Learning Outcomes

* 13-1 Describe the basic structural and organizational characteristics of the nervous system.
* 13-2 Discuss the structures and functions of the spinal cord, and describe the three meningeal layers that surround the central nervous system. Discuss how the membranes can become inflamed and what disease results.
* 13-3 Explain the roles of white matter and gray matter in processing and relaying sensory information and motor commands. Describe the organization of gray and white matter in the spinal cord
* 13-4 Describe the major components of a spinal nerve, and relate the distribution pattern of spinal nerves to the regions they innervate (e.g. four nerve plexuses and how they are distributed). Discuss the layers of connective tissue and how they function to organize the internal structure of a nerve. Discuss the structure and function of dermatomes. Identify how dermatomes are related to peripheral neuropathies and shingles. Discuss the peripheral distribution of spinal nerves and the steps involved in afferent and efferent distribution of impulses.
* 13-5 Discuss the significance of neuronal pools, and describe the 5 major patterns of interaction among neurons within and among these pools.
* 13-6 Describe the steps in a neural reflex, and *classify the types of reflexes*. *Discuss examples of the various types of reflexes*. *Diagram a reflex arc.*
* 13-7 Distinguish among the types of motor responses produced by various reflexes, and explain how reflexes interact to produce complex behaviors.
* 13-8 Discuss the Babinski reflex, including what should be seen in babies vs. adults.
* *Be able to answer questions similar to clinical scenario application questions.*

1. 13-2 Gross Anatomy of the Adult Spinal Cord
   1. Overall Structure
      1. Spinal cord is separated into 31 segments
      2. In adults, ends between vertebrae L1 and L2
      3. Elongation occurs until age 4
      4. Bilateral symmetry due to posterior median sulcus and anterior median fissure
   2. Each segment of spinal cord has a pair of:
      1. Dorsal root ganglia (cell bodies of neurons)
      2. Dorsal roots:
         1. Made up of axons
         2. bring sensory information to the spinal cord (afferent)
      3. Ventral roots:
         1. Made up of axons
         2. sends commands/impulses to effectors (efferent)
      4. Dorsal + ventral roots join to form spinal nerve
         1. Known as mixed nerves because they contain both afferent (sensory) and efferent (motor) fibers
   3. Enlargements
      1. Expanded segments of gray matter
      2. Gray matter greatest in segments dedicated to sensory and motor control in limbs
      3. Cervical enlargement: supplies nerves to shoulder and upper limbs
      4. Lumbar enlargement: supplies nerves to pelvis/lower limbs
   4. Inferior Structures
      1. Conus medullaris: tapered, conical region of spinal cord
      2. Filum terminale:
         1. slender strand of fibrous tissues which extends from inferior tip of conus medullaris
         2. provides longitudinal support to spinal cord
      3. Cauda equina
         1. “horse’s tail”
         2. Filum terminale + long dorsal and ventral roots
         3. Although spinal cord stops elongating at age 4, dorsal and ventral roots continue to elongate forming a network of roots that resembles the tail of a horse
   5. Spinal Meninges
      1. Meninges found surrounding spinal cord and brain
      2. Spinal meninges function to:
         1. Stabilize/protect spinal cord from bumps/shock
         2. Blood vessels within layers deliver oxygen and nutrients
      3. Dura mater
         1. Hard mother
         2. Outermost, tough layer covering spinal cord
         3. Made of dense collagen fibers
         4. Epidural space:
            1. Between dura mater and walls of vertebral canal
            2. Filled with areolar tissue, BVs and adipose tissue for protection
            3. Site of epidural

Epidural used to deliver anesthetic

Needle is inserted into epidural space

Catheter is threaded through needle

Needle is carefully removed while catheter is left in place to deliver medication

Affects only spinal nerves in immediate area

* + 1. Arachnoid mater
       1. Spider mother
       2. Middle layer consisting of a network of collagen and elastic fibers which resemble a spider web
       3. Subarachnoid space

Space between arachnoid mater and pia mater

Filled with cerebrospinal fluid (CSF)

Location of spinal anesthesia and spinal tap

Spinal tap (aka lumbar puncture) involves drawing a sample of CSF from the subarachnoid space

Can be used to diagnose meningitis, MS, brain/spinal cord cancers

* + 1. Pia mater
       1. Delicate mother
       2. Innermost layer
       3. BVs run along pia mater within subarachnoid space
    2. Meningitis
       1. Infection of meningeal membranes by bacteria/virus
       2. Infection causes inflammation = disruption to circulation of CSF = damage/death of neurons
       3. Vaccinations can be given to prevent some forms of meningitis
       4. Can be diagnosed by spinal tap
       5. Highest risk group are children under 5, followed by individuals 16-25
       6. Newest outbreak cause by steroid injections contaminated by a fungus

1. 13-3 Organization of Gray and White Matter in Spinal Cord
   1. Overview
      1. Anterior median fissure and posterior median sulcus divide spinal cord into right and left halves
      2. White matter: contains large numbers of Myelinated and Unmyelinated axons
      3. Gray matter: dominated by cell bodies of neurons, neuroglia and Unmyelinated axons
      4. Central canal: surrounded by gray matter
      5. Gray matter forms a butterfly shape, forming horns on each side of spinal cord
   2. Organization of Gray Matter
      1. Nuclei: masses of gray matter within the CNS
         1. Sensory nuclei: receive and relay sensory information from receptors
         2. Motor nuclei: issue motor commands to effectors
      2. Horns
         1. Posterior gray horns: contain somatic and visceral sensory nuclei
         2. Anterior gray horns: contain somatic motor nuclei
         3. Lateral gray horns

Located only in thoracic and lumbar segments

Contain visceral motor nuclei

* + 1. Gray commissures: contain axons that cross from one side to another before they reach an area in gray matter
  1. Organization of White Matter
     1. Divided into three regions called columns
        1. Posterior white columns: between posterior gray horns and posterior median sulcus
        2. Anterior white columns: between anterior gray horns and anterior median fissure
        3. Anterior white commissure: region where axons cross from one side of spinal cord to the other, interconnects anterior white columns
        4. Lateral white columns: white matter between anterior and posterior columns on each side
     2. Tracts (Fascicle)
        1. Axons in each column which share functional and structural characteristics
        2. Ascending tracts: carry sensory information toward the brain
        3. Descending tracts: convey motor commands to spinal cord

1. 31-4 Spinal Nerve Plexus
   1. Nerve Plexus: network of spinal nerves
   2. Anatomy of Spinal Nerve
      1. Organization of tissue forming nerve is similar to that of muscles – 3 layers of CT
         1. Epineurium
            1. Outermost layer
            2. Consists of dense network of collagen fibers
         2. Perineurium
            1. Middle layer
            2. Divide nerve into series of compartments which contain bundles of axons (fascicles)
         3. Endoneurium
            1. Innermost layer
            2. Surround individual axons
      2. BVs penetrate layers of CT to supply axons and Schwann cells
   3. Peripheral Distribution of Spinal Nerves
      1. Spinal Nerves:
         1. Consist of dorsal root + ventral root
         2. Branch to form pathways to destination
         3. Includes motor and sensory nerves
      2. Motor nerves
         1. 1st branches = white ramus and gray ramus
            1. White ramus caries visceral motor fibers to sympathetic ganglion
            2. Gray ramus contains fibers that innervate glands and smooth muscles in body walls/limbs
            3. White + gray ramus = rami communicantes (communicating branches)
         2. 2nd branches = dorsal and ventral ramus used to deliver motor commands from motor nuclei to effectors in various parts of body
      3. Sensory nerves
         1. Similar branching structure to motor nerves
         2. Used by sensory nuclei to receive/relay information from receptors in various parts of the body
      4. Dermatome
         1. Single pair of spinal nerves that monitor bilateral regions of skin surface
         2. Can help in identifying areas of damage/infection in spinal nerve
      5. Spinal Nerves and Clinical Applications
         1. Peripheral neuropathies
            1. Regional loss of sensory or motor function
            2. Due to trauma or compression
            3. Example: if your foot “falls asleep”
         2. Shingles
            1. Caused by varicella-zoster virus (chickenpox)
            2. After chickenpox, virus hides in neurons of spinal cord
            3. Later in life, attacks neurons in dorsal roots of nerves = painful rash/blisters
            4. Distribution of rash corresponds to dermatome nerves affected
   4. Nerve Plexuses
      1. Complex, interwoven networks of nerves
      2. Formed from blended fibers of ventral rami of adjacent spinal nerves
      3. Control skeletal muscles of the neck and limbs
      4. Four main plexus
         1. Cervical plexus: innervates muscles of neck and thoracic cavity (control diaphragm)
         2. Brachial plexus: innervates pectoral girdle and upper limbs
         3. Lumbar and Sacral plexus: innervates pelvic girdle and lower limbs
2. 13-5 Neuronal Pools
   1. Review: Three functional classifications of neurons:
      1. Sensory neurons: deliver information to CNS
      2. Motor neurons: distribute commands to effectors
      3. Interneurons: interpretation, planning, coordination of incoming/outgoing signals
   2. Neuronal pools
      1. Interneurons organized into function groups
      2. May stimulate or depress parts of the brain/spinal cord
      3. Five different ways organization takes place
         1. Divergence
            1. Spread of info from one neuron/pool to several neurons/pools
            2. Occurs when sensory neurons bring info to CNS
            3. Allows for message to reach multiple places at the same time
         2. Convergence
            1. Several neurons synapse on single post-synaptic neuron
            2. Allow for control of same motor neurons both consciously and subconsciously
         3. Serial processing
            1. Information relayed from one neuron to another in stepwise fashion
            2. Occurs when sensory info is relayed from one part of the brain to another
         4. Parallel processing
            1. Several neurons/pools process same info simultaneously
            2. Divergence must take place first
            3. Allows for responses to occur simultaneously
         5. Reverberation
            1. Branches of axons extend back toward source of impulse to trigger further stimulation
            2. Positive feedback loop
            3. Help maintain consciousness, muscular coordination and normal breathing
3. 13-6 Reflexes
   1. Automatic responses coordinated within spinal cord
   2. Neural Reflexes
      1. Rapid, automatic responses to specific stimuli
      2. One neural reflex produces one motor response
      3. Reflex arc: wiring of a single reflex which generally opposes original stimulus (negative feedback)
   3. Steps in a Neural Reflex
      1. Arrival of stimulus activates receptor
      2. Sensory Neurons are activated and produce AP
      3. AP = release of neurotransmitters which allow post-synaptic cell (interneuron or motor neuron) to process information
      4. Activation of motor neuron releases neurotransmitters
      5. Release of neurotransmitters leads to response by effector
   4. Classifications of Reflexes
      1. Development
         1. Innate reflexes
            1. Genetically determined
            2. Include chewing, suckling, tracking object with eyes, blinking when eyelash touched
         2. Acquired reflexes
            1. Learned motor patterns enhanced by repetition
            2. Driving, walking, skiing
      2. Response
         1. Somatic reflexes
            1. Involuntary control of skeletal muscle contractions
            2. Include superficial and stretch reflexes
            3. Provide rapid response that can be modified later by voluntary commands
         2. Visceral (automatic) reflexes: Controls actions of smooth/cardiac muscles, glands, adipose tissue
      3. Complexity of circuit
         1. Monosynaptic: one synapse, little delay between stimulus and response
         2. Polysynaptic: multiple synapses, longer delay between stimulus and response
      4. Processing site
         1. Spinal reflexes: Processing occurs in the spinal cord
         2. Cranial reflexes: Processing occurs in the brain
4. Spinal Reflexes
   1. The Stretch Reflex
      1. Most common monosynaptic reflex
      2. Example: patellar reflex
         1. Physician taps on patellar tendon
         2. Receptors in quadriceps are stretched
         3. Distortion of receptors stimulates sensory neurons
         4. This leads to reflex contraction of stretched muscle = kick
         5. Slow response can indicate defect with nerve conduction
         6. Patellar reflex helps with balance and walking, contracts muscle automatically when weight is put on feet during standing/walking
   2. Withdrawal Reflexes
      1. Type of polysynaptic reflex
      2. Example: flexor reflex
         1. Affects muscles of a limb
         2. Occurs when you grab a hot pan
            1. Grabbing hot pan stimulates pain receptors
            2. Sensory neurons activate interneurons in spinal cord
            3. Stimulate motor neurons in anterior gray horns
            4. Result=contraction of flexor muscles that yanks hand away from stove
            5. Inhibitory signals used to relax extensor muscles
   3. 13-8 The Babinski Reflexes
      1. Babinski sign (positive Babinski reflex)
         1. Occurs in absence of descending inhibition
         2. Normal in infants/pathological in adults
         3. If seen in adults = sign of damage to nerve paths connecting the spinal cord and brain
      2. Plantar reflex (negative Babinski reflex): Stroking lateral sole of foot produces curling of the toes