Ch. 5: Central Nervous System

Objectives:

1. Recognize the 6 brain regions & their primary functions.

2. Brain Blood Supply, Blood-Brain Barrier, and Brain Injuries

3. Brain Imaging Techniques Used in Medicine

Anatomy Review!

CNS = brain & spinal cord (where majority of neurons located).

PNS = other nervous tissue outside CNS
Part 1. Six Brain Regions & Their Functions

Anatomy Review! Pg 58-59 Wiki text

1. Cerebrum
2. Diencephalon
3. Midbrain
4. Pons
5. Medulla oblongata
6. Cerebellum

Ques:
What 3 brain regions make up the “brainstem”

Midbrain, Pons, Medulla

Region 1: Cerebrum (Forebrain) Pg 58-59 Wiki text

Motor areas involved with the control of voluntary muscles
Sensory areas involved with cutaneous and other senses
Motor speech area (Broca’s area)
General interpretive area
Lateral sulcus
Auditory area
Interpretation of sensory experiences, memory of visual and auditory patterns
Temporal lobe
Brain stem
Region 1: Cerebrum (Forebrain)

6 Cerebral Lobes and their major cortices

1. Frontal Lobe:
   - Has **Motor cortex (precentral gyrus)** – voluntary motor control
   - Has **Broca's motor speech area** – motor control for speech
   - Has **Prefrontal cortex** – higher thinking, sense of self, primal emotions.

2. Parietal Lobe:
   - Has **Sensory cortex (postcentral gyrus)** – perceiving touch, pressure, pain, temperature. Has part of **Wernike's area** for understanding the written & spoken word (language center).

3. Temporal Lobe:
   - Has **Auditory cortex** – for sound perception
   - Has **Olfactory cortex** – for smell
   - Has part of **Wernike's area**

4. Occipital Lobe:
   - Has **Visual cortex** for sight, & part of Wernike's area

5. Insula Lobe:
   - Has **gustatory cortex** – for perception of taste

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**Precentral gyrus** = primary motor cortex of frontal lobe which has motor control of body.

**Central sulcus**

**Postcentral gyrus** = primary somatosensory cortex of parietal lobe that receives sensory info from body (dermatome)

DO NOT need to memorize figure!
Cerebrum & Language

• Broca’s area:
  Controls muscles involved in speech, and even writing (to some extent).

• Wernicke’s area:
  Involved in processing and understanding language – both written and spoken words.

Aphasias = communication disorder that results from damage or injury to language parts of the brain.

**Broca’s aphasia** = (non-fluent aphasia) difficulty speaking but have understanding of words and language.

Click HERE for YouTube video of patient with Broca’s aphasia

**Wernike’s aphasia** = (fluent aphasia) fluid speech but it is nonsense because do not understand words and language (word salad)

Click HERE for YouTube video of patient with Wernike’s aphasia

Click HERE for FMU’s Speech Pathology Program
2 Sleep Categories:

1. non-REM = stages 1 – 4 (80% of sleep)

2. REM = stage 5 (20% of sleep)
   > Limbic (emotional) system remains active
   > GABA inhibition of:
     a. brain awareness of unimportant stimuli
     b. skeletal muscle (voluntary) movement

*Sleep twitch = “myoclonus”*

During sleep the reticular activating system (RAS) can arouse you with excitatory neurotransmitters if important stimuli sensed.
(see RAS later)

Cerebral Basal Nuclei (Ganglia) & Motor function:

- Nuclei located **deep within the cerebrum**
- Frontal motor cortex neurons communicate with basal nuclei
- Basal nuclei send inhibitory signals to thalamus which send signals back to frontal motor cortex.

[Diagram of Cerebral Basal Nuclei and Motor function]

- Putamen
- Globus pallidus
- Caudate nucleus
- Thalamus
- Claustrum

- Spinal cord
- Cerebellum
MOTOR Effects of cerebral basal nuclei:
- Maintaining purposeful motor activity but inhibit unwanted activity
- Monitor & coordinate slow sustained muscle contractions

   [Degeneration of neurons here associated w/ Huntington’s Chorea]
Cerebral basal nuclei & Emotions: The limbic system
Cerebral nuclei work with hypothalamic and thalamus nuclei to process primal emotions & behavioral drives.  

Papez Circuit = flow of info between cerebral nuclei & diencephalon (thalamus, & hypothalamus)

Limbic effects of cerebral nuclei:
- **Amygdala** – aggression, fear.
- **Cingulate gyrus** (above corpus callosum) = for forming associations between behavioral outcomes & motivation.
- **Septal nuclei** (below corpus callosum) = reinforces pleasurable behaviors.

Diencephalon structures:
- **Hypothalamus** = has nuclei for the 4 F's  1. feeding, 2. fighting, 3. fear, 4. fornicating
- **Thalamus** = relay station (helps info move between cerebral and hypothalamic nuclei)

Review

Brain Region 1: Cerebrum
- Cerebral lobe cortexes and their functions  
  (frontal, parietal, temporal, occipital, and insula)
- Cerebral division of motor and sensory perception in body  
  (precentral an postcentral gyrus.
- Cerebrum & language  (broca’s and wernike’s areas, and aphasias
- Cerebrum & sleep
- Cerebrum & memory
- Cerebral nuclei & motor function
- Cerebral nuclei & emotions (limbic system)
Brain Region 2: Diencephalon (forebrain)

- **Thalamus** = relay station that receives and sorts sensory (ascending) info & relays to appropriate cerebral cortex.

- **Hypothalamus** = has *many* neurons with many functions!
Hypothalamus nuclei & functions:
- Link between nervous & endocrine systems
- Controls pituitary gland
- Controls autonomic sympathetic response of body - adrenal medulla's production of epinephrine during fight/flight.

Hypothalamus nuclei & functions:

Has nuclei that functions in homeostasis:
- **Supraoptic** = osmolarity (water balance) center, produce ADH
- **Paraventricular** = produce oxytocin
- **Anterior** = regulates body temp (thermoregulation)
- **Ventromedial**
  > fullness (satiety) center,
  > fear, aggression, & reproductive (GnRH)
  the 4 F’s: **Fight**, **Fear/Flight**, **Feeding**, & **Fornicate**
- **Lateral** = hunger regulation
- **Preoptic** = thirst center
- **Suprachiasmatic** = regulates circadian rhythm (sleep/wake cycle).
Brain Region 3: Midbrain

1. **Superior colliculus** = reflex visual tracking of moving objects.

2. **Inferior colliculus** = reflex response to sound (turn head in direction of unexpected or scary sound).

3. **Red nucleus** = motor coordination of postural muscles.

4. **Substantia nigra:**
   - **Nigrostatinal dopamine system** - fine motor control.
   - **Mesolimbic dopamine system** – pleasure /reward center.

5. Part of RAS

**Drug Abuse & Dopamine Stimulation:**

- **Nicotine** - dopamine agonist
- **Heroin & morphine** - dopamine agonist by stopping GABA inhibition of dopamine
- **Benzodiazepine (Valium)** - dopamine agonist
- **Cocaine & amphetamines** – dopamine agonist
- **Alcohol** – dopamine agonist
Brain Regions 4 & 5: Pons & Medulla (hindbrain)

Pons
- Some of RAS
- 2 autonomic respiratory centers:
  - Pneumotaxic center
  - Apneustic center

Medulla oblongata
- Some of RAS
- Regulates involuntary sneezing, swallowing, gagging, and vomiting
- Primary site for crossover of motor control (decussation of pyramids)

Has 3 autonomic life-support centers:
  1. Cardiac center (control heart rate)
  2. Vasomotor center (arteriole dilation)
  3. Respiratory center for resp. rate.

The reticular activating system (RAS)
The reticular activating system (RAS) = system that distinguishes between unimportant and important (ex. life-threatening or saving) stimuli.

> In Midbrain, Pons, and Medulla (brainstem), thalamus & hypothalamus.

> Involves 4 neurotransmitters to arouse or inhibit cerebrum:

**Excitatory (wakefulness or awareness)**

1. ACh
2. Monoamines (dopamine & norepinephrine)
3. Hypocretin-1

**Inhibitory (promotes sleep or decreased awareness)**

4. GABA

*Read Clinical App Pg 139 and ONLINE: The effect of drugs on RAS.*
Brain Region 6: Cerebellum (also hindbrain)

➢ Receives sensory info from proprioceptors (in joints & muscles) to coordinate muscle movement for balance & posture.

➢ Stores learned motor patterns (“muscle memory”)

Cerebella ataxia

CLINICAL APPLICATIONS

Damage to the cerebellum produces ataxia—a lack of coordination resulting from errors in the speed, force, and direction of movement. The movements and speech of a person with ataxia may resemble those of someone who is intoxicated. A person with damage to the cerebellum may reach and miss an object, and then attempt to compensate by moving the hand in the opposite direction. This can produce back-and-forth oscillations of the arm.

Click HERE for YouTube video of “intention tremors”
**Review**

- **6 Brain Regions**
  - Know cortexes of cerebrum, wernike’s and broca’s areas.
    > aphasias
  - **Diencephalon** (Thalamus & hypothalamus functions)
  - **Midbrain & nuclei**
    - superior/inferior colliculus
    - Red nucleus
    - Substantia nigra
    - RAS
  - **Pons** (pneumotaxic and apneustic centers, RAS)
  - **Medulla oblongata** (cardiac, vasomotor, respiratory centers & RAS)
  - **Cerebellum**

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**CNS Meninges** = membranes the cover the brain & spinal cord.

### 3 Meninges:

1. **Dura mater** = outermost meninge

2. **Arachnoid mater** = middle meninge with a blood supply.

3. **Pia mater** = innermost meninge, with a blood brain barrier (BBB) of astrocytes.

**Common drugs that are lipid-soluble & cross BBB...**

- Ethanol
- Nicotine
- caffeine
- Tetrahydro-cannabinol (THC)
- *anesthetics*
**Brain blood supply:**

> Uses 15% of arterial blood supply
> Uses 50% of blood glucose!
> Few minutes of “ischemia” = brain tissue death!

**Ischemia** = interruption in blood flow to an organ or tissue.

**Stroke** = loss of blood flow to brain

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**Acute Cerebral Hemorrhage (Hematoma)**

Blunt force blow to head can rupture small blood vessels (hemorrhage) causing formation of hematoma (blood pocket).

Fluid buildup causes damaging pressure necrosis.

*Click HERE for YouTube surgical video on removal of a subdural hematoma (warning – graphic content)*

[Image link](http://www.iflscience.com/brain/watch-neurosurgeon-perform-subdural-hematoma-operation)
**READING ASSIGNMENT**

**Part 3. Techniques for Evaluating the Brain**

1) **X-Ray** = single x-ray beams sent through body part, which produces image showing high density tissue (bone or contrast media) as white and lower density tissues (soft tissue) as variations of gray, and air spaces as black.
   - Relatively cheap (national average for chest x-ray = $100, but depending on city and insurance can be more or less)
   - Best for viewing bone
   - Poor for viewing soft tissue

2) **CT Scan** = multiple x-ray beams sent through body, and tissue of different densities are analyzed by a computer to produce high quality images of tissues. Can show “slices” through a tissue. (computed tomography)
   - Expensive (national average cost = $1,200, but depending on city and insurance can be more or less)
   - Good for viewing soft tissue
3) MRI Scan = uses a powerful magnetic field and pulses of radio wave energy to make pictures of tissues. (magnetic resonance imaging)
• VERY expensive (national average cost = $2,600, but depending on city and insurance more or less)
• BEST for viewing high detail in soft tissue
• Not safe for use in patients with cochlear or pacemaker implants (etc...)

4) PET scan = uses radioactive glucose tracer to determine how tissues are working. (positron emission tomography)
• VERY expensive (national average cost = $1,600 – 4,000, but depending on city and insurance more or less)
• Can tell you if tissues or organs are functioning normally
**EEG** = Brain neuron activity measured with electrodes placed on scalp. (electroencephalogram)

**Review**

CNS meninges

Blood flow to brain

Hematomas and coup-contracoup brain injuries

Brain imaging techniques
- X-Ray
- CT scan
- MRI scan
- PET scan
- EEG
Blunt force injury to brain and hemorrhage and/or brain swelling

Ex. Coup-Contrecoup brain Injury (concussion):

Blunt force blow to one part of head causes brain to bounce within cranial cavity, hitting opposing side of skull.

Hard cranial bone damages soft brain tissue and can also cause hemorrhaging and hematomas.

Click HERE for GIF

Part 4. Spinal chord structure, spinal roots, and spinal nerves.

The Spinal Chord
- is part of CNS
- Has 4 paired regions:
  1. Cervical (C1-C8)
  2. Thoracic (T1-T12)
  3. Lumbar (L1 – L5)
  4. Sacral (S1 – S5)
  5. Coccygeal (1 pair)

Solid spinal cord ends ~L2 and branches into bundle of separate Lumbar & Sacral nerves called cauda equina (horse’s tail).
**CNS Division of White Matter Vs Gray Matter:**

White matter = myelinated neurons in brain and spinal cord. Functions to transmit info from one place to another.

- **In brain** – white matter found interior
- **In spinal chord** – white matter exterior

Gray matter = pigmented neurons found in brain & spinal cord. Function as integration centers where info is interpreted and motor commands made.

- **In brain** – gray matter in outer cortexes and cerebral nuclei center.
- **In spinal chord** – gray matter in center marks end of CNS, has butterfly shape.

Dorsal horn of spinal cord = receives sensory (afferent) info from body.
Ventral horn of spinal cord = delivers motor (efferent) commands to muscles/glands

> horns lead to dorsal & ventral roots (outside cord), which is start of PNS.
  - dorsal root has enlarged ganglion – where cell bodies of sensory neuron cell located.
> Roots merged into mixed spinal nerves (contain both sensory & motor info.)
Dorsal spinal roots receive sensory info. **Dermatome** = Skin’s sensory body map.

1. **Cervical (C1–C8)**
   - back of head
   - neck & shoulders
   - dorsal & lateral arms

2. **Thoracic (T1 – T12)**
   - torso

3. **Lumbar (L1 - L5)**
   - lower back
   - anterior legs

4. **Sacral (S1 – S5)**
   - groin & anus
   - posterior legs

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**Dermatome & Shingles**

“**Shingles**” = painful skin blisters & rashes that develop, usually on one side of body due to childhood exposure to chickenpox virus (varicella zoster), which lies dormant in dermatome.

**Virus** lies dormant in dermatome for years, reactivated later in life or w/immunosuppression.

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**5 THINGS YOU NEED TO KNOW ABOUT SHINGLES**

- Shingles is a disease that causes a painful skin rash.
- About **1 in 3 people** will get shingles, and your risk increases as you age.
- It comes from the same virus that causes chickenpox. Although there is no cure, shingles can be prevented or treated with vaccines.
There is now a Shingles vaccine. CDC recommends 2 doses, spaced 2 – 6 months apart

Ascending & Descending Tracts of Spinal Cord

• Tracts of axons carry information between spinal nerves and brain

1. Ascending tracts
   - carry sensory information UP to the brain
   • Originate in spinal cord
   • Sorted at thalamus
   • End in somatosensory cortex (postcentral gyrus)
   - Ex. spinothalamic tracts
     • Carry signals to thalamus
Tracts of axons carry information between spinal nerves and brain

1. Ascending tracts
2. Descending tracts
   - carry motor commands **down** from brain to motor neurons
   - **Corticospinal (pyramidal) tracts**
     - Originate in primary motor cortex (precentral gyrus)
     - Sorted at thalamus
     - End in spinal cord
     - Important for complex voluntary movements.
   - Extrapyramidal tracts
     - Originate at various locations

Clinical App: Babinski reflex – in normal infants or adults with corticospinal tract damage.

**Clinical Applications**

The corticospinal tracts appear to be particularly important for voluntary, complex movements. For example, speech is impaired if there is damage to the corticospinal tracts in the thoracic (chest) region of the spinal cord, whereas involuntary breathing continues. Damage to the corticospinal tracts can be medically tested by the presence of the Babinski reflex. In this test, the sole of the foot is stimulated in a particular way that causes normal adults to produce a downward flexion, or curling, of the toes. When normal infants or adults with damage to their corticospinal tracts are stimulated in this way, they produce the Babinski reflex: their toes fan and their great toe extends upward.

The **Babinski reflex** is dorsiflexion (splaying) of toes when plantar surface of foot is stroked. **Normal in babies** (click HERE) but abnormal in adults.

**In adults**, plantarflexion (curling) of toes is normal when stroke plantar surface of foot (Click HERE). Babinski reflex is abnormal.
Review

- **Spinal cord structure, spinal roots, and spinal nerves.**
  > diff division of white and gray matter between brain & spinal cord.
  > spinal cord has dorsal & ventral horn (sensory Vs motor info)
  > spinal horns give rise to spinal roots
  > dorsal root of spinal cord provides “dermatome”
  > Shingles

- **Ascending & Descending tracts of spinal cord.**