

NERVOUS SYSTEM

OBJECTIVES/RATIONALE

To pursue a career in health care, proficiency in anatomy and physiology is vital. The student will describe biological and chemical processes that maintain homeostasis; analyze forces and the effects of movement, torque, tension, and elasticity on the human body; associate the disease process with changes in homeostasis; identify changes in structure and function due to trauma and disease; and identify normal and abnormal anatomy and physiology.

TEKS: 121.3 (c)(1)(F)(H),
121.4 (c)(1)(G)(H)(I),
121.5 (c)(1)(E)(F)(G)

TAAS ELA 1
Science 1, 2

KEY POINTS

Powerpoint

- I. Introduction
 - A. Most highly organized system of the body
 - B. Fast, complex communication system that regulates thoughts, emotions, movements, impressions, reasoning, learning, memory, choices
 - C. Basic Characteristics
 1. Master control system
 2. Master communication system
 3. Regulates, maintains homeostasis
 - D. Functions
 1. Monitors change (stimuli) - sensory input
 2. Integrates impulses - integration
 3. Effects responses - motor output
- II. Organization of the Nervous System
 - A. CNS
 1. Brain and spinal cord
 2. Integrates incoming pieces of sensory information, evaluates the information, and initiates the outgoing responses
 3. NO potential for regeneration
 - B. PNS
 1. Made of 12 pairs of cranial nerves and 31 pairs of spinal nerves
 2. Afferent (sensory) division
 - a. Carries impulses toward the CNS
 - b. Somatic (skin, skeletal muscles, joints)
 - c. Visceral (organs within the ventral cavity)
 3. Efferent (motor) division

- a. Somatic: carries information to skeletal muscles (reflex and voluntary control)
- b. Autonomic: involuntary, regulates smooth muscles, cardiac muscle, glands
 - (1) Sympathetic: exit thoracic area of spinal cord and involved in preparing body for “fight or flight”
 - (2) Parasympathetic: exit cervical and lumbar areas of spinal cord and coordinates the body’s normal resting activities (“resting and digesting-repairing”)

III. Histology of Nervous Tissue

A. Basic Characteristics

- 1. Highly cellular
- 2. 2 types of cells - neurons and supporting cells (neuroglia)

B. Neuroglia Characteristics

- 1. Dense network of supporting cells for nerve tissue
- 2. Over 900 billion
- 3. CAN replace themselves
- 4. glia = glue
- 5. Supportive scaffolding; insulation; neuron health and growth
- 6. 6 types (4 in CNS, 2 in PNS)
- 7. Tic douloureux: painful disorder, supporting cells of fibers of trigeminal nerve (main sensory nerve of face) degenerate - touch sensations stimulate uninsulated pain fibers - agonizing pain with softest touch

C. Neuroglia

- 1. Astrocytes: star shaped cells in CNS
 - a. Most abundant, cling to neurons and capillaries
 - b. Make tight sheaths around the brain’s capillaries forming the blood-brain barrier that regulates the passage of certain molecules into the brain
 - c. Controls chemical environment (leaked K+, recapture/recycle neurotransmitters)
- 2. Microglia: small, ovoid, thorny cells in CNS
 - a. Phagocytic cells that fight infection by engulfing microbes
- 3. Ependymal: squamous to columnar, some ciliated in CNS
 - a. Form thin sheaths that line the ventricles and spinal canal
 - b. Help form CSF
 - c. Permeable barrier between CSF and CNS
 - d. Cilia circulate CSF
- 4. Oligodendrocytes: in CNS
 - a. Form myelin sheaths around axons of the CNS
 - b. Forms “white matter” of brain and spinal cord
 - c. Multiple Sclerosis: disease of oligodendrocytes where hard lesions replace the myelin and affected areas are invaded by inflammatory cells; nerve conduction is impaired;

chronic deterioration of myelin of CNS with periods of remission and relapses; causes: autoimmunity or viral

5. Schwann Cells: in PNS
 - a. Neurolemmocytes
 - b. Form myelin sheaths around axons of PNS
 - c. Area between Schwann cells form gaps called Nodes of Ranvier
 - d. As each Schwann cell wraps around the axon, its nucleus and cytoplasm are squeezed to the perimeter to form the neurilemma (sheath of Schwann) which is essential for nerve regeneration
 - e. Also act as phagocytes (cell debris)
6. Satellite/Attendant Cells: in PNS
 - a. Surround neuron cell bodies within ganglia
 - b. Control chemical environment

D. Neurons: Basic Characteristics

1. Over 100 billion
2. Highly specialized
3. Conduct messages in form of nerve impulses
4. Extreme longevity (>100 years)
5. Amitotic (no centrioles)
6. High metabolic rate
7. 3 functional components in common: receptive/input regions, conducting component/trigger zone, secretory/output component

E. Neuron Cell Body

1. Nucleus
2. Cytoplasm: contains neurofibrils (convey impulses)
3. Nissl bodies: for protein synthesis; rough ER
4. NO centrioles, therefore cannot divide by mitosis
5. Axon
 - a. Long, slender fiber that transmits impulses away from the cell body
 - b. One per neuron
 - c. Short, absent, or long (great toe - lumbar region: 3 to 4 feet = longest cells in body)
 - d. Long are called nerve fibers
 - e. Largest in diameter = most rapid conduction
 - f. Distal tip of axon ends in synaptic knob or end plate
6. Dendrites
 - a. Short, tapering diffusely branched (tree-like) fibers
 - b. Carry impulses toward the cell body from sensory receptors or other axons

F. Myelin Sheath

1. Whitish, fatty (protein lipid) segmented covering of axons
2. Myelinated fibers: conduct nerve impulses rapidly; electrical insulation

3. Unmyelinated fibers: conduct impulses slowly
4. White matter: myelinated sheaths around axons of the PNS gives the tissue a white color and forms myelinated nerves (axons = myelinated tracts)
5. Gray matter: concentrations of cell bodies and unmyelinated fibers (in PNS = ganglia; in CNS = nuclei)

G. Nerves

1. Bundles of PNS fibers held together by several layers of connective tissue
2. Endoneurium: fibrous connective tissue surrounding each nerve fiber
3. Perineurium: connective tissue holding together bundles of fibers
4. Epineurium: fibrous tissue holding complete nerve together

H. Synapse

1. Space between nerve fibers, the place where nerve impulses are transmitted from one neuron to another
2. Axonal terminal contains synaptic vesicles (membrane bound sacs containing neurotransmitters)
3. Receptor region on dendrite
4. Synaptic cleft: fluid filled space; electrical - chemical - electrical

IV. Neurons

A. Characteristics

1. Excitability: the ability to react to a stimuli, physical or chemical
2. Irritability: sensory adaptation, with prolonged stimulation, irritability is temporarily lost (i.e. smell)
3. Conductivity: the ability to transmit an impulse
 - a. Nonmyelinated fibers = 0.5 – 1 meter /sec (1 mph)
 - b. Myelinated fibers = 80 – 130 meters/sec (300 mph)

B. Structural Classification of Neurons: number of processes extending from cell bodies

1. Multipolar: several (3 or more) dendrites and one axon; most common; motor
2. Bipolar: 2 processes; one axon and one dendrite at either end of cell body; rare; retina of eye, olfactory mucosa, inner ear
3. Unipolar/pseudounipolar: single process; originate as bipolar then processes fuse; single short process from the cell body that divides like a T; ganglia of PNS as sensory neurons

C. Functional Classification of Neurons: direction in which the nerve impulse travels relative to the CNS

1. Sensory/Afferent: dendrites are connected to receptors where stimulus is initiated in skin/organs and carry impulse toward CNS; axons are connected to other neuron dendrites; unipolar except for bipolar neurons in special sense organs; cell bodies in sensory ganglia outside CNS

- a. Receptors: exteroceptors (pain, temperature, touch); interoceptors (organ sensation); proprioceptors (muscle sense, position, movement)
 - 2. Motor/Efferent: carry messages from CNS to effectors; dendrites are stimulated by other neurons and axons are connected to effectors (muscles and glands); multipolar except for some in ANS
 - 3. Association/Interneurons: carry impulses from one neuron to another (afferent to efferent); found only in CNS; lie between sensory and motor neurons; shuttle signals; 99% of neurons in body
- V. Regeneration
 - A. Neurons do not reproduce themselves, but they can regenerate new parts sometimes.
 - B. If a neuron is cut through a myelinated axon, the proximal portion may survive if the cell body is not damaged.
 - C. The distal portion will die (degenerate). Macrophages move into the area and remove debris.
 - D. Neuron cell body reorganizes its Nissl bodies to provide proteins necessary for axon growth.
 - E. The Schwann cells form a regeneration tube that helps guide the axon to its proper destination.
 - F. New fiber will eventually fill the myelin sheath and innervate the muscle. Growth occurs at 3-5 mm/day. (1 mm = 0.04 inch)
 - G. In the CNS, this repair is unlikely because the neurons lack the neurilemma necessary to form the regeneration tube. Also, the astrocytes quickly fill the damaged area forming scar tissue. Most CNS injuries cause permanent damage.
 - H. Crushing and bruising can also damage nerve fibers resulting in paralysis. Inflammation of the injury site damages more fibers. Early treatment with methyprednisolone reduces inflammation and decreases severity of injury. It must be given within 8 hours to be effective.
- VI. Conduction: “All or None Law” - when stimulated, a nerve fiber will either respond completely or not at all (no response)
 - A. Electrical: along the nerve
 - 1. Resting fiber = polarized = -70mV
 - a. Excess of negative ions on the inside of the membrane and an excess of positive ions on the outside of the membrane
 - b. The electrical difference is called the membrane potential. It is measured in millivolts, so -70 mV indicates that the potential difference has a magnitude of 70 mV and the inside of the membrane is negative.
 - 2. With a stimulus, a “sodium pump” is created - 3 Na⁺ move across the membrane and flow into the cell and 2 K⁺ diffuse out of the cell; the membrane is now depolarized.

3. Myelinated fibers are able to conduct impulses faster because the Na⁺/K⁺ exchange can only occur at the node, so the impulse leaps from node to node.
4. Before another electrical current can spread along the nerve fiber, the membrane must repolarize to its original condition. The refractory time is a brief period when a neuron resists restimulation until repolarization is complete.
5. The impulse can never move backward.

B. Chemical: at the synapse

1. Impulse arrives at the presynaptic terminal axon.
2. This impulse causes Ca⁺⁺ to enter the axon knob.
3. The Ca⁺⁺ causes synaptic vesicles to migrate to the presynaptic membrane and release hundreds of neurotransmitters into the synaptic cleft.
4. Neurotransmitter binds with receptors on the post synaptic membrane. Function is therefore determined by the post synaptic receptors, not by the neurotransmitter.
5. This binding opens channels in the post synaptic membrane, so Na⁺ moves into the post-cell and K⁺ moves out - temporary depolarization.
6. This causes excitation and the impulse is on its way - conduction has occurred.
7. Some neurotransmitters are transported back into the presynaptic knob, where they are repackaged into vesicles and used again.

C. Neurotransmitters

1. Acetylcholine: most common, it excites skeletal muscle, but inhibits cardiac muscle; is also involved with memory; deficiency of ACh could be a cause of Alzheimer's.
2. Amines: synthesized from amino acid molecules
 - a. Serotonin: CNS inhibitory; moods, emotions, sleep
 - b. Histamine: CNS stimulant; regulation of water balance and temperature, emotions
 - c. Dopamine: inhibitory effect on somatic motor; without dopamine body has general over stimulation of muscles = Parkinsonism tremors; cocaine blocks uptake of dopamine
 - d. Epinephrine: autonomic nervous response, beta receptors, dilation
 - e. Norepinephrine: autonomic nervous response, alpha receptors, constriction; antidepressants increase amount of norepinephrine in brain - relieving depression
3. Amino acids
 - a. Glutamate: CNS excitatory
 - b. Glycine: CNS inhibitory
4. Neuropeptides: short strands of amino acids called polypeptides
 - a. Enkephalins/endorphins: inhibitory, act like opiates to block pain

- b. VIP: vasoactive intestinal peptide
 - c. CCK: cholecystokinin
 - d. Substance P: excitatory, transmits pain information
- VII. Reflex: reflex arc is a conduction route to and from the CNS; a regulatory feedback loop
 - A. Structure
 - 1. Sensory receptor in PNS
 - 2. Sensory afferent neuron
 - 3. Interneuron(s) in CNS
 - 4. Motor efferent neuron
 - 5. Effector (muscle/gland) tissue in PNS
 - B. Types
 - 1. Deep tendon reflex: patellar tendon, knee jerk
 - 2. Pupil reflex: to light/dark, constricts/dilates
 - 3. Corneal reflex: with touch, causes blinking
 - 4. Gag reflex: to touch, sight, smell
 - 5. Plantar reflex: negative Babinski, toes curl under, sole stroked
 - C. First level reflex
 - 1. Predictable, fast, automatic
 - 2. Impulse travels only to spinal cord
 - 3. Example: jerking hand away from hot stove
 - D. Second level reflex
 - 1. Impulse travels to brain stem
 - 2. Usually protective
 - 3. Example: coughing, vomiting
 - E. Third level reflex
 - 1. Learned or conditioned reflex
 - 2. Involves cerebral cortex
 - 3. Example: bowel/bladder control, job skill
 - F. Ipsilateral: receptors and effectors are located on one side of the body
 - G. Contralateral: receptors and effectors are located on opposite sides of the body
- VIII. Central Nervous System
 - A. Brain: mass of 12 billion neurons and neuroglia weighing approximately 3 pounds, protected by cranial bones
 - B. Cerebrum: largest mass of brain (83% of brain mass); responsible for higher mental functions and distribution of impulses
 - 1. Cerebral cortex: outer layer of gray matter; short and long term memory
 - a. Convolutions: elevated ridges/folds that increases gray area of brain
 - b. Sulci: shallower grooves
 - c. Fissures: deep grooves (fetal folds)
 - (1) Longitudinal: separates right and left hemispheres; corpus callosum (large fibers that connect the two hemispheres)

- (2) Transverse: separates cerebrum from cerebellum
 - (3) Fissure of Rolando: divides frontal and parietal lobes at coronal suture
 - (4) Fissure of Sylvan/lateral fissure: divides frontal and temporal lobes
- 2. Cerebral medulla: white matter, conduction pathways
- 3. Divided into right and left hemispheres (left side governs right side of body, right side governs left side of body)
- 4. Lobes
 - a. Frontal: voluntary motor control, learning, planning, L = motor, speech
 - b. Parietal: sensory, distance, size, shape, cognitive/intellectual processes
 - c. Occipital: vision, visual memory
 - d. Temporal: auditory, olfactory, speech, judgment, reasoning, will power
- C. Cerebellum: below and posterior to cerebrum
 - 1. Right and left hemispheres connected by central vermis
 - 2. Outer gray, inner white forms arbor vitae
 - 3. Coordinates muscular movement, posture, balance, running, walking
 - 4. Damage produces ataxia (lack of coordination due to errors in speed, force, direction of movement)
- D. Brainstem (damage = coma)
 - 1. Midbrain: upper part of brainstem
 - a. Controls postural reflexes and walking
 - b. Visual reflexes and auditory control, 3-4 cranial nerves
 - 2. Pons: a two-way conduction pathway, mixed gray and white fibers
 - a. Controls inspiration
 - b. Transverse fibers give it a bridge appearance
 - c. Reflex mediation for 5-8 cranial nerves
 - 3. Medulla oblongata: the bulb (lowest part before the foramen magnum) made of white and gray fibers called reticular formation
 - a. 75% of fibers cross here
 - b. Controls vital functions: respiration and circulation
 - c. Pyramids: bulges of white tracts on ventral surface
- E. Diencephalon: area between cerebrum and midbrain
 - 1. Thalamus: gray matter, relay station for sensory incoming and motor outgoing impulses; damage - increased sensitivity to pain, loss of consciousness
 - 2. Hypothalamus: forms floor of third ventricle
 - a. Regulates autonomic control
 - b. Cardiovascular control: dilates/constricts
 - c. Temperature control

- d. Controls appetite: hunger and thirst
 - e. Water balance
 - f. GI control: peristalsis, intestinal secretions
 - g. Emotional states: fear, anger, pleasure, pain, sexual reflexes
 - h. Sleep control
 - i. Regulates pituitary secretions
 - j. CHO and fat metabolism
3. Epithalamus: contains the pineal body/gland (melatonin)
- F. Meninges: 3 membranous coverings with spaces between each
- 1. Dura mater: “tough mother”; strong, white, fibrous tissue that lines the skull bones; has inward extensions into the fissures
 - a. Epidural space: between the bone and the dura mater
 - b. Subdural space: between the dura and arachnoid layers
 - 2. Arachnoid: resembles fine cobwebs with fluid (CSF) filling the spaces
 - a. Subarachnoid space: between the arachnoid and pia layers
 - 3. Pia mater: “tender mother”; covers brain and spinal cord surface
- G. CSF: bathes the skull, brain, and spinal cord
- 1. Serves as shock absorber for the brain and spinal cord
 - 2. 400-500 ml produced daily, yet only 140 ml is circulating at any time
 - 3. Circulates through the ventricles and into the central canal and subarachnoid spaces and is absorbed back into the blood
 - 4. Provides nutrients and waste removal for brain tissues
 - 5. It is clear, colorless, and composed of water, 40-60% glucose, NaCl, K⁺, protein, and a few white blood cells
- H. Ventricles: CSF filled spaces of the brain; the rich network of blood vessels, the choroid plexus maintains selective permeability to protect brain tissue
- 1. Right lateral ventricle within each cerebrum
 - 2. Left lateral ventricle
 - 3. Foramen of Monro: connects lateral ventricles with third ventricle (behind and below laterals)
 - 4. Aqueduct of Sylvius: connects third with fourth ventricle
 - 5. In the roof of the fourth ventricle are openings, foramen of Magendie and foramen of Luschka, that allow CSF to move into the cisterna magna, a space behind the medulla that is continuous with the subarachnoid space
- I. Spinal Cord
- 1. Deep grooves: anterior median fissure (deeper) and posterior median sulcus
 - 2. 2 bundles of nerve fibers called roots project from each side of cord
 - a. Dorsal nerve root: sensory afferent fibers
 - b. Dorsal root ganglion: sensory cell bodies
 - c. Ventral nerve root: motor efferent fibers

- d. The nerve roots join together to form a single mixed nerve called a spinal nerve
- 3. "H"
 - a. Gray matter of cell bodies of interneurons and motor neurons, divided into anterior, posterior, and lateral horns
 - b. White matter surround gray "H"; divided into anterior, posterior, lateral columns (large bundles of nerve axons divided into smaller bundles called tracts); ascending and descending and lateral organizational tracts
 - c. TENS: transcutaneous electrical nerve stimulation unit; acts to close the gates of the ascending tracts therefore pain impulses are not allowed to get to the brain
 - d. Lumbar puncture: spinal tap between the 3rd and 4th lumbar vertebrae for CSF diagnostics

IX. Peripheral Nervous System

- A. Cranial Nerves (12 pairs: "On Old Olympus' Towering Top, A Finn and German Grew Some Hops", "Some Say Marry Money But My Brother Says, Bad Business, Marry Money")
 - 1. Olfactory: I, sensory, smell
 - 2. Optic: II, sensory, vision
 - 3. Oculomotor: III, motor, eye movement and pupil
 - 4. Trochlear: IV, motor, eye movement, peripheral vision
 - 5. Trigeminal: V, both, ophthalmic maxillary, mandibular (sensory); face and head (motor)
 - 6. Abducens: VI, motor, abducts eye
 - 7. Facial Nerve: VII, both, facial expression, taste, tongue movement
 - 8. Vestibulocochlear: VIII, sensory, hearing and balance
 - 9. Glossopharyngeal: IX, both, tongue, throat, swallowing
 - 10. Vagus: X, both, organ sense (thoracic and abdominal) inhibitor
 - 11. Accessory: XI, motor, spinal accessory, shoulder and head movement
 - 12. Hypoglossal: XII, motor, tongue and throat movement
- B. Spinal Nerves: 31 pairs of mixed nerves attached to spinal cord by ventral and dorsal roots
 - 1. 8 cervical (pass through intervertebral foramina), 12 thoracic, 5 lumbar (exit cord at 1st lumbar vertebra, but do not exit spinal canal until reaching their intervertebral foramina so gives cord a "cauda equina" look), 5 sacral, 1 coccygeal
 - 2. Each nerve forms several large branches + rami, which subdivide to four complex networks called plexuses (cervical, brachial, lumbar, sacral)
 - 3. Dermatome: mapping of skin surface of nerve intervention

X. Special Senses

- A. Sense of Taste
 - 1. Chemoreceptors respond to chemicals in aqueous solution

2. Taste: gustation
3. Taste buds: sensory receptor organs for taste; primarily on tongue papillae
4. Primary sensations: sweet, salty, sour, bitter
5. Sensitivity
 - a. Tip of tongue: sweet and salty
 - b. Sides of tongue: sour
 - c. Back of tongue: bitter
6. Thresholds
 - a. Bitter: minute amounts
 - b. Sour: less sensitive
 - c. Sweet and salty: least sensitive
7. Anterior 2/3 of tongue sensory stimulation travels by the facial nerve to the parietal lobe of the cerebral cortex for interpretation and appreciation of what is being tasted.
8. Posterior 1/3 of the tongue sensory stimulation travels by the glossopharyngeal nerve to the medulla oblongata and then to the parietal lobe of the cerebral cortex for interpretation
9. 80% of taste is actually smell
10. Other influences: thermoreceptors, mechanoreceptors, nociceptors (temperature and texture enhance or distract from taste i.e. chili peppers stimulate pain receptors)

B. Sense of Smell

1. Specialized neurons with olfactory cilia in upper nasal cavity
2. Stimulated by gas molecules or chemicals
3. Sniffing draws air forcefully up into the nose
4. Sensory cells live for an average of 30 days
5. Sensory cells affected by a variety of factors: age, nutrition, hormones, drugs, therapeutic radiation
6. Stimulated and send impulses by the olfactory nerve to the cerebral cortex for interpretation
7. Smell memory is long-lasting and stimulation by similar smells can trigger memory of events that occurred long ago
8. Olfactory receptors easily fatigued - adaptation occurs
 - a. Process of conforming to the environment after continuous stimulation of constant intensity
 - b. These changes in awareness of odors allows us to continue to function at an optimum level.
9. 7 primary odors: floral, musky, camphorous, pepperminty, ethereal, pungent (stinging), putrid (rotten)
10. Homeostatic imbalances
 - a. Anosomias: without smell; some genetic causes, head injuries that tear olfactory nerves, after effects of nasal cavity inflammation (cold, allergy, smoking), physical destruction of nasal cavity due to polyps, aging, zinc deficiency

- b. Uncinate fits: olfactory hallucinations,; epileptic auras (transient uncinate fits)

C. Sense of Vision

1. Anatomy

- a. Eyebrows: physical protection of eyes; short, coarse hairs
- b. Eyelids (palpebrae): physically protect the eye and prevent the cornea from drying via blink reflex; medial and lateral canthi (angle of eye); caruncle (fleshy elevation of medial canthus which contains sebaceous and sweat glands to produce “Sandman’s eye-sand”)
- c. Eyelashes: hairs with glands at the base for lubrication; inflammation = sty
- d. Meibomian glands: secrete a lipid tear film spread by blinking; reduces evaporation of tear film, prevents tear film from running down face, gives an even spread over the eyeball; inflammation = chalazion
- e. Lacrimal glands: secrete aqueous tear film containing globulins and lysozyme; supplies nourishment to the cornea and helps to provide antimicrobial activity; nasolacrimal duct (empties into nasal cavity; excess tears= tearing, nasal secretions; secretions decrease with age
- f. Conjunctiva: membrane that lines the eyelid; secretes a mucous tear component that helps reduce surface tension; it accumulates at the medial canthus (corner angle) as “sleep”; inflammation = pinkeye
- g. Extrinsic eye muscles: annular ring (tendinous ring from which originate the rectus muscles); rectus muscles (superior, inferior, lateral, medial move eye in direction of name); oblique muscles (superior, inferior move eye in vertical plane when eye is turned medially by rectus muscle); diplopia = double vision when movements not perfectly coordinated and can’t focus both eyes; strabismus = congenital weakness causing cross-eyed appearance (deviant eye becomes functionally blind)
- h. Sclera: outermost white covering of the eyeball; anchor site for muscles
- i. Cornea: the transparent front of the sclera; it has no blood vessels but richly supplied with sensory nerves; depends on tear film for nutrition, O₂, and removal of waste; window for light to enter; extraordinary capacity for regeneration; transplantation without rejection due to avascular nature
- j. Choroid: highly vascular middle layer of eye; dark membrane on posterior wall inside eye; provides nutrients to all tunics; pigment absorbs light to prevent scatter and reflection internally
- k. Ciliary body: encircles lens

- l. Anterior chamber: between cornea and iris filled with aqueous humor that supplies nutrients to cornea; helps maintain ocular shape; constantly being formed and excess drains through canal of Schlemm to the bloodstream; amount regulates intraocular pressure; increased pressure = glaucoma, which results in atrophy of the optic nerve - blindness
 - m. Iris: visible colored part of the eye; muscles control pupil size which regulates the amount of light entering the lens; sympathetic = dilation, parasympathetic = constriction
 - n. Pupil: round central opening of iris; allows light to enter
 - o. Lens: transparent spherical structure suspended by suspensory ligaments between the iris and the vitreous humor; being a convex lens - 1/3 of the refractive power of the eye; accommodation = as objects are brought closer to the eye, the ciliary muscles contract and make the lens more convex, increasing its refractive power; (presbyopia = aging process, lens loses elasticity; diabetes - excess glucose draws water into the lens causing opaque changes = cataracts)
 - p. Vitreous humor: secreted by the retinal cells and makes up the posterior chamber; maintains the shape of the eye and positions the retina against the choroid and transmits light
 - q. Retina: innermost pigment layer of the eye where the rods and cones (visual receptors) are located; absorbs light and recycles visual pigments; visual pigments Rhodopsin (in rods – dim light, peripheral vision) and Iodopsin (in cones – bright light, high acuity, color vision) are converted to opsin and retinal (vitamin A derivative) which stimulates bipolar neurons (converge to form optic nerve); diabetic retinopathy = small retinal hemorrhages occur due to excess glucose in blood - disrupts O₂ to the rods and cones - blindness; nyctalopia = deficiency of vitamin A - night blindness
 - r. Fovea: focus point for light rays for best visual acuity; composed mostly of cone cells
 - s. Optic disc: the “blind spot” where neurons exit the eyeball as the optic nerve
2. Sense of sight
 - a. Light waves bent first by the cornea, the eye’s fixed outer lens; bending of the light rays = refraction; iris, whose pigment gives an eye its color, contracts in bright light and expands in dim light to regulate the amount of light entering the pupil; ciliary muscles around the inner crystalline lens flex to focus the image precisely on the retina, a thin sheet of nerve tissue;

- b. Light floods the retina and activates photoreceptors, called rods and cones (due to their shape); cones specialize in bright light and are concentrated in a central patch of the retina called the fovea; cones provide acute central vision, rich with color; color-blind rods enable us to see in dim light; signals from the rods and cones are sent to the cerebral cortex by the optic nerve; as much as 1/3 of the cortex is devoted to visual processing; sight mediates and validates the other senses
- c. At the optic chiasm, the nerve splits, distributing input from each eye to relay stations in the thalamus; this circuitry enables us to see with one eye if necessary; different neurons transmit data about motion, color, fine detail, and depth perception
- d. Visual area of the temporal cortex identifies and recognizes the object; an area of the parietal cortex locates the object in relation to space
- e. Visual acuity: clearness/sharpness of visual perception recorded as 2 numbers
 - (1) First number represents the distance in feet between the subject and the test chart (Snellen Chart)
 - (2) Second number represents the number of feet a person with normal acuity would stand to see clearly
 - (3) 20-20 is considered normal acuity
 - (4) 20-100 means a person can see objects at 20 feet that a person with normal vision can see at 100 feet
 - (5) Visual acuity worse than 20-200 after correction is considered legally blind
- f. Homeostatic imbalances
 - (1) Myopia: nearsighted; focus falls short of the retina; far objects are blurred; radial keratotomy can correct or improve this condition
 - (2) Hyperopia: farsightedness; focus falls behind the retina; close objects are blurred
 - (3) Astigmatism: cornea is not spherical, focused image is distorted
 - (4) Color blindness: congenital lack of one or more types of cones (red, green, blue); sex-linked

D. Sense of Hearing

- 1. Anatomy of external ear
 - a. Auricle (Pinna): the flap that funnels sound waves; helix = rim; lobule = earlobe
 - b. External auditory meatus: opening to the auditory canal, lined with cerumen/wax glands

- c. External auditory canal: short, narrow chamber extends from auricle to tympanic membrane
 - d. Tympanic membrane: the eardrum that stretches across the canal and vibrates in response to sound waves; transmits them to the middle ear
2. Anatomy of the middle ear: tiny cavity in the temporal bone
- a. Auditory ossicles: 3 bones that vibrate to transmit sound waves to the inner ear
 - (1) Malleus: hammer shaped, handle is attached to the tympanic membrane
 - (2) Incus: anvil shaped
 - (3) Stapes: stirrup shaped
 - b. Oval/vestibular window: opens to internal ear
 - c. Round/Cochlear window: covered by membrane, opens to internal ear
 - d. Pharyngotympanic/auditory/Eustachian tube: connects middle ear to pharynx; helps to equalize pressure so eardrum will vibrate; children's tubes are more horizontal - otitis media (myringotomy = lancing of eardrum to relieve pressure - insertion of tubes for drainage of fluid/pus)
 - e. Mastoid sinuses: air spaces in the temporal bone that drain into the middle ear
3. Anatomy of the inner ear: labyrinth, located in the hollowed out portion of the temporal bone
- a. Vestibule and semicircular canals: involved in equilibrium; maculae found in the utricle and sacule of the vestibule provide information related to head position; crista ampullaris in semicircular canals respond to angular/rotational movements of head; tiny otoliths detect changes due to position and stimulate a reflex to restore normal body position
 - b. Cochlea: snail like part of the inner ear for hearing; surrounded by perilymph and filled with endolymph fluid
 - (1) Upper section is scala vestibuli
 - (2) Lower section is scala tympani
 - (3) Reissner's membrane = floor of cochlea
 - (4) Basilar membrane = floor of cochlea
 - (5) Organ of Corti: receptor organ for hearing - 8th cranial nerve; sense organ that rests on the basilar membrane consisting of hair cells; sensory dendrites are wrapped around the base of the hair cells, they transmit impulses to the axons that form the auditory nerve (acoustic nerve)
4. Physiology of hearing

- a. Sound waves caught by auricle, channeled through the auditory canal and strike against the tympanic membrane causing it to vibrate
- b. Vibrations move the malleus, incus, and stapes against the oval window
- c. Pressure is exerted inward into the perilymph of the scala vestibuli
- d. Ripple starts in the perilymph that is transmitted through the vestibular membrane to endolymph inside the organ of Corti
- e. Endolymph ripple causes basilar membrane to bulge up in response to sound wave vibrations; the higher the upward bulge, the more cilia are bent, the more cells are stimulated on the basilar membrane
- f. Stimulated cells transmit nerve impulses along the auditory nerve
- g. Impulses travel to the auditory cerebral cortex - interpreted as sound
- h. Sound volume is determined by the height (amplitude) of the waves; sound pitch is determined by the frequency of the waves; decibel unit is used for measuring sound

Decibel Level	Example of Noise	Dangerous Time
0	Lowest audible sound	
30	Quiet library	
50	Refrigerator noise	
70	Noisy restaurant	Critical level
80	Factory noise	8 + hours
90	Shop tools	Impairment
100	Chain saws	< 2 hours
120	Rock concert	Immediate harm
140	Gunshot blast	Damage probable
180	Rocket launchpad	Permanent loss

5. Homeostatic imbalances

- a. Conduction deafness: something interferes with the conduction of sound vibrations to the fluids of the inner ear i.e. impacted earwax, perforated/ruptured eardrum, otitis media, otosclerosis of ossicles
- b. Sensorineural deafness: damage to neural structures at any point from cochlear hair cells to auditory cortical cells; can be gradual loss of receptor cells, exposure to single loud noise, degeneration of cochlear nerve, cerebral infarcts, tumors; treatment can be cochlear implants
- c. Tinnitus: ringing or clicking sound in the ears in the absence of auditory stimuli; can be 1st symptom of cochlear

nerve degeneration or inflammation of middle/inner ear or side effect of some medications i.e. aspirin

- d. Meniere's Syndrome: labyrinth disorder that affects the semicircular canals and cochlea; transient but repeated attacks of severe vertigo
- e. Presbycusis: loss of the ability to hear high pitched sounds; becoming common in young people due to noise

E. Sense of Touch, Heat, Cold, Pain

1. Sensory receptors make it possible for the body to respond to environmental stimuli
2. Receptors respond to a stimulus and convert the stimulus to a nerve impulse
3. Nerve impulses travel by afferent sensory neurons to the brain for interpretation
4. Touch: mechanoreceptors/exteroceptors; located on the body surfaces; respond to touch, stretch, and pressure
 - a. Meissner's corpuscles: in fingertips, lips, and hairless body parts for fine touch
 - b. Pacinian corpuscles: in skin, joints, and genitals for deep pressure and stretch
 - c. Krause's end bulbs: in eyelids, lips, and genitals for light touch
 - d. Ruffini's corpuscles: found in skin for continuous touch
5. Heat/cold: thermoreceptors
6. Pain: nociceptors; free nerve endings for pain, tickle, itch; noci = pain, injury

XI. Disorders of the Nervous System

- A. Shingles: herpes zoster viral infection, causes inflammatory vesicles along peripheral nerves
- B. Neuralgia: sudden, sharp severe stabbing pain along a nerve pathway
- C. Neuritis: inflammation of nerve; causes pain, muscular atrophy, hypersensitivity, paresthesia
- D. Tic douloureux: degeneration of trigeminal nerves causes repeated, involuntary muscle twitching
- E. Bell's palsy: unilateral facial paralysis, sudden onset, viral inflammation of trigeminal nerve
- F. Poliomyelitis: viral infection of gray matter of spinal cord, permanent paralysis or weakness
- G. Encephalitis: viral inflammation of brain tissue, causes fever, lethargy, weakness, nuchal rigidity and opisthotonos, coma, death
- H. Meningitis: bacterial/viral inflammation of meninges, causes headache, fever, sore throat, back and neck pain, loss of mental alertness
- I. Meningocele: congenital hernia in which meninges protrude through opening in spinal cord
- J. Epilepsy: idiopathic recurring and excessive electrical discharge from neurons causing seizure activity (grand mal, petit mal)

- K. Hydrocephalus: increased accumulation of CSF within the ventricles, causes cranium to enlarge unless treated with a shunt to remove excess fluid
- L. Parkinson's disease: tremors, uncontrolled shaking, related to decreased amounts of dopamine
- M. Huntington's chorea: progressive dementia with bizarre involuntary movements, genetic
- N. Athetosis: slow, irregular, twisting, snakelike movements of the hands
- O. Hemiballism: jerking and twitching movements of one side of the body, caused by tumor of the thalamus
- P. Dysmetria: inability to fix the range of movement in muscle activity
- Q. Cerebral palsy: congenital brain disorder/damage causing damage to motor neurons, flaccid or spastic paralysis
- R. Multiple sclerosis: autoimmunity destruction of oligodendrocytes leading to demyelination with progressive muscular weakness
- S. Muscular dystrophy: genetic defect in muscle metabolism, causes progressive atrophy
- T. Myasthenia gravis: disease characterized by muscular weakness, possibly due to decreased amounts of acetylcholine at the muscle effector sites
- U. Alzheimer's disease: dementia producing lesions in the cerebral cortex
- V. Anencephalic: infants born without frontal cerebrum, congenital, possibly related to toxins, may be related to Folic Acid deficiency in mother.

ACTIVITIES

- I. Completion of sheep brain dissection.
- II. Completion of Cow/sheep eye dissection

MATERIALS NEEDED

Dissecting kits

Sheep brains

Cow/sheep eyes

Taste Terminology

Smell Terminology

Hearing Terminology

Vision Terminology

Nervous System Terminology

<http://www.medinfo.ufl.edu/year1/bcs/clist/neuro.html> Neurologic Exam

<http://www.gwc.maricopa.edu/class/bio201/cn/cranial.htm> Cranial Nerves

Guest speakers: neurologist, neurosurgeon, audiologist, speech pathologist, ophthalmologist, optometrist, optician

ASSESSMENT

Nervous System Test

Completion of activities

ACCOMMODATIONS

For reinforcement, the student will color code anatomical drawings and make flashcards of the anatomical parts and their function.

For enrichment, the student will research and present on a neurological disease.

REFLECTIONS

NERVOUS SYSTEM TEST

1. The nervous system exhibits all of these functions EXCEPT:
 - a.monitoring change
 - b.integrating impulses
 - c.storing calcium
 - d.effecting responses
2. Ciliated CNS neuroglia that play an active role in moving the CSF are:
 - a.ependymal cells
 - b.Schwann cells
 - c.oligodendrocytes
 - d.astrocytes
3. The Sheath of Schwann is also called:
 - a.axolemma
 - b.neurilemma
 - c.white matter
 - d.myelin sheath
4. An excitatory neurotransmitter secreted by motor neurons innervating skeletal muscle is:
 - a.cholinesterase (AChE)
 - b.norepinephrine
 - c.acetylcholine (ACh)
 - d.gamma aminobutyric acid
5. Which of the following is NOT a structural feature of a neuron?
 - a.synaptic cleft
 - b.Nissl body
 - c.dendrites
 - d.axon
6. The part of the neuron that conducts impulses away from its cell body is called:
 - a.dendrite
 - b.axon
 - c.neurolemma
 - d.Schwann cell
7. The point at which an impulse from one nerve cell is communicated to another nerve cell is the:
 - a.cell body
 - b.receptor
 - c.synapse
 - d.effector

8. Which of the following is NOT a function of the autonomic nervous system?
- a. innervation of smooth muscle of the digestive tract
 - b. innervation of cardiac muscle
 - c. innervation of glands
 - d. innervation of skeletal muscle
9. Collections of nerve cell bodies outside the CNS are called:
- a. nuclei
 - b. nerves
 - c. ganglia
 - d. tracts
10. The term “central nervous system” refers to the:
- a. autonomic nervous system
 - b. brain, spinal cord, and peripheral nerves
 - c. spinal cord and spinal nerves
 - d. brain and spinal cord
11. The substance released at axonal endings to propagate a nervous impulse is called a(n):
- a. ion
 - b. neurotransmitter
 - c. cholinesterase
 - d. biogenic amine
12. Saltatory conduction is made possible by
- a. the myelin sheath and Nodes of Ranvier
 - b. large nerve fibers
 - c. diphasic impulses
 - d. erratic transmission of nerve impulses
13. The part of the neuron that receives stimuli is called:
- a. axon
 - b. dendrite
 - c. neurolemma
 - d. Schwann cell
14. Place the following parts of the reflex arc in proper sequence:
- a. effector-motor neuron-integration center-sensory neuron-receptor
 - b. receptor-motor neuron-integration center-sensory neuron-effector
 - c. receptor-sensory neuron-integration center-motor neuron-effector
 - d. effector-sensory neuron-integration center-motor neuron-receptor

15. The sympathetic and parasympathetic are subdivisions of the:
 - a.central nervous system
 - b.voluntary nervous system
 - c.autonomic nervous system
 - d.somatic nervous system

16. Neuroglia that control the chemical environment around neurons by buffering potassium and recapturing neurotransmitters are:
 - a.astrocytes
 - b.oligodendrocytes
 - c.microglia
 - d.Schwann cells

17. Schwann cells are functionally similar to:
 - a.ependymal cells
 - b.microglia
 - c.oligodendrocytes
 - d.astrocytes

18. Reflexes are rapid, automatic responses to stimuli.
 - a.True
 - b.False

19. A motor neuron carries stimuli from the central nervous system to the effector.
 - a.True
 - b.False

20. Myelination of the nerve fibers in the CNS is the job of the oligodendrocytes.
 - a.True
 - b.False

21. Neurons do NOT undergo mitosis in the adult.
 - a.True
 - b.False

22. Afferent neurons transmit impulses from the periphery to the CNS.
 - a.True
 - b.False

23. Which of the following is NOT a characteristic of neurons?
 - a.extreme longevity
 - b.amitotic
 - c.stimulation
 - d.high metabolic rate

24. Neurons that transmit impulses from sensory receptors in the skin or internal organs toward the CNS are called:
- a. receptor neurons
 - b. axons
 - c. sensory neurons
 - d. motor neurons
25. Ohm's Law states:
- a. an action potential either happens completely or not at all
 - b. depolarization becomes self-generating at threshold
 - c. current varies directly with voltage and inversely with resistance
 - d. neurons communicate through neurotransmitters
26. The degeneration and hardening of the myelin sheath is known as:
- a. saltatory conduction
 - b. multiple sclerosis
 - c. synapses
 - d. depolarization

Matching.

- A. Frontal
- B. Parietal
- C. Occipital
- D. Temporal

27. Auditory area
28. Primary sensory cortex
29. Somatic motor cortex
30. Motor speech area
31. Premotor area
32. Seat of intelligence and abstract reasoning
33. Visual areas
34. Language/speech comprehension area
35. Taste (gustatory) area

- A.Dura mater
- B.Pia mater
- C.Arachnoid
- D.Subarachnoid space
- E.Ventricles

36. The innermost layer of the meninges, delicate, contains many blood vessels

37. The weblike, spidery middle meningeal layer

38. Normally, the CSF flows freely from the ventricle, then into the _____.

- A.Arachnoid villi
- B.Central canal
- C.Choroid plexus
- D.Meningitis
- E.Hydrocephalus

39. The CSF helps protect the brain and spinal cord against shock. It is filtered into the ventricles through the _____.

40. The CSF is returned to the blood in the venous sinuses through projections called _____.

41. Any obstruction to the normal flow of CSF within the brain may give rise to a condition called _____.

42. Inflammation of the brain coverings that may be due to pathogenic bacteria.

Multiple Choice

43. The brain stem consists of the:
- a.cerebrum, pons, midbrain, and medulla
 - b.midbrain, medulla, pons
 - c.pons, medulla, cerebellum, and midbrain
 - d.midbrain only

44. The vital centers for control of heart rate, respiration, and blood pressure are located in:
- a.the pons
 - b.the medulla
 - c.the midbrain
 - d.the cerebrum
45. Which of the following would you not find in normal cerebrospinal fluid?
- a.glucose
 - b.red blood cells
 - c.potassium
 - d.protein
46. Mr. J. H. was injured in an accident that completely severed his spinal cord at the level of T-12. You would expect to find all of the following EXCEPT:
- a.paralysis of the lower extremities
 - b.loss of sensation below the level of injury
 - c.slurred speech
 - d.perspiration in the affected area
47. The rough leathery meningeal layer is the:
- a.dura mater
 - b.subarachnoid
 - c.arachnoid
 - d.pia mater
48. The CSF:
- a.is secreted by the arachnoid villi
 - b.enters the four ventricles after filling and circulating through the subarachnoid space
 - c.is secreted mostly by the ependymal cells lining the brain ventricles
 - d.is formed mostly by the choroid plexuses
49. The hypothalamus:
- a.is the thermostat of the body since it regulates temperature
 - b.contains the feeding and hunger centers
 - c.contains neurons sensitive to the solute concentration of the blood
 - d.all of the above are correct
50. The blood-brain barrier is effective against:
- a.metabolic waste such as urea
 - b.nutrients such as glucose
 - c.alcohol
 - d.anesthetics

51. An electroencephalogram:
- a. is a record of the total body electrical activity
 - b. is a record of the electrical activity of the heart
 - c. can only detect normal electrical activity
 - d. is a record of the electrical activity of the brain

Matching.

- A. Cranial Nerve I (Olfactory)
- B. Cranial Nerve II (Optic)
- C. Cranial Nerve III (Oculomotor)
- D. Cranial Nerve V (Trigeminal)
- E. Cranial Nerve VII (Facial)
- F. Cranial Nerve VIII (Vestibulocochlear)
- G. Cranial Nerve X (Vagus)
- H. Cranial Nerve XII (Hypoglossal)

52. Hearing, equilibrium

53. Smell

54. Chewing, mouth /face touch and pain

55. Slows heart rate, stimulates digestive organs

56. Controls facial expressions, secretion of tears and saliva

57. Controls tongue movement

58. Vision

59. Eyelid and eyeball movement