N102
Nervous System Anatomy and Physiology Review

- Function of the Nervous System
  - Controls and coordinates the body's activities to maintain homeostasis (temp, resp, digestion)
  - Generation of sensory input to be processed
  - Processing of incoming data
  - Generation of impulses that control various voluntary and involuntary motor functions
  - Storage of information

- Cellular A&P
  - Two types of cells: neurons and neuroglia cells
    - Neurons – functional unit of the NS. Purpose is to transmit messages
      - Vary in shape and size but all have 3 common characteristics
        - excitability – ability to generate an impulse
        - conductivity – ability to transmit the impulse within itself
        - influence- able to transmit impulse to influence other neurons
      - Components of the neuron
        - Cell body – center of the neuron; form the gray matter of the brain
        - Dendrites –projects from the cell body – receives impulses and directs them toward the cell body
        - Axon – carries impulses away from the cell body –
          - may be with or without a myelin sheath
      - Myelin Sheath
        - Axons that are coated with a myelin sheath are known as myelinated
        - This covering insulates, maintains, and speeds axon transmission
        - Lipid substance that gives white color to white matter in CNS
      - Classification of Neurons: structural and functional
        - Structural –defined by the processes/ poles they have
          - Multipolar – cell body, 1 axon, several dendrites
          - Bipolar – 1 axon, 1 dendrite
          - Unipolar – only 1 pole or process – close to cell body
        - Functional – defined by the direction an impulse is conducted
          - Sensory (afferent) transmit nerve impulses toward CNS from peripheral sensory organs (skin)
          - Motor (efferent) – transmit nerve impulses away from CNS to muscles, glands, organs
          - Interneurons-transmit impulses from afferent (sensory) to efferent (motor) nerves
    - Neuroglia or glial cells
      - Repair, support, and protect the neurons
      - 5-10 times more numerous than neurons
      - Most common source of primary tumors because they are mitotic-they easily divide and replicate
      - Types of glial cells
        - Oligodendrocytes – important to know = produces myelin sheaths on axons-*What does it do?* Speeds transmission
        - Astrocytes – found mostly in gray matter, accumulate in areas where neurons have been damaged and contribute to formation of scar tissue (gliosis), feed neurons, form the BBB, aka star of NS
        - Ependymal cells – aid in secretion and regulation of CSF
    - Nerve Regeneration: all nerves when damaged will try to re-grow
      - CNS: neurons in the CNS have limited ability to repair themselves and once believed to have no ability to generate new cells

- PNS: nerve regeneration does occur but it is a slow process

➢ Nerve Impulse Conduction
  - travels by electrical transmission along axon and chemical transmission between neurons until impulse reaches its destination
    - electrical impulse is a result of K+ and Na+ ions moving in and out of the cells all along the length of the axon
      - resting state-no impulse-high K+ in cell
      - depolarization-channels in the cell membrane open and Na+ rushes in (deploys) high Na+ in cell
      - repolarization-K+ channels open and it slowly enters to bring balance back to the cell membrane (returns to resting)
  - Action potentials –electrical impulse that travels along the axon by depolarizing and repolarizing the length of the axon is an action potential-doing the WAVE
  - impulse reaches the end of the nerve fiber then is transmitted across the junction between nerve cells (synapse)
  - chemical interaction generates another action potential in the next neuron
  - this process is repeated until the impulse reaches its destination (muscle, gland, organ)
  - Saltatory conduction
    - Type of nerve conduction when the axon is myelinated
    - Myelin sheath coats the axon like sausage links
    - **Action potential** jumps from 1 node of Ranvier to the next – this hopping makes the impulse increase velocity (travel faster) and conserves energy
      - Nodes of Ranvier – gaps in the myelin on axons that speed impulse along
    - with saltatory conduction the Na+ and K+ ions are only required to move in and out of the cells at the nodes instead of depolarizing and repolarizing the entire length of the axon
  - synapse – junction or space where nerve impulse is transmitted from 1 neuron to another
    - neurotransmitter – *chemicals* involved in the transmission of an impulse across the synaptic cleft to the receiving neuron
      - ◆—acetylcholine –
      - ◆—serotonin –
      - ◆ norepinephrine –
      - ◆—dopamine

❖ Divisions of the nervous system – central and peripheral
➢ Central nervous system consists of the
  - brain
    - cerebrum
    - brainstem – midbrain, pons, medulla
    - cerebellum
  - spinal cord
➢ Peripheral nervous system consists of the
  - 12 pairs cranial nerves
  - 31 pairs spinal nerves
  - autonomic nervous system
    - sympathetic
    - parasympathetic
➢ Nervous System Protective Structures
  - cranium – bony protection for the brain
    - 14 facial bones
    - 8 cranial bones: 2 each fontal, temporal, parietal, occipital
    - skull is rigid and does not allow much extra space –
    - frontal – form forehead

- occipital – large bone at base of skull
- temporal – forms sides and base
- parietal – forms sides and top of skull
- Foramen magnum – largest hole in our skull. What comes through here? brain stem extends to spine foramen means opening and magnum meaning big

- Scalp – outermost layer of protection – fibrous and freely movable
- Meninges – beneath our rigid skull with all its bones is the meninge layers
  - Layers (3) of protective membrane that surround the brain and spinal cord
    - Dura mater – outermost, thickest and toughest
    - Arachnoid – middle layer – thin, delicate, loosely encloses the brain and spinal cord. Pathway for the flowing of CSF in the brain and Spinal Cord
    - Pia Mater – innermost layer covering the surface of the brain and spinal cord, mesh like, vascular
  - spaces of the meninges
    - epidural – epi-above so above the dura-potential space between skull and outer dura of the brain
    - subdural – below the dura, between dura and arachnoid layer
    - subarachnoid - between arachnoid and pia mater – where the CSF is contained
  - Protective Anatomy
    - Falx cerebri-fold of dura that separates the 2 cerebral hemispheres allows for some expansion without pressure being placed on the opposite cerebral hemisphere
    - Tentorium cerebelli – double dura layer folds between the cerebral hemispheres and the cerebellum to prevent them from pressing on one another
      - So the cerebrum can expand some and the thick dura protects it from affecting the cerebellum and brainstem
    - supratentorial – surgery above the tentorium
    - infratentorial – surgery below the tentorium

- Cerebrospinal fluid
  - Clear, colorless, odorless
    - On average we have ~135ml
  - Purpose: “shock absorber” – cushions brain and SC against injury due to movement (like a built in liquid pillow)
  - Provides nutrients: content similar to plasma (different %’s)
    - no RBC’s
    - water
    - sm amt protein
    - O2 and CO2
    - Na, K, Cl, glucose (important nutrient)
  - Choroids plexus – are cauliflower-like structures located in portions of the ventricles –produces and secretes CSF
    - Choroid plexus consist of many capillaries-blood enters, is filtered, and secreted as CSF (like super ultrafiltrated blood)
    - Continually being formed
  - CSF flow
    - Termed the 3rd circulation and is a closed system
    - Pools in the ventricles and flows throughout the subarachnoid space and BATHES the brain and SC
  - CSF is absorbed daily by the arachnoid villi projections

- Cerebral circulation
  - Brain does not store nutrients and requires a constant supply of oxygen Need is met through cerebral circulation

- Brain receives 750 ml/min of blood or 20% or our total cardiac output
- Brain requires 25% of body's total oxygen and glucose requirements

- Venous drainage (unique) –how all the blood gets out of the CNS
  - Exit via 2 vascular channels formed by the dural layers called dural sinuses
  - cerebral veins empty into the dural sinuses which empty into the jugular veins for return to the heart
  - Unique feature is absence of valves – gravity is important in maintaining optimal venous outflow
- Arterial supply
  - Enters skull thru the largest opening in the skull? Which is the Foramen magnum
  - Anterior circulation supplied by common carotids in the neck which branch into the internal and external carotids
  - Posterior Circulation is supplied by the subclavian artery that branches into 2 vertebral arteries
    - These vertebrals unite and become the basilar artery
  - Circle of Willis – allows blood to circulate from one hemisphere to the other so it acts as a safety valve to protect from differential pressures or occlusion
    - Formed at the junction of the basilar artery (posterior circulation) with the internal carotid arteries (anterior circulation)
    - Has a protective function to shunt blood between anterior and posterior cerebral circulation
  - Another protective function of the brain is termed autoregulation- brain can self regulate its blood supply to meet changes in metabolic needs
    - How? Regulates blood vessel diameters independent of systemic BP –WOW
  - Blood brain barrier
    - Physiological barrier between blood capillaries and brain tissue. Made up of tight capillaries and astrocytes. Brain capillaries are more selective with what is allowed to pass to brain tissue
    - Protects brain from certain potentially damaging agents, organisms, and toxins while allowing nutrients and gases to enter
    - Only certain drugs/medications can pass BBB
      - Its ability to limit entry into the CNS makes treatments for CNS disorders challenging.

- Brain
  - Consists of 3 major divisions – cerebrum, brain stem, cerebellum
  - anatomical landmarks
    - gyrus – "convolution" fold on the surface of the brain that increases its surface area
    - fissure – deep predictable separation in cerebral hemispheres
      - Great longitudinal fissure – divides cerebral hemispheres into Rt and Lt
  - cerebrum
    - largest part of the brain
    - nerve centers associated with sensory and motor functions and higher mental functions located here (memory, reasoning)
    - cerebral cortex – outer layer- gray matter What's in there? Billions of neuron cell bodies and dendrites cover each hemisphere – under this is white matter (myelinated axon tracts)
    - 2 hemispheres
      - 2 hemispheres divided by? Great longitudinal fissure
      - Each hemisphere has four lobes
        - frontal, parietal, temporal, and occipital
      - frontal
        - right controls left side of body
        - left controls right side of body (contra-lateral)
        - voluntary gross motor function

- memory
- higher cognitive function (problem solving)
- judgment
- Broca's area – found in frontal lobes = responsible for expressive speech the formation of spoken words (motor). Able to understand well but difficulty saying words. (Ie.. how did you get to the office today? D-d-d-d-drive c-c-c-car) words forced out slow with stuttering.
  - damage here in dominant hemisphere = expressive aphasia (no motor integration of lips, mouth, inability to express thoughts) can't form words
  - cerebral dominancy for 90% of persons is in the Left frontal lobe – all right handed people and most left handed

➢ Parietal lobes
- primary sensory area – interpretation of sensory thought
- sensations of touch, pressure, position
- body awareness- for example- where is your L buttocks? If you have to turn and look then something is wrong with your parietal lobe.
- spatial awareness? Ability to comprehend your position in relation to the world around you ie furniture-It is why I don't walk into the podium (usually)

➢ Temporal lobes
- auditory reception – hearing and interpreting sound
  - we hear music, have memory of sound, and understanding of language and music (ability to recite lyrics)
- Wernicke's area – responsible for understanding and interpretation of written and spoken language (reading a book, listening to lecture)
  - damage= receptive aphasia
    - able to form words but unable to understand others

➢ Occipital lobes
- primary receptive area for vision and visual association
- What happens with damage to this lobe?
  - Inability to recognize & identify objects

➢ Special structures of the cerebrum
- Basal Ganglia – basal (base) ganglia (clump of neurons)
- base of the cerebrum-deep in the center of the cerebral hemispheres (put one finger through your eye and one through your ear and you found it).
  - initiation, execution, and completion of voluntary movement
  - automatic motor movements (ie swallow, blink, arm swinging)
- Diencephalons
  - area in the brain sits on top of the brainstem includes the thalamus and hypothalamus
  - Thalamus – relay station for all sensations -grand central. Impulses regarding sensations sent through here
  - Hypothalamus – Very Busy- regulates the autonomic NS (involuntary body functions) endocrine function (effecting pituitary secretions) and influence is responsible for temp control, fluid balance, reproduction, metabolism, hunger center controlling appetite,
  - Limbic system- Primal human features. Feeding and sexual behaviors, and emotional responses rage, fear, and depression.

- Brainstem – second major subdivision of brain
  - connects the spinal cord with the cerebrum and cerebellum
  - contains ascending and descending pathways for impulses going to and from the brain
  - point of attachment for CN III (3) through XII (12)
    - 10/12 cranial nerves originate in the brainstem

- contains many reflexes – swallowing, cough, vomiting, hiccup.
- midbrain, pons, medulla oblongata
- Medulla oblongata –primary rhythm center-
  - Responsible for respirations, vasomotor (BP), and cardiac function (HR).
- —Reticular Formation-specialized system of neurons responsible for controlling the sleep-wakefulness cycle. Known as the RAS-reticular activating system. Involves consciousness and attention span(Why we wake in the middle of the night with a loud noise).

- Cerebellum – located in posterior (back) fossa, superior to the brain stem, and inferior to the occipital lobe
  - Responsible for coordination of motor function and fine, smooth movement, balance, and trunk stability
  - Feedback loops correct movements by receiving impulses from the cerebral cortex and influencing motor activity

- Spinal Cord
  - Continuous with the brainstem and exits the cranial cavity (thick as a finger)
  - Elongated mass of nerve fibers that occupies the upper 2/3 of the vertebral canal
    - Extends from C1 to L1 (first cranial to first lumbar)
    - Protected by: vertebral column and meninges (Dura, arachnoid, pia)
  - Spinal Cord Matter-a cross section (bread slice) of the spinal cord shows an H shaped central core of nerve cell bodies (grey) surrounded by white matter ascending and descending tracts (myelinated axons)
    - Gray matter-motor neuron cell bodies, nuclei
      - Anterior/ventral – wider arms of the H
        - here is the primary *motor* neurons through which the spinal tracts carry motor response messages to the periphery (end organs)
      - Posterior (Dorsal)– thinner arms of the H
        - here are the primary *sensory* neuron through which peripheral nerve messages enter spinal cord and synapse with ascending tracts
    - White matter – myelinated nerve tracts – carry motor messages between the brain and the periphery
      - Sensory – afferent – message up, ascending tracts
      - Motor- efferent – message down, descending tracts
- Ascending tracts – carry specific sensory (afferent) information to the brain from receptors in the peripheral NS
  - dorsal column (posterior) – carry impulses of position sense and movement, deep touch, pressure, vibration, kinesthesia (our appreciation of movement, weight, and body parts)
  - spinocerebellar tracts – enters spine ends at cerebellum
    - carry subconscious info about muscle tension and body position to cerebellum for coordination of movement
    - impulse enters sc and straight to the cerebellum (no crossing)
  - spinothalamic tracts – enters spine ends at thalamus
    - What is the function of the thalamus? Major relay station
    - carry pain and temperature control
- Descending Tracts – carry motor impulses that are responsible for muscle movement. Exit the spinal cord via ventral root (wide H)
  - —Corticospinal
    - Originate – primary motor cortex of frontal lobe
    - Crosses at medulla
    - Responsible for voluntary motor function
      - Each side of the brain controls the skeletal muscles on the opposite side of the body-Why? Because cross at medulla
- Upper and Lower motor neurons carry efferent messages that influence skeletal muscle

- damage to either can cause weakness and paralysis
- Upper Motor Neurons (UMN)
  - Located in cerebral cortex
  - Lesions generally cause weakness, paralysis, hyperreflexia, and increased muscle tone (spastic)
- Lower motor neurons-originate in the spinal cord
  - Final step of the nerve impulse before stimulation of skeletal muscle-connect CNS to muscle
  - Lesions/Damage cause weakness, paralysis, decreased muscle tone (flaccid), hyporeflexia (think slower lower Delaware)

▪ Reflexes
- Involuntary response to a stimulus – pathway is a reflex arc
- receptor organ – has specific sensory fibers that are sensitive to stimulus
- Monosynaptic Reflex-simplest type-four steps
  - Receptor organ ie.. skin
  - Sensory neuron activated by stimulus (afferent pathway)
  - Information processed in the spinal cord
  - Motor neuron activated (efferent pathway)
- Example: superficial or cutaneous reflex– skin touches a hot stove, sensory impulse sent to spinal cord, motor message pulls hand away

➢ Peripheral Nervous System
▪ Includes all nervous system structures that lie outside CNS
▪ 12 pairs cranial nerves; 31 pairs spinal nerves and autonomic NS
▪ Cranial Nerves
- Carry sensory fibers or motor fibers or both
- Come in pairs (one for each eye, ear, etc)
- CN innervate a specific segment of the brain (remember 10/12 exit at the brainstem)

❖ Cranial Nerve #	❖ Name (s) (m)	❖ Function	❖ How to test
❖ I	❖ Olfactory (s)	❖ smell	❖ ID familiar odors with eyes closed-coffee, vanilla. Test both sides
❖ II	❖ Optic (s)	❖ vision	❖ Visual acuity-use snellen chart ❖ Peripheral vision-focus on examiner nose w one eye closed and ID when ex. finger in periphery is first seen or when wiggled
❖ III	❖ Oculomotor (m)	❖ Eye movement ❖ Eyelid elevation ❖ Pupil constriction	❖ 3,4,6 tested together b/c all are involved in eye movement. Follow examiner fingers as moves horiz and vert making an N or wide H ❖ 3-evaluate for lid drooping-ptosis ❖ 3-pupil constriction- absence can be an early sign of brain herniation
❖ IV	❖ Trochlear (m)	❖ Eye movement	
❖ V	❖ Trigeminal (s,m)	❖ face sense	❖ Feel cotton wisp on forehead,

		❖ chewing	cheek, jaw with eyes closed ❖ Clench teeth and open jaw with resistance
❖ VI	❖ Abducens (m)	❖ Eye movement	❖ Same testing as CN III
❖ VII	❖ Facial (s,m)	❖ taste ❖ facial muscles expressions	❖ Taste-sugar/salt on anterior tongue (both sides) ❖ Have pt imitate you-wrinkle forehead, frown, smile-look for symmetry ❖ Try to open the pt closed eyes
❖ VIII	❖ Acoustic (s) or Vestibulocochlear	❖ hearing and equilibrium	❖ Hearing tested with a tuning fork, watch ticking, rustling fingers ❖ Equilibrium-ask pt to walk in straight line
❖ IX	❖ Glossopharyngeal (s,m)	❖ tongue, pharynx/larynx (taste) ❖ superior pharynx muscles (gag-swallow)	❖ 9,10 are tested together because control similar functions. Test gag reflex with a tongue depressor to each side of pharynx. ❖ Say ahh and check for uvula movement ❖ Observe pt ability to swallow
❖ X	❖ Vagus (s,m)	❖ ph/lar sense ❖ smooth muscle of palate, larynx, pharynx (gag-swallow) and Parasymp NS-heart, lungs, digestive system	
❖ XI	❖ Spinal Accessory (m)	❖ Muscles: neck, sternocleidomastoid and trapezius	❖ Shrug shoulders and turn head
❖ XII	❖ Hypoglossal (m)	❖ tongue muscle	❖ Stick tongue out and observe for deviation.

- Spinal Nerves – 31 pairs exiting the SC
  - Spinal nerves are always combined having both motor and sensory fibers
- Dorsal root- attachment point to the spinal cord for sensory fibers
- Ventral root-detachment point from the spinal cord for motor fibers
- Dermatomes – area of skin innervated by the sensory fibers of a single root
  - Interruption of 1 sensory nerve root may result in paresthesia or pain in that dermatone area
  - So when a patient reports numbness for example in a certain location it alerts the evaluator to what spinal nerve is involved. Because there are specific nerves connected to specific locations.
- Myotome– muscle group innervated by primary motor neurons of a single root
- Cauda equina – latin term meaning “horse’s tail”
  - All nerve roots exit horizontally except in the lumbar, sacral, and coccygeal roots which descend down giving the horse tail appearance

➢ Autonomic nervous system
- responsible for involuntary functions of cardiac, smooth muscles, and glands
  - Do you tell your heart to pump?
- 2 major subdivisions = sympathetic and parasympathetic
- purpose – maintain a relatively stable internal environment for the body
  - Through the para and symp NS working together

- Systems often have dual and reciprocal innervation of structures
  - Ie sympathetic increases HR and parasymp dec HR
- sympathetic-self-preservation instincts
  - activated during stress situations (fright, fight, flight)
    - inc HR, B/P, vasoconstriction of peripheral blood vessels
    - cell bodies originate in T1 to L2 thoracic and lumbar regions of the spinal core (thoracolumbar division)
- parasympathetic-rest and digest
  - conserves and restores to body's energy stores
    - dec HR, bronchi constriction, increased peristalsis
    - originates in brain stem and sacrum (craniosacral division)