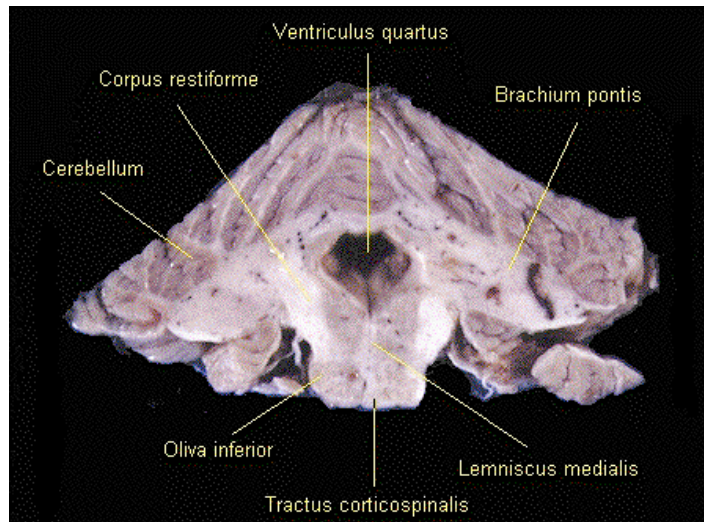


V. THE BRAIN (CEREBRUM)

THE MEDULLA



BLOOD SUPPLY

- **Vertebral Arteries** supplies caudal medulla.
- **Posterior Inferior Cerebellar Artery** supplies mid-medulla.

THE CLOSED MEDULLA

LEVEL OF THE PYRAMIDAL DECUSSATION: **The Spino-Medullary Junction.**

The most caudal section of the medulla, right above the Foramen Magnum.

- **SENSORY NUCLEI:**
 - **Nucleus Cuneatus:** Laterally, carrying vibratory-sense neurons from upper limb, from Fasciculus Cuneatus. The fasciculus surrounds it dorsally.
 - **Nucleus Gracilis:** Medially, carrying vibratory-sense neurons from lower limb, from Fasciculus Gracilis. The fasciculus surrounds it dorsally.
- **MOTOR NUCLEI: The Pyramids and the Pyramidal Decussation.**
 - Most cervical motor fibers decussate most rostrally. More sacral fibers decussate more caudally in the medulla.
 - **Anterior Corticospinal Tract:** Contains the 10% of motor fibers that don't decussate in the pyramidal decussation.

THE LEVEL OF THE INTERNAL ARCUATE DECUSSATION: Next level up, where sensory fibers from the Nuclei Gracilis and Cuneatus are crossing, heading ventrally, to go to the contralateral **medial lemniscus**.

- **SEGMENTAL MARKER: HYPOGLOSSAL NUCLEUS CN XII**, located just dorsal to the Medial Longitudinal Fasciculus.
 - **LESION:** Ipsilateral Lower-Motor Paralysis of tongue.
 - When you stick your tongue out, it will deviate toward the *damaged side*.
 - CN XII Nucleus is located toward the midline, just ventral to central grey.
- **Medial Lemniscus:** Carries the Contralateral Secondary Sensory Neurons for vibratory sense.
 - **SEGMENTOTOPIC ORGANIZATION:** Cervical is most dorsal (toward the center), Sacral is most ventral.

LATERAL SPINOTHALAMIC TRACT: Contained in the **Anterolateral System**, throughout the medulla.

- It is continuous with the Spinothalamic tract of the spinal cord.
- It contains fibers for contralateral pain and temperature information. These fibers cross in the spinal cord.

SEGMENTAL MARKERS FOR THE LOWER (CLOSED) MEDULLA:

- **CRANIAL NERVE XI: SPINAL ACCESSORY NUCLEUS:** It is located only in the lower medulla.

THE TRIGEMINAL NERVE (V) AND NUCLEI—The Nuclei are in the open and closed medulla, and the Pons.

- **SENSORY NUCLEI OF CN V:** All of these fibers eventually wind up in the *Ventral Posteromedial (VPM) Nucleus* of Thalamus.
 - **SPINAL TRIGEMINAL NUCLEUS:** It is a *very long nucleus*, traversing the entire length of the medulla.
 - All three divisions of the Trigeminal N converge on this nucleus
 - The Nucleus is like a dorsal-root (i.e. pseudo-unipolar) ganglion.
 - **MAIN SENSORY NUCLEUS:** It is located in the *Pons*. It houses the secondary neurons for the Touch Pathway for the head and face.
 - **MESENCEPHALIC NUCLEUS:** In the Mesencephalon, it houses proprioception for *all the muscles of the head and face*.
- **Motor Nucleus of V: The Masticator Nucleus** houses nuclei for V₃ that innervate muscles of mastication.
- **SPINAL TRIGEMINAL TRACT:** Carries first order neurons from the **Trigeminal (Semilunar) Ganglion** to the Spinal Nucleus.
- **TRIGEMINOTHALAMIC TRACTS:** Carries second order neurons from the various trigeminal nuclei to the Ventral Posteromedial (VPM) Nucleus of the Thalamus.
 - **Ventral Trigeminal Lemniscus (Trigeminothalamic Tract)**
 - **Dorsal Trigeminal Lemniscus (Trigeminothalamic Tract)**
- **PAIN AND TEMPERATURE PATHWAY OF THE HEAD AND NECK:**
 - **PRIMARY NEURON: Gasserian (aka Trigeminal aka Semilunar) Ganglion** houses the cell bodies -----> Pons -----> Down the **Spinal Trigeminal Tract** to the **Spinal Trigeminal Nucleus** where it SYNAPSES.
 - **SECONDARY NEURON: Spinal Nucleus** -----> CROSS MIDLINE -----> **Ventral Trigeminothalamic Tract** -----> **Ventral Posteromedial (VPM) Nucleus of Thalamus**.
 - **TERTIARY NEURON: VPM of Thalamus** -----> Post-Central (Sensory) Cerebral Cortex.
- **DISCRIMINATIVE TOUCH PATHWAY:** Cutaneous sensation follows the same pathway as Pain and Temperature, except it synapses in the **Main Sensory Nucleus of V**.
- **PROPRIOCEPTION PATHWAY:** It follows the same pathway as Pain and Temperature, except it synapses in the **Mesencephalic Nucleus of V**.
- **MIDLINE BILATERAL INNERVATION:** Sensory and motor fibers that supply midline structures, especially **the mouth**, tend to go back to the cortex bilaterally, as we need bilateral control over the mouth.
- **Tic Douloureux:** Trigeminal Neuralgia. A stabbing pain in the Mandibular and Maxillary nerves.
 - Cause is variable and uncertain. Compression of Trigeminal Nerve is found.

MEDIAL MEDULLARY SYNDROME: Occlusion of the **Anterior Spinal Artery** at the level of the **Obex**, i.e. right at the junction of the open and closed medulla.

LOST STRUCTURE	SYMPTOM	NOTES
Pyramid	Contralateral Upper Motor Hemiplegia	Spastic Paralysis Hyperreflexia, Positive Babinski on contralateral side
The Medial Lemniscus	Contralateral loss of vibratory sense and proprioception	This is right at the level of the Sensory Decussation
Hypoglossal Nucleus (XII)	Ipsilateral paralysis of tongue	Tongue will deviate toward the affected (ipsilateral) side.

OPEN MEDULLA

INFERIOR OLIVARY NUCLEUS: GOOD INDICATOR that you are in the medulla. It is found in the medulla and nowhere else.

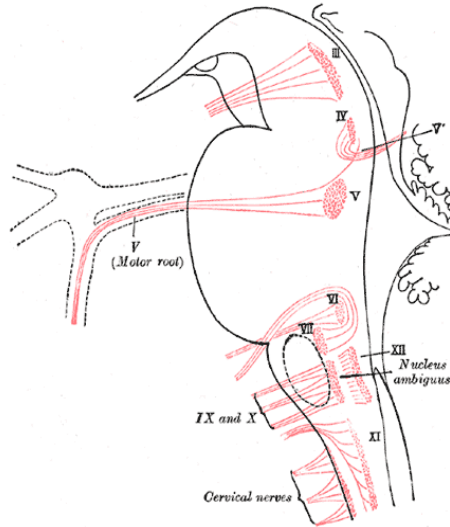
VESTIBULAR NUCLEUS (VIII): SEGMENTAL MARKER for the Open Medulla. Carries balance-information from the inner ear.

INFERIOR CEREBELLAR PEDUNCLE: Generally connects the spinal cord to the cerebellum. Receives three sets of afferent fibers and conveys them into the cerebellum:

- **Dorsal Spinocerebellar Tract:** Unconscious Proprioception
- **Vestibulocerebellar Tract:** Fibers from the Vestibular Nuclei.
- **Inferior Olivary Fibers:** Fibers from the Inferior Olivary Nucleus (extra-pyramidal system)

DORSAL MOTOR NUCLEUS (DMV) OF THE VAGUS (X): Send parasympathetics to the thorax and abdomen. Receives input from the **Nucleus of the Tractus Solitarius** which is just lateral to it.

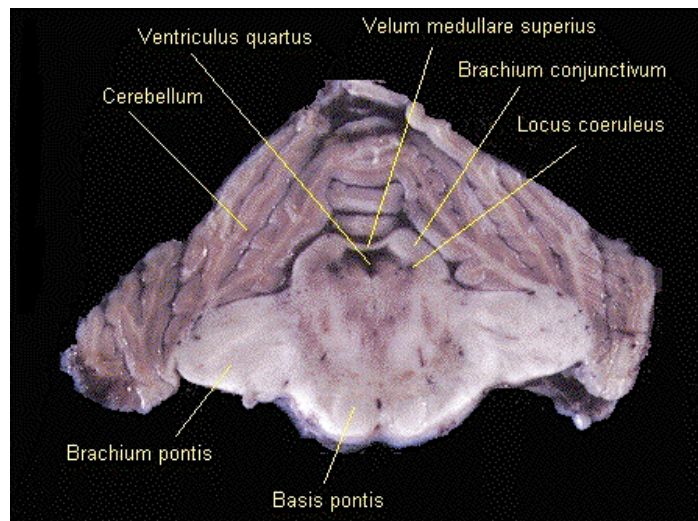
NUCLEUS AMBIGUUS (NA): Located in the open medulla that will carry motor innervation to the branchial arches via cranial nerves IX, X, and XI (i.e. larynx and pharynx).



LATERAL MEDULLARY (Wallenberg's) SYNDROME: Occlusion of **Posterior Inferior Cerebellar Artery (PICA)**, which perfuses the dorsolateral *upper (open) medulla*.

LOST STRUCTURE	SYMPTOM	NOTES
Vestibular Nucleus (VIII)	Dizziness and Nystagmus (movement of eyes to accommodate for dizziness)	
Inferior Cerebellar Peduncle	Loss of coordination and balance; nausea; no unconscious proprioception	They can't keep their balance with their eyes closed.
Descending Sympathetic Fibers	Ipsilateral Horner's Syndrome —ptosis, miosis, anhydrosis	These fibers are diffuse and hard to pinpoint. They influence intermediolateral neurons in spinal cord.
Lateral Spinothalamic Tract	CONTRALATERAL loss of pain and temperature sensation in lower body	
Nucleus Ambiguus	Impaired Gag Reflex , hoarseness, dysphagia	
Spinal Trigeminal Nucleus and Tract	IPSILATERAL loss of pain and temperature sensation in face	This is exact opposite as that for the body—this SPLIT in pain/temp loss indicates a medullar syndrome

THE PONS



BLOOD SUPPLY

- **Superior Cerebellar Artery**
- **Pontine Branches of the Basilar Artery**

THE BASILAR PONS: The ventral aspect of the Pons.

- **LONGITUDINAL FIBER BUNDLE:**
 - **Corticospinal Fibers:** They carry the traditional corticospinal fibers, headed for the pyramidal decussation and then the contralateral spinal cord.
 - **Corticobulbar Fibers:** These are the *upper motor neurons for Cranial Nerve nuclei*, analogous to corticospinal fibers.
 - **Corticopontine Fibers:** These fibers come from the cerebral cortex and are headed for the Pontine Nuclei of the Basilar Pons.
- **TRANSVERSE FIBER BUNDLE: Pontocerebellar Fibers.** They contain the post-Pontine-Nuclei fibers that are headed to the contralateral Cerebellum. They cross through the midline.
 - These fibers go to the contralateral *Middle Cerebellar Peduncle*.
- **PONTINE NUCLEI:** They are throughout the Basilar Pons, filling in the spaces between the fiber tracts.
 - They receive afferents from the Corticopontine fibers.
 - They send efferents to the *Contralateral Cerebellum*.
- **MIDDLE CEREBELLAR PEDUNCLE:** Generally connects the Pons to the Cerebellum. They carry **Pontocerebellar Fibers**—the *Transverse Fibers* from the Pontine Nuclei, headed to the ipsilateral cerebellum.
 - This fiber-bundle allows for fine motor coordination and *planning* of motor activity, such as typing and piano playing, where each movement is not consciously processed.

THE PONTINE TEGMENTUM: That portion of the Pons dorsal to the Basilar Pons and ventral to the Fourth Ventricle.

- **MEDIAL LEMNISCUS:** It's still there. It has moved laterally.
 - **SEGMENTOTOPIC ORGANIZATION:** The cervical segments are now *medial* and the sacral segments *lateral*.
- **ABDUCENS NUCLEUS (VI):** It is just ventral to the fourth ventricle.
 - **SEGMENTAL MARKER:** CN VI goes medially and posteriorly to exit near the motor fibers of the pons.
- **PONTINE CENTER FOR LATERAL GAZE (PCLG):** Right around the Abducens Nucleus, it coordinates CN VI and CN III in bilateral movement of eyes.
 - If you look to the Left: The *Left Abducens* stimulates the left lateral rectus, and the *Right Oculomotor* stimulates the Right Medial Rectus.
 - These impulses are coordinated by the PCLG.
 - **LESION of PCLG can be DIAGNOSED:** If the lateral gaze of one eye cannot pass medial to the midline—but you can still look cross-eyed, then the problem is in the PCLG, or **Medial Longitudinal Fasciculus**, rather than in CN III.

- **MEDIAL LONGITUDINAL FASCICULUS (MLF):** It is found throughout Medulla and Pons.
 - It is near the PCLG.
 - **Multiple Sclerosis:** The MLF is one of the first things to go. Hence *lateral gaze paralysis* is a common early symptom.
- **FACIAL NUCLEUS (VII):** Found in the caudal, dorsolateral pons.
 - This is the nucleus for muscles of facial expression. Submandibular and Sublingual gland are also carried by VII, but they originate from the Superior Salivatory Nucleus.
 - **INTERNAL GENU OF VII:** The Facial Nerve fibers come out of the medial part of the nucleus, and then bend dorsally and laterally to *bend around the Abducens Nerve (VI)*.
 - The Facial Nucleus is divided into two halves:
 - **PERIPHERAL LESION OF VII:** Damage to Facial Nucleus or nerve. Ipsilateral paralysis of facial muscles both above and below the eyes.
 - **CENTRAL LESION OF VII:** Damage to the *Corticobulbar Tract*, at any point above the Facial Nucleus.
 - The supraorbital region of the face will still be innervated by the other (undamaged) side.
- **THE MAIN SENSORY NUCLEUS (V):** SEGMENTAL MARKER for the Pons. See Trigeminal Nerve for details.

MEDIAL INFERIOR PONTINE SYNDROME: Occlusion of the **Paramedian Branch of the Basilar Artery**

LOST STRUCTURE	SYMPTOM	NOTES
Pyramids of Basilar Pons	Contralateral Upper Motor Neuron Hemiplegia	
Pontine Nuclei Pontocerebellar Fibers	Bilateral Limb Ataxia	Lost influence of fine motor coordination and “planning” of motor activity
Medial Lemniscus	Contralateral loss of proprioception and vibratory sense	The Medial Lemniscus has moved laterally now.
Abducens Nucleus (VI)	Ipsilateral Internal Strabismus—eye points inward (III) and downward (IV)	SEGMENTAL MARKER
Facial Nucleus (VII)	Contralateral facial paralysis both above and below eye.	SEGMENTAL MARKER. Above and Below eye indicates

CORNEAL REFLEX: Touch the cornea and see whether one or both eyes blink.

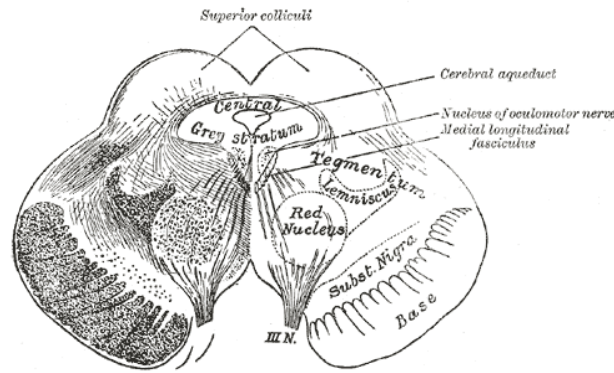
- Afferent Limb of the Reflex: *The Ophthalmic, V¹* -- sensory information from cornea.
- Efferent Limb of the Reflex: *The Facial, VII*—Orbicularis Oculi. The impulse is sent out *bilaterally*.
- **Direct Response:** The same eye blinks as was stimulated.
- **Consensual Response:** The other eye blinks when an eye is stimulated.
- **Normal Response:** Normally, both eyes should blink. If one eye doesn’t blink, then there is damage to the afferent or efferent limb.

MEDIAL SUPERIOR PONTINE SYNDROME: Caused by occlusion of the **Upper Branch of the Basilar Artery**.

LATERAL SUPERIOR PONTINE SYNDROME: Caused by occlusion of the **Superior Cerebellar Artery**.

- Both motor and sensory divisions of CN V would be damaged.

THE MIDBRAIN



THE CRUS CEREBRI: Also known as the **Cerebral Peduncle**. It is the major pathway of motor neurons out of the cortex. It is segmentotopically organized as follows:

- **Medial One Fifth:**
 - **FRONTOPONTINE TRACT:** Frontal Cortex -----> Pontine Nuclei in Basilar Pons -----> Middle Cerebellar Peduncle
- **Central Two Fifths:**
 - **CORTICOBULBAR TRACT:** Pre-Central Gyrus -----> Upper motor innervation of Cranial Nerve Nuclei.
 - **CORTICOSPINAL TRACT:** Pre-Central Gyrus -----> Pyramidal Decussation -----> Lateral Corticospinal Tract of spinal cord.
- **Lateral Two Fifths:**
 - **TEMPOROPONTINE TRACT:** Influence of Temporal Lobe (hearing) on Pontine Nuclei.
 - **PARIETOPONTINE TRACT:** Influence of Parietal Lobe (somatic sensation) on Pontine Nuclei.
 - **OCCIPITOPONTINE TRACT:** Influence of Occipital Lobe (vision) on Pontine Nuclei.

SUBSTANTIA NIGRA: Located between the Tegmentum and the Crus Cerebri.

- **Dopamine** is released in its neurons.
 - **Parkinson's Disease:** Lesions of the Substantia Nigra and/or Dopamine Deficiencies result in Parkinson's Disease.
- **MELANIN** can be found in Substantia Nigra neurons, making them darkly stained, hence the name.
- **PATH:** Substantia Nigra -----> Basal Ganglia (Caudate Nucleus, Putamen, Globus Pallidus).
- **FNXN:** Substantia Nigra *inhibits activity in the Basal Ganglia*. It is part of the extrapyramidal motor system.

TEGMENTUM: That region of the Mesencephalon, between the Substantia Nigra and the Cerebral Aqueduct. The Tegmentum also refers to the corresponding regions in the Medulla and Pons.

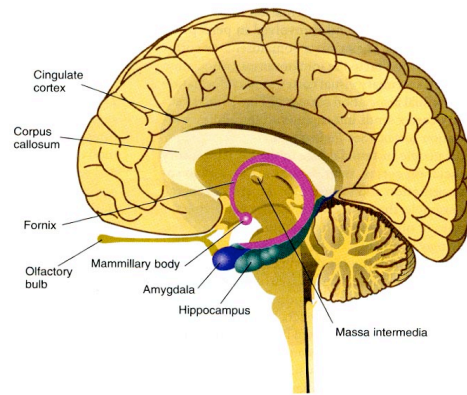
- The Tegmentum generally contains ascending fiber tracts, cranial nerve nuclei, and the **Reticular Formation**.
- **THE TROCHLEAR NERVE (CN IV):** At the level of the Inferior Colliculus, at the top of the Tegmentum.
 - CN IV innervates the Superior Oblique muscle of the ipsilateral eye. It pulls the eye downward and inward.
 - **EXIT PATH:** The Trochlear Nerve passes dorsally up and around central grey, to exit dorsally on the contralateral side.
- **THE OCULOMOTOR NERVE (CN III):** At the level of the Superior Colliculus, at the top of the Tegmentum.
 - **EDINGER-WESTPHAL NUCLEUS:** It is located most dorsomedially. It supplies Pre-Ganglionic Parasympathetics to the ipsilateral eye.
 - **CN III** fibers travel ventrally through the Tegmentum and then exit out the **Interpeduncular Fossa** to supply the ipsilateral eye.
- **MEDIAL LONGITUDINAL FASCICULUS (MLF):**
 - **LOCATION:**
 - **FNXN:** The MLF contains two tracts that are crucial to coordination of gaze.
 - **LESION TO MLF:** **INTRANUCLEAR OPHTHALMOPLEGIA** = no coordination of gaze, diagnosable as *lateral gaze paralysis*.

- **DECUSSATION OF THE SUPERIOR CEREBELLAR PEDUNCLE:** Ventral, central part of Tegmentum, at the level of the Inferior Colliculus.
 - **CEREBELLORUBRAL TRACT:** Will influence *lower motor neurons* via the Red Nucleus and Rubrospinal Tract.
 - **CEREBELLOTHALAMIC TRACT:** Will influence *upper motor neurons*, via the Thalamus and Thalamic Projections.
 - **RED NUCLEUS:** At the level of the Superior Colliculi, the Red Nuclei receive afferents from the Cerebellorubral Tract, and send efferents down the **Rubrospinal Tract** as a principle part of the extrapyramidal motor system.
 - **SENSORY TRACTS of the Tegmentum: From Medial to Lateral**
 - **MEDIAL LEMNISCUS:**
 - *Level of the Inferior Colliculus:* It is oriented laterally (from side to side), and located just dorsal to the Substantia Nigra.
 - *Level of the Superior Colliculus:* It is located just dorsolateral to the Red Nucleus.
 - **THE ANTEROLATERAL SYSTEM:** It is now continuous with the Medial Lemniscus, as both tracts head for the VPL of thalamus.
 - **LATERAL LEMNISCUS:** It is located just ventrolateral to the Inferior Colliculus. It forms a “capsule” around the Inferior Colliculus.
- TECTUM:** That region of the Mesencephalon dorsal to the Cerebral Aqueduct, containing the two Superior colliculi and two Inferior Colliculi.
- **INFERIOR COLLICULUS:** Relay station for *Auditory Pathway*.
 - Auditory Pathway: Lateral Lemniscus -----> Inferior Colliculus -----> **Brachium** of the Inferior Colliculus -----> **Medial Geniculate Body of Thalamus** -----> Primary Auditory Cortex.
 - **SUPERIOR COLLICULUS:** Involved in Foveation and Eye-Reflexes.
 - Afferent Fibers received from:
 - Efferent Fibers:

WEBER’S SYNDROME: Paramedian infarct of the Midbrain.

LOST STRUCTURE	SYMPTOM	NOTES
CRUS CEREBRI: Frontopontine Tract		
CRUS CEREBRI: Corticobulbar Tract	Contralateral paralysis of lower half (suborbital) of the face.	The <i>Central Lesion of VII</i> is what is easily identifiable clinically
CRUS CEREBRI: Corticospinal	Contralateral Spastic Paralysis, Hyperreflexia, Positive Babinski	Upper Motor Neuron Hemiplegia
CRUS CEREBRI: Occipito/Tempero/Parieto Pontine Tracts	Contralateral General Ataxia	Lost sensation-feedback from somatic, auditory, and vision lobes.
Oculomotor Nucleus (III)	1) Ipsilateral External Strabismus (Down and Out) 2) No pupillary reflex (dilated eyes) 3) Complete Ptosis (closed eyelid)	SEGMENTAL MARKER 1) Due to lost GSE fibers. 2) Due to lost Parasympathetics to Pupillary Muscle 3) Due to lost innervation of Levator Palpebrae
Substantia Nigra	Parkinsonian Symptoms	Affects extrapyramidal motor system. Limb ataxia.

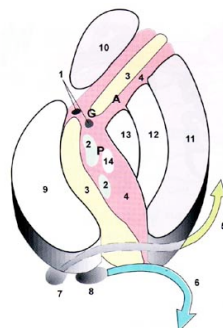
THE DIENCEPHALON AND BASAL GANGLIA



THE DIENCEPHALON:

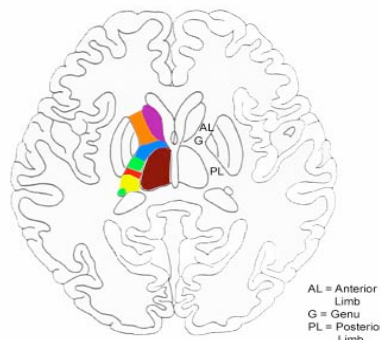
- **THE THALAMUS:** Same thing as the “Dorsal Thalamus.” The **Internal Medullary Lamina** divides the Thalamus into three major clusters of Nuclei.
 - **ANTERIOR NUCLEAR GROUP:**
 - **DORSOMEDIAL NUCLEUS:**
 - **VENTRAL TIER NUCLEI:**
 - Receives fibers from Cerebellum, Globus Pallidus, and Substantia Nigra -----> Primary Motor Cortex (Area 4) and Frontal Cortex (Area 6)
- **SUBTHALAMIC NUCLEUS:**
- **EPITHALAMUS (PINEAL BODY):**
 - LOCATION: It is on the dorsal surface of the Thalamus, right above the Tectum.
- **HYPOTHALAMUS:**
 - **Mamillary Bodies**

THE INTERNAL CAPSULE: It is the main highway of communication between the cortex and brainstem.



1. Corticobulbar tract
2. Corticospinal tract
3. Corticothalamic fiber
4. Thalamocortical fiber
5. Auditory radiation
6. Optic radiation
14. Corticorubral fiber

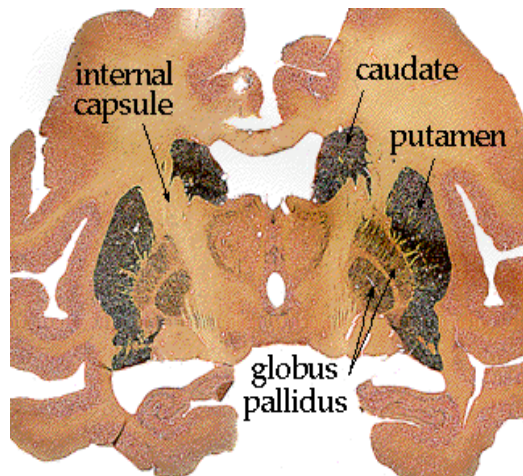
- **ANTERIOR LIMB OF INTERNAL CAPSULE:** Located between the Caudate Nucleus and Lentiform Nucleus.
 - **VASCULAR SUPPLY:** **Anterior Cerebral Artery**
 - **CORTICAL AFFERENT FIBERS:** **Anterior Thalamic Radiations** from the Anterior and Medial Thalamic Nuclei.
 - **CORTICAL EFFERENT FIBERS:** **Frontopontine Fibers**



AL = Anterior Limb
G = Genu
PL = Posterior Limb

- **GENU OF INTERNAL CAPSULE:** Central Bend in Internal Capsule.
 - VASCULAR SUPPLY: **Internal Carotid Artery**
 - CORTICAL AFFERENT FIBERS: **Superior Thalamic Radiations**
 - CORTICAL EFFERENT FIBERS: **Corticobulbar Tract.**
- **POSTERIOR LIMB OF INTERNAL CAPSULE:** Lies between the Dorsal Thalamus and the Lentiform Nucleus.
 - *The **Crus Cerebri** is continuous with the Posterior Limb of the Internal Capsule.*
 - VASCULAR SUPPLY: **Anterior Choroidal Artery**
 - CORTICAL AFFERENT FIBERS:
 - This would be the third order neuron from the Ventral Posterolateral *and* Ventral Posteromedial Nuclei of the Thalamus.
 - Each Optic Radiation carries information for the contralateral *field of vision*.
 - CORTICAL EFFERENT FIBERS:
 - Upper limb fibers are *nearest the Genu*.
 - Lower Limb fibers are *nearest the Occipital Pole*.

THE BASAL GANGLIA (CORPUS STRIATUM): They are Telencephalon (forebrain) derivatives.



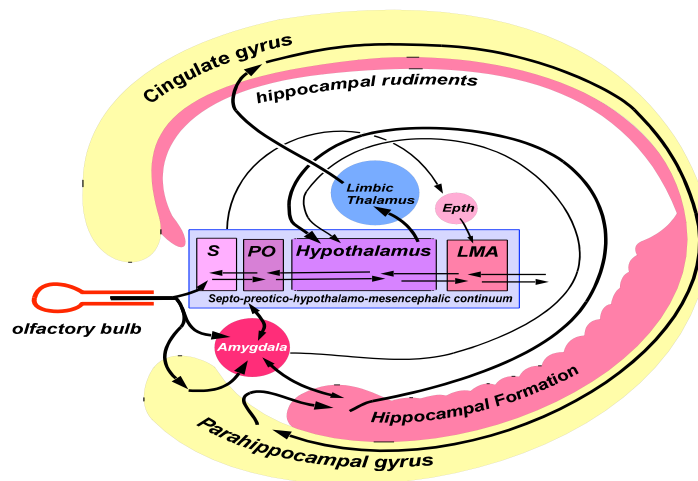
- **CAUDATE NUCLEUS:** Directly lateral to the lateral ventricles.
 - VASCULAR SUPPLY: **A1 Branch of the Anterior Cerebral Artery**
 - STRUCTURE: It can be divided into a Head, Body, and Tail.
- **LENTIFORM NUCLEUS:** Lateral to the Caudate Nucleus (anteriorly) or the Thalamus (Posteriorly).
 - VASCULAR SUPPLY: **Lateral Striate Branches of the Middle Cerebral Artery**
 - **GLOBUS PALLIDUS:** Most medially placed in Lentiform Nucleus.
 - **PUTAMEN:** Larger, most laterally placed in Lentiform Nucleus.
- **AMYGDALOID NUCLEUS:** Function is closely related to hypothalamus.
 - LOCATION: It joins with the Caudate Nucleus in the core of the Temporal Lobe.

POSTERIOR LIMB SYNDROME: Occlusion of the **Anterior Choroidal Artery**.

LOST STRUCTURE	SYMPTOM	NOTES
Corticospinal Fibers in the Posterior Limb	Contralateral Upper Motor Hemiplegia	Spastic Paralysis, Positive Babinski, Hyperreflexia
Lost Somatosensory Fibers (Superior Thalamic Radiations) in Posterior Limb	Contralateral loss of somatic sensation.	There is a <i>crude awareness of pain</i> retained by the intact Thalamus
Lost Optic Radiations	Contralateral Homonymous Hemianopia —loss of the contralateral field of vision	SEGMENTAL MARKER for the Posterior Limb.

THE LIMBIC SYSTEM

Components of the Limbic System



● TELEENCEPHALON

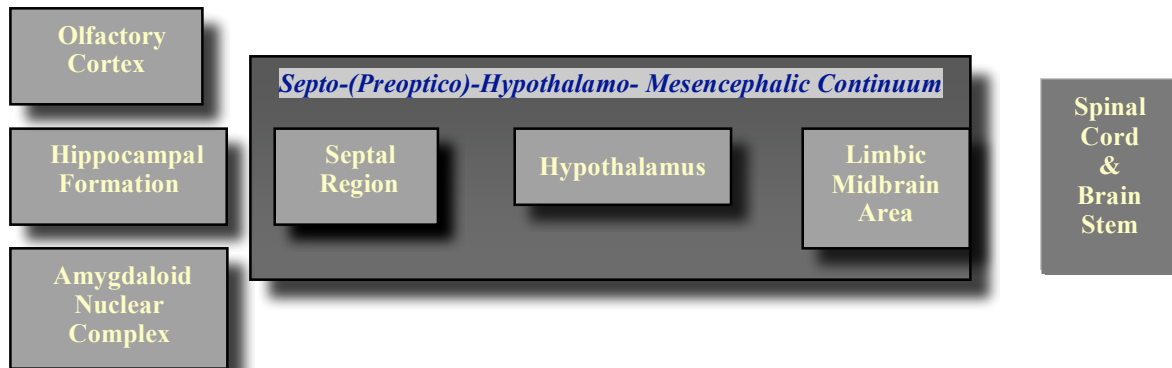
- Limbic Lobe
 - Gyrus Fornicatus
 - Cingulate Gyrus
 - Parahippocampal Gyrus
 - Hippocampal Formation
 - Hippocampus
 - Dentate Gyrus
 - Subiculum
 - Hippocampal Rudiments
 - Fasciolar Gyrus
 - Indusium Griseum
- Olfactory Cortex (Rhencephalon) - Piriform Lobe
 - Prepiriform Cortex
 - Periamygdaloid Cortex
 - Entorhinal Cortex
- Basal Forebrain Area
 - Substantia Innominata
 - Basal Nucleus of Meynert
 - Ventral Pallidum
 - Nucleus Accumbens (Septi)
- Septal Region
 - Septal Area
 - Paraterminal Gyrus
 - Subcallosal Gyrus
 - Septal Nuclei
 - Dorsal, Lateral and Medial Septal Nuclei
 - Nucleus of Diagonal Band of Broca
 - Bed Nucleus of Stria Terminalis
- Amygdaloid Nuclear Complex
 - Corticomedial Nuclear Group
 - Basolateral Nuclear Group
 - Central Nucleus

● DIENCEPHALON

- Thalamus, Limbic
 - Anterior Nuclear Group
 - Mediodorsal (MD) Nucleus
 - Midline Nuclei

- Hypothalamus
 - Preoptic Region
 - Preoptic Periventricular Nucleus
 - Medial Preoptic Nucleus
 - Supraoptic Region
 - Suprachiasmatic Nucleus
 - Anterior Nucleus
 - Supraoptic Nucleus
 - Paraventricular Nucleus
 - Tuberal Region
 - Dorsomedial Nucleus
 - Ventromedial Nucleus
 - Infundibular (Arcuate) Nucleus
 - Mammillary Region
 - Lateral, Medial and Intermediate Mammillary Nucleus
 - Posterior Nucleus
- Epithalamus
 - Habenular Nucleus
 - Medial Habenular Nucleus
 - Lateral Habenular Nucleus
 - Pineal Gland
- MESENCEPHALON
 - Limbic Midbrain Area
 - Median Raphe Nucleus
 - Dorsal Raphe Nucleus
 - Ventral Tegmental Area
 - Dorsal Tegmental Nucleus
 - Periaqueductal Gray

Anatomical Structures of the Limbic System



- Neocortex: Two structures located lateral, rather than medial, to the Sylvian Sulcus.
 - **Dorsolateral cortex:** Pre-Frontal Association Cortex.
 - **Orbitofrontal cortex:** It is involved in the motor events associated with emotion.
- Allocortex:
 - **Cingulate Gyrus:** Paleocortex (most primitive)
 - **Parahippocampal gyrus:** Paleocortex (most primitive)
 - **Hippocampal formation:** The only structure that is exclusively part of limbic system. Locale is at the base of the Temporal Lobe.
 - Structure: Three layers containing Pyramidal Cells
 - Molecular Layer: Receives input from Dentate Nucleus
 - Pyramidal Cell Layer: Pyramidal cell bodies.
 - Polymorphic Layer: Output through Fornix or to other Hippocampal structures.
 - **Anoxia:** The hippocampus is extraordinarily sensitive to Anoxia.
 - Outputs: The hippocampus has several outputs.
 - Back to Neocortex: Consolidation of Short-Term Memory into Long-Term Memory.

- Fornix → To Hypothalamus: Modulate autonomic / hypothalamic behavior.
- Septum: A way station for information headed to the hypothalamus.
- **Hippocampus** general **function** is to *consolidate short-term memory into long-term memory*
- **Lesion** of only **hippocampus** results in anterograde amnesia. Patient would be no longer able to remember new things, but previous memories would remain intact.
- Structure: Three layers containing Granule Cells
- Molecular Layer: Outer layer, receives input from Entorhinal Cortex
- Granule Cell Layer: Granule Cell bodies
- Polymorphic Layer: Inner Layer, sends output to the Hippocampus
- Input: It receives direct olfactory input, as well as association input for the other senses.
- Output: The Dentate Nucleus.
- **Amygdala:** Attaches the subjective components of emotions and feelings to autonomic components.
Amygdaloid Nuclei:
 - Corticomedian Group → Hypothalamus
 - Corticomedian Group → Stria Terminalis → Septum
 - Basolateral Nuclei ↔ Neocortex
 - Basolateral Nuclei → Dorsomedial Nucleus of Thalamus → Pre-Frontal Cortex
 - Basolateral Nuclei → Nucleus Accumbens
 - Some info also sent to brainstem nuclei in Pons.
- **Diencephalon:**
 - **Fornix:** The tract over which the Hippocampus sends information to the Hypothalamus.
 - **Septum:** A way station between the Hippocampus and Hypothalamus.
 - **Anterior nucleus, thalamus**
 - **Medial dorsal nucleus, thalamus**
 - **Hypothalamus:**
- **Striatum (Basal Ganglia):** Modulates motor activity in the Limbic System.
 - **Nucleus Accumbens:**
 - This circuit modulates the motor behaviors associated with emotion.
 - It is referred to as a “closed circuit”

Papez Circuit: The fundamental interaction between higher sensory input from the cortex and more primitive functions from the sub-cortex and the rest of the body.

- **Posterior parietal association cortex:** Information that enters Papez’ Circuit originates from the sensory association cortex (combination of visual, auditory, somatosensory)
 - **Olfaction:** Olfactory information, on the other hand, enters the Limbic System directly.
- Incoming signal: Association-Cortex → Cingulate Gyrus → Hippocampal formation → Entorhinal Cortex (synapse) → Hippocampus
- Outgoing signal: Hippocampus → Fornix → Mamillary Bodies → Mammillothalamic Tract → Anterior Nucleus of Thalamus

Kluver-Bucy Syndrome: Results from bilateral lesions of the Amygdala and Hippocampus.

- **Antegrade Amnesia**
- **Hypermetamorphosis:** Old visual stimuli are repeatedly approached as if they are new.
- **Hypersexuality & Loss of sexual preference.**
- **Increase Oral exploratory behavior:** Put everything in their mouth.
- **Placidity:** Passive and exhibit little emotions toward extreme stimuli.
- **Psychic blindness:** Seen objects are treated inappropriately.

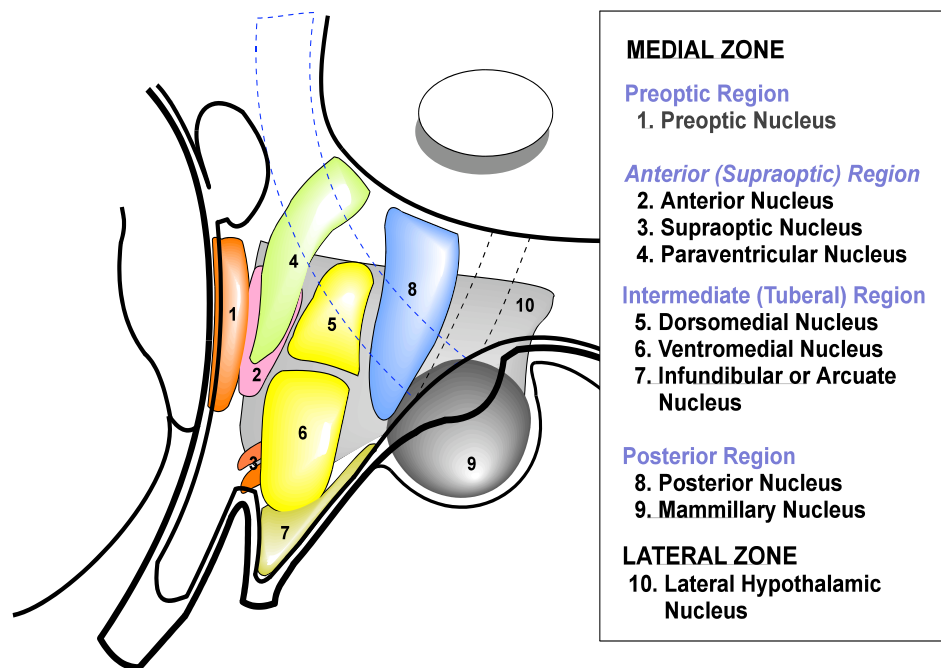
Schizophrenia: A splitting of the cognitive with the emotional aspects of behavior.

- **Dopamine:** Two Dopaminergic systems are implicated in Schizophrenia.
 - **Mesolimbic system:** Provides Dopaminergic neurons to the Nucleus Accumbens.
 - **Mesocortical system:** Projects dopaminergic neurons to PreFrontal Cortex.
- **Positive symptoms:** Overproduction of Dopaminergic Mesolimbic Neurons → over expression of limbic system
 - This problem could be treated with dopamine antagonists
 - Positive Symptoms = hallucinations and uncontrolled emotions
- **Negative symptoms:** A decrease in dopaminergic output of the mesocortical system → pre-frontal cortex. They think this may be involved.
 - This problem could theoretically be treated with dopamine itself, but that treatment doesn’t work.
 - Negative Symptoms = lack of motivation, lack of planning, lack of foresight

THE HYPOTHALAMUS

- **Borders:** The Hypothalamus forms the walls of the **Third Ventricle**
 - **Optic Chiasm:** Anterior-Ventral border
 - **Anterior Commissure:** Posterior-Rostral border.
 - **Mamillary Complex:** Forms the Ventral-Caudal border. It is very easy to see on the gross-brain but we don't know its function.
- **Blood supply:**
 - **Hypothalamic Arteries:** They come off the Circle of Willis.
 - **Superior Hypophyseal Artery:** Supplies the basal hypothalamus (**median eminence**) and then goes on to supply the **Adenohypophysis** (anterior pituitary).
 - **Inferior Hypophyseal Artery:** It supplies the **Neurohypophysis** (posterior pituitary).
 - **Hypophyseal Vein:** The neurohypophysis dumps its contents (oxytocin, ADH) out of hypothalamic nerves, and into the hypophyseal vein, where it then makes its way into the general circulation.

NUCLEI, PARTS, AND FUNCTIONS OF THE HYPOTHALAMUS



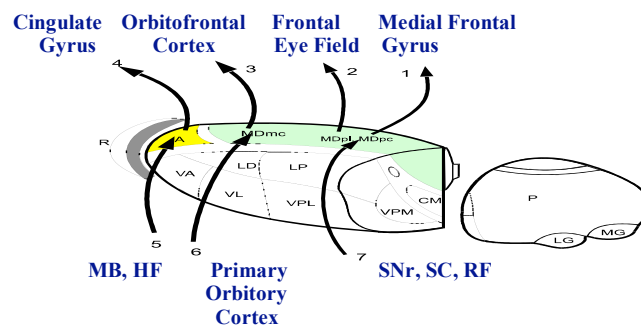
- **Mamillary Bodies:** The most caudal part of the hypothalamus.
- **Pre-Optic Area:** The most anterior part of the Hypothalamus, near the optic chiasm.
- **Paraventricular Nucleus:** Above the pre-optic area, surrounding the third ventricle on either side. The sites of origin of the Neurohypophyseal hormones.
- **Supraoptic Nucleus:** Near the paraventricular nucleus. The sites of origin of the neurohypophyseal hormones (Oxytocin, ADH).
- **Suprachiasmatic Nucleus:** Right above the optic chiasm, it regulates circadian rhythms.
- **Arcuate Nucleus:** Sits right above the pituitary gland. All pituitary factors pass through this nucleus before reaching the pituitary.
 - **Median Eminence** is next to Arcuate Nucleus, and is where a lot of the neurons terminate on blood vessels.
- **Ventral Medial Nucleus:** Important in feeding behavior and emotional behavior.
 - Lesion of this nucleus can result in Rage, as Amygdala becomes dominant to Hypothalamus.
 - This nucleus contains **the satiety center** which tell you when you are full.
- **Dorsal Medial Nucleus:** when stimulated in animals results in savage behavior.

FUNCTIONAL ASPECTS OF HYPOTHALAMUS

- **Endocrine:** Hypothalamus is the ultimate homeostasis machine.
 - Hormones of the Neurohypophysis - ADH, Oxytocin (Supraoptic and Paraventricular Nucleus)
 - Releasing and Inhibiting Hormones (Tuberal region)
 - Hypothalamo-Hypophyseal Portal System
- **Autonomic (Visceral):** Hypothalamus plays important roles in regulating autonomic system.

- **Emotion:**
 - Hypothalamus does not originate emotions, but it integrates them. Emotion has two mental components.
 - Cognition: An awareness of what is going on in your environment.
 - Conation: The urge to act on feelings.
 - Rage: Lesion of *Ventral Medial Nucleus* results in uncontrolled rage. This is because there is a balance between Hypothalamus and Amygdala in controlling emotional behavior
 - **Kluver-Bucy Syndrome** results when both Amygdala and Hypothalamus are lesioned.
 - Sex behavior: Androgens play primary role in regulating sexual behavior. At least that's true in animals. Humans, it may be less true as higher cortical functions are more dominant.
- **Motivational states:**
 - Feeding:
 - It has some CCK-Receptors, and this may play role in satiety. There are also some local CCK neurons, and they don't know whether the CCK is originating locally or from the digestive system.
 - Thirst: Two primary determinants of thirst.
- **Temperature Regulation:**
 - The hypothalamus contains the thermostat for regulating our body temperature.
 - Anterior Hypothalamic Area is the Warm Sensitive area. It tries to get rid of heat (sweating and vasodilation). Loss of the Anterior Hypothalamus result in Hyperthermia.
 - Posterior Hypothalamic Area is the Cold Sensitive area. It tries to create more heat (shivering)
 - Fever: Bacterial infection releases endotoxins that causes release of interleukins by circulating blood cells, especially IL-1. In the brain, IL-1 causes the hypothalamus to reset the thermostat to a higher level.
- **Circadian rhythm:** Mediated by Suprachiasmatic Nucleus.
 - Temperature regulation: You have higher temperature in morning, and while you're awake, than when you are sleeping.
 - Melatonin has a circadian rhythm: It is released at night, during sleep, but not during day.
 - ACTH / Cortisol has circadian rhythm.

CONNECTIONS TO HYPOTHALAMUS: *Most of the neural connections with the Hypothalamus are part of the Limbic System.*



- **Mammillothalamic tracts:** Mamillary Complex (posterior part of Hypothalamus) → **Anterior Thalamus**
 - These fibers are heavily myelinated and constitute a major nerve tract.
- **Fornix: Hippocampus** → Hypothalamus (Pre-Optic Area) → Mamillary Bodies
- **Stria terminalis: Amygdala** → Hypothalamus
 - This tract also goes from Amygdala to other area of the brain.
- **Medial forebrain bundle: Locus Ceruleus** of Brainstem → Hypothalamus
 - This is the only place in the brain where norepinephrine is used as a Neurotransmitter. All the nerves come from the Locus Ceruleus.
 - The Locus Ceruleus also sends norepinephrine neurons to other locales, but the medial forebrain bundle is the one that goes to the Hypothalamus.

Posterior pituitary pathway: **Paraventricular Nucleus** → **Superoptic Nucleus** → **Arcuate Nucleus** → **Infundibulum** → **Neurohypophysis**

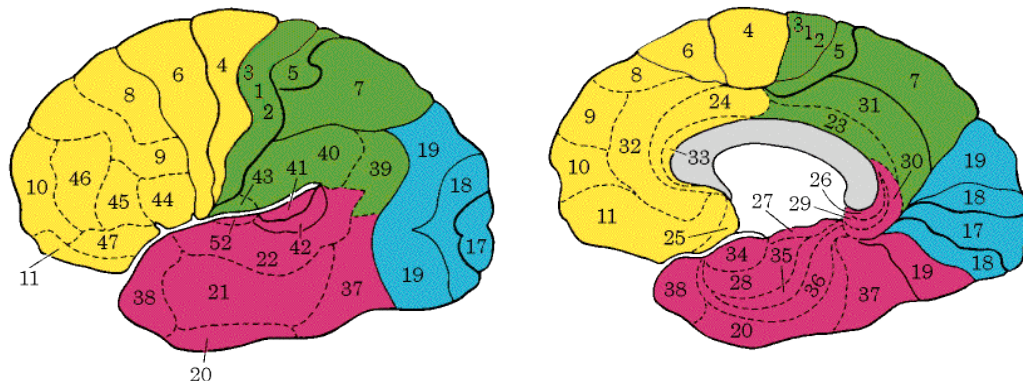
- **Magnocellular neurons:** Neurons that follow this path and make the hormones Oxytocin + ADH.
 - These neurons have larger cell bodies.
- **Parvocellular neurons:** These neurons have smaller cell bodies and make the small peptides (releasing factors) that control the adenohypophyses.

THE CEREBRAL CORTEX

- Cerebral Lobes
 1. Frontal lobe
 2. Parietal lobe
 3. Occipital lobe
 4. Temporal lobe
 5. Limbic lobe
- Gyri of the Frontal Lobe
 - Lateral Surface
 - Precentral Gyrus --- primary motor area
 - Superior Frontal Gyrus
 - Middle Frontal Gyrus
 - Inferior Frontal Gyrus
 - Pars Opercularis
 - Pars Triangularis
 - Pars Orbitalis
 - Medial Surface
 - Medial Frontal Gyrus
 - Paracentral Lobule
 - Basal Surface
 - Rectus Gyrus
 - Orbital Gyrus
 - Inferior Frontal Gyrus
- Gyri of the Parietal Lobe
 - Lateral Surface
 - Postcentral Gyrus ---- primary somesthetic area
 - Superior Parietal Lobule
 - Inferior Parietal Lobule ---- Wernicke's area
 - Supramarginal Gyrus
 - Angular Gyrus
 - Medial Surface
 - Paracentral Lobule
 - Precuneus
- Gyri of the Occipital Lobe
 - Lateral Surface
 - Lateral Occipital Gyrus
 - Superior Occipital Gyrus
 - Inferior Occipital Gyrus
 - Medial Surface
 - Cuneus
 - Lingual Gyrus
 - Basal Surface
 - Lingual Gyrus
 - Occipitotemporal Gyrus
- Gyri of the Temporal Lobe
 - Lateral Surface
 - Superior Temporal Gyrus
 - Middle Temporal Gyrus
 - Inferior Temporal Gyrus
 - Basal Surface
 - Lingual Gyrus
 - Occipitotemporal Gyrus
 - Medial Occipitotemporal Gyrus
 - Lateral Occipitotemporal Gyrus
- Gyri of the Limbic Lobe
 - Outer Ring
 - Cingulate Gyrus
 - Isthmus of Cingulate Gyrus
 - Parahippocampal Gyrus
 - Uncus, Uncinate Gyrus

- Inner Ring
 - Hippocampal Formation
 - Hippocampus, Ammon's Horn
 - Dentate Gyrus
 - Fasciolar Gyrus
 - Indusium Griseum (Supracallosal Gyrus)
 - Paraterminal Gyrus (Subcallosal Gyrus)
 - Subcallosal Area (Parolfactory Area)

CEREBRAL BRODMANN AREAS



FRONTAL LOBE

- **PRIMARY MOTOR CORTEX (Area 4):**
 - Its fibers make up the Corticobulbar and Corticospinal Tracts.
 - SEGMENTOTOPIC ORGANIZATION (**HOMUNCULUS**):
- **PREMOTOR CORTEX (Area 6):** Rostral to the Primary Frontal Cortex.
 - FNXX: *Gross coordination of voluntary motor activity*, such as adducting or abducting a limb.
- **FRONTAL EYE-FIELD (Area 8):** Rostral to the Primary Frontal Cortex.
 - FNXX: *Voluntary conjugate movement of the eyes*.
 - LOCATION: It close to the region responsible for movement of the eye.
 - **REFLEX FOLLOWING CENTER** in Parietal Lobe works with this lobe to allow eyes to follow an object in space.
 - LESION to this lobe will make eyes deviate toward the affected side.
- **BROCA'S MOTOR SPEECH CORTEX (Area 44, 45):** Inferior Frontal Gyrus.
 - LEFT SIDE ONLY: This area is responsible for *formulation of Propositional Language*, or meaningful language.
 - RIGHT SIDE ONLY: *Formulation of emotional inflection and tone in speech*.
- **PREFRONTAL CORTEX:** JUDGMENT, FORESIGHT, PERCEPTION

PARIETAL LOBE

- **PRIMARY SOMATOSENSORY CORTEX (Area 1, 2, 3):** Post-Central Gyrus.
 - FNXX: Conscious perception of pain, temperature, proprioception, touch. The termination of third order sensory neurons from the VPL and VPM of Thalamus.
 - SEGMENTOTOPIC ORGANIZATION (**HOMUNCULUS**):
- **SOMATOSENSORY ASSOCIATION CORTEX (Area 5, 7):** Ability to recognize sensations, recognize objects by touch, for example. They receive input from the Primary Cortex
 - LEFT SIDE ONLY:
 - LESION = **ASTEROGNOSIS**: Inability to recognize an object, such as a quarter, with eyes closed, by touch.
 - RIGHT SIDE ONLY: *Areas 5 and 7 give us spatial control related to the visual system* (such as ability to move with eyes closed).
- **NEGLECT SYNDROME:** A lesion to the *posterior* Parietal Lobe of the Non-Dominant Hemisphere.
 - It is posterior *because more sophisticated sensory association fibers tend to converge on the Parieto-Occipital Junction*, from three areas:
 - SYMPTOMS: The person doesn't recognize half of his body as being his own. Only able to dress one half of his body, etc. Strange...

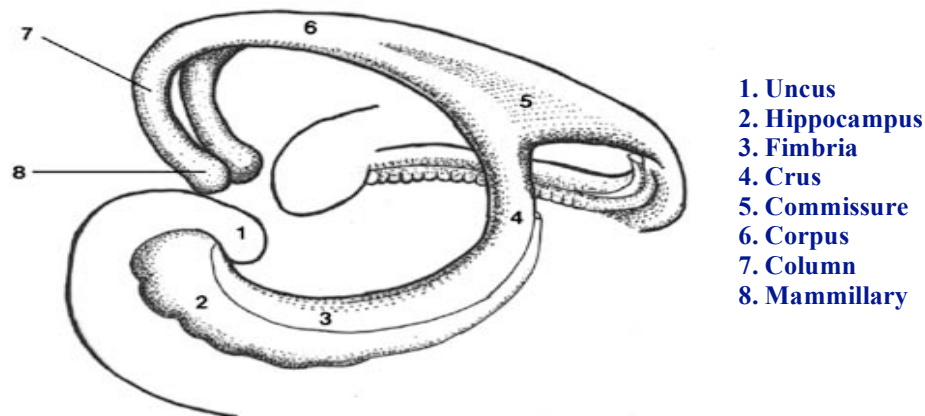
OCCIPITAL LOBE

- **PRIMARY VISUAL CORTEX (Area 17):** It surrounds the **Calcarine Fissure**
 - FNXX: Each side of Area 17 receives visual info from the contralateral field of vision.
 - LESION: **Hemianopia**, blindness to the contralateral field of vision.
- **VISUAL ASSOCIATION CORTEX (Area 18, 19):** Extending outward from calcarine sulcus, on medial and lateral occipital lobe.
 - FNXX: Recognition of visual images; relate present to past visual experiences.

TEMPORAL LOBE

- **PRIMARY AUDITORY CORTEX (Area 41, 42):** Concealed within the lateral fissure, on the Transverse Temporal Gyri.
 - FNXX Hearing. It is the end of the pathway that started with Lateral Lemniscus -----> Inferior Colliculus -----> Medial Geniculate Body -----> Primary Auditory Cortex
- **AUDITORY ASSOCIATION CORTEX (Area 22):** One of the Superior Temporal Gyri.
 - GENERAL FUNCTION: Association and integration of auditory information.
 - **WERNICKE'S RECEPTIVE SPEECH (Area 22):** The Caudal part of the Auditory Association Cortex on the dominant
- **ANGULAR GYRUS:** Posterior Temporal Lobe, surrounding the Superior Temporal Sulcus.
 - FNXX: It is responsible for *interpretation of written language (i.e. reading)*.
- **SUPRAMARGINAL GYRUS:** Wraps around the end of the Lateral Fissure, contiguous with Wernicke's Area.
 - FNXX: It is responsible for the *ability to write meaningful language (i.e. write cursive)*.

STRUCTURES OF FOMIX



LEFT FRONTAL LOBE: *Occlusion in the distribution of Middle Cerebral Artery*

- AREA 44&45: Lost motor speech.
- AREA 8: Loss of contralateral (right) visual eye field.
- AREA 4: Lose the lateral part of area 4
 - *Contralateral lower facial paralysis* (Central Lesion of VII—the most important marker).
 - Also paralysis of upper extremity.

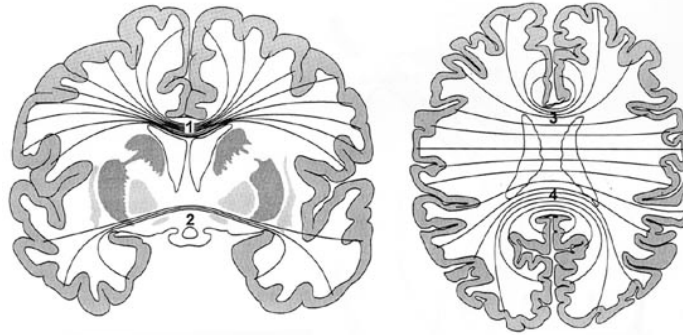
LESION TO LEFT TEMPORAL AND POSTERIOR PARIETAL LOBE: *Occlusion in the distribution of Middle Cerebral Artery.*

- **ANGULAR GYRUS:** Loss of ability to read.
- **SUPRAMARGINAL GYRUS:** Loss of ability to write.
- **WERNICKE'S AREA:** Loss of ability to understand spoken language.

CEREBRAL WHITE MATTER

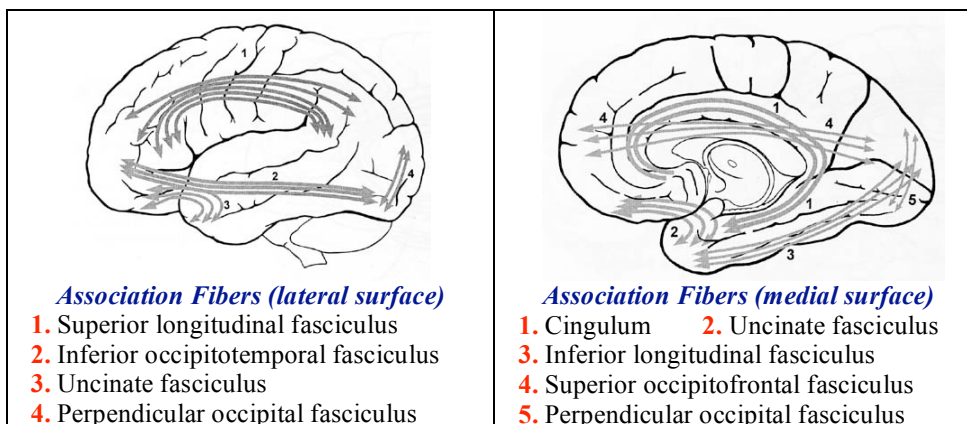
TYPES OF CEREBRAL FIBERS: Cerebral Cortex has about *15 billion neurons, about as many glial cells, and a rich capillary network.*

- **COMMISSURAL FIBERS:** Fibers that traverse from one cerebral hemisphere to the other.



- **Corpus Callosum (1)** carries most of this traffic
 - Rostrum, Genu, Trunk, Splenium
- **Anterior Commissure (2)** carries some crossing traffic.
- Commissure of Fornix
- Forceps minor (3)
- Forceps major (4)

- **ASSOCIATION FIBERS:** Interconnect areas of the same cerebral hemisphere.



- **SHORT ASSOCIATION FIBERS:** Join Neighboring regions.
- **LONG ASSOCIATION FIBERS:** Join separate lobes (frontal to occipital, e.g.)
 - **DISCONNECTION SYNDROME:** Loss of the Arcuate Fasciculus, resulting in poor processing and formulation of speech.
- **PROJECTION FIBERS (CORONA RADIATA):** Afferent fibers coming into the Cerebral Cortex, and efferent fibers leaving the Cerebral Cortex.

HIGHER CORTICAL FUNCTION

Allo cortex: All cortical structures below the Rhinal (Collateral) Sulcus. It contains the following (The **neocortex** is everything else)

- Hippocampus
- Parahippocampal Gyrus
- Entorhinal Cortex Cortical Neurons:
- **Pyramidal cells** have long axons that project to other lobes of the brain or to subcortical structures.
 - They are excitatory neurons and use **glutamate** as neurotransmitter.
- **Fusiform Cells** have long axons
- **Granule (Stellate) Cells** are interneurons with short axons.
 - These neurons project to neighboring neurons in the same region of the brain.
 - These interneurons can be either excitatory (glutamate) or inhibitory (GABA)

Cortical lamina: Layers of the Cerebral Cortex

- Layers I-III: Supra granular layers, most superficial layers.
 - Cortico-cortical inputs (associations) terminate primarily in one of these layers.
- LAYER IV: Granular layer. It contains granule cells.
 - *Thalamic projections* (subcortical information) terminate primarily in this layer.
- Layer V: Output in this layer projects primarily to the Brainstem.
- Layer VI: Deepest layer, next to white matter. Output in this layer projects primarily to Thalamus.

Cytoarchitecture

- **Granular cortex:** The Primary Sensory regions of the Cortex, which cytologically contains granules: Primary and Secondary Somatosensory Cortices (Brodmann 1, 2, 3a & 3b), Primary Visual (Striate) Cortex (17), and Primary Auditory Cortex (41).
- **Agranular cortex:** The Primary Motor regions of the Cortex (4) do not contain granules.

ASSOCIATION CORTICES: The sign of higher intelligence. There are three association cortices.

- **Posterior parietal association cortex:** The convergence of somatosensory, visual, and auditory association cortices. This is basically the area where we process special-sensory stimuli.
 - Lesions = Neglect Syndrome, Astereognosias, Aphasias.
- **Prefrontal association cortex:** Short-Term Memory, foresight, and judgment.
 - Short-term memory expt: Lesion in this area in monkeys, and they cannot select food under an opaque cup that was just placed there ten seconds ago.
 - *Dopamine* is a prominent
- **Limbic association cortex:** Memory, olfaction, and emotion.
 - Cingulate Cortex Lesion → Sham Rage in monkeys. Motor actions of rage without provocation.
 - Orbitofrontal Cortex Lesion → Decrease normal aggressiveness and emotional response.
 - Inferior Temporal Lobe: This portion of limbic association cortex is concerned with long-term memory. Stimulation of this region resulted in vivid hallucinations of past experiences.

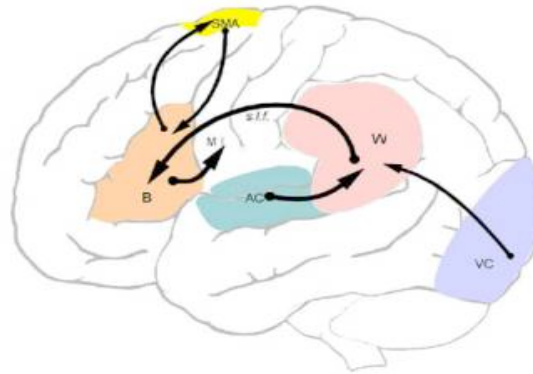
CORTICAL HEMISPHERES:

- Dominant hemisphere: Is defined as that one which contains specialized language (Wernicke's) areas.
- Wernicke's area will be *larger* on the dominant side.
 - The relationship between hemispheric dominance and handedness is complex. They often correspond but not always.
 - For right or left-handed individuals, the left hemisphere is most often dominant, then codominance. Right-hemisphere dominance is least common.
- **Sodium amytal test:** Test to see which hemisphere is dominant. Put this barbiturate into each of the Carotid Arteries, and have the subject count down from 10. When you have injected it into the dominant hemisphere, the subject will stop counting.
- **Corpus callosectomy:** Split the interconnections between left-brain and right-brain, such that left and right-brain function cannot communicate. If a subject is presented an apple in exclusively one visual field or the other:
 - Right visual field → Left Visual Cortex → The subject is able to verbally identify the object as an apple.
 - Left visual field → Right Visual Cortex → The subject could not identify it as an apple, even though he knew it was, because he had no access to language acquisition.
 - The subject was still able to pick it out from among different objects or identify it in other non-verbal ways.
- Non-dominant (right) hemisphere:
 - Contains lots of association areas
 - Concerned with spatial-perceptual orientation
 - Facial recognition.

LANGUAGE

- **Aphasias:** Disturbances of language production, comprehension, or both.
 - This is not a strict motor problem, but one where problem lies in higher cortical centers. Some strictly motor problems:
 - **Wernicke's aphasia:** Deficit in comprehension of language.
 - **Broca's aphasia:** Deficit in forming meaningful language.
 - **Conduction aphasia:** Damage to the Arcuate Fasciculus, which interconnects Broca's and Wernicke's areas.

- **Language Areas:**
 - **Wernicke's Speech Reception Area (42):** Speech comprehension.
 - **Broca's Motor Speech Area:** Speech formation; formation of fluent, meaningful speech.
 - **Arcuate fasciculus:** The pathway that interconnects the two above.
- **Wernicke-Geschwind Model:** Describes the neural pathway by which a person reads a word and then vocally says what the word is. The pathway goes in the following order:



- Visual Stimulus → Visual Cortex → Visual Association Cortex → Angular Gyrus (in Parietal Association cortex): This step turns the written word into an auditory signal. Language is stored primarily as an auditory signal.
- Angular Gyrus → Wernicke's Area: Interpretation of what the auditory signal means
- Wernicke's Area → Arcuate Fasciculus → Broca's Area: speech formation signals are generated
- Broca's Area → Facial part of motor cortex: The word is vocalized.
- **Alexia:** Inability to read, resulting from damage to Angular Gyrus.
- **Aprosodia:** Deficit in singing, intonation, or inflection of voice. A flat affect to the voice.
 - This results from a lesion to the speech-area on the non-dominant side, which is responsible for emotional inflection of voice.
- **Agraphia:** Inability to write. Also from damage to angular gyrus.
 - This can occur when visual symbols cannot gain access to the language system.
- **Apraxia:** Inability to perform learned motor movement, such as a saluting or flipping a coin.
 - This occurs from a Disconnection Syndrome and involves disruption of pathways going from Wernicke's Area to Premotor Cortex.

LEARNING AND MEMORY

- **Reflexive memory:** Remembering how to do something, like riding a bike.
 - Conditioning: Classical condition is a form of reflexive memory. Pavlov's dog salivates when he hears the bell rings, after constantly being presented with a bell followed by food.
 - Cerebellar nuclei have been discovered to play a role in reflexive memory.
 - Operant Conditioning: Conditioning of behaviors based on the consequences (reward / punishment).
- **Declarative memory:** Conscious memory and recall.
 - Two-stage model of Memory Processing: Memories are formed by putting information in short-term memory into long-term memory.
 - Hippocampus is known to perform the function of consolidating short-term memory into long-term memory.