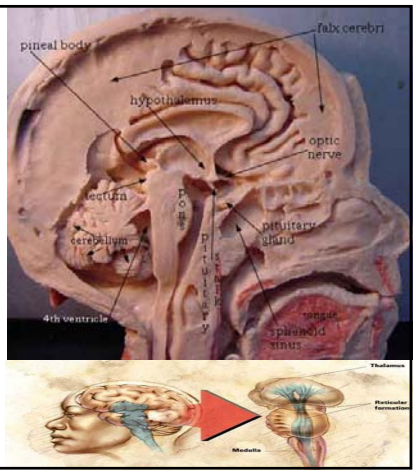
The Brain

Danil Hammoudi.MD



http://publish.uwo.ca/~jkiernan/neuslide.htm

Cell bodies in CNS: nuclei

Cell bodies in PNS: ganglia

Nerves: bundles of axons!

Divisions of the Human Brain:

1 - Myelencephalon, which includes the medulla

2 - Metencephalon, which includes the pons and cerebellum

3 - Mesencephalon, which includes the midbrain (tectum and tegmentum)

4 - Diencephalon, which includes the thalamus and hypothalamus

5 - Telencephalon, which includes the cerebrum (cerebral cortex, basal ganglia, & medullary body)

New Terms: Brain Division

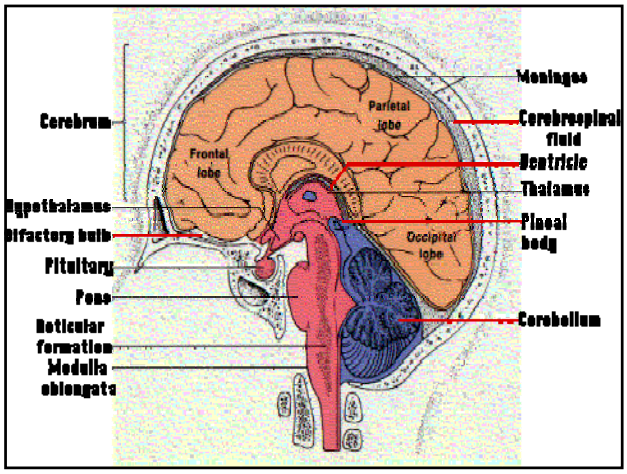
Telencephalon | Diencephalon | Mesencephalon | Metencephalon | Myelencephalon

Telencephalon
- –Cerebral Cortex
- –Limbic system
- –Basal Ganglia

Pons:

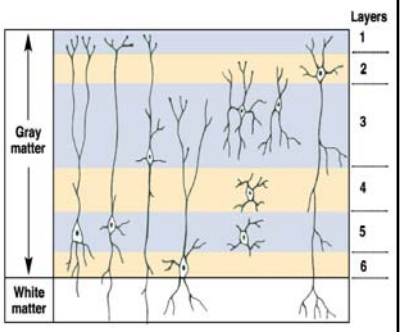
Cerebellum:

Medulla



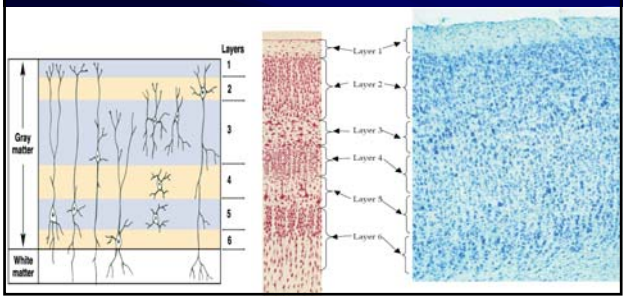
Cerebral Cortex

- Allows for sensation, voluntary movement, self-awareness, communication, recognition, and more.
- Gray matter!
- 40% of brain mass, but only 2-3 mm thick.
- Each cerebral hemisphere is concerned with the sensory and motor functions of the opposite side (a.k.a. contralateral side) of the body.



The standard areas of cortex (isocortex) is characterized as having six distinct layers. From outside inward:

1. Molecular layer
2. External granular layer
3. External pyramidal layer
4. Internal granular layer
5. Internal pyramidal layer
6. Multiform layer.



I-Molecular layer or plexiform layer: Contains few cells and a rich nerve fiber plexus made up of axons and dendrites of cells in other laminae as well as cells in this lamina.

II-External granular layer: Closely packed small neurons.

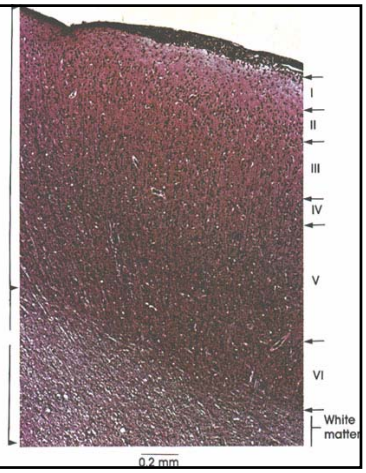
III-External pyramidal layer: Composed mainly of pyramidal neurons and many granule cells and cells of Martinotti.*

IV-Internal granular layer: Composed chiefly of stellate cells that are closely packed.

V-Internal pyramidal or ganglionic layer: Consists of medium-sized and large pyramidal cells intermingled with granule cells.

VI-Multiform layer or layer of fusiform cells: Contains a variety of cell types.

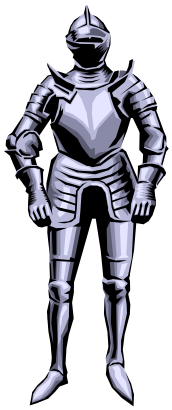
White matter: Contains incoming and outgoing nerve fibers.



Structures of the Brain:

Protection

- What is the major protection for the brain?
- There are also 3 connective tissue membranes called the meninges:
  - Cover and protect the CNS
  - Protect blood vessels
  - Contain cerebrospinal fluid
- The 3 meninges from superficial to deep:
  - Dura mater
  - Arachnoid mater
  - Pia mater



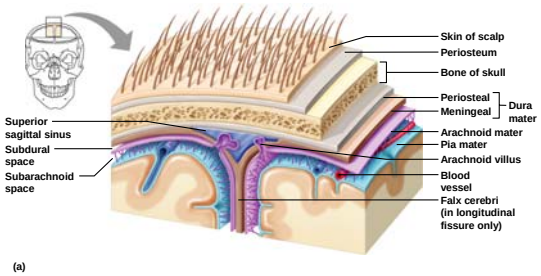
MENINGES

Dura Mater
- Leathery, strong meninx composed of two fibrous connective tissue layers
- The two layers separate in certain areas and form dural sinuses
- Three dural septa extend inward and limit excessive movement of the brain
- Falx cerebri – fold that dips into the longitudinal fissure
- Falx cerebelli – runs along the vermis of the cerebellum
- Tentorium cerebelli – horizontal dural fold extends into the transverse fissure

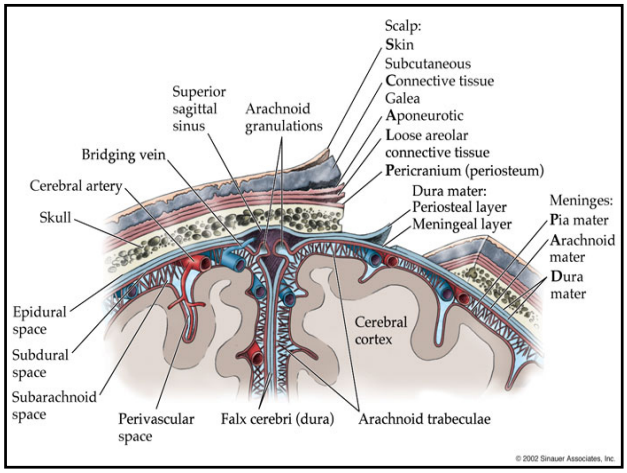
Arachnoid Mater
- The middle meninx, which forms a loose brain covering
- It is separated from the dura mater by the subdural space
- Beneath the arachnoid is a wide subarachnoid space filled with CSF and large blood vessels
- Arachnoid villi protrude superiorly and permit CSF to be absorbed into venous blood

Pia Mater
- Deep meninx composed of delicate connective tissue that clings tightly to the brain

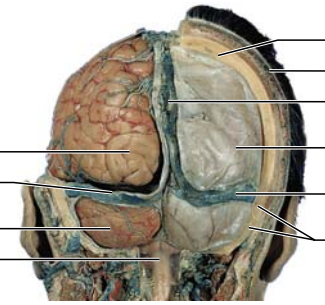
Meninges,



(a)



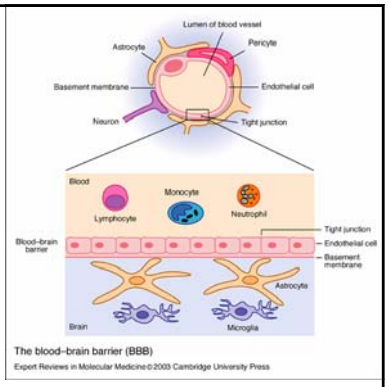
Meninges,

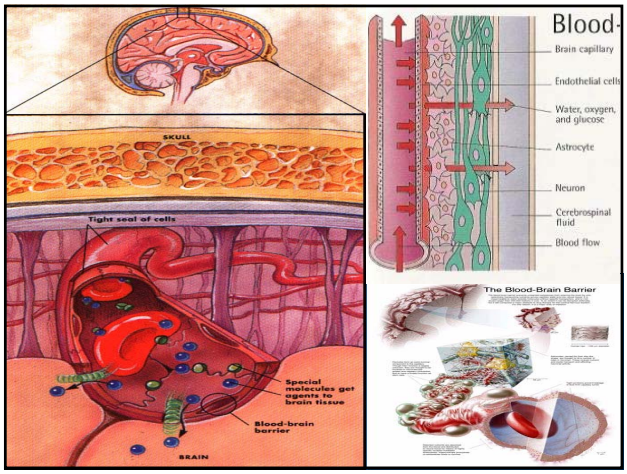


(b)

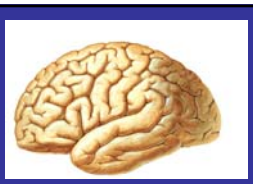
Blood-Brain Barrier
Protective mechanism that helps maintain a stable environment for the brain
Bloodborne substances are separated from neurons by:
Continuous endothelium of capillary walls
Relatively thick basal lamina
Bulbous feet of astrocytes

Blood-Brain Barrier: Functions
Selective barrier that allows nutrients to pass freely
Is ineffective against substances that can diffuse through plasma membranes
Absent in some areas (vomiting center and the hypothalamus), allowing these areas to monitor the chemical composition of the blood
Stress increases the ability of chemicals to pass through the blood-brain barrier





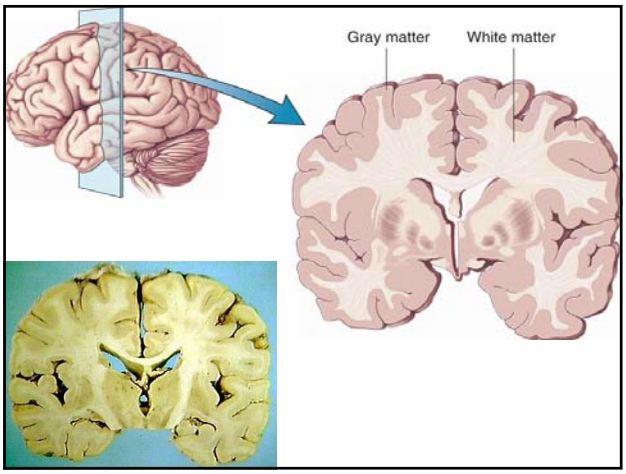
Cerebral Cortex



- 3 types of functional areas:
  1. Motor → Control voluntary motor functions
  2. Sensory → Allow for conscious recognition of stimuli
  3. Association → Integration

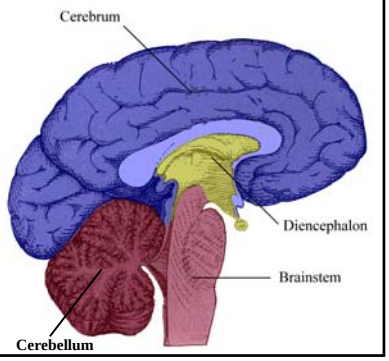
Gray and White Matter

- Microscopically, the CNS contains 2 neural elements:
  - Neuron cell bodies (clusters are known as nuclei)
  - Nerve fibers (axons) in bundles called tracts.
- Viewed macroscopically, CNS tissues can be distinguished by color:
  - Gray matter consists of somata, dendrites, and unmyelinated axons.
  - White matter consists primarily of myelinated axons.



Brain Regions

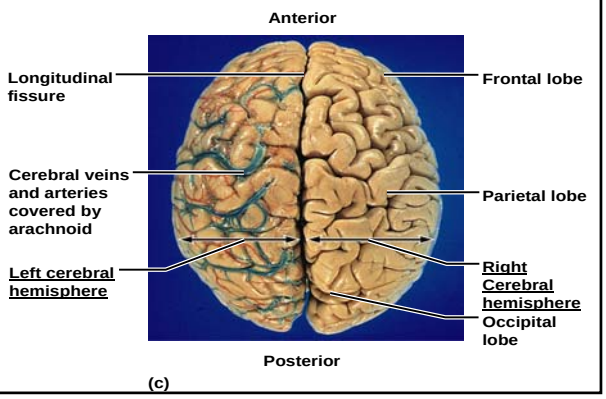
1. Cerebrum
2. Diencephalon
3. Brainstem
4. Cerebellum



Cerebrum -The largest division of the brain.

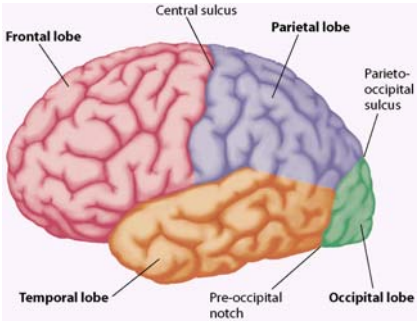
- The cerebrum is divided in to two hemispheres, the right and left hemispheres each of which is divided into four lobes
- The dividing point is a deep grove called the longitudal cerebral fissure.
- The different sides of the cerebrum do different things for the opposite sides of the body.
- The right side of the cerebrum controls things such as imagination and 3-D forms.
- The other side of the brain, the left side, controls numbering skills, posture, and reasoning.

Lobes and fissures of the cerebral hemispheres,



Major Structures of the Cortex

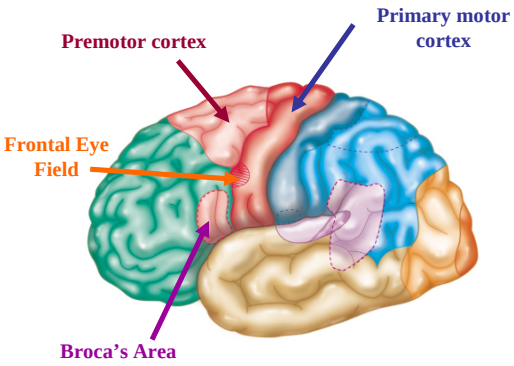
- 4 Lobes
  - –Frontal Lobe
  - –Parietal Lobe
  - –Occipital Lobe
  - –Temporal Lobe
- **insula:** forms part of the floor
- Major Fissures
  - –Central Sulcus
  - –Longitudinal Fissure
  - –Sylvian Fissure



- *The lobes are distinguished both structurally and functionally*

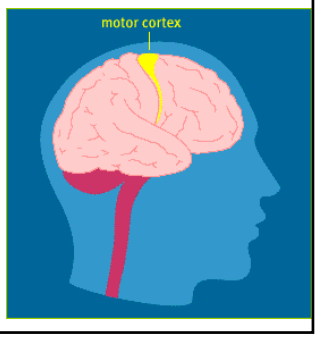
Cortical Motor Areas

1. Primary Motor Cortex
2. Premotor Cortex
3. Broca's Area
4. Frontal Eye Field



Primary (Somatic) Motor Cortex

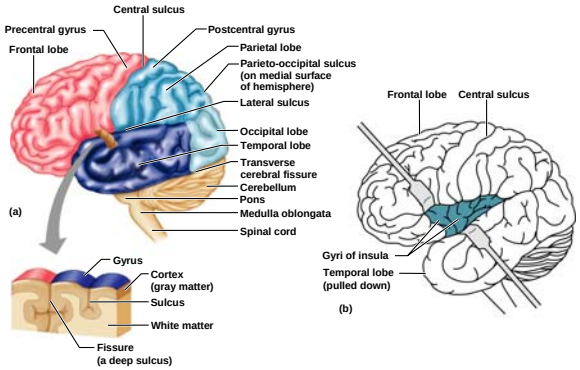
- Located in the precentral gyrus of each cerebral hemisphere.
- Contains large neurons (pyramidal cells) which project to SC neurons which eventually synapse on skeletal muscles
  - Allowing for voluntary motor control.
  - These pathways are known as the corticospinal tracts or pyramidal tracts.

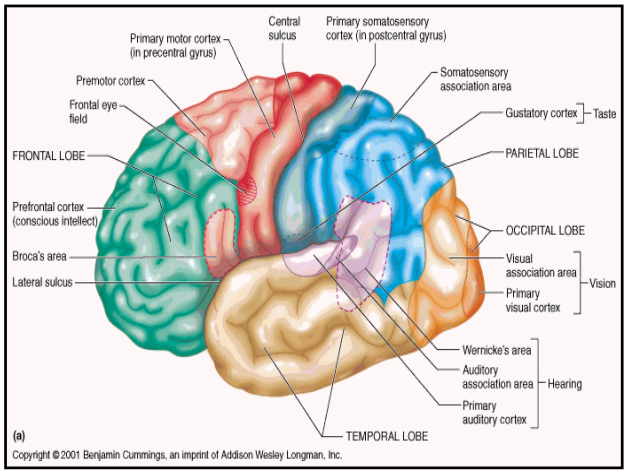


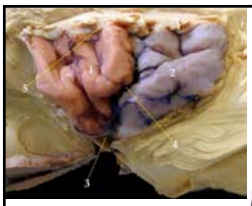
Primary (Somatic) Motor Cortex

- Somatotopy
  - The entire body is represented spatially in the primary motor cortex, i.e., in one region we have neurons controlling hand movements and in another region leg movements, etc.
    - Neurons controlling movement of different body regions do not intermingle.
- What does it mean to say that motor innervation is contralateral?
- Let's look at the motor homunculus.

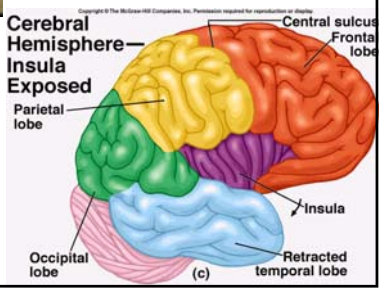
Lobes and fissures of the cerebral hemispheres,.

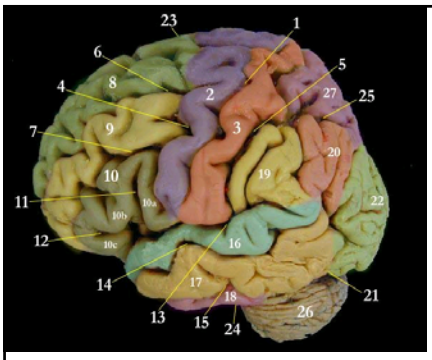






1.Gyri breves insulae
2.Gyri longi insulae
3.Limen insulae
4.Sulcus centralis insulae
5.Sulcus circularis insulae





1.Sulcus centralis
2.Gyrus praecentralis
3.Gyrus postcentralis
4.Sulcus praecentralis
5.Sulcus postcentralis
6.Sulcus frontalis superior
7.Sulcus frontalis inferior
8.Gyrus frontalis superior
9.Gyrus frontalis medius
10.Gyrus frontalis inferior
10a.Pars opercularis
10b.Pars triangularis
10c.Pars orbitalis
Sulcus lateralis
11.Ramus ascendens
12.Ramus anterior
13.Ramus posterior
14.Sulcus temporalis superior
15.Sulcus temporalis inferior
16.Gyrus temporalis supeior
17.Gyrus temporalis medius
18.Gyrus temporalis inferior
19.Gyrus supramarginalis
20.Gyrus angularis
21.Sulcus parietooccipitalis
20+21.Lobulus parietalis inf.
22.Lobus occipitalis
23.Margo superior
24.Margo inferior
25.Sulcus intraparietalis
26.Cerebellum
27.Lobulus parietalis sup.

Cerebral hemisphere (*hemispherium cerebrale*)

•Is defined as one of the two regions of the brain that are delineated by the body's median plane.

•The brain can thus be described as being divided into **left** and **right cerebral hemispheres**. Each of these hemispheres has an outer layer of grey matter called the cerebral cortex that is supported by an inner layer of white matter.

• The hemispheres are linked by the corpus callosum, a very large bundle of nerve fibers, and also by other smaller commissures, including the anterior commissure, posterior commissure, and hippocampal commissure.

•These commissures transfer information between the two hemispheres to coordinate localized functions.

• The architecture, types of cells, types of neurotransmitters and receptor subtypes are all distributed among the two hemispheres in a markedly asymmetric fashion.

• However, it must be noted that, while some of these hemispheric distribution differences are consistent across human beings, or even across some species, many observable distribution differences vary from individual to individual within a given species.

CEREBRAL FEATURES:

• **Gyri** – Elevated ridges "winding" around the brain.

• **Sulci** – Small grooves dividing the gyri

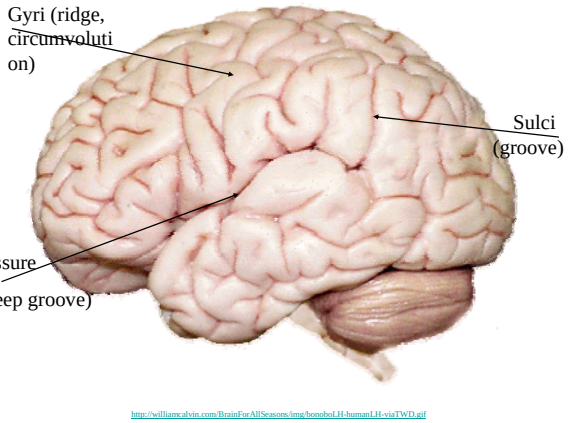
– **Central Sulcus** – Divides the Frontal Lobe from the Parietal Lobe

• **Fissures** – Deep grooves, generally dividing large regions/lobes of the brain

– **Longitudinal Fissure** – Divides the two Cerebral Hemispheres

– **Transverse Fissure** – Separates the Cerebrum from the Cerebellum

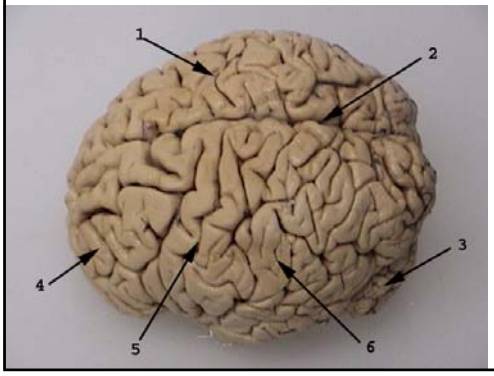
– **Sylvian / Lateral Fissure** – Divides the Temporal Lobe from the Frontal and Parietal Lobes



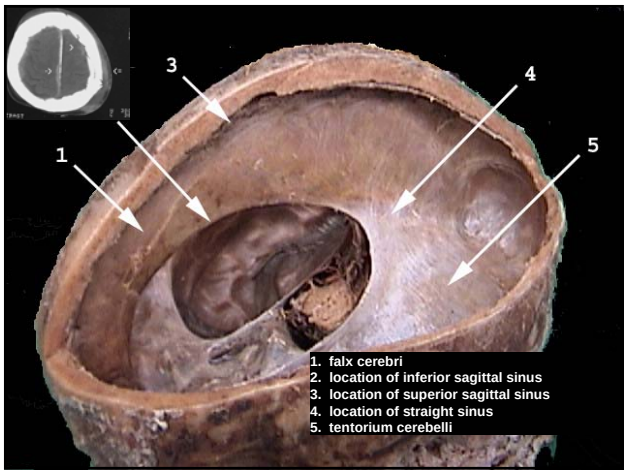
http://williamcalvin.com/BrainForAllSeasons/img/bonoboLH-humanLH-viaTWD.gif

The **medial longitudinal fissure** (or **longitudinal cerebral fissure**, or **longitudinal fissure**, or **interhemispheric fissure**) is the deep groove which separates the two hemispheres of the vertebrate brain.

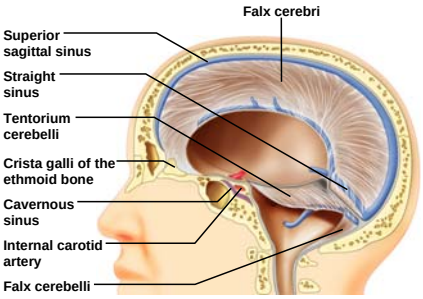
The falx cerebri, a dural brain covering, lies within the medial longitudinal fissure.

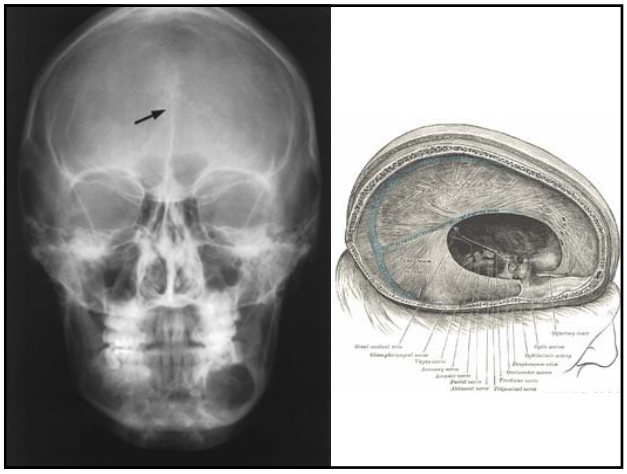


1. right cerebral cortex
2. longitudinal fissure
3. cerebellum
4. frontal lobe
5. central sulcus
6. parietal lobe



Partitioning folds of dura mater in the cranial cavity,

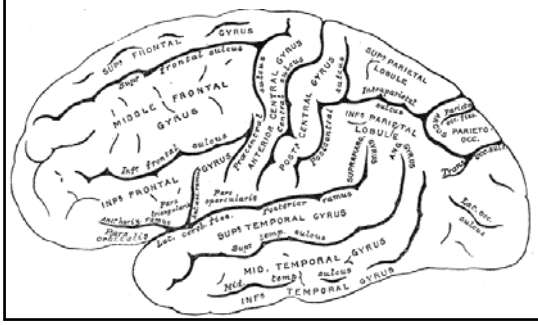




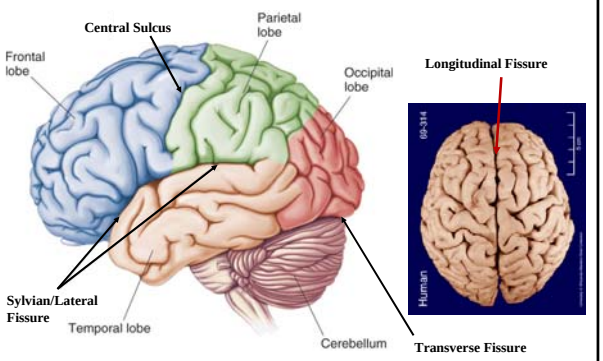
Sulcus a **sulcus** is a depression or fissure in the surface of the brain. It surrounds the gyri, creating the characteristic appearance of the brain in humans and other large mammals.

Large furrows (sulci) that divide the brain into lobes are often called *fissures*.

The large furrow that divide the two hemispheres - the interhemispheric fissure - is very rarely called a "sulcus".



Specific Sulci/Fissures:



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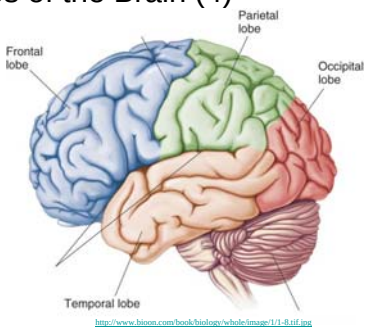
Lobes of the Brain (4)

- Frontal
- Parietal
- Occipital
- Temporal



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* Note: Occasionally, the Insula is considered the fifth lobe. It is located deep to the Temporal Lobe.

Central sulcus= between frontal and parietal lobes.

Frontal lobe:

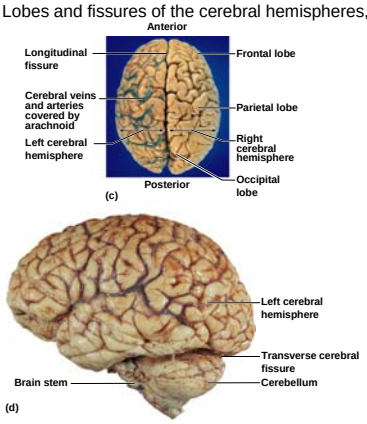
precentral gyrus: motor neurons.

Parietal lobe:

Poscentral gyrus: somatesthetic sensation (cutaneous touch, pain, heat, muscles and joints).

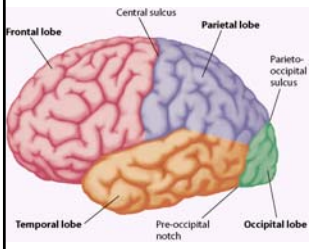
MAP of motor and of sensory control (homunculus)

Lobes and fissures of the cerebral hemispheres,

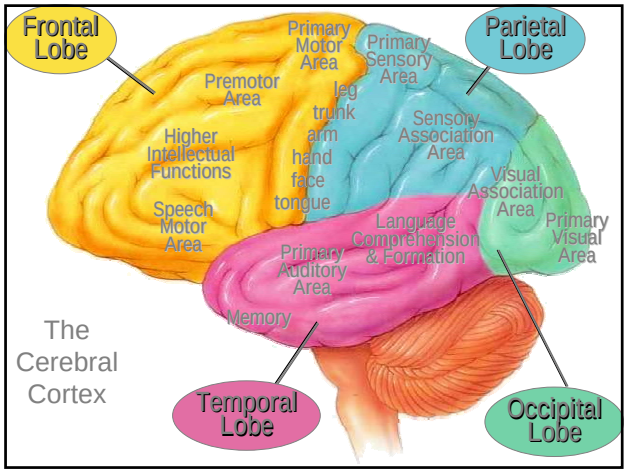


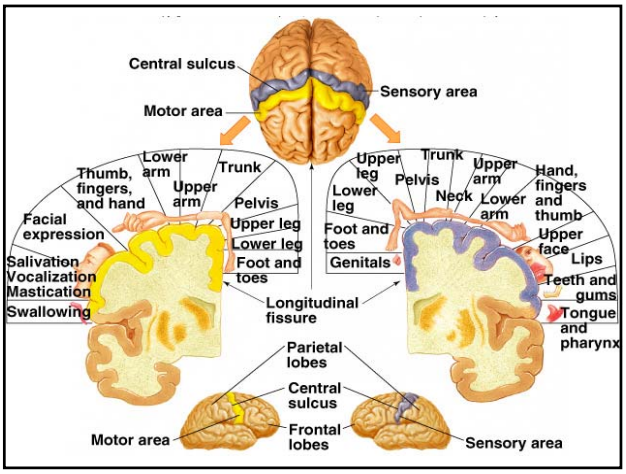
LOBES

Cortical Function

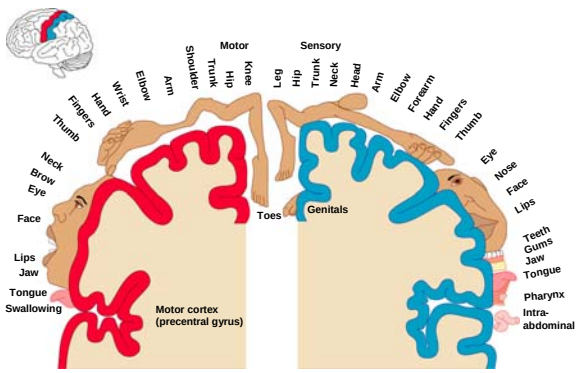


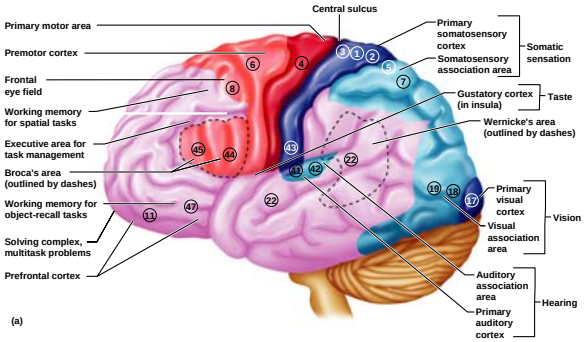
- **Frontal Lobe**
  - **Higher thought processing; decision making; abstract thinking**
  - **Primary "precentral" motor area**
- **Parietal Lobe**
  - **Primary "postcentral" somatosensory area: sensation of muscles, organs, and skin**
- **Occipital Lobe**
  - **Visual processing**
- **Temporal Lobe**
  - **Auditory & equilibrium processing**
  - **Left temporal lobe involved in speech and comprehension of language**





Motor and sensory areas of the cerebral cortex,





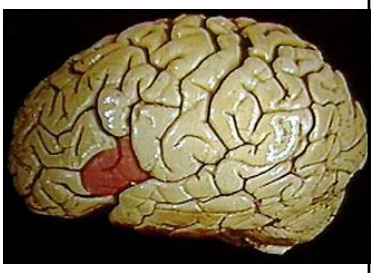
Functional and structural areas of the cerebral cortex, .

Premotor Cortex

- Located just anterior to the primary motor cortex.
- Involved in learned or patterned skills.
- Involved in planning movements.
- How would damage to the primary motor cortex differ from damage to the premotor cortex?

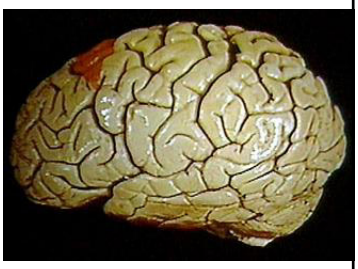
Broca's Area

- Typically found in only one hemisphere (often the left), anterior to the inferior portion of the premotor cortex.
- Directs muscles of tongue, lips, and throat that are used in speech production.
- Involved in planning speech production and possibly planning other activities.



Frontal Eye Field

- Controls voluntary eye movements.
- Found in and anterior to the premotor cortex, superior to Broca's area.
- What muscles would be affected if this area was damaged?

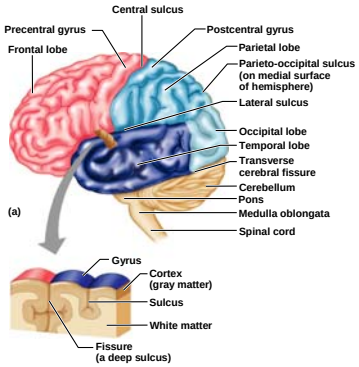


Sensory Areas

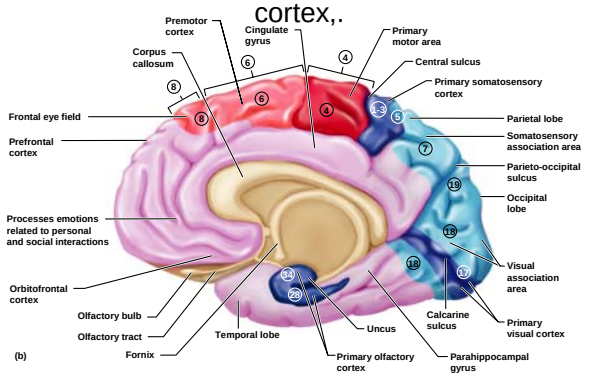
- Found in the parietal, occipital, and temporal lobes.

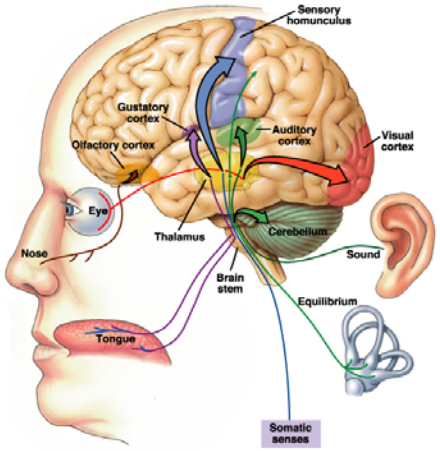
1. Primary somatosensory cortex
2. Somatosensory association cortex
3. Visual areas
4. Auditory areas
5. Olfactory cortex
6. Gustatory cortex
7. Vestibular cortex

Lobes and fissures of the cerebral hemispheres,



Functional and structural areas of the cerebral cortex,.

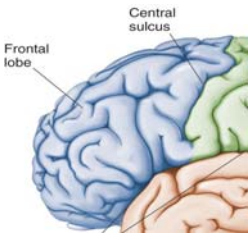




Lobes of the Brain - Frontal

- The Frontal Lobe of the brain is located deep to the Frontal Bone of the skull.
- It plays an integral role in the following functions/actions:
  - Memory Formation
  - Emotions
  - Decision Making/Reasoning
  - Personality

Investigation (Phineas Gage)



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Frontal Lobe - Cortical Regions

• **Primary Motor Cortex (Precentral Gyrus)** – Cortical site involved with controlling movements of the body.

• **Broca's Area** – Controls facial neurons, speech, and language comprehension. Located on ***Left*** Frontal Lobe.

– **Broca's Aphasia** – Results in the ability to comprehend speech, but the decreased motor ability (or inability) to speak and form words.

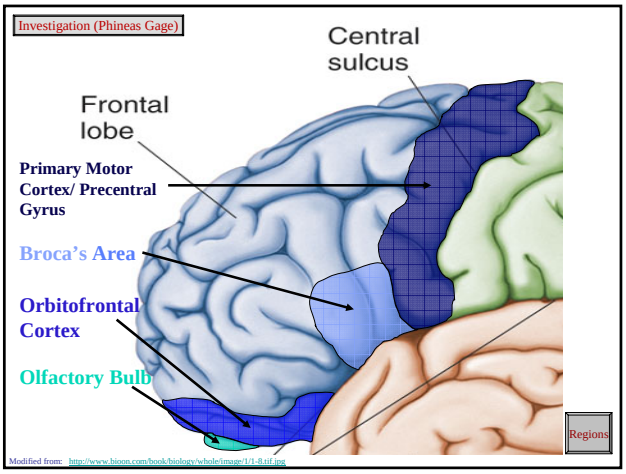
• **Orbitofrontal Cortex** – Site of Frontal Lobotomies

* **Desired Effects:**
- Diminished Rage
- Decreased Aggression
- Poor Emotional Responses

* **Possible Side Effects:**
- Epilepsy
- Poor Emotional Responses
- Perseveration (Uncontrolled, repetitive actions, gestures, or words)

• **Olfactory Bulb** - Cranial Nerve I, Responsible for sensation of Smell

Investigation (Phineas Gage)



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Parietal Lobe - Cortical Regions

• **Primary Somatosensory Cortex (Postcentral Gyrus)** – Site involved with processing of tactile and proprioceptive information.

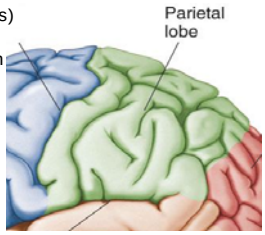
• **Somatosensory Association Cortex -** Assists with the integration and interpretation of sensations relative to body position and orientation in space. May assist with visuo-motor coordination.

• **Primary Gustatory Cortex** – Primary site involved with the interpretation of the sensation of Taste.

Lobes of the Brain - Parietal Lobe

- The Parietal Lobe of the brain is located deep to the Parietal Bone of the skull.
- It plays a major role in the following functions/actions:

  - Senses and integrates sensation(s)
  - Spatial awareness and perception (Proprioception - Awareness of body/ body parts in space and in relation to each other)



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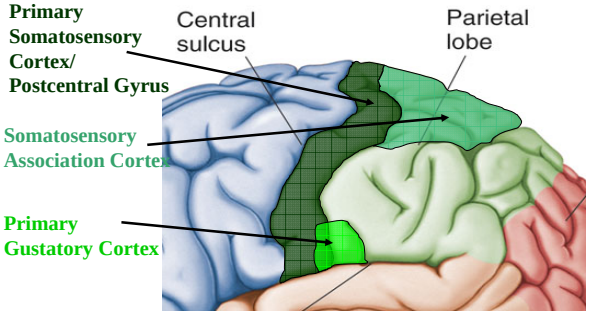

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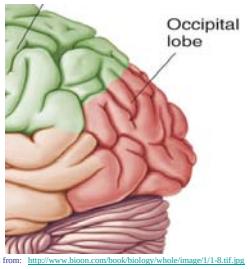
Regions

Lobes of the Brain – Occipital Lobe

- The Occipital Lobe of the Brain is located deep to the Occipital Bone of the Skull.
- Its primary function is the processing, integration, interpretation, etc. of VISION and visual stimuli.



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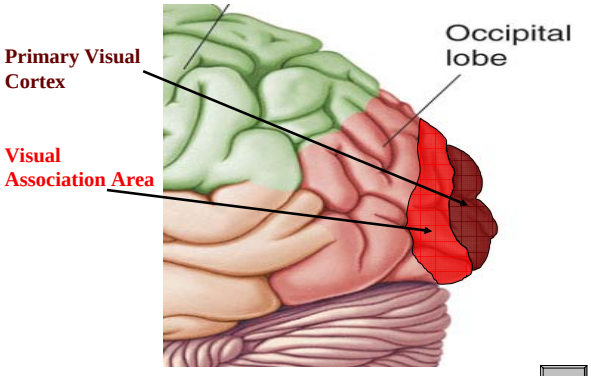
Occipital Lobe – Cortical Regions

- **Primary Visual Cortex** – This is the primary area of the brain responsible for sight -recognition of size, color, light, motion, dimensions, etc.
- **Visual Association Area** – Interprets information acquired through the primary visual cortex.



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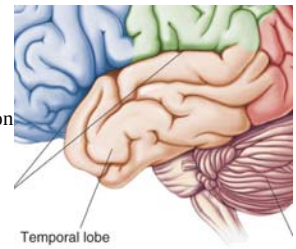
Regions

Lobes of the Brain – Temporal Lobe

- The Temporal Lobes are located on the sides of the brain, deep to the Temporal Bones of the skull.
- They play an integral role in the following functions:

  - Hearing
  - Organization/Comprehension of language
  - Information Retrieval (Memory and Memory Formation)



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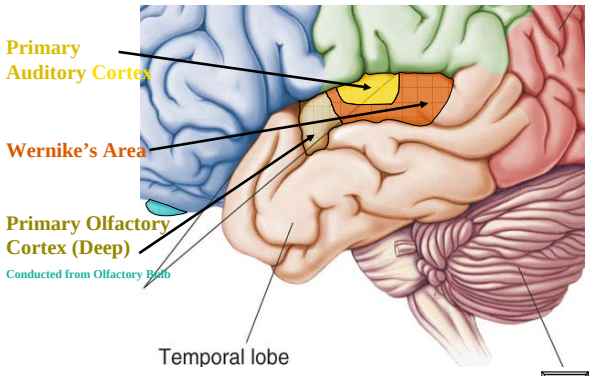
Temporal Lobe – Cortical Regions

- **Primary Auditory Cortex** – Responsible for hearing
- **Primary Olfactory Cortex** – Interprets the sense of smell once it reaches the cortex via the olfactory bulbs. (Not visible on the superficial cortex)

- **Wernicke's Area** – Language comprehension. Located on the ***Left*** Temporal Lobe.

- Wernicke's Aphasia – Language comprehension is inhibited. Words and sentences are not clearly understood, and sentence formation may be inhibited or non-sensical.



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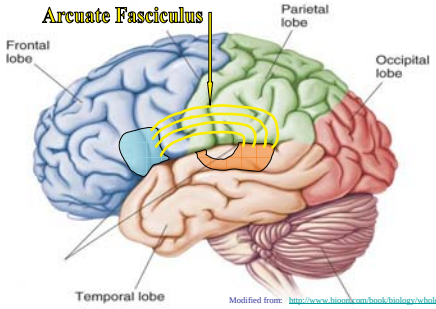
- **Arcuate Fasciculus** - A white matter tract that connects Broca's Area and Wernicke's Area through the Temporal, Parietal and Frontal Lobes. Allows for coordinated, comprehensible speech. Damage may result in:

- Conduction Aphasia - Where auditory comprehension and speech articulation are preserved, but people find it difficult to repeat heard speech.



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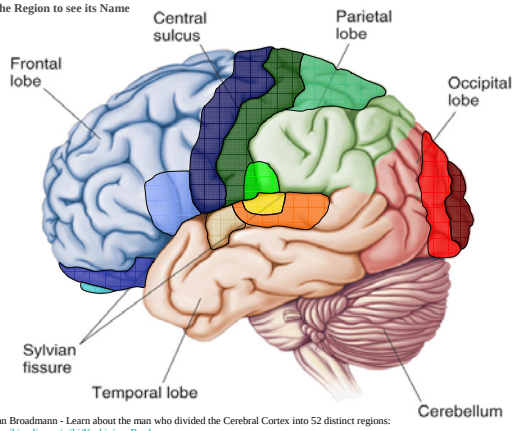
Click the Region to see its Name



Korbinian Broadmann - Learn about the man who divided the Cerebral Cortex into 52 distinct regions: http://en.wikipedia.org/wiki/Korbinian_Brodmann

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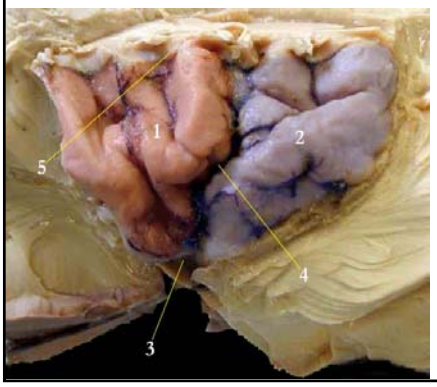
Insular cortex



lies deep to the brain's lateral surface, within the lateral sulcus which separates the temporal lobe and inferior parietal cortex.
These overlying cortical areas are known as opercula (meaning "lids"), and parts of the frontal, temporal and parietal lobes form opercula over the insula. The latin name for the insular cortex is *lobus insularis*.

insular cortex is also known by the name **Island of Reil**,

1.Gyri breves insula
2.Gyri longi insula
3.Limen insula
4.Sulcus centralis insula
5.Sulcus circularis insula

Insula:

Implicated in memory encoding.

Integration of sensory information with visceral responses.

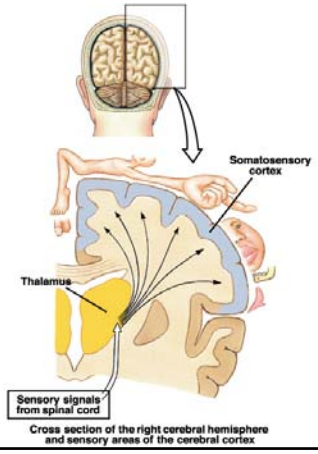
Coordinated cardiovascular response to stress.

The insular cortex is a complex structure which contains areas that subserve
•visceral sensory,
•motor,
•vestibular,
• and somatosensory functions.

•The role of the insular cortex in auditory processing was poorly understood until recently.
•However, recent case studies indicate that bilateral damage to the insulae may result in total auditory agnosia.
•Functional imaging studies demonstrate that the insulae participate in several key auditory processes, such as allocating auditory attention and tuning in to novel auditory stimuli, temporal processing, phonological processing and visual-auditory integration.
•These studies do not clarify the issue of further specialisation within the insular cortex, e.g. whether the posterior insulae are primarily sensory areas, while the anterior insulae serve mainly as integration/association auditory areas, two hypotheses that would be compatible with the cytoarchitectonic structure and connectivity of the insulae.

Primary Somatosensory Cortex

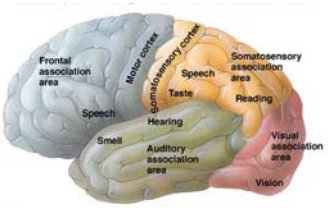
- What does "somato" mean?
- Found in the postcentral gyrus.
- Neurons in this cortical area receive info from sensory neurons in the skin and from proprioceptors which monitor joint position.
- Contralateral input.
- How was the motor somatotopic map arranged?
  - Do you think the somatotopic map will be identical?



Cross section of the right cerebral hemisphere and sensory areas of the cerebral cortex

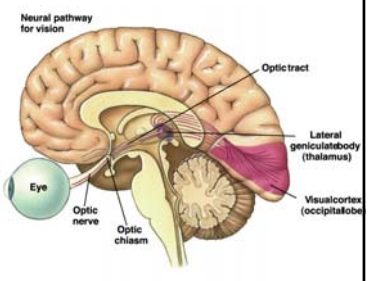
Somatosensory Association Cortex

- Found posterior to the primary somatosensory cortex and is neurally tied to it.
- Synthesizes multiple sensory inputs to create a complete comprehension of the object being felt.
  - How would damage to this area differ from damage to the primary somatosensory cortex?



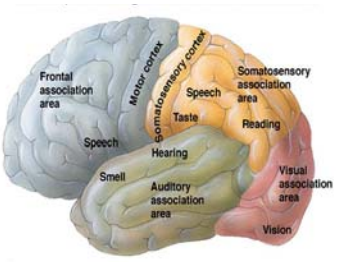
Primary Visual Cortex

- Found in the posterior and medial occipital lobe.
- Largest of the sensory cortices.
  - What does this suggest?
- Contralateral input.



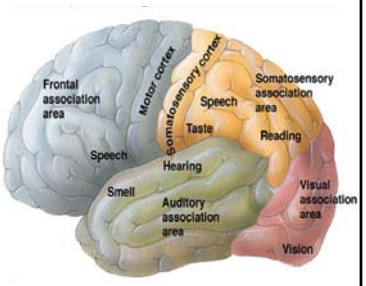
Visual Association Area

- Surrounds the primary visual cortex.
- Basically vision is the sensation of bars of light on our retinal cells. The primary visual cortex tells which cells are being stimulated and how. The association area lets us "see" what we're looking at.



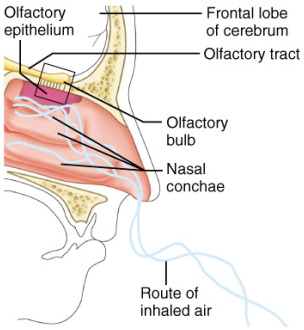
Auditory Cortex

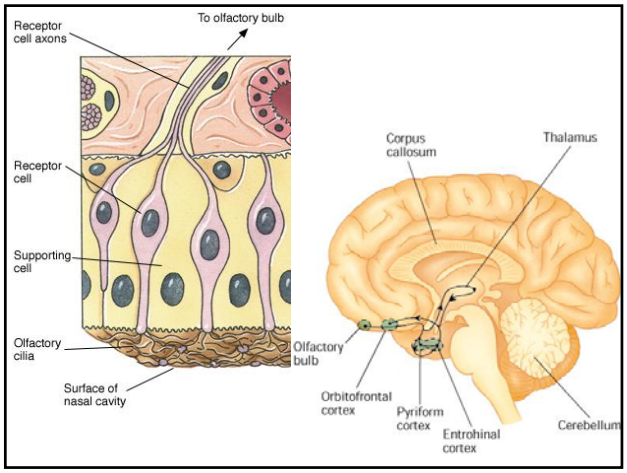
- Found in the superior margin of the temporal lobe, next to the lateral sulcus.
- Sound waves excite cochlear receptors in the inner ear which send info to the auditory cortex.
- There is also an auditory association area which lets us interpret and remember sounds.



Olfactory Cortex

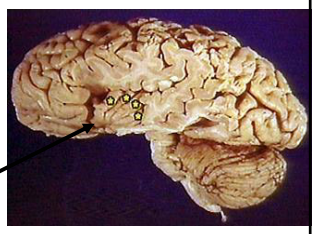
- Found in the frontal lobe just above the orbits.
- Receptors in the olfactory epithelium extend through the cribriform plate and are excited by the binding of oderants. They then send their info to the olfactory cortex.
- Very much involved in memory and emotion.

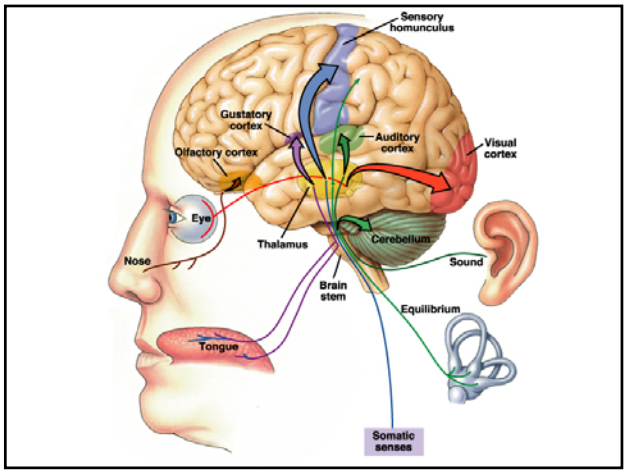




Gustatory and Vestibular Cortices

- Gustatory cortex is involved in taste and is in the parietal lobe just deep to the temporal lobe.
- Vestibular cortex is involved in balance and equilibrium and is in the posterior insula



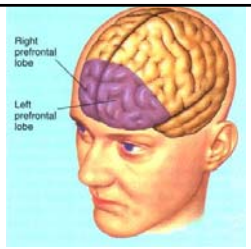


Association Areas

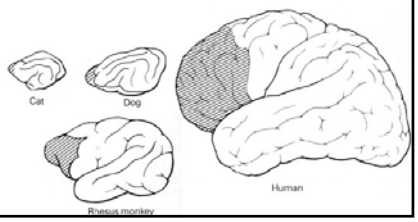
- Allows for analysis of sensory input.
- Multiple inputs and outputs. Why?

1. Prefrontal cortex
2. Language areas
3. General interpretation area
4. Visceral association area

Prefrontal Cortex

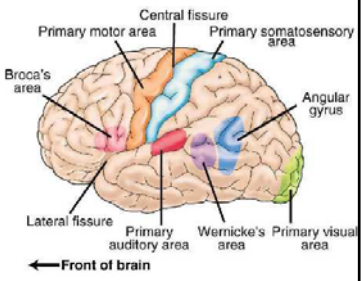


- Anterior frontal lobes
- Involved in analysis, cognition, thinking, personality, conscience, & much more.
- What would a frontal lobotomy result in?
- Look at its evolution →



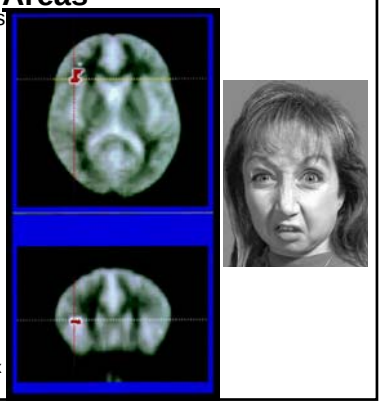
Language Areas

- Large area for language understanding and production surrounding the lateral sulcus in the left (language-dominant) hemisphere
- Includes:
  - Wernicke's area → understanding oral/written words
  - Broca's area → speech production
  - Lateral prefrontal cortex → language comprehension and complex word analysis
  - Lateral and ventral temporal cortex → integrates visual and auditory stimulate

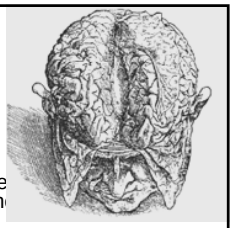


General and Visceral Association Areas

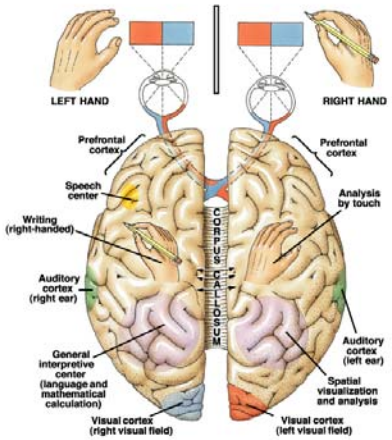
- General area integrates multiple stimuli into a single cogent "understanding of the situation."
  - Found on only one hemisphere – typically left.
  - Contained by 3 lobes: temporal, occipital, and parietal.
- Visceral association area is involved in perception of visceral sensations (such as disgust).
  - Located in insular cortex



Lateralization

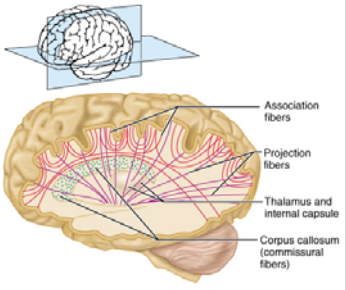


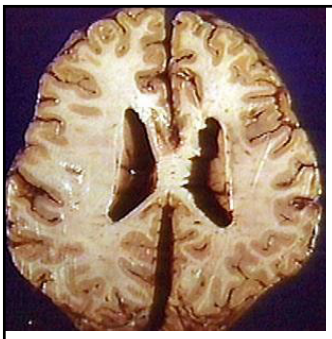
- The fact that certain activities are the almost exclusive domain of one of th 2 hemispheres.
- In most people, the left hemisphere has a more control over language, math, and logic.
- While the right hemisphere is geared towards musical, artistic and other creative endeavors.
- Most individuals with left cerebral dominance are right-handed.

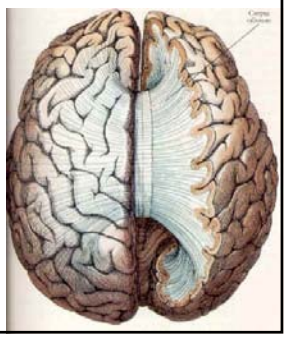


Cerebral White Matter

- Is white matter involved in communication?
- 3 types of fibers:
  1. Commissural – connect corresponding areas of the 2 hemispheres. Largest is the corpus callosum.
  2. Association fibers – connect different parts of the same hemisphere
  3. Projection fibers – fibers entering and leaving the cerebral hemispheres from/to lower structures

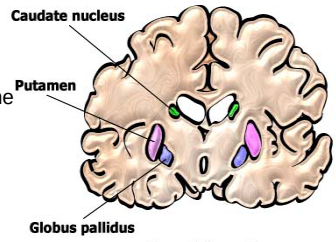






Basal Nuclei

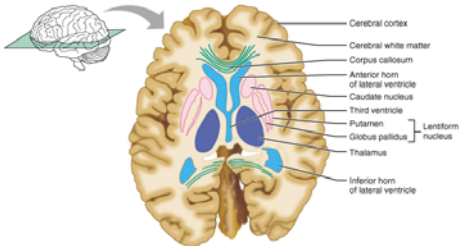
- Set of nuclei deep within the white matter.
- Includes the:
  - Caudate Nucleus
  - Lentiform Nucleus
    - Globus pallidus
    - Putamen



- Components of the extrapyramidal system which provides subconscious control of skeletal muscle tone and coordinates learned movement patterns and other somatic motor activities.
- Doesn't initiate movements but once movement is underway, they assist in the pattern and rhythm (especially for trunk and proximal limb muscles

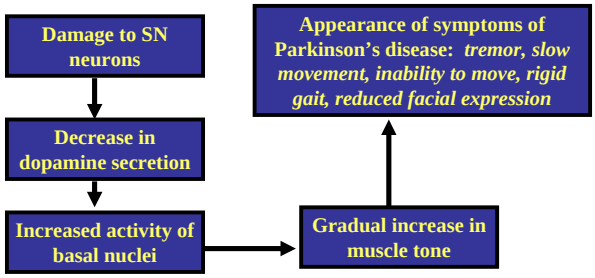
Basal Nuclei

- Info arrives at the caudate nucleus and the putamen from sensory, motor, and association areas of the cortex.
- Processing and integration occurs w/i the nuclei and then info is sent from the globus pallidus to the motor cortex via the thalamus.
- The basal nuclei alter motor commands issued by the cerebral cortex via this feedback loop.



Parkinson's Disease

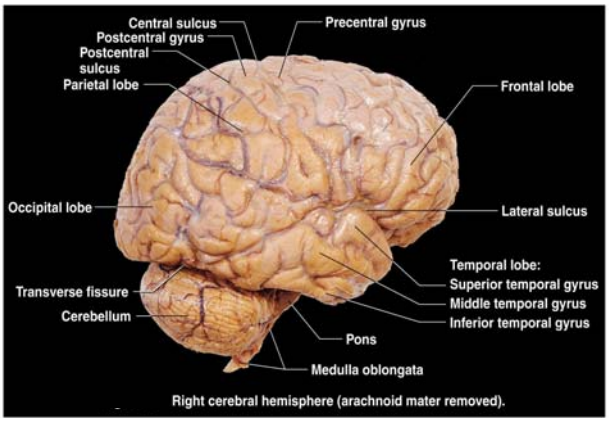
- Each side of the midbrain contains a nucleus called the *substantia nigra*.
- Neurons in the substantia nigra inhibit the activity of basal nuclei by releasing dopamine.



Diencephalon

- Forms the central core of the forebrain
- 3 paired structures:
  1. Thalamus
  2. Hypothalamus
  3. Epithalamus

All 3 are gray matter



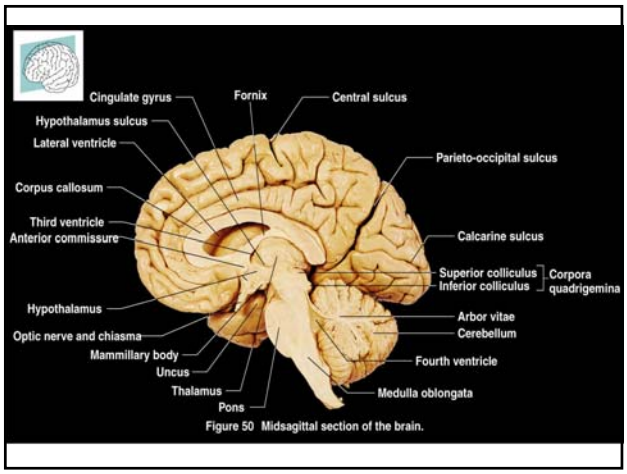


Figure 50 Midsagittal section of the brain.

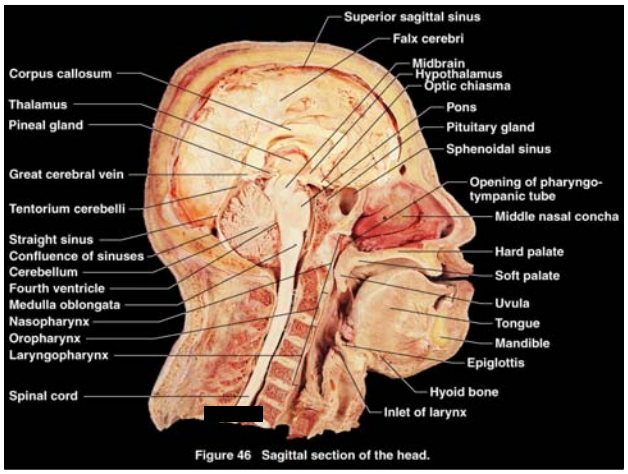
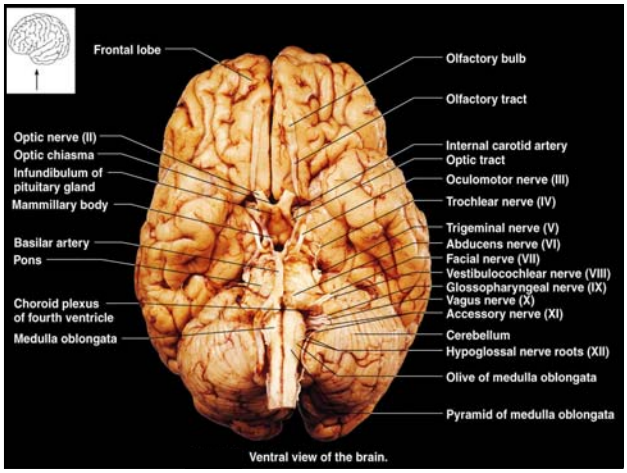


Figure 46 Sagittal section of the head.



Ventral view of the brain.

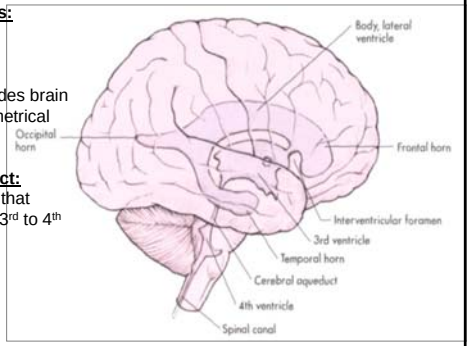
The Four Ventricles

Lateral Ventricles:
largest

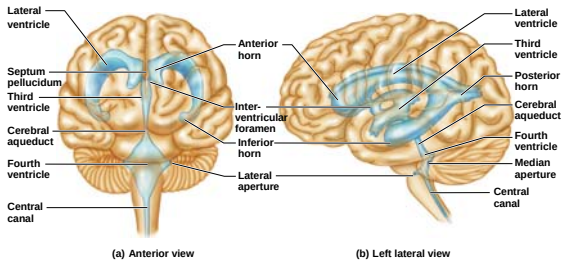
Third Ventricle:
"wall" divides brain into symmetrical halves

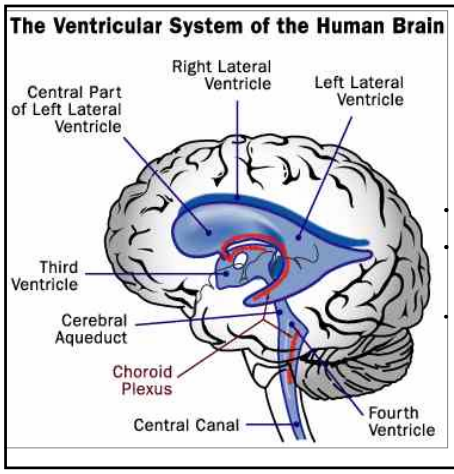
Cerebral aqueduct:
long tube that connects 3rd to 4th ventricle

Fourth Ventricle



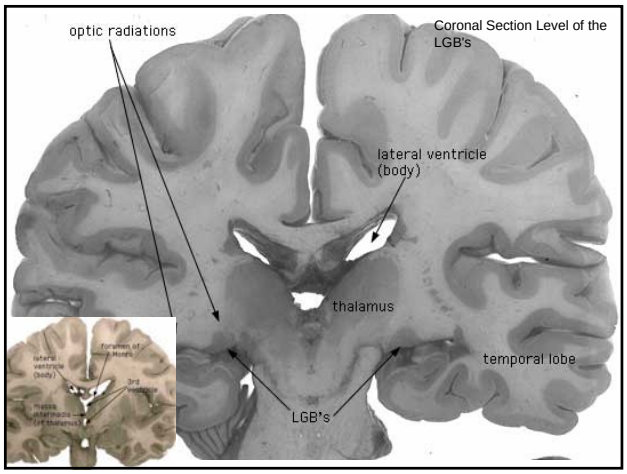
Ventricles of the brain,

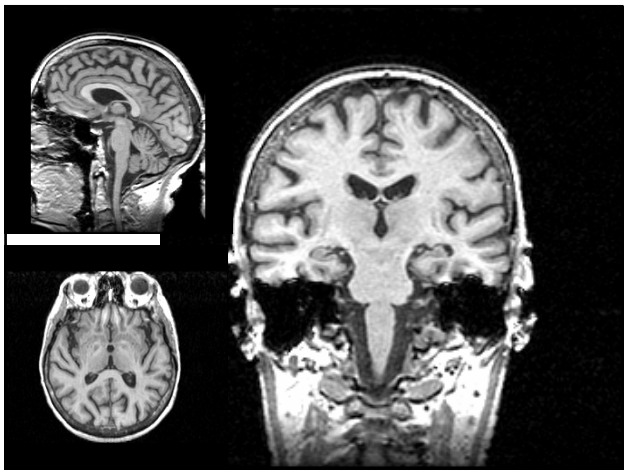


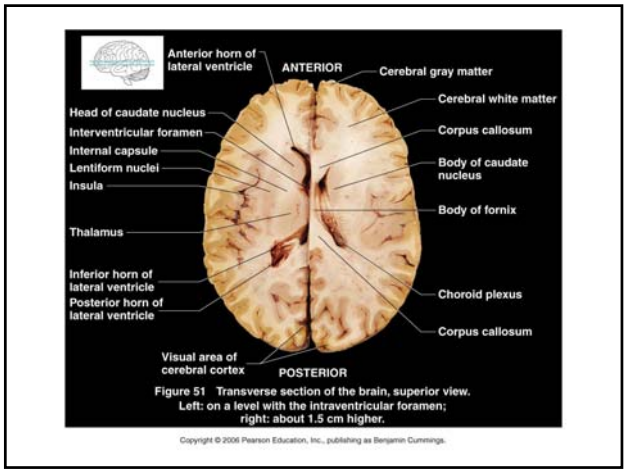


The Four Ventricles

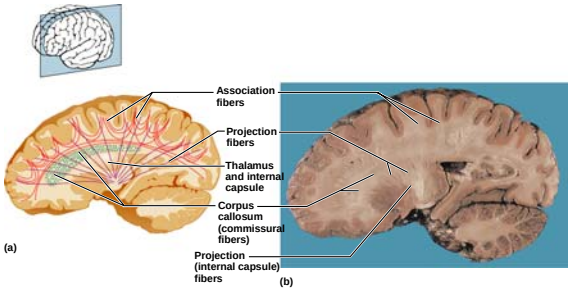
- *Protects Brain From Trauma*
- *Provides Pathway for Circulation of CSF*
- *Continuous w/each other + central canal of spinal cord*







Types of fiber tracts in white matter,



Functional Brain System

- Networks of neurons working together and spanning wide areas of the brain
- The two systems are:
  - Limbic system
  - Reticular formation

Limbic System

- Structures located on the medial aspects of cerebral hemispheres and diencephalon
- Includes the rhinencephalon, amygdala, hypothalamus, and anterior nucleus of the thalamus

Limbic System

- Parts especially important in emotions:
  - Amygdala – deals with anger, danger, and fear responses
  - Cingulate gyrus – plays a role in expressing emotions via gestures, and resolves mental conflict
- Puts emotional responses to odors – e.g., skunks smell bad

Limbic System

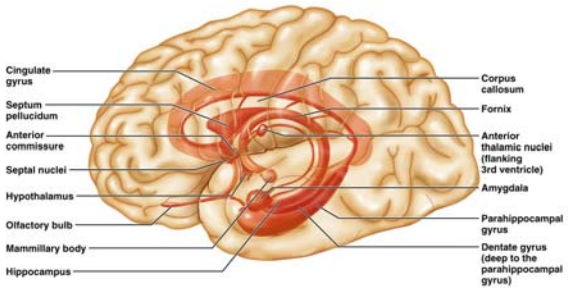


Figure 12.18

Limbic System: Emotion and Cognition

- The limbic system interacts with the prefrontal lobes, therefore:
  - One can react emotionally to conscious understandings
  - One is consciously aware of emotion in one's life
- Hippocampal structures – convert new information into long-term memories

Reticular Formation

- Composed of three broad columns along the length of the brain stem
  - Raphe nuclei
  - Medial (large cell) group
  - Lateral (small cell) group
- Has far-flung axonal connections with hypothalamus, thalamus, cerebellum, and spinal cord

Reticular Formation

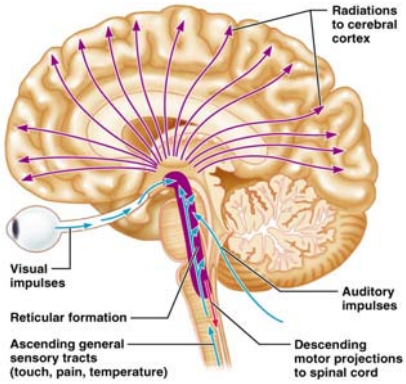
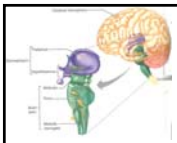
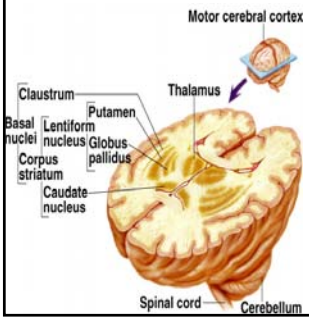


Figure 12.19

DIENCEPHALON



DIENCEPHALON



2 Major Structures

- Thalamus
- Hypothalamus

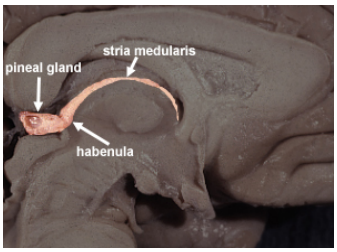
Diencephalon

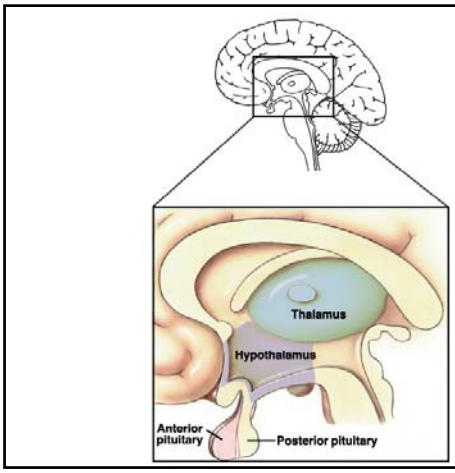
- Forms the central core of the forebrain
- 3 paired structures
  1. Thalamus
  2. Hypothalamus
  3. Epithalamus

All 3 are gray matter

Epithalamus

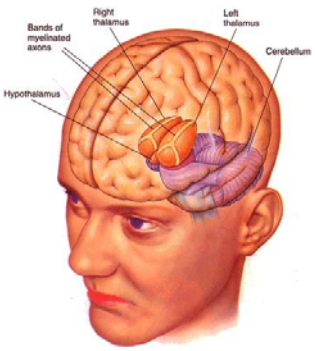
- Above the thalamus
- Contains the pineal gland which releases melatonin (involved in sleep/wake cycle and mood).
- Contains a structure called the habenula – involved in food and water intake

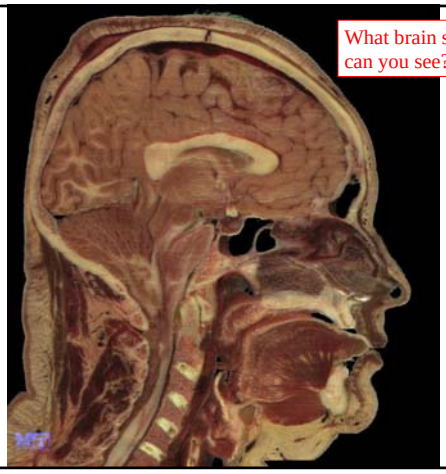




Thalamus

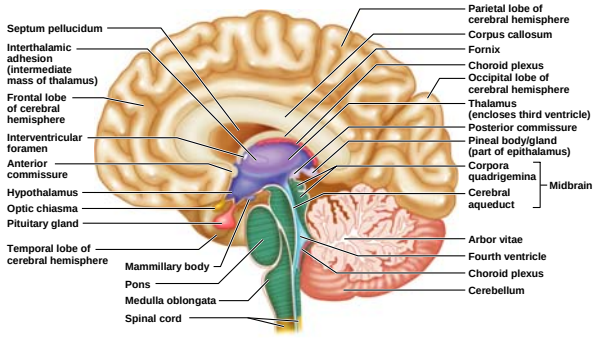
- 80% of the diencephalon
- Sensory relay station where sensory signals can be edited, sorted, and routed.
- Also has profound input on motor (via the basal ganglia and cerebellum) and cognitive function.
- Not all functions have been elucidated.





What brain structures can you see?

Midsagittal section of the brain illustrating the diencephalon and brain stem



Thalamus

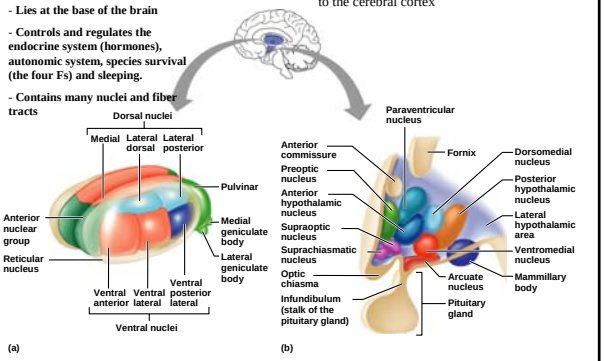
Hypothalamus

- Lies at the base of the brain

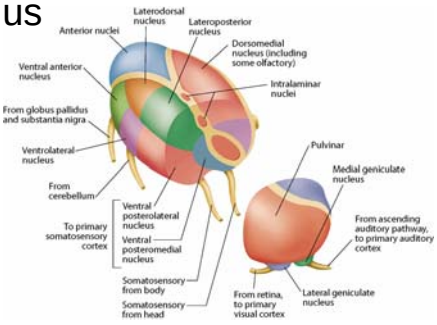
- Controls and regulates the endocrine system (hormones), autonomic system, species survival (the four Fs) and sleeping.

- Contains many nuclei and fiber tracts

- Two lobes that relay sensory projection fiber info to the cerebral cortex



Thalamus



- *All sensory modalities relay through the thalamus*

Thalamus – "gateway" to the

Afferent impulses from all senses converge and synapse in the thalamus

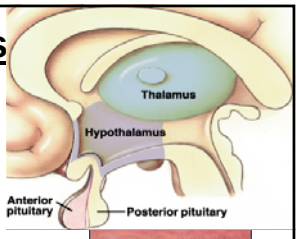
Impulses of similar function are sorted out, "edited", and relayed as a group to the appropriate area of the sensory cortex or association areas

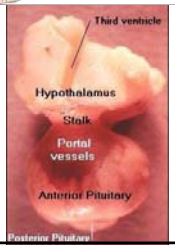
All inputs ascending to the cerebral cortex pass through the thalamus

Plays a key role in mediating sensation, motor activities, cortical arousal, learning, and memory

Hypothalamus

- Functions:
  - Autonomic regulatory center
    - Influences HR, BP, resp. rate, GI motility, pupillary diameter.
    - Can you hold your breath until you die?
  - Emotional response
    - Involved in fear, loathing, pleasure
    - Drive center: sex, hunger
  - Regulation of body temperature
  - Regulation of food intake
    - Contains a satiety center
  - Regulation of water balance and thirst
  - Regulation of sleep/wake cycles
  - Hormonal control
    - Releases hormones that influence hormonal secretion from the anterior pituitary gland.
    - Releases oxytocin and vasopressin





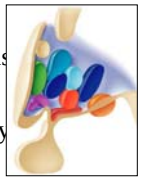
Hypothalamus

Below the thalamus, it caps the brainstem and forms the inferolateral walls of the third ventricle

Mammillary bodies - small, paired nuclei bulging anteriorly from the hypothalamus - relay stations for olfactory pathways

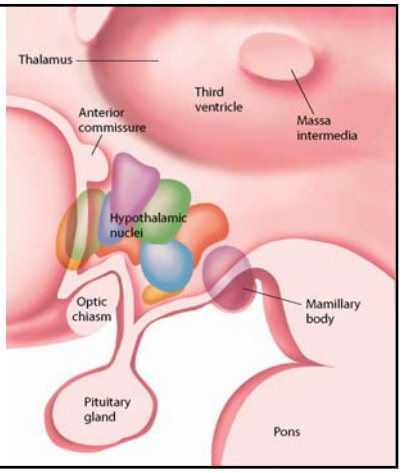
Infundibulum – stalk of the hypothalamus connecting to the pituitary gland

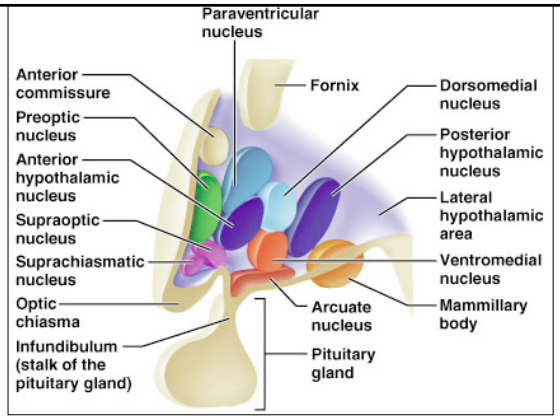
Main visceral control center of the body important to overall body homeostasis



Hypothalamus

- *A group of nuclei critical for regulating homeostasis, the four Fs, and hormones*





Hypothalamic Nuclei

Hypothalamic Function

Regulates ANS by controlling activity of centers in brains stem and spinal cord

Regulates blood pressure, rate and force of heartbeat, digestive tract motility, respiratory rate and depth, pupil size, and many other visceral activities

Center for emotional response - involved in perception of pleasure, fear, rage

Regulates body temperature – the body's "thermostat"

Regulates food intake - feelings of hunger and satiety

Regulates sleep-wake cycle

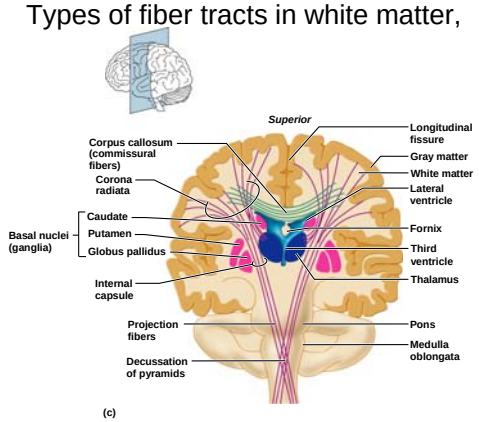
Endocrine Functions of the Hypothalamus

Releasing hormones control the secretion of hormones by the anterior pituitary

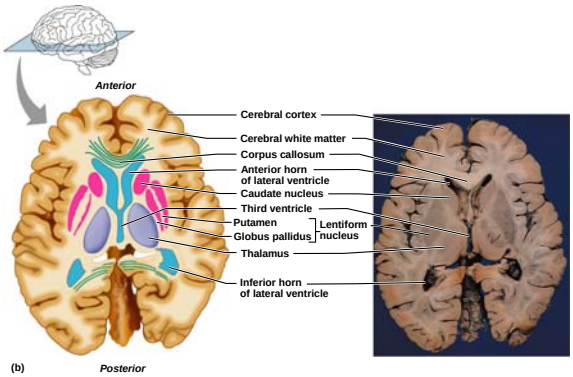
Stimulates ADH release from the posterior pituitary

Anti-diuretic hormone- causes kidneys to retain water

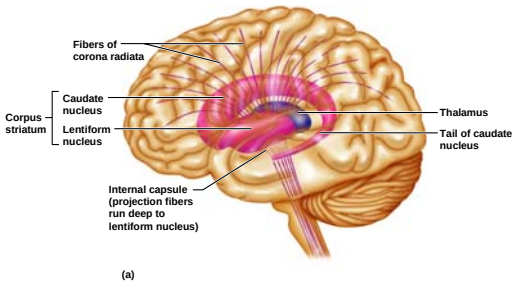
Types of fiber tracts in white matter,



Basal nuclei

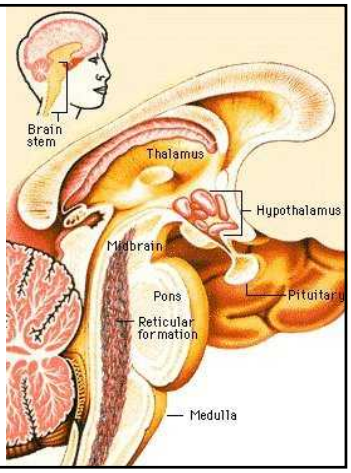


Basal nuclei,

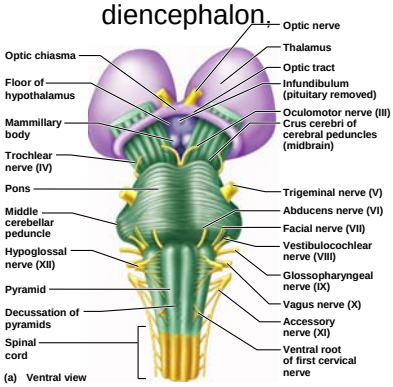


Brain Stem

- Located btwn the cerebrum and the SC
  - Provides a pathway for tracts running btwn higher and lower neural centers.
- Consists of the midbrain, pons, and medulla oblongata.
  - Each region is about an inch in length.
- Microscopically, it consists of deep gray matter surrounded by white matter fiber tracts.
- Produce automatic behaviors necessary for survival.

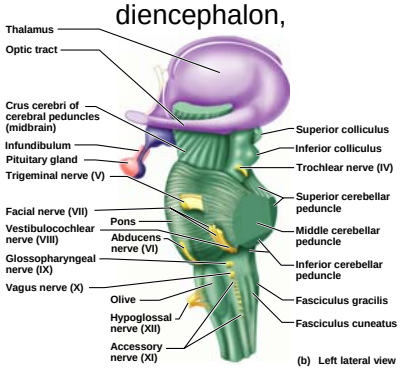


Relationship of the brain stem and the diencephalon,



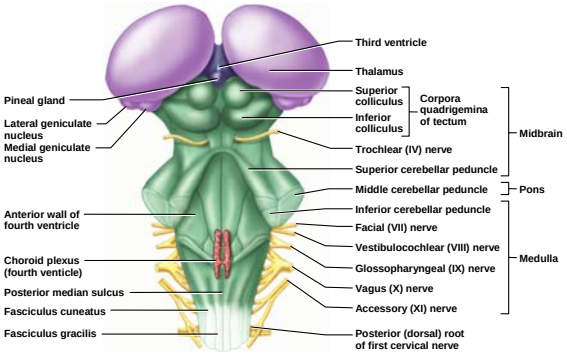
(a) Ventral view

Relationship of the brain stem and the diencephalon,



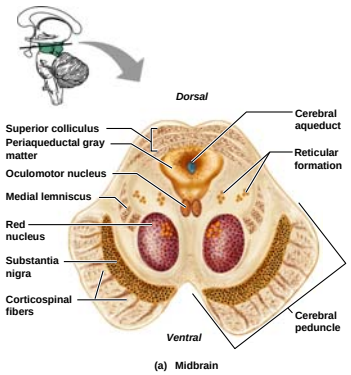
(b) Left lateral view

Relationship of the brain stem and the diencephalon,



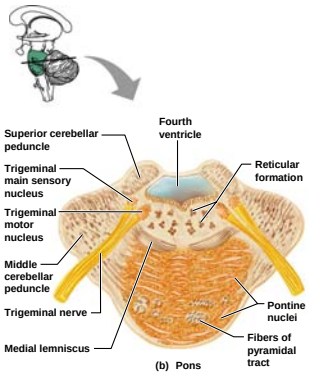
(c) Dorsal view

Important brain stem nuclei,



(a) Midbrain

Important brain stem nuclei,



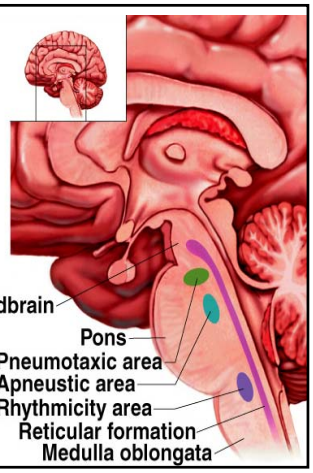
(b) Pons

Pons:

- Connects other parts.
- several nuclei associated with cranial nerves
- respiratory centers.

Cerebellum:

- "little brain"
- Receives input from proprioceptors (joints, muscles, tendons).
- Refinement/coordination of movement.



Reticular formation -
1 - portions located in the spinal cord, medulla, pons, midbrain, & hypothalamus
2 - needed for arousal from sleep & to maintain consciousness

Cerebellum -
1 - functions in coordination, maintenance of posture, & balance

Cerebrum -
1 - largest portion of the human brain
2 - consists of 2 hemispheres divided by a fissure

3 - includes cerebral cortex, medullary body, & basal ganglia:
Cortex:
outer 2 - 4 mm of the cerebrum
consists of gray matter (cell bodies & synapses; no myelin)

'folded', with upfolded areas called gyri & depressions or grooves called sulci
consists of four primary lobes

Medullary body:
the 'white matter' of the cerebrum; consists of myelinated axons
types of axons include:
commissural fibers - conduct impulses between cerebral hemispheres (and form the corpus callosum)

projection fibers - conduct impulses in & out of the cerebral hemispheres
association fibers - conduct impulses within hemispheres
Basal ganglia:
masses of gray matter in each cerebral hemisphere
important in control of voluntary muscle movements

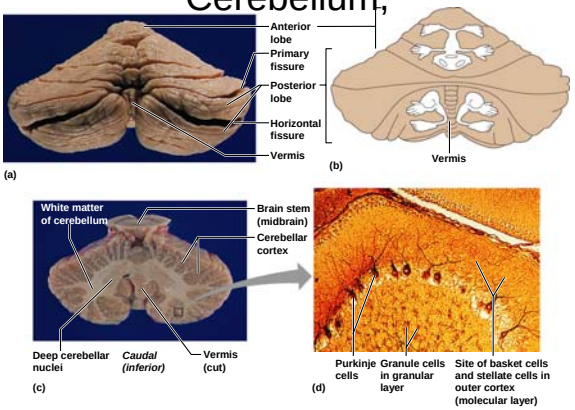
Limbic System -
1 - consists of a group of nuclei + fiber tracts
2 - located in part in cerebral cortex, thalamus, & hypothalamus
3 - Functions:
aggression
fear
feeding
sex (regulation of sexual drive & sexual behavior)

SENSORY PATHWAYS

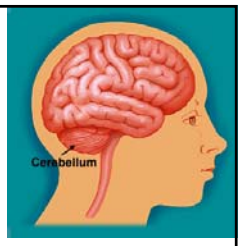
	RECEPTORS	NUCLEUS	THALAMUS	CORTEX
Body	Touch (C2–S5)	Post. column (Medial lemn.)	VPL (Int. capsule)	SI
	Pain (C2–S5)	Dorsal horn (Spinothalamic tr.)	VPL (Int. capsule)	SI
			VM (Int. capsule)	Insula
			MD (Int. capsule)	Cingulate
			IL (Int. capsule)	Diffuse activation
Face	Touch (V, VII, IX, X)	Main V (Trigeminal lemn.)	VPM (Int. capsule)	SI
	Pain (V, VII, IX, X)	Spinal V (Trigeminothalamic tr.)	VPM (Int. capsule)	SI
			VM (Int. capsule)	Insula
			MD (Int. capsule)	Cingulate
			IL (Int. capsule)	Diffuse activation

CEREBELLUM

Cerebellum,

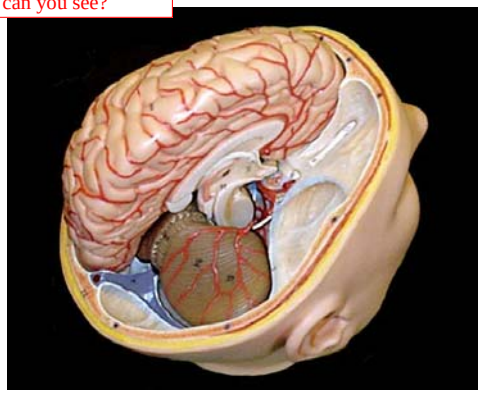


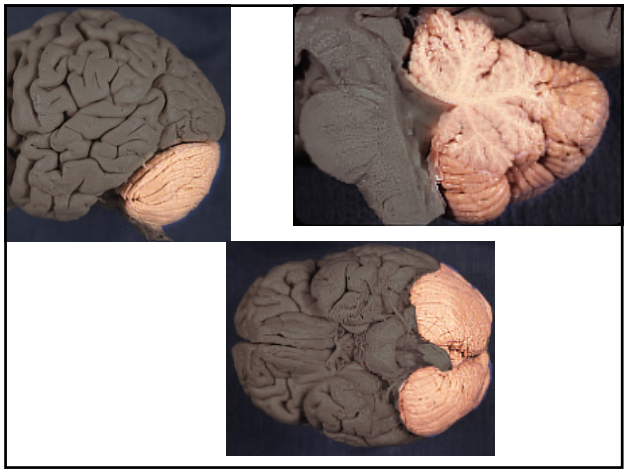
Cerebellum



- Lies inferior to the cerebrum and occupies the posterior cranial fossa.
- 2nd largest region of the brain.
  - 10% of the brain by volume, but it contains 50% of its neurons
- Has 2 primary functions:
  1. Adjusting the postural muscles of the body
     - Coordinates rapid, automatic adjustments, that maintain balance and equilibrium
  2. Programming and fine-tuning movements controlled at the subconscious and conscious levels
     - Refines learned movement patterns by regulating activity of both the pyramidal and extrapyramidal motor pathways of the cerebral cortex
     - Compares motor commands with sensory info from muscles and joints and performs any adjustments to make the movement smooth

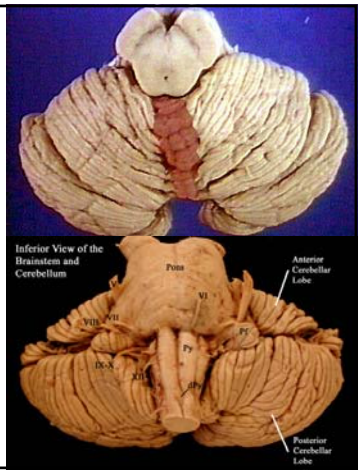
Do you see the cerebellum?
What else can you see?





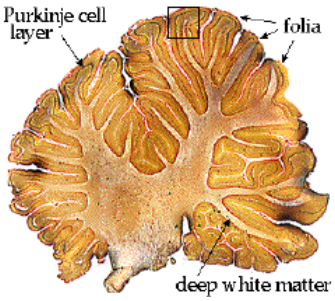
Cerebellum

- Has a complex, convoluted cortical surface with multiple folds (folia) which are less prominent than the gyri of the cerebrum.
- Has anterior and posterior lobes separated by the primary fissure.
- Along the midline, a narrow band of cortex called the vermis separates the cerebellar hemispheres.
- The floccunodular lobe lies anterior to the vermis and btwn the cerebellar hemispheres.



Cerebellum

- Cerebellar cortex contains huge, highly branched Purkinje cells whose extensive dendrites can receive up to 200,000 synapses.
- Internally, the white matter forms a branching array that in a sectional view resembles a tree – for this reason, it's called the *arbor vitae*



Cerebellum

- Tracts that link the cerebellum w/ the brain stem, cerebrum, and spinal cord leave the cerebellar hemispheres as the *superior, middle, and inferior cerebellar peduncles*.
  - SCP carries instructions from cerebellar nuclei to the cerebral cortex via midbrain and thalamus
  - MCP connects pontine nuclei to the cerebellum. This info ultimately came from the cerebral cortex and informs the cerebellum of voluntary motor activities
  - ICP connects the cerebellum and the medulla oblongata and carries sensory information from muscles and from the vestibular apparatus of the inner ear.

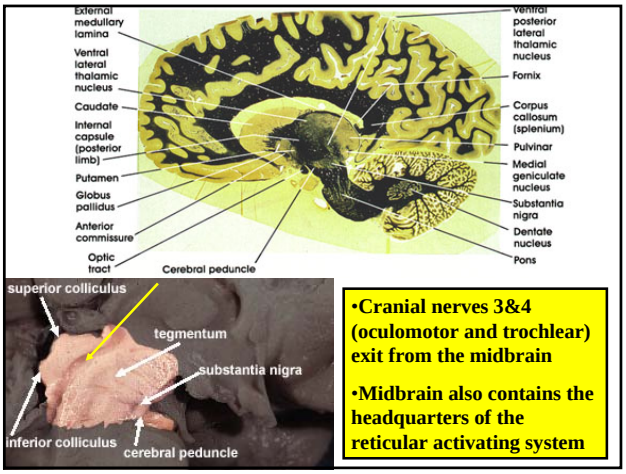
Cerebellum

- The cerebellum can be permanently damaged by trauma or stroke or temporarily affected by drugs such as alcohol.
- These alterations can produce ataxia – a disturbance in balance.

LIMBIC SYSTEM

Midbrain

- Located btwn the diencephalon and the pons.
  - 2 bulging cerebral peduncles on the ventral side. These contain:
    - Descending fibers that go to the cerebellum via the pons
    - Descending pyramidal tracts
  - Running thru the midbrain is the hollow cerebral aqueduct which connects the 3rd and 4th ventricles of the brain.
  - The roof of the aqueduct (the *tectum*) contains the corpora quadrigemina
    - 2 superior colliculi that control reflex movements of the eyes, head and neck in response to visual stimuli
    - 2 inferior colliculi that control reflex movements of the head, neck, and trunk in response to auditory stimuli

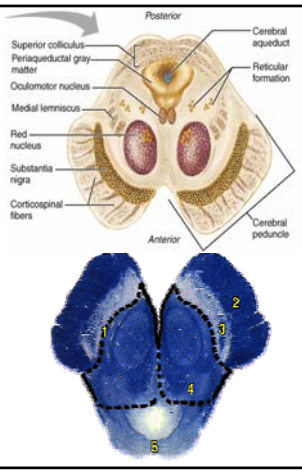


•Cranial nerves 3&4 (oculomotor and trochlear) exit from the midbrain

•Midbrain also contains the headquarters of the reticular activating system

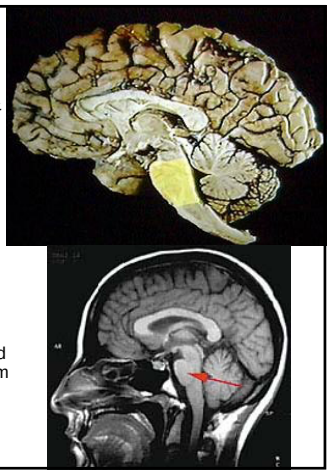
Midbrain

- On each side, the midbrain contains a *red nucleus* and a *substantia nigra*
  - Red nucleus contains numerous blood vessels and receives info from the cerebrum and cerebellum and issues subconscious motor commands concerned w/ muscle tone & posture
  - Lateral to the red nucleus is the melanin-containing substantia nigra which secretes dopamine to inhibit the excitatory neurons of the basal nuclei.
    - Damage to the substantia nigra would cause what?



Pons

- Literally means “bridge”
- Wedged btwn the midbrain & medulla.
- Contains:
  - Sensory and motor nuclei for 4 cranial nerves
    - Trigeminal (5), Abducens (6), Facial (7), and Auditory/Vestibular (8)
  - Respiratory nuclei:
    - Apneustic & pneumotaxic centers work w/ the medulla to maintain respiratory rhythm
  - Nuclei & tracts that process and relay info to/from the cerebellum
  - Ascending, descending, and transverse tracts that interconnect other portions of the CNS

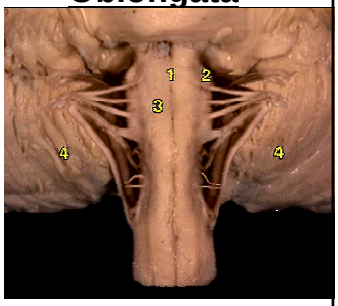


Medulla Oblongata

- Most inferior region of the brain stem.
- Becomes the spinal cord at the level of the foramen magnum.
- Ventrally, 2 ridges (the medullary pyramids) are visible.
  - These are formed by the large motor corticospinal tracts.
  - Right above the medulla-SC junction, most of these fibers cross-over (decussate).

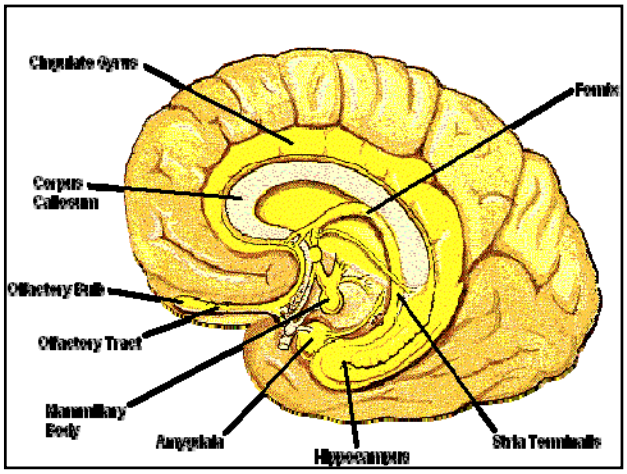
Medulla Oblongata

- Nuclei in the medulla are associated w/ autonomic control, cranial nerves, and motor/sensory relay.
- Autonomic nuclei:
  - Cardiovascular centers
    - Cardioinhibitory/cardioacceleratory centers alter the rate and force of cardiac contractions
    - Vasomotor center alters the tone of vascular smooth muscle
  - Respiratory rhythmicity centers
    - Receive input from the pons
  - Additional Centers
    - Emesis, deglutition, coughing, hiccupping, and sneezing



Medulla Oblongata

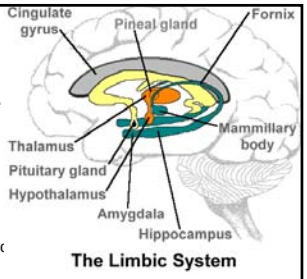
- Sensory & motor nuclei of 5 cranial nerves:
  - Auditory/Vestibular (8), Glossopharyngeal (9), Vagus (10), Accessory (11), and Hypoglossal (12)
- Relay nuclei
  - Nucleus gracilis and nucleus cuneatus pass somatic sensory information to the thalamus
  - Olivary nuclei relay info from the spinal cord, cerebral cortex, and the brainstem to the cerebellar cortex.



What brainstem structures are visible here?

Limbic System

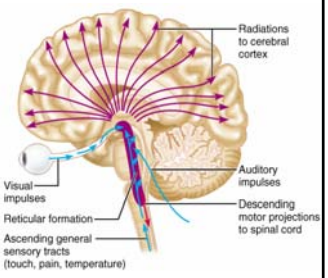
- Includes nuclei and tracts along the border btwn the cerebrum and the diencephalon.
- Functional grouping rather than anatomical
- Functions include:
  1. Establishing emotional states
  2. Linking conscious cerebral cortical functions w/ unconscious functions c the brainstem
  3. Facilitating memory storage and retrieval
- Limbic lobe of the cerebrum consists of 3 gyri that curve along the corpus callosum and medial surface of the temporal lobe.
- Limbic system → the center of emotion – anger, fear, sexual arousal, pleasure, and sadness.



The Limbic System

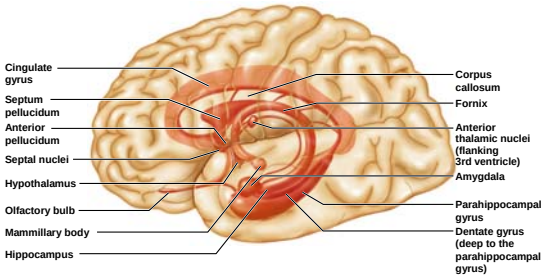
Reticular Formation

- Extensive network of neurons that runs thru the medulla and projects to thalamic nuclei that influence large areas of the cerebral cortex.
  - Midbrain portion of RAS most likely is its center
- Functions as a net or filter for sensory input.
  - Filter out repetitive stimuli. Such as?
  - Allows passage of infrequent or important stimuli to reach the cerebral cortex.
  - Unless inhibited by other brain regions, it activates the cerebral cortex – keeping it alert and awake.

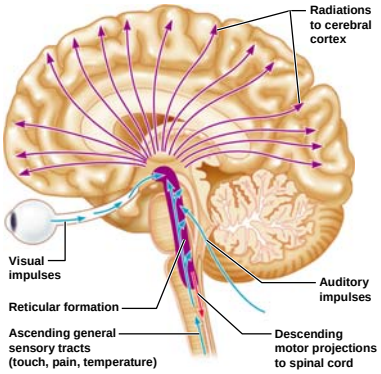


How might the "sleep centers" of your brain work? Why does alcohol make you tired?

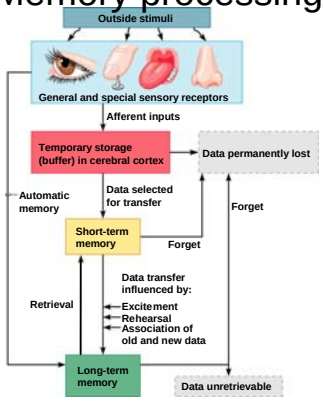
The limbic system,



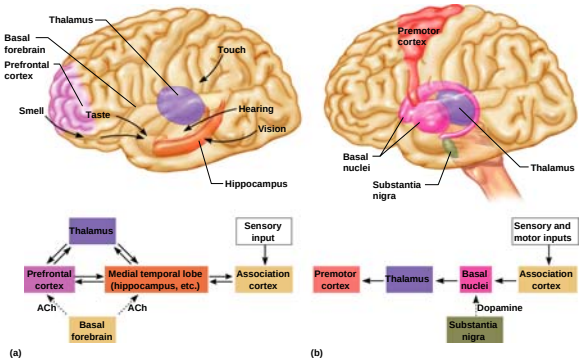
The reticular formation,



Memory processing,



Proposed memory circuits,

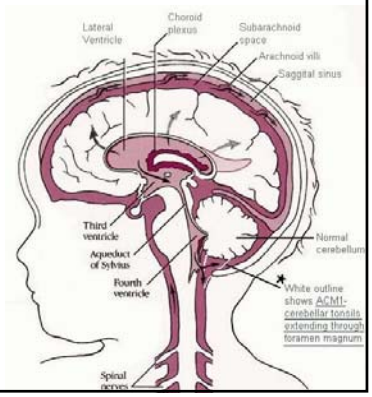


Cerebrospinal Fluid (CSF)
Watery solution similar in composition to blood plasma
Contains less protein and different ion concentrations than plasma

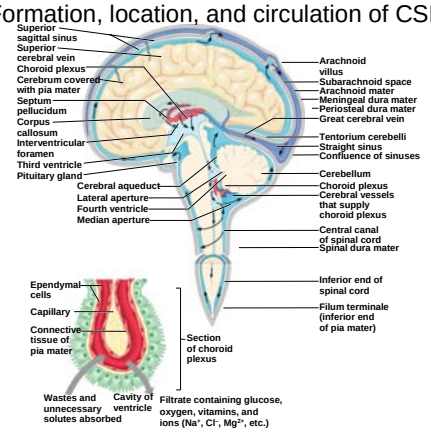
Forms a liquid cushion that gives buoyancy to the CNS organs
Prevents the brain from crushing under its own weight
Protects the CNS from blows and other trauma
Nourishes the brain and carries chemical signals throughout it

HYDROCEPHALUS WHEN CSF DO NOT CIRCULATE INCREASING ITS PRESSURE

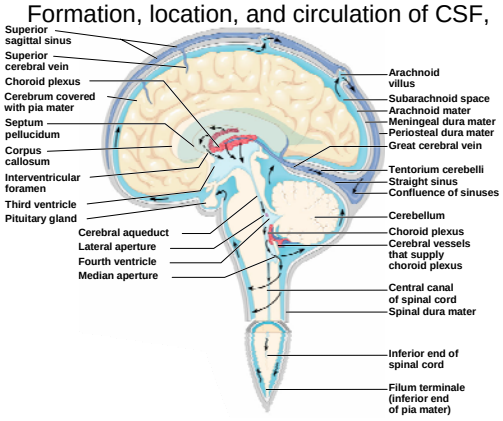
CSF

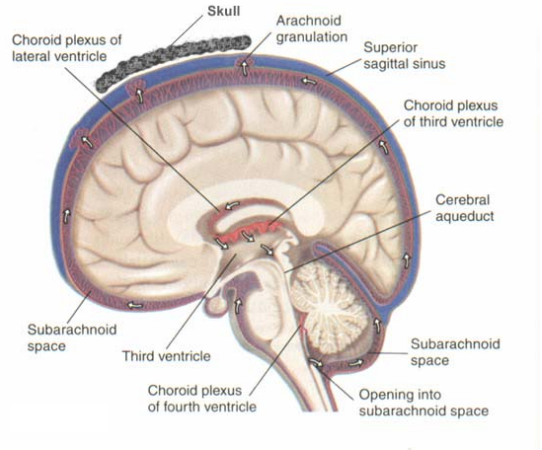


Formation, location, and circulation of CSF,

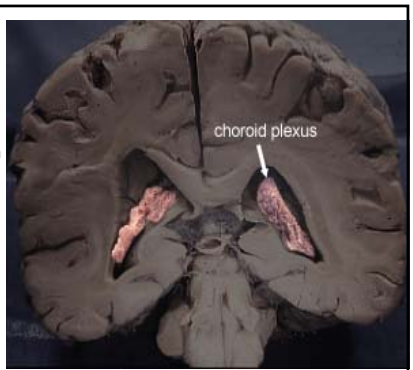


Formation, location, and circulation of CSF,



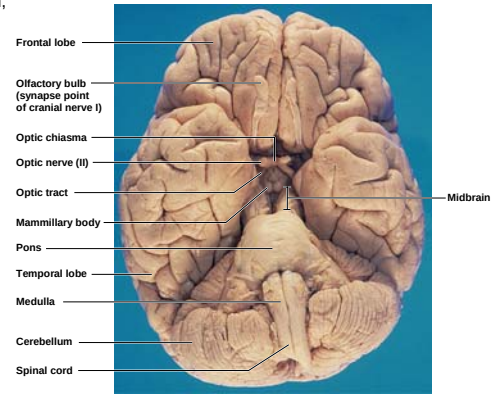


Choroid Plexuses
Clusters of capillaries that form tissue fluid filters, which hang from the roof of each ventricle
Have ion pumps that allow them to alter ion concentrations of the CSF
Help cleanse CSF by removing wastes



•It produces the cerebrospinal fluid (CSF) which is found within the ventricles of the brain and in the subarachnoid space around the brain and spinal cord.
•It is comprised of a rich capillary bed, pia mater, and choroid epithelial cells.
•It is located in certain parts of the ventricular system of the brain.

Ventral aspect of the human brain, showing the three regions of the brain stem,



SPINAL CORD

Spinal Cord

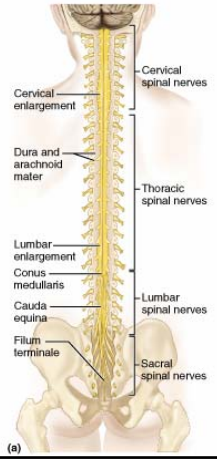
- Functions to transmit messages to and from the brain (white matter) and to serve as a reflex center (gray matter).
- Tube of neural tissue continuous w/ the medulla at the base of the brain and extends about 17" to just below the last rib. (Ends at L1)
- Majority of the SC has the diameter of your thumb
- Thicker at the neck and end of the cord (cervical and lumbar enlargements) b/c of the large group of nerves connecting these regions of the cord w/ the arms and legs.

Spinal Cord

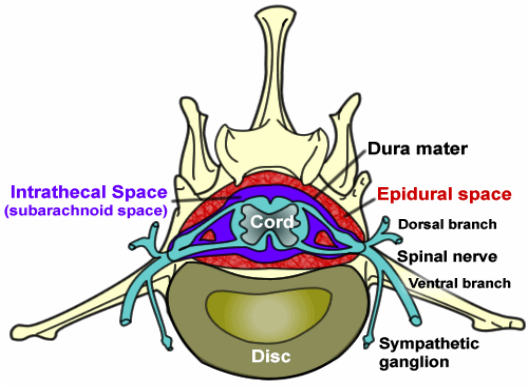
- Surrounded by a single layered dura mater and arachnoid and pia mater.
- Terminates in cone shaped structure called the conus medul
  - The filum terminale, a fibrous extension of the pia mater, extends to the posterior surface of the coccyx to anchor the spinal cord.
- The cord does not extend the entire length of the vertebral column – so a group of nerves leaves the inferior spinal cord and extends downward. It resembles a horses tail and is called the cauda equina.

Spinal Cord

- Notice the gross features of the spinal cord on the right.
- 31 pairs of spinal nerves attach to the cord by paired roots and exit from the vertebral canal via the intervertebral foramina.



SPINAL CORD ANATOMY



Lumbar Tap

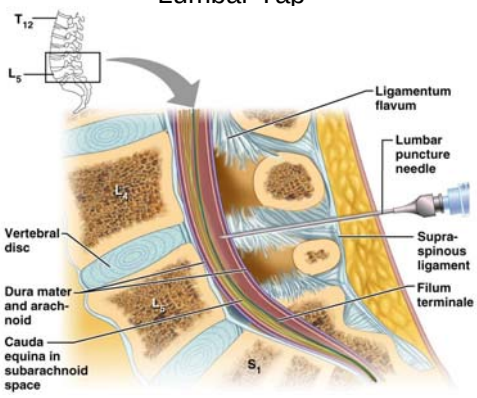
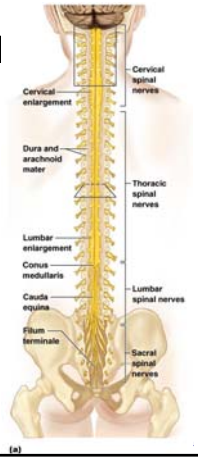


Figure 12.30

Spinal Cord



There are 31 spinal cord segments:

- 8 cervical segments
- 12 thoracic segments
- 5 lumbar segments
- 5 sacral segments
- 1 coccygeal segment

There are two regions where the spinal cord enlarges:

- **Cervical enlargement** - corresponds roughly to the brachial plexus nerves, which innervate the upper limb. It includes spinal cord segments from about C4 to T1. The vertebral levels of the enlargement are roughly the same (C4 to T1).

- **Lumbosacral enlargement** - corresponds to the lumbosacral plexus nerves, which innervate the lower limb. It comprises the spinal cord segments from L2 to S3, and is found about the vertebral levels of T9 to T12.

Spinal Cord

- Conus medullaris – terminal portion of the spinal cord
- Filum terminale – fibrous extension of the pia mater; anchors the spinal cord to the coccyx
- Denticulate ligaments – delicate shelves of pia mater; attach the spinal cord to the vertebrae

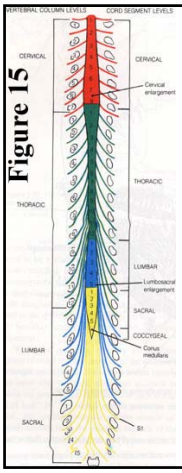
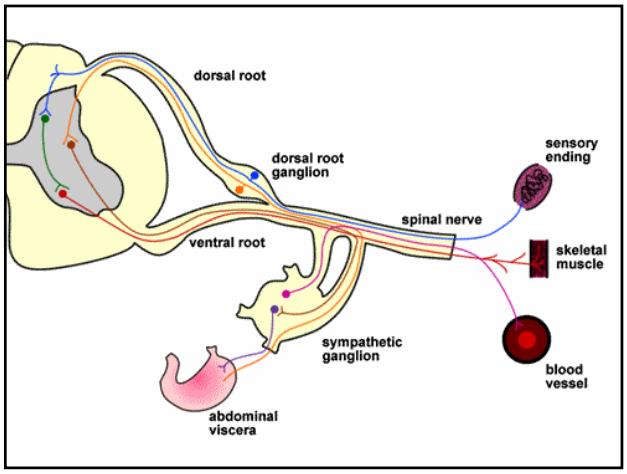
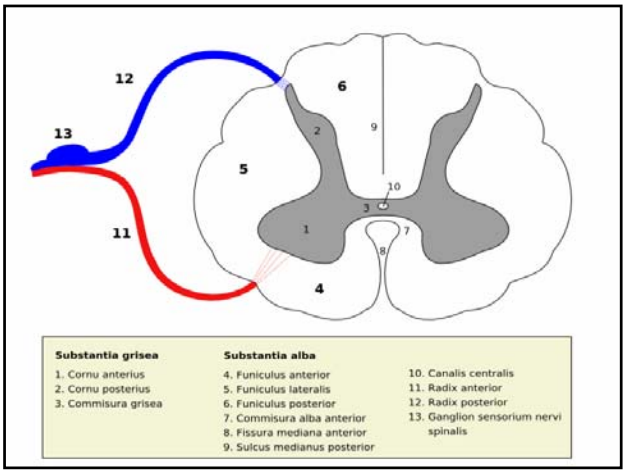
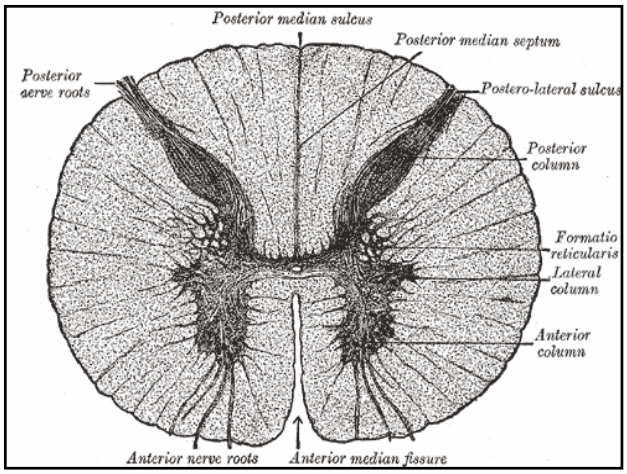


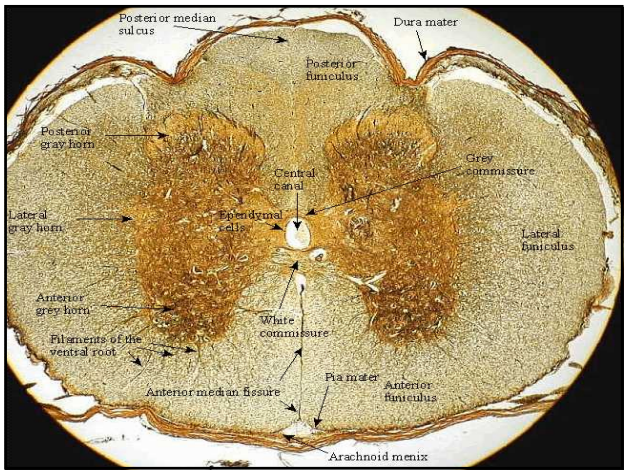
Figure 15

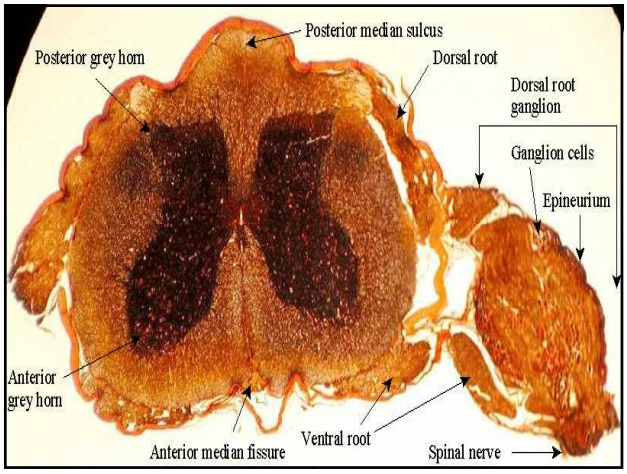
The spinal cord proper begins at the level of the foramen magnum of the skull and ends at the level of the L1ÐL2 intervertebral joint

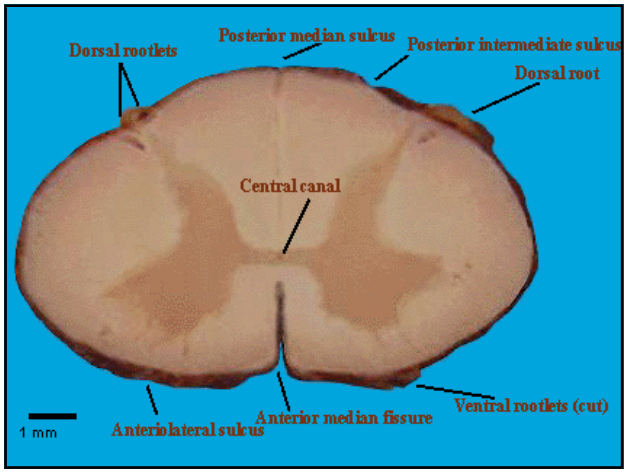


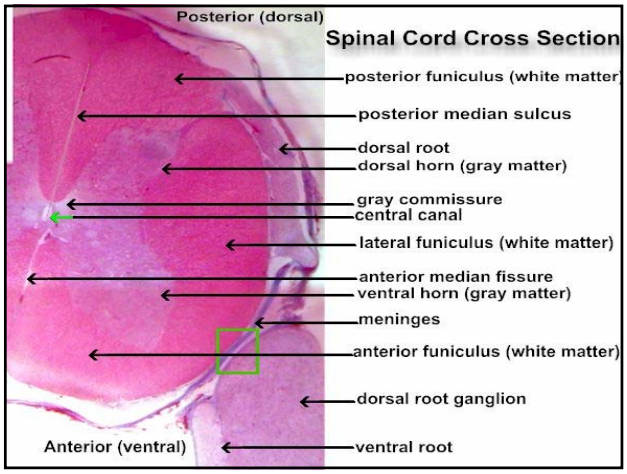


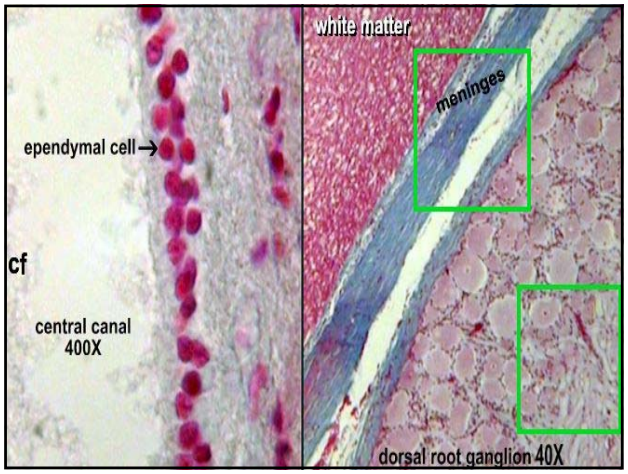

Posterior median sulcus
Posterior median septum
Posterior nerve roots
Postero-lateral sulcus
Posterior column
Formatio reticularis
Lateral column
Anterior column
Anterior nerve roots
Anterior median fissure

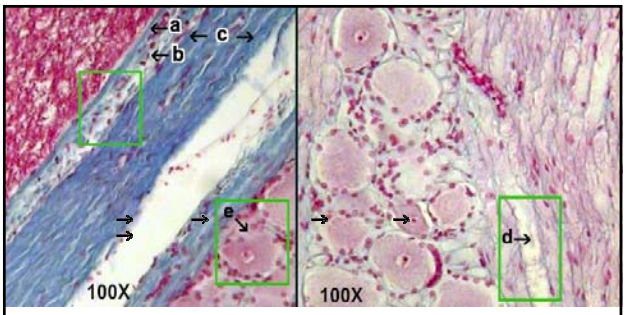

Posterior median sulcus
Dura mater
Posterior funiculus
Posterior gray horn
Grey commissure
Central canal
Lateral gray horn
Ependymal cells
Lateral funiculus
Anterior grey horn
White commissure
Filaments of the ventral root
Pia mater
Anterior median fissure
Anterior funiculus
Arachnoid menix


Posterior median sulcus
Posterior grey horn
Dorsal root
Dorsal root ganglion
Ganglion cells
Epineurium
Anterior grey horn
Anterior median fissure
Ventral root
Spinal nerve

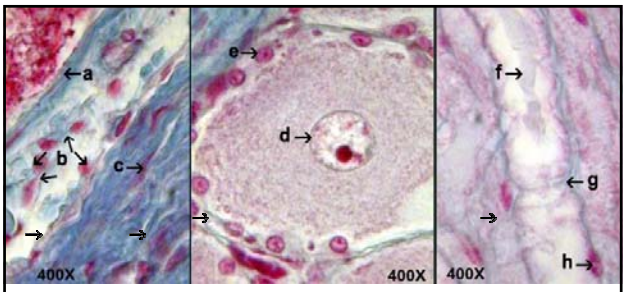

Dorsal rootlets
Posterior median sulcus
Posterior intermediate sulcus
Dorsal root
Central canal
1 mm
Anteriolateral sulcus
Anterior median fissure
Ventral rootlets (cut)


Posterior (dorsal)
Spinal Cord Cross Section
posterior funiculus (white matter)
posterior median sulcus
dorsal root
dorsal horn (gray matter)
gray commissure
central canal
lateral funiculus (white matter)
anterior median fissure
ventral horn (gray matter)
meninges
anterior funiculus (white matter)
dorsal root ganglion
Anterior (ventral)
ventral root

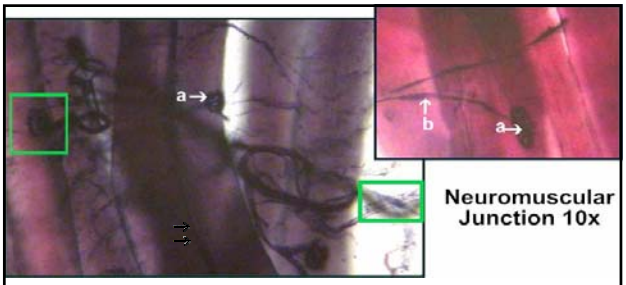

white matter
meninges
ependymal cell
cf
central canal
400X
dorsal root ganglion 40X



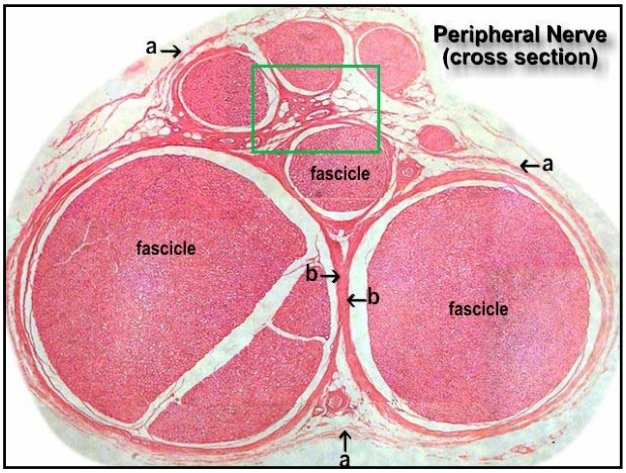
a pia mater b subarachnoid space c dura mater d myelinated axon e unipolar neuron of the dorsal root ganglion surrounded by satellite cells (neuroglia).

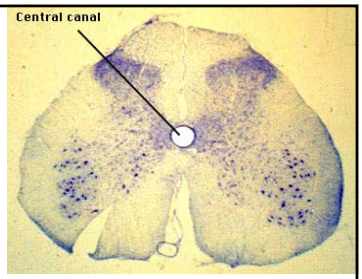


a → Pia mater b → Subarachnoid space filled with cerebral spinal fluid, wastes and various cells. c → Fibrocyte mixed in the blue collagen fibers of the dura mater. d → Nucleus & nucleolus of unipolar neuron e → Nucleus of one of many tiny satellite cells surrounding the large unipolar neuron. f → Myelinated axon g → Node of Ranvier h → Nucleus of white Schwann cell



a Synaptic bulbs over the motor end plate - neuromuscular junction
b Neuron axon terminal - black fibers





The **central canal** is the cerebrospinal fluid-filled space that runs longitudinally through the length of the entire spinal cord. The central canal is contiguous with the ventricular system of the brain.

The PNS is separated into 2 divisions:

1. the afferent division, which carries sensory information from sensory receptors of the PNS to the CNS. Receptors include neurons or specialized cells that detect changes or respond to stimuli, and complex sensory organs such as the eyes and ears.

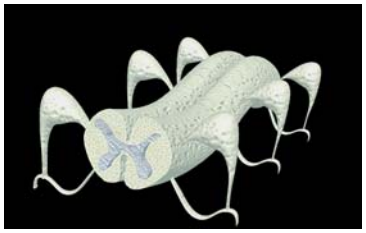
2. the efferent division, which carries motor commands from the CNS to muscles and glands of the PNS. The cells or organs that respond to efferent signals by doing something are called effectors

The efferent division is divided into 2 parts:
1. the somatic nervous system (SNS), which controls skeletal muscle contractions
a. voluntary muscle contractions
b. involuntary muscle contractions (reflexes)

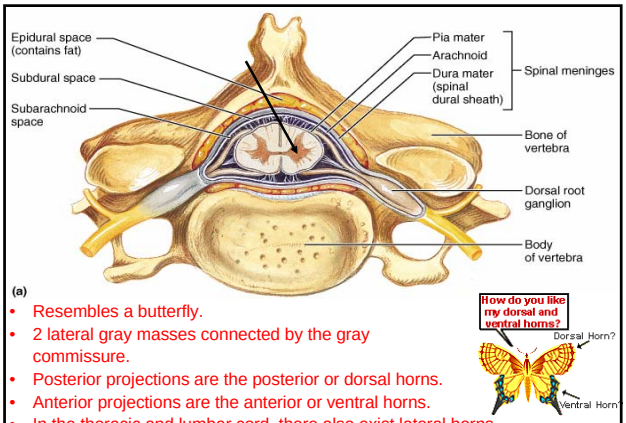
2. the autonomic nervous system (ANS), which controls subconscious actions such as contractions of smooth muscle and cardiac muscle, and glandular secretions.

The ANS is separated into 2 divisions:
1. the sympathetic division, which has a stimulating effect
2. the parasympathetic division, which has a relaxing effect

Cross Sectional Anatomy of the Spinal Cord

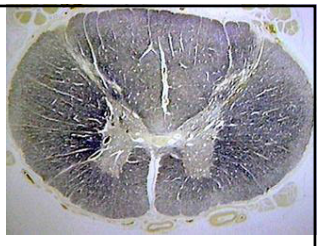


- Flattened from front to back.
- Anterior median fissure and posterior median sulcus partially divide it into left and right halves.
- Gray matter is in the core of the cord and surrounded by white matter.

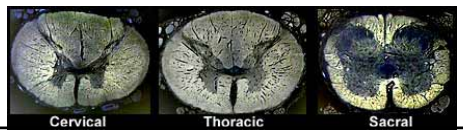


- Resembles a butterfly.
- 2 lateral gray masses connected by the gray commissure.
- Posterior projections are the posterior or dorsal horns.
- Anterior projections are the anterior or ventral horns.
- In the thoracic and lumbar cord, there also exist lateral horns.

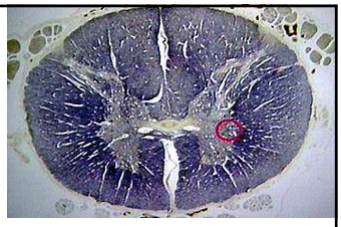
Gray Matter



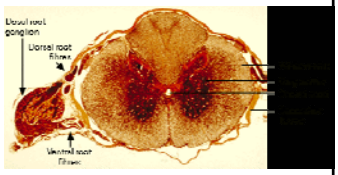
- Posterior horns contain interneurons.
- Anterior horns contain some
- interneurons as well as the cell bodies of motor neurons.
  - These cell bodies project their axons via the ventral roots of the spinal cord to the skeletal muscles.
  - The amount of ventral gray matter at a given level of the spinal cord is proportional to the amount of skeletal muscle innervated.

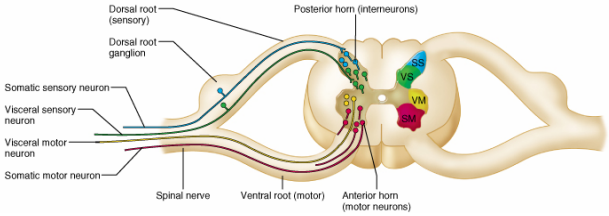


Gray Matter



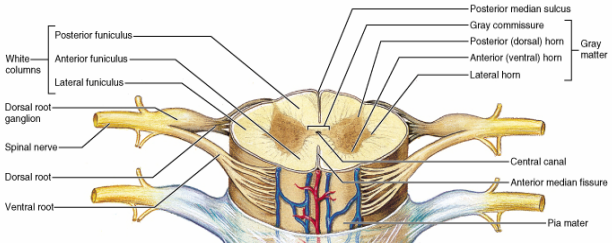
- Lateral horn neurons are sympathetic motor neurons serving visceral organs.
  - Their axons also exit via the ventral root.
- Afferent sensory fibers carrying info from peripheral receptors form the dorsal roots of the spinal cord. The somata of these sensory fibers are found in an enlargement known as a dorsal root ganglion.
- The dorsal and ventral roots fuse to form spinal nerves.





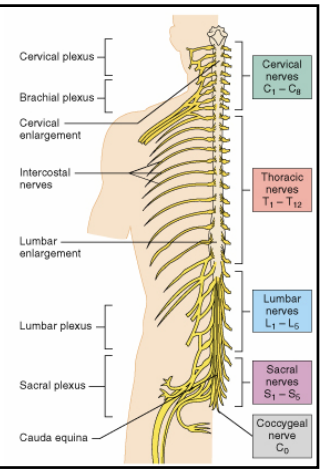
White Matter

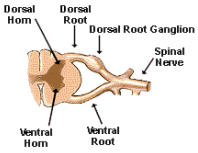
- Myelinated nerve fibers.
- Allows for communication btwn the brain and spinal cord or btwn different regions of the spinal cord.
- White matter on each side of the cord is divided into columns or funiculi.
  - Typically, they are ascending or descending.
    - What does that mean?



Spinal Nerves

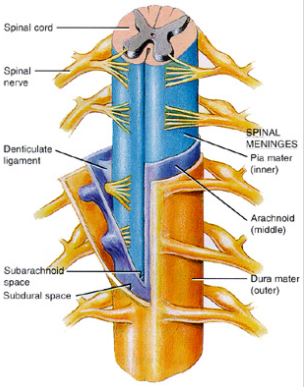
- 31 nerves connecting the spinal cord and various body regions.
  - 8 paired cervical nerves
  - 12 paired thoracic nerves
  - 5 paired lumbar nerves
  - 5 paired sacral nerves
  - 1 pair of coccygeal nerves





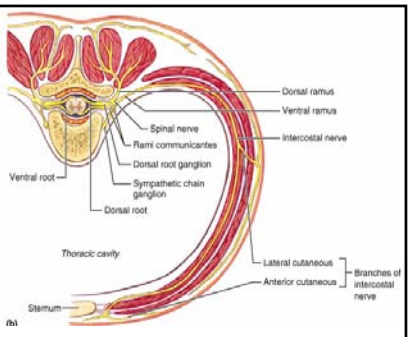
Spinal Nerves

- Each connects to the spinal cord by 2 roots – dorsal and ventral.
- Each root forms from a series of rootlets that attach along the whole length of the spinal cord segment.
- Ventral roots are motor while dorsal roots are sensory.

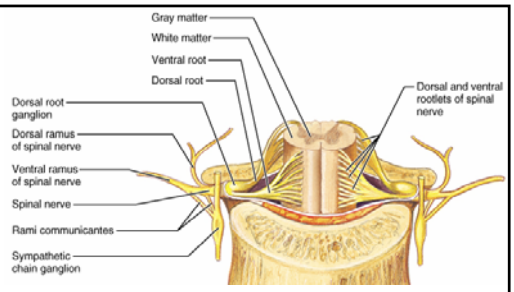


Spinal Nerves

- The 2 roots join to form a spinal nerve prior to exiting the vertebral column.
- Roots are short and horizontal in the cervical and thoracic regions while they are longer and more horizontal in the sacral and lumbar regions.



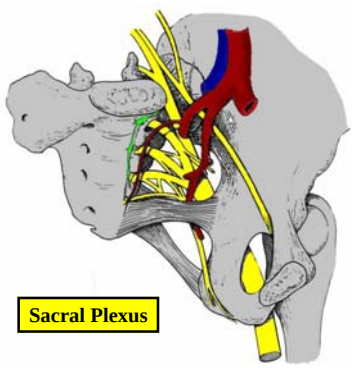
- Almost immediately after emerging from its intervertebral foramen, a spinal nerve will divide into a dorsal ramus, a ventral ramus, and a meningeal branch that reenters and innervates the meninges and associated blood vessels.



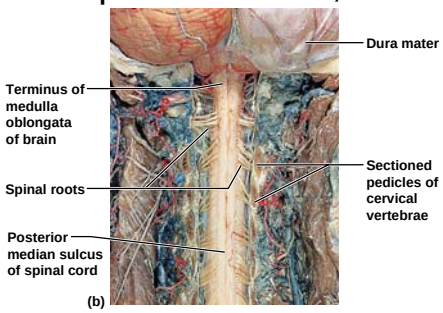
- Each ramus is mixed.
- Joined to the base of the ventral rami of spinal nerves in the thoracic region are the rami communicantes. These are sympathetic fibers that we'll deal with shortly.
- Dorsal rami supply the posterior body trunk whereas the thicker ventral rami supply the rest of the body trunk and the limbs.

Plexuses

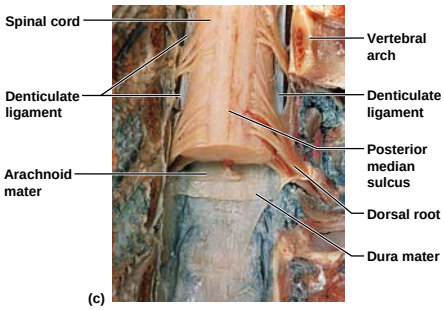
- Except for T_2 to T_{12}, all ventral rami branch extensively and join one another lateral to the vertebral column forming complicated nerve plexuses.
- W/i a plexus, fibers from different rami crisscross each other and become redistributed.



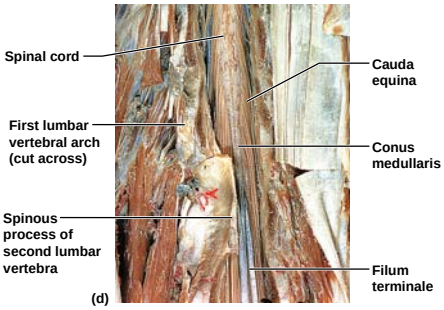
Gross structure of the spinal cord, posterior view,



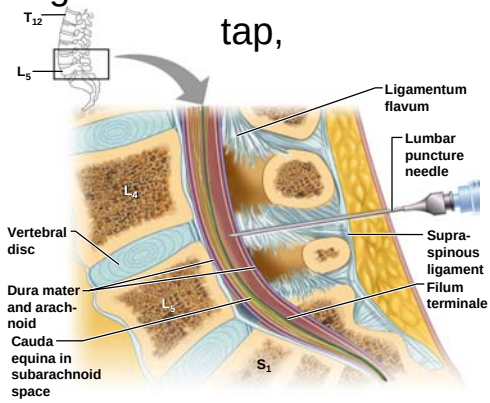
Gross structure of the spinal cord, posterior view,



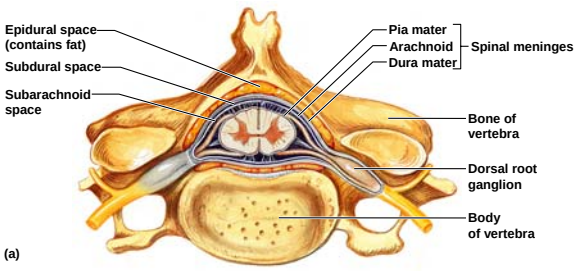
Gross structure of the spinal cord, posterior view,



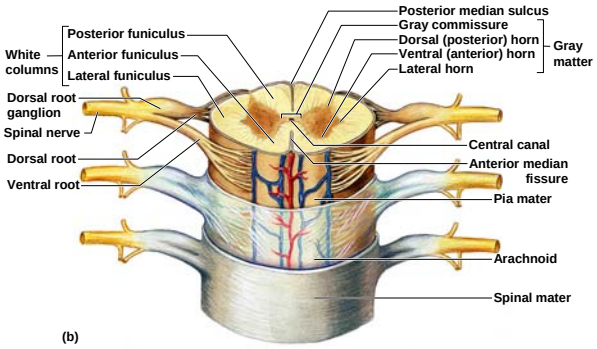
Diagrammatic view of a lumbar tap,



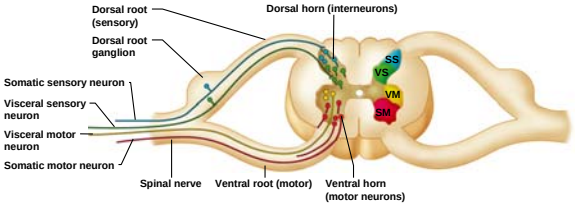
Anatomy of the spinal cord,



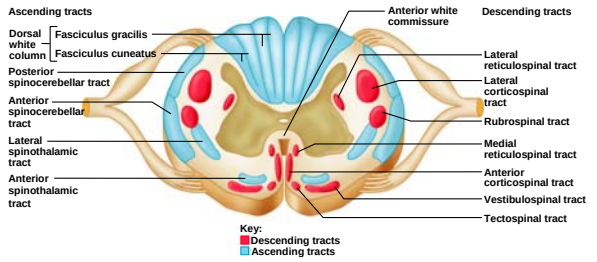
: Anatomy of the spinal cord,



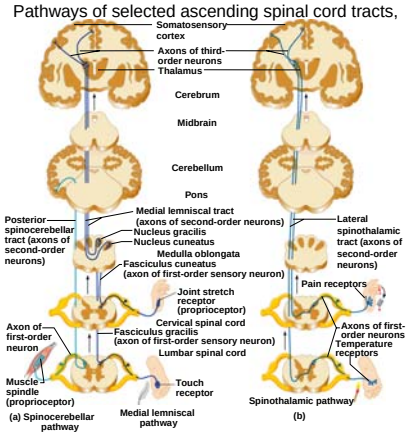
Organization of the gray matter of the spinal cord,.



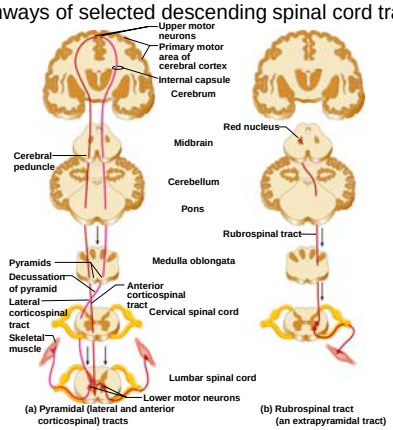
Major ascending (sensory) and descending (motor) tracts of the spinal cord, cross-sectional view,



Pathways of selected ascending spinal cord tracts,



Pathways of selected descending spinal cord tracts,



Reflexes

- A reflex is a rapid, predictable motor response to a stimulus
- Reflexes may:
  - Be inborn (intrinsic) or learned (acquired)
  - Involve only peripheral nerves and the spinal cord
  - Involve higher brain centers as well

Reflex Arc

- There are five components of a reflex arc
  - Receptor – site of stimulus
  - Sensory neuron – transmits the afferent impulse to the CNS
  - Integration center – either monosynaptic or polysynaptic region within the CNS
  - Motor neuron – conducts efferent impulses from the integration center to an effector
  - Effector – muscle fiber or gland that responds to the efferent impulse

Reflex Arc

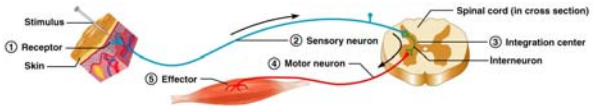


Figure 13.14

Stretch and Deep Tendon Reflexes

- For skeletal muscles to perform normally:
  - The Golgi tendon organs (proprioceptors) must constantly inform the brain as to the state of the muscle
  - Stretch reflexes initiated by muscle spindles must maintain healthy muscle tone

Muscle Spindles

- Are composed of 3-10 intrafusal muscle fibers that lack myofilaments in their central regions, are noncontractile, and serve as receptive surfaces
- Muscle spindles are wrapped with two types of afferent endings: primary sensory endings of type Ia fibers and secondary sensory endings of type II fibers
- These regions are innervated by gamma (γ) efferent fibers
- Note: contractile muscle fibers are extrafusal fibers and are innervated by alpha (α) efferent fibers

Muscle Spindles

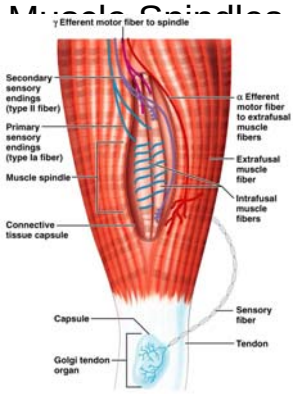


Figure 13.15

Operation of the Muscle Spindles

- Stretching the muscles activates the muscle spindle
  - There is an increased rate of action potential in Ia fibers
- Contracting the muscle reduces tension on the muscle spindle
  - There is a decreased rate of action potential on Ia fibers

Operation of the Muscle Spindle

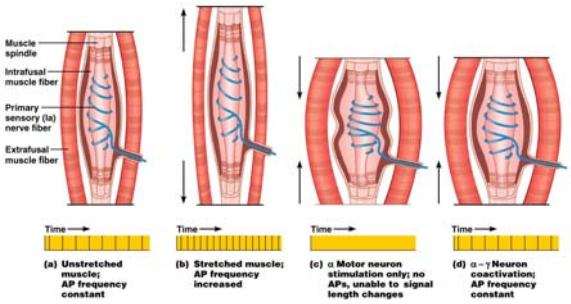


Figure 13.17

Stretch Reflex

- Stretching the muscle activates the muscle spindle
- Excited γ motor neurons of the spindle cause the stretched muscle to contract
- Afferent impulses from the spindle result in inhibition of the antagonist
- Example: patellar reflex
  - Tapping the patellar tendon stretches the quadriceps and starts the reflex action
  - The quadriceps contract and the antagonistic hamstrings relax

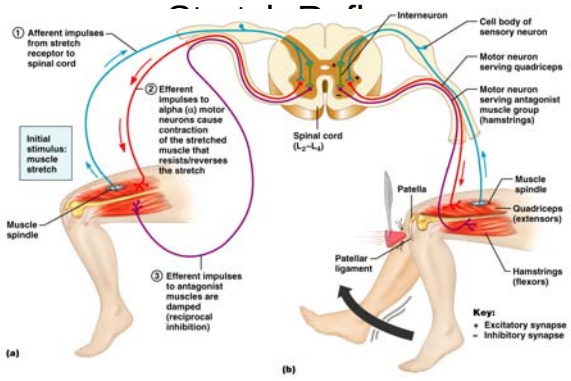


Figure 13.16

Golgi Tendon Reflex

- The opposite of the stretch reflex
- Contracting the muscle activates the Golgi tendon organs
- Afferent Golgi tendon neurons are stimulated, neurons inhibit the contracting muscle, and the antagonistic muscle is activated
- As a result, the contracting muscle relaxes and the antagonist contracts

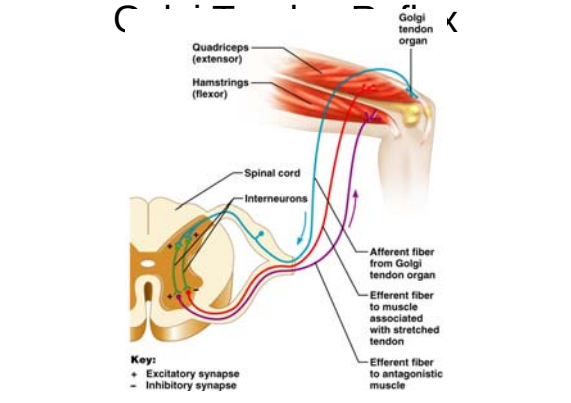


Figure 13.18

Flexor and Crossed Extensor Reflexes

- The flexor reflex is initiated by a painful stimulus (actual or perceived) that causes automatic withdrawal of the threatened body part
- The crossed extensor reflex has two parts
  - The stimulated side is withdrawn
  - The contralateral side is extended

Crossed Extensor Reflex

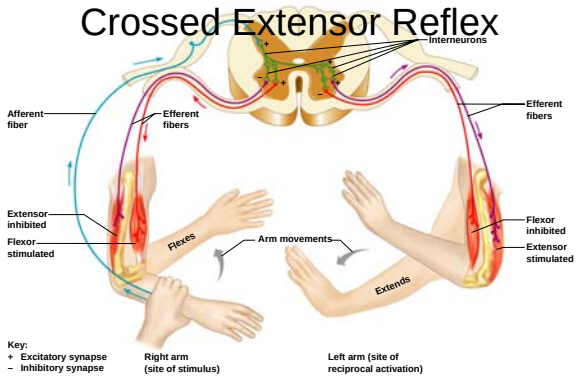


Figure 13.19

Crossed Extensor Reflex

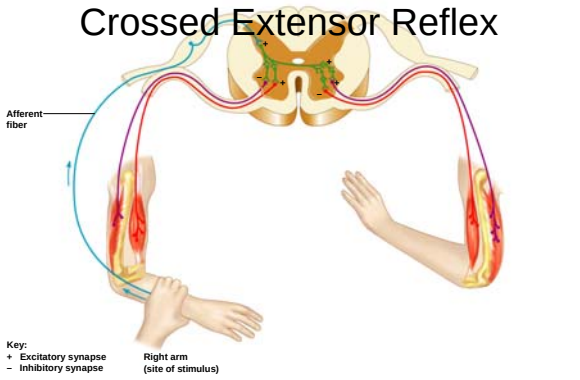


Figure 13.19

Crossed Extensor Reflex

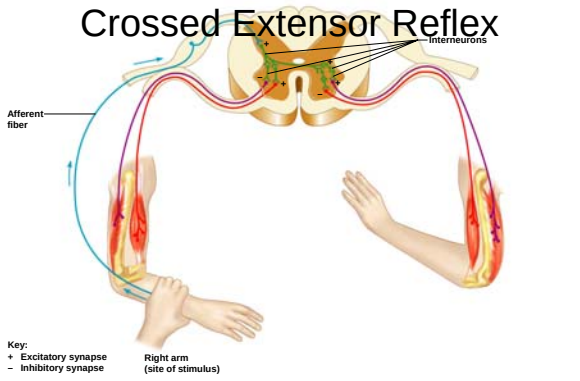


Figure 13.19

Crossed Extensor Reflex

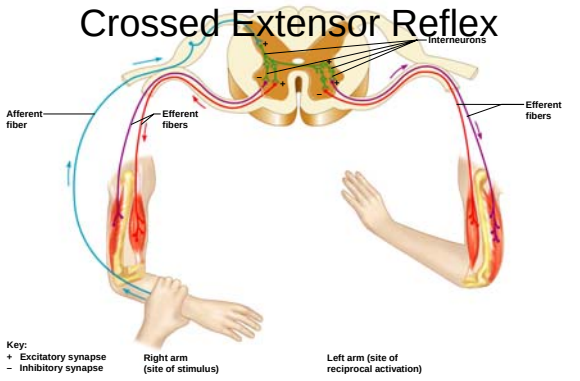


Figure 13.19

Crossed Extensor Reflex

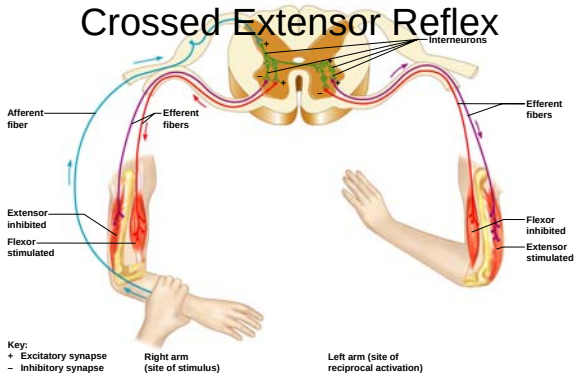


Figure 13.19

Crossed Extensor Reflex

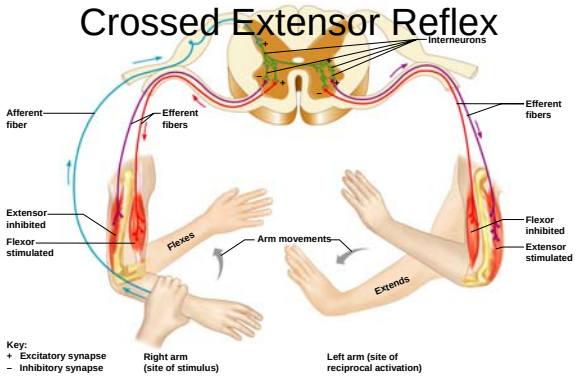


Figure 13.19

Superficial Reflexes

- Initiated by gentle cutaneous stimulation
- Example:
  - Plantar reflex is initiated by stimulating the lateral aspect of the sole of the foot
  - The response is downward flexion of the toes
  - Indirectly tests for proper corticospinal tract functioning
  - Babinski's sign: abnormal plantar reflex indicating corticospinal damage where the great toe dorsiflexes and the smaller toes fan laterally

Developmental Aspects of the PNS

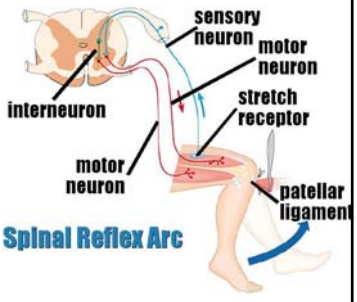
- Spinal nerves branch from the developing spinal cord and neural crest cells
  - Supply motor and sensory function to developing muscles
- Cranial nerves innervate muscles of the head

Developmental Aspects of the PNS

- Distribution and growth of spinal nerves correlate with the segmented body plan
- Sensory receptors atrophy with age and muscle tone lessens
- Peripheral nerves remain viable throughout life unless subjected to trauma

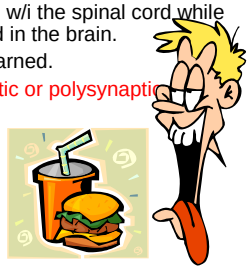
Reflex Arcs

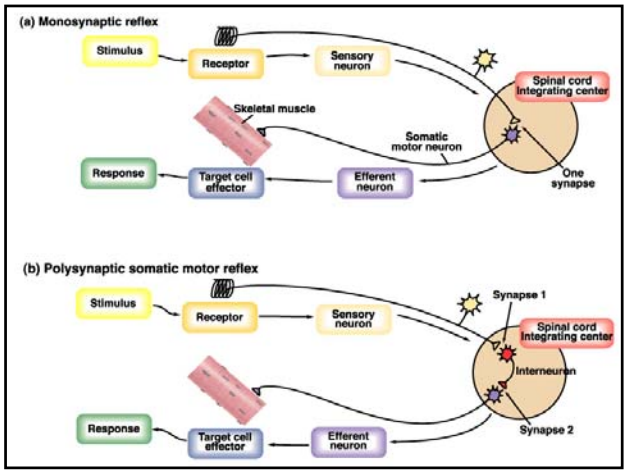
- A reflex is a rapid, predictable motor response to a stimulus. Unlearned and involuntary.
- Example?
- Components of a reflex arc:
  - Receptor → site of stimulus
  - Sensory neuron → transmits afferent info to CNS
  - Integration center → 1 or more interneurons
  - Motor neuron → transmits efferent signals to effector
  - Effector → muscle or gland



Reflexes

- Reflexes involving skeletal muscles and somatic motor neurons are somatic.
- Reflexes controlled by autonomic neurons are autonomic.
- Spinal reflexes are integrated w/i the spinal cord while cranial reflexes are integrated in the brain.
- Reflexes may be inborn or learned.
- Reflexes may be monosynaptic or polysynaptic
  - Difference?

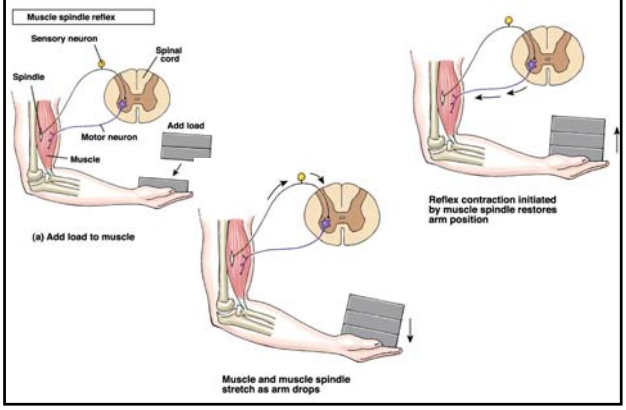




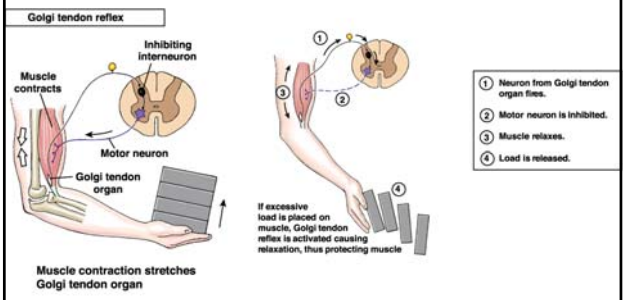
Somatic Reflexes

- Let's look at the muscle spindle reflex and the Golgi tendon reflex and figure out:
  - What they are?
  - Why are they somatic?
  - Are they mono- or polysynaptic?
  - Are they ipsilateral or contralateral reflexes?

Muscle Spindle Reflex

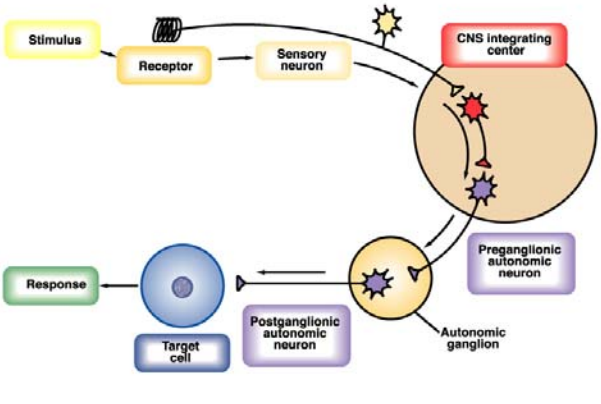


Golgi Tendon Reflex

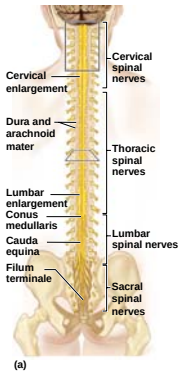


Autonomic Reflexes

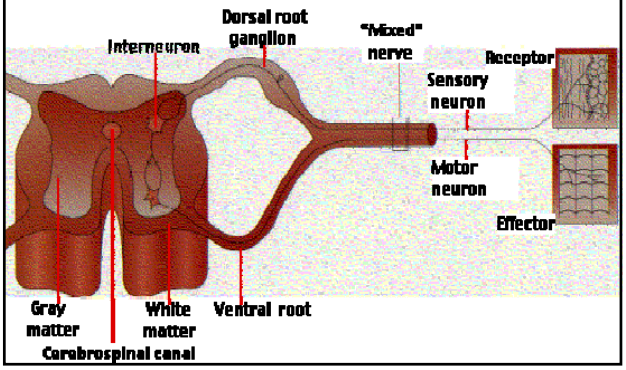
- May be spinal (e.g., urination and defecation) or modified by higher brain structures.
- The thalamus, hypothalamus and brain stem are in charge of multiple reflexes – HR, BP, breathing, eating, osmotic balance, temperature, vomiting, gagging, sneezing.
- All are polysynaptic.



Gross structure of the spinal cord, posterior view,



Spinal cord



The spinal cord extends from the skull (foramen magnum) to the first lumbar vertebra.

Like the brain, the spinal cord consists of gray matter and white matter.

The gray matter (cell bodies & synapses) of the cord is located centrally & is surrounded by white matter (myelinated axons).

The white matter of the spinal cord consists of ascending and descending fiber tracts, with the ascending tracts transmitting sensory information (from receptors in the skin, skeletal muscles, tendons, joints, & various visceral receptors) and the descending tracts transmitting motor information (to skeletal muscles, smooth muscle, cardiac muscle, & glands).

The spinal cord is also responsible for spinal reflexes.

Reflex- rapid (and unconscious) response to changes in the internal or external environment needed to maintain homeostasis

Reflex arc - the neural pathway over which impulses travel during a reflex. The components of a reflex arc include:

1 - receptor - responds to the stimulus

2 - afferent pathway (sensory neuron) - transmits impulse into the spinal cord

3 - Central Nervous System - the spinal cord processes information

4 - efferent pathway (motor neuron) - transmits impulse out of spinal cord

5- effector - a muscle or gland that receives the impulse from the motor neuron & carries out the desired response