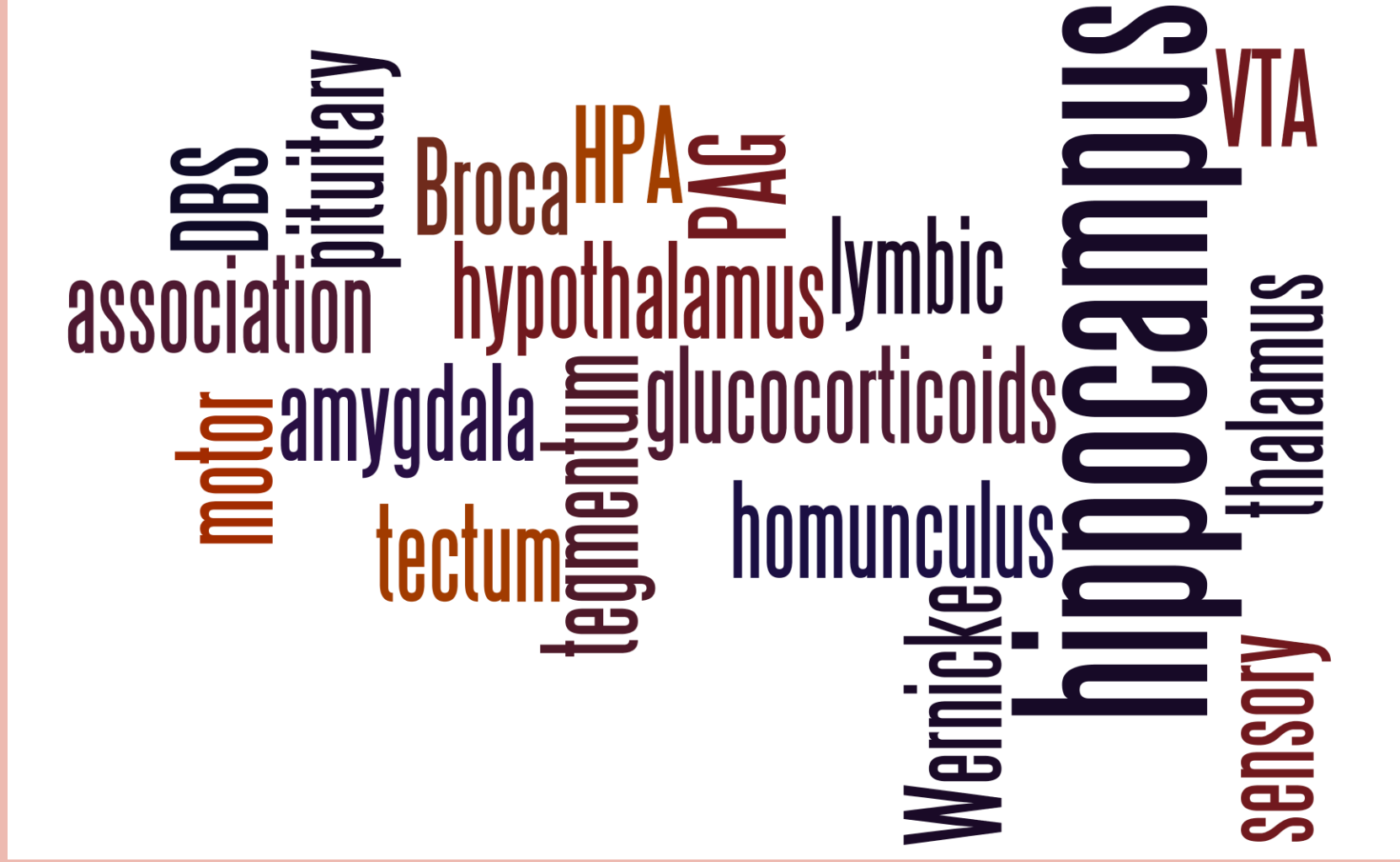




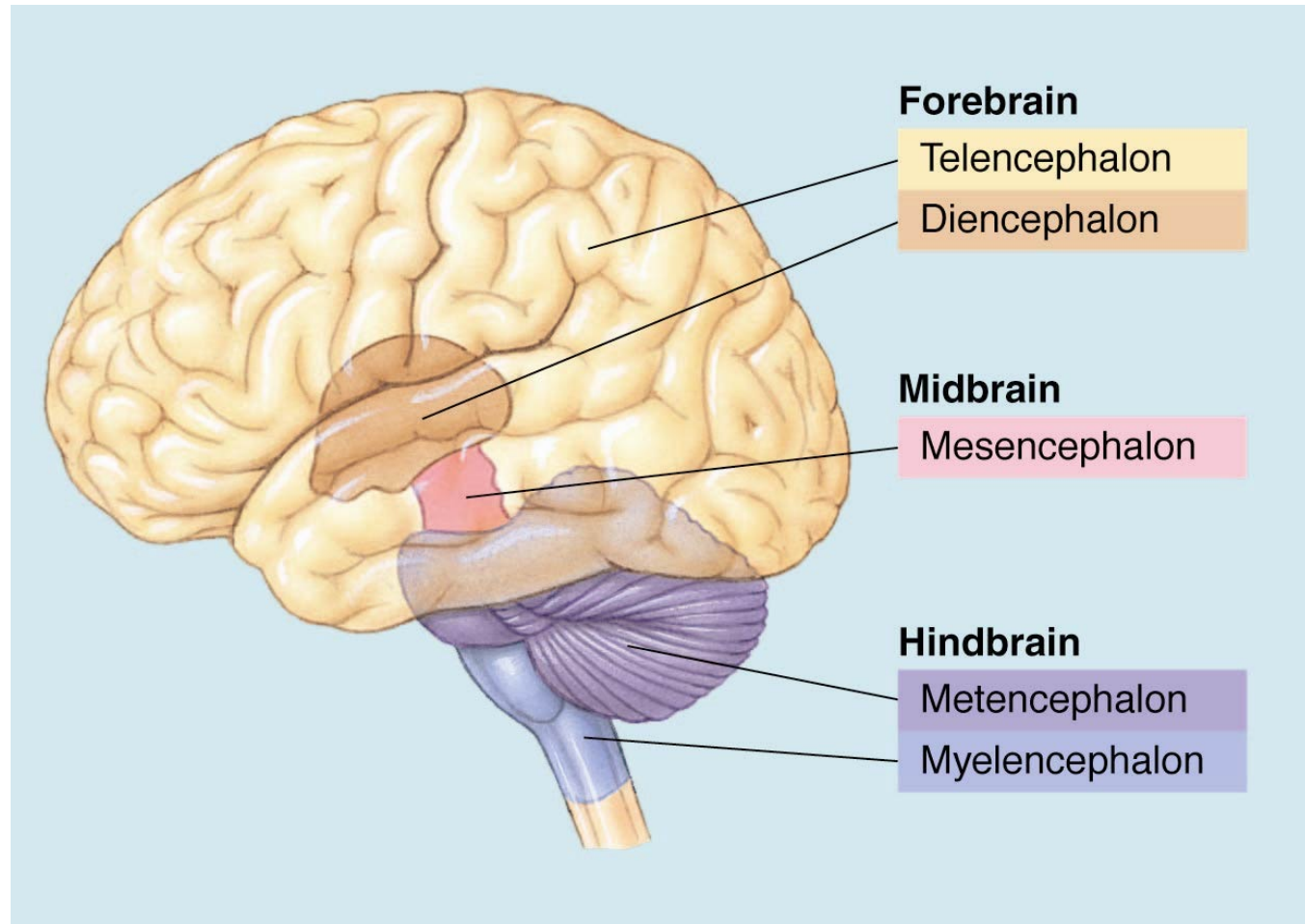
WEEK 2

BRAIN ANATOMY PART II

Keywords



The 5 Major Division of the Brain



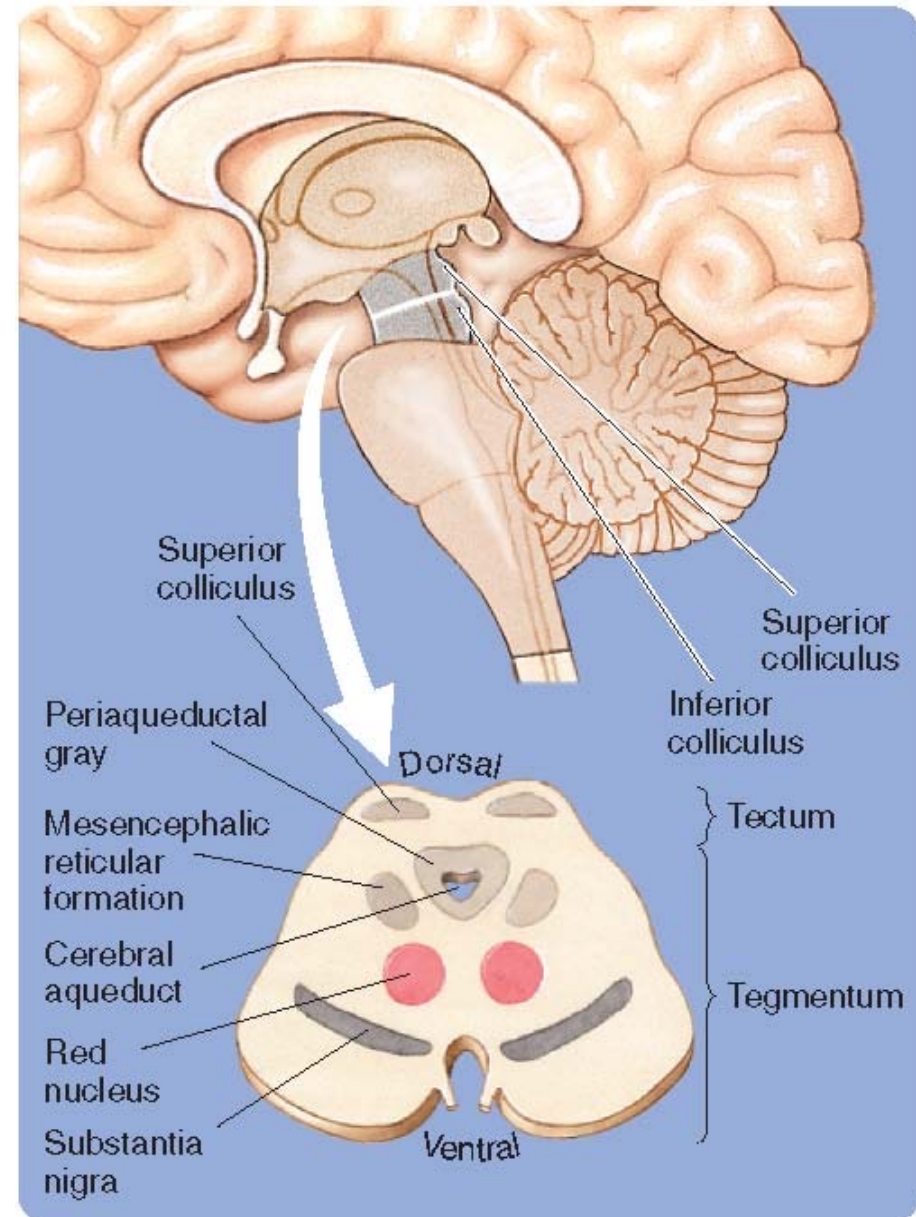
3) Mesencephalon

- **Tectum**

- Inferior colliculi: Audition
- Superior colliculi: Vision

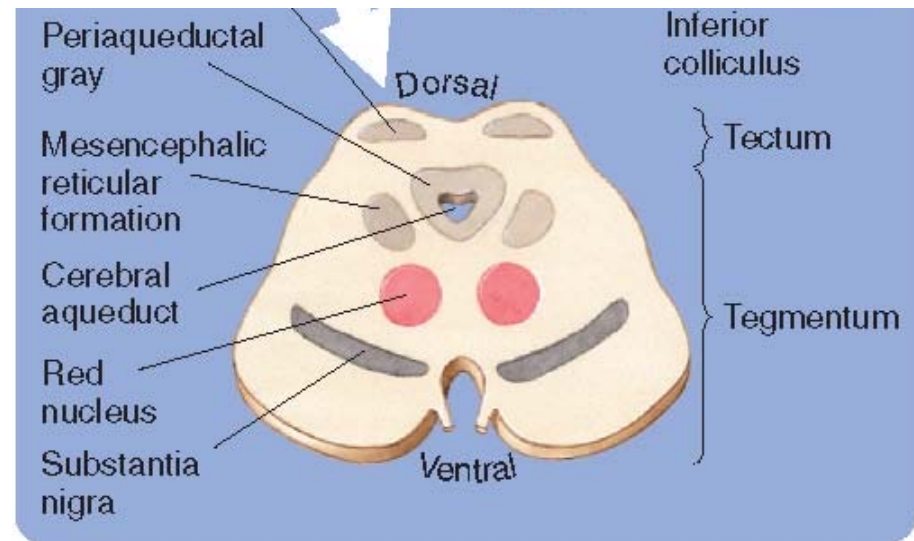
- **Tegmentum**

- Reticular formation
 - 1) Periaqueductal grey
 - 2) Substantia nigra
 - 3) Red nucleus



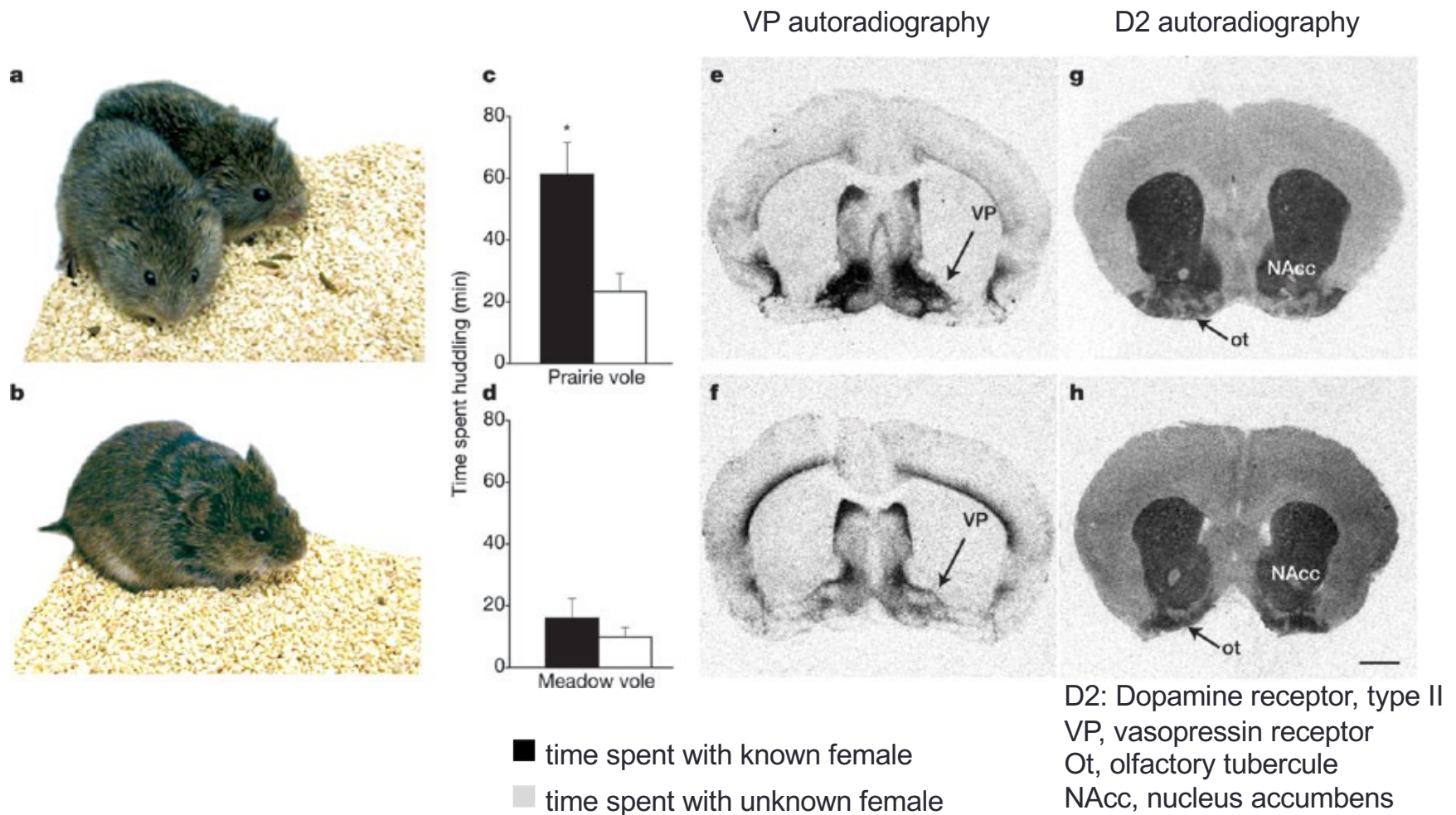
3) Mesencephalon - Tegmentum

- **Periaqueductal grey**
 - Pain sensation
 - Defensive behavior
 - Maternal behavior
 - High density of oxytocin/vasopressin receptors



3) Mesencephalon tegmentum

- The behavior of colonial prairie vs. solitary meadow voles can be attributed to hormone receptor density



3) Mesencephalon - tegmentum

- **Tegmentaum: Substantia nigra**

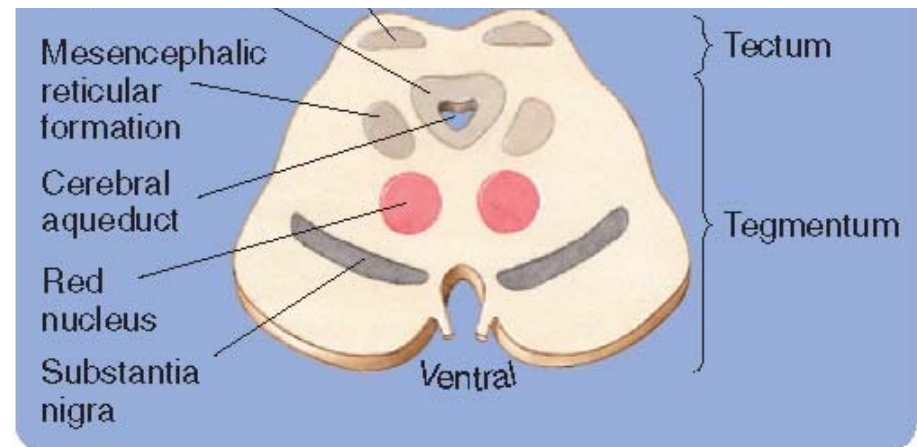
- Sensorimotor function
- Compromised in Parkinson's disease and Schizophrenia

- **Red nucleus**

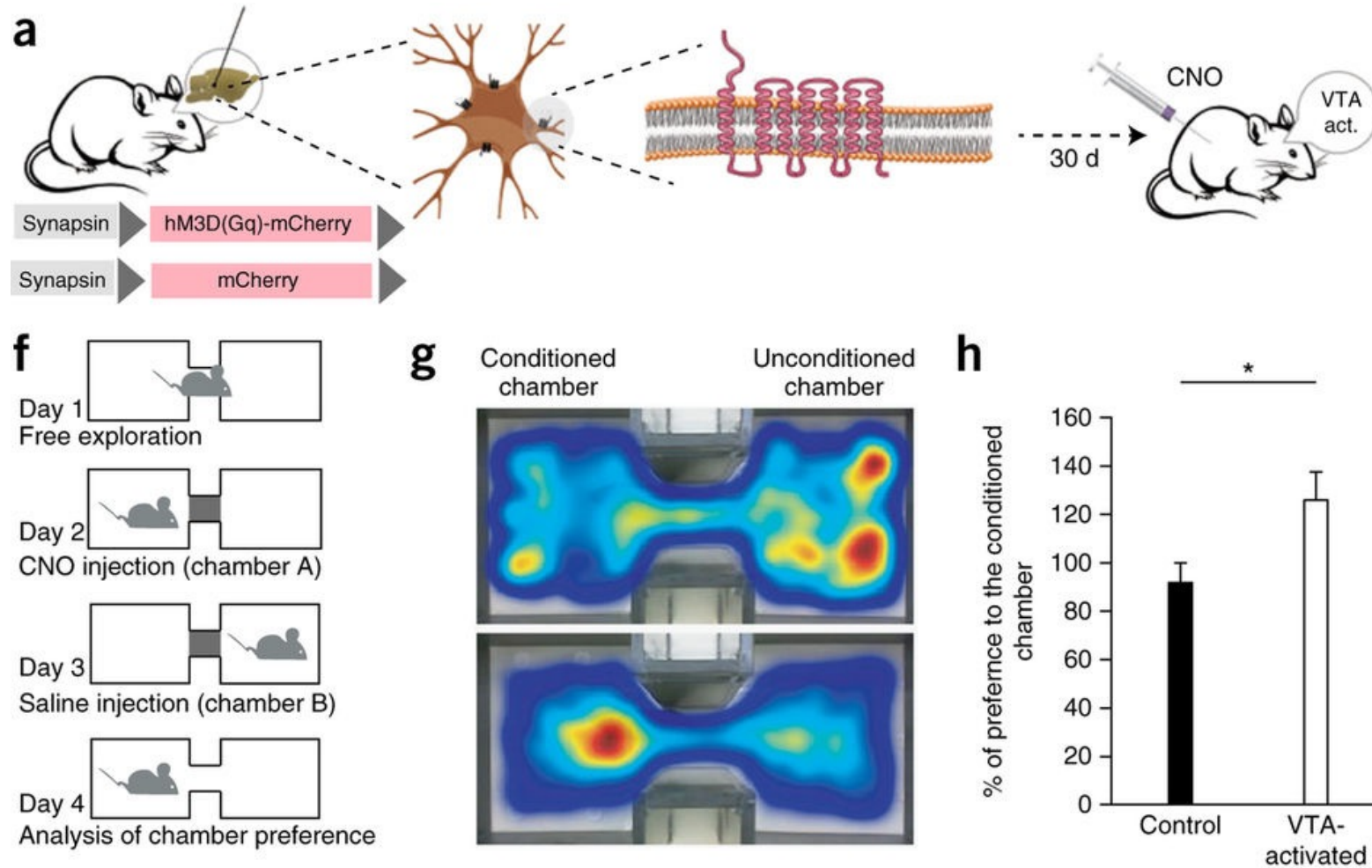
- Sensorimotor function - Gait

- **Ventral tegmental area**

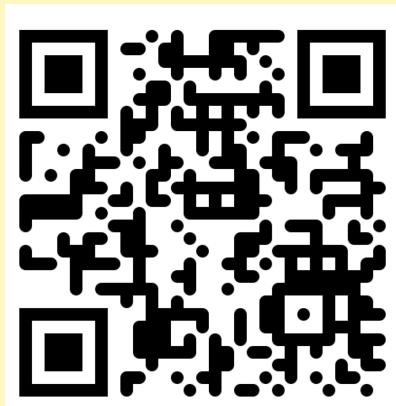
- Reward system (mesocorticolimbic)



- **Activating the VTA drives reward-related behaviors**

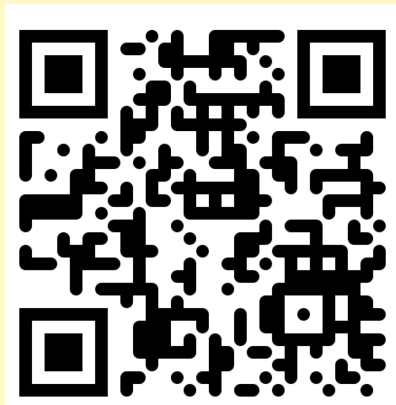


What have we learnt so far?



What are the major subdivisions of the human brain from ventral to dorsal?

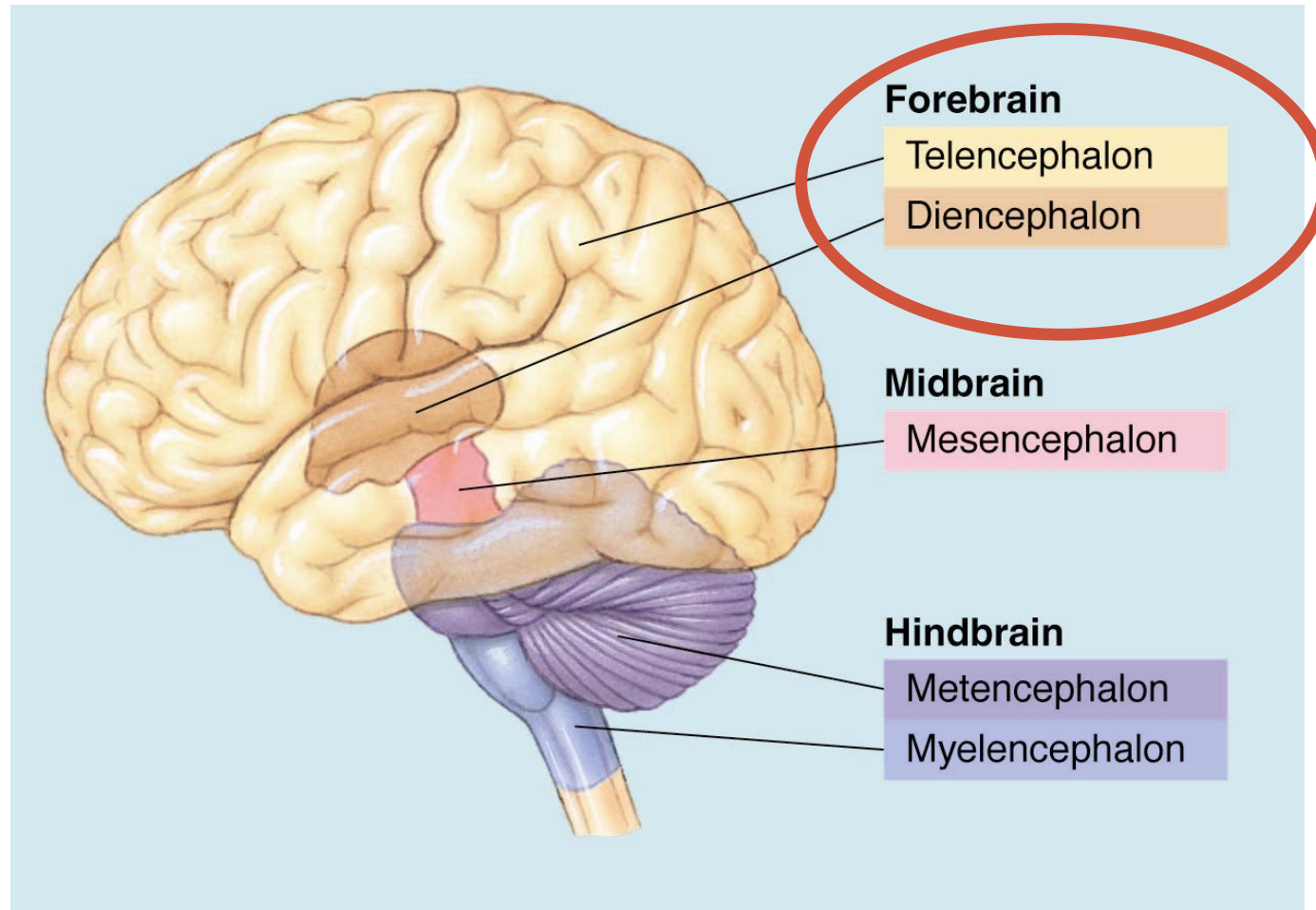
- A. Telencephalon-Diencephalon-Mesencephalon-Metencephalon-Myelencephalon
- B. Myelencephalon-Metencephalon-Mesencephalon-Diencephalon-Telencephalon
- C. Metencephalon-Mesencephalon-Telencephalon-Diencephalon-Myelencephalon
- D. I have no clue



Which of the following brain areas is most implicated in sleep regulation?

- A. Ventral tegmental area
- B. Cerebellum
- C. Pons
- D. Choroid plexus

The 5 Major Division of the Brain



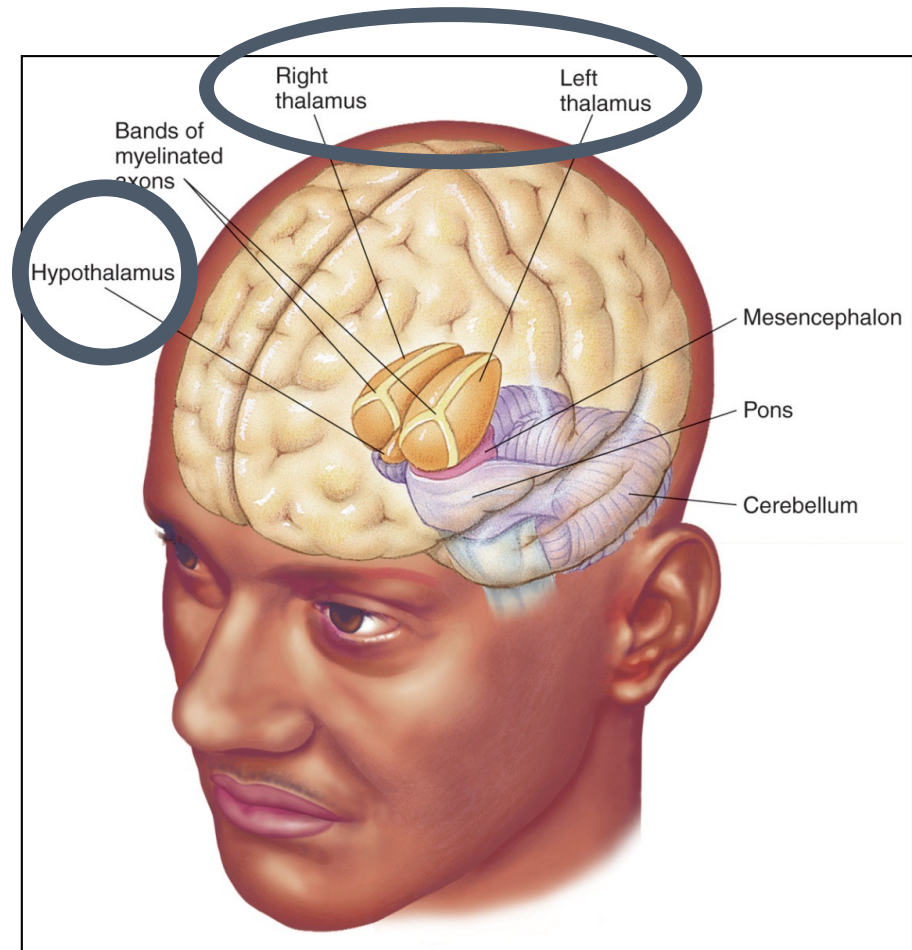
4) Diencephalon

- **Thalamus**

- Contains several sensory relay nuclei

- **Hypothalamus**

- located below (“hypo”) thalamus

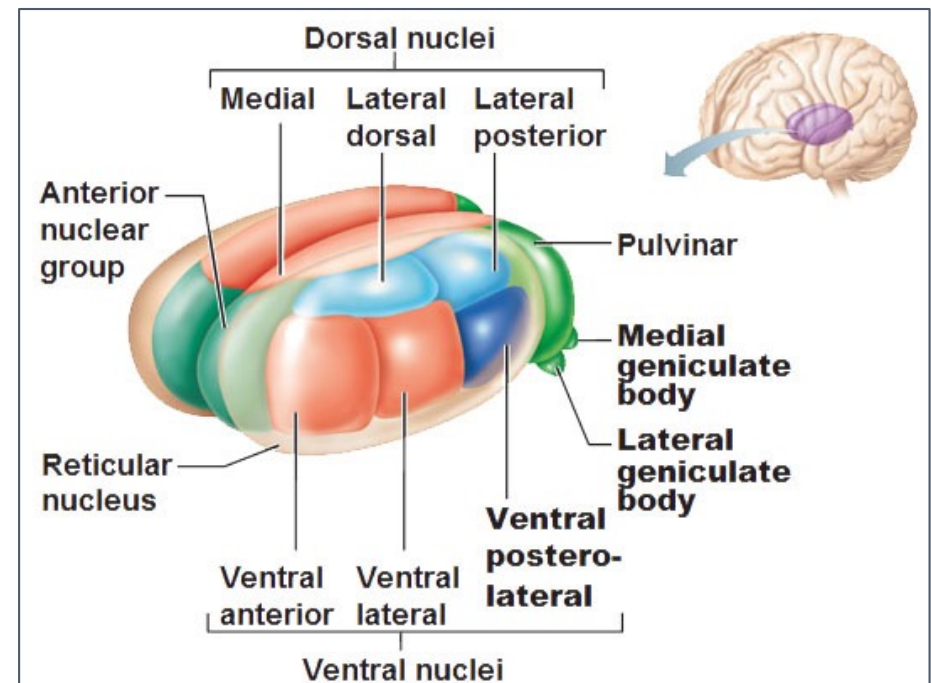


4) Diencephalon

- **Thalamus**

- Major Sensory Relay Nuclei

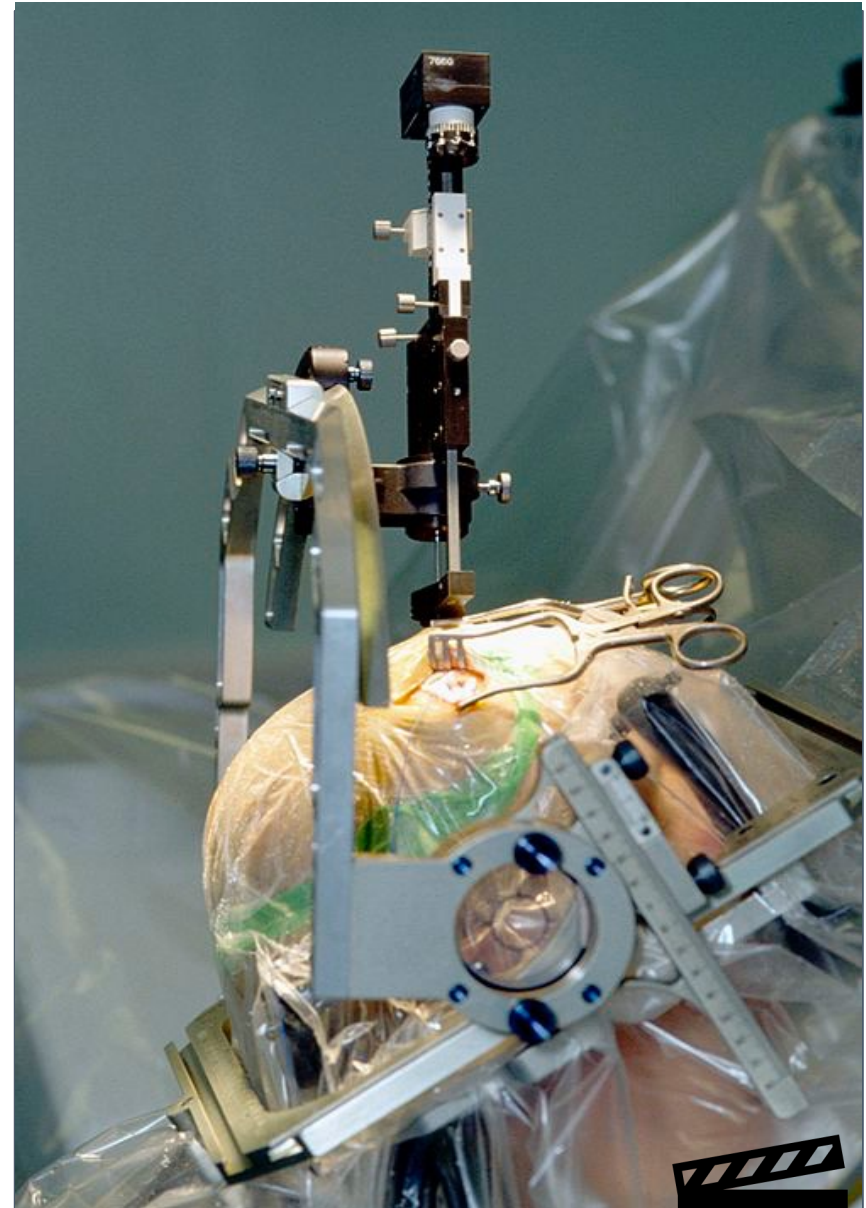
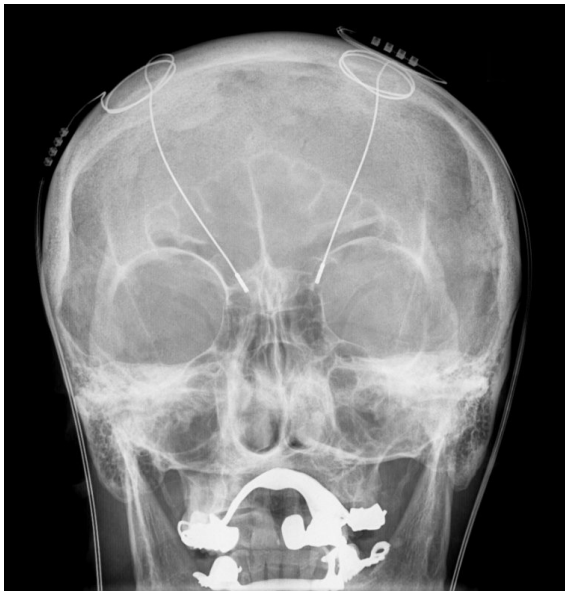
- Vision: Lateral Geniculate Nucleus
- Hearing: Medial Geniculate Nucleus
- Touch: Ventral Posterior Nucleus
- Smell: Medial Dorsal Nucleus
- Taste: Ventral Posterior Nucleus



4) Diencephalon

- **Thalamus**

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



- **Deep brain stimulation (DBS) – supplemental information**

- Currently over 160'000 patients implanted worldwide

- Essential tremor*
- Parkinson's disease*
- Dystonia*
- Obsessive compulsive disorder (OCD*)
- Epilepsy*
- *Depression*
- *Addiction*
- *Anorexia*



Approved treatments

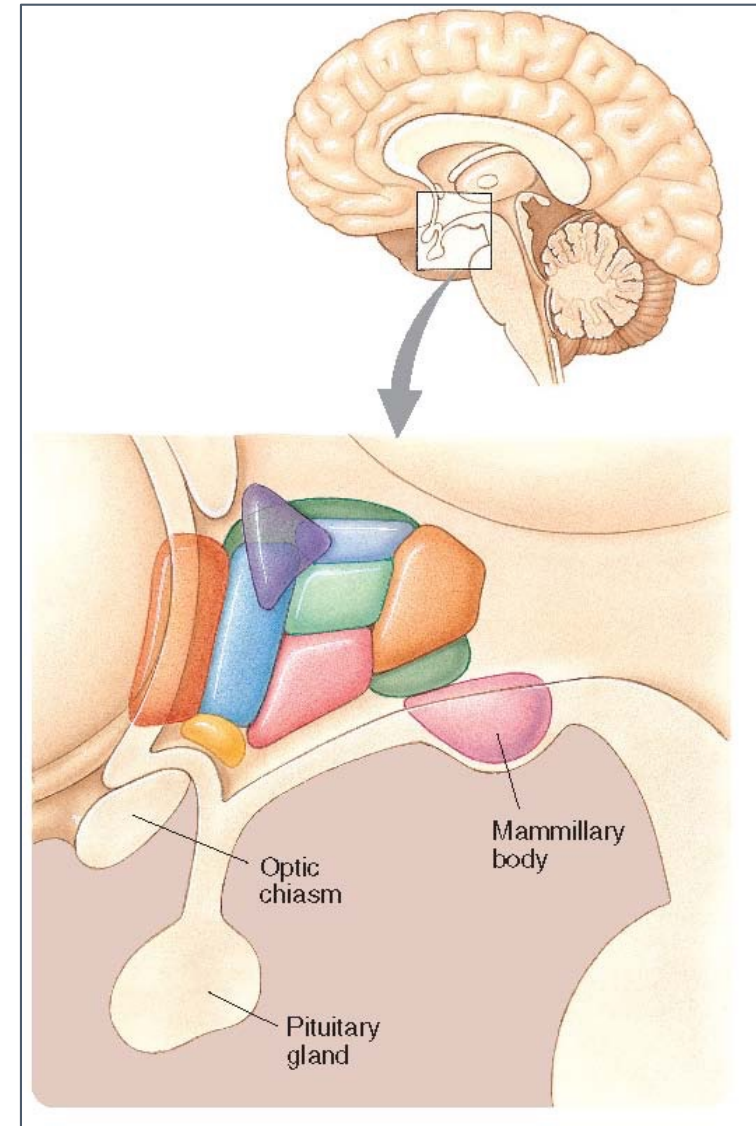


in clinical trials

4) Diencephalon

- **Hypothalamus**

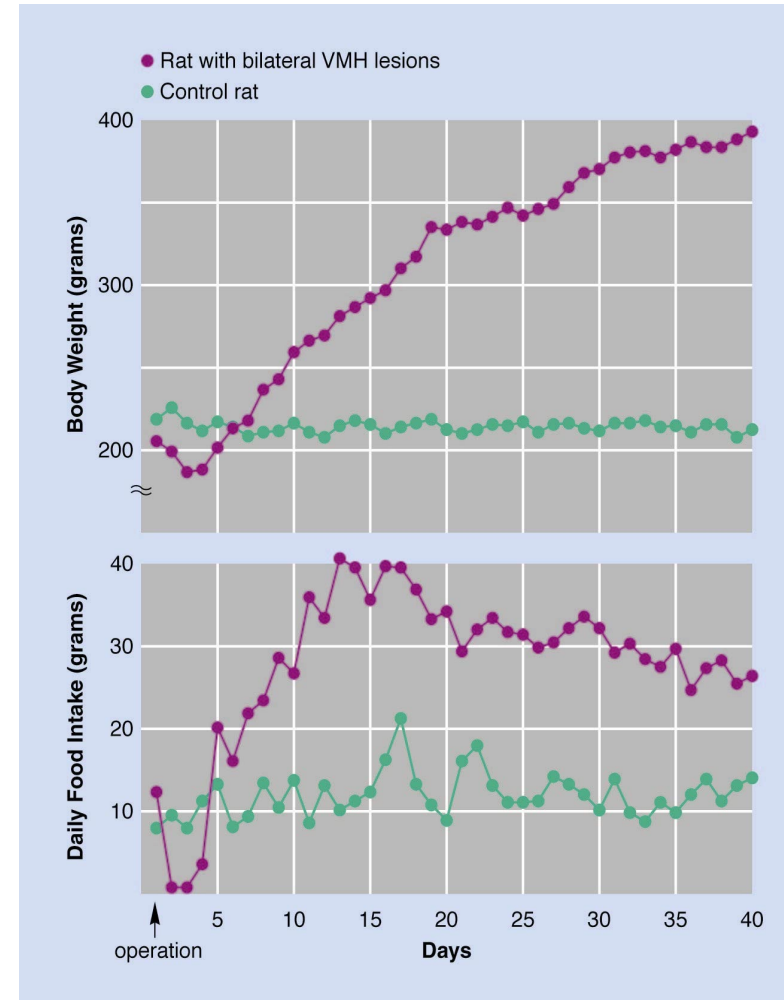
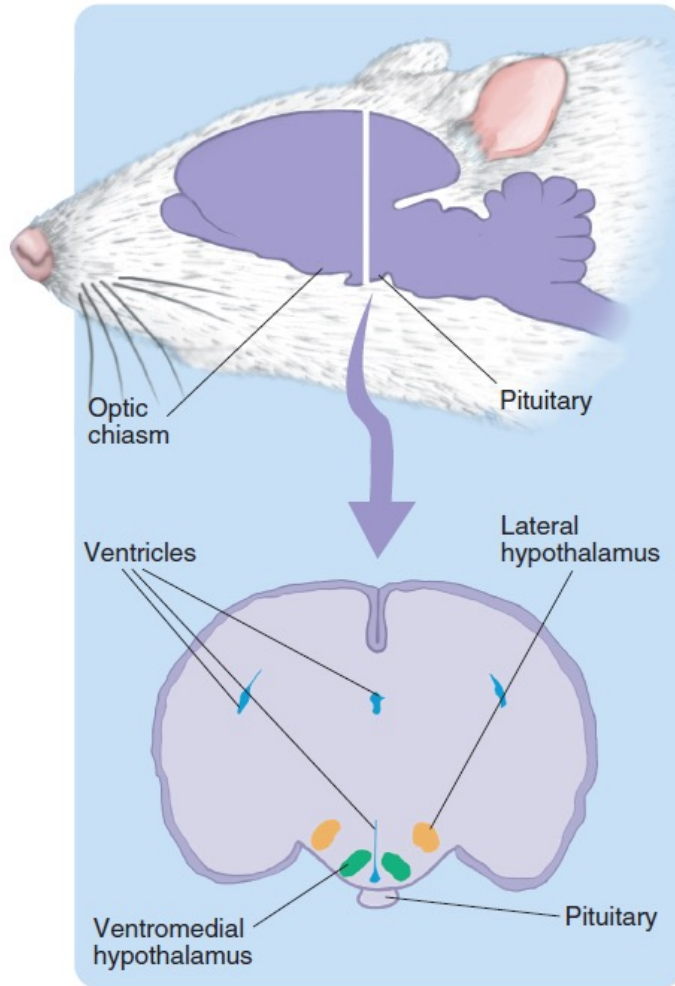
- Contains several subdivisions (nuclei)
- Interconnected with limbic system regions (e.g. HPA axis)
- Detection of “need” states
 - hormone regulation
 - body temperature regulation
 - fluid & nutrient regulation



- Hypothalamic nuclei – supplemental information:**

<i>Nucleus</i>	<i>Zone(s)</i>	<i>Region(s)</i>	<i>Functions</i>
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

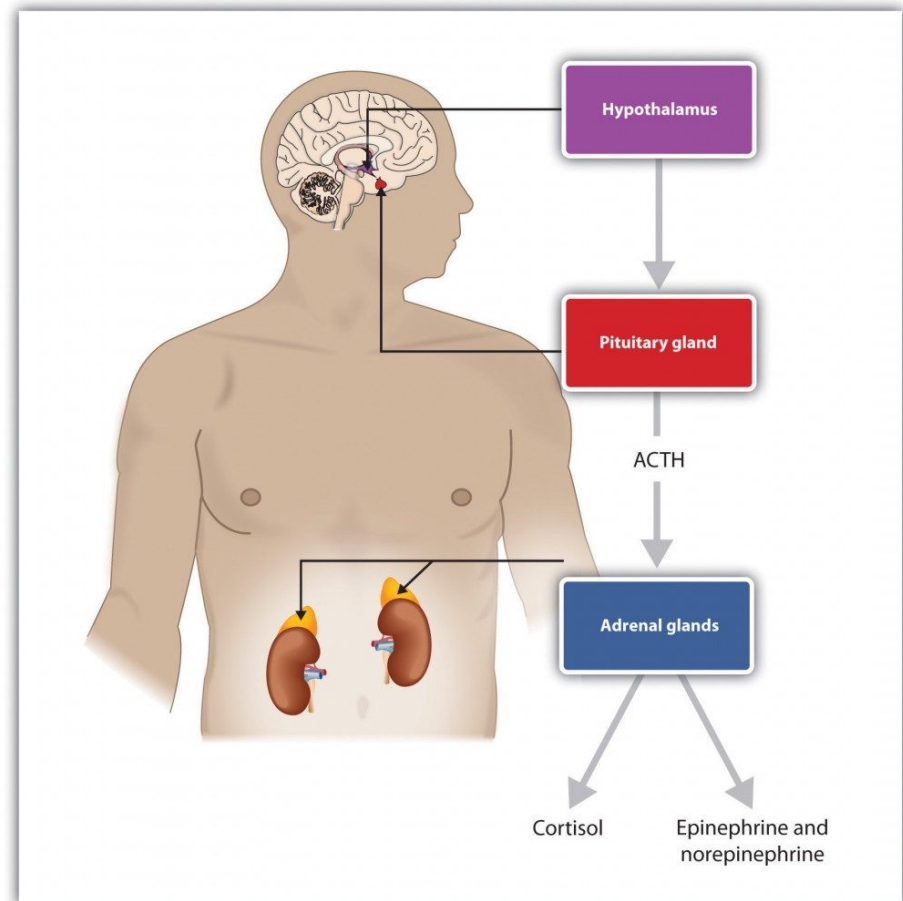
Supplemental information: Bilateral ventromedial hypothalamic lesions -> abnormal feeding behavior



4) Diencephalon

- **Hypothalamus**

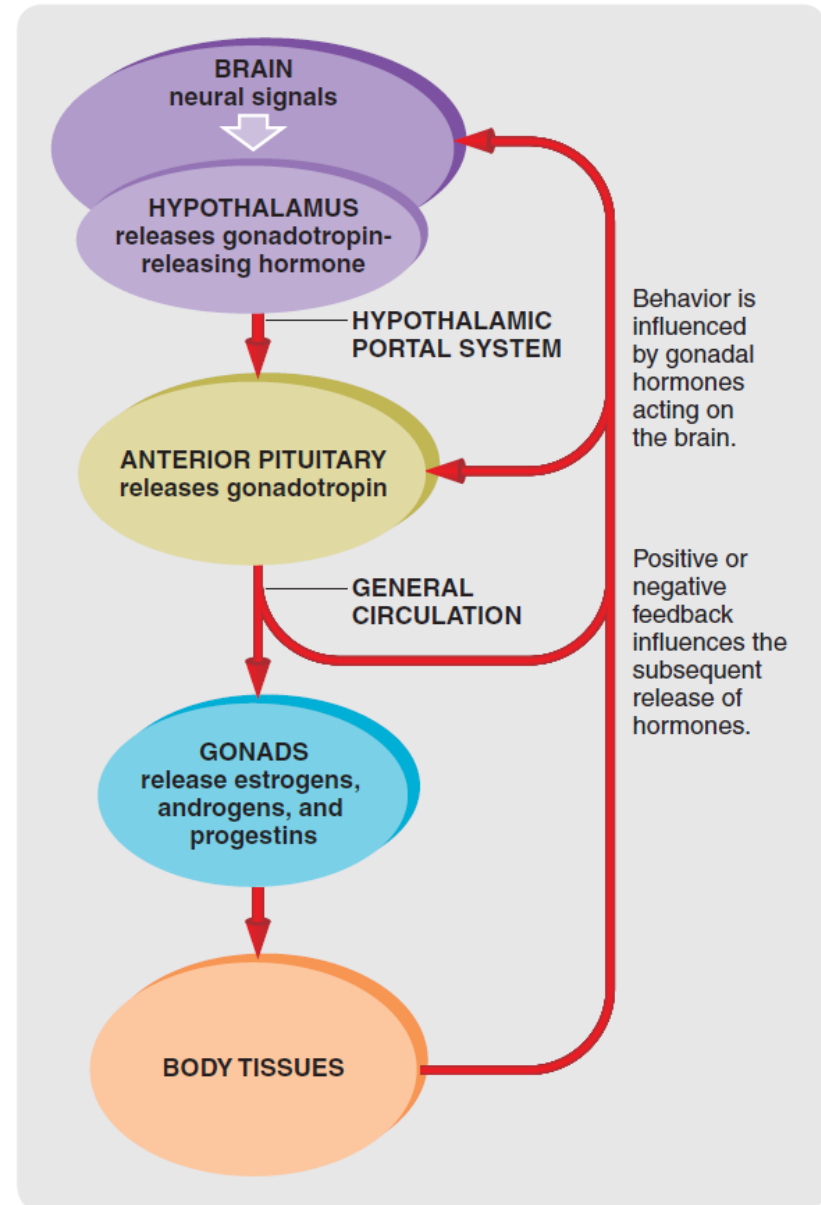
- Part of the **HPA axis**
 - Hypothalamus
 - Pituitary
 - Adrenal glands



4) Diencephalon

• Hypothalamus

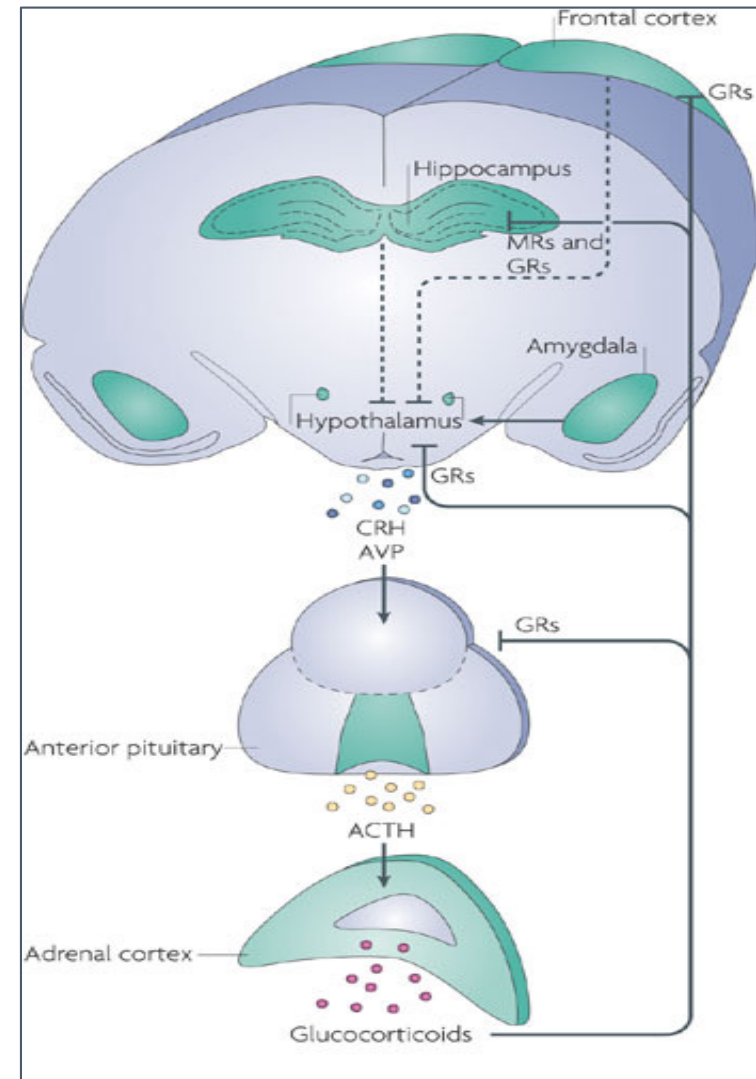
- Part of the **HPA axis**
 - Hypothalamus
 - Pituitary
 - Adrenal glands
- Involved in reproductive functions and behavior
 - Secretion of gonadal hormones
 - Estrogens, androgens, progestins



4) Diencephalon c'd

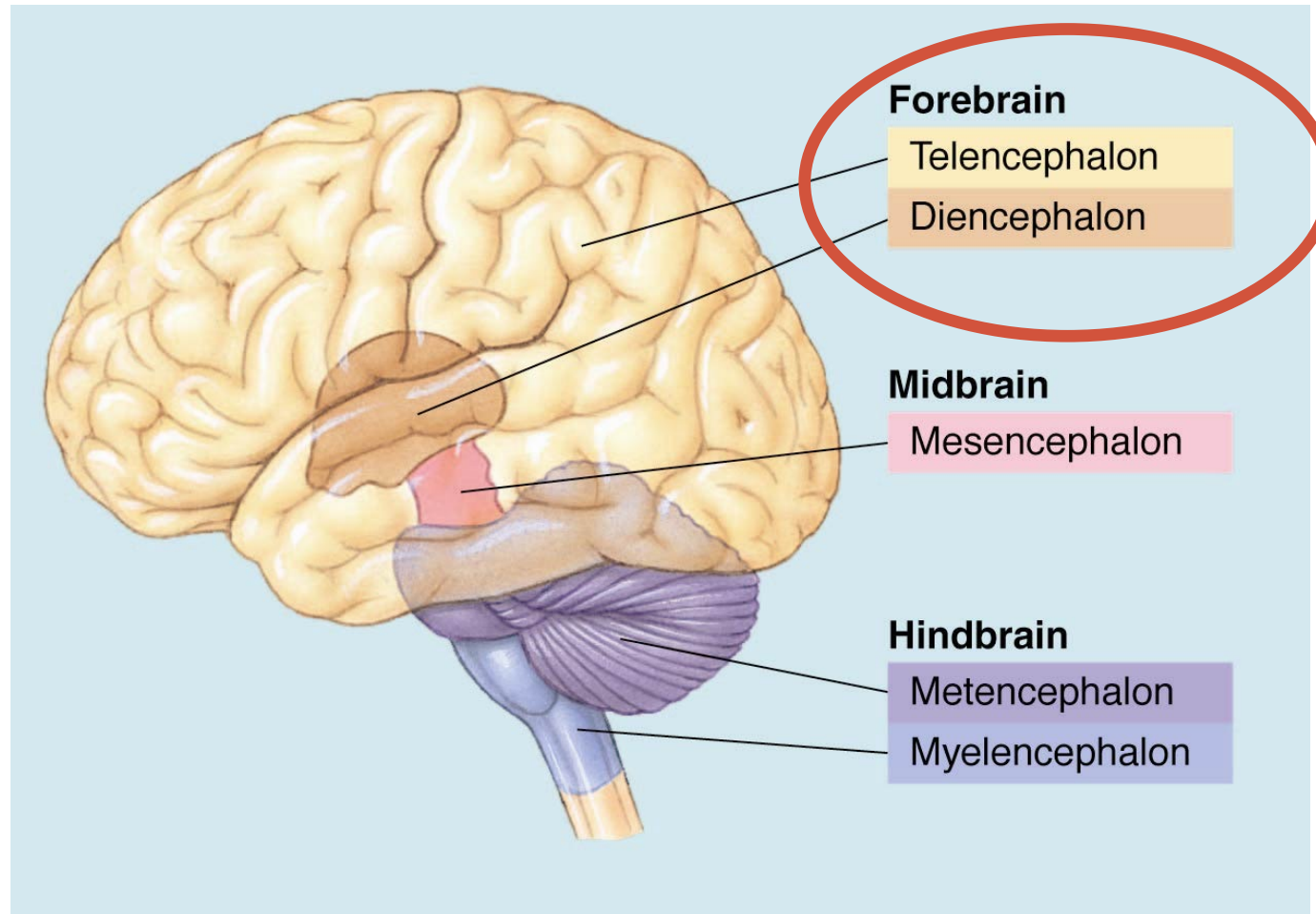
• Hypothalamus

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



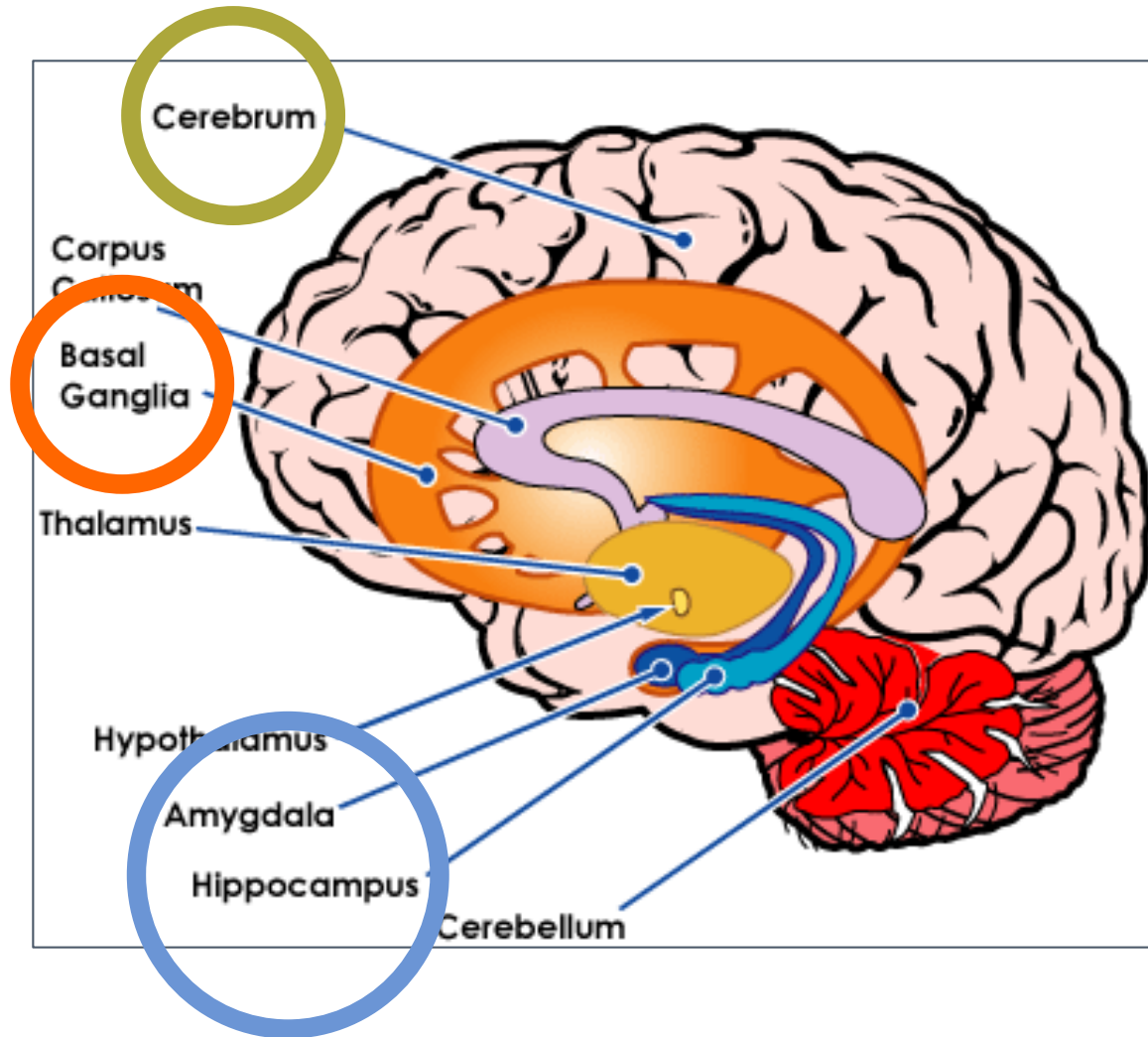
CRH, corticotropin releasing hormone
AVP, arginine vasopressin
ACTH, adrenocorticotropin
GR, glucocorticoid receptor

The 5 Major Division of the Brain



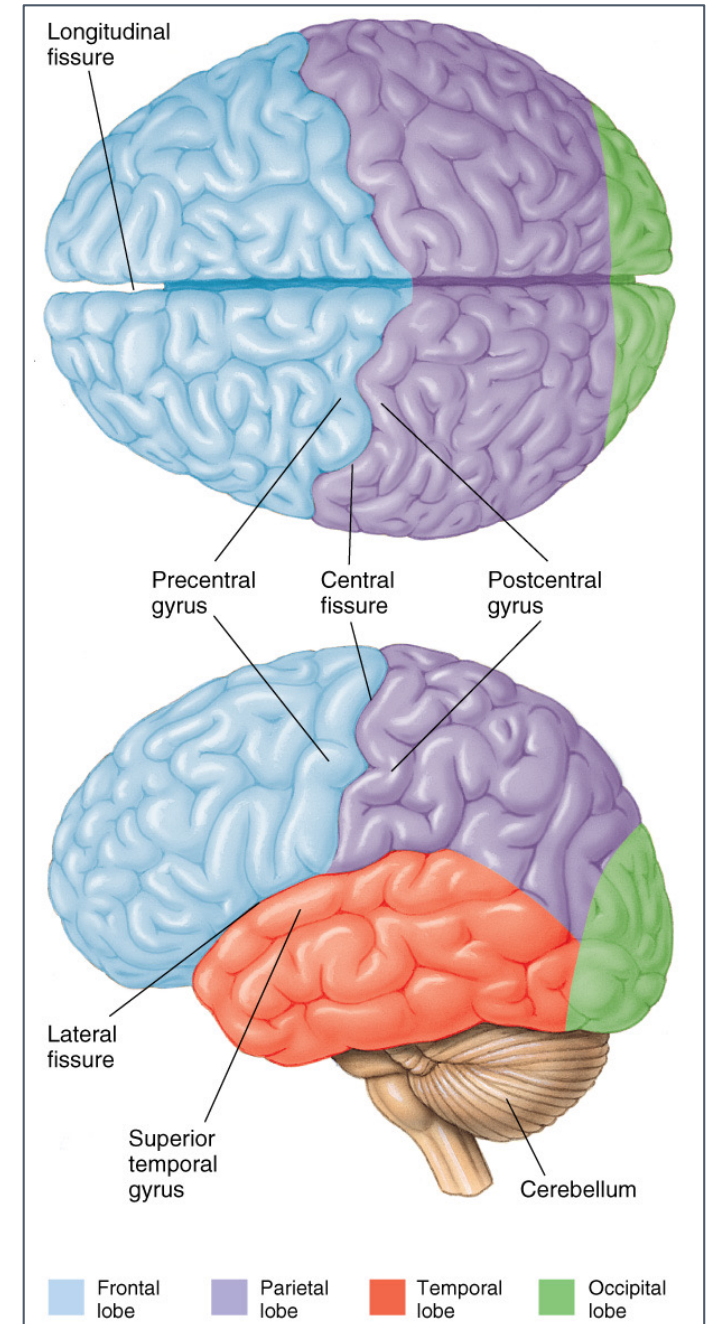
5) Telencephalon

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



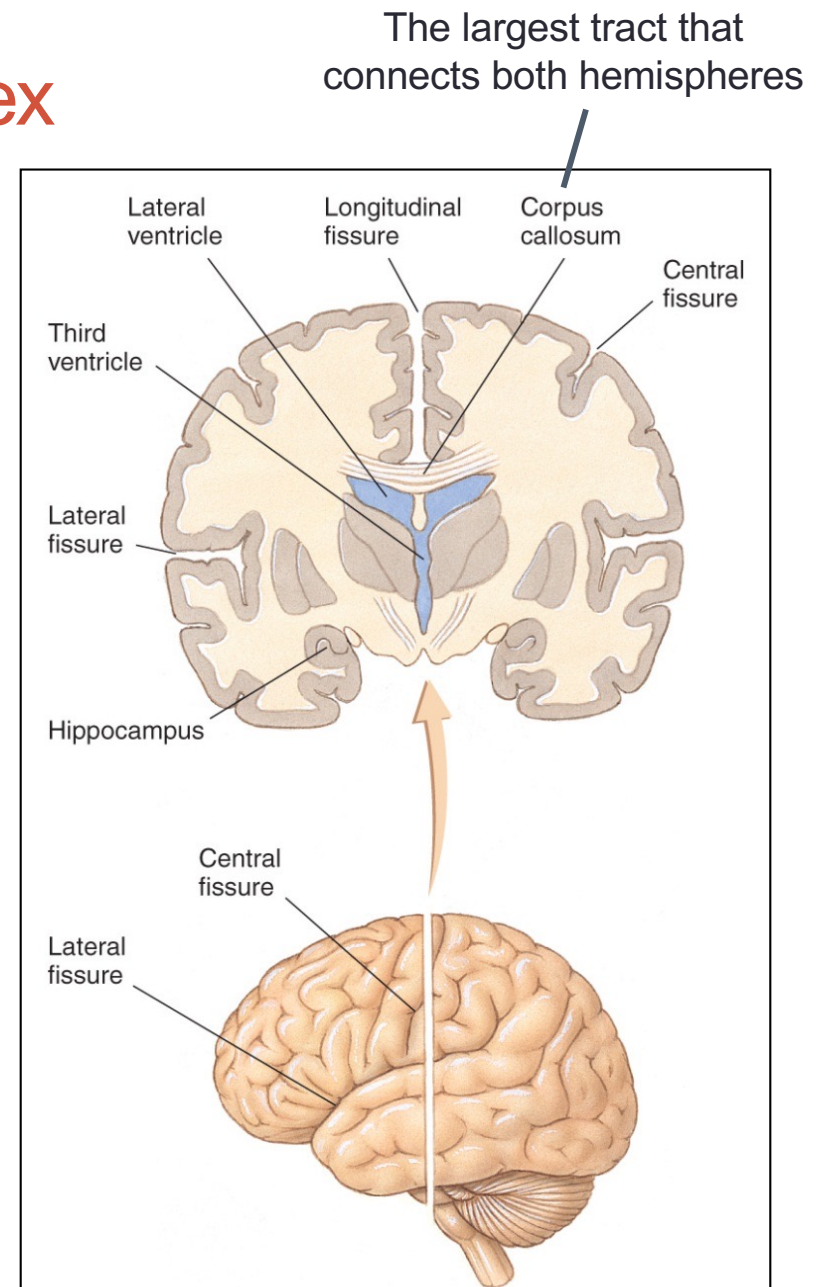
5) Telencephalon – Cerebral cortex

- 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

- Convolutions serve to increase surface area
- Characterized by
 - **gyri** (sg: gyrus)
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 - 4 lobes can be identified in the human cerebrum

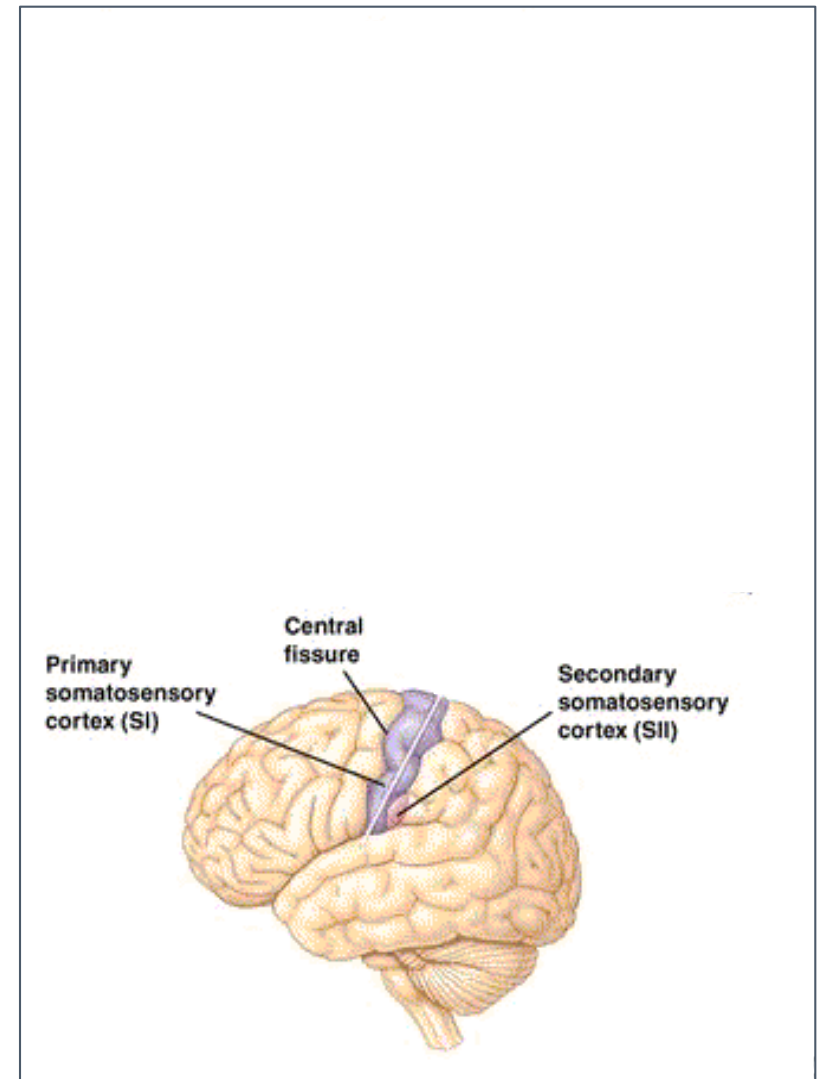


5) Telencephalon – Cerebral cortex

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

5) Telencephalon – Cerebral cortex

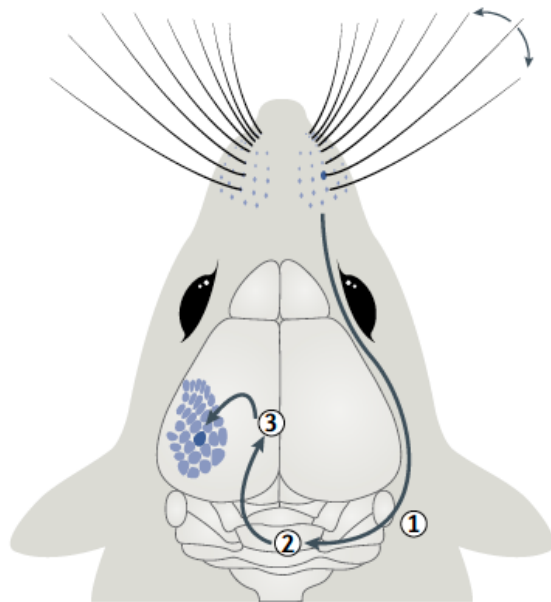
- **Main functions** of the cerebral cortex
 - **Somatosensation**
 - Somatosensory cortex
 - Somatosensory homunculus



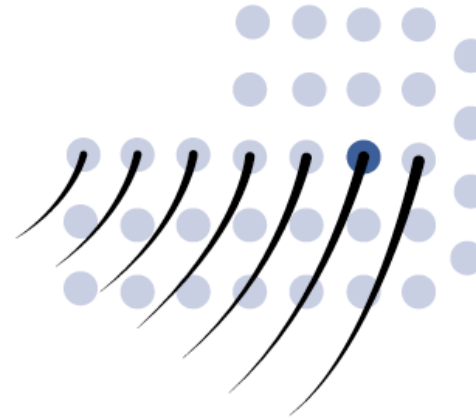
The whisker pathway:



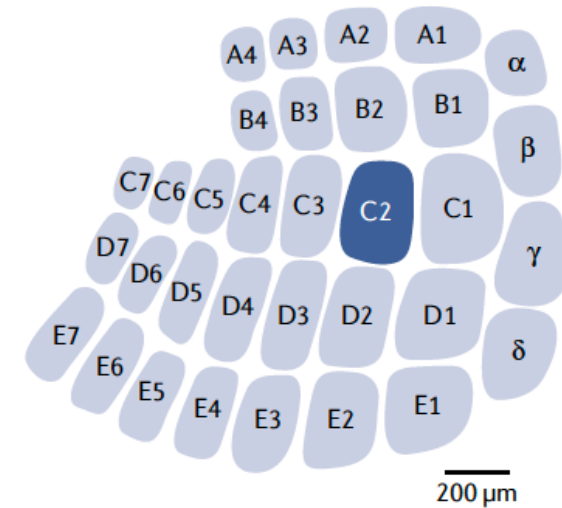
Whisker to cortex



Whisker pad



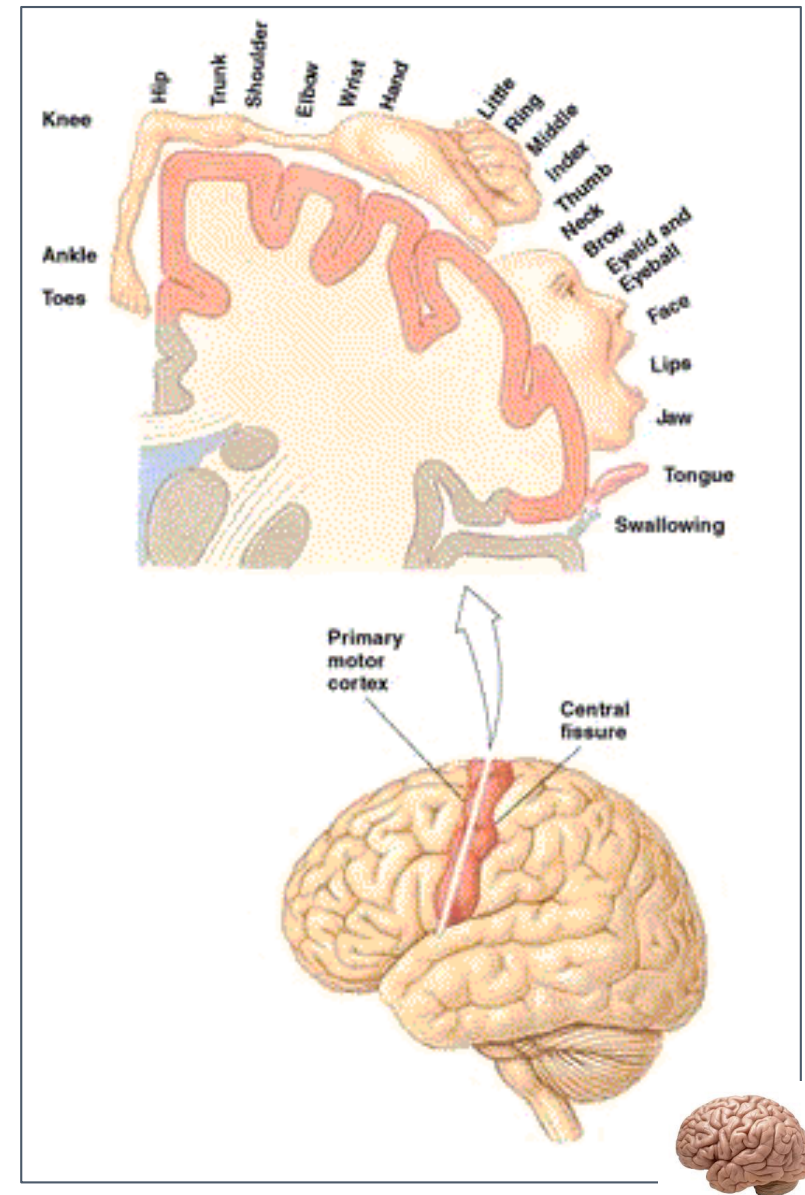
Barrel cortex (wS1)



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

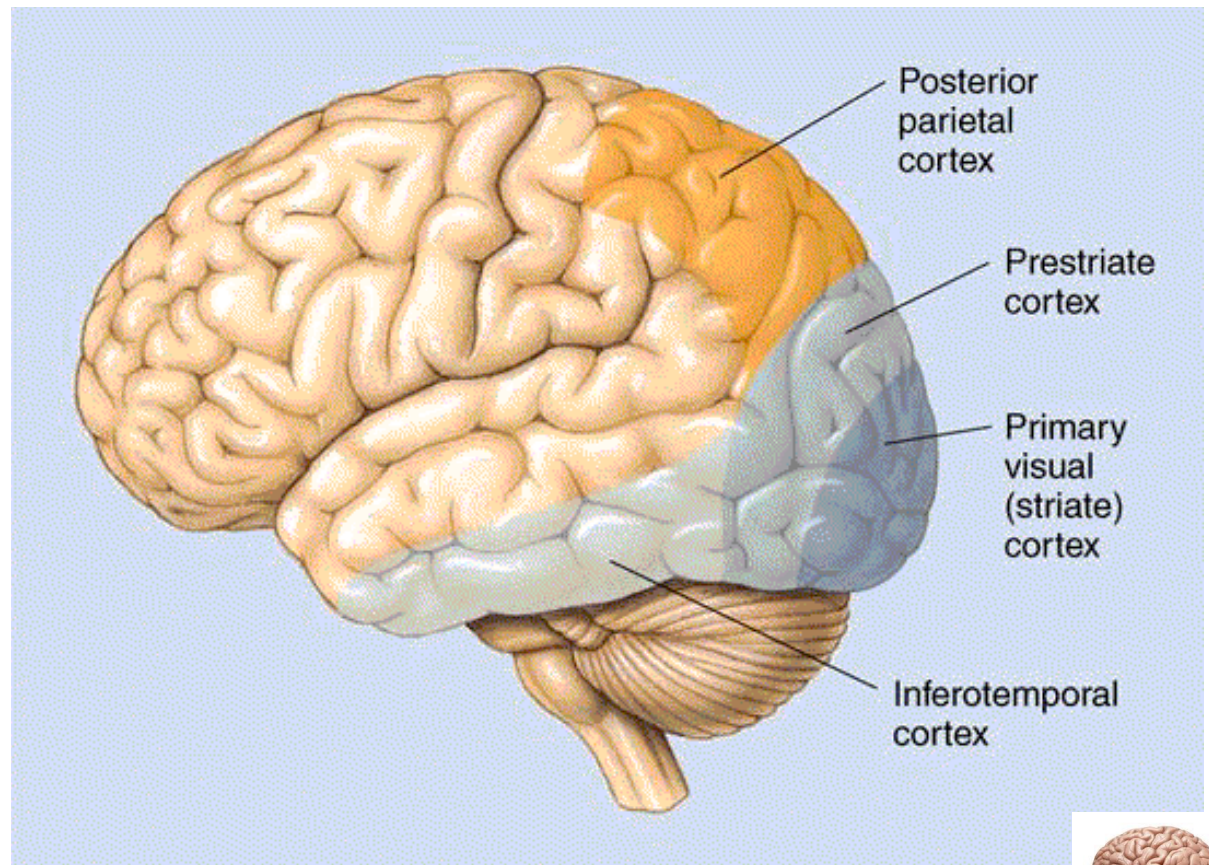


5) Telencephalon – Cerebral cortex

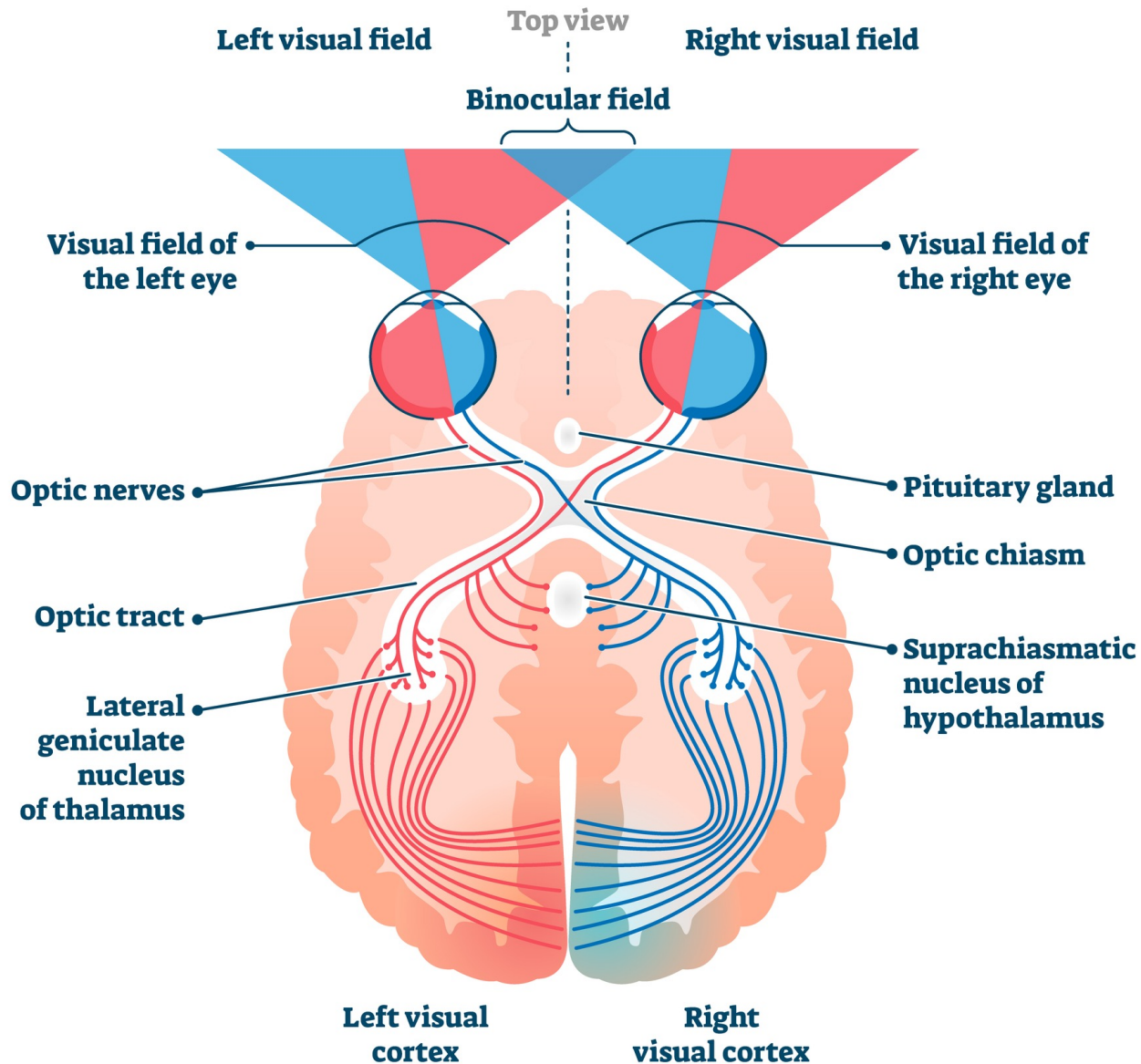
- **Main functions** of the cerebral cortex

- **Vision**

- Visual cortex
- No homunculus



The visual pathway – supplemental information:

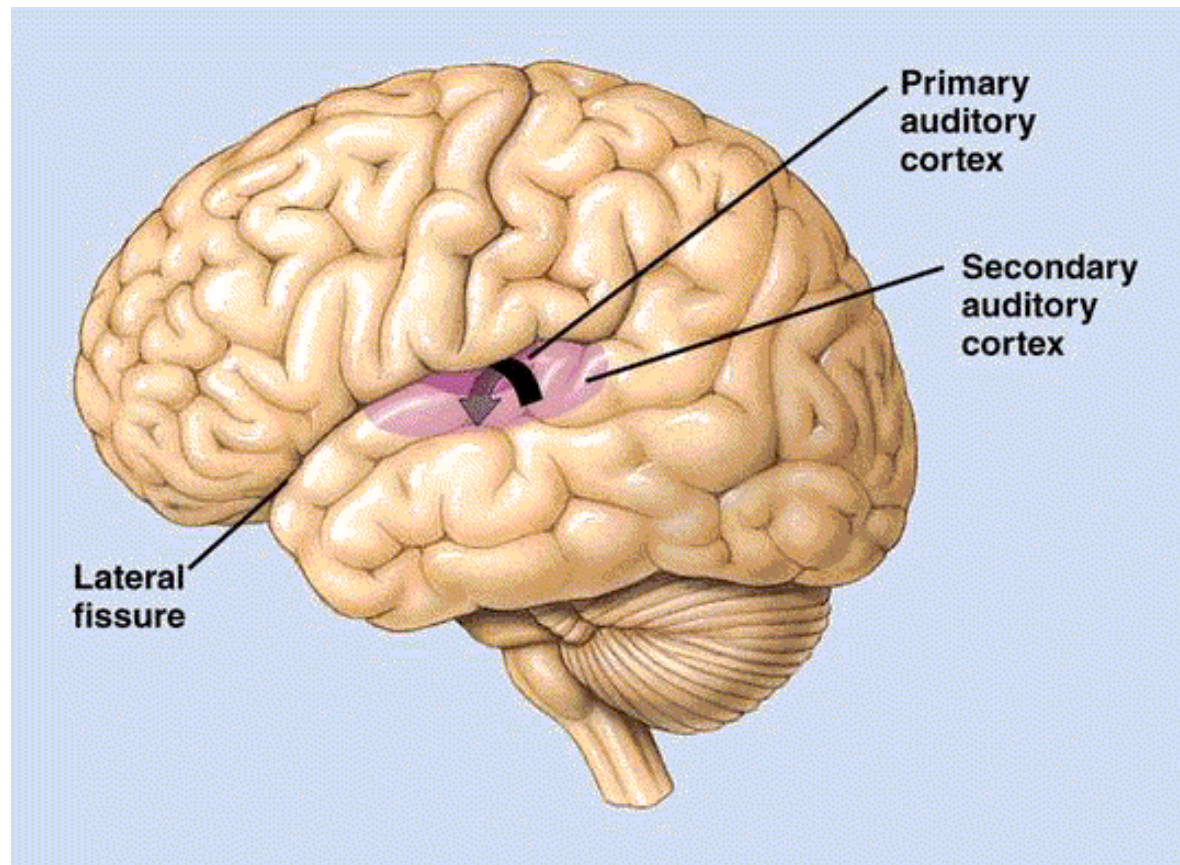


5) Telencephalon – Cerebral cortex

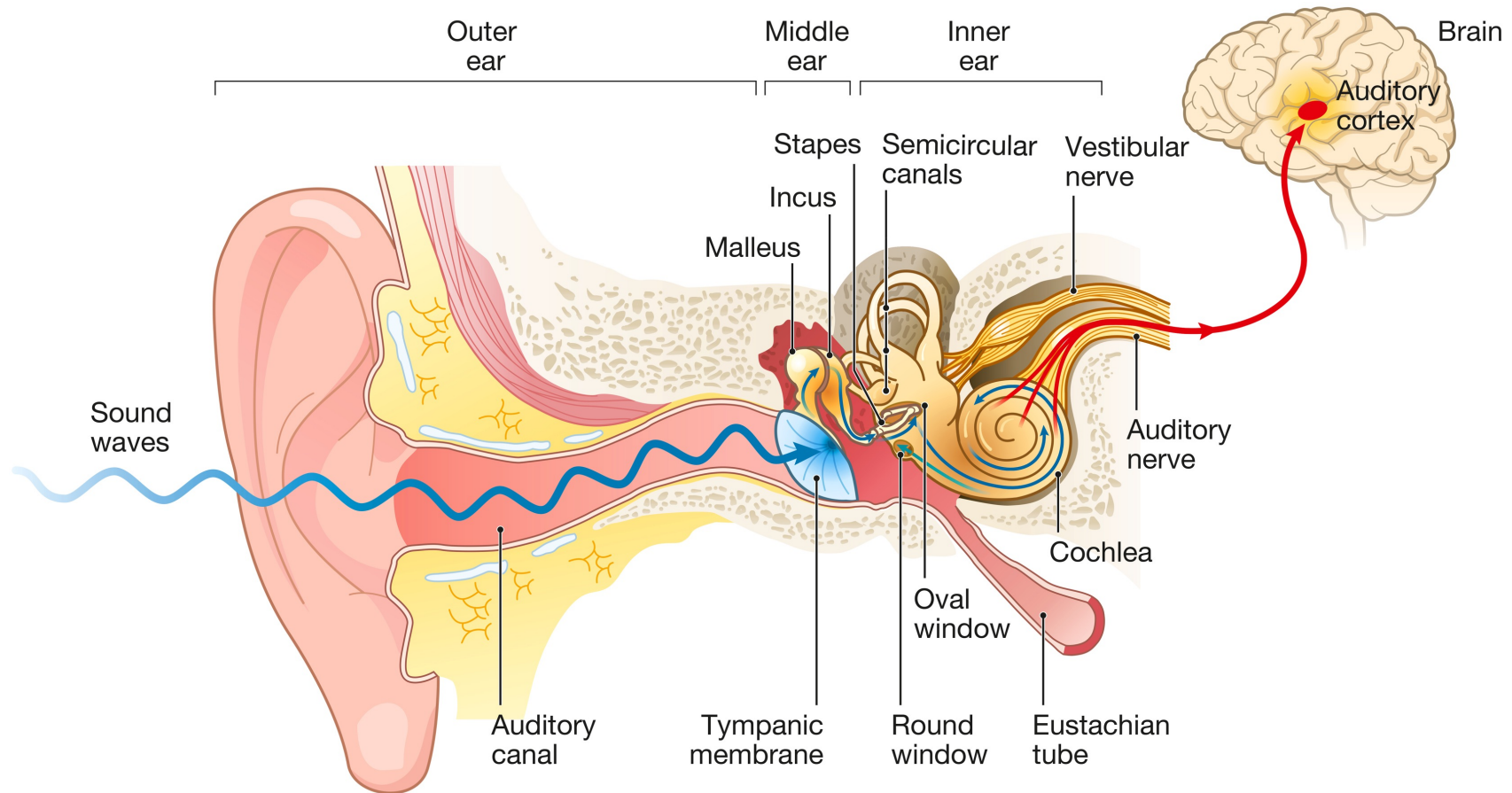
- **Main functions** of the cerebral cortex

- **Audition**

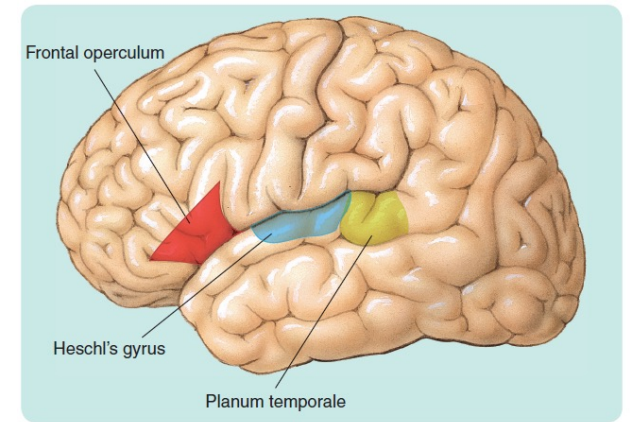
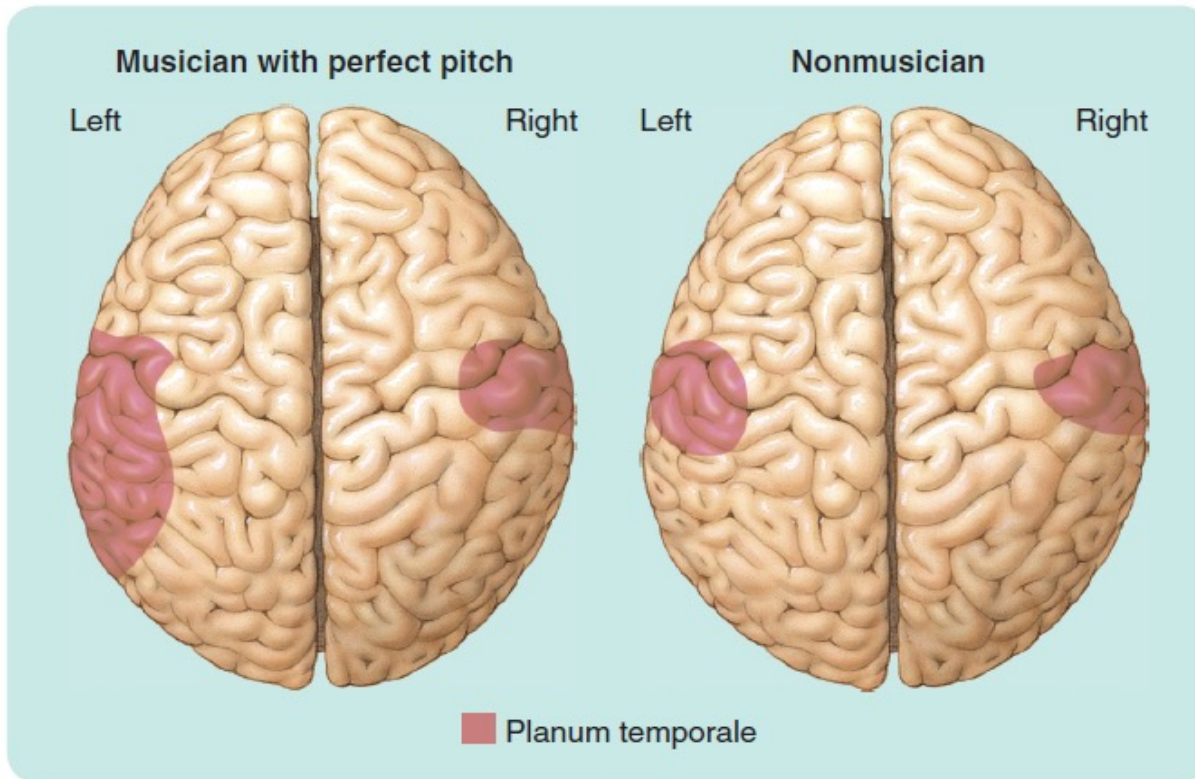
- Auditory cortex
- No homunculus



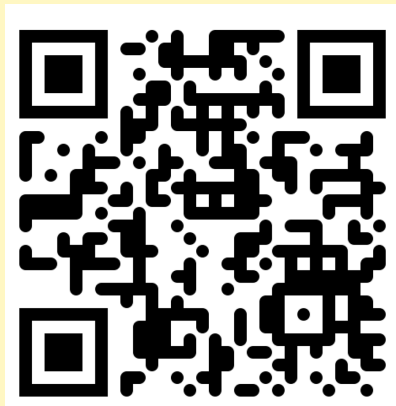
The auditory pathway – supplemental information:



The anatomical asymmetry in the planum temporale of professional musicians

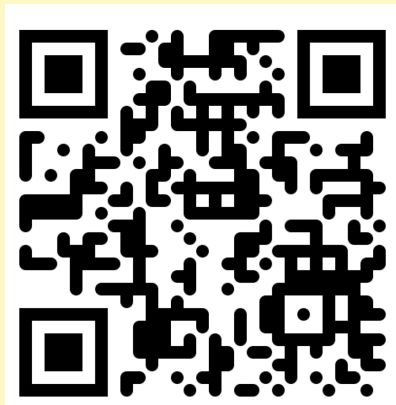


What have we learnt so far?



Which of the following brain areas does not “contain a homunculus”?

- A. Motor cortex
- B. Somatosensory cortex
- C. Central fissure
- D. Planum temporale



Which of the following brain areas is often targeted against essential tremor with deep brain stimulation (DBS)?

- A. Hypothalamus
- B. Thalamus
- C. HPA axis
- D. Ventral tegmental area

5) Telencephalon – Cerebral cortex

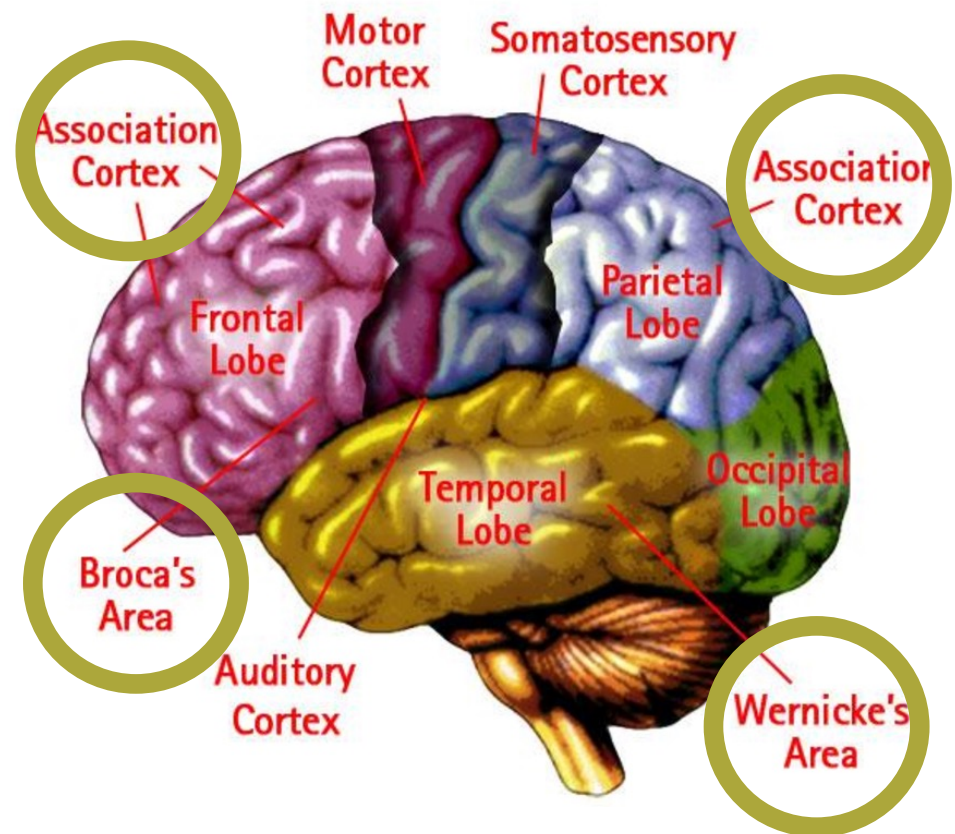
- **Main functions of the cerebral cortex**

- **Language**

- Broca's and Wernicke's area
 - Learning and speaking a language

- **Forming associations**

- Several associative cortices
- Complex mental tasks
 - Planning
 - Social skills



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 o'clock... doctors ... and... teeth...”

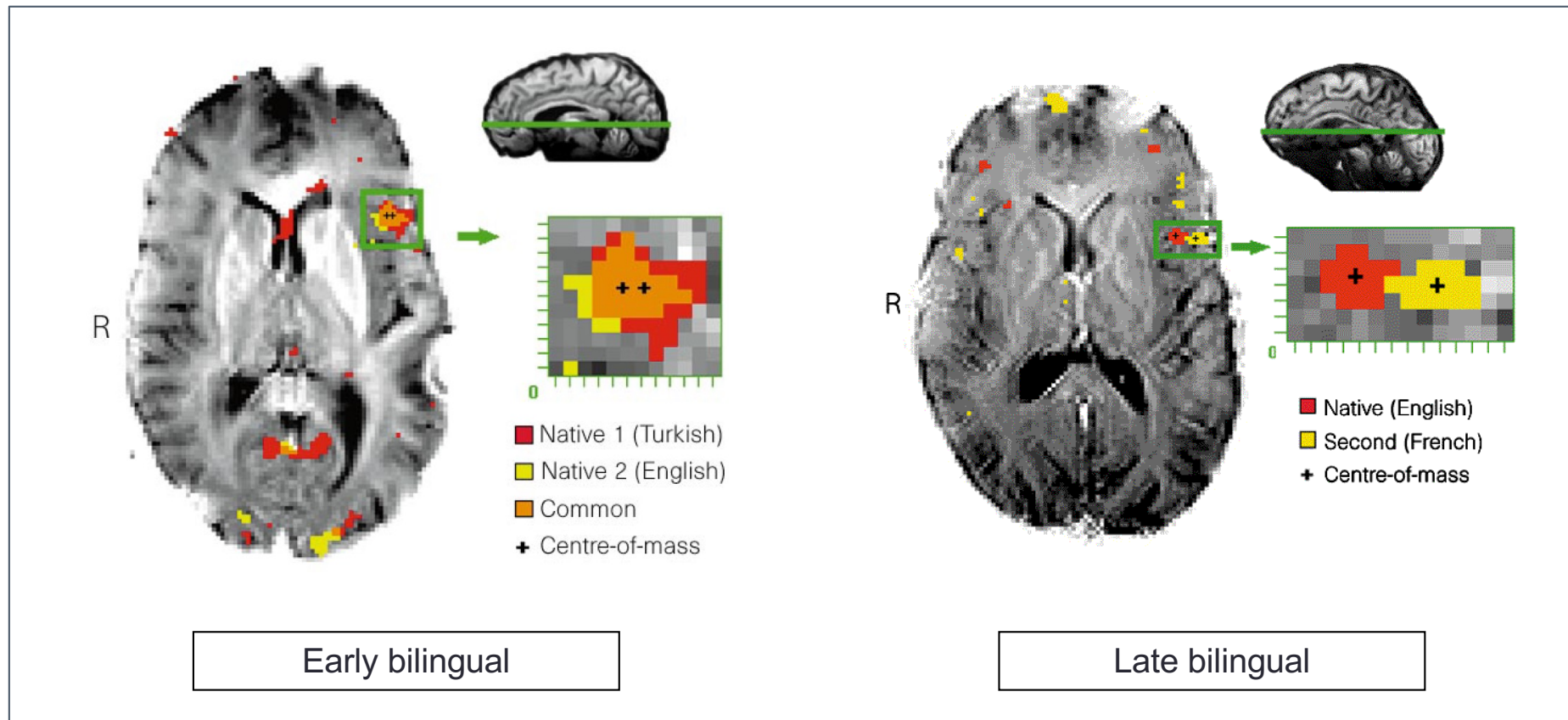
- **Wernicke's aphasia** (receptive aphasia: Meaningless, but normal speech)

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

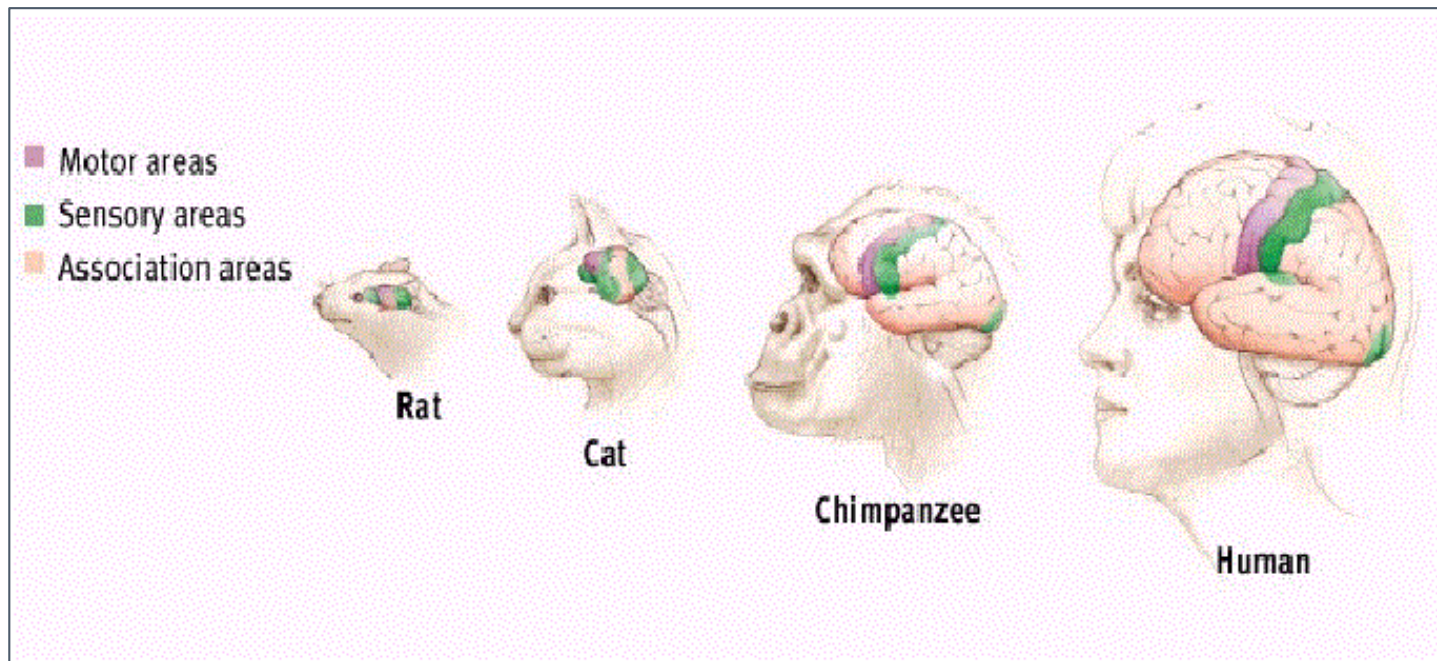
“Mother is away here working her work to get her better, but when she's looking the two boys looking in the other part. She's working another time.”

Timing of learning of a second language – supplemental information

- Broca's area



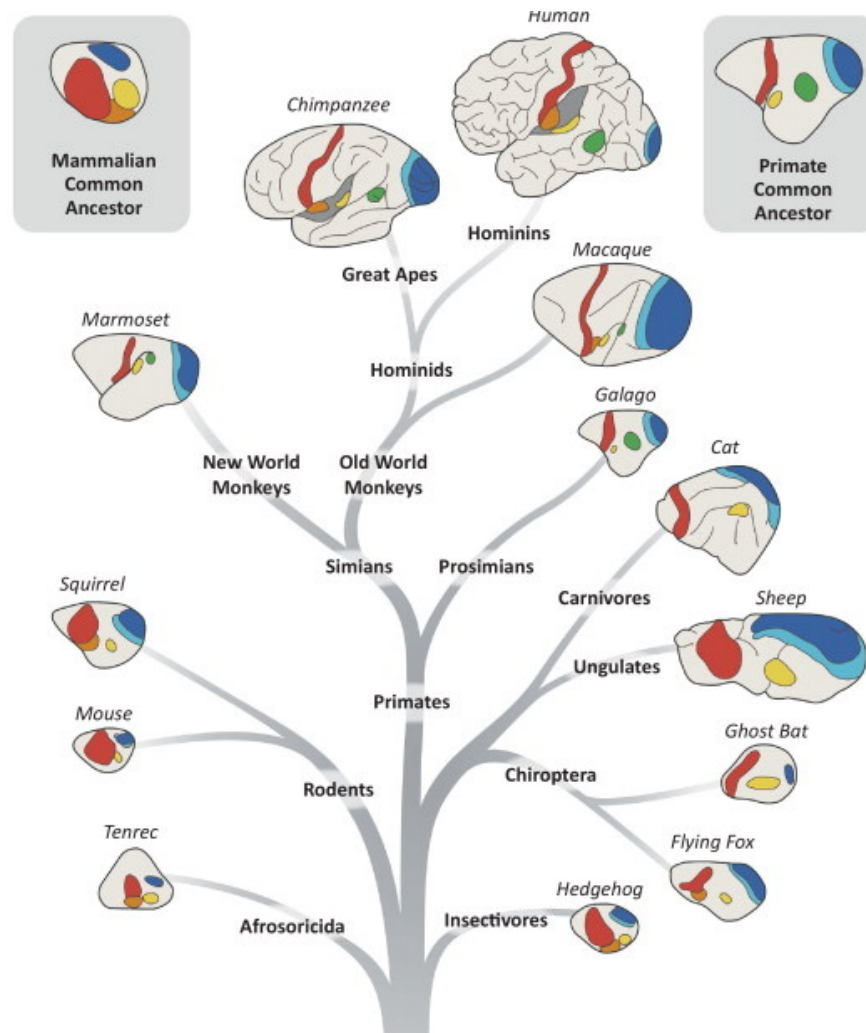
Association cortex increased with complexity in evolution...



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

Brain Anatomy - Divisions and their function

...whereas other cortical areas retained the same size.



Somatosensory cortex

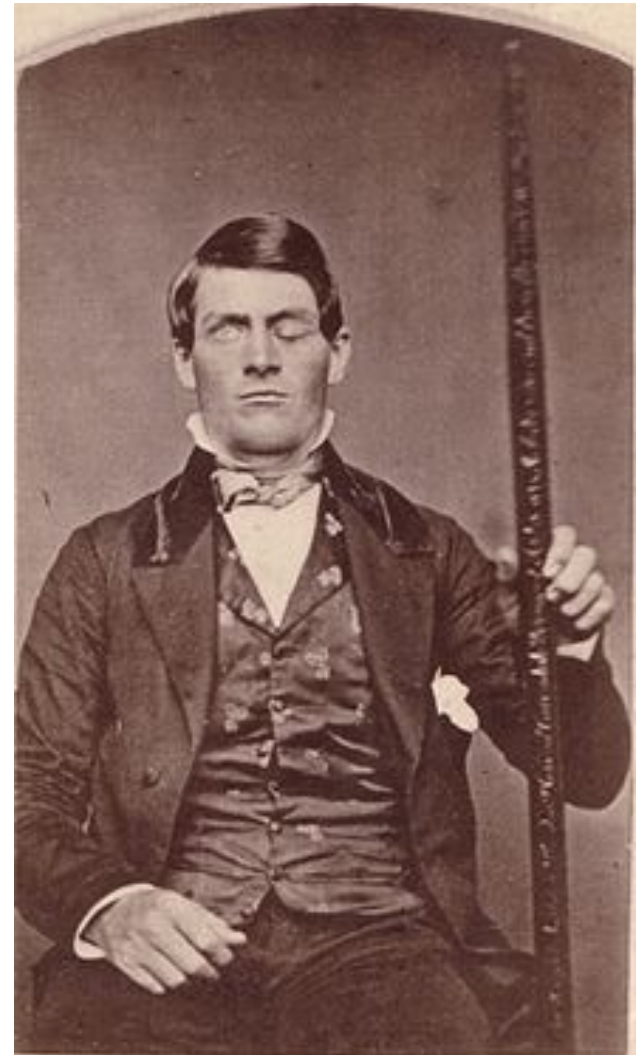
Primary visual cortex

Secondary visual cortex

Auditory cortex

Roles of the association cortex:

- **Learning associations**
- **Complex mental tasks**
 - Planning
 - Social skills



Phineas Gage (1823-1860)

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

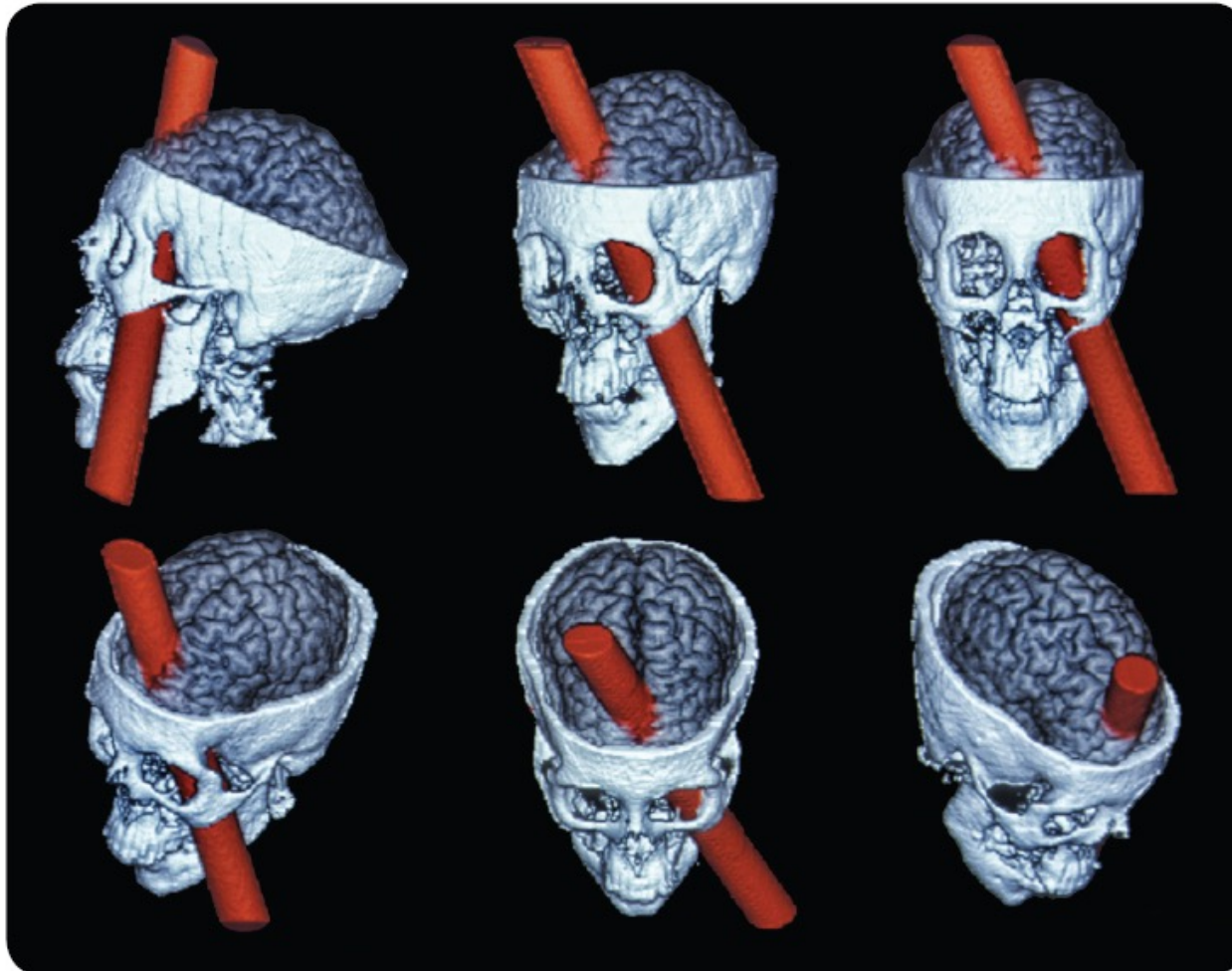
- During railroad construction's in the mid 1800s, a steel rod entered and exited his brain during an explosion...

"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."

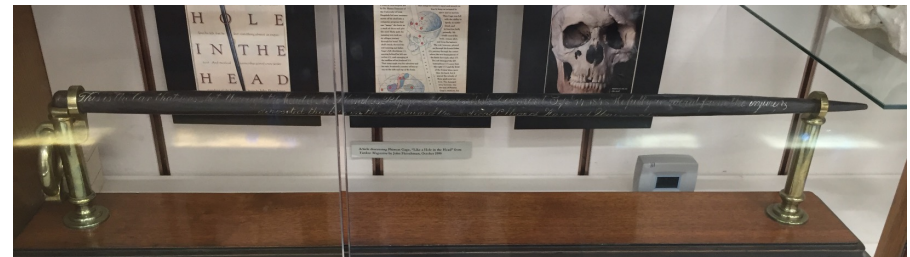
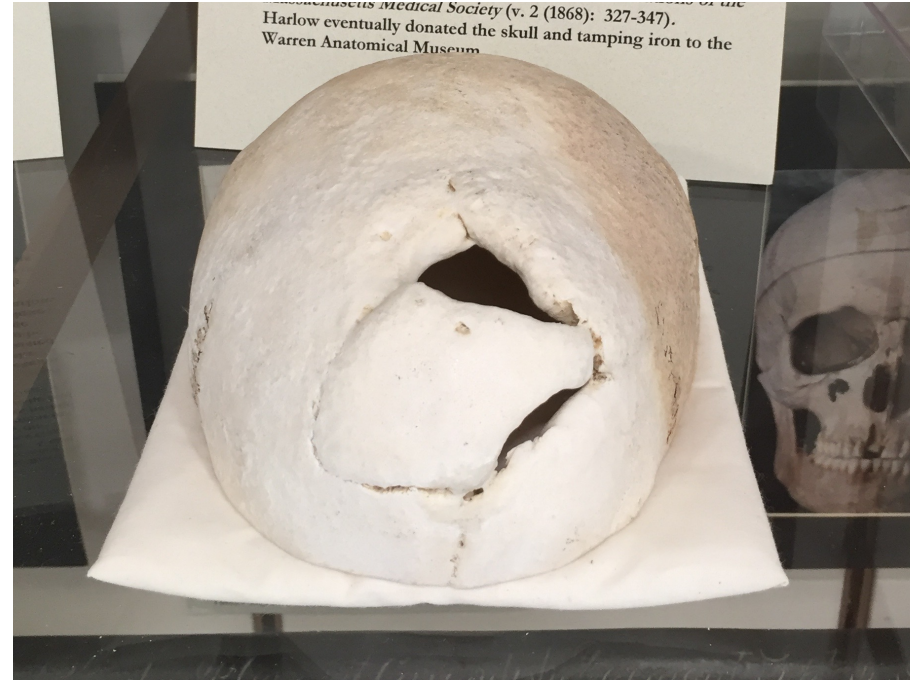
"You will excuse me for remarking here, that the picture presented was, to one unaccustomed to military surgery, truly terrific."

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

The Mind-Blowing Case of Phineas Gage

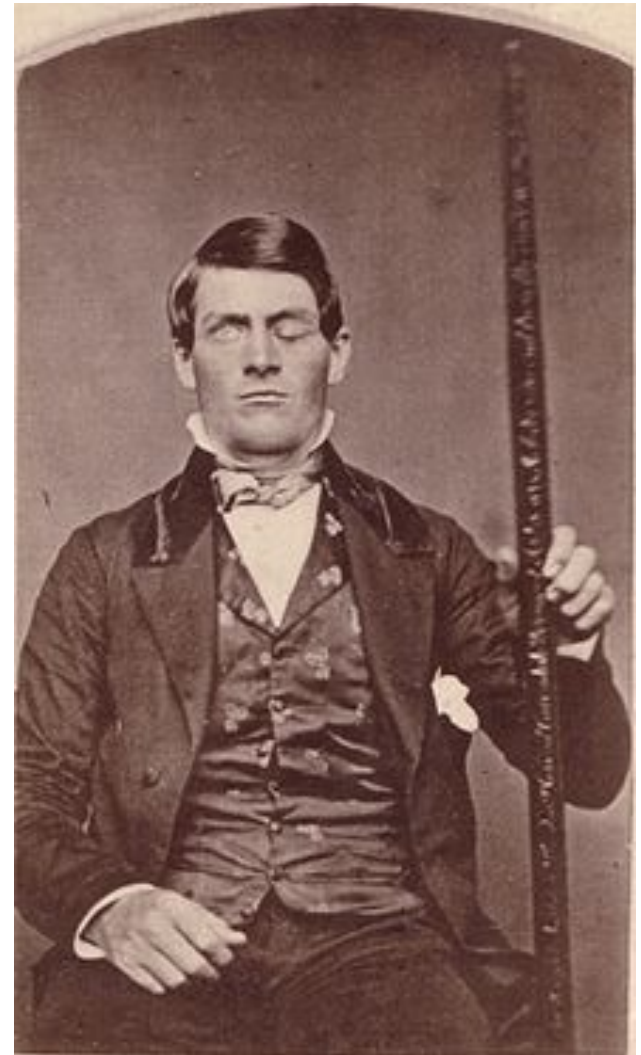


The Mind-Blowing Case of Phineas Gage



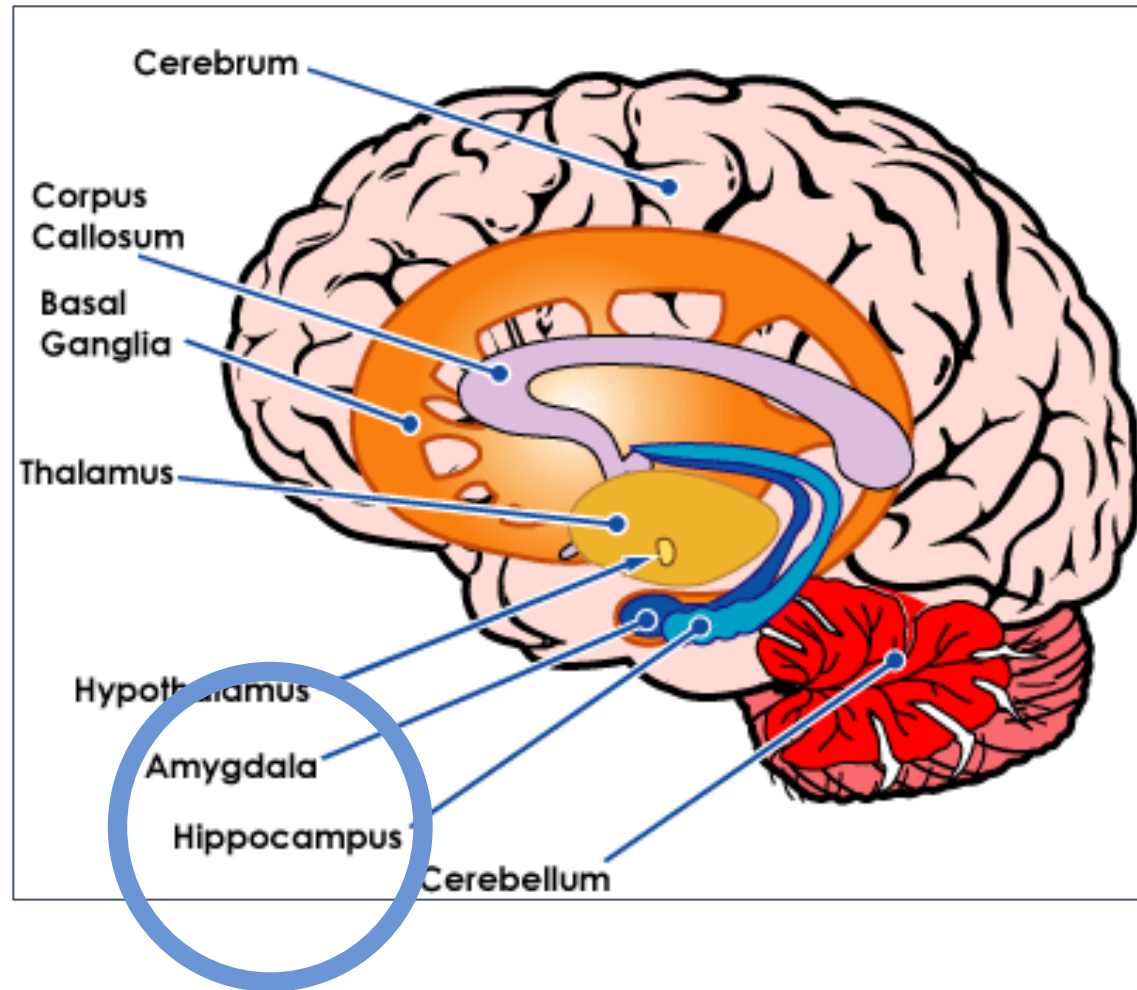
The Mind-Blowing Case of Phineas Gage

- 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



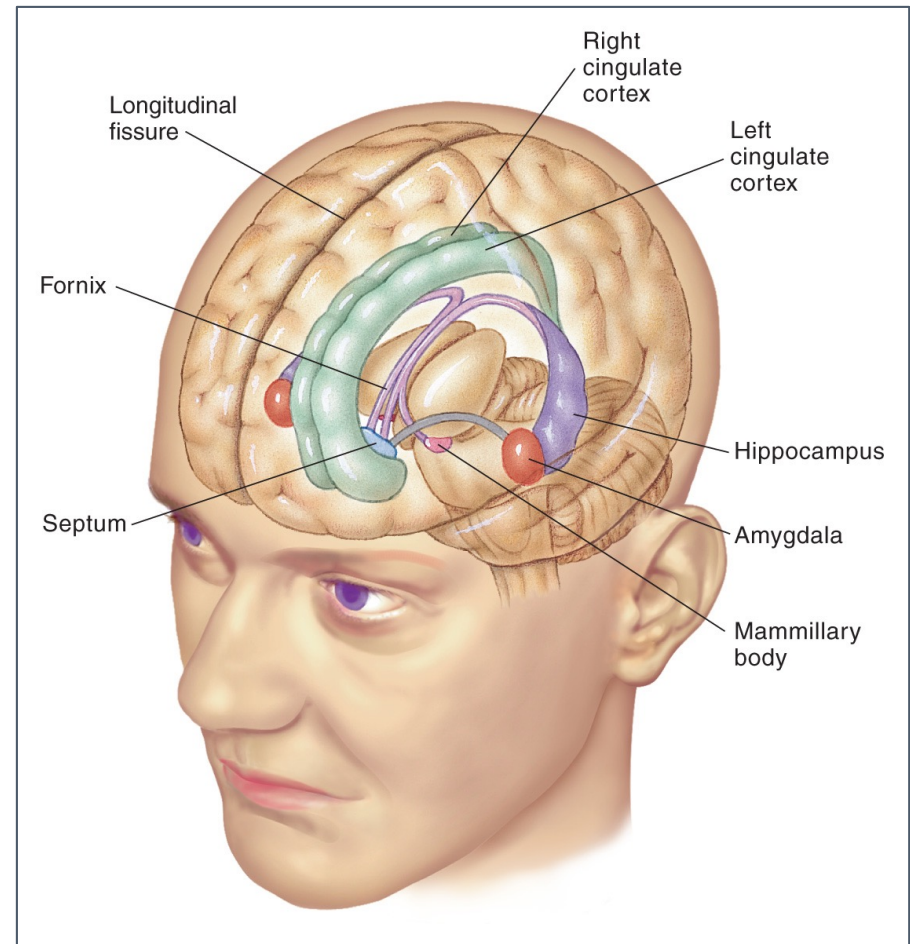
5) Telencephalon

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



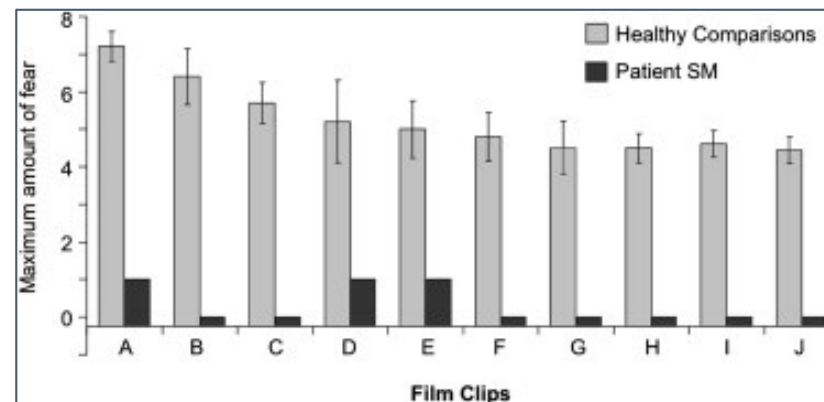
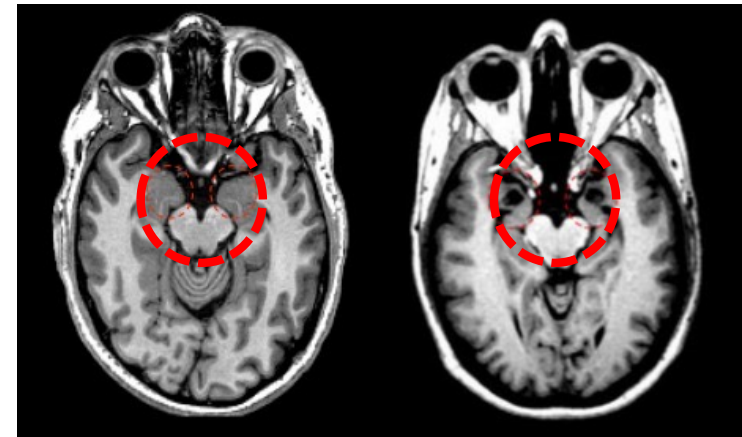
5) Telencephalon – Lymbic system

- Implicated in **learning and memory**
- Structures:
 - Amygdala
 - Hippocampus
 - Cingulate Cortex
 - Fornix
 - Septum



Amygdala

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



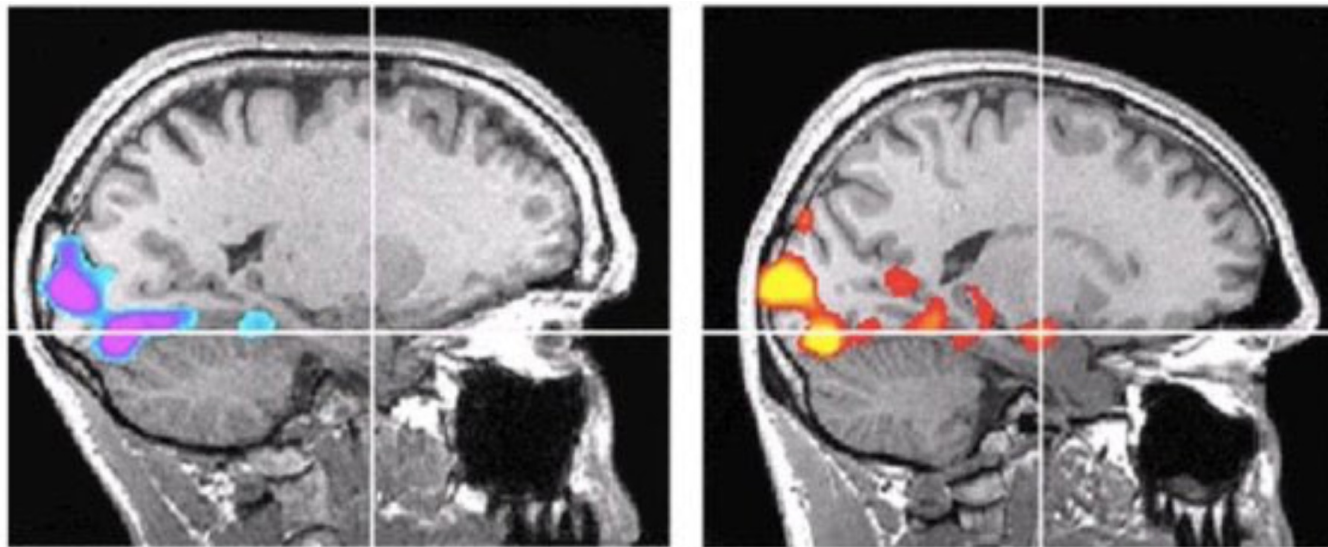
Amygdala

- **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.

Amygdala

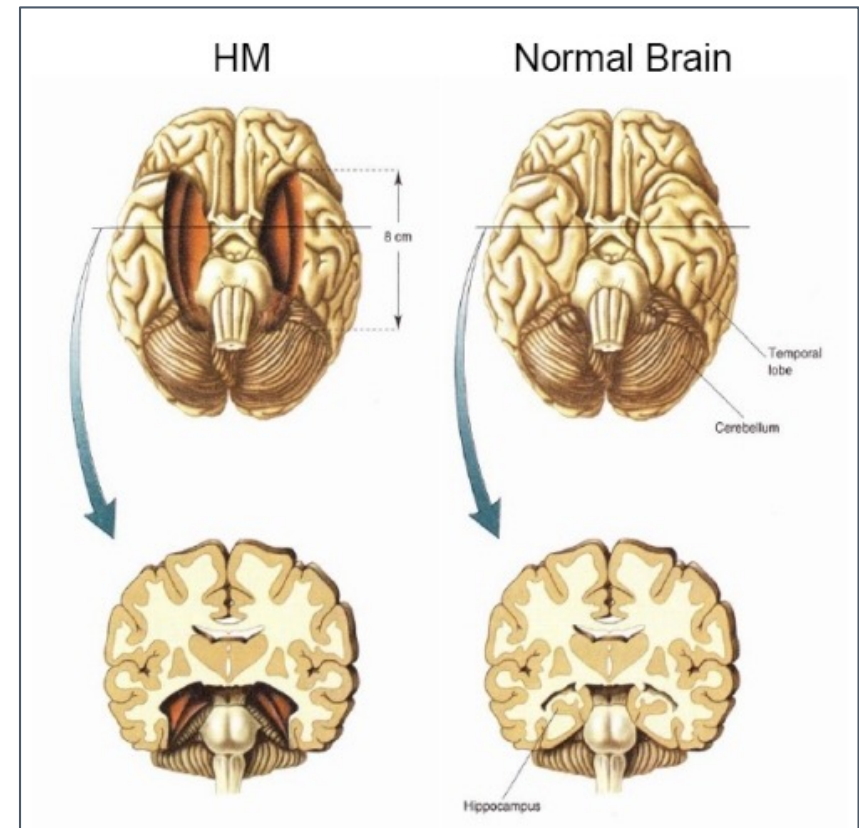
- "I've spent 25 years conditioning myself to work in extreme conditions, so of course my brain is different." Honnold says that, if anything, it is his preparation that is abnormal. For years, for instance, Honnold was afraid of El Capitan—a 3,000-ft rock wall in Yosemite. "I'd drive into Yosemite," 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.
- Unlike the genetically encoded **Urbach-Wiethe disease**, Honnold's absence of fear is acquired/learnt, and thus environmentally induced.

Hippocampus

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



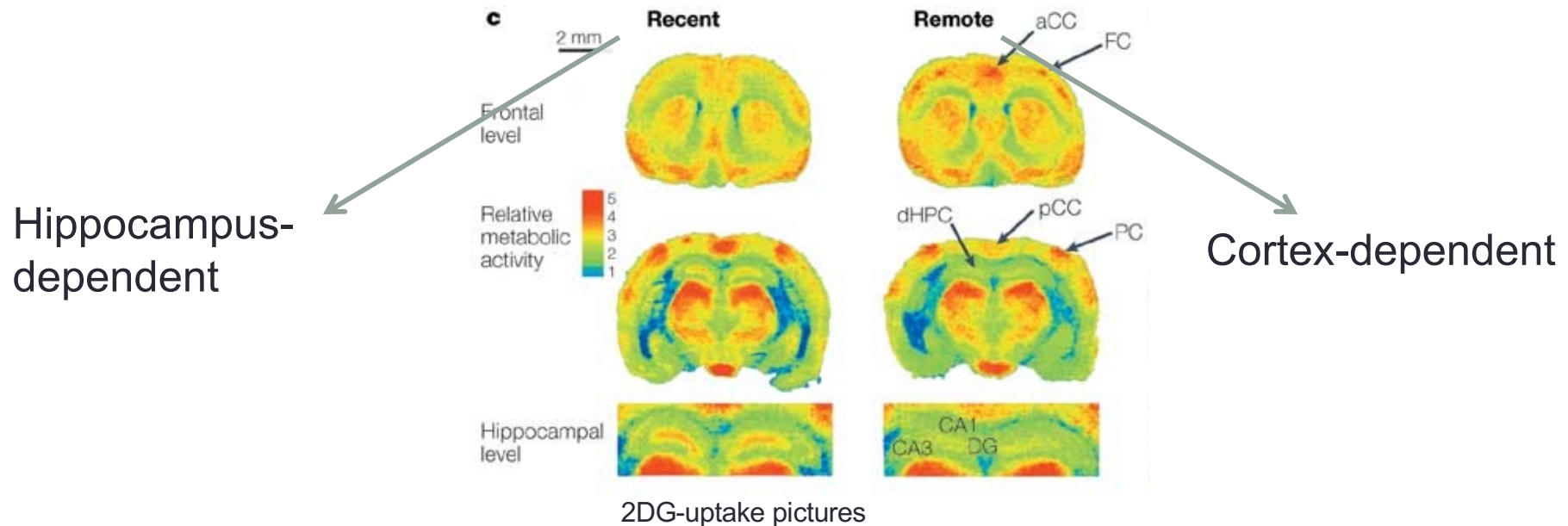
- Henry Molaison (1926-2008) had part of his temporal lobe removed during a lobectomy to treat his epilepsy



Hippocampus

- **H.M. Removal of temporal lobe - hippocampus**

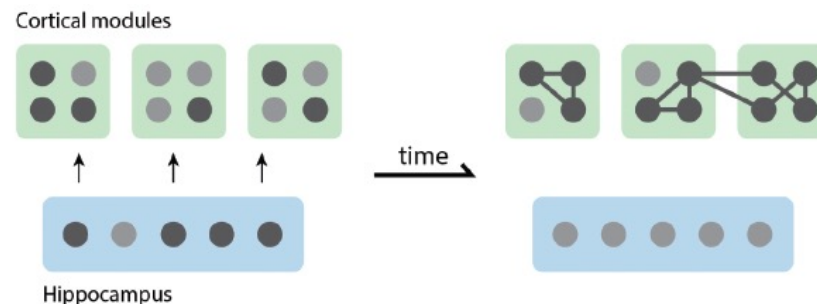
- His long-term memory from before the surgery remained intact
- But he wasn't capable of forming new long-term memories
- Confirmed in mice:



Hippocampus - Cortex

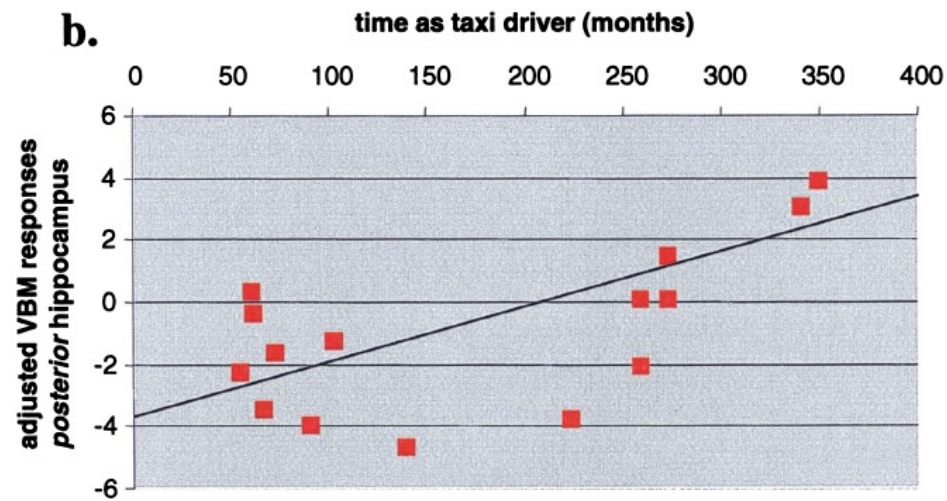
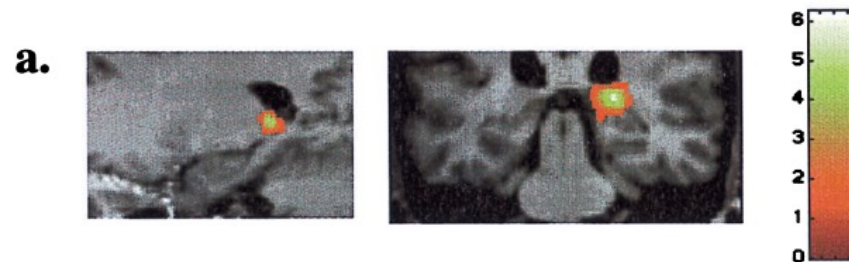
• Memory consolidation

- **Initial hippocampal dependence:** New declarative memories are first stored in the hippocampus.
- **Gradual cortical reorganization:** Through repeated reactivation (during sleep, recall, or replay), hippocampal-cortical interactions strengthen direct connections between cortical areas.
- **Shift in reliance:** Over time, memories become less dependent on the hippocampus and more stabilized in the cortex, supporting long-term storage.
- **Functional outcome:** This shift explains why recent memories are vulnerable to hippocampal damage, while remote memories are more resilient (e.g., patient HM)



Hippocampus

- The case of London taxi drivers



VBM=Voxel-based morphometry

Hippocampus and cortical areas

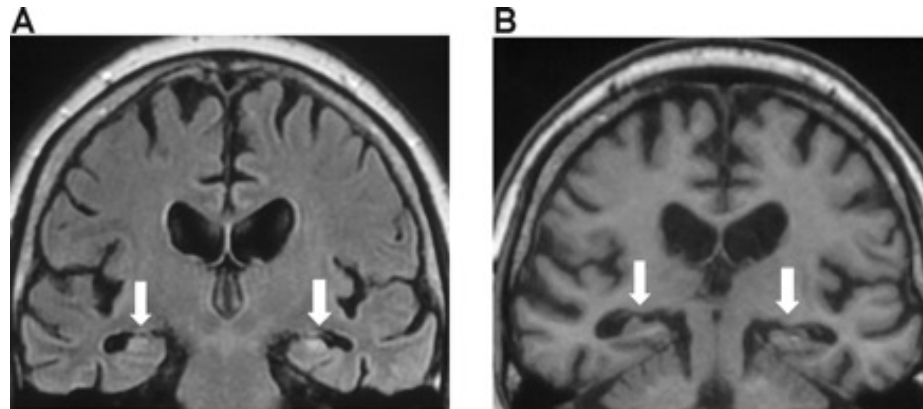
- **The case of London taxi drivers – the exception proves the rule...**

[doi:10.1093/brain/awl286](https://doi.org/10.1093/brain/awl286)

Brain (2006) 129, 2894–2907

Navigation around London by a taxi driver with bilateral hippocampal lesions

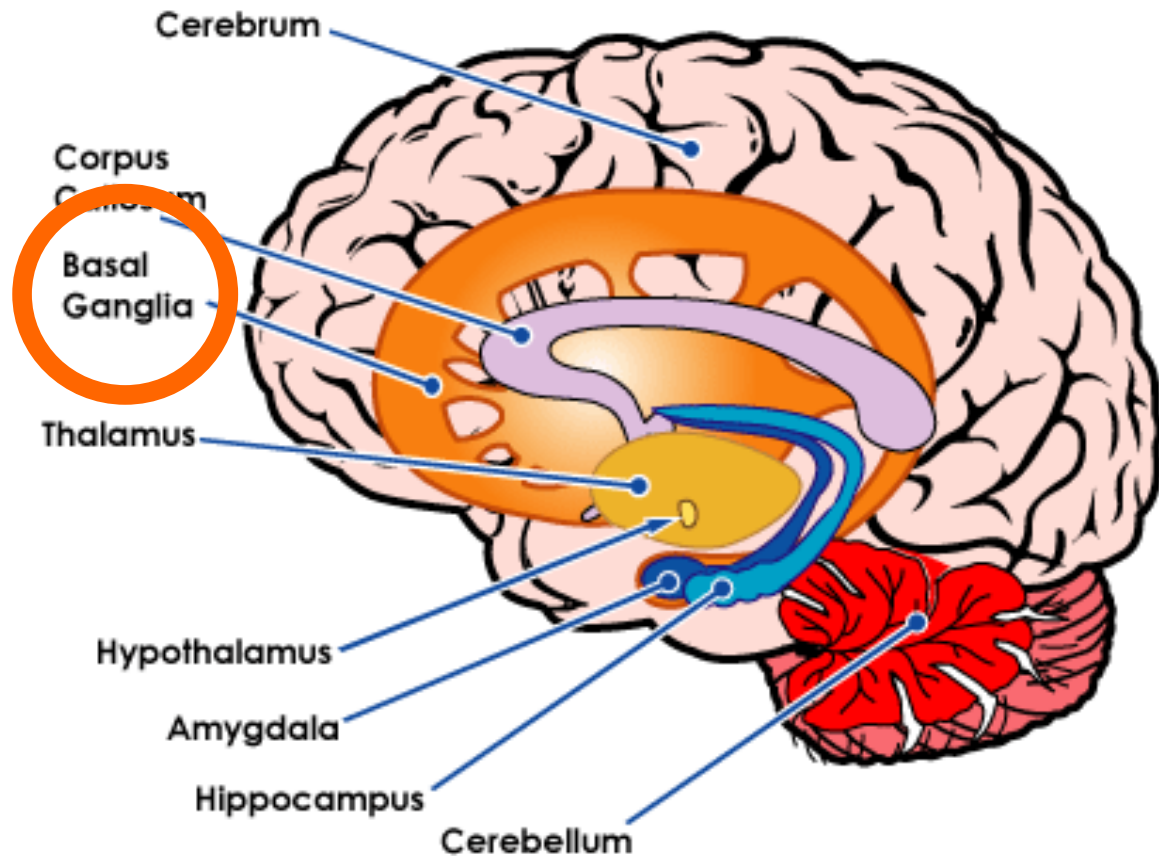
Eleanor A. Maguire, Rory Nannery and Hugo J. Spiers



- This cab driver performed equally well in spatial memory.
- Compensatory mechanisms?! Plastic learning systems?!

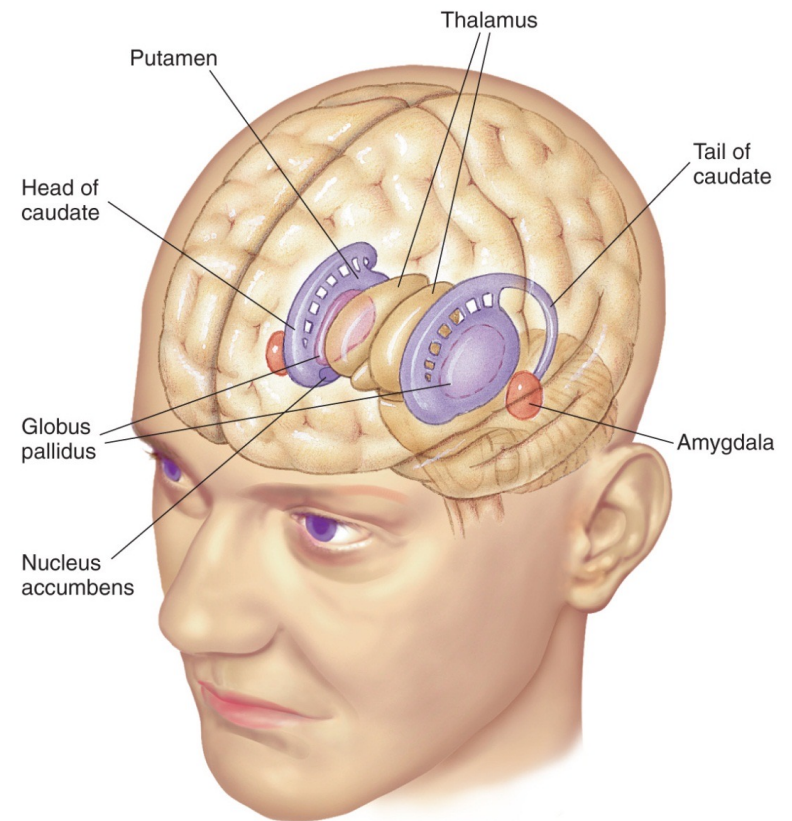
5) Telencephalon

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

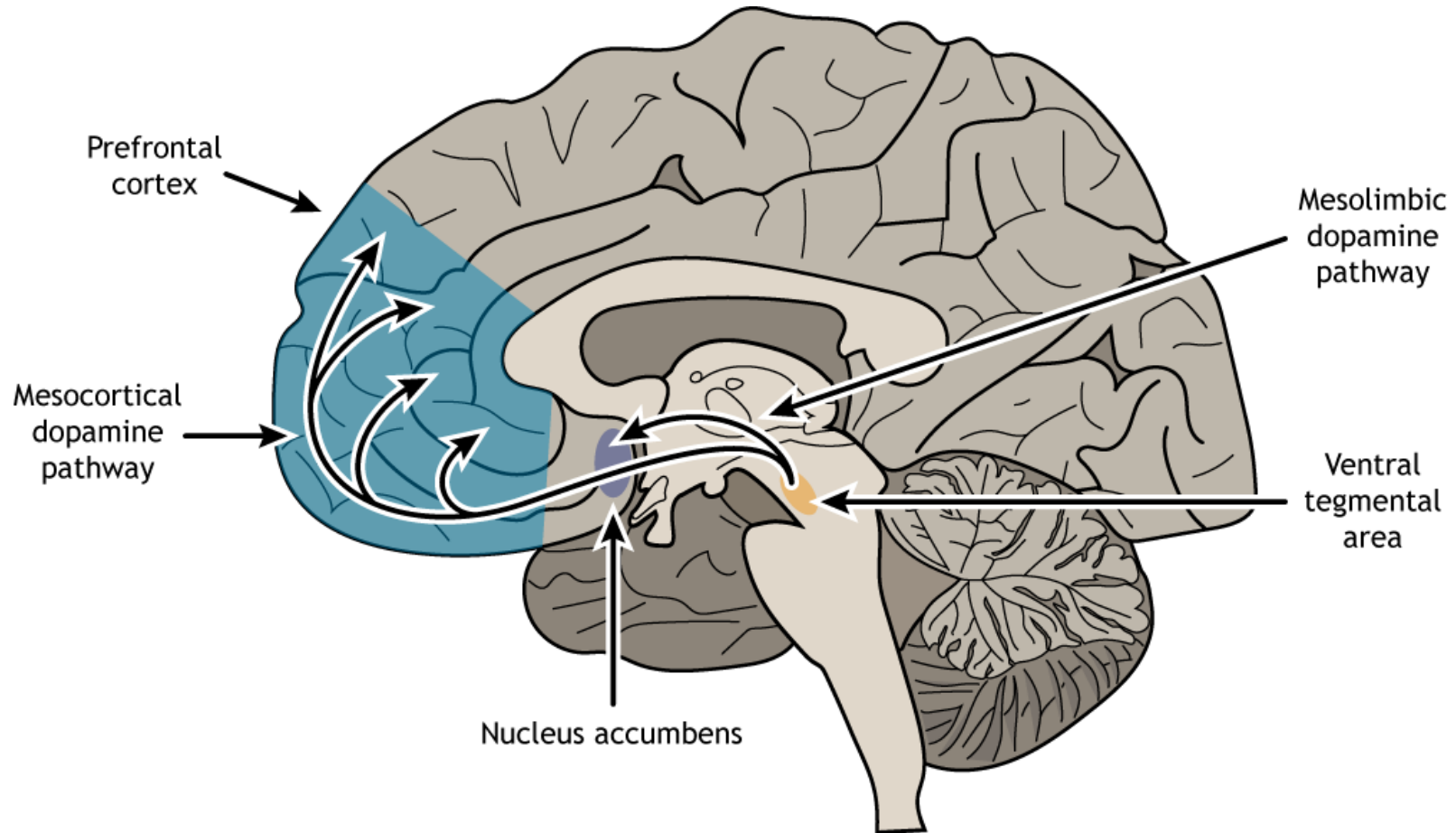


5) Telencephalon – Basal ganglia

- 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



Reward circuitry – Nucleus accumbens



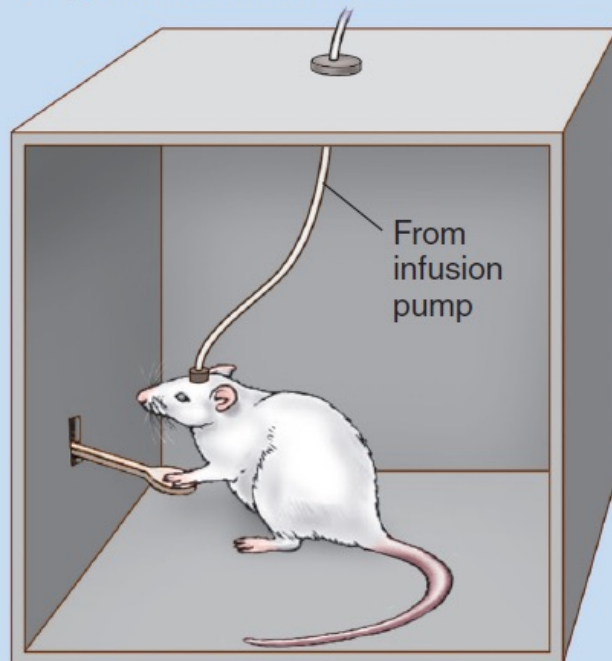
Exercise (Think – Pair – Share)

- Reward circuitry: How would you test that the nucleus accumbens is implicated in reward behavior (e.g., drug preferences)?

Reward circuitry - addiction

- How to study addictive behaviors in animal models?

Drug Self-Administration



The rat presses the lever to self-inject a drug, either into an area of its brain or into general circulation.

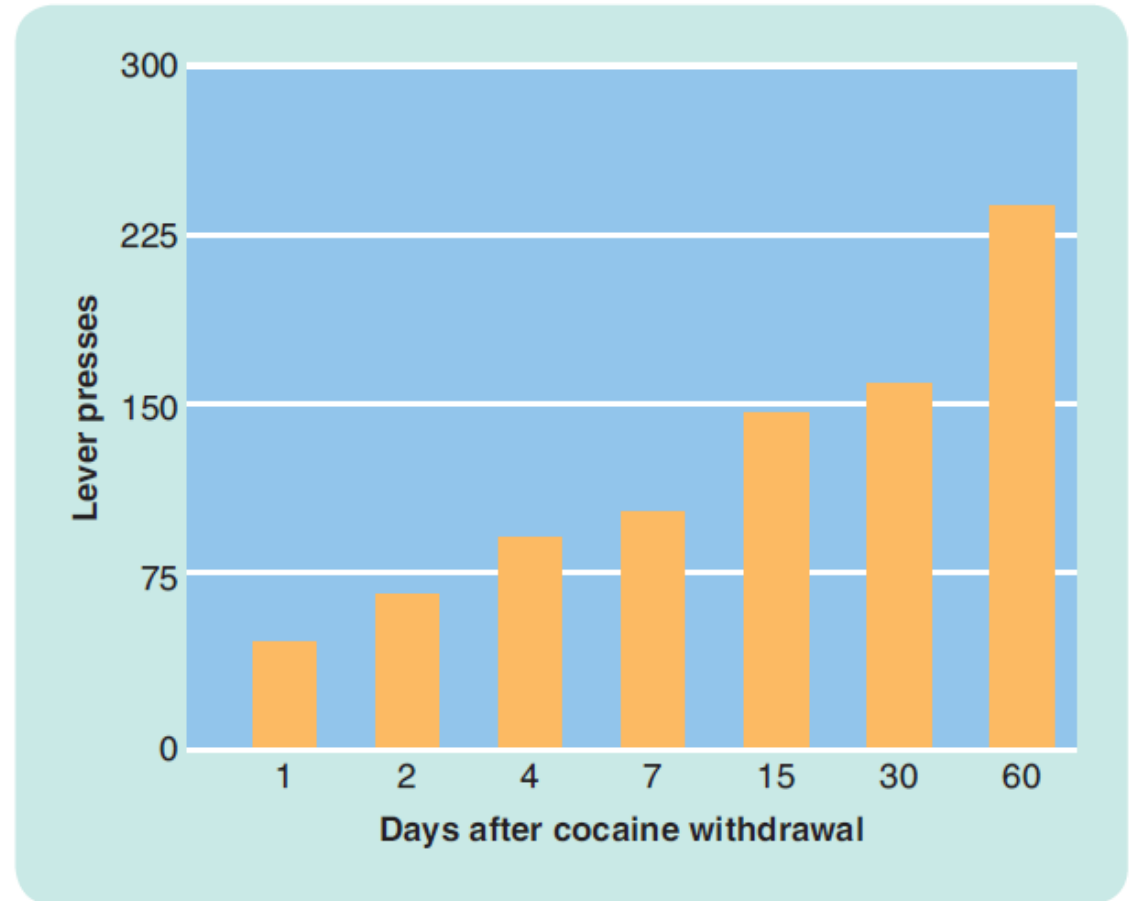
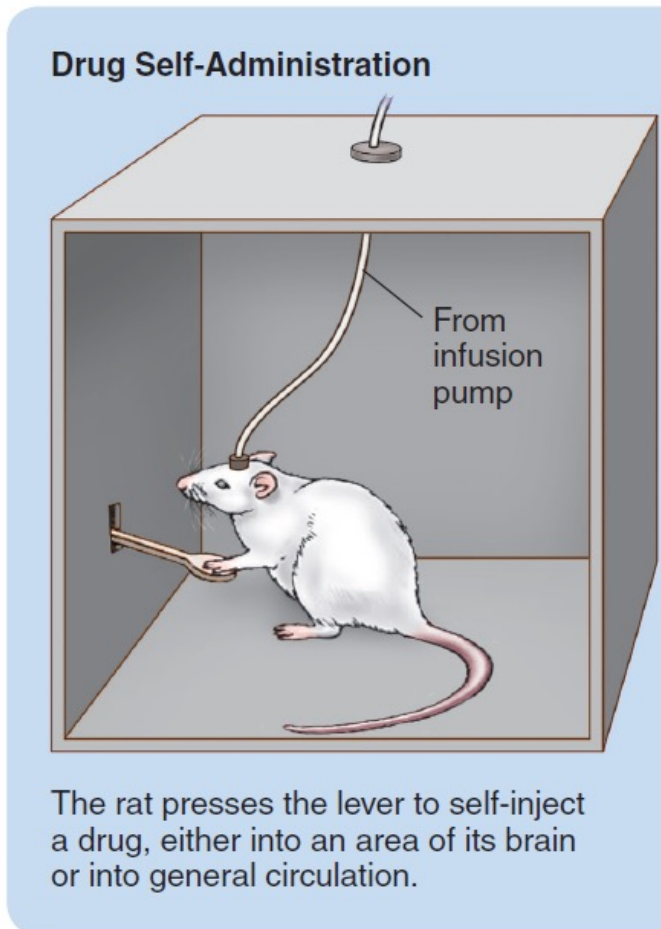
Conditioned Place Preference



A rat repeatedly receives a drug in one of two distinctive compartments. Then, on the test, the tendency of the rat, now drug-free, to prefer the drug compartment is assessed.

Reward circuitry - addiction

- How to study addictive behaviors in animal models?

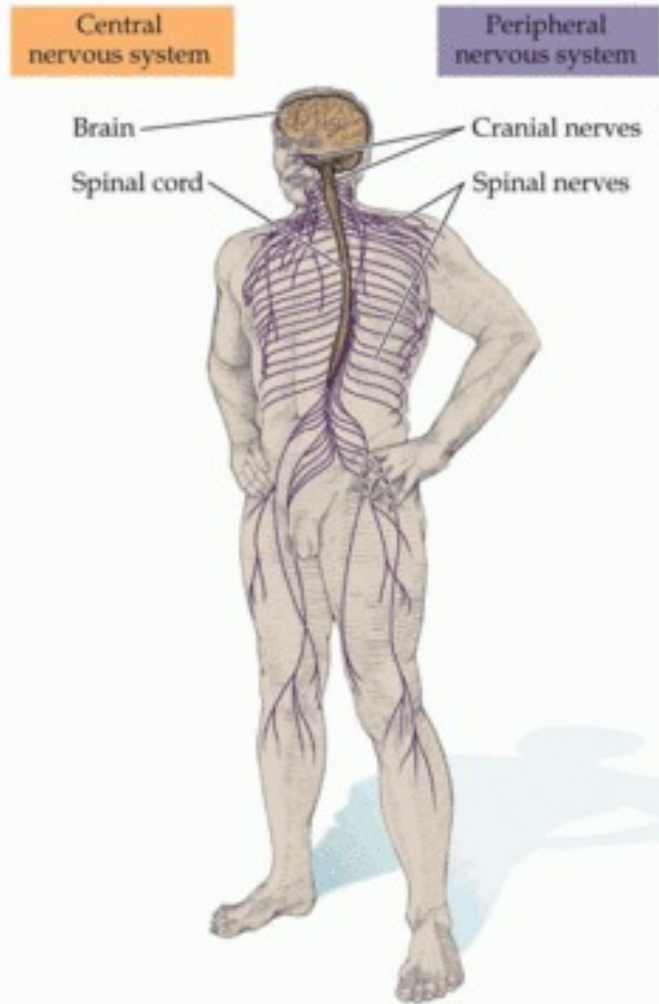


Exercise (Think – Pair – Share)

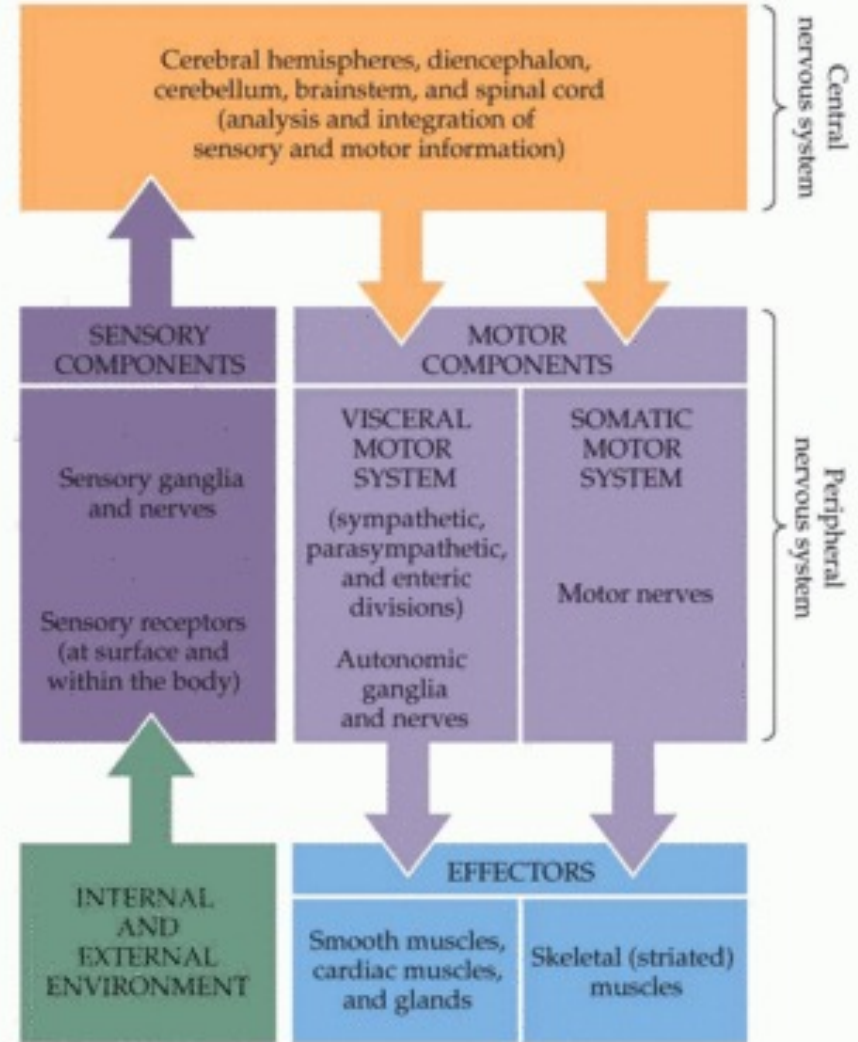
- **Memory circuitry:** How would you test that the amygdala is implicated in fear learning?

Brain Anatomy - Divisions and their function - SUMMARY

(A)



(B)



Brain Anatomy - Divisions and their function - 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	

Brain Anatomy - Divisions and their function - 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 } Striatum Putamen } Globus pallidus
	Cerebral commissures	Corpus callosum