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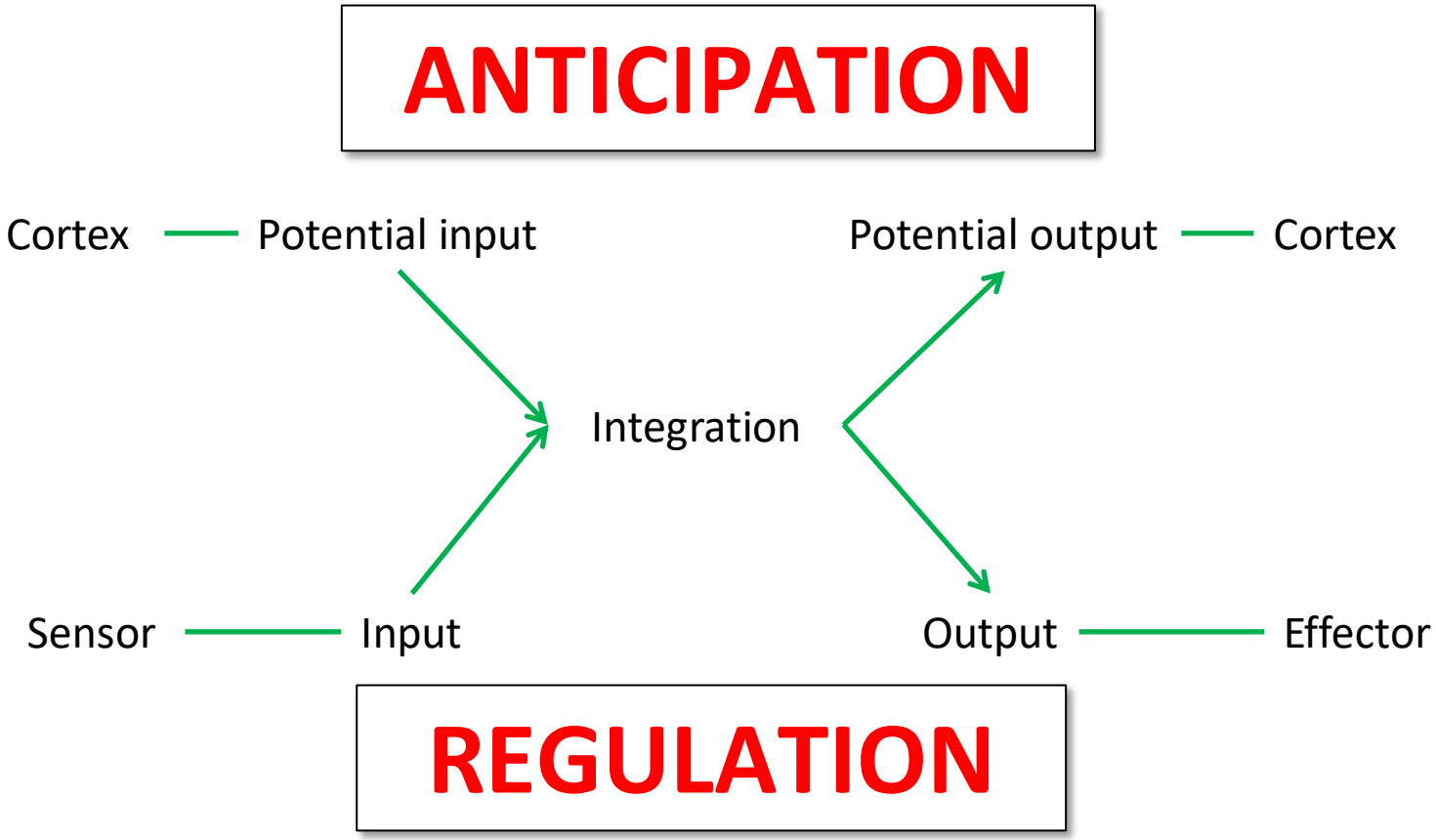
# Limbic system
# Neocortex I

# The role of nervous system



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# Hypothalamus

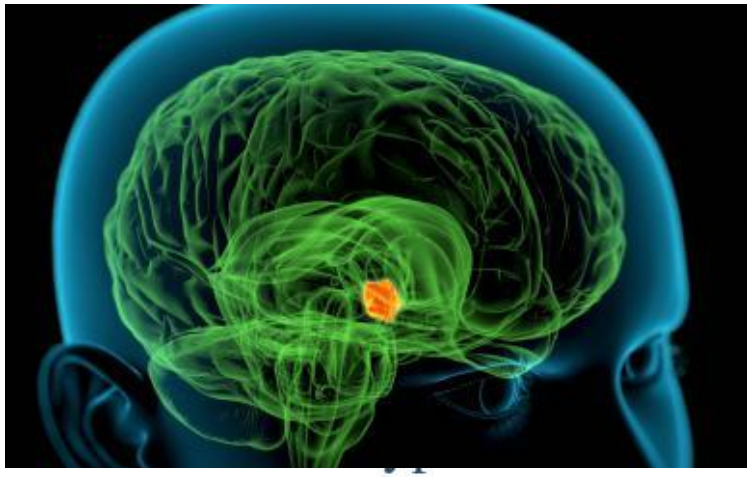
- Key center of autonomic regulations and coordination
- Integration of the information from inner and outer environment

↓

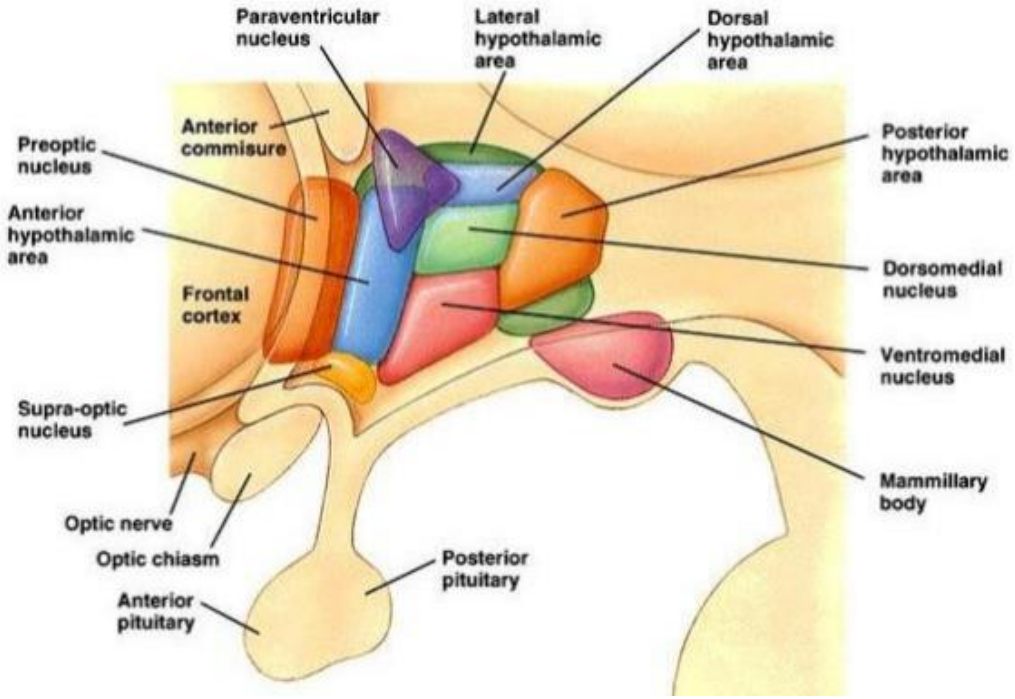
- Behavioral modulation
- Regulation of autonomic nervous system

↓

- **Maintenance of homeostasis**



http://biology.about.com/od/anatomy/p/Hypothalamus.htm




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



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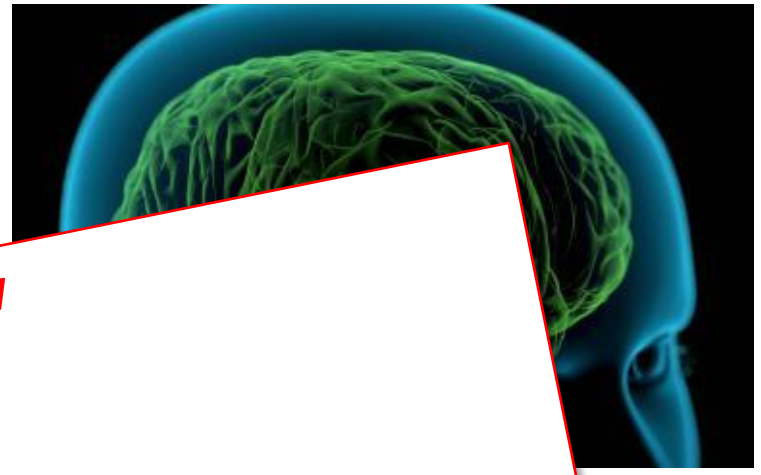
# Hypothalamus

- Key center of autonomic regulations and coordination
- Integration of the inform… from inner… enviro…
- Behavic…
- Regulati… nervous …
- **Maintena…**



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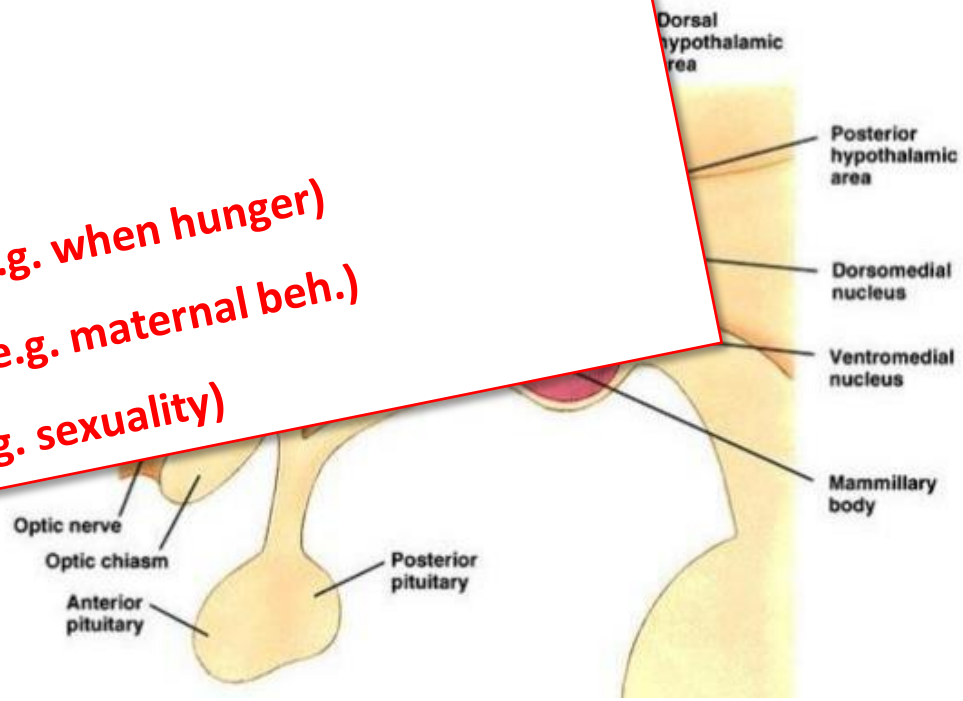
- ✓Biological clock – circadian /seasonal activity
- ✓Autonomic nervous system regulation
- ✓Endocrine system regulation
- ✓Food and water intake regulation
- ✓Regulation of body temperature
- ✓„Immediate“ behavior regulation (e.g. when hunger)
- ✓ „Long-term“ behavior regulation (e.g. maternal beh.)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

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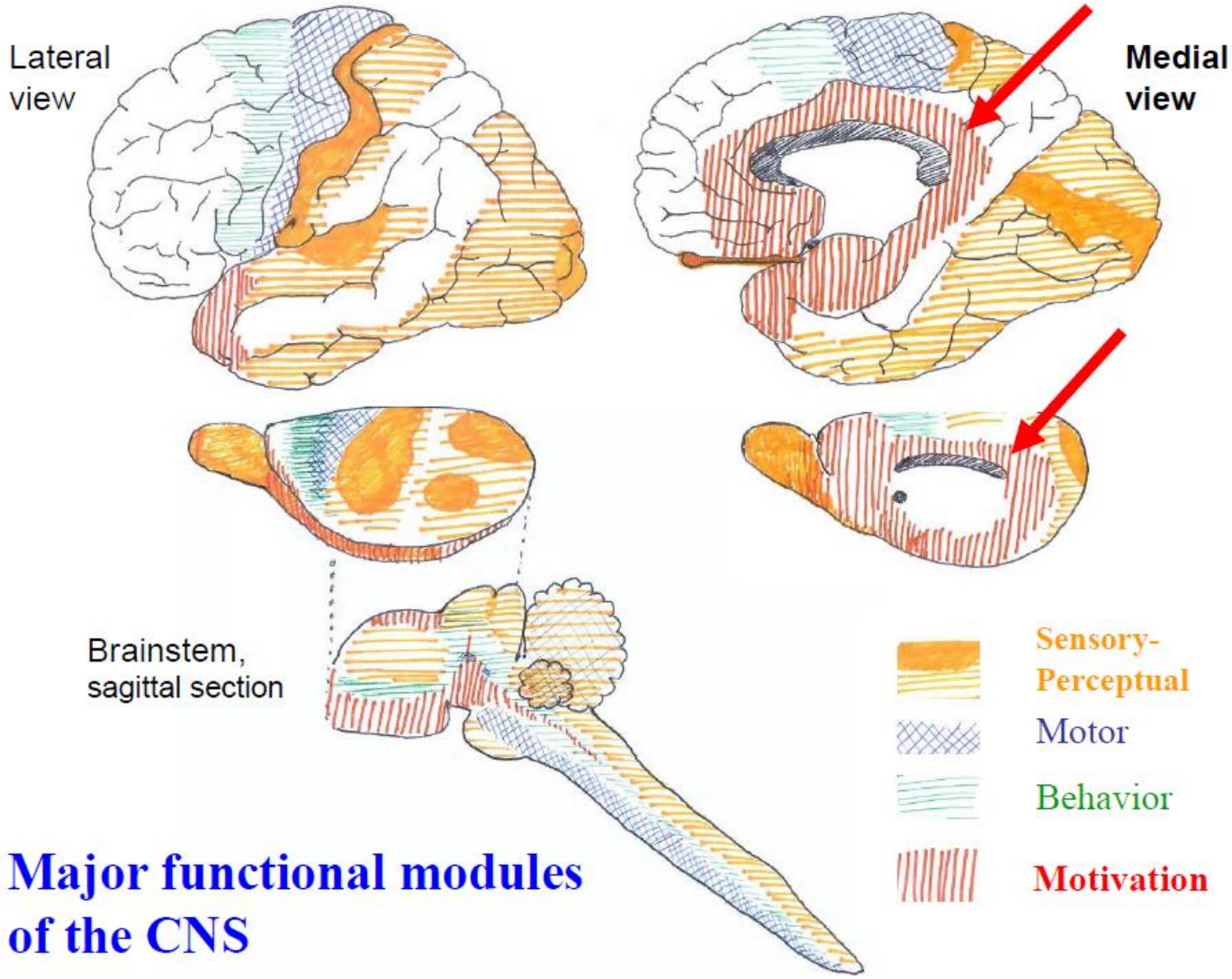
# Limbic system

**Limbus = border**






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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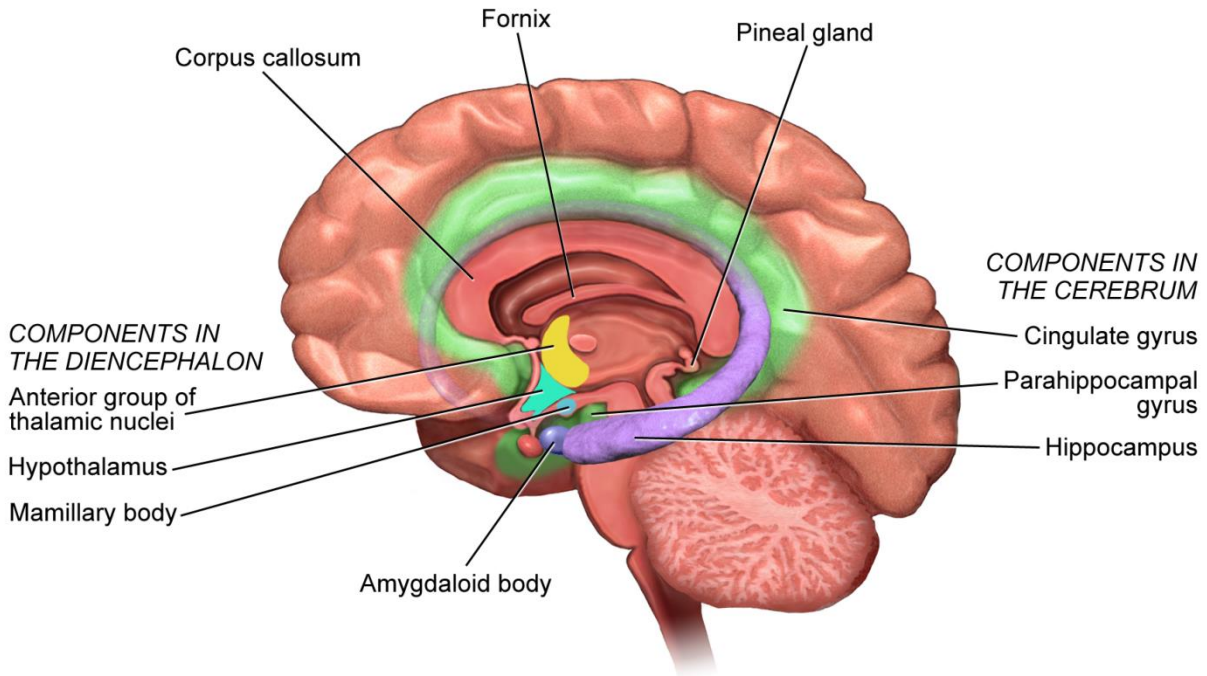
# Concept of the limbic system

- Voluntary

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

- Automatic

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




https://upload.wikimedia.org/wikipedia/commons/d/d1/Blausen_0614_LimbicSystem.png



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# Concept of the limbic system

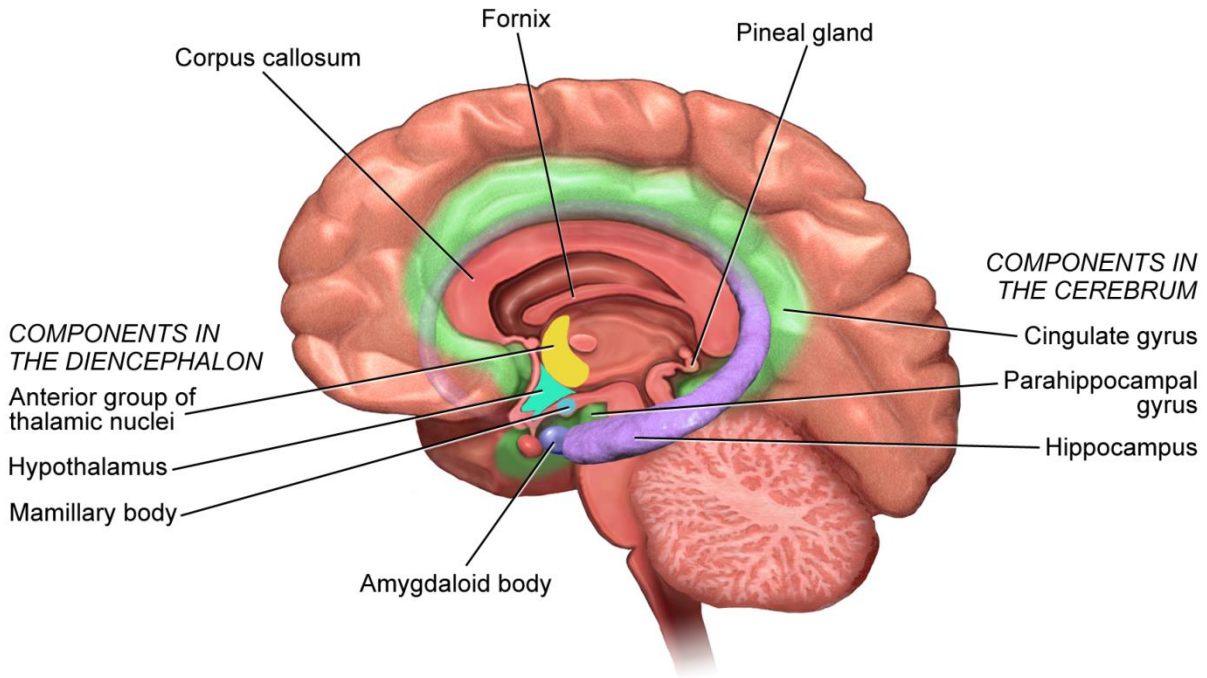
- Voluntary

↑

Potencial conflict

↓

- Automatic

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# Concept of the limbic system

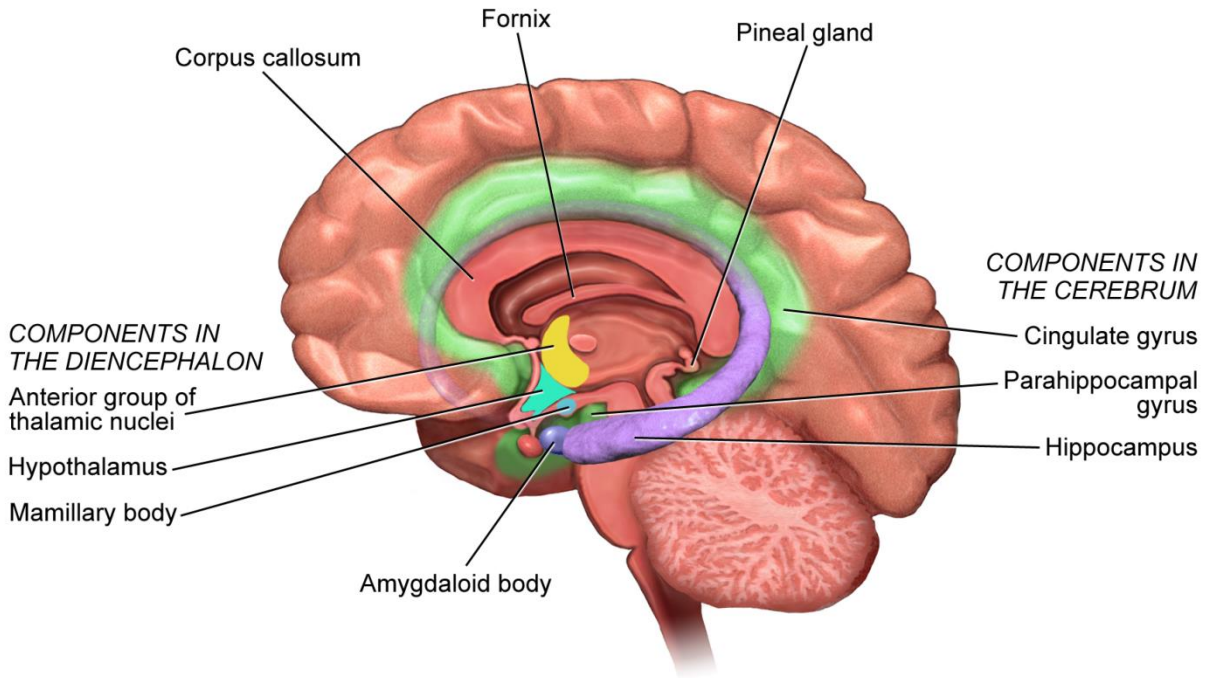
- Voluntary

Modulation

**Limbic system**

Control

- Automatic

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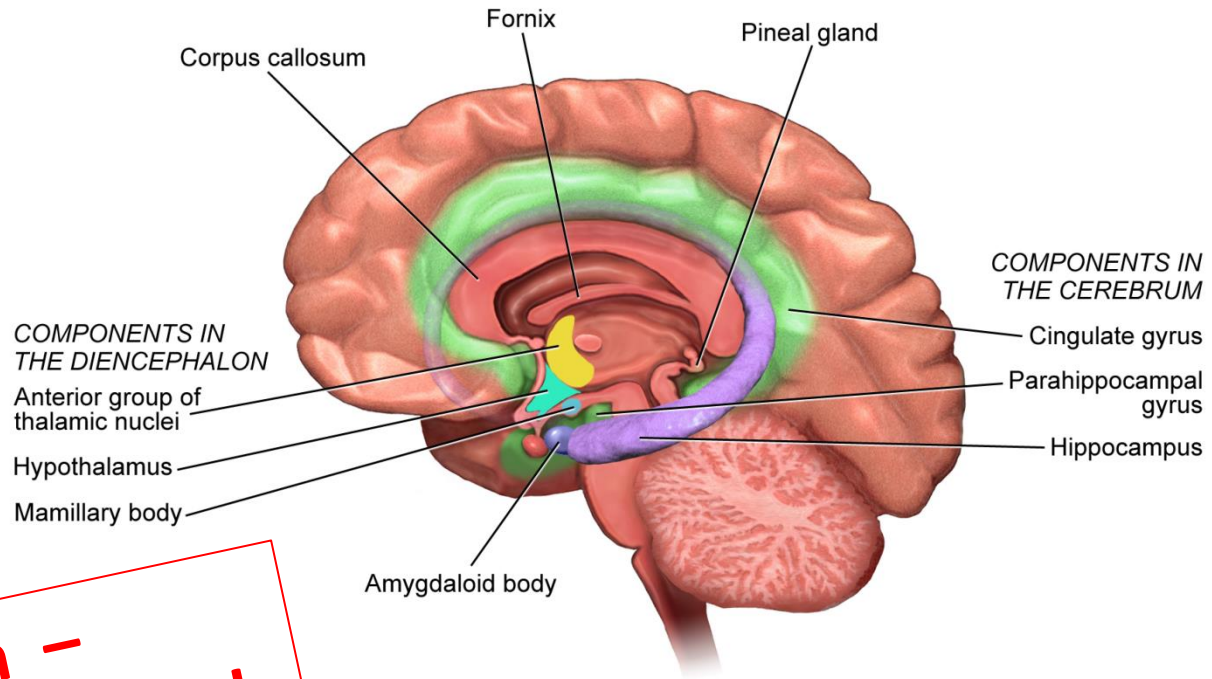
- Voluntary

↑ Modulation

**Limbic system**

↓ Control

- Automatic




**Limbic system – hypothalamus and related structures**

https://upload.wikimedia.org/wikipedia/commons/d/d1/Blausen_0614_LimbicSystem.png



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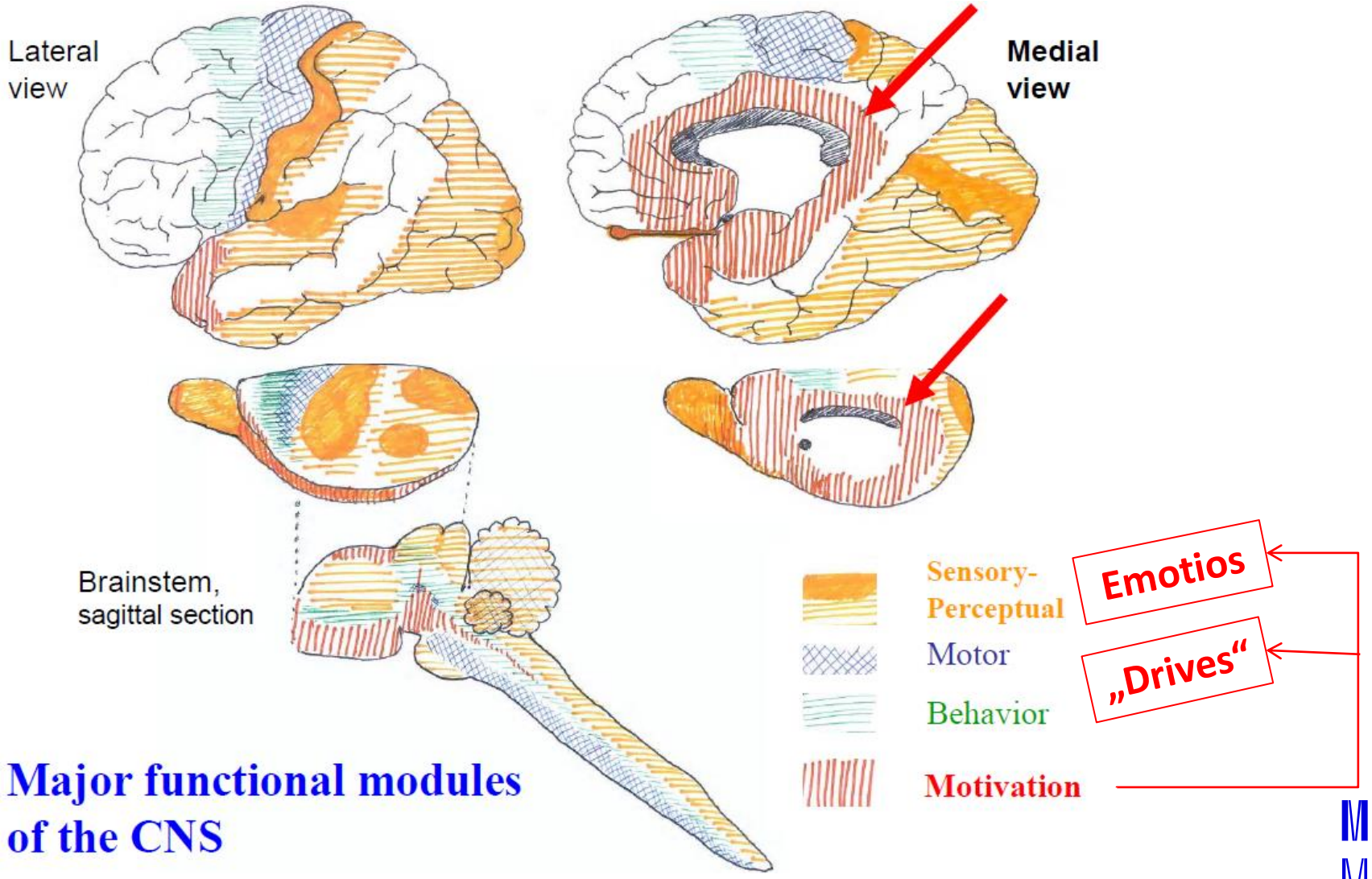
# Limbic system

**Limbus = border**




**Major functional modules of the CNS**



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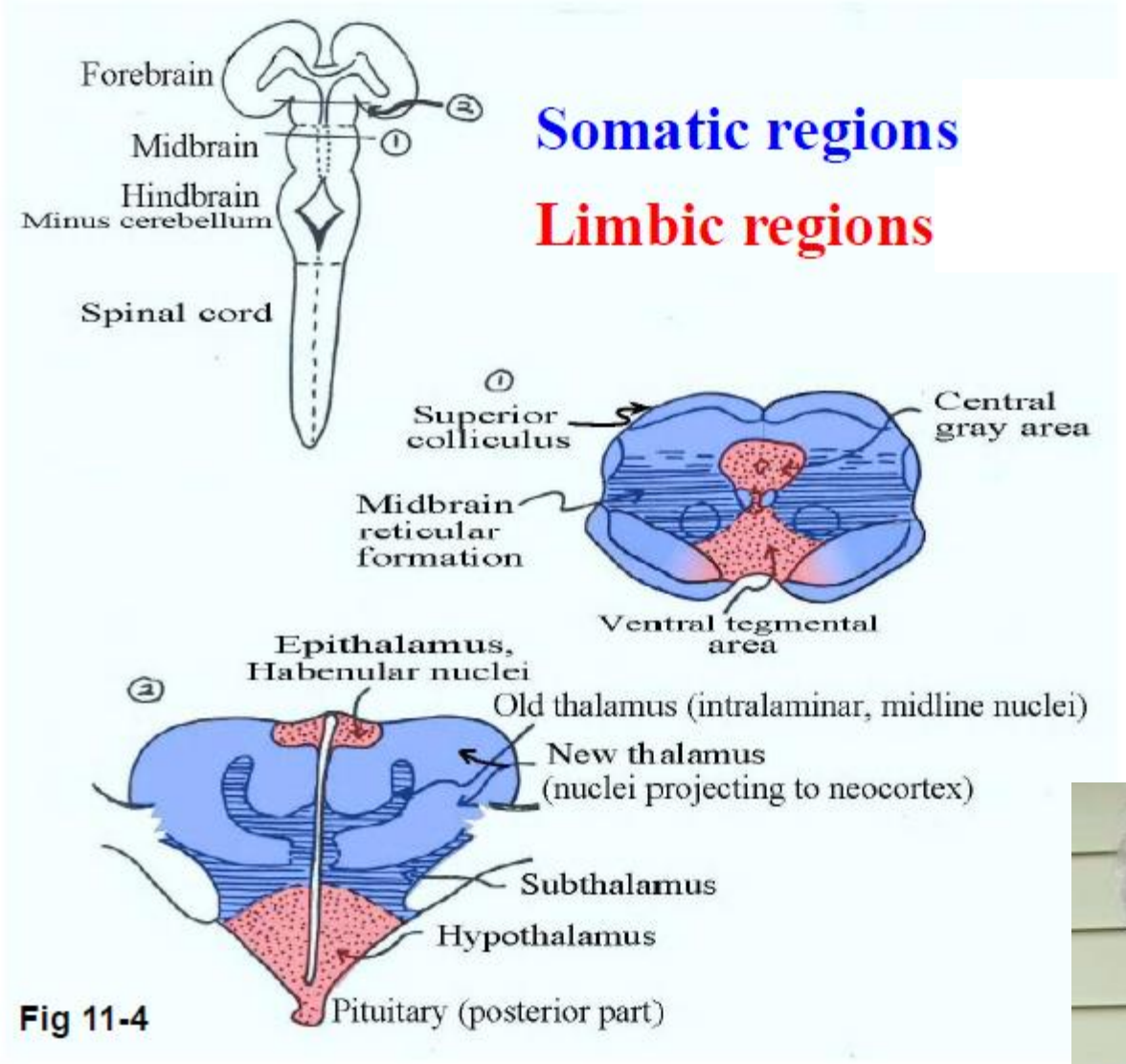


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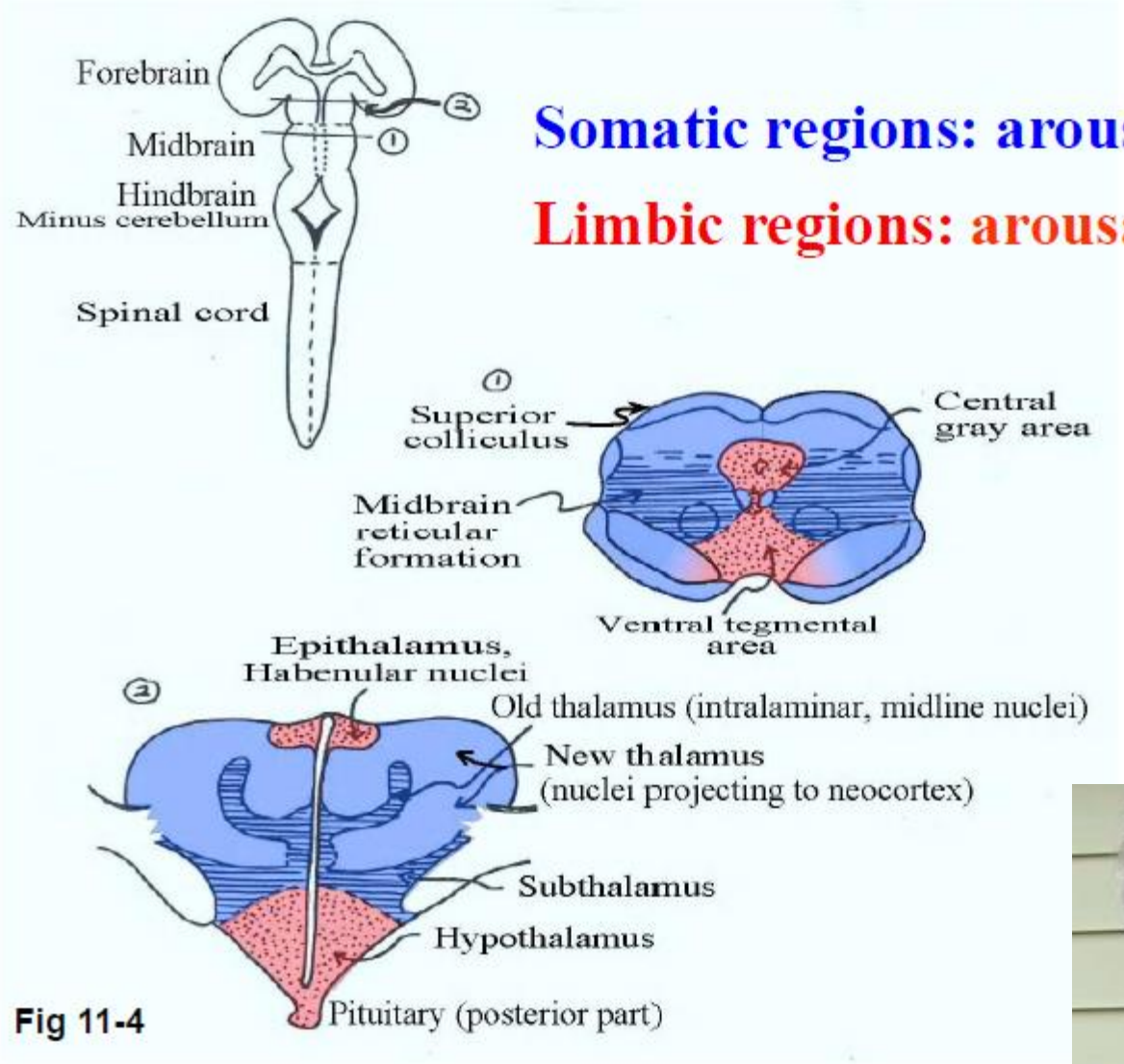


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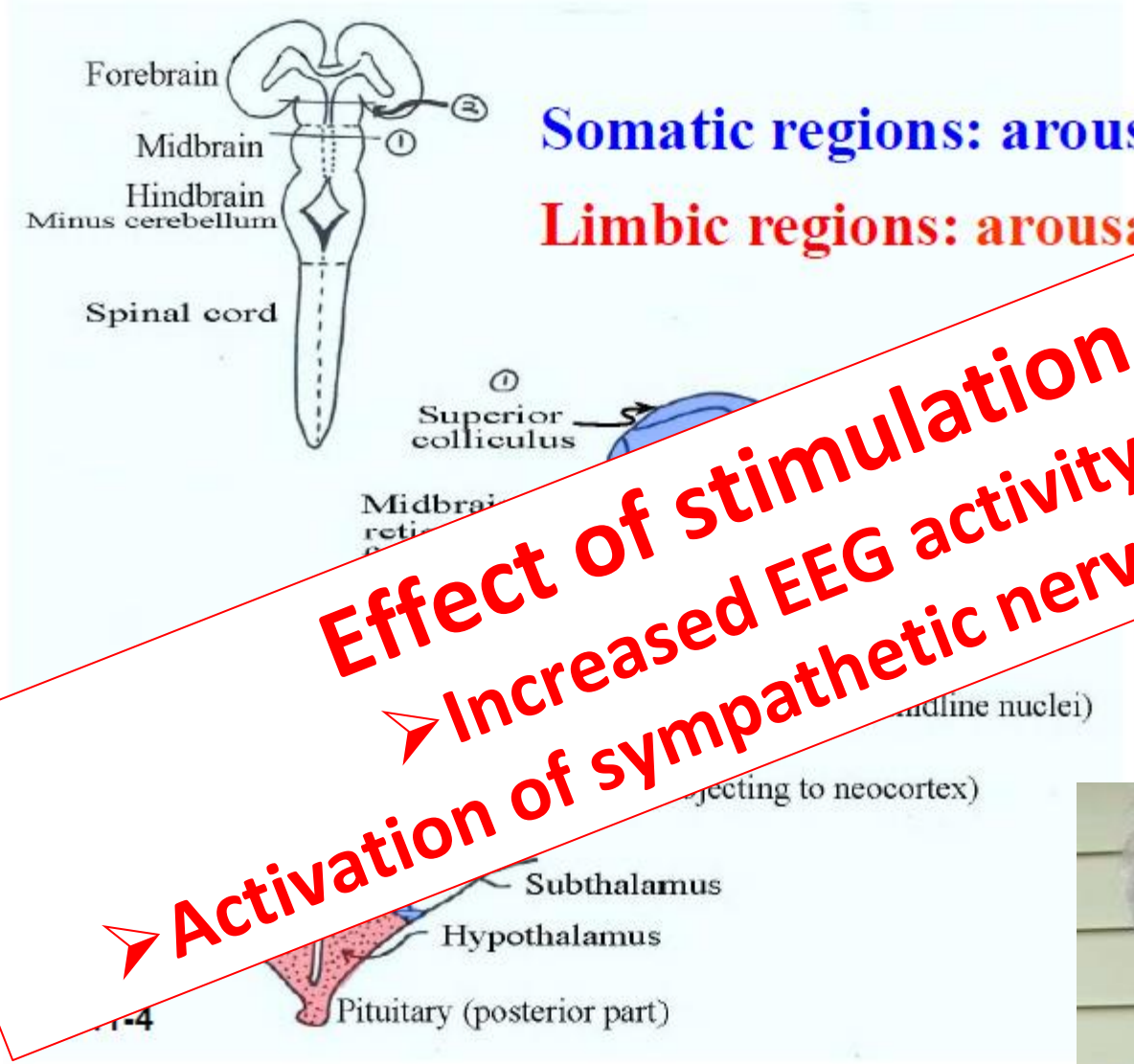


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# Arousal type 1 (somatic)

**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



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# 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

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# Arousal type 1 (somatic)

**ARAS (ascendent retikulation activati**

- Eff

**Effect of stimulation**

➢**Increased EEG activity**

➢**Activation of sympathetic nervous system**

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

ystem

trong activation of

„reward/ punishin

vity, pain

- nections
  - Neocortex, corpus striatum, thalamus
- Descendent connections
  - Hypothalamus and other limbic areas, amygdala



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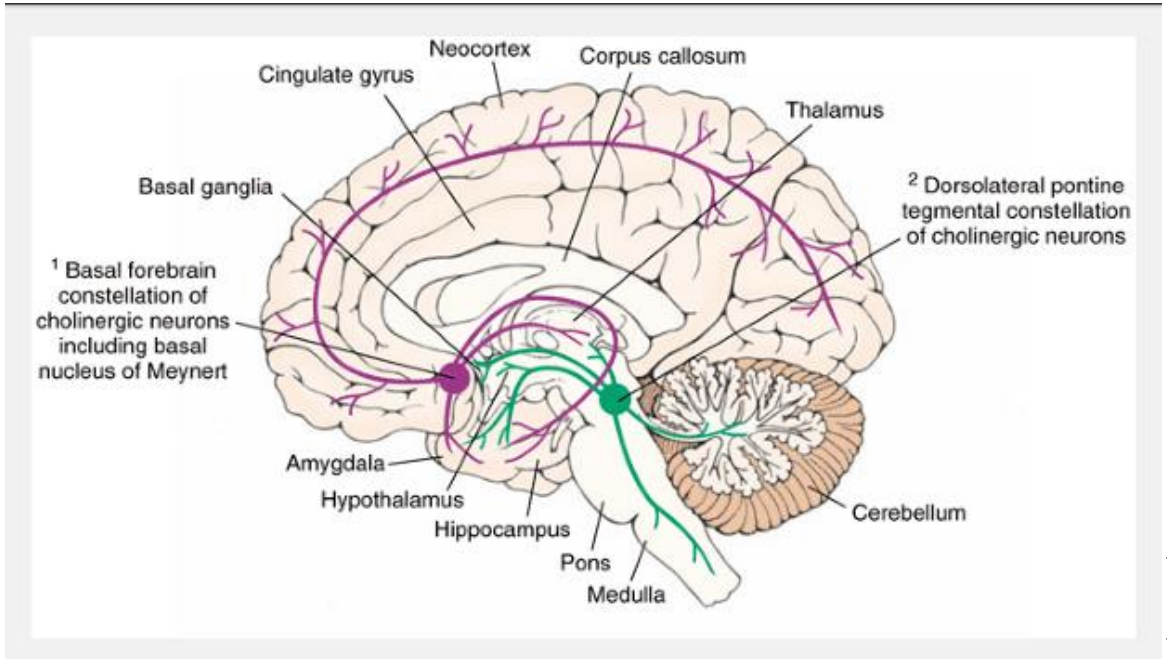
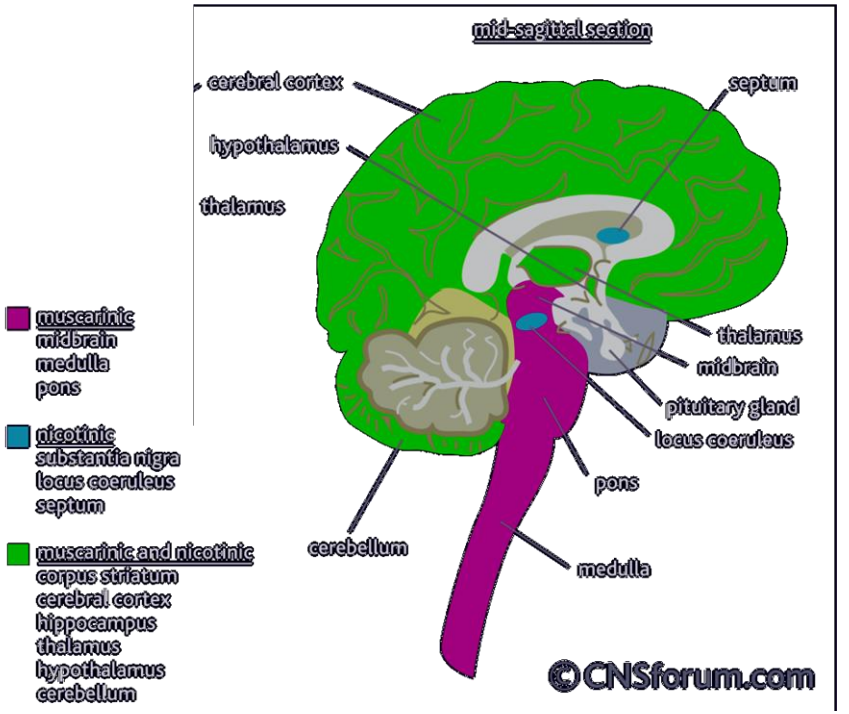
# Acetylcholine

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

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




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



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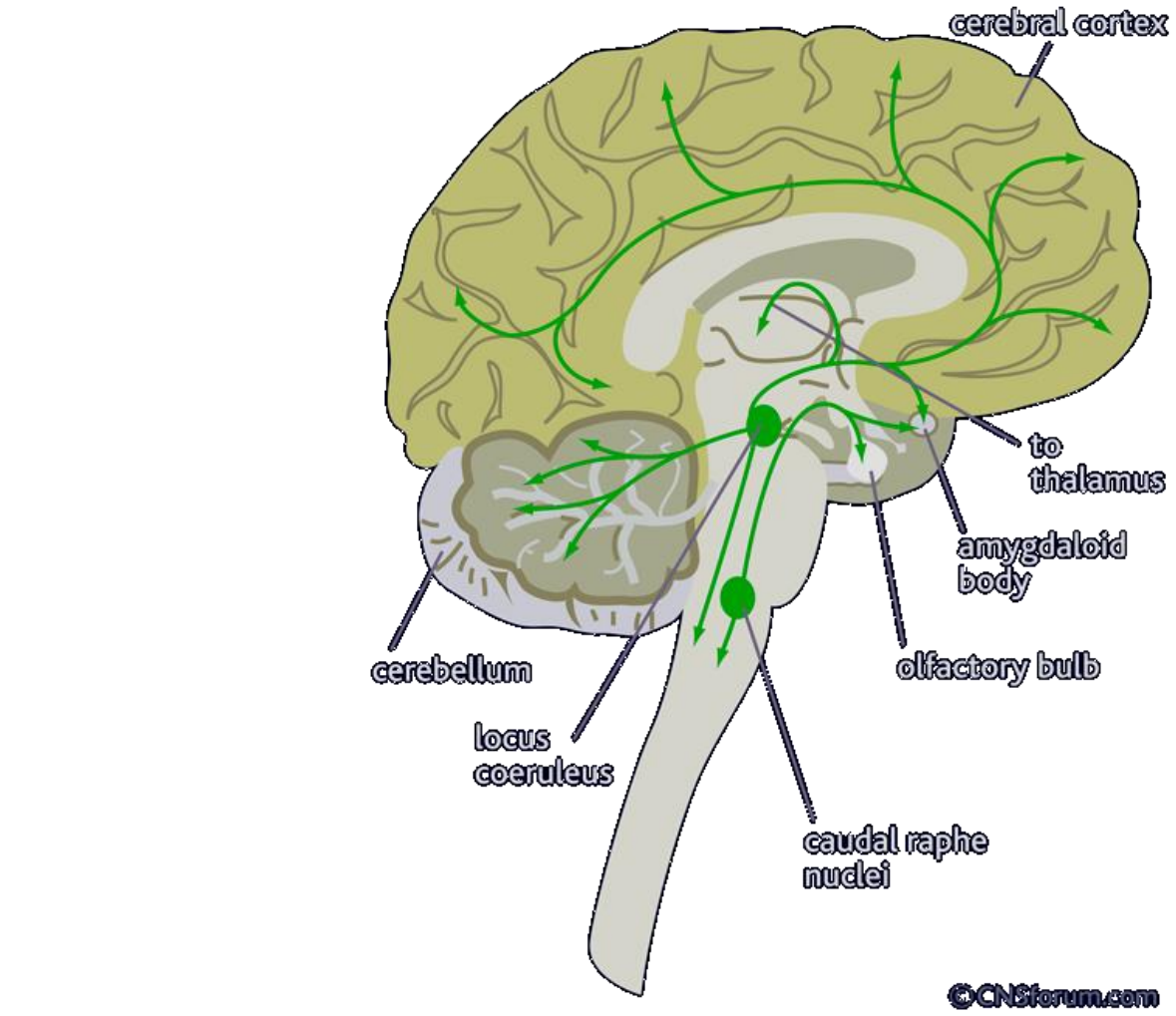
# Norepinefrine

- Locus coeruleus
- Nuclei raphe caudalis

- Vigilance
- Responsiveness to unexpected stimuli
- Memory
- Learning




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



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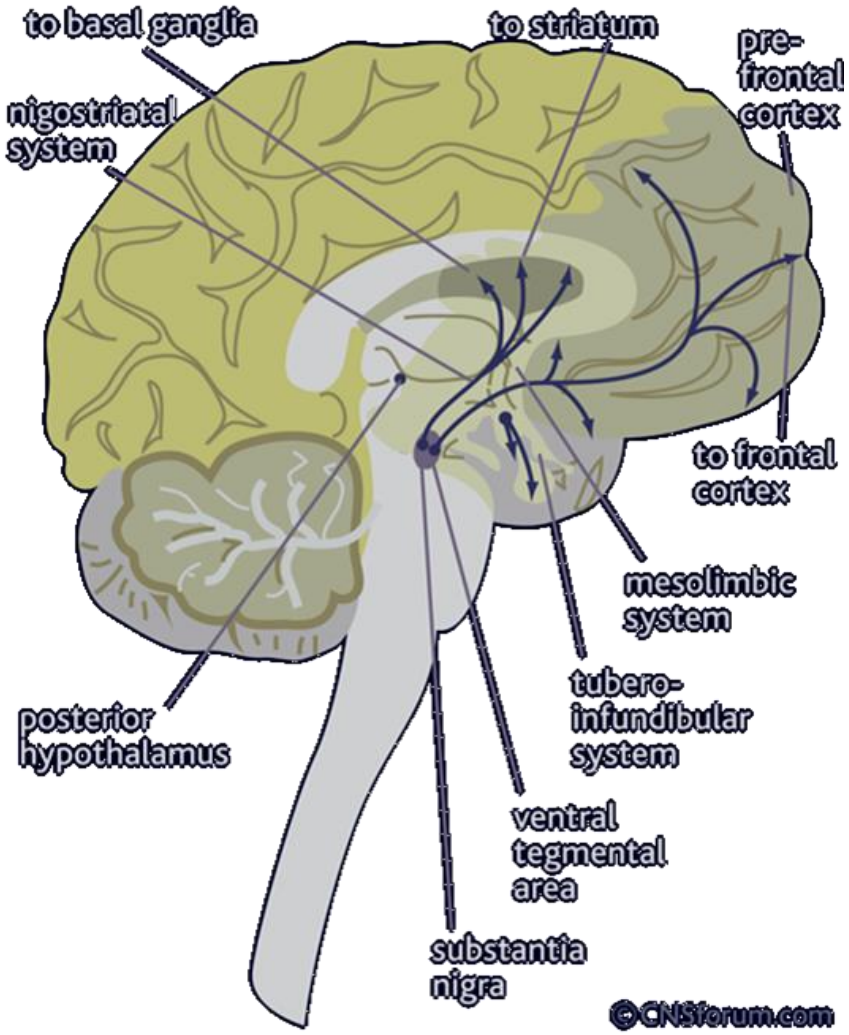
# Dopamine

- Nigrostriatal system
  - Movement
  - Sensory stimuli
- Ventrotegmentno-mesolimbic-frontal system
  - Reward
  - Cognitive function
  - Emotional behavior
- Tubero-infundibular system
  - Hypotalamic-pituatory regulation
- D1 receptors – excitatory
- D2 receptors - inhibitory

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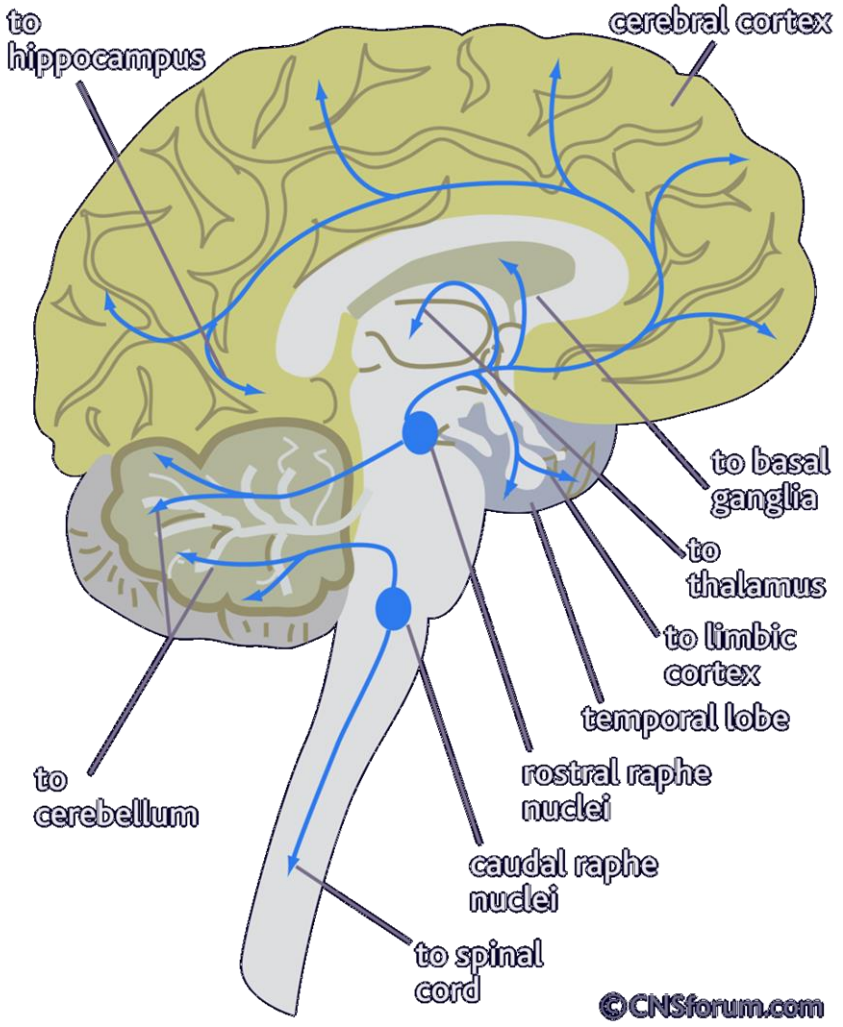
# Serotonin

- Nuclei raphe rostralis
- Nuclei raphe caudalis

- Anxiety/relaxation
- Impulsive behavior
- Sleep

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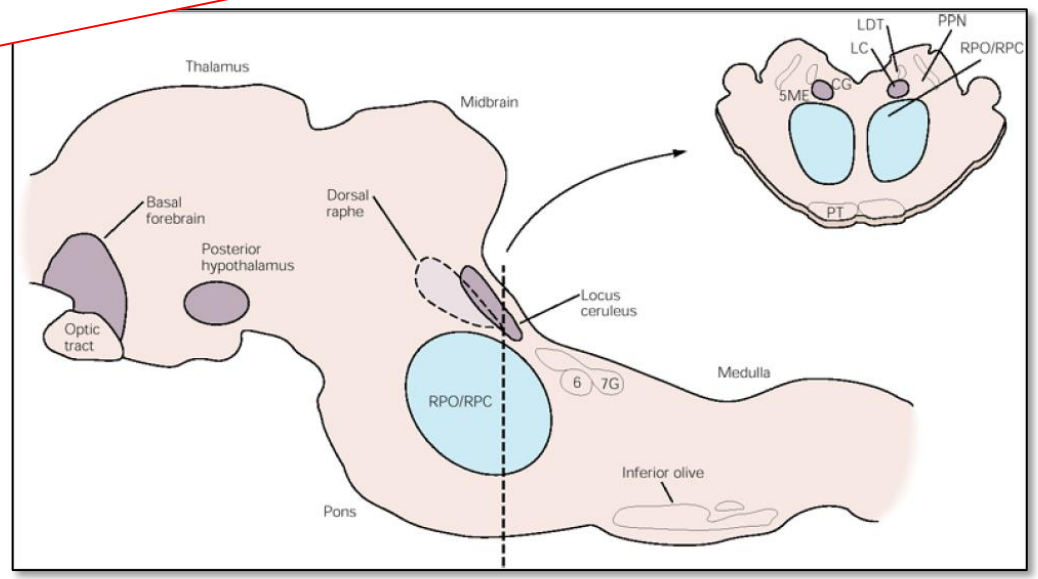
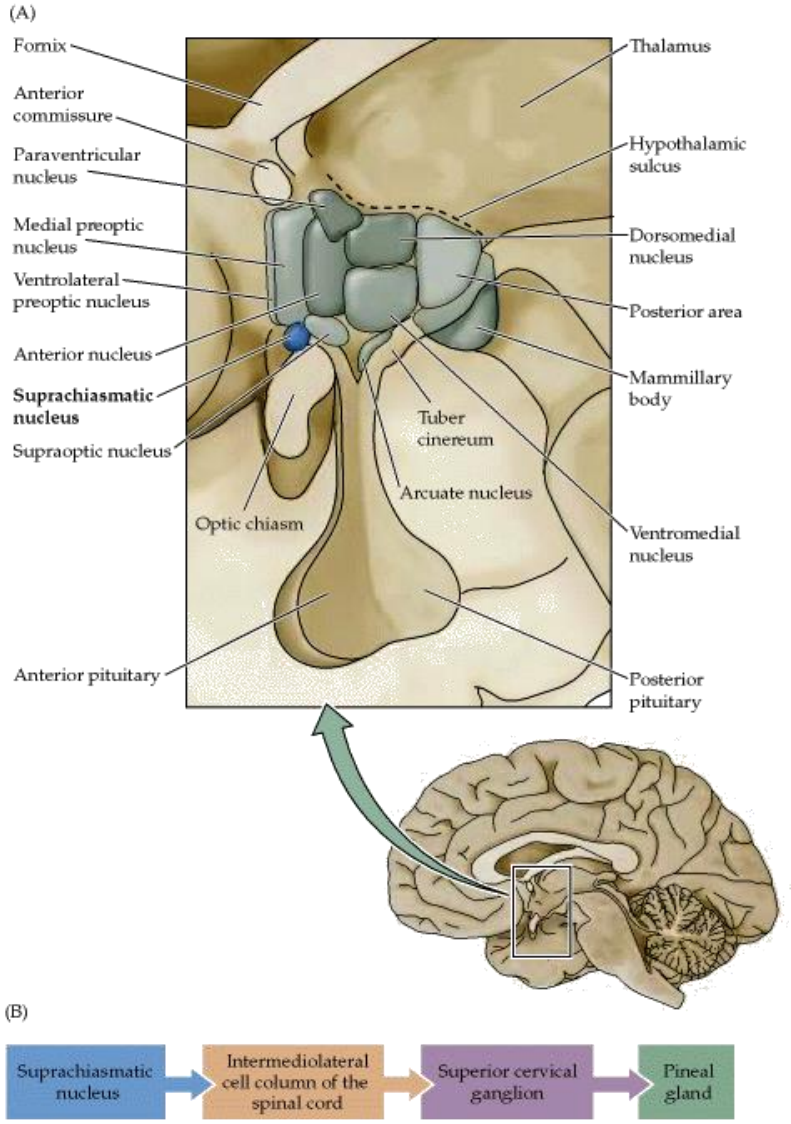
# Sleep and wakefulness

**Cooperation of ARAS and limbic activating system**




RPO/RPC – nucleus reticularis pontis oralis/caudalis



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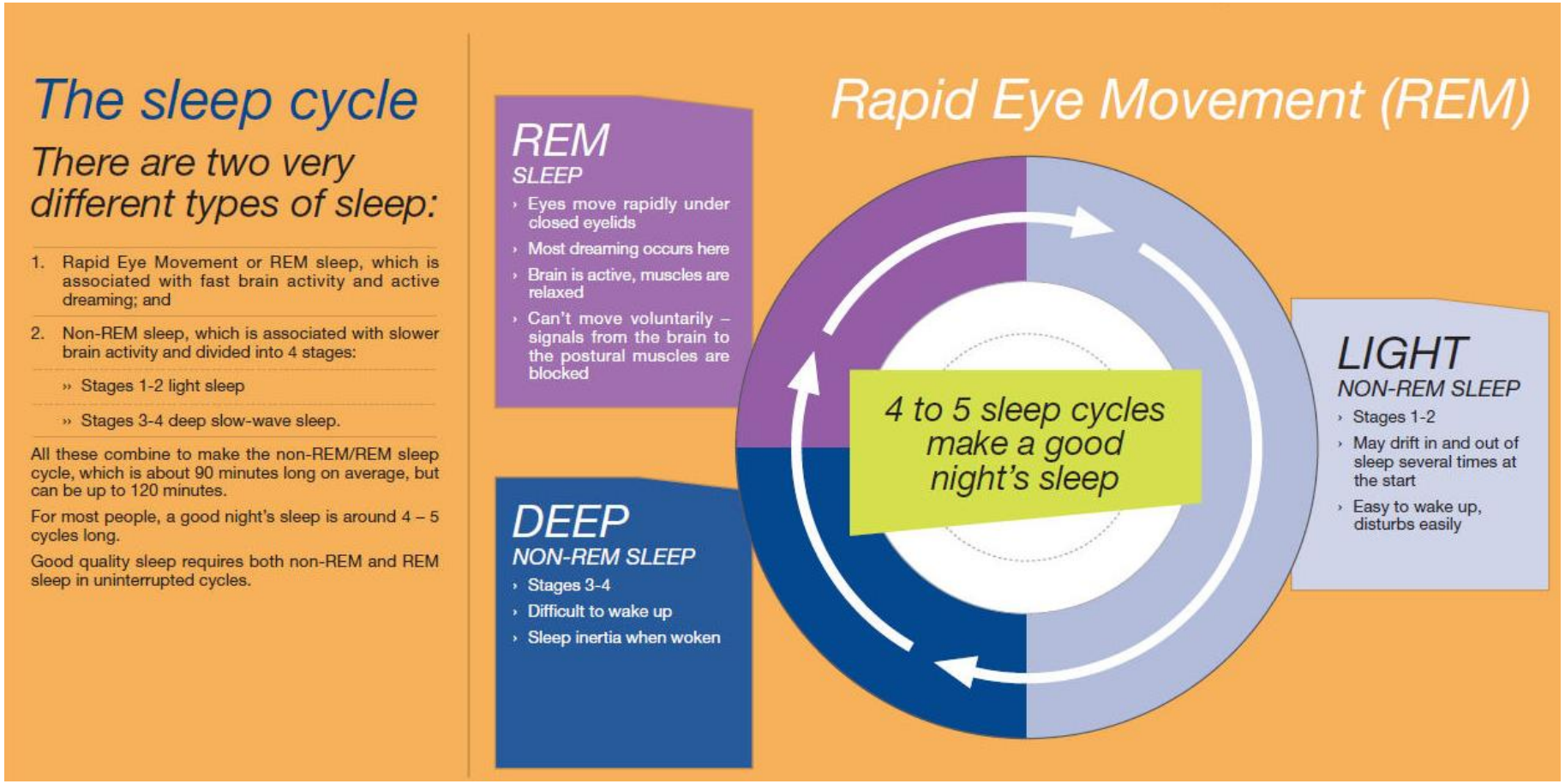
# Sleep

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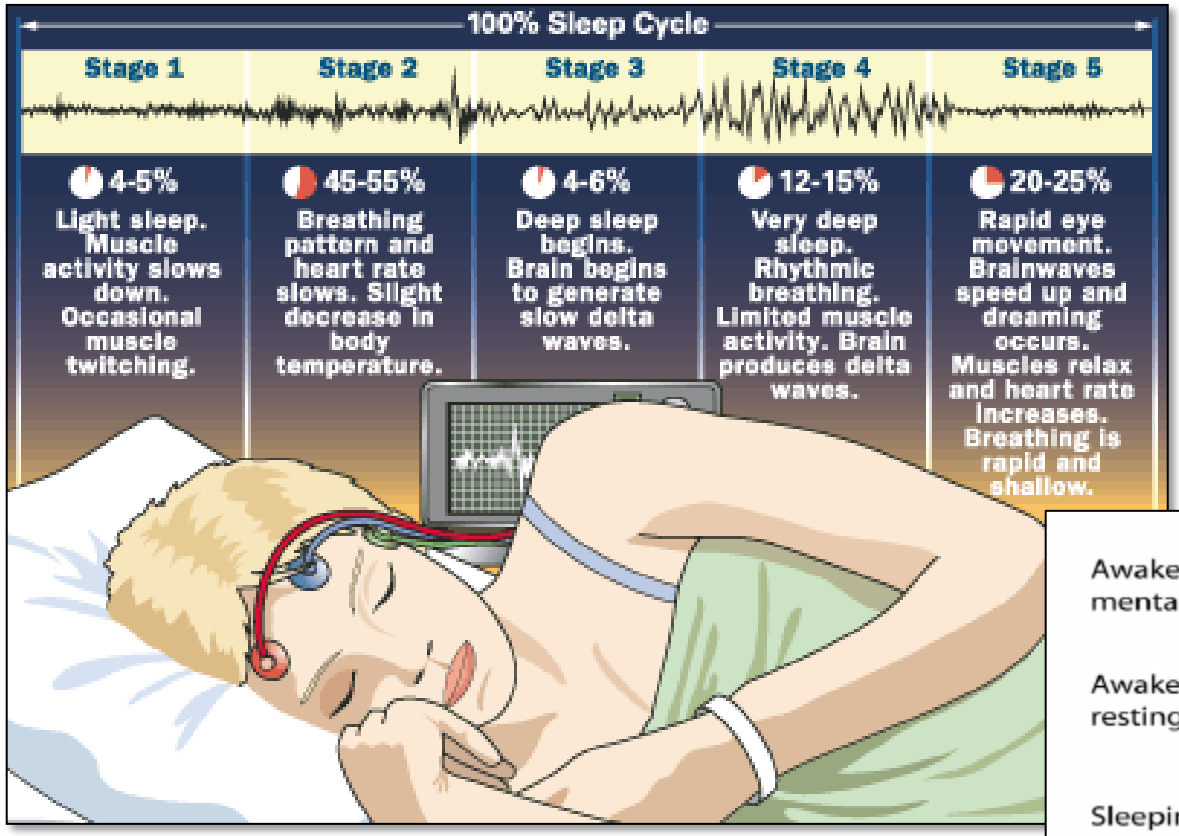
# Sleep

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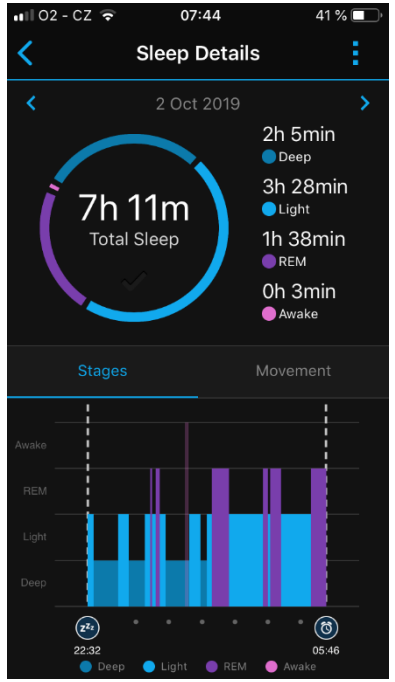
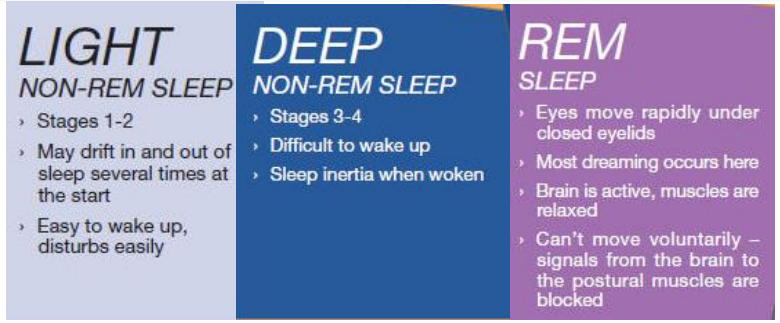
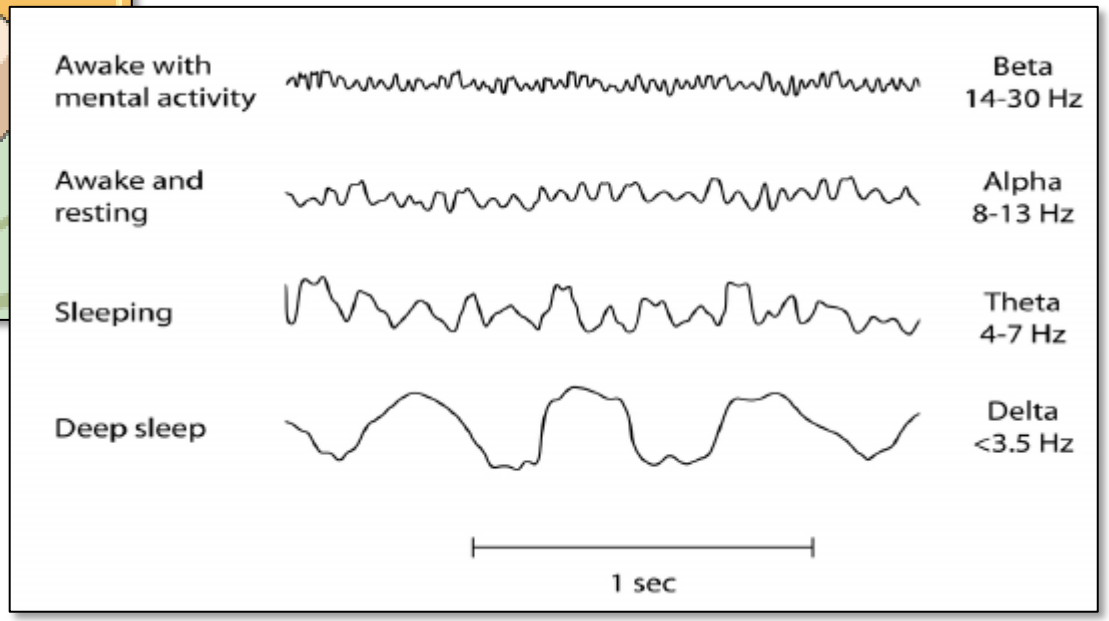



https://connect.garmin.com/modern/


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




https://www.researchgate.net/profile/Priyanka_Abhang3/publication/281801676/figure/fig4/AS:305025248186371@1449735094401/Fig-4-EEG-waves-for-different-signals.png



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# 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 |

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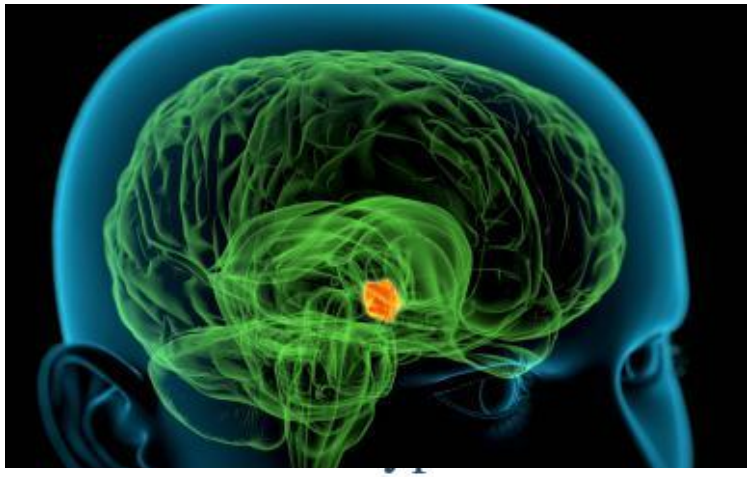

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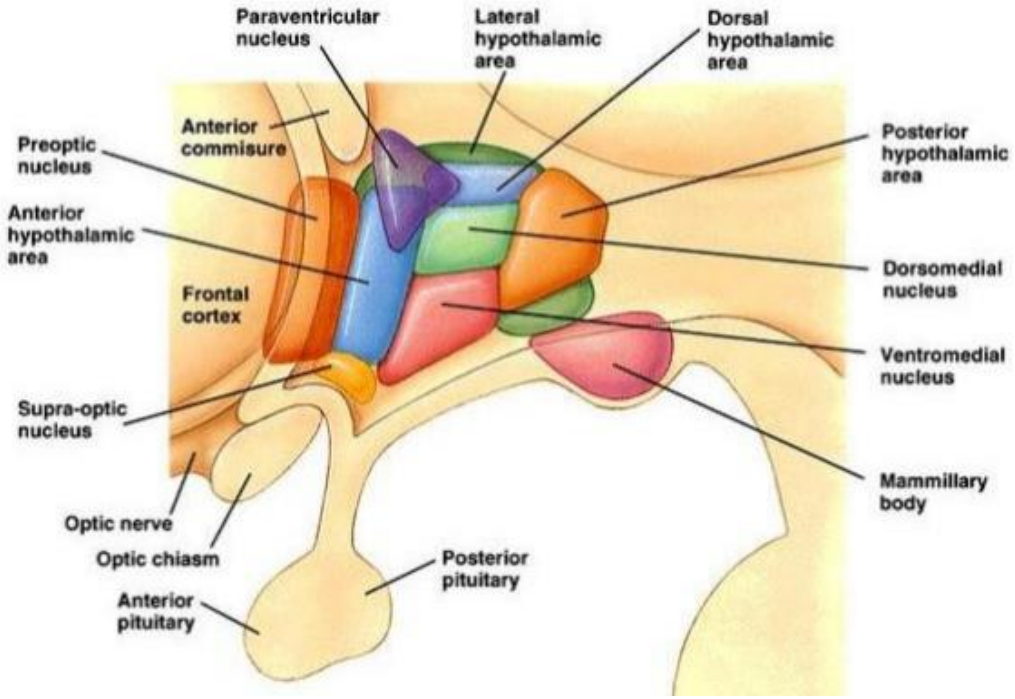


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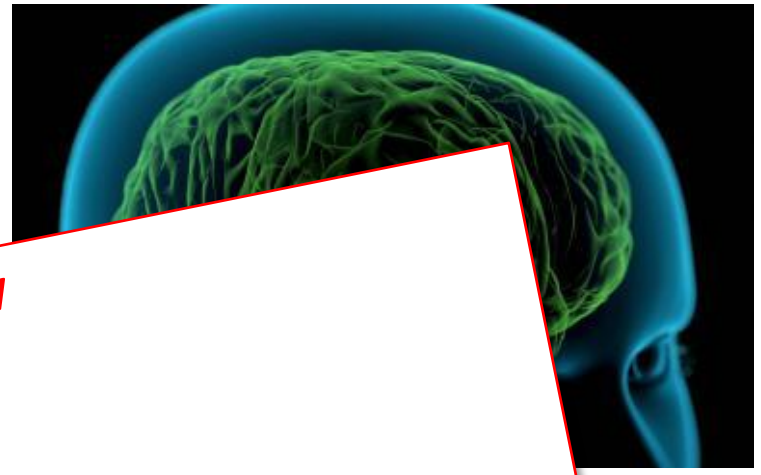

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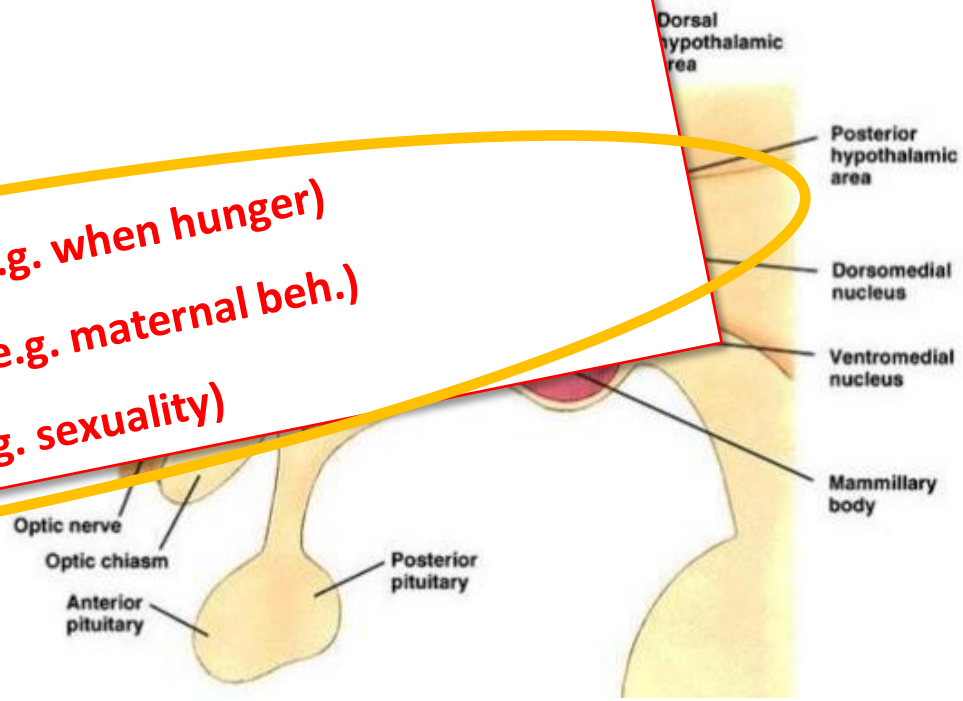


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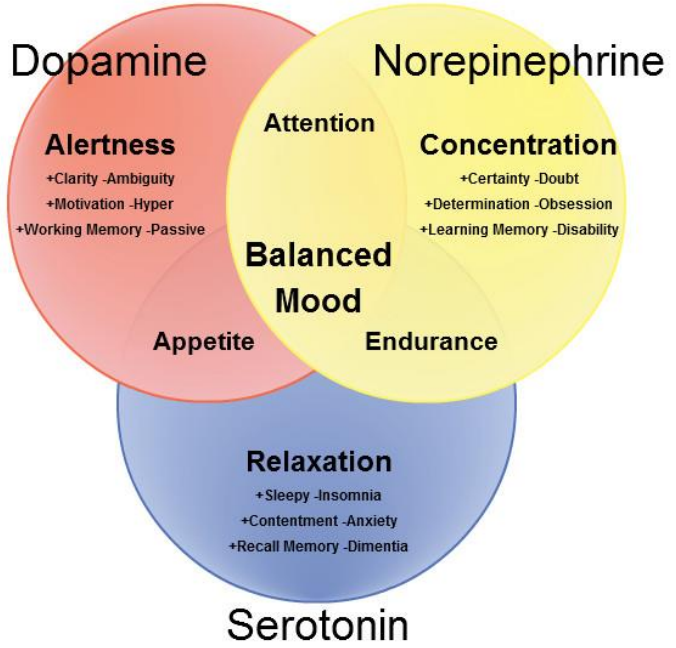
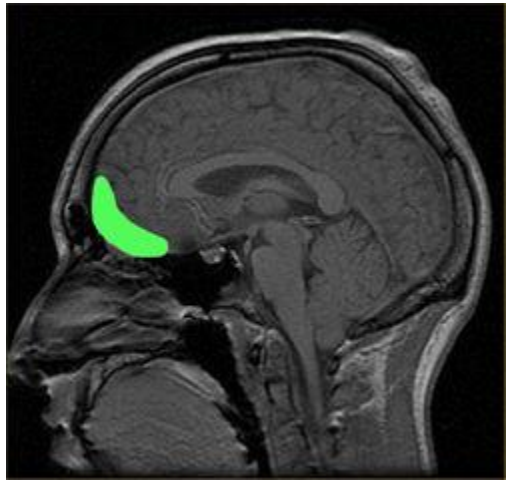
# Influence of hypothalamus on neocortex

- Via neuromodulating systems
  - Consciuosness (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



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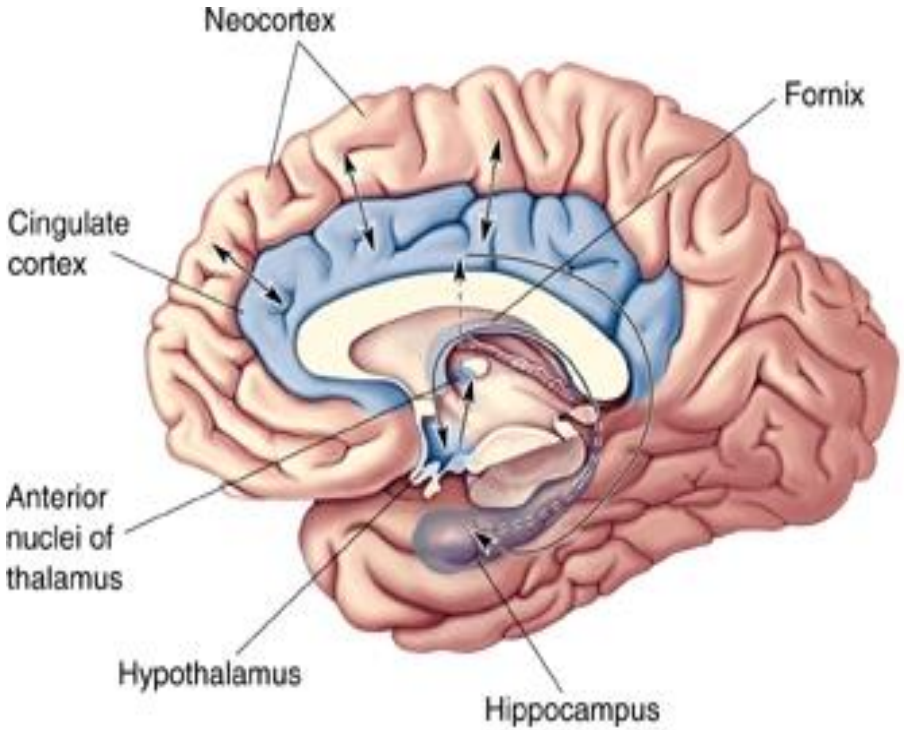
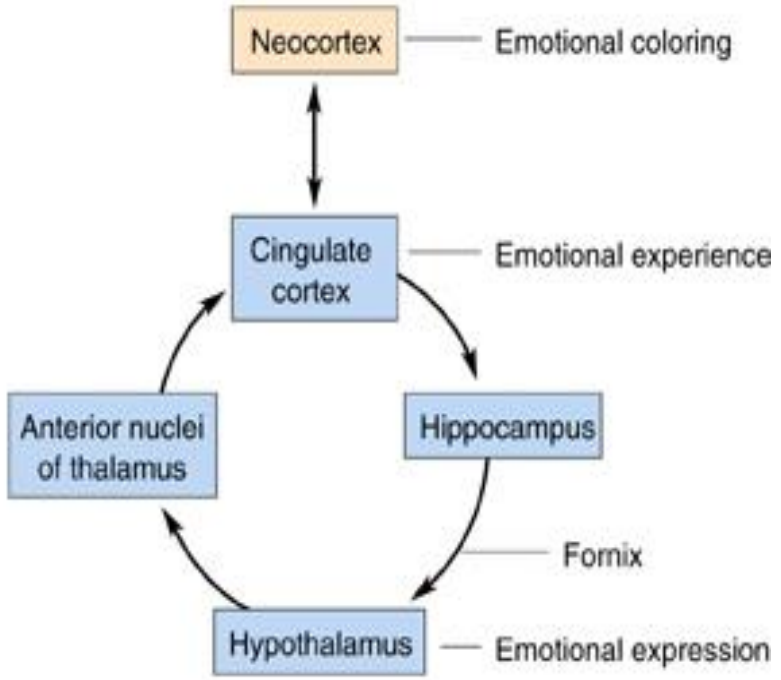
# Papez circuit

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# Papez circuit

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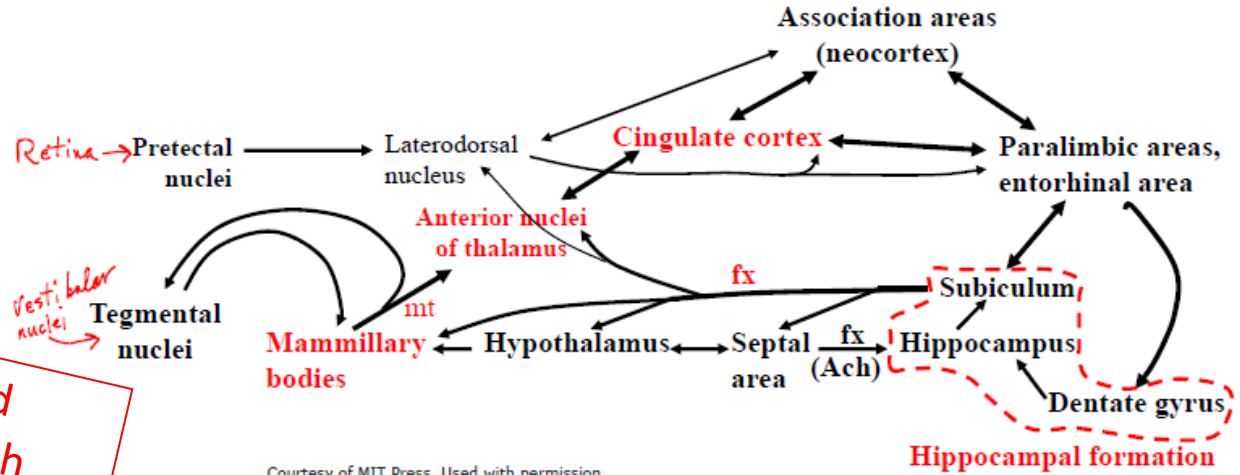
Prof. Gerald Schneider

- ***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

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Spatial orientation and emotions associated with particular place



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# Papez circuit

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Prof. Gerald Schneider

- 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**
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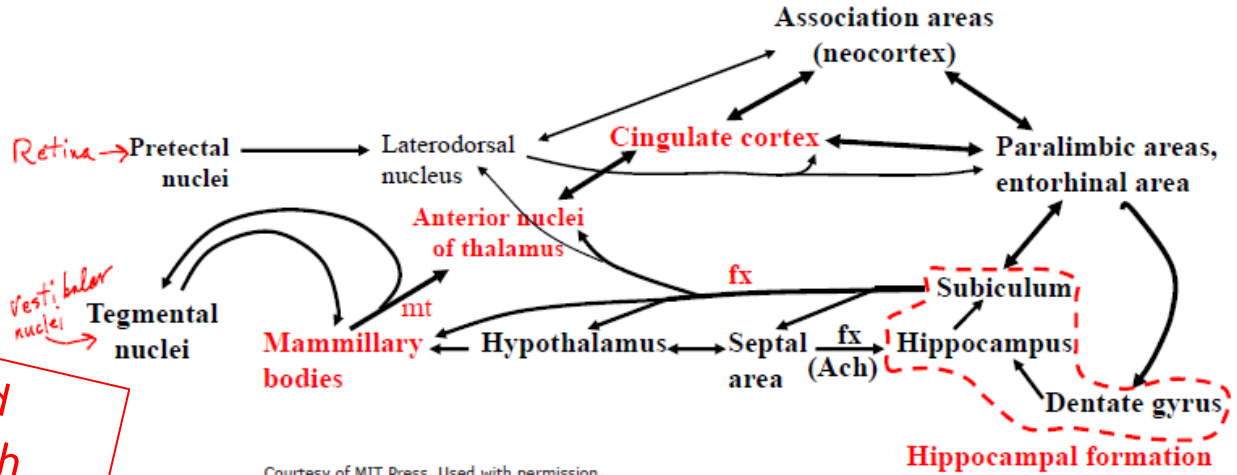
**mt** = mammillothalamic tract
**fx** = fornix bundle

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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.

Spatial orientation and emotions associated with particular place



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# Papez circuit

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Object oriented...

Location oriented...

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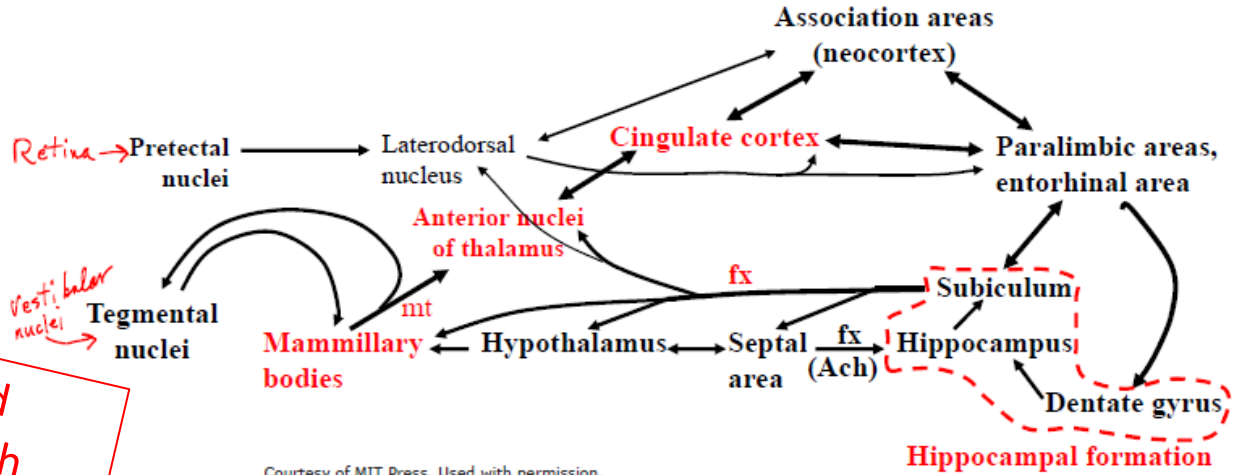


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# Learning and memory

- 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**
– „Hard disk“



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- Declarative memory (explicit)
  - Based on hippocampus
  - Explicit information is stored and later recollected
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  - „Construction of the maps (relationships)“ – spatial or abstract

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

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

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

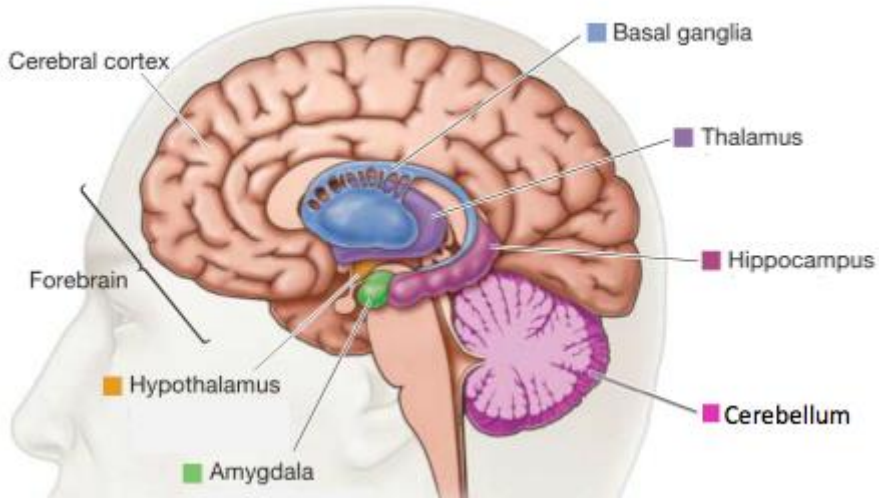
# Amygdala

***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 subcortica lstructures
- Modiffied corpus striatum
- Plasticity – memory formation

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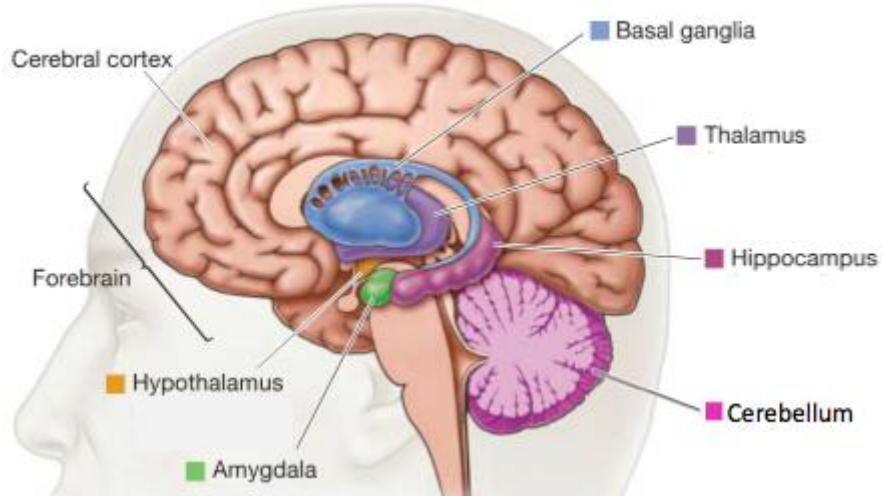
- Connections to all major cortical and subcortica lstructures
- Modiffied corpus striatum
- Plasticity – memory formation
- „Influence of information from outer environment on limbic system“
- „Amygdala hijack“
- „Affective tags“
  - Both possitive and negative
  - Higher responsiveness to negative

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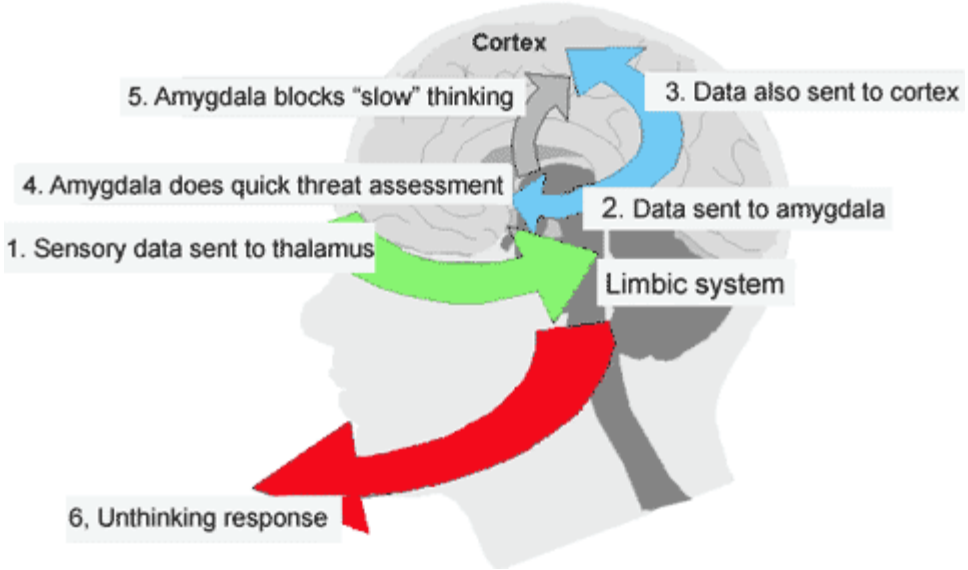


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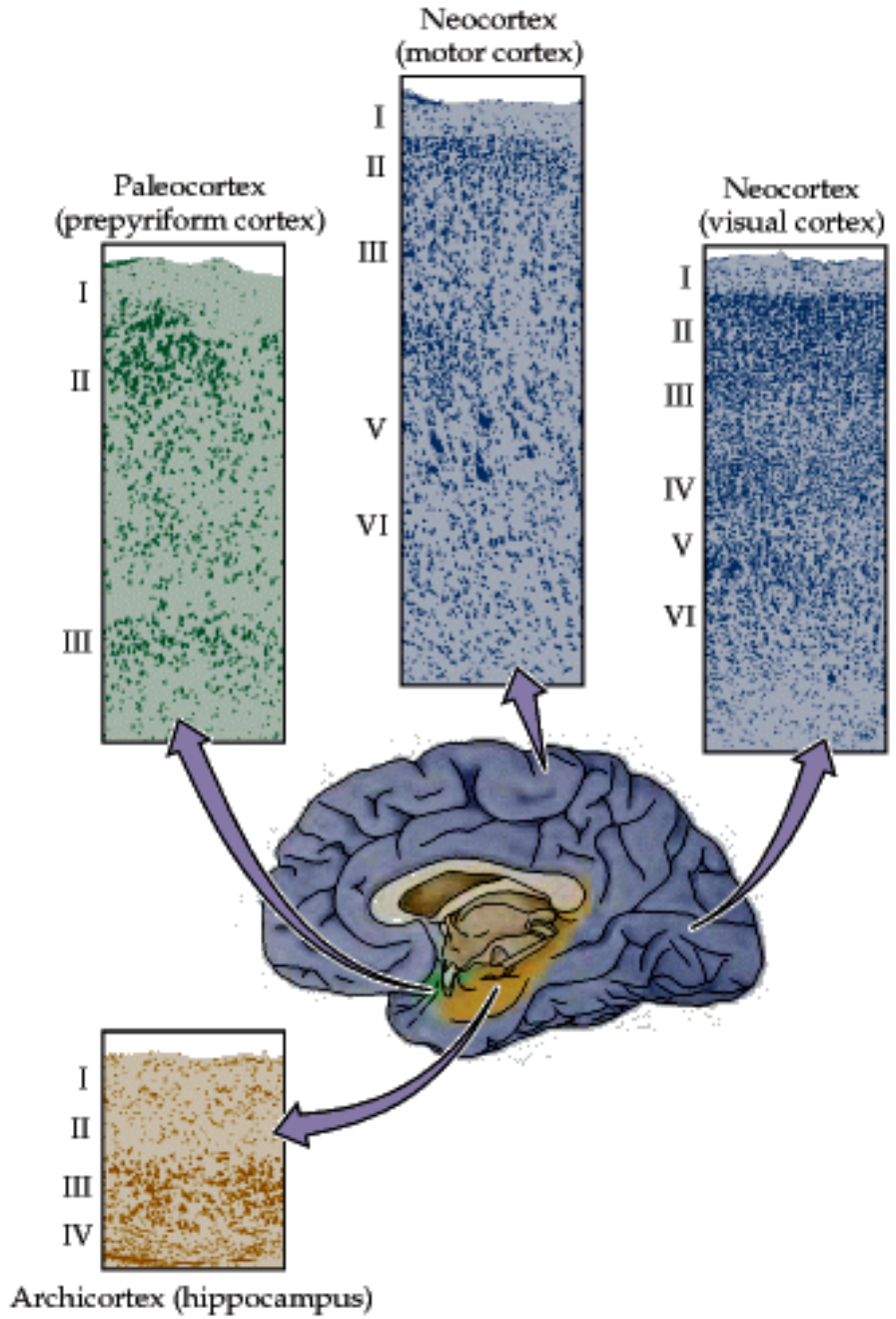
# Neocortex

# Cerebral cortex

- Paleocortex (1%)
  - 3 layers
  - rhinencephalon
- Archicortex (4%)
  - 3-4 layers
  - hippocampus
- Neocortex
  - 6 layers

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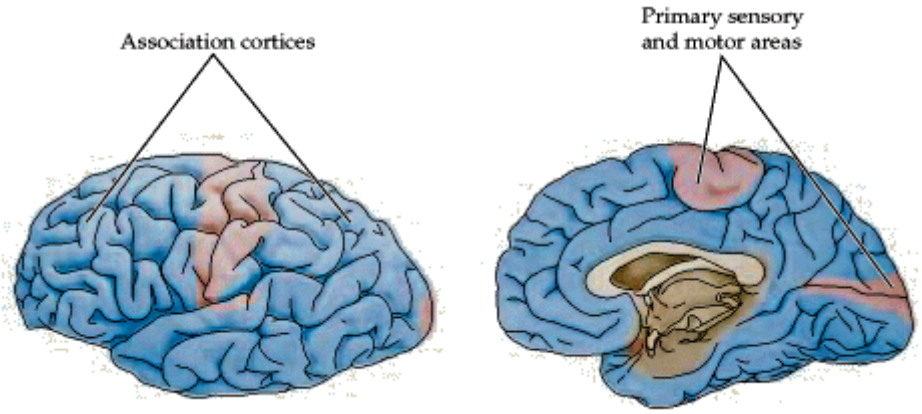
# Neocortex




**Primary areas**

✓Somathotopic organization

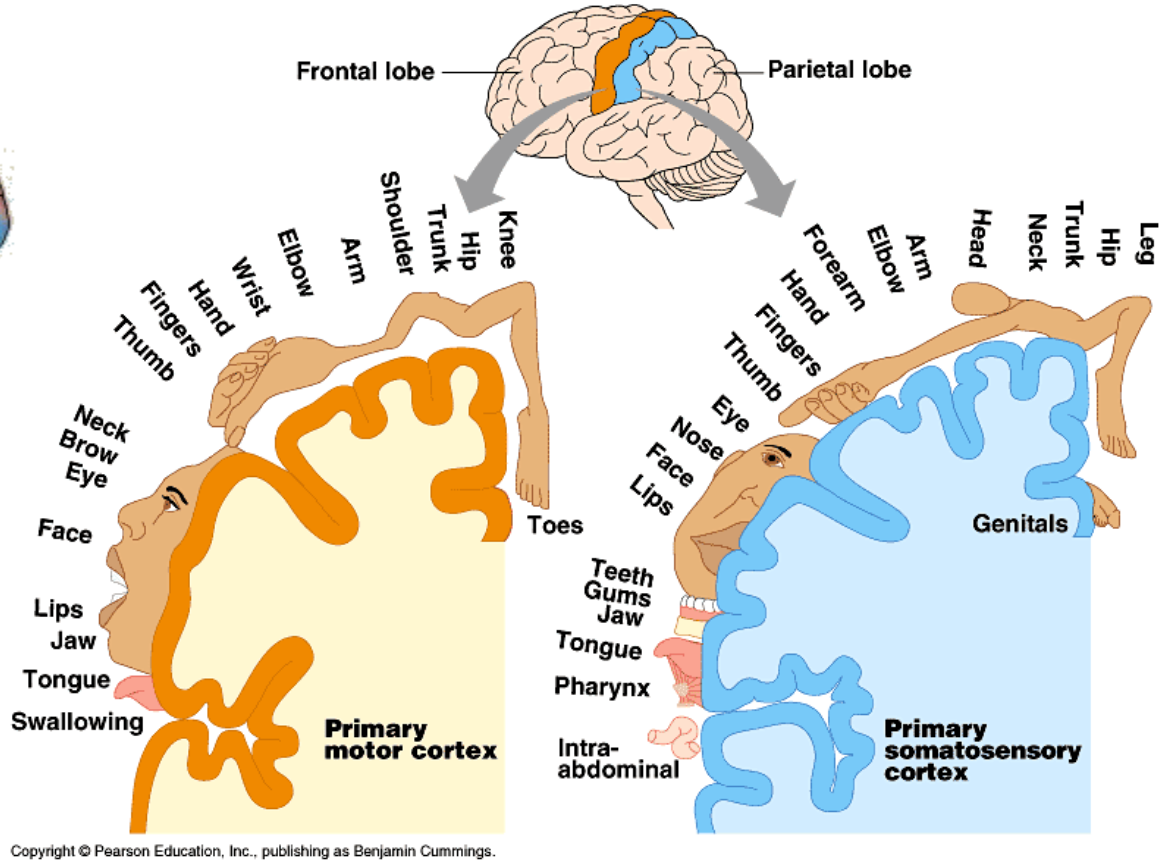
**Association areas**

✓No somathotopic organization

✓Unimodal

✓Polymodal

✓Association areas are thought to be the anatomical substrates of the highest brain functions—conscious thought, perception, and goal-directed action




http://www.emunix.emich.edu



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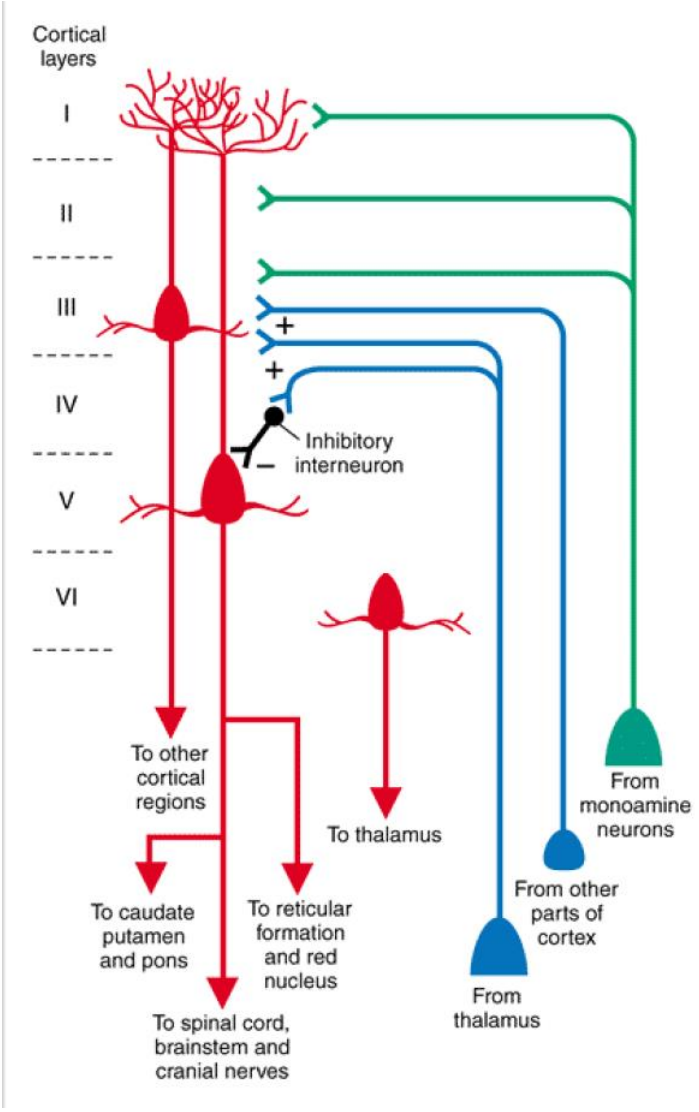
# Organization of neocortex

- Specific inputs/outputs to/from each layer
- Vertical and horizontal connections in each layer
- Each layer usually contains cells with similar functions

- Local differences in cytoarchitecture were used by Brodmann for construction of the map of brain areas

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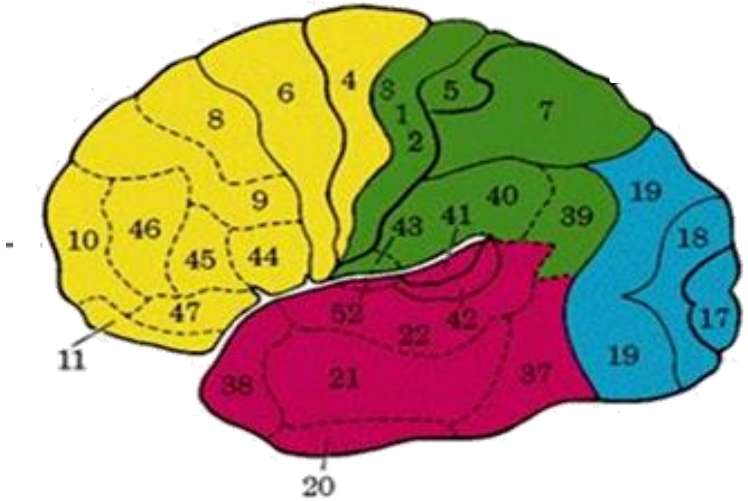
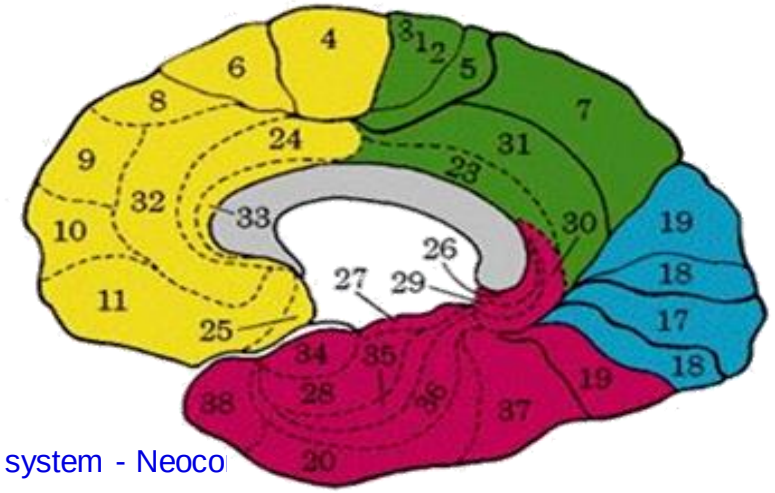
# Brodman areas




| Broadman's # | NAME | FUNCTION |
|---|---|---|
| 17 | Occipital Lobe | Visual Projection Cortex |
| 18 | | Visual Association Cortex |
| 19 | Posterior Parietal Lobe | Visual Association Cortex |
| 37 | Tempero-parietal-occipital area | General Sensory Association Cortex |
| 39 | Angular Gyrus | Word Recognition |
| 40 | Supramarginal Lobe | Somatosensory Association Cortex |
| 1,2,3 | Postcentral Gyrus | Somatosensory Projection Cortex |
| 5, 7 | Superior Parietal Lobule | General Sensory Association Cortex |
| 41, 42 | Middle 1/3 of Superior Temporal Cortex | Auditory Projection Cortex |
| 22 | Superior Temporal Gyrus | Auditory Association Cortex |
| 21, 20, 38 | Inferior Temporal Cortex | General Sensory Association Cortex |
| 4 | Precentral Gyrus | Primary Motor Cortex |
| 1,2,3 | Postcentral Gyrus | Somatosensory Projection Cortex |
| 6,8,9 | Premotor Cortex | Motor Association Cortex |
| 41, 42 | Middle 1/3 of Superior Temporal Cortex | Auditory Projection Cortex |
| 44,45,46 | Broca's Area | Motor Association Cortex - Specific to speech |
| 10 | Preftontal Cortex | General Motor Association Cortex |
| 11 | Orbital Gyri | General Motor Association Cortex |



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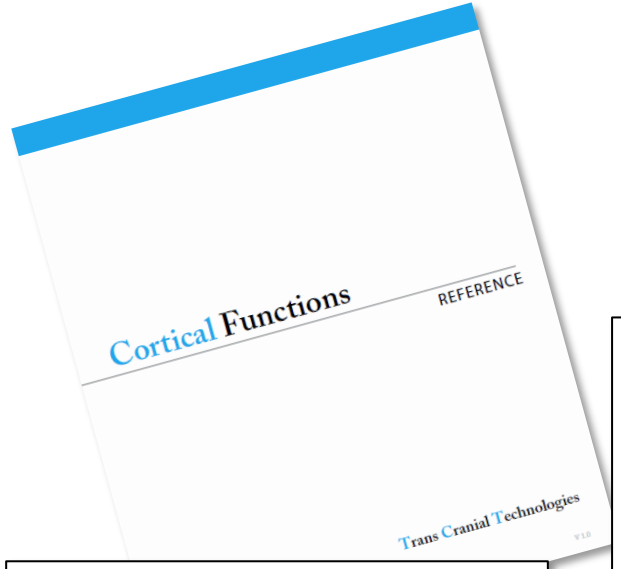
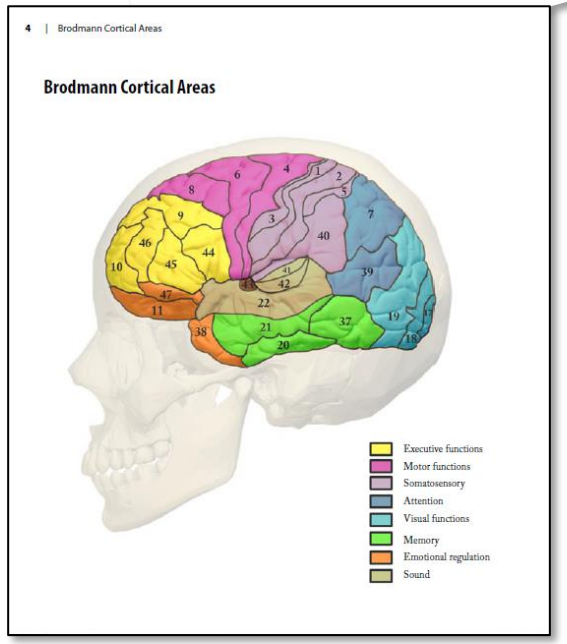
https://www.trans-cranial.com/docs/cortical_functions_ref_v1_0_pdf.pdf


Cortical Functions

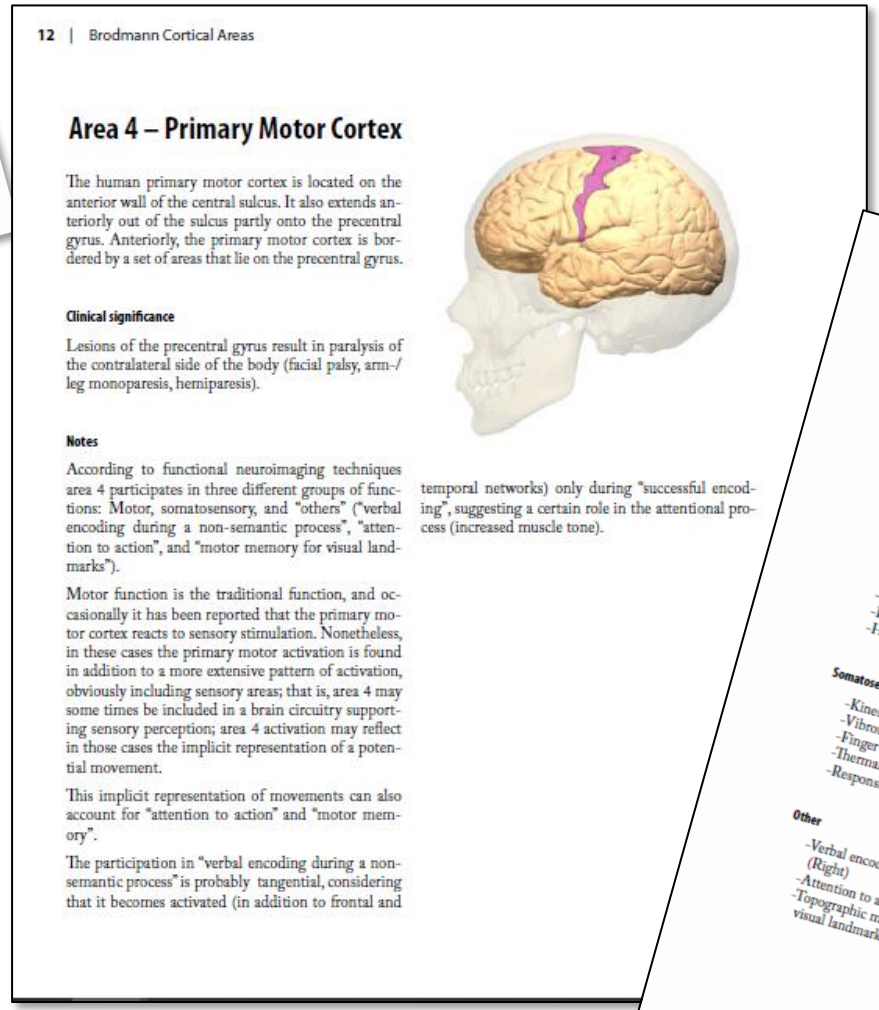
REFERENCE

Trans Cranial Technologies


4 | Brodmann Cortical Areas

Brodmann Cortical Areas

Executive functions
Motor functions
Somatosensory
Attention
Visual functions
Memory
Emotional regulation
Sound


12 | Brodmann Cortical Areas

## Area 4 – Primary Motor Cortex

The human primary motor cortex is located on the anterior wall of the central sulcus. It also extends anteriorly out of the sulcus partly onto the precentral gyrus. Anteriorly, the primary motor cortex is bordered by a set of areas that lie on the precentral gyrus.

**Clinical significance**

Lesions of the precentral gyrus result in paralysis of the contralateral side of the body (facial palsy, arm-/leg monoparesis, hemiparesis).

**Notes**

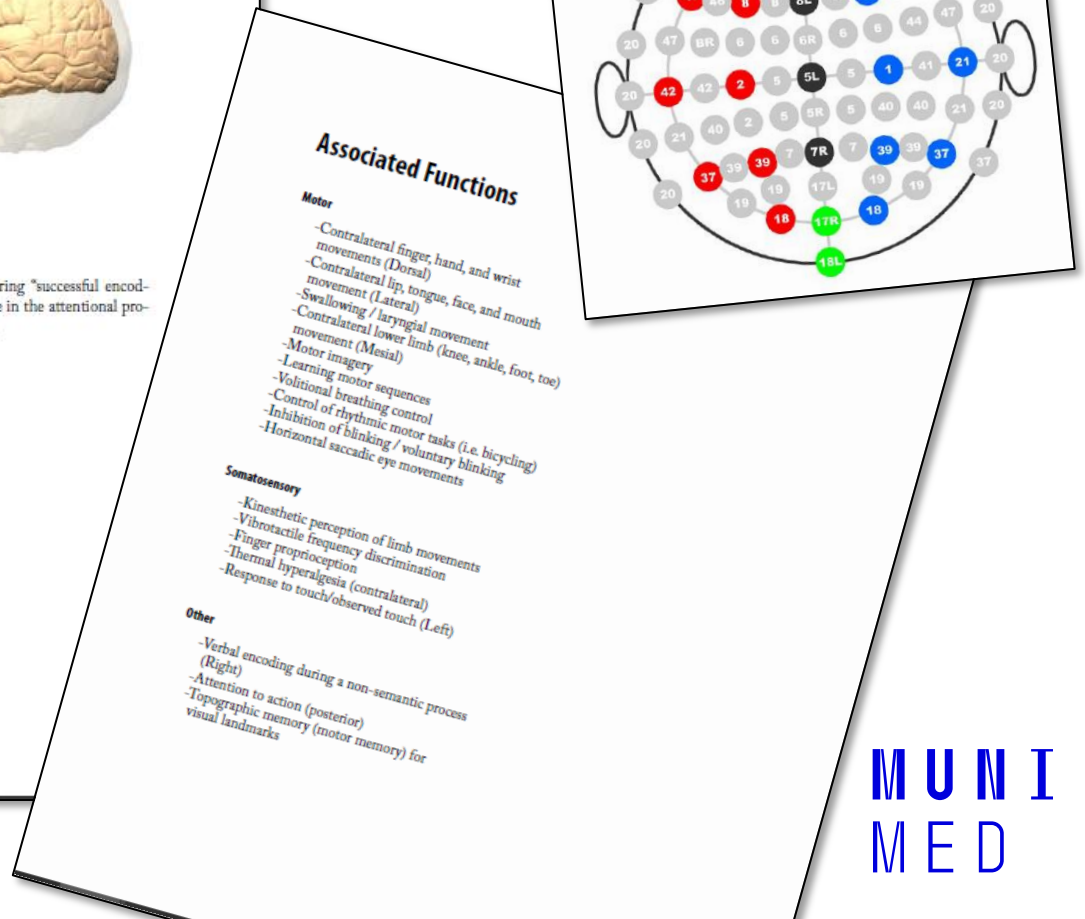
According to functional neuroimaging techniques area 4 participates in three different groups of functions: Motor, somatosensory, and "others" ("verbal encoding during a non-semantic process", "attention to action", and "motor memory for visual landmarks").

Motor function is the traditional function, and occasionally it has been reported that the primary motor cortex reacts to sensory stimulation. Nonetheless, in these cases the primary motor activation is found in addition to a more extensive pattern of activation, obviously including sensory areas; that is, area 4 may some times be included in a brain circuitry supporting sensory perception; area 4 activation may reflect in those cases the implicit representation of a potential movement.

This implicit representation of movements can also account for "attention to action" and "motor memory".

The participation in "verbal encoding during a non-semantic process" is probably tangential, considering that it becomes activated (in addition to frontal and temporal networks) only during "successful encoding", suggesting a certain role in the attentional process (increased muscle tone).




Associated Functions

**Motor**

-Contralateral finger, hand, and wrist movements (Dorsal)
-Contralateral lip, tongue, face, and mouth movement (Lateral)
-Swallowing / laryngial movement
-Contralateral lower limb (knee, ankle, foot, toe) movement (Mesial)
-Motor imagery
-Learning motor sequences
-Volitional breathing control
-Control of rhythmic motor tasks (i.e. bicycling)
-Inhibition of blinking / voluntary blinking
-Horizontal saccadic eye movements

**Somatosensory**

-Kinesthetic perception of limb movements
-Vibrotactile frequency discrimination
-Finger proprioception
-Thermal hyperalgesia (contralateral)
-Response to touch/observed touch (Left)

**Other**

-Verbal encoding during a non-semantic process (Right)
-Attention to action (posterior)
-Topographic memory (motor memory) for visual landmarks


Corresponding Brodmann Areas



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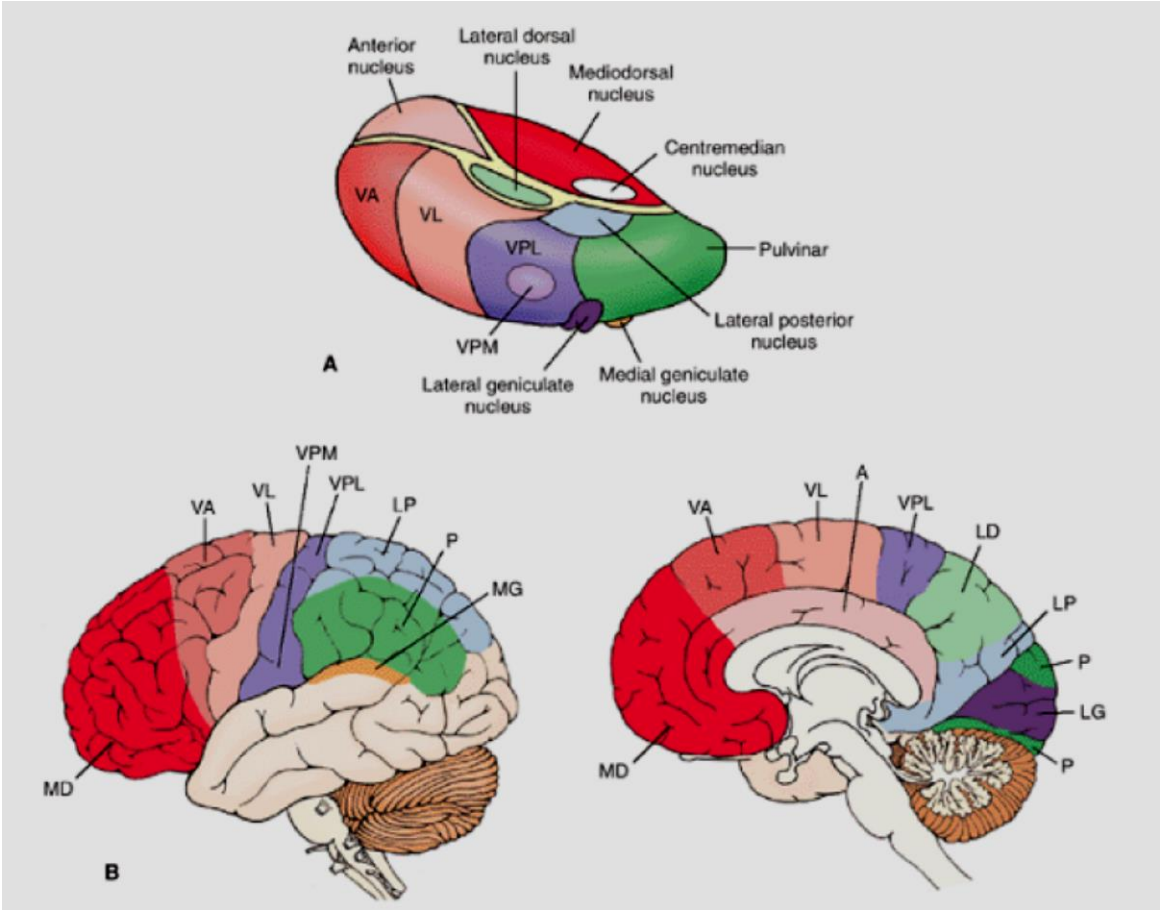
# Cerebral cortex and thalamus

- Close cooperation between cerebral cortex and thalamus
- Bilateral connections
- Almost all sensory information reaching cerebral cortex is gated by thalamus
- Exception - olfaction

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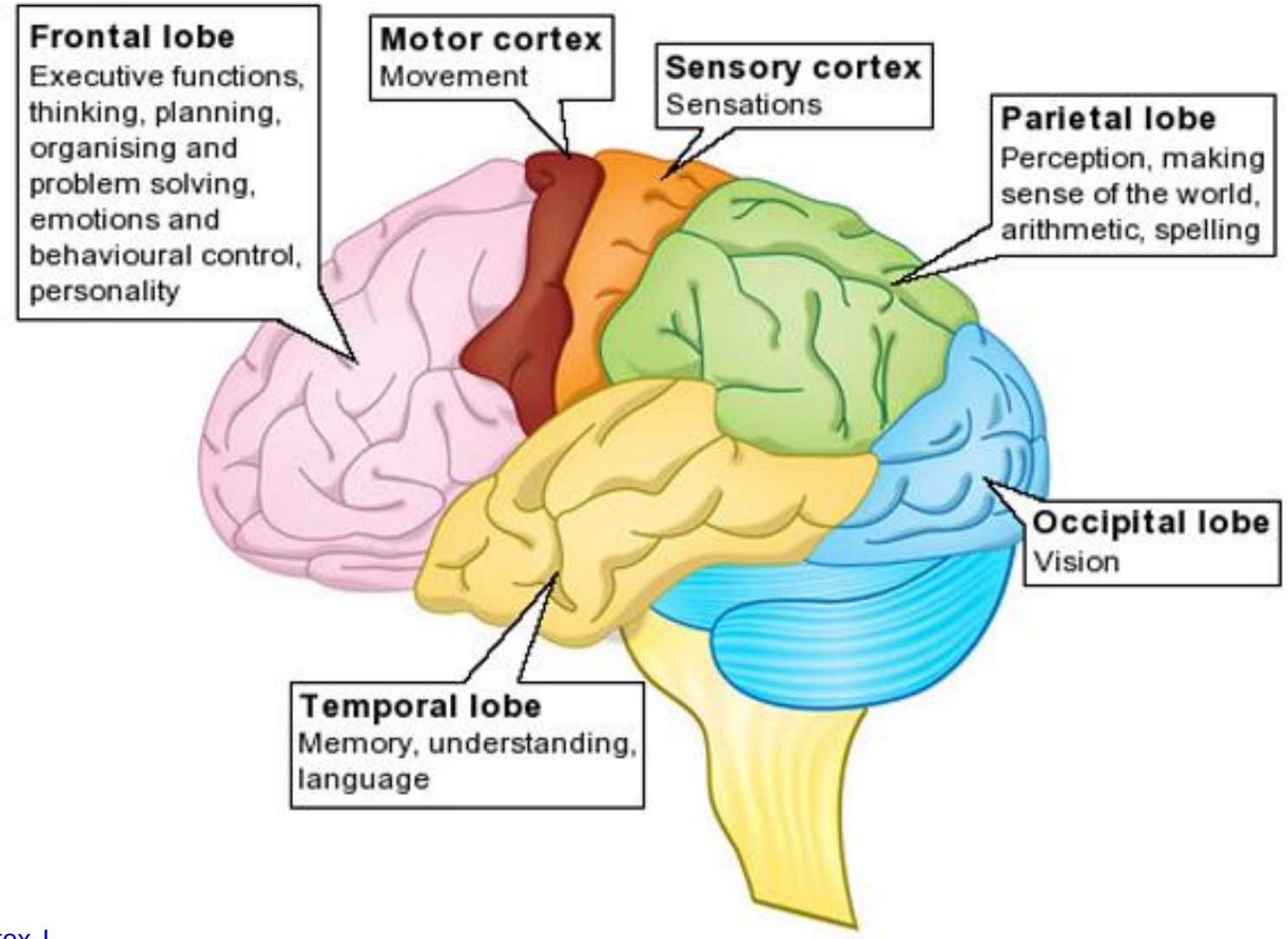
# Cortical functions




http://www.modernfamilyideas.com



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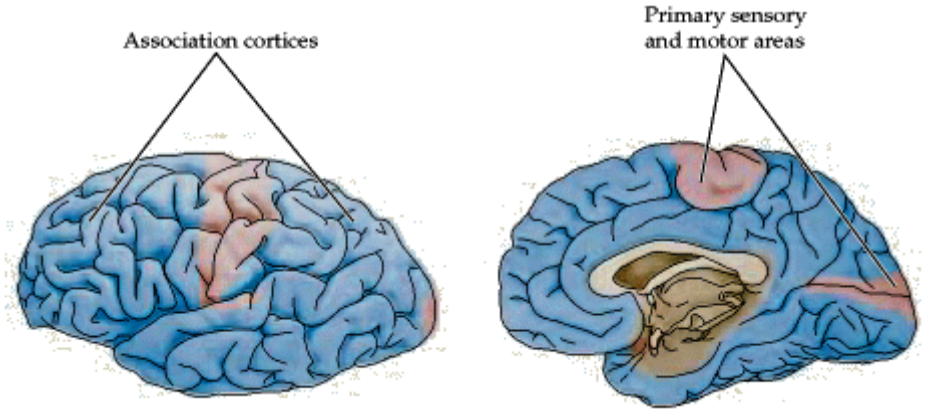
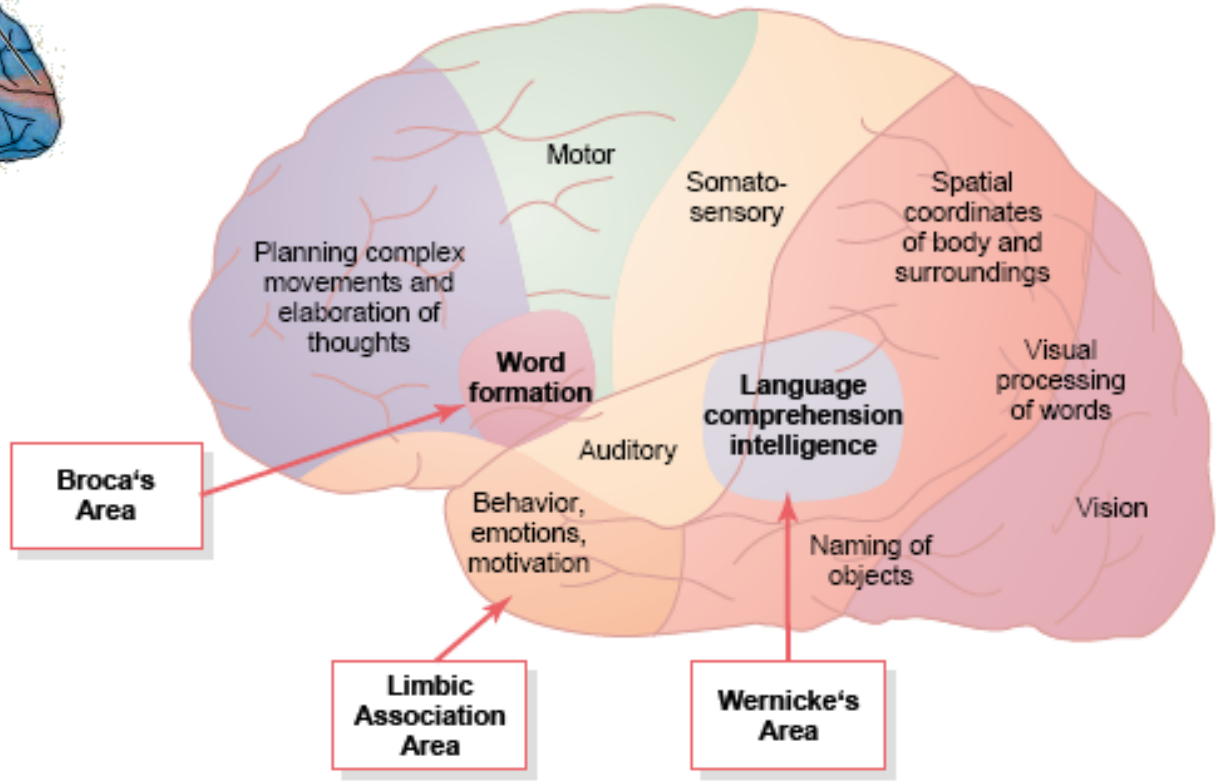
# Association areas




- Neither receptive
- Nor effector

- Integrative function

- Limbic
- Parieto-occipito-temporal
- Frontal

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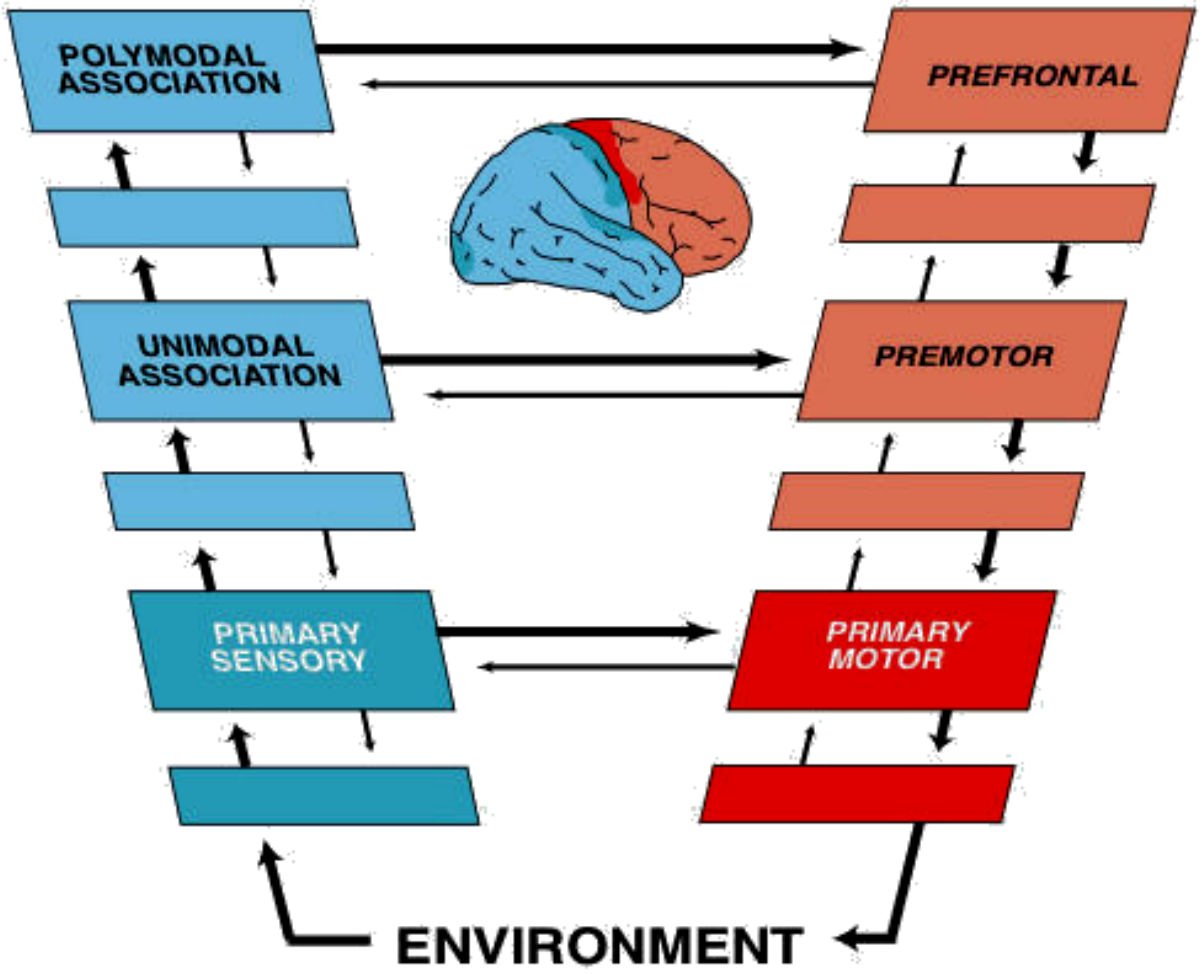
# Signal processing algorithm

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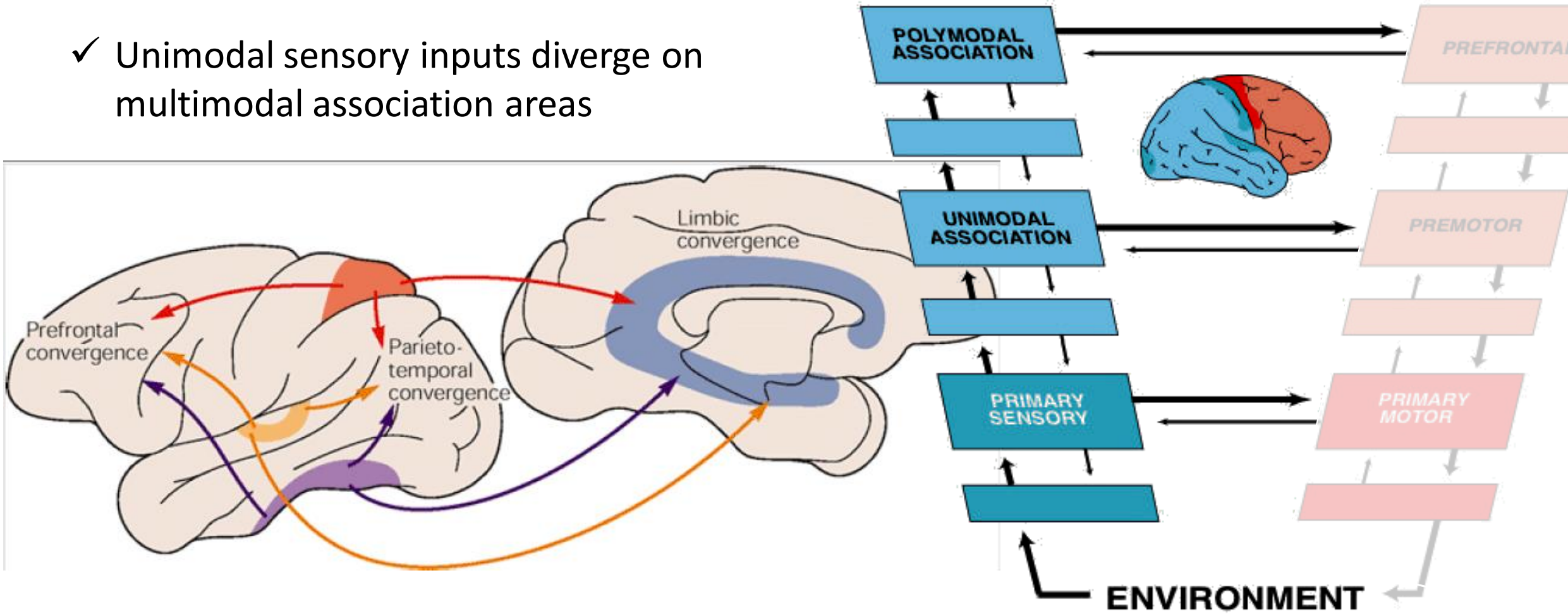
# Aferentation

- ✓ Unimodal sensory inputs diverge on multimodal association areas

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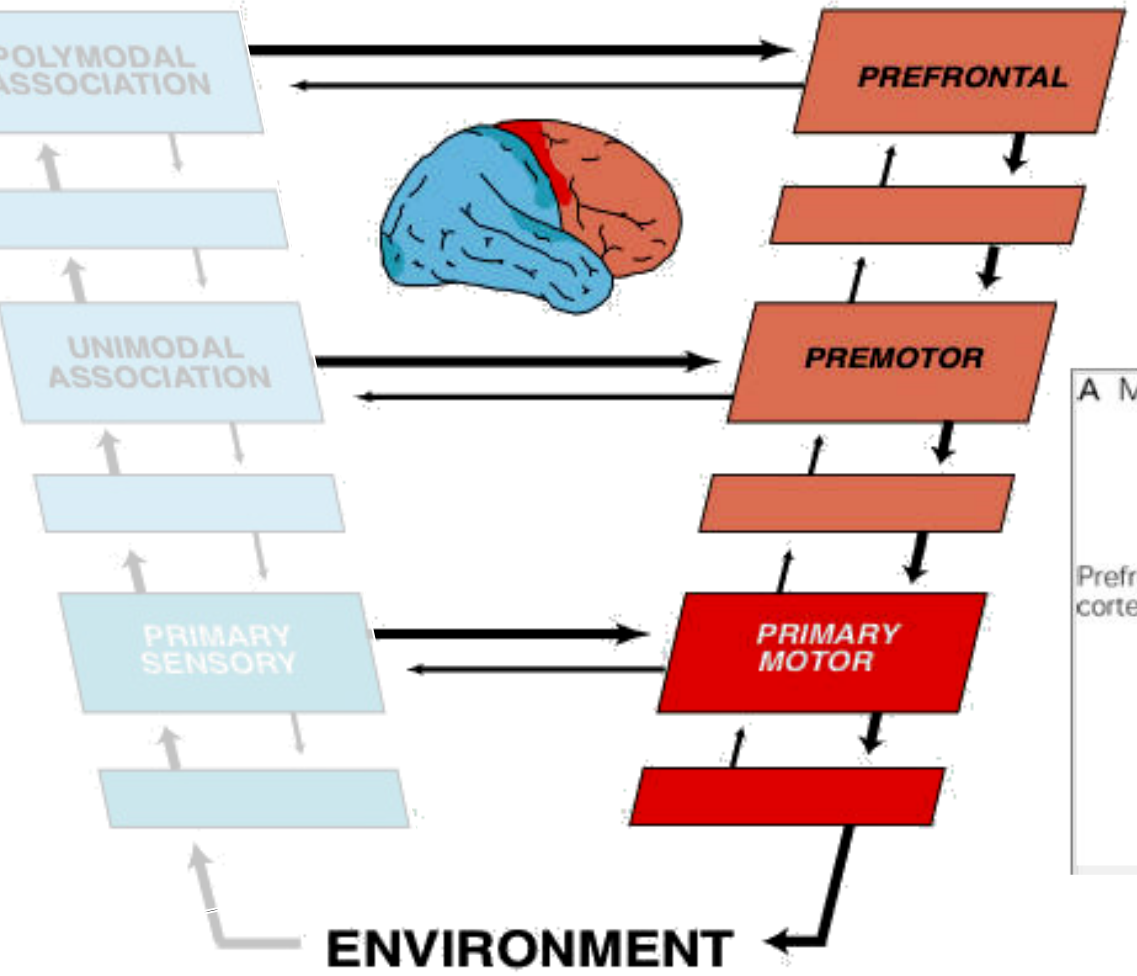
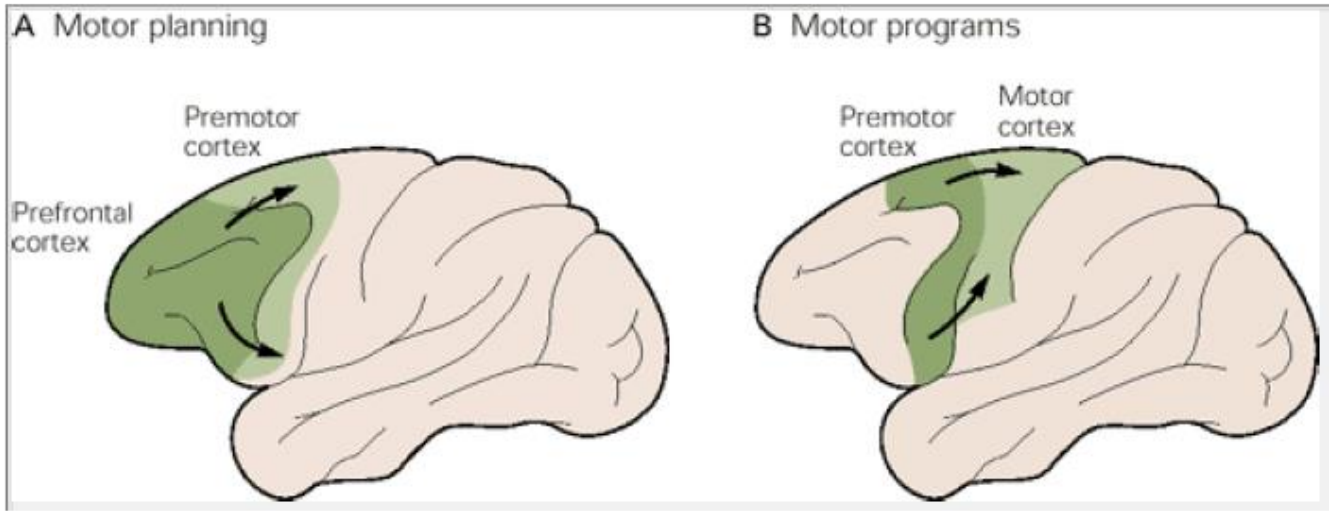
# Eferentation




- ✓ The Sequence of Information processing Is Reversed in the Motor System

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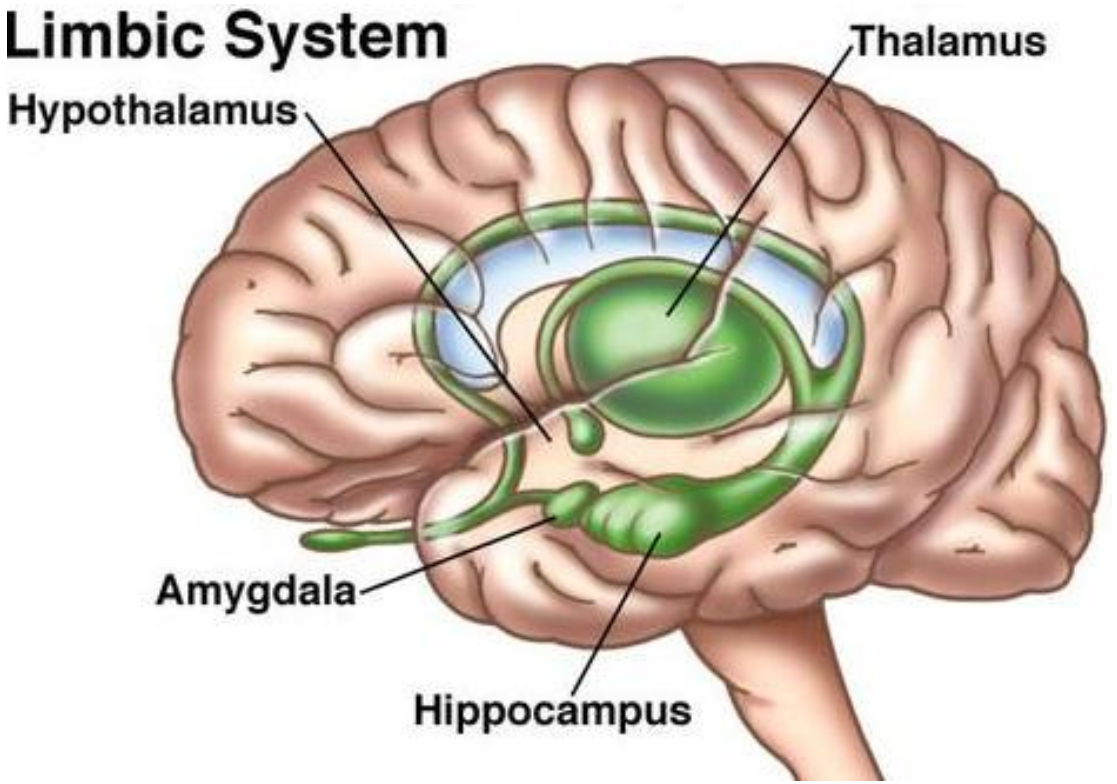
# Limbic association area

- Integration of information from inner and outer environment

- Hypothalamus

- Emotions
- Motivation
- Instinct behavior




http://www.mhhe.com/biosci/genbio/enger/student/olc/art_quizzes/genbiomedia/0665.jpg



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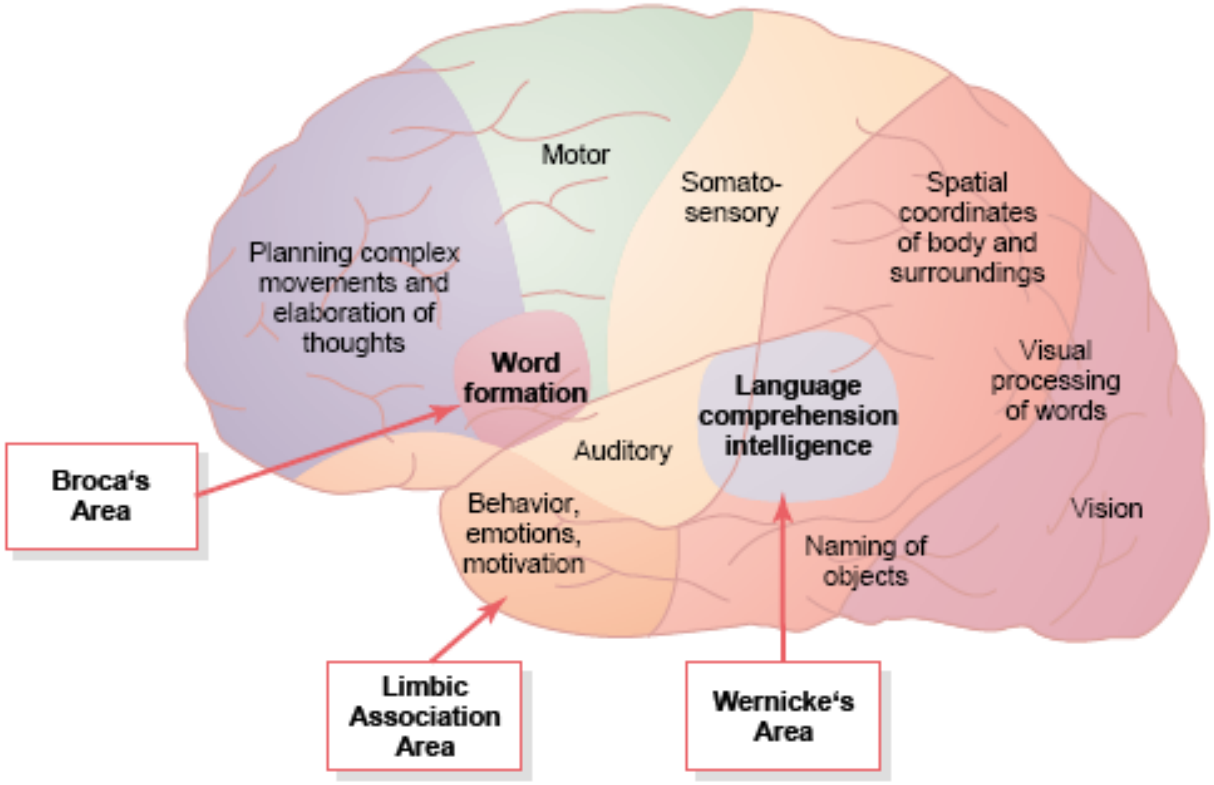
# Parieto-occipito-temporal association area

- Linkage and interpretation of information from several sensory modalities

- Visual – acoustic – sensory analysis
- Object recognition and categorization
- Language comprehension
- Attention

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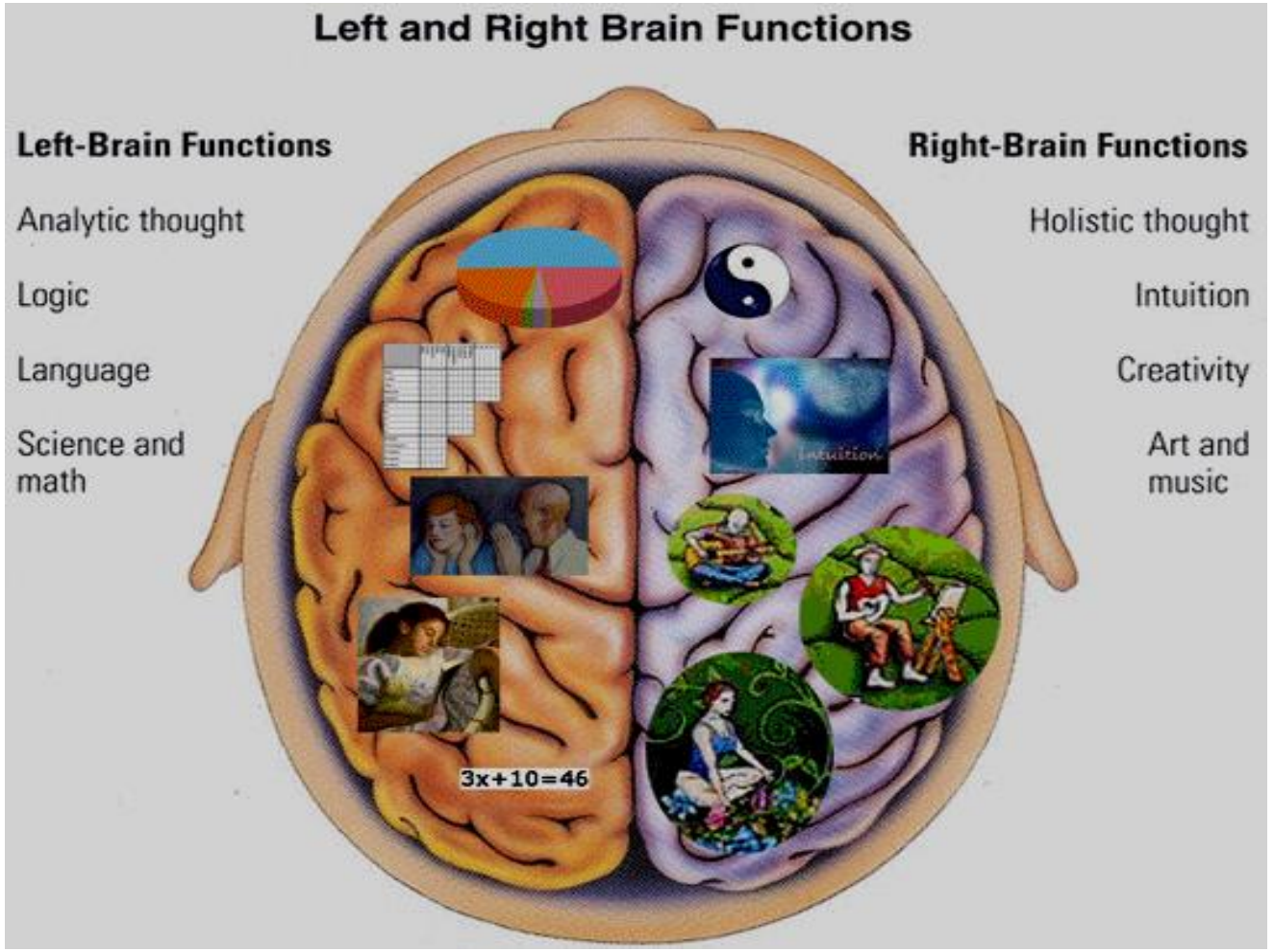
# Lateralization of cerebral functions

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# Lateralization of cerebral functions

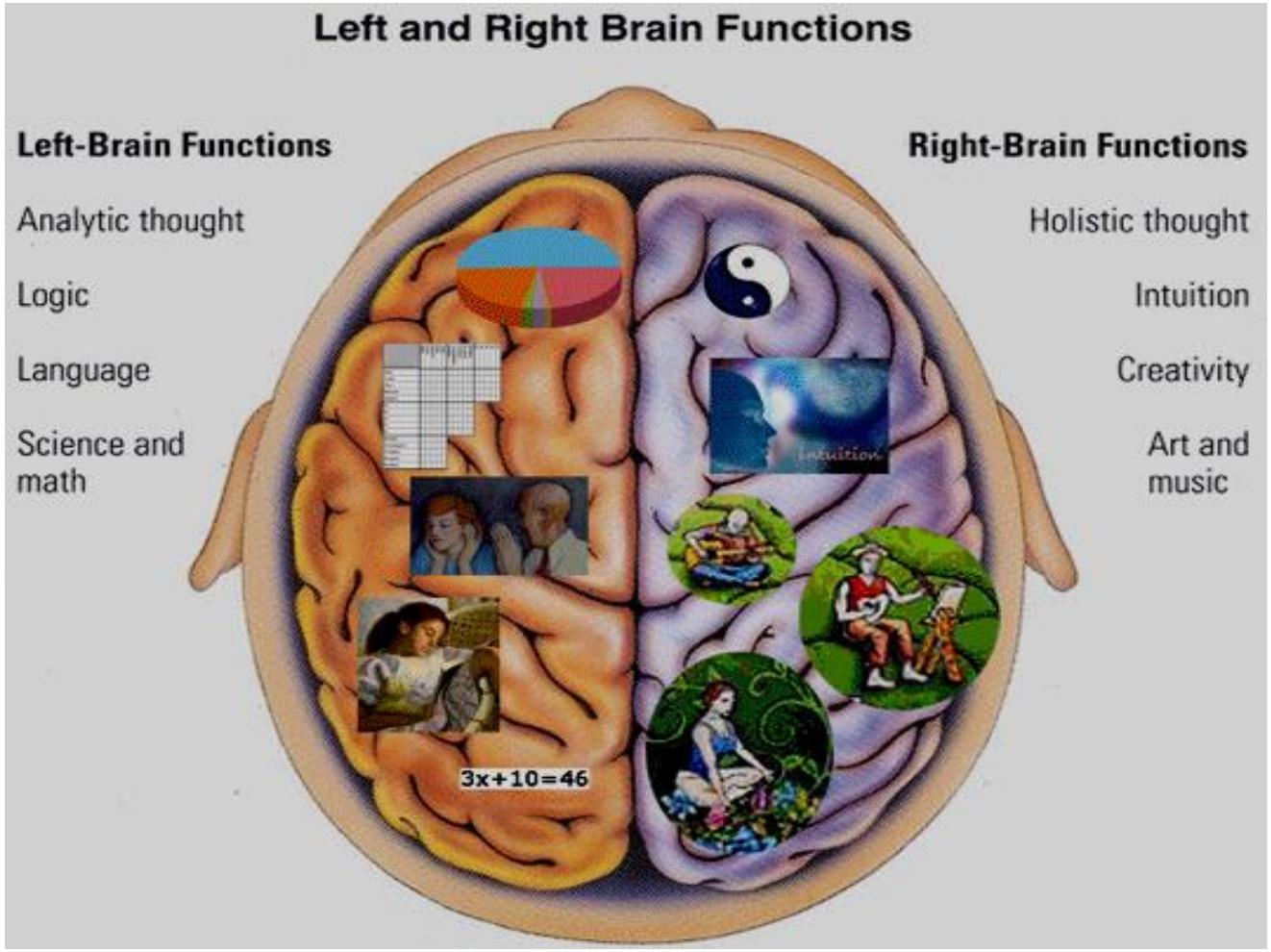
Aphasia

Acalculia

Tactile agnosia

Conceptual apraxia

Ideomotor apraxia




Orientation disorders

Constructional apraxia

Anosognosia

Neglect syndrome

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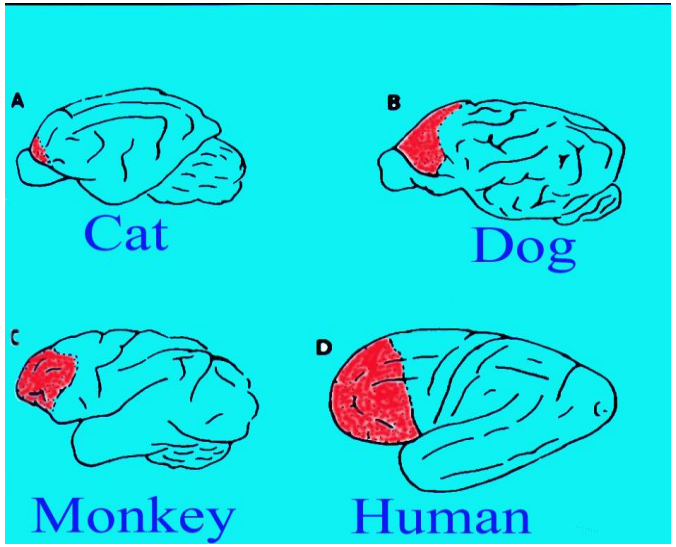
# Frontal association area

- Executive function
  - Motor / behavioral
  - Cognitive

- Mostly developed in human

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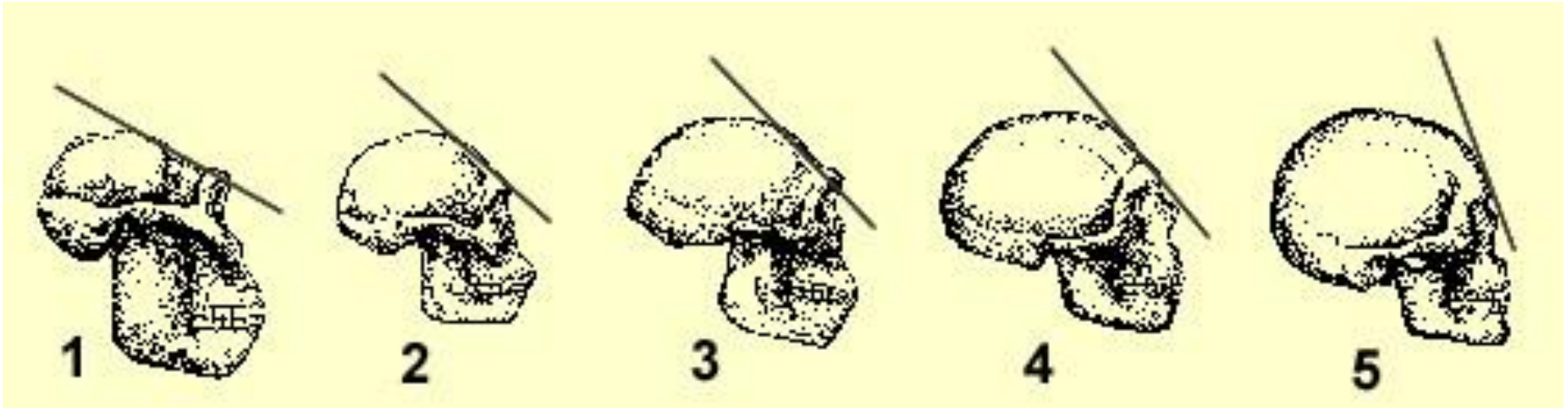
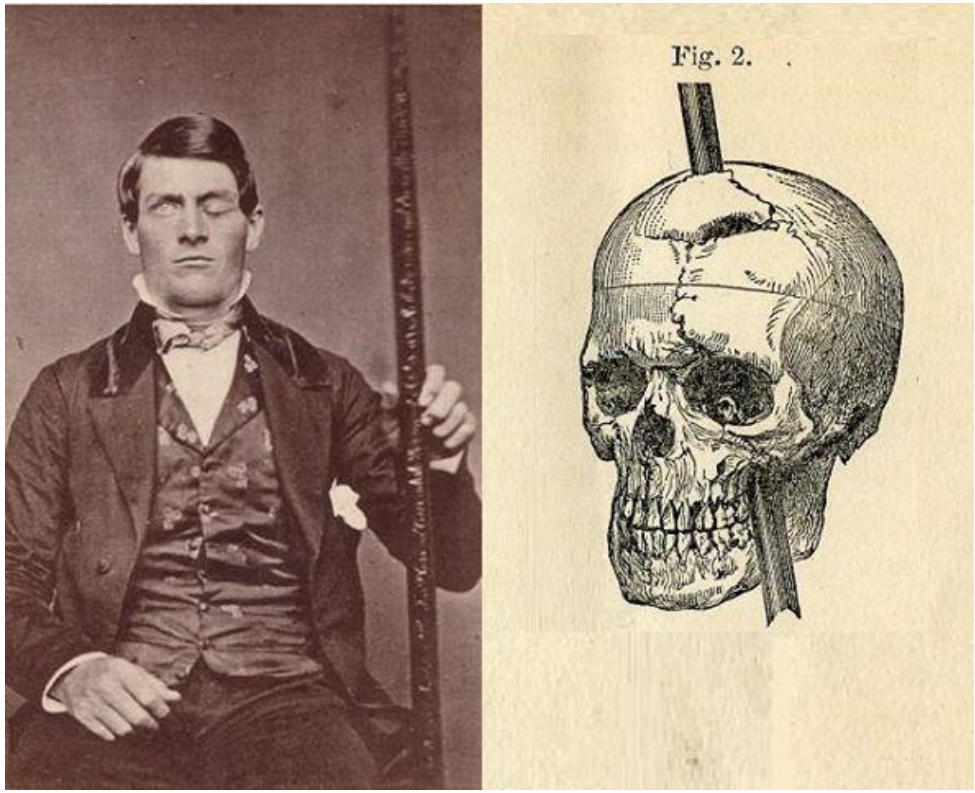



1. *Australopithecus robustus* 2. *Homo habilis* 3. *Homo erectus* 4. *Homo sapiens neanderthalensis* 5. *Homo sapiens sapiens*

# Phinease Gage (1823 – 1860)

- 1848 – work injury
- Before injury
  - Reliable
  - Friendly
  - Responsible
  - Polite
- After injury
  - Unreliable
  - Hostile
  - Irresponsible
  - Rude
- 1860 – died from status epilepticus

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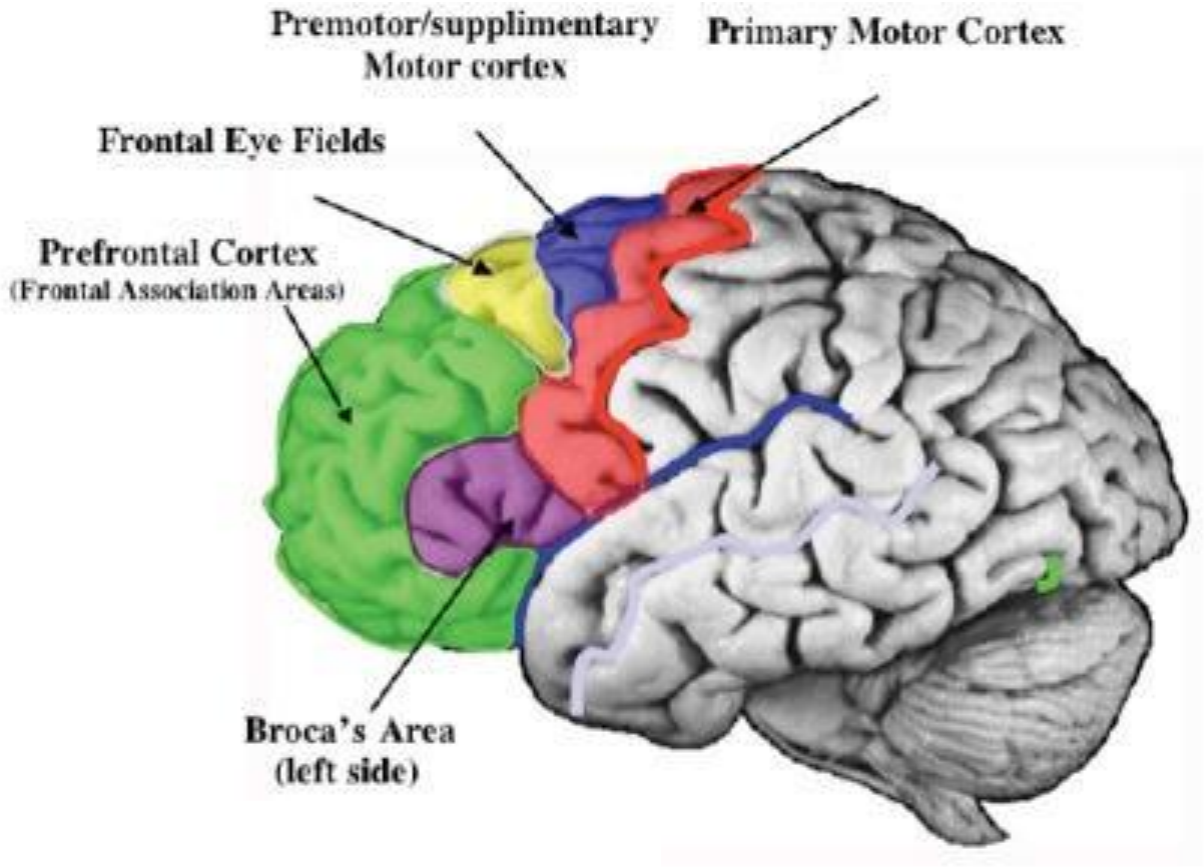
# Frontal lobe

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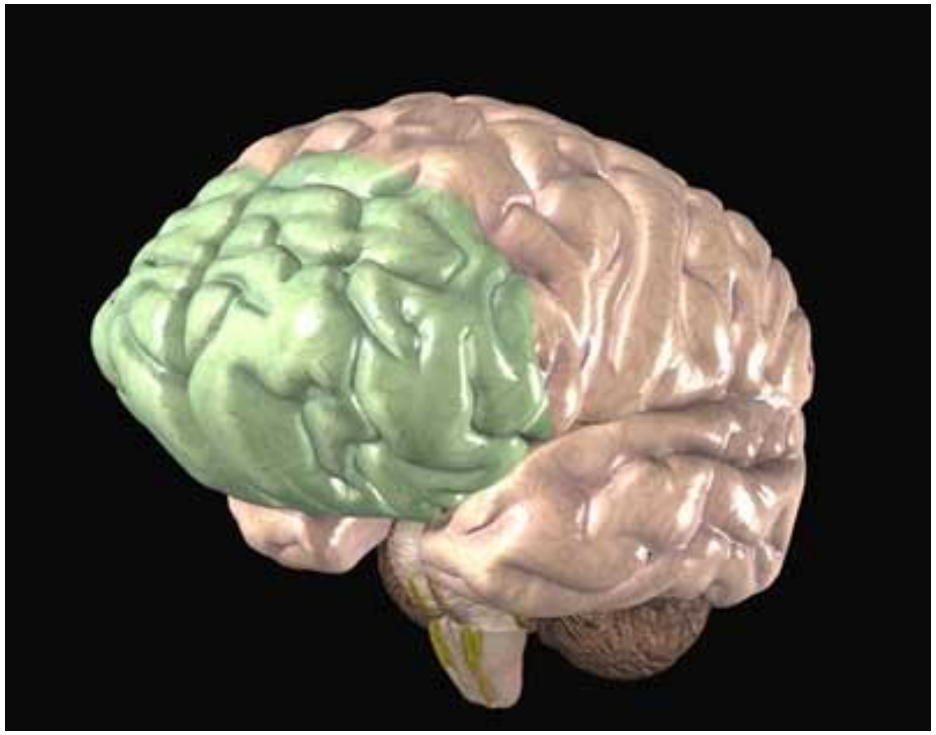
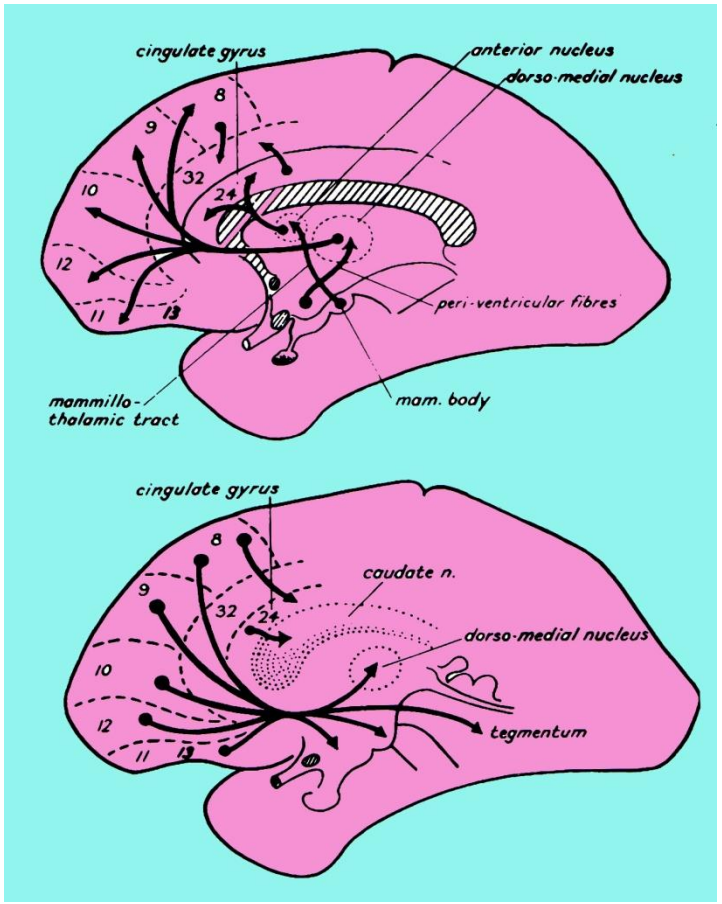
# Frontal association area

- ~ 1/3 of neocortex
- One of the evolutionary youngest cortical areas
- Late development in ontogeny
  - Differentiation during  the 1st year of life
  - Mostly developed around the 6th year of life
  - ? End of maturation around the 20th year of life?



# Frontal association area

- Input from association cortex
  - P-O-T association area
  - Limbic association area
- Reciprocal connections:
  - prefrontal processing modulates perceptual processing
  - „Loops“
- Input to premotor areas




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



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# Functions of frontal association area

- Motor/non-motor planning/organization - strategy - anticipation

http://thenextweb.com/wp-content/blogs.dir/1/files/2015/03/jerry1.jpg

- Thinking – mental models processing
- Attention – „information filtering“
- Behavioral control
  - Facilitation of „wanted“
  - Inhibition of „unwanted“

http://thenextweb.com/wp-content/blogs.dir/1/files/2015/03/jerry1.jpg



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# 1. Motor planning / organization

- Frontal association area
- Premotor area

✓ Close cooperation with motor cortex

✓ Planning and preparing of complex motor action (in cooperation with Basal ganglia)

✓ Close cooperation with P-O-T area which sends visual-acoustic-sensory-spatial information

✓ Voluntary motor control

http://www.123rf.com/stock-photo/brain_icon.html?mediapopup=14828479



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# 2. Thinking skills

- Organization
  - The ability to arrange information in a meaningful system
- Planning
  - The ability to create a strategy for reaching goals
- Time management
  - The ability to estimate time needed for reaching goals
- Working memory
  - The ability to hold information in awareness while performing a mental operation

http://www.123rf.com/stock-photo/brain_icon.html?mediapopup=14828479



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# 3. Attention

- Selective attention
  - –The ability to filter information
- Sustained attention
  - –The ability to actively attend to a task
- Divided attention
  - –The ability to attend to two tasks at once
- Shifting attention
  - –The ability to shift attention between two or more tasks

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# 4. Behavioral control

- Facilitation/ initiation of „wanted“ (re)action
- Inhibition of „unwanted“ (re)action
  - –Anticipation
  - –Self-regulation x procrastination
- Flexibility
  - – The ability to revise plans when it is needed
- Goal-directed persistence
  - –The ability to self-motivate
- Social brain
  - –Mentalization
  - –Empathy
  - ➢Social behavior - frontal association area
  - ➢Instinct behavior - limbic association area

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# Frontal lobe and mental arousal

- Right frontal lobe
  - –Bilateral influence
  - –Inhibition
- Left frontal lobe
  - –Unilateral influence
  - –Activation
- Left frontal lobe damage
  - –Reduced spontaneous activity
  - –Reduced self-control; impulsive instinct behavior


http://www.anna-om-line.com/BRAIN-GRAPHICS-by-annaOMline.jpg



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# Frontal lobe functions

| Motor | Cognitive | Behavior | Arousal |
|---|---|---|---|
| Voluntary movements | Memory | Personality | Attention |
| Language Expression | Problem solving | Social and sexual | |
| Eye movements | Judgment | Impulse control | |
| Initiation | Abstract thinking | Mood and affect | |
| Spontaneity | | | |

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