MRCPsych yr1 2016/7: Neurosciences and Psychopharmacology

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Basic Neuroanatomy: Principal Structures and Circuits

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Medical Research Council

Newcastle University

The Institute of Neuroscience

Pioneers of Functional Neuroanatomy

The Nobel Prize in Physiology or Medicine 1906

"in recognition of their work on the structure of the nervous system"

Camillo Golgi

Italy

Pavia University
Pavia, Italy
1843 - 1926

Santiago Ramón y Cajal

Spain

Madrid University
Madrid, Spain
1852 - 1934

Pioneers of Functional Neuroanatomy

Korbinian Brodmann
Neurologist

German neurologist known for his definition of the cerebral cortex into 52 distinct regions from their cytoarchitectonic characteristics
Konstanz, Munich
1869-1918

Franz Nissl

German medical researcher. A noted neuropathologist
Munich
1860-1919

Constantin Freiherr von Economo

Romanian psychiatrist and neurologist of Greek origin. He is mostly known for his discovery of encephalitis lethargica and his atlas of cytoarchitectonics of the cerebral cortex
Vienna
1876-1931

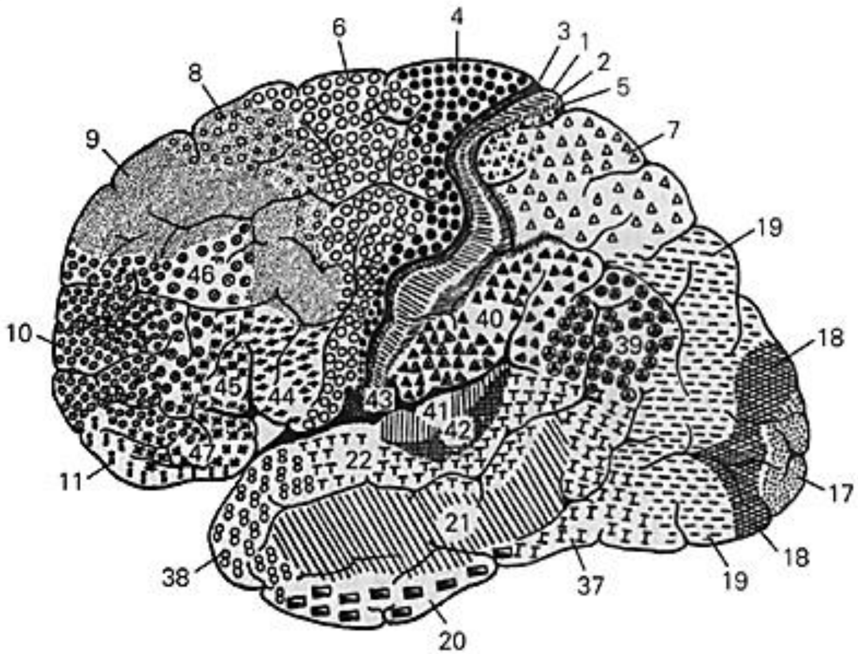
Functional Neuroanatomy

Lateral view of right hemisphere

Adult human brain weighs 1.3-1.5 Kg .
It is the most complex end organ of the body. Only 2% of body weight yet demands 20% of body's resources

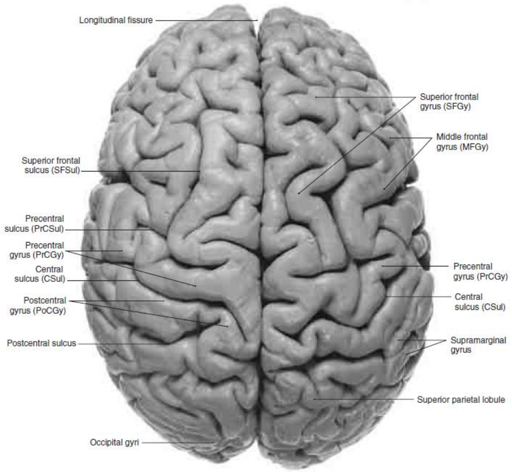
Korbinian Brodmann's Areas

Division of cerebral cortex into 52 discrete areas on the basis of distinctive nerve cell structures and characteristic arrangements of cell layers.

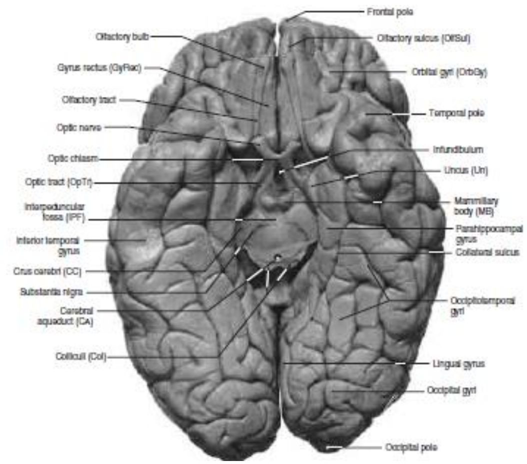


After Dr Evelyne Sernagor, ION

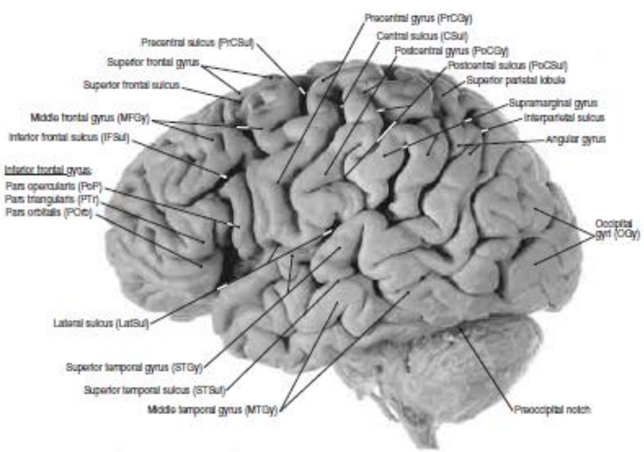
Views of the human brain different angles



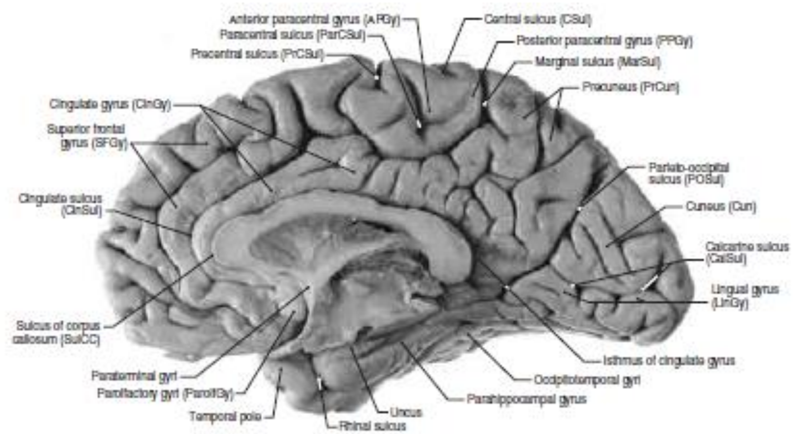
Dorsal view of the brain



Ventral view of the brain

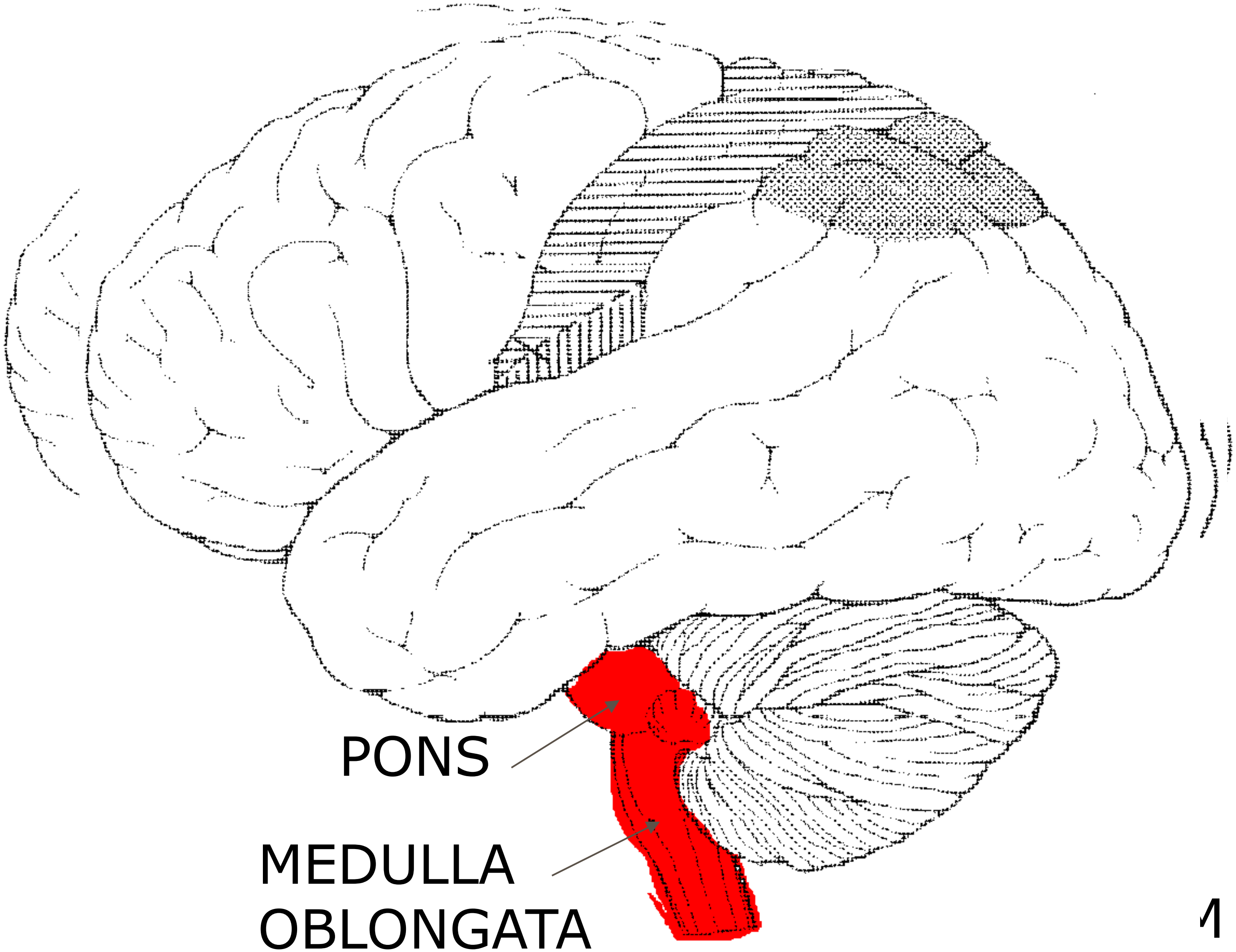


Left hemisphere lateral view

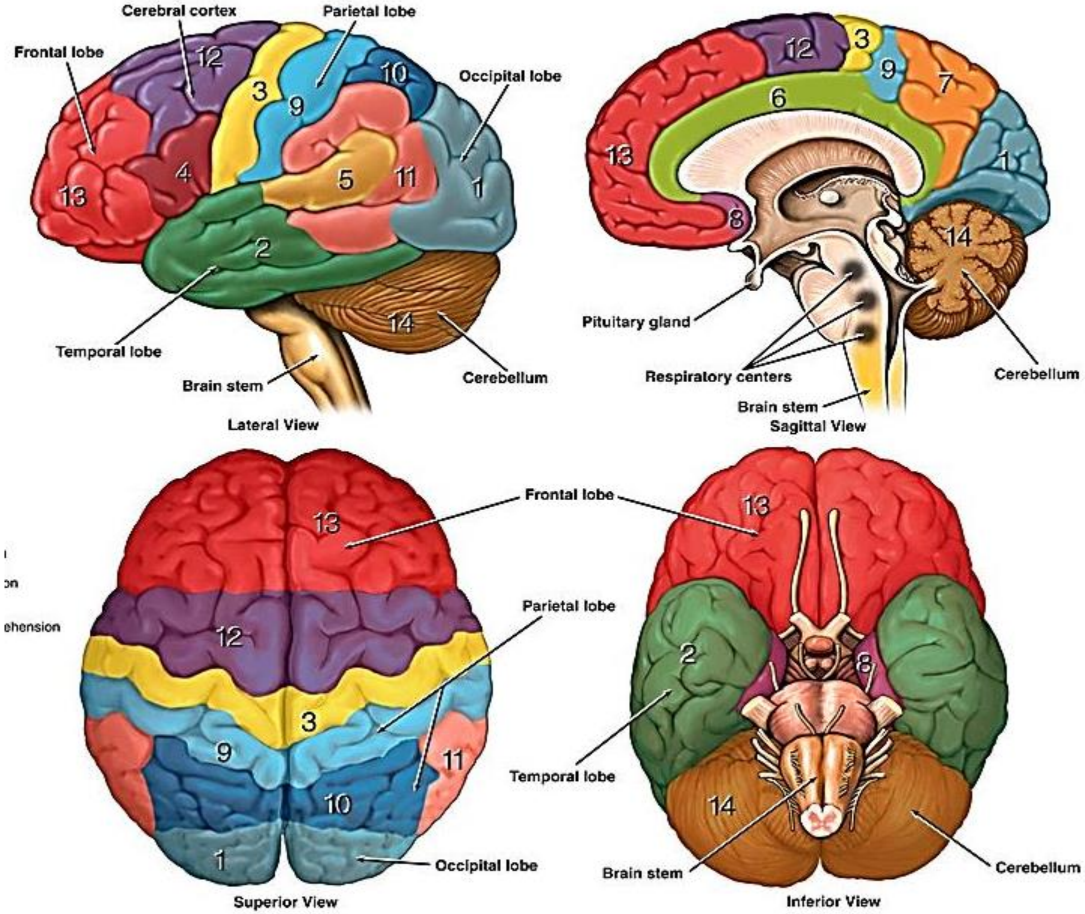


Mid-Sagittal plane of right hemisphere

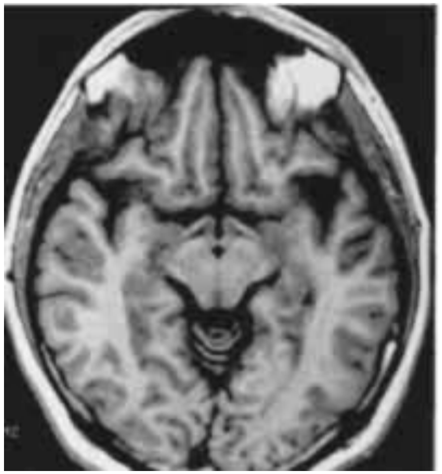
Overall external brain divisions



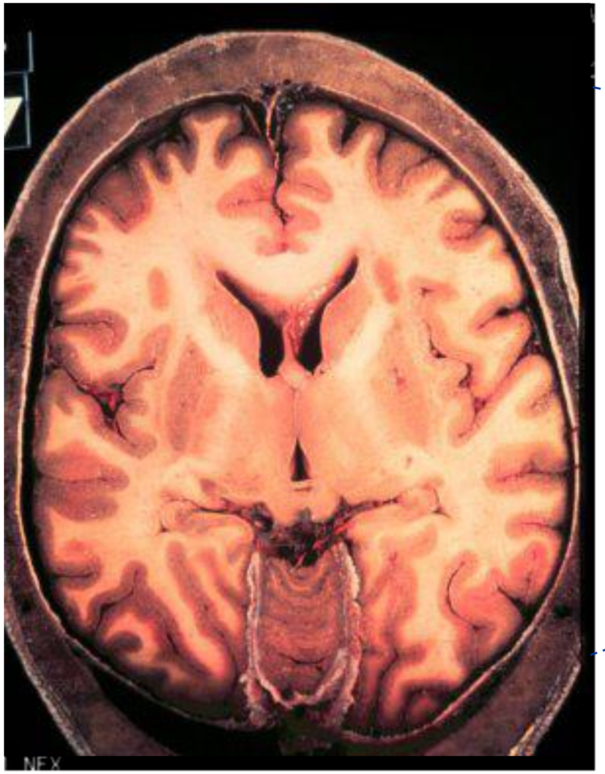
View the Brain as a 3-D Structure

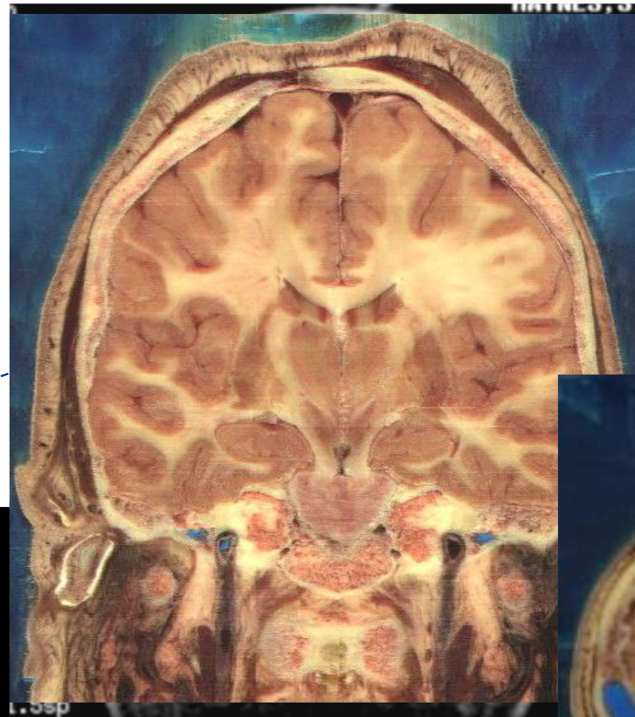


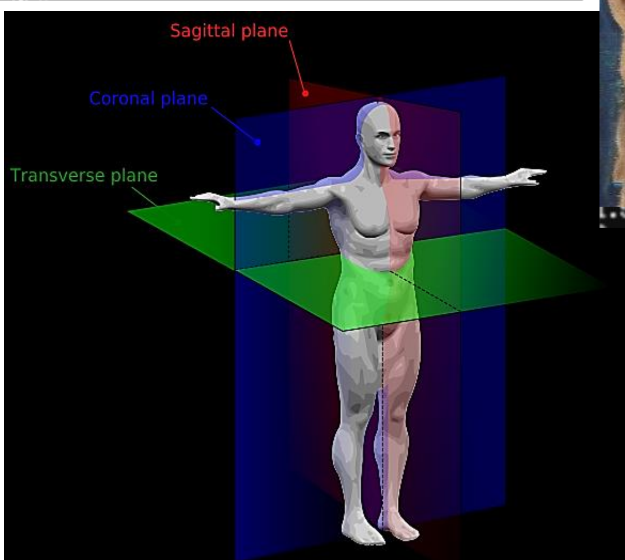
Neuroimaging-MTI

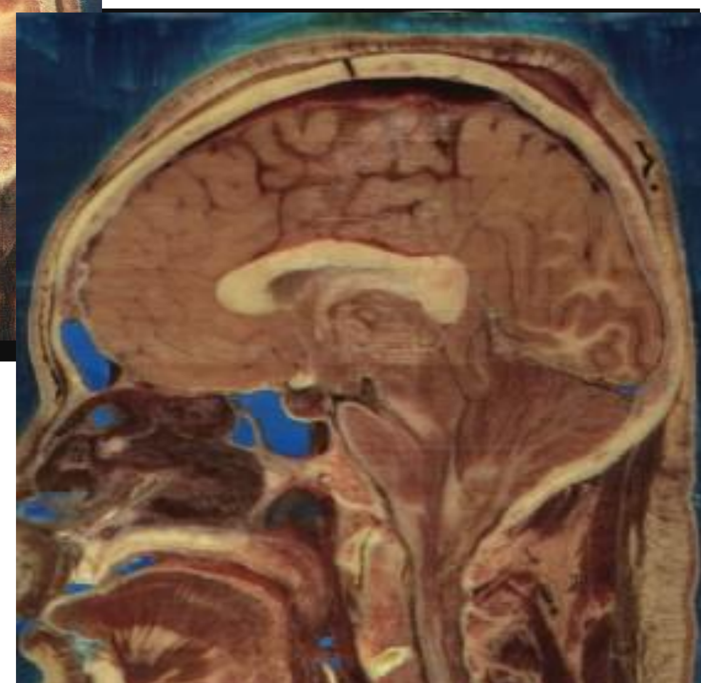


Brain MR Imaging Planes

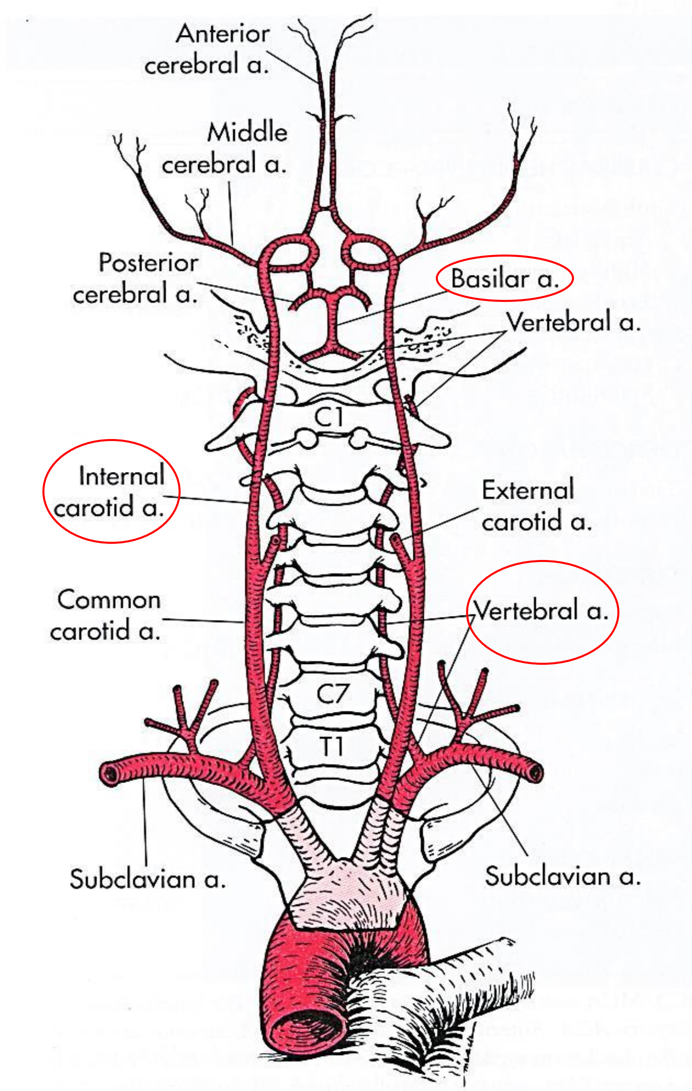








Blood Supply to the Brain: Arteries



Two pairs of large arteries bring blood:

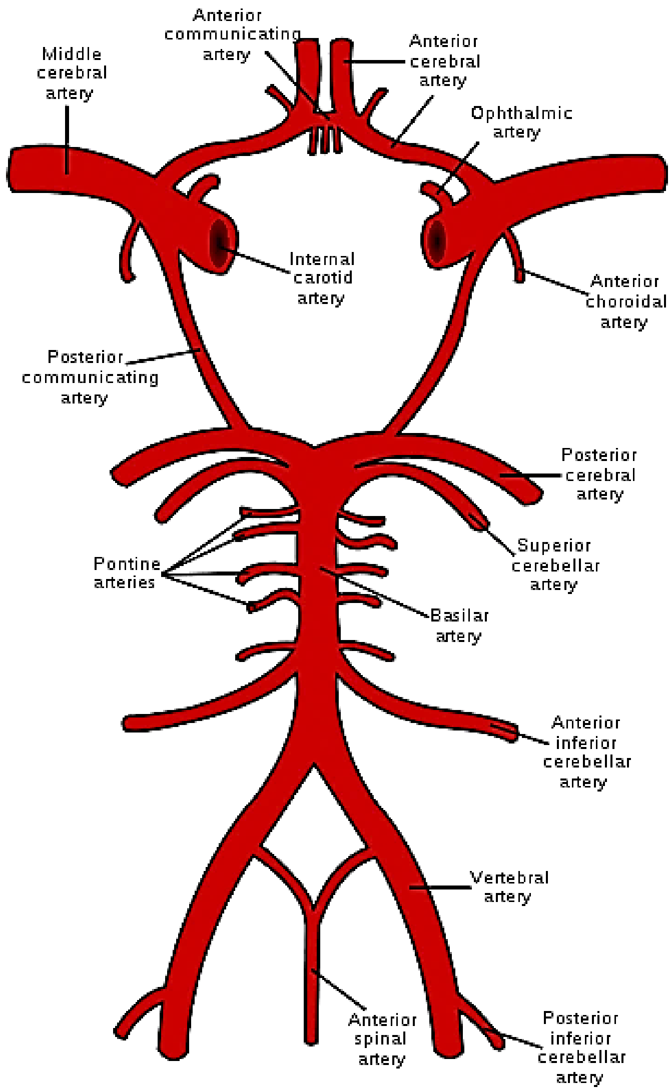
- **Anterior flow (~70% CBF) via iCAs**
- **Posterior flow (~30%) through vertebral arteries- fuse to form the basilar artery**

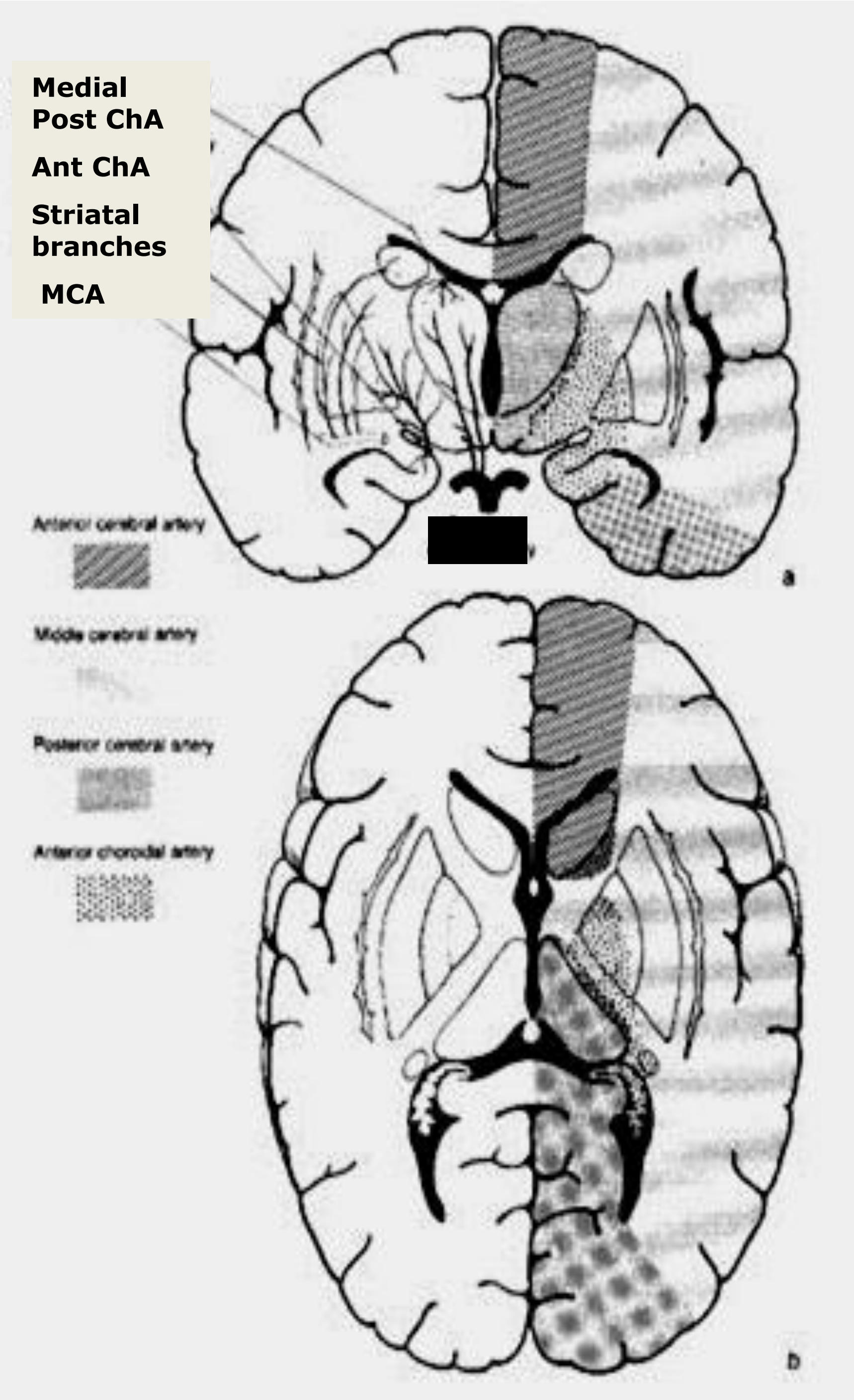
Brain Vessels fall into 5 groups

1. Meningeal, ophthalmic and glandular branches
2. Cortical branches to the surface of the brain
3. Central (basal, nuclear, medullary) branches
4. Choroidal branches
5. Spinal arteries

Circle of Willis

(an arterial ring)





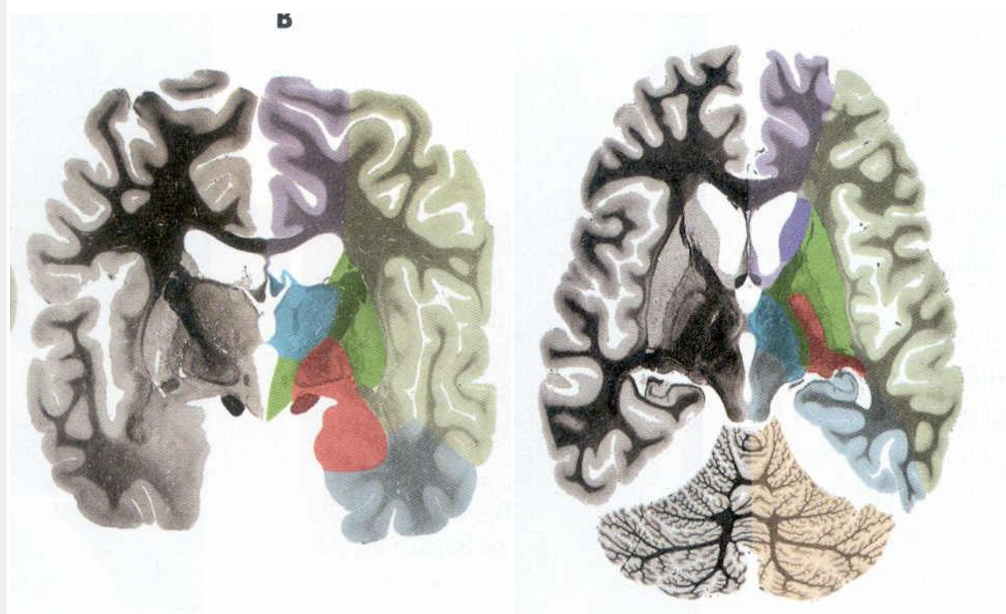
Arterial territories and perfusion of the Brain

Middle cerebral artery (MCA)

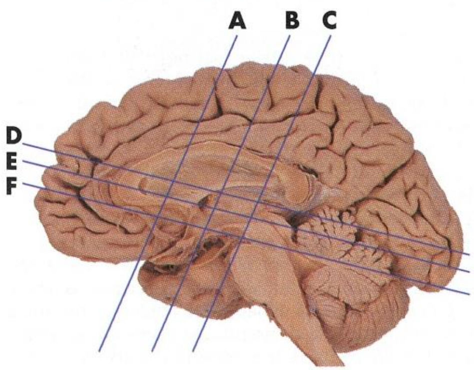
Medial branch of posterior choroidal artery (Post ChA)

Anterior choroidal artery (Ant ChA)

Striatal branches (Striatal branches of MCA)



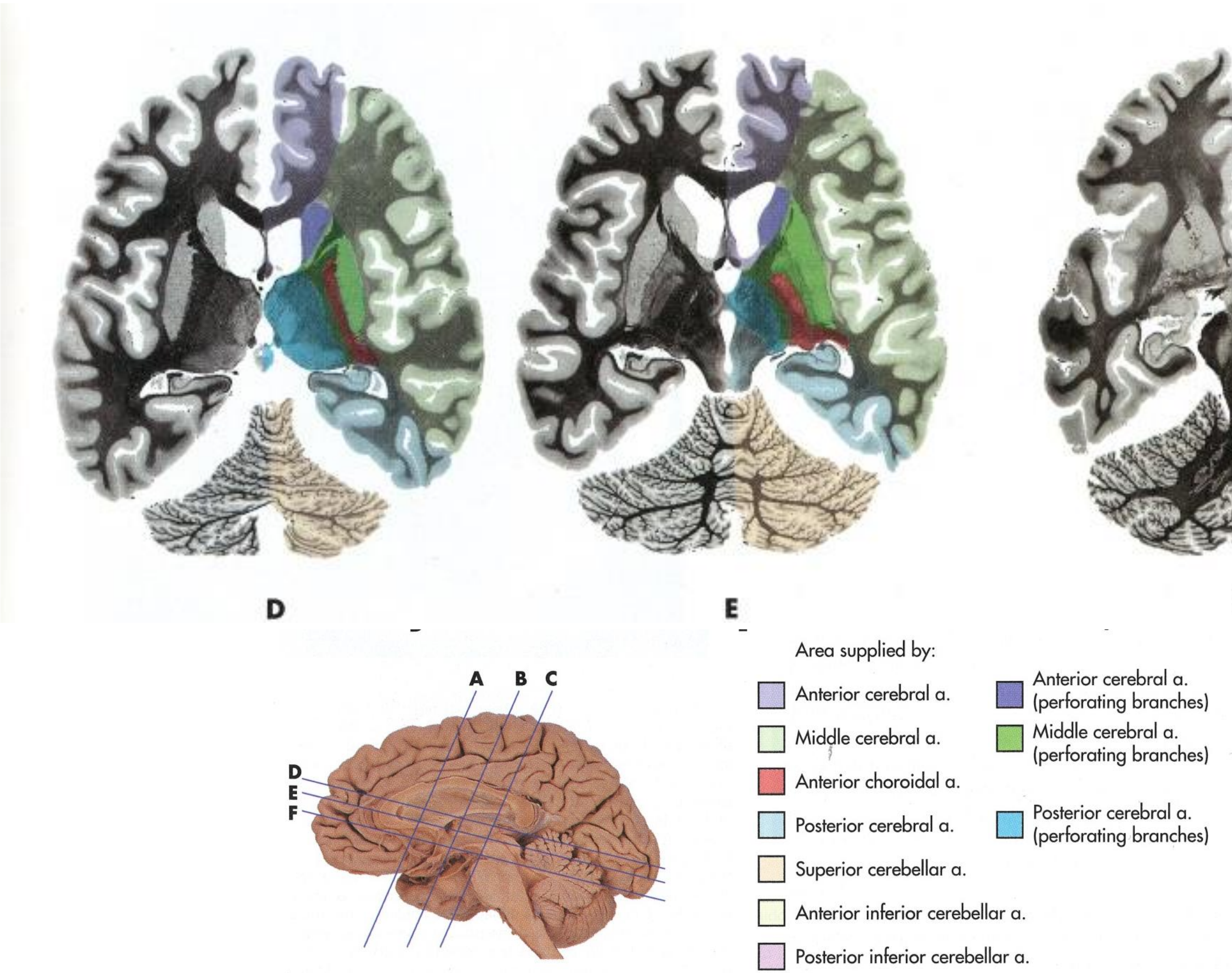
Arteries Territories (coronal)



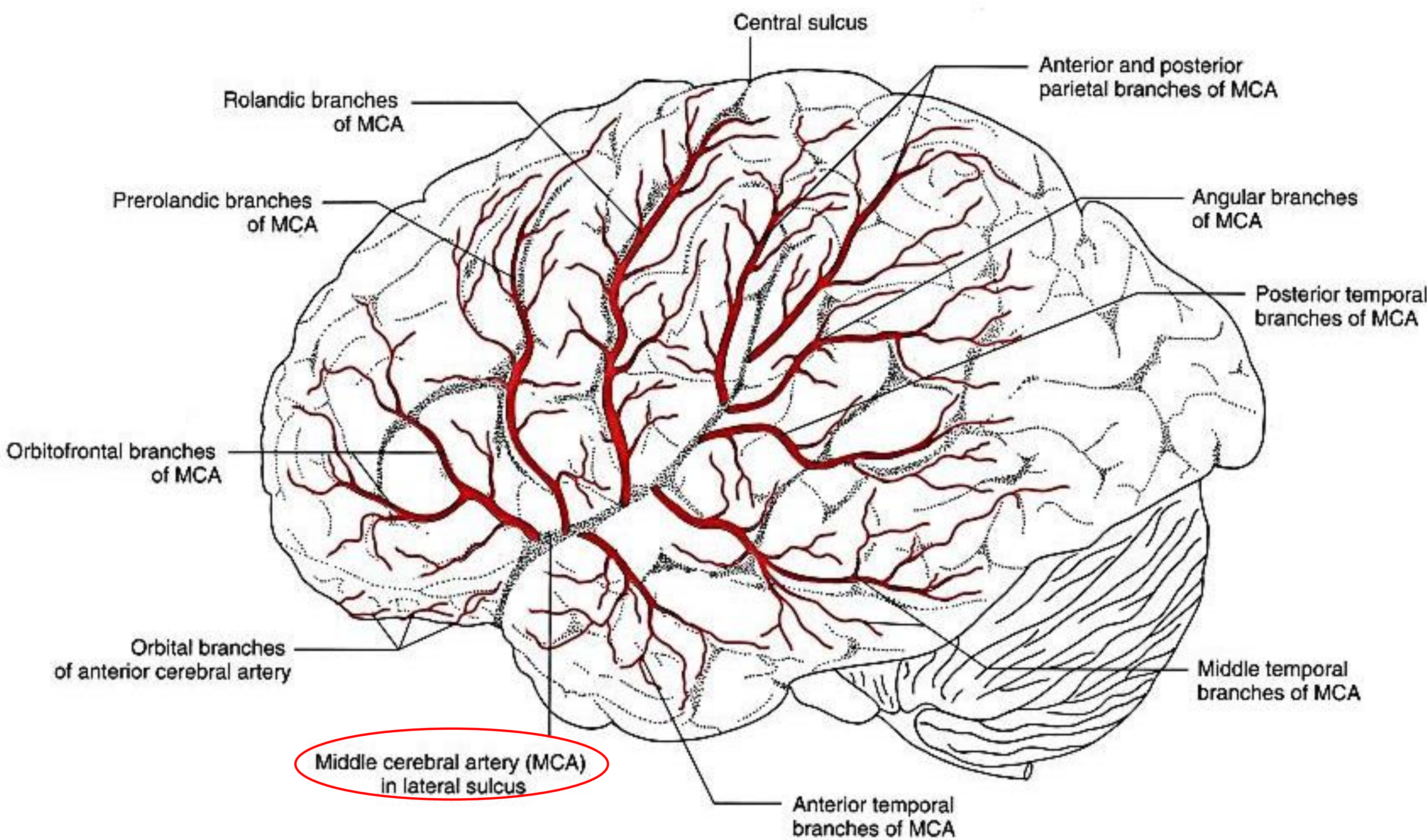
Area supplied by:

- Anterior cerebral a.
- Anterior cerebral a. (perforating branches)
- Middle cerebral a.
- Middle cerebral a. (perforating branches)
- Anterior choroidal a.
- Posterior cerebral a.
- Posterior cerebral a. (perforating branches)
- Superior cerebellar a.
- Anterior inferior cerebellar a.
- Posterior inferior cerebellar a.

Arterial Territories (Transverse)

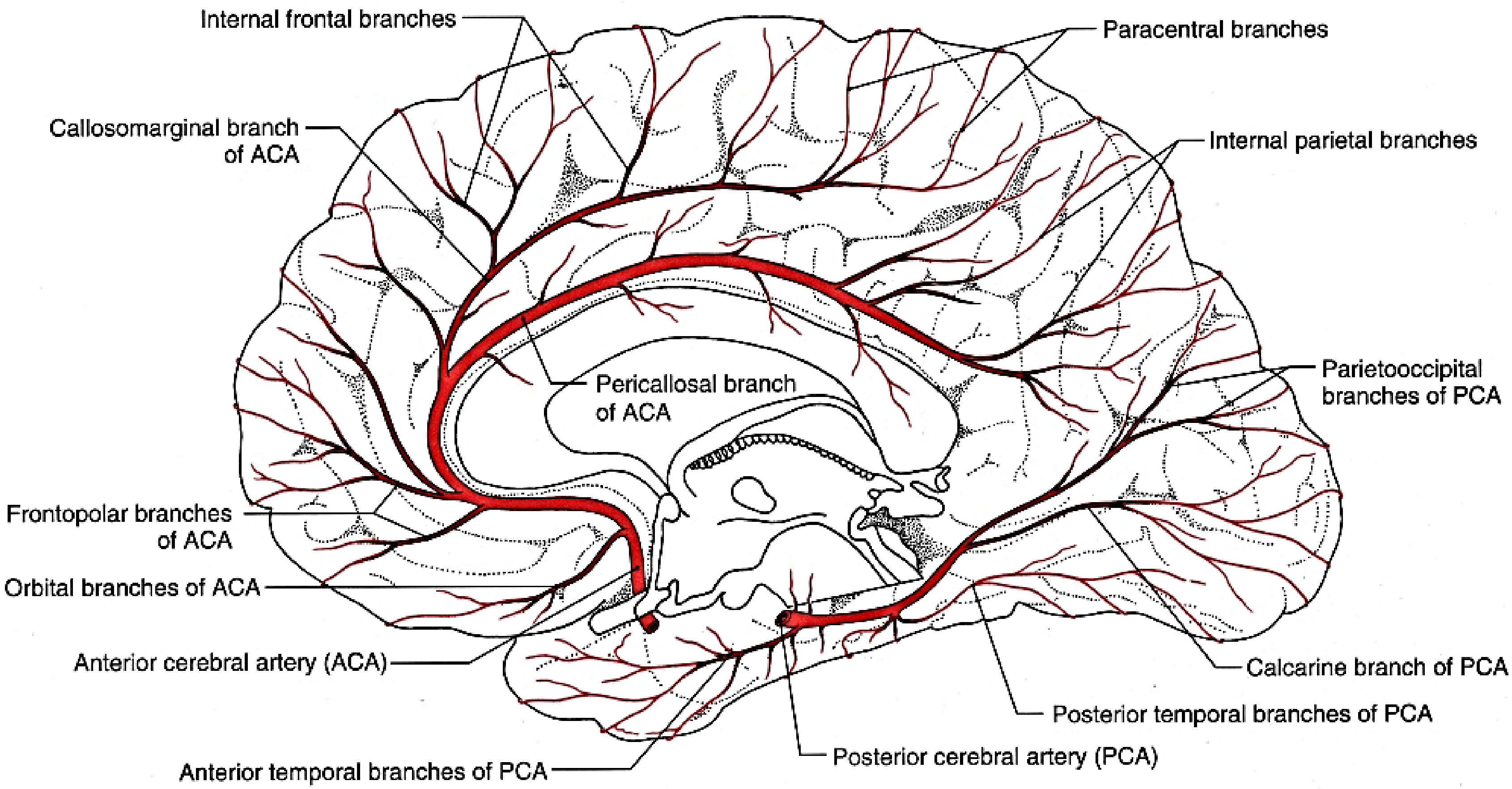


Branching Pattern of MCA

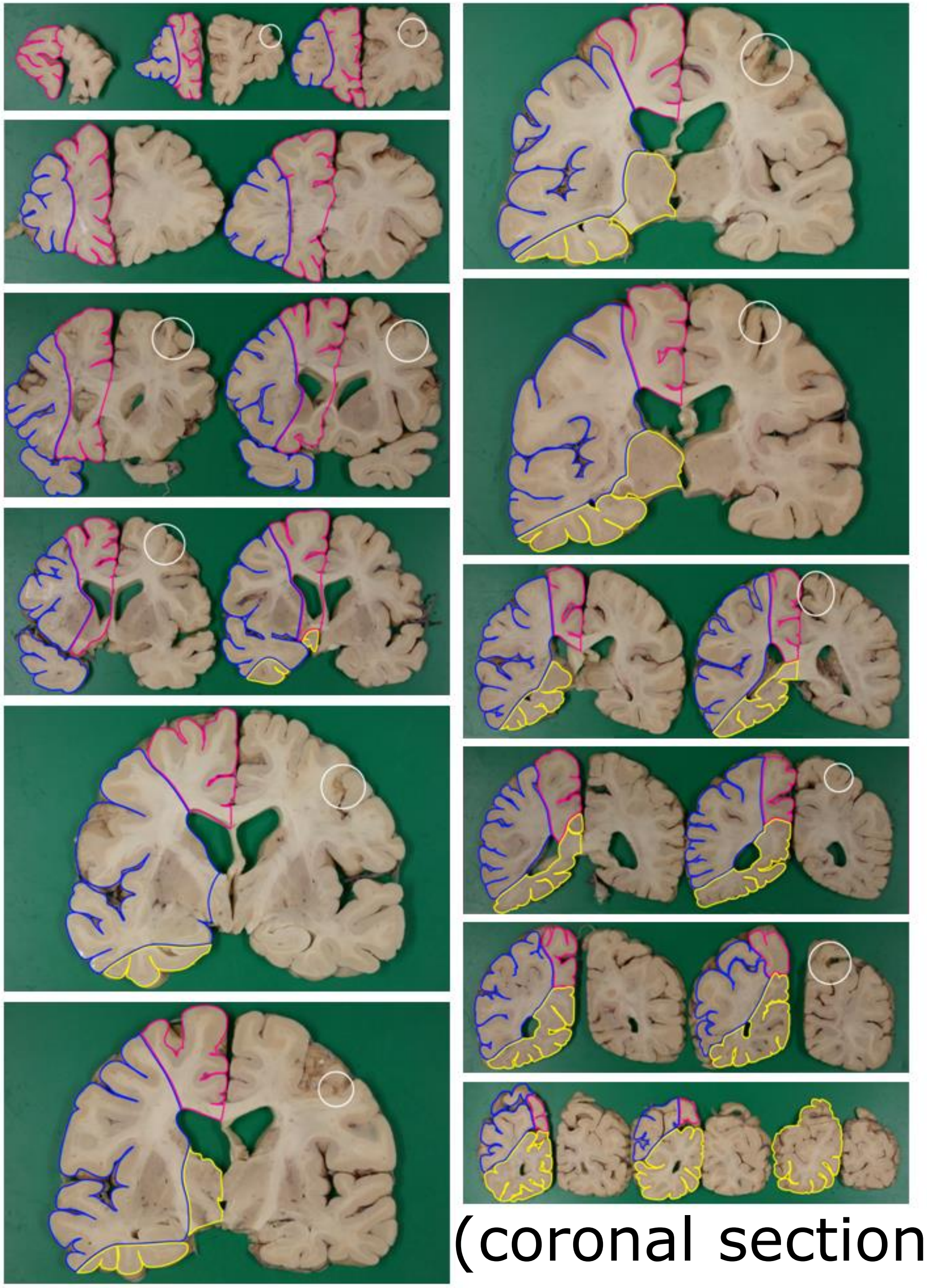


Lateral View

Branching Patterns of ACA and PCA



Midsagittal View



(coronal sections)

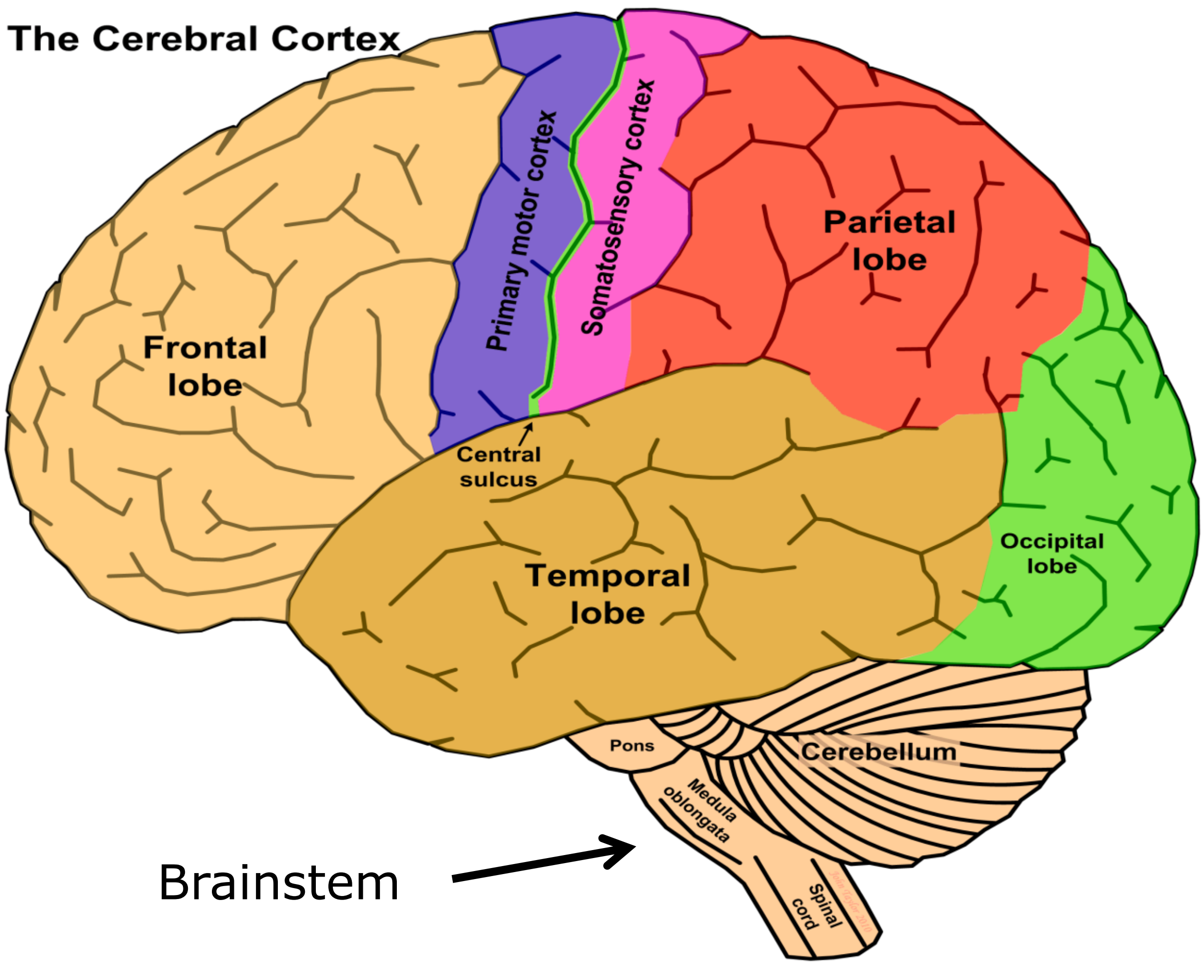
Main Arterial territories of the Brain

Anterior Cerebral Artery (ACA) - RED

Middle cerebral artery (MCA) - BLUE

Posterior Cerebral Artery (PCA) –YELLOW

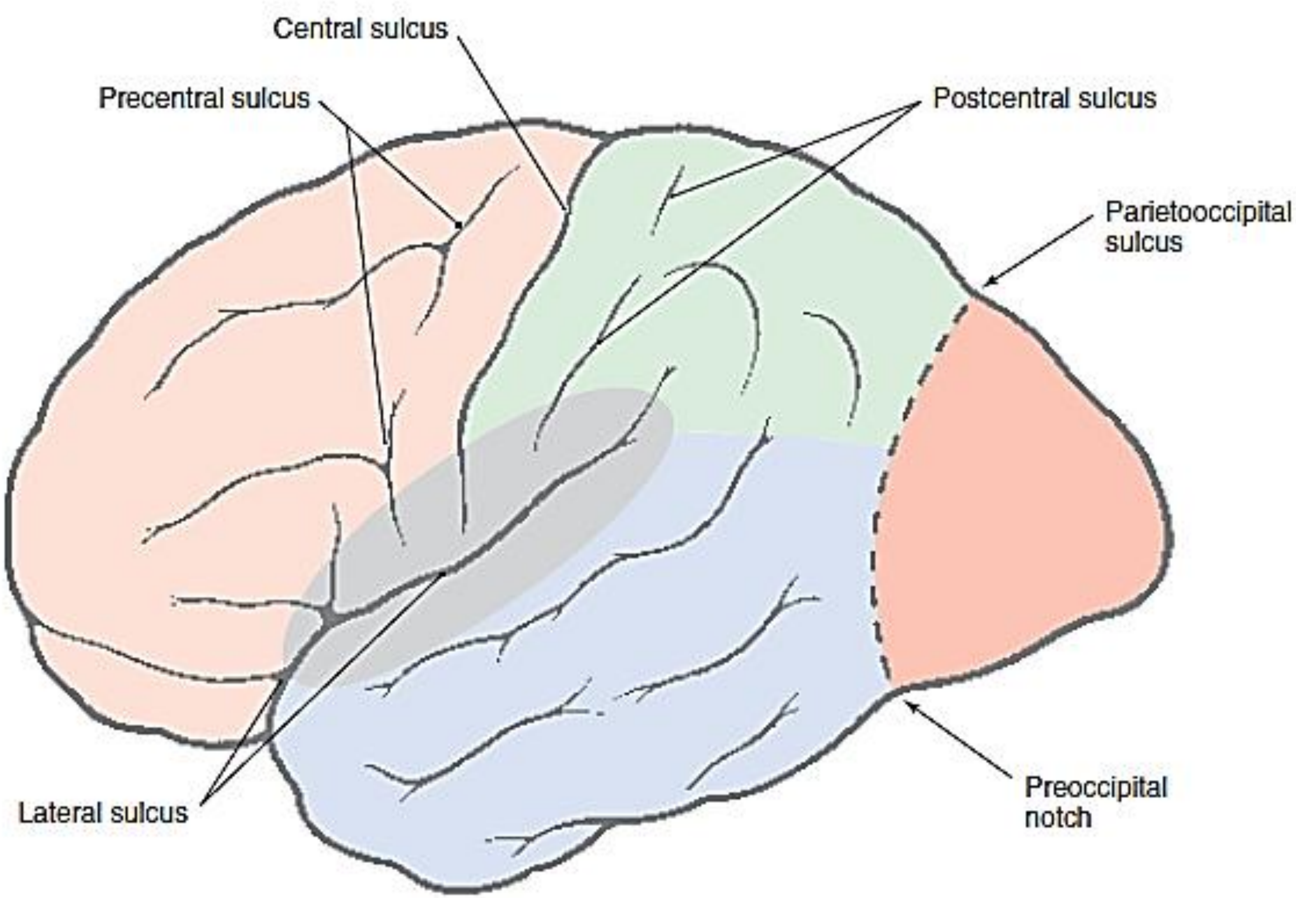
Main external brain divisions



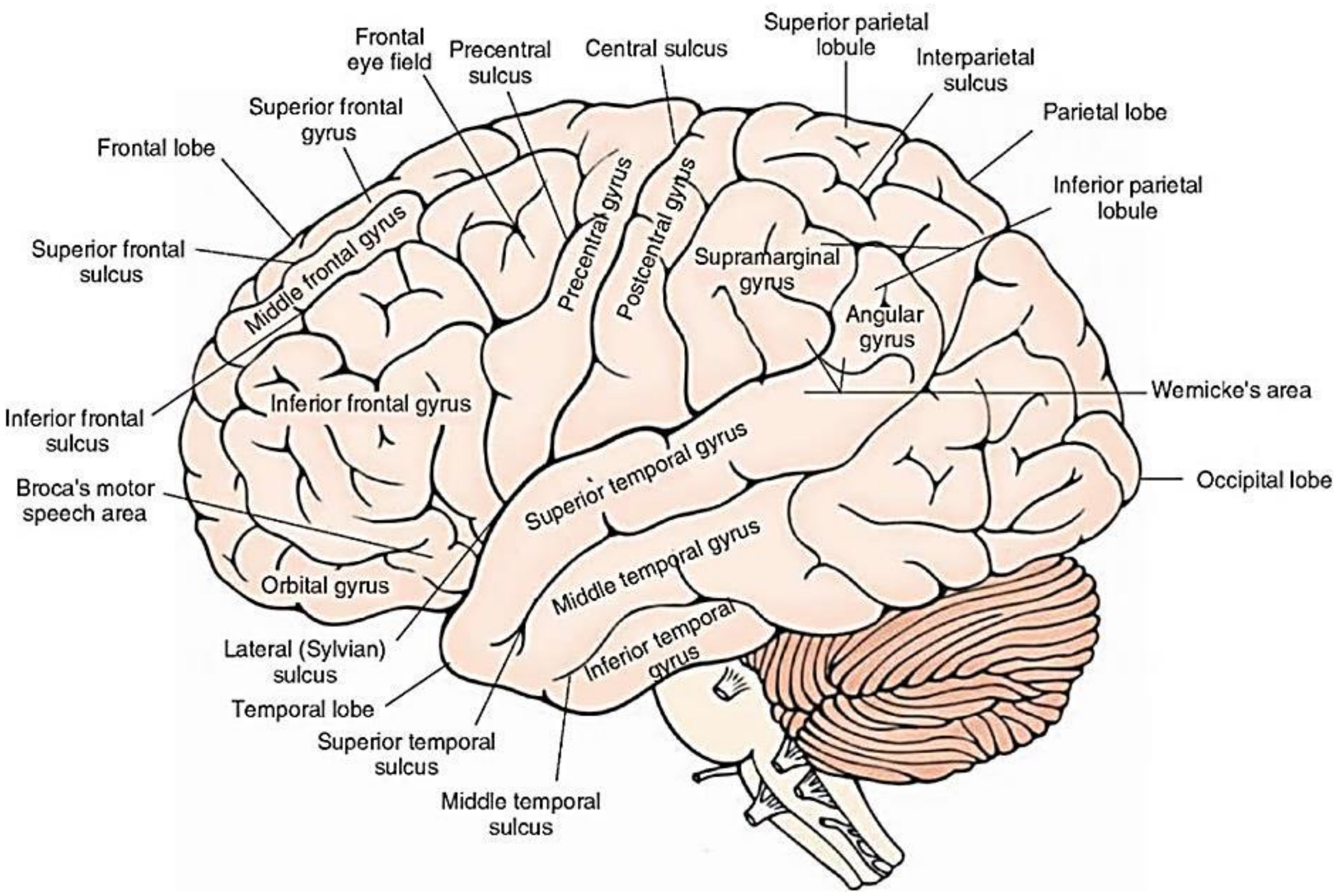
Supratentorial structures
(Forebrain= telencephalon + diencephalon cerebrum)

Infratentorial structures
Mesencephalon
Metencephalon
Myelencephalon

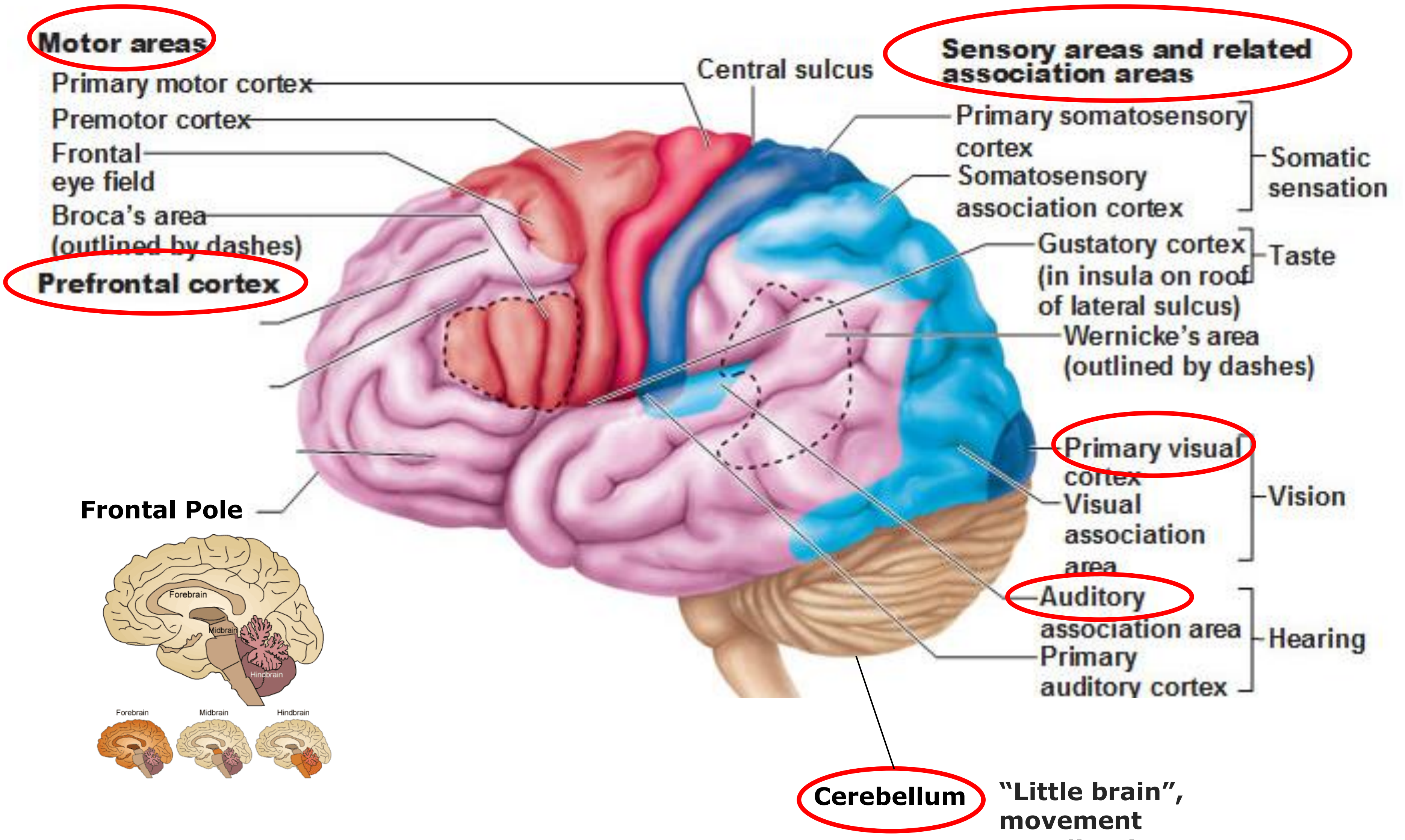
Major sulci of the cerebrum



Principle gyri of the cerebrum

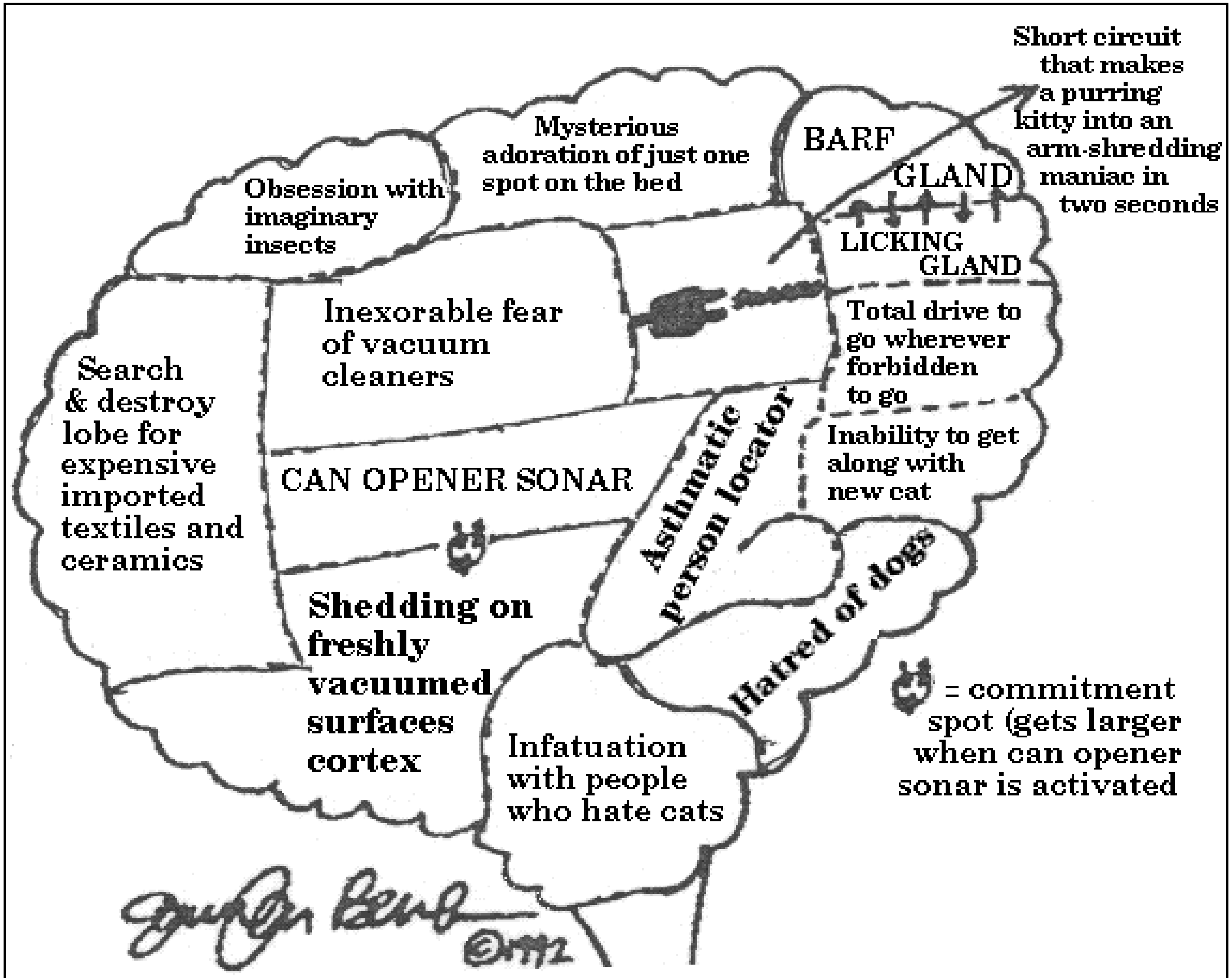


Functional Organisation of the Brain



How are these different brain areas organised from a functional perspective?

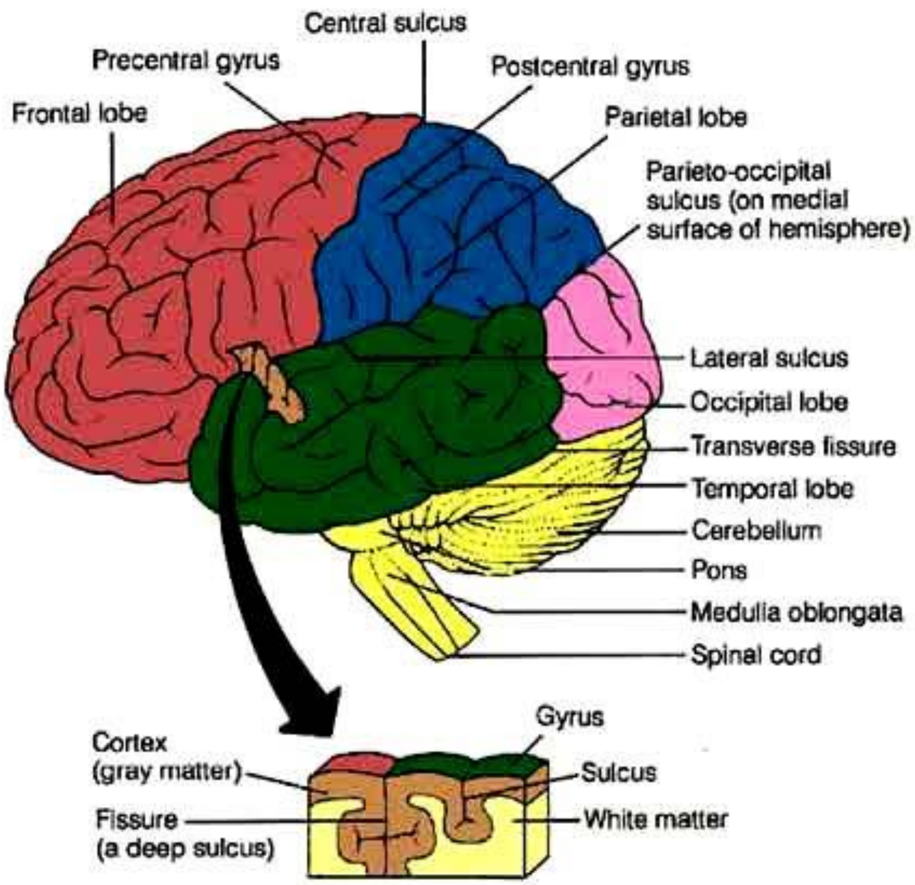
Inside a cat brain….



How are the functional neurotomical areas organised in a man's brain?

Inside Simpson's Brain

Cerebral Cortex of the brain



Cerebral Cortex

- Neocortex
- Allocortex

The largest part of the human brain is the *cerebral cortex* (cortex means bark in Latin – the brain does all information processing on six surface layers).

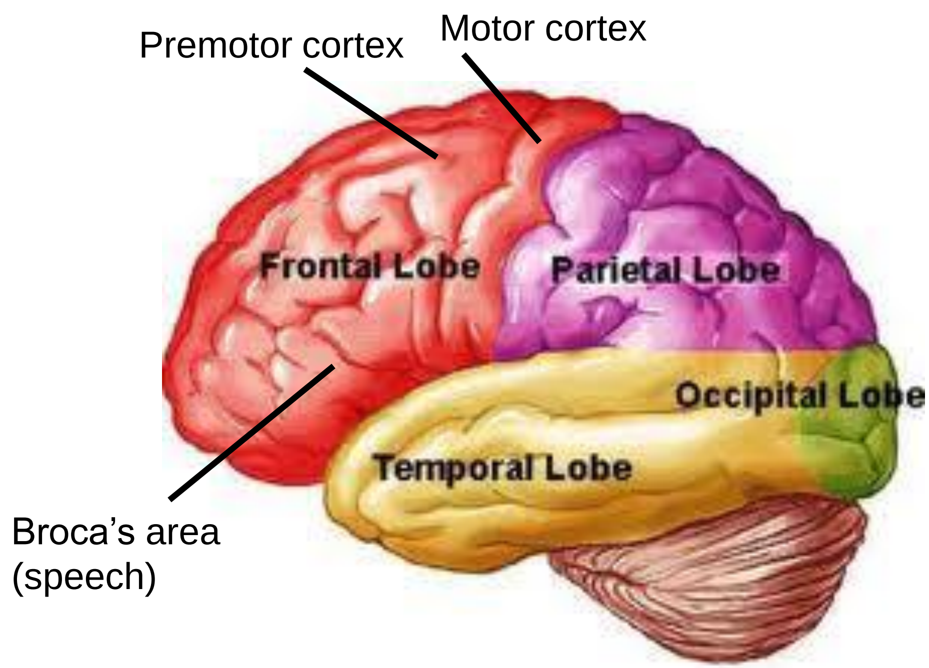
The cortex is like a giant sheet squeezed into many folds inside the skull. The folds are called *sulci.*

Different areas are segmented by deep *sulci* (fissures), and by functional aspects.

The brain is split into the left and right hemispheres by the longitudinal fissure.

Motor areas of the cerebrum

Made of three cortices concerned with muscle activity



Motor Cortex

- controls specific muscles throughout the body, especially hand movements and lip and mouth movements for talking and eating.

Premotor Cortex

- elicits co-ordinated movements involving sequences of muscle movements or the combined movement of many muscles (important for learning skilful sports).

Broca's area

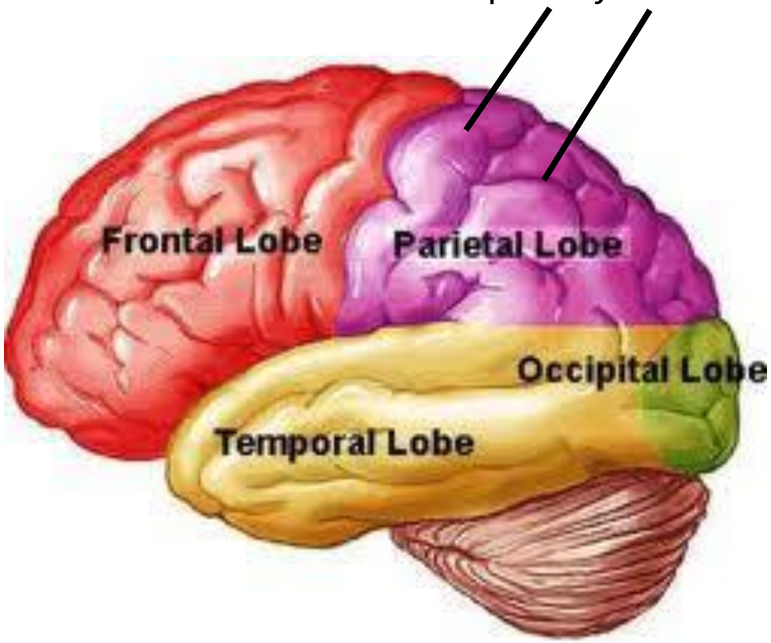
-Speech centre: planning of co-ordination of mouth and laryngeal movements to produce the words and sounds of speech.

-Damage to the Broca's area impairs speech production but not language understanding.

Somatosensory areas of the cerebrum

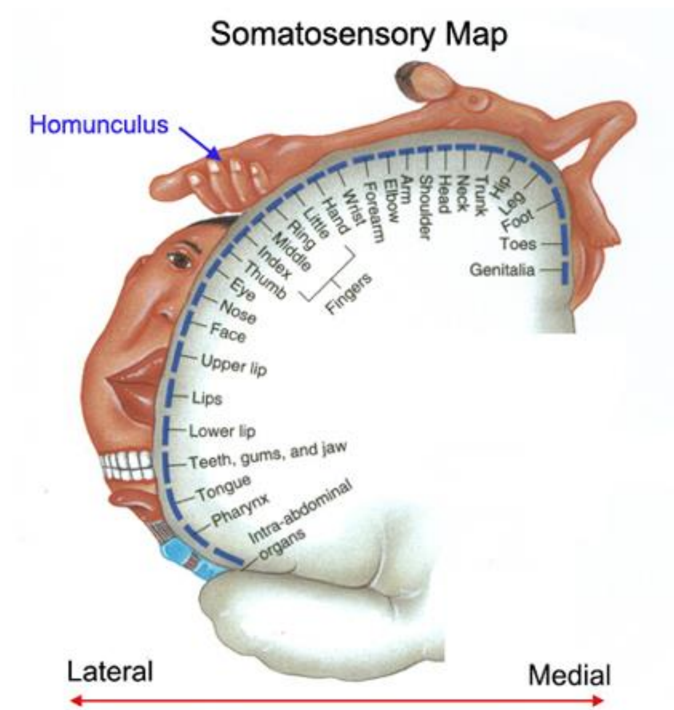
somatosensory perception

primary secondary

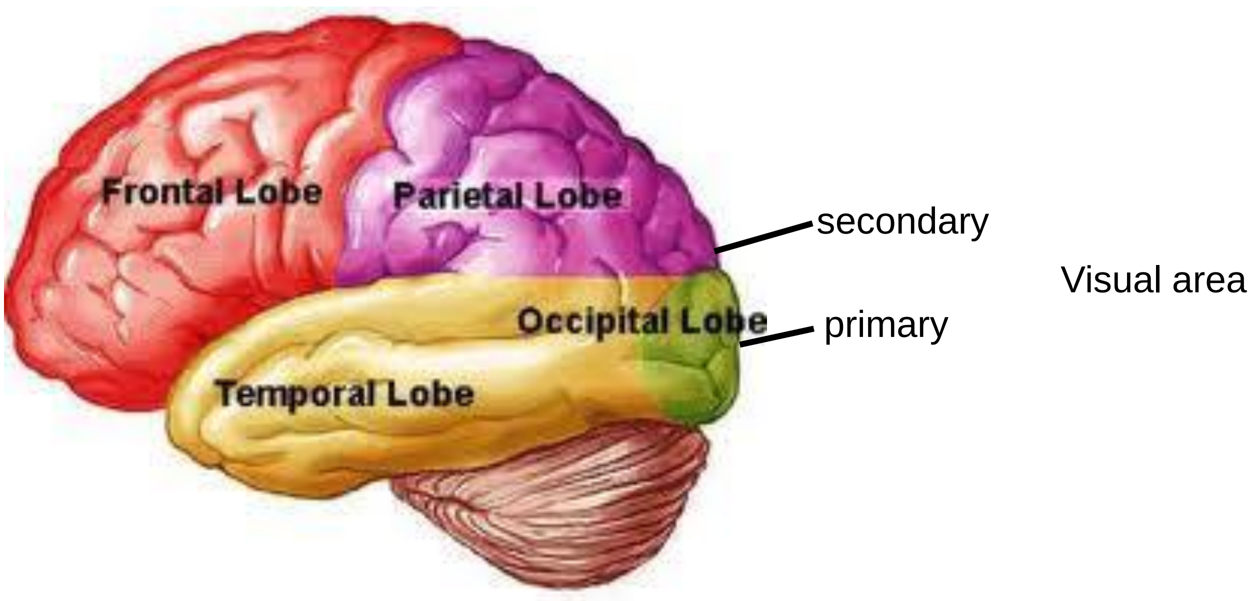


Somatosensory sensations are touch, pressure, temperature and pain.

The somatosensory area occupies the entire parietal lobe

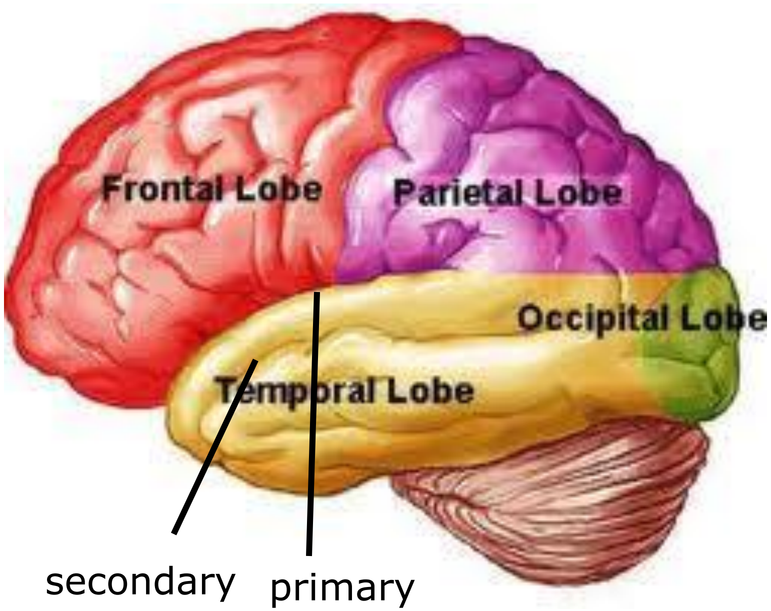


Visual area of the cerebrum



The visual area occupies the entire occipital lobe, along the calcarine sulcus, and is divided into primary and secondary areas.
The primary area detects light spots and orientation of lines.
The secondary area interprets the information.

The auditory area of the cerebrum

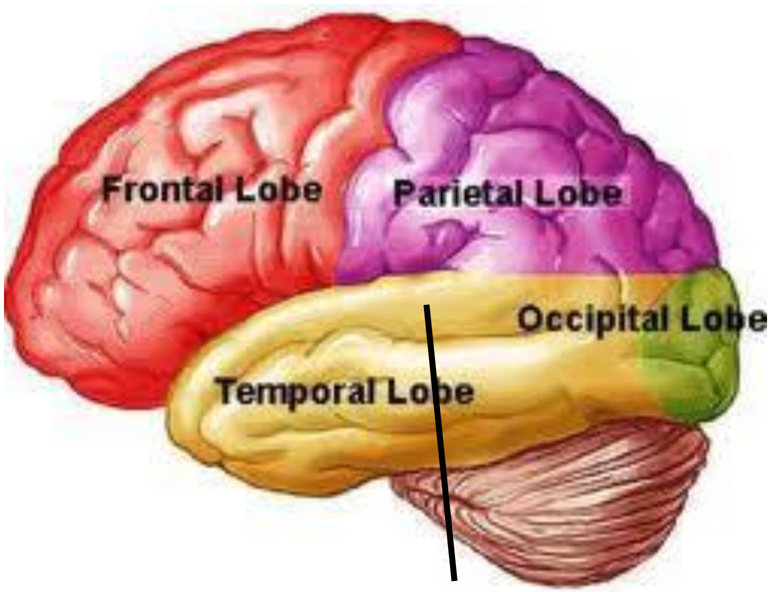


Auditory area

The primary auditory area is involved in the detection of tone, loudness and other sound qualities.

In the secondary area the sounds detected are interpreted into speech or music. This area is a focus of transmagnetic stimulation, particularly in schizophrenic patients with auditory hallucinations.

Wernicke's area and language perception



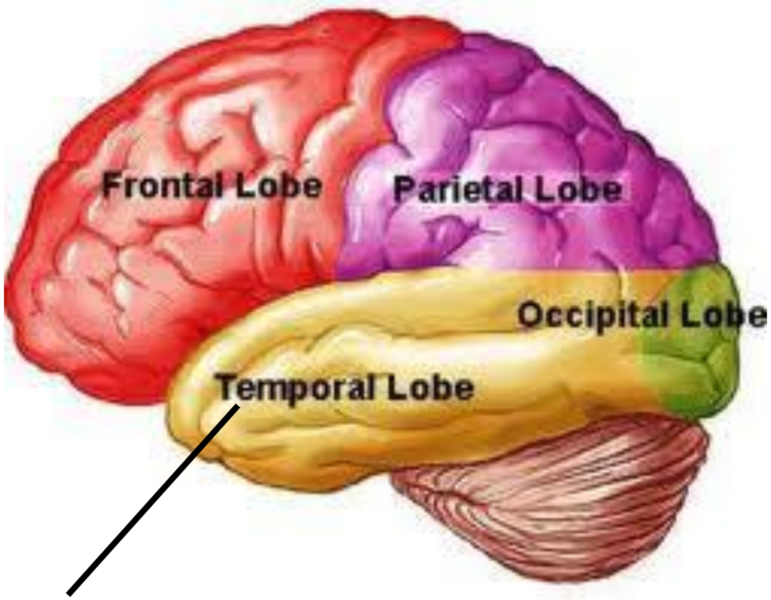
Wernicke's area

The Wernicke area is very important for language perception and recognition.

Damage to the Wernicke's area leads to the loss of language production, although the person can still speak clearly. The words that are put together make no sense (word salad).

Wernicke's aphasia or receptive aphasia, fluent aphasia or sensory aphasia is a type of aphasia traditionally associated with neurological damage (e.g. stroke) to Wernicke's area not be confused with Wernicke-Korsakoff syndrome

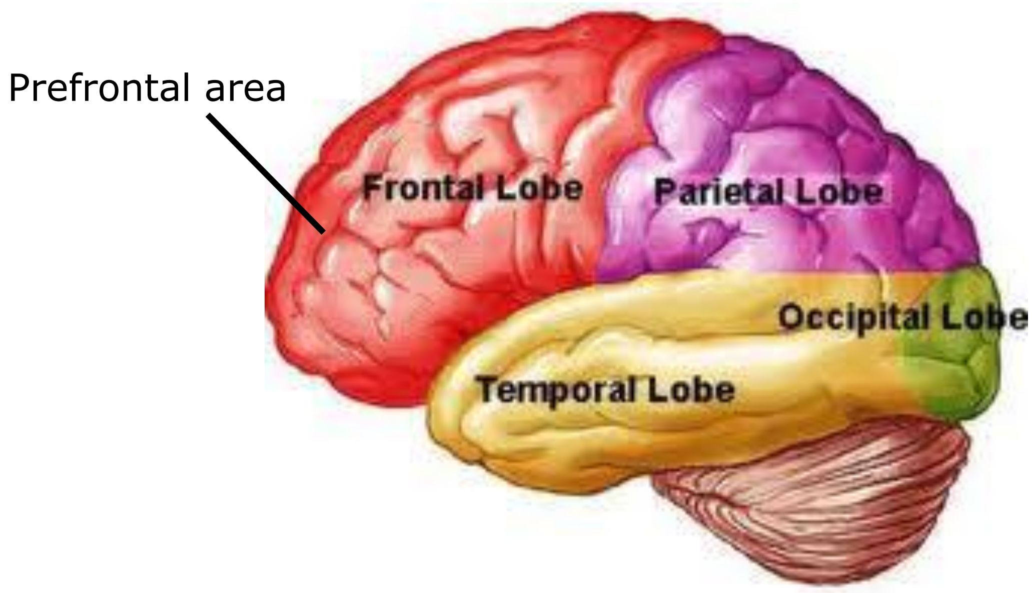
The short-term memory area of the temporal lobe



short-term memory area

The lower half of the temporal lobe is important for the storage of short-term memories of a few minutes to a few weeks.

The prefrontal area of the cerebrum

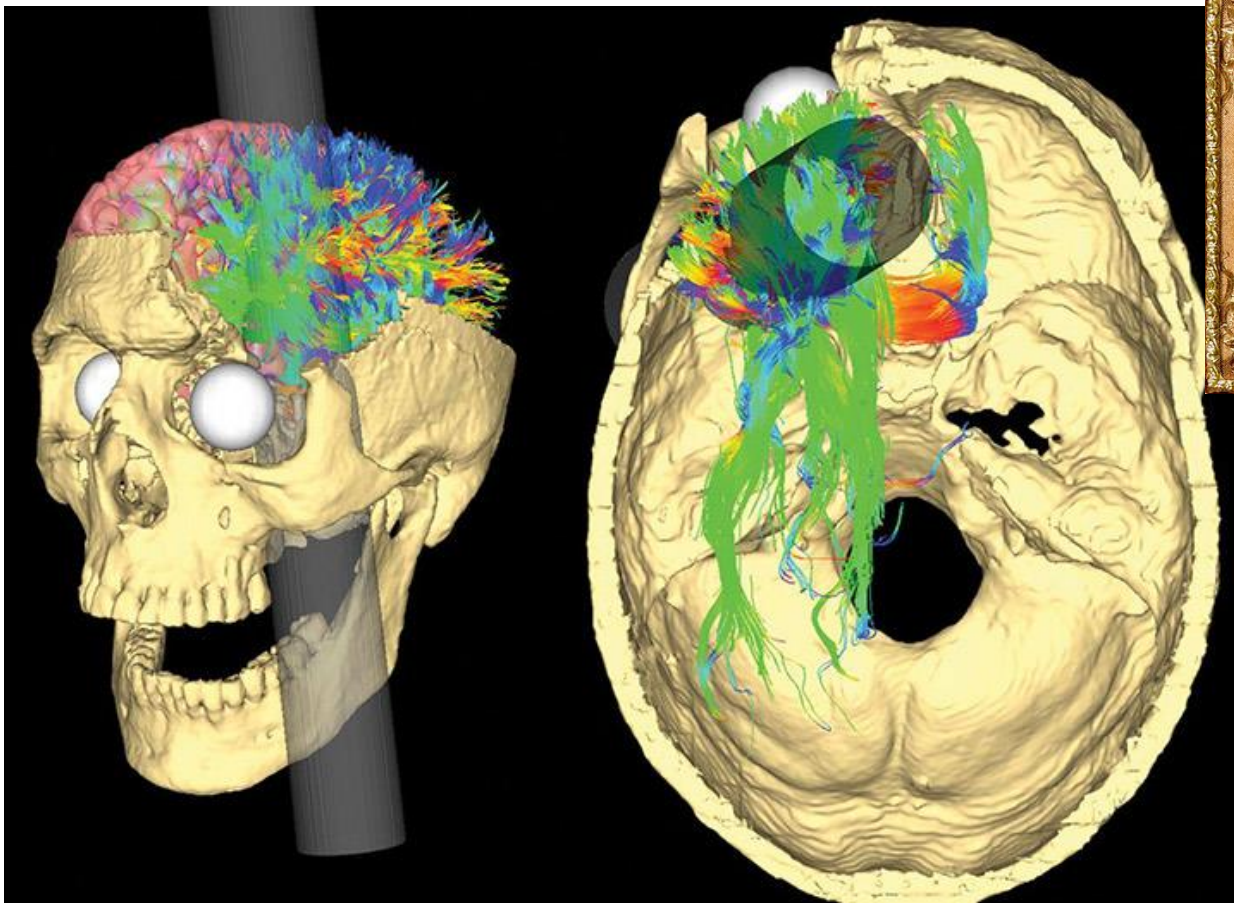


The prefrontal area is located in the anterior half of the frontal lobe.

Its function is less understood than other areas of the brain.

It is considered to be involved in thought and emotion, particularly depression. The dorsolateral prefrontal cortex is particularly targeted in TMS for patients with depression.

Phineas Gage and the Prefrontal area

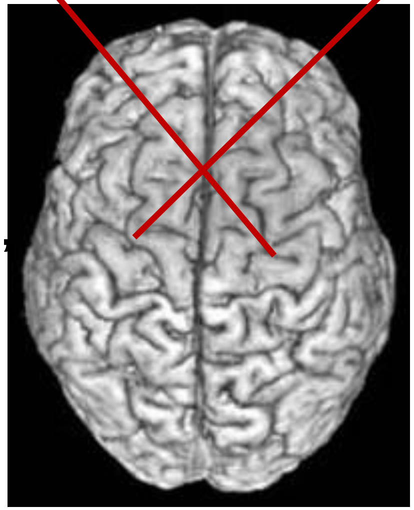


From a respectable, hardworking man (railway worker) to an impulsive, aggressive and unreasonable person

Cerebral dominance: one hemisphere dominant over the other for particular cerebral functions

Left Handed

Dominant in the control of speech, language and analytical processing, mathematics, mechanics, relies on reason, egocentric…
Damage causes depression

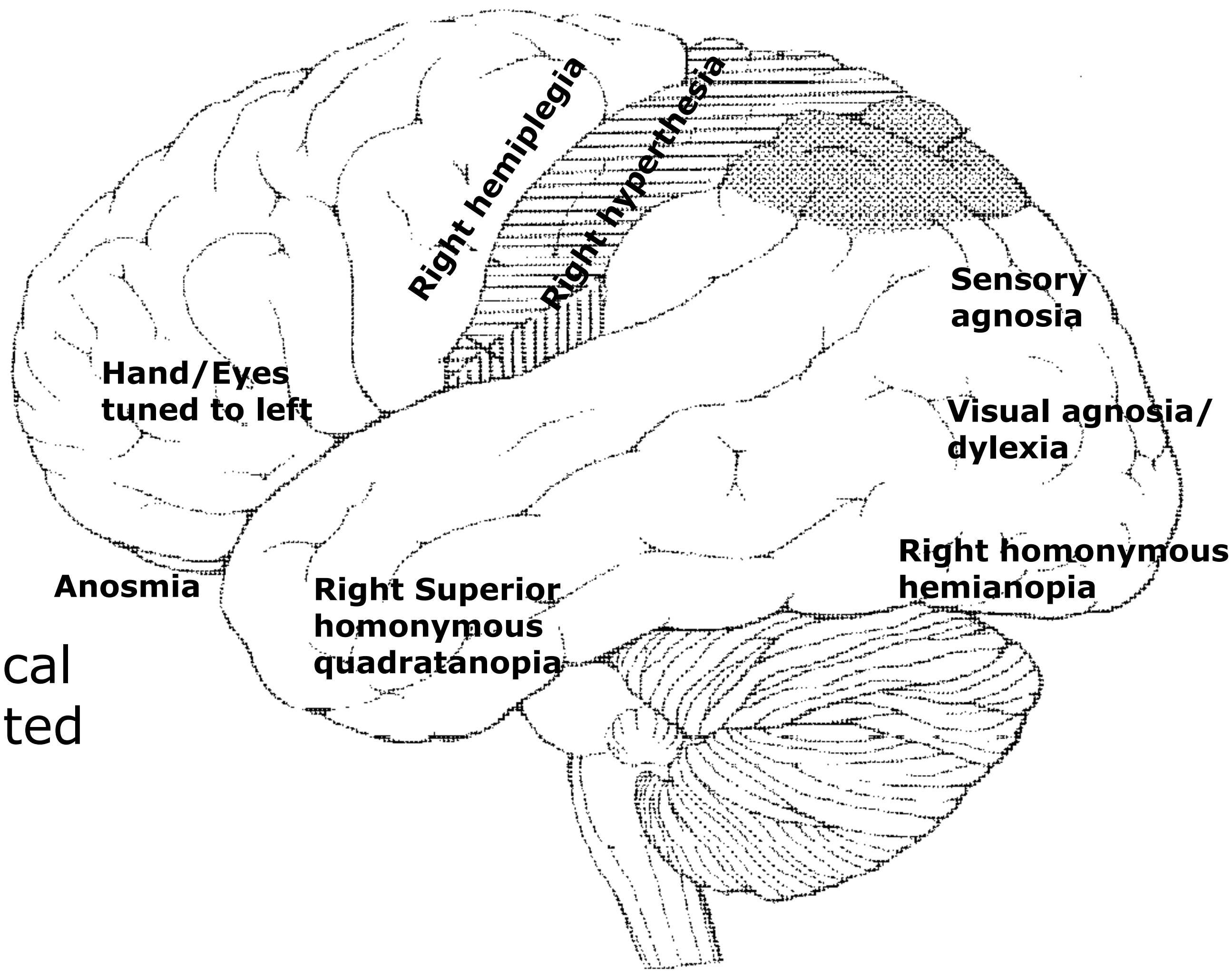


Right Handed

Dominant in processing spatial concepts and language as related to certain types of visual images; important in visuospatial skills, artistic, relies in instinct
Damage causes emotional flattening.

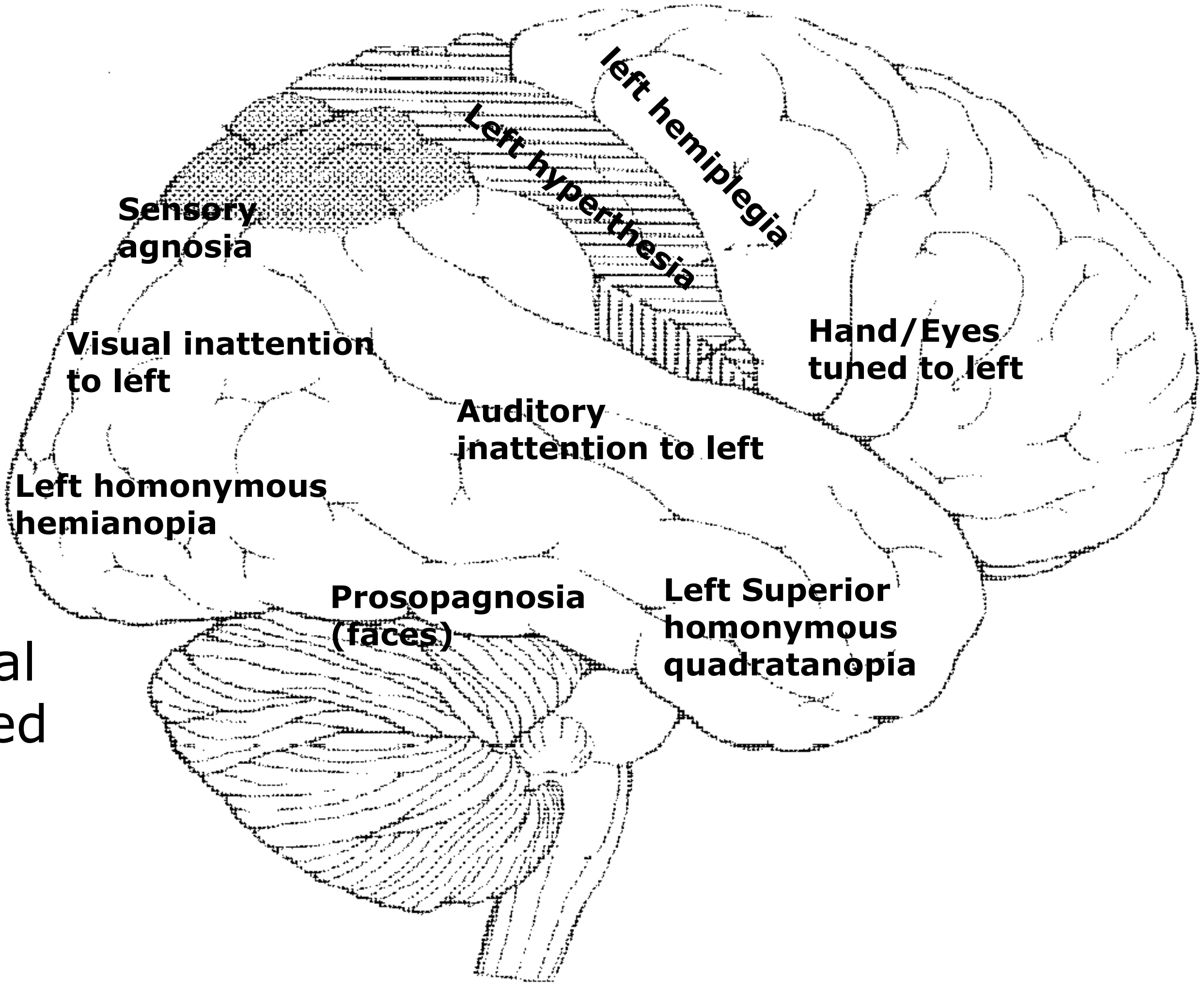
Handedness (right-handed people have left cerebral dominance) is considered a general *indication* of cerebral dominance.

Major Neurological Signs & Symptoms



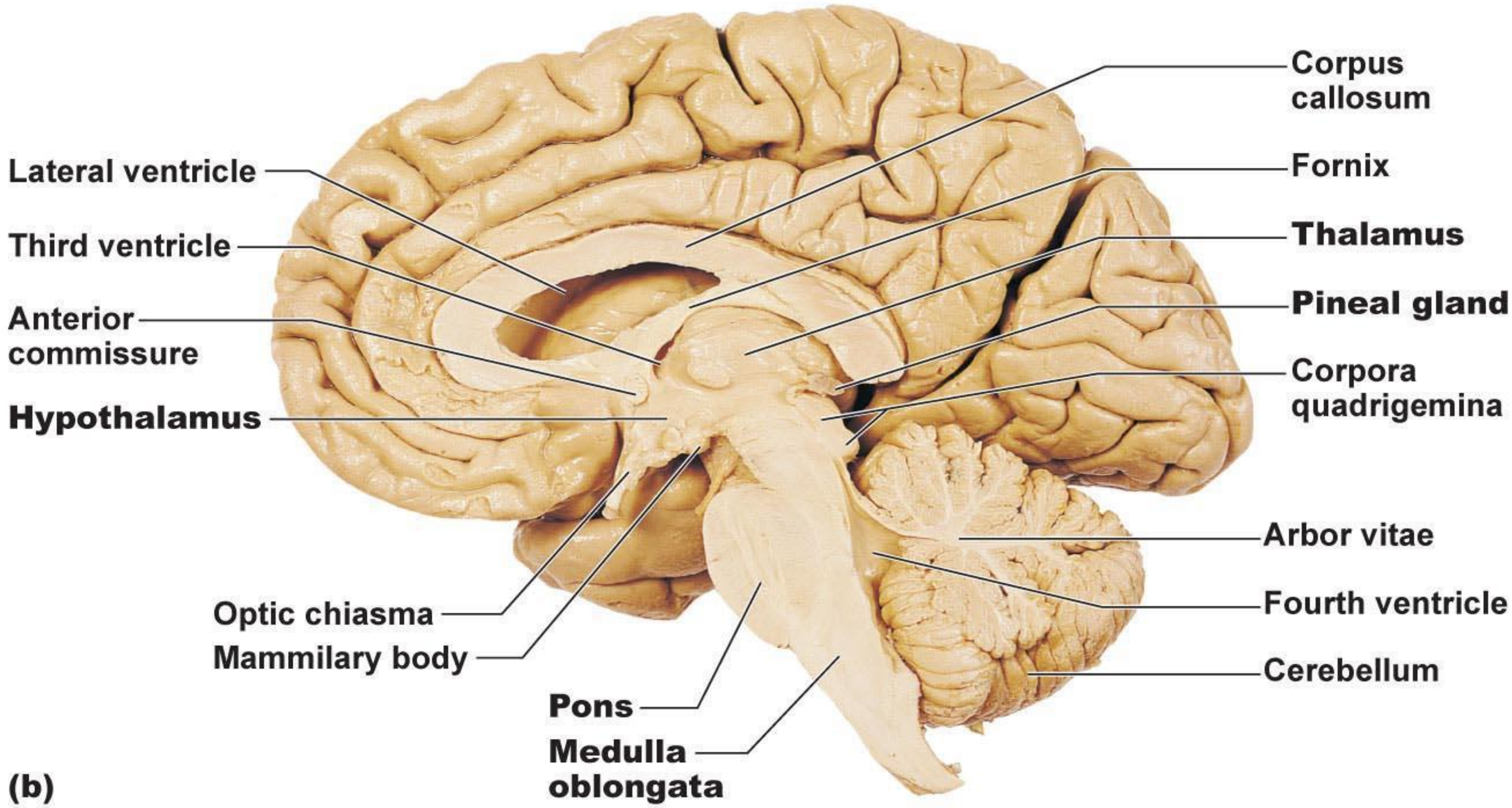
Focal Neurological Lesions associated with Left Brain

Major Neurological Signs & Symptoms

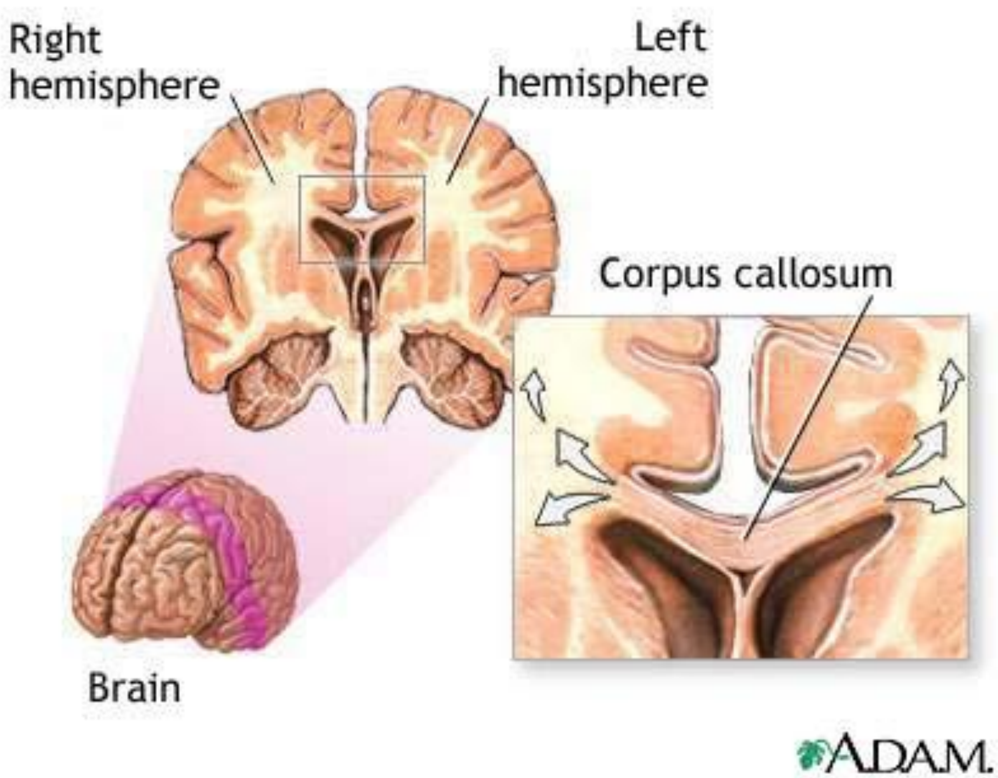


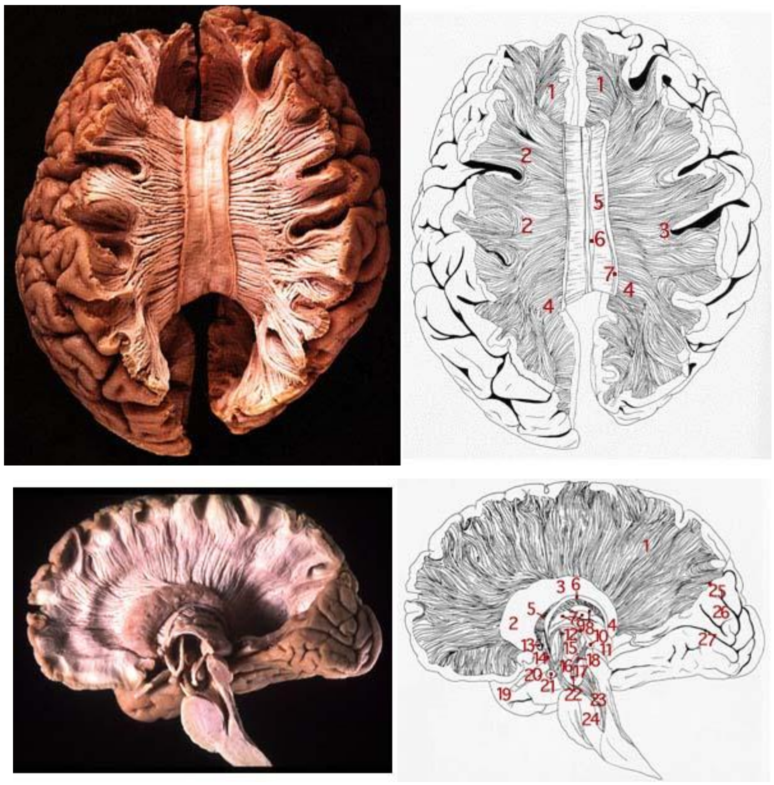
Focal Neurological Lesions associated with Right Brain

There are many more important structures *inside* the brain



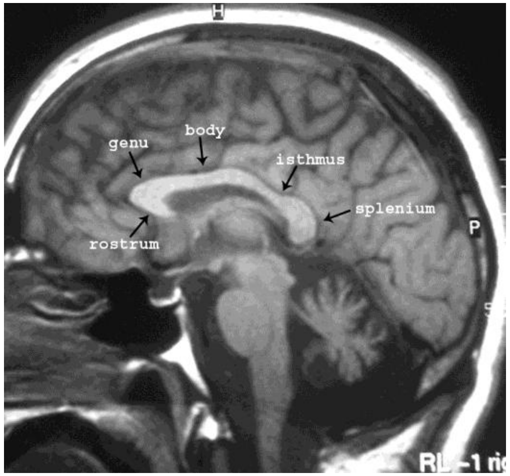
The corpus callosum





The corpus callosum is the structure deep in the brain that connects the right and left hemispheres of the cerebrum, coordinating the functions of the two halves.

Disorders of the Corpus Callosum

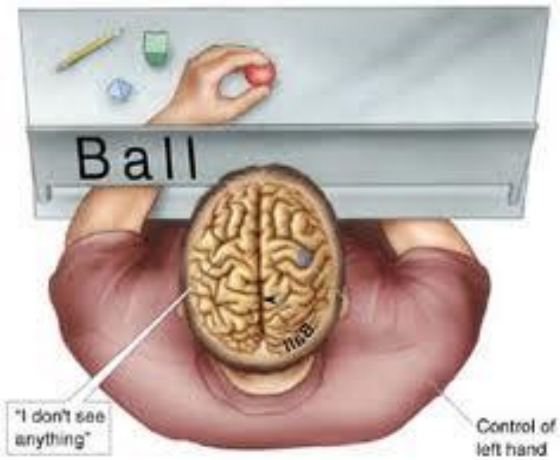


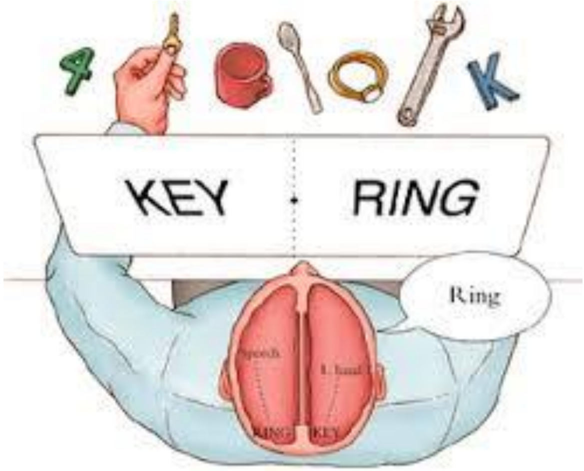
Pathology of the CC

- Alien hand syndrome
- Alexia (without agraphia- splenium)
- Agenesis (also dysgenesis, hypogenesis, hypoplasia, malformations)

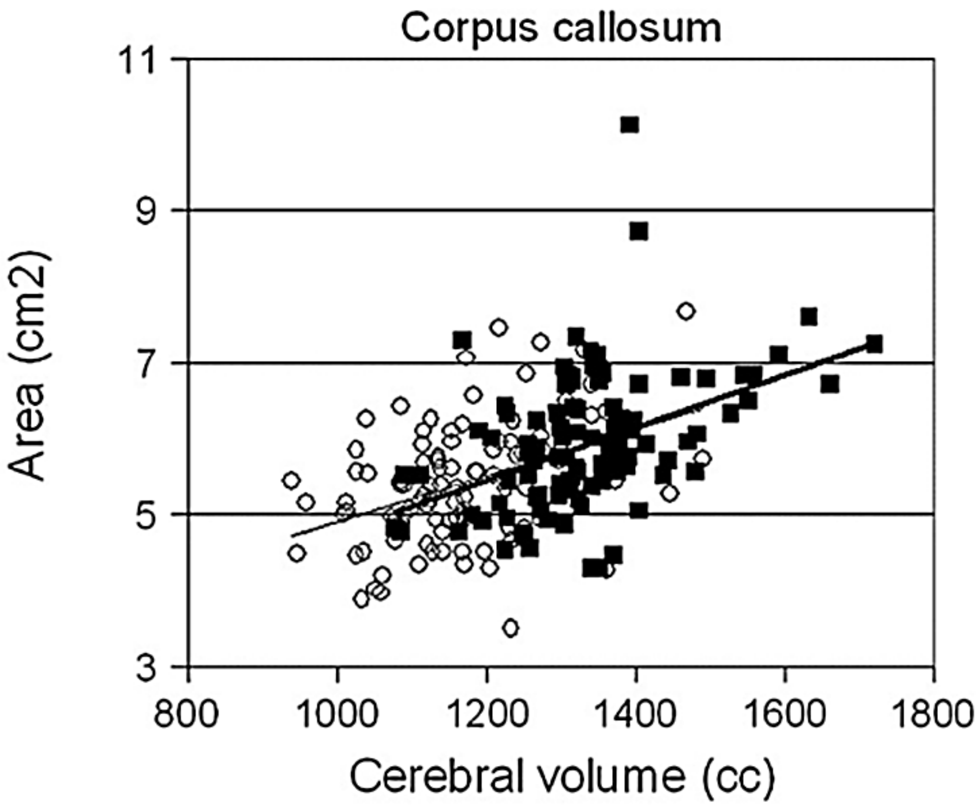
- **Split-brain**

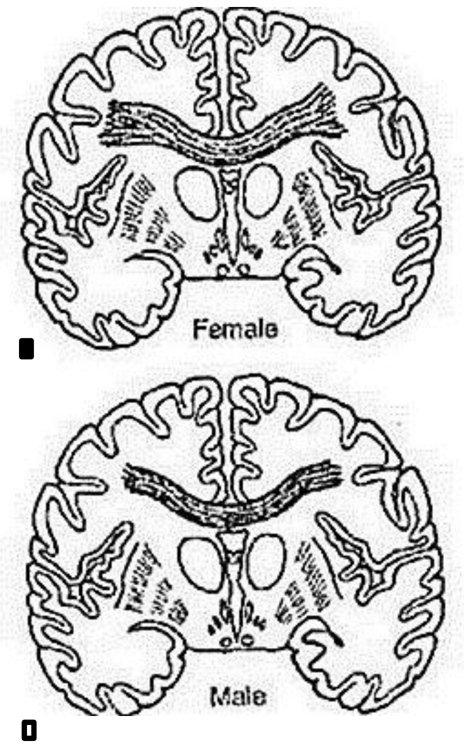
- Septo-optic dysplasisa (deMorsier syndrome)
- MS with symptom *Dawson's* fingers
- Mild encephalopathy with reversible splenial lesion (MERS)



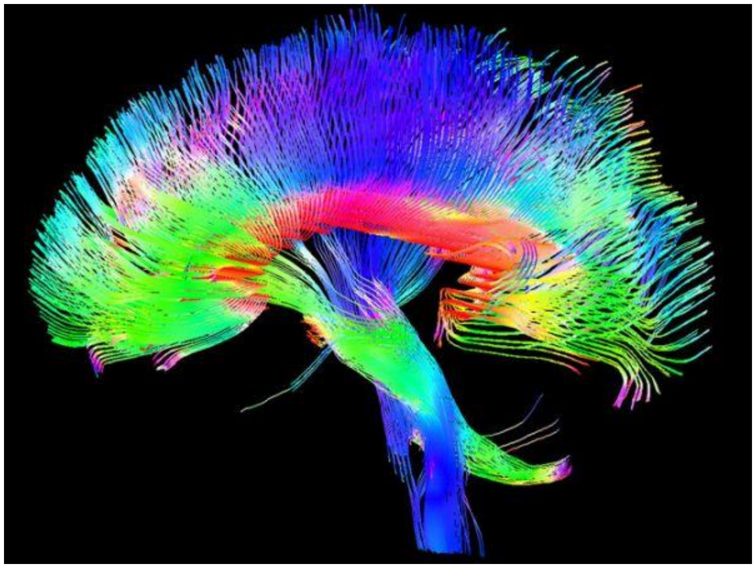


Corpus Callosum and Gender

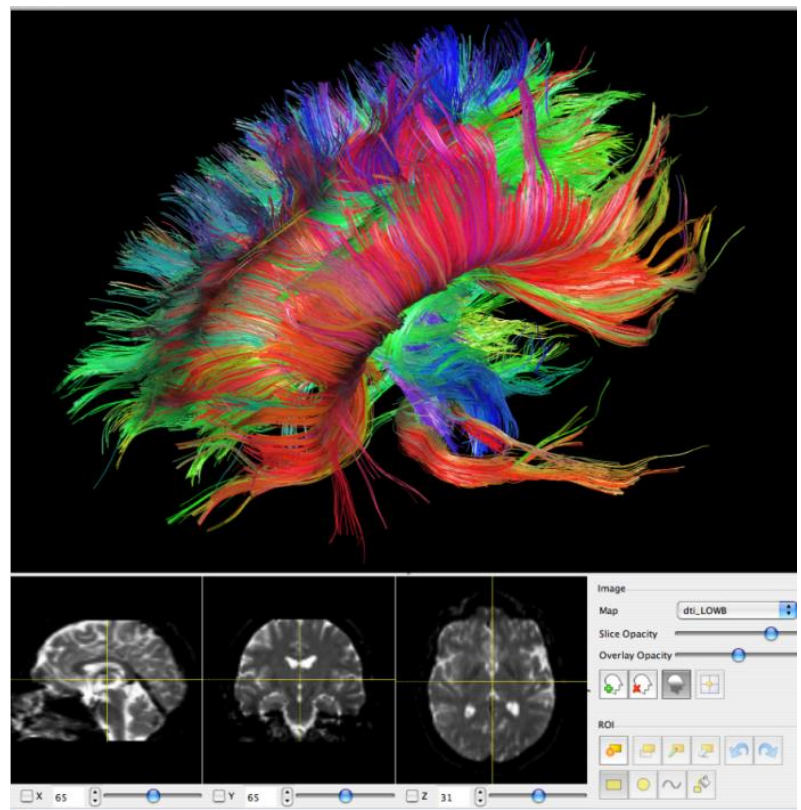




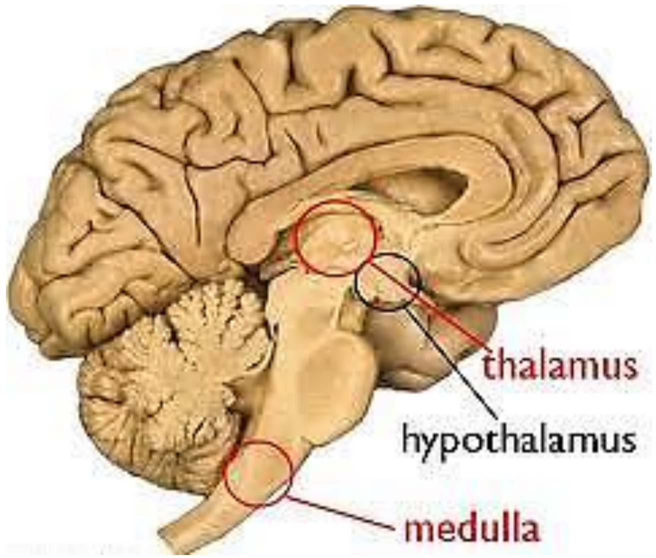
The corpus callosum and corona radiata

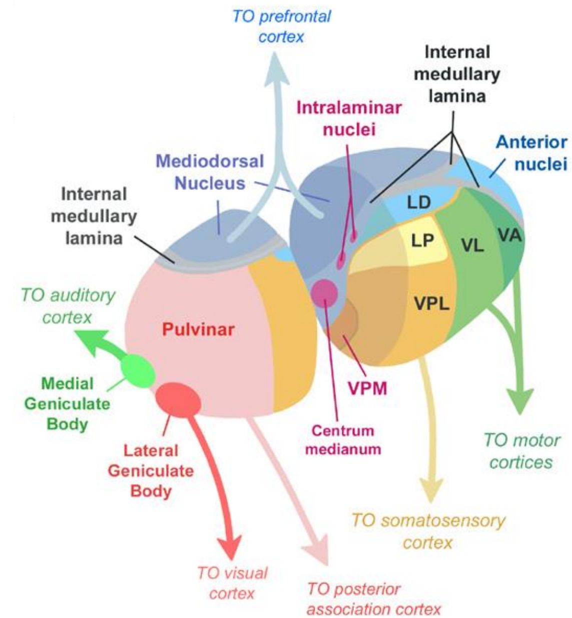


MR DTI- diffusion tensor imaging allows study of WM tracts



The thalamus: gateway to the brain

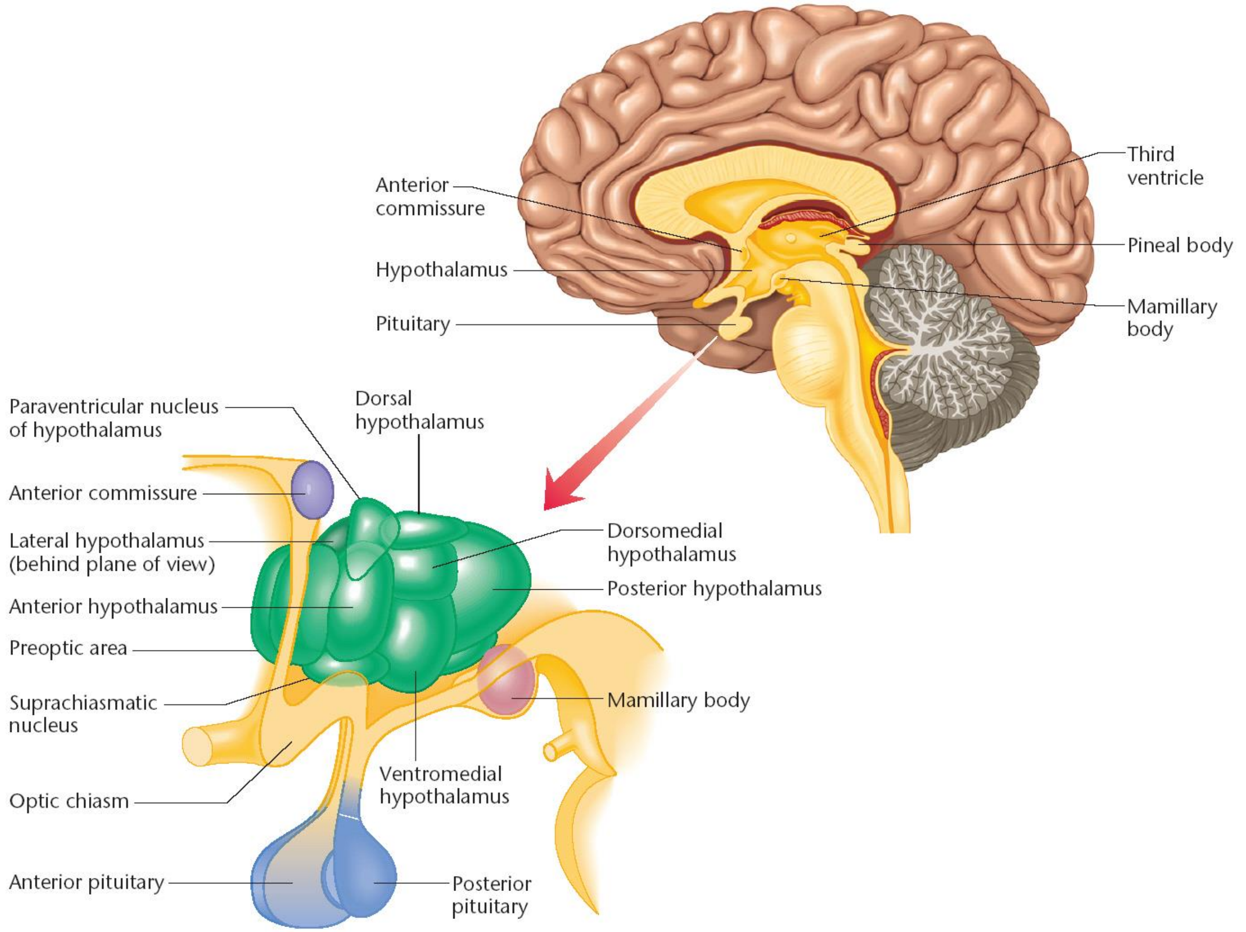




The thalamus connects peripheral sensory organs (except for olfaction) to the various sensory cortices.
The thalamus also has profound influence on motor and cognitive function.

Behind the thalamus is the *Pineal Gland* , involved in body rhythms and sexual activity.

Hypothalamus and endocrine control

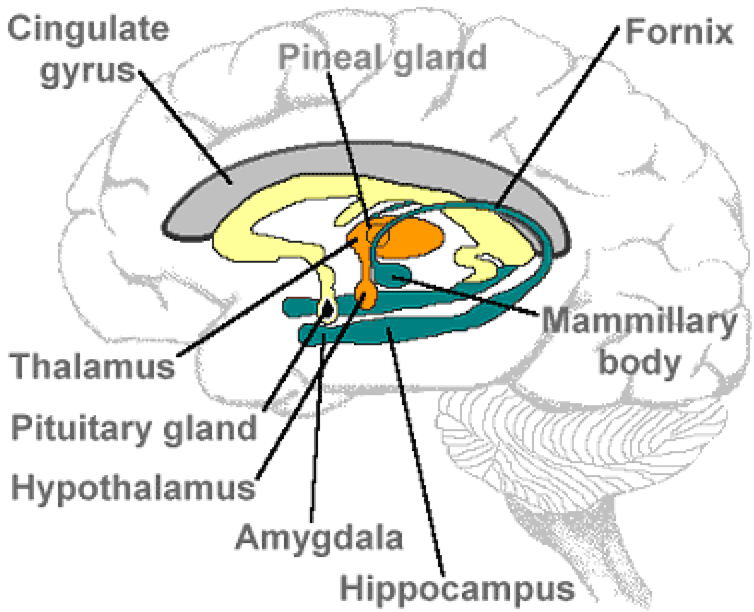


The hypothalamus exerts control over endocrine function via the pituitary gland. It has extensive connections with brainstem autonomic nuclei.

Circadian rhythms are controlled in the hypothalamus (suprachiasmatic nucleus).

Lesions of the hypothalamus affect appetite, emotional behaviour, temperature control, and numerous other autonomic and endocrine-influenced behaviours.

The limbic system: emotion and memory



Limbus: rim in Latin.
limbic cortex forms a ring around the brainstem and diencephalon (thalamus, hypothalamus).
Limbic structures include:
amygdala, hippocampus and parahippocampal gyrus, cingulate cortex, orbitofrontal, and insular cortex.

Emotion

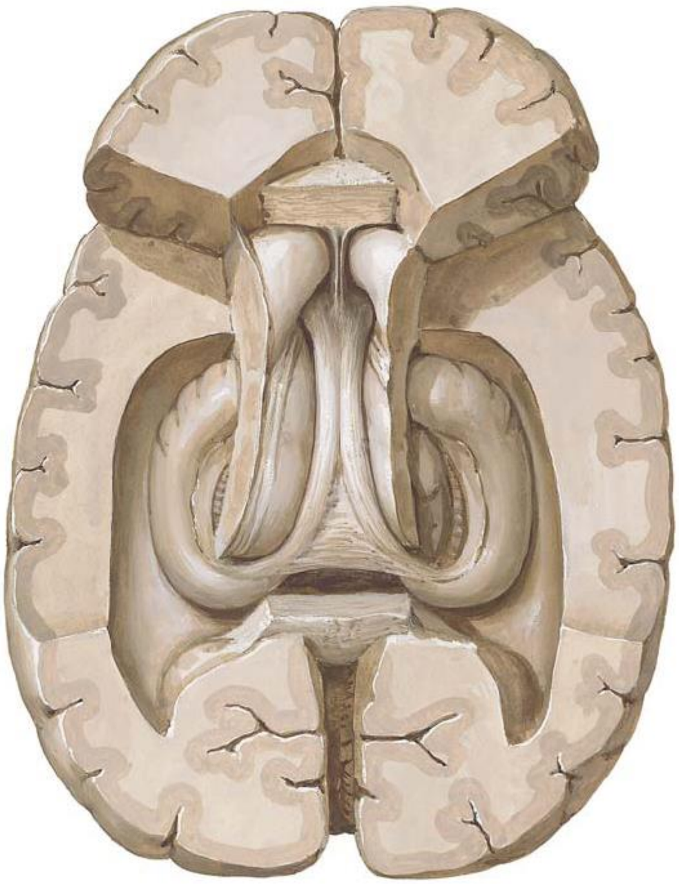
The limbic system controls emotions (motivation, mood, pleasure/pain, fear) through its position (and connections) between the cortex and the hypothalamus.

Lesions in the Limbic System can result in voracious appetite, increased (often perverse) sexual activity, and docility (including loss of normal fear and anger responses).

Memory

Lesions affecting the hippocampus and its connections profoundly affect memory.

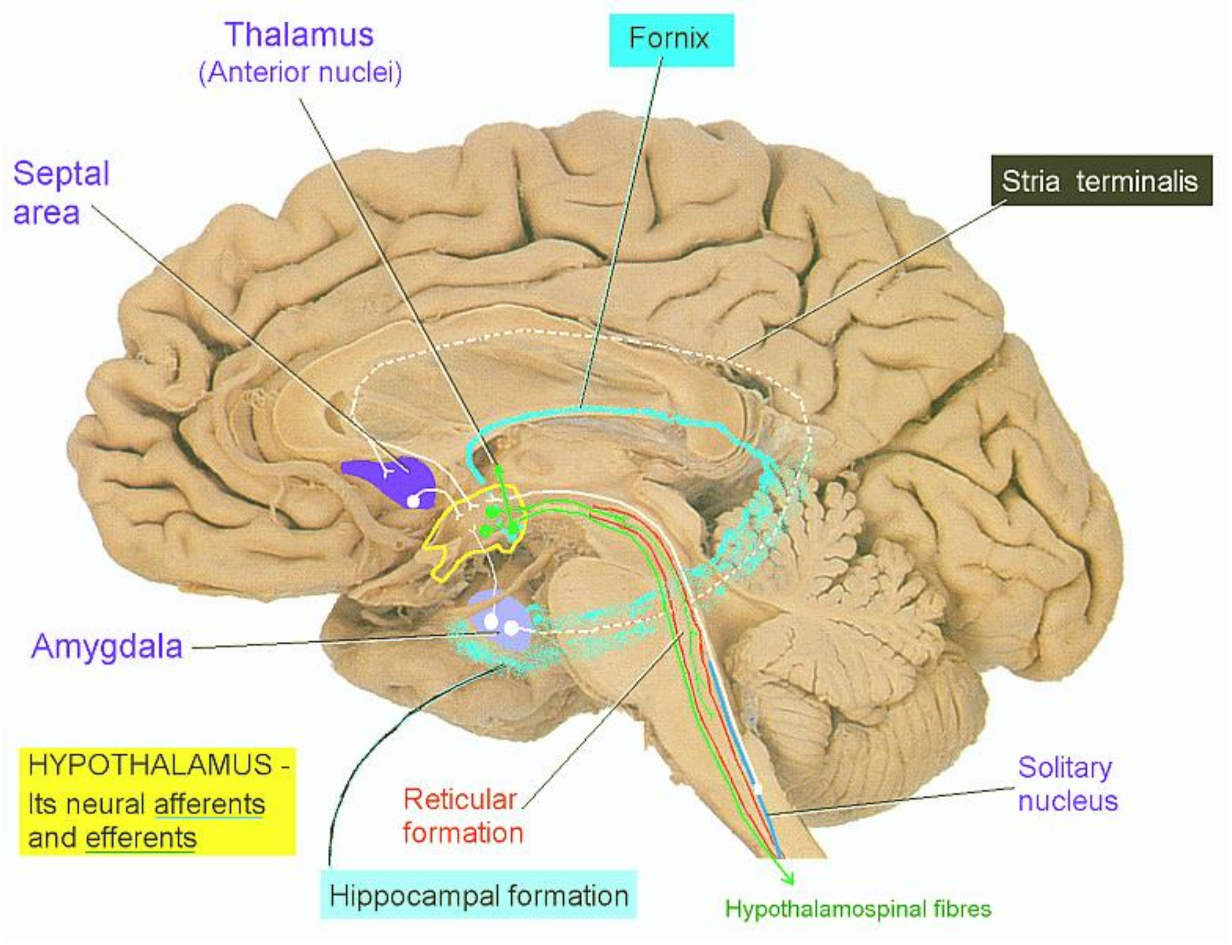
The limbic system: anatomical limbic lobe and deep-lying structures

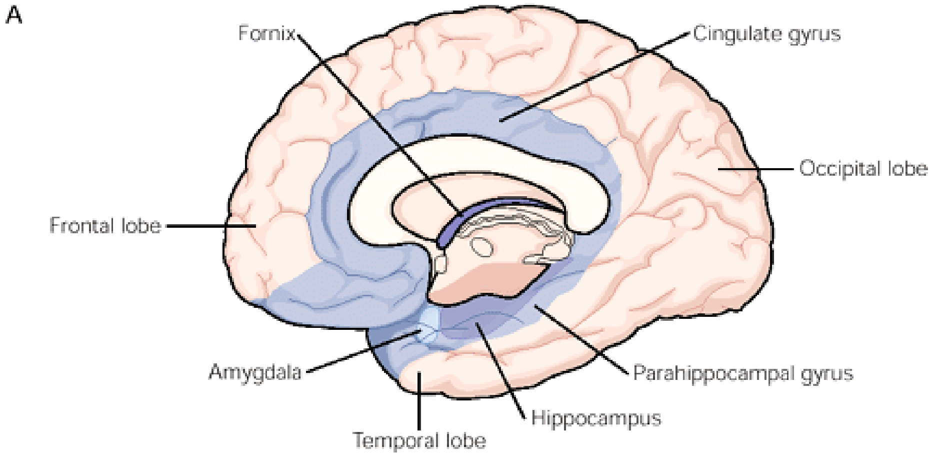


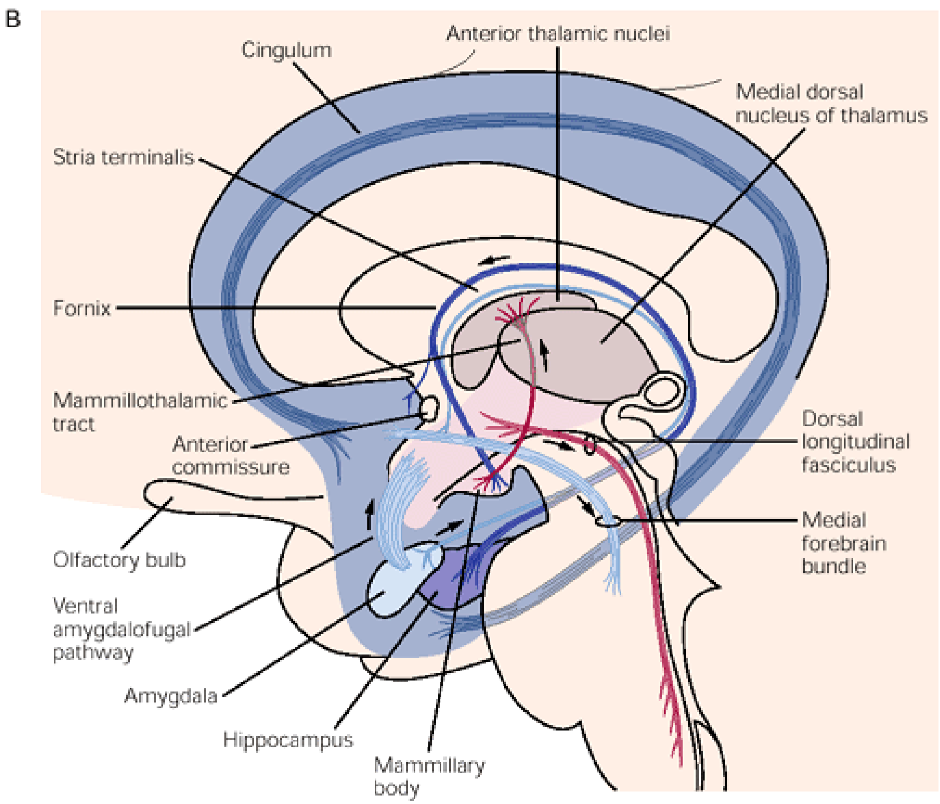
The limbic system: the hypothalamus, the telencephalon (cingulate, parahippocampal, and subcallosal gyri), the amygdala and hippocampal formation.

The limbic system functions in linking emotion and motivation (amygdala), learning and memory (hippocampal formation), and sexual behavior (hypothalamus).

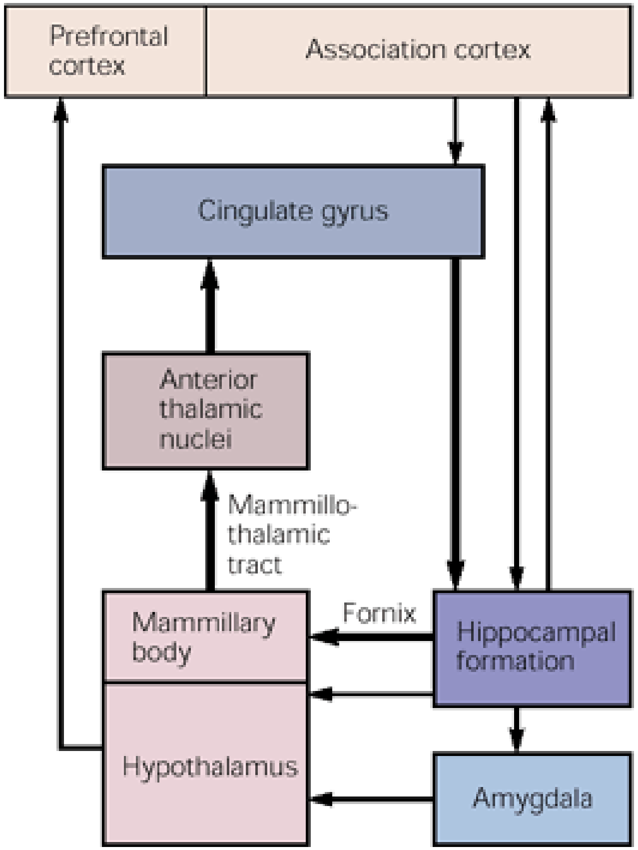
The limbic system circuits





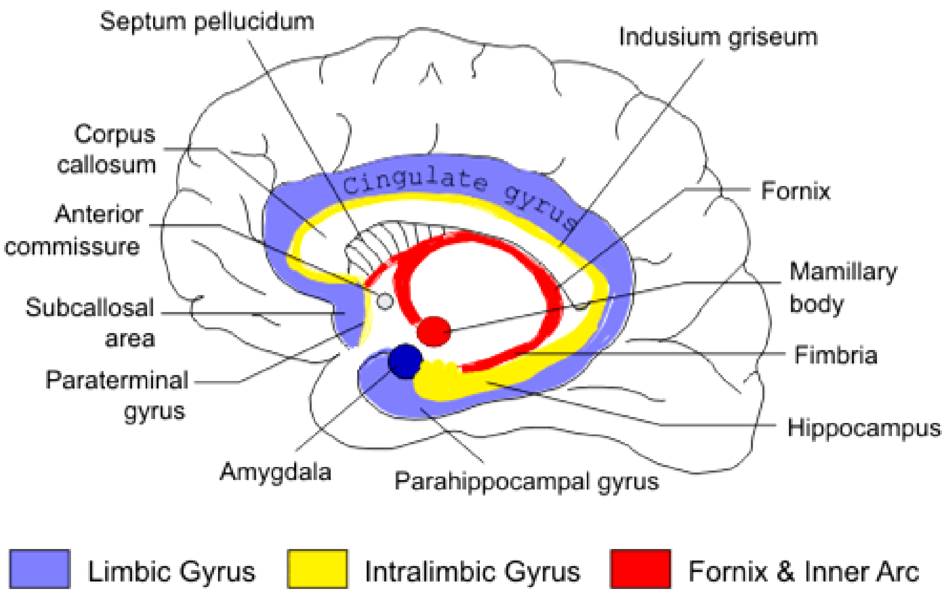


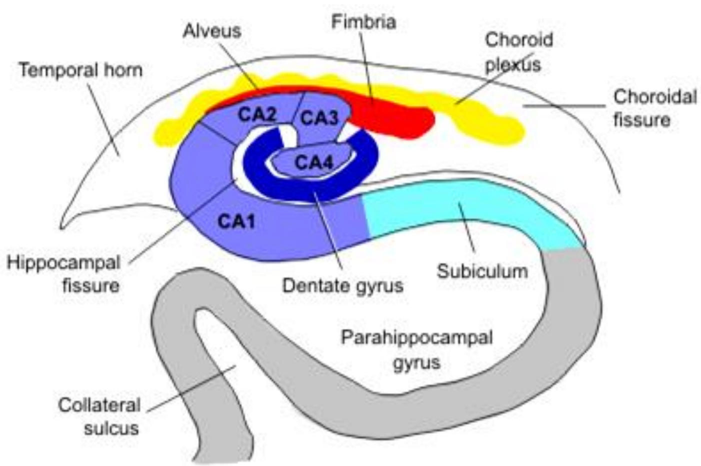
The limbic system consists of the limbic lobe and deep-lying structures

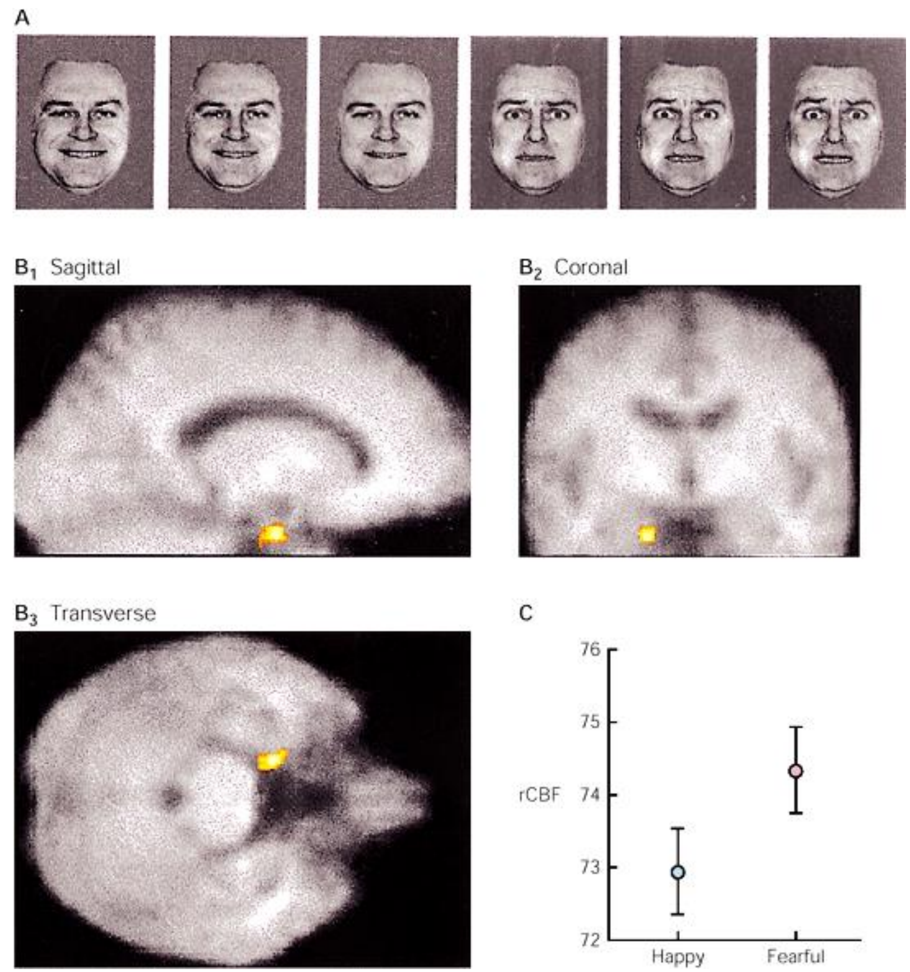


A neural circuit for emotion proposed by James Papez and extended by Paul MacLean

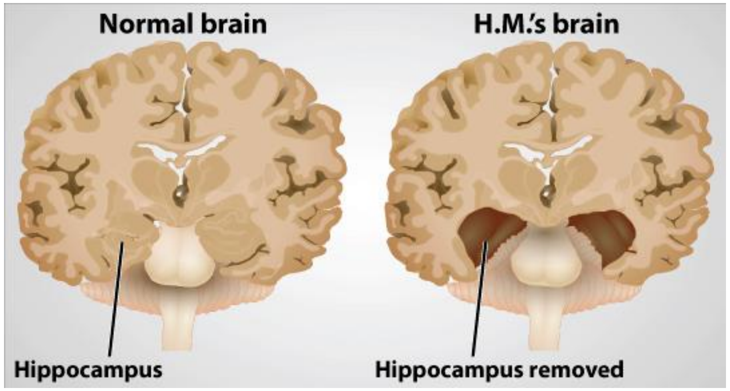
Limbic system and the role of amygdala in emotional responses





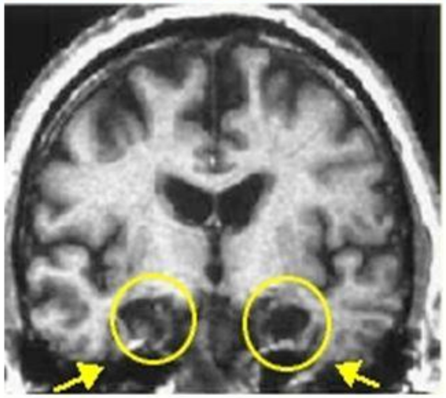


Patient HM, Amnesia and Memory



Henry Gustav Molaison

Patient HM

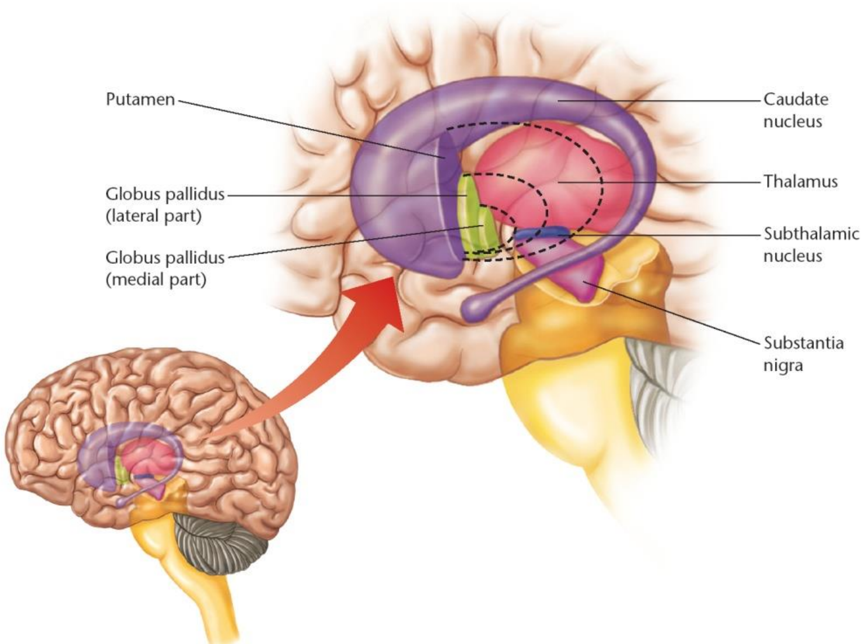


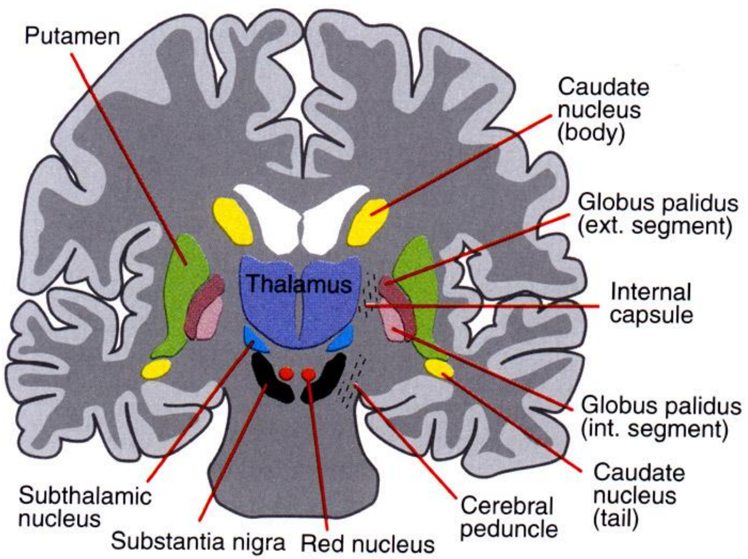
Born: February 26, 1926
Surgery: September 1, 1953 (age 27)
Died: December 2, 2008 (age 82)

- Severe anterograde declarative memory disorder
- Retrograde memory disorder back 11 years
- Intact: immediate memory, procedural memory, priming, & release from proactive interference

Scoville WB, Milner B. Loss of recent memory after bilateral hippocampal lesions. J Neurol Neurosurg Psychiatr 1957;20:11-21.

The basal ganglia: motor programming areas





caudate and putamen=striatum

Clinical syndromes linked to the basal ganglia:

Parkinsonism

Loss of dopaminergic neurons in the substantia nigra that normally project to the striatum, associated with rigidity, bradykinesia (slow movement), tremor, and loss of postural reflexes.

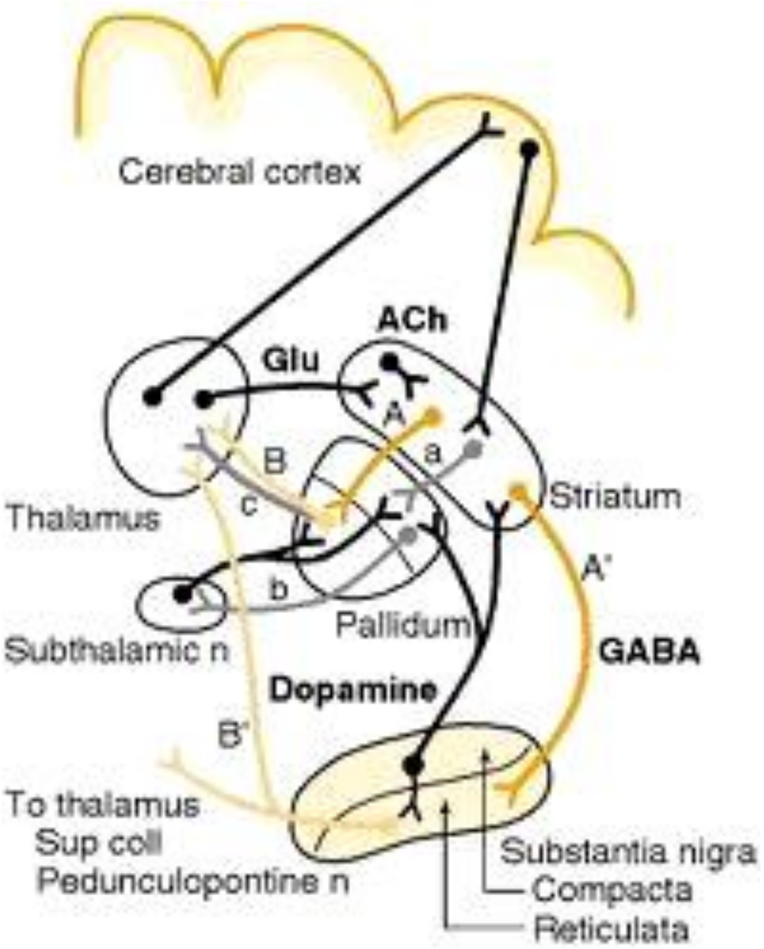
Huntington's disease

an hereditary disease characterized by progressive dementia and chorea (brief, irregular contractions that appear to flow between muscles), associated with atrophy of the caudate nucleus.

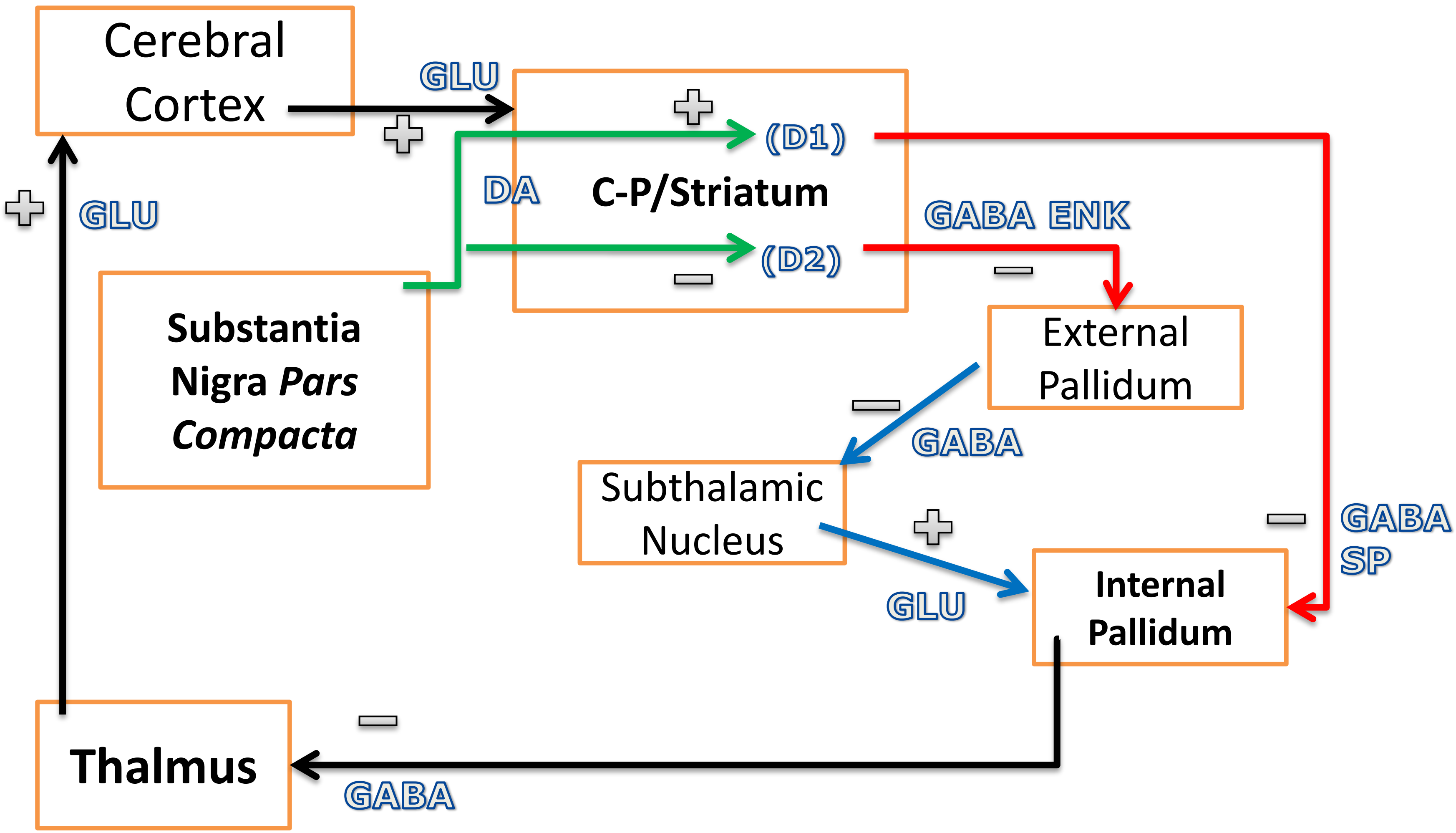
Hemiballismus (hemichorea) (involuntary movement)

associated with damage to the contralateral subthalamic nucleus.

The basal ganglia: Transmitter pathways

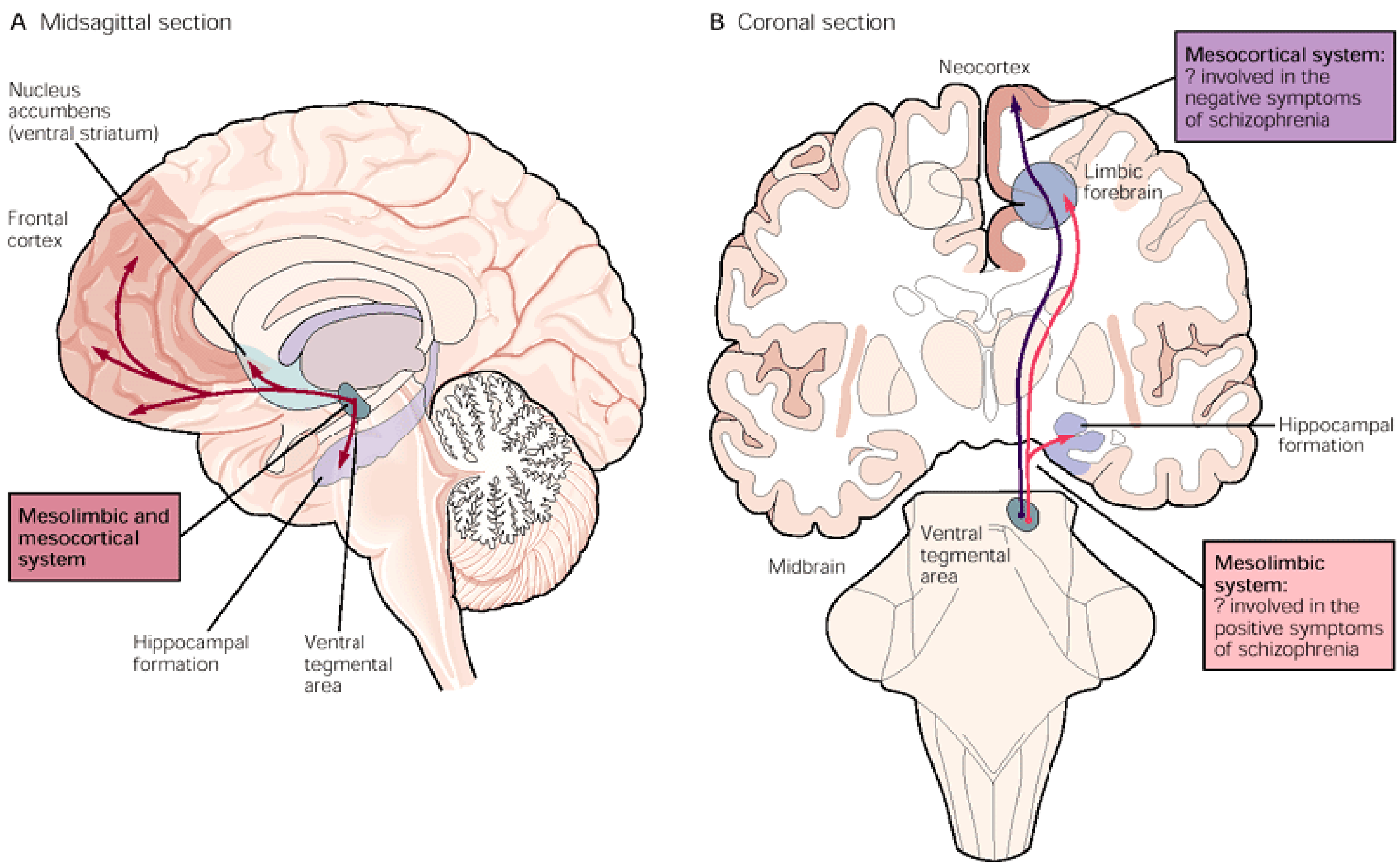


The basal ganglia: Transmitter pathways



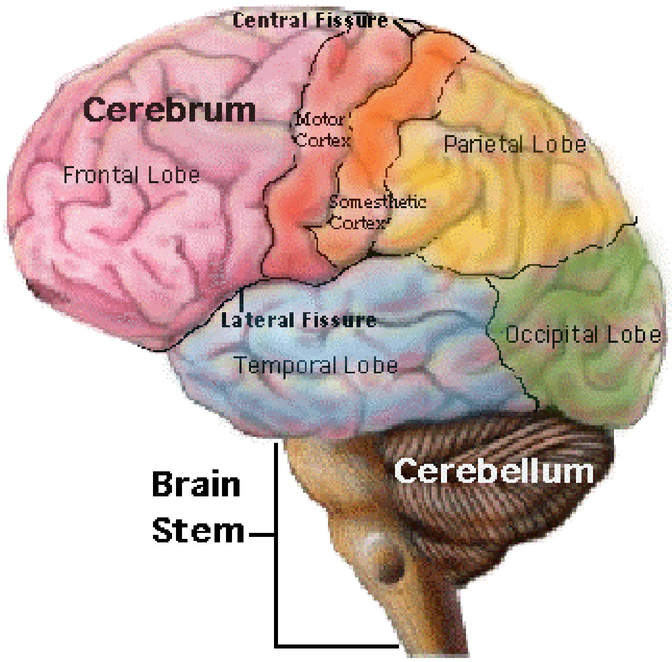
Courtesy of Ridhi Kalaria, 2010

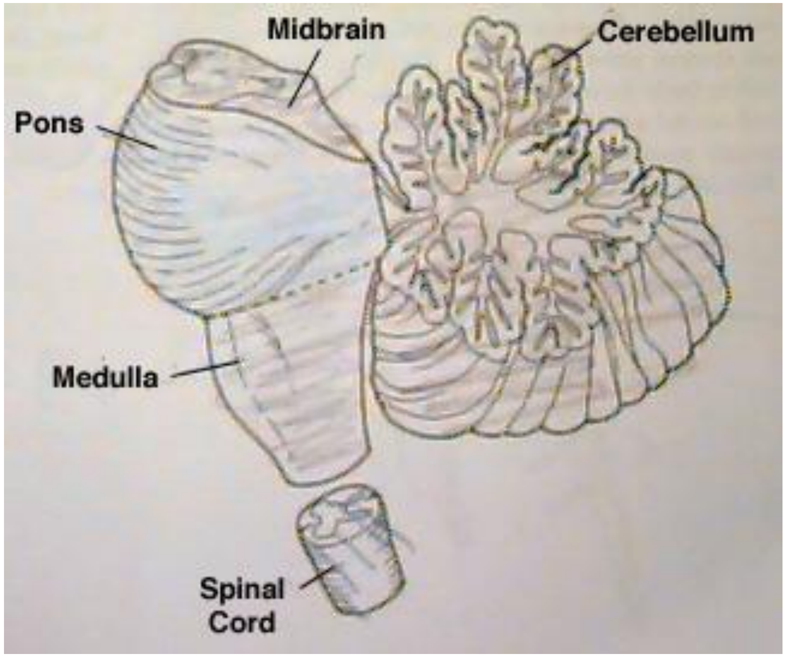
Major dopaminergic tracts of the brain



Four in total- other 2 are: The nigrostriatal system courses from the substantia nigra to the putamen and caudate. The tuberoinfundibular system originates in the arcuate nucleus of the hypothalamus and projects to the pituitary stalk.

Brain stem: links the brain to the spinal cord

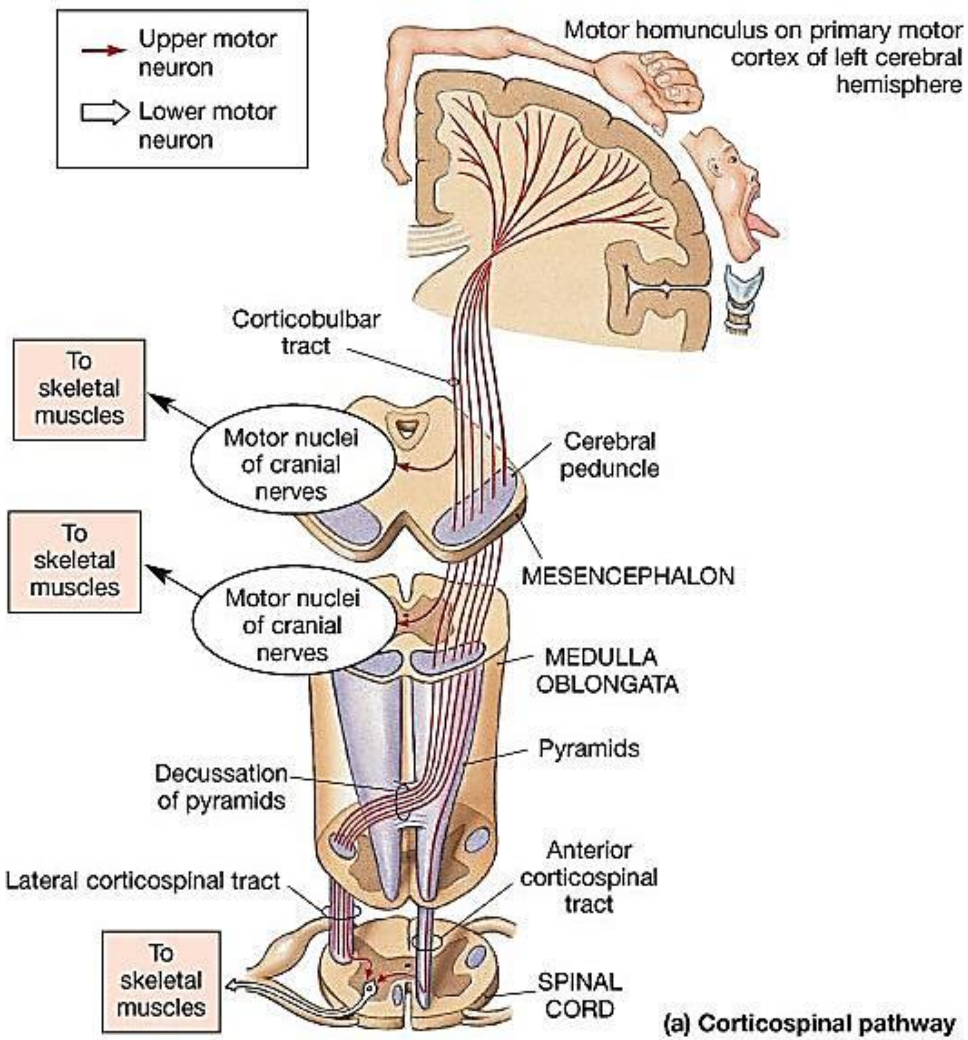




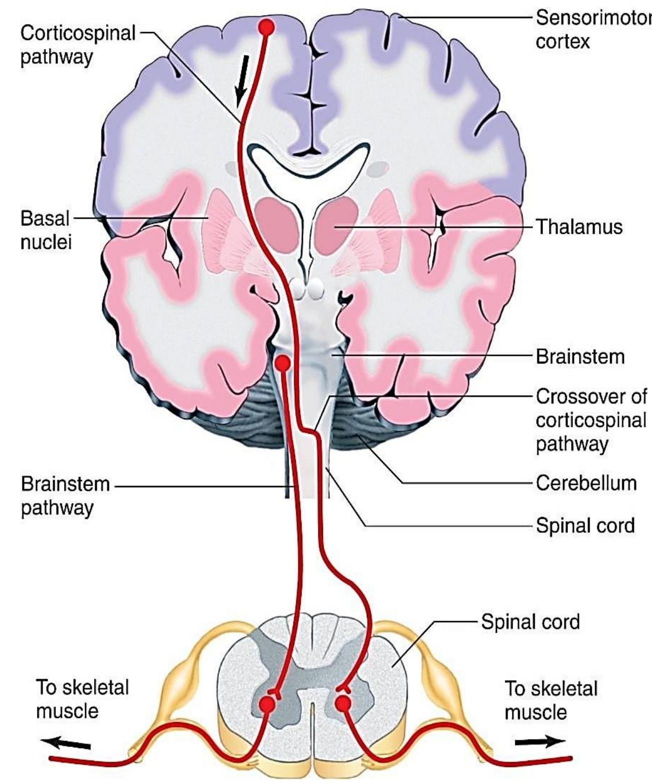
The brain stem is composed of:
The *Midbrain*: controls reflex patterns associated with vision and hearing.
The *Pons*: serves as a relay station between the cerebral cortex and the cerebellum.
The *Medulla*: controls vital functions such as respiration and heartbeat.
The *Cerebellum:* controls synchronised movements.

The **Reticular Formation:**
Composed of multiple nuclei spread throughout the medulla, pons, and midbrain. They control muscle tone via projections to the spinal cord.

Major Motor (Corticospinal) pathways

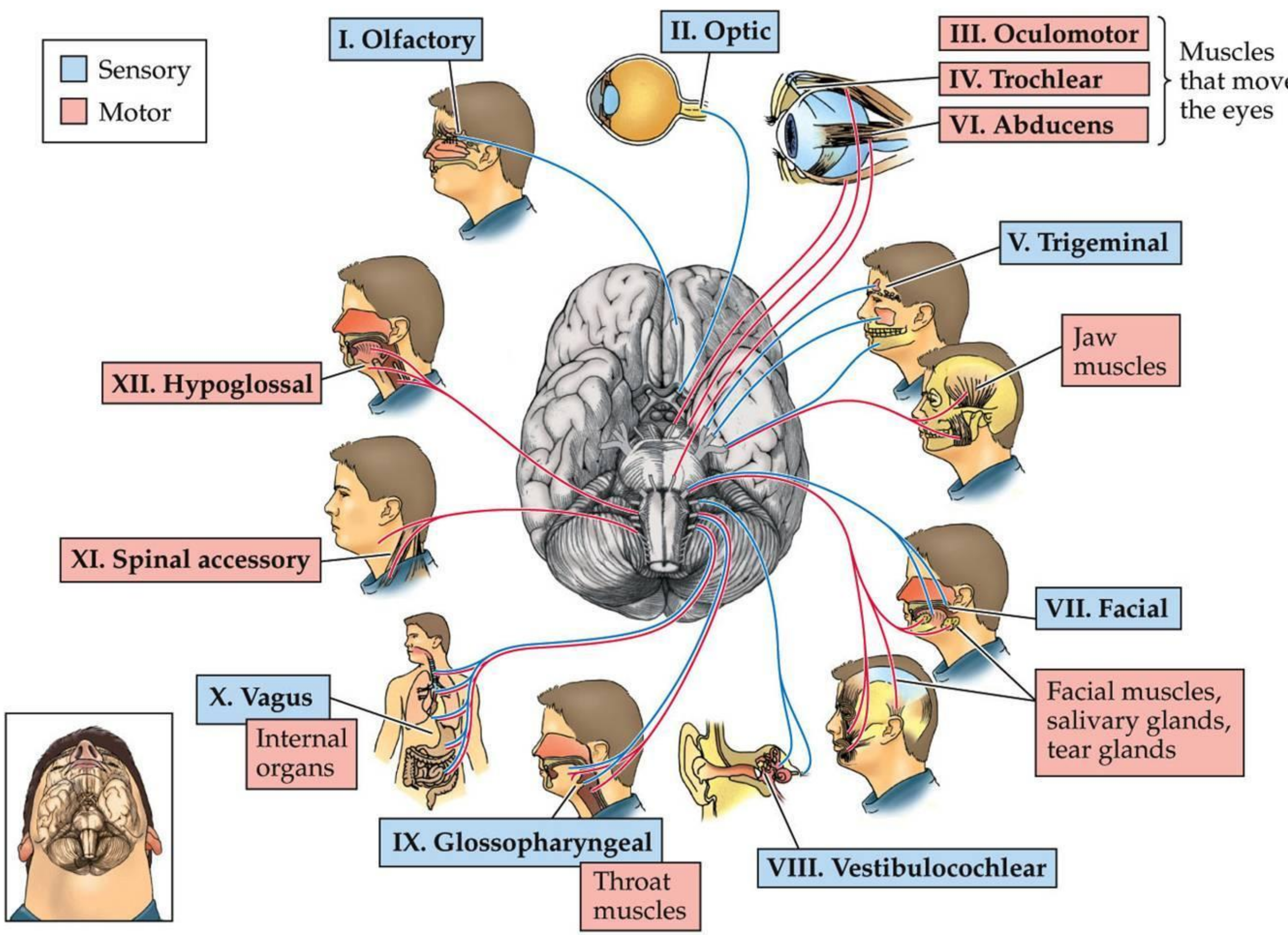


(a) Corticospinal pathway



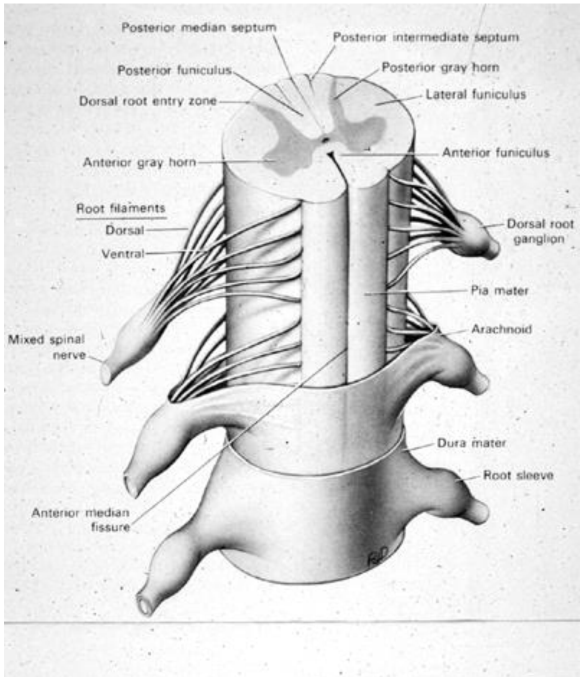
About 80% of the axons in the corticospinal tracts from primary motor cortex via internal capsule cross over in medulla. The rest (~20%) carry on same side

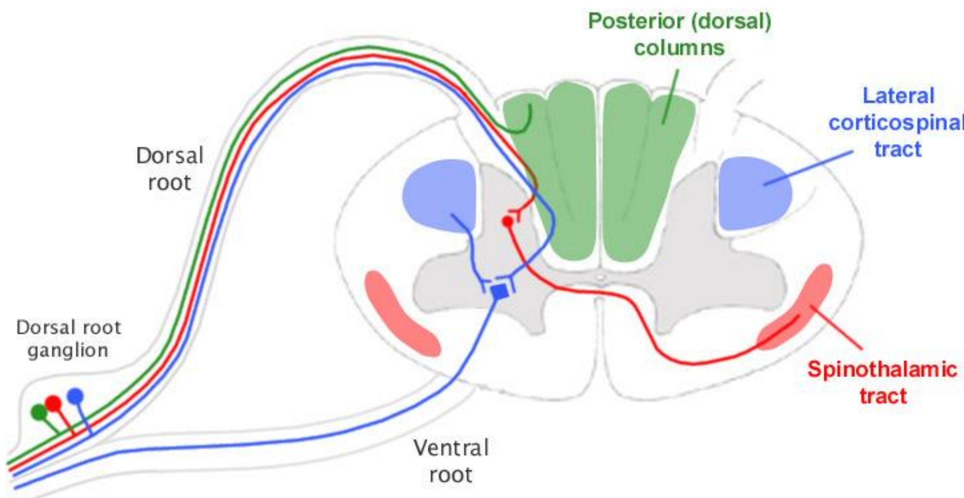
Cranial Nerves and sensory organs



OOOTroTriAFVGVSH

The spinal cord: main pathway for information connecting the brain and peripheral nervous system



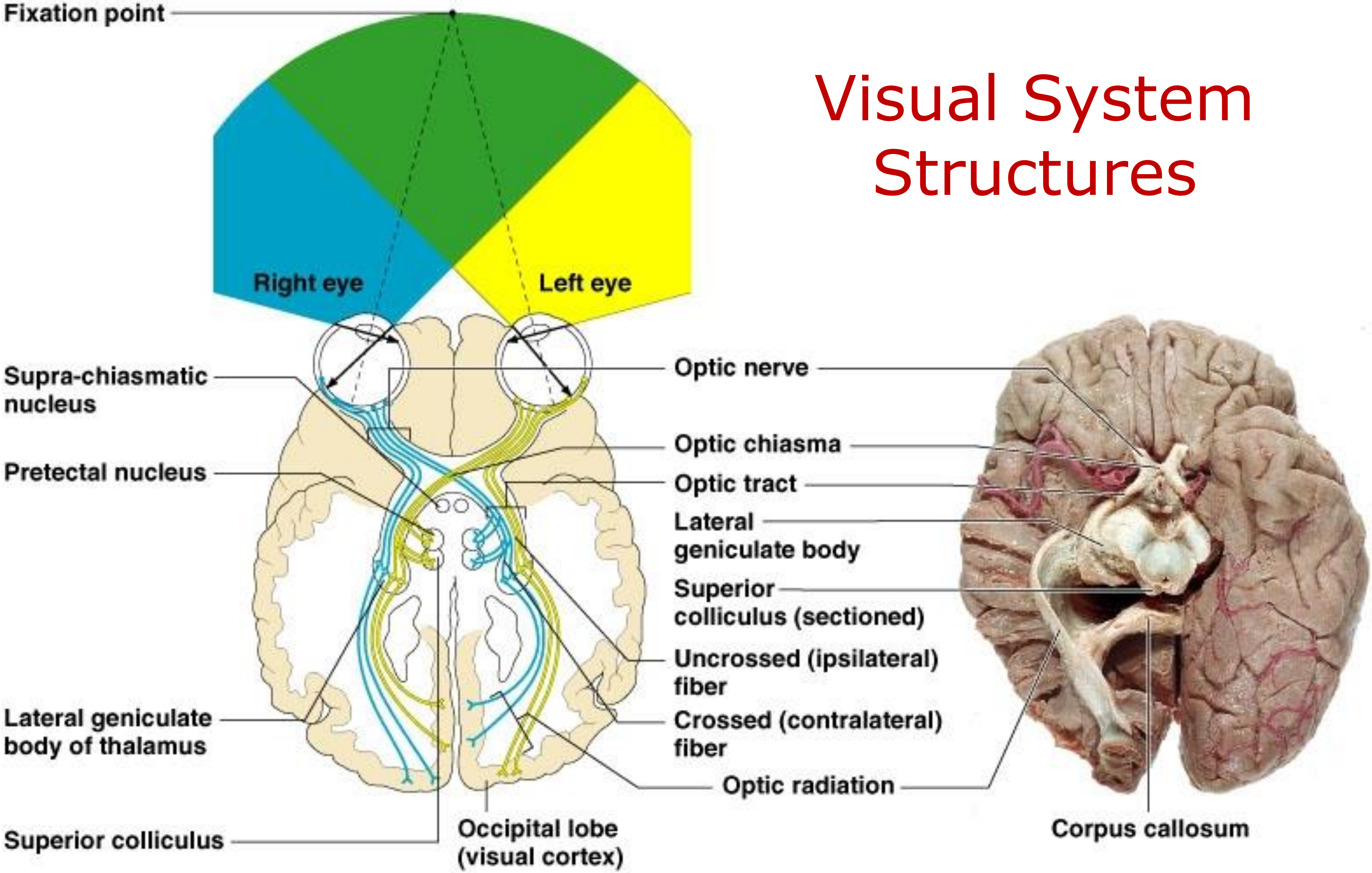


Receptors in the skin or in muscles send information to the spinal cord through spinal nerves (cell bodies located in the *dorsal root ganglion)* entering the spinal cord through the *dorsal root*.

Some fibres make synapses with other neurones in the *dorsal horn* and others in the ventral horn. Others continue up to the brain.

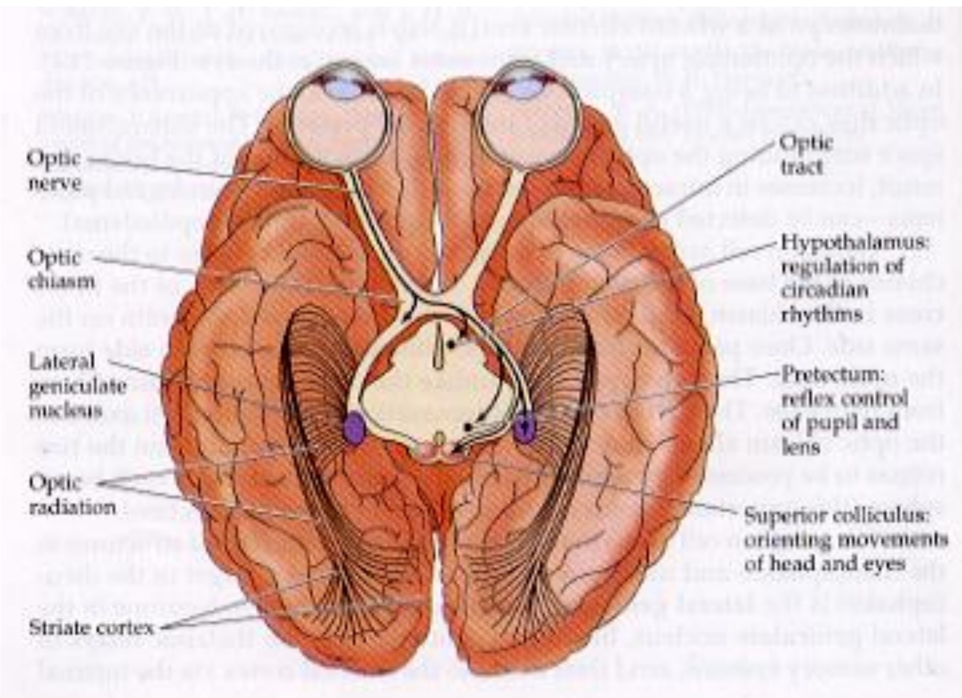
Many cell bodies (α-motoneurones) in the *ventral horn* of the spinal cord send axons through the *ventral root* to muscles to control movement.

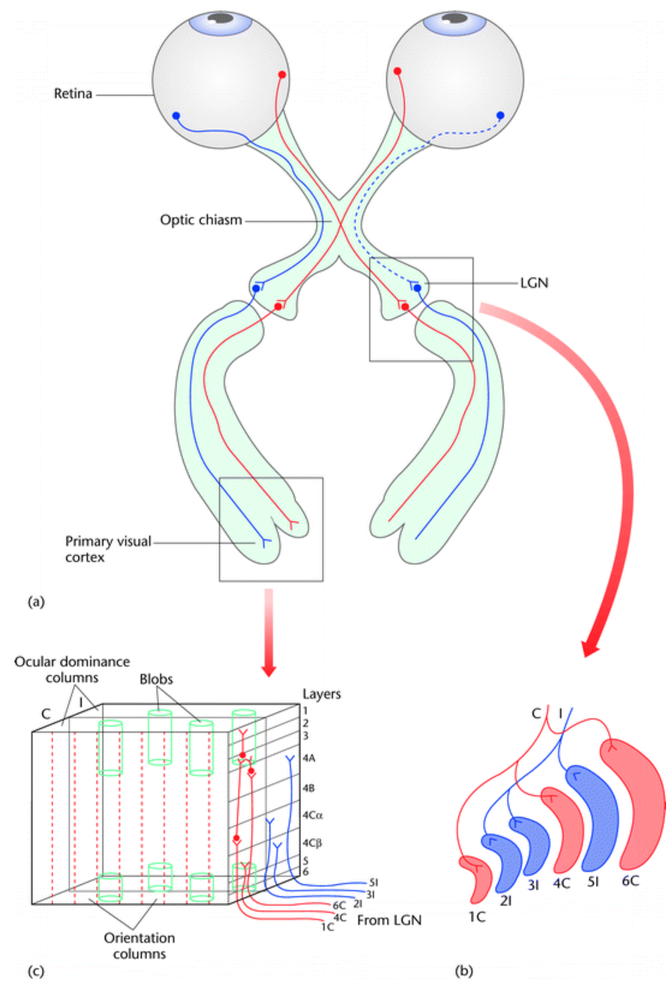
Visual System Structures



(a) (b)

Major visual pathways



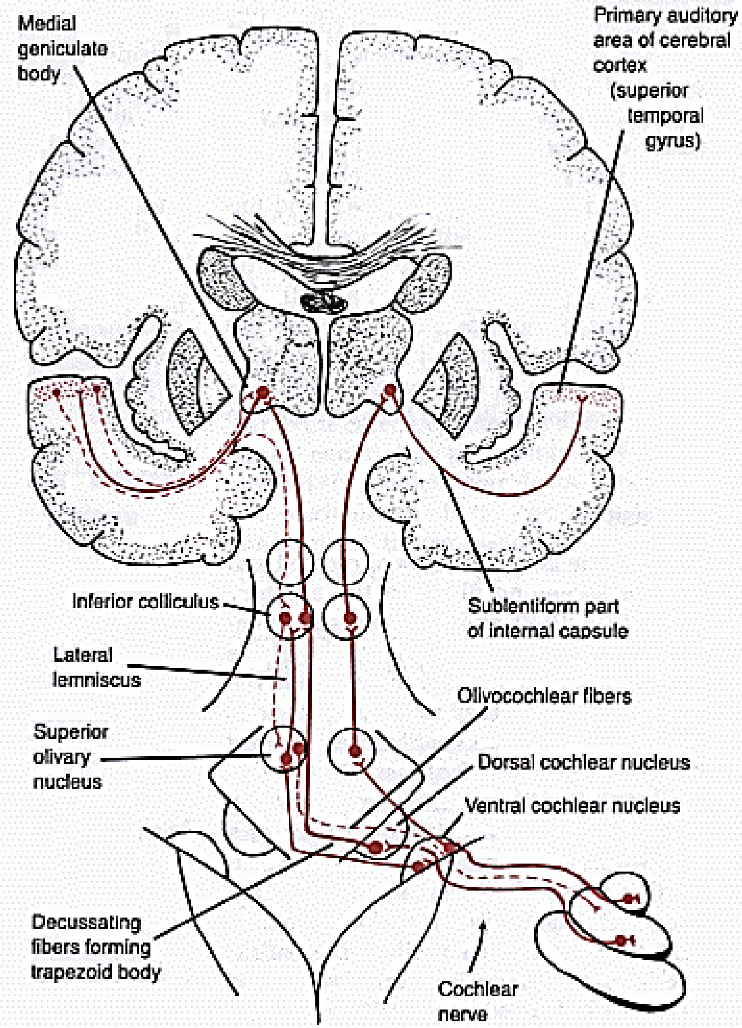


Major auditory pathways

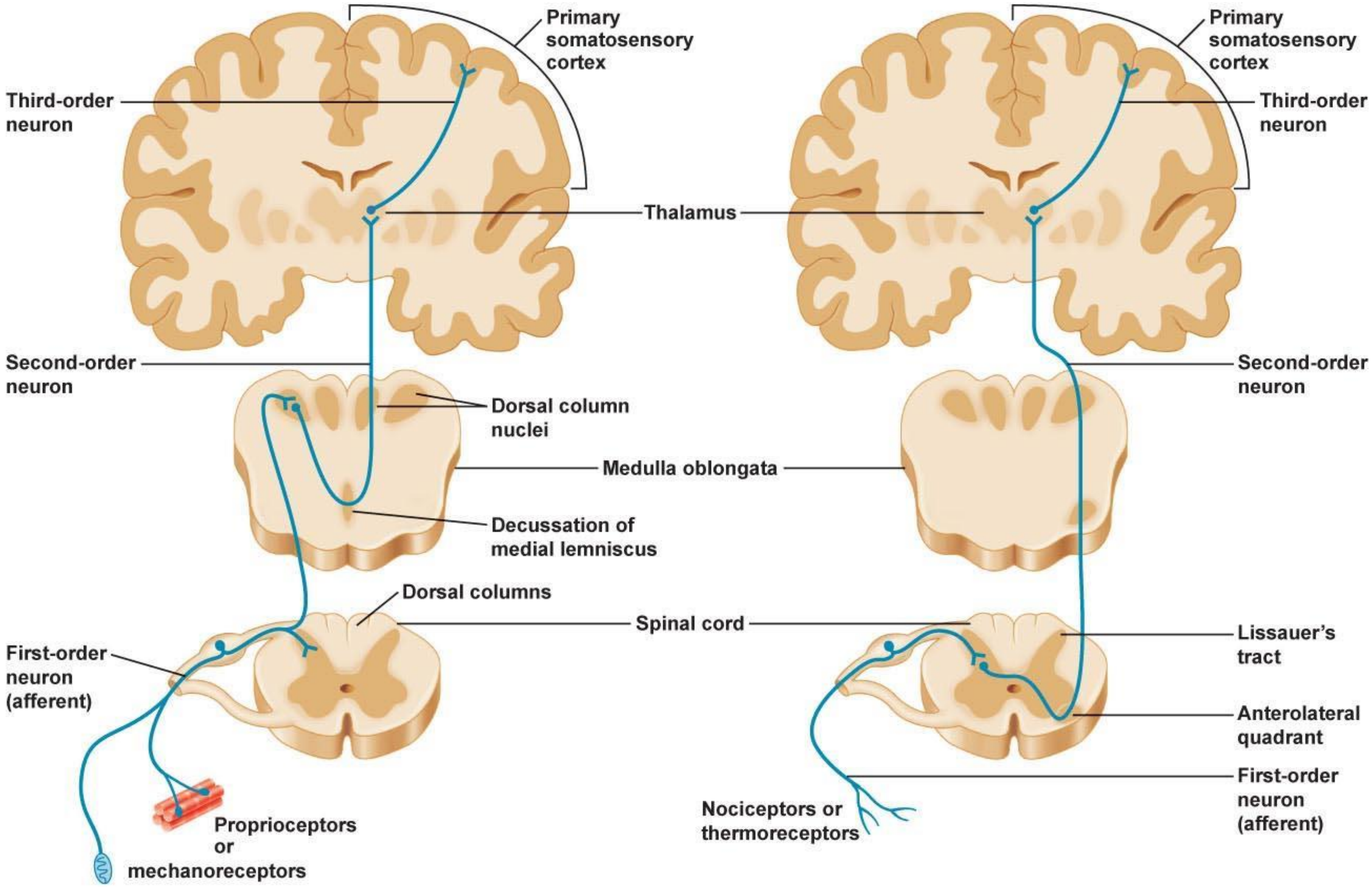
The principal central connections of hearing.

Solid coloured lines show the ascending pathways to the primary auditory cortex.

Descending connections are represented by broken lines.



Major somatosensory pathways



(a) Dorsal column–medial lemniscal pathway

(b) Spinothalamic tract **/ Anterolateral system**

light touch, vibration & proprioception
(limb position/motion sense).

Somatosensory pathways: Summary of modalities

Dorsal Column
Modalities

A Types
Fine touch
Fine pressure
Two point description
Vibration
Kinesthesia

b. Range
Discrete

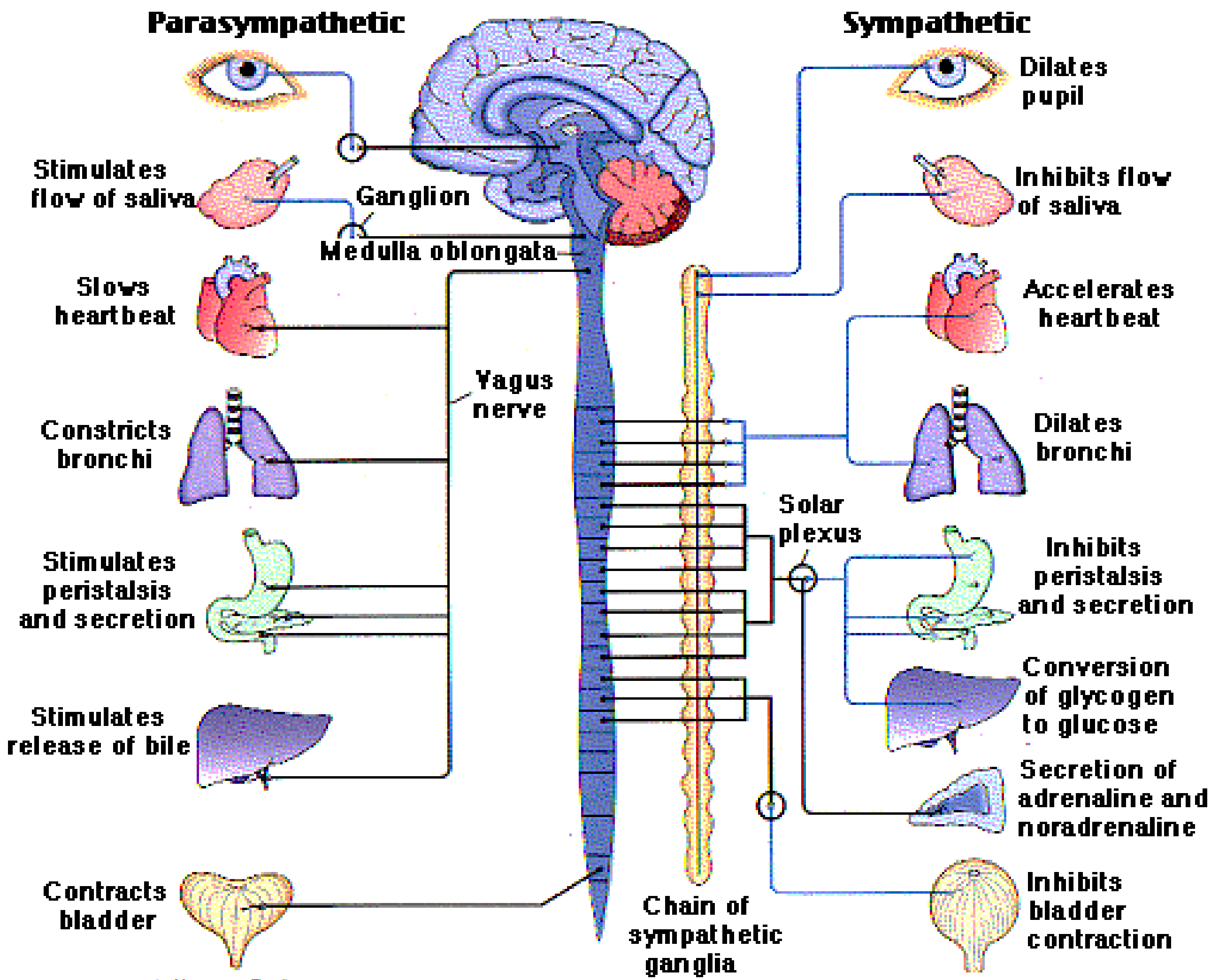
c. Gradation
Up to 100

Anterolateral system
Modalities

A Types
Crude touch
Crude pressure
Pain
Temperature
Ticket + Itch
Sexual Sensations Range
wide

c. Gradation
10-20

Autonomic Function Targets



Learning Objectives

Summary

- General structure of the brain
- Functional areas of the brain and specificity
- Motor and sensory perception pathways
- The limbic system and function
- The basal ganglia and dopamine tracts
- Brain stem components
- Building blocks of the Brain: Neurons , glial cells and cerebral vessels: Neurovascular unit

Acknowledgements

Campus for
Ageing & Vitality

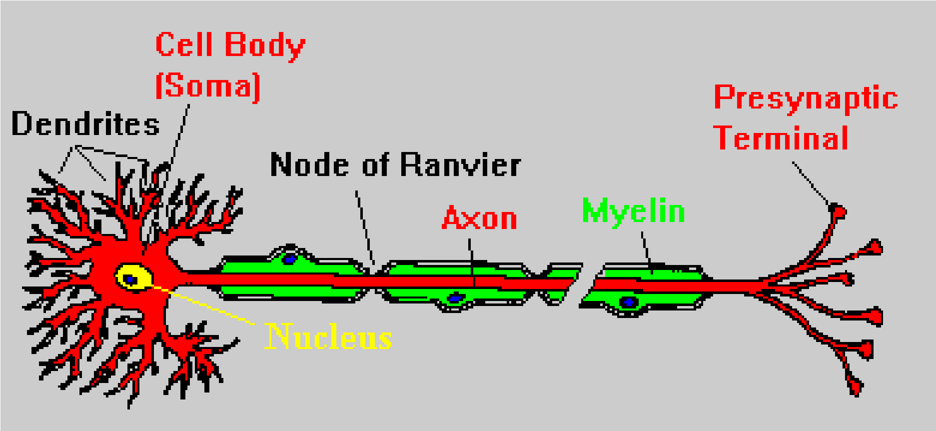
INSTITUTE FOR AGEING AND HEALTH

Neurones are the building blocks of the brain

What distinguishes neurones from other cells?

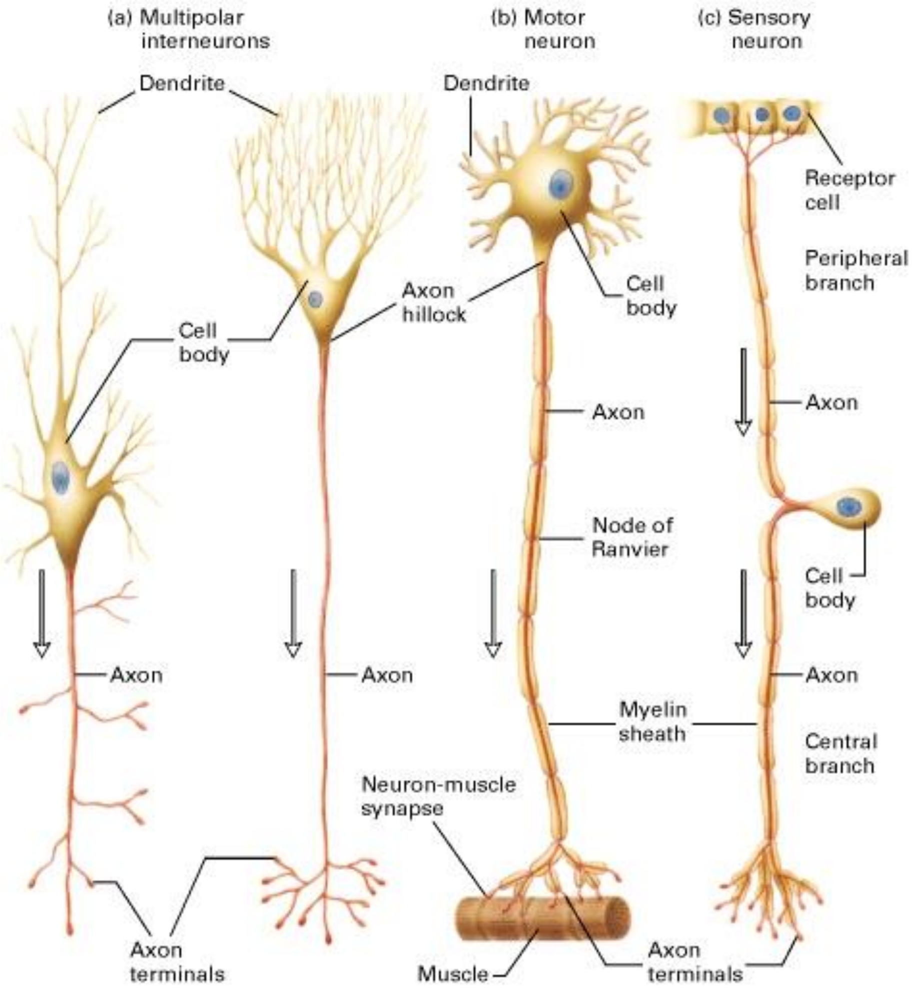
- They have special properties allowing them to **receive**, **process** and **transmit** information to other cells.

- These specialised functions are reflected in the overall shape and in the subcellular architecture of neurones.



The dendrites receive and process information.
The soma (cell body) processes information. It is responsible for metabolic maintenance of the cell.
The axon transmits information to other cells.

Different types of neurones



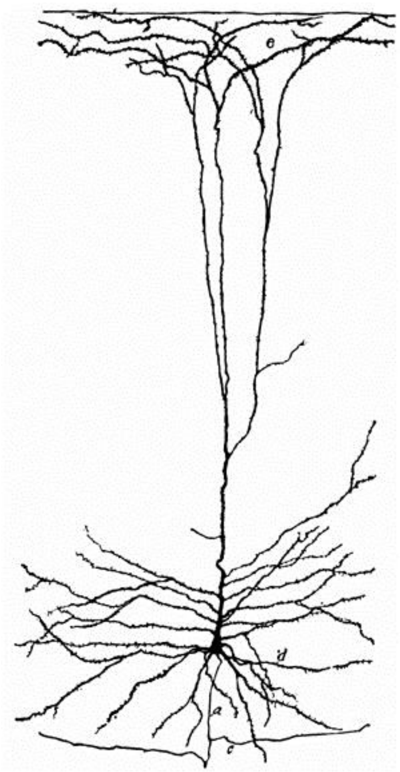
Multipolar neurones
Interneurones form all the neural wiring within the CNS.

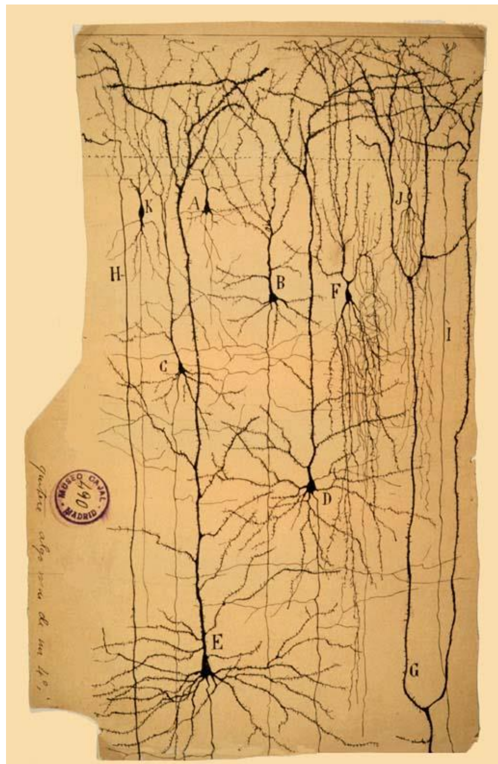
Motoneurones carry signals from the CNS to muscles and glands (efferent neurones).

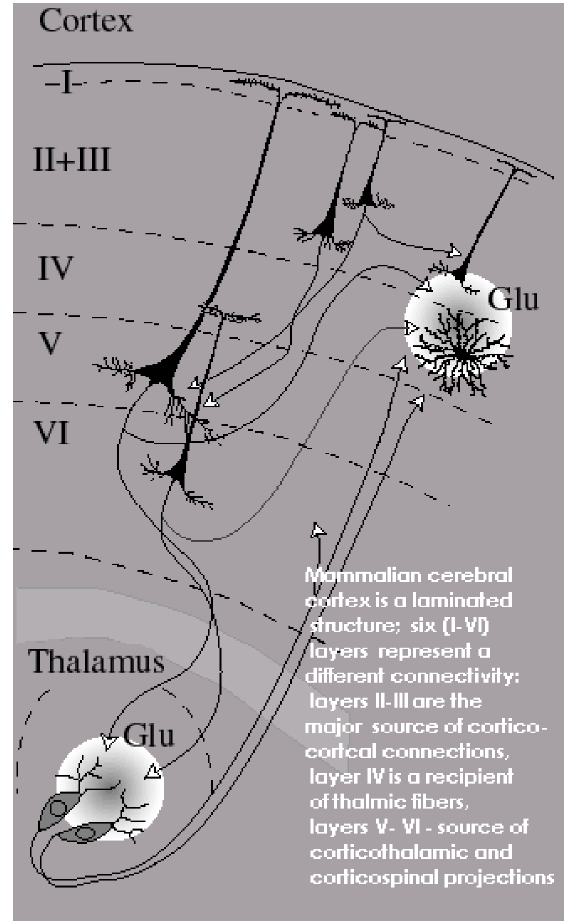
Multipolar neurones have many processes originating from the cell body (e.g. spinal motor neurones, pyramidal neurones, Purkinje cells.)

Sensory neurones or bipolar neurones
-Carry messages from the body's sense receptors (eyes, ears, etc.) to the CNS (afferent neurones).
-Account for 0.9% of all neurones.
-They have two axons (instead of an axon and a dendrite). One axon communicates with the sense organ; the other axon communicates with the CNS (e.g. dorsal root ganglion cells in the spinal cord).

Another example of how dendritic layout helps functional organisation: the cortical pyramidal cell





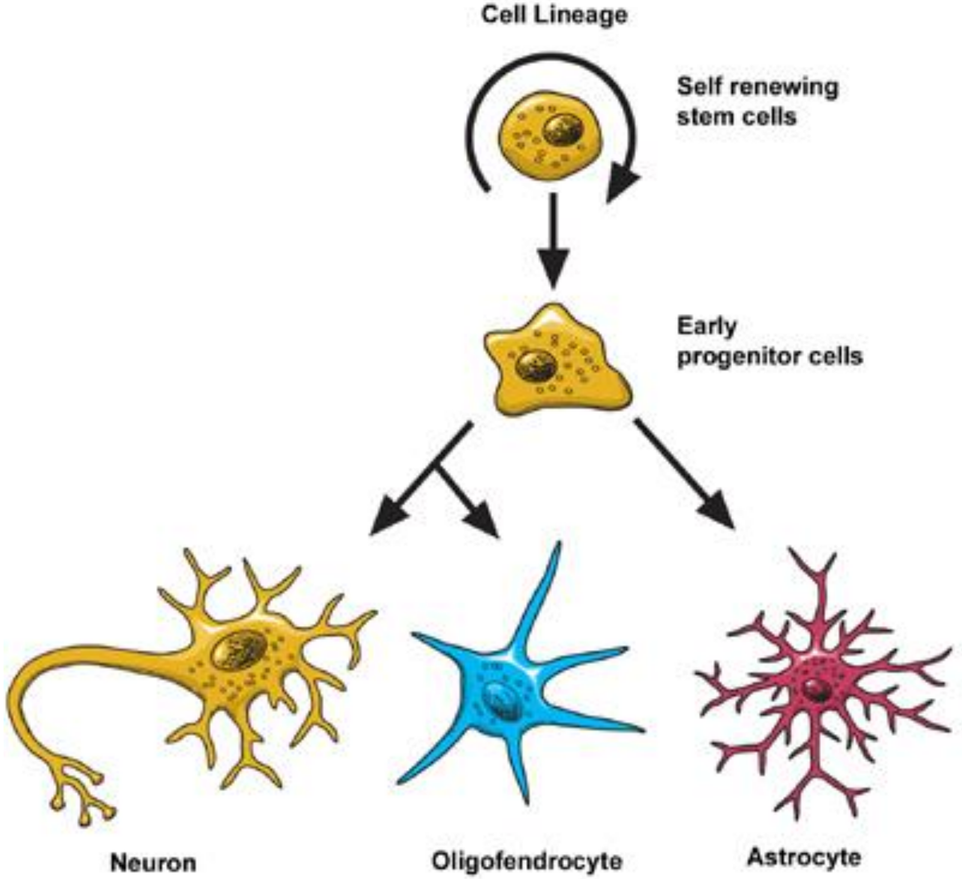


The cerebral cortex is organised in LAYERS.
Pyramidal cells, with their layered dendritic tree, can receive and process information within these different layers.

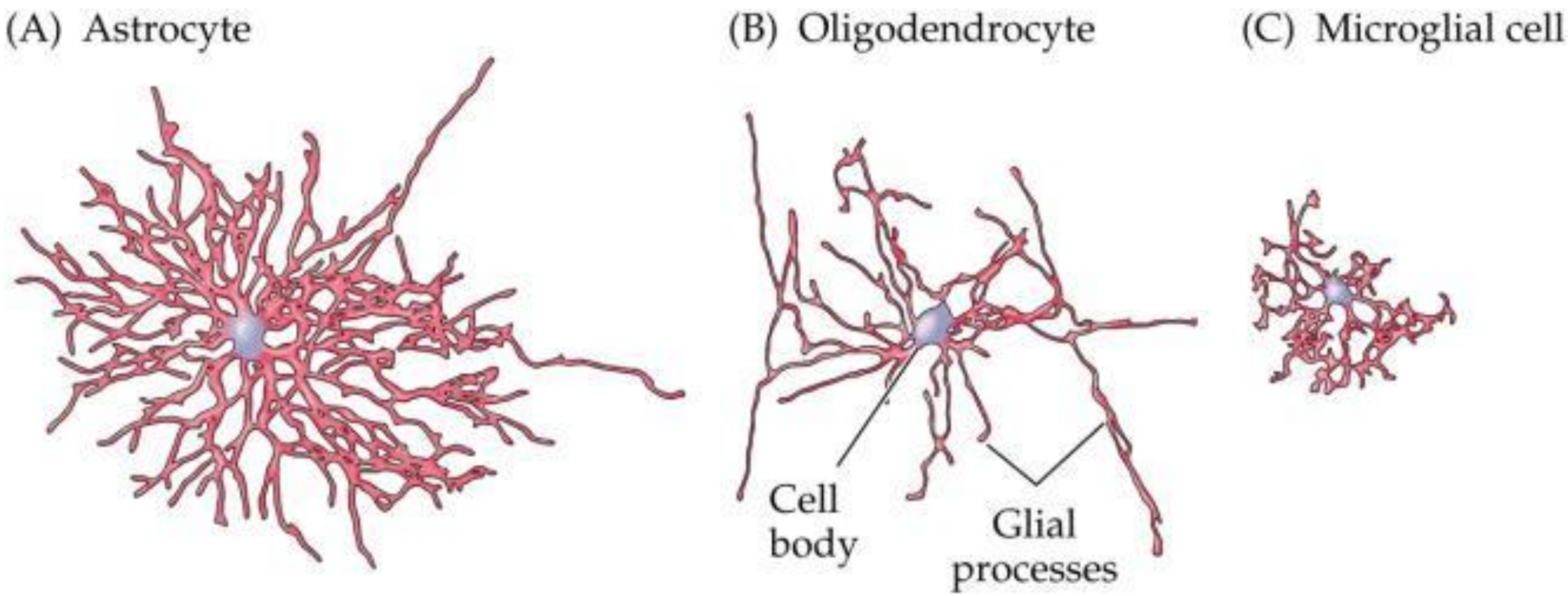
Glial cells

-Glia (meaning “glue”) make up 90% of the brain cells.
-Glia are nerve cells that do not carry nerve impulses.
-They perform many important functions, including digestion of parts of dead neurones, manufacturing myelin for neurones, providing physical and nutritional support for neurones, and more.

Glial cells and neurones originate from the same progenitors



Different types of glial cells



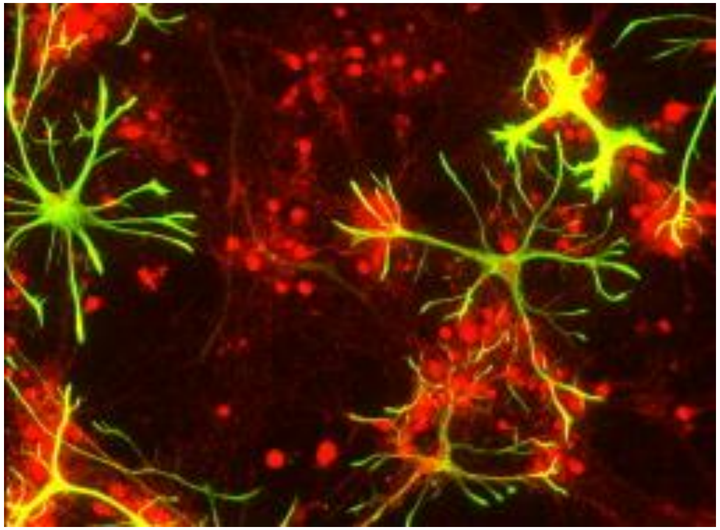
1. *Astrocytes*: help to regulate extracellular ionic concentrations.

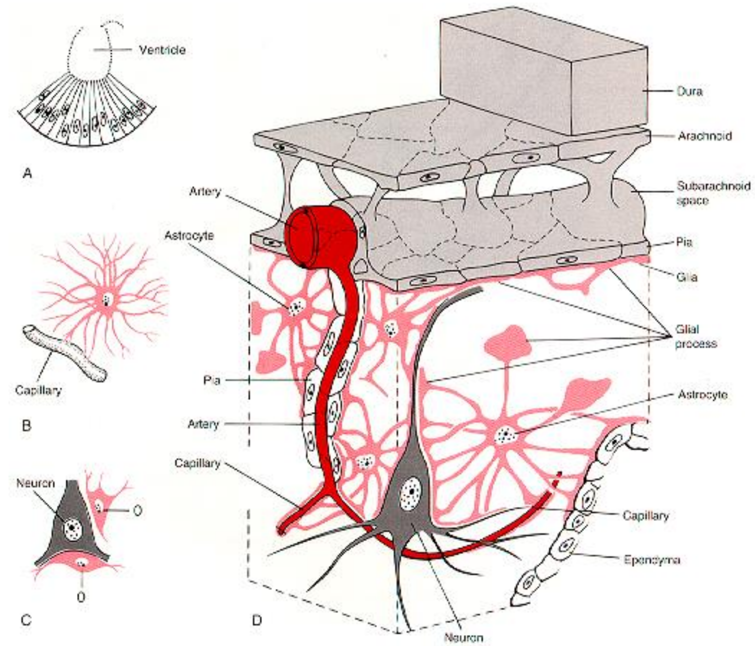
2. *Oligodendrocytes*: form myelin around axons for electrical insulation in the CNS.

3. *Microglia*: serve as "garbage collectors" to clean up dead tissue.

4. *Schwann cells*: form myelin in the PNS.

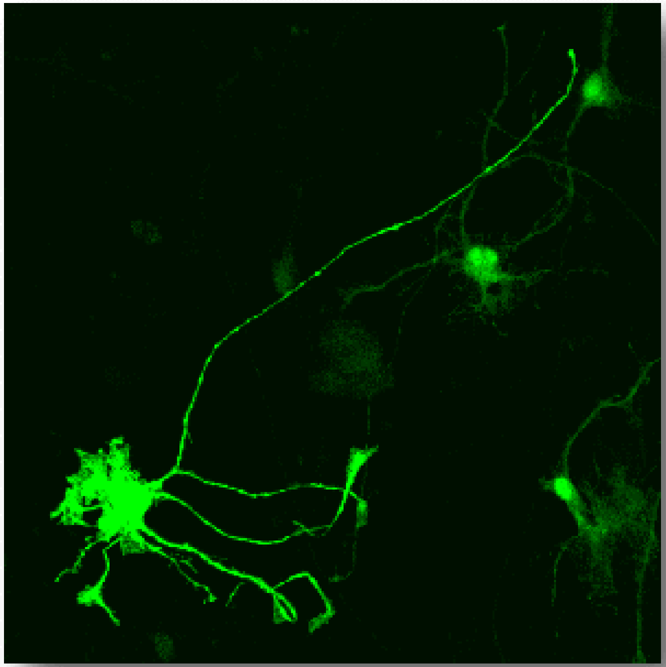
Astrocytes





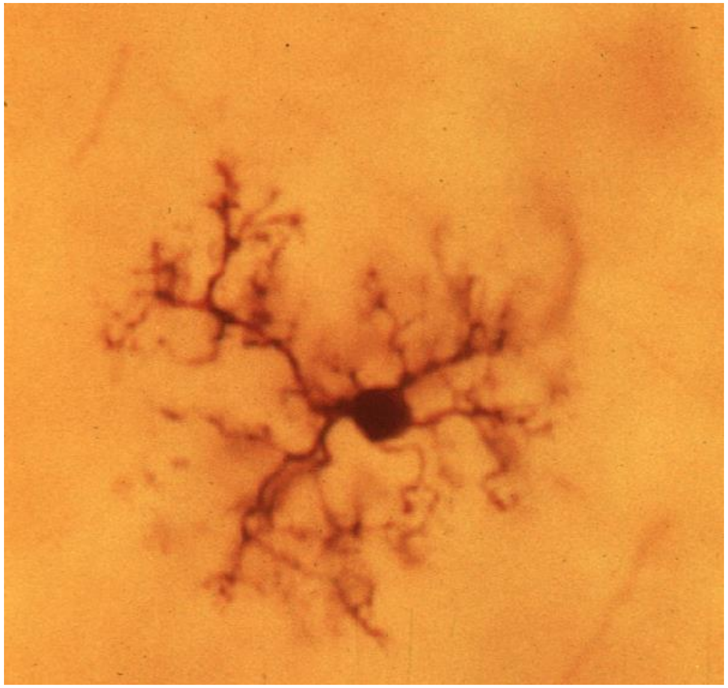
- Astrocytes are star-shaped cells.
- Their processes are often in contact with a blood vessel (*perivascular foot processes*).
- Astrocytes provide physical and metabolic support to the neurones of the CNS.
- They participate in the maintenance of the composition of the extracellular fluid.
- Astrocytes are also the scar-forming cells of the CNS.

Oligodendrocytes



- Olygodendrocytes have fewer and shorter processes.
- They form myelin sheaths around axons in the CNS and are the functional homologue of peripheral ***Schwann cells***.
- Oligodendrocytes may, in contrast to Schwann cells in the periphery, form parts of the myelin sheath around *several* axons.

Microglia



- Microglia are small cells with complex shapes.
- In contrast to neurones, astrocytes and oligodendrocytes, microglia are of of mesodermal origin, the same cell line which gives rise to macrophages.
- Therefore, microglia are phagocytic cells, cleaning cellular debris in case of tissue damage.

Despite having the same basic subcellular structure, different types of neurones exhibit huge differences (even within the same area of the nervous system)