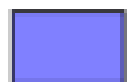
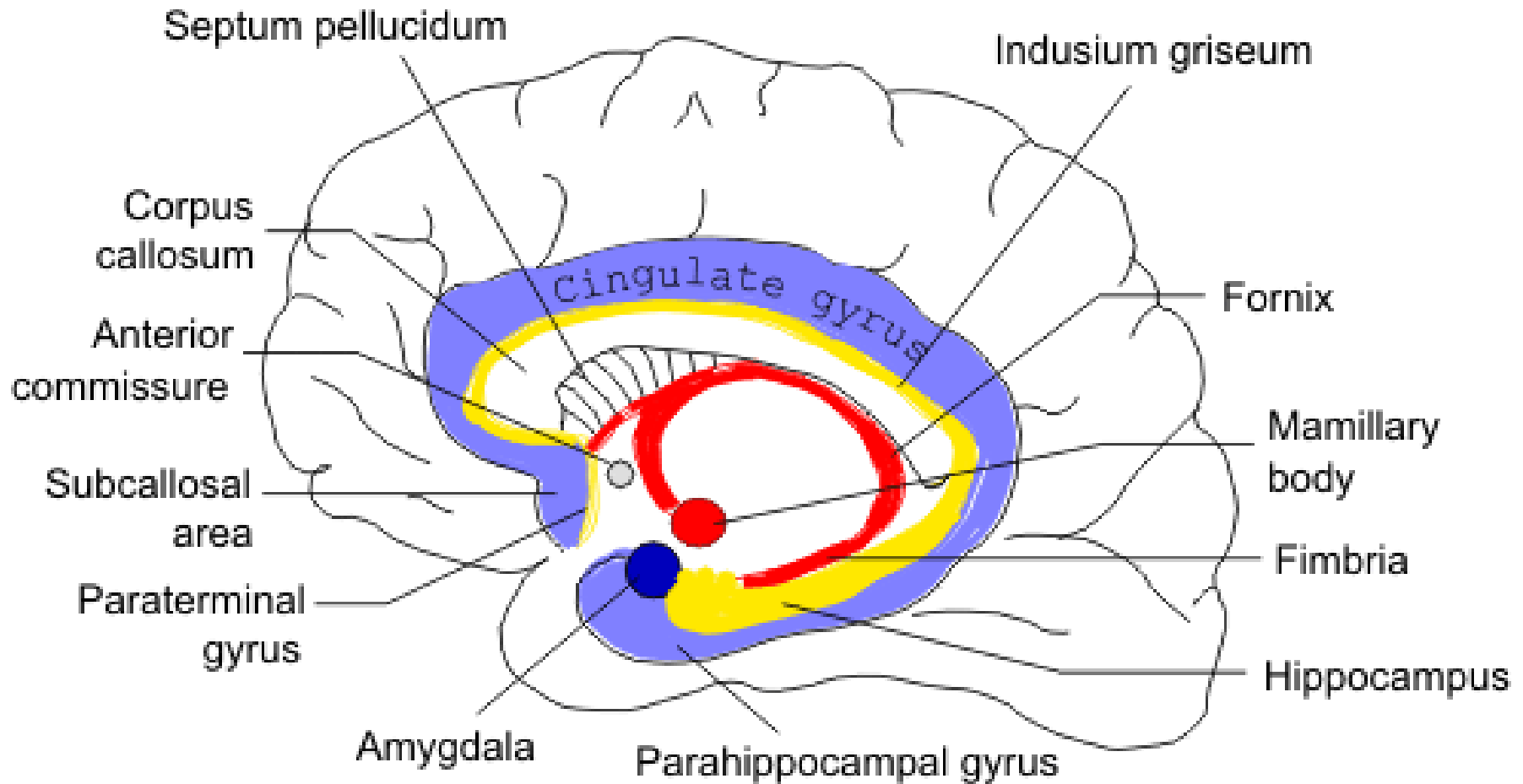


# LIMBIC SYSTEM

# Limbic system

- „*visceral brain*“
- management of homeostasis
- emotional reactions
- sexual behavior
- care for offspring
- social behavior
- memory and motivation
- control of autonomic functions

# The Limbic System



Limbic Gyrus



Intralimbic Gyrus



Fornix & Inner Arc

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# Classification

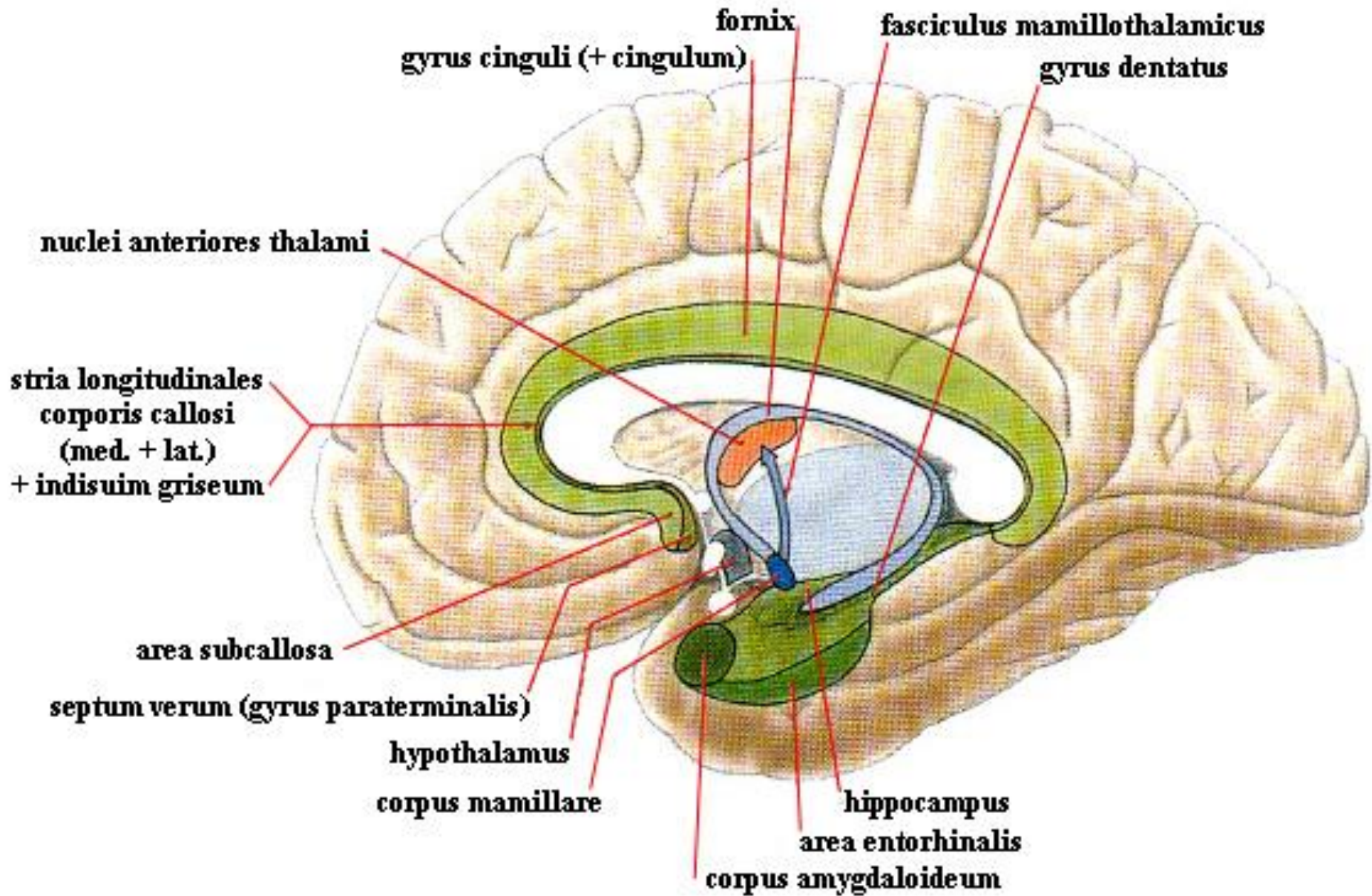
- cortical
  - **regions**  
correspond to cortical areas according to their histological structure
  - **functional zones**  
related to functional connection
- subcortical (nuclei)
  - within tele-, di-, mesencephalon, pons

# Cortical regions

- paleocortical
  - primary olfactory cortex
- archicortical = hippocampal formation
  - hippocampus
  - subiculum
  - gyrus dentatus
- mesocortical (transitional)
  - area entorhinalis et perirhinalis
  - presubiculum
- neocortical
  - area subcallosa
  - gyrus cinguli
  - gyrus parahippocampalis

# Zones

- innermost zone
  - corpora mammillaria, fornix, fimbria hippocampi
- inner zone („gyrus intralimbicus Brocae“)
  - hippocampus, gyrus dentatus, indusium griseum
- outer zone („gyrus limbicus“)
  - subiculum, presubiculum, parasubiculum
  - area entorhinalis
  - uncus g.p. et gyrus parahippocampalis
  - gyrus cinguli, area subcallosa
- neocortical paralimbic cortex
  - insula, anterior pole of temporal lobe, medial and orbital part of frontal lobe





**Hippocampus and Fornix**  
Schema of Fornix



**Hippocampus and Fornix**  
Coronal Section - Posterior View





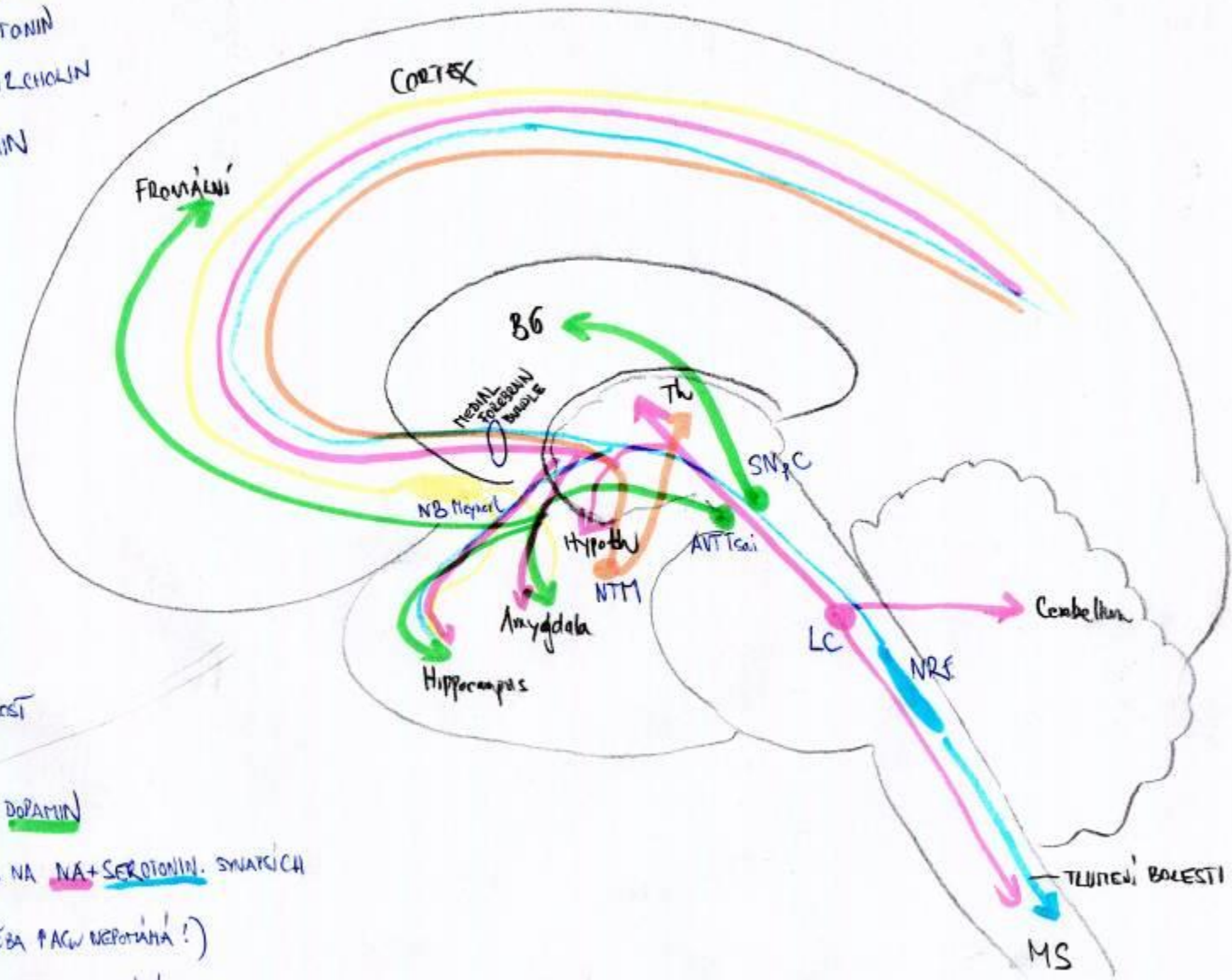
# Subcortical – nuclei

- **corpus amygdaloideum**
- **septum verum**
- **nucleus accumbens**
- **ncl. mammillares**
- **ncll. habenulares**
- **ncll. anteriores thalami**
- **ncl. interpeduncularis**
- **(ncl. tegmentalis dorsalis *Guddeni*)**
- **ncl. parabrachiales med.+lat.**

# Chemical nuclei

- monoaminergic
  - catecholaminergic system
    - adrenergic
    - dopaminergic
  - serotonergic
- cholinergic
- histaminergic
- glutamatergic
- GABAergic

- NORADRENALIN
- DOPAMIN
- SEROTONIN
- ACETYLCHOLIN
- HISTAMIN



ANTI-HISTAMINIKA ⇒ ospalost

SCHIZOFRENIE

- ANTI-PSYCHOTIKA blokujúci DOPAMIN

DEPRESE

- ANTI-DEPRESIVA ↑ PŘENOS NA NA + SEROTONIN. SYMPTOMŮ

ALZHEIMER

= ↓ ACh NEURONŮ (LÉČBA ↑ ACh NEPOTŘÁHA!)

PARKINSON

- ↓ Dop NEURONŮ (LÉČBA ↑ Dop POTŘÁHA)

# Chemical nuclei noradrenergic system

- **noradrenalin (norepinephrin, NA)**
- A1-A7 (RF of pons and medulla oblongata)
- autoregulation of cerebral arteries
- modulation of activity of neuronal circuits of all levels of CNS
- systems of attention, emotions and behavior, consciousness and memory
- part of ARAS
- **locus caeruleus (A7)**
  - medulla, nuclei of brainstem and cerebellum
  - thalamus, hypothalamus, neocortex, hippocampus, corpus amygdaloideum

# Chemical nuclei dopaminergic system

- **dopamine (D)**
- motorics, reaction of reward and punishment, perception of reality
- sleep and vigilance, attention and memory, learning ability
- **nucleus retrorubralis (A8)** – to hippocampal formation
- **pars compacta substantiae nigrae (A9)** – to striatum (nigrostriatal tract) for proper activity of BG
- **nucleus subbrachialis (area ventralis tegmentalis *Tsai* – A10)**
  - **mesolimbic, mesocortical and tuberoinfundibular**
  - to prefrontal cortex and M1, corpus amygdaloideum, hypothalamus, striatum, ncl. accumbens and other parts of limbic systém
  - tuberoinfundibular projection (from ncl. arcuatus hypothalami) inhibits secretion of prolactine (milk production and libido)

# Chemical nuclei serotonergic system

- **serotonine (5-HT)**
- system of „mood and anxiety“
- **B1-B9 (ncll. raphes)**
- medulla, brainstem, cerebellum, thalamus, hypothalamus, cortex and limbic system
- changes of mood and behavior
- tractus raphespinalis – suppression of pain transmission in posterior horns of spinal cord

# Chemical nuclei cholinergic system

- acetylcholine (Ach)
- Ch1-Ch6
- **septum verum (Ch1)** – to hippocampus and corpus amygdaloideum
- limbic system (Ch2-3)
- **nucleus basalis Meynerti (Ch4)**
  - to cerebral cortex, hippocampus and corpus amygdaloideum
  - behavior and cognitive function (consciousness, memory, learning)
- RF (Ch5-6) – part of ARAS (extrapyramidal motorics and limbic circuits)



# Chemical nuclei histaminergic system

- histamine (H)
- posterior hypothalamus
  - transmission of pain, motorics, thermoregulation, biorythms, food and fluids intake
  - **ncl. tuberomammillaris**
    - to cortex and medulla
    - vigilance-sleep cycle
      - supply of histamine is crucial for arousal

# Chemical nuclei glutamatergic system

- glutamate (Glu)
- principal excitatory mediator of CNS
- majority of tracts and circuits
  - **ncl. subthalamicus**
  - **neurons of cerebral and cerebellar cortex**

# Chemical nuclei

## GABAergic system

- gamma-aminobutyric acid (GABA)
- principal inhibitory mediator of CNS
  - glycine in medulla !
- majority of cortical and subcortical structures

# Chemical nuclei

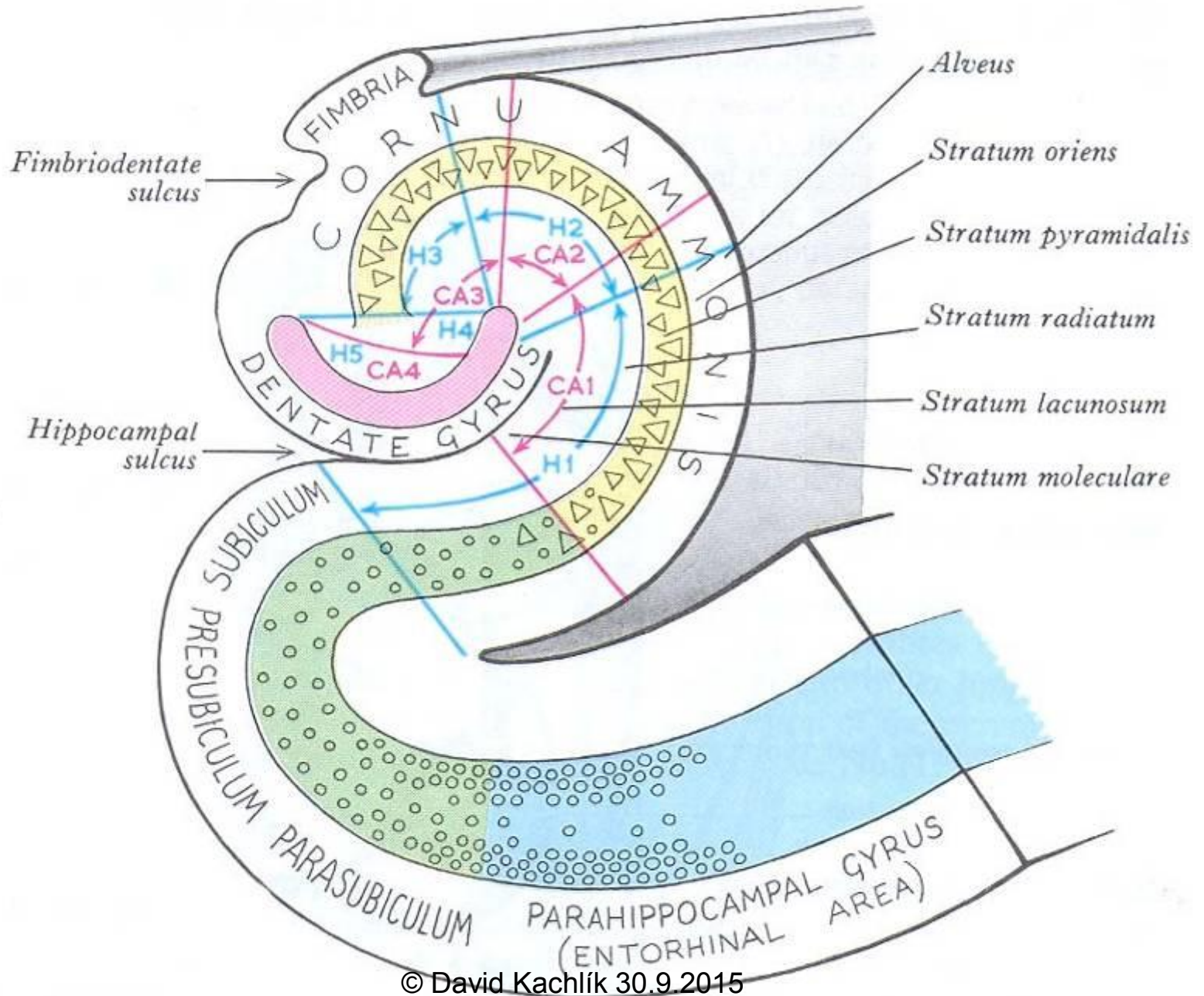
- *cholinergic nuclei*: ncl. basalis Meynerti, ncl. tractus diagonalis *Brocae* + septalis med. v septum verum, ncl. preopticus magnocellularis v hypothalamu
- *dopaminergic nuclei* : pars compacta substantiae nigrae, nucleus subbrachialis formationis reticularis (= area tegmentalis ventralis Tsai)
- *noradrenergic nuclei* : locus caeruleus
- *serotonergic nuclei* : ncl. raphei med.+dors., ncl. centralis superior tegmenti *Bechterevi* (v RF)
- *histaminergic nuclei*: ncl. tuberomamillaris hypothalami

# Olfaction

- cortex piriformis – in rostral part of temporal lobe
- cortical part of corpus amygdaloideum
- uncus gyri parahippocampalis
- rostral end of gyrus parahippocampalis
  
- *area entorhinalis = area28*
- *highest center of olfaction* – orbitofrontal cortex

# Hippocampal formation

- **hippocampus proprius**
- **subiculum**
- **gyrus dentatus**
- function: storing of information into long-term memory (consolidation of memory trace)
- AF: area enthorinalis, thalamus, association areas of neocortex (via gyrus cinguli et parahippocampalis)
- stimulation: NA (A6), Ach (Ch1), 5-HT (B1-9)
- EF: fornix → hypothalamus → thalamus  
area entorhinalis → association areas of neocortex





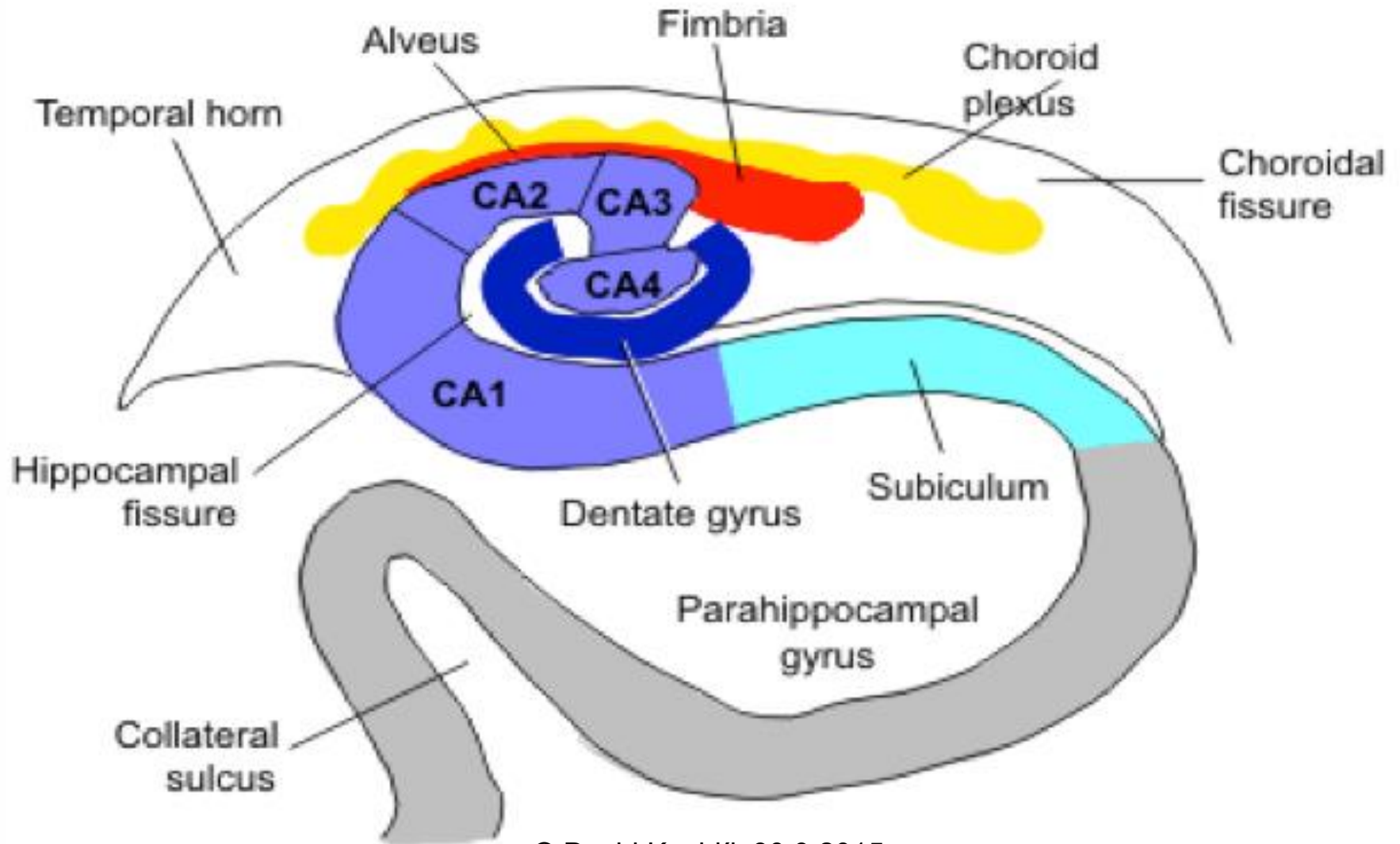
# Hippocampus proprius = cornu Ammonis

- part of gyrus parahippocampalis facing cornu inferius ventriculi lateralis (5 cm long prominence)
- alveus = fibers layer on surface of hippocampus under ependyma leading into fimbria hippocampi
- regio I-IV (CA 1-CA 4)
  - stratum moleculare (+ substratum lacunosum)
  - stratum oriens
  - stratum pyramidale
  - stratum radiatum

# Subicular complex

- **subiculum** (archicortex)
  - on superior surface of gyrus parahippocampalis
  - *distinguish situations of danger and reward*
- **presubiculum** (periarchicortex)
  - band of periarchicortex on internal surface of temporal lobe, medial to subiculum, rostro-caudal direction
- **parasubiculum** (periarchicortex)

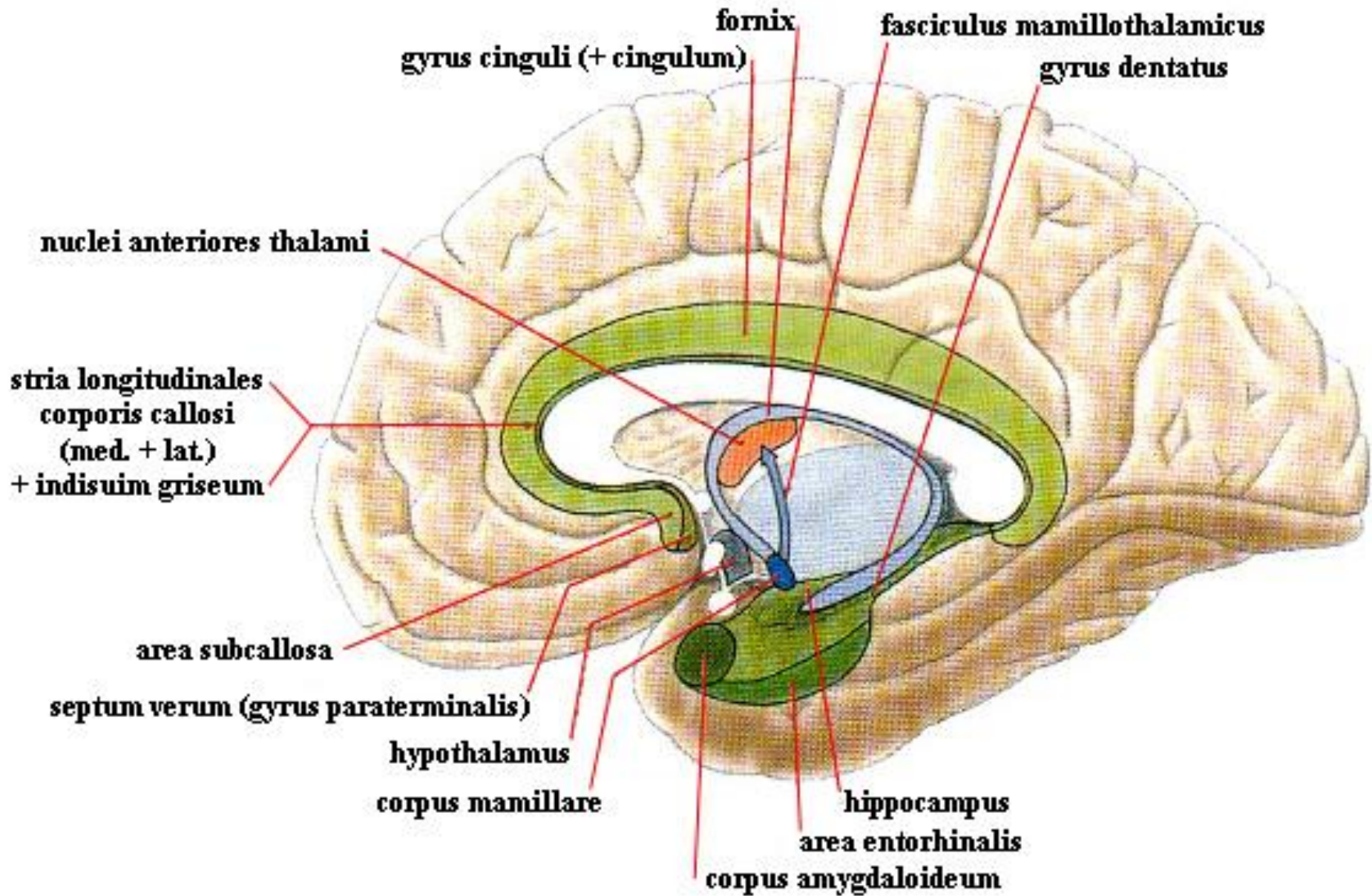
# Hippocampal Anatomy



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# Gyrus dentatus

- 3 layers: stratum moleculare, granulare, multiforme
- under fimbria hippocampi, medial to hippocampus
- rostrally gets narrower and terminates as oblique *taenia Giacomini*
  - separates uncus gyri parahippocampalis
- accompanies fimbria hippocampi as far as below splenium corporis callosi
- from there it continues as **gyrus fasciolaris** and further into **indusim griseum** as **striae longitudinales corporis callosi**



# Gyrus cinguli

- area 23-25,29-31
- AF: association areas of temporal, parietal and occipital lobe
- EF: feedbacks to cortex and subcortical areas (striatum, thalamus, cerebellum)
- emotional reactions (ventral part), verbal memory and spatial orientation (dorsal part)
- cingulum – tract leading to gyrus parahippocampalis

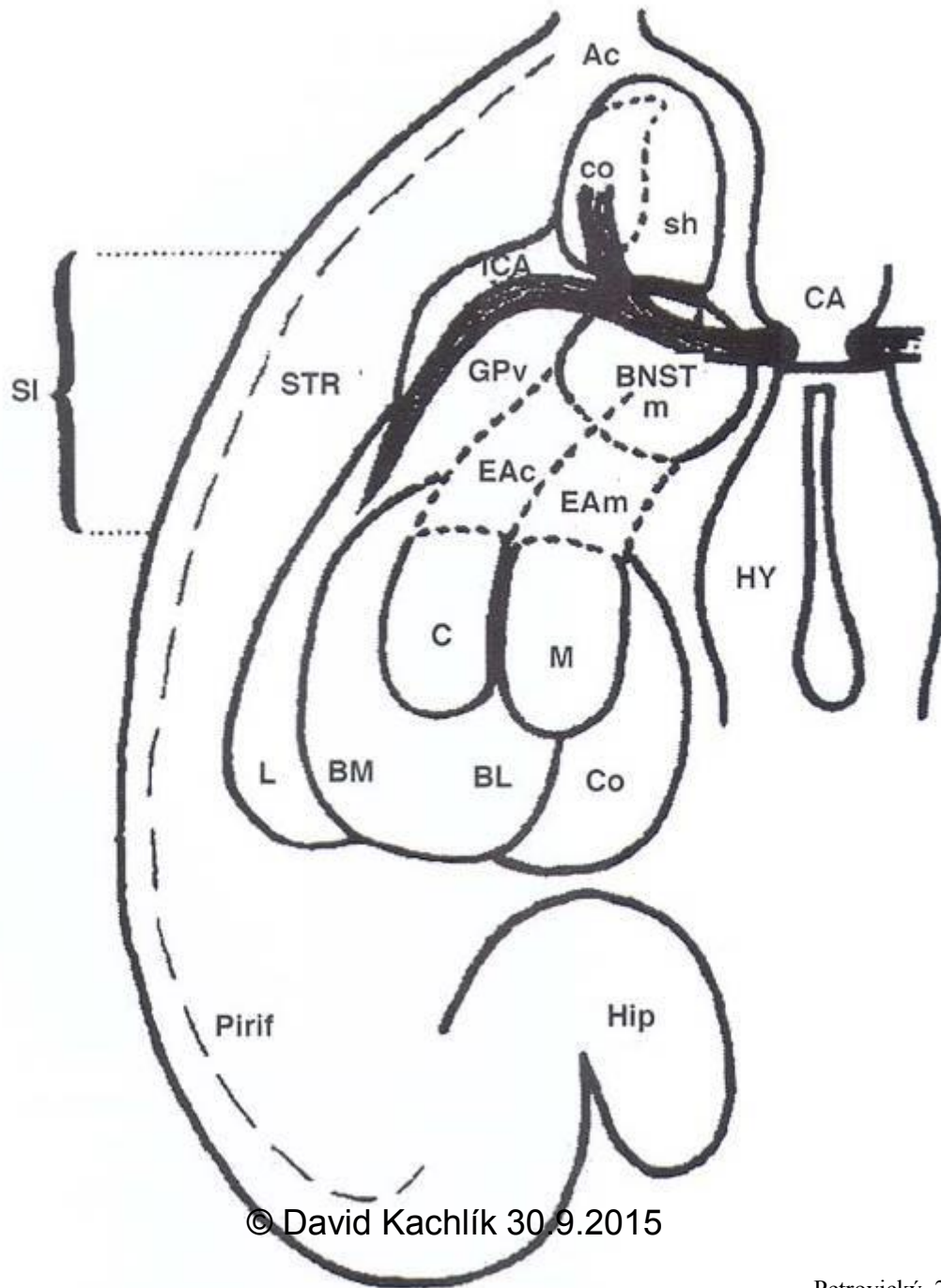
# Gyrus parahippocampalis

- uncus – rostrally
- area entorhinalis (area 28)
- area perirhinalis (area 35, 36)
- spatial memory, orientation and ability to distinguish and recognize objects
- AF: association areas, hippocampal formation, corpus amygdaloideum, thalamus
- EF: hippocampal formation, corpus amygdaloideum, thalamus (ncl. anteriores)



# Corpus amygdaloidum

- = amygdala = nucleus amgydalaе = archistriatum
- morphologically and developmentally basal ganglion
  - functionally and connected to **limbic system**
  - locate within temporal lobe rostral to cornu inferius ventriculi lateralis and to cauda ncl. caudati
  - complex of nuclei
  - younger = **baso-lateral part**
    - connection to cortex
  - older = **cortico-centromedial part**
    - connection to olfactory areas, hypothalamus nad brainstem
  - cortex periamygdalaris



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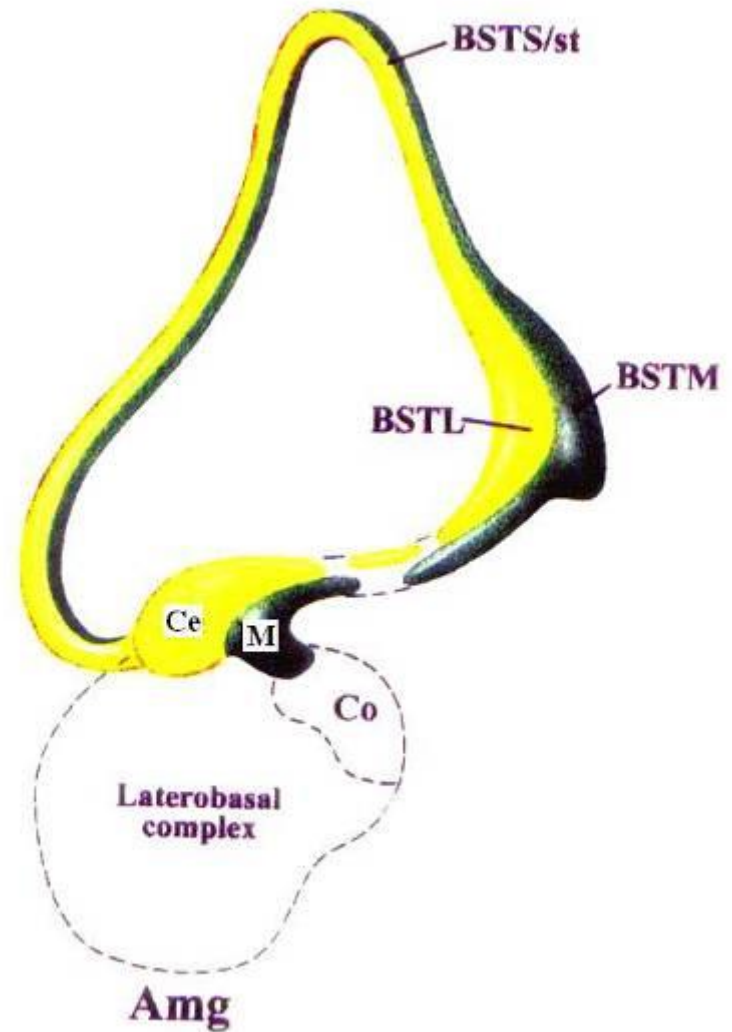
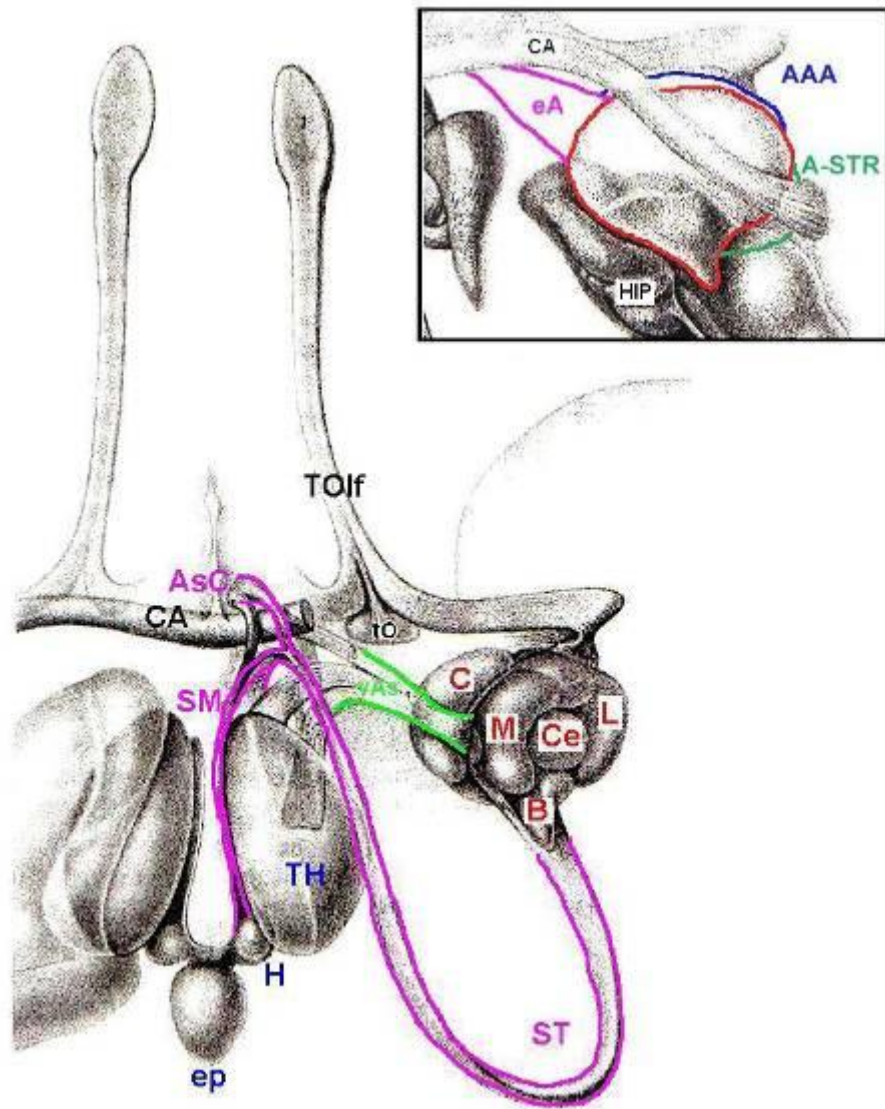
Petrovický, 2008

# Corpus amygdaloidum

- „center of emotions and fear“
- influences hypothalamus („drive-related behavior“)
- subjective feelings (fear, aggression) and defensive reactions
- formation and storing of memories connected with emotional events
- reactions to impulses with bad events / unpleasant smells
- fear reaction (stiffness, tachycardia, tachypnoe, clenched stomach)
- also connected to perception of pleasant impulses (love, desire, envy)
- *disorder: in contralateral damage → no aggressiveness*

# Corpus amygdaloidum – *connection*

- AF: rich sensory and visceral
- EF:
  - **stria terminalis** = dorsal amygdalofugal tract (along ncl. caudatus and v. thalamostriata) → septum verum + hypothalamus
  - **ventral amygdalofugal tract** (pod ncl. lentiformis) → septum verum + hypothalamus + piriform, orbital and anterior cingular cortex, ncl. accumbens, ncl. dorsomedialis thalami
  - to hippocampus (related to storing of memory)
  - to motor, premotor areas and BG (involuntary motorics)
  - to visceromotor nuclei of cranial nerves and spinal cord (influence of sympathetic and parasympathetic system)



# Connection of amygdala and extended amygdala, Petrovický et al., 1998

St – stria terminalis, Amg – amygdalar complex, BST – bed nucleus striae terminalis, Ce – centromedial nc. of amygdala, M – Medial amygdalar nucleus, ep – epiphysis, CA – anterior commissure, TOlf – tractus olfactorius, SM – stria medullaris

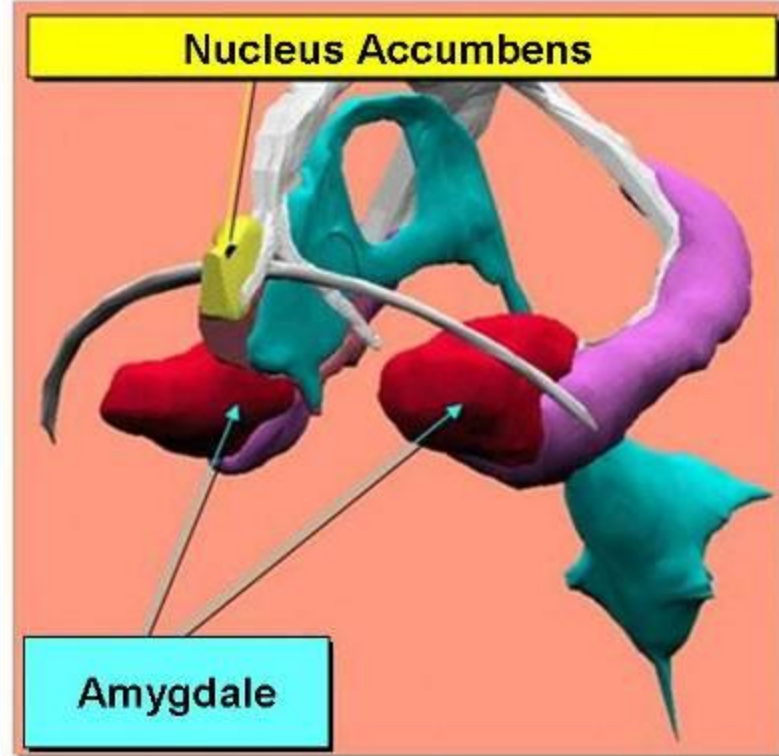
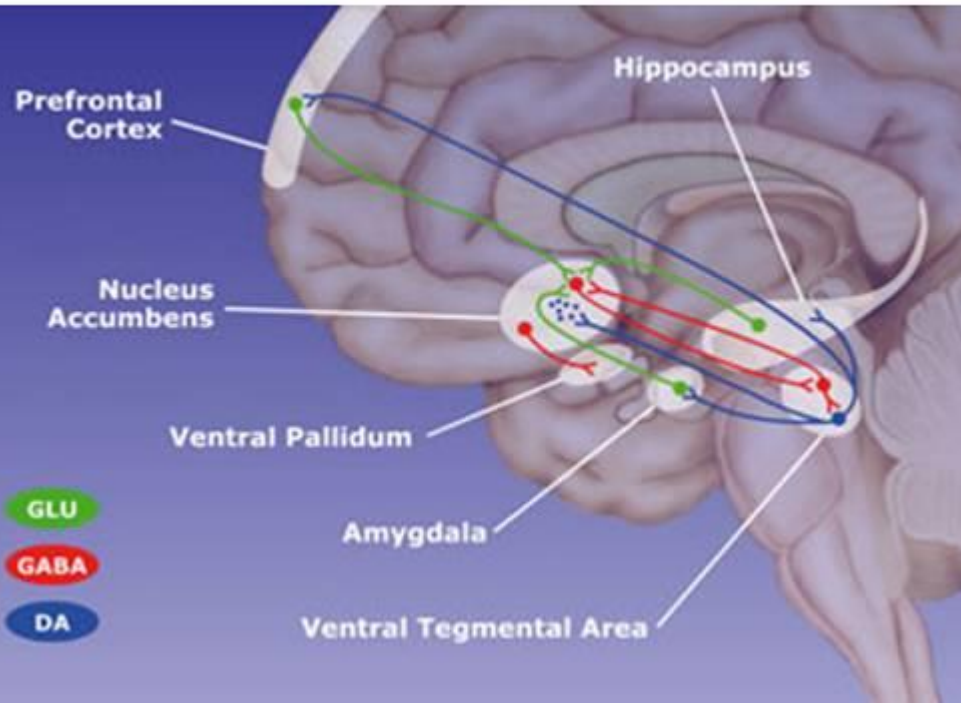
# Nucleus accumbens

= striatum ventrale

- developmentally to basal ganglia
- adjacent to septum verum, connected to limbic circuits
- „center of addiction of desire“
- related to addiction, reward and pleasure, fear and placebo effect

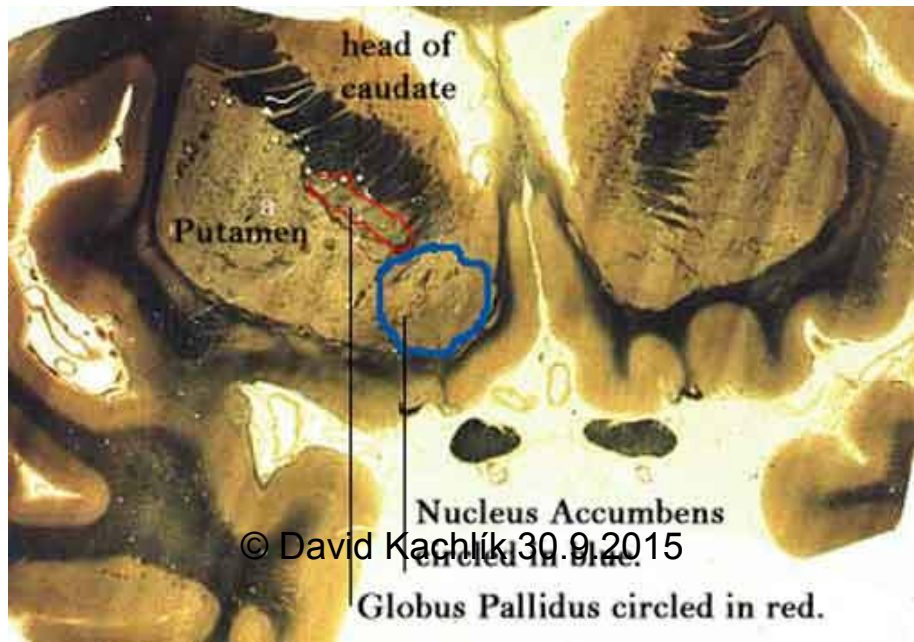


# The Reward Circuit



<http://mybrainnotes.com/brain-nucleus-accumbens.jpg>

[http://2.bp.blogspot.com/-0Hb2\\_pd7QwQ/UPmBdmeNFQI/AAAAAAAAA2E/YbZ6u0PMj0/s1600/nuc+accumbense.jpg](http://2.bp.blogspot.com/-0Hb2_pd7QwQ/UPmBdmeNFQI/AAAAAAAAA2E/YbZ6u0PMj0/s1600/nuc+accumbense.jpg)



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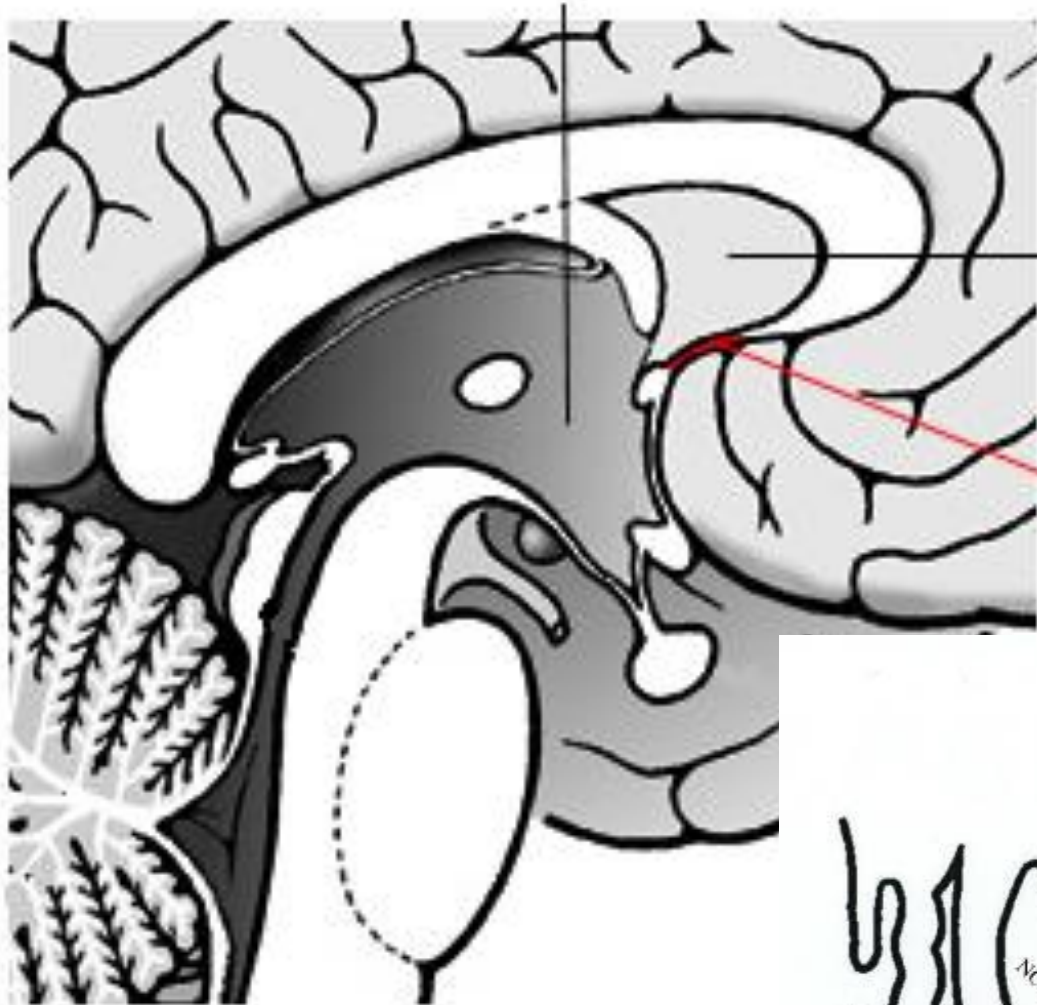
<http://www.personal.psu.edu/afr3/blogs/siowfa12/the-reward-circuit-nucleus-accumbens-ventral-pallidum-ventral-tegmental-area-and-amygdala.jpg>



# Septum verum

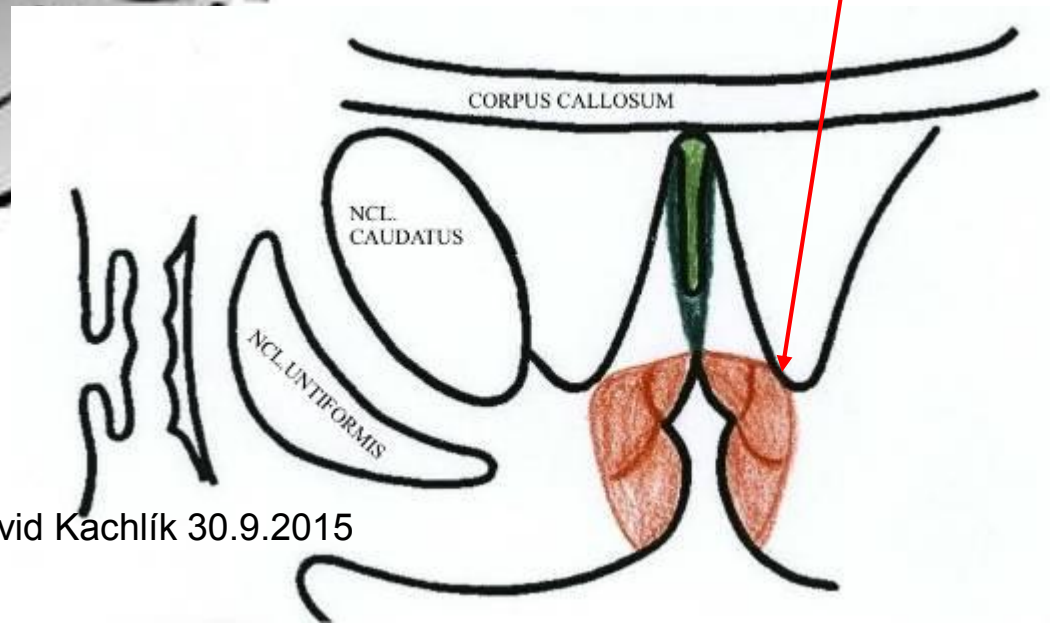
- basal part of pars septalis telencephali
- superficial projection = gyrus paraterminalis (it is not a cortex histologically!)
- laterally it forms medial surface of cornu anterius ventriculi lateralis
- caudally it reaches the commissura anterior
- function: closely related to limbic system
  - supply acetylcholine to hippocampus (Ch1)
- *center of pleasure, hedonie and reward*

### III. mozková komora



mediální stěna  
předních rohů  
postranních komor

**septum verum**



# Insula = Lobus insularis

- area 13-16 (4-6 gyri)
- viscerosensory (ventral) part
- taste, olfaction, regulation of immune response
- visceromotor (intermediate) part
  - breathing, digestion, speech, heart activity
- vestibular (dorsal) part
  - perception of position and movements of head
- emotional component of pain
- functional view:
  - ventral part: physiological changes during course of emotions
  - dorsal part: physiological changes of body state and its perception

# Insula – new classification

- dorsal insula
  - activity of fibers corresponds to physiological state of body (temperature, pain, itching, sensual touches, visceral and muscular feelings)
  - perception of heart action, full urinary bladder and distension of stomach
  - integration of auditory and motor information
- ventral insula
  - functional background of feelings
  - physiological changes in course of emotional states
  - emotions
  - regulations of tonus of sympathetic and parasympathetic system in cooperation with hypothalamus

# Pathways of limbic system

## fornix

- columnae
  - pars tecta
    - fibrae precommissurales → septum verum, gyrus cinguli
    - fibrae retrocommissurales → corpora mammillaria, ncl. anteriores thalami
  - pars libera
- corpus
- crura
  - commissura fornicis = *Lyra Davidis*
- fimbria hippocampi (laying on hippocampus in cornu inferius ventriculi lateralis)
  - taenia fornicis = insertion line of plexus choroideus ventriculi lateralis to fornix including its fimbria hippocampi



# Pathways of limbic systemu

- **tractus mamillothalamicus**
  - within lamina medullaris medialis thalami
  - corpora mammillaria → ncll. anteriores thalami
- **tractus mammilotegmentalis**
  - corpora mammillaria → tegmentum mesencephali and RF
- **amygdalofugal pathways**
  - stria terminalis = dorsal amygdalofugal tract
  - ventral amygdalofugal tract
- **stria medullaris thalami**
  - hypothalamus + septum verum → ncll. habenulares
- **fasciculus habenulointerpeduncularis (retroflexus *Meynerti*)**
  - ncll. habenulares → ncl. interpeduncularis
- **commissura anterior**
- **striae longitudinales corporis callosi medialis + lateralis**
  - septum verum + area subcallosa → gyrus dentatus + hippocampus
- **cingulum** – association bundle within gyrus cinguli
- **fasciculus longitudinalis posterior**
  - pathway of visceral brain
  - hypothalamus ↔ autonomic nuclei of brainstem

# Two principal subsystems (levels) of limbic systemu

- **hippocampus** (→ gyrus cinguli + gyrus parahippocampalis → neocortex) ~ **ncl. anteriores thalami + corpus mammillare**
- **corpus amygdaloideum** (→ prefrontal (orbital) cortex and anterior temporal cortex → neocortex) ~ **ncl. dorsomedialis thalami**

# Circuits of limbic system

- **limbic circuit (loop) of basal ganglia**

hippocampus, gyrus cinguli, orbitofrontal cortex, temporal cortex → ncl. accumbens → substantia nigra → pallidum ventrale → thalamus (ncl. DM) → orbitofrontal and anterior cingular cortex

- somatomotor and visceromotor expression of emotional states
- influences motor expressions of emotions (muscle shivering muscles, trembling voice, laugh, cry, nonverbal communication)
- visceromotor response via hypothalamus



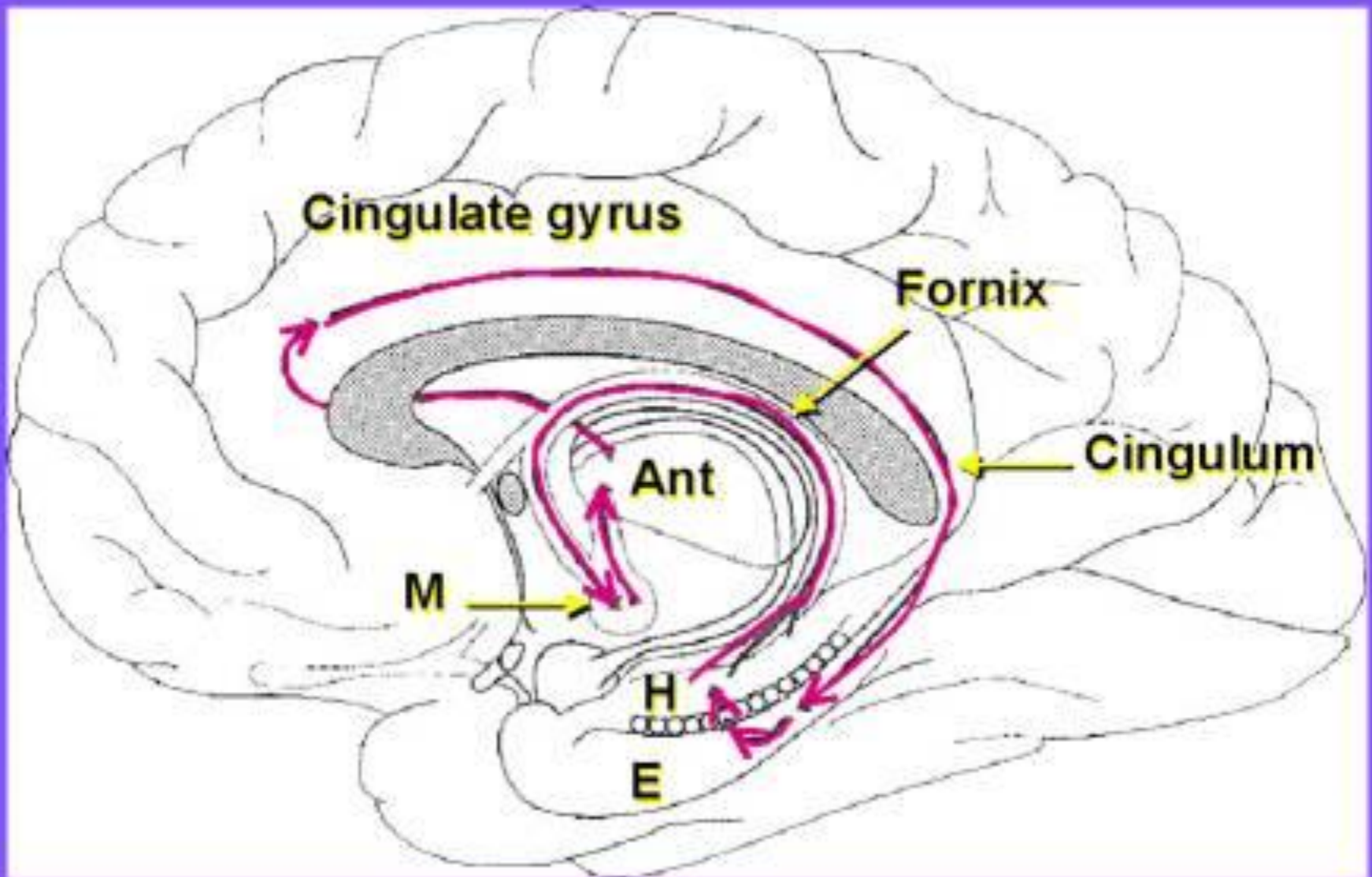
# Circuits of limbic systemu

- **Papez's limbic circuit** (*John Papez 1937*)

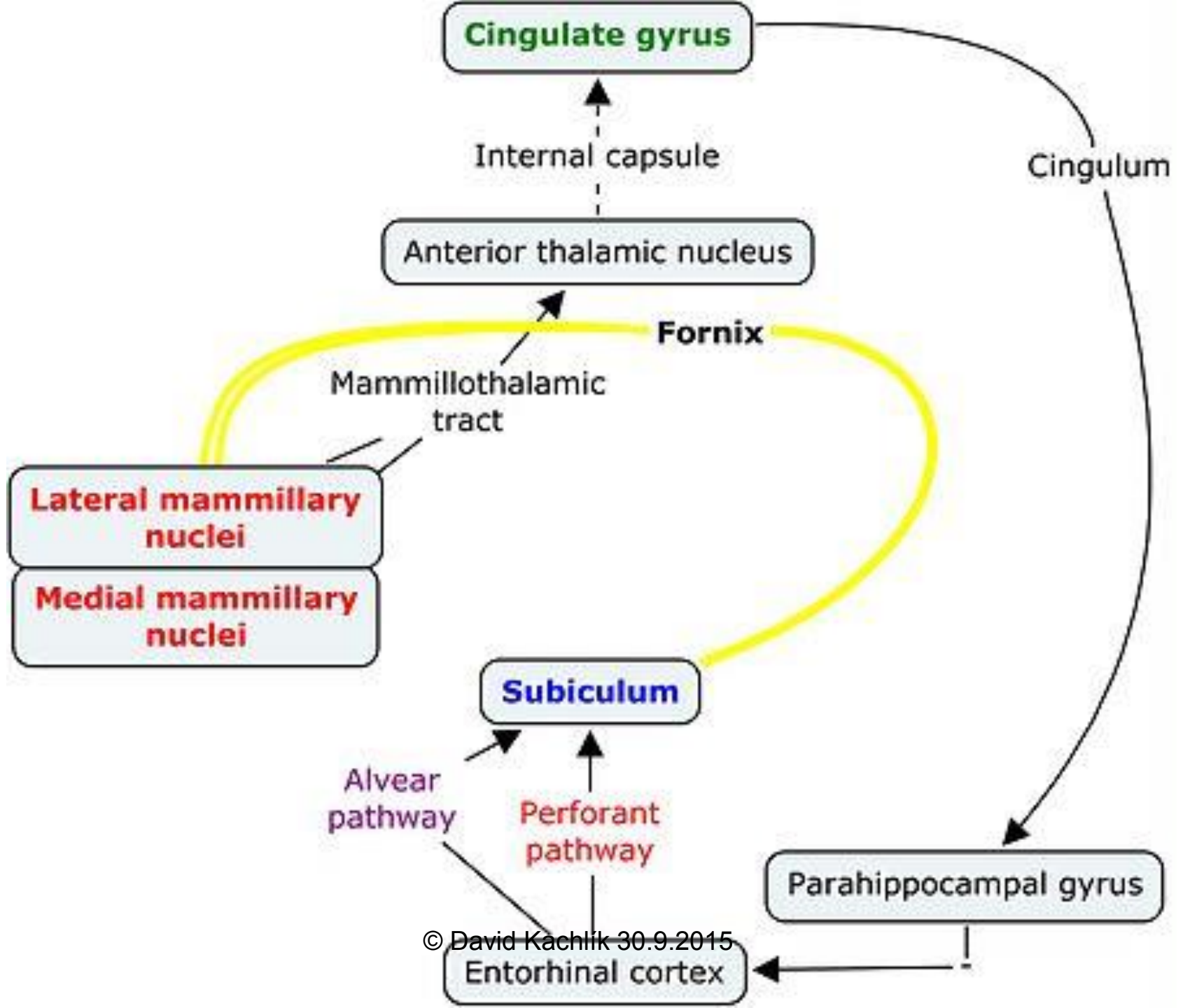
hippocampus → fornix → corpora mammillaria → fasciculus mammillothalamicus → ncll. anteriores thalami → area cingularis posterior → cingulum → area entorhinalis → subiculum + hippocampus

- *new, short verison skips hypothalamus*
- branches to: hypothalamus, ncl. accumbens, septum verum, ncl. habenulares, RF and motor nuclei of cranial and spinal nerves

# Circuit of Papez

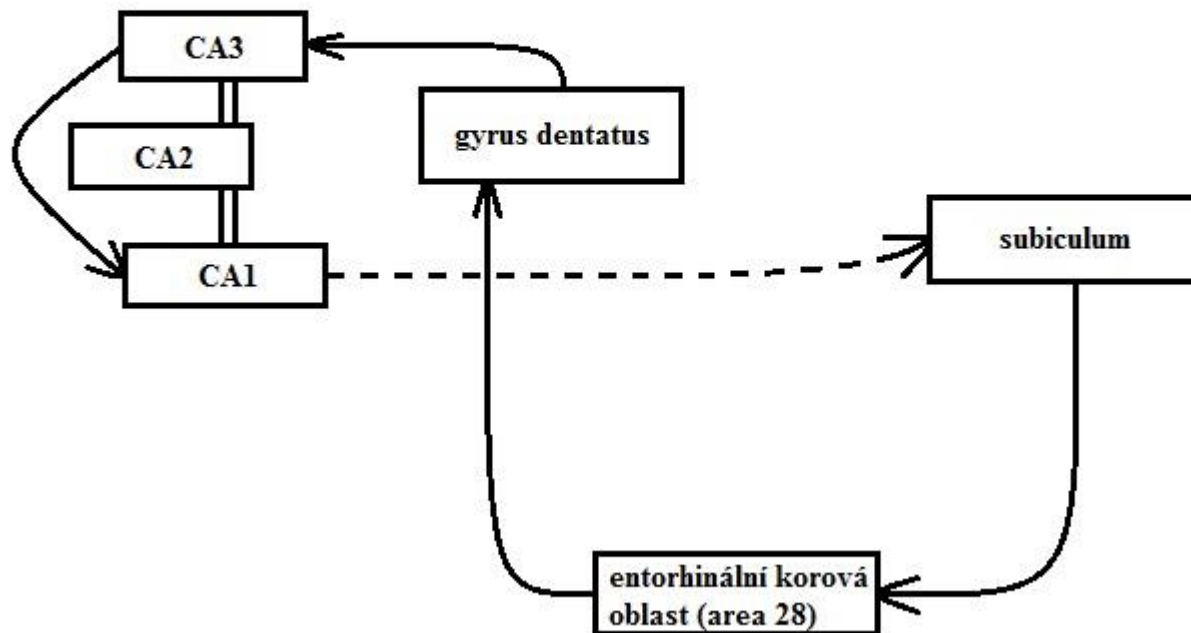


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# Andersen's circuit only for lover of neuroanatomy 😊

Andersenův okruh (vnitřní zapojení  
hippokampální formace)



# Principle output axis of limbic system

septum verum → hypothalamus → RF of  
mesencephalon

- coursing along fasciculus medialis  
telencephali (MFB)

# Limbic system – disorders

- disorders of hippocampus
  - disorders of declarative memory (facts, events)
    - little retrograde amnesia
    - full anterograde amnesia (except short-term memory)
- disorders of corpora mammillaria
  - chronic alcoholism
  - can cause Korsakoff psychosis (amnestic confabulatory syndrome)