

M U N I

M E D

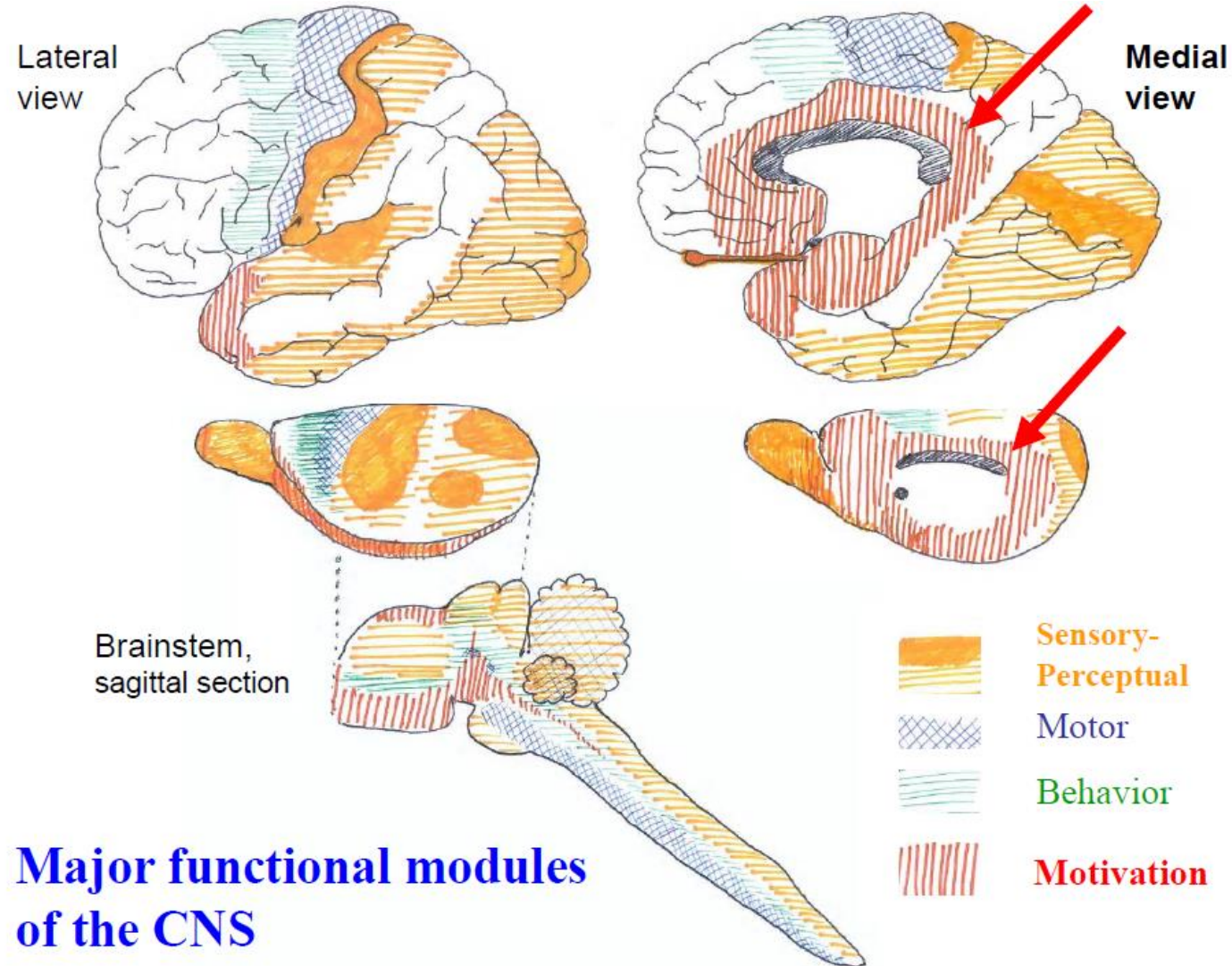
**M U N I**  
**M E D**

**14**

# **Limbic system**

# Limbic system

Limbus = border



## Major functional modules of the CNS

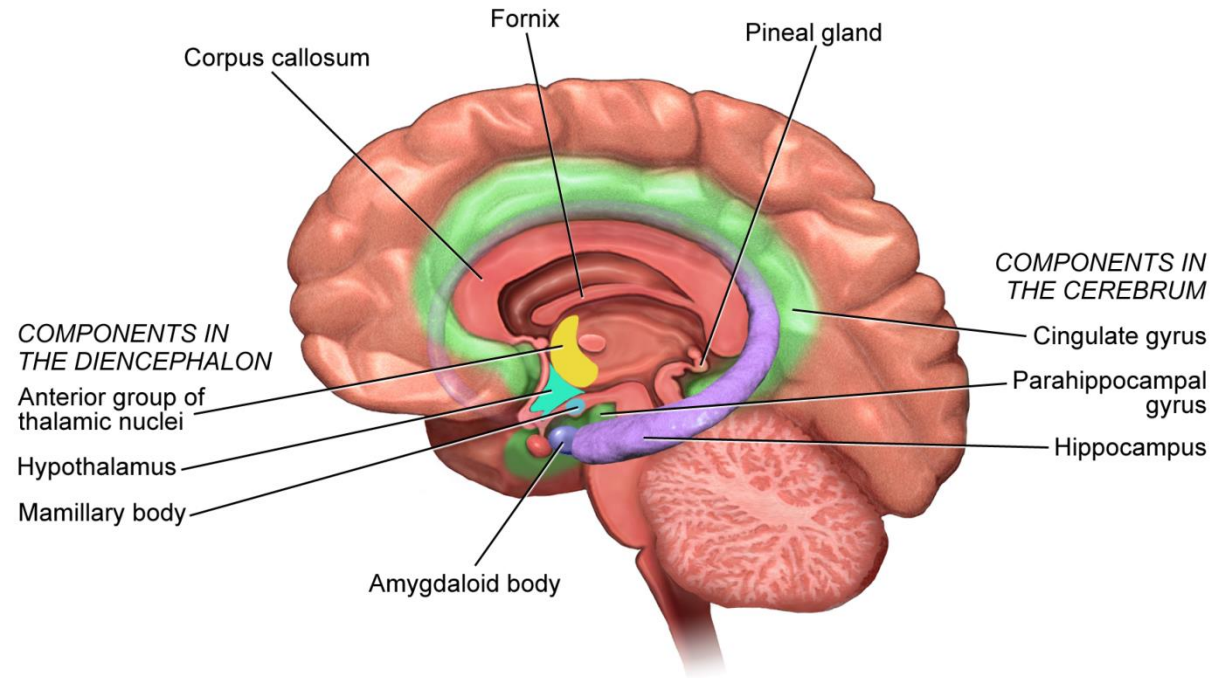
# The concept of limbic system

- Voluntary

Somatic nervous system  
Inputs – mainly from outer environment  
Control – skeletal muscle

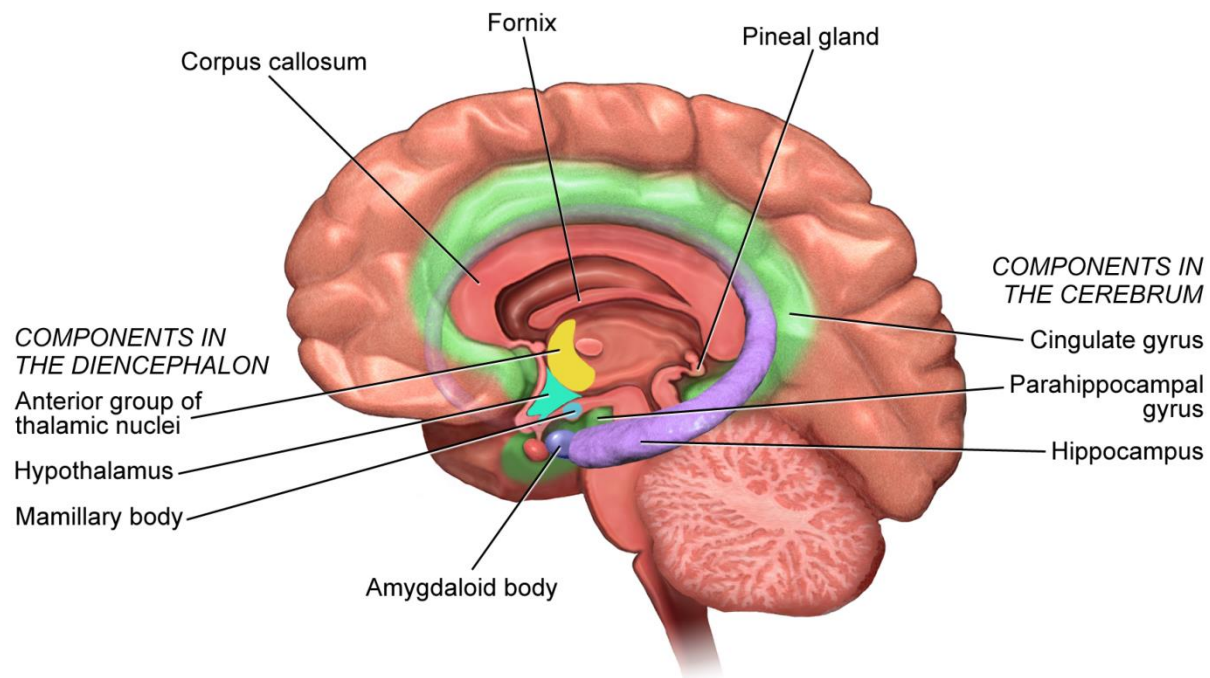
- Automatic

Autonomic nervous system  
Inputs – mainly inner environment  
Control – smooth/cardiac m., glands

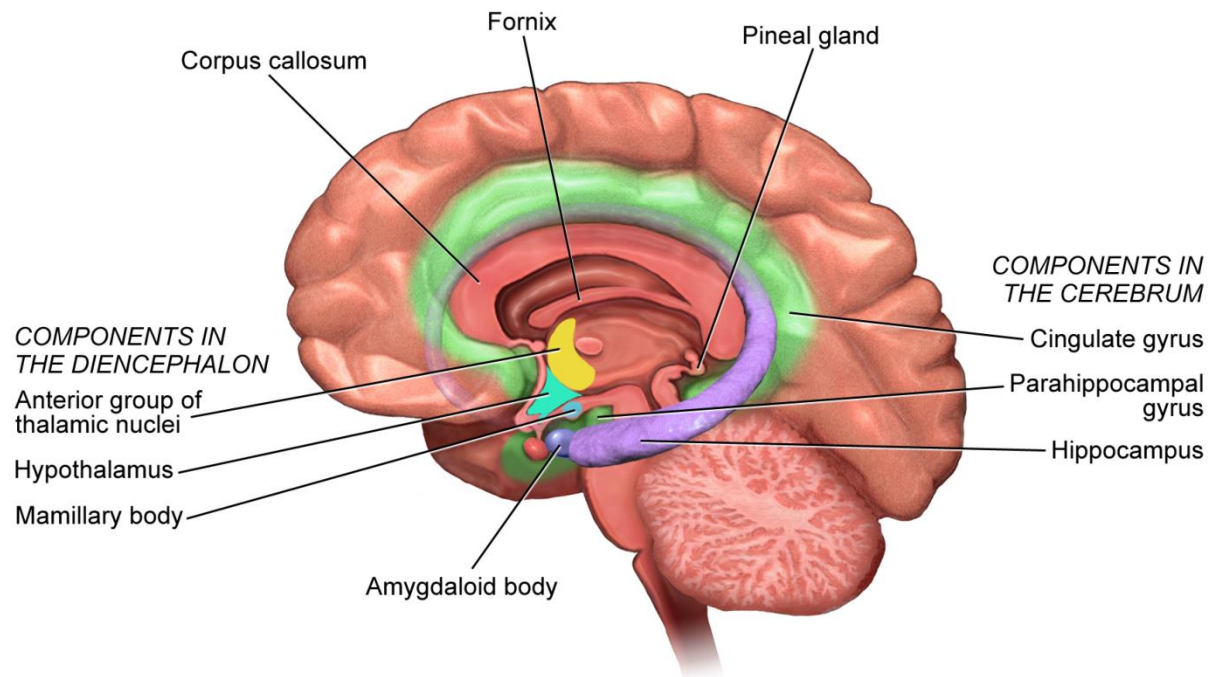
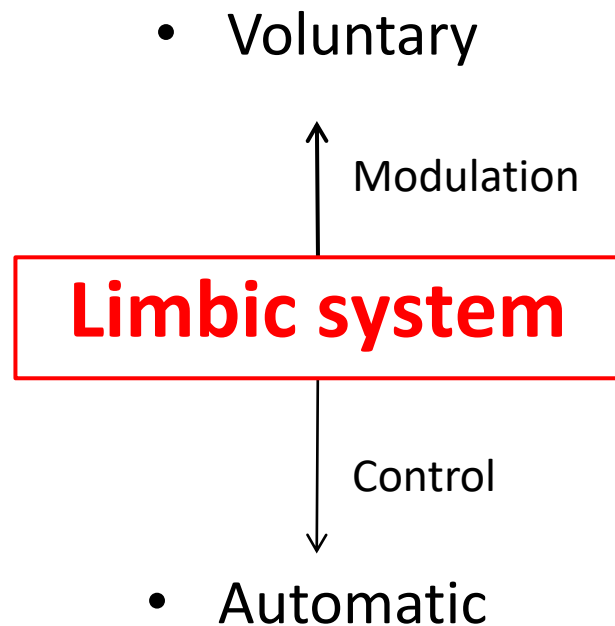


# The concept of limbic system

- Voluntary
- ↑
- Potential conflict
- ↓
- Automatic



# The concept of limbic system



# The concept of limbic system

- Voluntary

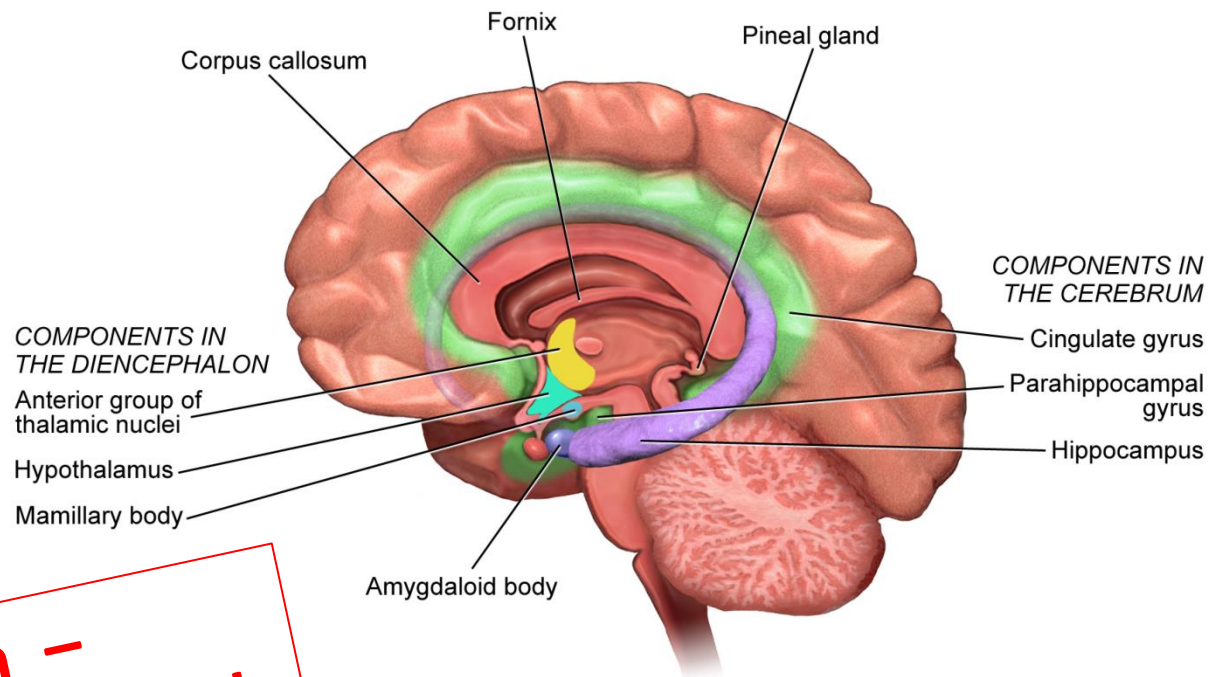
↑  
Modulation

**Limbic system**

↓  
Control

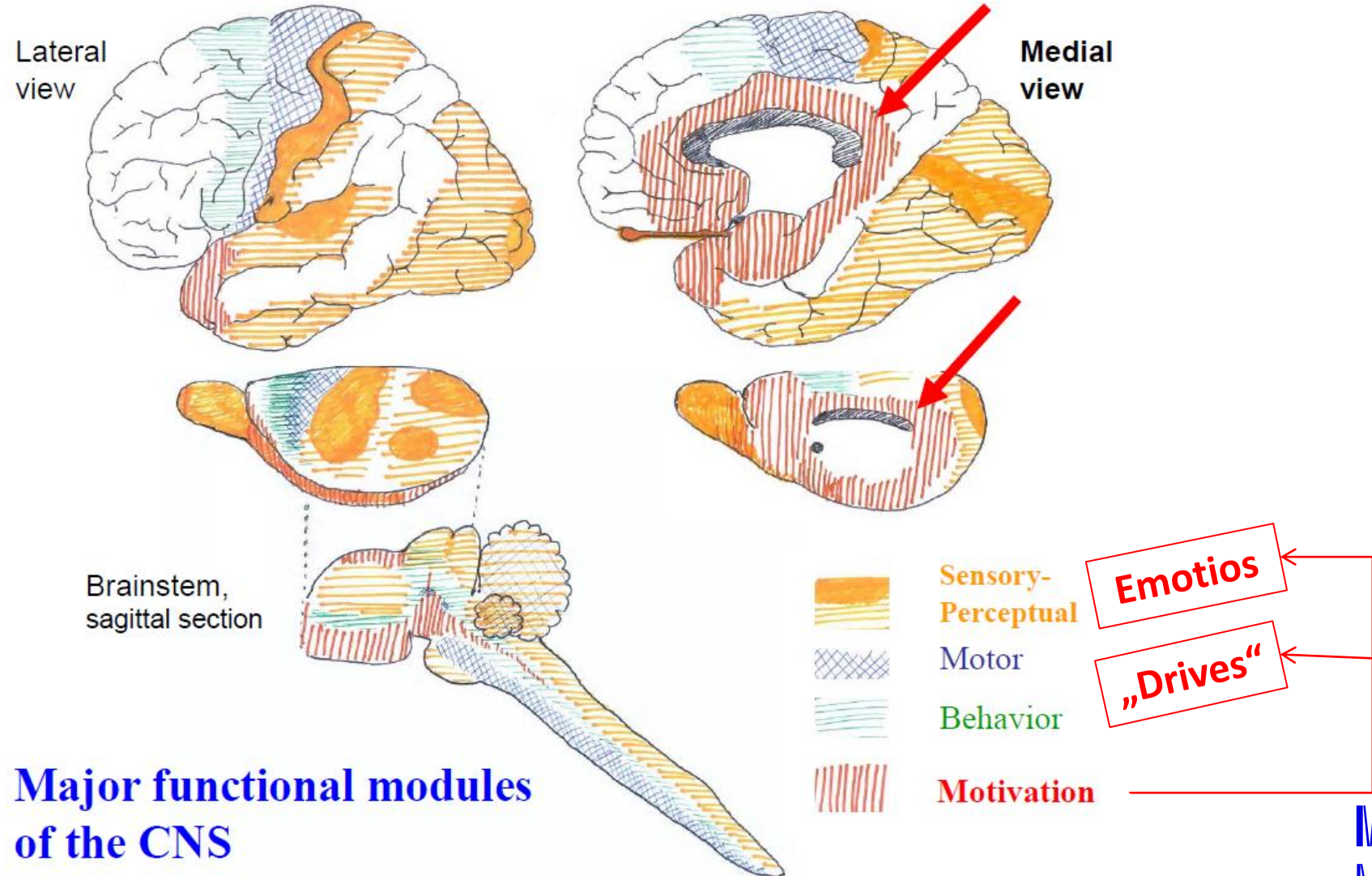
- Automatic

**Limbic system –  
hypothalamus and related  
structures**



# Limbic system

Limbus = border



## Major functional modules of the CNS



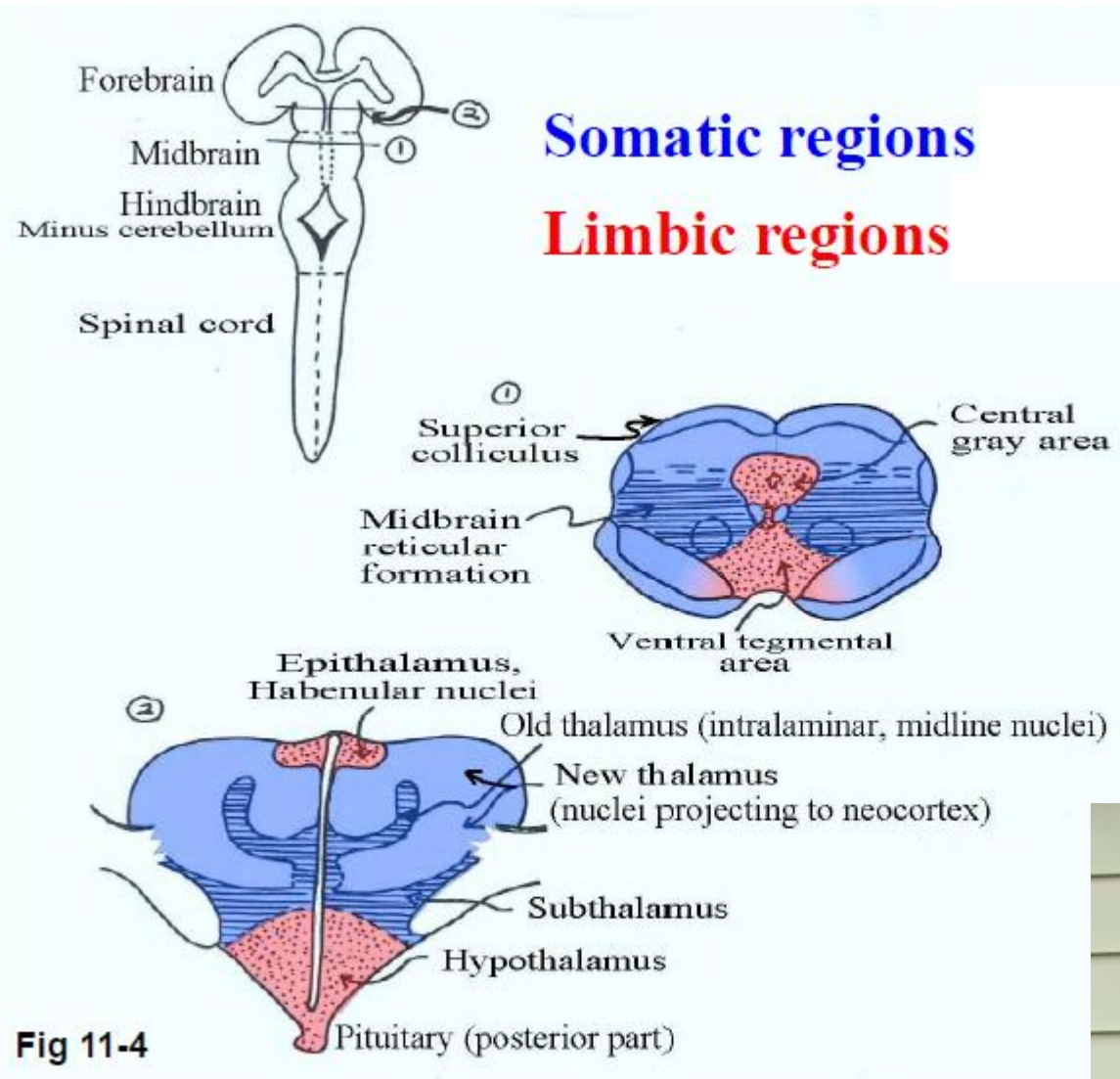


Fig 11-4

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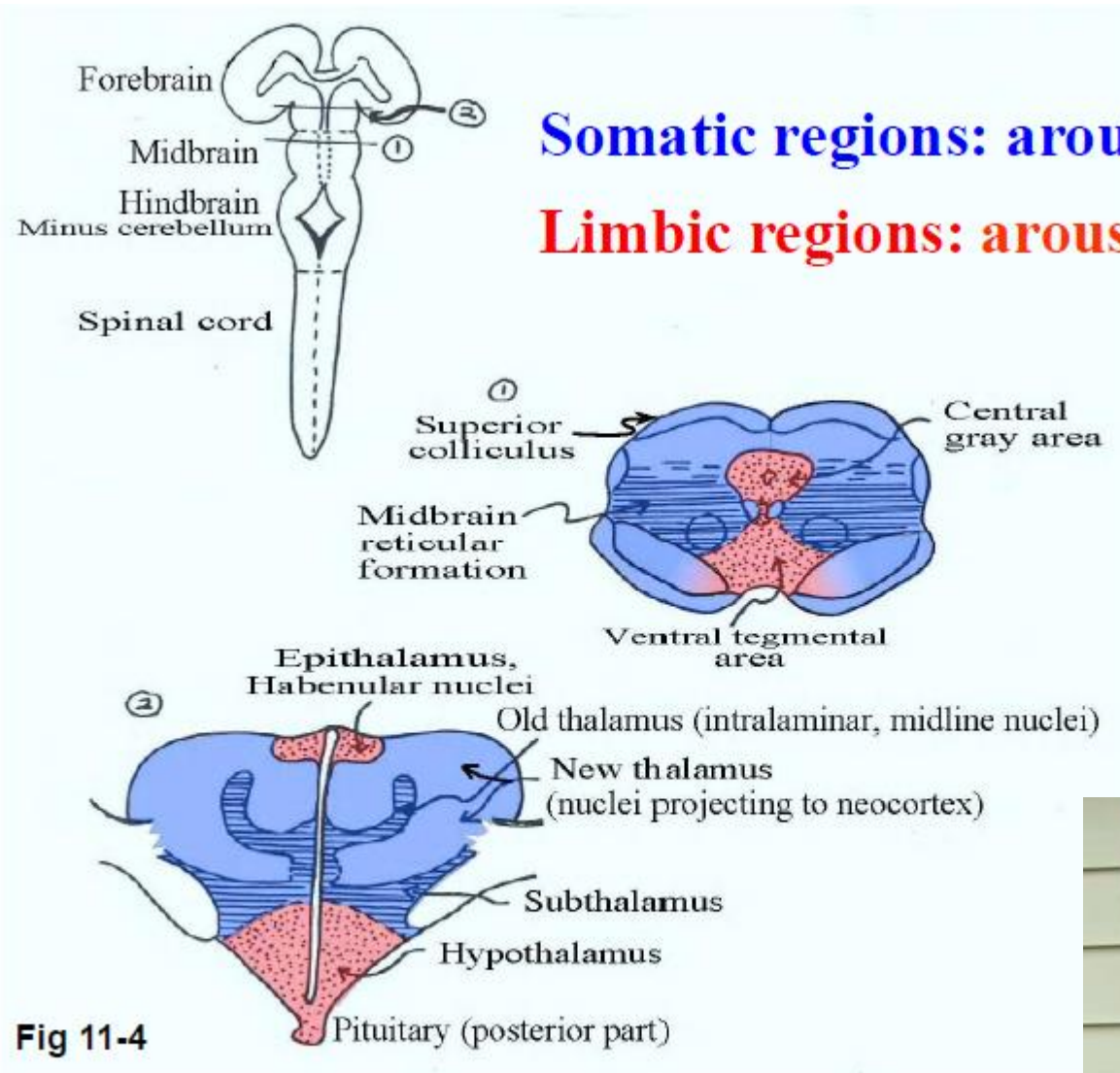
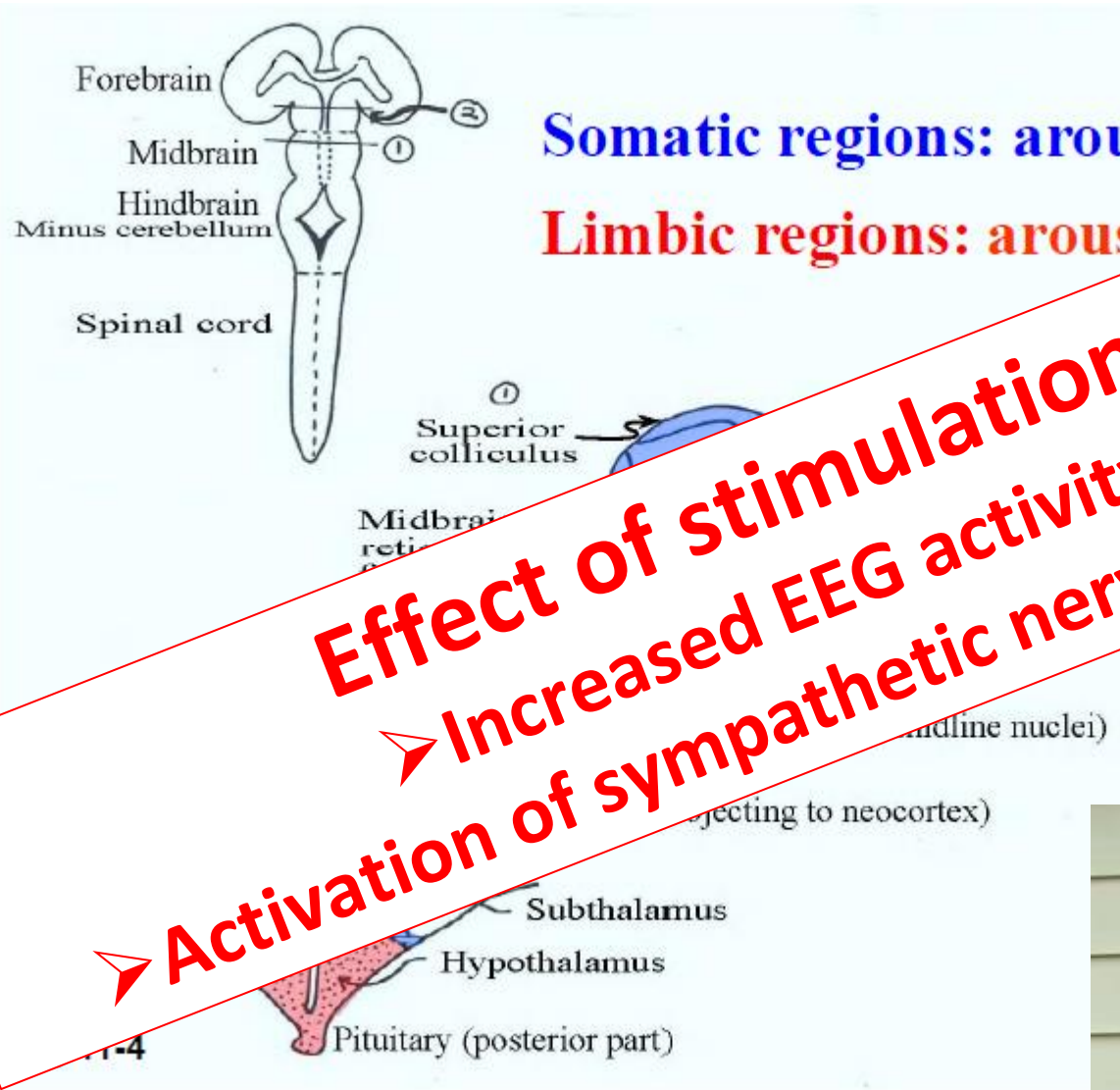


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**Somatic regions: arousal type 1**

**Limbic regions: arousal type 2**

**Effect of stimulation**  
➤ Increased EEG activity  
➤ Activation of sympathetic nervous system



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## Arousal type 1 (somatic)

### ARAS (ascendent retikulation activation system)

- Effect of stimulation
  - Habituation
  - Minimal activation of „reward/punishing“ system

## Arousal type 2 (limbic)

- Effect of stimulation
  - Minimal habituation
  - Strong activation of „reward/ punishing“ system
    - Central gray area –CGA - negative
    - Ventral tegmental area – VTA – positive

## Arousal type 1 (somatic)

### ARAS (ascendent retikulation activation system)

- Effect of stimulation
  - Habituation
  - Minimal activation of „reward/punishing“ system
- Ascendent connections
  - Somatosensetivity, visual s., auditory s., vestibular s., cerebellum
- Descendent connections
  - Neocortex, corpus striatum, thalamus

## Arousal type 2 (limbic)

- Effect of stimulation
  - Minimal habituation
  - Strong activation of „reward/ punishing“ system
    - Central gray area –CGA - negative
    - Ventral tegmental area – VTA – positive
- Ascendent connections
  - Mainly viscerosenzitivity, pain
- Descendent connections
  - Hypothalamus and other limbic areas, amygdala

## Arousal type 1 (somatic)

ARAS (ascendent retikulation activation)

- EEG

### Effect of stimulation

- Increased EEG activity
- Activation of sympathetic nervous system

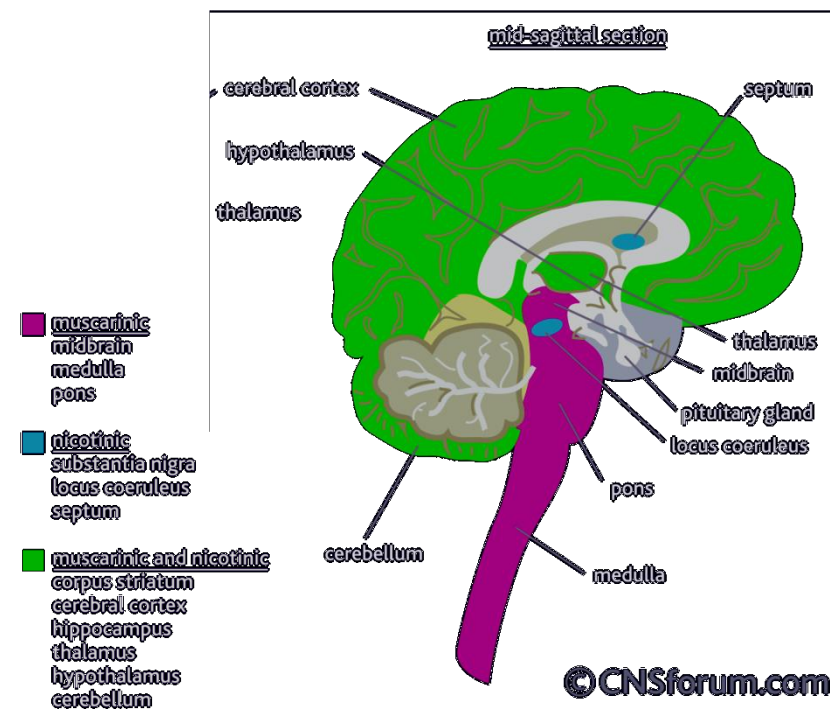
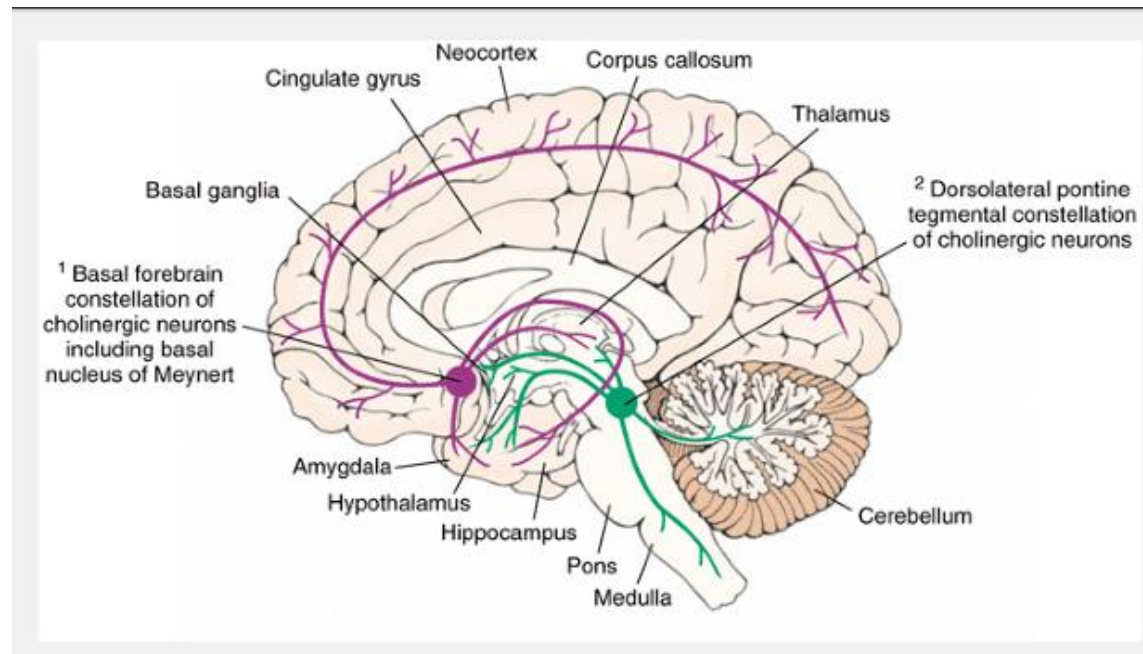
Cooperation of both systems is a key to maintaining consciousness (through neuromodulation)

- Ascending connections  
Neocortex, corpus striatum, thalamus

- Descendent connections
  - Hypothalamus and other limbic areas, amygdala

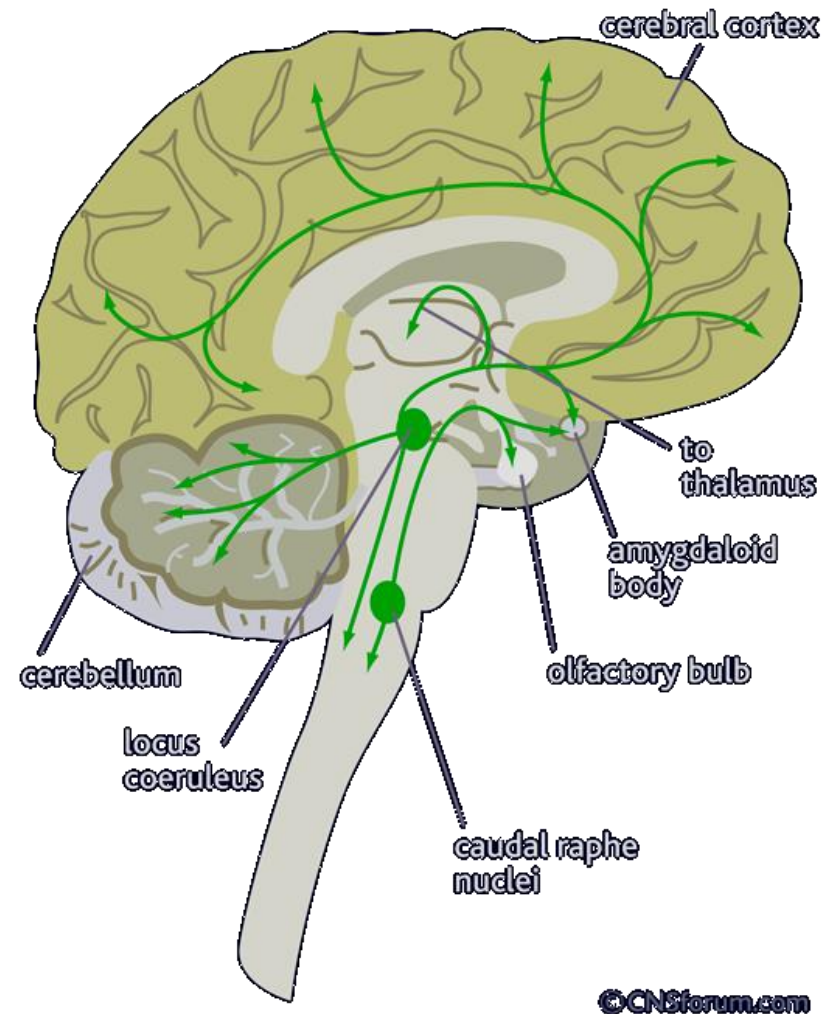
# Acetylcholine

- Nucleus basalis (Meynerti) and other nuclei
- Nicotin receptors
- Muscarin receptors
  
- Sleep/wake regulation
- Cognitive functions
- Behavior
- Emotions



# Norepinefrine

- Locus coeruleus
- Nuclei raphe caudalis
  
- Vigilance
- Responsiveness to unexpected stimuli
- Memory
- Learning

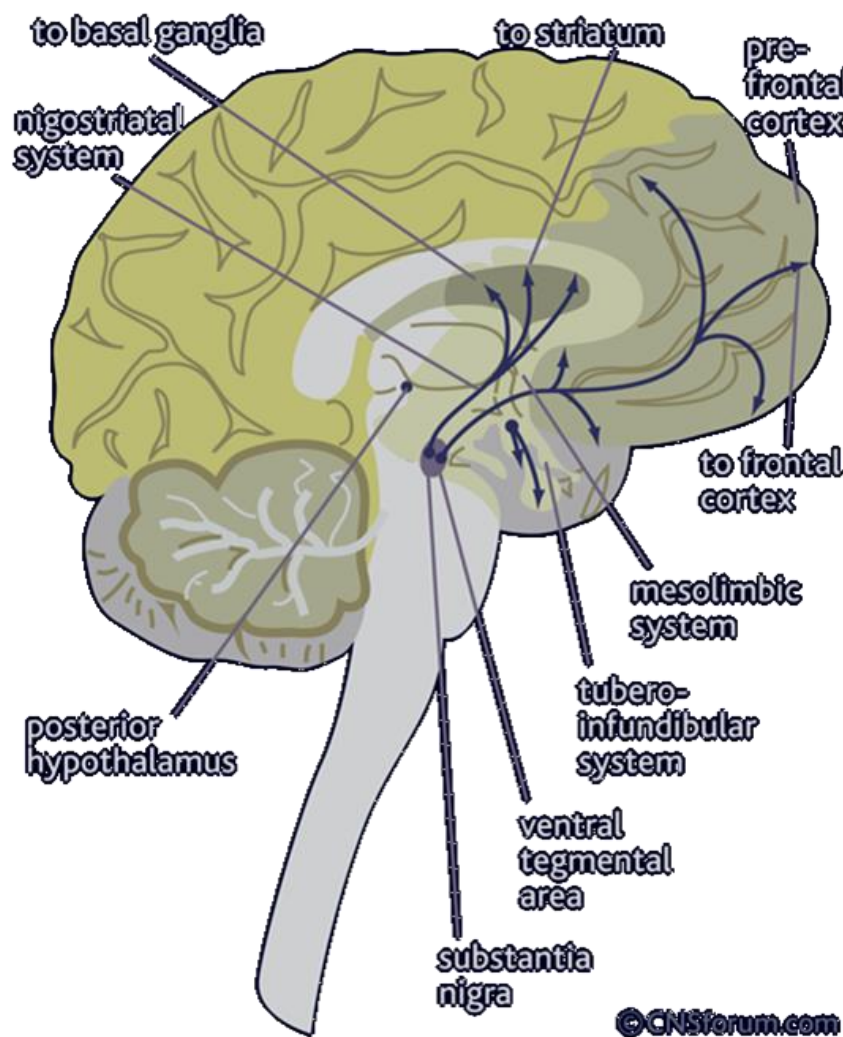


<http://www.slideshare.net/drpsdeb/presentations>



# Dopamine

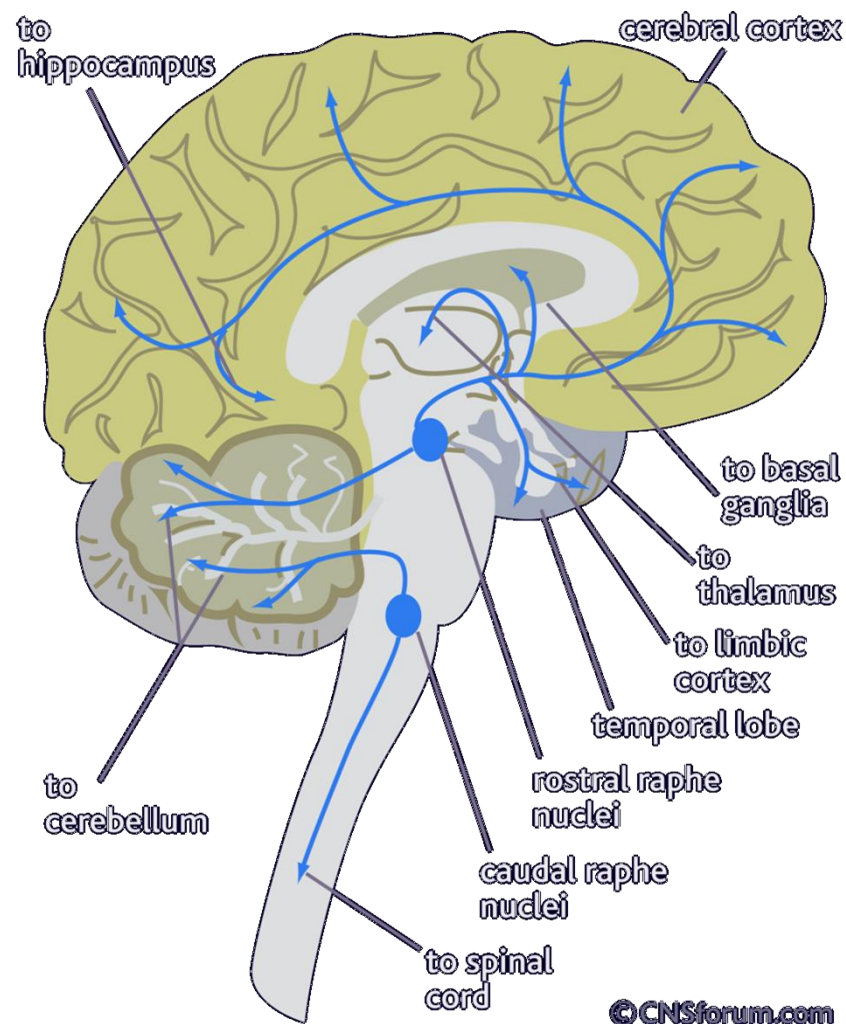
- Nigrostriatal system
  - Movement
  - Sensory stimuli
- Ventro- tegmentno-mesolimbic-frontal system
  - Reward
  - Cognitive function
  - Emotional behavior
- Tubero-infundibular system
  - Hypothalamic-pituitary regulation
- D1 receptors – excitatory
- D2 receptors - inhibitory



<http://www.slideshare.net/drpsdeb/presentations>

# Serotonin

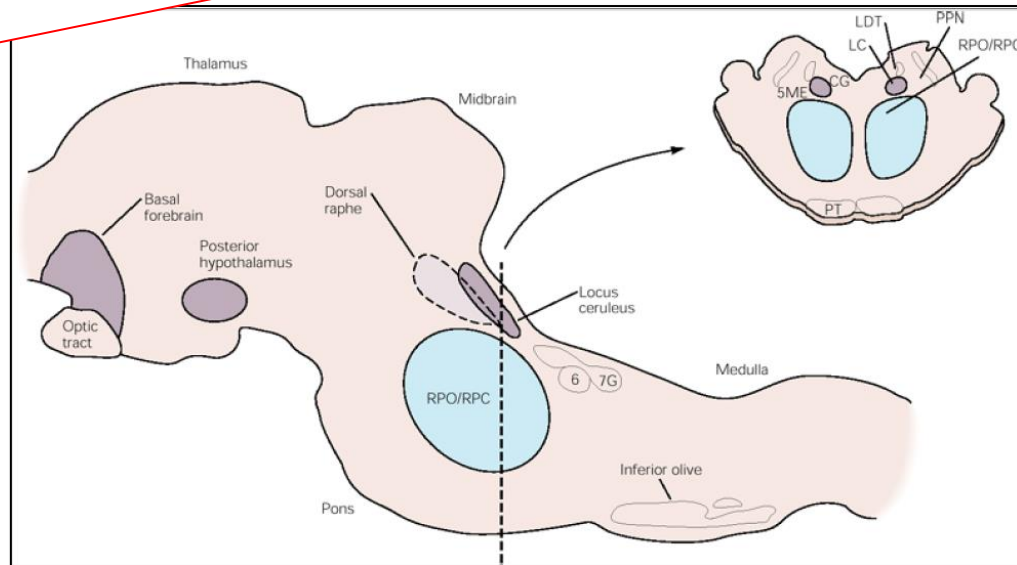
- Nuclei raphe rostralis
- Nuclei raphe caudalis
  
- Anxiety/relaxation
- Impulsive behavior
- Sleep



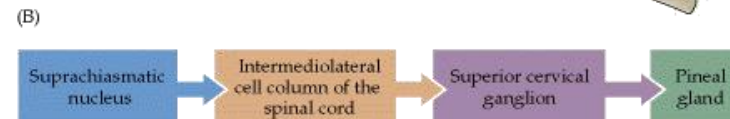
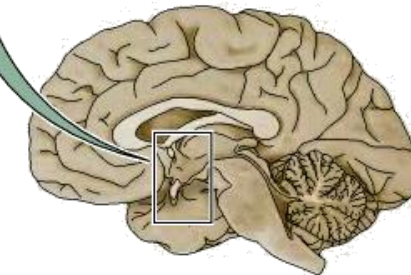
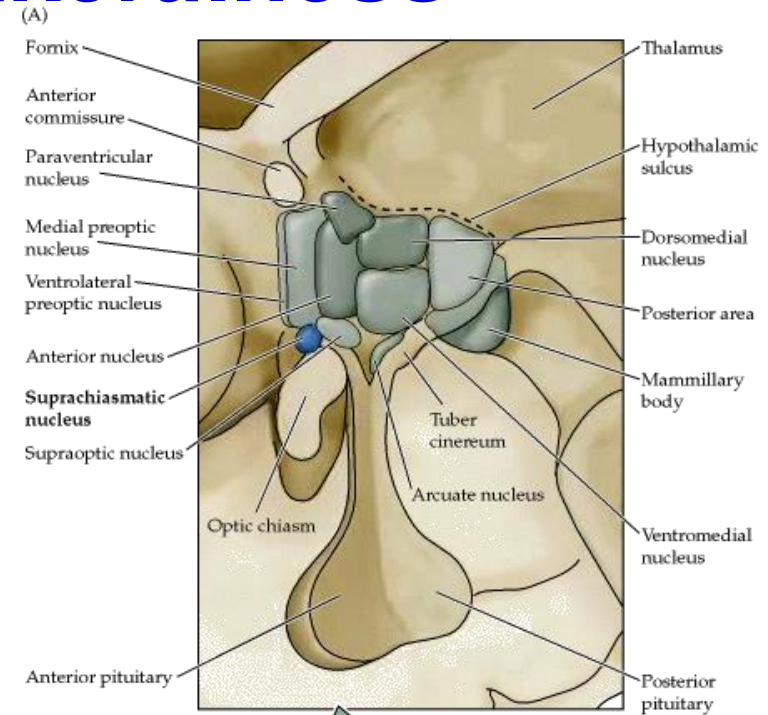
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# Sleep and wakefulness

**Cooperation of ARAS and limbic activating system**



19 Limbic system RPO/RPC – nucleus reticularis pontis oralis/caudalis



# Sleep

## The sleep cycle

There are two very different types of sleep:

1. Rapid Eye Movement or REM sleep, which is associated with fast brain activity and active dreaming; and
2. Non-REM sleep, which is associated with slower brain activity and divided into 4 stages:
  - » Stages 1-2 light sleep
  - » Stages 3-4 deep slow-wave sleep.

All these combine to make the non-REM/REM sleep cycle, which is about 90 minutes long on average, but can be up to 120 minutes.

For most people, a good night's sleep is around 4 – 5 cycles long.

Good quality sleep requires both non-REM and REM sleep in uninterrupted cycles.

### REM SLEEP

- › Eyes move rapidly under closed eyelids
- › Most dreaming occurs here
- › Brain is active, muscles are relaxed
- › Can't move voluntarily – signals from the brain to the postural muscles are blocked

### DEEP NON-REM SLEEP

- › Stages 3-4
- › Difficult to wake up
- › Sleep inertia when woken

## Rapid Eye Movement (REM)

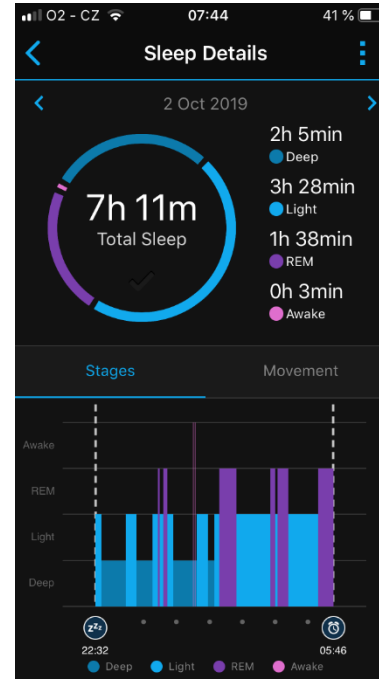
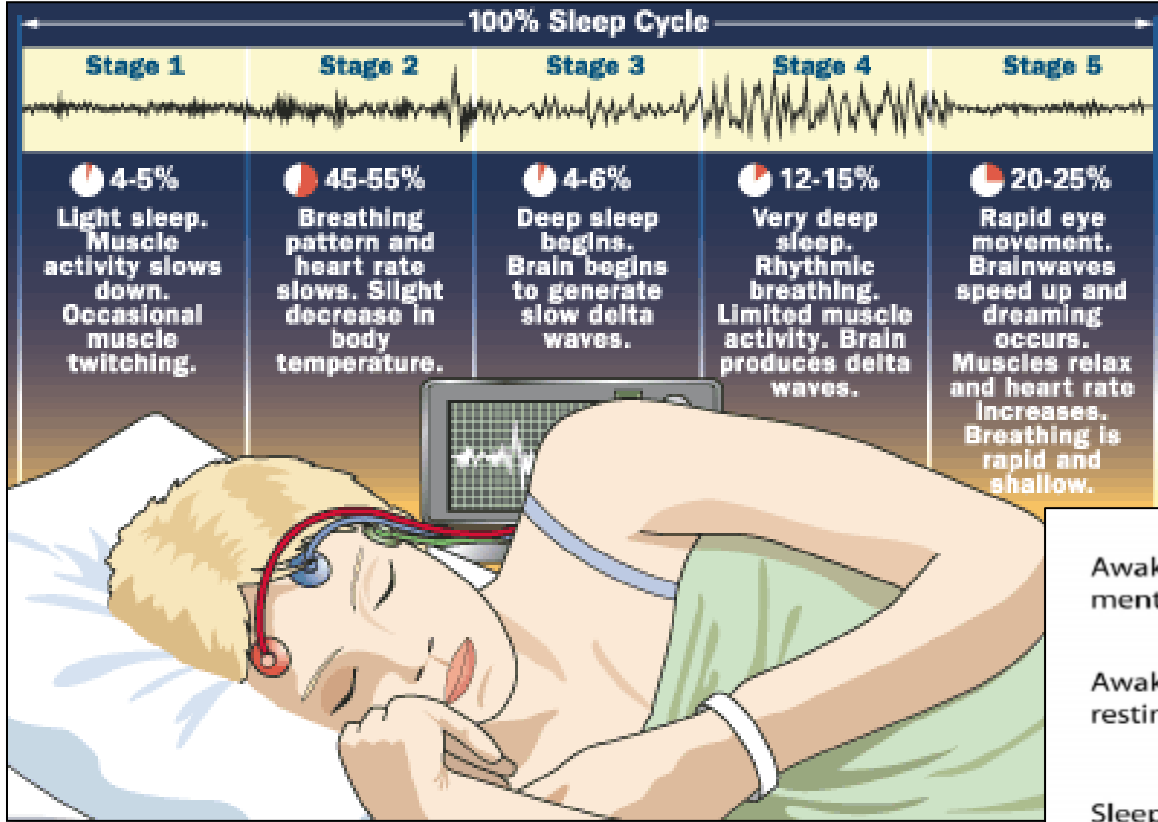
### LIGHT NON-REM SLEEP

- › Stages 1-2
- › May drift in and out of sleep several times at the start
- › Easy to wake up, disturbs easily

4 to 5 sleep cycles make a good night's sleep

# Sleep

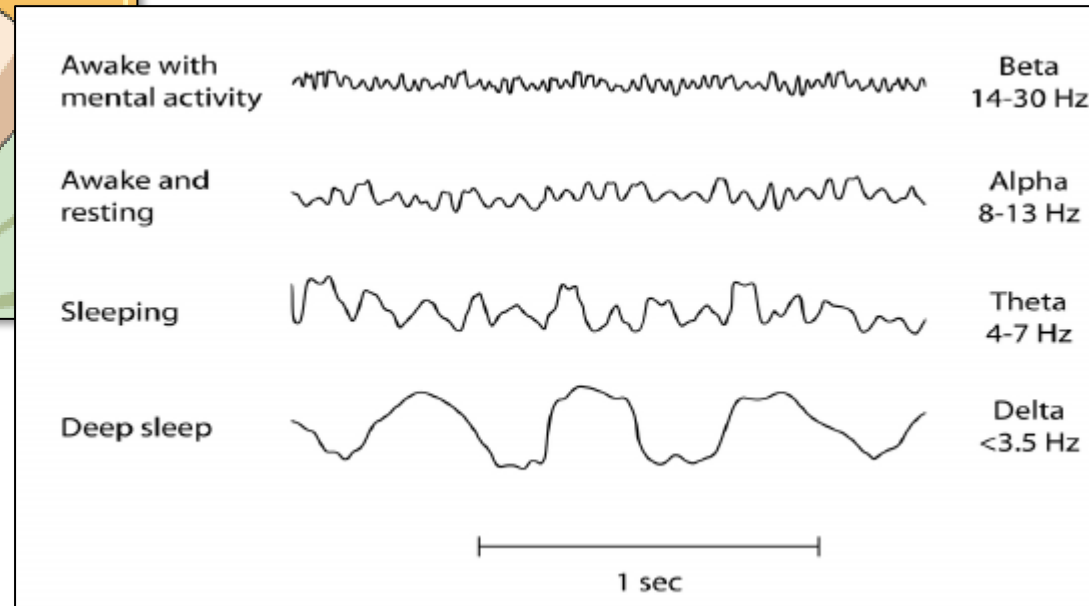
http://www.slideshare.net/dripsdeb/presentations



https://connect.garmin.com/modern/



LIGHT NON-REM SLEEP	DEEP NON-REM SLEEP	REM SLEEP
<ul style="list-style-type: none"> <li>Stages 1-2</li> <li>May drift in and out of sleep several times at the start</li> <li>Easy to wake up, disturbs easily</li> </ul>	<ul style="list-style-type: none"> <li>Stages 3-4</li> <li>Difficult to wake up</li> <li>Sleep inertia when woken</li> </ul>	<ul style="list-style-type: none"> <li>Eyes move rapidly under closed eyelids</li> <li>Most dreaming occurs here</li> <li>Brain is active, muscles are relaxed</li> <li>Can't move voluntarily – signals from the brain to the postural muscles are blocked</li> </ul>



https://www.researchgate.net/profile/Priyanka\_Abhang3/publication/281801676/figure/fig4/AS:305025248186371@1449735094401/fig-4-EEG-waves-for-different-signals.png

http://www.dailymail.co.uk/sciencetech/article-3042230/Sleeping-habits-world-revealed-wakes-grumpy-China-best-quality-shut-eye-South-Africa-wakes-earliest.html

# Sleep and wakefulness

## Brainstem nuclei responsible

## Neurotransmitter

## Activity state

### *WAKEFULNESS*

Cholinergic nuclei of pons-midbrain junction

Acetylcholine

Active

Locus coeruleus

Norepinephrine

Active

Raphe nuclei

Serotonin

Active

### *NON-REM SLEEP*

Cholinergic nuclei of pons-midbrain junction

Acetylcholine

Decreased

Locus coeruleus

Norepinephrine

Decreased

Raphe nuclei

Serotonin

Decreased

### *REM SLEEP ON*

Cholinergic nuclei of pons-midbrain junction

Acetylcholine

Active

Raphe nuclei

Serotonin

Inactive

### *REM SLEEP OFF*

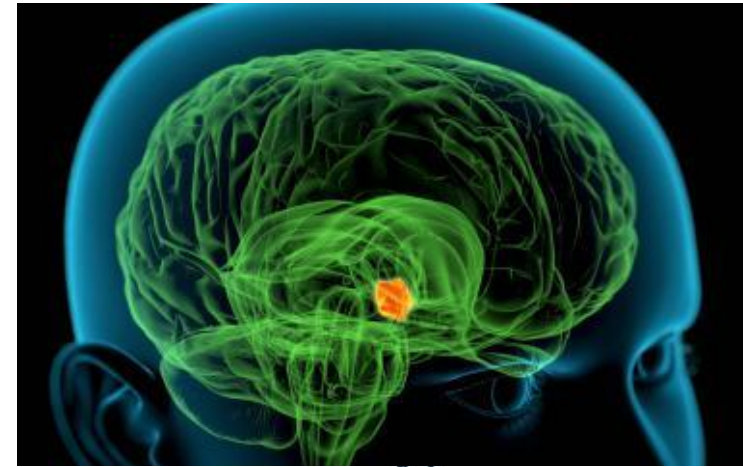
Locus coeruleus

Norepinephrine

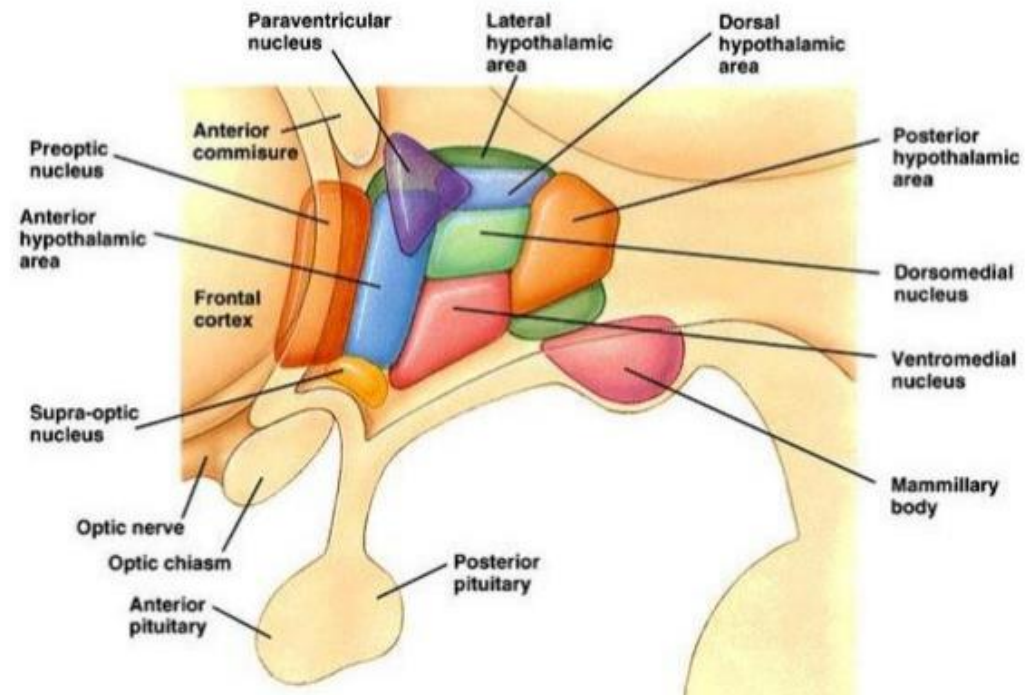
Active

# Hypothalamus

- Key center of autonomic regulations and coordination
  - Integration of the information from inner and outer environment
- ↓
- Behavioral modulation
  - Regulation of autonomic nervous system
- ↓
- **Maintenance of homeostasis**



<http://biology.about.com/od/anatomy/pl/Hypothalamus.htm>



<http://www.slideshare.net/physiologymgmcri/hypothalamus-15-apr-2016>

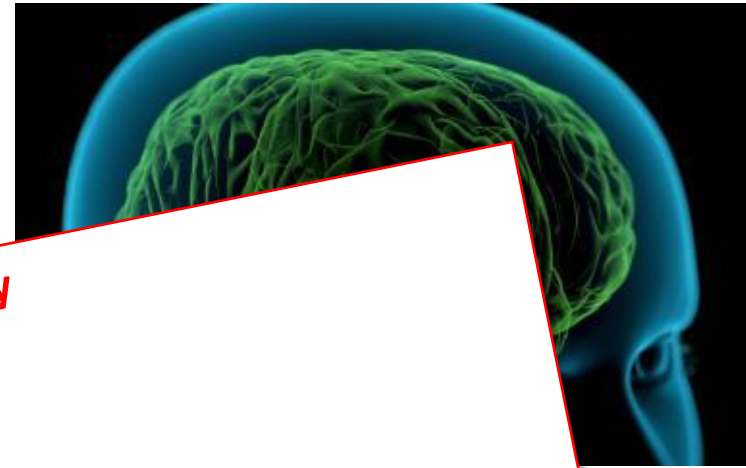
# Hypothalamus

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- Integration of the information from inner and outer environment

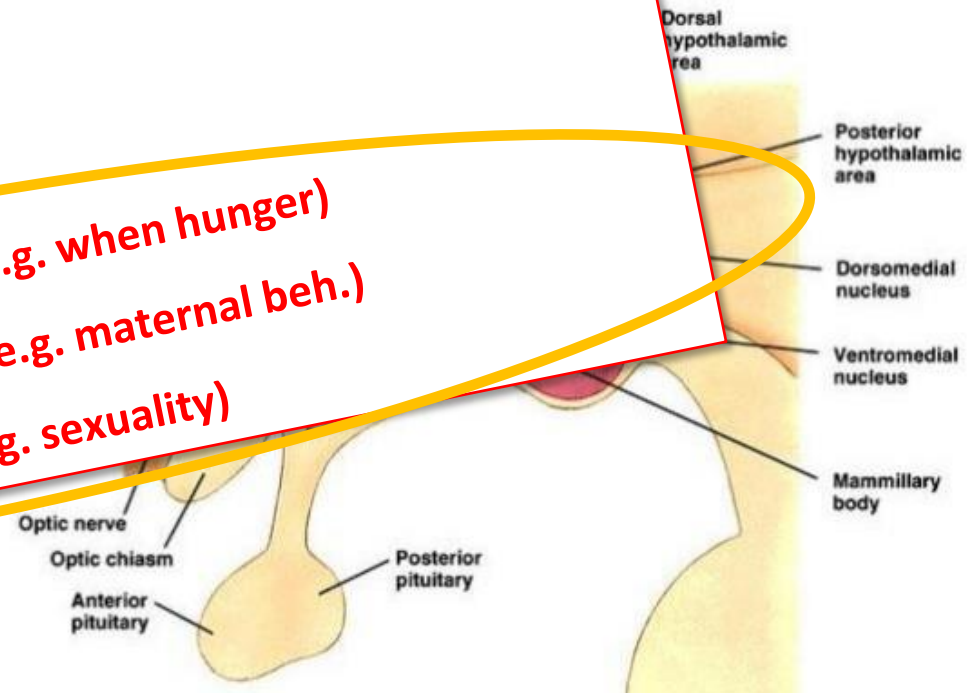
- Behavior
- Regulation of nervous system

- Maintenance of homeostasis

- ✓ Biological clock – circadian /seasonal activity
- ✓ Autonomic nervous system regulation
- ✓ Endocrine system regulation
- ✓ Food and water intake regulation
- ✓ Regulation of body temperature
- ✓ „Immediate“ behavior regulation (e.g. when hunger)
- ✓ „Long-term“ behavior regulation (e.g. maternal beh.)
- ✓ Instinctive behavior regulation (e.g. sexuality)



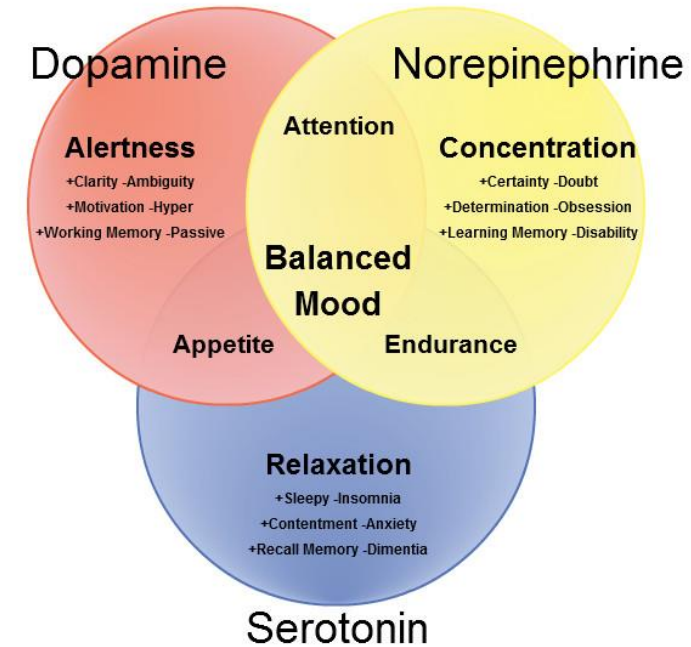
<http://biology.about.com/od/anatomy/pl/Hypothalamus.htm>





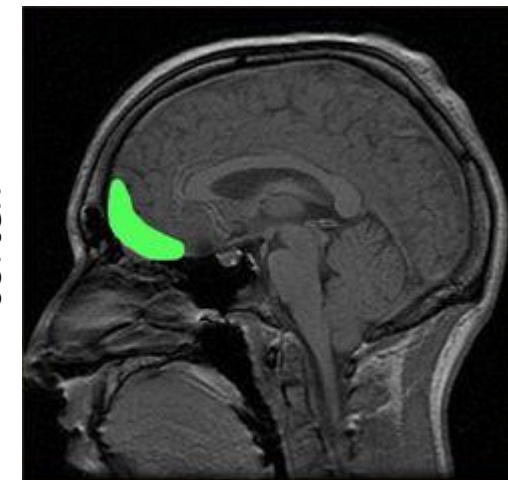
# Influence of hypothalamus on neocortex

- Via neuromodulating systems
  - Consciousness (see above)
  - Mood
- Via thalamus
  - Via nucleus mediodorsalis to orbitofrontal cortex (influence on decision making)
  - Influence gating function of other thalamic nuclei
- Papez circuit



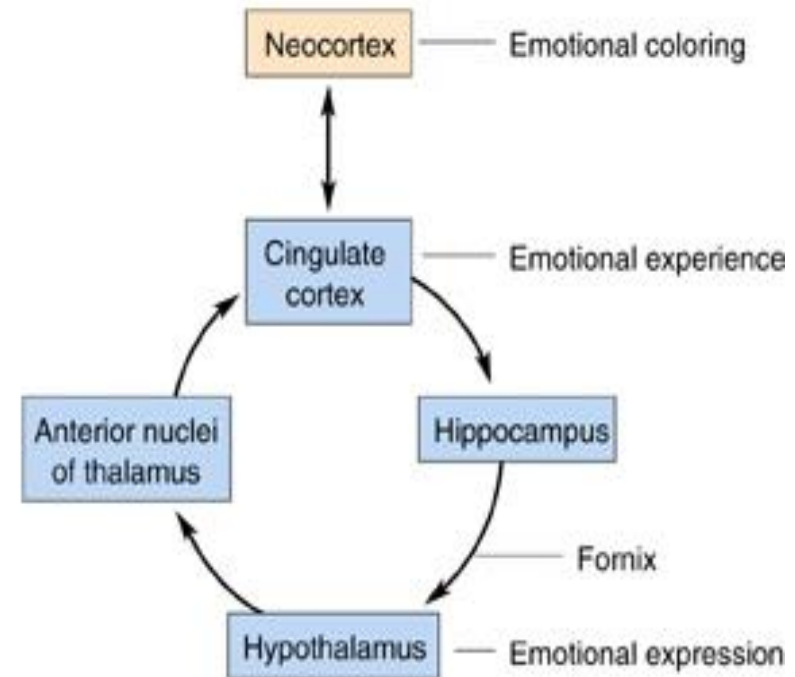
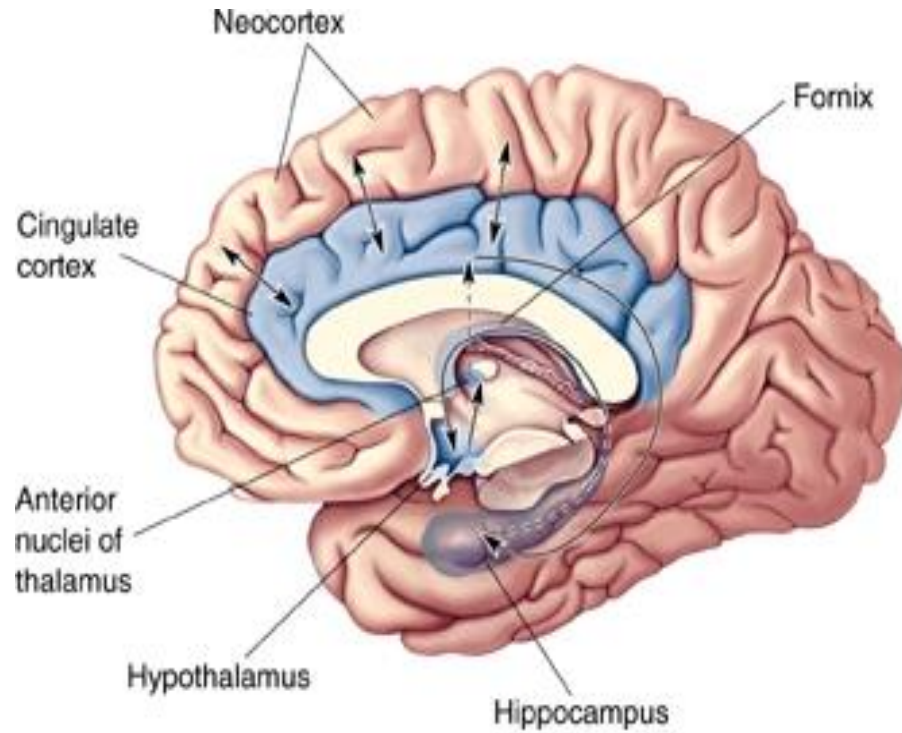
[http://ausm.org.uk/wp-content/uploads/2015/02/Dopamine\\_Norepinephrine\\_Serotonin.jpg](http://ausm.org.uk/wp-content/uploads/2015/02/Dopamine_Norepinephrine_Serotonin.jpg)

Orbitofrontal cortex



[https://en.wikipedia.org/wiki/Orbitofrontal\\_cortex](https://en.wikipedia.org/wiki/Orbitofrontal_cortex)

# Papez circuit



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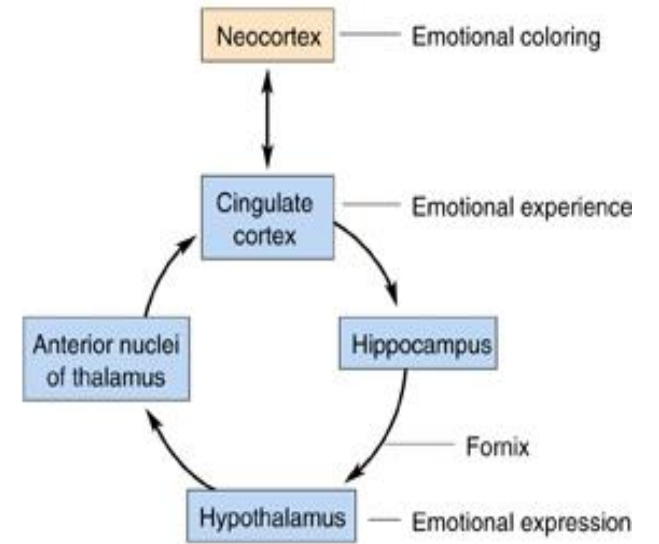
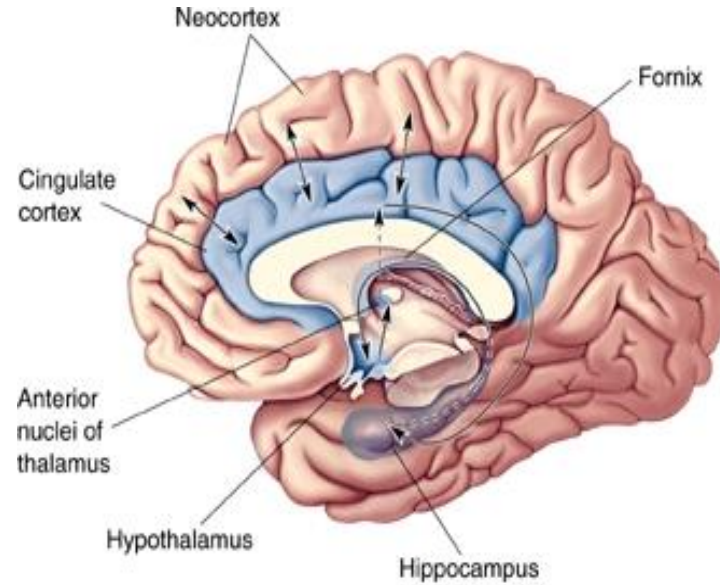
<http://www.slideshare.net/drsunilsuthar/neurobiology-of-emotion>

# Papez circuit

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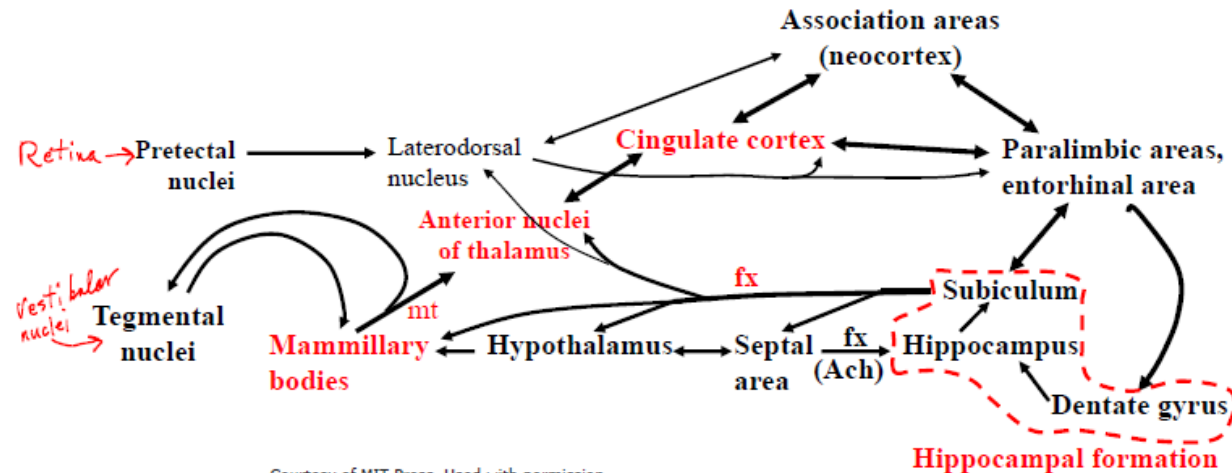


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mt = mammillothalamic tract  
fx = fornix bundle



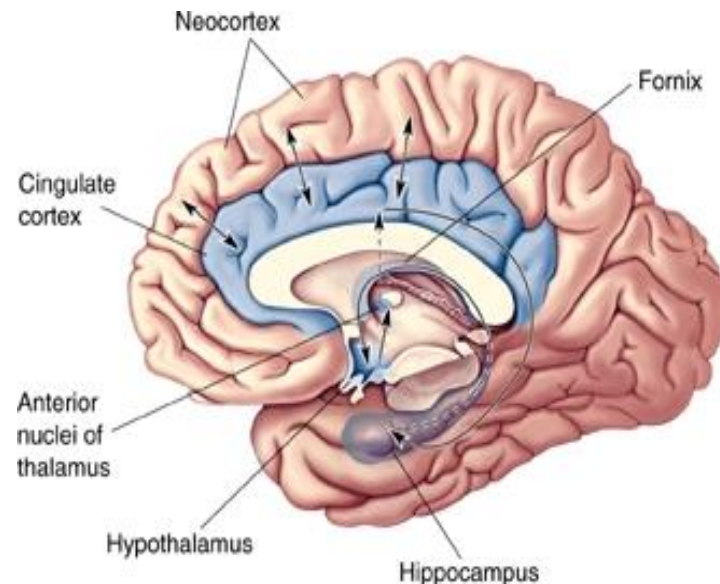
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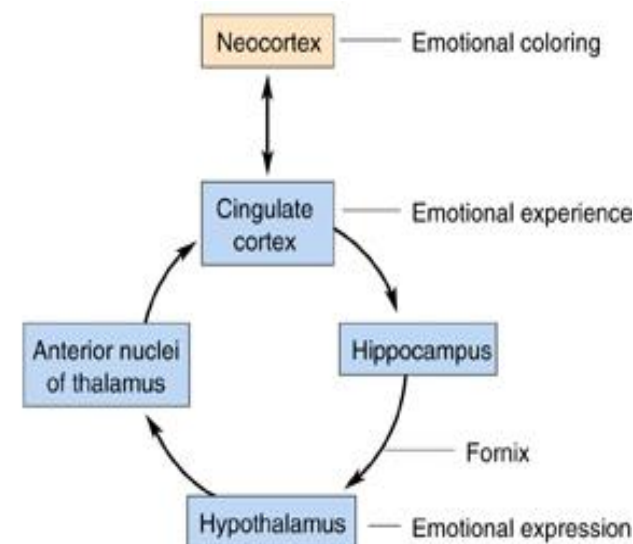
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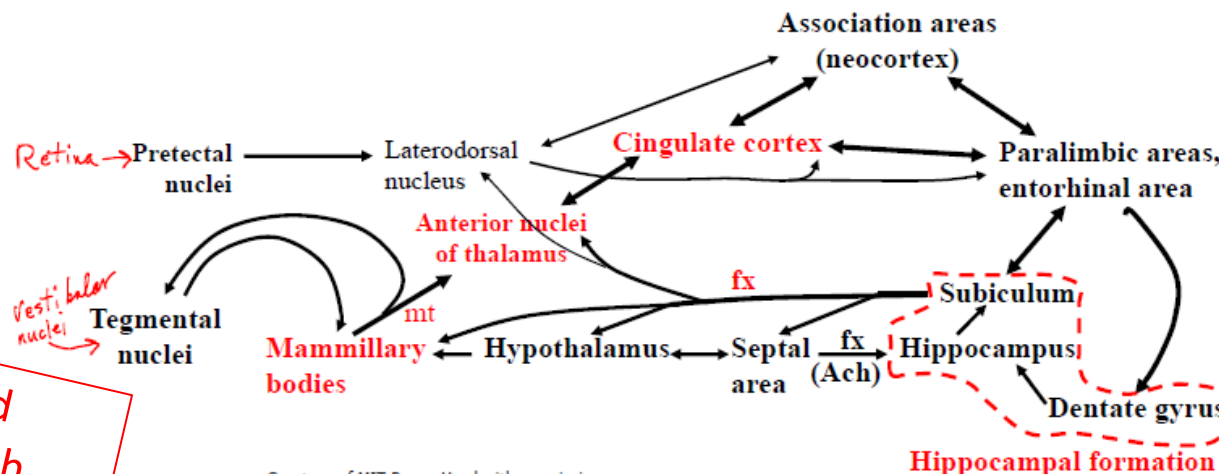
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Spatial orientation and emotions associated with particular place

# Papez circuit

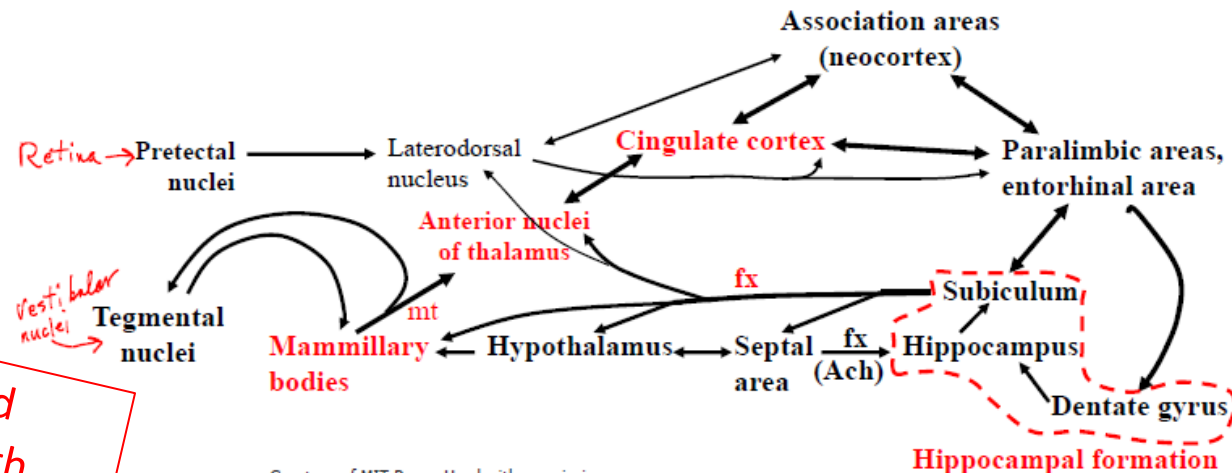
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- *Suggestion: the ascending axons of this circuit are continuously activating memories of places that lie ahead, in the direction indicated by the current direction of the head.* Thus, decisions about direction of locomotion are influenced by memories of those places, including their good or bad values.
- *Axons in the Papez circuit are of more than one type. Only the ones signaling head direction have been characterized.*
- *What is the hippocampus sending to other parts of the hypothalamus? It may alter motivational levels according to remembered information about locations in the current frame of reference.*

mt = mammillothalamic tract  
fx = fornix bundle



Spatial orientation and emotions associated with particular place

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# Papez circuit

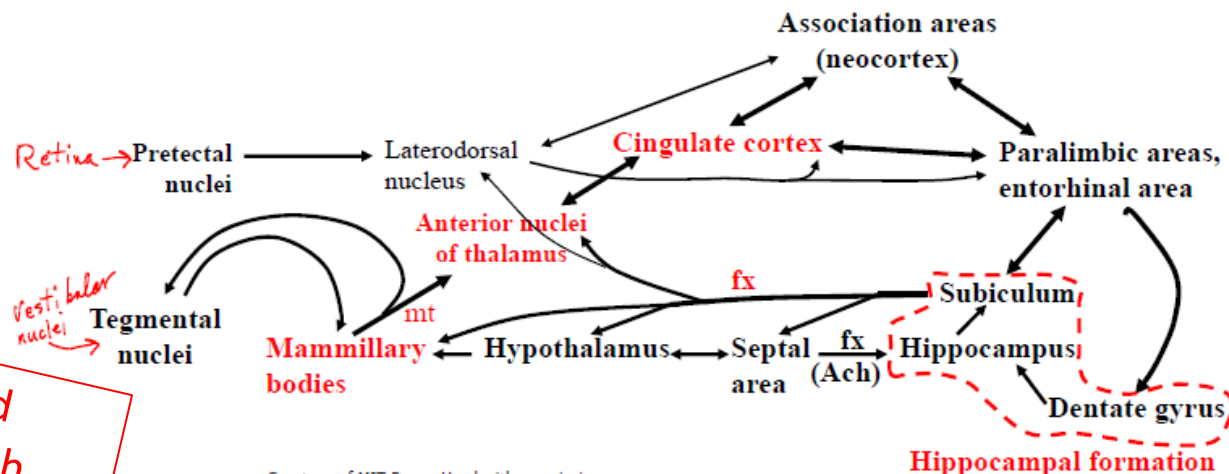
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- Origins of endbrain: Structures underlying olfaction
- Two major links between olfactory system and the motor systems of the midbrain
  - 1) Through the ventral endbrain, which became corpus striatum and basal forebrain (including much of the septal area)
    - Outputs to hypothalamus, (epithalamus, subthalamus), midbrain
    - These outputs affected locomotion and orienting movements
    - The links were plastic, so habits were formed according to rewarding effects mediated, e.g., by taste effects.
  - 2) Through the medial part of the dorsal endbrain, which became medial pallium—the hippocampal formation
    - Outputs to ventral striatum, hypothalamus, epithalamus
    - The links were plastic, but the “habits” formed were different: The association of place with good or bad consequences of approach.

mt = mammillothalamic tract  
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Spatial orientation and emotions associated with particular place

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# Papez circuit

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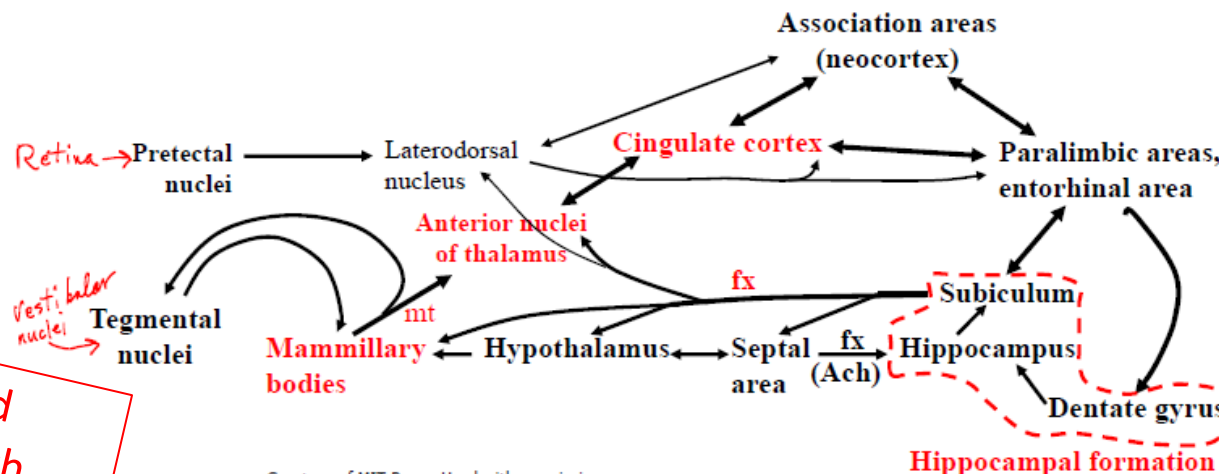
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Object oriented...

Location oriented...

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Spatial orientation and emotions associated with particular place

# Papez circuit

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## Review

### Evolution of corpus striatum: *basic outline of a story*

1. Beginnings: a link between olfactory inputs and motor control: The link becomes “Ventral striatum”. It was a modifiable link (capable of experience-induced change).

2. Non-olfactory inputs invade the striatal integrating mechanisms (via paleothalamic structures).

3. Early expansions of endbrain: striatal and pallial.

4. Pre-mammalian & then mammalian expansions of cortex and striatum: For the striatum, the earlier outputs and inputs remain as connections with neocortex expand.

Figure 1. Postulated beginnings in primitive chordates

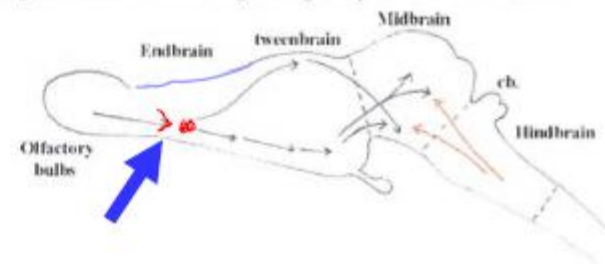


Figure 2. Other inputs reached the striatum

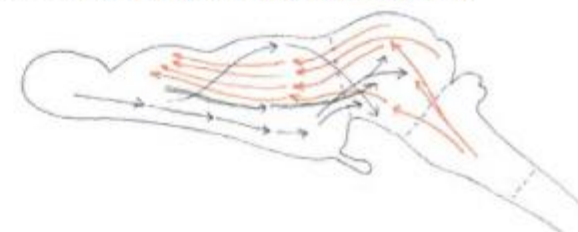


Figure 3. Early expansion of striatal and adjacent “limbic” areas

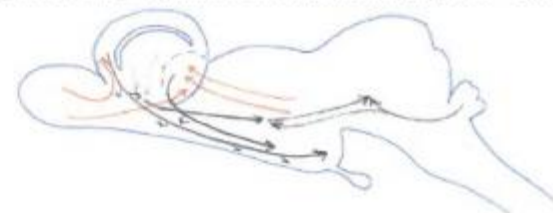


Figure 4. Pre-mammalian, and then mammalian expansions



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# Learning and memory

**Working/Short term  
memory**

– „RAM“

**Long term memory**

– „Hard disk“

# Learning and memory

- Connections of striatum and hippocampus are plastic
- Plasticity is a base of learning
- Learning is a forming of long- term memory

**Working/Short term  
memory**  
– „RAM“

**Long term memory**  
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# Learning and memory

- Connections of striatum and hippocampus are plastic
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- Procedural memory (implicit)
  - Based on striatum
  - Habitual learning – motor skills, but also social habits
  - „Construction of the algorithms“

# Learning and memory

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  - Habitual learning – motor skills, but also social habits
  - „Construction of the algorithms“
- Declarative memory (explicit)
  - Based on hippocampus
  - Explicit information is stored and later recollected
  - „Construction of the maps (relationships)“ – spatial or abstract

# Learning and memory

- Connections of striatum and hippocampus are plastic
- Plasticity is a base of learning
- Learning is a forming of long- term memory
- Procedural memory (implicit)
  - Based on striatum
  - Habitual learning – motor skills, but also social habits
  - „Construction of the algorithms“
- Declarative memory (explicit)
  - Based on hippocampus
  - Explicit information is stored and later recollected
  - „Construction of the maps (relationships)“ – spatial or abstract

**Object oriented:**  
Can I eat it and how to eat  
it?

**Location oriented:**  
Where am I and what has  
happened here?

# Cognitive maps

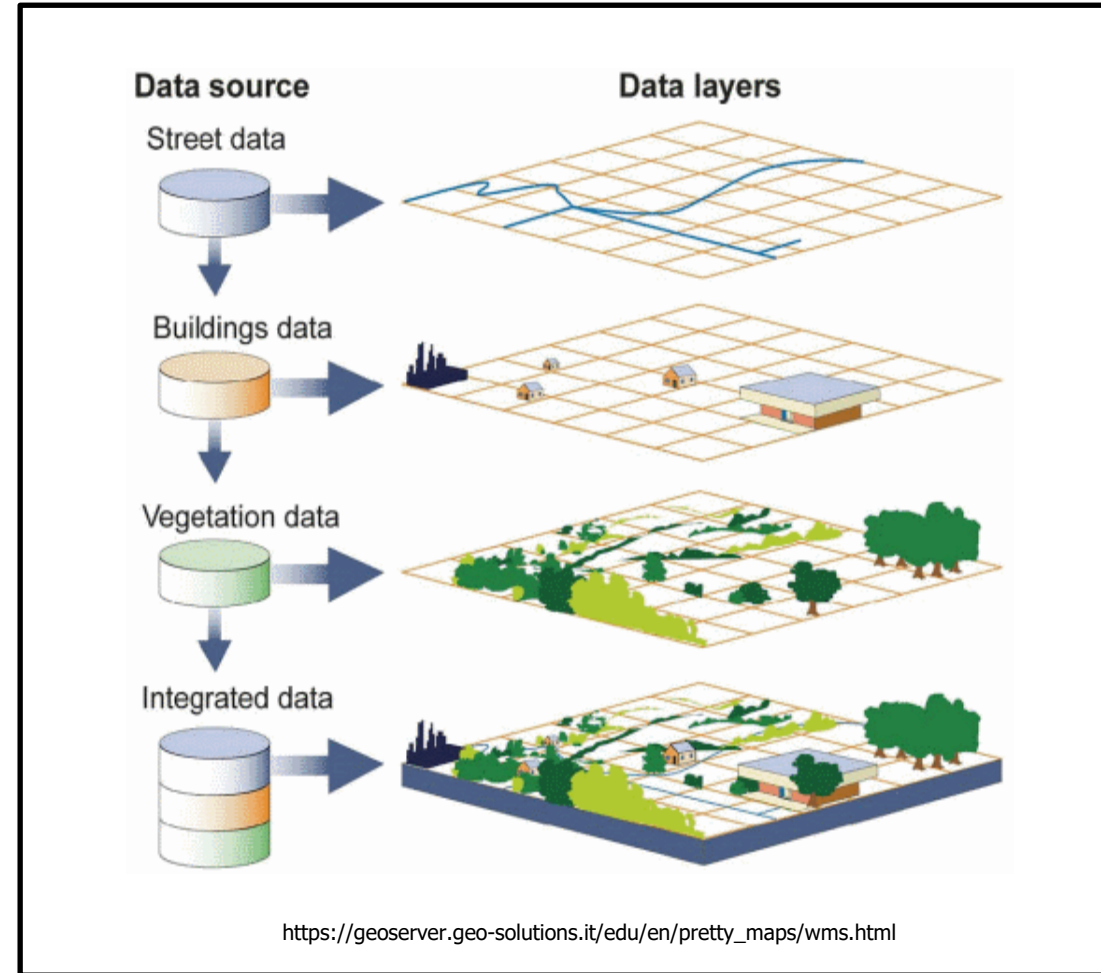
Type of **mental representation** which serves an individual to acquire, code, store, recall, and decode information about the **relative locations and attributes** of phenomena in their everyday or metaphorical spatial environment.

Wikipedia

- ✓ Unique
- ✓ Egocentric, but multiple points of view
- ✓ Complex

Later generalized to refer to a kind of **semantic network** representing an individual's personal **knowledge or schemas**.

Wikipedia



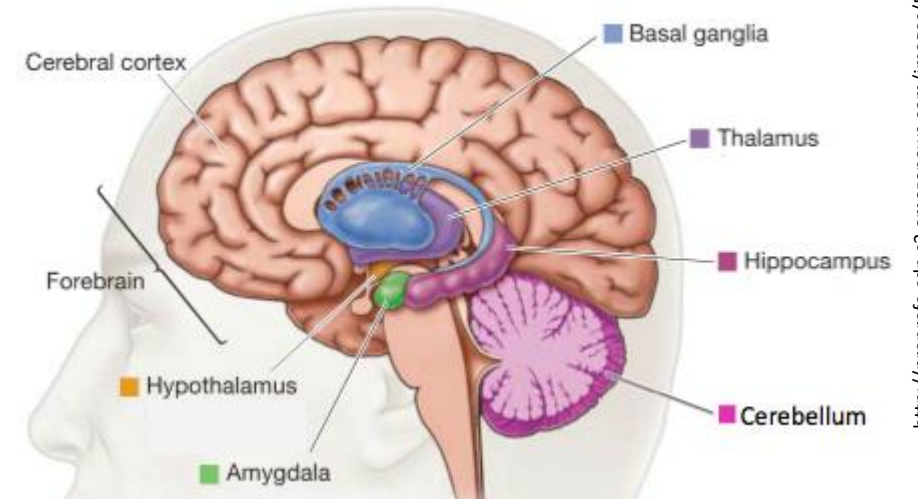
# Amygdala

*Corticomedial: Inputs from olfactory bulbs, hypothalamus & lateral amygdala; outputs to hypothalamus, amygdala, ANS*

*Basolateral: Inputs from thalamus, neocortex, hippocampus; outputs to prefrontal cortex, ventral striatum, other amygdala nuclei*

*Central: Intra-amygdalar inputs; outputs through stria terminalis (see later slides)*

- Connections to all major cortical and subcortical structures
- Modified corpus striatum
- Plasticity – memory formation



[http://proprofs-cdn.s3.amazonaws.com/images/FC/user\\_images/1406217/9806788916.png](http://proprofs-cdn.s3.amazonaws.com/images/FC/user_images/1406217/9806788916.png)

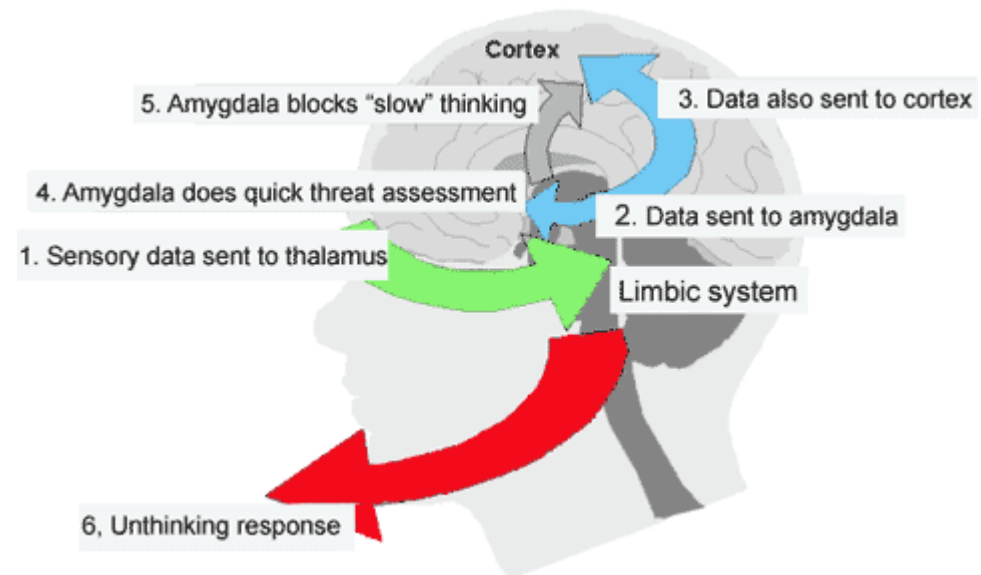
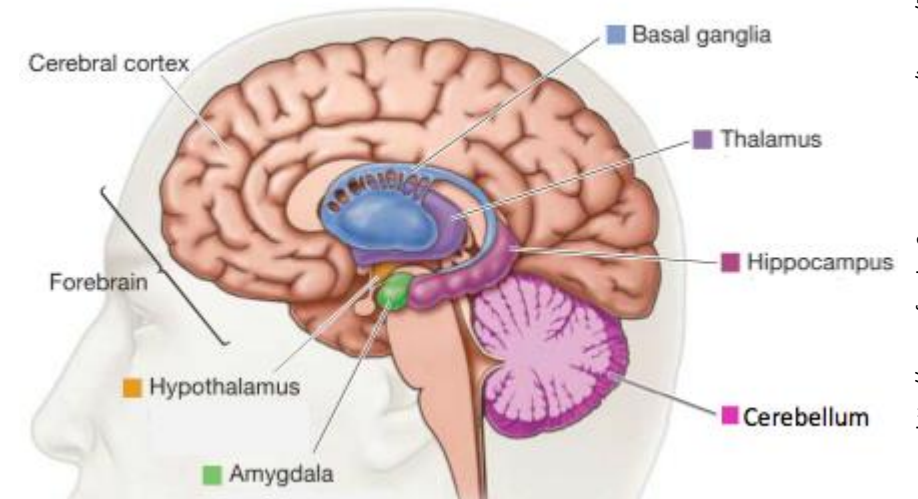
# Amygdala

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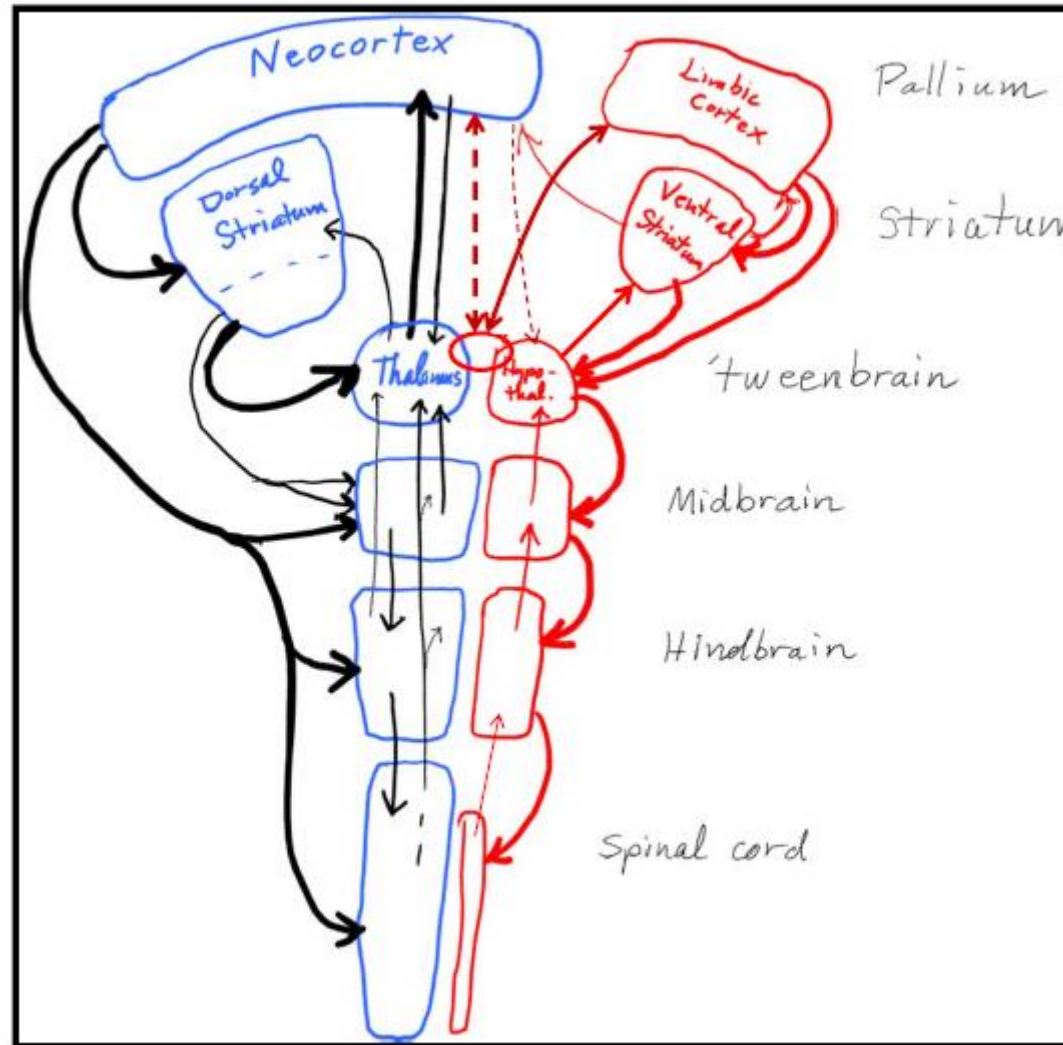
*Central: Intra-amygdalar inputs; outputs through stria terminalis (see later slides)*

- Connections to all major cortical and subcortical structures
- Modified corpus striatum
- Plasticity – memory formation
- „Influence of information from outer environment on limbic system“
- „Amygdala hijack“
- „Affective tags“
  - Both positive and negative
  - Higher responsiveness to negative





Gerald Schneider. *9.14 Brain Structure and Its Origins, Spring 2014*. (Massachusetts Institute of Technology: MIT OpenCourseWare), <http://ocw.mit.edu> (Accessed). License: Creative Commons BY-NC-SA



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Schneider, G. E. *Brain structure and its Origins: In the Development and in Evolution of Behavior and the Mind*. MIT Press, 2014. ISBN: 9780262026734.

## 83. The importance of limbic system and brief characterization of basic functions – somatic and limbic arousal systems, sleep and wakefulness

- Concept, definition and structures of limbic system
  - Integration of information from inner and outer environment
  - Hypothalamus is a central structure...
- Somatic vs. limbic arousal system
- Habituation, association with reward punishing system, connections...
- Sleep/wakefulness – cooperation of somatic and limbic activation system via neuromodulation
- Phases of sleep, basic EEG characteristics

## 84. The importance of limbic system and brief characterization of basic functions – learning and memory, the influence of hypothalamus on neocortex, the role of amygdala

- Concept, definition and structures of limbic system
  - Integration of information from inner and outer environment
  - Hypothalamus is a central structure...
  - Brief overview of hypothalamic functions
  - Influence of hypothalamus on neocortex
- Learning and memory
  - Learning is based on plasticity, learning is forming of long-term memory
  - Explicit memory – hippocampus
  - Implicit memory - striatum
- Amygdala
  - Influence of information from outside (neocortex) on limbic system
  - Amygdal hijack, affective tags

M U N I

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