for short periods, often not noticed for years
        iii. Jacksonian (usually from trauma) – one-sided seizures (left brain damage, right body seizures and vice versa)
3. **Electroencephalogram:** graphic representation of voltage changes in the brain used to evaluate brain activity

B. Spinal cord

a. Outer part is composed of white matter made up of many bundles of axons called tracts

i. Interior is composed of gray matter made up mainly of neuron dendrites and cell bodies

b. Functions as the center for all spinal cord reflexes
   i. **Sensory tracts** conduct impulses to the brain
   ii. **Motor tracts** conduct impulses from the brain

C. Covering and fluid spaces of the brain and spinal cord
   a. Coverings
      i. Cranial bones and vertebrae
      ii. Cerebral and spinal meninges: the dura mater, arachnoid mater and the pia mater
   b. Fluid spaces :
      i. subarachnoid spaces of meninges,
      ii. central canal inside cord
      iii. ventricles in brain

PERIPHERAL NERVOUS SYSTEM

A. cranial nerves
   a. **12 pair:** attached to undersurface of the brain
   b. Connect brain with the neck and structures in the thorax and abdomen

B. Spinal nerves:
   a. Structure: contain dendrites of sensory neurons and axons of motor neurons
   b. Functions: conduct impulses necessary for sensations and voluntary movements

C. Peripheral nervous disorders:
   a. **Neuritis:** general term referring to nerve inflammation
      i. Sciatic: is inflammation of the sciatic nerve that innervates the legs
      ii. Neuralgia: muscle pain, often accompanies neuritis
   b. **Trigeminal neuralgia:** recurring episodes of stabbing pain along one or more branches of the trigeminal (fifth cranial)nerve in the head
   c. **Bells' palsy:** paralysis of facial features resulting from damage to the facial (seventh cranial) nerve
   d. Herpes zoster or shingles
      i. Viral infection caused by chickenpox virus that has invaded the dorsal root ganglion and remained dormant until an episode of shingles
      ii. Usually affects a single dermatome, producing characteristic painful plaques or vesicles

AUTONOMIC NERVOUS SYSTEM

A. **Autonomic nervous system:** motor neurons that conduct impulses from the central nervous system to cardiac muscle, smooth muscle, and glandular epithelial tissue; regulates the body's automatic or involuntary functions

B. Autonomic neurons:

a. preganglionic autonomic neurons conduct from spinal cord or brainstem to an autonomic ganglion,
b. postganglionic neurons conduct from autonomic ganglia to cardiac muscle, smooth muscle, and glandular epithelial tissue

C. **autonomic or visceral effectors**:
   a. tissues to which autonomic neurons conduct impulses (that is cardiac and smooth muscle and glandular epithelial tissue

D. composed of two divisions:
   a. sympathetic
   b. parasympathetic

E. Autonomic conduction paths:
   a. Consist of two-neuron relays (that is preganglionic neurons from the central nervous system to autonomic ganglia, synapses, postganglionic neurons from ganglia to visceral effectors
   b. In contrast, somatic motor neurons conduct all the way from the CNS to somatic effectors with no intervening synapses

F. Sympathetic nervous systems
   a. Structure:
      i. Dendrites and cell bodies of sympathetic preganglionic neurons are located in the gray matter of the thoracic and upper lumbar segments of the spinal cord
      ii. Axons leave the spinal cord in the anterior roots of spinal nerves, extend to sympathetic, or collateral ganglia, and synapse with several postganglionic neurons whose axons extend to spinal or autonomic nerves to terminate in visceral effectors
      iii. A chain of sympathetic ganglia is in front of and at each side of spinal column
   b. Functions
      i. Serves as the emergency of stress system, controlling visceral effectors during strenuous exercise and strong emotions (anger, fear, hate, or anxiety)
      ii. Group of changes induced by sympathetic control is called the *fight-or-flight* response

G. Parasympathetic nervous system
   a. Structure
      i. Parasympathetic preganglionic neurons have dendrites and cell bodies in the gray matter of the brainstem and the sacral segments of the spinal cord
      ii. Parasympathetic preganglionic neurons terminate in parasympathetic ganglia located in the head and the thoracic and abdominal cavities close to visceral effectors
      iii. Each parasympathetic preganglionic neuron synapses with postganglionic neurons to only one effector
   b. Functions

i. Dominates control of many visceral effectors under normal, everyday conditions

H. Autonomic neurotransmitters

a. Cholinergic fibers: preganglionic axons of parasympathetic and sympathetic systems and parasympathetic postganglionic axons release acetylcholine
b. Adrenergic fibers: axons of sympathetic postganglionic neurons release norepinephrine (noradrenalin)

I. Autonomic nervous system as a whole

a. Regulates the body's automatic functions in ways that maintain or quickly restore homeostasis
b. Many visceral effectors are doubly innervated (that is they receive fibers from parasympathetic and sympathetic divisions and are influenced in opposite ways by the two divisions

J. Disorders of the autonomic nervous system

a. Stress induced disease

i. Prolonged or excessive response to stress can disrupt normal functioning throughout the body
ii. Examples of stress-induced conditions
1. Heart disease
2. Digestive problems
3. Reduced resistance to disease

b. **Neuroblastoma:** a highly malignant tumor of the sympathetic nervous system, primarily affecting young children

VOCABULARY

Acetylcholine
Anesthesia
Arachnoid
Astrocytes
Axon
Blood-brain barrier
Catecholamines
Dendrite
Dopamine
Dura mater
Effectors
endorphins
enkephalins
fight-or-flight response
ganglion
glia
interneuron
limbic system
meninges
microglia
motor neuron
myelin
neurons
neurotransmitters
node of Ranvier
norepinephrine
oligodendrocytes
parasympathetic system
pia mater
postganglionic neurons
postsynaptic neuron
preganglionic neuron
presynaptic neuron
receptors
reflex arc
salutatory conduction
sensory neuron
serotonin
sympathetic system
synapse
synaptic cleft
tract

DISEASES AND OTHER CLINICAL TERMS

Alzheimer disease
Anesthesia
Bell's palsy
Cerebral palsy
Cerebrovascular Accident (CVA)
Dementia
Electro encephalogram (EEG)
epilepsy
hemiplegia
herpes zoster (shingles)
Huntington disease (HD)
hydrocephalus
meningitis
multiple sclerosis
multiple neurofibro-matosis
neuralgia
neuritis
neuroblastoma
neuroma
paraplegia
Parkinsonism
Parkinson disease
quadriplegia
seizure
spastic paralysis
trigeminal neuralgia
triplegia

The SENSES

CLASSIFICATION OF SENSE ORGANS

A. General sense organs
   a. Often exist as individual cells or receptor units
   b. Widely distributed throughout the body

B. Special sense organs
   a. Large complex organs
   b. Localized grouping of specialized receptors

C. Classification by presence or absence of covering capsule
   a. Encapsulated
   b. Unencapsulated ("free" or "naked")

D. Classification by type of stimuli required to activate receptors
   a. Photoreceptors (light)
   b. Chemoreceptors (chemicals)
   c. Pain receptors (injury)
   d. Thermoreceptors (temperature change)
   e. Mechanoreceptors (movement or deforming of capsule)
   f. Proprioceptors (position of body parts or changes in muscle length or tension)

CONVERTING A STIMULUS INTO A SENSATION

A. All sense organs have **common functional characteristics**
   a. All are able to detect a particular stimulus
   b. A stimulus is converted into a nerve impulse
   c. A nerve impulse is received as a sensation in the CNS

GENERAL SENSE ORGANS

A. Distribution is widespread; single-cell receptors are common
B. Examples

a. Free nerve endings: pain, crude touch and temperature
b. Meissner's corpuscles: fine touch and vibration
c. Ruffini's corpuscles: touch and pressure
d. Pacinian corpuscles: pressure and vibration
e. Krause's end bulbs: touch
f. Golgi tendon receptors: proprioception
g. Muscle spindles: proprioception

SPECIAL SENSE ORGANS

A. The eye
   a. Layers of eyeball
      i. Sclera: tough outer coat, "white of the eye"
      ii. Cornea is transparent part of sclera over the iris
   b. Choroid
      i. Pigmented vascular layer prevents scattering of light
      ii. Front part of this is layer made of ciliary muscle and iris, the colored part of the eye
      iii. The pupil is the hole in the center of the iris
      iv. Contraction of iris muscle dilates or constricts pupil
   c. Conjunctiva: mucus membrane covering the front surface of the sclera and lining the eyelid
   d. Lens: transparent body behind the pupil; focuses light rays on the retina
   e. Eye fluids
      i. Aqueous humor: in the anterior cavity in front of the lens
      ii. Vitreous humor: in the posterior cavity behind the lens
   f. Visual pathway
      i. Innermost layer of retina contains rods and cones
         1. Rods work in dim light and are more sensitive to black and white and contrast
            a. In the periphery of the retina
         2. Cones:
            a. Three types: red, green and blue
            b. Allow us to see the spectrum of color
            c. Work best in bright light
            d. Less cones than rods
            e. Concentrated in the center of the eye
      ii. Impulse travels from the rods and cones through the bipolar and ganglion layers of retina
      iii. Nerve impulse leaves the eye through the optic nerve
         1. Point of exit is free of receptors and is therefore a blind spot
      iv. Visual interpretation occurs in the visual cortex of the cerebrum
B. Visual disorders

a. Refraction disorders
    i. Myopia (nearsightednesso is often caused by elongation of the eyeball
    ii. Hyperopia (farsightedness) is often caused by a shortened eyeball
    iii. Astigmatism is distortion caused by an irregularity of the cornea or lens
    iv. Conjunctivitis (inflammation of the conjunctiva) can
        1. Trachoma: chronic clamydia infection
        2. Acute bacterial conjunctivitis: highly contagious infection that produces a discharge of mucus pus (pink eye)
        3. Conjunctivitis can be caused by allergies
    v. Strabismus: improper alignment of eyes
        1. Eyes can converge (cross) or diverge
        2. If not corrected, can cause blindness
b. Disorders of the retina
    i. Retinal detachment can be complication of aging, eye tumors or head trauma
    ii. Diabetic retinopathy: damage to retina from hemorrhages and growth of abnormal vessels associated with diabetes mellitus
    iii. Glaucoma: intraocular pressure that decreases the blood flow in retina and thus causes retinal degeneration
    iv. Nyctalopia (night blindness) or the inability to see in dim light is caused by retinal degeneration or lack of vitamin A
    v. Macular degeneration: progressive degeneration of central part of retina; leading cause of permanent blindness in the elderly
    vi. Red-green color blindness: an X linked genetic condition in which certain colors are not seen properly; it is caused by an abnormality in the cones' photopigmentation.
c. Disorders of the visual pathway
    i. Degeneration of the optic nerve resulting from diabetes, glaucoma, and other causes can impair vision
    ii. Scotoma is the loss of only the central visual field when only certain nerve pathways are damaged
    iii. Cerebrovascular accidents (CVAs) can damage visual processing centers; example is acquired cortical color blindness
d. The ear
    i. The ear functions in hearing and in equilibrium and balance
        1. Receptors for hearing and equilibrium are mechanoreceptors
    ii. Divisions of the ear
        1. External ear:
            a. Auricle (pinna)
            b. External auditory canal
                i. Curving canal 2.5 cms in length
                ii. Contains Ceruminous glands

iii. Ends at the tympanic membrane

2. Middle ear:
    a. Houses ear ossicles—malleus, incus, stapes
    b. Ends in the oval window
    c. The auditory (Eustachian) tube connects the middle ear to the throat
    d. Inflammation is called otitis media
3. Inner ear:
    a. Bony labyrinth filled with perilymph
        i. This cradles the membranous labyrinth
    b. Subdivided into the vestibule, semicircular canals and cochlea
    c. Membranous labyrinth filled with endolymph
        i. Lies within the bony labyrinth
        ii. Endolymph is thick fluid than perilymph
    d. The receptors for balance in the semicircular canals are called cristae ampullaris
    e. Specialized hair cells on the organ of Corti respond when bent by the movement of surrounding endolymph set in motion by sound waves

e. Hearing disorders
    i. Conduction impairments
        1. Can be caused by blockage of the external or middle ear (for example cerumen and tumors)
        2. Otosclerosis—inherited bone disorder involving irregularity of the stapes;
            a. First appears as a tinnitus (ringing) then progresses to hearing loss
        3. Otitis—ear inflammation caused by infection, can produce swelling and fluids that block sound conduction
    ii. Nerve impairment
        1. Presbycusis—progressive nerve deafness associated with aging
        2. Progressive nerve deafness can also result from chronic exposure to loud noise
        3. Meniere's disease—chronic inner ear disorder characterized by tinnitus, nerve deafness and vertigo
    iii. The taste receptors
        1. Receptors are chemoreceptors called taste buds
        2. Cranial nerves VII and IX carry gustatory impulses
        3. Only four kinds of taste sensations—sweet, sour, bitter, salty
        4. Gustatory and olfactory senses work together
    iv. The smell receptors

1. Receptors for fibers of olfactory mucosa of nasal cavity
2. Olfactory receptors are extremely sensitive but easily fatigued
3. Odor-causing chemicals initiate a nervous signal that is interpreted as a specific odor by the brain

VOCABULARY

Aqueous humor	crista ampullaris	organ of Corti	pupil
Auricle	endolymph	ossicles	retina
Chemoreceptor	gustatory cells	papillae	sclera
Choroid	lacrimal gland	perilymph	semicircular canals
Cochlea	lens	photoreceptors	tympanic membrane
Conjunctive	mechanoreceptor	proprioception	vitreous humor

DISEASES AND OTHER CLINICAL TERMS

Astigmatism	Hyperopia	Nyctalopia	scotoma
Cataracts	LASIK	otitis	strabismus
Color blindness	macular degeneration	otosclerosis	tinnitus
Conjunctivitis	Meniere's disease	presbycusis	trachoma
Glaucoma	myopia	presbyopia	vertigo

ANATOMY AND PHYSIOLOGY OF THE NERVOUS SYSTEM

Nervous tissue: There are two types of nerve cells: neurons and neuroglia

a) Neurons: nerve cells responsible for conducting the action potential. Neurons cannot mitotically divide to from new or additional neurons. Therefore, once dead, a neuron cannot be replaced. However, neurons can regenerate to allow a severed segment of the cell to grow back.

i) Cell body: the main mass of the nerve cell; contains the nucleus.

ii) Dendrites: sensory receptors extending from the cell body; bring the action potential into the cell body.

iii) Axon: a long extension of the cell body, responsible for conducting the action potential away from the cell body.

iv) Axon terminal: the far end of the axon; contains synaptic vesicles.

v) Synaptic vesicles: tiny vesicles or sacs that contain the neurotransmitters produced by the neuron.

b) Neuroglia: supportive cells for the neurons in the central and peripheral nervous systems.

   i) Neurilemmocytes (Schwann Cells): specific type of neuroglia cells that form the insulating myelin sheath around the nerves of the peripheral nervous system. Myelin is very important for the neurons of the peripheral nervous system. It protects the neuron itself, protects the action potential, and increases the action potential transmission rate. The nervous systems of infants are still growing myelin around the neurons. This helps explain why their motor movements are uncontrolled. As their myelin develops, their motor skills improve.

   ii) Nodes of Ranvier: tiny gaps in the myelin sheath at which the action potential is relayed along the neuron.

c) Nerve**:** a collection of nerve cells outside the central nervous system

Nerve impulse transmission

a) Synapse: the space between a dendrite and a connecting axon terminal.

b) Neurotransmitters: hormones or chemical messengers contained and released by the synaptic vesicles; they stimulate or inhibit action potentials. We experience stress in many different forms: physical stress, mental stress, emotional stress, and social stress. Although it might affect us all differently, it is something we all must face. Our bodies have built-in responses to stress. When something stressful happens, we may experience sweaty palms, dry mouth, or knots in the stomach. These responses are primarily caused by the release of hormones (or neurotransmitters) into the blood, such as epinephrine (adrenalin). Other physiologic responses include dilated pupils and increased hart rate, respiration, and blood pressure, and blood flow to muscles.

c) If the cause of stress is temporary, the physical effects are usually short term as well. For example, the pressure of taking exams has been linked to increased severity of acne among college students. Once the exams are over, the acne decreases. The longer our minds feel stressed, however, the longer our physical reaction systems remain activated. Therefore, when we are under prolonged stress, we may experience increased healing times, elevated blood pressure, and suppressed immune systems, as well as predisposition to cardiovascular disease, arthritis, diabetes, and even some types of cancers.

   i) Epinephrine: (*adrenalin*) a sympathetic hormone released into the blood to prepare the body for “fight or flight.”

   ii) Acetylcholine: a parasympathetic hormone released at the neuromuscular junction to initiate muscle contraction.

divisions of the nervous system

a) **Central Nervous System:** (CNS) the main control center of the body; includes the brain and spinal cord only

b) **Peripheral Nervous System**: (PNS) includes all parts of the nervous system except the brain and spinal cord

i) **Somatic nervous system**: nerves that control skeletal muscle contraction

ii) **Autonomic nervous system**: nerves that control smooth muscle, cardiac muscle, internal organs and glands

(1) **Sympathetic Nervous system**: prepares the body for stress, also called the "fight or flight" system. This system is sometimes called the Thoracolumbar System.

(2) **Parasympathetic Nervous System**: prepares the body for rest; also called the "rest and digest" system. This system is also known as the Cranial-Sacral System.

Central nervous system

a) **Meninges:** three layers of tissue surrounding the central nervous system.

i) **Dura Mater**: (dura (Latin) = tough; Mater (Latin) = mother.) The thickest, most external layer of the meninges.

ii) **Arachnoid membrane (mater):** (arachnoid= like a spider web) the delicates, web like layer between the dura and pia maters. Provides a space for the cerebral spinal fluid to circulate.

iii) **Pia Mater (pia (Latin)** = soft or tender.) The thin, very vascular, innermost layer of the meninges; supports the blood vessels that supply nutrients to the brain.

b) **Cerebrospinal Fluid** (CSF): clear liquid formed in the ventricles of the brain that supports or buoys the brain, cushions the central nervous system, and carries nutrients (like synovial fluid does.)

Brain

Structure of the Brain:

Cerebrum: the superior portion of the brain; comprises about 80% of total brain mass; divided into right and left hemispheres by the longitudinal fissure; subdivided into lobes.

(1) **Gyri:** the convoluted ridges or elevations in the cerebrum

(2) Sulci: the shallow grooves in the cerebrum

(a) Central Sulcus: separates the frontal and parietal lobes

(b) Lateral sulcus: separates the parietal and temporal lobes

Cerebellum: the second largest structure of the brain; found posterior and inferior to the cerebrum; also divided into hemispheres

Brainstem: inter-connects many nervous pathways and helps regulate many visceral functions

(1) *Diencephalon*: composed of the thalamus and hypothalamus
(2) *Midbrain:* found below the diencephalon
(3) *Pons:* (Latin, bridge) rounded structure under the midbrain
(4) *Medulla oblongata:* enlarged portion of the brainstem directly above the spinal cord

Ventricles: four pockets or spaces in the brain; cerebrospinal fluid is produced there.

CEREBRUM:

(1) **Right Hemisphere**: contains the sensory and motor pathways for the left side of the body; dominant for creativity, fantasy, and art and music appreciation

(2) **Left Hemisphere**: contains the sensory and motor pathways for the right side of the body; dominant for logic, science, higher math, languages and verbal ideas.

(3) The Lobes of the Cerebrum correspond in location to the bones of the skull.

(a) **Frontal Lobe:** responsible for personality, judgment, planning, and speech; contains the MOTOR CORTEX, which initiates movement of skeletal muscles.

(b) **Parietal Lobe:** responsible for determining distance, size, and shape; contains the sensory cortex, which detects general sensory impulses from the skin (e.g., temperature, pain, texture.)

(c) **Temporal Lobe:** contains the auditory and olfactory areas; stores memories of auditory and visual experiences

(d) **Occipital Lobe:** contains the visual area for interpreting impulses for the retina of the eye.

(e) **Insular lobe:** lies deep to the other four lobes; integrates the cerebral activities, may also assist in memory.

CEREBELLUM: functions include

(1) Coordination of voluntary muscles

(2) Maintenance of balance

(3) Maintenance of muscle tone

BRAINSTEM:

(1) **Diencephalon:** composed of the thalamus and hypothalamus

(a) **Thalamus:** sorts out incoming sensory impulses (except smell) and directs them to the proper areas of the cerebral cortex; also helps to filter out unimportant stimuli

(b) **Hypothalamus:** controls the pituitary gland; regulates water and electrolyte balance, hunger, body temperature, sleep, sexual response and emotions (e.g. anger, fear, irritation, pleasure)

(2) **Midbrain:** responsible for visual and auditory reflexes

(3) **Pons:** contains centers that control respiration

(4) **Medulla Oblongata:** contains a cardiac control center, a vasomotor center, and a respiratory center.

SPINAL CORD: the spinal cord descends from the foramen magnum in the occipital bone down to about L1 and then

(1) **Dorsal Horns:** gray matter in the spinal cord that extends posteriorly

(2) **Ventral Horns:** gray matter in the spinal cord that extends anteriorly

(3) **Reflex Arc:** the route followed by nerve impulses to provide a protective response to a potentially harmful stimulus. The reflex arc does not involve the brain. Nervous impulses need only travel through the spinal cord (not the brain) to produce a response, thus saving valuable time. About the time the response has been produced, the brain is informed of what happened. In some reflex arcs (e.g., knee jerk reflex) there is no interneuron. The afferent neuron synapses directly with the efferent neuron.

(a) **Receptor organ:** the organ that contains the dendrites of the sensory neuron and receives the stimulus

(b) **Afferent (sensory) Neuron:** relays the action potential to the spinal cord.

(4) **Interneuron:** a short neuron in the central nervous system.

(a) **Efferent (motor) neuron:** conducts the action potential to the effector organ to elicit in a response.

(5) **Effector organ:** the organ that produces or carries out a response; usually a skeletal muscle.

peripheral nervous system

Cranial Nerves: 12 pairs of cranial nerves arise from the underside of the brain. The 12 pairs fall into four groups based on their functions:

i) There are many devices to help memorize the order of the cranial nerves. A version of the most famous is: **On** -> Olfactory, **Old** -> Optic, **Olympus'** -> Oculomotor, **Towering** -> Trochlear, **Tops** -> Trigeminal, **A** -> Abducens, **Finn** -> Facial, **And** -> Vestibulochoclear (formerly the Auditory nerve), **German** -> Glossopharangeal, **Viewed** -> Vagus, **A** -> Accessory, **Hawk** -> Hypoglossal.

(1) **Special Sensory (SS)** – smell, taste, vision, among others

(2) **General Sensory (GS)** – pain, touch, temperature, among others

(3) **Somatic Motor (SM)** – voluntary movement

(4) **Visceral Motor (VM)** – involuntary movement

Spinal Nerves: there are 31 pairs of spinal nerves:

(1) **Cervical nerves** – 8 pair

(2) **Thoracic nerves** – 12 pairs

(3) **Lumbar nerves** – 5 pair

(4) **Sacral nerves** – 5 pair

(5) **Coccygeal nerves** – 1 pair

ii) **Dorsal Root** – the nerve root that protrudes from the spinal cord.

(1) **Dorsal root ganglion** – collection of sensory nerve cell bodies outside of the dorsal root of the spinal cord.

iii) **Ventral Root** – the nerve root that protrudes anteriorly from the spinal cord

iv) **Dermatome** – the sensory area of the skin innervated by a particular spinal nerve root; follows a kind of "zebra-stripe" pattern on the skin

Nerve Plexus – a network of interconnecting nerves

(1) **Cervical plexus** – arises from nerve roots C1 through C4 and a portion of C5; provides sensory innervations for the skin around the head, neck, and shoulders as well as motor innervations for some muscles in this same region.

(2) **Brachial Plexus** – arises from nerve toots C5 through T1 and is sometime accompanied by portions of C4 and/or T2; provides sensory and motor innervations for the entire upper extremities and some neck muscles; gives rise to the axillary nerve, musculocutaneous nerve, radial nerve, median nerve, and the ulnar nerve. (The brachial complex runs from the cervical region down through the armpit and into the arm. Trauma that affects either the neck or the upper arm and shoulder region can damage the brachial plexus, resulting in numbness, tingling or paralysis down the arm and into the fingers.)

(a) **Axillary nerve (C5 and C6)** sensory -> lateral shoulder over the deltoid muscle, motor -> deltoid and teres minor muscles

(b) **Musculocutaneous nerve (C5 – C7)** – sensory -> lateral forearm; motor -> biceps brachii, brachialis and coracobrachialis muscles.

(c) **Radial nerve (C5 through T1)** sensory -> posterior forearm; motor -> shoulder, elbow, wrist, and finger extensors, supinator muscle.

(d) **Median nerve** – sensory -> anterior side of fingers one through three and the lateral half of the fourth fingers; motor -> elbow, wrist, and finger flexors, pronators, and thenar eminence (anterior muscles of the thumb.) [the median nerve becomes compressed in carpal tunnel syndrome]

(e) **Ulnar nerve (C8 – T1)** – sensory -> fifth finger and medial half of fourth finger; motor => intrinsic muscles of the hand. [The ulnar nerve is often referred to as the funny bone as it runs under the medial epicondyle of the humerus.]

(3) **Lumbosacral Plexus** – arises from nerve roots L1 through S4; provides sensory and motor innervations for the lower extremities; gives rise to the obturator nerve, femoral nerve, and the sciatic nerve.

(a) **Obturator nerves (L2-L4)**: sensory -> upper medial thigh; motor -> adductors and the gracilis muscle.

(b) **Femoral nerve (L2-L4) sensory:** -> anterior and lateral thigh; motor -> quadriceps, iliopsoas, Sartorius, and pectineus muscles.

(c) **Sciatic nerve (L4-S3):** sensory -> posterior thigh; motor -> hamstrings [The sciatic nerve divides just above the knee and becomes the common peroneal nerve and the tibial nerve. The common peroneal nerve comes around the lateral aspect of the lower

leg just below the head of the fibula while the tibial nerve continues down the posterior calf. The tibial nerve further divides just below the medial malleolus into the medial and lateral plantar nerves, which innervate the skin and intrinsic muscles of the foot.

(d) **Tibial Nerve** – sensory -> posterior calf; motor -> triceps surae muscle and flexors.

(e) **Common peroneal nerve** – sensory -> anterior calf and dorsal surface of the foot; motor -> extensors and the peroneal muscles.

THE SENSORY SYSTEM

VISION: THE EYE

ANATOMY OF THE EYE:

i. **Sclera** – the outer white layer of the eye; the anterior portion becomes the cornea
ii. **Cornea** – the convex, clear part of the anterior sclera
iii. **Choroid** – the middle layer of the eye; contains large numbers of blood vessels
iv. **Retina** – the innermost layer of the eye; contains a pigmented, reflective later and a layer of neurons (rods and cones) to detect light
    1. **Rods** – neurons positioned in the peripheral areas of the retina that detect black and white
    2. **Cones** – neurons concentrated within the fovea centralis (area of sharpest vision in the retina) that detect color. [Just as there is an area of most acute vision in the eye, there is also a blind spot. The small area where the optic nerve attaches to the eye contains no rods or cones; this area is referred to as the optic disk.]
v. **Iris** – the colored part of the eye; composed of smooth muscle; controls the amount of light that comes into the eye by dilating or constricting the pupil
    1. **Pupil** – the space or opening in the iris.
vi. **Crystalline lens** – a clear structure in the eye located between the iris and the vitreous humor; responsible for accommodation (adjustments to refract, or bend, the incoming light rays on the fovea centralis of the retina.)
vii. **Ciliary Muscle** – the circular muscle that surrounds the lens; responsible for adjusting the size of the lens in accommodation.
viii. **Suspensory ligament** – a ligament made up of tiny fibers that connect the ciliary muscle to the lens
ix. **Anterior chamber** – the space between the cornea and the lens; filled with aqueous humor

x. **Vitreous chamber** – the space behind the lens, filled with vitreous humor and vitreous body

a. **Extrinsic Muscles:**
   i. **Superior rectus muscle** – rotates the eye upward and toward the midline.
   ii. **Lateral rectus muscle** – rotates the eye away from the midline.
   iii. **Inferior rectus muscle** – rotates the eye downward and toward the midline
   iv. **Medial rectus muscle** – rotates the eye toward the midline
   v. **Superior oblique muscle** – rotates the eye downward and away from the midline
   vi. **Inferior oblique muscle** – rotates the eye upward and away from the midline

b. **Intrinsic Muscles:** the intrinsic muscles in the eye are the iris and the ciliary muscles. Under autonomic control, these muscles control the amount of incoming light and help focus the light on the fovea centralis.

c. **Refractive Structures:**
   i. Cornea
   ii. Aqueous humor
   iii. Lens
   iv. Vitreous humor and the vitreous body
   v. As light enters the eye, the cornea, aqueous humor, lens and vitreous humor help to refract (bend) the light rays to focus the image onto the fovea centralis.

d. **Protective structures:**
   i. **Eyebrow and eyelashes** – shade the eye and prevent particles and perspiration from falling into the eye.
   ii. **Socket** – forms a bony rim around the eye to protect against objects striking the eye.
   iii. **Eyelid** – a movable covering for the eye that brushes off particles and moves tears over the surface of the eye
   iv. **Conjunctiva** – the external lining that covers the anterior surface of the eyeball and the posterior surface of the eyelid; prevents particles from scratching the cornea and prevents objects (e.g. contact lenses) from moving posteriorly behind the eye.
   v. **Lachrymal apparatus** – consists of the tear-producing glands and their ducts.
   vi. **Lachrymal gland** – an almond shaped gland that secretes the lachrymal fluid (tears) onto the upper lateral corner of the eye.
   vii. **Nasolacrimal** duct – a duct through the lachrymal bone that carries tears from the eye to the nasal cavity.

HEARING: THE EAR

a. **EXTERNAL EAR:**
   viii. **Pinna (auricle)** – the external portion of the ear; used to collect sound waves and direct them into the middle and inner ear.

ix. **External Acoustic (auditory)** meatus – a canal in the temporal bone through which the external ear canal runs.
x. **Ceruminous glands** – specialized wax-producing glands located in the tissue lining the external ear canal.
xi. **Tympanic membrane (eardrum)** – detects sound waves

b. **MIDDLE EAR:** sound waves are first detected by the tympanic membrane. The sounds waves then travel from the Malleus to the incus to the stapes and then to the inner ear.
xii. **Ossicles** – small bones of the middle ear; server to amplify incoming sound waves
1. **Malleus** – hammer
2. **Incus** – anvil
3. **Stapes** – stirrup
xiii. **Auditory tube (eustachian tube)** – a canal that connects the middle ear to the pharynx; used to equalize the pressure on both sides of the tympanic membrane

c. **INTERNAL EAR:**
xiv. **Cochlea** – (cochlea = small shell) the functional unit of hearing contains the organ of Corti
xv. **Organ of Corti** – the organ that transforms sound waves into nerve impulses
xvi. **Vestibule** – the cavity in the inner ear that is sensitive to gravity and linear movement of the head
xvii. **Semicircular canals** – the three bony canals that lie in each of the three cardinal planes; detect angular or rotational movement.

smell: the nose

a. **Olfactory hairs** – the sensitive portions of the olfactory cells; lie in the epithelial tissue of the nose. [Olfactory pathway goes like this: olfactory hairs -> olfactory nerves -> olfactory bulb -> olfactory tract -> temporal love of the cerebrum.]
b. **Olfactory bulb** – the structure positioned above the olfactory hairs, relays sensory information from the olfactory hairs to the olfactory tract, which is the first cranial nerve.

Taste: tongue and mouth

a. **Taste buds** – receptors located mostly in the tongue that are sensitive to taste.
xviii. **Sweet** – on the tip of the tongue
xix. **Sour** – on the side of the tongue
xx. **Bitter** – on the back of the tongue
xxi. **Salty** – concentrated on the sides of the tongue

Position – the proprioceptors

a. **Proprioceptors** – specialized receptors found in joints, tendons, and muscles that sense body position
b. **Muscle spindles** – found in muscles; provide information about the length or change in length of skeletal muscles
c. **Golgi tendon organs** – located where the muscle joins the tendon; protects the tendon by preventing excessive muscle tension from being applied to the tendon.

The Nervous System SYNOPSIS

This presents the major components of the nervous system, describing structure and function of neurons and the details of the autonomic nervous system. Various cell types are discussed, as well as physiological aspects involved in nerve impulse transmission, regeneration, and reflex arcs. The nervous system transmits information rapidly by means of nerve impulses conducted from one body area to another.

Information concerning the brain and cranial nerves are also included in this chapter. The autonomic nervous system is divided into two components: the sympathetic and the parasympathetic. The sympathetic division carries messages to ganglia that are located near the spinal cord. The parasympathetic division is made up of ganglia that terminate close to body effectors.

LEARNING OBJECTIVES WITH RATIONALE

the student will be able to:

1. List the organs and divisions of the nervous system and describe the generalized functions of the system as a whole.

The nervous system is made up of the brain and spinal cord, the many nerves of the body, the specialized sense organs such as the eyes and ears, and the microscopic sense organs found in the skin.

Its two principal divisions are the central nervous system and the peripheral nervous system. The function of this system is to pick up information from the environment and rapidly transmit that information by means of nerve impulses from one body area to another.

2. Identify the major types of cells in the nervous system and discuss the function of each.

Two general types of cells are found in the nervous system: **neurons** and **neuroglia**. *Neurons have the ability to transmit information.* They can be classified according to the direction in which they transmit impulses. Sensory neurons transmit impulses to the spinal cord and brain from all parts of the body. Motor neurons transmit impulses away from the brain and spinal cord to muscles and glands.

Interneurons conduct impulses from sensory neurons to motor neurons.

Neuroglia do not transmit impulses. Instead they are special types of connective tissue cells. Some neuroglia are large, star-shaped cells called astrocytes. They have threadlike branches that attach to both neurons and small blood vessels, holding those structures close together. Microglia are small cells that usually remain stationary. When brain tissue shows signs of inflammation or degeneration, they enlarge and move about, acting as microbe-eating scavengers. Oligodendroglia help hold nerve fibers together and also produce the fatty myelin sheath that surrounds neurons in the brain and spinal cord.

3. Identify the anatomical and functional components of the three-neuron reflex arc.

Compare and contrast the propagation of an action potential along a nerve fiber and across a synaptic cleft. Three-neuron reflex arcs consist of sensory neurons, interneurons, and motor neurons. Impulse conduction normally starts in receptors. Receptors are the beginnings of sensory neurons' dendrites.

Impulses travel the full length of the sensory neuron's dendrite through its cell body to the branching ends of its axon. The ends of the sensory neuron's axon contact interneurons. A microscopic space called the synapse separates the axon endings of one neuron from the dendrites of another neuron.

After crossing the synapse, the impulses continue along the dendrites, cell bodies, and axons of the interneurons. They then cross another synapse. Finally, they travel over the dendrites, cell bodies, and axons of motor neurons to effectors, which are muscles or glands that respond.

When an adequate stimulus acts on a neuron it greatly increases the permeability of the membrane at that point to sodium ions. These positive ions enter into the interior of the neuron, thus leaving an excess of negative ions on the outside. An area of electrical negativity is created on the neuron's surface, and a nerve impulse is begun. This self-propagating wave of electrical negativity speeds point by point along the entire length of the neuron's surface. Because neurons are separated from one another by a space called a synapse, chemicals called neurotransmitters must be used to pass messages from one neuron to the next. These chemicals are released by structures called synaptic knobs that exist at ends of axons on the presynaptic neuron. They then combine with receptor molecules in the plasma membrane of the postsynaptic neuron. The neurotransmitters then stimulate or inhibit impulse transmission in the postsynaptic neuron.

4. Identify the major anatomical components of the brain and spinal cord, and briefly comment on the function of each.

The spinal cord consists of an H-shaped core of gray matter that is composed primarily of dendrites and cell bodies of neurons. Interneurons located in this gray matter transfer incoming sensory impulses to outgoing motor impulses, thus allowing spinal cord reflexes, or "reflex arcs," to occur.

Columns of white matter form the outer portion of the cord. These columns, made up of myelinated nerve fibers, are called spinal tracts. Tracts carry messages into (ascending tracts) and out of (descending tracts) the brain.

The brain separated into the following divisions: brainstem, cerebellum, diencephalon, and cerebrum. The lowest part of the brainstem is called the medulla; it connects the brain to the spinal cord. Immediately above the medulla lies a structure called the pons, and above the pons is the midbrain. All three of these parts function as two-way conduction pathways, carrying messages into and out of other areas of the brain. They also contain reflex centers that control cardiac, respiratory, and vasomotor functions. The

cerebellum, which is a small, folded mass on top of the brainstem, coordinates movement, maintains equilibrium, and sustains normal posture.

The diencephalon is made up of the thalamus and the hypothalamus. The thalamus is a mass of gray matter that lies deep inside the cerebrum. It helps produce sensations and associates sensations with emotions. It plays a part in the arousal, or alerting, mechanism. The hypothalamus is located below the thalamus. It exerts control over virtually all internal organs. It regulates water balance, influences appetite, and helps maintain normal body temperature.

The cerebrum is the largest and uppermost part of the brain. It controls consciousness, mental processes, sensations, emotions, and voluntary movements.

5. Compare and contrast spinal and cranial nerves.

Thirty-one pairs of nerves, called spinal nerves, attach directly to the spinal cord: 8 pairs to the cervical segments, 12 pairs to the thoracic segments, 5 pairs to the lumbar segments, 5 pairs to the sacrospinal segments, and 1 pair to the coccygeal segment. These nerves conduct impulses between the spinal cord and the parts of the body not supplied by cranial nerves. These nerves contain both sensory and motor fibers, thereby making possible both sensations and movements. Twelve pairs of cranial nerves attach to the undersurface of the brain. Their fibers conduct impulses between the brain and various structures in the head and neck and in the thoracic and abdominal cavities.

6. Discuss the anatomical and functional characteristics of the two divisions of the autonomic nervous system.

The two major divisions of the autonomic nervous system are the sympathetic system and the parasympathetic system.

In the sympathetic division:

Preganglionic neurons have cell bodies and dendrites in gray matter of the thoracic and upper lumbar sections of the spinal cord.

Preganglionic axons leave the spinal cord in anterior roots of spinal nerves. They then enter actual spinal nerves and quickly leave these nerves to extend through sympathetic ganglia and terminate in collateral ganglia. They synapse with postganglionic neurons.

Postganglionic neurons have dendrites and cell bodies in sympathetic ganglia or in collateral glands. These sympathetic ganglia are located in front and at each side of the spinal column.

Axons of sympathetic postganglionic neurons travel in spinal nerves to an array of body effectors.

In the parasympathetic division:

Dendrites and cell bodies of preganglionic neurons are located in the gray matter of the brainstem and the sacral segments of the spinal cord.

Preganglionic axons leave these regions through cranial and spinal nerves. They extend some distance before terminating in parasympathetic ganglia that are located close to visceral effectors.

Preganglionic neurons synapse with postganglionic neurons.

The dendrites and cell bodies of parasympathetic postganglionic neurons are located in the outlying parasympathetic ganglia, and their short axons extend into nearby body effectors.

LECTURE OUTLINE

I. ORGANS AND DIVISIONS OF THE NERVOUS SYSTEM

A. Central nervous system (CNS)—brain and spinal cord
B. Peripheral nervous system (PNS)—all nerves
C. Autonomic nervous system (ANS)
    1. Parasympathetic system: "rest and relax," cranial-sacral system
    2. sympathetic system: "fight or flight (freak, faint)," thoraco-lumbar system

II. CELLS OF THE NERVOUS SYSTEM

A. Neurons
    1. Consist of three main parts—dendrites (conduct impulses to cell body of neuron); cell body of neuron; and axon (conducts impulses away from cell body of neuron)
    2. Neurons classified according to function—sensory: conduct impulses to the spinal cord and brain; motor: conduct impulses away from brain and spinal cord to muscles and glands; and interneurons: conduct impulses from sensory neurons to motor neurons
B. Glia (neuroglia)
    1. Support cells, bringing the cells of nervous tissue together structurally and functionally
    2. Three main types of connective tissue cells of the CNS
        a. Astrocytes—star-shaped cells that anchor small blood vessels to neurons
        b. Microglia—small cells that move in inflamed brain tissue carrying on phagocytosis
        c. Oligodendroglia—form myelin sheaths on axons in the CNS
    3. Schwann cells form myelin sheaths on axons of the PNS

III. NERVES

A. Nerve—bundle of peripheral axons
    1. Tract—bundle of central axons

2. White matter—tissue composed primarily of myelinated axons (nerves or tracts)
3. Gray matter—tissue composed primarily of cell bodies and unmyelinated fibers

B. Nerve coverings—fibrous connective tissue

1. Endoneurium—surrounds individual fibers within a nerve
2. Perineurium—surrounds a group (fascicle) of nerve fibers
3. Epineurium—surrounds the entire nerve

IV. REFLEX ARCS

A. **Nerve impulses**—conducted from receptors to effectors over neuron pathways or reflex arcs; conduction by a reflex arc results in a reflex (that is, contraction by a muscle or secretion by a gland)

B. *Simplest reflex arcs* are two-neuron arcs—consist of sensory neurons synapsing in the spinal cord with motor neurons; three-neuron arcs consist of sensory neurons synapsing in the spinal cord with interneurons that synapse with motor neurons

V. NERVE IMPULSES

A. *Definition*—self-propagating wave of electrical disturbance that travels along the surface of a neuron membrane

B. *Mechanism*

1. A stimulus triggers the opening of sodium ions (Na+) channels in the plasma membrane of the neuron
2. Inward movement of positive Na+ leaves a slight excess of negative ions outside at a stimulated point; marks the beginning of a nerve impulse

VI. THE SYNAPSE

A. *Definition*—chemical compounds released from axon terminals (of a **presynaptic neuron**) into a **synaptic cleft**

B. **Neurotransmitters** bind to specific receptor molecules in the membrane of a **postsynaptic neuron,** opening ion channels and thereby stimulating impulse conduction by the membrane

C. Names of neurotransmitters—*acetylcholine, catecholamines* (*norepinephrine, dopamine*, and *serotonin*), and other compounds

VII. CENTRAL NERVOUS SYSTEM

A. Divisions of the brain

1. **Brainstem**
    a. Consists of three parts of brain; named in ascending order, they are the *medulla oblongata, pons, and midbrain*
    b. *Structure*—white matter with bits of gray matter scattered through it
    c. *Function*—gray matter in the brainstem functions as reflex centers (for example, for heartbeat, respirations, and blood vessel diameter); sensory tracts in the brainstem conduct impulses to the higher parts of the brain; motor tracts conduct from the higher parts of the brain to the spinal cord
2. **Diencephalon**
    a. Structure and function of the hypothalamus

(1) Consists mainly of the posterior pituitary gland, pituitary stalk, and gray matter
(2) Acts as the major center for controlling the ANS; therefore helps control the functioning of most internal organs
(3) Controls hormone secretion by anterior and posterior pituitary glands; therefore indirectly helps control hormone secretion by most other endocrine glands
(4) Contains centers for controlling appetite, wakefulness, pleasure, etc.

b. Structure and function of the thalamus
(1) Dumbbell-shaped mass of gray matter in each cerebral hemisphere
(2) Relays sensory impulses to cerebral cortex sensory areas
(3) In some way produces the emotions of pleasantness or unpleasantness associated with sensations

3. **Cerebellum**
a. Second-largest part of the human brain
b. Helps control muscle contractions to produce coordinated movements so that we can maintain balance, move smoothly, and sustain normal postures

4. **Cerebrum**
a. Largest part of the human brain
b. Outer layer of gray matter is the cerebral cortex; made up of lobes; composed mainly of dendrites and cell bodies of neurons
c. Interior of the cerebrum composed mainly of white matter (nerve fibers arranged in bundles called tracts)
d. Functions of the cerebrum—mental processes of all types including sensations, consciousness, memory, and voluntary control of movements

B. **Spinal cord**
1. Outer part is composed of white matter made up of many bundles of axons called tracts; interior composed of gray matter made up mainly of neuron dendrites and cell bodies 2. Functions as the center for all spinal cord reflexes; sensory tracts conduct impulses to the brain, and motor tracts conduct impulses from the brain

C. Coverings and fluid spaces of the brain and spinal cord
1. Coverings
a. Cranial bones and vertebrae
b. **Cerebral and spinal meninges**—the **dura mater**, the **pia mater**, and the **arachnoid**
2. Fluid spaces—**subarachnoid spaces** of meninges, **central canal inside cord,** and **ventricles** in brain

VIII. PERIPHERAL NERVOUS SYSTEM

A. Cranial nerves
1. Twelve pairs—attached to undersurface of the brain

2. Connect brain with the neck and structures in the thorax and abdomen

B. Spinal nerves

1. Structure—contain dendrites of sensory neurons and axons of motor neurons
2. Functions—conduct impulses necessary for sensations and voluntary movements

IX. AUTONOMIC NERVOUS SYSTEM

A. **Autonomic nervous system**—motor neurons that conduct impulses from the central nervous system to cardiac muscle, smooth muscle, and glandular epithelial tissue; regulates the body's automatic or involuntary functions

B. **Autonomic neurons**—preganglionic autonomic neurons conduct from spinal cord or brainstem to an autonomic ganglion; postganglionic neurons conduct from autonomic ganglia to cardiac muscle, smooth muscle, and glandular epithelial tissue

C. **Autonomic or visceral effectors**—tissues to which autonomic neurons conduct impulses (cardiac and smooth muscle and glandular epithelial tissue)

D. Composed of two divisions—the **sympathetic system** and the **parasympathetic system**

E. **Autonomic conduction paths**

1. Consist of two-neuron relays (preganglionic neurons from the central nervous system to autonomic ganglia, synapses, postganglionic neurons from ganglia to visceral effectors)
2. In contrast, somatic motor neurons conduct all the way from the CNS to somatic effectors with no intervening synapses

F. **Sympathetic nervous system**

1. *Structure*
   a. Dendrites and cell bodies of sympathetic preganglionic neurons are located in the gray matter of the thoracic and upper lumbar segments of the spinal cord
   b. Axons leave the spinal cord in the anterior roots of spinal nerves, extend to sympathetic or collateral ganglia, and synapse with several postganglionic neurons whose axons extend to spinal or autonomic nerves to terminate in visceral effectors
   c. A chain of sympathetic ganglia is in front and at each side of the spinal column
2. *Functions*
   a. Serves as the emergency or stress system, controlling visceral effectors during strenuous exercise and strong emotions (anger, fear, hate, or anxiety)
   b. Group of changes induced by sympathetic control is called the fight-or-flight response

G. **Parasympathetic nervous system**

1. *Structure*
   a. Parasympathetic preganglionic neurons have dendrites and cell bodies in the gray matter of the brainstem and the sacral segments of the spinal cord

b. Parasympathetic preganglionic neurons terminate in parasympathetic ganglia located in the head and the thoracic and abdominal cavities close to visceral effectors

c. Each parasympathetic preganglionic neuron synapses with postganglionic neurons to only one effector

2. *Function*—dominates control of many visceral effectors under normal, everyday conditions

H. **Autonomic neurotransmitters**

1. **Cholinergic fibers**—preganglionic axons of parasympathetic and sympathetic systems and parasympathetic postganglionic axons release acetylcholine

2. **Adrenergic fibers**—axons of sympathetic postganglionic neurons release norepinephrine (noradrenaline)

I. Autonomic nervous system as a whole

1. Regulates the body's automatic functions in ways that maintain or quickly restore homeostasis

2. Many visceral effectors are doubly innervated (they receive fibers from parasympathetic and sympathetic divisions and are influenced in opposite ways by the two divisions)

Review Questions

1. Draw and label the three parts of the neuron and explain the function of the dendrite and axon.

Answer: The three parts of a neuron are the cell body, dendrites, and the axon. Dendrites are the projections that transmit impulses to the neuron cell bodies or axons. Axons are the processes that transmit impulses away from the dendrites and neuron cell bodies.

2. Name the three types of neurons classified according to the direction in which the impulse is transmitted.

Answer:

(1) Sensory neurons, also called afferent neurons, are able to transmit impulses to the brain and spinal cord from all areas of the body.

(2) Motor neurons, also called efferent neurons, transmit impulses away from the brain and spinal cord.

(3) Interneurons, also called central or connecting neurons, conduct impulses from sensory neurons to motor neurons.

3. Define or explain the following terms: myelin nodes of Ranvier, and neurolemma.

Answer: Nodes of the Ranvier are indentations between adjacent Schwann cells, which form a white fatty substance called myelin, which wraps around some axons. The outer cell membrane of a Schwann cell is called the neurolemma.

4. Name and give the function of the three types of glial cells.

Answer: (1) Astrocytes, meaning star cells, have threadlike branches that attach to neurons and small blood vessels holding them close together. They also form a two-layer structure called the blood-brain barrier (BBB), which separates blood and nervous tissue, thereby protecting vital brain tissue from harmful chemicals that might be circulating in the blood. (2) Microglia are small cells that move in inflamed brain tissue carrying on phagocytosis. (3) Oligodendrocytes hold nerve fibers together and produce the fatty myelin sheath that envelops nerve fibers in the brain and spinal cord.

5. Define or explain the following terms: epineurium, perineurium, and endoneurium.

Answer: Epineurium is the tough fibrous sheath that covers the whole nerve. Perineurium is a thin fibrous tissue sheath surrounding a bundle of nerve fibers (fascicle). Endoneurium is a thin fibrous connective tissue that covers axons in a nerve.

6. What is the physical difference between gray matter and white matter?

Answer: White matter of the PNS is tissue composed primarily of myelinated axons. Gray matter is tissue composed primarily of cell bodies and unmyelinated axons and dendrites.

7. Explain how a reflex arc functions.

Answer: A reflex arc is a specialized type of neuron pathway. The two-neuron arc consists of the sensory neurons and motor neurons. The three-neuron arc consists of the sensory neurons, the interneurons, and the motor neurons. Reflex arcs allow impulse conduction to travel in only one direction.

8. Explain what occurs during a nerve impulse. What is saltatory conduction?

Answer: A nerve impulse, in an unmyelinated fiber, is a self-propagating wave of electrical disturbance that travels in one direction along the surface of a neuron membrane. In a myelinated fiber, the action potential jumps around the insulating myelin in a rapid type of conduction called saltatory conduction.

9. Explain fully what occurs at a synapse. Explain two ways in which neurotransmitter activity is terminated.

Answer: A synapse is where impulses are transmitted from the presynaptic neuron to the postsynaptic neuron. There are three structures that make up a synapse. The synaptic knob is a tiny bulge or sac containing chemical compounds called neurotransmitters; they are found at the end of the presynaptic neuron axons. When the impulse arrives at the synaptic knob, the neurotransmitter molecules are released into the synaptic cleft. The synaptic cleft is the space between a synaptic knob and the plasma membrane of the postsynaptic neuron. The plasma membrane has protein molecules embedded in it opposite each synaptic knob. These protein molecules serve as receptors that neurotransmitter molecules bind to. This binding can then initiate an impulse in the postsynaptic neuron by opening ion channels in the postsynaptic membrane. Neurotransmitter activity

can be terminated by two morphine like neurotransmitters called endorphins and enkephalins, which are released in various spinal cord and brain synapses in the pain conduction pathways. These neurotransmitters inhibit conduction of pain impulses. *They are natural painkillers.*

10. Describe and list the functions of the medulla oblongata.

Answer: The medulla oblongata is an enlarged upward extension of the spinal cord that lies inside the cranial cavity above the hole in the occipital bone. It is the lowest part of the brainstem. It has a two-way conduction pathway between the spinal cord and higher brain centers, such as the cardiac, respiratory, and vasomotor centers.

11. Describe and list the functions of the hypothalamus.

Answer: The hypothalamus acts as a major center for controlling the ANS, therefore helping to control the functions of most internal organs. It consists of the posterior pituitary gland, the pituitary stalk, and gray matter. It is able to control hormone secretions by the anterior and posterior pituitary glands, as well as other endocrine glands. The hypothalamus regulates body temperature, water balance, sleep cycle, appetite, and sexual arousal.

12. Describe and list the functions of the thalamus.

Answer: The thalamus is a dumbbell-shaped mass of gray matter in each cerebral hemisphere. It relays sensory impulses from various body areas to the cerebral cortex sensory areas. The thalamus is associated with emotional sensations that are either pleasant or unpleasant. How these feelings are produced is still being studied.

13. Describe and list the functions of the cerebellum.

Answer: The cerebellum is the second-largest part of the brain. It plays an essential part in smooth coordinated movement, maintaining equilibrium, and sustaining normal posture.

14. Describe the functions of the cerebrum. What are the specific functions of the occipital and temporal lobes?

Answer: The cerebrum is the largest part of the brain. The outer layer of gray matter is the cerebral cortex, made up of lobes composed mainly of dendrites and cell bodies of neurons. The interior of the cerebrum is composed of white matter. The functions of the cerebrum consist of sensory perception, emotions, voluntary movements, consciousness, and memory.

The lobes are named for the bones that lie over them. The occipital lobe is responsible for vision, and the temporal lobes' auditory areas interpret incoming nervous signals from the ears.

15. Describe and list the function of the spinal cord.

Answer: The outer part of the spinal cord is composed of white matter, which is made up of many bundles of axons, called tracts. The interior is composed of gray matter made mainly of neuron dendrites and cell bodies. It lies inside the spinal

column in the spinal cavity and extends from the occipital bone down to the bottom of the first lumbar vertebra. The spinal cord functions as the center for all spinal cord reflexes. The sensory tracts conduct impulses to the brain and the motor tracts conduct impulses from the brain.

16. Name and explain the three layers of the meninges.

Answer: The brain and spinal cord are surrounded by a tough fluid-containing membrane called the meninges. It is made up of (1) Dura mater—the outer layer that lines the brain and vertebral canal; (2) pia mater—the innermost membrane that covers the brain and spinal cord; (3) arachnoid—the membrane between the dura and the pia mater.

17. What is the function of cerebrospinal fluid? Where and how is it produced?

Answer: The function of cerebrospinal fluid is one of protection and support. It also is a reservoir of circulating fluid, which is monitored by the brain to detect changes in the internal environment. It forms continually from fluid filtering out of brain capillaries, called choroid plexus, and into the ventricles. Then it moves down and around the cord and up around the brain and returns to the blood in the veins of the brain.

18. How many nerve pairs are generated from the spinal cord? How many nerve pairs are generated from each section of the spinal cord and how are they named? What is a plexus?

Answer: Thirty-one pairs of nerves are attached to the spinal cord in the following manner:
cervical nerves—8 pairs; thoracic nerves—12 pairs; lumbar nerves—5 pairs; sacral nerves—5 pairs;
coccygeal nerves—1 pair.
Nerve fibers from several spinal nerves are reorganized to form a single peripheral nerve. These intersecting or braided branches are called a plexus.

19. Explain the structure and function of the sympathetic nervous system.

Answer: The dendrites and cell bodies of the sympathetic preganglionic neurons are located in the gray matter of the thoracic and upper lumbar segments of the spinal cord. Axons leave the spinal cord in the anterior roots of the spinal nerves, extend to sympathetic or collateral ganglia, and synapse with several postganglionic neurons whose axons extend to spinal or autonomic nerves to terminate in visceral effectors. The sympathetic nervous system functions as an emergency or stress system, controlling visceral effectors during strenuous exercise and strong emotions such as anger, fear, hate, or anxiety.

20. Explain the structure and function of the parasympathetic nervous system.

Answer: Parasympathetic preganglionic neurons have dendrites and cell bodies in the gray matter of the brainstem and the sacral segments of the spinal cord. The parasympathetic preganglionic neurons terminate in the parasympathetic ganglia located in the head and thoracic and abdominal cavities close to visceral effectors. Each parasympathetic preganglionic neuron synapses with postganglionic neurons

to only one effector. Function of the parasympathetic nervous system dominates control over many visceral effectors under normal conditions.

Critical Thinking Questions

21. List the functional regions of the frontal, parietal, occipital, and temporal lobes.

Answer: (1) Frontal functional region—primary motor area (precise muscle control); premotor area (muscle coordination); prefrontal association area (conscious thought); Broca's area (motor speech area). (2) Parietal functional region—primary somatic sensory area (body sense perception); primary taste area; somatic sensory association area (body sense perception); Wernicke's area (sensory speech area). (3) Occipital functional region—visual cortex association area; visual cortex. (4) Temporal lobes functional region—auditory association area; primary auditory area.

22. Which of the cranial nerves deal primarily with motor functions? Which deal primarily with sensory functions?

Answer: Twelve pairs of cranial nerves are attached to the undersurface of the brain, mostly to the brain stem. The following are the classifications of cranial nerves.

Name	Number	Function
Olfactory	1	Sensory
Optic	2	Sensory
Oculomotor	3	Motor
Trochlear	4	Motor
Trigeminal	5	Mixed
Abducens	6	Motor
Facial	7	Mixed
Vestibulocochlear	8	Sensory
Glossopharyngeal	9	Mixed
Vagus	10	Mixed
Accessory	11	Motor
Hypoglossal	12	Motor

23. What medication inhibits the function of acetylcholinesterase (the enzyme that deactivates acetylcholine)? Explain the side effects the medication would have on the visceral effectors.

Answer: Anticholinesterase drugs are designed to inhibit acetylcholinesterase, which is an enzyme that deactivates acetylcholine. As an impulse moves down the nerve, acetylcholine is released and crosses to the muscle, causing a muscle contraction. The muscle contraction is stopped by acetylcholinesterase, which is located in the muscle. Side effects of anticholinesterase medication on visceral effectors might include the following: abdominal cramps, nausea, vomiting, diarrhea, and excess salivation.

CLASSROOM APPLICATION

The following questions can be used as individual assignments or for small-group discussion. Note: to copy the questions, cover the answers with a blank sheet of paper and print, thus leaving space for answers or note-taking.

1. Some individuals who are depressed have an abnormally small amount of the neurotransmitter serotonin at certain synapses in the brain. One category of antidepressant drugs is called selective serotonin reuptake inhibitors. Can you deduce what action this drug has at a synapse to increase the amount of serotonin present in the synaptic cleft?

Answer: The name of the drug category tells you that the drug decreases the amount of serotonin that is taken back into the presynaptic knob after a nerve impulse has caused its release into the synaptic cleft. Because the amount of serotonin being taken from the synaptic cleft decreases, the amount remaining in the synaptic cleft increases. This restores the chemical imbalance associated with depression and hopefully relieves the symptoms. (Hint: The name of the drug is a clue.)

2. Another type of antidepressant inhibits the enzymes that naturally break down serotonin at the synaptic cleft. Can you explain how this might reduce the symptoms of depression?

Answer: As explained in the text, some neurotransmitter molecules are taken back into the presynaptic knob, whereas others are broken down by specific enzymes. This particular category of antidepressants inhibits the breakdown of serotonin after it is released. Such inhibition of serotonin destruction increases the amount of serotonin present in the synaptic cleft, restoring the original balance and removing the chemical basis for depression.

3. Multiple sclerosis (MS) is a disease we are hearing more about in recent years. A great deal of research is being conducted and yet there are still unanswered questions and no definitive answers. Do some investigation concerning MS. Start with some basic information such as: (1) define MS, (2) etiology, (3) symptoms, (4) treatment/cure. Discuss your findings in class.

Answer: (1) MS is a primary disorder of the central nervous system. It is characterized by myelin loss and destruction, varying degrees of oligodendrocyte cell injury, and death. This results in demyelination of white matter of the CNS (central nervous center). (2) Etiology may be related to autoimmune disease and or viral infections in some individuals. (3) Symptoms vary—as the myelin around axons is lost, nerve conduction is impaired and general weakness is noted. Other symptoms may include a lack of coordination, visual impairment, and speech disturbance. It is more common in women between 20 and 40 years of age. This disease is prolonged and may have periods of remission and relapses lasting over many years. (4) Treatment is palliative; there is no known cure.

PRACTICAL/CREATIVE LEARNING ACTIVITIES

1. Demonstrate simple reflex behaviors in a person: patellar tendon reflex (hitting knee), Achilles' tendon reflex (hitting back of lower leg), Babinski's reflex (tickling foot), ciliospinal reflex (touching back of neck with ice and observing pupils).

2. Explain how a cold compress on an injured ankle will reduce the swelling and also relieve the pain. Explain the mechanism involved as pain sensation is blocked.

STUDENT ASSIGNMENT THE NERVOUS SYSTEM

Multiple Choice

1. What are neurons that pick up sensations from receptors and carry them into the brain or spinal cord called?

A. motor neurons
B. central neurons
C. interneurons
D. sensory neurons

2. What are the brain cavities that are filled with cerebrospinal fluid called?

A. hydrocephalics
B. ventricles
C. mater
D. meninges

3. What is the innermost layer of connective tissue that surrounds the brain and spinal cord?

A. pia mater
B. dura mater
C. arachnoid
D. pons mater

4. A nurse is caring for a patient with a tumor of the cerebellum. In view of the functions of this part of the brain, which of the following symptoms should the nurse expect to observe?

A. irregular heartbeat and increased blood pressure
B. inability to coordinate body movements
C. loss of speech
D. inability to control emotions

5. What is the result of stimulation of the sympathetic nervous system?

A. accelerated heart rate
B. constriction of blood vessels in skeletal muscles
C. increased peristalsis
D. all of the above

6. What releases the autonomic transmitter acetylcholine?

A. sympathetic preganglionic axon
B. parasympathetic preganglionic axon
C. parasympathetic postganglionic axon
D. all of the above

7. Which of the following statements about Schwann cells is true?

A. They are found in the PNS.
B. They produce myelin.
C. They are separated by nodes of Ranvier.
D. All of the above.

8. What are the areas of the neuron that secrete neurotransmitters called?

A. synapses
B. synaptic clefts
C. synaptic knobs
D. gliomas

9. Which of the following statements about the neural tissues called tracts is true?

A. They are located outside of the central nervous system.
B. They appear gray.
C. When carrying messages upward they are called ascending, and when carrying messages
downward they are called descending.
D. All of the above.

10. Which of the following statements about the autonomic division of the nervous system is true?

A. Messages are carried over cranial and spinal nerves.
B. Preganglionic and postganglionic neurons are involved in response pathways.
C. Effectors are visceral organs.
D. All of the above.

Matching

Select the most correct answer from Column B for each statement in Column A. (Only one answer is correct for each.)

Column A	Column B
_____ 11. Tract	A. Transmits away from cell body
_____ 12. Axon	B.Interneuron
_____ 13. Brainstem	C. White matter
_____ 14. Neurotransmitter	D. Cranial nerve
_____ 15. Reflex arc	E. Thalamus
_____ 16. Skin map	F. Glioma
_____ 17. Tumor	G. Parkinson's disease
_____ 18. Diencephalon	H. Acetylcholine
_____ 19. Vagus	I. Dermatome
_____ 20. Basal ganglia	J. Medulla oblongata

Complete the following sentences using the terms listed below (one term is used more than once.)

A. Cerebrum
B. Synapse
C. Autonomic nervous system
D. Multiple sclerosis
E. Basal ganglia
F. Medulla
G. Neurotransmitter
H. Hypothalamus
I. Cerebrospinal fluid

21. The most common disorder of the CNS is a myelin disorder called _____.
22. Each synaptic knob contains many small sacs or vesicles. Each vesicle contains a very small quantity

of a chemical compound known as _____.
23. The junction between adjacent neurons is referred to as _____.
24. The lowest part of the brainstem is the _____.
25. The largest and uppermost part of the brain is _____.
26. Fluid that fills the subarachnoid spaces and also fills the spaces in the brain is the _____.
27. The part of the nervous system that regulates involuntary functions is known as _____.
28. A few islands of gray matter within the interior of the cerebrum are known as _____.
29. The antidiuretic hormone (ADH) is produced by _____.
30. The part of the brainstem that connects the brain to the spinal cord is called _____.

Multiple Choice

Mrs. Martha Leep has suffered a cerebrovascular accident (CVA). It has been determined that the damage is to the left side of the cerebrum.

31. What part of her lower body will most likely be affected?
    A. the lower extremities
    B. both right and left extremities
    C. the right side of the body
    D. impaired swallowing on the left side

32. If Mrs. Leep has indeed suffered a stroke (CVA) and the cerebrum on the left side is damaged, which of the following will she need?
    A. a specialist in the field of endocrinology
    B. a wheelchair, because she will be unable to use her right or left leg
    C. help with eating, because she is left-handed
    D. assistance in walking, because her balance will be affected by the neurological effects on the right side of her body

The Senses SYNOPSIS

This chapter discusses the body's senses. The body has an innate ability to sense change in its internal and external environment, which enables it to maintain a state of homeostasis and continued survival. The senses are classified as special or general sense organs. All sense organs have some characteristics in common, such as the ability to detect certain stimuli, to convert a stimulus into a nerve impulse, and to perceive nerve impulses as a sensation in the central nervous system (CNS).

LEARNING OBJECTIVES WITH RATIONALE

the student will be able to:

1. Classify sense organs as special or general, and explain the basic differences between the two groups.

a. General sense organs are specialized with localized receptors found in almost every area of the body. They are classified as follows:

1. Free nerve endings found in the skin and epithelial layers
2. Encapsulated nerve endings found in a number of areas such as the skin, subcutaneous tissue, subserous tissue, around joints, mammary glands, external genitals, near junctions of tendons, and skeletal muscle

b. Special sense organs are characterized by large and complex organs, each with a unique function.

The following is a list of the of special sense organs:

1. Eye
2. Ear
3. Nose
4. Taste buds (tongue)

2. Discuss how a stimulus is converted into a sensation.

The first component necessary for a sensation to be realized is that the organ or body tissue must be able to sense or detect a stimulus in the environment. It is understood that, with each sense organ, stimuli received and detected in most circumstances will be different. Once the stimulus is converted into a nerve impulse, the signal is transmitted over the nerve pathways to the brain, where the sensation is actually perceived.

3. Discuss the general sense organs and their functions.

Groups of highly specialized and localized receptors are typically associated with the special senses. In the general sense organs, receptors are found in almost every part of the body. Stimulation of some receptors leads to the sensation of heat or cold, and stimulation of others gives the sensation of pain or pressure.

4. Describe the structure of the eye and the functions of its components.

The eye is made up of three primary layers: the sclera, the choroid, and the retina. The sclera is the tough, outermost, white layer that surrounds and protects the eye. Its front surface, called the cornea, is transparent to let light enter the eye. The choroid coat is the middle layer of the eye. It consists of the colored portion of the eye known as the iris. The iris has a hole in its center called the pupil. Light enters through the pupil, and the size of the pupil is regulated by the iris. The lens of the eye lies directly behind the pupil and it is held in place by ciliary muscles. It focuses images. The retina is the innermost layer of the eye. It contains microscopic structures called rods, which enable us to see in dim light, and cones, which enable us to see color. Aqueous humor and vitreous humor are fluids that fill the hollow inside of the eyeball, thus giving it shape.

5. Discuss the anatomy of the ear and its sensory function in hearing and equilibrium.

The ear is divided into three parts: the external ear, the middle ear, and the internal ear. The external ear is made up of a fleshy flap called the pinna and a curved tube called the ear canal. The middle ear contains three small moveable bones called the malleus, incus, and stapes. The tympanic membrane, or eardrum, separates the middle ear from the external ear canal.

The inner ear is made up of bones and membranes. It is divided into three parts: vestibule, semicircular canals, and cochlea. The sense organ of hearing, called the organ of Corti, lies inside the cochlea. It is stimulated by vibrations that have reached the inner ear from the outside environment.

The specialized mechanoreceptors for balance and equilibrium are located in the three semicircular canals and the vestibule.

6. Discuss the chemical receptors and their functions.

Receptors for the sense of smell lie in the mucosa of the upper part of the nasal cavity. These receptors are stimulated by odor-causing chemicals in the environment. They pass messages to cranial nerves that connect to the brain.

Receptors for gustatory sensations are found within taste buds that cover the tongue. Chemicals stimulate these receptors, and four sensations—sweet, sour, bitter, and salty—are carried to the brain by cranial nerves.

LECTURE OUTLINE

I. CLASSIFICATION OF SENSE ORGANS

A. General sense organs

1. Often exist as individual cells or receptor units
2. Widely distributed throughout the body

B. Special sense organs
    1. Large and complex organs
    2. Localized grouping of specialized receptors
C. Classification by presence or absence of covering capsule
    1. Encapsulated
    2. Unencapsulated ("free" or "naked")
D. Classification by type of stimuli required to activate receptors
    1. Photoreceptors (light)
    2. Chemoreceptors (chemicals)
    3. Pain receptors (injury)
    4. Thermoreceptors (temperature change)
    5. Mechanoreceptors (movement or deforming of capsule)
    6. Proprioceptors (position of body parts or changes in muscle length or tension)

II. CONVERTING A STIMULUS INTO A SENSATION

A. All sense organs have common functional characteristics
    1. All are able to detect a particular stimulus
    2. A stimulus is converted into a nerve impulse
    3. A nerve impulse is perceived as a sensation in the CNS

III. GENERAL SENSE ORGANS

A. Distribution is widespread; single-cell receptors are common
B. Examples
    1. Free nerve endings—pain and crude touch
    2. Meissner's corpuscles—fine touch and vibration
    3. Ruffini's corpuscles—touch and pressure
    4. Pacinian corpuscles—pressure and vibration
    5. Krause's end-bulbs—touch
    6. Golgi tendon receptors—proprioception
    7. Muscle spindles—proprioception

IV. SPECIAL SENSE ORGANS

A. The eye
    1. Layers of eyeball
        a. Sclera—tough outer coat; "white" of eye; cornea is transparent part of sclera over iris
        b. Choroid—pigmented vascular layer prevents scattering of light; front part of this layer made of ciliary muscle and iris, the colored part of the eye; the pupil is the hole in the center of the iris; contraction of iris muscle dilates or constricts pupil
        c. Retina (Figure 9-3)—innermost layer of the eye; contains rods (receptors for night vision) and cones (receptors for day vision and color vision)

2. Conjunctiva—mucous membrane covering the front surface of the sclera and lining the eyelid
3. Lens—transparent body behind the pupil; focuses light rays on the retina
4. Eye fluids
    a. Aqueous humor—in the anterior cavity in front of the lens
    b. Vitreous humor—in the posterior cavity behind the lens
5. Visual pathway
    a. Innermost layer of retina contains rods and cones
    b. Impulse travels from the rods and cones through the bipolar and ganglionic layers of retina
    c. Nerve impulse leaves the eye through the optic nerve; the point of exit has no receptors and is therefore called the blind spot
    d. Visual interpretation occurs in the visual cortex of the cerebrum

B. The ear
1. The ear functions in hearing and in equilibrium and balance
    a. Receptors for hearing and equilibrium are mechanoreceptors
2. Divisions of the ear (Figure 9-4)
    a. External ear
        (1) Auricle (pinna)
        (2) External auditory canal
            (a) Curving canal 2.5 cm (1 inch) in length
            (b) Contains ceruminous glands
            (c) Ends at the tympanic membrane
    b. Middle ear
        (1) Houses ear ossicles—malleus, incus, and stapes
        (2) Ends in the oval window
        (3) The auditory (eustachian) tube connects the middle ear to the throat
        (4) Inflammation called otitis media
    c. Inner ear
        (1) Bony labyrinth filled with perilymph
        (2) Subdivided into the vestibule, semicircular canals, and cochlea
        (3) Membranous labyrinth filled with endolymph
        (4) The receptors for balance in the semicircular canals are called cristae ampullaris
        (5) Specialized hair cells on the organ of Corti respond when bent by the movement of surrounding endolymph set in motion by sound waves

C. The taste receptors
1. Receptors are chemoreceptors called taste buds
2. Cranial nerves VII and IX carry gustatory impulses

3. Only four kinds of taste sensations—sweet, sour, bitter, salty
4. Gustatory and olfactory senses work together

D. The smell receptors

1. Receptors for fibers of olfactory or cranial nerve I lie in olfactory mucosa of nasal cavity
2. Olfactory receptors are extremely sensitive but easily fatigued
3. Odor-causing chemicals initiate a nervous signal that is interpreted as a specific odor by the brain

Review Questions

1. Name the general sense receptors in the skin or subcutaneous tissue and list the type of stimuli to which each of them respond.

Answer: The general sense receptors found in the skin are (1) free nerve endings—unencapsulated specialized receptors in skin that respond to pain, touch, and possibly temperature; (2) Meissner's corpuscles—sensory receptors located in the skin close to the surface that detect light touch and vibration; (3) Ruffini's corpuscles—encapsulated sensory nerve endings found in the subcutaneous tissue of fingers and dermis of the skin that detect touch and pressure; (4) Pacinian corpuscles—receptors found deep in the dermis and subcutaneous tissue that detect pressure and vibration; (5) Krause's end-bulbs—receptors found in the dermis and subcutaneous tissue that detect touch, low-frequency vibration, and possibly temperature.

2. Name the two general senses of proprioception and give the location of each.

Answer: (1) Golgi tendon receptors—found near junction of tendons and muscles; able to recognize body position. (2) Muscle spindles—found in skeletal muscle; able to detect position and movement.

3. What type of information do proprioceptors provide us?

Answer: Proprioceptors provide information concerning position and movement.

4. Explain how the iris changes the size of the pupil.

Answer: As the fibers of the iris contract, the pupils dilate, letting in more light. Other fibers are circular. When they contract, the pupils constrict, letting in fewer light rays. Normally the pupils constrict in bright light and dilate in dim light.

5. Explain how the ciliary muscles allow the eye to focus on near and far objects.

Answer: When we look at an object from a distance, the ciliary muscle is in a relaxed state. The lens has only a slightly curved shape. When we focus on near objects, the ciliary muscle contracts, pulling the choroid coat forward toward the lens, thereby causing the lens to bulge and curve even more.

6. What is presbyopia, and what is its cause?

Answer: Presbyopia is farsightedness, a common condition that occurs as we age. It is the inability to focus on close objects because our lenses have lost their elasticity and can no longer bulge enough to bring near objects into focus.

7. Name the two types of receptor cells in the retina. Explain the difference between these two receptors.

Answer: The retina contains microscopic receptor cells called rods and cones. The rods are receptors for night vision and can be stimulated by dim light. Cones are receptors for daytime vision and need bright light to be stimulated.

8. What is glaucoma, and what is its cause?

Answer: Glaucoma is a disorder characterized by elevated pressure in the eye. When drainage of aqueous humor in the anterior chamber of the eye is blocked, pressure increases, resulting in damage that could lead to blindness.

9. What are cataracts, how are they caused, and what can be done to prevent them?

Answer: Cataract formation may occur in one or both eyes. It is a condition in which the lens of the eye becomes hard and loses transparency, taking on a milky appearance. In some individuals exposure to ultraviolet radiation in sunlight may cause cataracts to form. The condition tends to be progressive and may result in blindness. Cataracts can be removed surgically and a defective lens can be replaced.

10. What is meant by visual pathway? Where is the blind spot, and what causes it?

Answer: The visual pathway is the innermost layer of the retina containing the rods and the cones. An impulse travels from the rods and cones through the bipolar and ganglionic layers of the retina. The nerve impulse leaves the eye through the optic nerve. The point of exit has no receptors and is therefore called the blind spot.

11. Briefly explain the structure of the external ear.

Answer: The external ear is composed of two parts: (1) the auricle is the appendage on the side of the head surrounding the opening of the external auditory canal; (2) the external auditory canal is a curved tube that extends into the temporal bone and ends at the tympanic membrane.

12. Explain how sound waves are transmitted through the middle ear.

Answer: The middle ear is a tiny, thin, epithelium-lined cavity hollowed out of the temporal bone. It contains three small ear bones called the ossicles. The names of the bones describe their shape: the malleus (hammer), the incus (anvil), and the stapes (stirrup). When sound waves cause the eardrum

to vibrate, the movement is transmitted and amplified by the ear ossicles as it passes through the middle ear. Movement of the stapes against the oval window causes movement of fluid in the inner ear.

13. Explain how sound waves are converted to an auditory impulse.

Answer: As sound waves strike the tympanic membrane it begins to vibrate. This vibration causes the membrane of the oval window to vibrate. This vibration causes the perilymph in the bony labyrinth of the cochlea to move, which causes the endolymph in the membranous labyrinth of the cochlea or cochlear duct to move. This movement of endolymph stimulates hair cells on the organ of Corti to generate a nerve impulse. The nerve impulse travels over the cochlear nerve, which becomes a part of the cranial nerve VIII. Once the nerve impulses reach the auditory cortex they are interpreted as sound.

14. Explain how the structures in the inner ear help maintain balance or equilibrium.

Answer: The inner ear (also called labyrinth) contains the semicircular canals and the cochlea. Within the cochlea are the hair cells and neurons that allow sound perception and transmission to travel to the auditory center of the brain. The semicircular canals are filled with endolymph and are the primary organs in maintaining balance and equilibrium. Damage or disease to this part of the ear not only affects balance but also may result in permanent hearing loss.

15. Where are gustatory cells located and to what four tastes do they respond?

Answer: Gustatory cells, or taste buds, are located on structures on the tongue called papillae, certain tissues in the mouth, and the throat. There are four kinds of taste sensations: sweet, sour, bitter, and salty.

16. Explain how the sense of smell is stimulated.

Answer: The chemoreceptors (olfactory receptors) responsible for the sense of smell are located in a small area of epithelial tissue in the upper part of the nasal cavity. Each olfactory cell has a number of specialized cilia that sense different chemicals and cause the cell to respond by generating a nervous impulse. To be detected by olfactory receptors, chemicals must be dissolved in the watery mucus that lines the nasal cavity.

Critical Thinking Questions

17. Explain why food loses some of its taste when you have a bad cold with a stuffy nose.

Answer: All flavors result from a combination of taste bud and olfactory receptor stimulation. For this reason, a cold that interferes with the stimulation of the olfactory receptors markedly dulls taste sensations.

18. Explain why the longer you are in a newly painted room, the less you are able to smell the paint.

Answer: Olfactory receptors are very sensitive, but they adapt easily, which explains why odors that are at first very noticeable are not sensed at all after a short period of time.
19. Where in the eye is light sensed? Where is it perceived (be specific). Answer: The innermost layer of the retina contains the rods and cones, which are the photoreceptor cells of the eye. Visual interpretation occurs in the visual cortex of the cerebrum.

20. Explain why the smell of a doctor's office or the smell of a turkey cooking on Thanksgiving can easily generate an emotional response.

Answer: The pathways taken by olfactory nerve impulses and the area where these impulses are interpreted are closely associated with areas of the brain important in memory and emotion. For this reason, we may retain vivid and long-lasting memories of particular smells and odors.

CLASSROOM APPLICATION

The following questions can be used as individual assignments or for small-group discussion. Note: to copy the questions, cover the answers with a blank sheet of paper and print, thus leaving space for answers or note-taking.

1. We have discussed the importance of maintaining homeostasis in our bodies. We have seen how the integumentary system and muscular system contribute to homeostasis. How would you suggest that the general and special senses contribute to homeostasis?

Answer: The general and special senses help maintain homeostasis in the body by monitoring the conditions in our environment. For instance, heat and cold receptors help us to avoid conditions that will adversely affect temperature regulation in our body. Pain receptors tell us to avoid touching certain things. Because of special senses such as sight and hearing, we are able to avoid many dangerous situations, which helps maintain conditions within a normal range in the body. Our general and special senses are constantly accumulating data that are integrated with memory and reflexes to produce homeostatic responses.

2. Why might the special senses of smell and taste be important for helping to maintain homeostasis in our body?

Answer: Smell and taste are, of course, important for detecting "good" food and avoiding spoiled, rotten, or otherwise contaminated food. Obtaining good food is important because functions of the body require energy that we obtain from the chemical breakdown of food. Our sense of smell also allows us to detect corrosive chemicals, burning materials, or even unhealthful conditions of our own bodies, and to avoid or correct the situation.

3. What is taking place with individuals who are unable to focus at a close distance?

Answer: As people age—onset is usually around age 40–45—they become farsighted and develop presbyopia due to the loss of elasticity of crystalline lens. Usually reading glasses compensate for this condition.

LAB ACTIVITIES

Have students perform the following exercise with a lab partner:

1. Have your partner cover his or her right eye with an index card. Hold a small penlight about 6 inches above your partner's left eye. Shine the light into the eye for about 2 seconds. What did you observe about the pupil size—and/or reaction? Do the same to the other eye. Write down your observations.

2. Have the students dry their tongues thoroughly with gauze pads then sprinkle a few grains of salt or sugar on the tongue. Have them describe the taste. Without saliva the sugar or salt is difficult to dissolve, and the taste is markedly reduced.

3. Have the students choose a lab partner. Have one student from each pair sit in a chair and close both eyes. The other student will hold a watch at an audible distance (about 7 inches) from the first student's ear. As the watch is moved to different areas, ask the seated student to point in the direction of the ticking watch. Is the sound heard equally well in all positions?

PRACTICAL/CREATIVE LEARNING ACTIVITIES

1. Have students choose a lab partner and research four of the following diseases. Have them include in their report the following information, in this order: (1) definition of disease, (2) etiology, (3) symptoms, (4) incidence (e.g., more women than men), (5) treatment, and (6) prognosis. Encourage them to use visual aids and handouts. Be sure to list reference material used.

Scotoma	Meniere's disease
Otosclerosis	Otitis media
Astigmatism	Cataracts
Glaucoma	Retinal detachment
Myopia	Nyctalopia
Conjunctivitis	Presbyopia

THE SENSES

Multiple Choice

1. Where are the sensations of hearing and balance located?

A. inner ear
B. malleus
C. helix
D. all of the above

2. The organ of Corti is the organ of what sense?

A. sight
B. hearing
C. pressure
D. taste

3. Where are taste sensations interpreted?

A. cerebral cortex
B. area of stimulation
C. nasal cavity
D. none of the above

4. On what does the lens, a transparent body behind the pupil, focus light?

A. cornea
B. fovea
C. retina
D. none of the above

5. Which of the following statements about the cornea is true?

A. It is a mucous membrane.
B. It is called the "window of the eye."
C. It lies behind the iris.
D. All of the above.

6. Which of the following are general sense organs?

A. gustatory receptors
B. Pacinian corpuscles
C. olfactory receptors
D. all of the above

7. Which of the following statements about proprioception is true?

A. It is a sense of position and movement.
B. It is called kinesthesia.
C. It is an ability to sense the position of body parts.
D. All of the above.

8. Which two involuntary muscles make up the front part of the eye?

A. malleus
B. iris and ciliary muscle
C. retina and Pacinian muscle
D. sclera and iris

9. Which of the following statements about gustatory sense organs is true?

A. They are called taste buds.
B. They are innervated by cranial nerves VII and IX.
C. They work together with the olfactory senses.
D. All of the above.

10. Of what does the external ear consist?

A. auricle and auditory canal
B. labyrinth
C. organ of Corti and cochlea
D. none of the above

True or False

Indicate whether the following statements are true or false.

11. The tympanic membrane separates the middle ear from the external ear. T or F

12. Glaucoma may result from a blockage of flow of vitreous humor. T or F

13. The condition of presbyopia results when the eye lens loses its elasticity. T or F

14. The crista ampullaris is located in the nasal cavity. T or F

15. Myopia occurs when images are focused in front of the retina rather than on it. T or F

16. Light enters through the pupil, and the size of the pupil is regulated by the iris. T or F

17. The retina is the innermost layer of the eye. It contains the structures called rods. T or F

18. A commonly used name for the "white of the eye" is the sclera. T or F

19. The olfactory receptors are chemical receptors. T or F

20. The organ of Corti contains mechanoreceptors. T or F

Matching

Select the most correct answer from Column B for each statement in Column A. (Only one answer is correct for each.)

Column A	Column B
_____ 21. Nearsightedness	A. Iris
_____ 22. Senses color vision	B. Myopia
_____ 23. Between middle and inner ear	C. Rods
_____ 24. Sense(s) vision in dim light	D. Auricle
_____ 25. Surrounds membranes labyrinth	E. Malleus
_____ 26. Inflammation of middle ear	F. Cones
_____ 27. Bone in middle ear	G. Bony labyrinth
_____ 28. Connects middle ear with throat	H. Otitis media
_____ 29. Colored part of the eye	I. Oval window
_____ 30. Outer portion of the ear	J. Auditory tube

Multiple Choice

Chad Tanton, a 6-year-old child, is suffering from an acute earache. Chad's pediatrician says Chad has an ear infection that needs to be treated with antibiotics.

31. In addition to the diagnosis, what else might the doctor have said?

A. This condition occurs most often in the middle ear.
B. The medical term used for an ear infection is otitis media.
C. It is possible for this infection to spread to the mastoid spaces.
D. All of the above statements and that hearing can also be affected.

32. Chad is having difficulty hearing. What is the sense organ of hearing?

A. organ of Corti
B. tympanic membrane
C. mastoid process
D. cochlear nerve

33. You explain to Chad that the ear is divided into three anatomical areas. What are they?

A. external ear, lacrimal glands, midbrain
B. middle ear, gustatory glands, inner ear
C. inner ear, external ear, middle ear
D. medial rectus muscle, anterior cavity, middle ear

Practice Test Questions for the Nervous system and special senses and the key

Multiple Choice
Identify the choice that best completes the statement or answers the question.

____ 1. Which of the following is a division of the autonomic nervous system and is most active under calm conditions?
a. Homeostatic nervous system
b. Beta nervous system
c. Parasympathetic nervous system
d. Sympathetic nervous system

____ 2. What are impulse-conducting cells that possess properties of excitability and conductibility?
a. Neuroglia
b. Neurons
c. Reflexes
d. Neurotransmitters

____ 3. What are the gaps located at intervals along myelinated axons that increase their rate of conduction?
a. Synaptic gaps
b. Axon terminale
c. Nodes of Golgi
d. Nodes of Ranvier

____ 4. Which is a division of the peripheral nervous system that is involuntary, supplying mainly smooth muscle, cardiac (heart) muscle, and glands?
a. Autonomic nervous system
b. Spatial nervous system
c. Central nervous system
d. Visceral nervous system

____ 5. What is the junction between two neurons or between a neuron and a muscle or gland, where transmission of nerve impulses takes place?
a. Goid
b. Synapse
c. Plexus
d. Nodes of Ranvier

____ 6. What is a substance formed by Schwann cells that creates a fatty insulating sheath, which surrounds most axons in the peripheral nervous system?
a. Neuroglia
b. Adipose neuroma
c. Myelin
d. Alpha substance

____ 7. What division of the nervous system contains the brain, spinal cord, cerebrospinal fluid, and meninges?

a. Peripheral nervous system
b. Cranial nervous system
c. Axial nervous system
d. Central nervous system

____ 8. What is a bundle of neurons held together by several layers of connective tissue called?
a. Neuroglia
b. Nerve
c. Compilation
d. Assemblage

____ 9. What division of the nervous system is composed of the cranial and the spinal nerves?
a. Peripheral nervous system
b. Central nervous system
c. Visceral nervous system
d. Axial nervous system

____ 10. What division of the autonomic nervous system is stimulated during physical exertion or emotional stress and has thus earned the nickname “fight-or-flight”?
a. Sympathetic nervous system
b. Visceral nervous system
c. Parasympathetic nervous system
d. Appendicular nervous system

____ 11. Which type of connective tissue supports, nourishes, protects, insulates, and organizes the neurons?
a. Meninges
b. Neuroglia
c. Astrocytes
d. Endoneurium

____ 12. Which of the following is the collective term for the chemical messengers involved in nerve impulse transmission?
a. Neurotransmitters
b. Neural enzymes
c. Synaptic secretions
d. Histamines

____ 13. What is an instantaneous, automatic response to a stimulus from either inside or outside the body?
a. All-or-none response
b. Recruitment
c. Adaptation
d. Reflex

____ 14. Which are the neural extensions that carry the impulses away from the neuron toward another neuron, a muscle cell, or a gland?
a. Dendrites
b. Microvilli

c. Axons
d. Neural cilia

____ 15. Which are the neural extensions that are narrow and highly branched and receive and transmit stimuli toward the cell body?
a. Axons
b. Dendrites
c. Microvilli
d. Neural cilia

____ 16. What is the term used to describe the connective tissue coverings deep in the skull and spine surrounding the brain and spinal cord?
a. Neuroglia
b. Myelin
c. Meninges
d. Neuraltome

____ 17. What part of the brain governs muscle tone, coordinates complex movements, and regulates posture and balance?
a. Medulla oblongata
b. Cerebrum
c. Pons
d. Cerebellum

____ 18. What is the term used to describe a network of intersecting nerves in the peripheral nervous system?
a. Plexus
b. Ganglion
c. Neuroma
d. Hematoma

____ 19. What are the sensory receptors that detect pain?
a. Mechanoreceptors
b. Photoreceptors
c. Chemoceptors
d. Nociceptors

____ 20. What part of the brainstem contains the respiratory, cardiac, and vasomotor centers and is considered the most vital part of the brain?
a. Cerebellum
b. Medulla oblongata
c. Cerebrum
d. Pons

____ 21. What is the term used to describe a cluster of nerve cell bodies located in the peripheral nervous system?
a. Axon
b. Ganglion
c. Plexus

d. Reflex

____ 22. What is an area of skin that is served by a specific sensory nerve root?
a. Neurotome
b. Plexus
c. Dermatome
d. Ganglion

____ 23. What is a decrease in sensitivity to a prolonged stimulus?
a. All-or-none response
b. Adaptation
c. Desensitization response
d. Recruitment

____ 24. What is the principal that states that an impulse can only be conducted at maximum capacity and never at partial capacity?
a. All-or-none response
b. Adaptation
c. Action potential
d. Recruitment

____ 25. Which receptors are activated by both tension and excessive stretch and respond by inhibiting motor neurons, and thus contraction?
a. Krause receptors
b. Pacinian corpuscles
c. Muscle spindles
d. Golgi tendon organs

____ 26. Which of the following are stretch-sensitive receptors that monitor changes in muscle length as well as the rate of this change and cause reflexive contraction?
a. Muscle spindles
b. Golgi tendon organs
c. Krause receptors
d. Pacinian corpuscles

____ 27. Which of the following terms best describes an active neuron or one conducting an impulse?
a. All-or-none response
b. Adaptation
c. Action potential
d. Depolarization

____ 28. Which brain wave state represents a person who is awake but relaxed and nonattentive?
a. Alpha
b. Beta
c. Theta
d. Delta

____ 29. Which brain wave state is associated with wakeful consciousness and mental activity?
a. Alpha

b. Beta
c. Theta
d. Delta

____ 30. What is the general term for receptors that are located in the skin, ears, muscles, tendons, joints, and fascia and respond to movement and position?
a. Nociceptors
b. Chemoceptors
c. Photoreceptors
d. Proprioceptors

____ 31. Which one of the following is NOT a function of the nervous system?
a. Integration
b. Sensory input and motor output
c. Emotional responsiveness
d. Produce and secrete wastes

____ 32. The nervous system is divided into two major divisions. What are they?
a. Epi-nervous system and endo-nervous system
b. Central nervous system and peripheral nervous system
c. Axial nervous system and appendicular nervous system
d. Central nervous system and superficial nervous system

____ 33. The autonomic nervous system is divided into which of the following?
a. Somatic and autogenic divisions
b. Brain and spinal cord
c. Sympathetic and parasympathetic divisions
d. Cranial nerves and spinal nerves

____ 34. When a stimulus is of sufficient intensity to generate a nerve impulse, it is called
a. Threshold stimulus
b. Subthreshold stimulus
c. All-or-none-response
d. Sufficient stimulus

____ 35. What are the sac-like structures located within the synaptic bulbs that produce and store neurotransmitters?
a. Transmitter pockets
b. Neural bladders
c. Synaptic vesicles
d. Bulbs of Ranvier

____ 36. Every time you move your fingers, which of the following are you using?
a. Sensory nerves
b. Photoreceptors
c. Motor nerves
d. Chemoreceptors

____ 37. What is the most inferior portion of the brainstem called?

a. Mesencephalon
b. Pons
c. Inferiosso cranioso
d. Medulla oblongata

____ 38. Which are the major regions of the brain?
a. Pia mater, arachnoid, dura mater
b. Cerebrum, diencephalon, cerebellum, brainstem
c. Cerebellum, corpus callosum, midbrain, hindbrain
d. Cerebrum, midbrain, hindbrain

____ 39. Which is the largest region of the brain?
a. Cerebellum
b. Medulla oblongata
c. Cerebrum
d. Diencephalon

____ 40. Which receptor detects smells, tastes, and changes in blood chemistry?
a. Culinarioceptor
b. Nociceptor
c. Chemoreceptor
d. Baroreceptor

____ 41. The brain is NOT protected by which of the following?
a. Nociceptors
b. Meninges
c. Cerebrospinal fluid
d. Osseous tissue

____ 42. Which part of the brain houses the thalamus and hypothalamus?
a. Cerebrum
b. Cerebellum
c. Diencephalon
d. Brainstem

____ 43. Which of the following is NOT a structure located in the brainstem?
a. Pons
b. Medulla oblongata
c. Midbrain
d. Pineal gland

____ 44. What is the semipermeable wall of blood capillaries with a thick basement membrane and neuroglial cells that prevent or slow down the passage of some chemical compounds and disease-causing organisms from traveling from the blood into the central nervous system?
a. Blood-brain barrier
b. Cerebrospinal boundary
c. Neurotransmitter block
d. Neurocranial barrier

____ 45. A person with a severely damaged cerebellum might suffer from which of the following?
a. Inability to learn
b. Uncontrollable hunger and rage
c. Lack of coordination
d. High blood pressure

____ 46. Which of the following is NOT one of the 12 cranial nerves?
a. Olfactory
b. Oculomotor
c. Trigeminal
d. Brachial

____ 47. If the sympathetic nervous system increases blood pressure, which decreases blood pressure?
a. Somatic nervous system
b. Parasymphonic nervous system
c. Parasympathetic nervous system
d. Amygdala

____ 48. Which sensory receptors are sensitive to temperature changes and are types of free nerve endings?
a. Chemoreceptors
b. Nociceptors
c. Thermoreceptors
d. Photoreceptors

____ 49. Which sensory receptors are located in the retina?
a. Chemoreceptors
b. Nociceptors
c. Thermoreceptors
d. Photoreceptors

____ 50. The sympathetic nervous system is also called which of the following?
a. Relaxation response
b. Housekeeping system
c. Thoracolumbar outflow
d. Craniosacral outflow

____ 51. Which of the following is a term used to describe the parasympathetic nervous system?
a. Alarm response
b. Craniosacral outflow
c. Thoracolumbar outflow
d. Somatic division

____ 52. Which of the following is NOT an effect of the parasympathetic nervous system?
a. Decrease in heart rate and strength of contraction
b. Increase in gastrointestinal motility
c. Stimulation of salivation
d. Increase in respiration rate

____ 53. Which of the following is a structure associated with the axon?
a. Ribosomes
b. Nissl bodies
c. Dendrites
d. Telodendria

____ 54. Which part of the neuron contains the nucleus?
a. Cell body
b. Axon
c. Synaptic end bulb
d. Dendrite

____ 55. What is the name of the clear fluid that circulates around the brain and spinal cord?
a. Cerebrospinal fluid
b. Blood-brain fluid
c. Neurotransmitter fluid
d. Neurocranial secretions

____ 56. Which of the following is NOT a neurotransmitter?
a. Acetylcholine
b. Renin
c. Serotonin
d. Dopamine

____ 57. What are the areas within the cerebrum named for the bones that lie beneath?
a. Neural spaces
b. Cranial zones
c. Lobes
d. Cerebral tracts

____ 58. What are the stretch receptors located in the wall of the carotid arteries and aortic arch?
a. Muscle spindles
b. Vasoreceptors
c. Golgi tendon organs
d. Baroreceptors

____ 59. Which cells form the myelin sheaths that surround axons in the peripheral nervous system?
a. Astrocytes
b. Schwann cells
c. Oligodendrocytes
d. Satellite cells

____ 60. Which cell type is part of the blood-brain barrier?
a. Astrocyte
b. Oligodendrocyte
c. Satellite cell
d. Schwann cell

____ 61. Which cell type produces the axon's myelin in central nervous system?

a. Astrocyte
b. Satellite cell
c. Oligodendrocytes
d. Schwann cell

____ 62. Any impulse that travels toward the central nervous system is called
a. Active
b. Sensory
c. Exemplary
d. Motor

____ 63. Which of the following carries impulses from the brain and spinal cord to smooth muscle, cardiac muscle, skeletal muscle, and glands?
a. Active
b. Sensory
c. Exemplary
d. Motor

____ 64. What are the large bundles of transverse fibers that connect the right and left cerebral hemispheres called?
a. Gyri
b. Tract
c. Sulci
d. Corpus callosum

____ 65. Which of the following is a synonym for sensory nerves?
a. Active
b. Afferent
c. Exemplary
d. Efferent

____ 66. Which of the following is a synonym for motor nerves?
a. Active
b. Afferent
c. Efferent
d. Exemplary

____ 67. Which structure is nearly 80% of the diencephalon and relays sensory information (except olfaction) to appropriate parts of the cerebrum?
a. Thalamus
b. Pons
c. Hypothalamus
d. Medulla oblongata

____ 68. What is the proper order of spinal cord meninges from in to out?
a. Dura mater → arachnoid → pia mater
b. Dura mater → pia mater → arachnoid
c. Arachnoid → pia mater → dura mater

d. Pia mater →← arachnoid → dura mater

____ 69. How many pairs of cranial nerves are there?
a. 12
b. 24
c. 26
d. 31

____ 70. How many pairs of spinal nerves are there?
a. 12
b. 24
c. 26
d. 31

____ 71. Which photoreceptors produce color vision?
a. Nodes
b. Cones
c. Rods
d. Otoliths

____ 72. Which photoreceptors are sensitive to shades of black, white, and gray?
a. Nodes
b. Cones
c. Rods
d. Otoliths

____ 73. Which receptor responds to stimuli originating from outside of the body, such as touch, pressure, or sound?
a. Exteroceptor
b. Proprioceptor
c. Interceptor
d. Peripherecеptor

____ 74. What is the quality of a tone or sound and is dependent on vibration speed?
a. Amplitude
b. Diameter
c. Volume
d. Pitch

____ 75. What is the loudness of sound called?
a. Amplitude
b. Pitch
c. Volume
d. Diameter

____ 76. Which receptor responds to stimuli originating from within the body regarding the function of the internal organs, such as digestion, excretion, and blood pressure, and is located in the viscera?
a. Exteroceptor

b. Proprioceptor
c. Interceptor
d. Visceroeceptor

____ 77. What are the grooves in the outer layer of the brain?
a. Sulci
b. Gyri
c. Nodes
d. Lobes

____ 78. What are the elevated ridges of tissue in the outer layer of the brain?
a. Sulci
b. Lobes
c. Gyri
d. Nodes

____ 79. Which of the following regulates the autonomic nervous system?
a. Medulla oblongata
b. Thalamus
c. Pons
d. Hypothalamus

____ 80. What type of receptor is a Golgi tendon organ?
a. Mechanoreceptor
b. Nociceptor
c. Photoreceptor
d. Thermoreceptor

____ 81. Which cerebral lobe contains a center for visual input?
a. Frontal lobe
b. Parietal lobe
c. Temporal lobe
d. Occipital lobe

____ 82. Which cerebral lobe governs somatosensory input (namely, the skin and muscles)?
a. Frontal lobe
b. Parietal lobe
c. Temporal lobe
d. Occipital lobe

____ 83. Which cerebral lobe regulates motor output, cognition, and speech production?
a. Frontal lobe
b. Parietal lobe
c. Temporal lobe
d. Occipital lobe

____ 84. Which cerebral lobe houses auditory and olfactory areas, as well as Wernicke's area?
a. Frontal lobe
b. Parietal lobe

c. Temporal lobe
d. Occipital lobe

____ 85. What exits the skull through the foramen magnum and extends to about the L2 region?
a. Spine
b. Spinous process
c. Spinal cord
d. Pons

____ 86. What is the term used to describe the lower end of the spinal cord that is marked by the thread-like fibrous extension of the pia mater?
a. Filum terminale
b. Axon filaments
c. Filum equina
d. Cauda equina

____ 87. What are the ends of the spinal cord that fan out like a horse's tail?
a. Filum terminale
b. Axon filaments
c. Filum equina
d. Cauda equina

____ 88. Which is the study of the nervous system?
a. Phrenology
b. Craniology
c. Neurology
d. Psychology

____ 89. What is the term used to describe changes detected by the nervous system?
a. Activation
b. Stimuli
c. Somatic input
d. Retraction

____ 90. Which is the connective tissue that surrounds the entire nerve?
a. Epineurium
b. Endoneurium
c. Transneurium
d. Perineurium

____ 91. What is a collection of nerves running in a column up and down the spinal cord?
a. Ganglion
b. Plexus
c. Path
d. Tract

____ 92. What is the term used to describe the amount of stimuli needed to reach a threshold stimulus and create a nerve impulse?
a. Reflex

b. Action potential
c. Summation
d. Adaptation

____ 93. What is the term used to describe the inside of the neural membrane bearing a negative charge and the outside of the neural membrane bearing a positive charge?
a. Polarized
b. Depolarized
c. Repolarized
d. Desensitized

____ 94. What is the method that produces and maintains the resting potential in a neuron?
a. All-or-none response
b. Adaptation
c. Sodium–potassium pump
d. Repolarization

____ 95. What are impulses called that are conducted along myelinated axons?
a. Continuous conduction
b. Schwann conduction
c. Ranvier conduction
d. Saltatory conduction

____ 96. What is the simplest functional unit of the nervous system?
a. Nephron
b. Reflex arc
c. Neuron
d. Activation summation

____ 97. What is the term used to describe an abnormal reflex arc that has an increase in stimuli or an increase in the amount of afferent impulses entering the cord?
a. Somatic reflex arc
b. Visceral reflex arc
c. Physiopathological reflex arc
d. Physiological reflex arc

____ 98. Which neurotransmitter is involved with emotions and moods and is implicated in attention and learning?
a. Acetylcholine
b. Dopamine
c. Serotonin
d. Epinephrine

____ 99. Which of the following divisions of the peripheral nervous system is voluntary?
a. Somatic nervous system
b. Autonomic nervous system
c. Homeostatic nervous system
d. Volitional nervous system

____ 100. Which of the following is the most common neurotransmitter, vital for stimulating muscle contraction and found in junctions between motor nerves and muscles?
a. Dopamine
b. Serotonin
c. Histamine
d. Acetylcholine

Matching

Match each item with the correct statement below.
a. Arndt-Schultz Law
b. Sherrington's Law (reciprocal inhibition)
c. Davis' Law
d. Hilton's Law
e. Law of Facilitation
f. Pfluger's Law of Unilaterality
g. Pfluger's Law of Symmetry
h. Pfluger's Law of Intensity
i. Pfluger's Law of Radiation
j. Pfluger's Law of Generalization

____ 101. If a mild irritation is applied to one or more sensory nerves, the movement will take place usually on one side only, on the side that is irritated.

____ 102. Reflex movements are usually more intense on the side of irritation; at times the movements of the opposite side equal them in intensity, but they are usually less pronounced.

____ 103. Weak stimuli excite physiological activity; moderately strong ones favor it; strong ones retard it; and very strong ones arrest it.

____ 104. When an impulse has passed once through a certain set of neurons to the exclusion of others, it will tend to take the same course on future occasions, and each time it traverses this path the resistance will be less.

____ 105. If muscle ends are brought closer together, the pull of tonus is increased, thereby shortening the muscle, which may even cause hypertrophy. If muscle ends are separated beyond normal, then tonus is lessened or lost, thereby weakening the muscle.

____ 106. When the irritation becomes very intense, it is propagated in the medulla oblongata, which becomes a focus from which stimuli radiate to all parts of the cord, causing a general increase of tonus in all muscles of the body.

____ 107. When a muscle receives a nerve impulse to contract, its antagonist receives simultaneously an impulse to relax.

____ 108. If the stimulation is sufficiently increased, motor reaction is manifested, not only by the irritated side but also in similar muscles on the opposite side of the body.

____ 109. A nerve trunk that supplies a joint also supplies the muscles of the joint and the skin over the insertions of such muscles.

____ 110. If the excitation continues to increase, it is propagated upward, and reactions take place through centrifugal nerves coming from the cord segments higher up.

7

Answer Section

MULTIPLE CHOICE

1.	ANS:	C	PTS:	1
2.	ANS:	B	PTS:	1
3.	ANS:	D	PTS:	1
4.	ANS:	A	PTS:	1
5.	ANS:	B	PTS:	1
6.	ANS:	C	PTS:	1
7.	ANS:	D	PTS:	1
8.	ANS:	B	PTS:	1
9.	ANS:	A	PTS:	1
10.	ANS:	A	PTS:	1
11.	ANS:	B	PTS:	1
12.	ANS:	A	PTS:	1
13.	ANS:	D	PTS:	1
14.	ANS:	C	PTS:	1
15.	ANS:	B	PTS:	1
16.	ANS:	C	PTS:	1
17.	ANS:	D	PTS:	1
18.	ANS:	A	PTS:	1
19.	ANS:	D	PTS:	1
20.	ANS:	B	PTS:	1
21.	ANS:	B	PTS:	1
22.	ANS:	C	PTS:	1
23.	ANS:	B	PTS:	1
24.	ANS:	A	PTS:	1
25.	ANS:	D	PTS:	1
26.	ANS:	A	PTS:	1
27.	ANS:	C	PTS:	1
28.	ANS:	A	PTS:	1
29.	ANS:	B	PTS:	1
30.	ANS:	D	PTS:	1
31.	ANS:	D	PTS:	1
32.	ANS:	B	PTS:	1
33.	ANS:	C	PTS:	1
34.	ANS:	A	PTS:	1
35.	ANS:	C	PTS:	1
36.	ANS:	C	PTS:	1
37.	ANS:	D	PTS:	1
38.	ANS:	B	PTS:	1
39.	ANS:	C	PTS:	1
40.	ANS:	C	PTS:	1
41.	ANS:	A	PTS:	1

42.	ANS:	C	PTS:	1
43.	ANS:	D	PTS:	1
44.	ANS:	A	PTS:	1
45.	ANS:	C	PTS:	1
46.	ANS:	D	PTS:	1
47.	ANS:	C	PTS:	1
48.	ANS:	C	PTS:	1
49.	ANS:	D	PTS:	1
50.	ANS:	C	PTS:	1
51.	ANS:	B	PTS:	1
52.	ANS:	D	PTS:	1
53.	ANS:	D	PTS:	1
54.	ANS:	A	PTS:	1
55.	ANS:	A	PTS:	1
56.	ANS:	B	PTS:	1
57.	ANS:	C	PTS:	1
58.	ANS:	D	PTS:	1
59.	ANS:	B	PTS:	1
60.	ANS:	A	PTS:	1
61.	ANS:	C	PTS:	1
62.	ANS:	B	PTS:	1
63.	ANS:	D	PTS:	1
64.	ANS:	D	PTS:	1
65.	ANS:	B	PTS:	1
66.	ANS:	C	PTS:	1
67.	ANS:	A	PTS:	1
68.	ANS:	D	PTS:	1
69.	ANS:	A	PTS:	1
70.	ANS:	D	PTS:	1
71.	ANS:	B	PTS:	1
72.	ANS:	C	PTS:	1
73.	ANS:	A	PTS:	1
74.	ANS:	D	PTS:	1
75.	ANS:	C	PTS:	1
76.	ANS:	C	PTS:	1
77.	ANS:	A	PTS:	1
78.	ANS:	C	PTS:	1
79.	ANS:	D	PTS:	1
80.	ANS:	A	PTS:	1
81.	ANS:	D	PTS:	1
82.	ANS:	B	PTS:	1
83.	ANS:	A	PTS:	1
84.	ANS:	C	PTS:	1
85.	ANS:	C	PTS:	1
86.	ANS:	A	PTS:	1
87.	ANS:	D	PTS:	1

88.	ANS:	C	PTS:	1
89.	ANS:	B	PTS:	1
90.	ANS:	A	PTS:	1
91.	ANS:	D	PTS:	1
92.	ANS:	C	PTS:	1
93.	ANS:	A	PTS:	1
94.	ANS:	C	PTS:	1
95.	ANS:	D	PTS:	1
96.	ANS:	B	PTS:	1
97.	ANS:	C	PTS:	1
98.	ANS:	B	PTS:	1
99.	ANS:	A	PTS:	1
100.	ANS:	D	PTS:	1

MATCHING

101.	ANS:	F	PTS:	1
102.	ANS:	H	PTS:	1
103.	ANS:	A	PTS:	1
104.	ANS:	E	PTS:	1
105.	ANS:	C	PTS:	1
106.	ANS:	J	PTS:	1
107.	ANS:	B	PTS:	1
108.	ANS:	G	PTS:	1
109.	ANS:	D	PTS:	1
110.	ANS:	I	PTS:	1