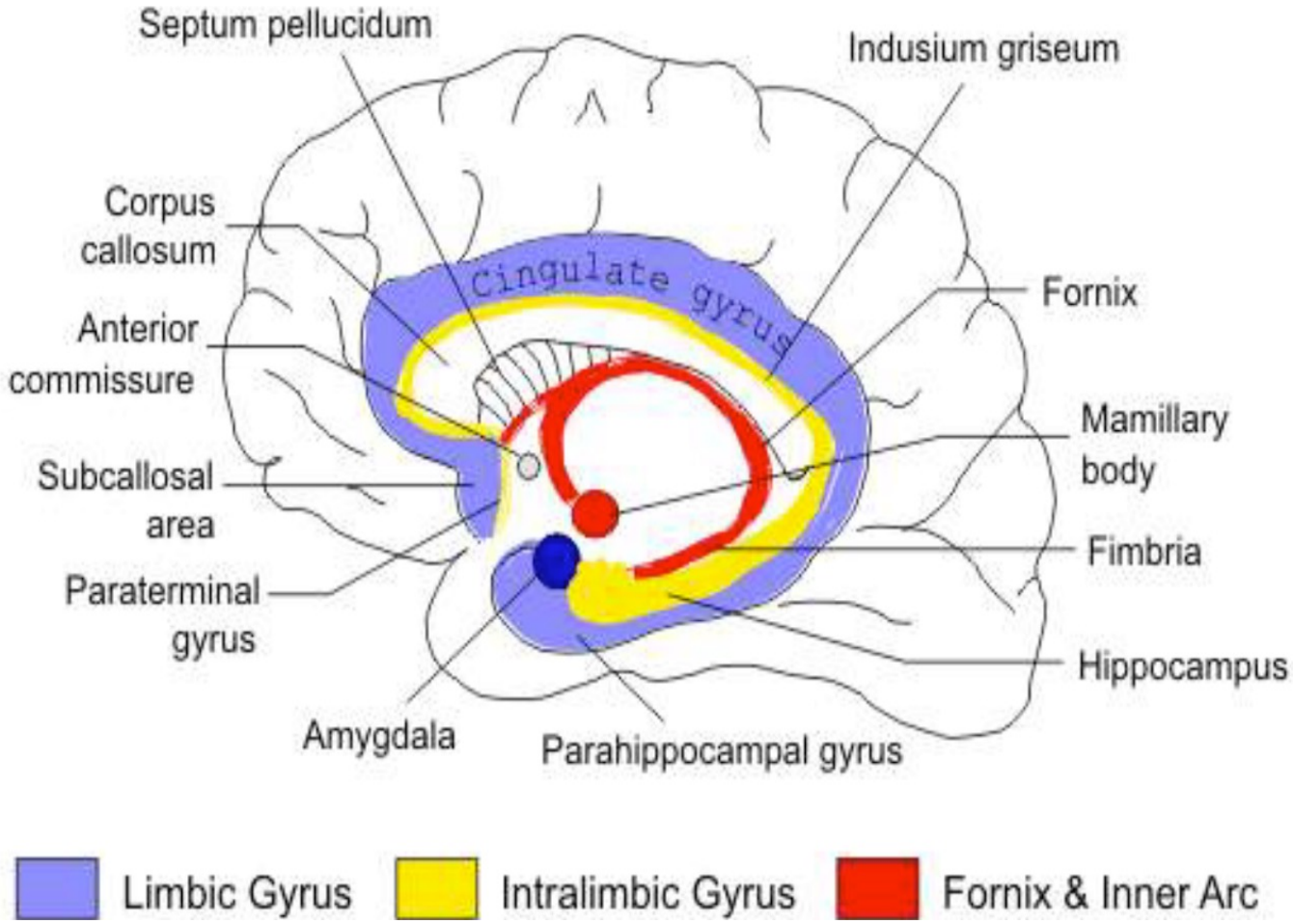
UNIVERSITY OF ZAMBIA
SCHOOL OF MEDICINE

- **HUMAN ANATOMY**
- **LIMBIC SYSTEM**



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Introduction

- The limbic system includes diverse cortical and subcortical structures located mainly in the medial and ventral regions of the cerebral hemispheres
- These structures are unified by their evolutionarily ancient origins and constitute the major portion of the forebrain in many species
- Only in higher mammals has the larger neocortical mantle surpassed the limbic system in size
- The functions of the limbic system are also ancient and they play an important role for survival in the animal kingdom

Introduction

- Limbic functions can be divided into the following four basic categories:

1. **Olfaction**
2. **Memory**
3. **Emotions and drives**
4. **Homeostatic functions, including autonomic and neuroendocrine control**

Mnemonic: HOME (Homeostasis, Olfaction, Memory and Emotion)

- **Numerous limbic structures participate in each of these functions**
- **The various components of the limbic system form a complex network with multiple reciprocal connections**

Main Components of the Limbic System

- **Limbic cortex**
- Parahippocampal gyrus
- Cingulate gyrus
- Medial orbitofrontal cortex
- Temporal pole
- Anterior insula
- **Hippocampal formation**
- Dentate gyrus
- Hippocampus
- Subiculum
- **Amygdala**
- **Olfactory cortex**
- **Diencephalon**
- Hypothalamus
- Thalamus (anterior nucleus, mediodorsal nucleus)
- Habenula
- **Basal ganglia**
- Ventral striatum (nucleus accumbens, ventral caudate and putamen)
- Ventral pallidum
- **Basal forebrain**
- **Septal nuclei**
- **Brainstem**

Simplification of Limbic Functions and Corresponding Key Structure

Limbic Function	Key Structure
Olfaction	Olfactory cortex
Memory	Hippocampal formation
Emotions and drives	Amygdala
Homeostasis; autonomic and neuroendocrine control	Hypothalamus

Overview of Limbic Structures

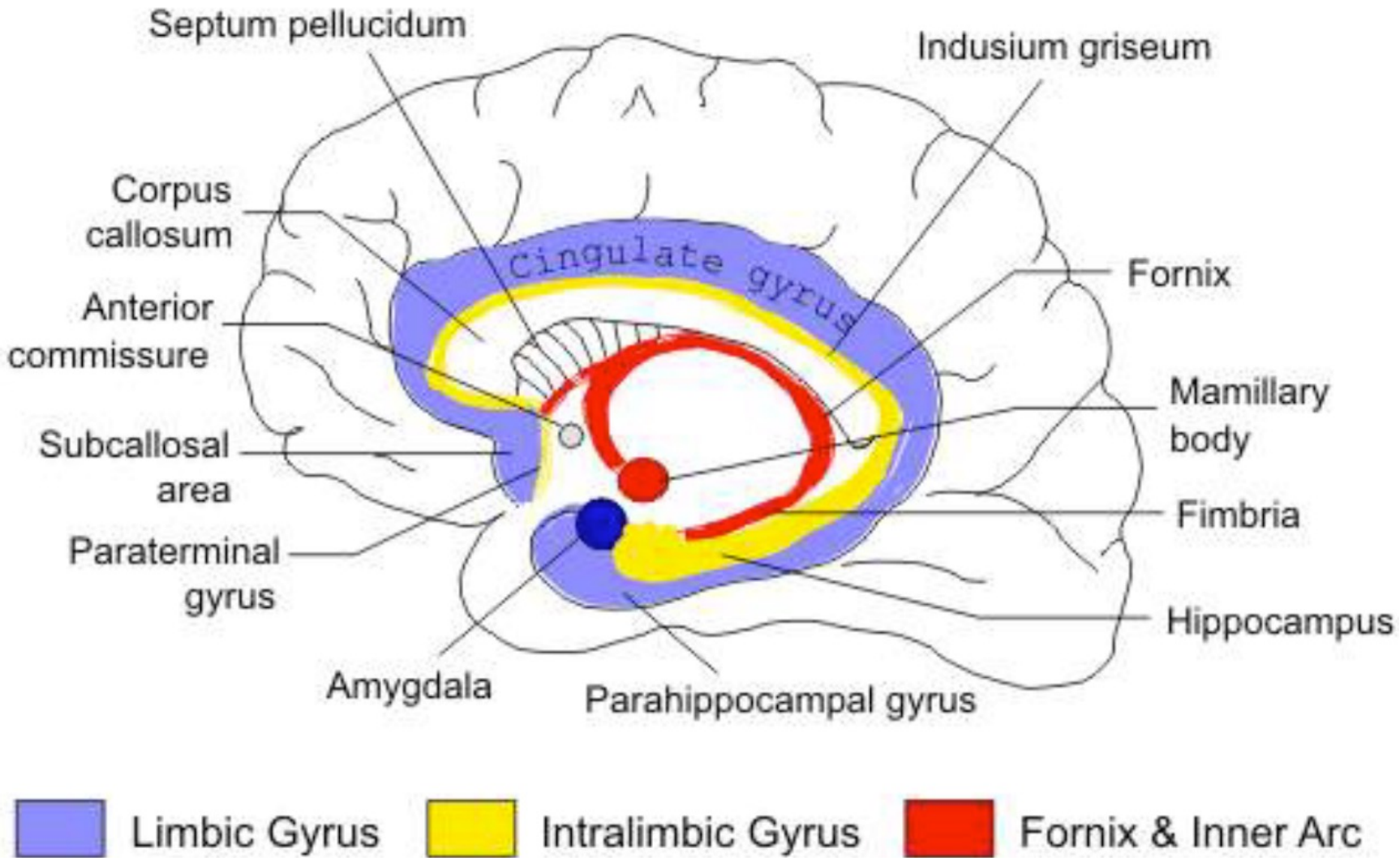
- Consists of various structures extending from forebrain to brainstem
- Most of these structures lie hidden within the medial and ventral regions of the cerebral hemispheres and not readily visible from the lateral surface
- Limbus means ”border” or “edge” in latin

Overview of Limbic Structures

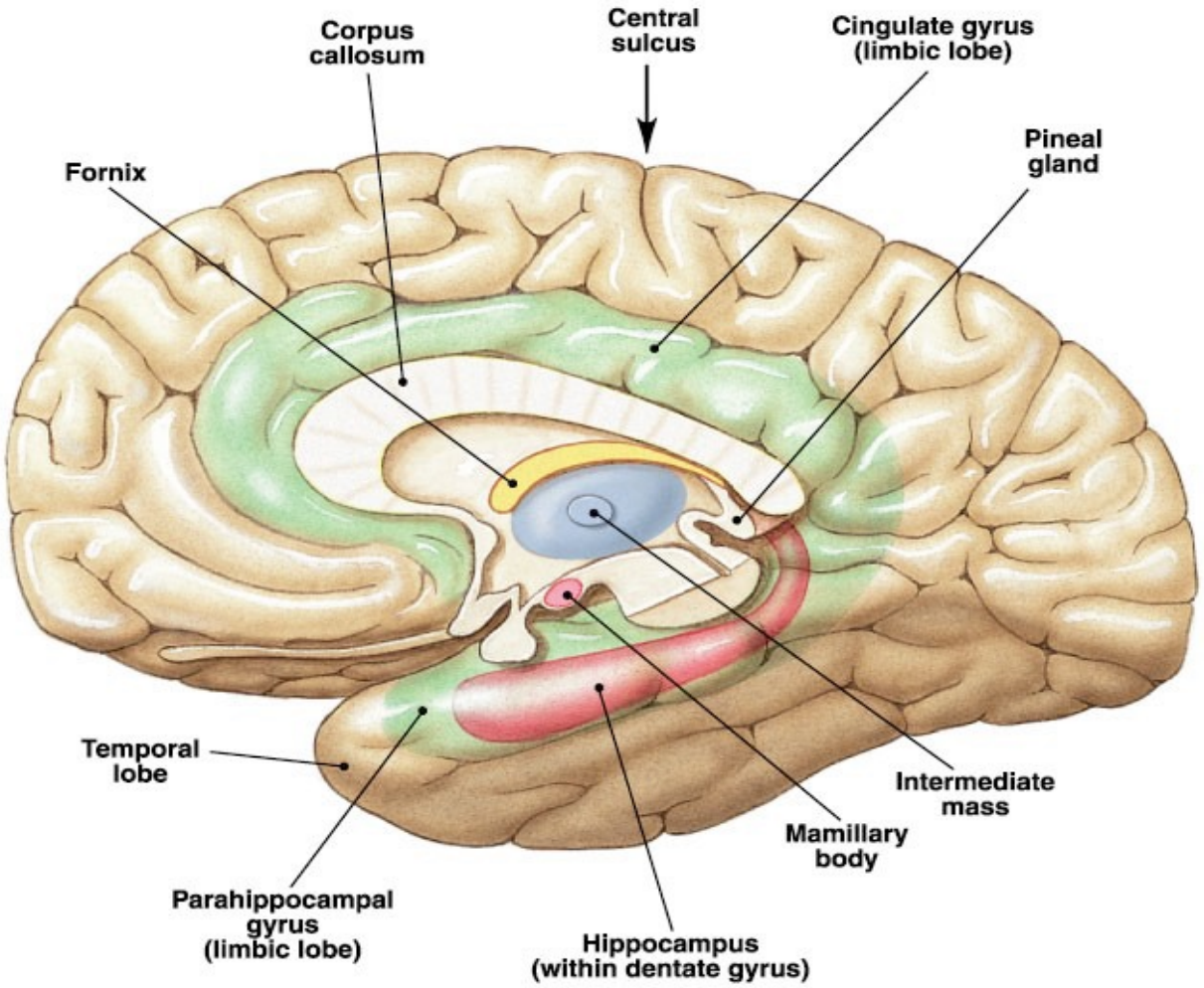
Limbic Cortex

- Forms a ringlike **limbic lobe** around the edge of the cortical mantle which surrounds the corpus callosum and upper brainstem-diencephalic junction
- This *"grand lobe limbique"* was first described by Paul Broca in 1878
- The main components of the limbic cortex visible on a medial view are the **cingulate gyrus** and **parahippocampal gyrus**
- The parahippocampal gyrus is separated from the remainder of the temporal lobe by **collateral sulcus** which continues anteriorly as the **rhinal sulcus**
- The **uncus** is a bump visible on the anterior medial parahippocampal gyrus
- Cingulate gyrus continues anteriorly and inferiorly as the **subcallosal and paraterminal gyri**
- Cingulate gyrus joins the parahippocampal gyrus posteriorly at the isthmus
- Other regions of the limbic cortex consists of **medial orbitofrontal gyri** and **temporal poles** and the **anterior insula cortex**

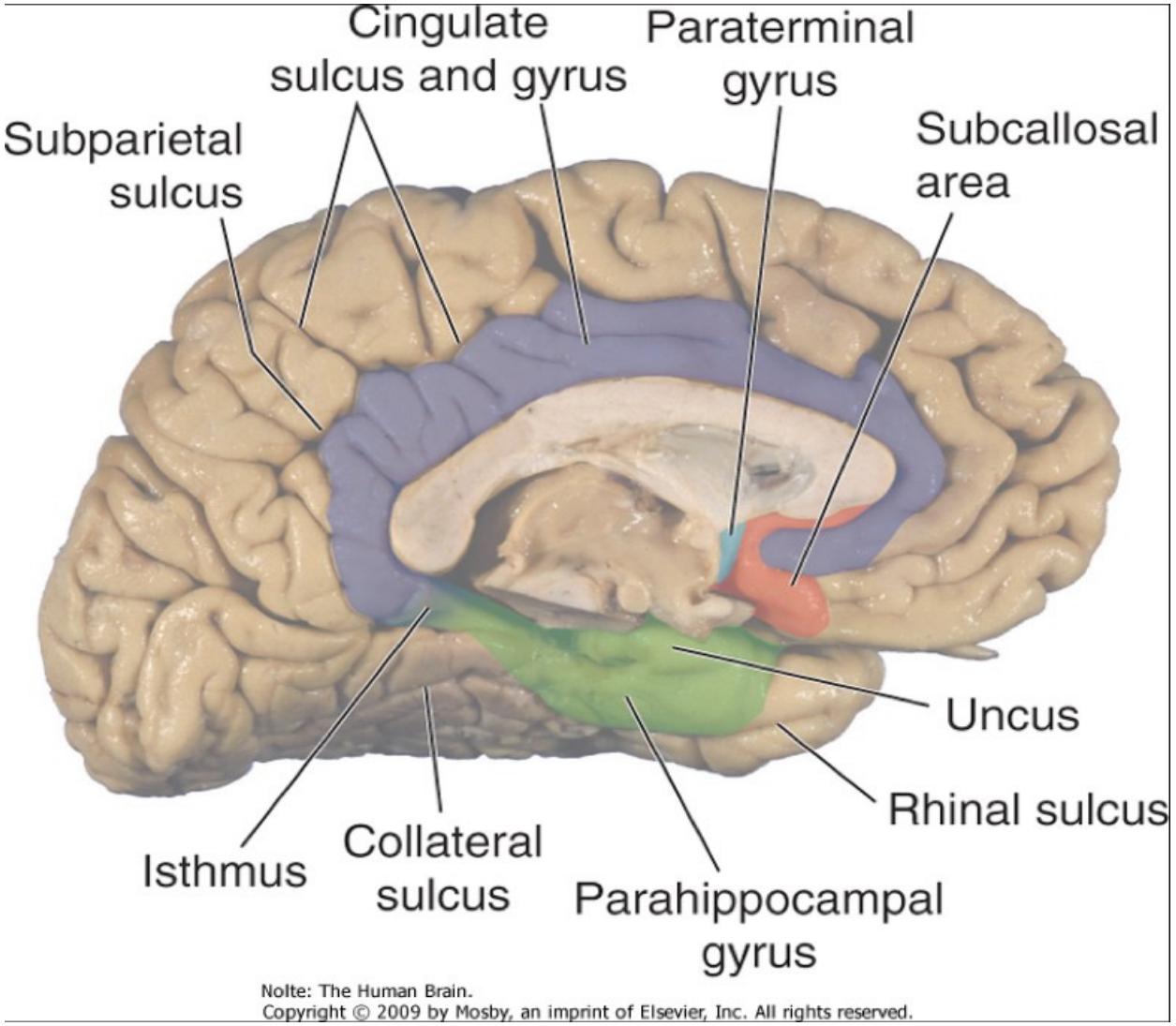
Overview of Limbic Structures

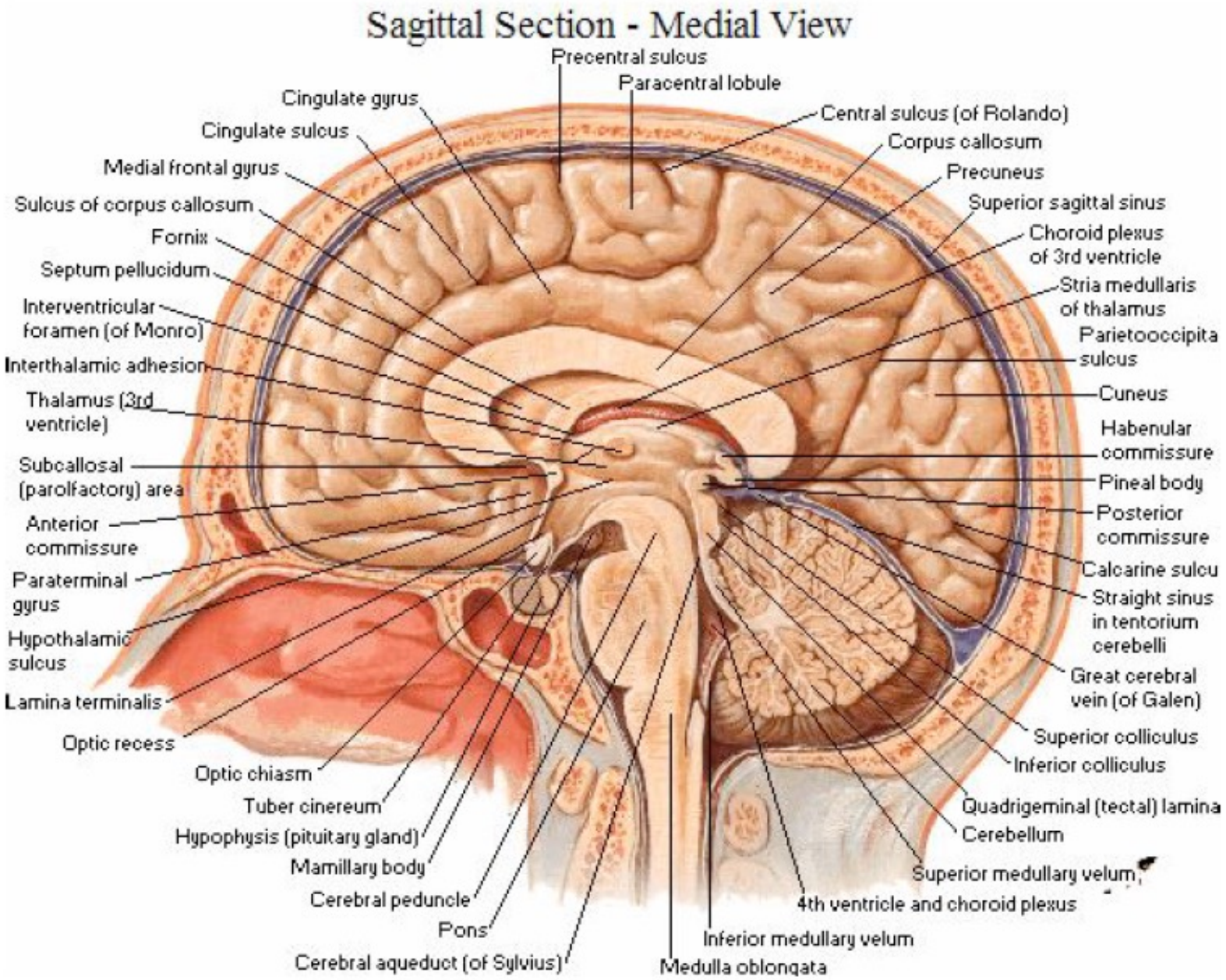


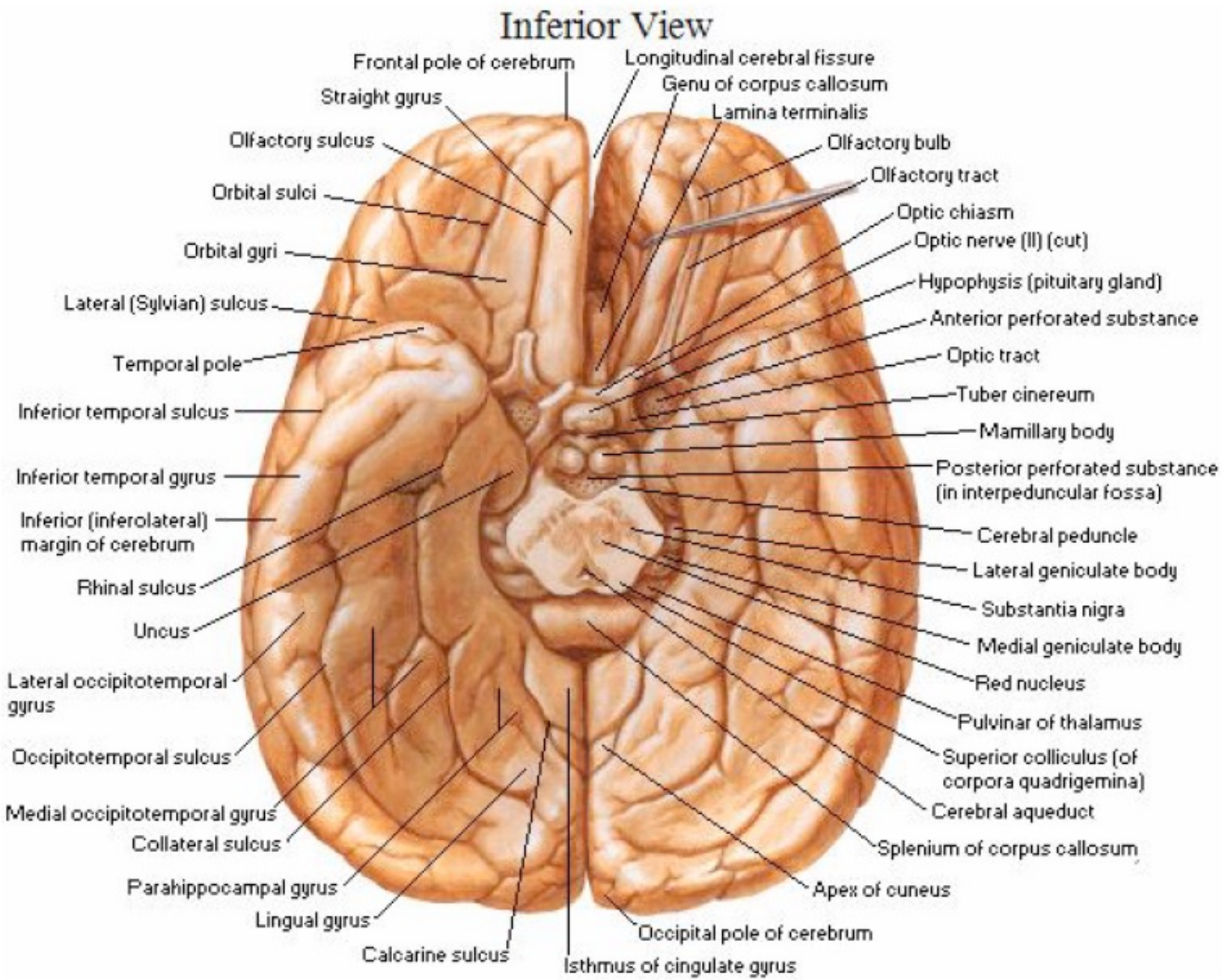
Overview of Limbic Structures



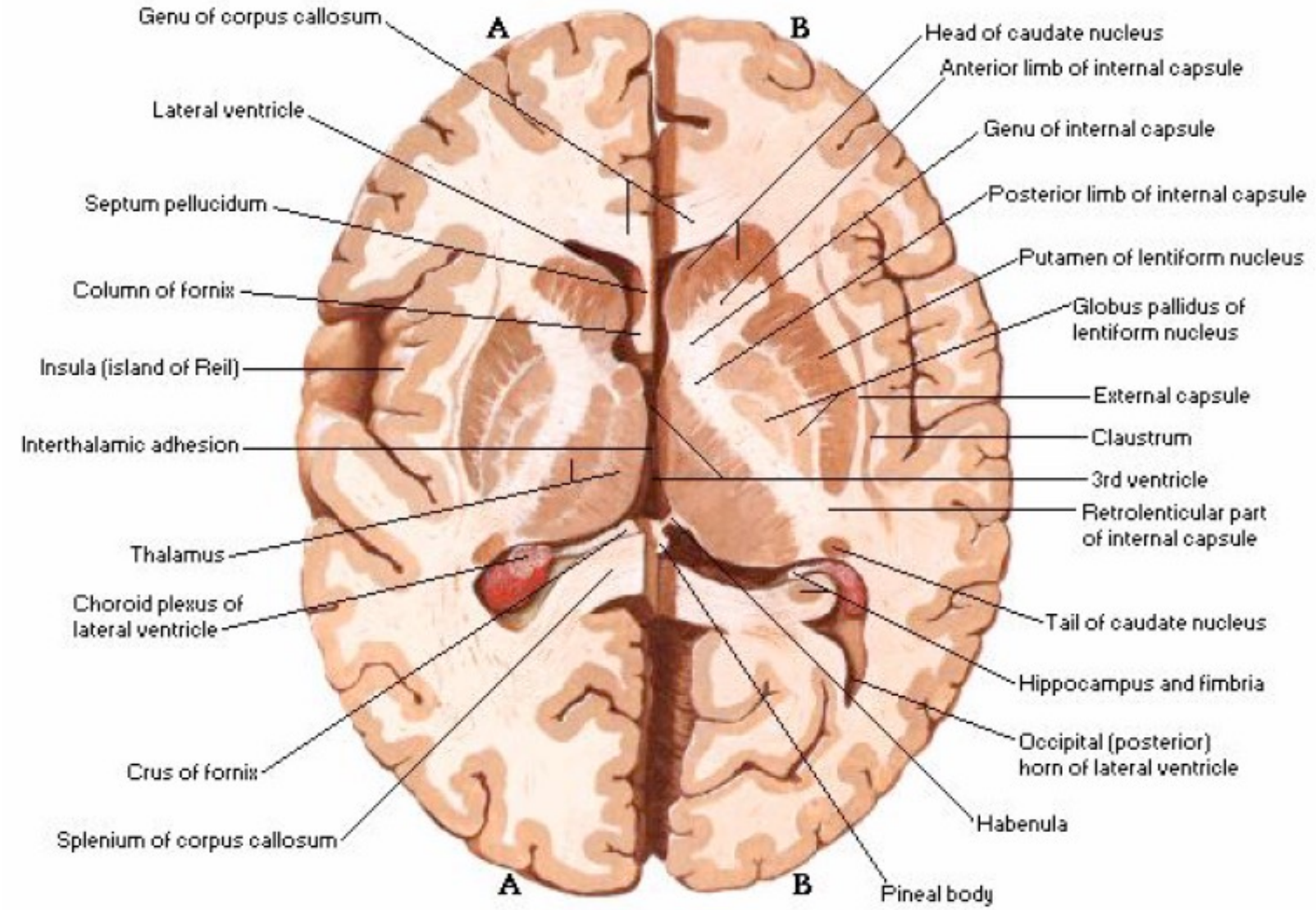
Overview of Limbic Structures



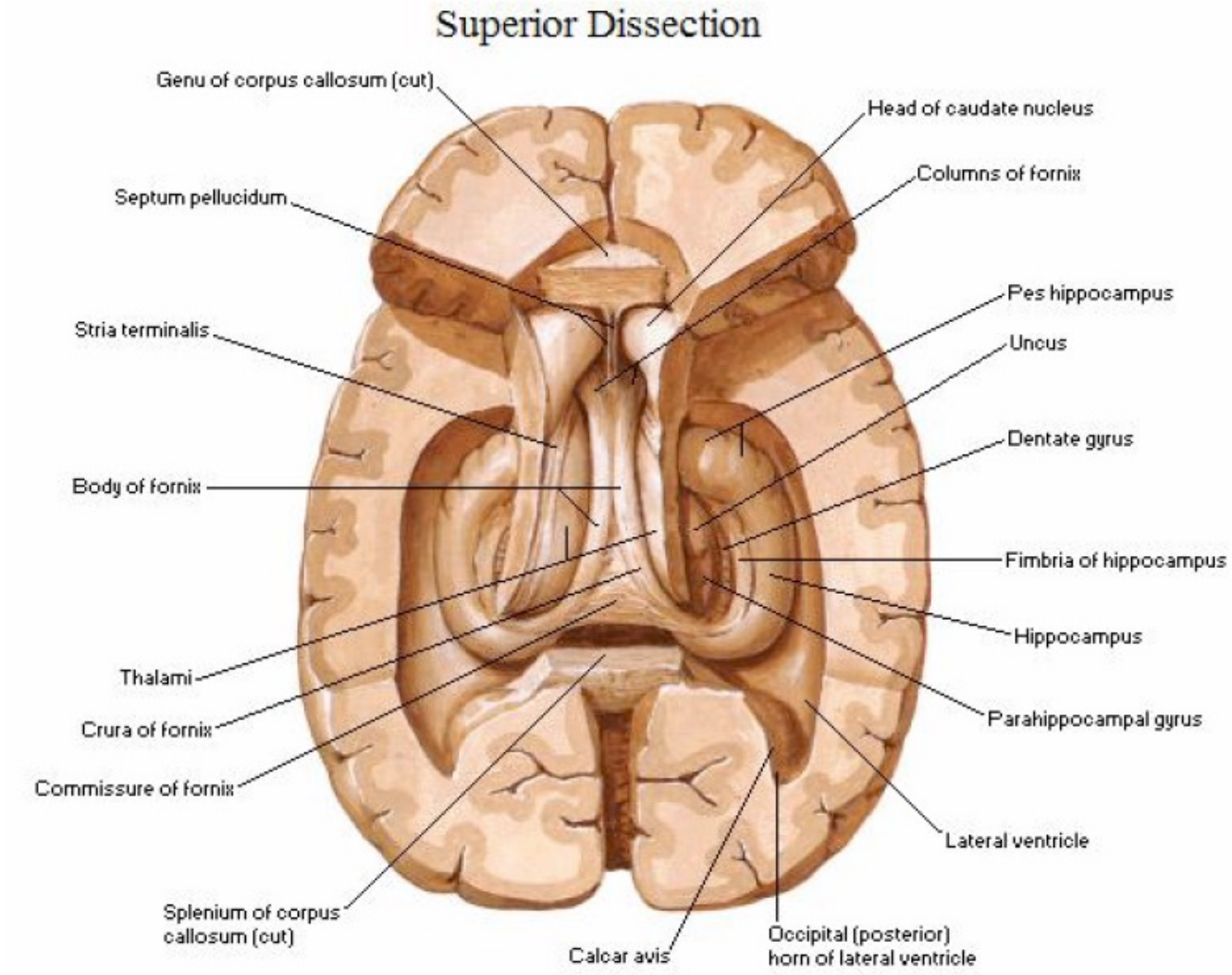

Sagittal Section - Medial View
Precentral sulcus
Paracentral lobule
Cingulate gyrus
Central sulcus (of Rolando)
Cingulate sulcus
Corpus callosum
Medial frontal gyrus
Precuneus
Sulcus of corpus callosum
Superior sagittal sinus
Fornix
Choroid plexus of 3rd ventricle
Septum pellucidum
Stria medullaris of thalamus
Interventricular foramen (of Monro)
Parietooccipita sulcus
Interthalamic adhesion
Cuneus
Thalamus (3rd ventricle)
Habenular commissure
Subcallosal (parolfactory) area
Pineal body
Anterior commissure
Posterior commissure
Paraterminal gyrus
Calcarine sulcu
Straight sinus in tentorium cerebelli
Hypothalamic sulcus
Great cerebral vein (of Galen)
Lamina terminalis
Superior colliculus
Optic recess
Inferior colliculus
Optic chiasm
Quadrigeminal (tectal) lamina
Tuber cinereum
Cerebellum
Hypophysis (pituitary gland)
Superior medullary velum
Mamillary body
4th ventricle and choroid plexus
Cerebral peduncle
Inferior medullary velum
Pons
Medulla oblongata
Cerebral aqueduct (of Sylvius)


Inferior View
Frontal pole of cerebrum
Longitudinal cerebral fissure
Genu of corpus callosum
Straight gyrus
Lamina terminalis
Olfactory sulcus
Olfactory bulb
Olfactory tract
Orbital sulci
Optic chiasm
Optic nerve (II) (cut)
Orbital gyri
Hypophysis (pituitary gland)
Lateral (Sylvian) sulcus
Anterior perforated substance
Optic tract
Temporal pole
Tuber cinereum
Inferior temporal sulcus
Mamillary body
Posterior perforated substance
(in interpeduncular fossa)
Inferior temporal gyrus
Cerebral peduncle
Inferior (inferolateral)
margin of cerebrum
Lateral geniculate body
Substantia nigra
Rhinal sulcus
Medial geniculate body
Uncus
Red nucleus
Lateral occipitotemporal
gyrus
Pulvinar of thalamus
Superior colliculus (of
corpora quadrigemina)
Occipitotemporal sulcus
Cerebral aqueduct
Medial occipitotemporal gyrus
Splenium of corpus callosum
Collateral sulcus
Apex of cuneus
Parahippocampal gyrus
Lingual gyrus
Occipital pole of cerebrum
Calcarine sulcus
Isthmus of cingulate gyrus

Horizontal Sections through Cerebrum



Overview of Limbic Structures



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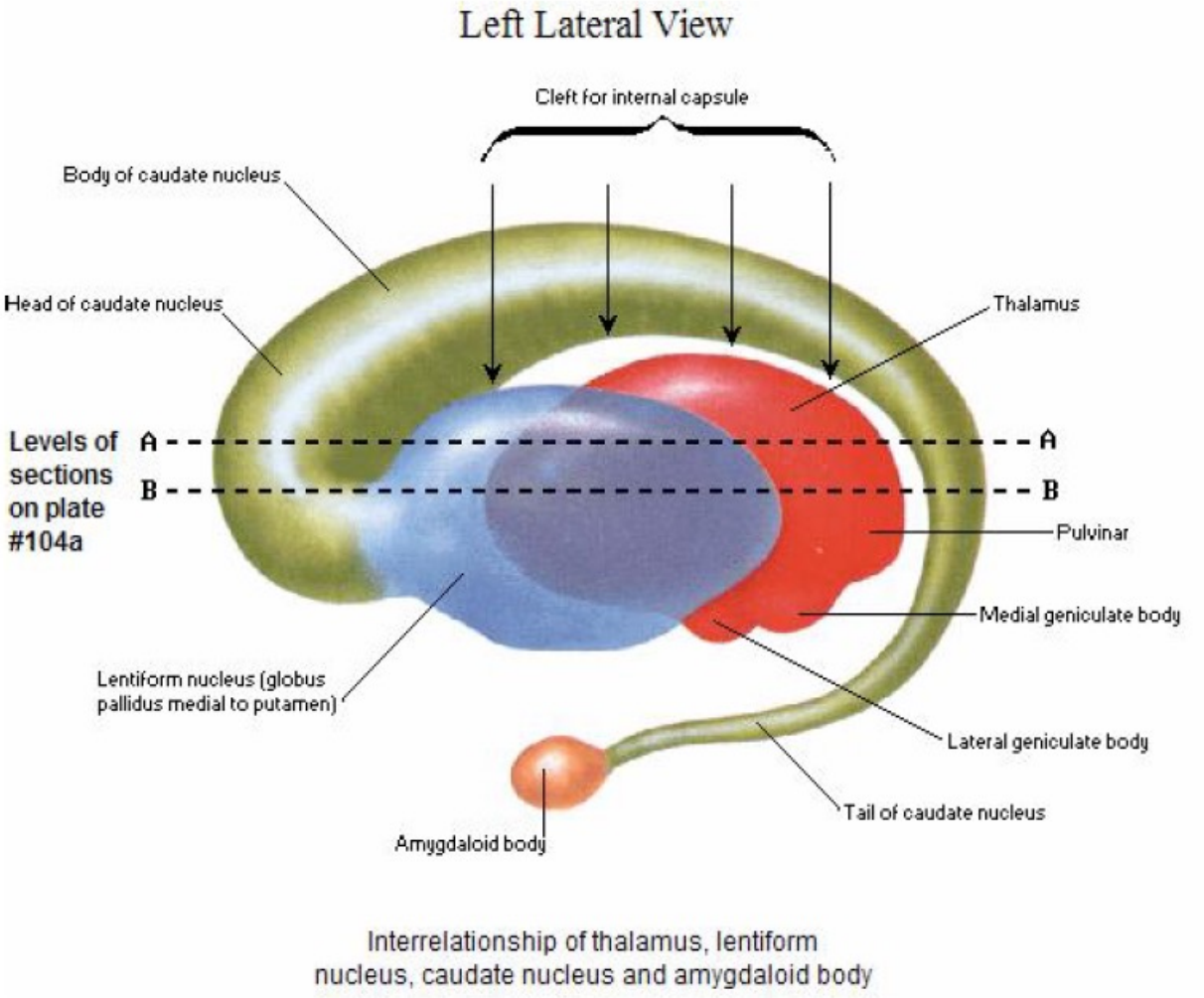
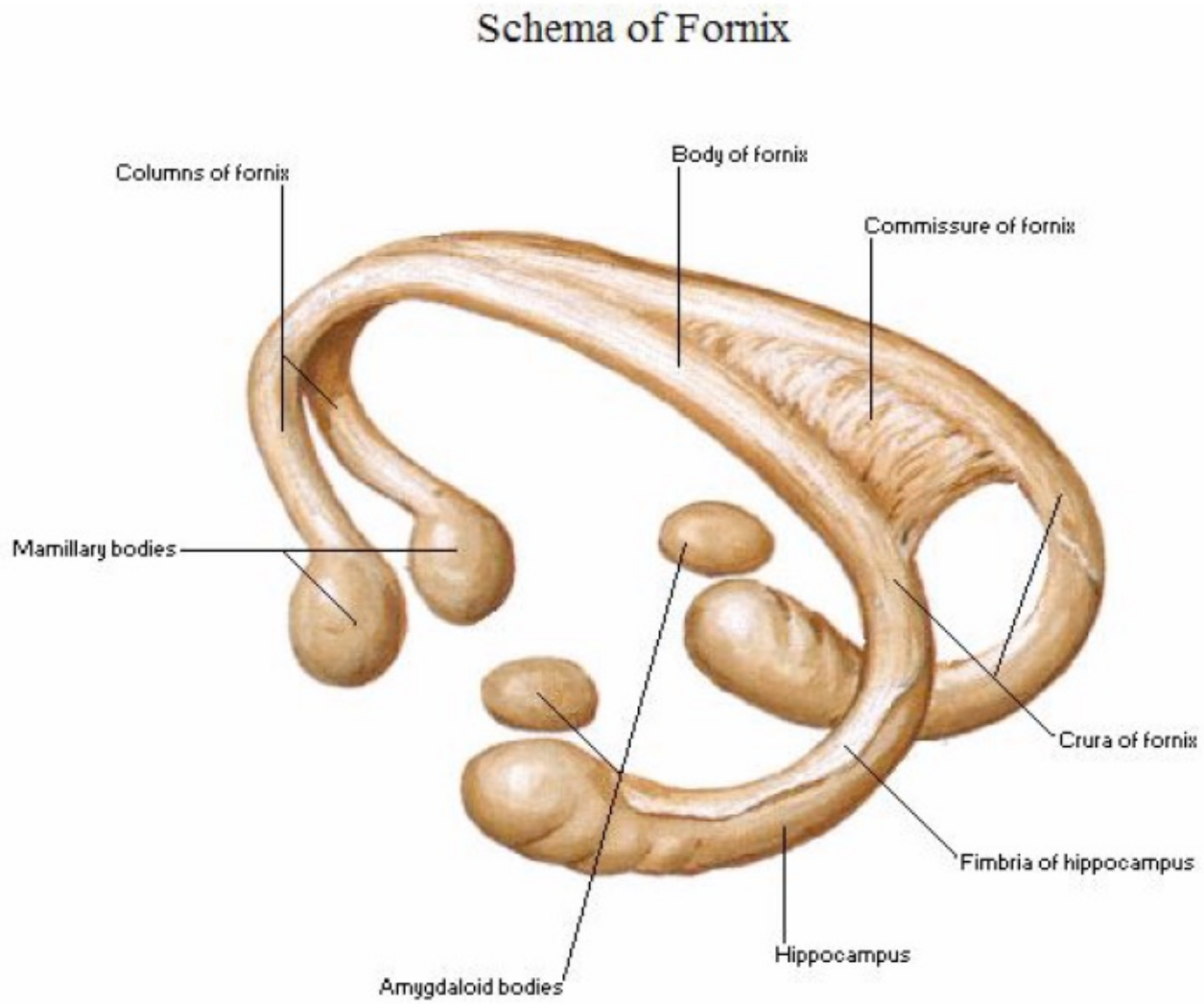


Interrelationship of thalamus, lentiform nucleus, caudate nucleus and amygdaloid body

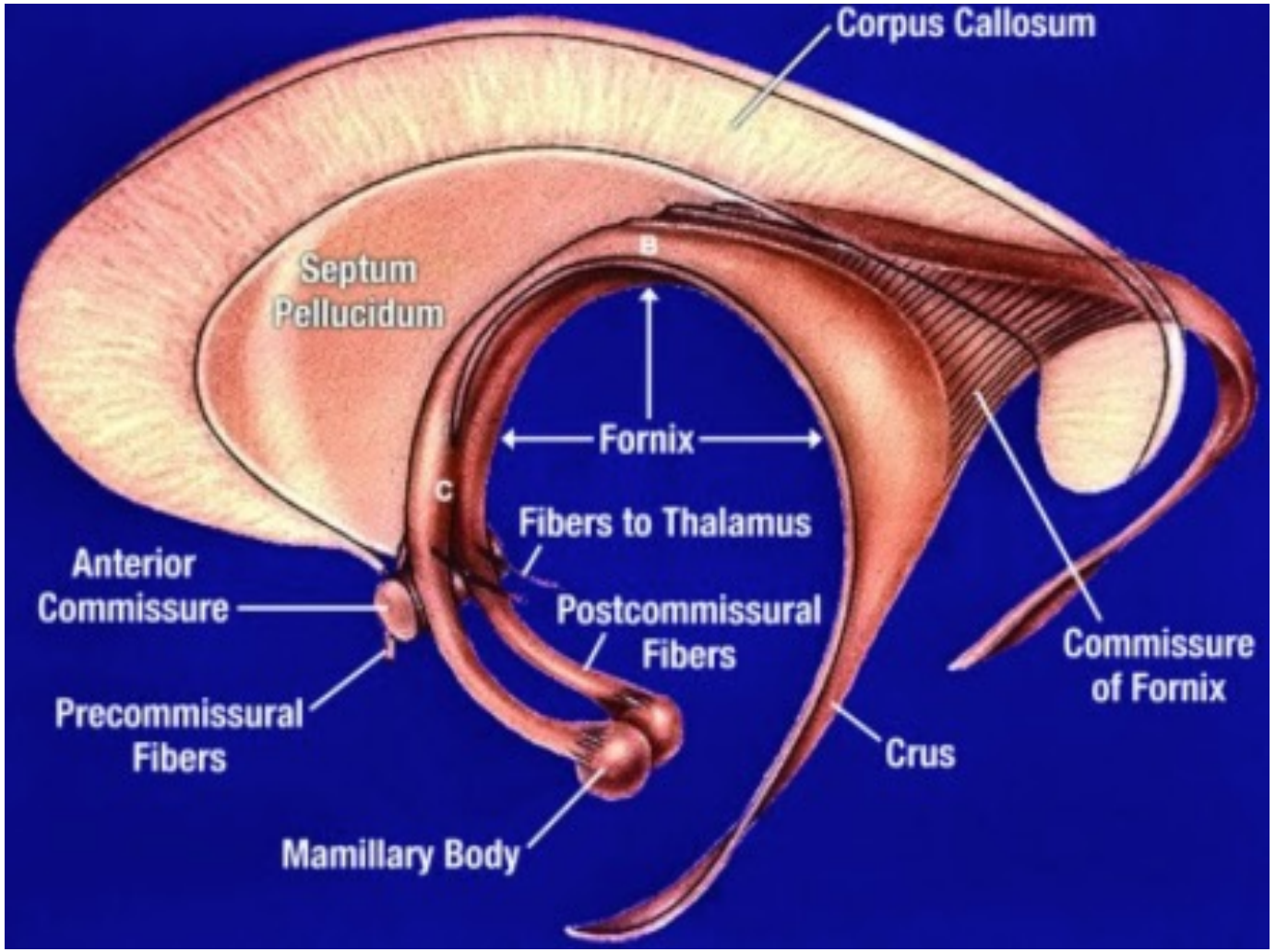
Fornix

- Fornix meaning ”arch” in Latin is a white matter structure that curves through the ventricular system from hippocampal formation to the diencephalon and septal area
- Is a “C” shaped tract (in sagittal section)
- Begins as the bundle of fibres called the **alveus**
- The alveus is white matter consisting of myelinated afferents and efferents
- As the fibers of the alveus travel posteriorly, they aggregate medially to form the **fimbria** of the fornix
- Fimbria means fringe and in this case it is the fringe of the hippocampus
- The fimbria looks like a thick rubber band
- Fimbria of each hippocampus thickens as it moves posteriorly and eventually splits off from the hippocampus forming the **crura or “legs”** (singular—crus) of each hippocampus
- Crus from each side curves posteriorly and superiorly under the splenium of corpus callosum
- The two crura curve around the posterior surface of the thalamus

Fornix


Schema of Fornix
Columns of fornix
Body of fornix
Commissure of fornix
Mamillary bodies
Crura of fornix
Fimbria of hippocampus
Hippocampus
Amygdaloid bodies

Fornix


Corpus Callosum
Septum Pellucidum
B
Fornix
C
Fibers to Thalamus
Anterior Commissure
Postcommissural Fibers
Precommissural Fibers
Commissure of Fornix
Crus
Mamillary Body

Fornix

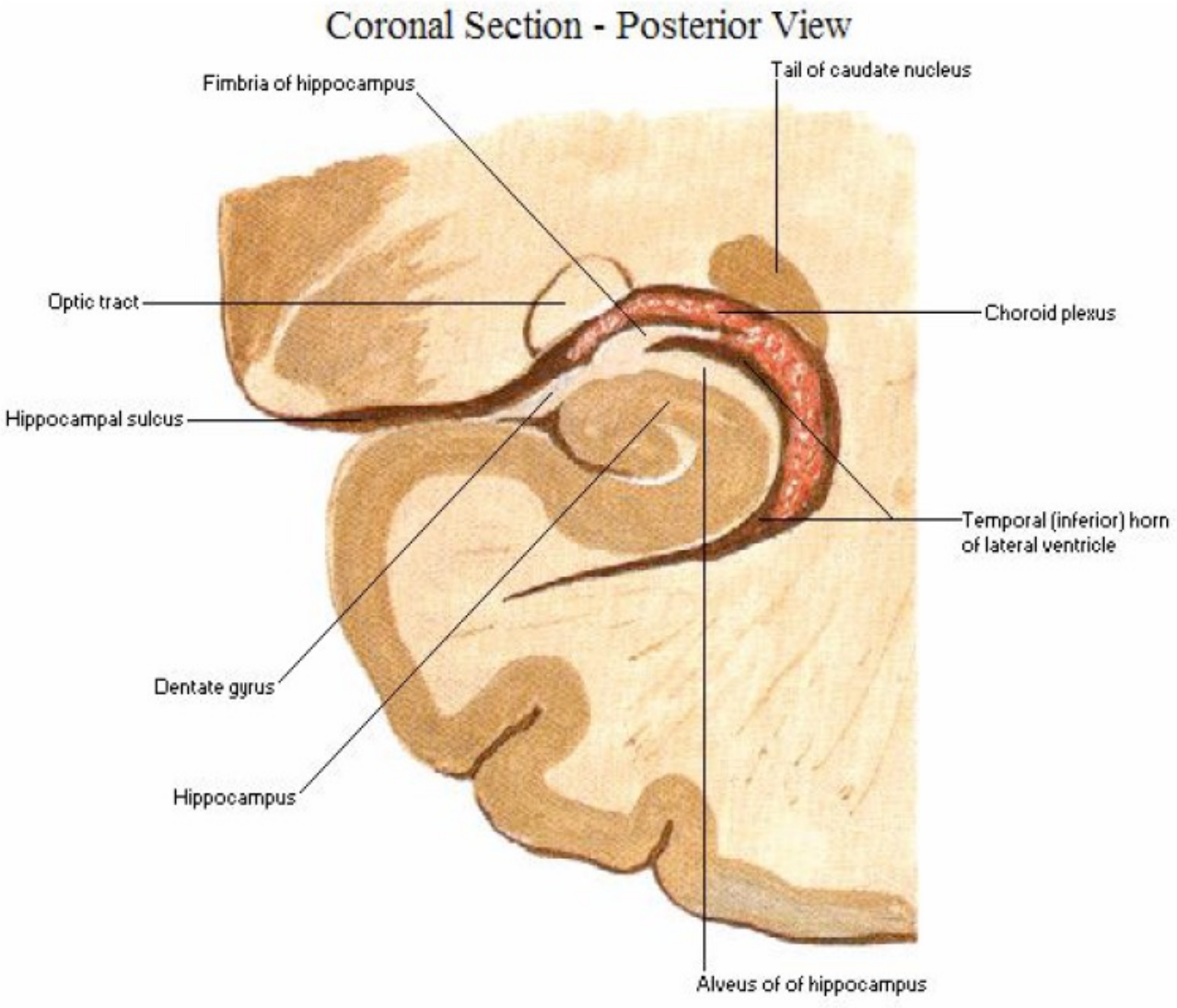
- The two crura come together and form the hippocampal commissure
- The **hippocampal commissure** provides one of two major paths whereby the hippocampi communicate with each other
- After the hippocampal commissure the single fibre bundle is referred to as the **body of fornix**
- The crura join in the midline, just under the corpus callosum to form the body of fornix
- The body of the fornix is very closely applied to the inferior surface of the corpus callosum
- Septum pellucidum is a very thin nervous structure that connects the body of fornix to the undersurface of corpus callosum
- The tela choroidea and the ependymal roof of the third ventricle are located just below the body of fornix

Fornix

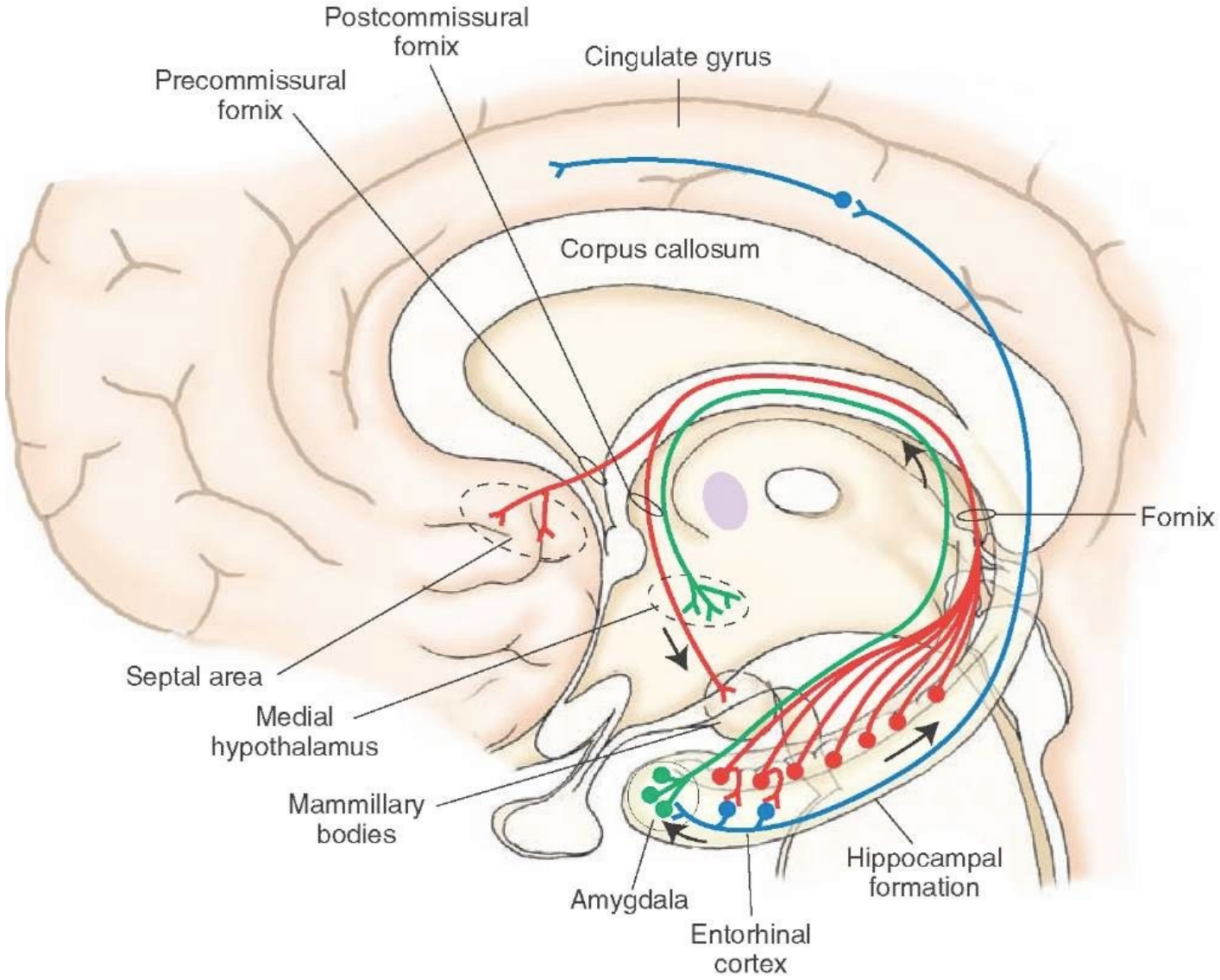
- Body of the fornix anteriorly divides into two **columns of fornix**
- The two columns diverge slightly lateral to the midline
- These columns then curve downwards
- They arch just in front of the interventricular foramen
- These columns descend to the anterior commissure
- The anterior commissure is important as a landmark because this is where the fornix splits into three parts and goes to different structures:

1. The split just before the anterior commissure is called the precommissural fornix and this branch goes to the **septal nuclei, the ventral striatum, and the cingulate cortex.**
2. Some fibers from the fornix also pass through the anterior commissure to the contralateral hippocampus. This is the second of the two major paths by which the hippocampi communicate with each other.
3. The split after the anterior commissure is called the postcommissural fornix and this branch goes to the **mammillary bodies of the hypothalamus and the anterior nuclei of the thalamus.**

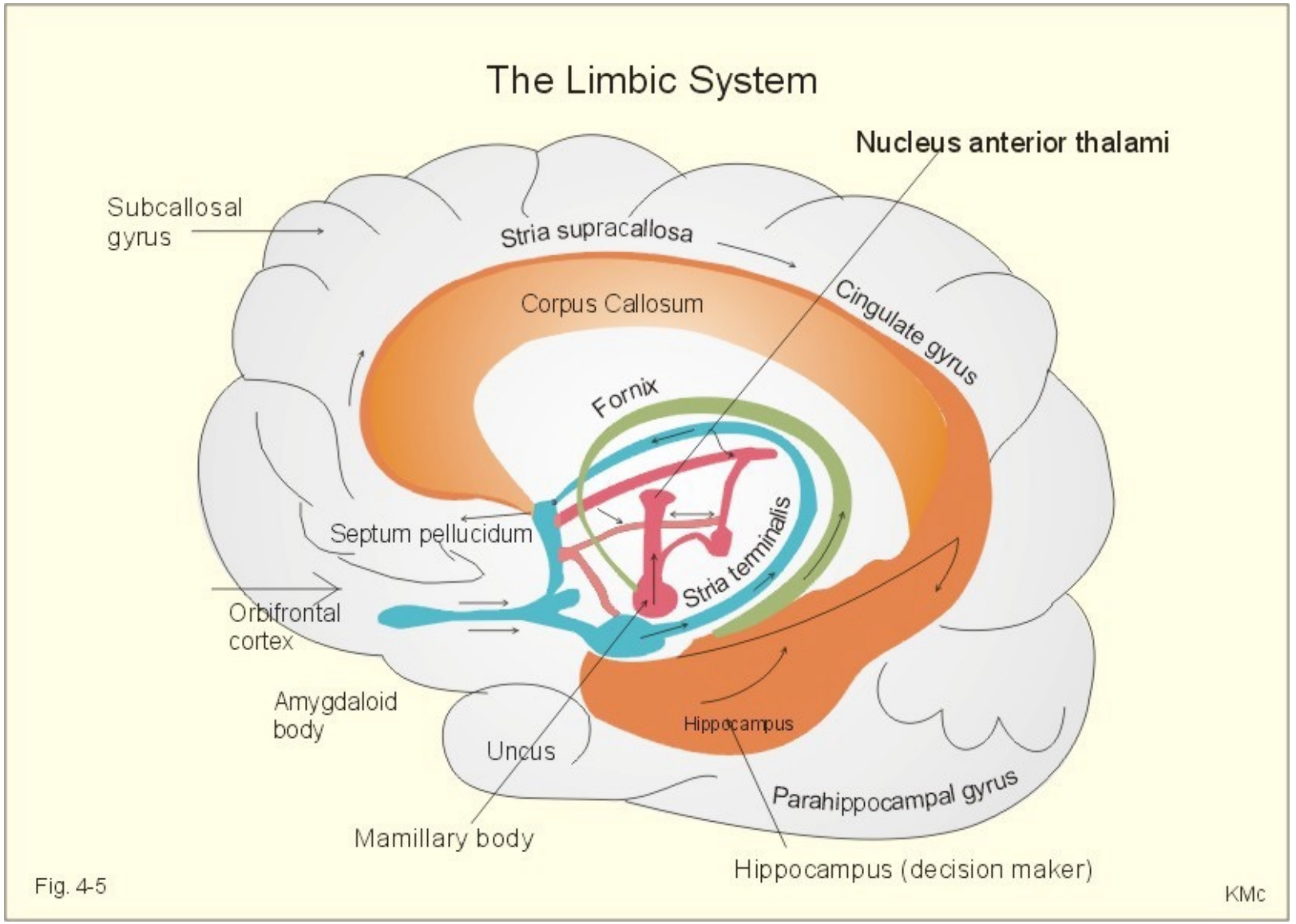
Overview of Limbic Structures



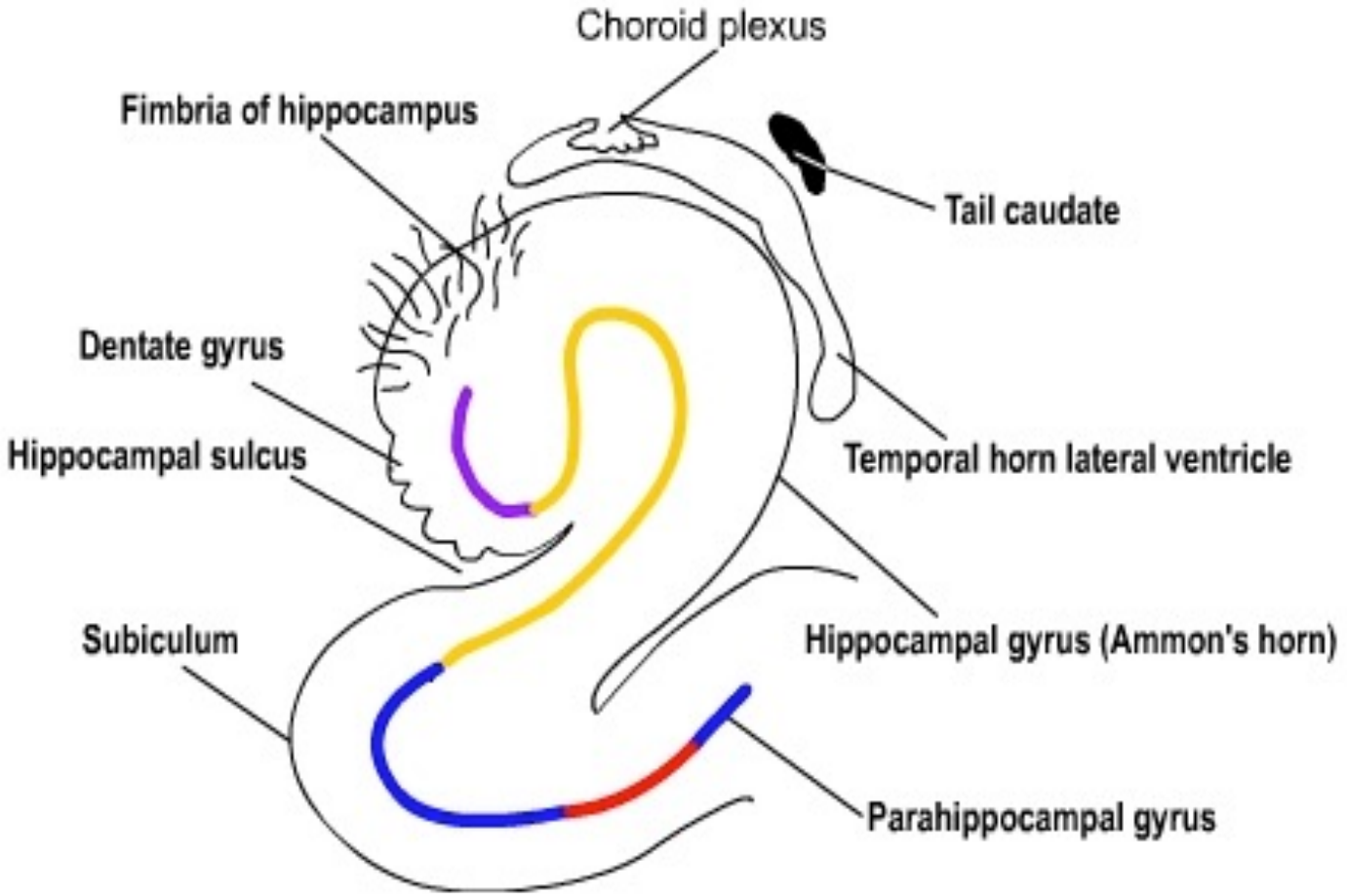
Overview of Limbic Structures

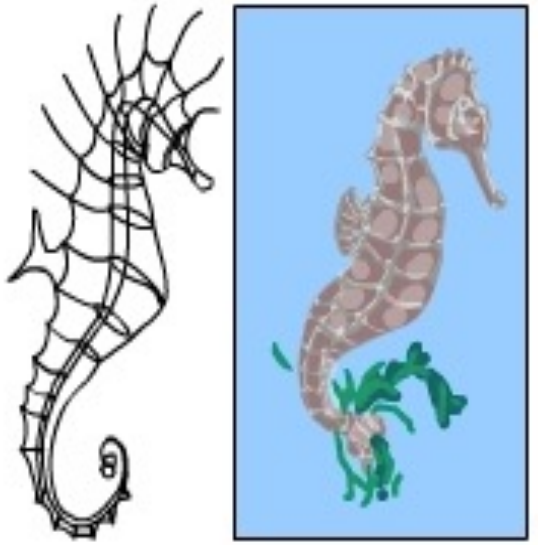


Connecting Pathways of the Limbic System



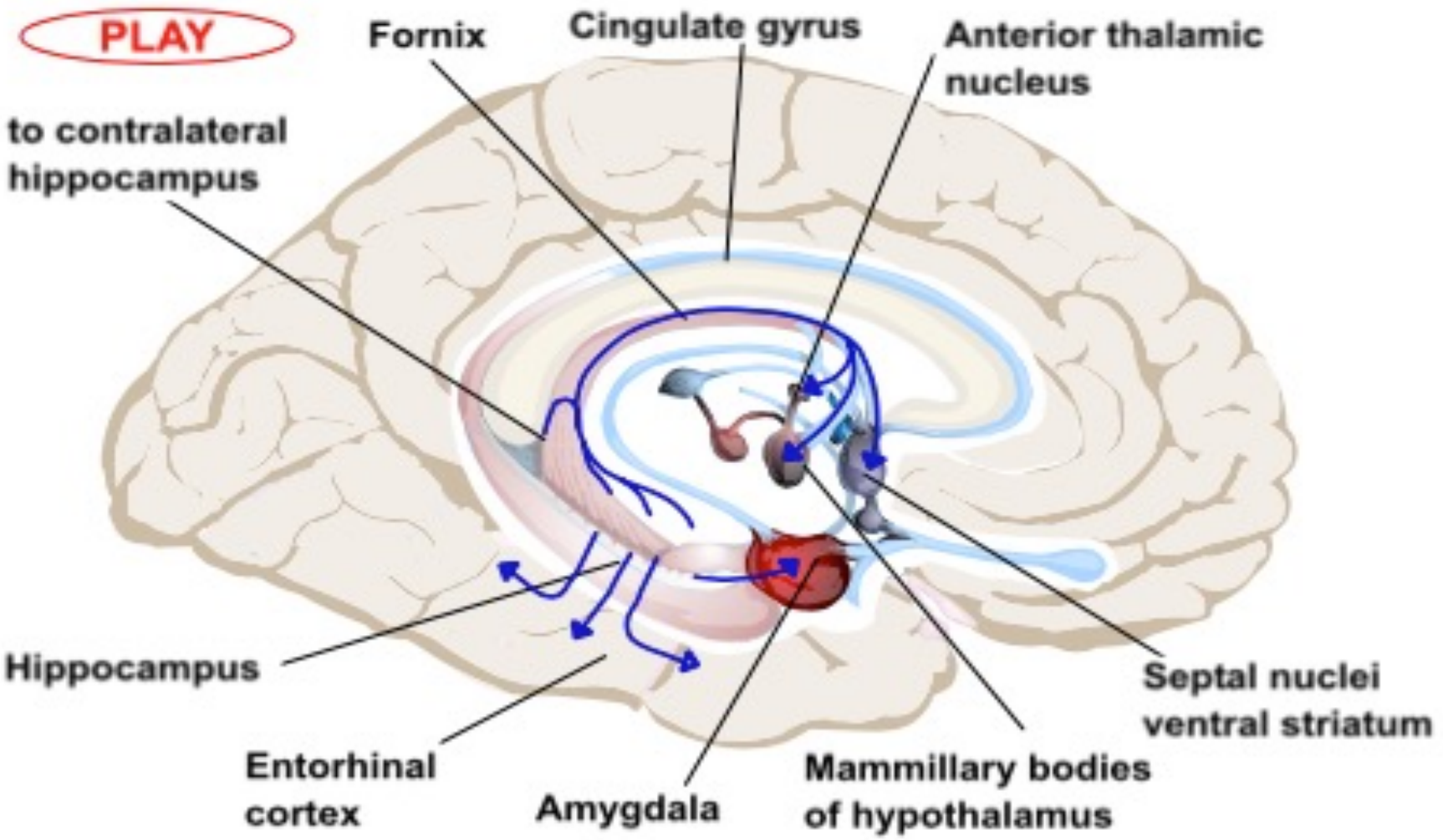
Overview of Limbic Structures





Geneus Hippocampus

Output Pathways of the Hippocampus



Overview of Limbic Structures

Hippocampal formation

- Is the medial and dorsal continuation of the parahippocampal gyrus
- Buried within the medial temporal lobe forming the floor of the temporal horn of the lateral ventricle
- One of several C-shaped structures in the limbic system
- Unlike the six-layered neocortex, it has only three layers and is called archicortex
- Has an elaborate curving S or inverted S shape on coronal sections
- This appearance inspired the names hippocampus (meaning “sea horse” in Greek) and cornu Ammonis (Latin for “horn of the ancient Egyptian ram-headed god Ammon”)
- The three components of the hippocampal formation are:

- **Dentate gyrus**
- **Hippocampus**
- **Subiculum**

- Sometimes the term “hippocampus” is used to refer to all three components

Overview of Limbic Structures

- During embryological development, the three layered archicortex of the medial temporal lobe folds over itself twice
- This leads to the pial or gray matter surfaces of the dentate gyrus and subiculum fuse and ventricular or white matter surfaces of the subiculum and parahippocampal gyrus fuse
- The hippocampal formation is largest anteriorly where it forms the **pes hippocampi (hippocampal head)**
- Hippocampal formation curves back along the floor of temporal horn, tapers to a smaller hippocampal tail and finally disappears as it curves under the ventral posterior edge of the splenium of corpus callosum
- A minor vestigial remnant of the hippocampal formation called **indusium griseum** continues along the dorsal surface of corpus callosum

Overview of Limbic Structures

- **Components of Parahippocampal Gyrus**

- Piriform cortex
- Periamygdaloid cortex
- Presubicular cortex
- Parasubicular cortex
- Entorhinal cortex
- Prorhinal cortex
- Perirhinal cortex
- Parahippocampal cortex

Overview of Limbic Structures

Amygdala

- Is a nuclear complex that lies in the anteromedial temporal lobe
- Overlaps the anterior end of the hippocampus and lies dorsal to the tip of the temporal horn of the lateral ventricle
- The posterior amygdala and anterior hippocampus lie just underneath the uncus
- It has three main nuclei:

- **Corticomedial**
- **Basolateral**
- **Central**

- The C-shaped bed nucleus of the stria terminalis is considered part of amygdala
- Serves important functions in emotional, autonomic and neuroendocrine circuits of the limbic system

Overview of Limbic Structures

Other structures

- Diencephalic structures participate in all functions of the limbic system
- These structures include hypothalamus, mediodorsal nucleus of the thalamus, anterior nucleus of thalamus and habenula
- Ventral portions of basal ganglia process limbic information
- Limbic inputs to the basal ganglia arrive at the ventral striatum and nucleus accumbens and are then relayed via the ventral pallidum to the mediodorsal nucleus of the thalamus which projects to the anterior cingulate limbic cortices

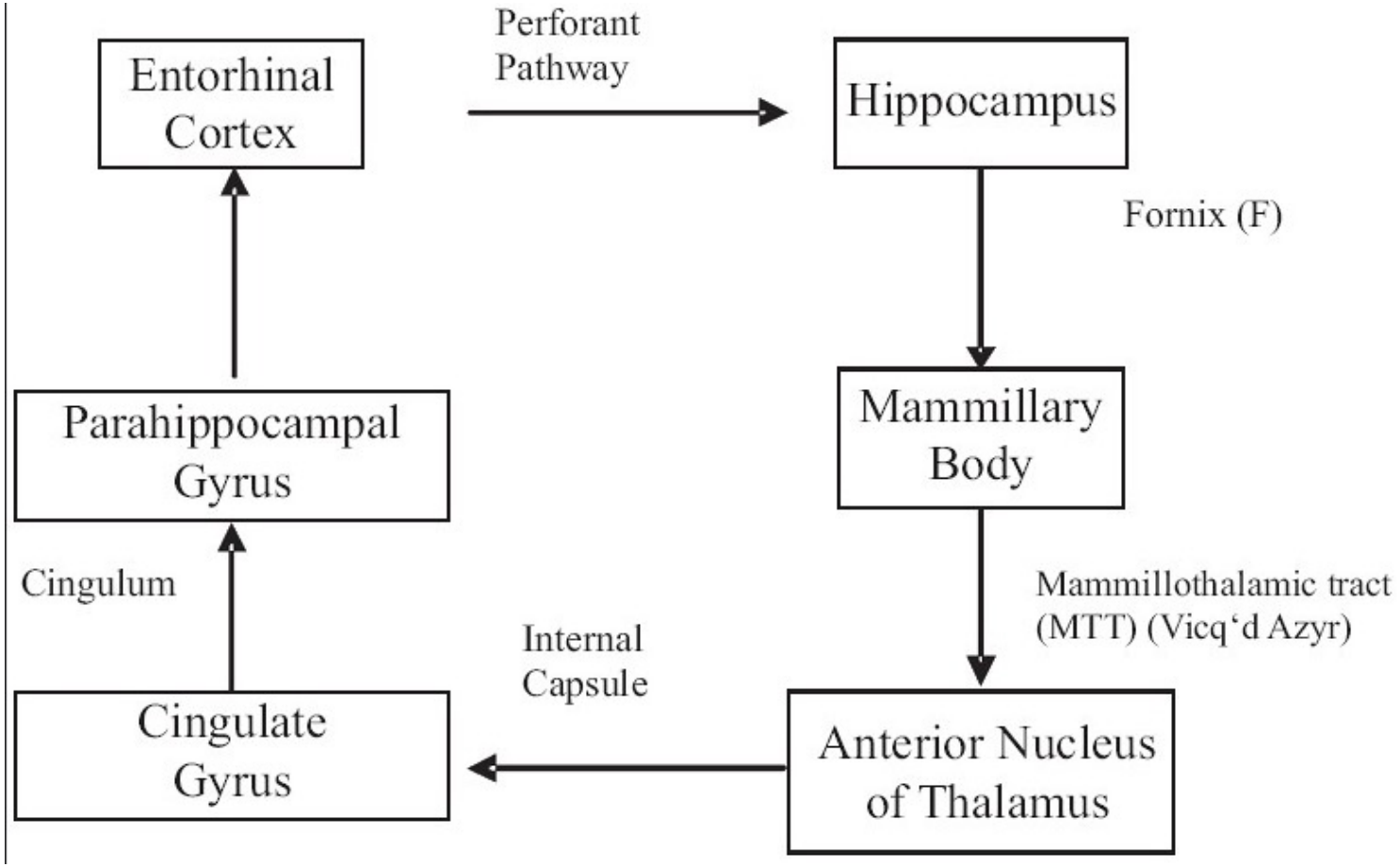
Overview of Limbic Structures

- Basal forebrain (including the **nucleus basalis of Meynert**) and septal region are contiguous and sometimes lumped together
- The nucleus basalis of Meynert provides the major cholinergic innervation for the entire cerebral cortex
- Numerous brainstem nuclei have reciprocal connections with limbic pathways and are sometimes considered part of limbic system
- Examples include interpenduncular nucleus, superior central nucleus, dorsaland ventral tegmental nucleus, parabrachial nucleus, periaqueductal gray, reticular formation, nucleus solitarius and dorsal motor nucleus of vagus
- Brainstem nuclei may help link limbic pathways to mechanisms for autonomic and behavioural arousal

Papez Circuit

- In 1937, the anatomist **James Papez** described a circuit involving several limbic structures thereby stimulating the development of the concept of the limbic system in the 1950s
- Although the structures in this circuit have subsequently been shown to have many other important connections as well, the Papez circuit remains a useful heuristic device for reviewing some of the major limbic pathways
- The circuit begins with fibres arising from the subiculum of the hippocampal formation which enter the fornix and travel forward to both the medial and the lateral mammillary nuclei of the hypothalamus
- The medial mammillary nucleus then projects via the mammillothalamic tract to the anterior thalamic nucleus

Papez Circuit



Papez Circuit

- Recall that the anterior thalamic nucleus also receives a direct projection from the fornix
- The anterior thalamic nucleus next projects via the internal capsule to the cingulate gyrus
- Finally, a prominent white matter pathway underlying the cingulate gyrus called **cingulate bundle or cingulum** passes from the cingulate cortex to the parahippocampal gyrus
- From the parahippocampal gyrus, projections continue to the entorhinal cortex and hippocampal formation completing the loop

Medical applications

- **Types of memory**
- Declarative (explicit) vs non-declarative (implicit)
- Short term vs long term
- Episodic vs semantic
- Retrospective vs prospective

- **Memory disorders**
- Amnesia
✓Retrograde amnesia
✓Anterograde amnesia
✓Transient global amnesia
✓Psychogenic amnesia
✓Post-traumatic amnesia
- Autism
- Dementia
- Alzheimer's disease
- Wernicke-Korsakoff syndrome

- **Seizures and epilepsy**

Read about the famous story of Patient H.M.

End