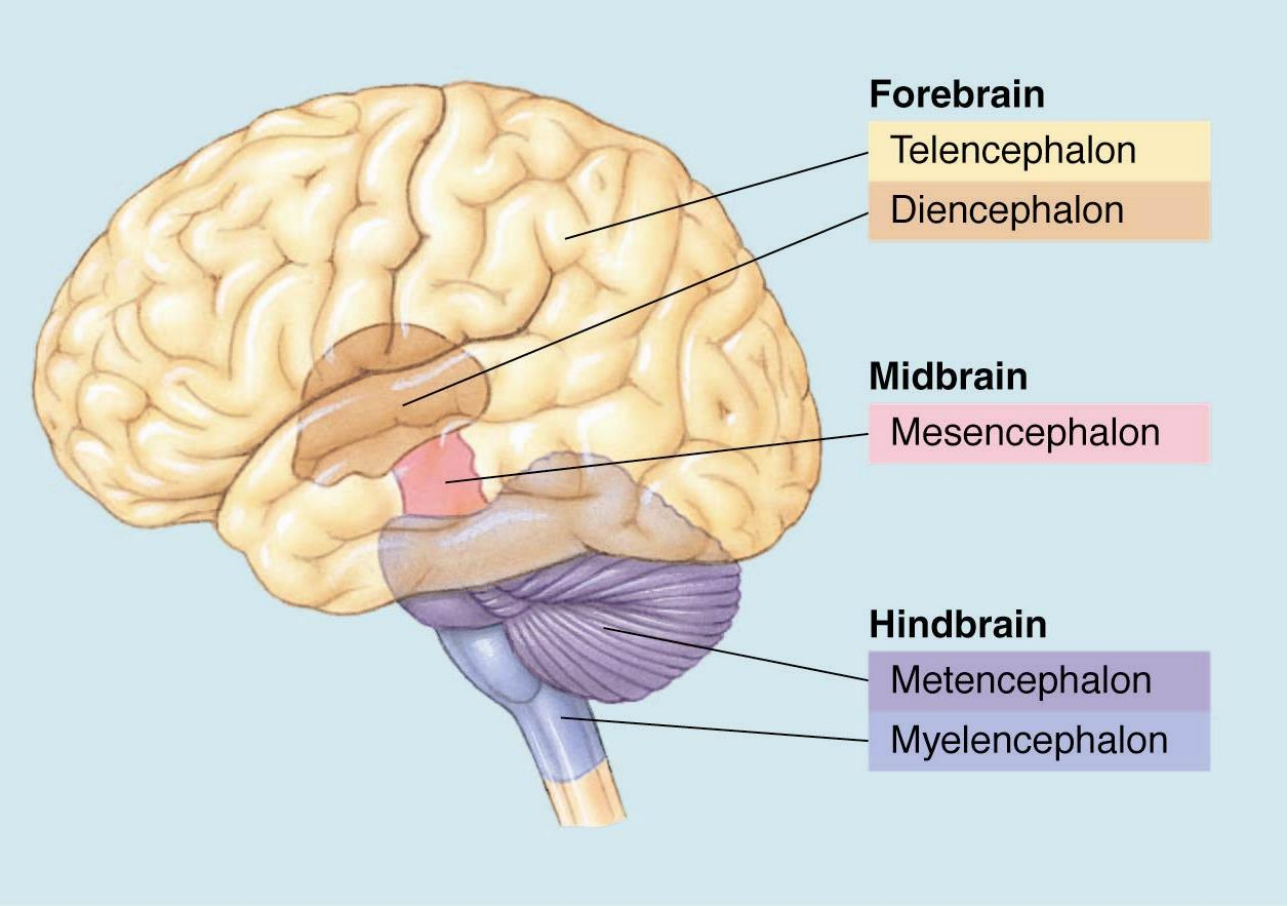
WEEK 2

BRAIN ANATOMY

Learning objectives

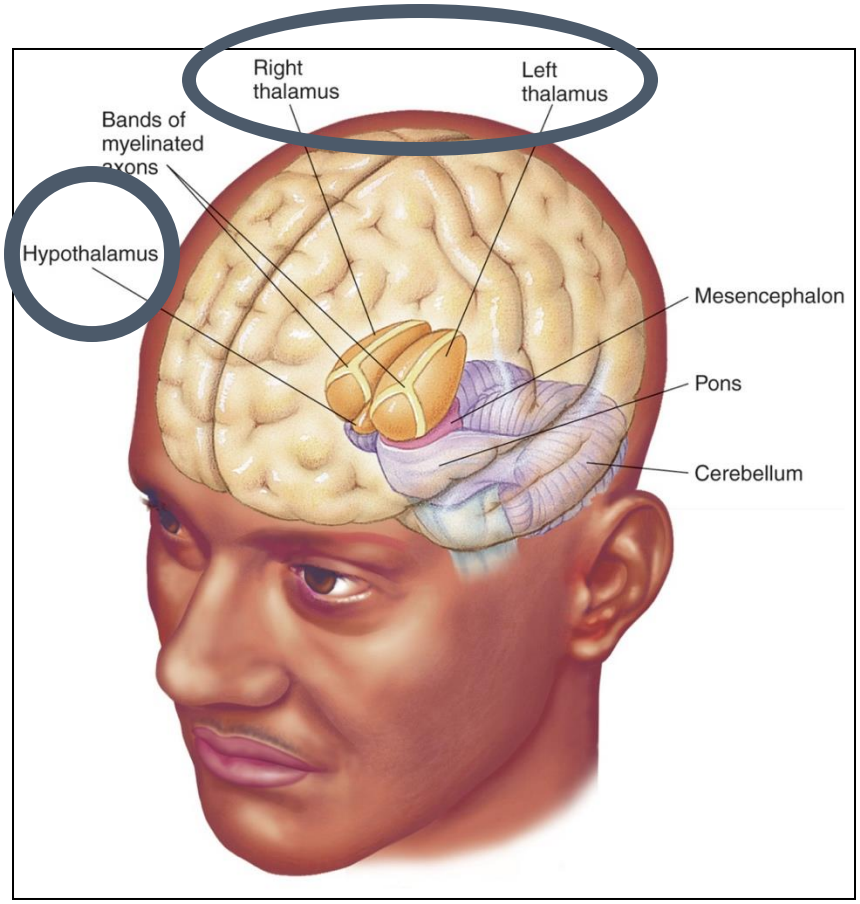
- Know the major subdivision of the brain
- Know about brain areas implicated in learning
- Know about brain areas implicated in movement control
- Know about the brain’s protection mechanisms

The 5 Major Division of the Brain



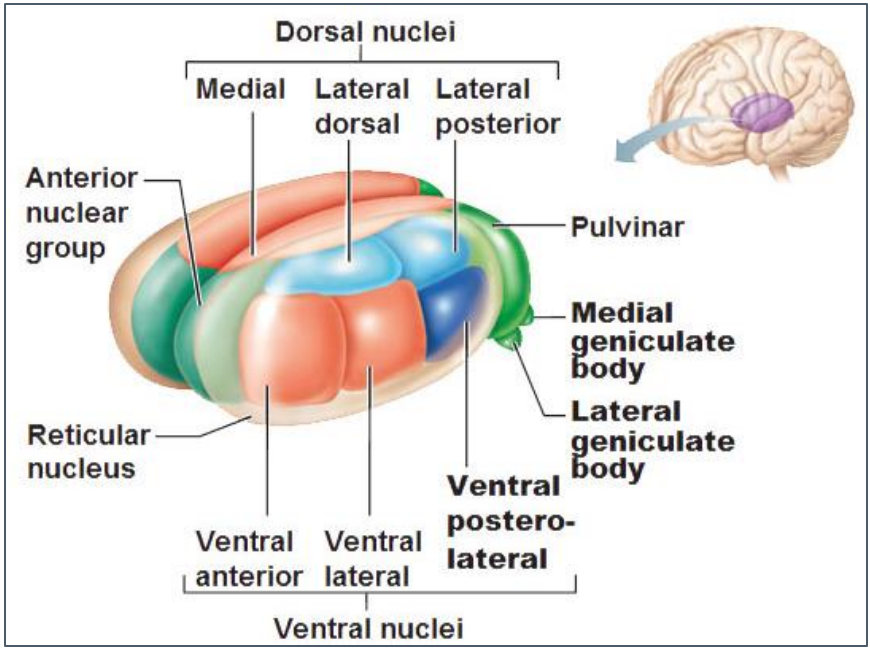
4) Diencephalon

- **Thalamus**
  - Contains several sensory relay nuclei
- **Hypothalamus**
  - located below (“hypo“) thalamus



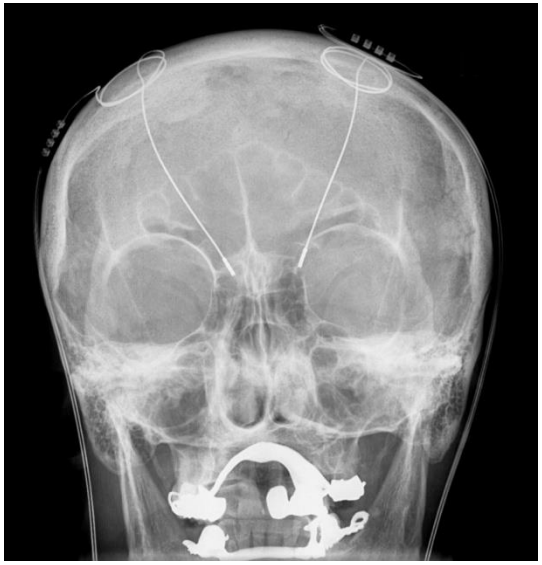
4) Diencephalon c'd

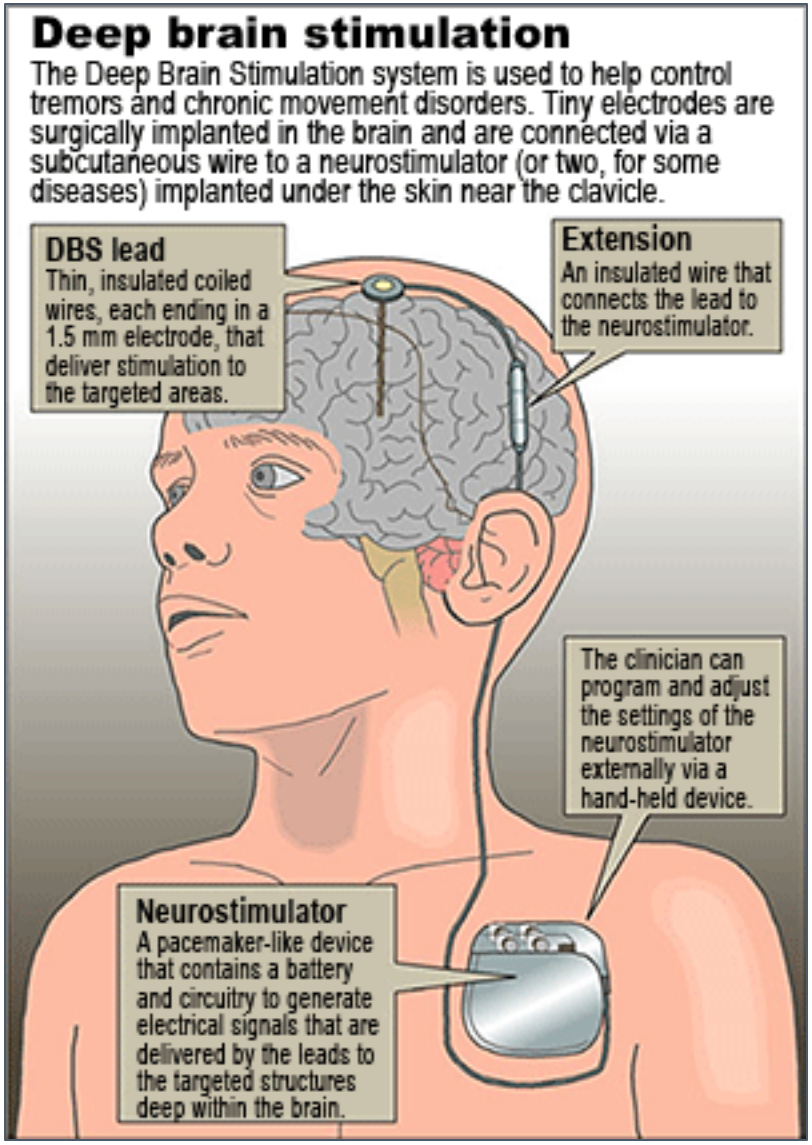
- **Thalamus**
  - Two lobes at the anterior portion of the brain stem surrounding the third ventricle
  - Major Sensory Relay Nuclei
    - Vision: Lateral Geniculate Nucleus
    - Hearing: Medial Geniculate Nucleus
    - Touch: Ventral Posterior Nucleus
    - Smell: Medial Dorsal Nucleus
    - Taste: Ventral Posterior Nucleus
  - Spinothalamic tract



4) Diencephalon c'd

- **Thalamus**
  - Target area for deep-brain stimulation (DBS) against **essential tremor**





- Deep brain stimulation (DBS)
  - Currently over 120’000 patients implanted worldwide
    - Essential tremor*
    - Parkinson’s disease*
    - Dystonia*
    - OCD*
    - Epilepsy*

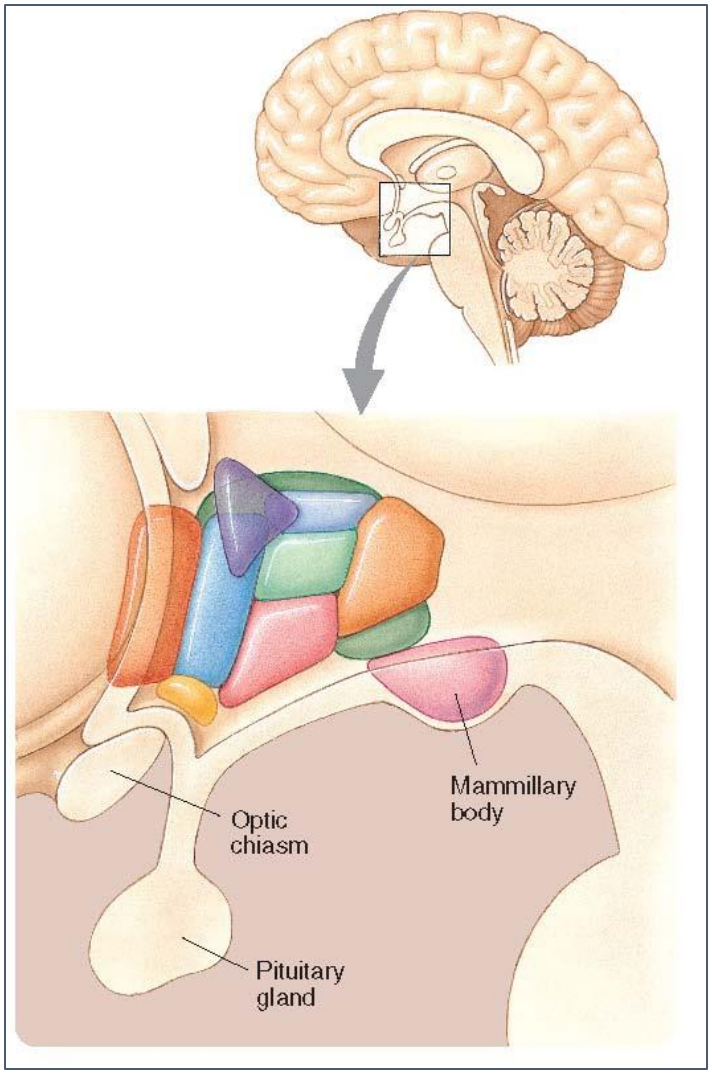
    FDA approved

    - *Depression*
    - *Addiction*
    - *Anorexia*

    Clinical trials

4) Diencephalon c'd

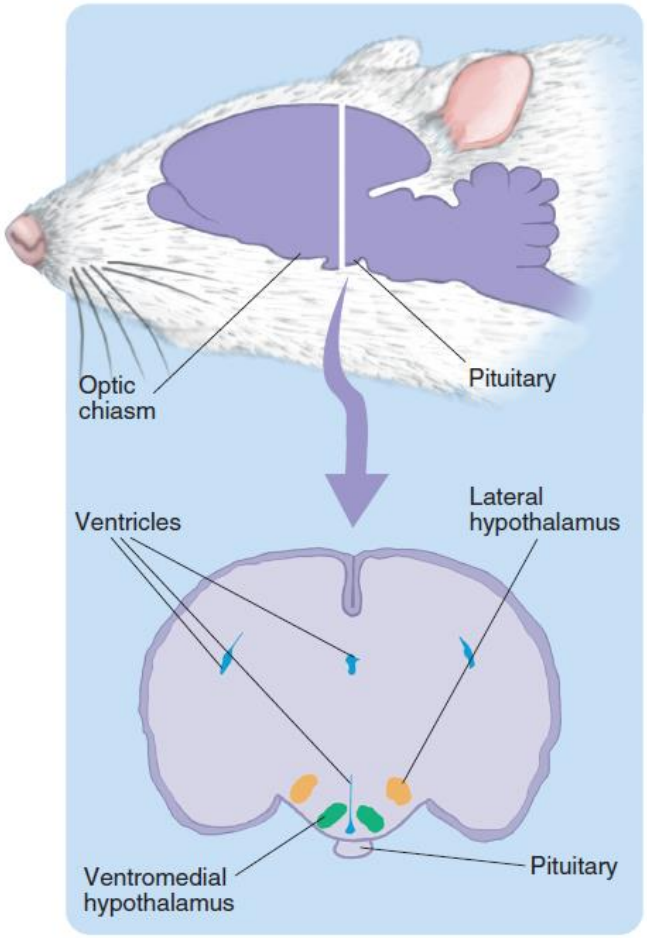
- **Hypothalamus**
  - Contains several subdivisions (nuclei) and interconnected with limbic system regions
  - Detection of "need" states
    - hormone regulation
    - body temperature regulation
    - fluid & nutrient regulation

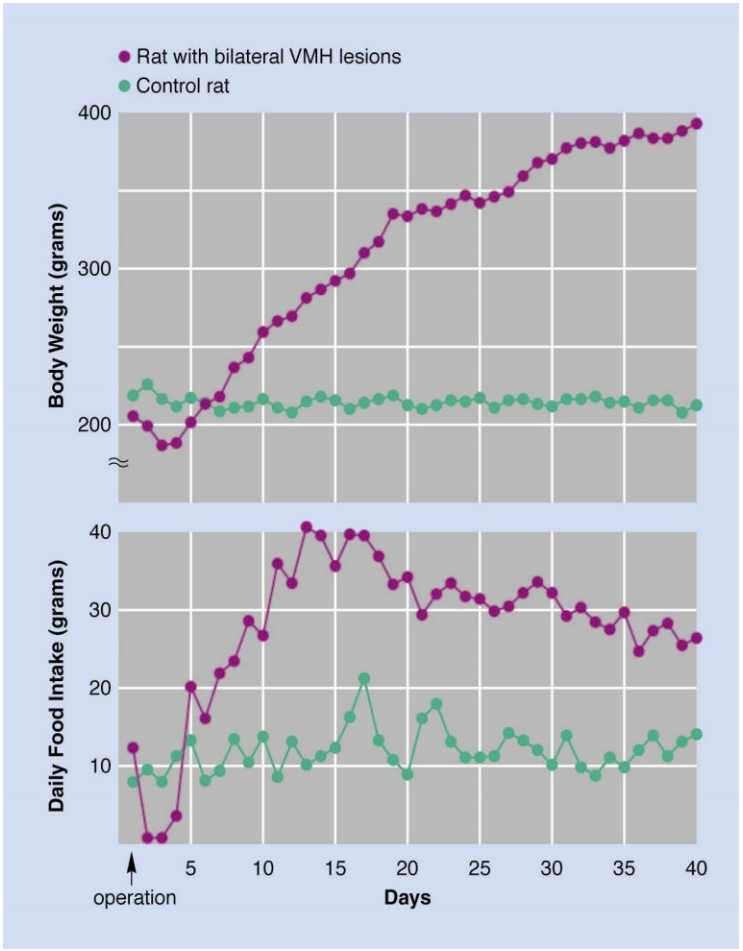


- Hypothalamic nuclei:

Nucleus	Zone(s)	Region(s)	Functions
Paraventricular	Periventricular, Medial	Anterior,Tuberal	Fluid balance, milk let-down, parturition, autonomic & anterior pituitary control
Preoptic	Medial, Lateral	Anterior	Lateral anterior thermoregulation, sexual behavior
Anterior	Medial	Anterior	Lateral anterior thermoregulation, sexual behavior
Suprachiasmatic	Medial	Anterior	Biological rhythms
Supraoptic	Medial, Lateral	Anterior	Fluid balance, milk let-down, parturition
Dorsomedial	Medial	Tuberal	Emotion (rage)
Ventromedial	Medial	Tuberal	Appetite, body weight, insulin regulation
Arcuate	Periventricular, Medial	Tuberal	Control of anterior pituitary, feeding
Posterior	Medial	Posterior	Thermoregulation
Mammillary	Medial	Posterior	Emotion and short-term memory
Lateral Complex	Lateral	Tuberal	Appetite and body weight control

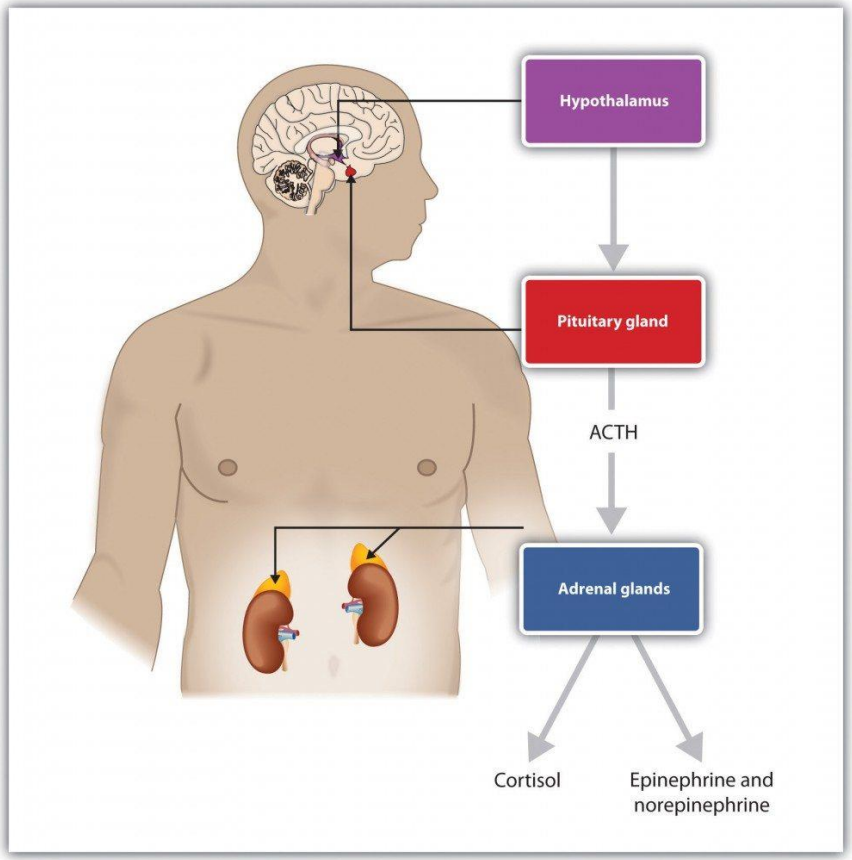
Bilateral ventromedial hypothalamic lesions -> abnormal feeding behavior





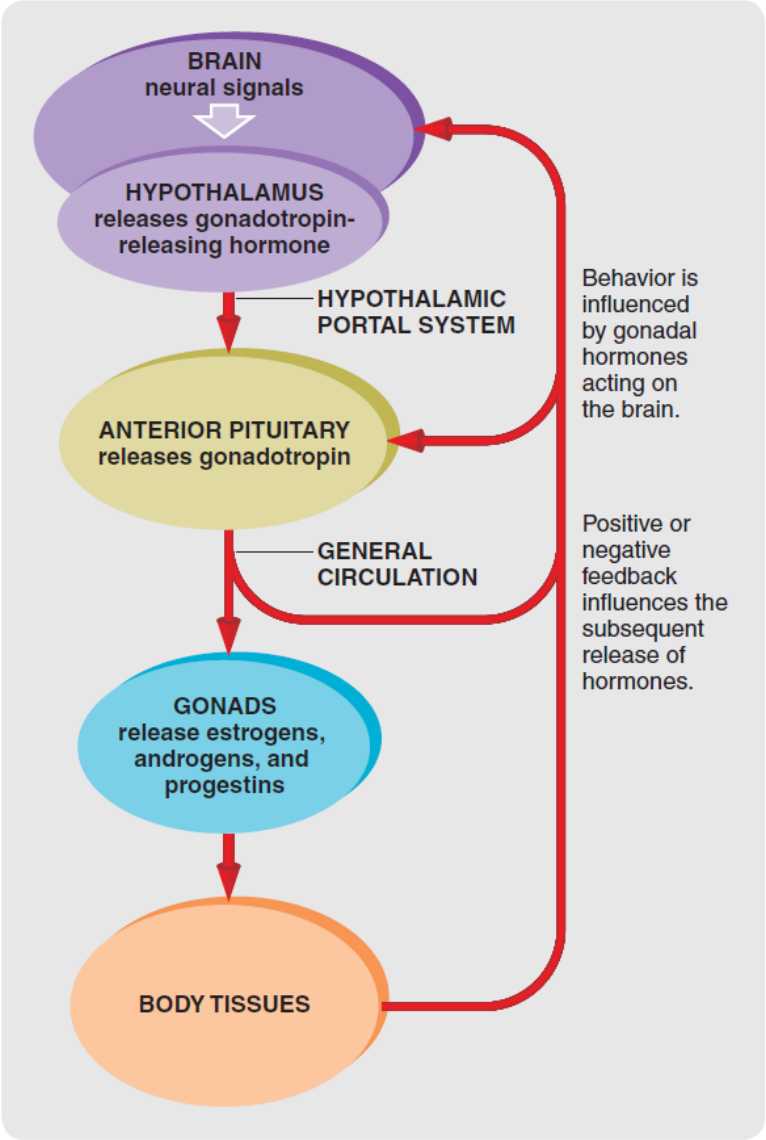
4) Diencephalon c'd

- **Hypothalamus**
  - Part of the **HPA axis**
    - Hypothalamus
    - Pituitary
    - Adrenal glands



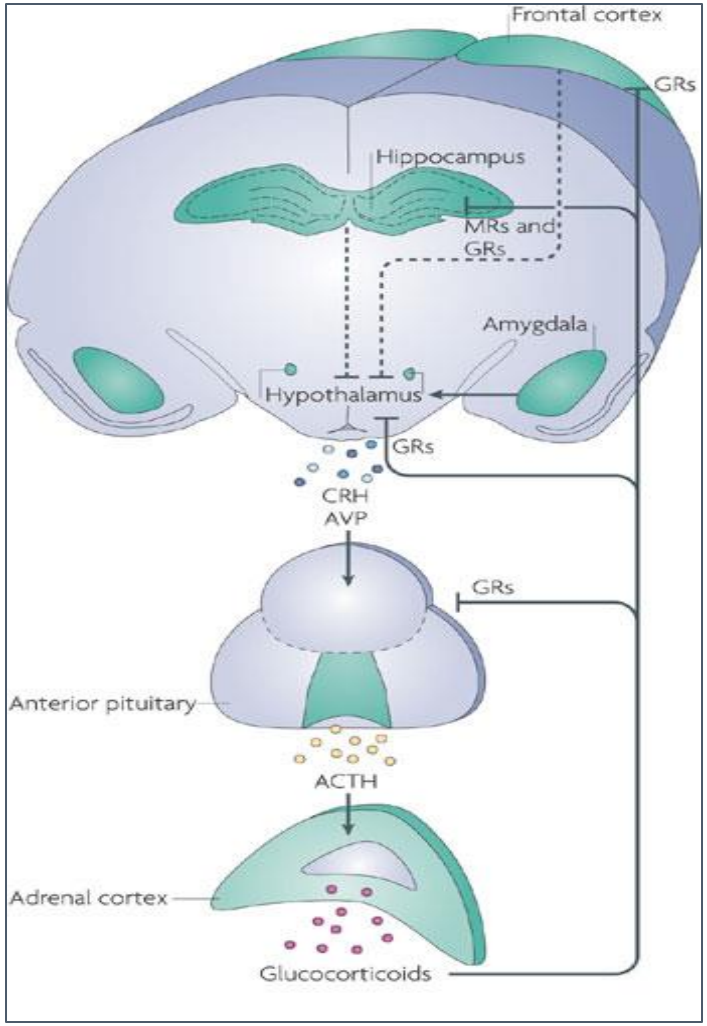
4) Diencephalon c'd

- **Hypothalamus**
  - Part of the **HPA axis**
    - Hypothalamus
    - Pituitary
    - Adrenal glands
  - Involved in reproductive functions and behavior
    - Secretion of gonadal hormones
      - Estrogens, androgens, progestins



4) Diencephalon c'd

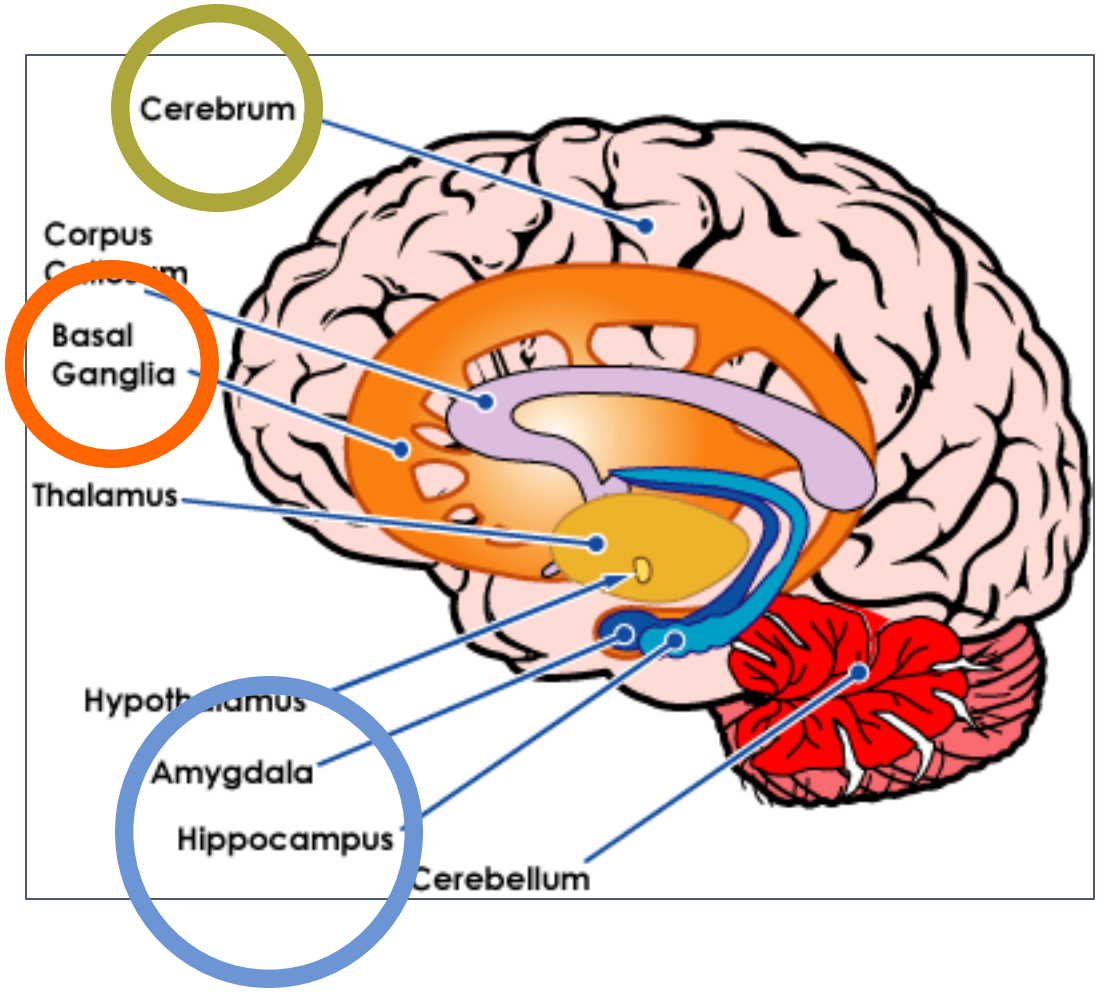
- **Hypothalamus**
  - Part of the **HPA axis**
    - Hypothalamus
    - Pituitary
    - Adrenal glands
  - Involved in the <u>stress response</u>
    - Secretion of <u>stress hormones</u>
      - glucocorticoids, mineralocorticoids



CRH, corticotropin releasing hormone
AVP, arginine vasopressin
ACTH, adrenocorticotropin
GR, glucocorticoid receptor

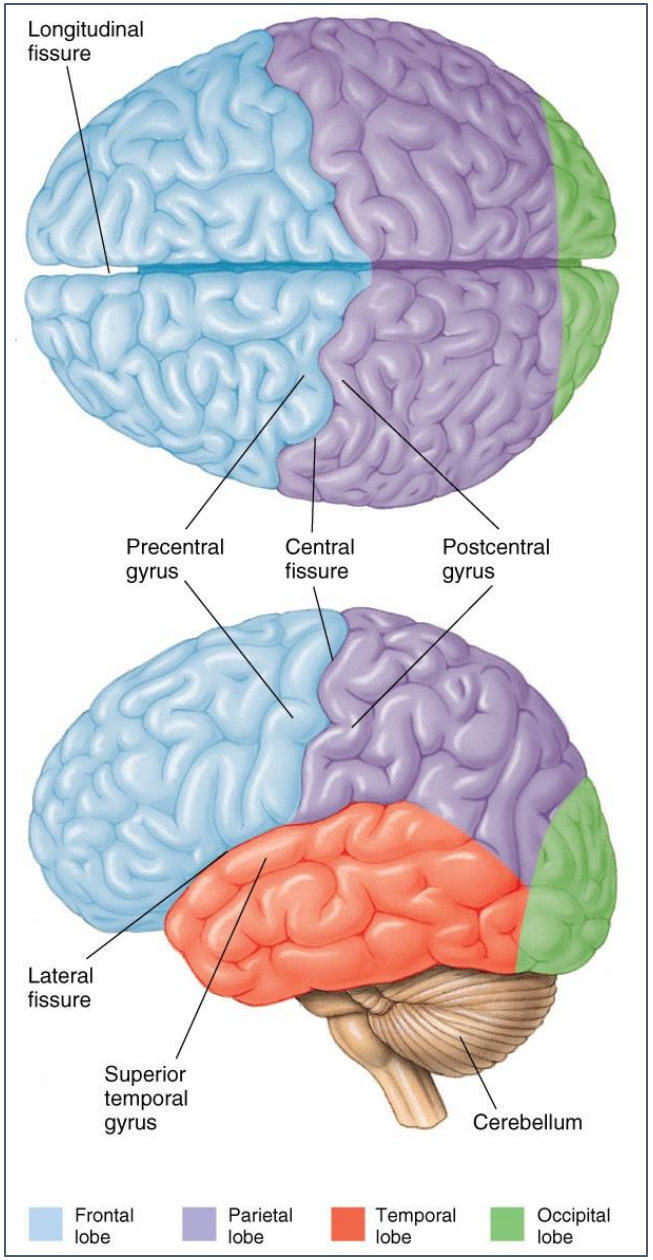
5) Telencephalon

- **Cerebral cortex**
- **Lymbic system**
- **Basal ganglia**



5) Telencephalon – Cerebral cortex

- Convolutions serve to increase surface area
- Characterized by
  - **gyri** (sg: gyrus)
    = crests of folded cortical tissue
  - **sulci/fissures** (sg: sulcus)
    = grooves that divide gyri from another
  - **lobes**
    - 4 lobes can be identified in the human cerebrum



5) Telencephalon – Cerebral cortex

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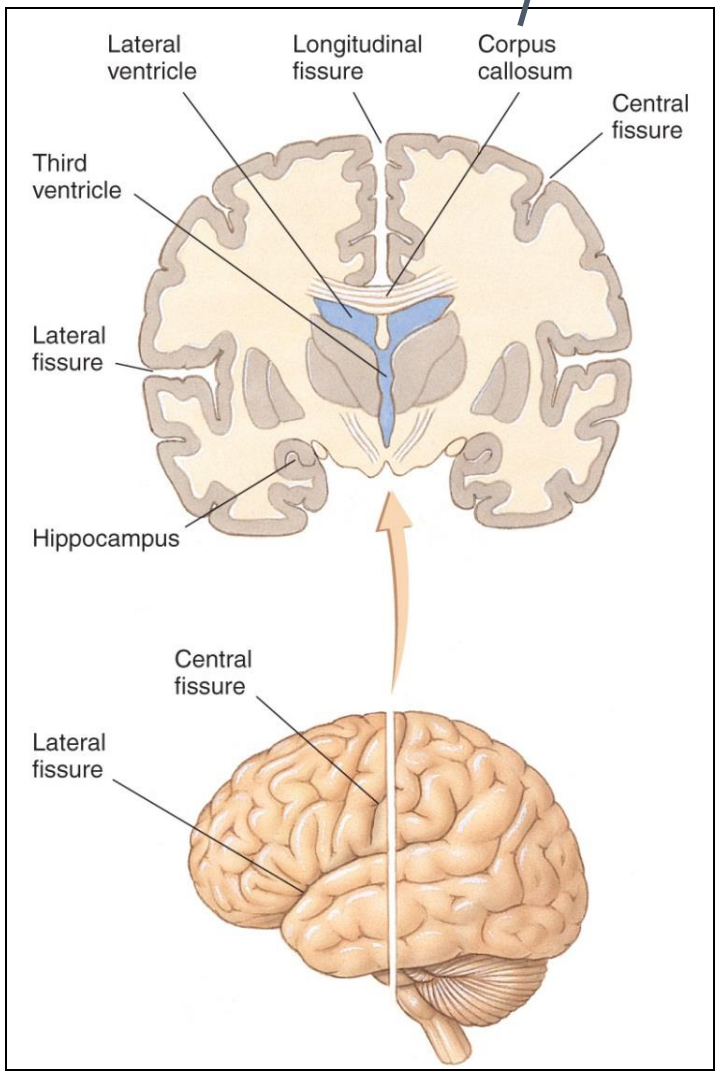
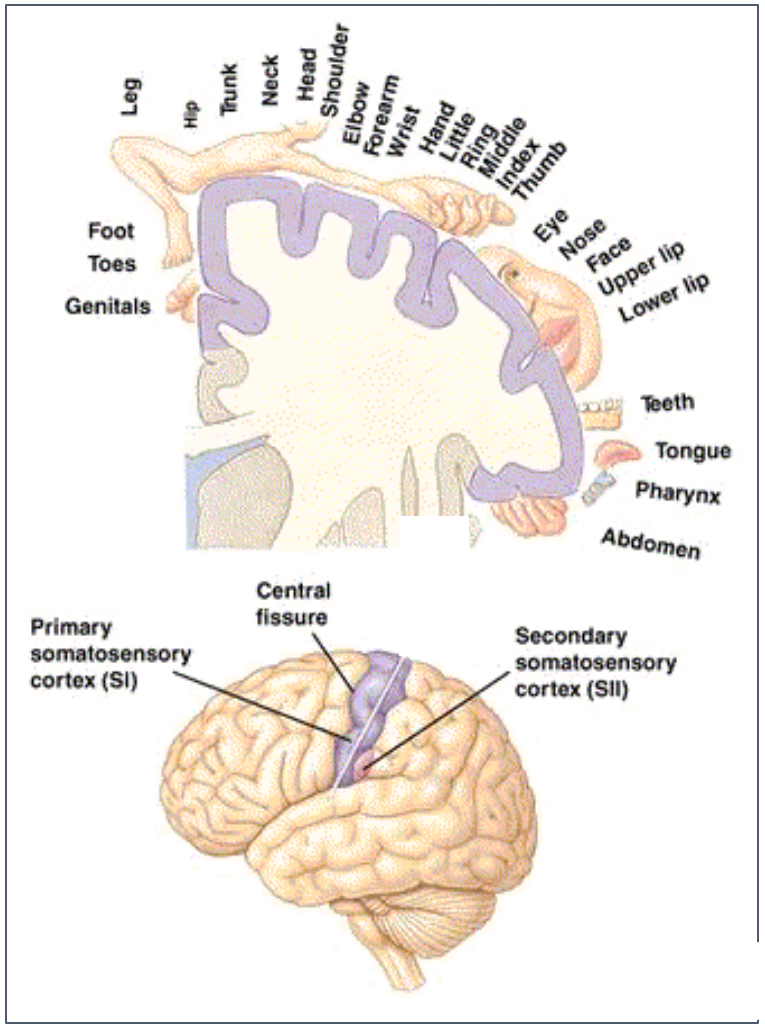


5) Telencephalon – Cerebral cortex

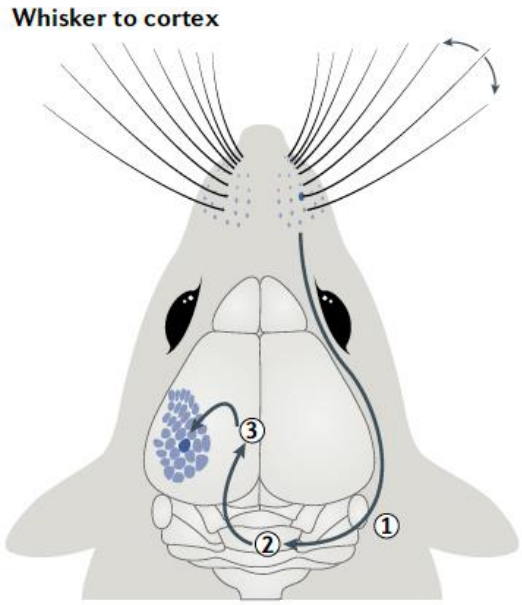
- **Main functions** of the cerebral cortex
  - Somatosensation
  - Motor functions
  - Vision
  - Audition
  - Association
  - Consciousness

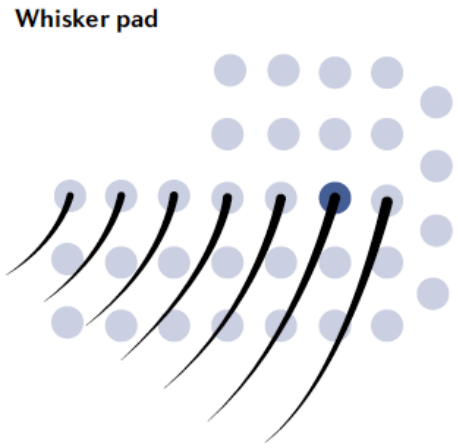
5) Telencephalon – Cerebral cortex

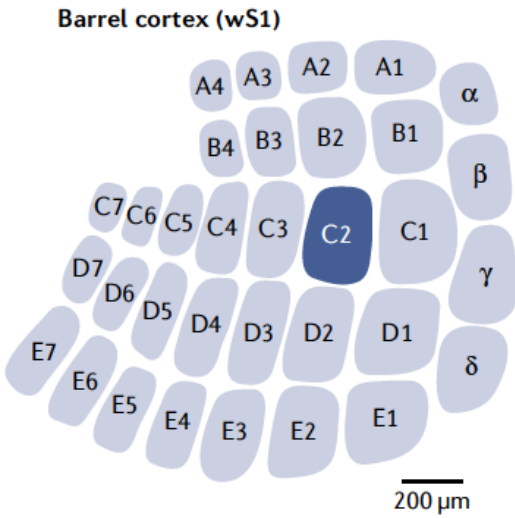
- **Main functions** of the cerebral cortex
  - **Somatosensation**
    - Somatosensory cortex
    - Somatosensory homunculus



The whisker pathway:



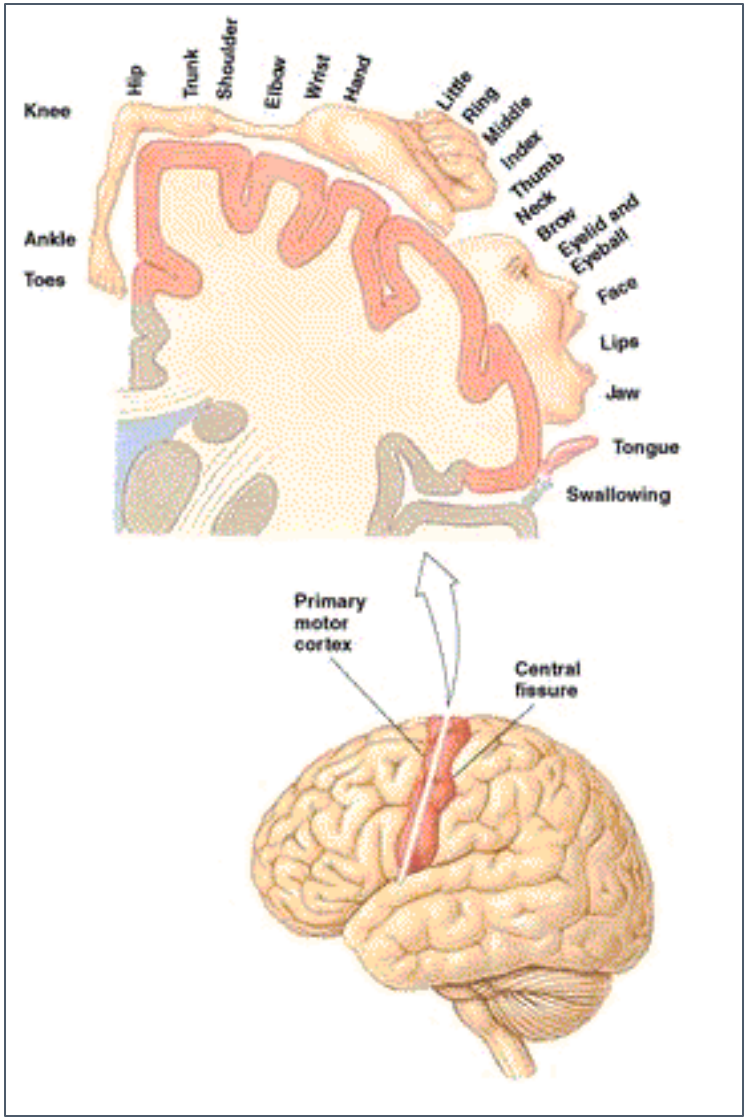




Whisker deflection evokes a sequence of activity in primary sensory neurons (1), brainstem neurons (2) and thalamic neurons (3) before reaching the whisker somatosensory cortex (wS1), also called barrel cortex.

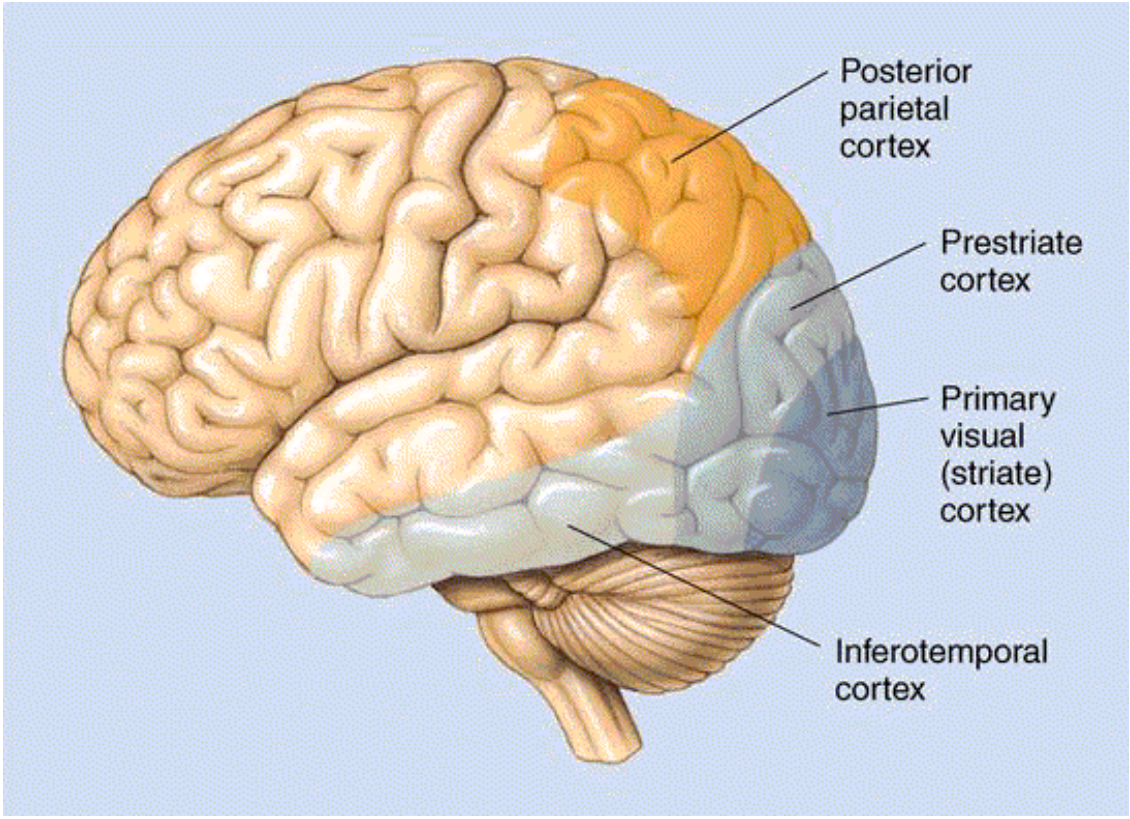
5) Telencephalon – Cerebral cortex

- **Main functions** of the cerebral cortex
  - **Motor functions**
    - Motor cortex
    - Motor homunculus

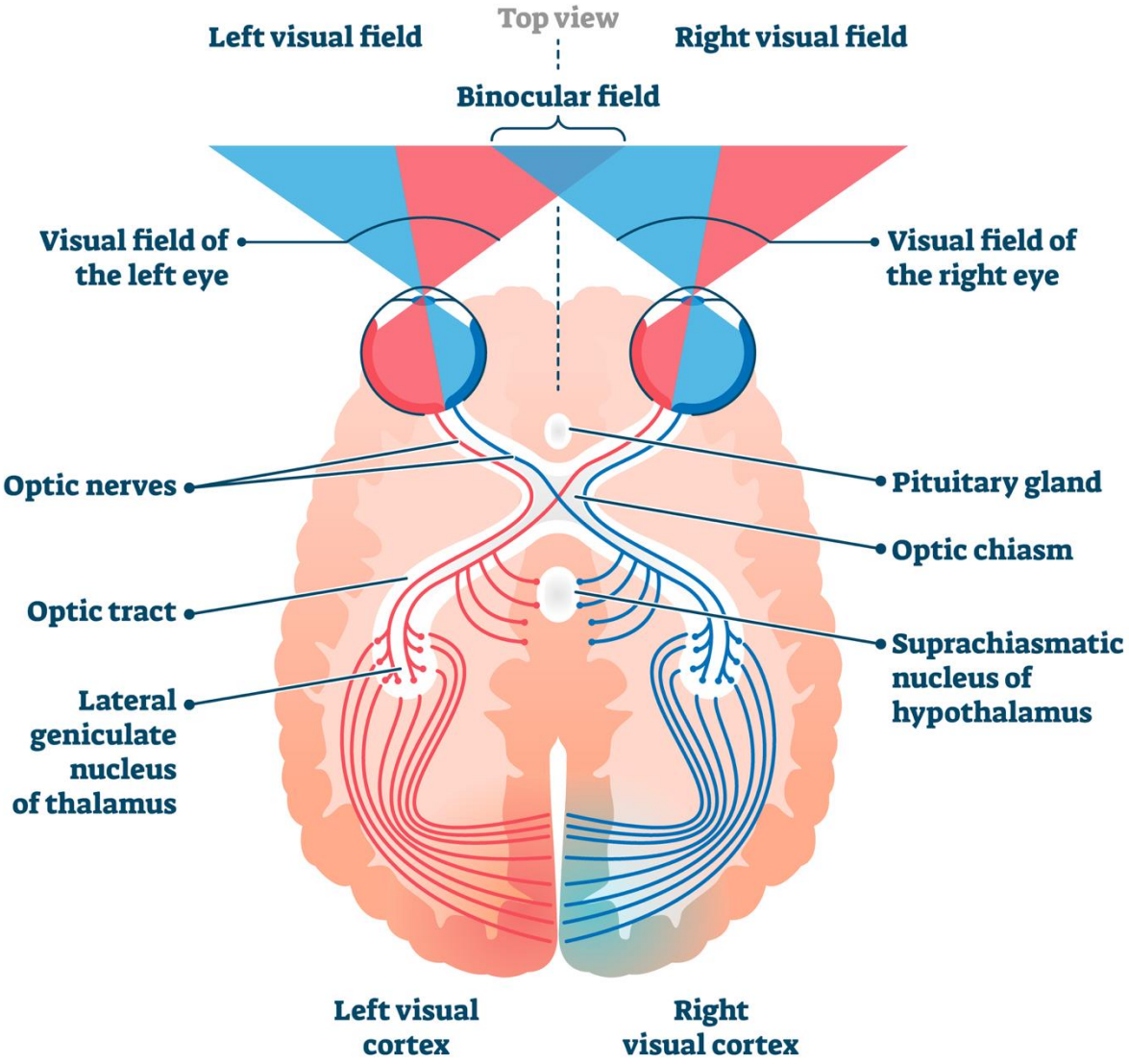


5) Telencephalon – Cerebral cortex

- **Main functions** of the cerebral cortex
  - **Vision**
    - Visual cortex
    - No homunculus

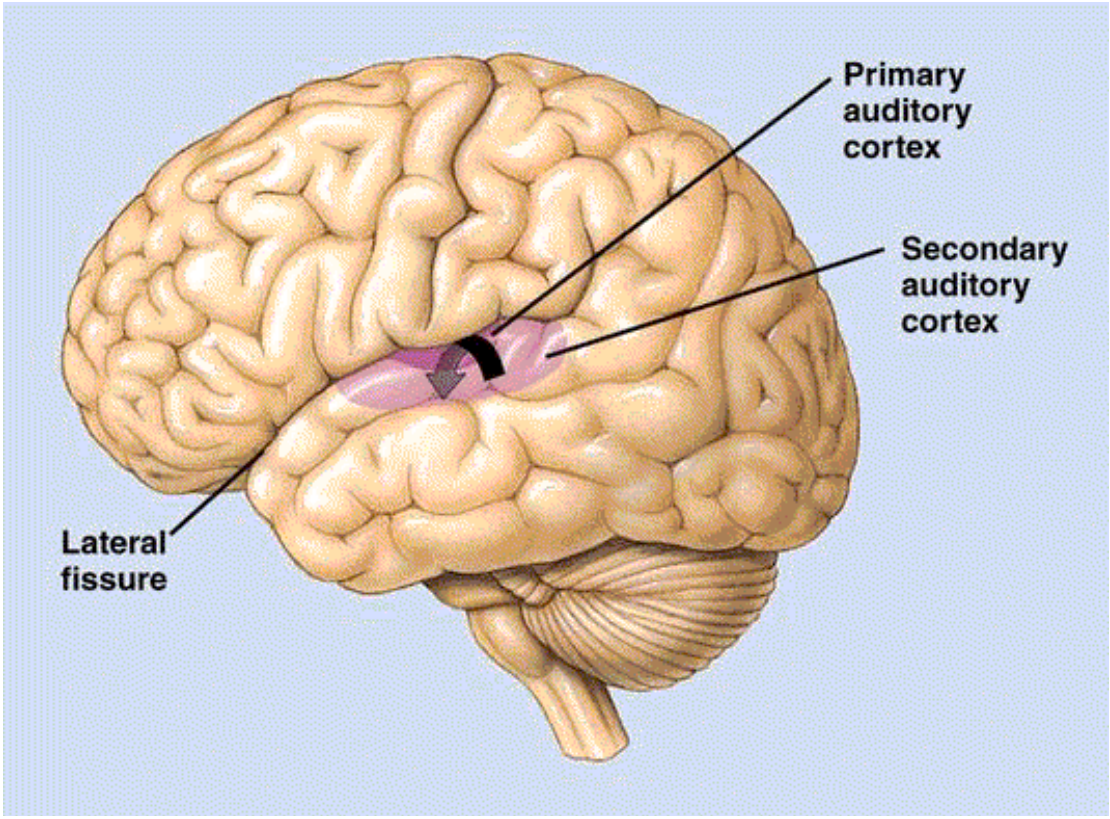


The visual pathway:

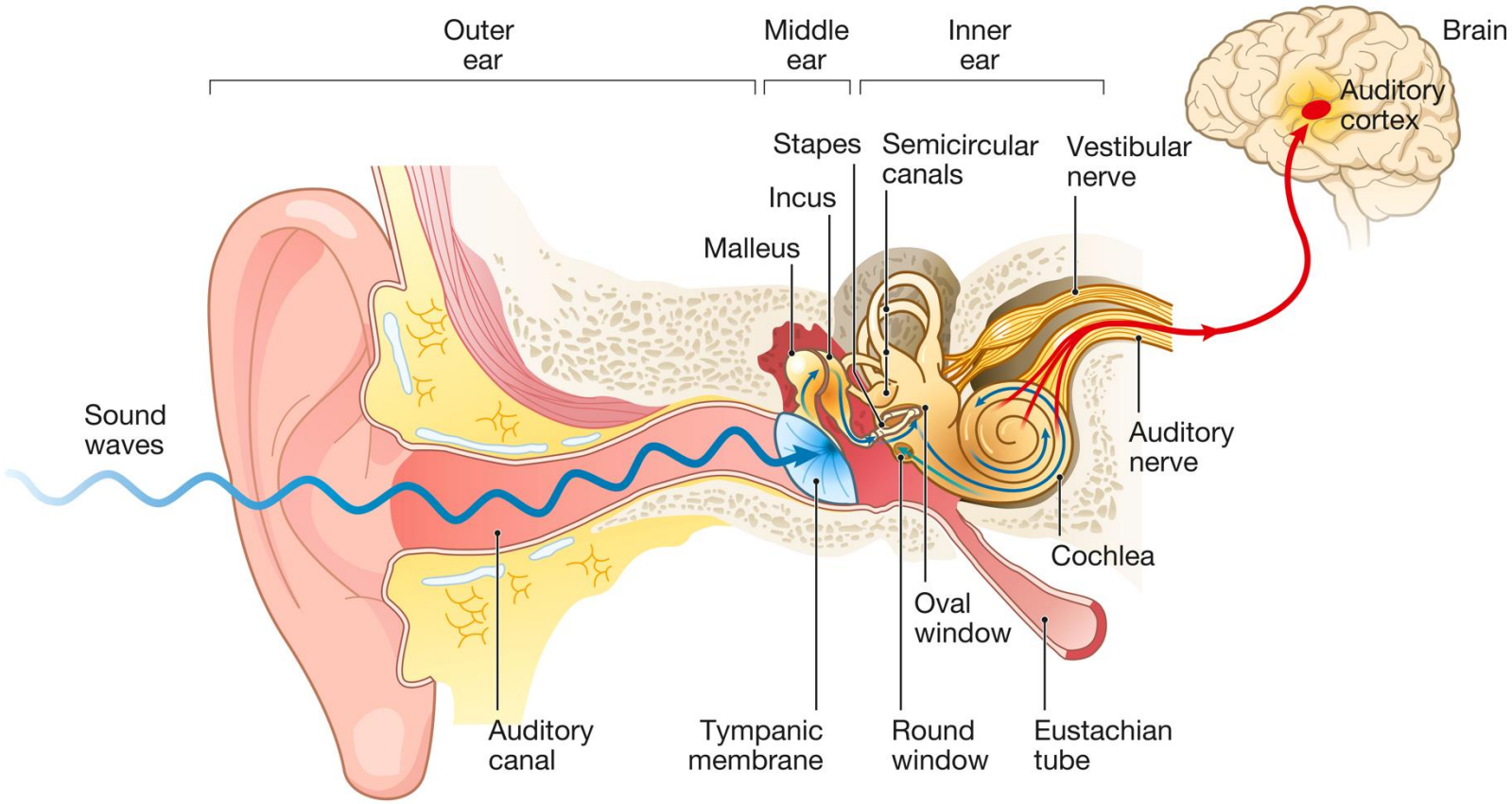


5) Telencephalon – Cerebral cortex

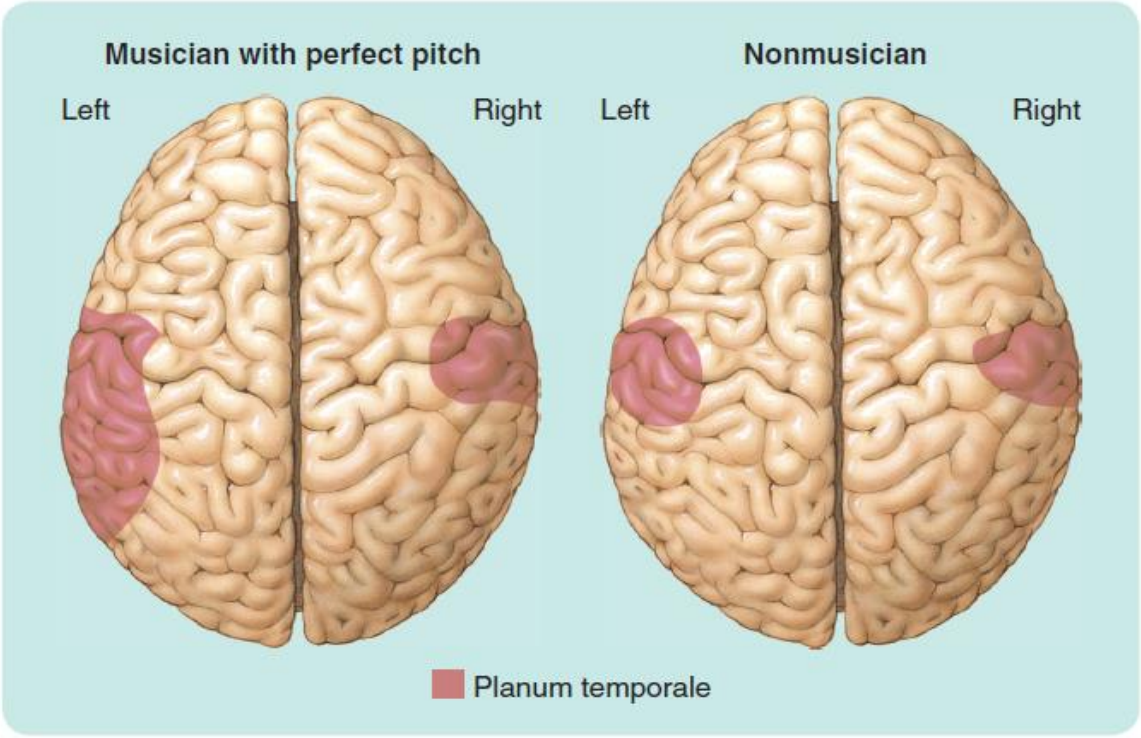
- **Main functions** of the cerebral cortex
  - **Audition**
    - Auditory cortex
    - No homunculus

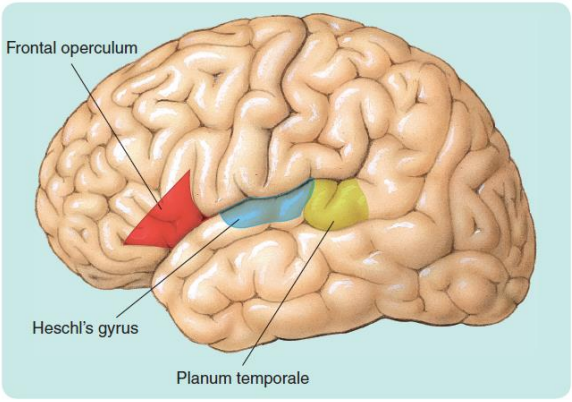


The auditory pathway:



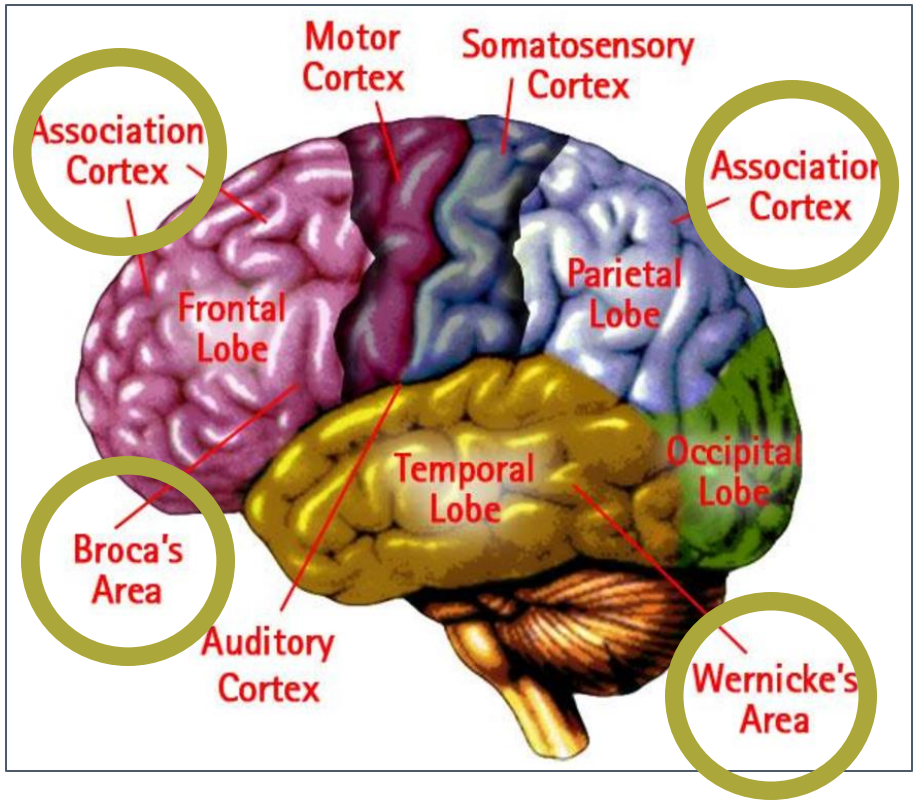
The anatomical asymmetry in the planum temporale of professional musicians





5) Telencephalon – Cerebral cortex

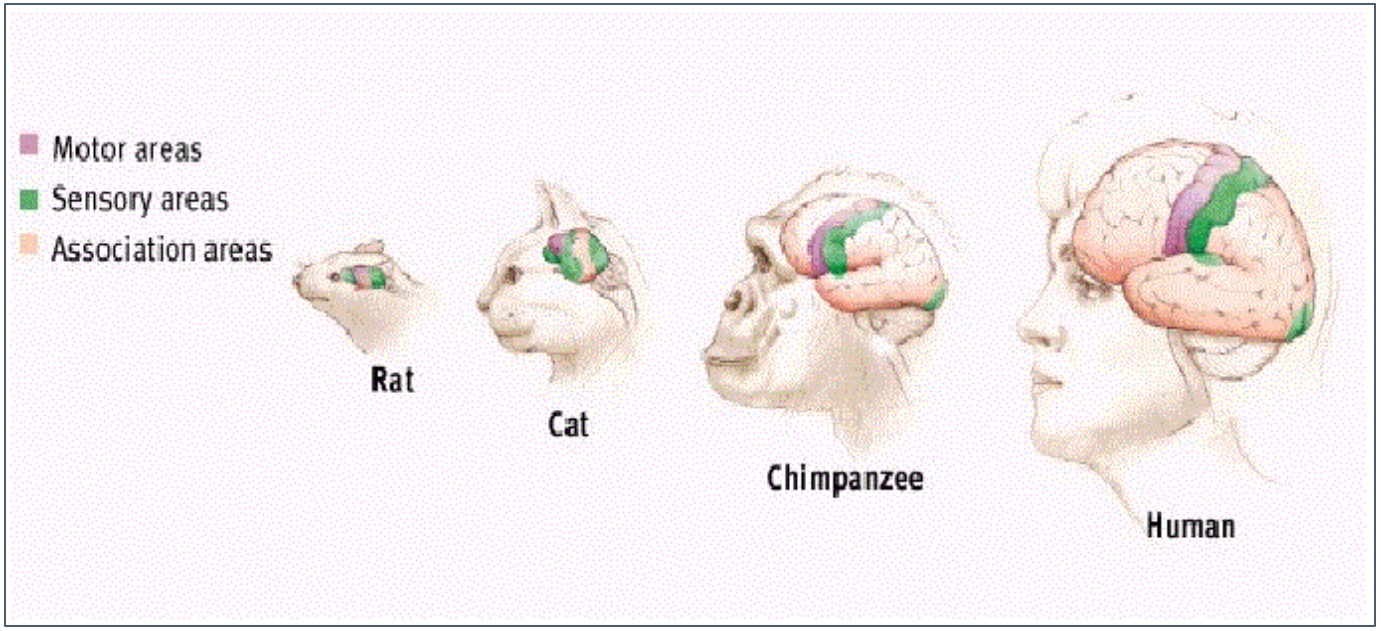
- **Main functions** of the cerebral cortex
  - **Association**
    - **Several associative cortices**
      - Complex mental tasks
        - Planning
        - Social skills
      - Language



5) Telencephalon – Cerebral cortex

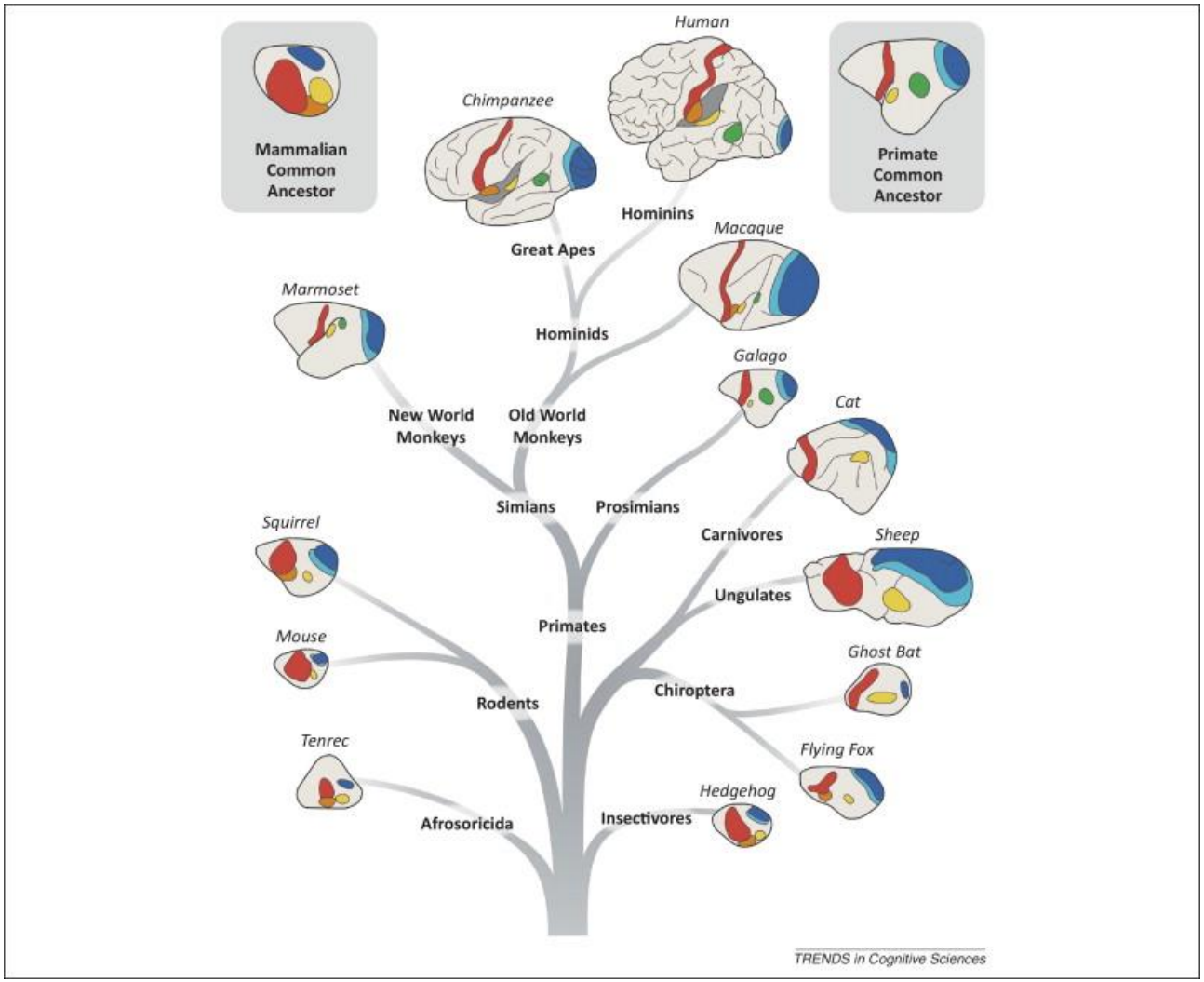
- **Main functions** of the cerebral cortex
  - **Association**
    - **Several associative cortices**
      - Complex mental tasks
        - Planning
        - Social skills
      - Language

Association cortex increases with complexity…



With increased brain size between species**, the association cortex takes up a larger percentage of the entire cortical area.**

…whereas other cortical areas show the same size.



Somatosensory cortex

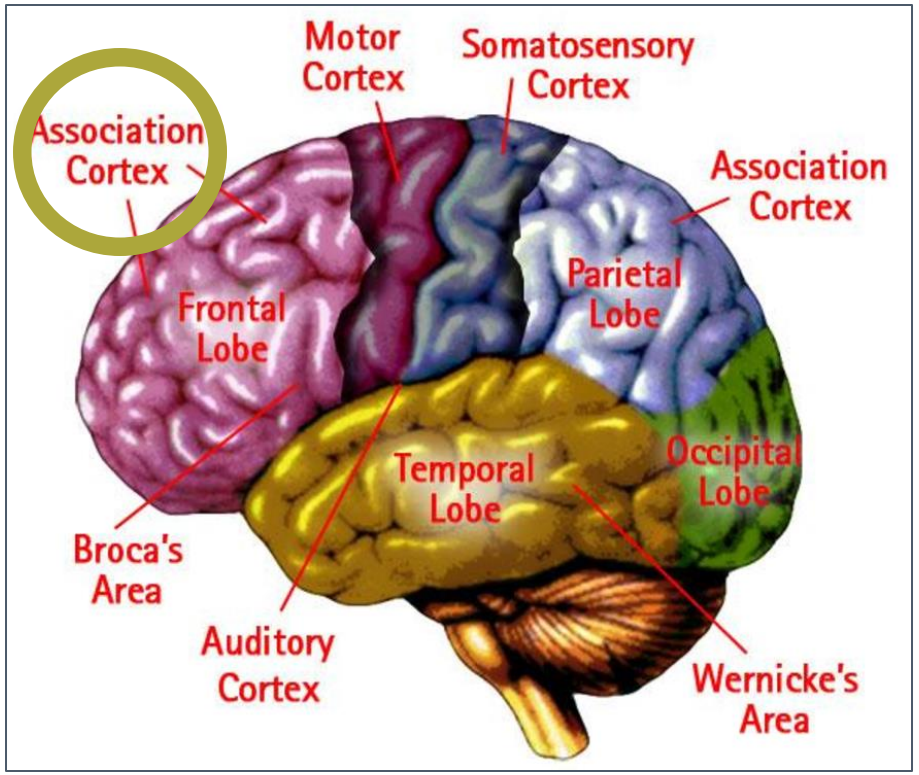
Primary visual cortex

Secondary visual cortex

Auditory cortex

Roles of the association cortex:

- **Main functions** of the cerebral cortex
  - **Association**
    - Several associative cortices
      - **Complex mental tasks**
        - Planning
        - Social skills
      - Language



The Mind-Blowing Case of Phineas Cage (1823-1860)

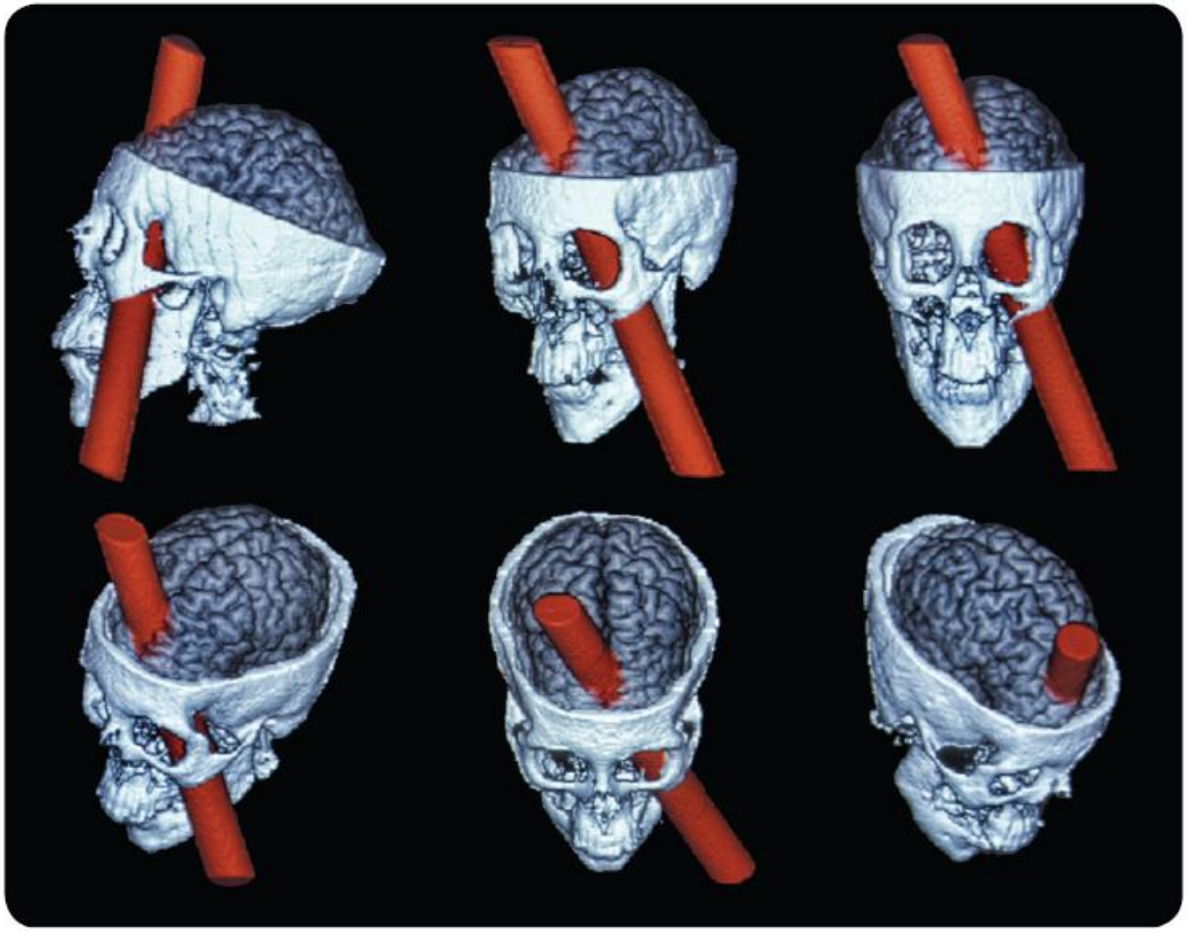
- During railroad construction's in the mid 1800s, a steel rod entered and exited his brain during an explosion…

"I first noticed the wound upon the head before I alighted from my carriage, the pulsations of the brain being very distinct. The top of the head appeared somewhat like an inverted funnel, as if some wedge-shaped body had passed from below upward. Mr. Gage, during the time I was examining this wound, was relating the manner in which he was injured to the bystanders. I did not believe Mr. Gage's statement at that time, but thought he was deceived. Mr. Gage persisted in saying that the bar went through his head. Mr. G. got up and vomited; the effort of vomiting pressed out about half a teacupful of the brain, which fell upon the floor."

"You will excuse me for remarking here, that the picture presented was, to one unaccustomed to military surgery, truly terrific."

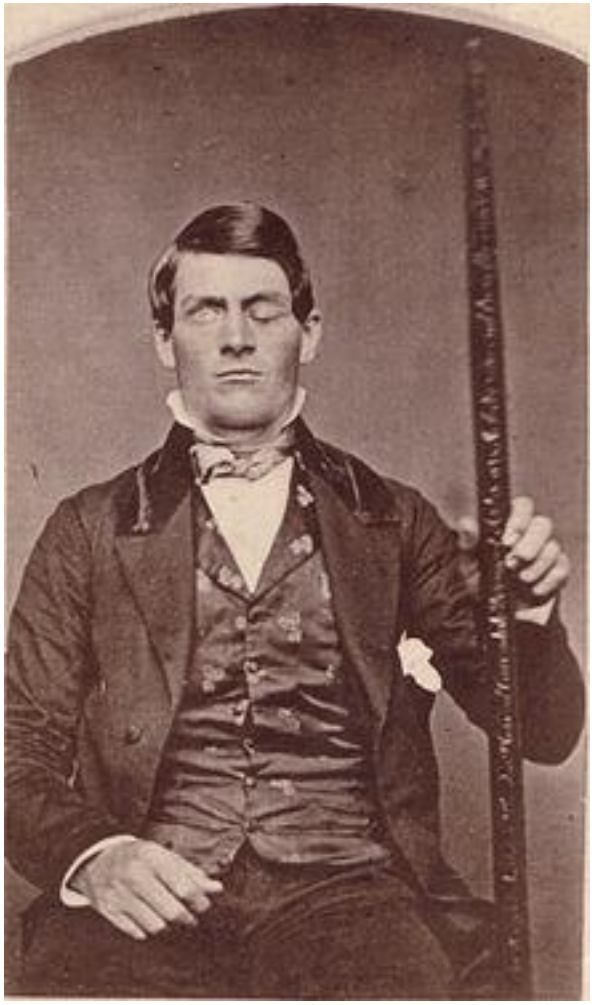
Statements from Cage's doctor, John. H. Harlow

The Mind-Blowing Case of Phineas Cage

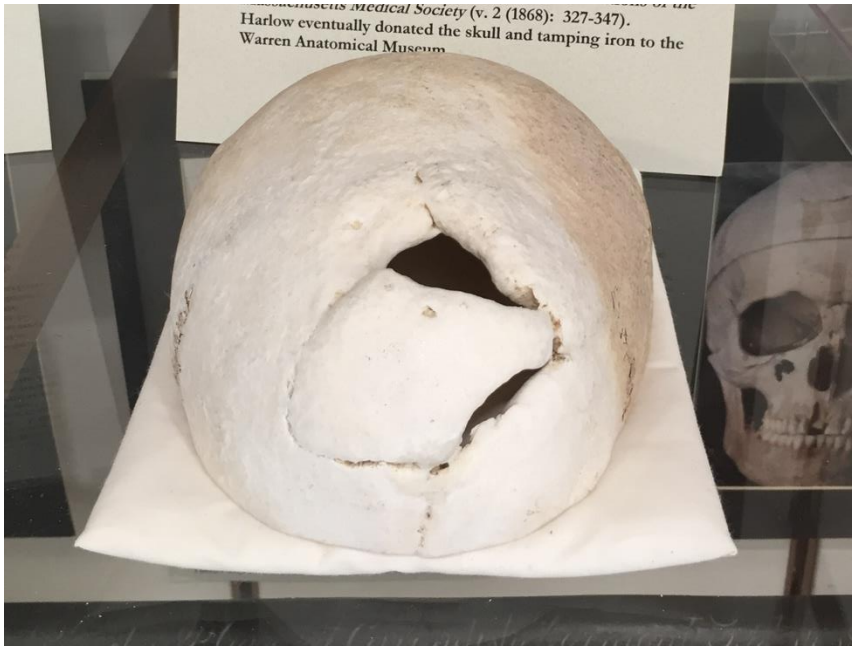


The Mind-Blowing Case of Phineas Cage

- Full physical recovery (except for one eye) within months after the accident
- But his personality changed:
  - Normal social interactions no longer possible
  - No practical planning possible anymore
  - ➢ Lost his job as a foreworker

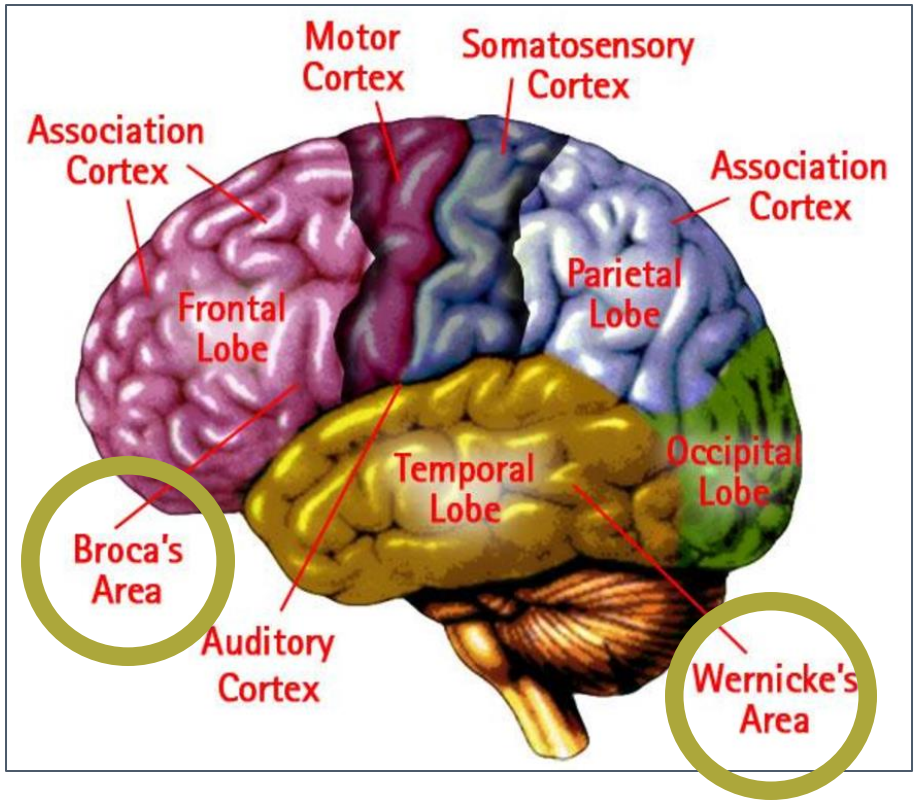


The Mind-Blowing Case of Phineas Cage



Roles of the association cortex:

- **Main functions** of the cerebral cortex
  - **Association**
    - Several associative cortices
      - Complex mental tasks
    - **Language**



5) Telencephalon – Cerebral cortex

- **Language**
  - **Broca's aphasia** (expressive aphasia: Meaningful, but awkward speech)

A patient who was asked about a dental appointment replied haltingly and indistinctly:

"Yes… Monday… Dad and Mum… Wednesday nine o'clock… 10 c'clock… doctors … and… teeth…"

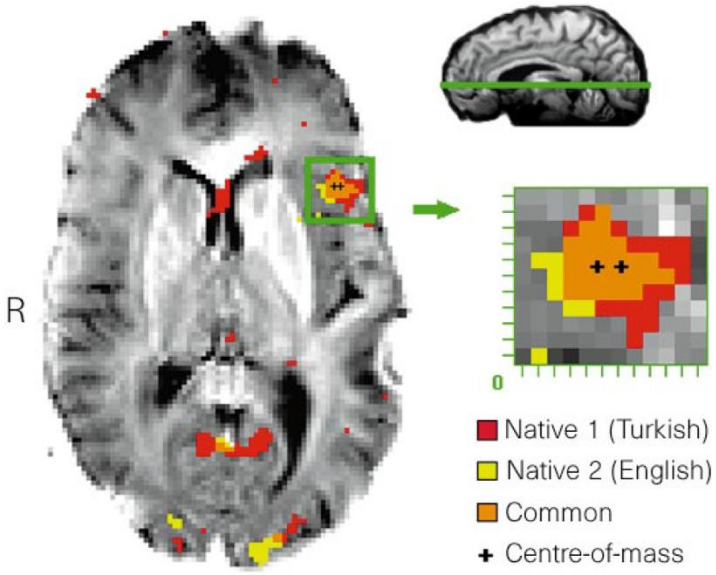
  - **Wernicke's aphasia** (receptive aphasia: Meaningless, but normal speech)

A patient who was asked to describe a picture that showed two boys stealing cookies reported smoothly:

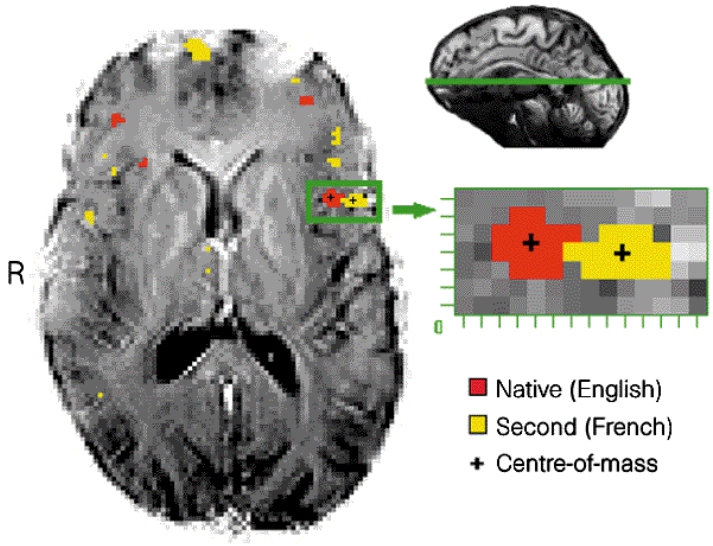
"Mother is away here working her work to get her better, but when she's looking the two boys looking in the other part. She's working another time."

Timing of learning of a second language

- Broca's area



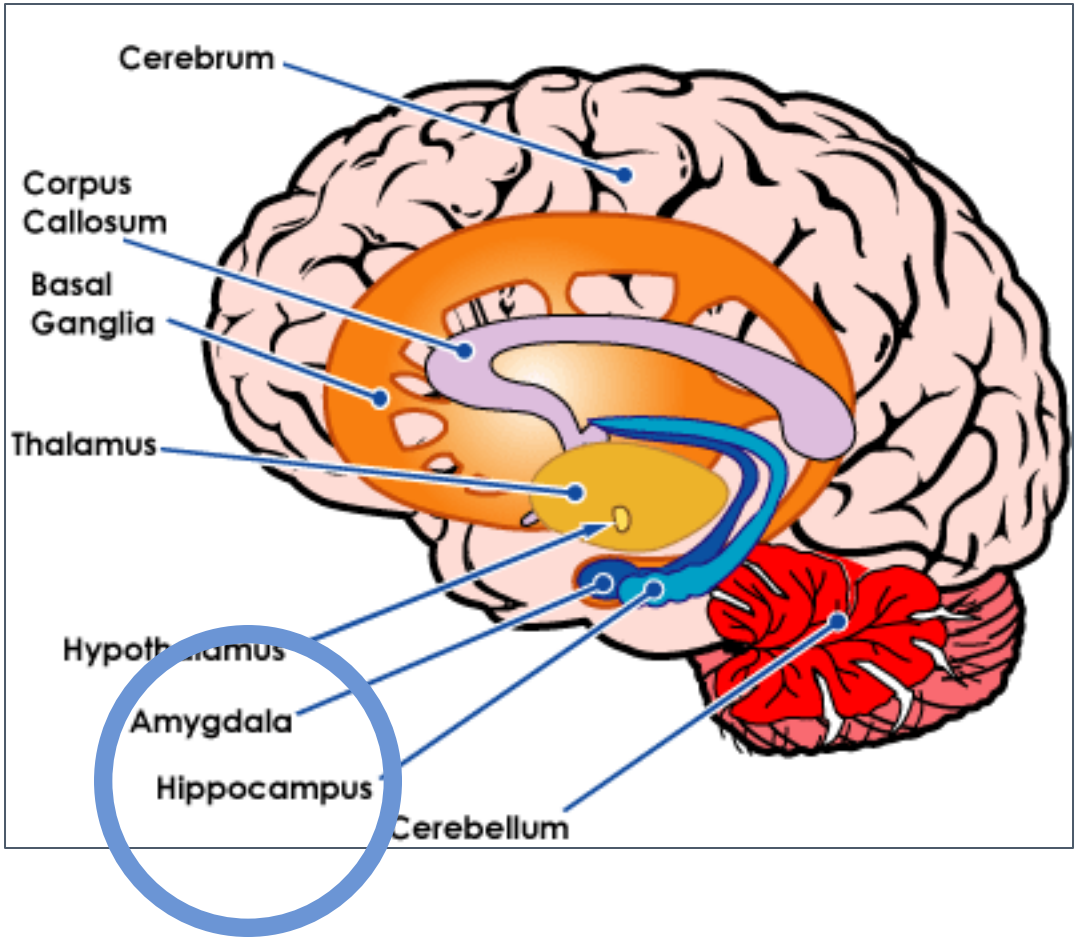
Early bilingual



Late bilingual

5) Telencephalon

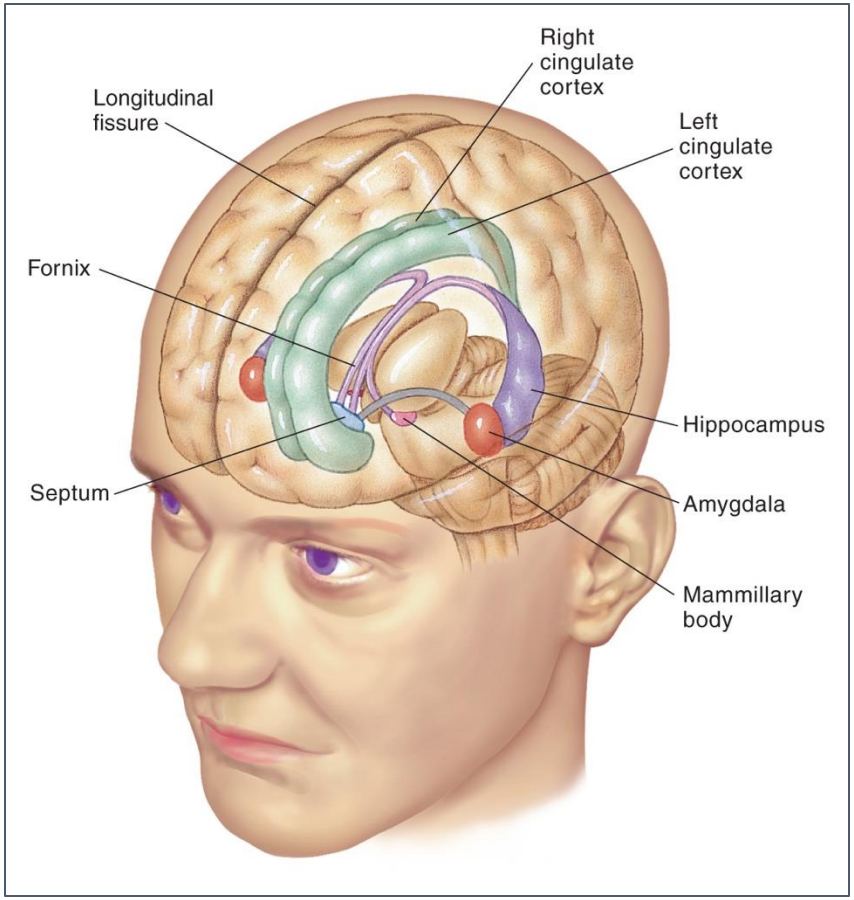
- Cerebral cortex
- **Lymbic system**
- Basal ganglia



5) Telencephalon – Lymbic system

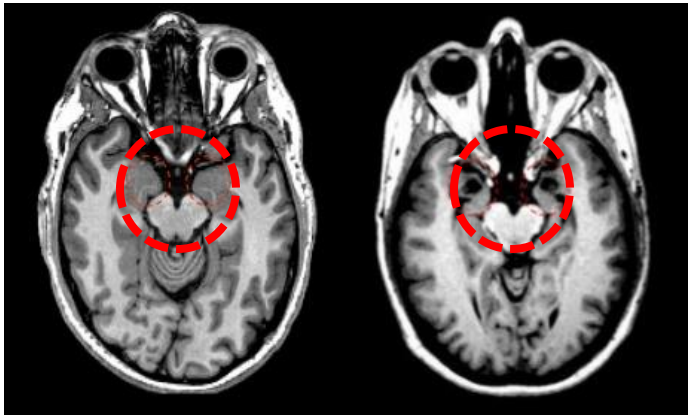
- Implicated in **learning and memory**

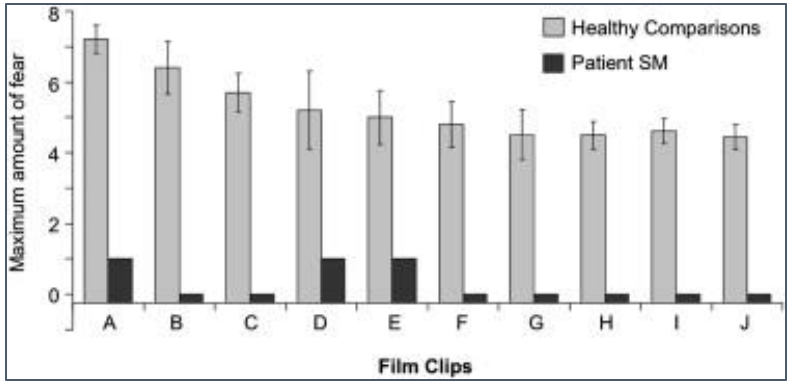
- Structures:
  - Amygdala
  - Hippocampus
  - Cingulate Cortex
  - Fornix
  - Septum



5) Telencephalon – Lymbic system – Amygdala

- The rare case of **Urbach-Wiethe disease**
  - Autosomal recessive disease
  - **Bilateral atrophy of amygdala**
    - No subjective experience of fear
    - Other emotions not affected



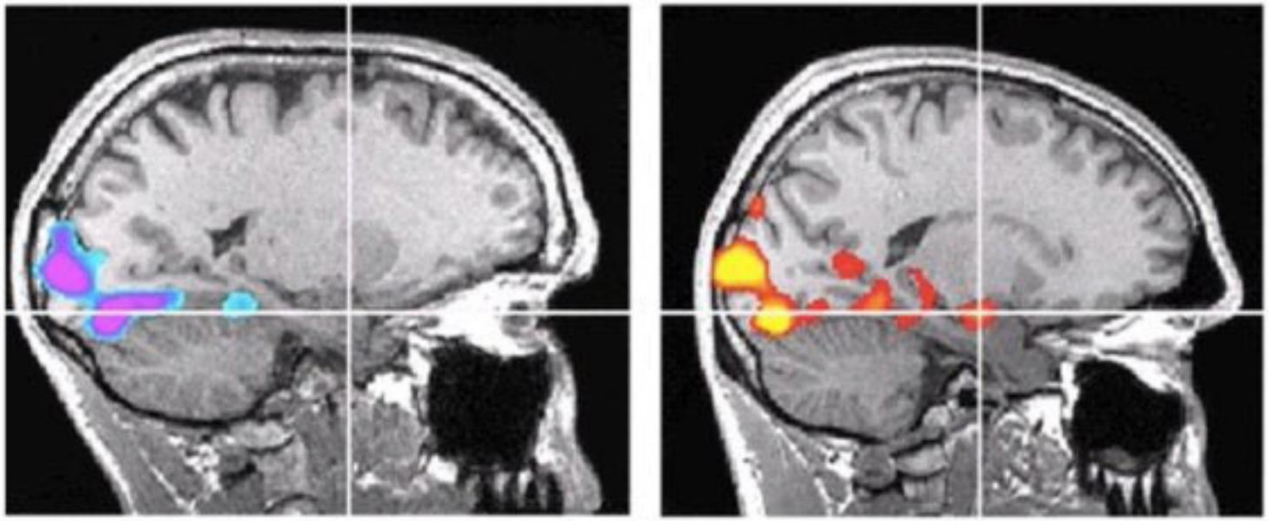


Amygdala

- **Fear learning**
  - Alex Honnold

Amygdala

- **Fear learning**



ABSENCE OF FEAR: Scans compare Honnold's brain (left) with a control subject's (right), a rock climber of a similar age. Crosshairs mark the amygdala, a group of nuclei involved in generating fear. As both climbers look at the same arousing images, the control subject's amygdala glows, while Honnold's remains inert, showing no activity whatsoever.

https://twitter.com/bpoppenheimer/status/1661852924455034890

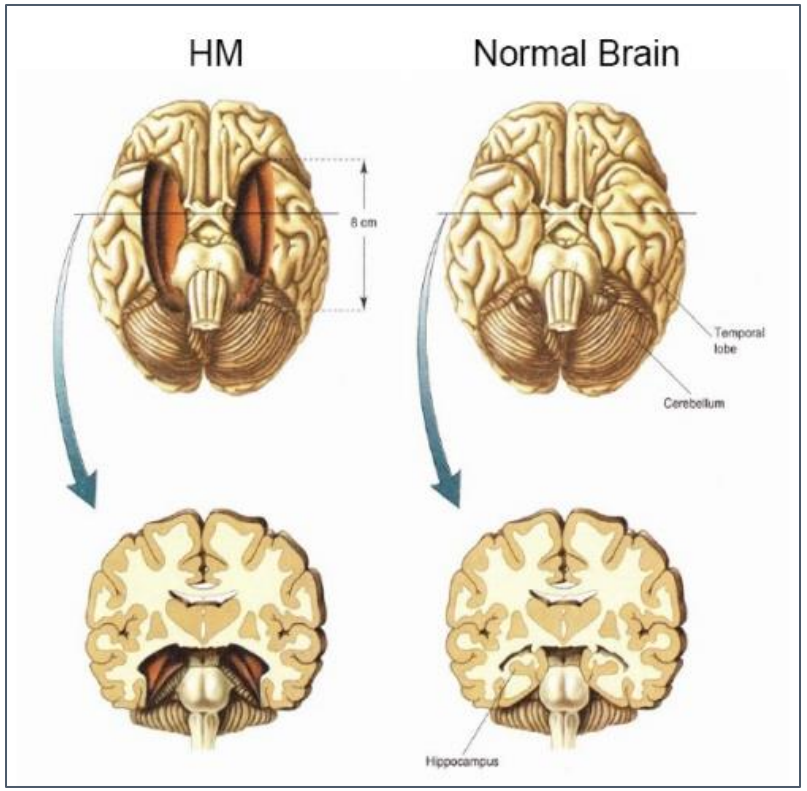
Amygdala

- "I've spent 25 years conditioning myself to work in extreme conditions, so of course my brain is different." Honnold says that, if anything, it is his preparation that is abnormal. For years, for instance, Honnold was afraid of El Capitan—a 3,000-ft rock wall in Yosemite. “I’d drive into Yosemite,” he said, “look at the wall, and think, ‘No way. Too scary.'” So, "to gradually expand my comfort zone," Honnold said, he climbed El Cap hundreds of times with a rope. Then on June 3, 2017, Honnold became the first to climb El Cap without a rope.

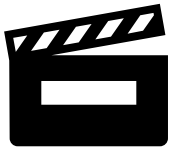
https://twitter.com/bpoppenheimer/status/1661852924455034890

5) Telencephalon – Lymbic system – Hippocampus

- **The case of H.M.**



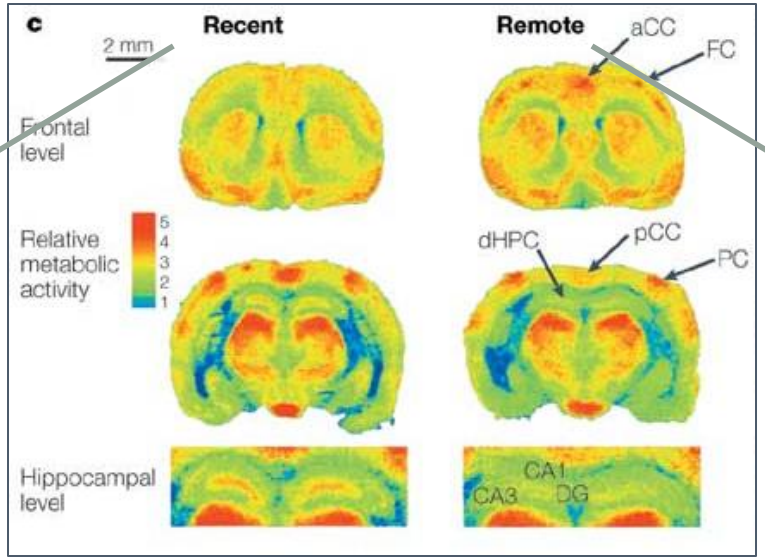
- Henry Molaison (1926-2008) had part of his temporal lobe removed during a lobectomy to treat his epilepsy



5) Telencephalon – Lymbic system – Hippocampus

- **H.M. Removal of temporal lobe - hippocampus**
  - His long-term memory from before the surgery remained intact
  - But he wasn't capable of forming new long-term memories

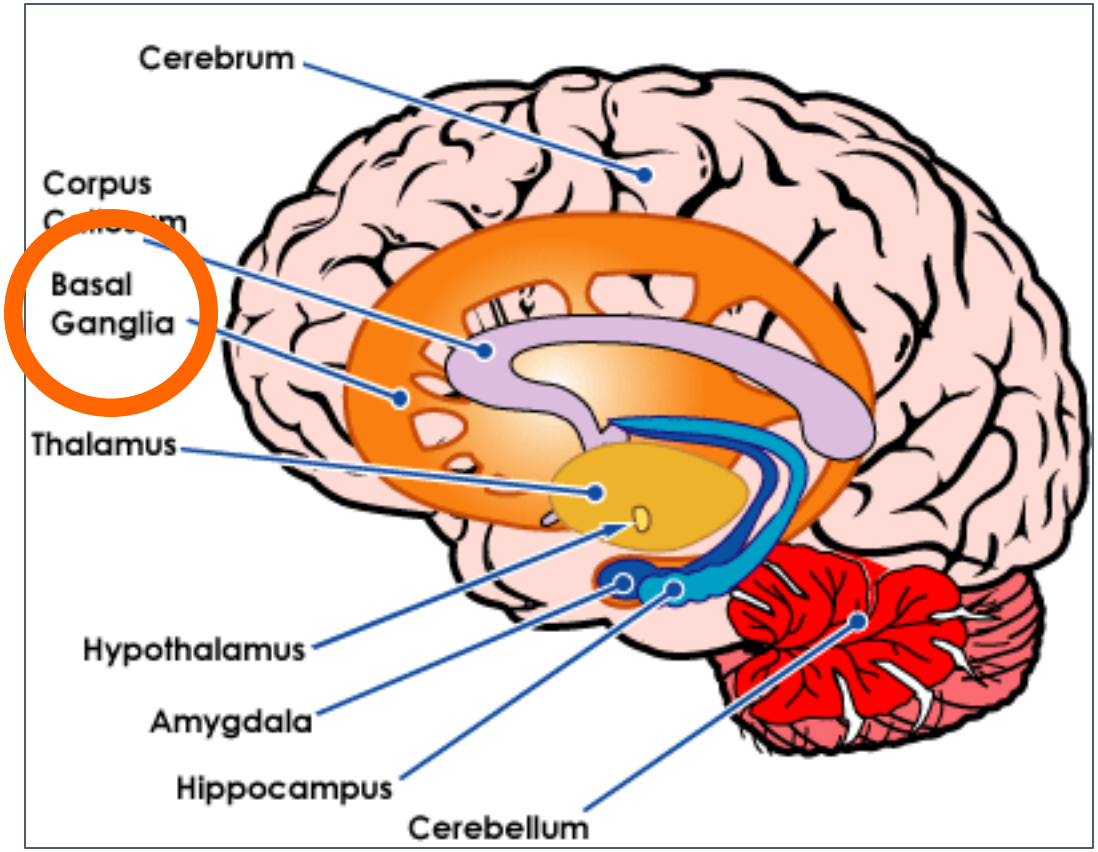
Hippocampus-dependent



Cortex-dependent

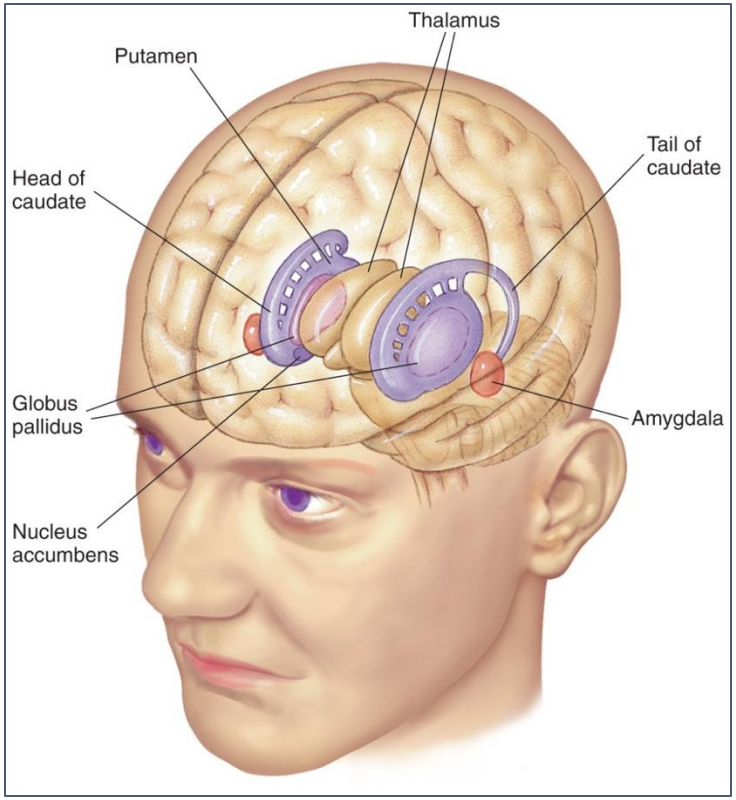
5) Telencephalon

- Cerebral cortex
- Lymbic system
- **Basal ganglia**

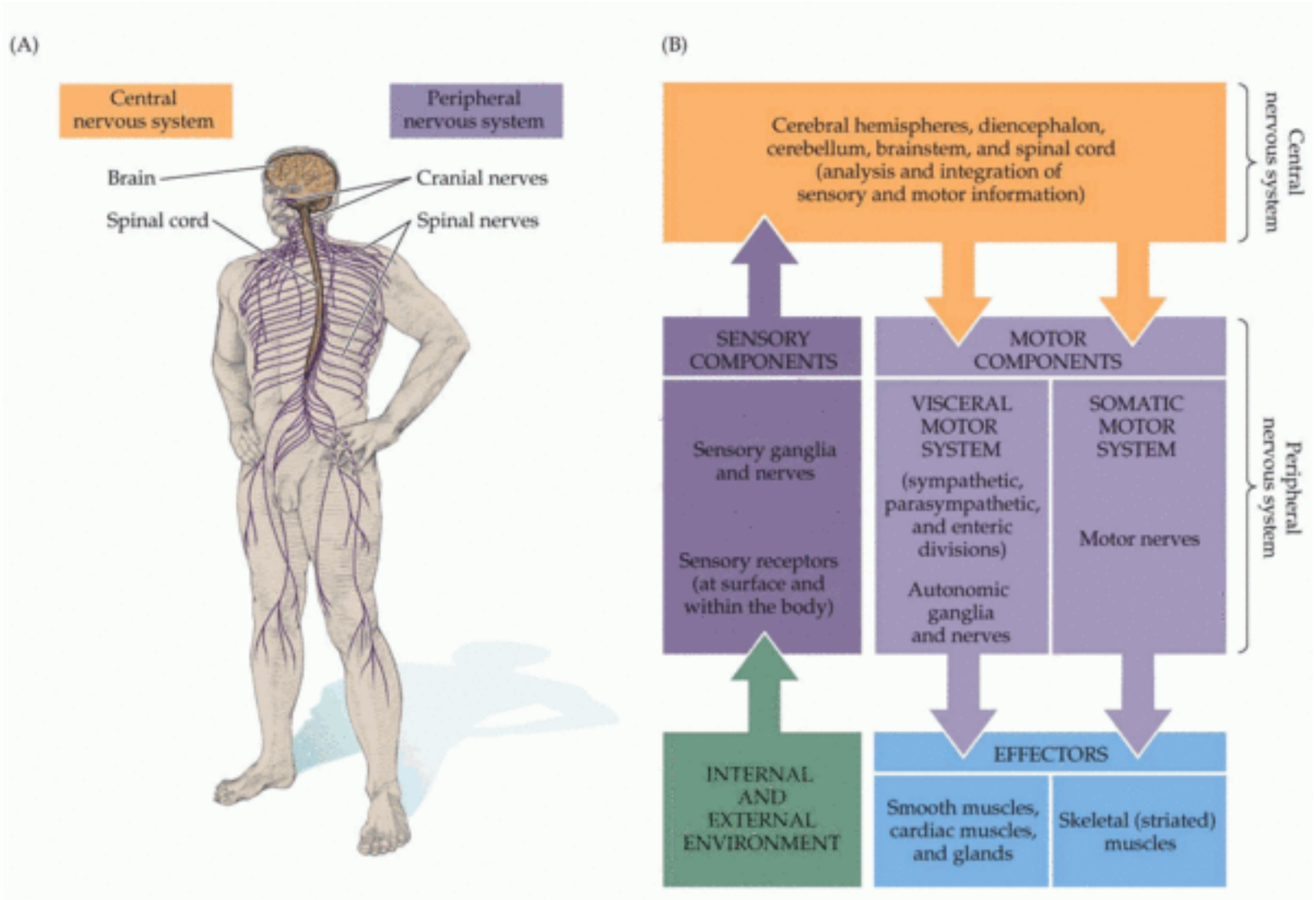


5) Telencephalon – Basal ganglia

- Main Components
  - Caudate Nucleus
  - Putamen
  - Globus Pallidus
  - Nucleus accumbens
- Major Functions
  - Motor Control
  - Somatosensory-Motor Integration
  - Reward circuitry
- Diseases of the BG
  - Parkinson's Disease
  - Huntington's Disease



Divisions of the Nervous System - SUMMARY



Divisions of the Nervous System - SUMMARY

Diencephalon	Thalamus	Massa intermedia Lateral geniculate nuclei Medial geniculate nuclei Ventral posterior nuclei
	Hypothalamus	Mammillary bodies
	Optic chiasm	
	Pituitary gland	
Mesencephalon	Tectum	Superior colliculi Inferior colliculi
	Tegmentum	Reticular formation Cerebral aqueduct Periaqueductal gray Substantia nigra Red nucleus
Metencephalon	Reticular formation Pons Cerebellum	
Myelencephalon or Medulla	Reticular formation	

Divisions of the Nervous System - SUMMARY

Telencephalon	Cerebral cortex	Neocortex Hippocampus
	Major fissures	Central fissure Lateral fissure Longitudinal fissure
	Major gyri	Precentral gyrus Postcentral gyrus Superior temporal gyrus Cingulate gyrus
	Four lobes	Frontal lobe Temporal lobe Parietal lobe Occipital lobe
	Limbic system	Amygdala Hippocampus Fornix Cingulate cortex Septum Mammillary bodies
	Basal ganglia	Amygdala Caudate, Putamen } Striatum Globus pallidus
	Cerebral commissures	Corpus callosum