Ch. 4, part 2: Central Nervous System

PowerPoint updated 2/9/25

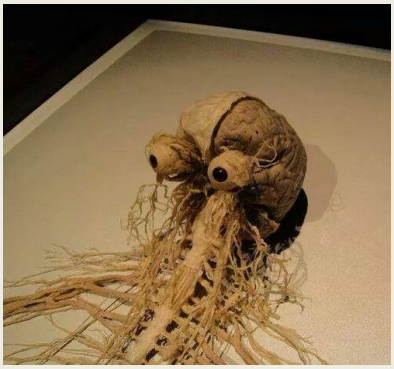
Objectives:

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**

1

Anatomy Review!

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



PNS = other nervous tissue outside CNS

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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

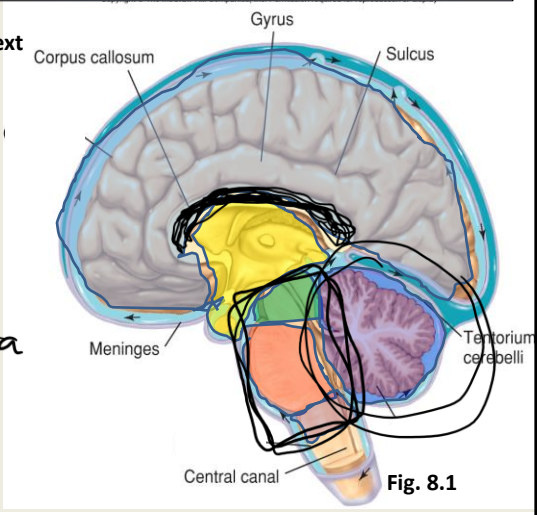


Fig. 8.1

Ques:

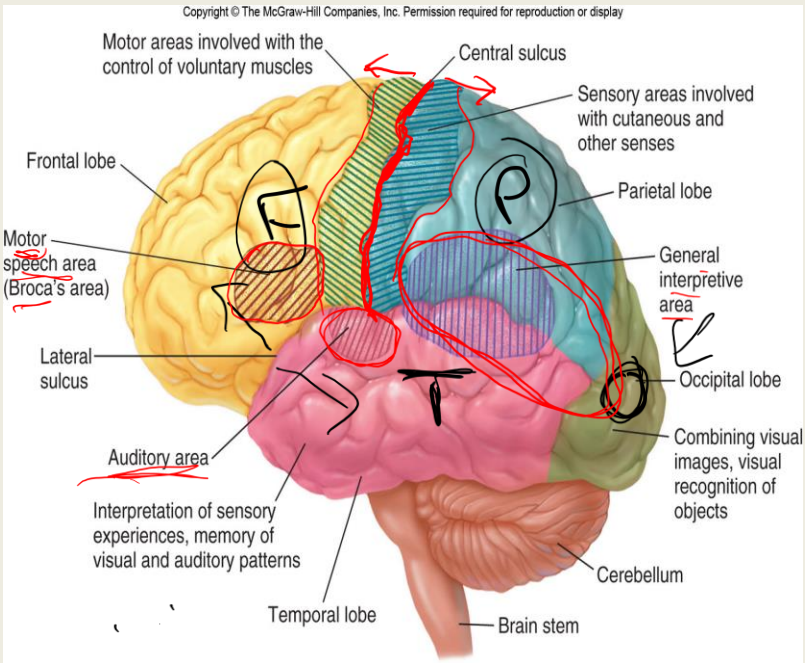
What 3 brain regions make up the "brainstem"

Midbrain, Pons, Medulla

3

Region 1: Cerebrum (Forebrain)

Pg 58 -59 Wiki text



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Region 1: Cerebrum (Forebrain)

6 Cerebral Lobes and their major cortexes = gray matter that receives sensory or motor feedback, interprets info, & if needed sends out motor command.

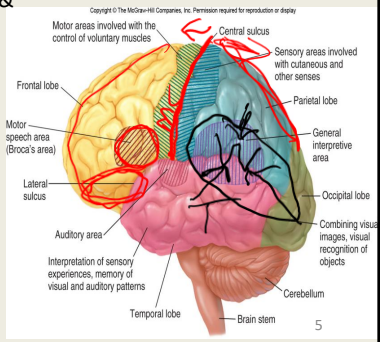
1. Frontal Lobe:
Has **Motor cortex (precentral gyrus)** – voluntary motor control
Has **Broca's motor speech area** – motor control for speech Has
Prefrontal cortex – higher thinking, sense of self, primal emotions.

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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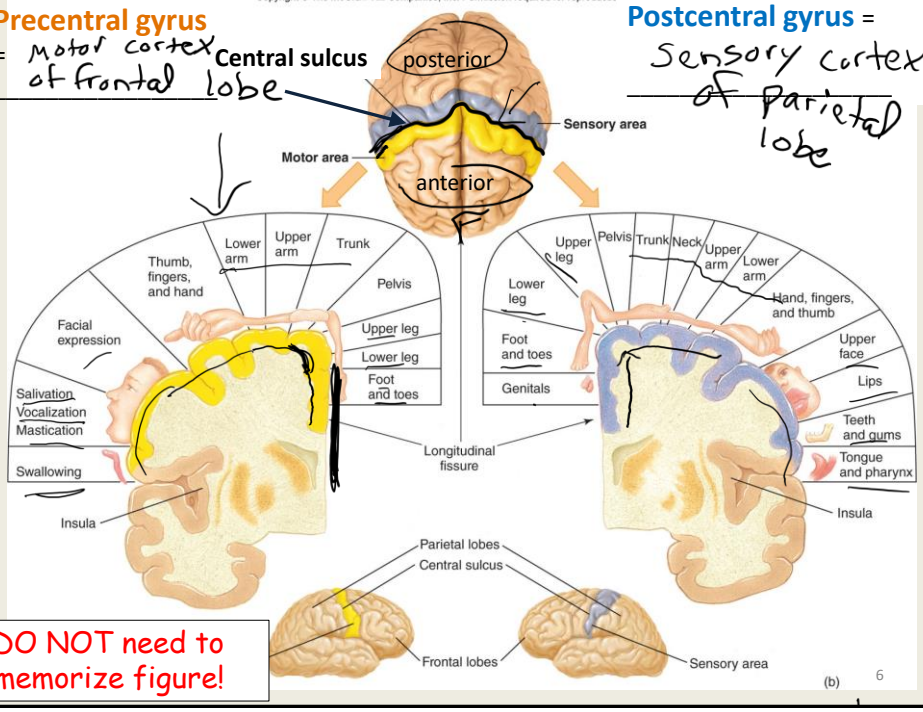
Precentral gyrus = motor cortex of frontal lobe

Central sulcus

Postcentral gyrus = Sensory cortex of Parietal lobe



DO NOT need to memorize figure!

6

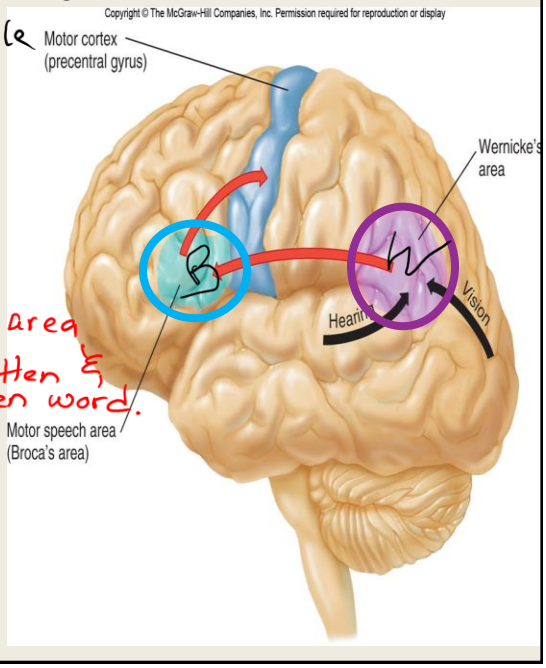
6

Cerebrum & Language

Pg 64 -65 Wiki Text

- **Broca's area:** motor muscle control of speech.

- **Wernicke's area:** Language area (pronounced "vernicka") for understanding written & spoken word.



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

Broca's aphasia = (non-fluent aphasia)

Understand language, BUT hard time getting words out.

Click **HERE** for YouTube video of patient with Broca's aphasia

Wernike's aphasia = (fluent aphasia)

Can speak clearly (words come out easy), BUT language understanding problem. Gibberish. "Word salad"

I have aphasia

Click **HERE** for YouTube video of patient with Wernike's aphasia

Click HERE for FMU's Speech Pathology Program

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Cerebrum & Sleep

rapid eye movement

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. awareness of unimportant stimuli

b. skeletal muscles – so you don't get up & move around when unconscious.

Sleep twitch = "myoclonus"

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

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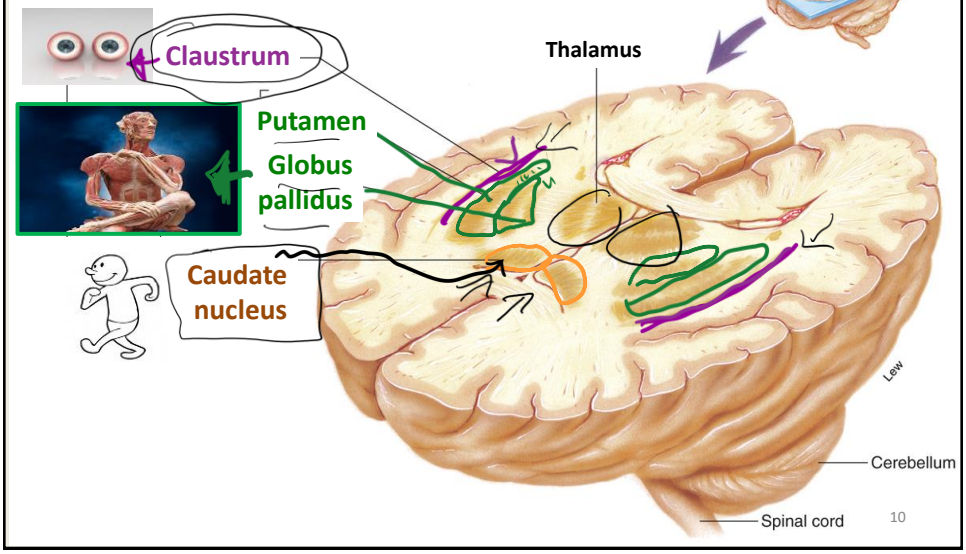
Cerebral Basal Nuclei (Ganglia) & Motor function:

- 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.



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Cerebral Basal Nuclei (Ganglia) & Motor function:

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MOTOR Effects of cerebral basal nuclei: ***Updated 2/13/25***

- Maintaining purposeful motor activity but inhibit unwanted activity
- Monitor & coordinate slow sustained muscle contractions

1. Claustrum – control movement & balance with visual feedback. May play role in consciousness & awareness. When you close your eyes, it was hard to stay balanced.

2. Putamen – movement learning, planning, & execution. Communicates with substantia nigra of midbrain, and globus pallidus. Damage associated w/Parkinson's.
Click HERE for disorders of putamen. **Put a** plan in place to move.

3. Globus pallidus – important for conscious movement (mostly by inhibiting unwanted movement). Damage to it associated w/tremors, jerks, & chorea (involuntary movement)

4. Caudate nucleus – regulate rhythmic swinging of arms & legs while moving. Communicates with substantia nigra of midbrain. Is attached to putamen (together they're called the striatum).
[Degeneration of neurons here associated w/**Huntington's Chorea**

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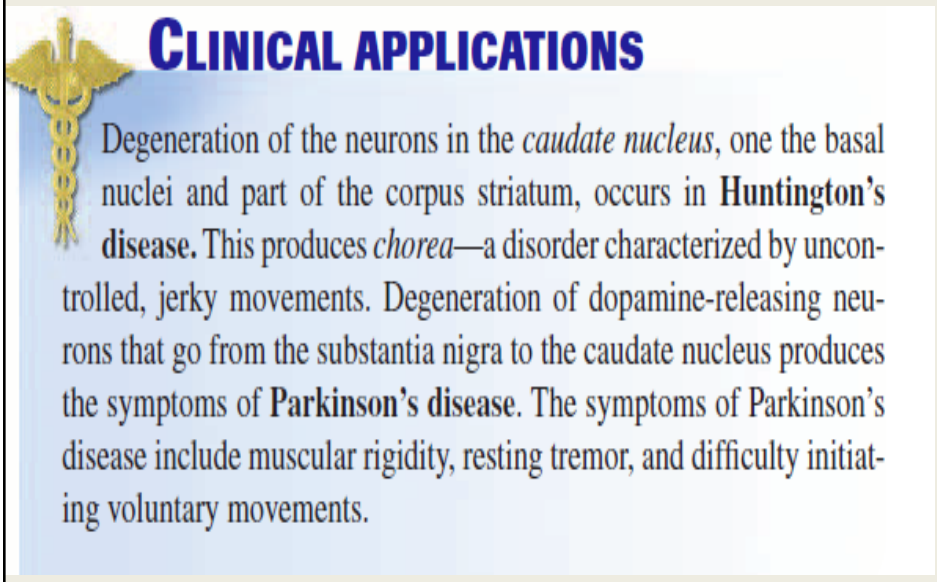

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Cerebral basal nuclei & Emotions : The limbic system

Cerebral nuclei work with hypothalamic and thalamus nuclei to process primal emotions & behavioral drives. **Pg 60 Wiki Text**

Limbic effects of cerebral nuclei :

Amygdala – fear center. AAAAAhhh! So scary

Cingulate gyrus (above corpus callosum) = forms associations between behaviors and positive or negative outcomes. Could Go either way + or - experience

Septal nuclei (below corpus callosum) = forms associations between behavior and positive (pleasurable) outcomes.

Diencephalon structures:

Hypothalamus = see later slides

Thalamus = relay station for ascending and descending information.

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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)

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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!

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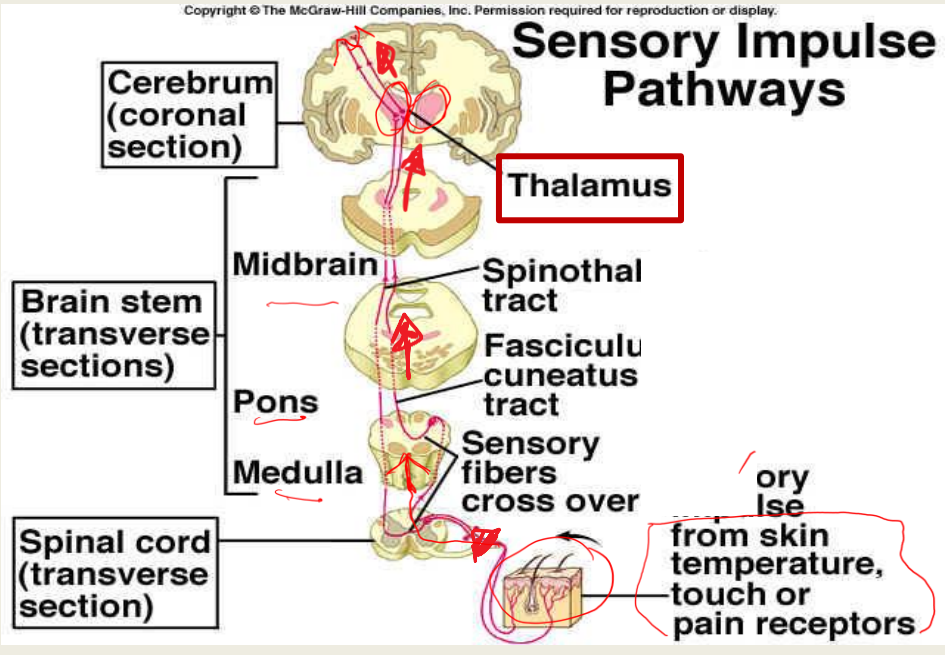
Brain Region 2: Diencephalon (forebrain) – the thalamus



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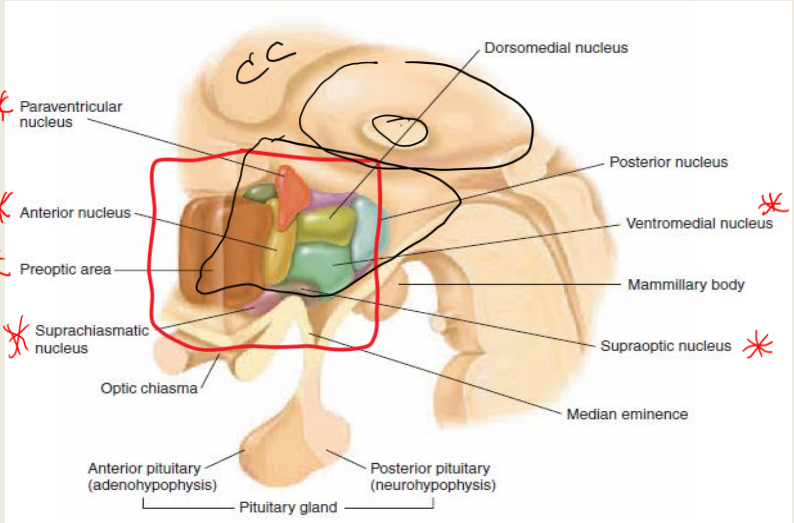
Hypothalamus nuclei & functions:

- **Link between nervous & endocrine systems**
- **Controls pituitary gland**
- **Controls autonomic sympathetic response of body** - adrenal medulla's production of epinephrine during fight/flight.



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Hypothalamus nuclei & functions:

Has nuclei that functions in homeostasis: → Anti-diuretic hormone – makes you retain water.

Supraoptic = Secretes ADH

Paraventricular = Secretes oxytocin

Anterior = regulating body temperature
Antarctica

Ventromedial
Venus
>fullness (satiety) center,

>fear, aggression, & reproductive (GnRH)

the 4 F's: Fight, Flight (Fear), Feeding, & Fornicating

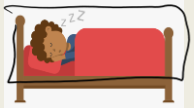
Lateral = regulating hunger

Updated 2/27

P - pacific
O - ocean

Preoptic = thirst drive when dehydrated.

Suprachiasmatic = regulates day/night cycle (circadian rhythm)



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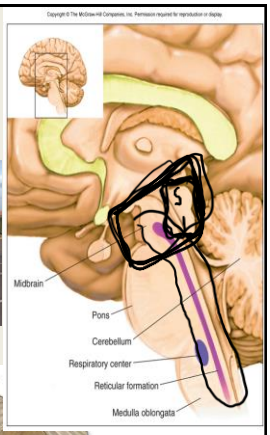
Brain Region 3: Midbrain



1. Superior colliculus = regulates reflex response to visual info.

2. Inferior colliculus = reflex turning towards unexpected sound.

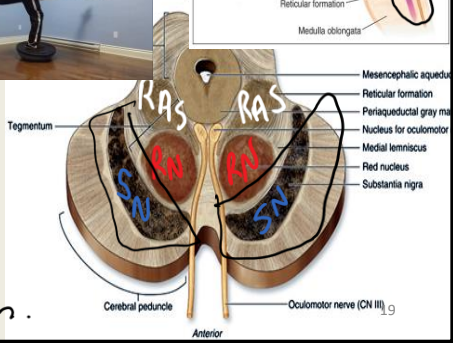
3. Red nucleus = motor coordination of postural muscles.

4. Substantia nigra:

> Nigrostantial dopamine system –
produces dopamine involved in fine motor control.

> Mesolimbic dopamine system –
plays role in addiction.

5. Part of RAS – reticular activating system.



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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

CLINICAL APPLICATION

The positive reinforcement elicited by **abused drugs** involves the release of dopamine by axons of the mesolimbic system. These axons arise in the midbrain and terminate in the nucleus accumbens of the forebrain, deep in the frontal lobe. *Nicotine* from tobacco stimulates dopaminergic neurons in the midbrain by means of nicotinic ACh receptors. Chronic exposure to nicotine desensitizes the nicotinic ACh receptors in the midbrain, contributing to nicotine tolerance and increased dependence. The opioids (*heroin* and *morphine*) stimulate opioid receptors, and the *cannabinoids* (from marijuana) stimulate endocannabinoid receptors in the midbrain. This leads to reduced activity of GABA-releasing inhibitory neurons that synapse on the dopaminergic neurons in the ventral tegmental area. Benzodiazepines (*Valium* and *zolpidem*) may similarly reduce the inhibition of these dopaminergic neurons, increasing dopamine release by the mesolimbic dopamine system. *Cocaine* and *amphetamine* promote dopamine stimulation in the nucleus accumbens by inhibiting the reuptake of dopamine into presynaptic axons. Ironically, drug abuse can desensitize neurons to dopamine and so lessen the rewarding effects of dopamine release.

Ethanol (alcohol) stimulates the mesolimbic dopamine pathways, particularly in the nucleus accumbens, but it also affects receptors for other neurotransmitters. These include NMDA (glutamate), GABA, serotonin, nicotinic ACh, opioid, and endocannabinoid receptors. By influencing these receptors, ethanol affects the function of a variety of brain regions including the prefrontal cortex, hippocampus, amygdala, and other structures of the limbic system. Some changes in chronic alcohol abuse are permanent, perhaps because of epigenetic effects (chapter 3) that have recently been demonstrated.

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Brain Regions 4 & 5: Pons & Medulla (hindbrain)

Pons

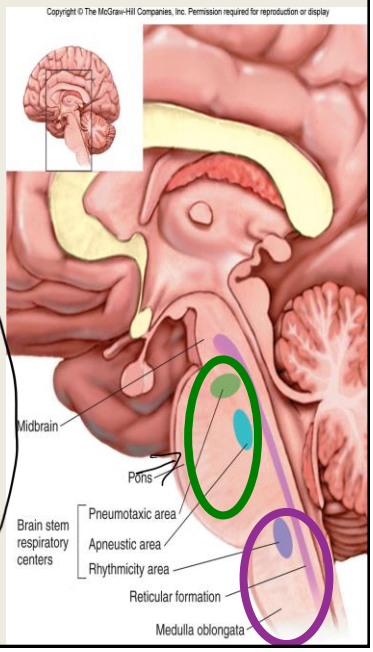
- Some of RAS
- 2 autonomic respiratory centers:
  - Apneustic center
  - pneumotaxic center

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 } regulate BP
2. Vasomotor center }
3. Respiratory center.



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The reticular activating system (RAS)

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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. Norepinephrine +
3. Hypocretin + (low hypocretin with narcolepsy)

Inhibitory (promotes sleep or decreased awareness)

4. GABA −

Read Clinical App Pg 139 and ONLINE:
The effect of drugs on RAS.

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CLINICAL APPLICATION

Many drugs act on the RAS to promote either sleep or wakefulness. Amphetamines, for example, enhance dopamine action by inhibiting the dopamine reuptake transporter, thereby inhibiting the ability of presynaptic axons to remove dopamine from the synaptic cleft. This increases the effectiveness of the monoamine-releasing neurons of the RAS, enhancing arousal. The antihistamine *Benadryl*, which can cross the blood-brain barrier, causes drowsiness by inhibiting histamine-releasing neurons of the RAS. (The antihistamines that don't cause drowsiness, such as *Claritin*, cannot cross the blood-brain barrier.) Drowsiness caused by the benzodiazepines (such as *Valium*), barbiturates, alcohol, and most anesthetic gases is due to the ability of these agents to enhance the activity of GABA receptors. Increased ability of GABA to inhibit the RAS then reduces arousal and promotes sleepiness.

Is also an antagonnist to acetylcholine (ACh)

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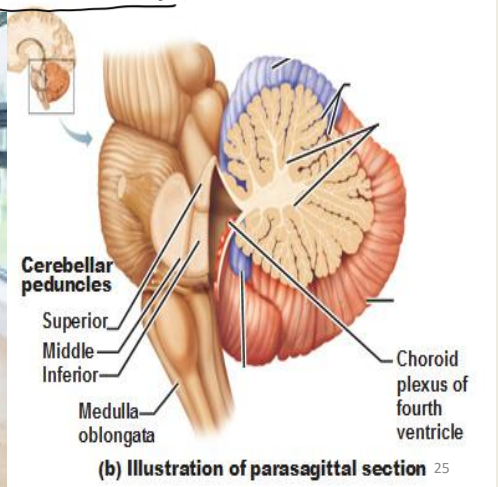
Brain Region 6: Cerebellum (also hindbrain)

- Receives sensory info from proprioreceptors (in joints & muscles) to coordinate muscle movement for **balance & posture.**
- Stores learned motor patterns ("**muscle memory**")



(b) Illustration of parasagittal section 25

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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"

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Cerebella hypoplasia = ↓ growth of cerebellum.
growth

In humans: Click **HERE** for YouTube video (~4 min)

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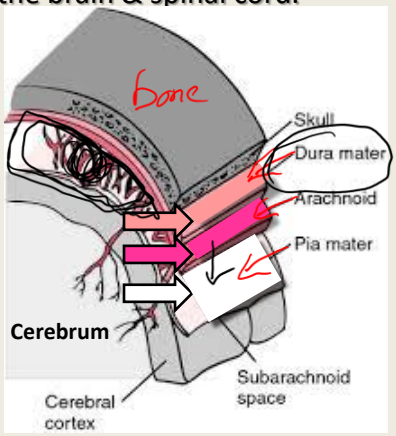
CNS Meninges = membranes the cover the brain & spinal cord.

3 Meninges:

1. **Dura mater =** outermost
2. **Arachnoid mater =** middle
3. **Pia mater =** innermost (part blood brain barrier)



Common drugs that are lipid-soluble & cross BBB…

- **Ethanol**
- **Nicotine**
- **caffeine**
- **Tetrahydro-cannabinol (THC)**
- ***anesthetics***

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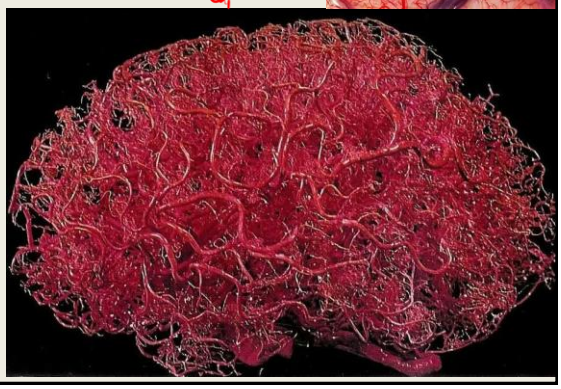
Brain blood supply:

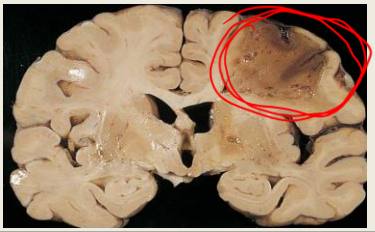
> Uses 15% of arterial blood supply
> Uses 50% of blood glucose!
> Few minutes of "ischemia" = brain tissue death!

Ischemia = loss of blood flow to a part of the body.

Stroke = loss of blood flow to the brain.



Necrosis typical of Ischemic stroke



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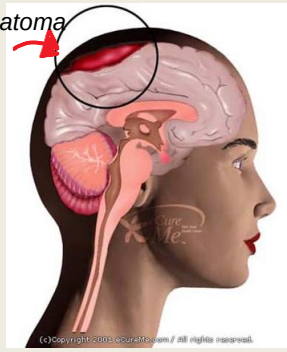
Acute Cerebral Hemorrhage (Hematoma)

Subdural 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)

http://www.iflscience.com/brain/watch-neurosurgeon-perform-subdural-hematoma-operation

Intra-Cerebral Hemorrhage 31

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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

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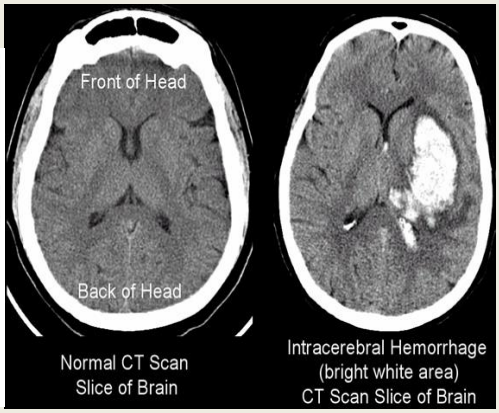
2) CT Scan = multiple x-ray beams sent through body, and tissue of different densities are analyzed by a computer to produce high quality images of tissues. Can show "slices" through a tissue. (computed tomography)

- Expensive (national average cost = $1,200, but depending on city and insurance can be more or less)
- Good for viewing soft tissue



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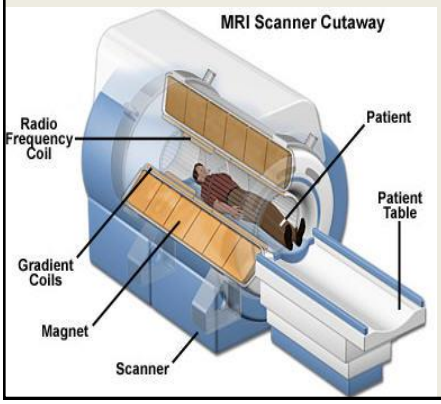
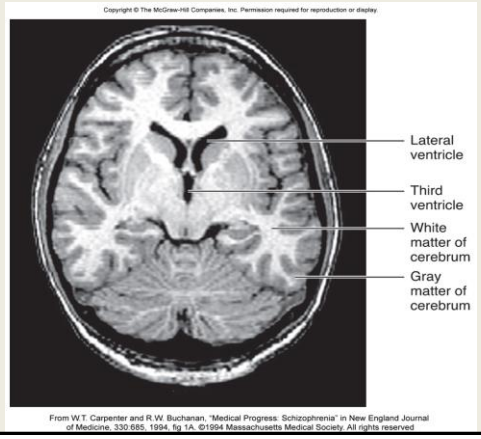
3) MRI Scan = uses a powerful magnetic field and pulses of radio wave energy to make pictures of tissues. (magnetic resonance imaging)

- 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…)





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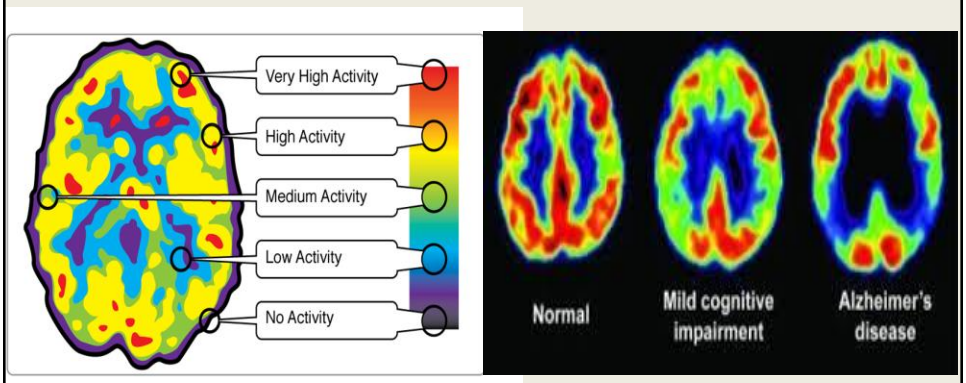
4) PET scan = uses radioactive glucose tracer to determine how tissues are working. (positron emission tomography)

- 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



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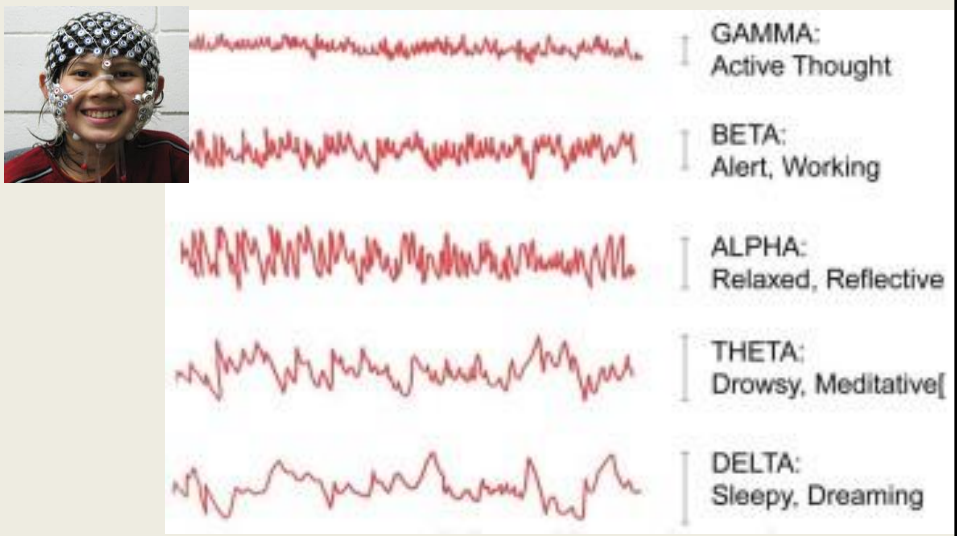
5) EEG = Brain neuron activity measured with electrodes placed on scalp. (electroencephalogram)



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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

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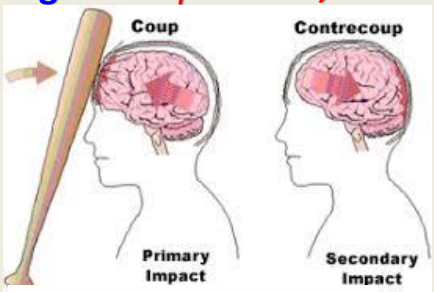
Blunt force injury to brain and hemorrahge and/or brain swelling *slide updated 2/17*

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



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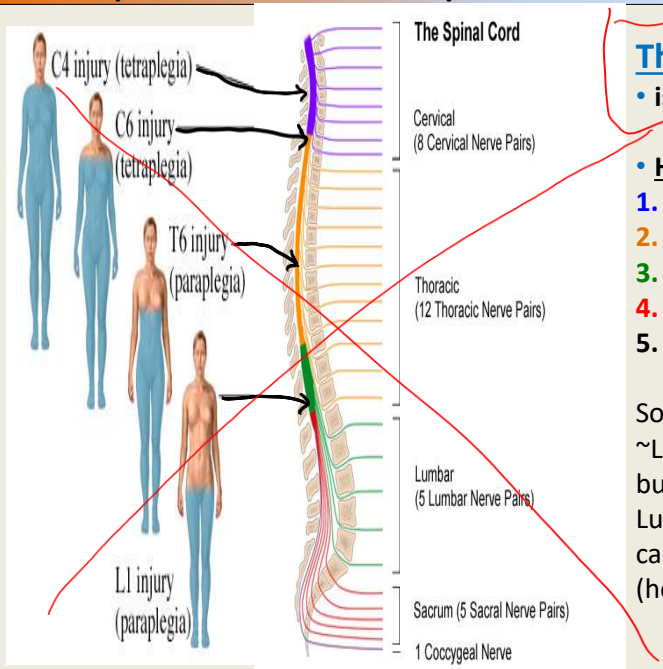
Part 4. Spinal chord structure, spinal roots, and spinal nerves.



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).

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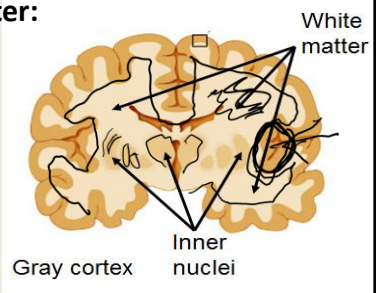
CNS Division of White Matter Vs Gray Matter:

(typos corrected 2/17)



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

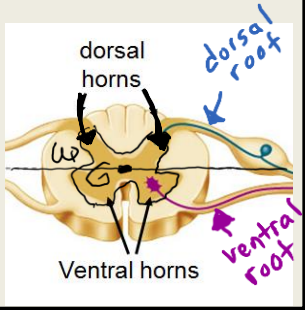
> **In brain** – white matter found interior

> **In spinal cord** – 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 cord** – gray matter in center marks end of CNS, has butterfly shape.



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

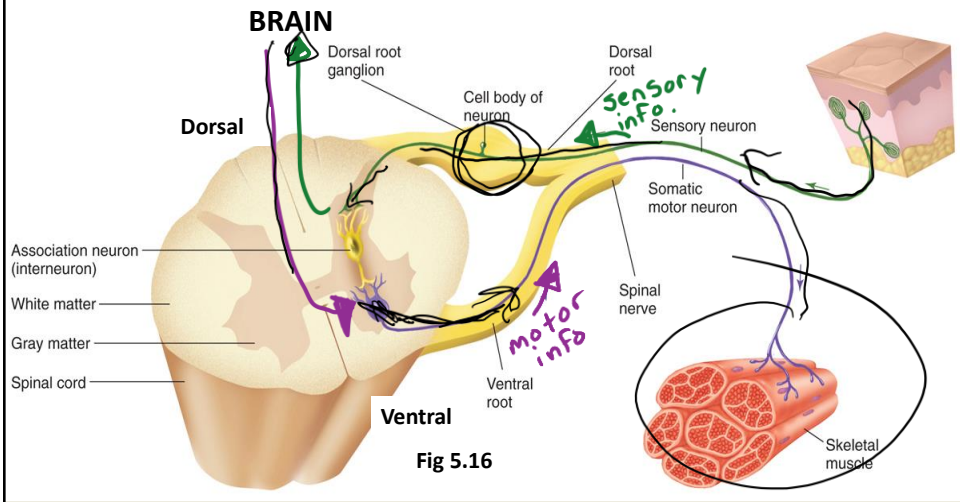

Fig 5.16

> 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.)

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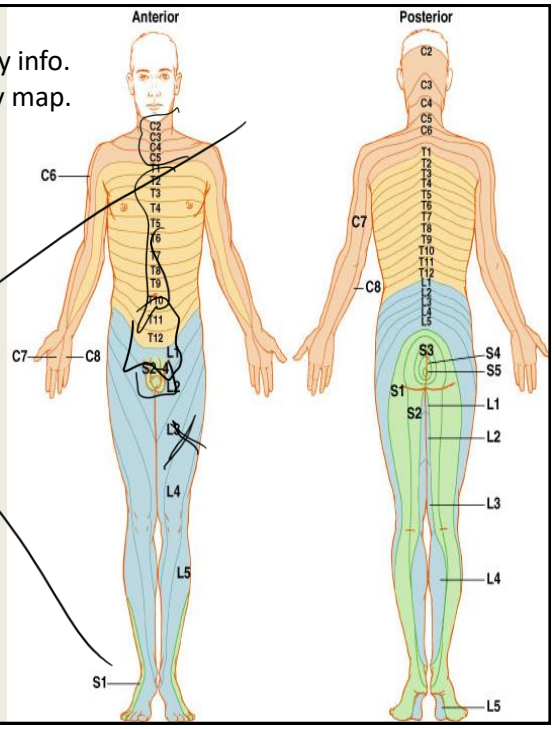
Dorsal spinal roots receive sensory info.
Dermatome = Skin's sensory body map.

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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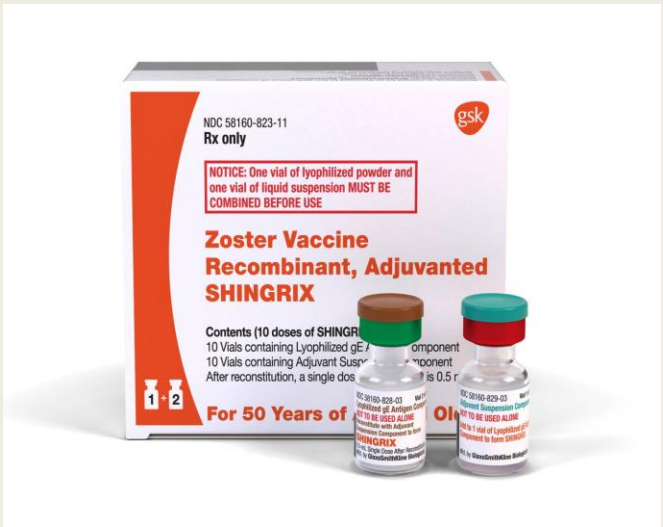
There is now a Shingles vaccine.
CDC recommends 2 doses, spaced 2 – 6 months apart



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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 parietal sensory cortex (postcentral gyrus)
- ~~Ex. *spinothalamic tracts*~~
  - Carry signals to thalamus

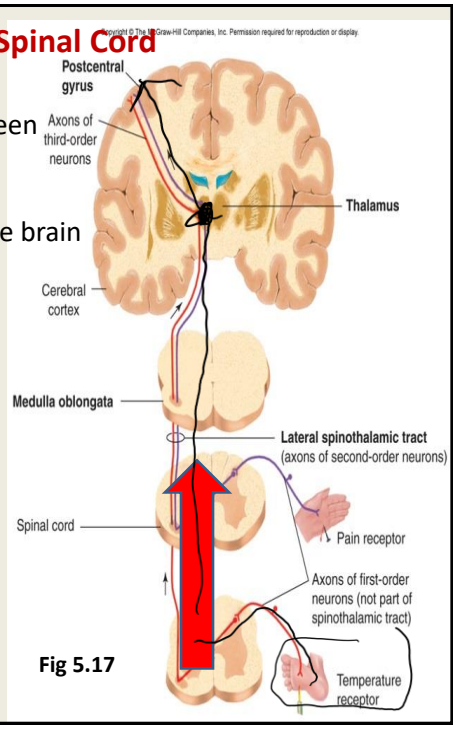

Fig 5.17

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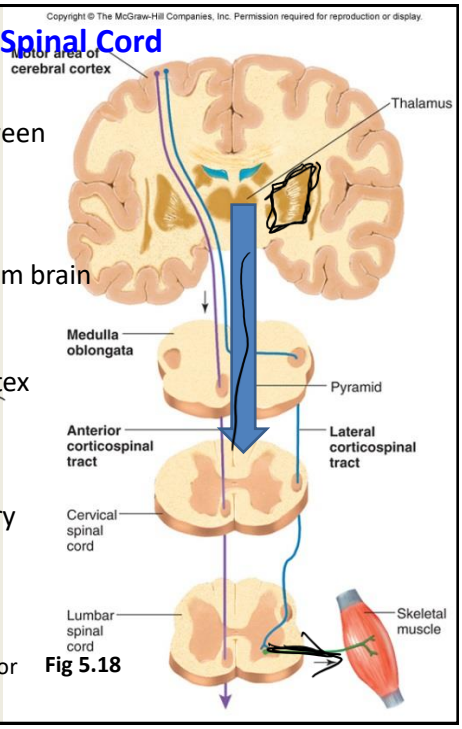
Ascending & Descending Tracts of Spinal Cord

- 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.



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

Fig 5.18

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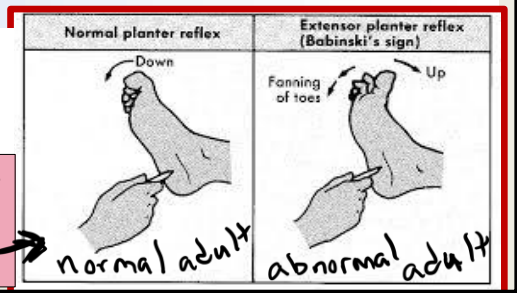
CLINICAL APPLICATIONS

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.



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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.**
  Babinski reflex

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