

M U N I

M E D

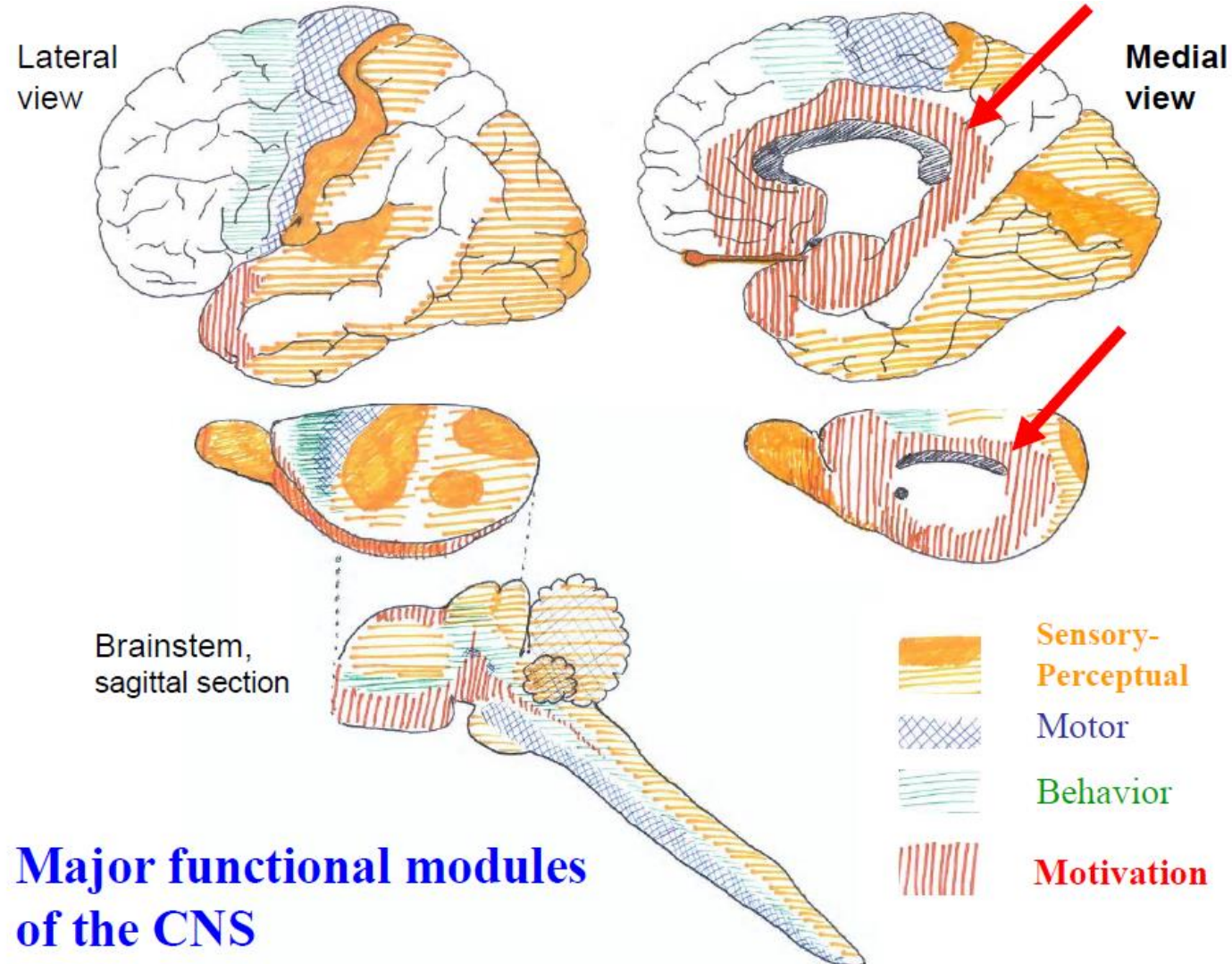
M U N I
M E D

14

Limbic system

Limbic system

Limbus = border



Major functional modules of the CNS

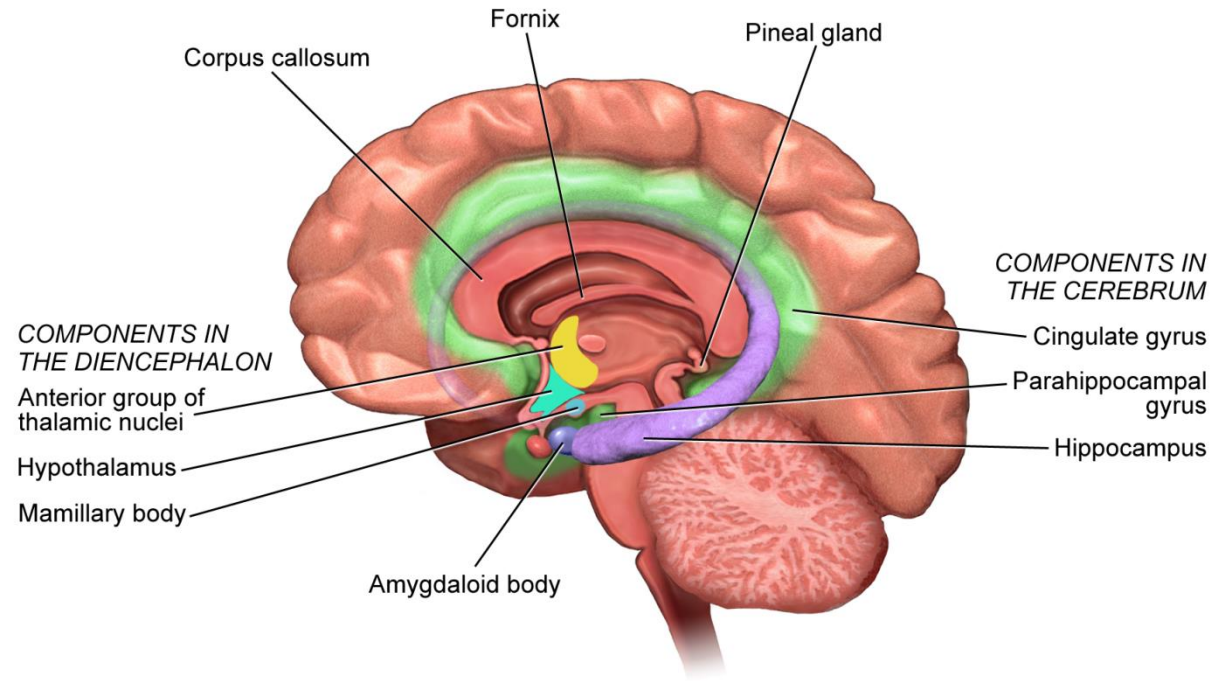
The concept of limbic system

- Voluntary

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

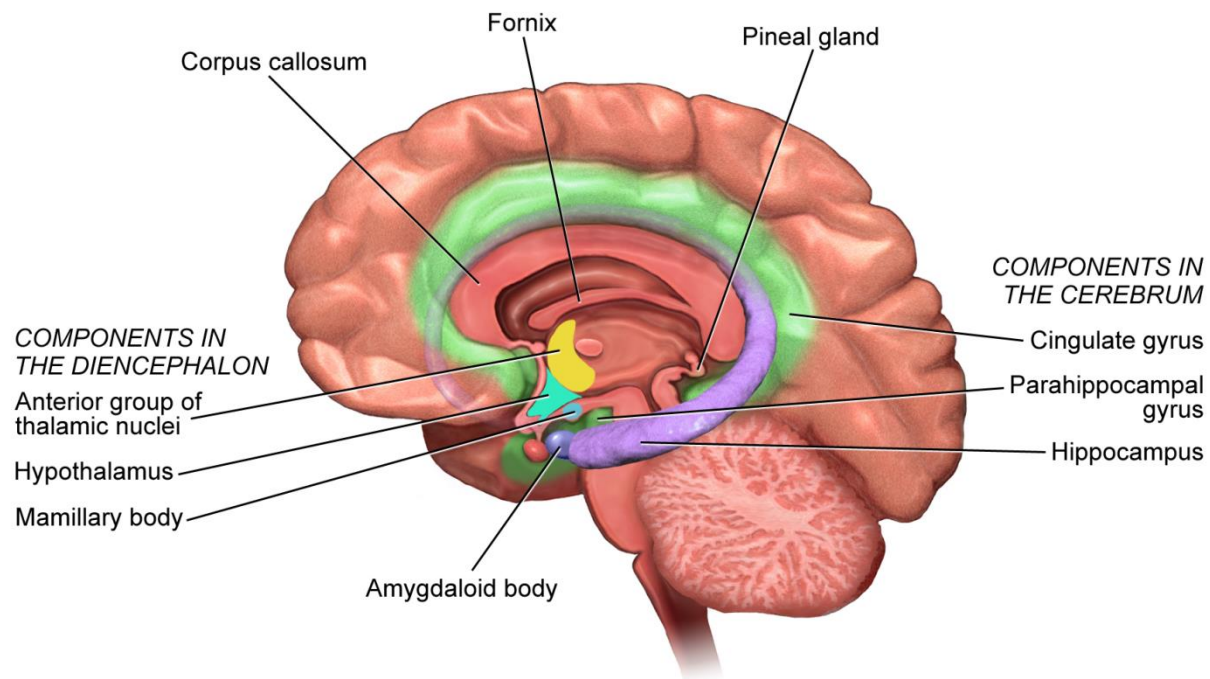
- Automatic

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

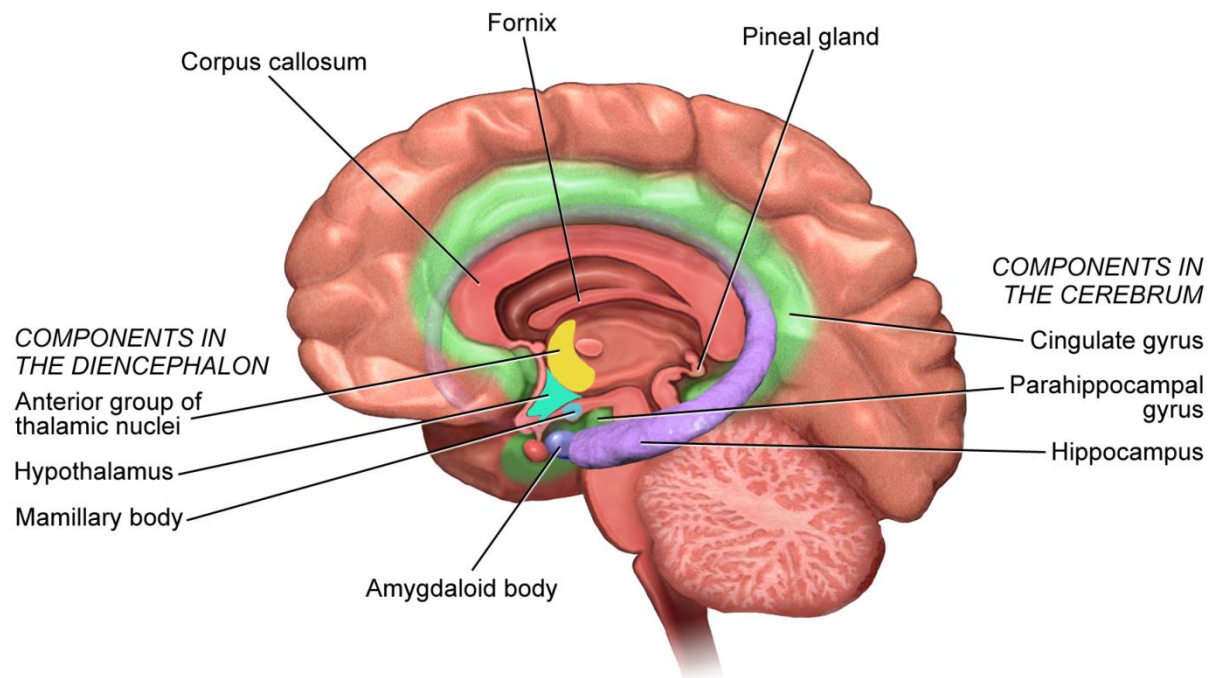
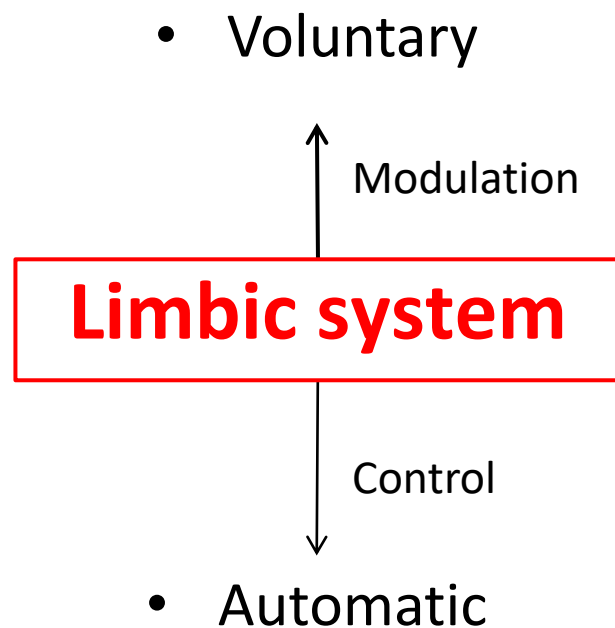


The concept of limbic system

- Voluntary
- ↑
- Potential conflict
- ↓
- Automatic



The concept of limbic system



The concept of limbic system

- Voluntary

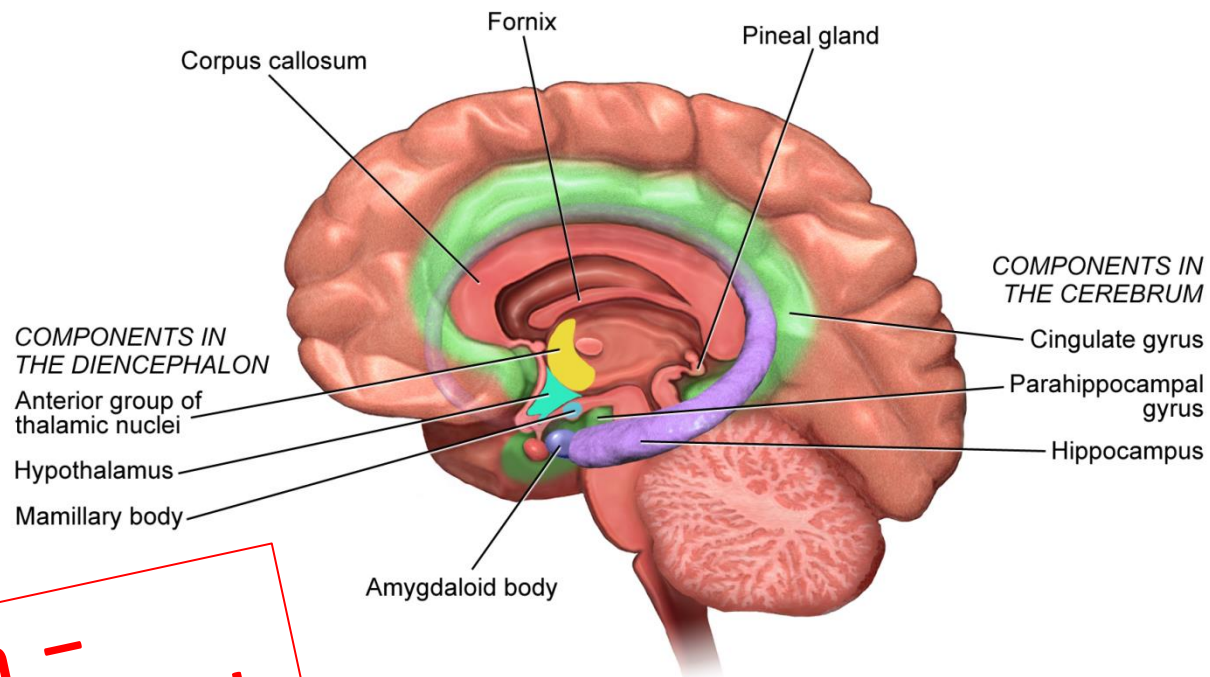
↑ Modulation

Limbic system

↓ Control

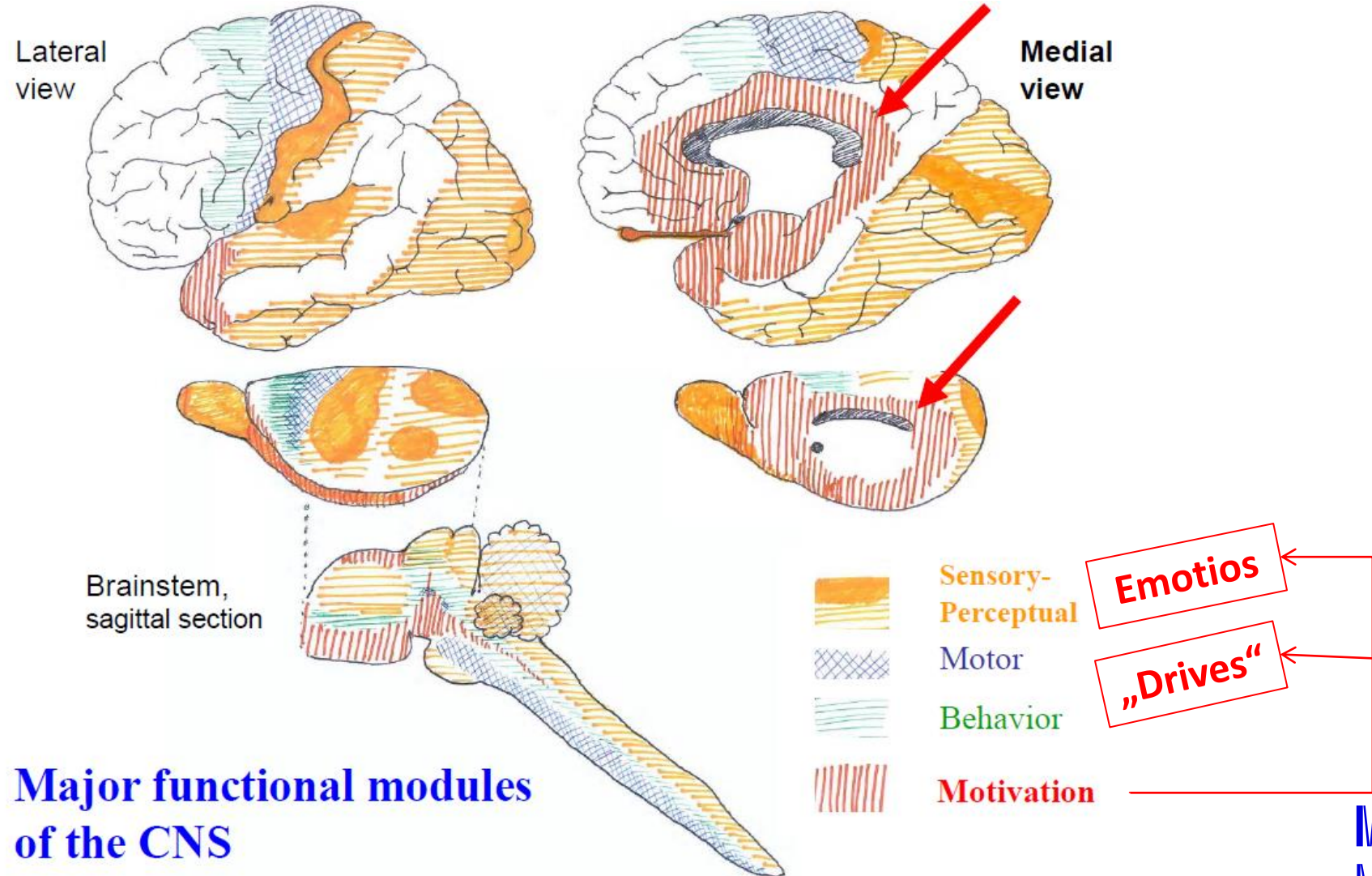
- Automatic

**Limbic system –
hypothalamus and related
structures**



Limbic system

Limbus = border



Major functional modules of the CNS

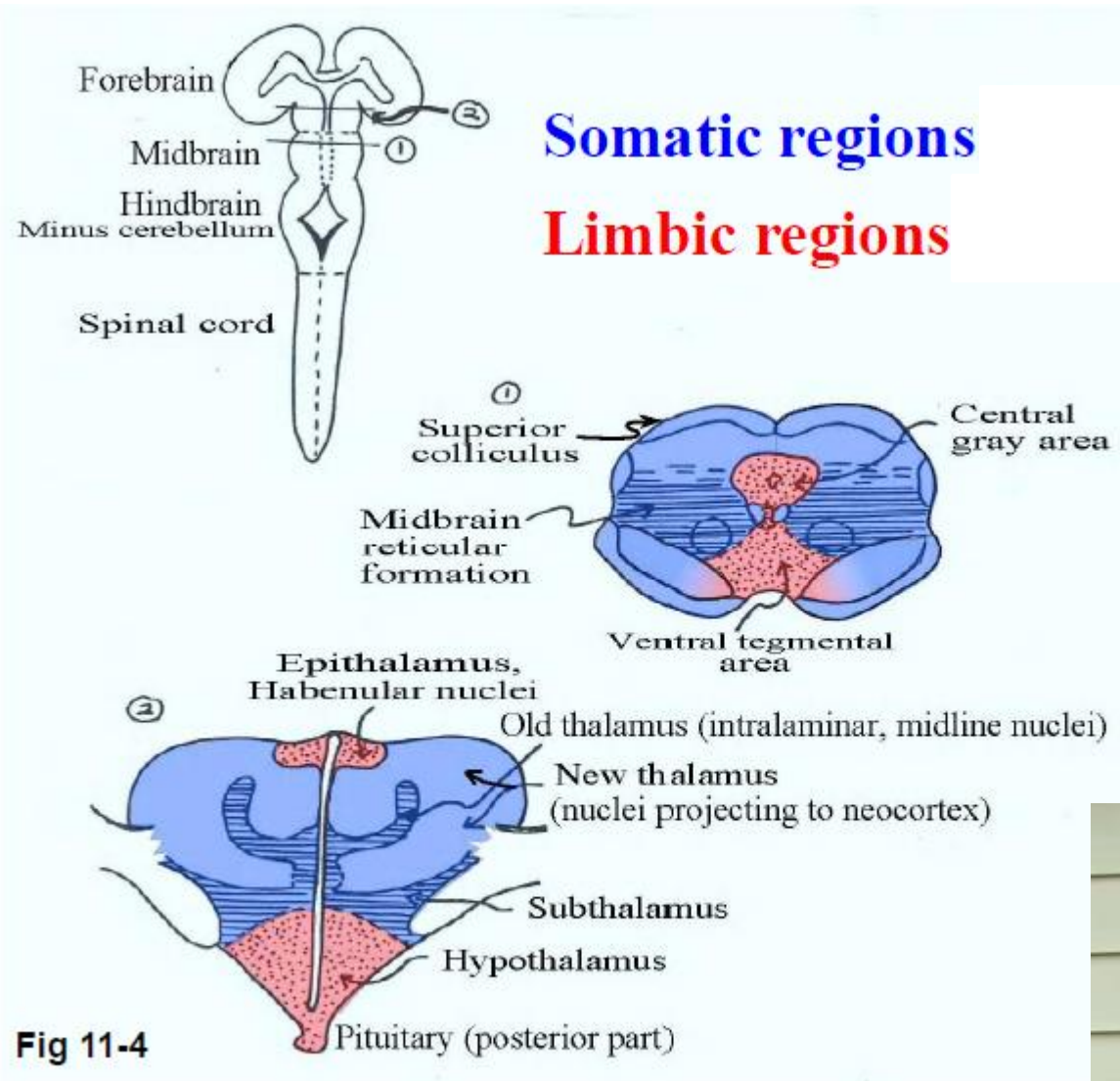


Fig 11-4

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



Prof. Gerald Schneider

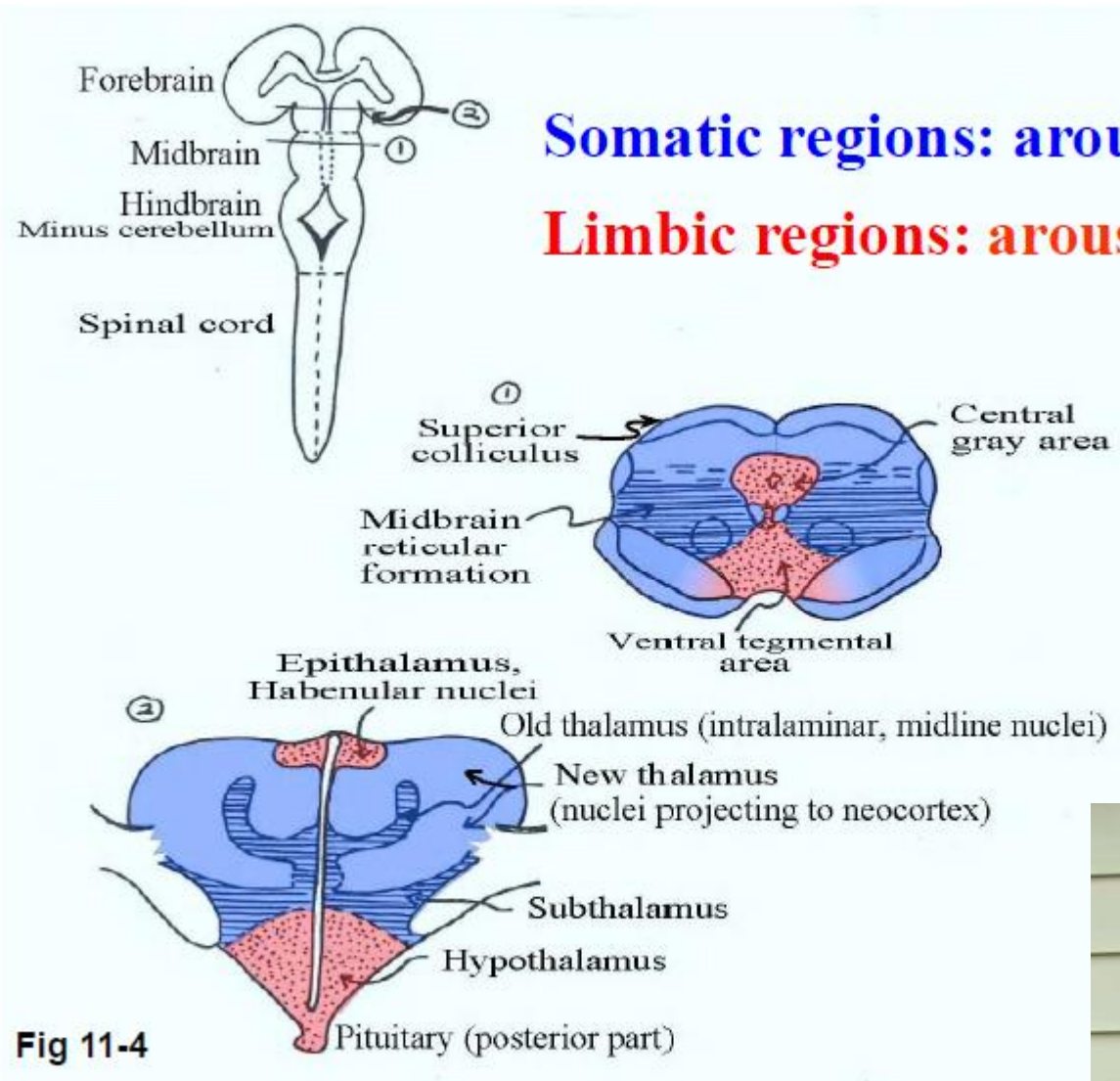
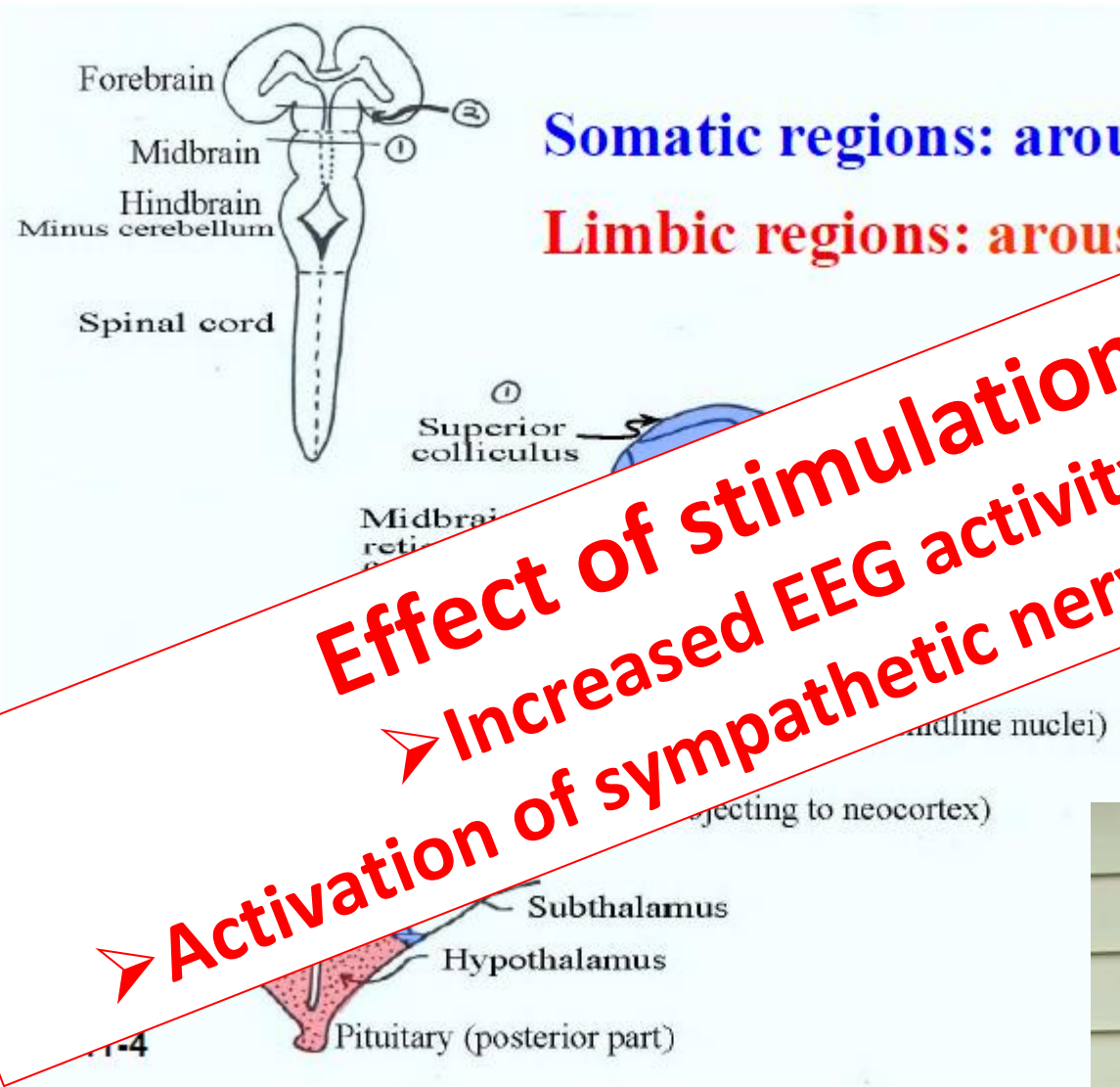


Fig 11-4

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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)

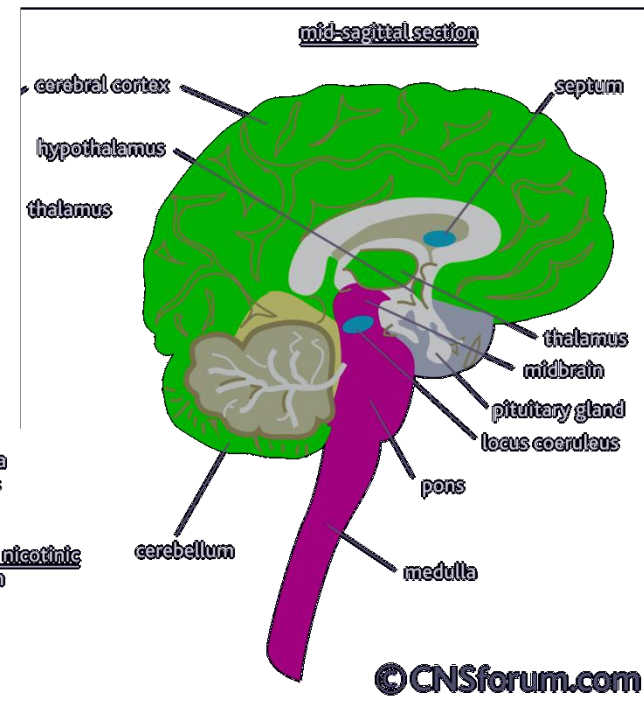
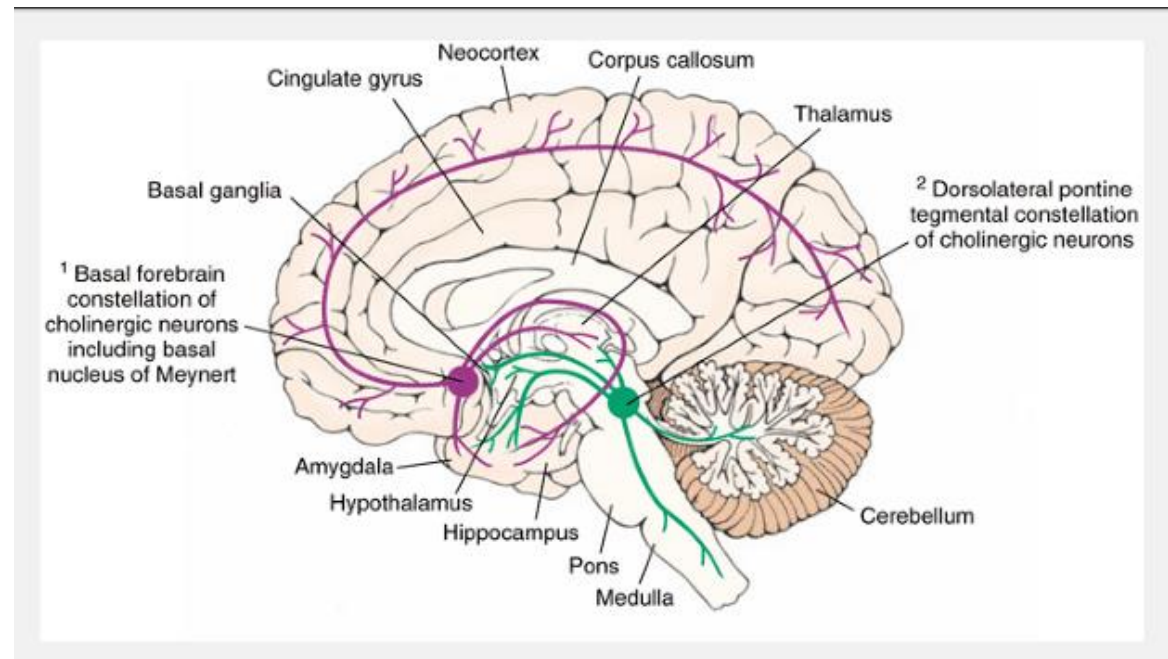
- Ascending connections
Neocortex, corpus striatum, thalamus

- Descendent connections
 - Hypothalamus and other limbic areas, amygdala

Acetylcholine

- Nucleus basalis (Meynerti) and other nuclei
- Nicotin receptors
- Muscarin receptors

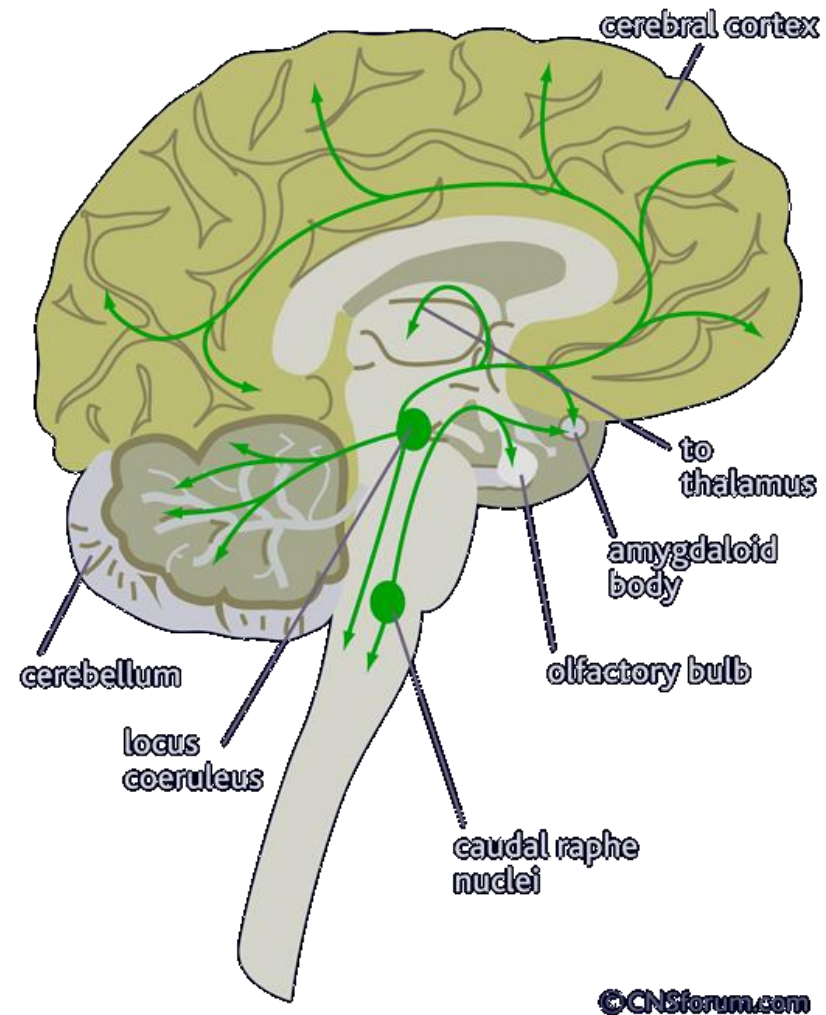
- Sleep/wake regulation
- Cognitive functions
- Behavior
- Emotions



Norepinefrine

- Locus coeruleus
- Nuclei raphe caudalis

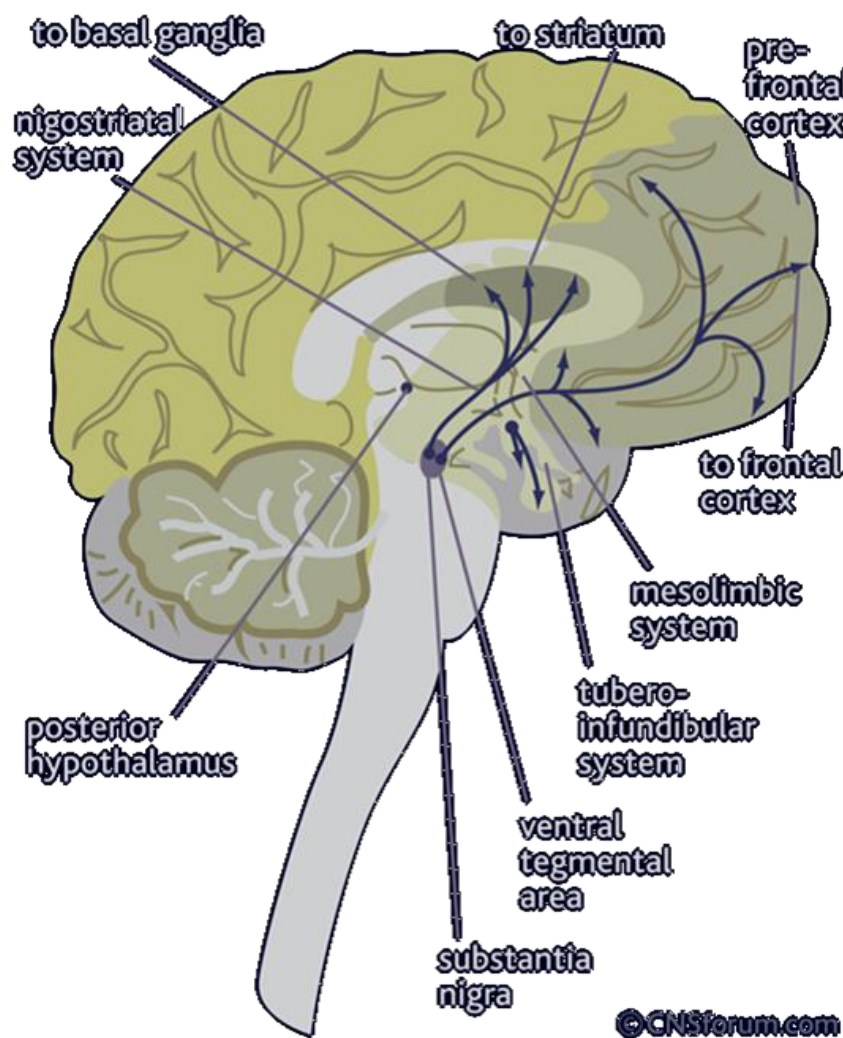
- Vigilance
- Responsiveness to unexpected stimuli
- Memory
- Learning



<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

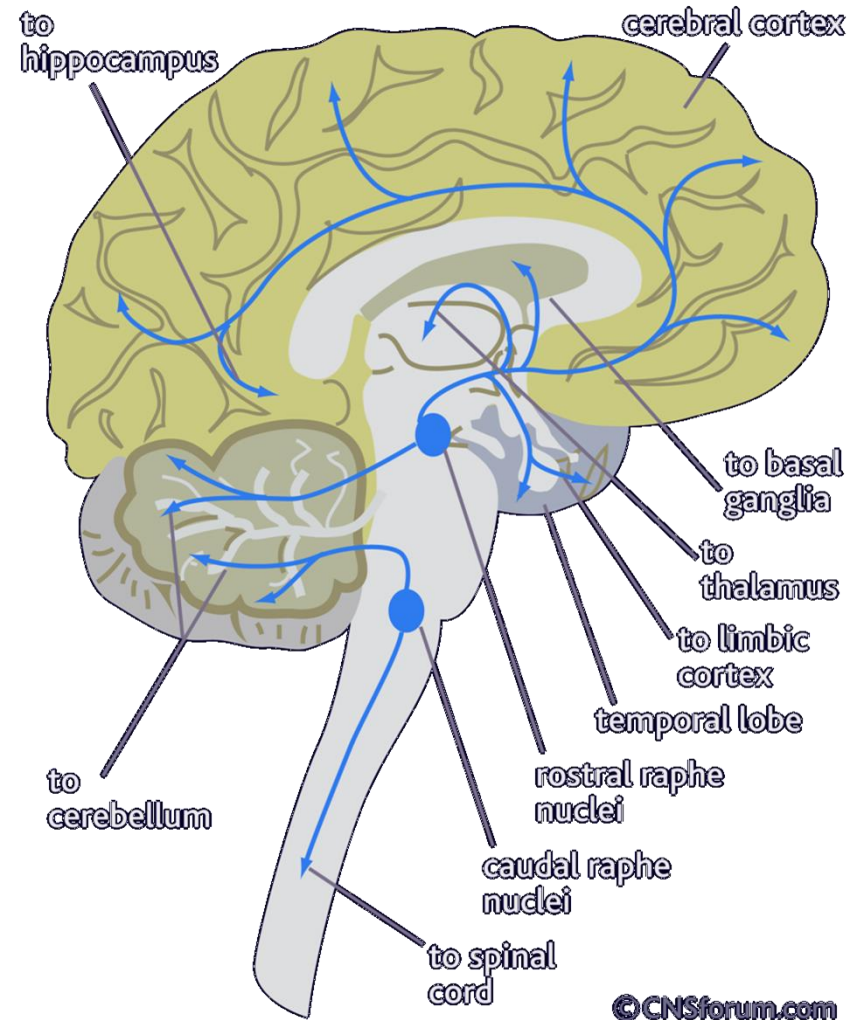


<http://www.slideshare.net/drpsdeb/presentations>

Serotonin

- Nuclei raphe rostralis
- Nuclei raphe caudalis

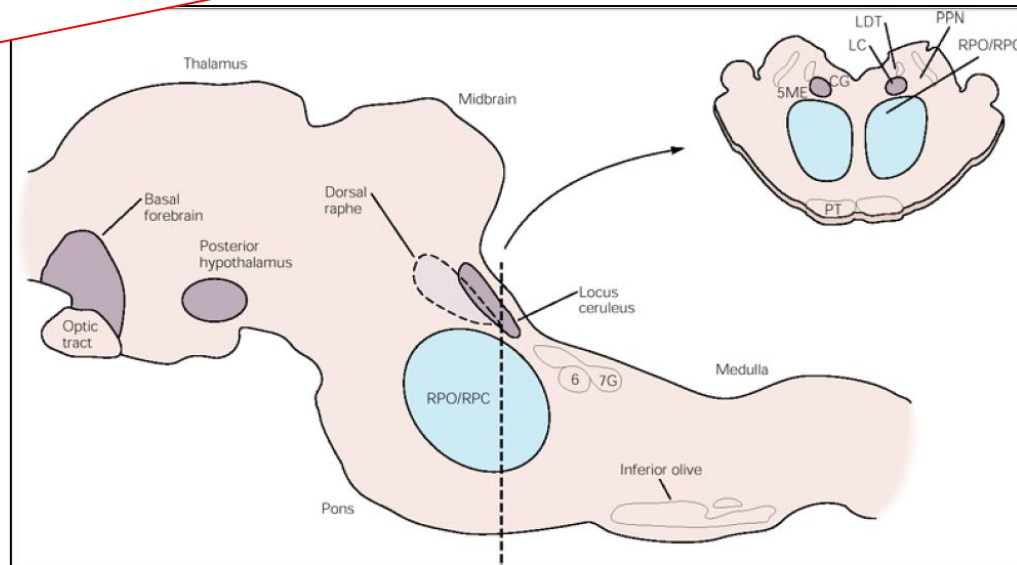
- Anxiety/relaxation
- Impulsive behavior
- Sleep



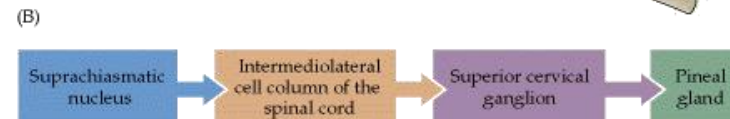
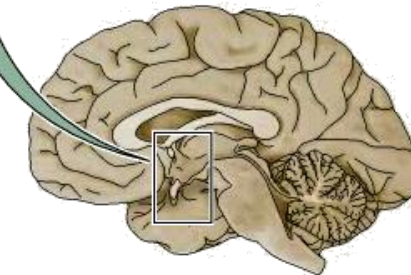
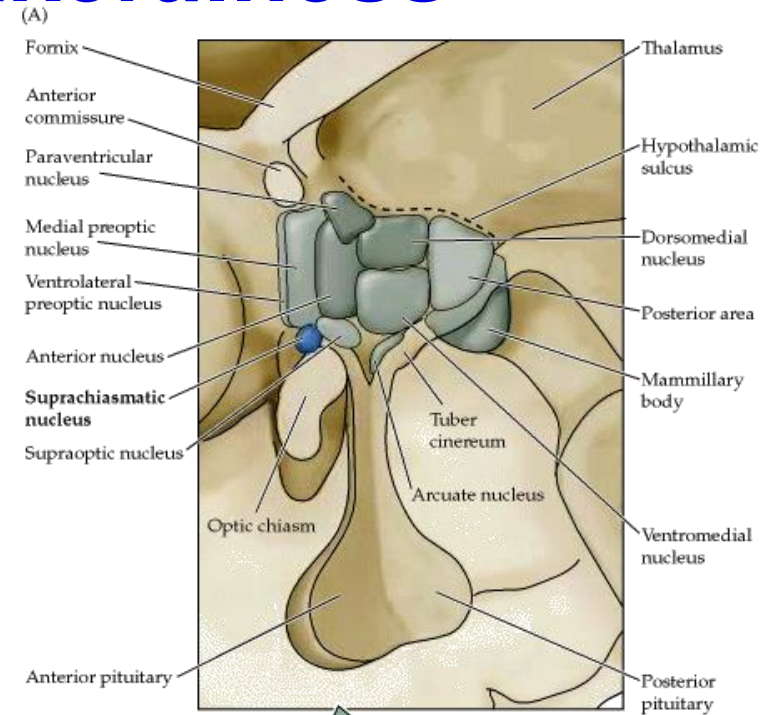
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Sleep and wakefulness

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)

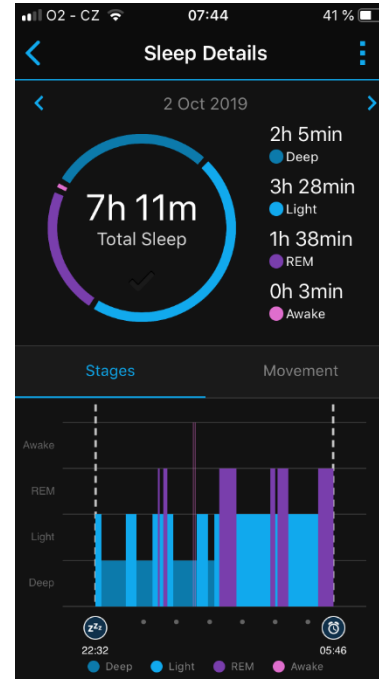
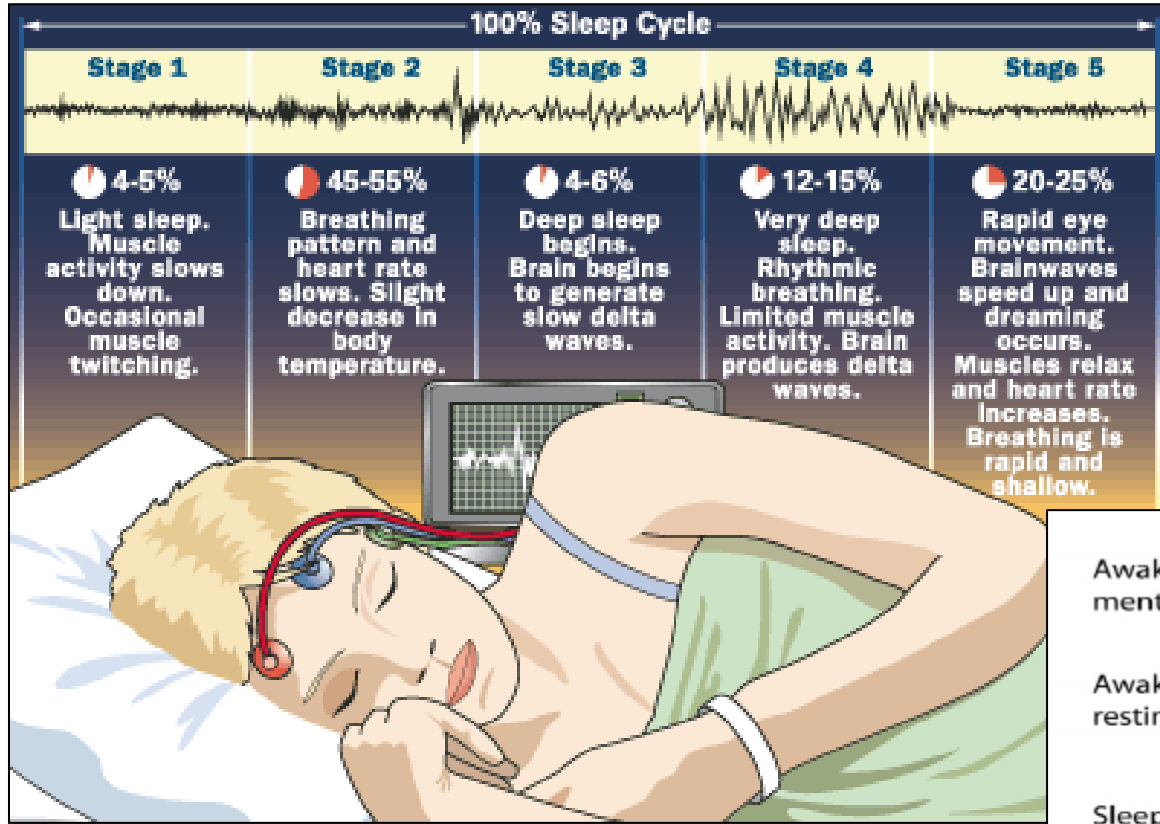
LIGHT NON-REM SLEEP

- › 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

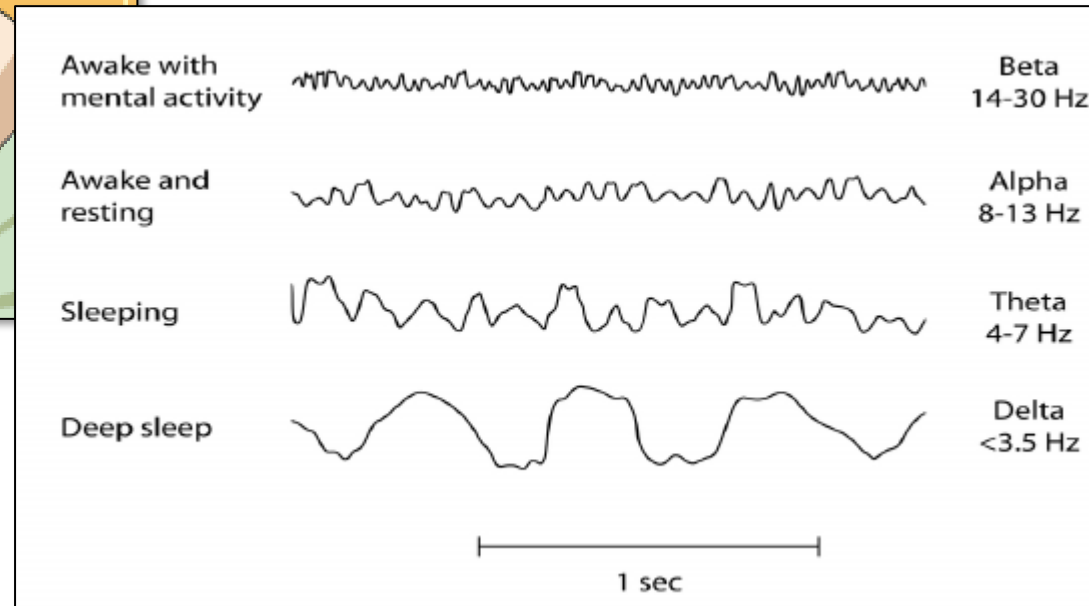
http://www.slideshare.net/dipsdeb/presentations



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



LIGHT NON-REM SLEEP	DEEP NON-REM SLEEP	REM SLEEP
<ul style="list-style-type: none"> Stages 1-2 May drift in and out of sleep several times at the start Easy to wake up, disturbs easily 	<ul style="list-style-type: none"> Stages 3-4 Difficult to wake up Sleep inertia when woken 	<ul style="list-style-type: none"> 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



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

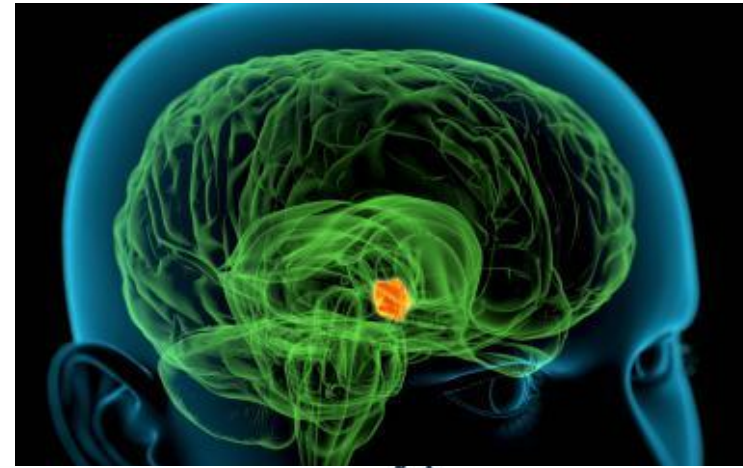
- Key center of autonomic regulations and coordination
- Integration of the information from inner and outer environment



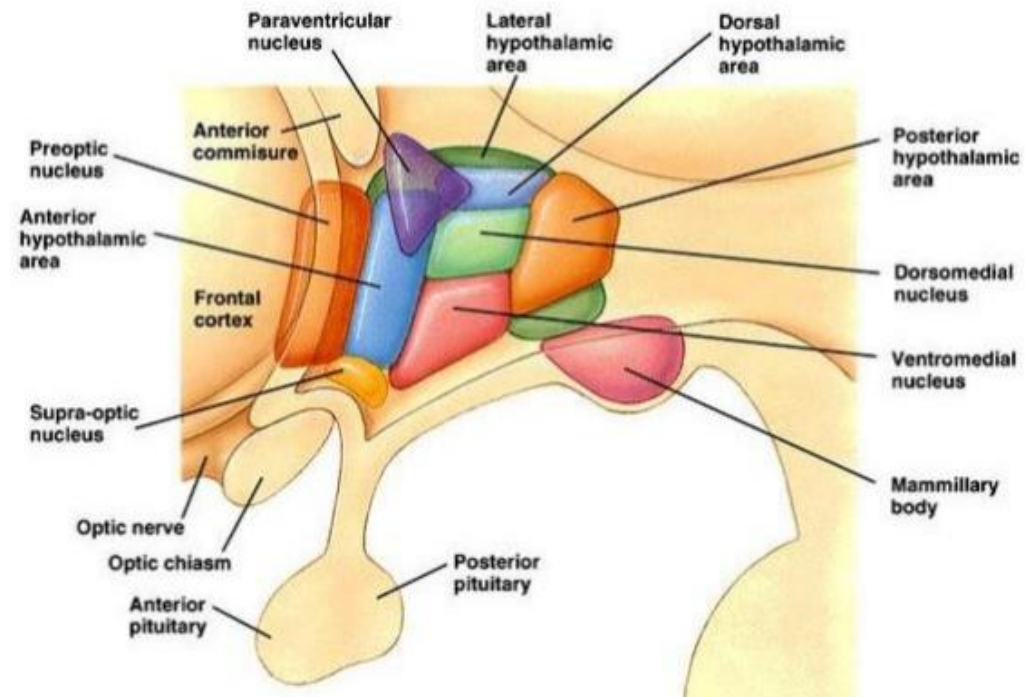
- Behavioral modulation
- Regulation of autonomic nervous system



- **Maintenance of homeostasis**



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



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

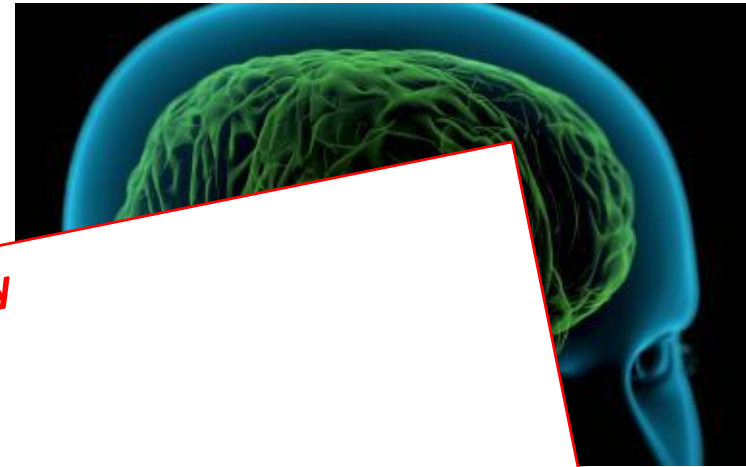
Hypothalamus

- Key center of autonomic regulations and coordination
- Integration of the information from inner and outer environment

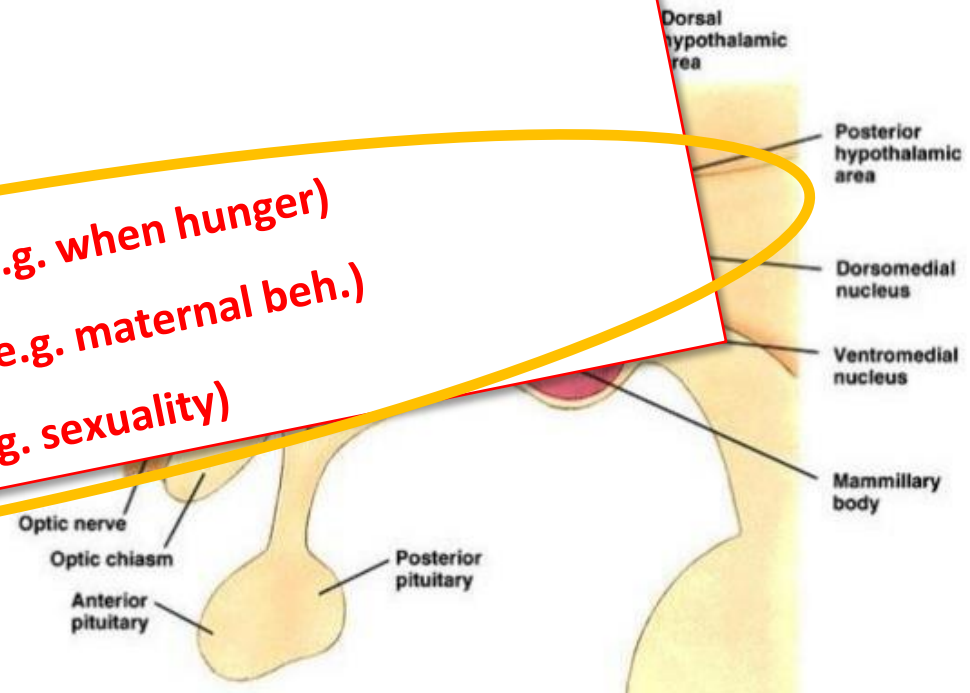
- Behavior
- Regulation of nervous system

- 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)



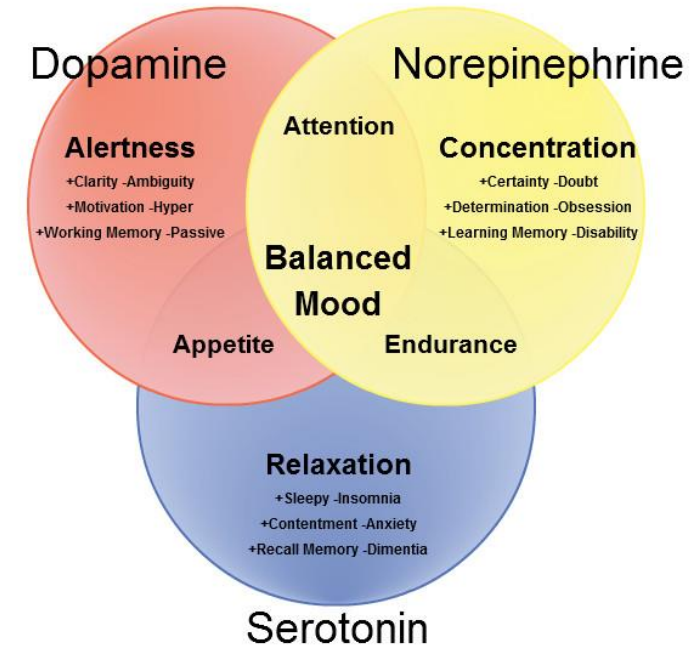
<http://biology.about.com/od/anatomy/pl/Hypothalamus.htm>



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

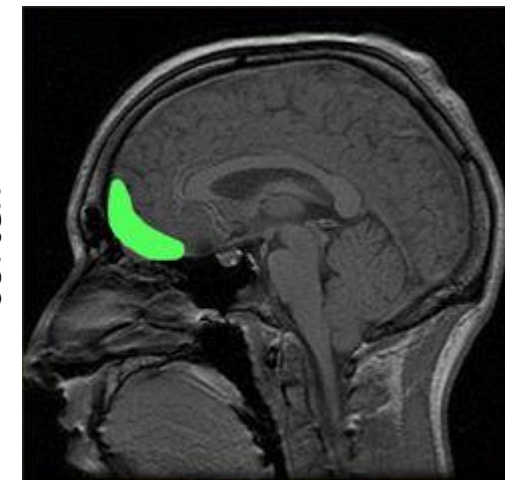
Influence of hypothalamus on neocortex

- 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



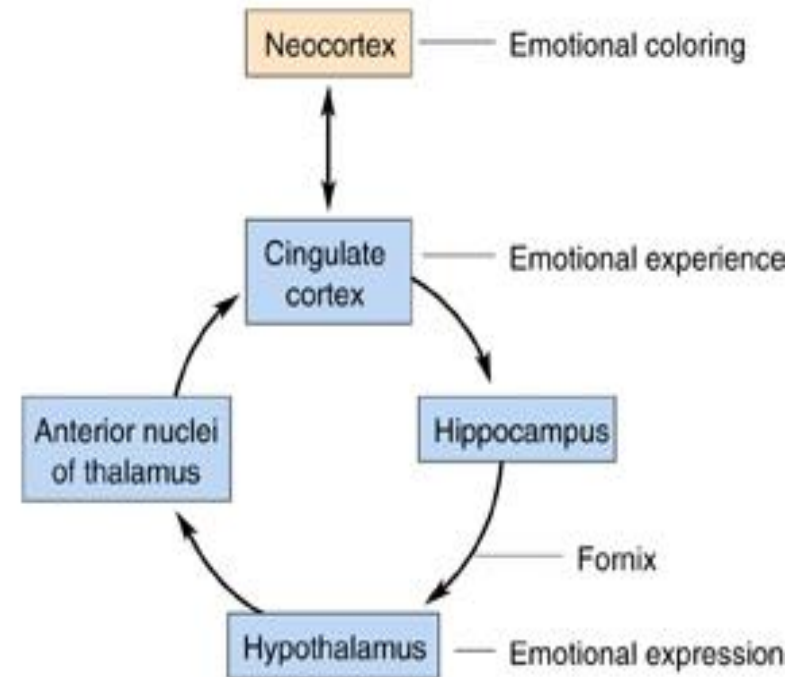
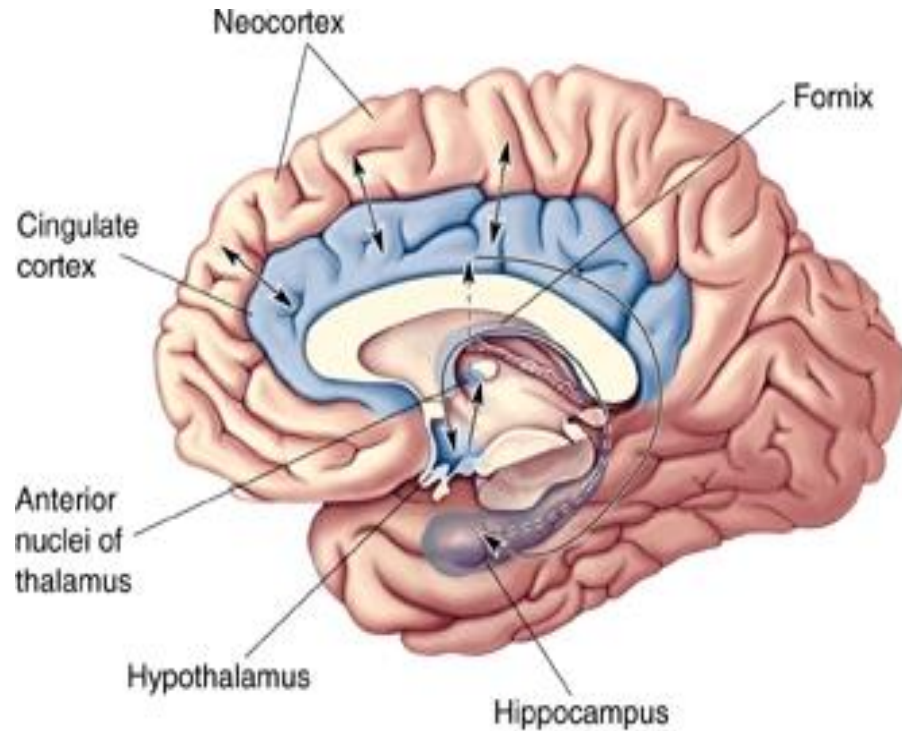
http://ausm.org.uk/wp-content/uploads/2015/02/Dopamine_Norepinephrine_Serotonin.jpg

Orbitofrontal cortex



https://en.wikipedia.org/wiki/Orbitofrontal_cortex

Papez circuit



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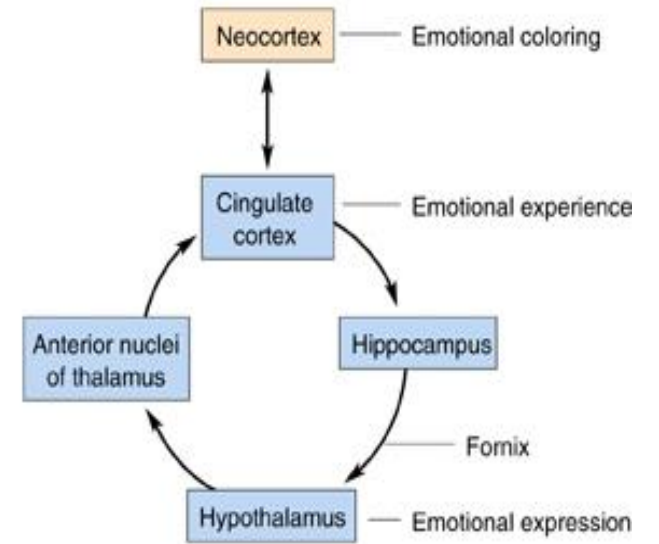
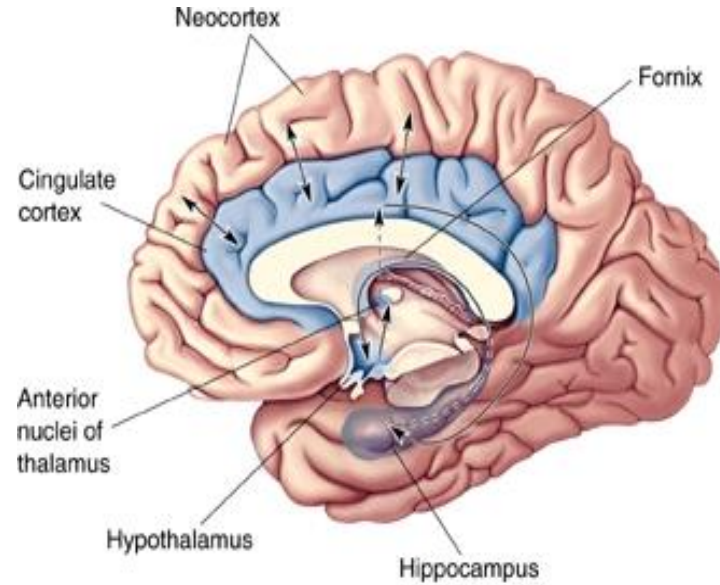
<http://www.slideshare.net/drsunilsuthar/neurobiology-of-emotion>

Papez circuit

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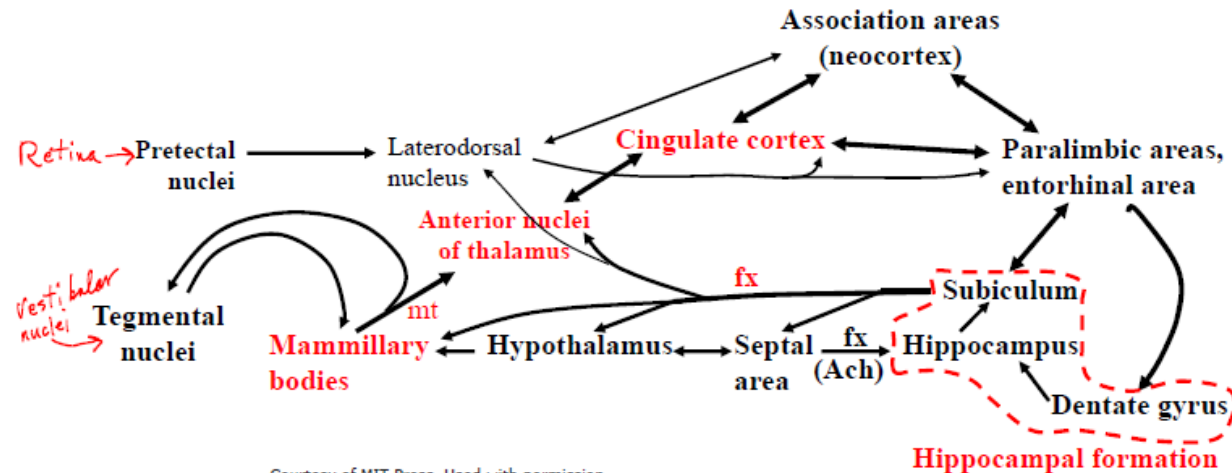


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mt = mammillothalamic tract
fx = fornix bundle



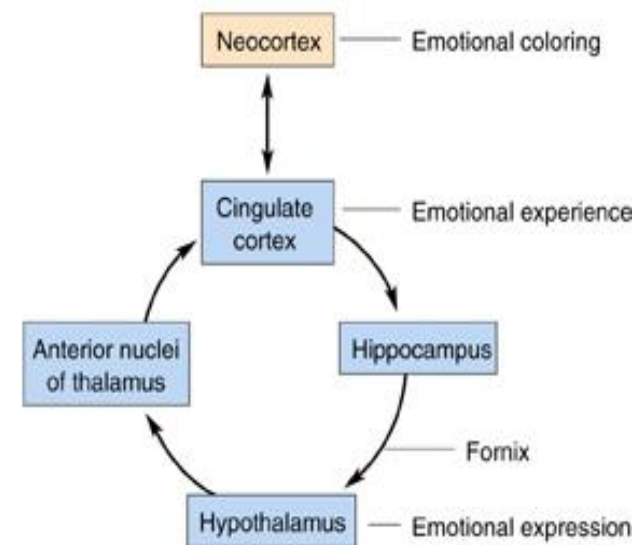
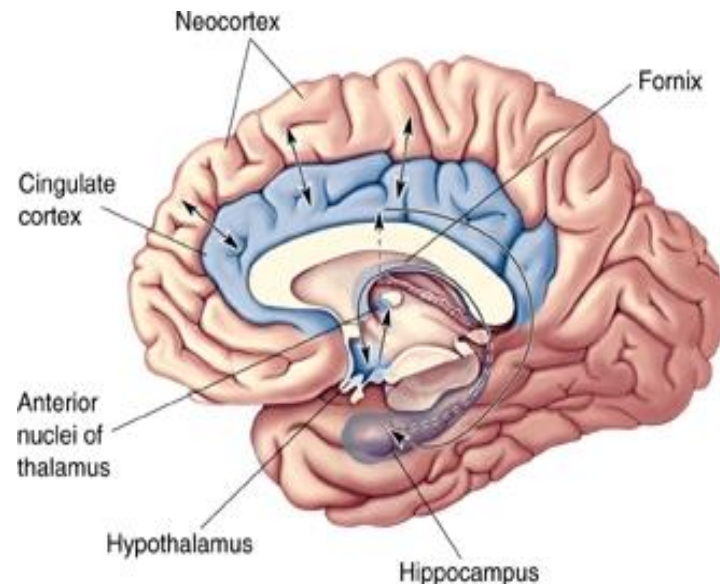
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Papez circuit

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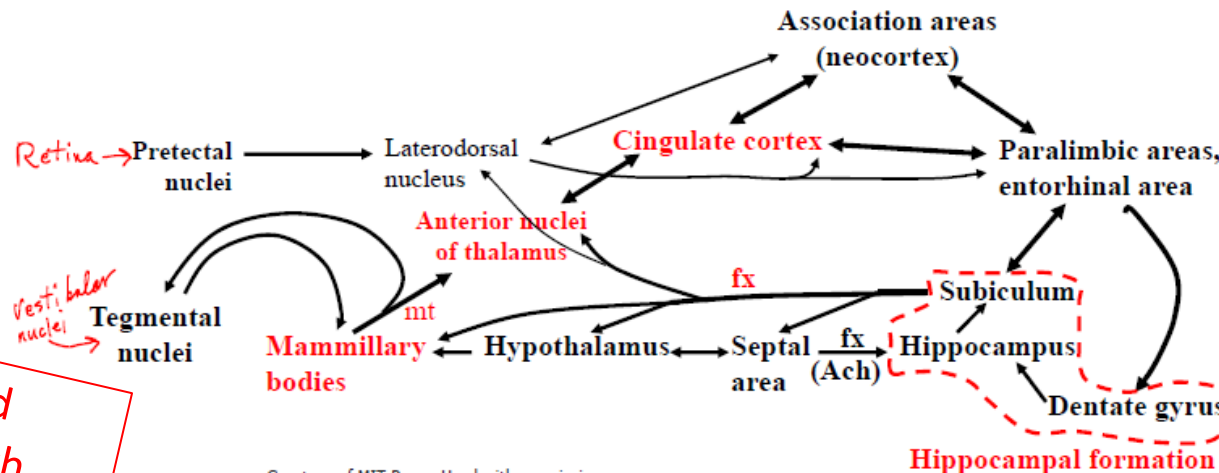


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Spatial orientation and emotions associated with particular place

Papez circuit

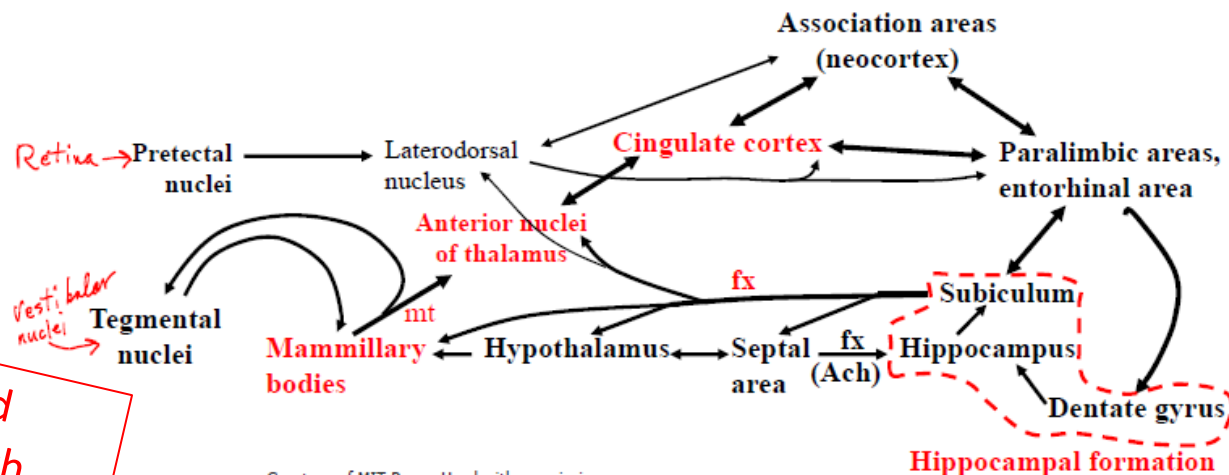
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- *Suggestion: the ascending axons of this circuit are continuously activating memories of places that lie ahead, in the direction indicated by the current direction of the head.* Thus, decisions about direction of locomotion are influenced by memories 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

Papez circuit

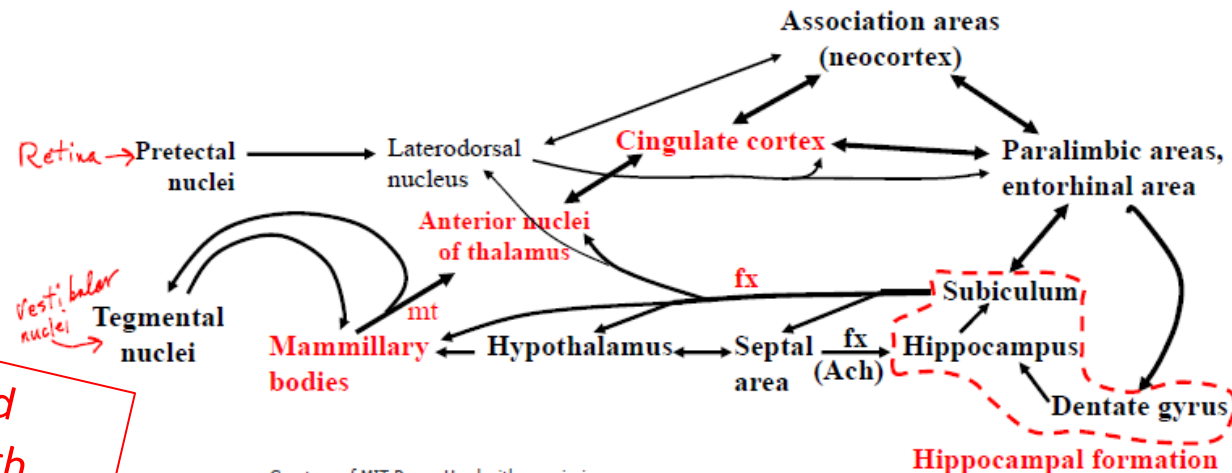
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- Origins of endbrain: Structures underlying olfaction
- Two major links between olfactory system and the motor systems of the midbrain
 - 1) Through the ventral endbrain, which became corpus striatum and basal forebrain (including much of the septal 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
fx = fornix bundle



Spatial orientation and emotions associated with particular place

Papez circuit

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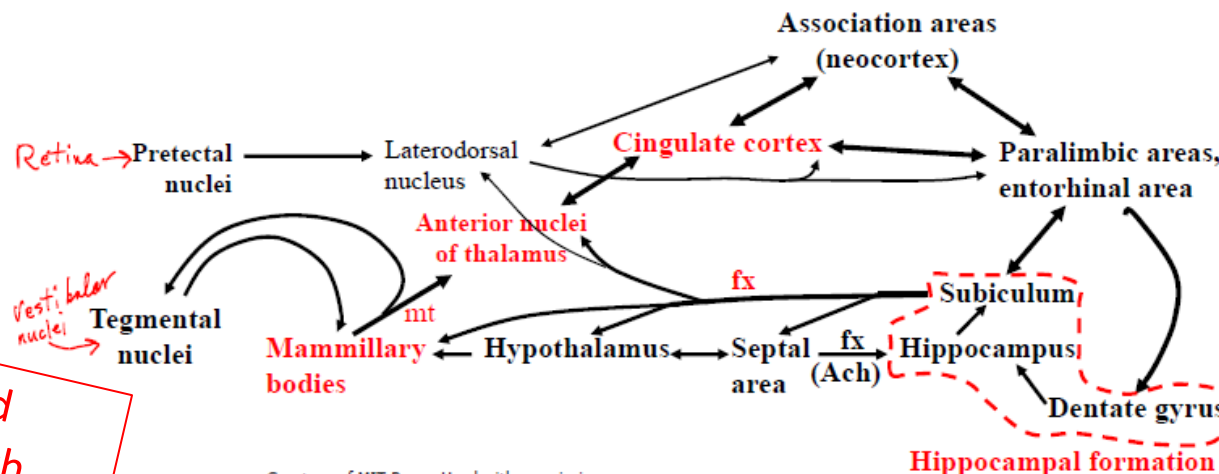
Prof. Gerald Schneider

Object oriented...

Location oriented...

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Spatial orientation and emotions associated with particular place

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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

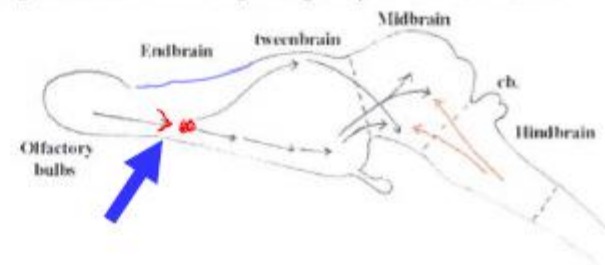


Figure 2. Other inputs reached the striatum

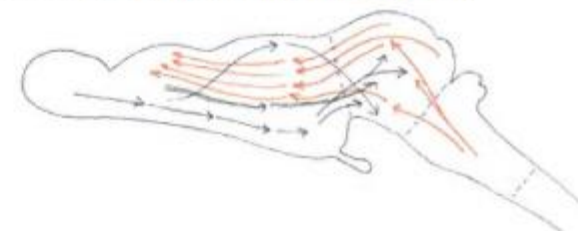


Figure 3. Early expansion of striatal and adjacent “limbic” areas

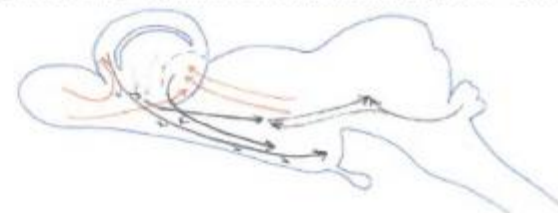


Figure 4. Pre-mammalian, and then mammalian expansions



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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

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

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 - Explicit information is stored and later recollected
 - „Construction of the maps (relationships)“ – spatial or abstract

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

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

Cognitive maps

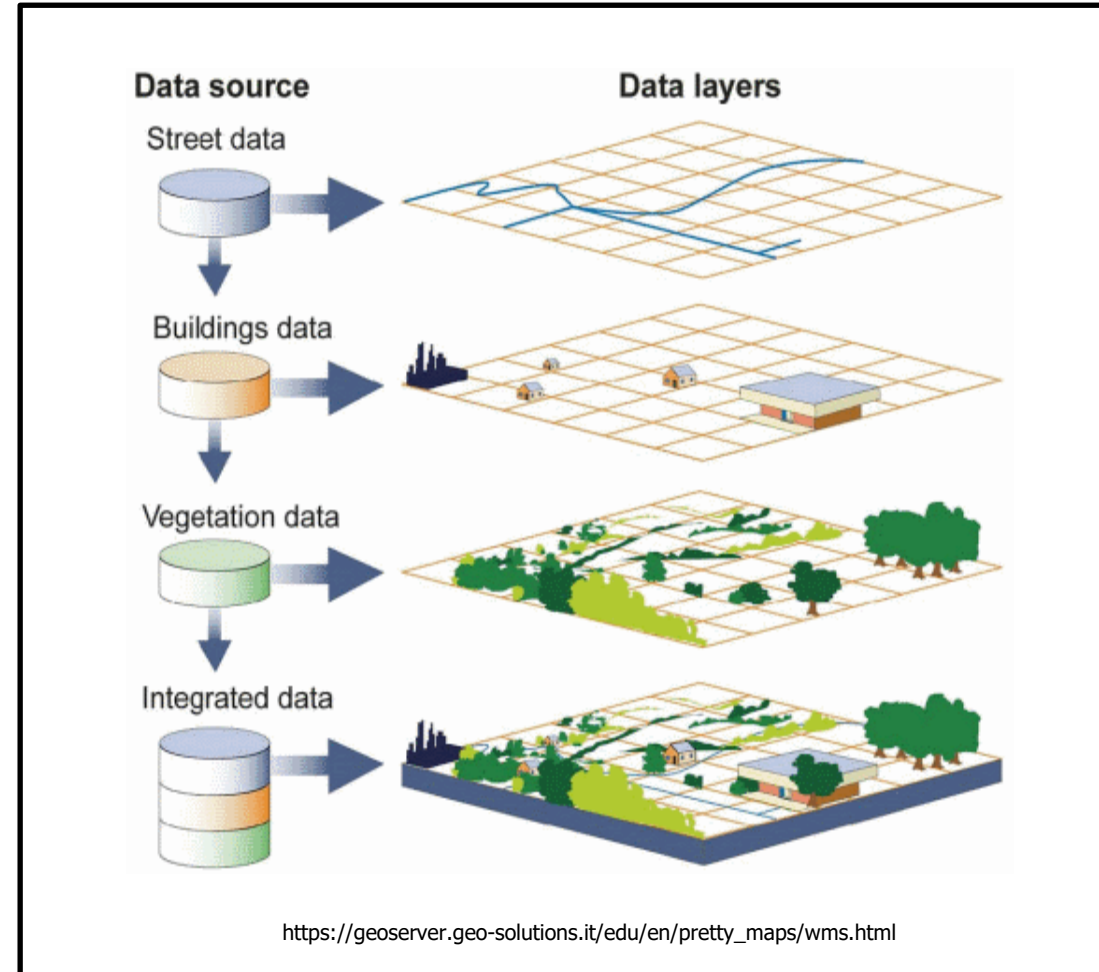
Type of **mental representation** which serves an individual to acquire, code, store, recall, and decode information about the **relative locations and attributes** of phenomena in their everyday or metaphorical spatial environment.

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



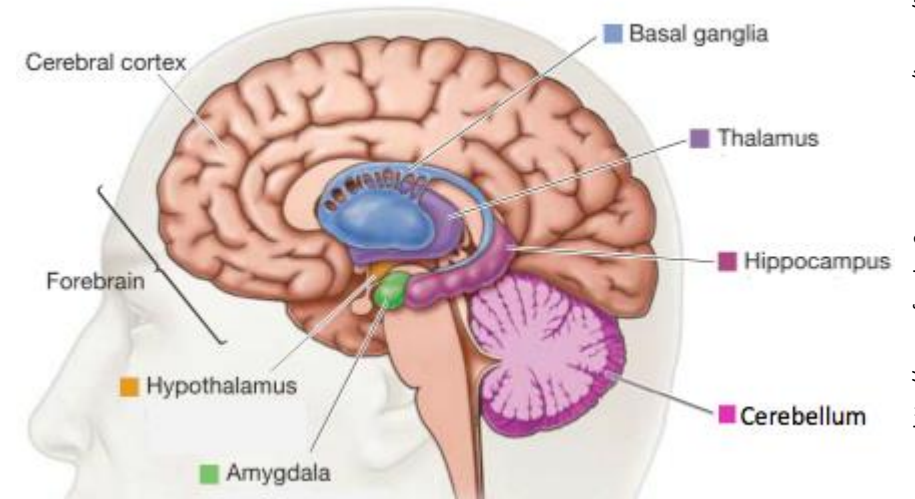
Amygdala

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



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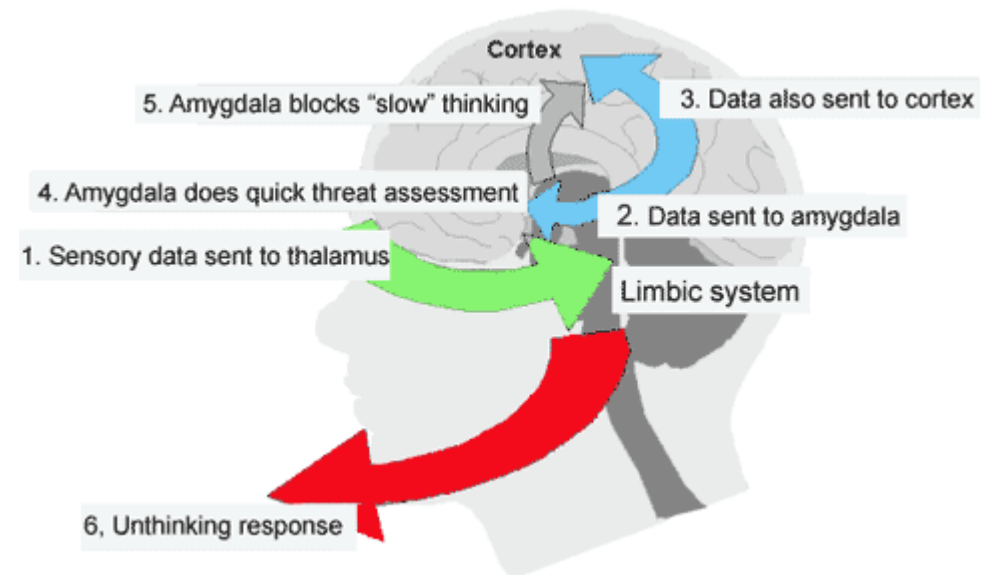
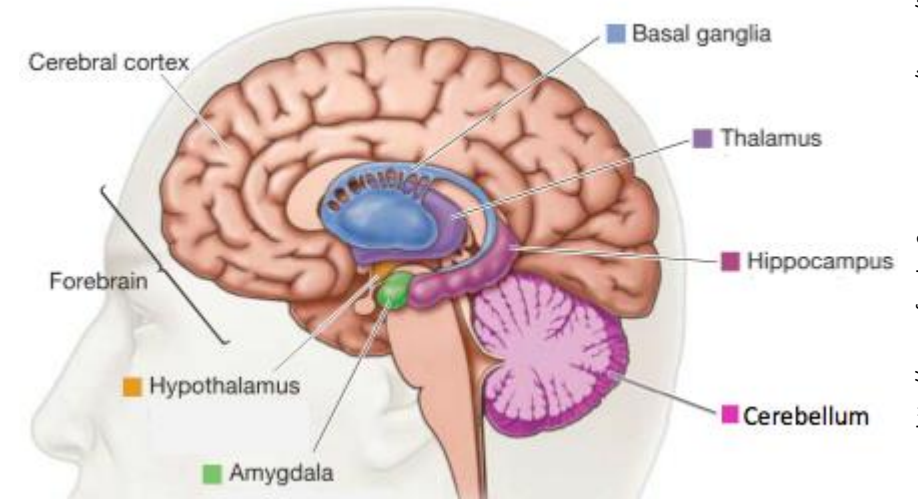
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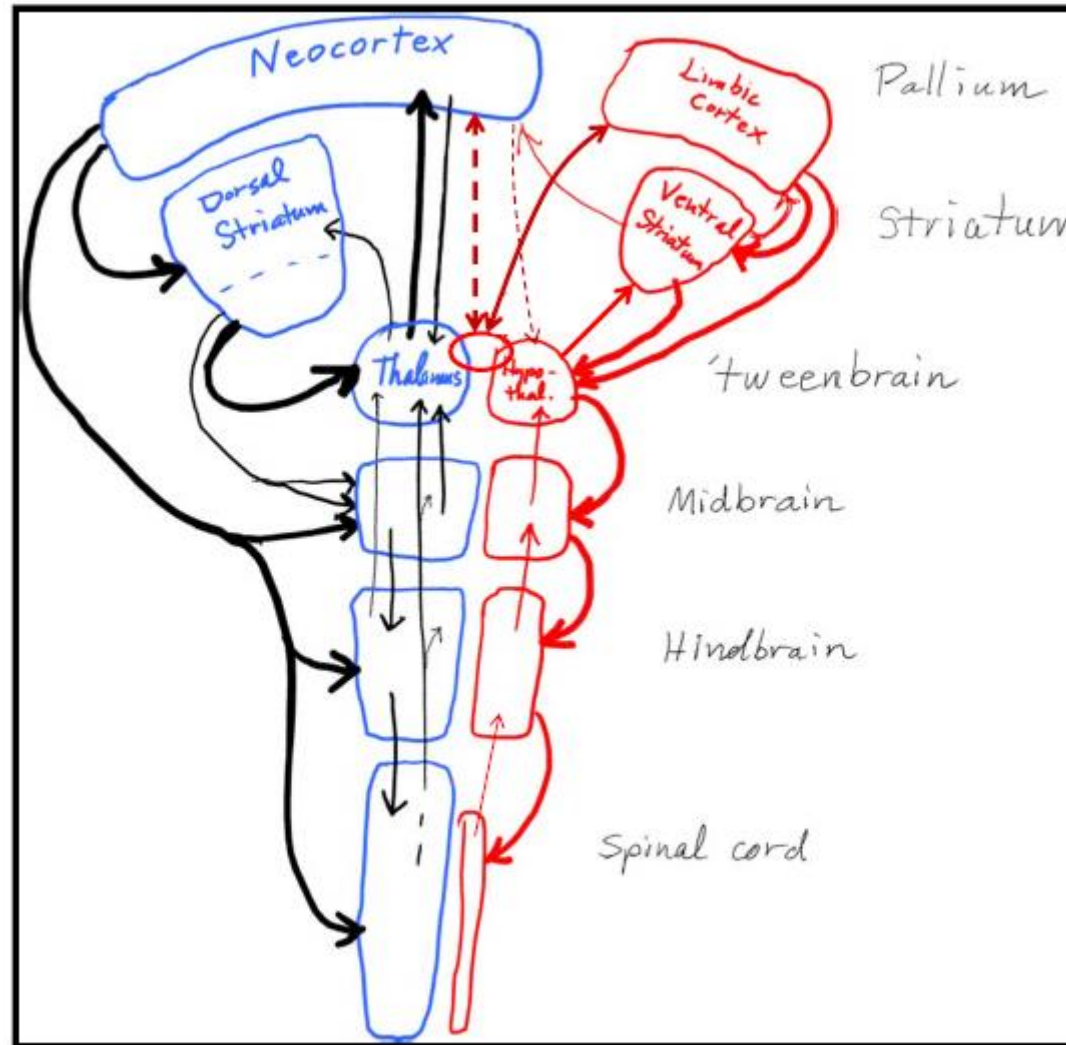
Basolateral: Inputs from thalamus, neocortex, hippocampus; outputs to prefrontal cortex, ventral striatum, other amygdala nuclei

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- 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

M E D