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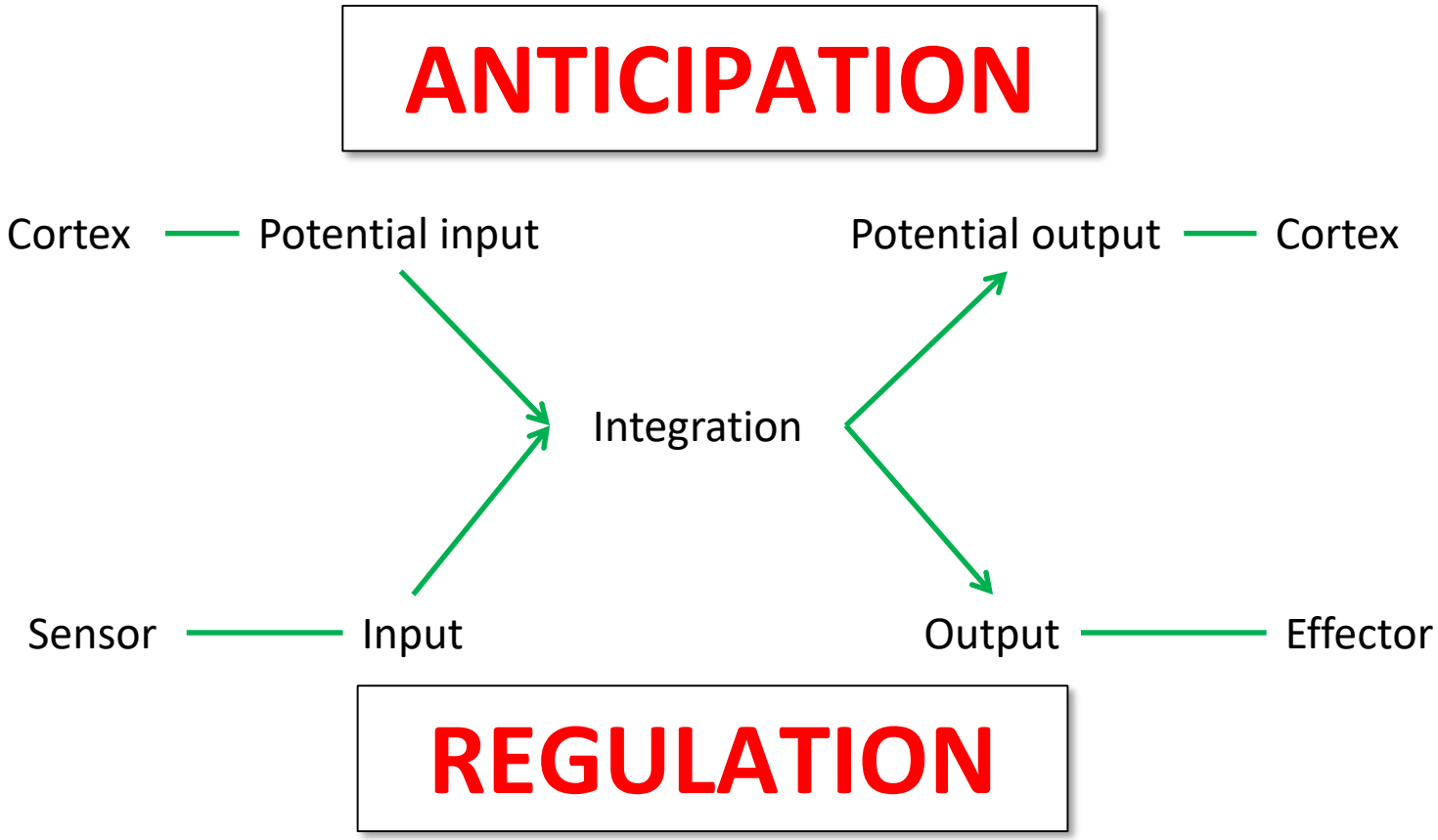
Limbic system
Neocortex I

The role of nervous system



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Hypothalamus

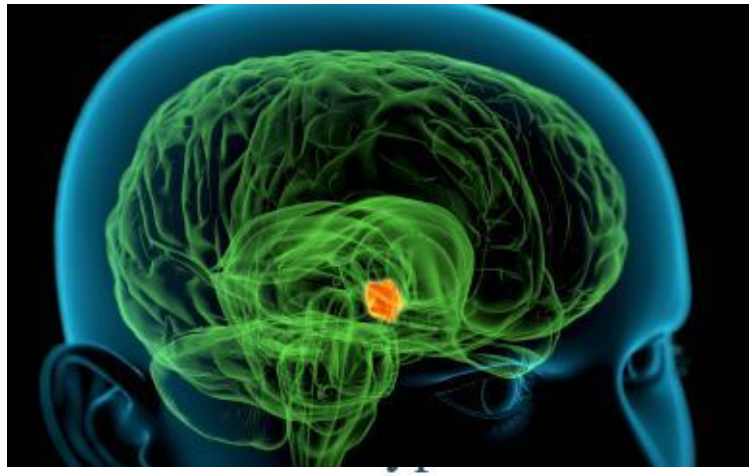
- Key center of autonomic regulations and coordination
- Integration of the information from inner and outer environment

↓

- Behavioral modulation
- Regulation of autonomic nervous system

↓

- **Maintenance of homeostasis**



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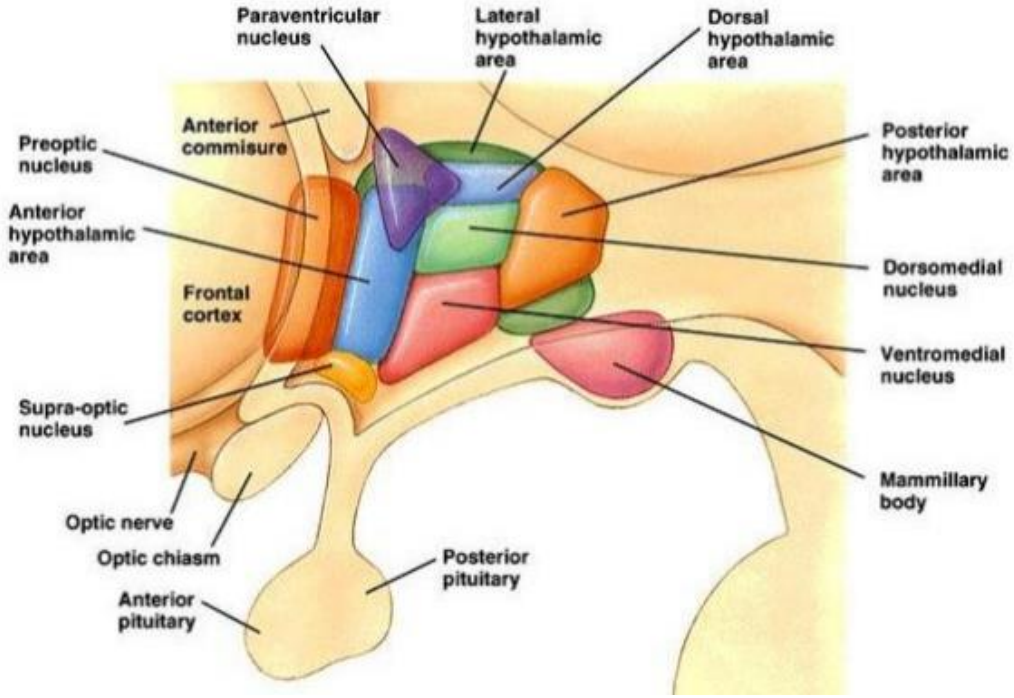

http://www.slideshare.net/physiologymgmcri/hypothalamus-15-apr-2016

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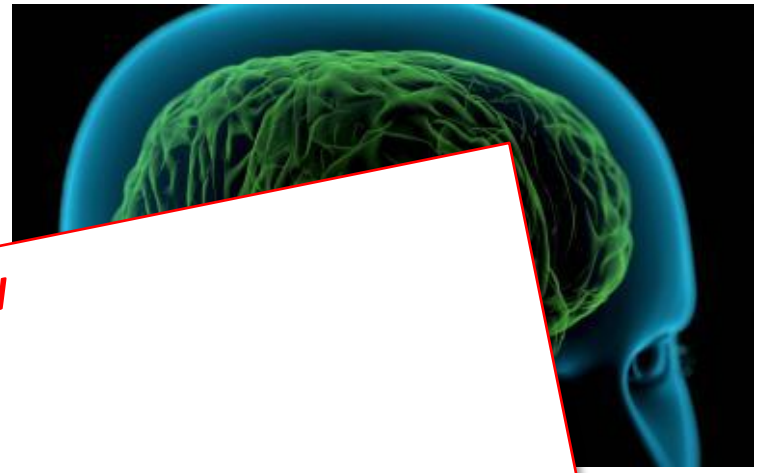
Hypothalamus

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



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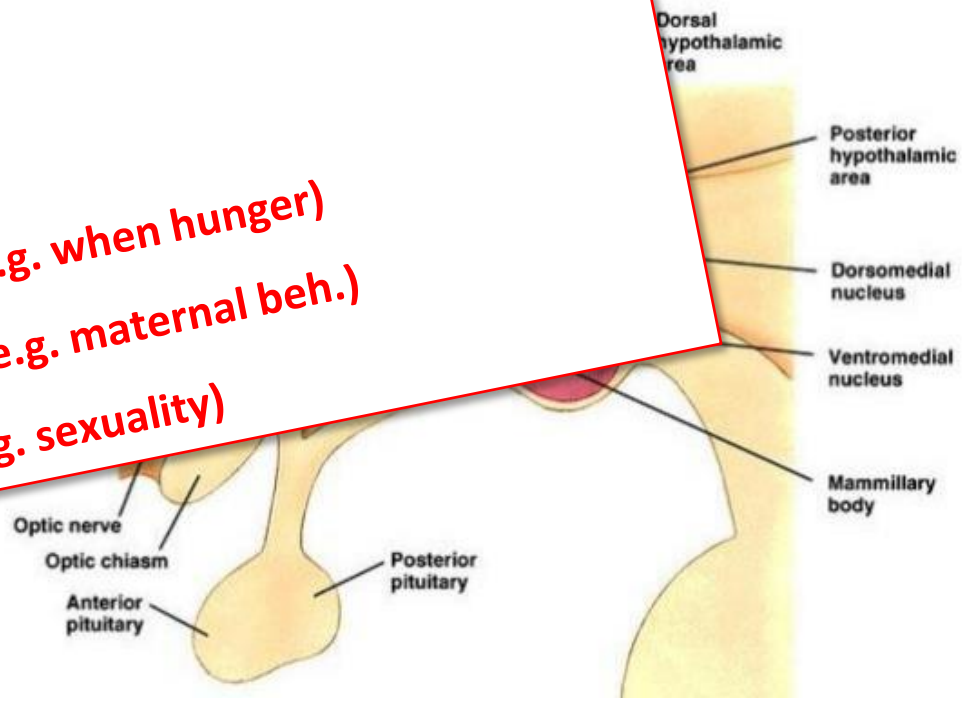
- ✓Biological clock – circadian /seasonal activity
- ✓Autonomic nervous system regulation
- ✓Endocrine system regulation
- ✓Food and water intake regulation
- ✓Regulation of body temperature
- ✓„Immediate“ behavior regulation (e.g. when hunger)
- ✓ „Long-term“ behavior regulation (e.g. maternal beh.)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



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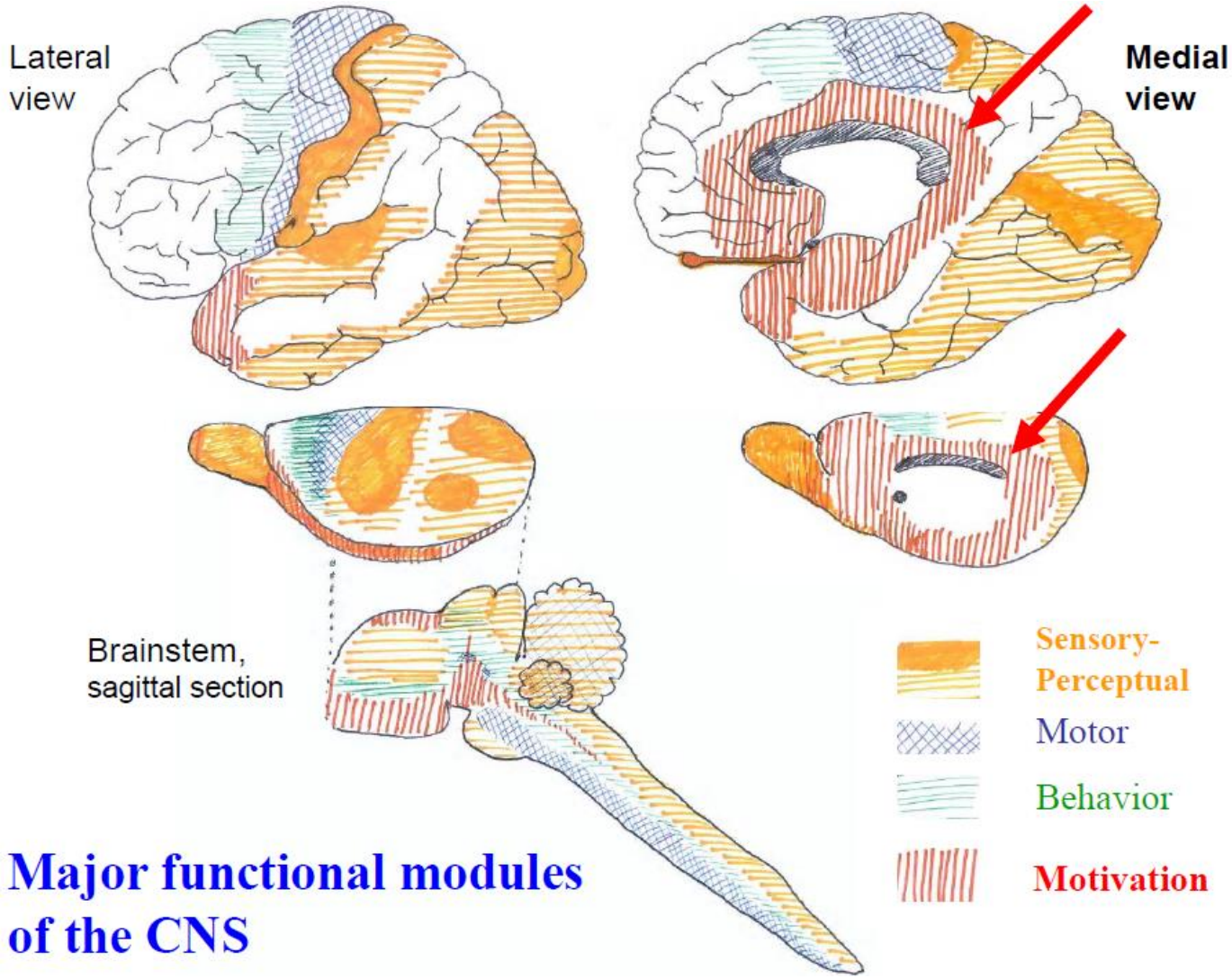
Limbic system

Limbus = border



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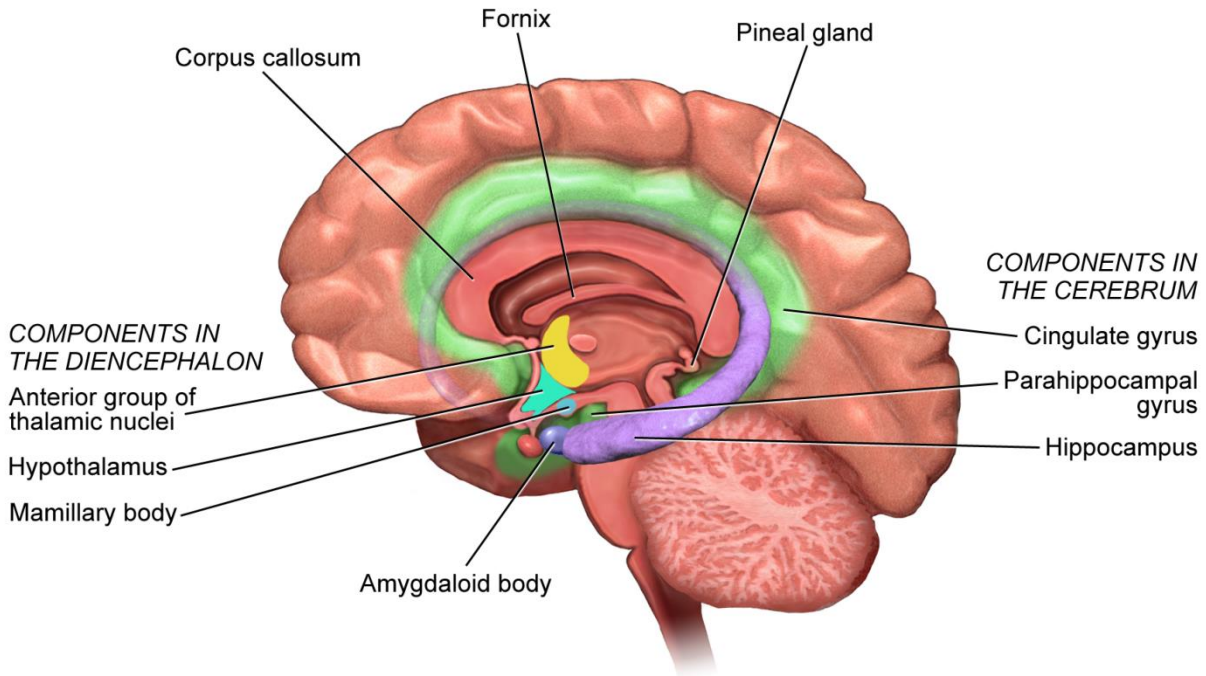
Concept of the limbic system

- 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

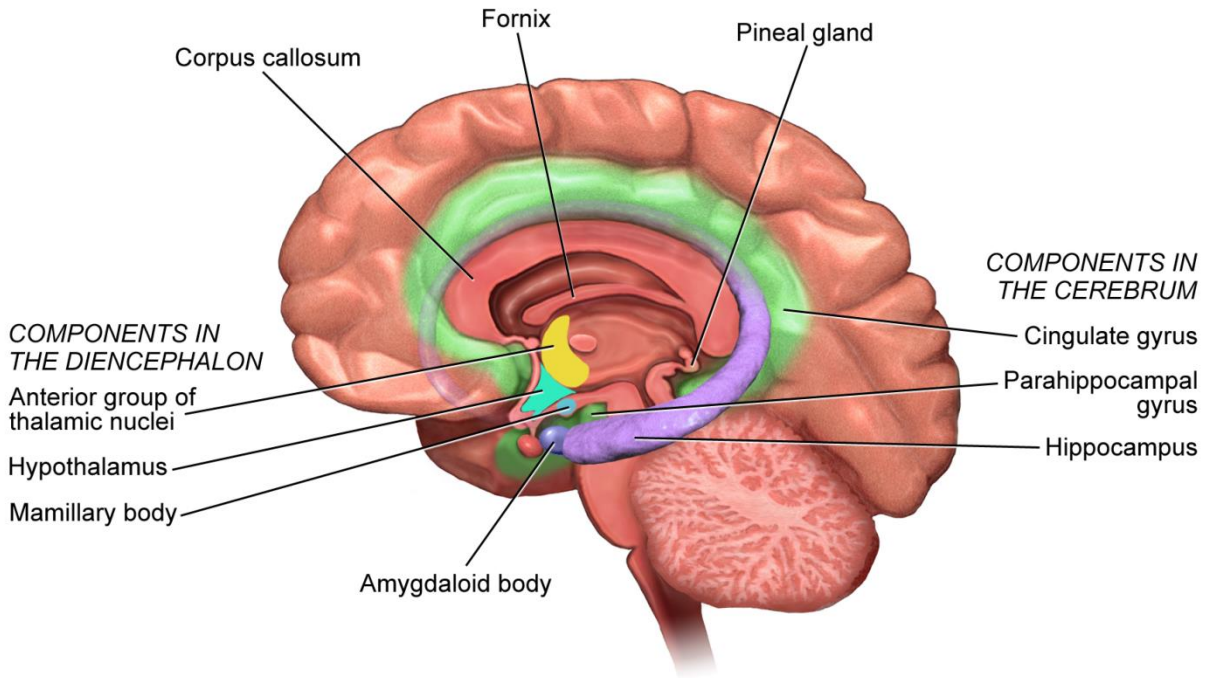
- Voluntary

↑

Potencial conflict

↓

- Automatic



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Concept of the limbic system

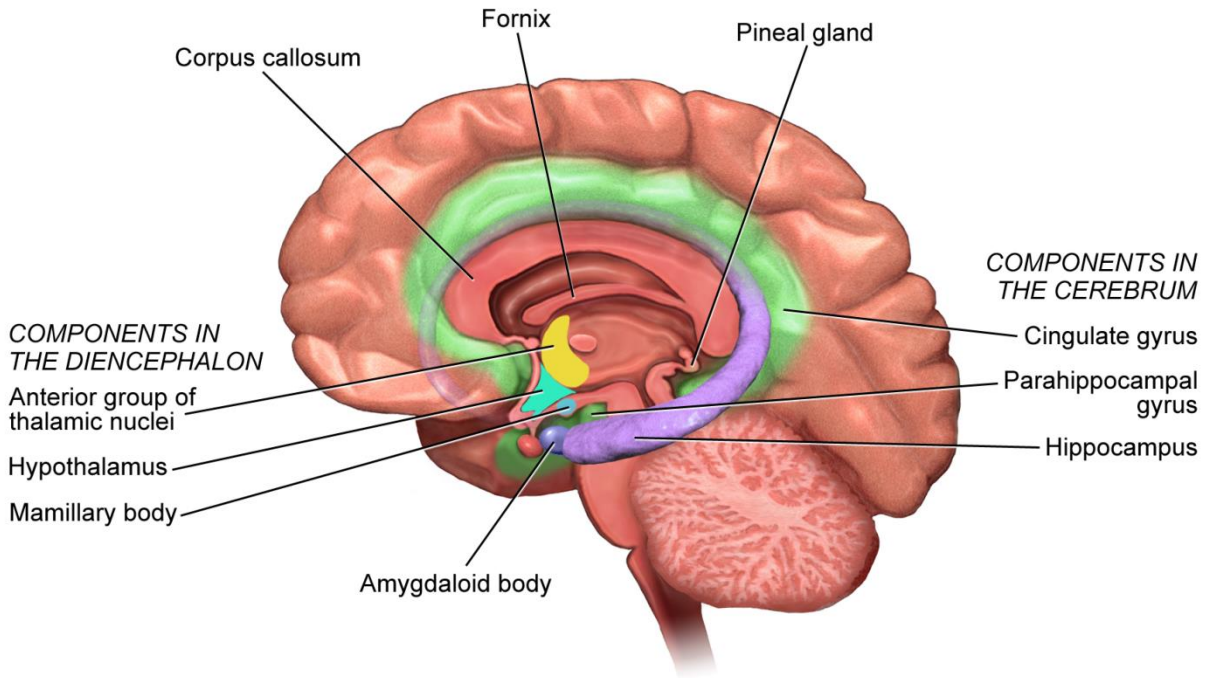
- Voluntary

Modulation

Limbic system

Control

- Automatic



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Concept of the limbic system

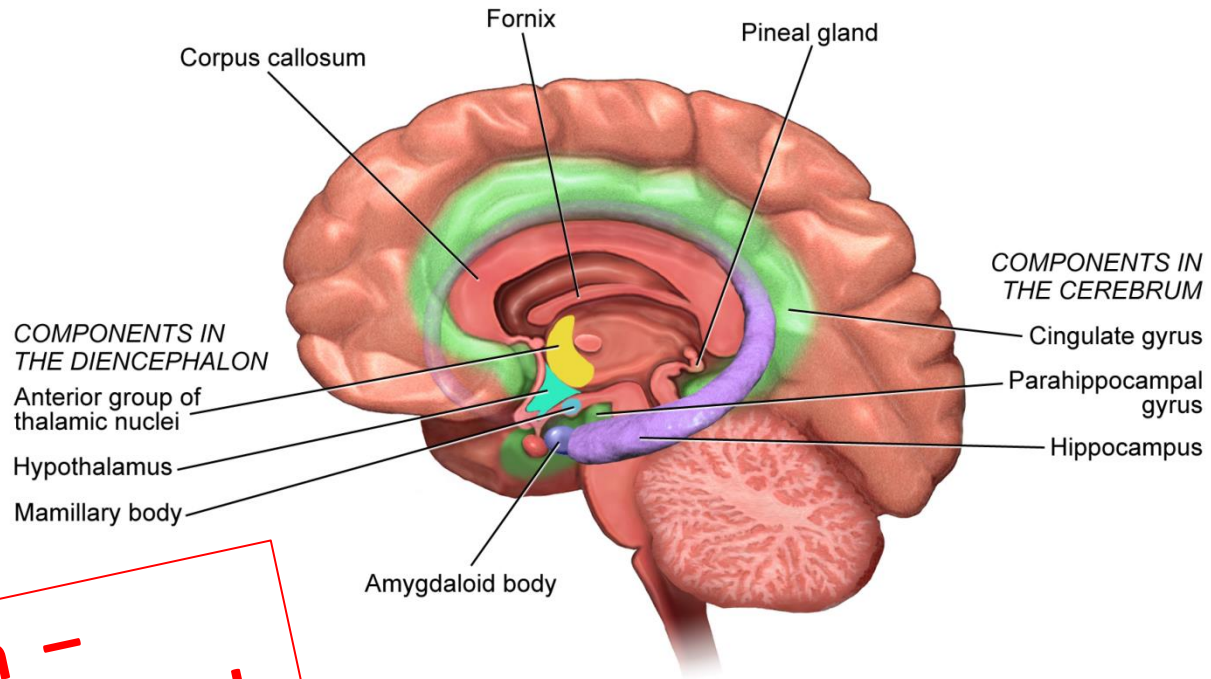
- Voluntary

↑ Modulation

Limbic system

↓ Control

- Automatic



Limbic system – hypothalamus and related structures

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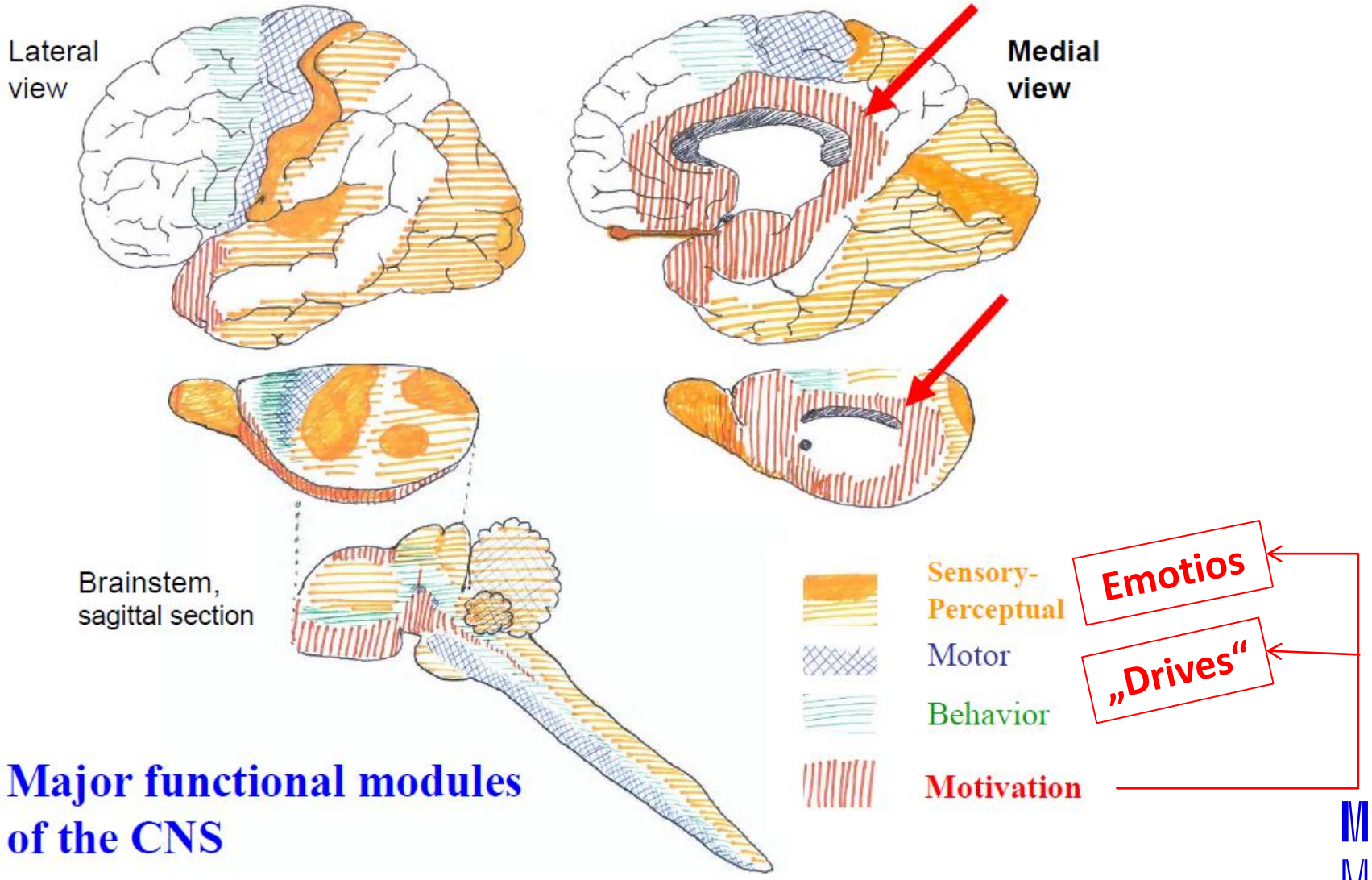
Limbic system

Limbus = border



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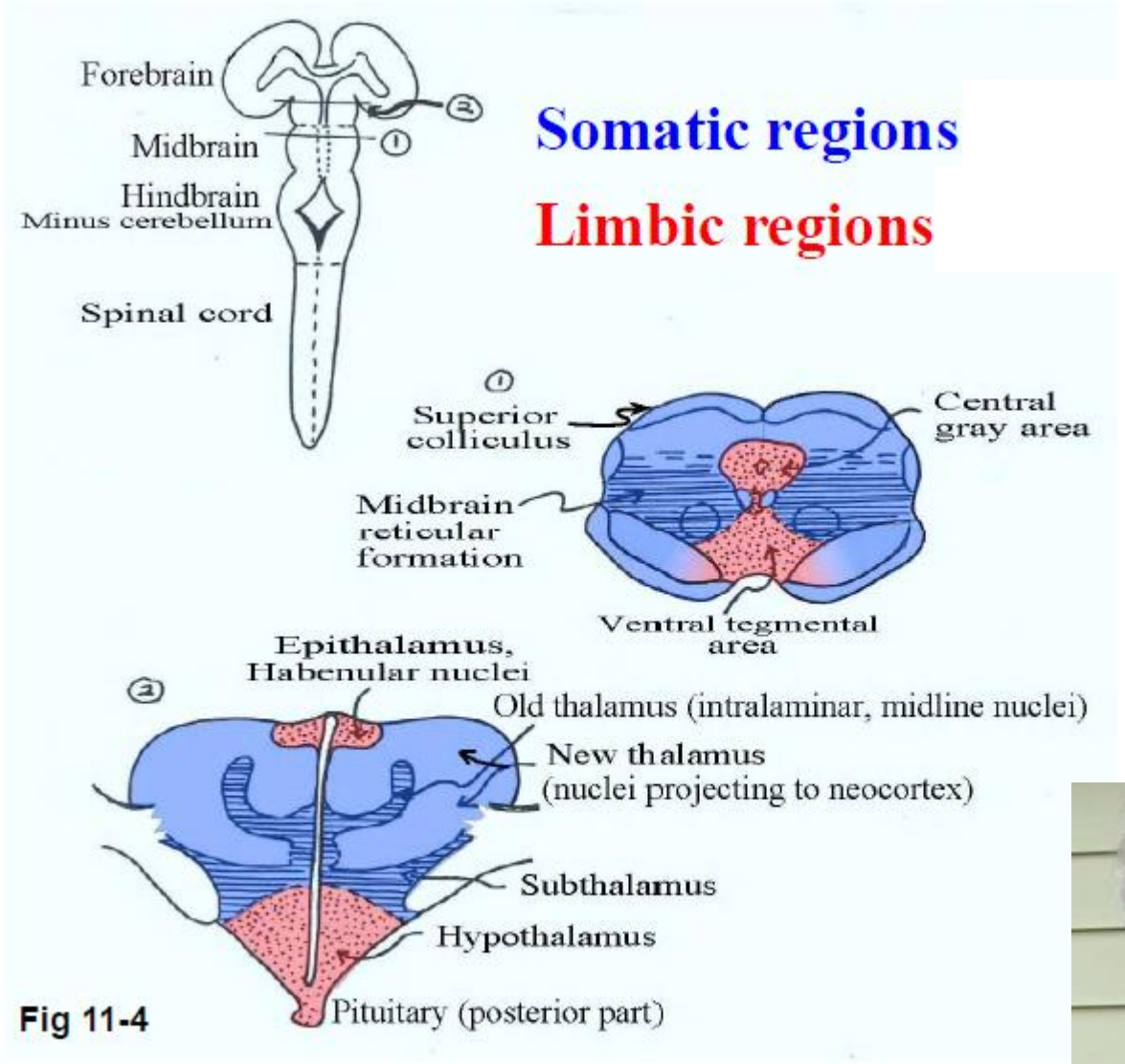

Prof. Gerald Schneider

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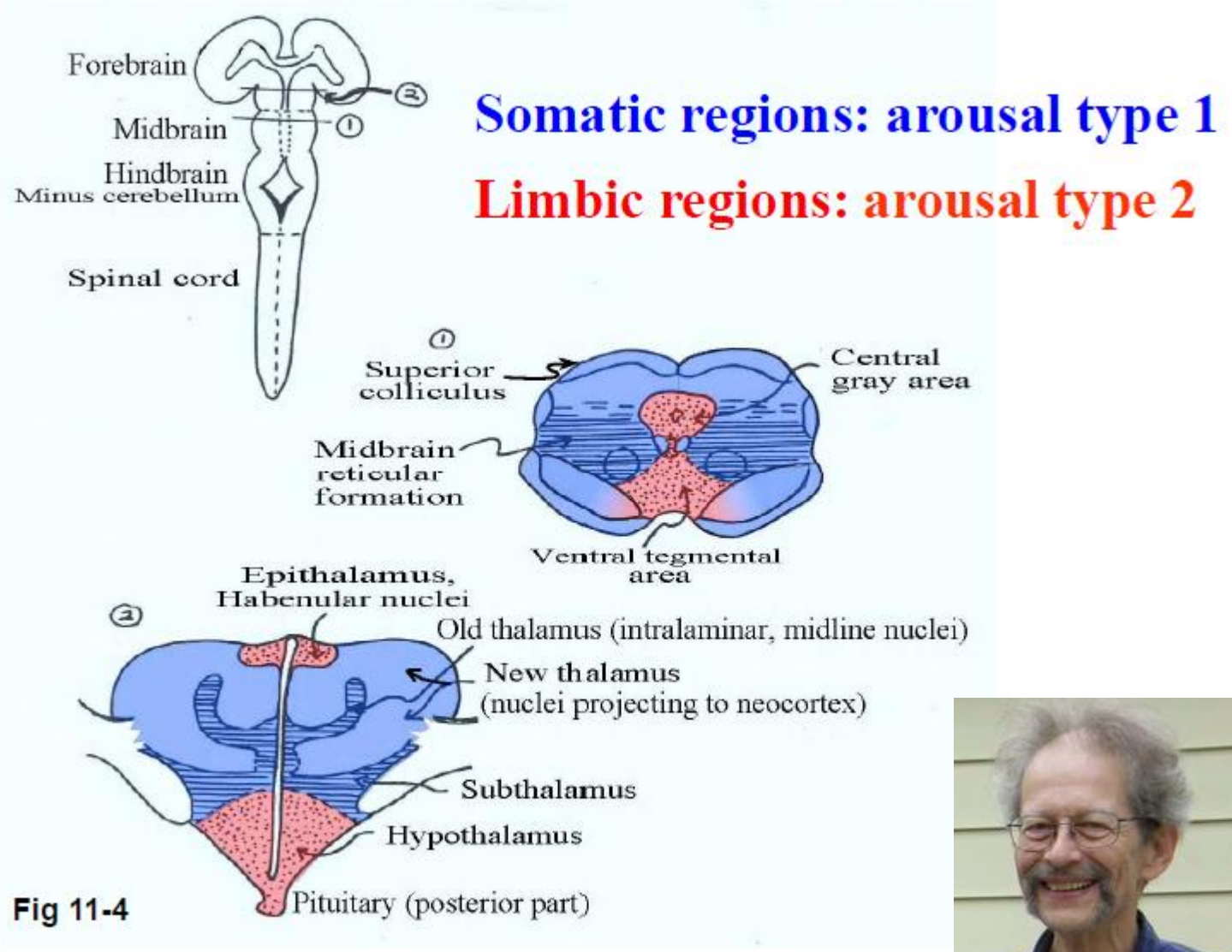

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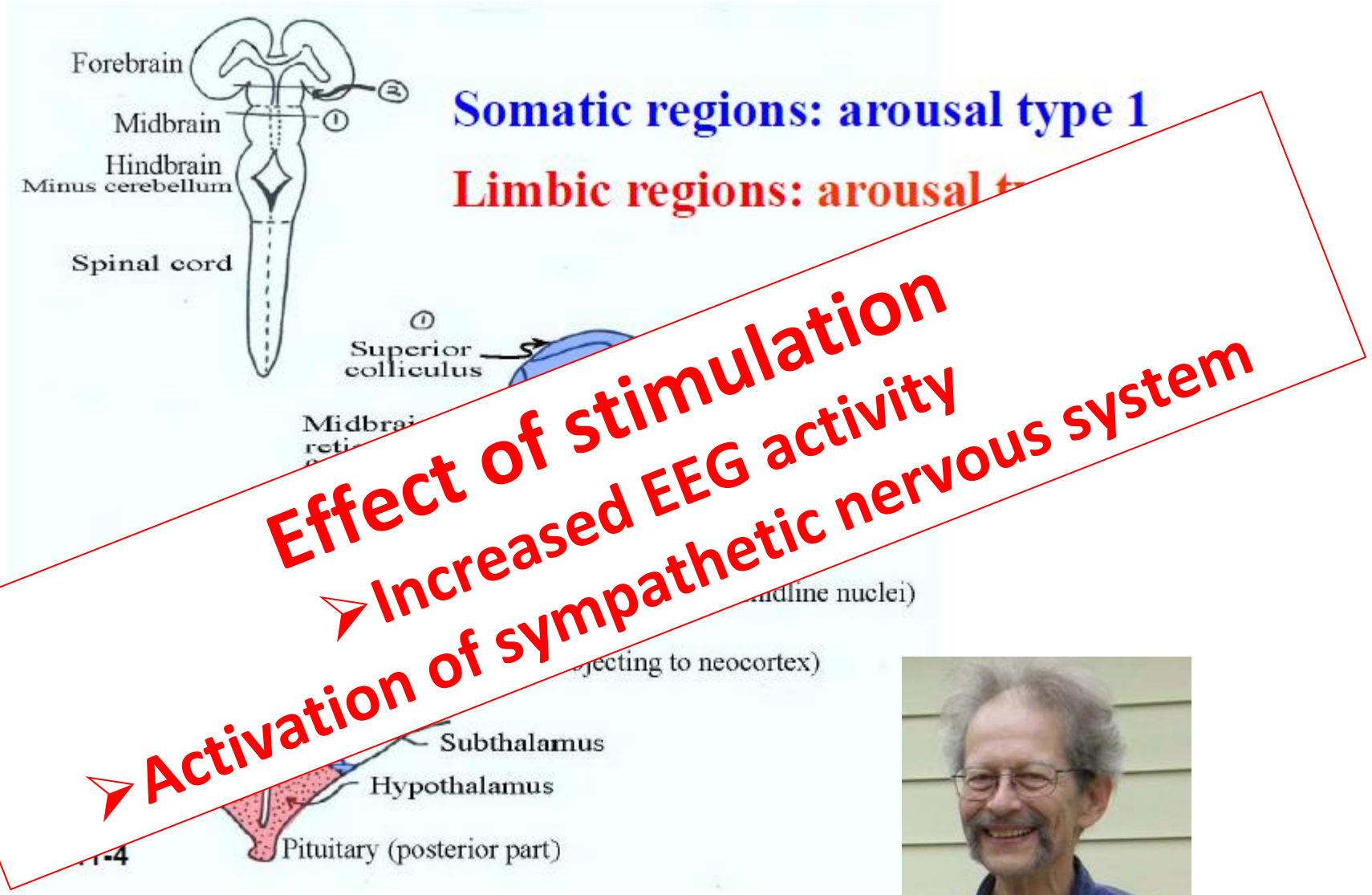

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Arousal type 1 (somatic)

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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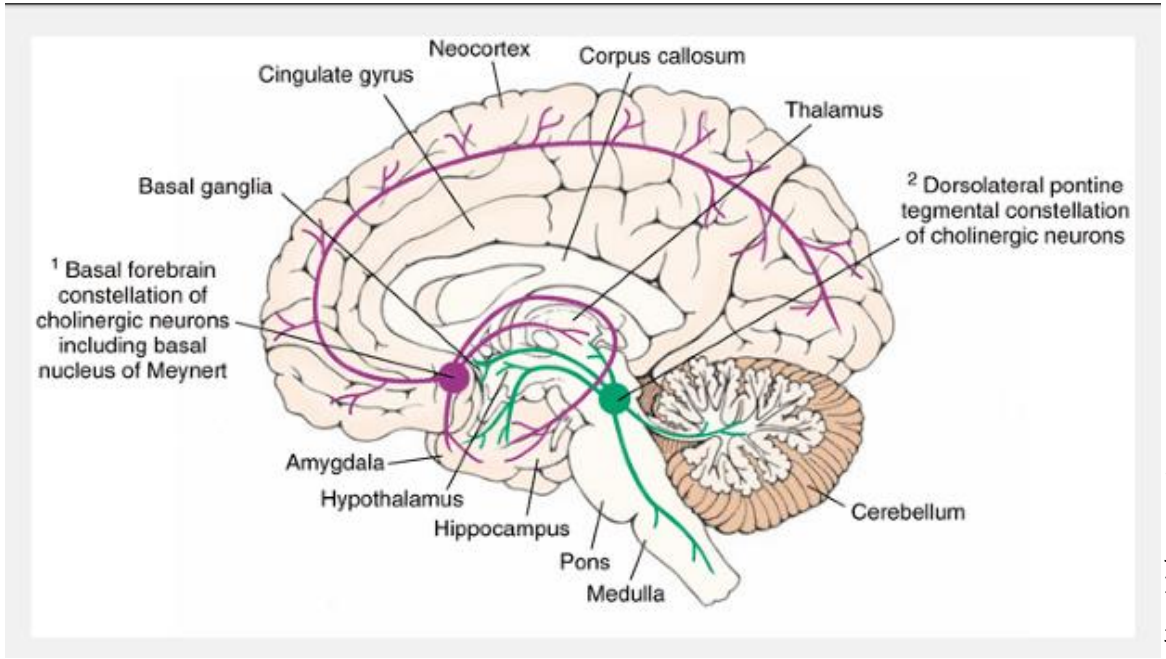
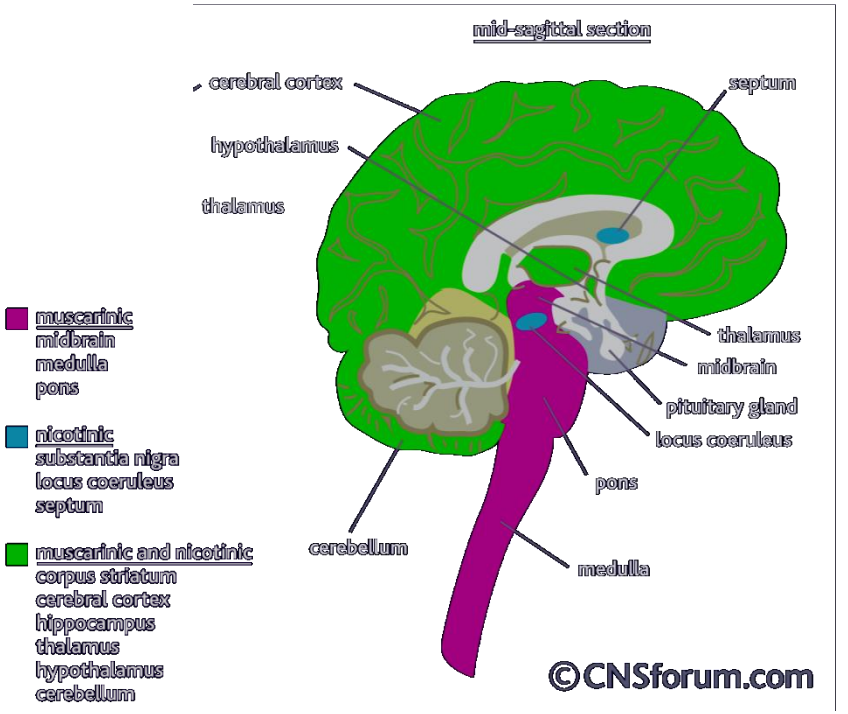
Acetylcholine

- 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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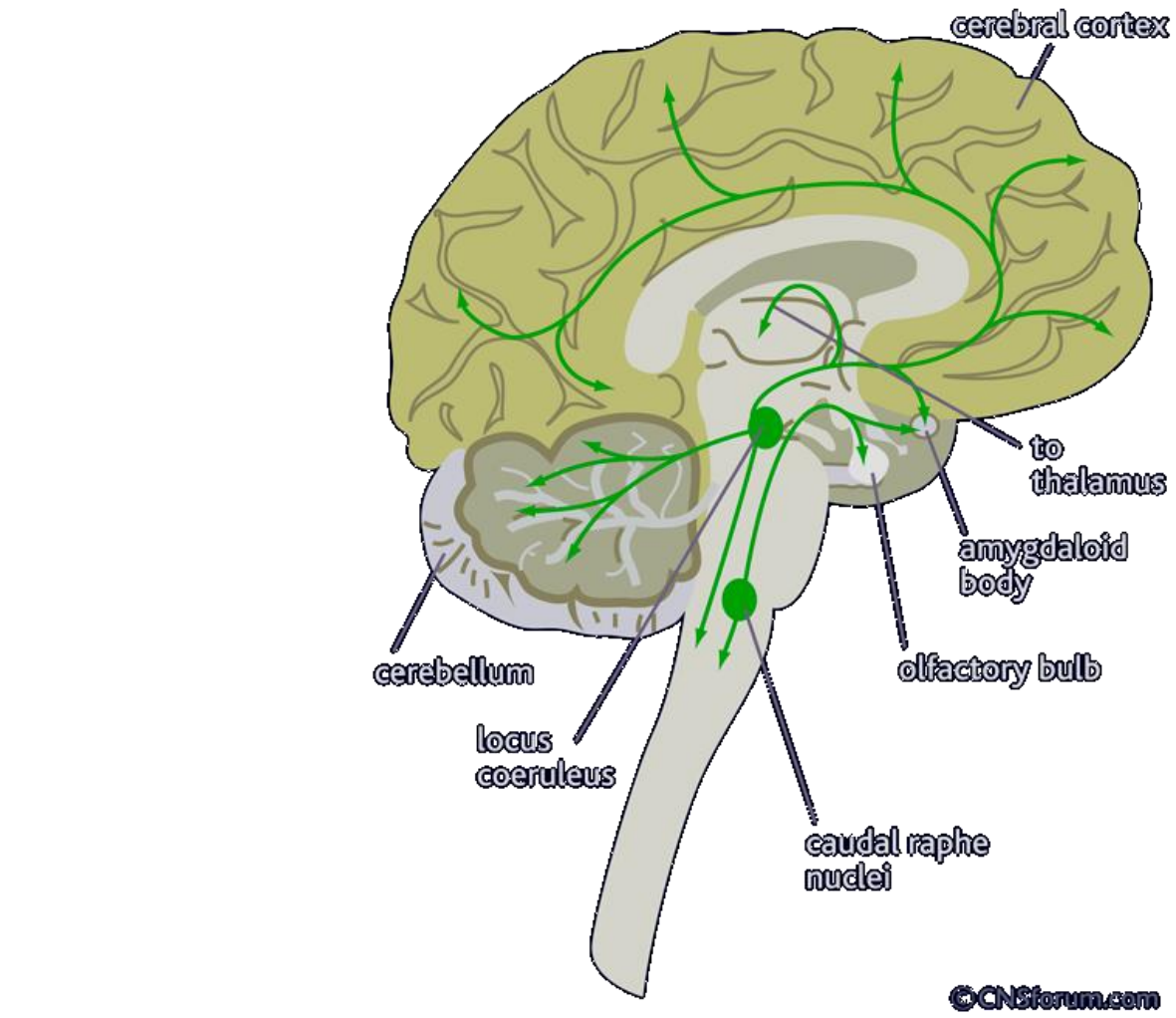
Norepinefrine

- Locus coeruleus
- Nuclei raphe caudalis

- Vigilance
- Responsiveness to unexpected stimuli
- Memory
- Learning



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

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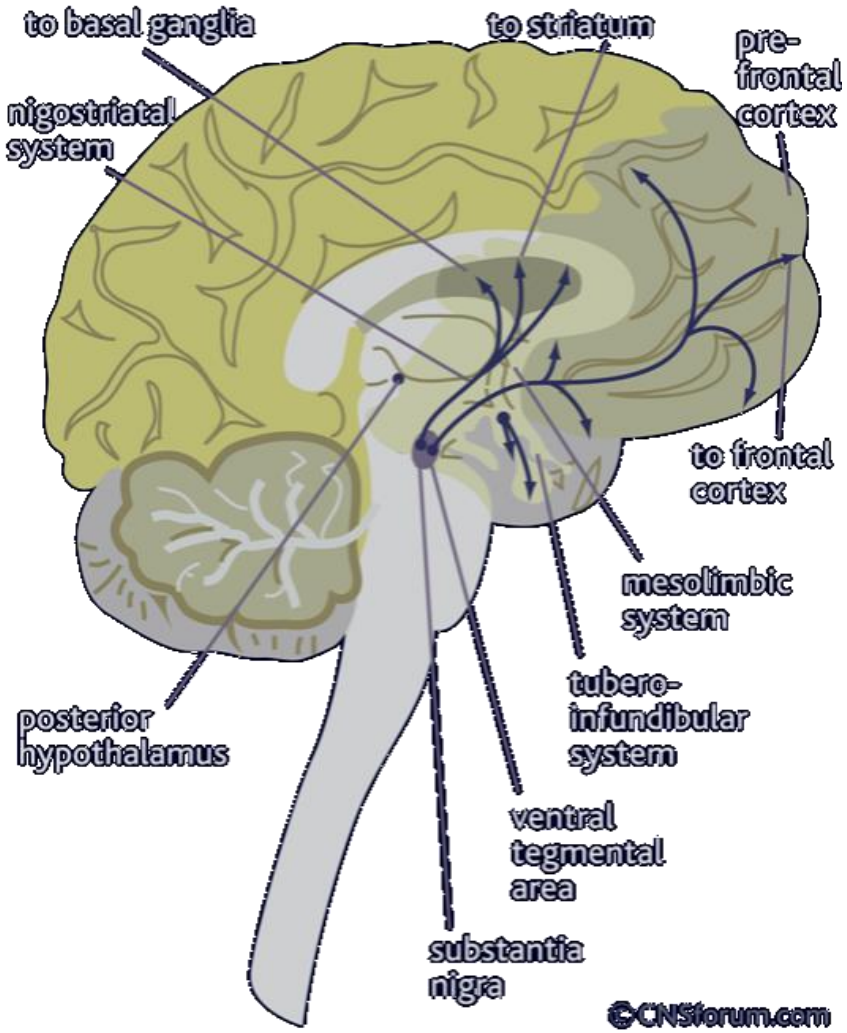
Dopamine

- 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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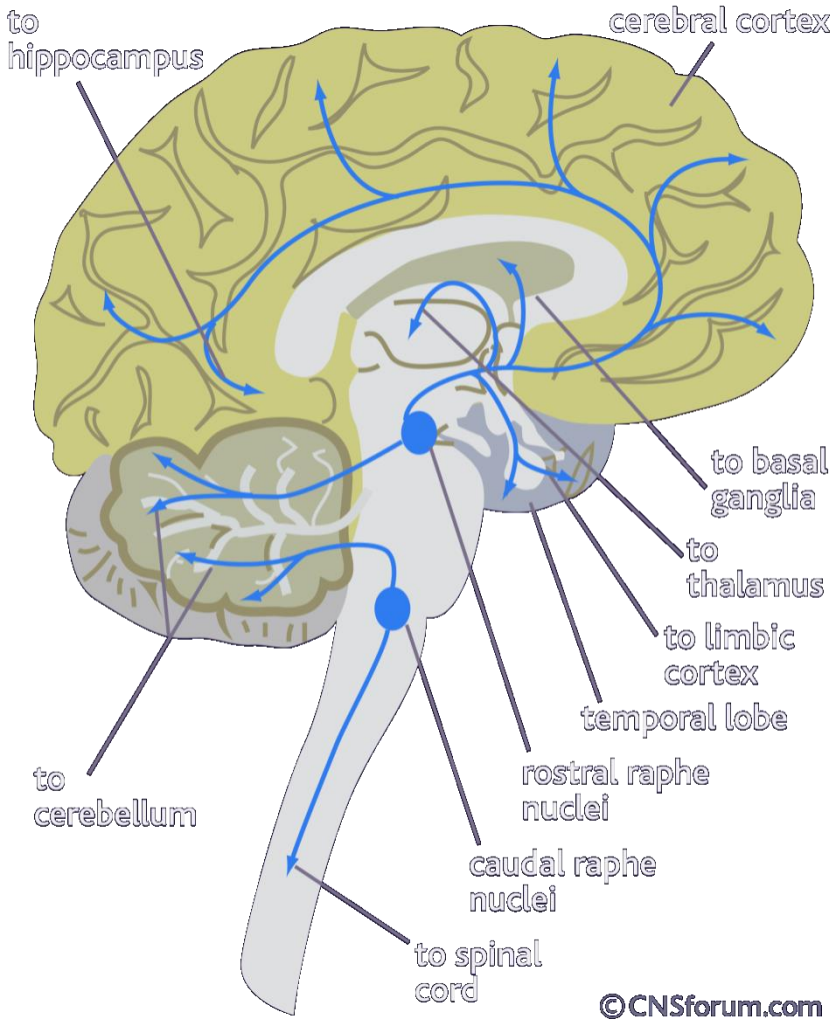
Serotonin

- Nuclei raphe rostralis
- Nuclei raphe caudalis

- Anxiety/relaxation
- Impulsive behavior
- Sleep



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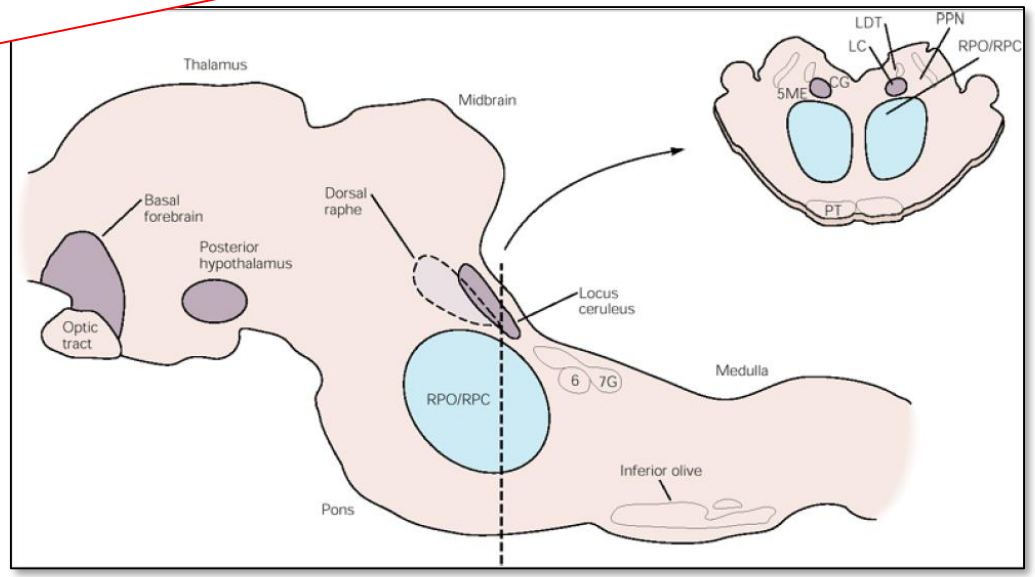
Sleep and wakefulness

Cooperation of ARAS and limbic activating system



RPO/RPC – nucleus reticularis pontis oralis/caudalis

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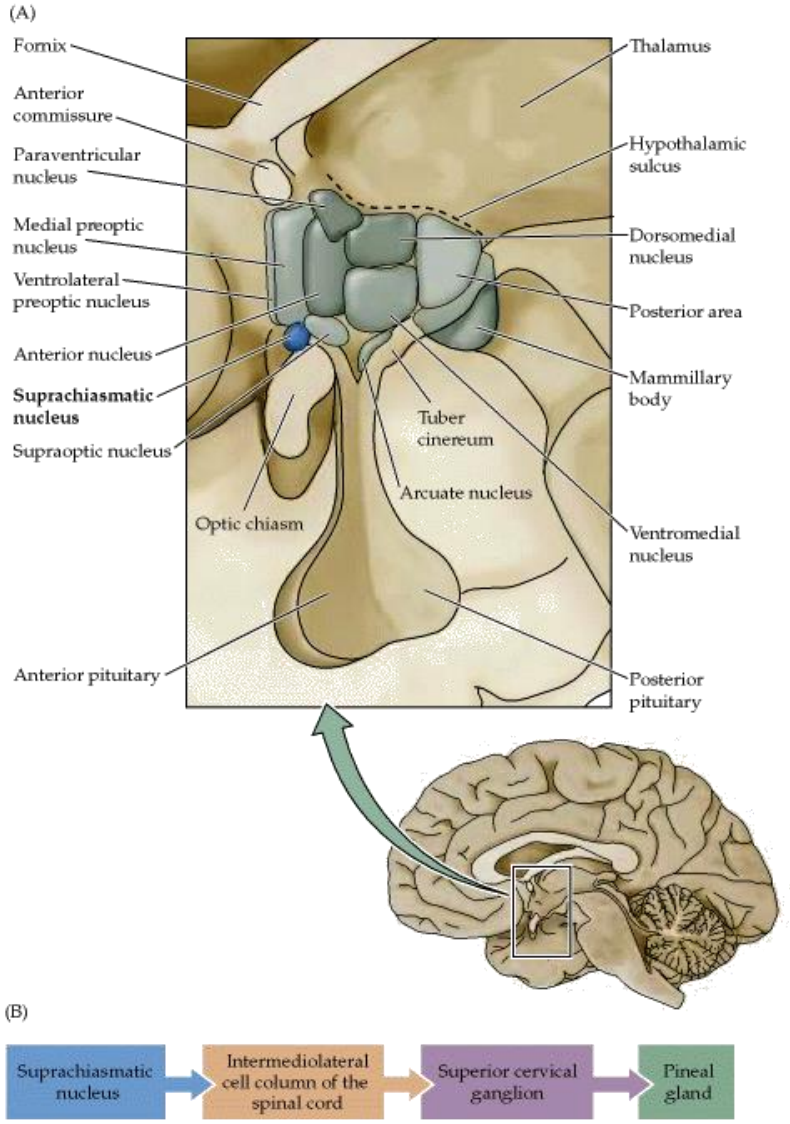

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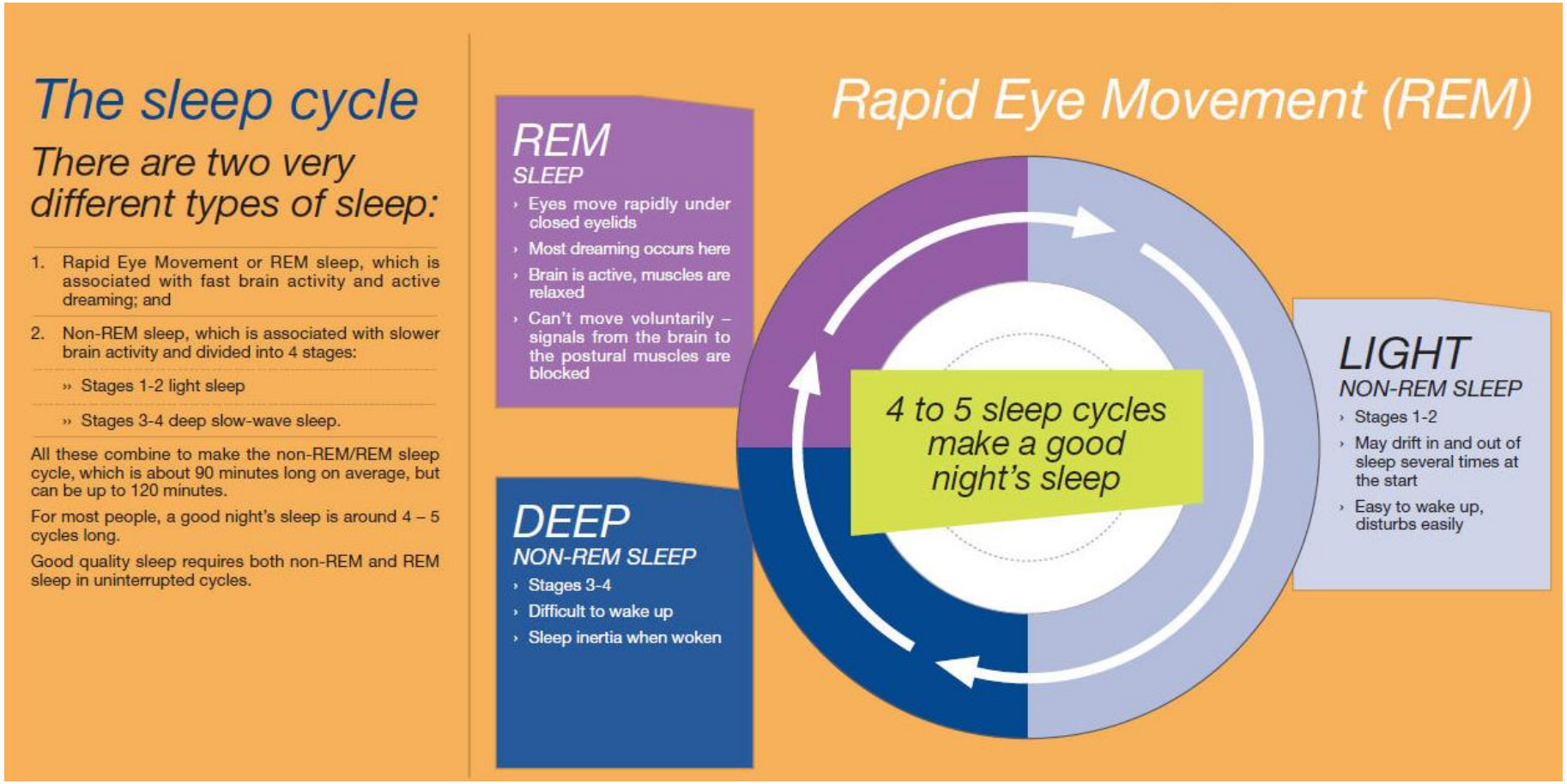
Sleep



http://anchortime.com/portal/images/stories/MNZ_sleep_cycles_1.jpg

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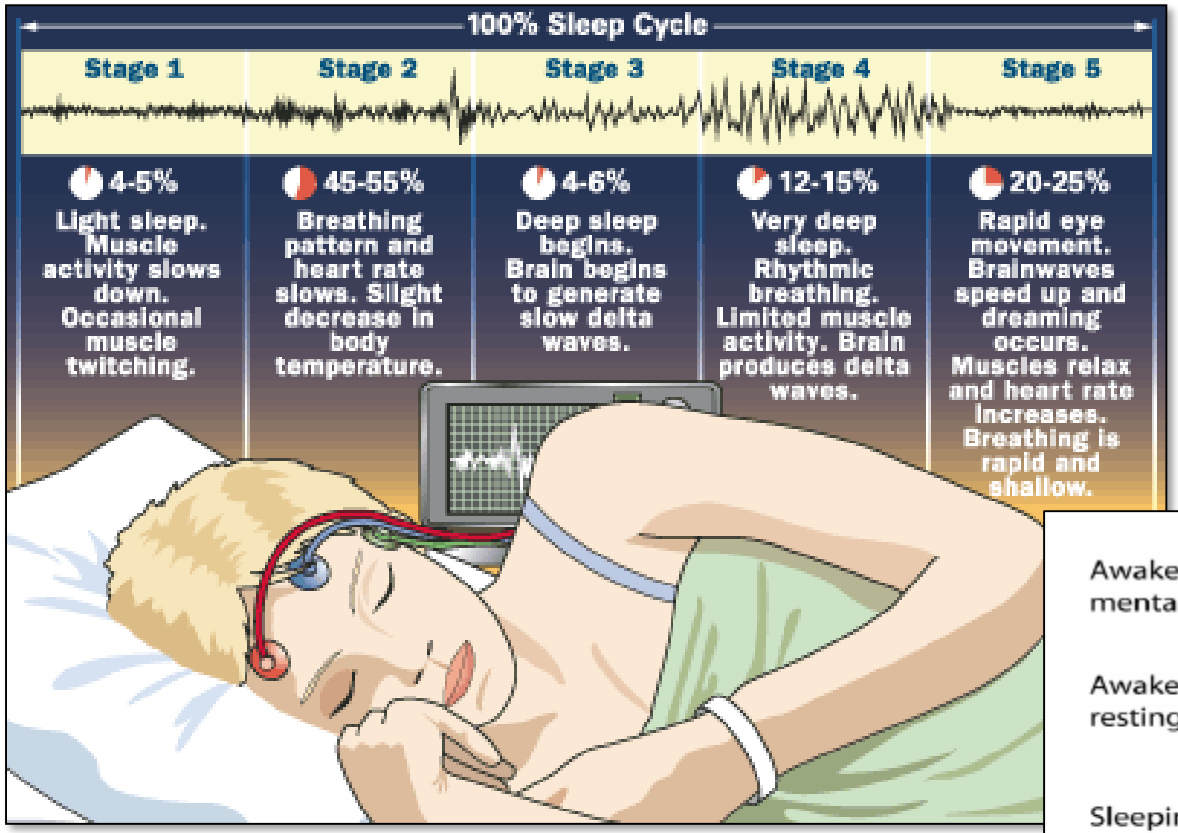
Sleep



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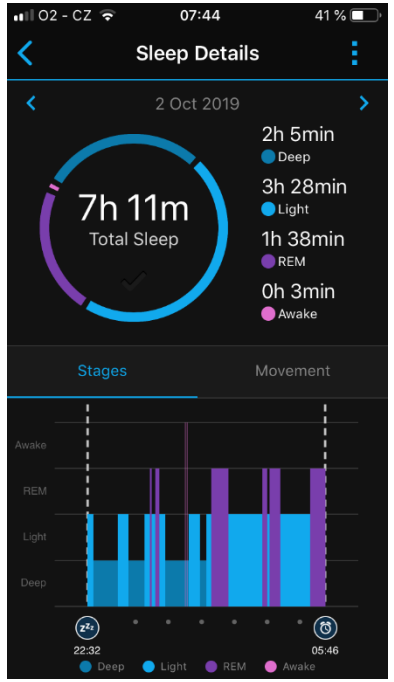
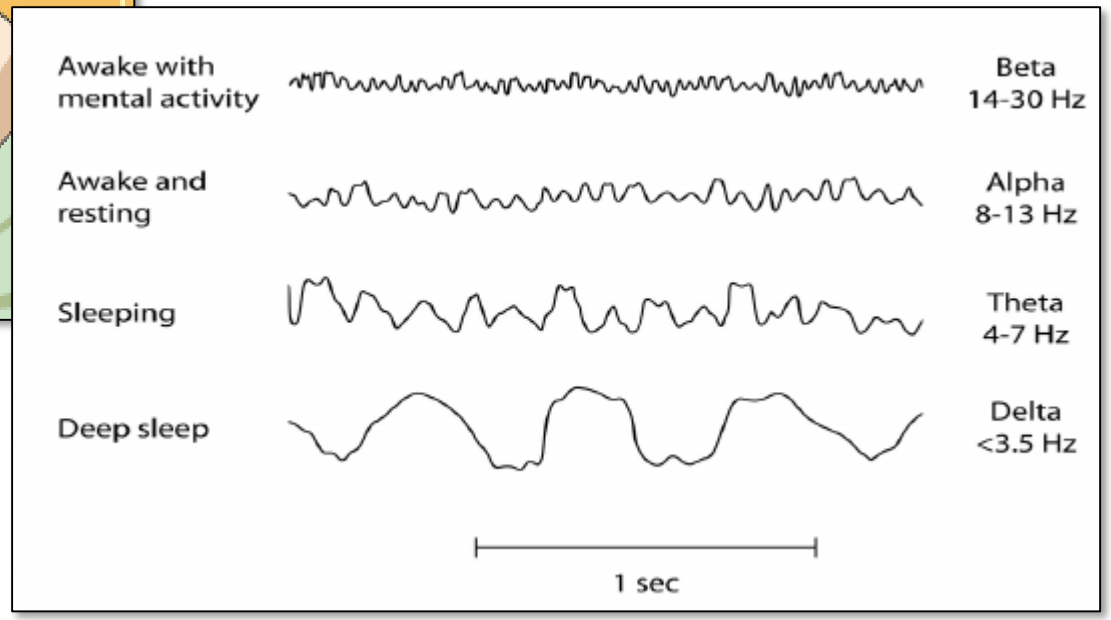


https://connect.garmin.com/modern/

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

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

DEEP
NON-REM SLEEP
- Stages 3-4
- Difficult to wake up
- Sleep inertia when woken

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

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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

Hypothalamus

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

↓

- Behavioral modulation
- Regulation of autonomic nervous system

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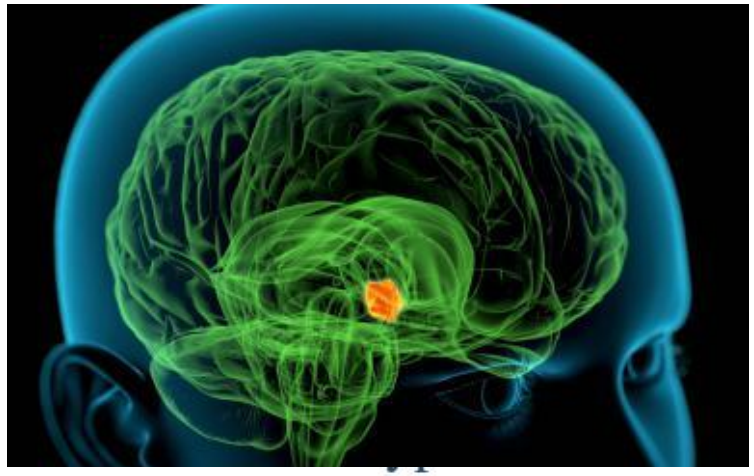
- **Maintenance of homeostasis**



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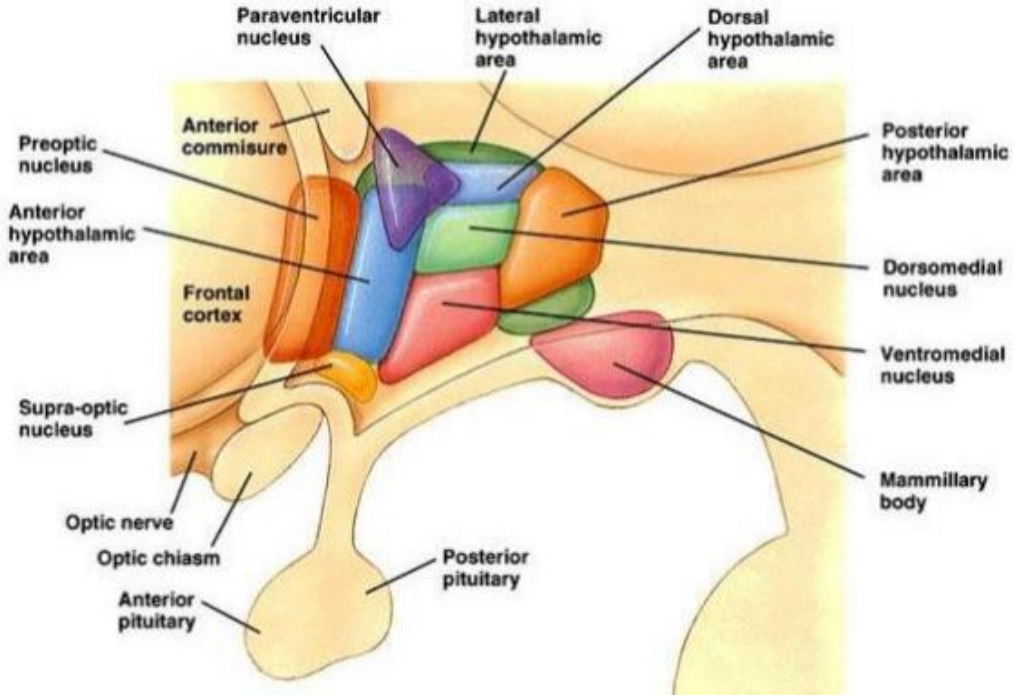

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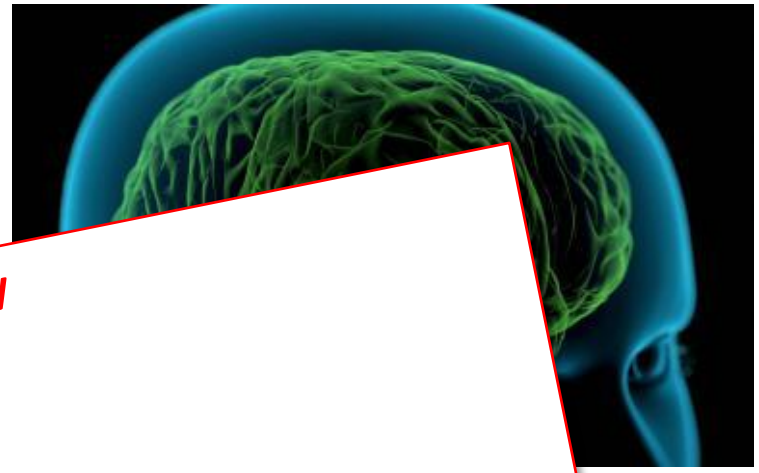

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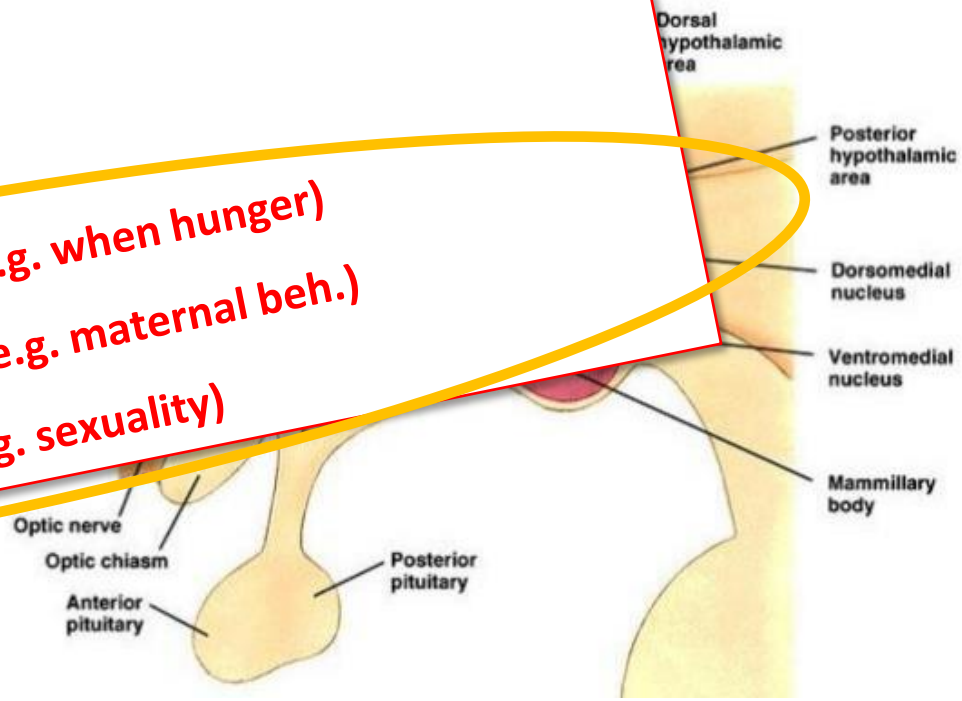

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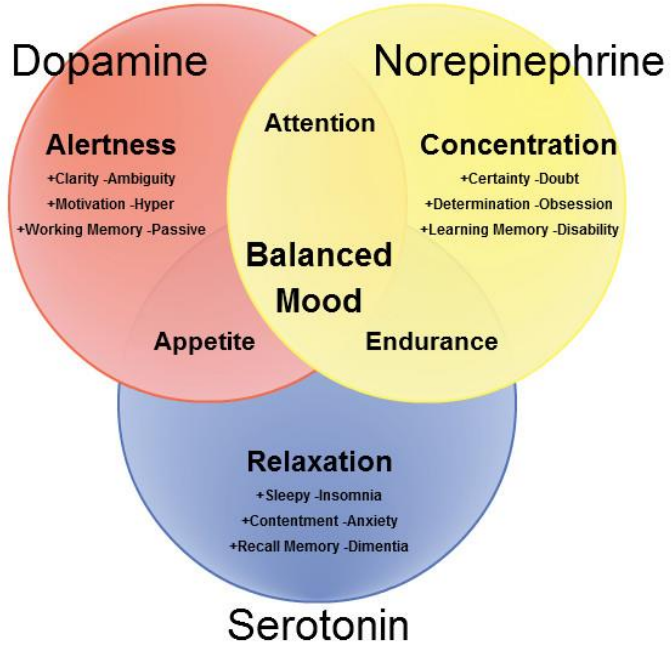
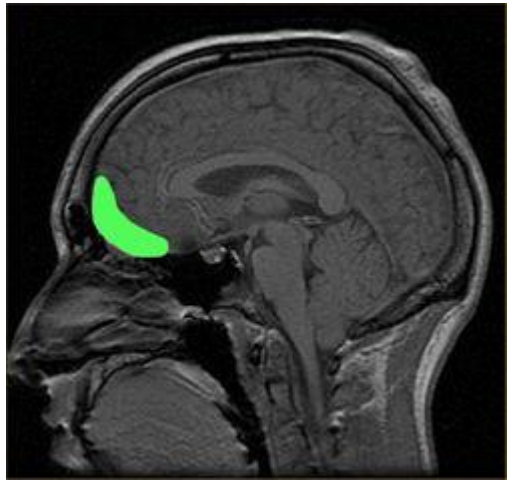
Influence of hypothalamus on neocortex

- 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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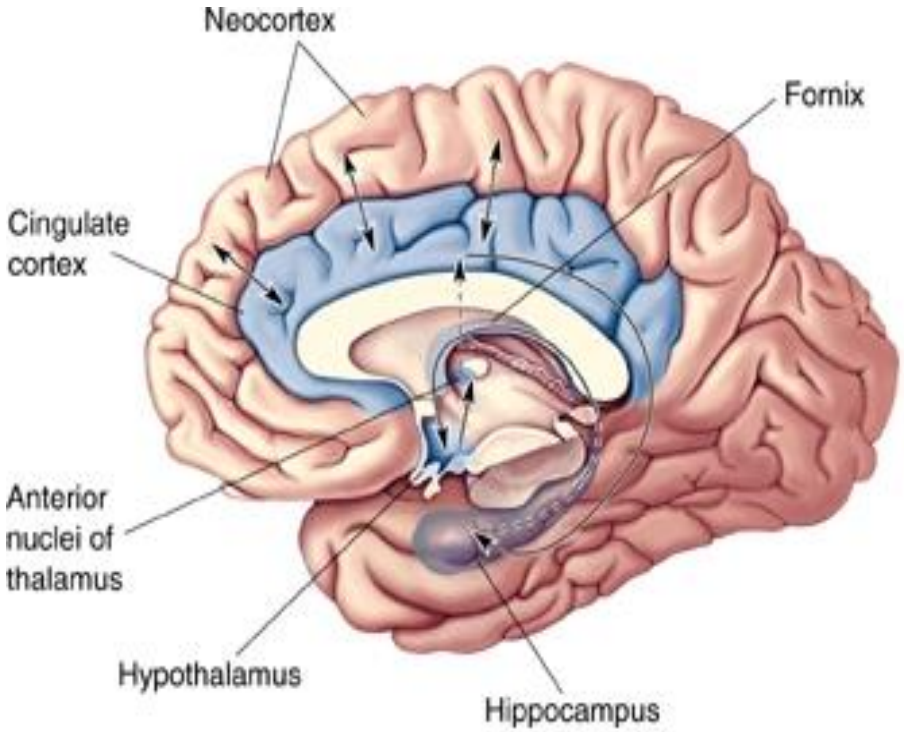
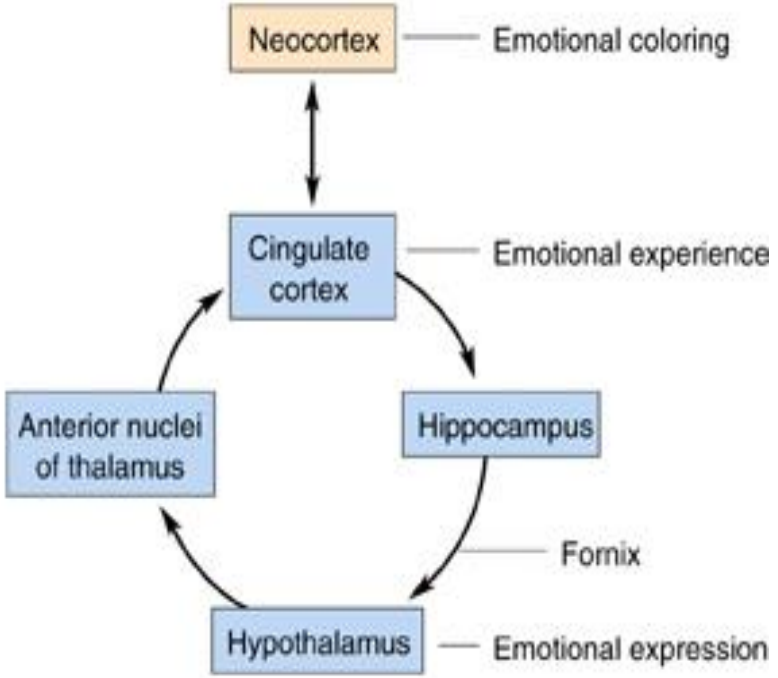
Papez circuit





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

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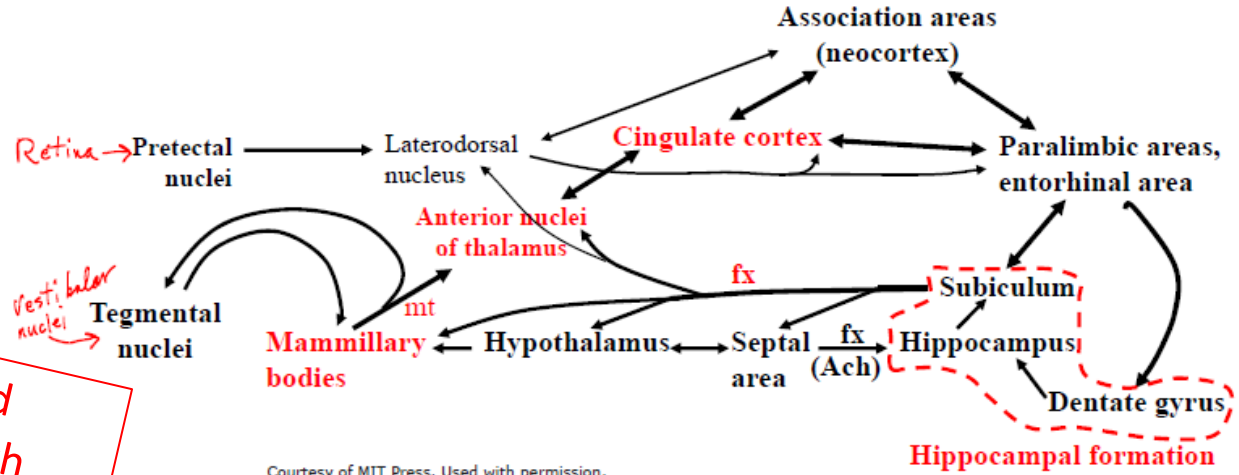
Papez circuit

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



Spatial orientation and emotions associated with particular place

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Papez circuit

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**
     - **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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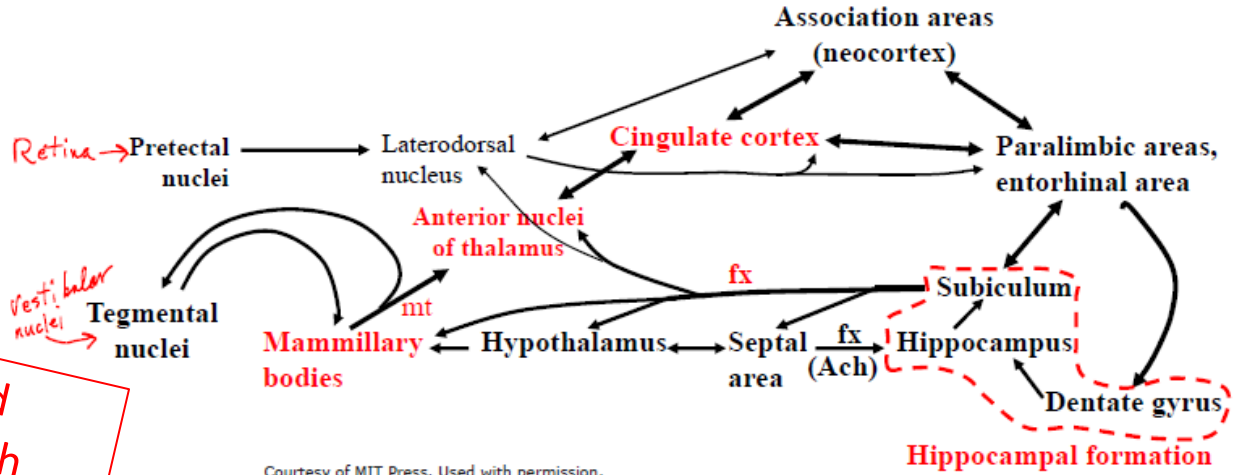

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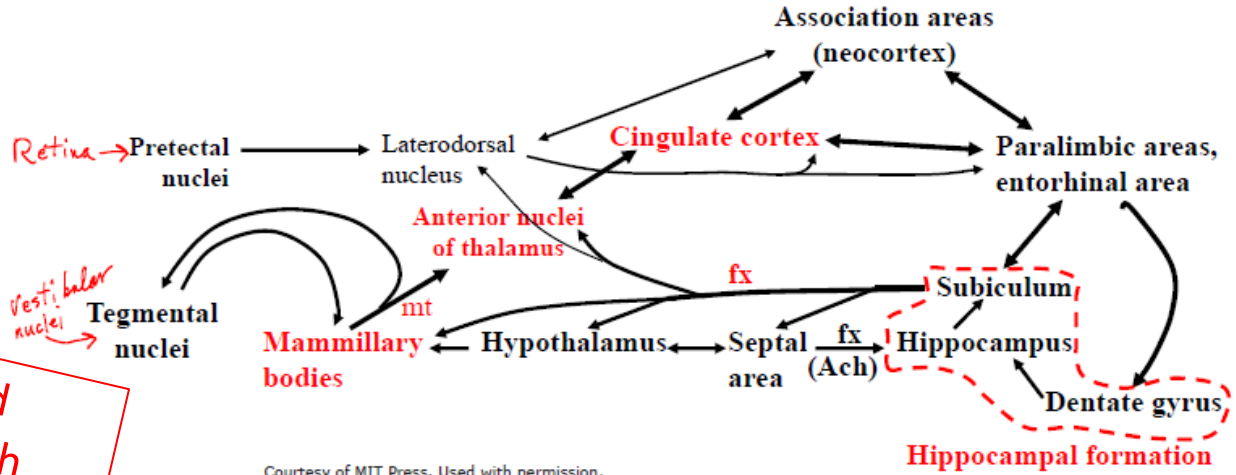
     - **The links were plastic, but the "habits" formed were different: The association of place with good or bad consequences of approach.**

Object oriented...

Location oriented...

mt = mammillothalamic tract
fx = fornix bundle



Spatial orientation and emotions associated with particular place

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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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Learning and memory

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

- 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

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

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

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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?

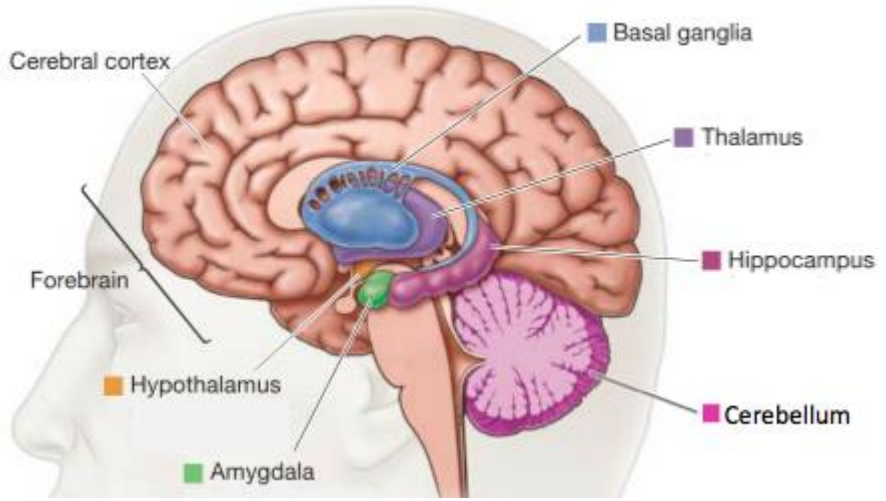
Amygdala

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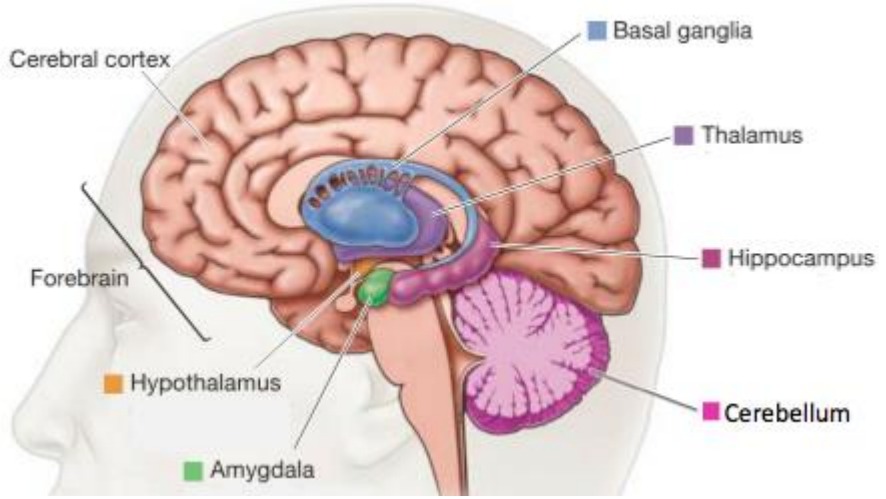
- Connections to all major cortical and subcortica lstructures
- Modiffied corpus striatum
- Plasticity – memory formation
- „Influence of information from outer environment on limbic system“
- „Amygdala hijack“
- „Affective tags“
  - Both possitive and negative
  - Higher responsiveness to negative



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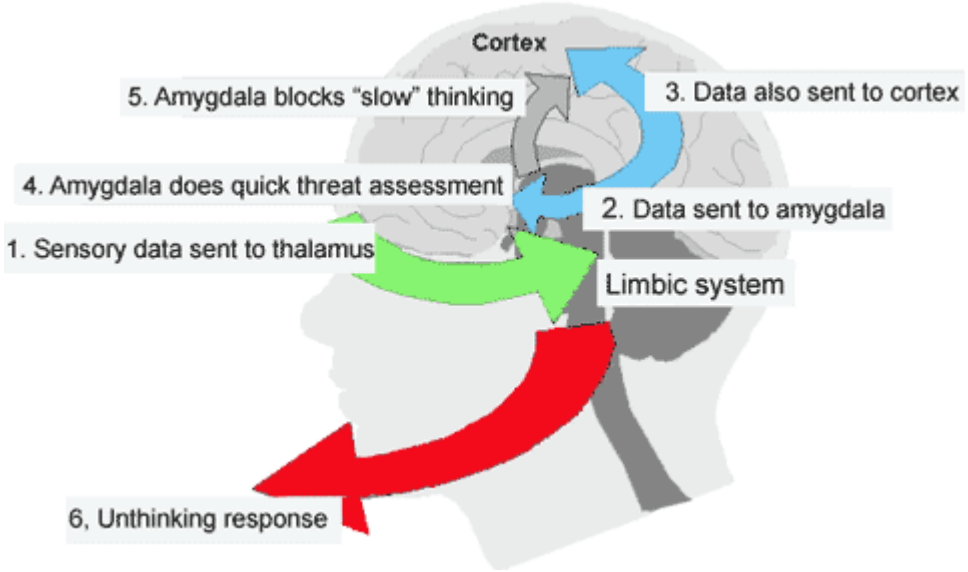

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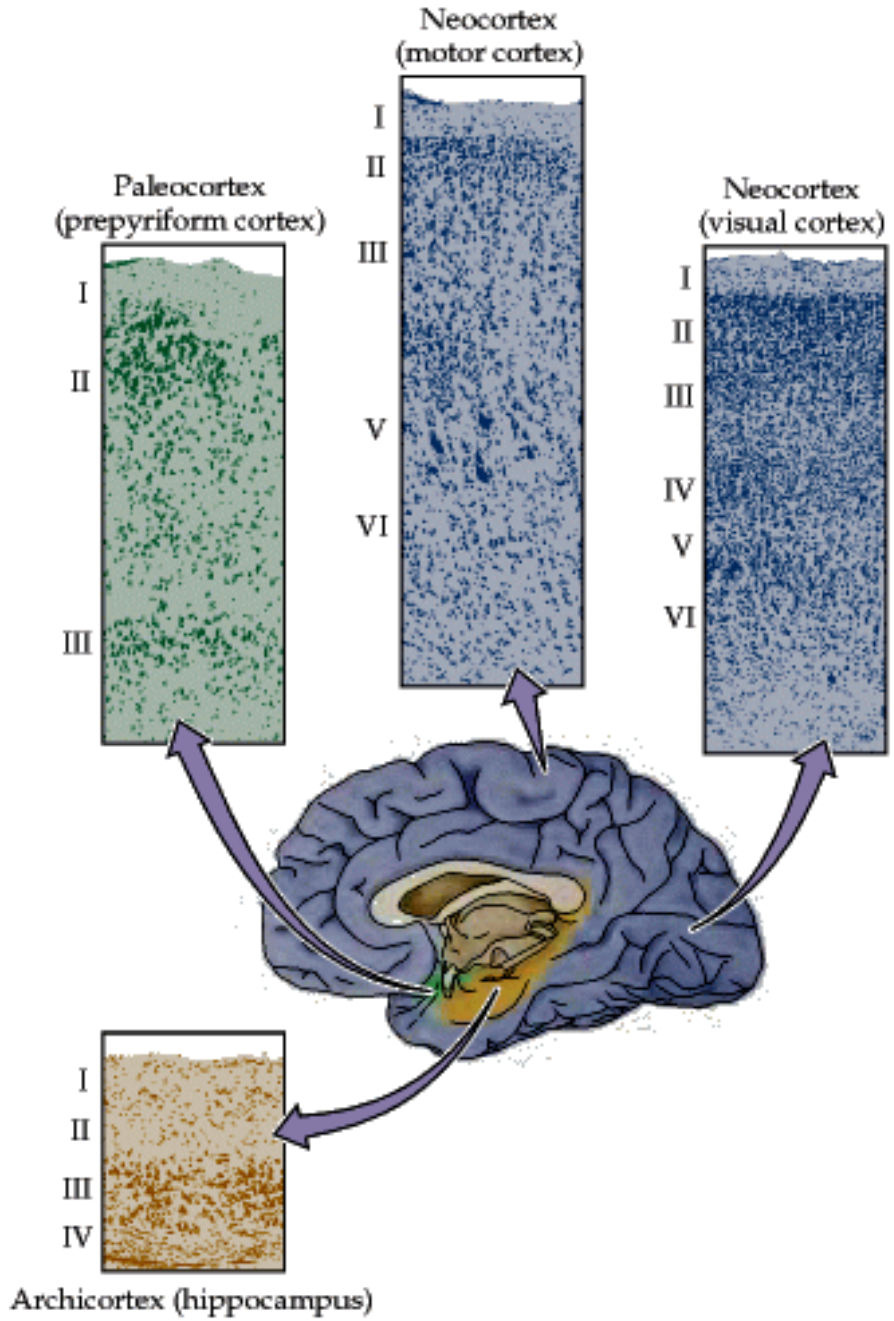
Neocortex

Cerebral cortex

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



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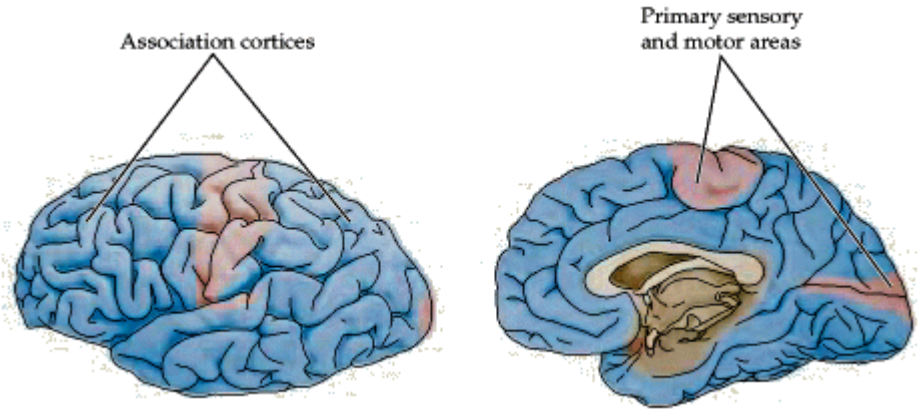
Neocortex



Primary areas

✓Somathotopic organization

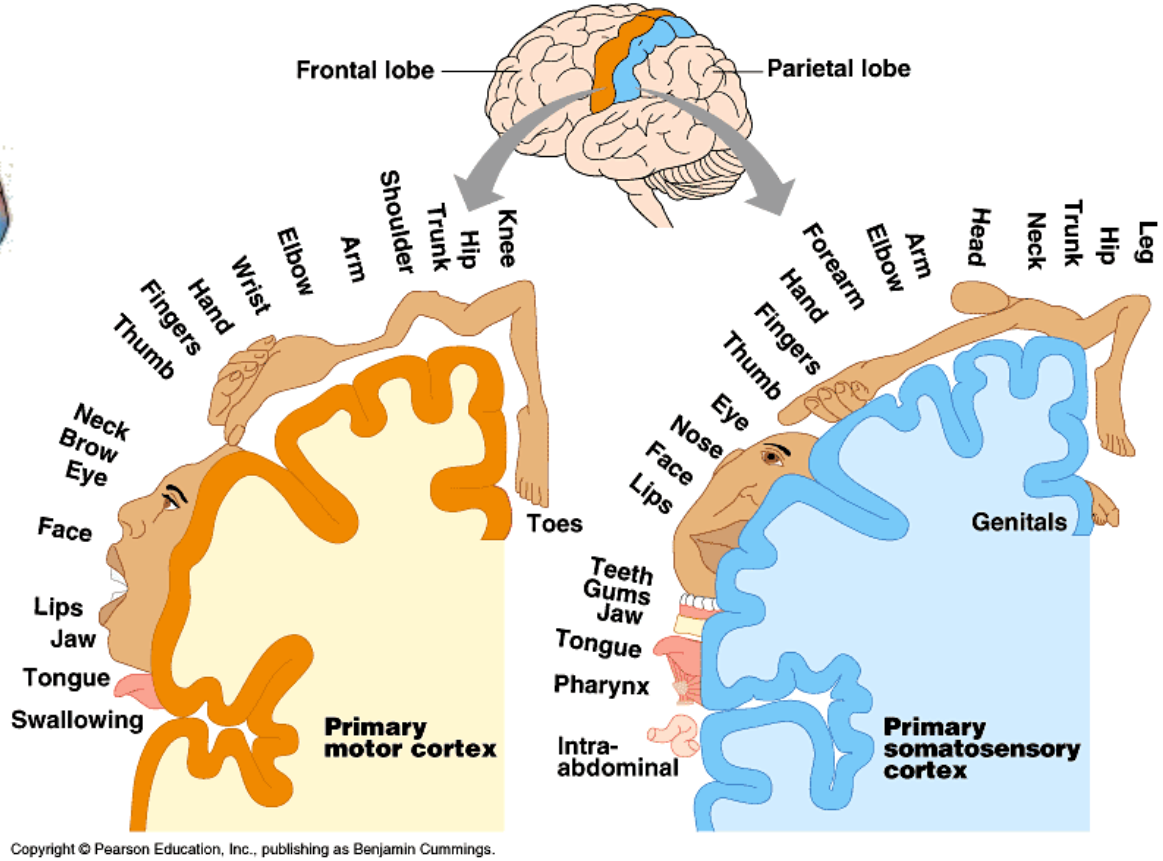
Association areas

✓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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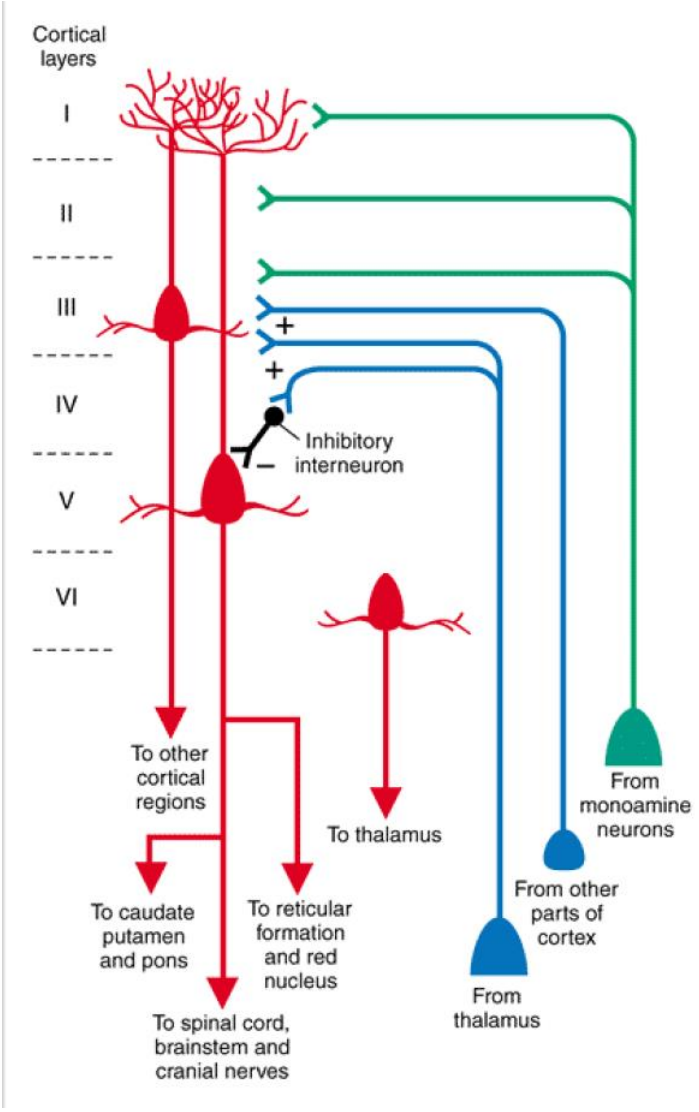
Organization of neocortex

- 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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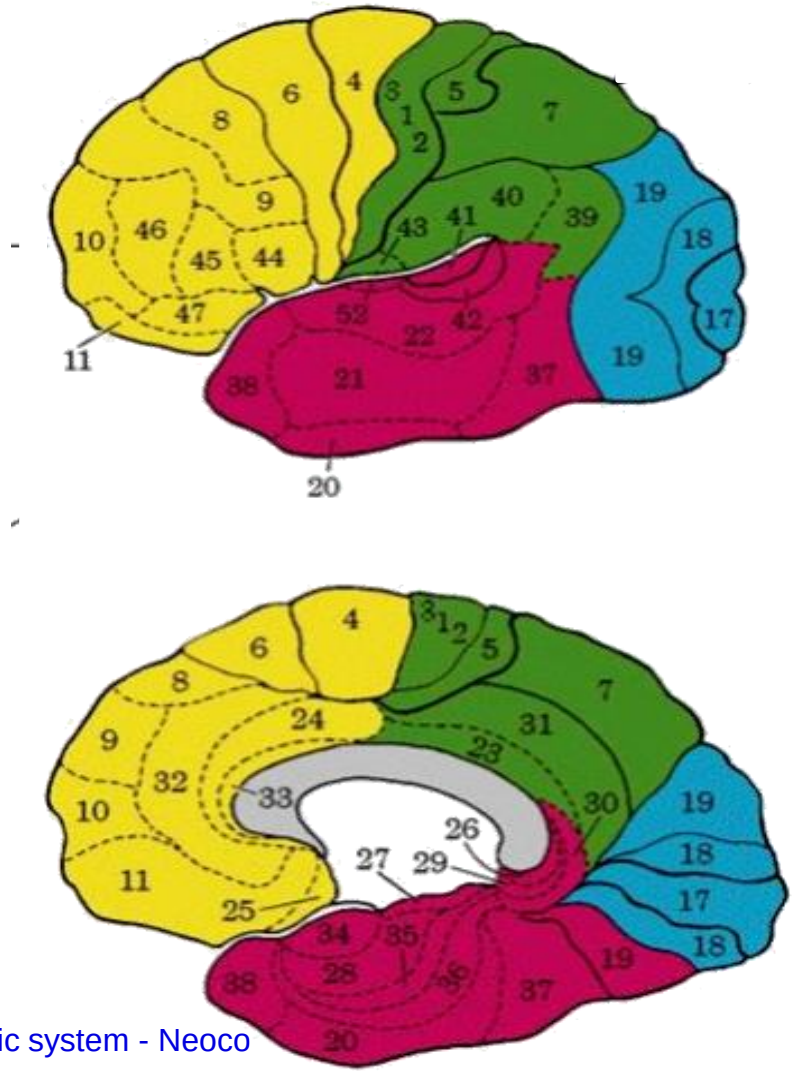
Brodman areas



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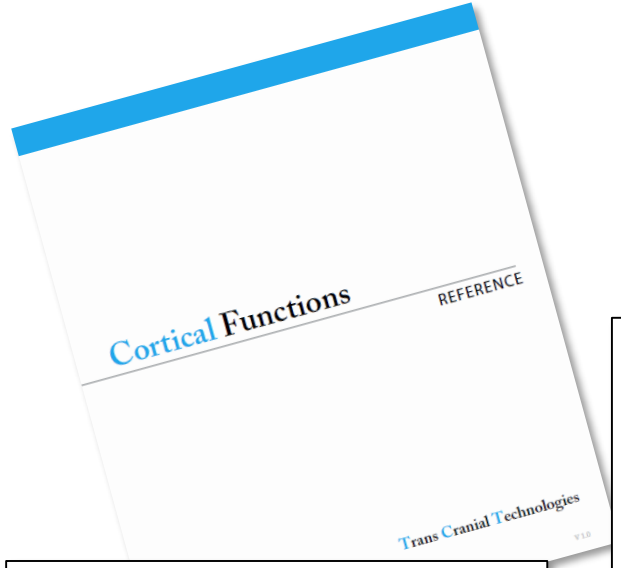
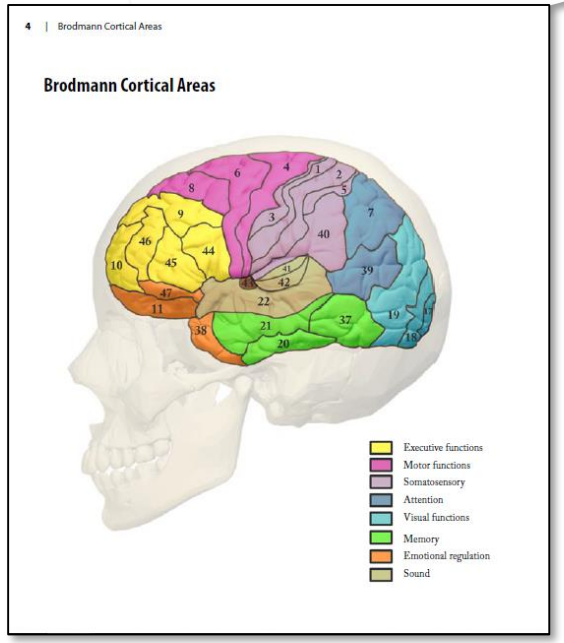
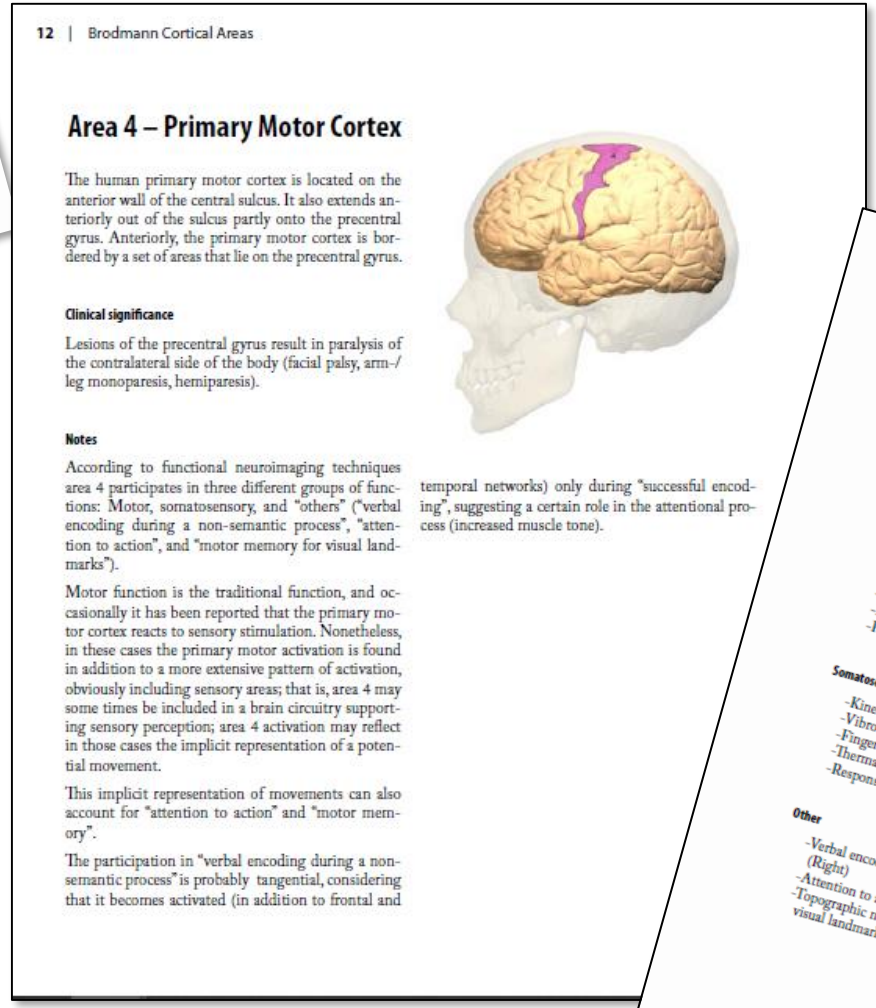
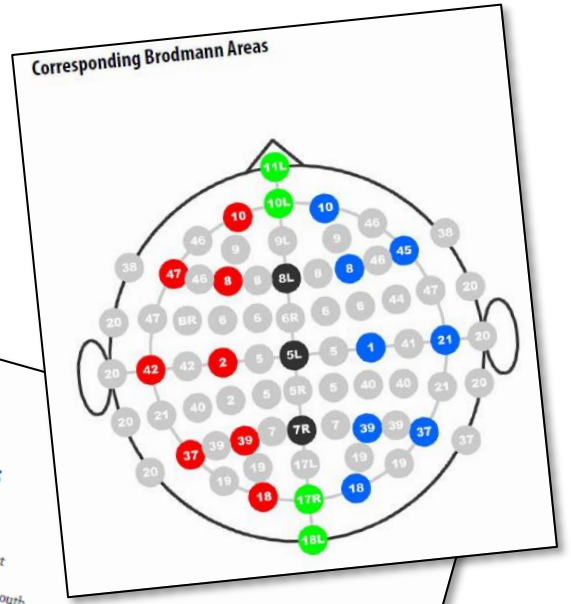
https://www.trans-cranial.com/docs/cortical_functions_ref_v1_0_pdf.pdf









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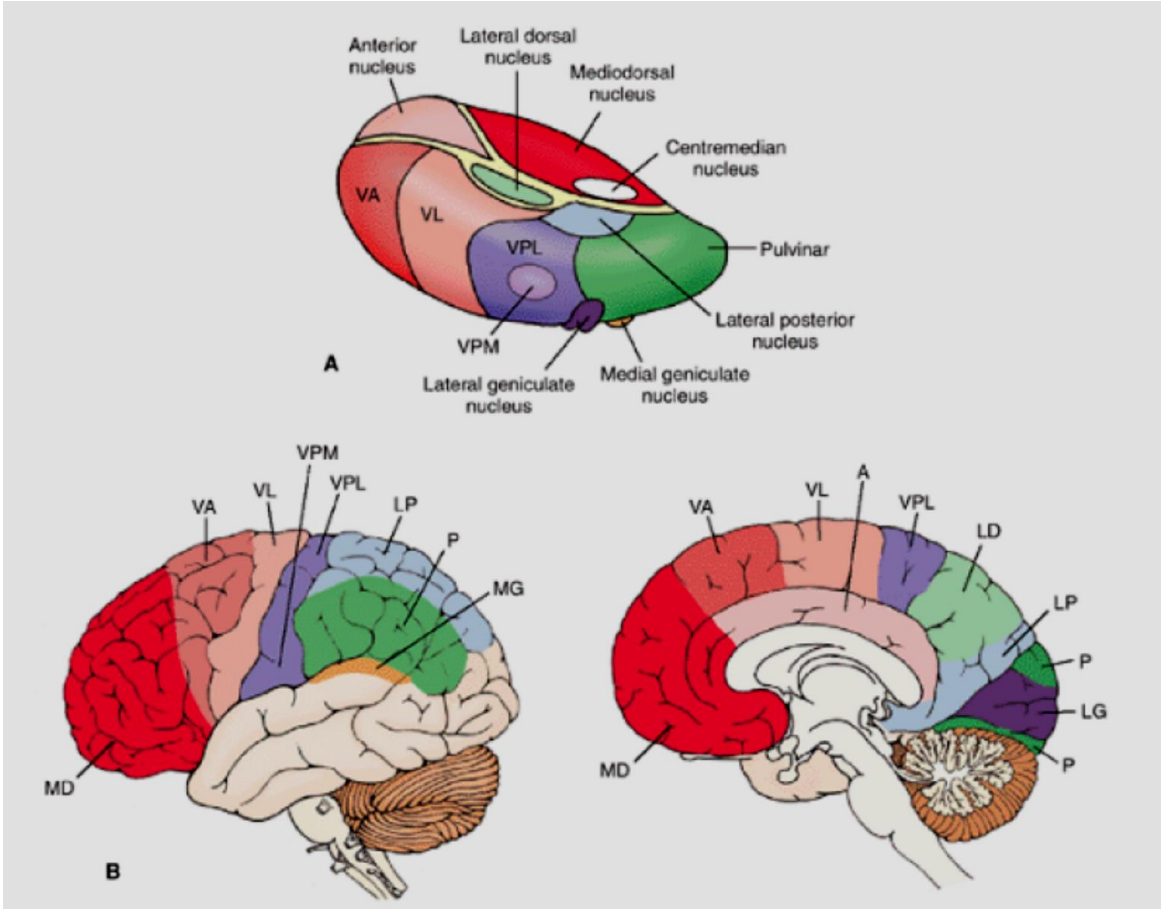
Cerebral cortex and thalamus

- 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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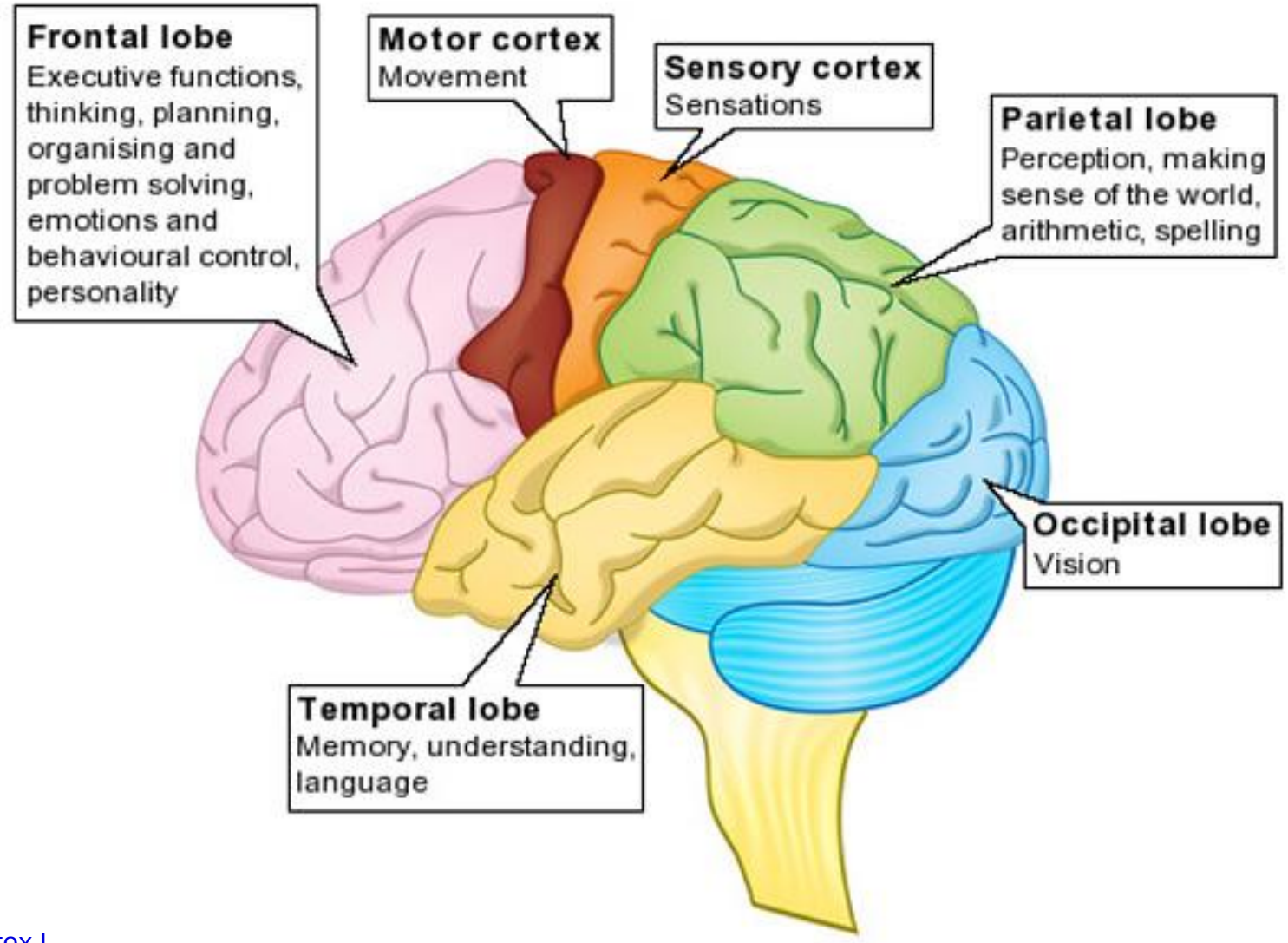
Cortical functions



http://www.modernfamilyideas.com

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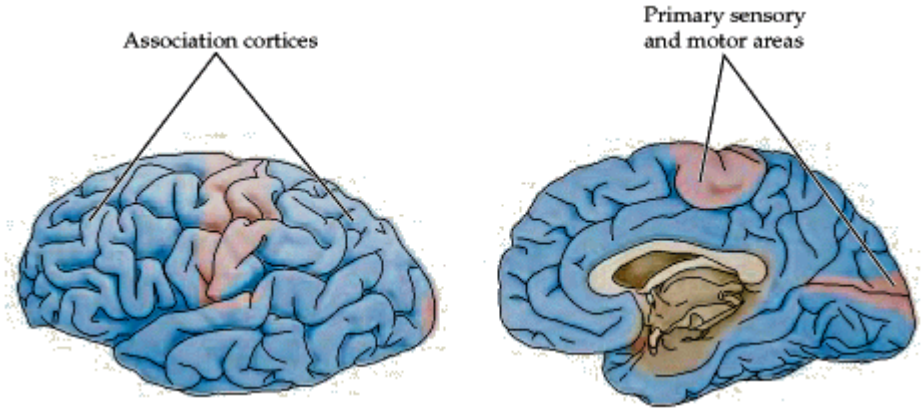
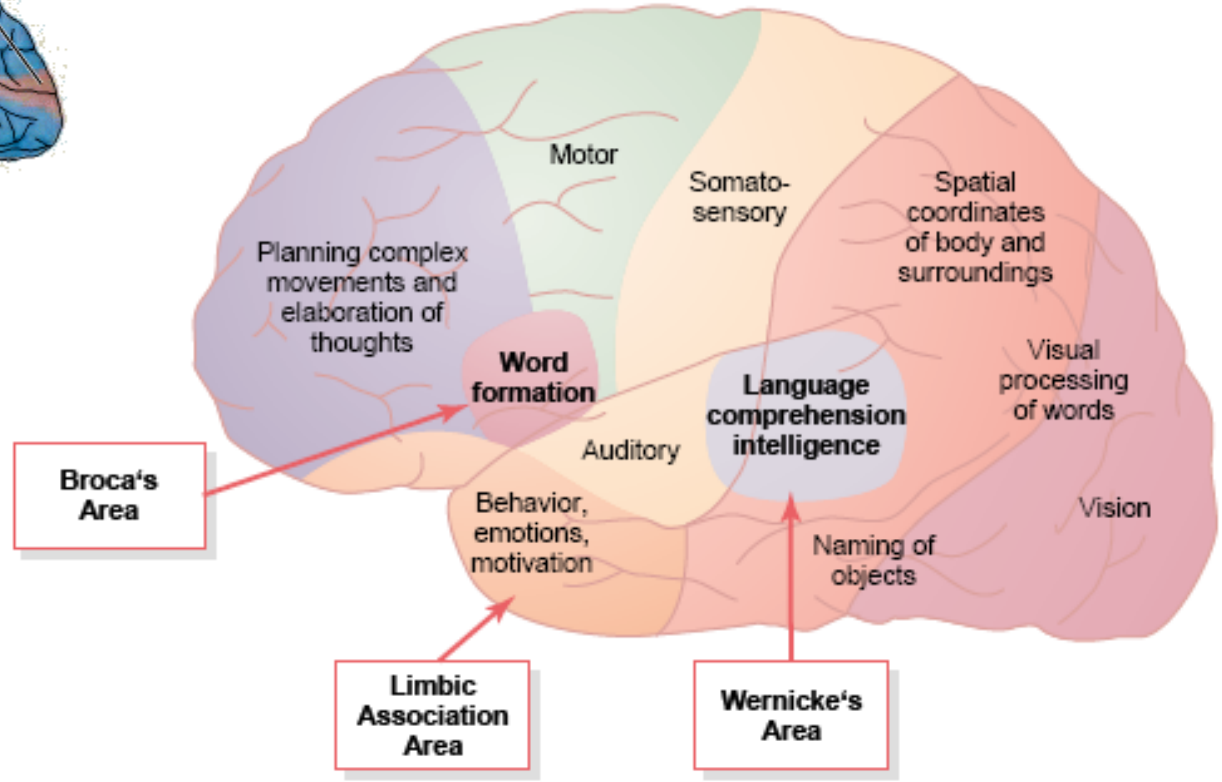
Association areas



- Neither receptive
- Nor effector

- Integrative function

- Limbic
- Parieto-occipito-temporal
- Frontal



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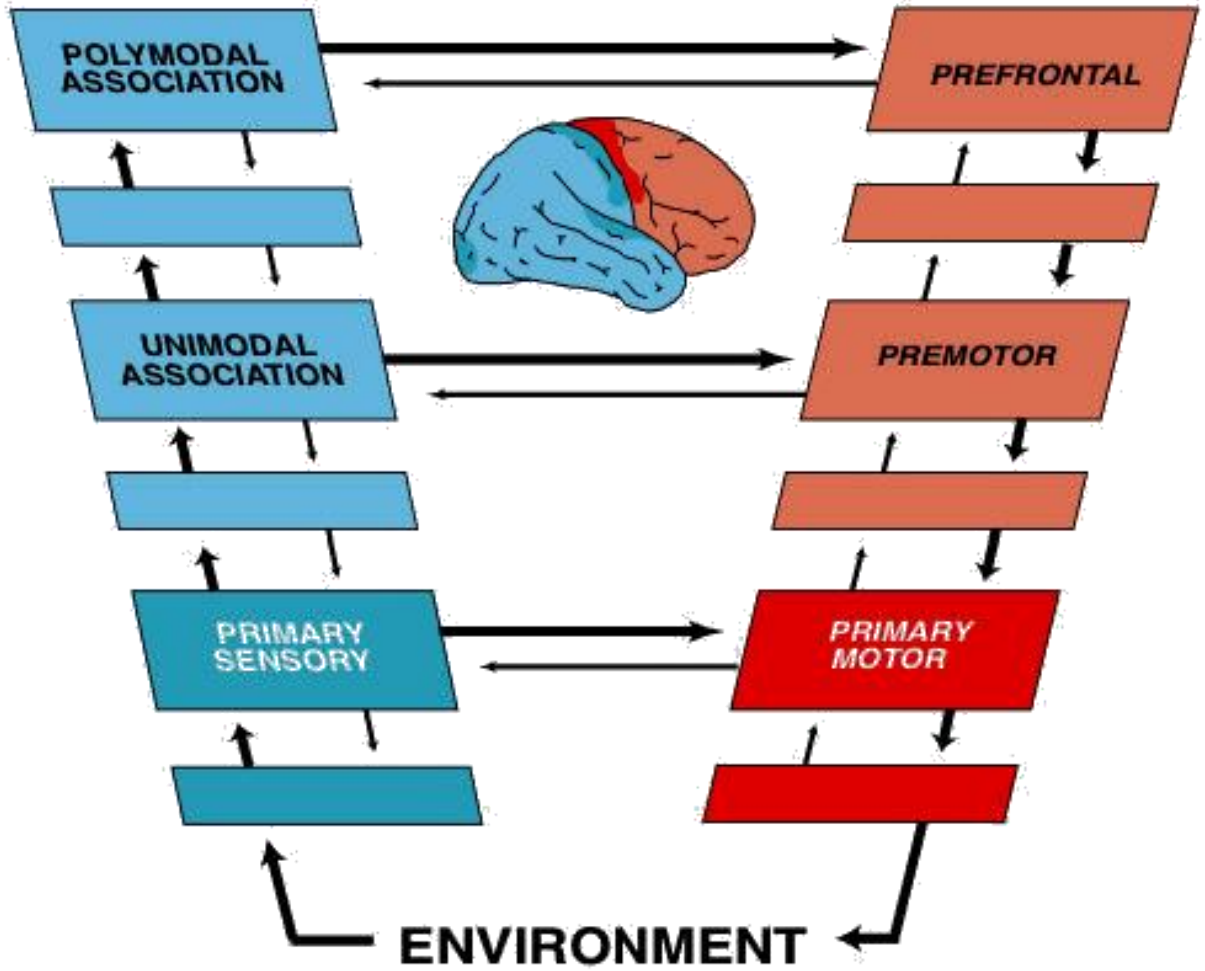
Signal processing algorithm



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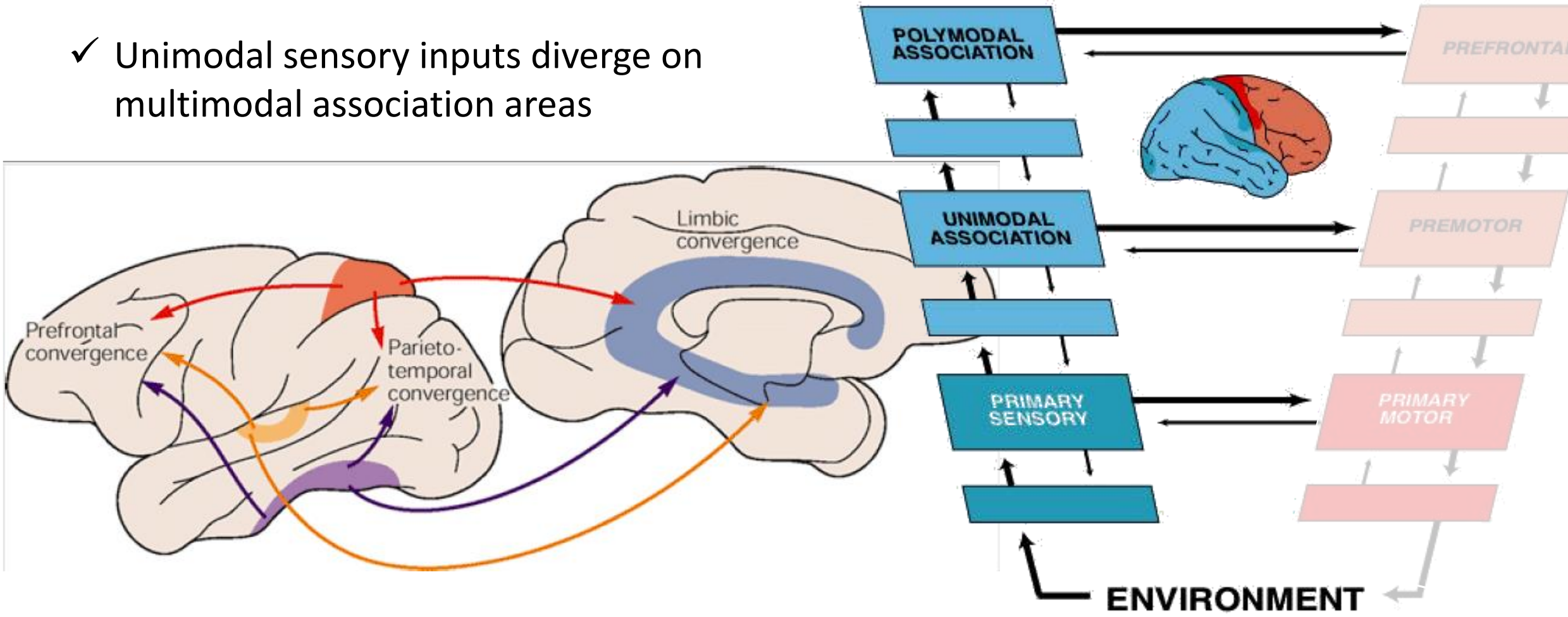
Aferentation

- ✓ Unimodal sensory inputs diverge on multimodal association areas



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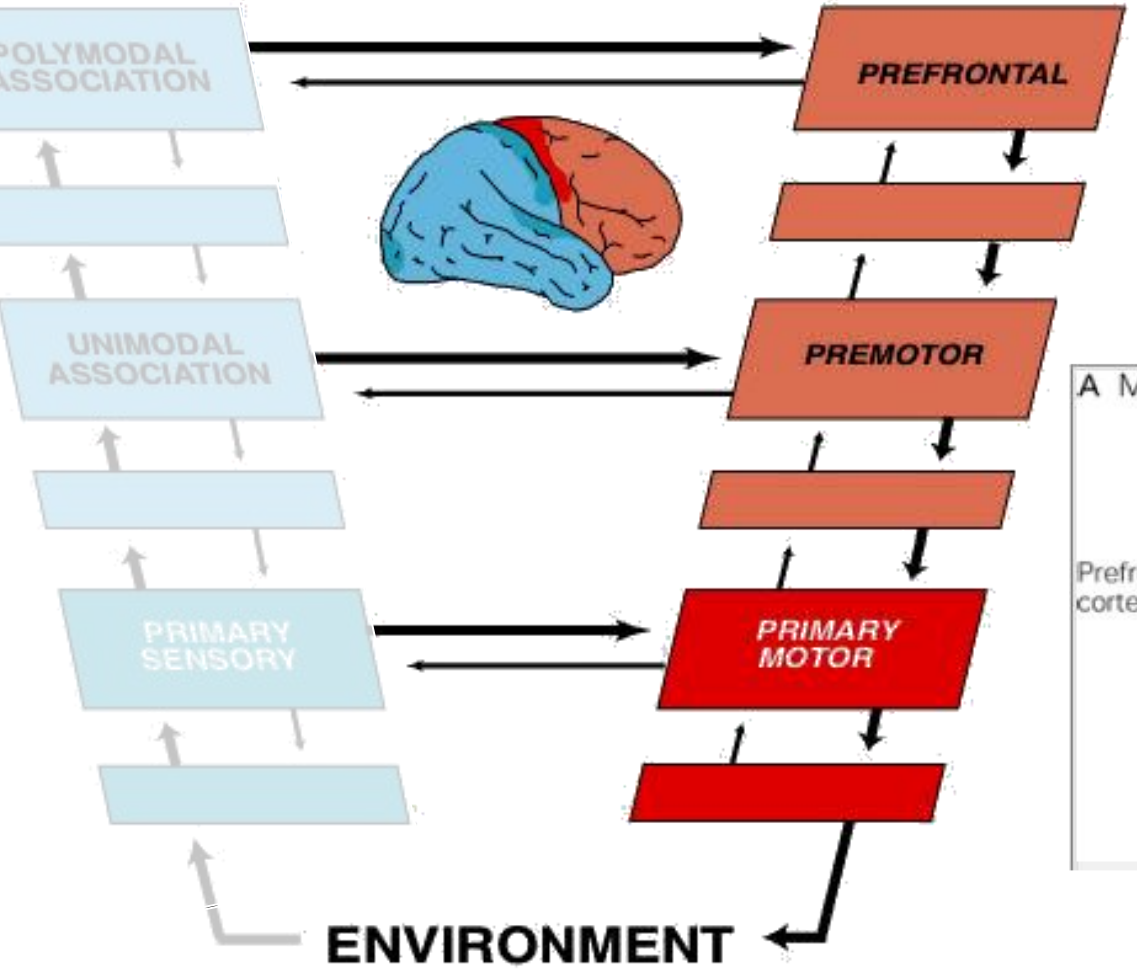
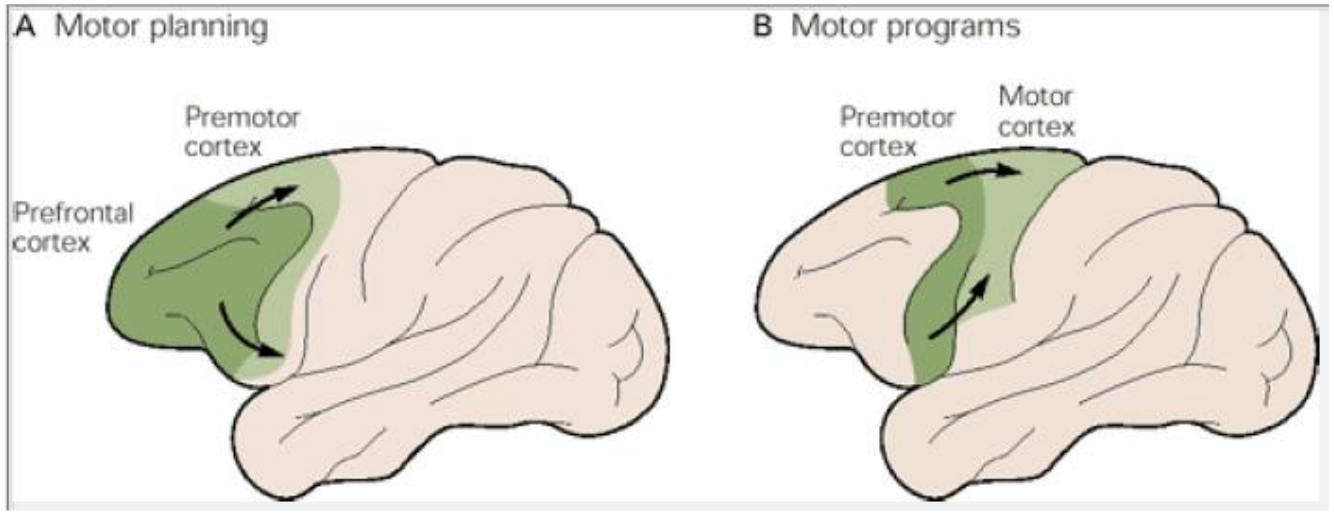
Eferentation



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



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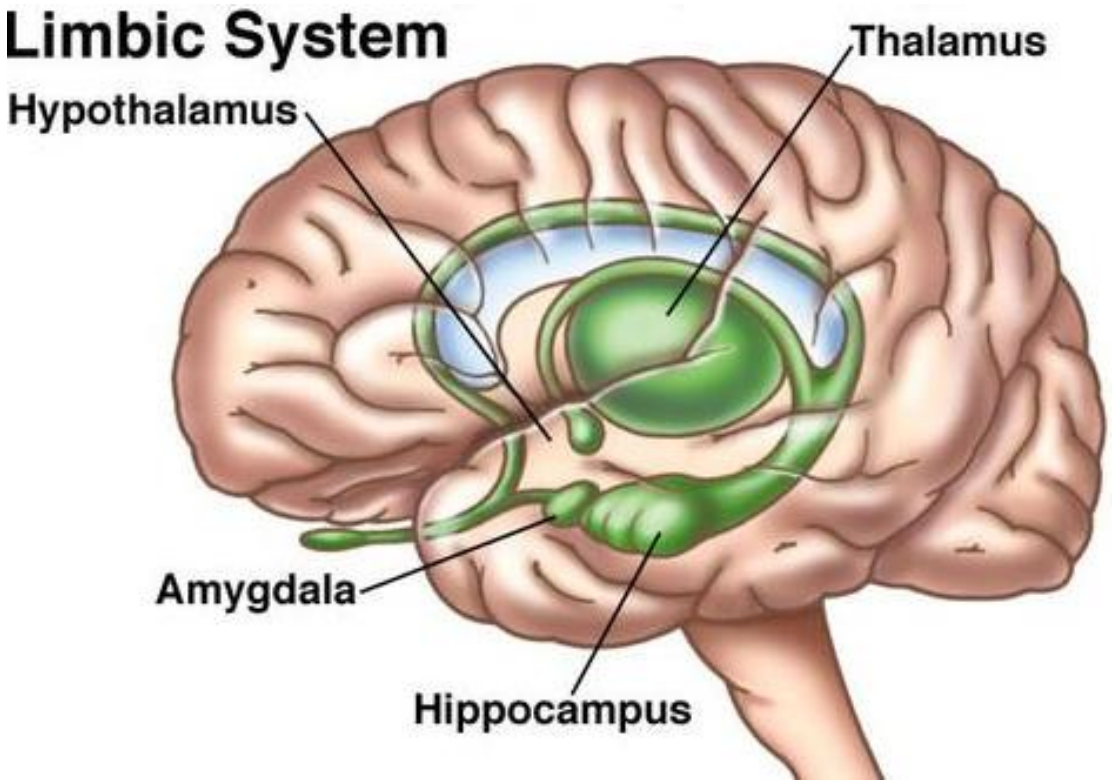
Limbic association area

- 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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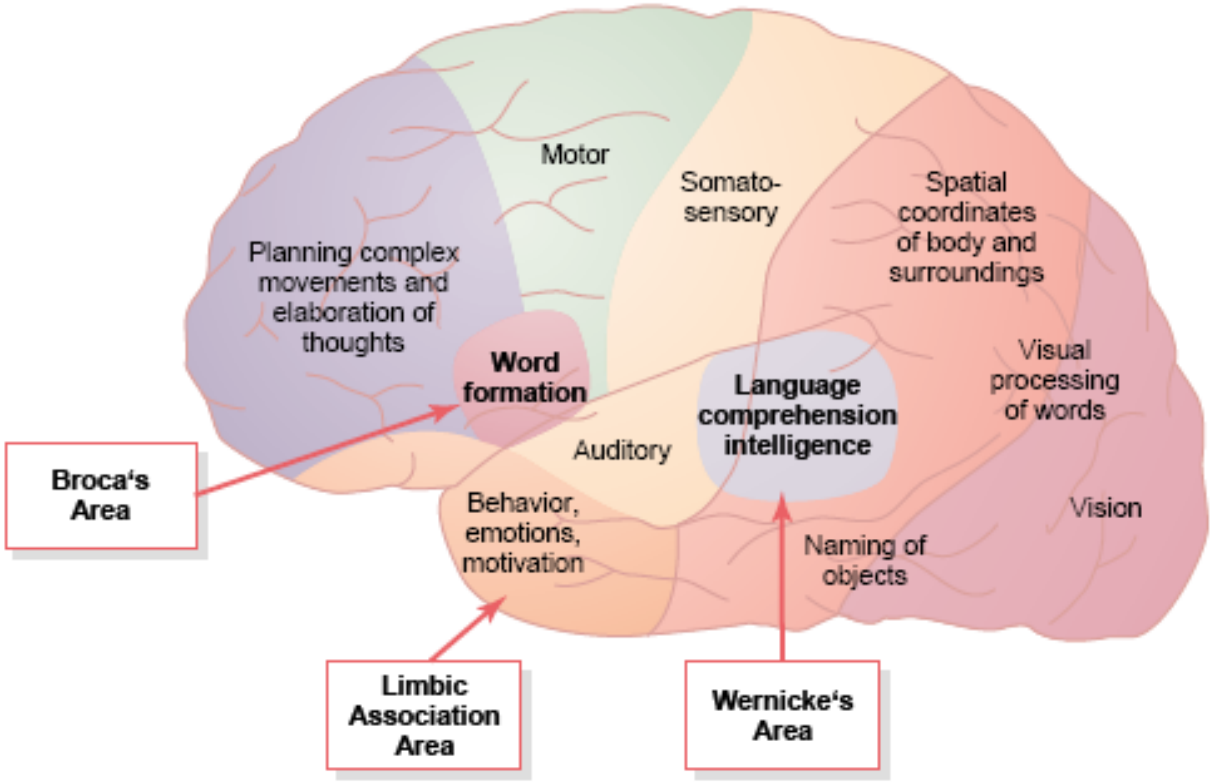
Parieto-occipito-temporal association area

- Linkage and interpretation of information from several sensory modalities

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



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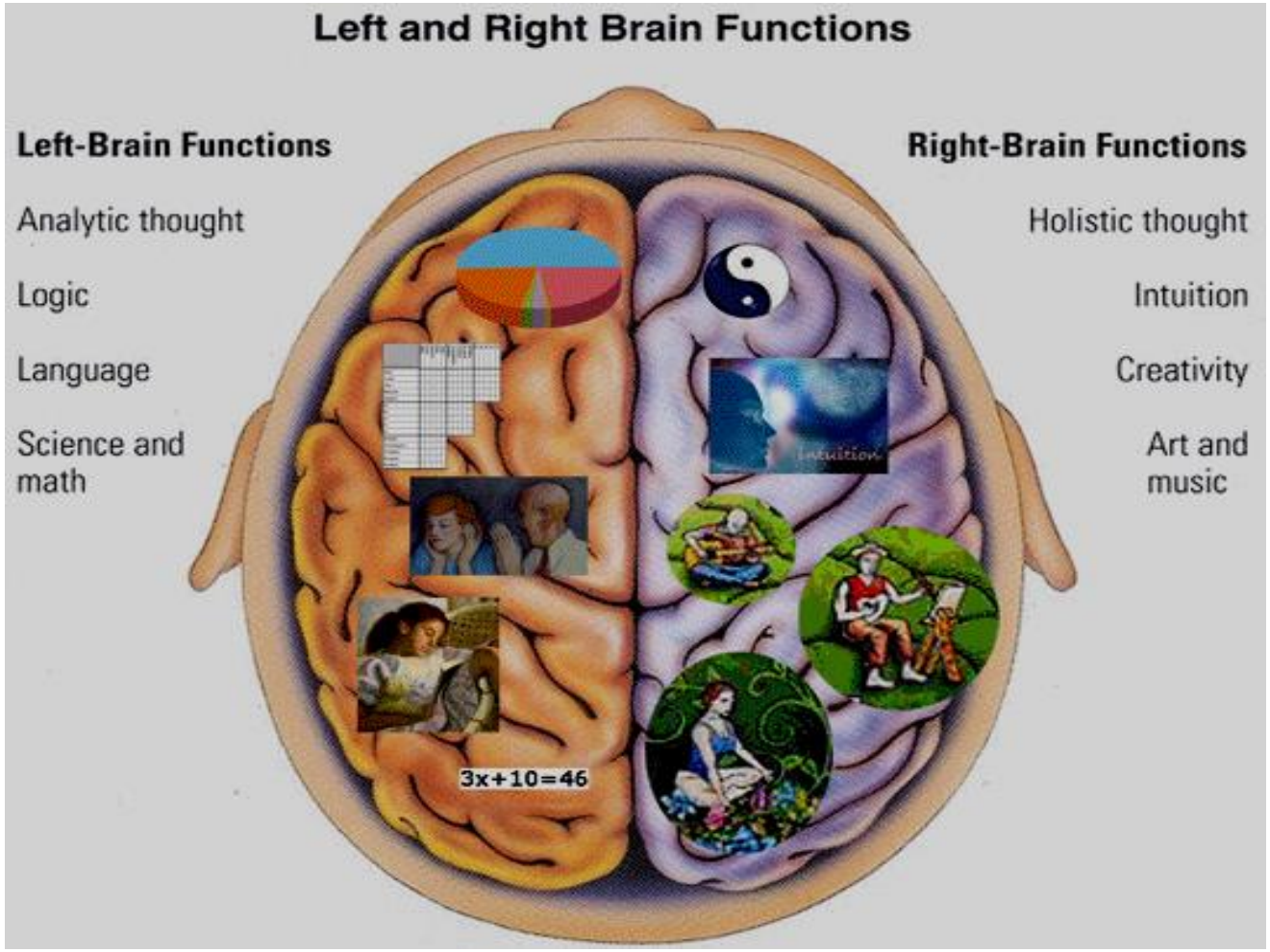
Lateralization of cerebral functions



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Lateralization of cerebral functions

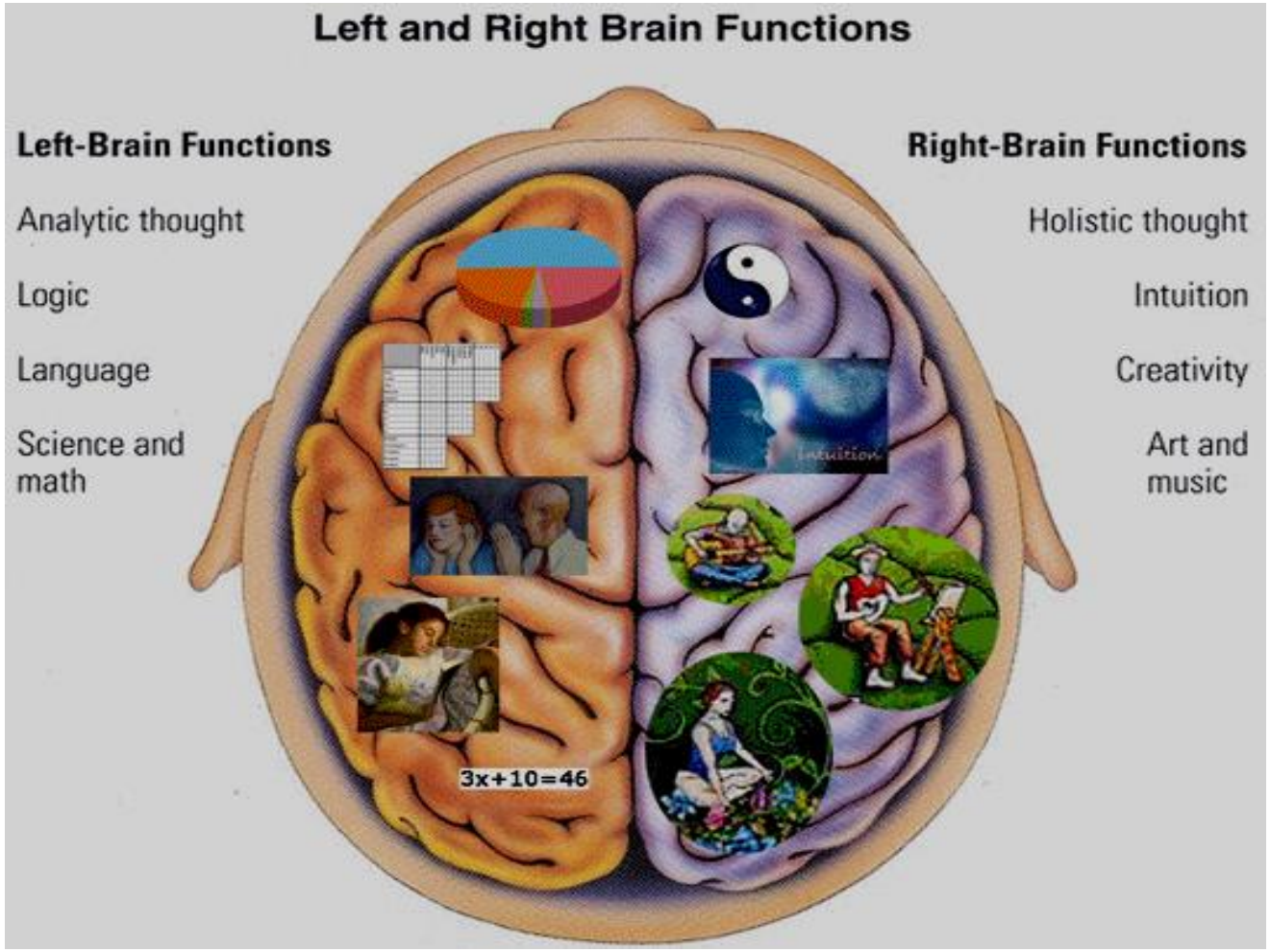
Aphasia

Acalculia

Tactile agnosia

Conceptual apraxia

Ideomotor apraxia



Orientation disorders

Constructional apraxia

Anosognosia

Neglect syndrome

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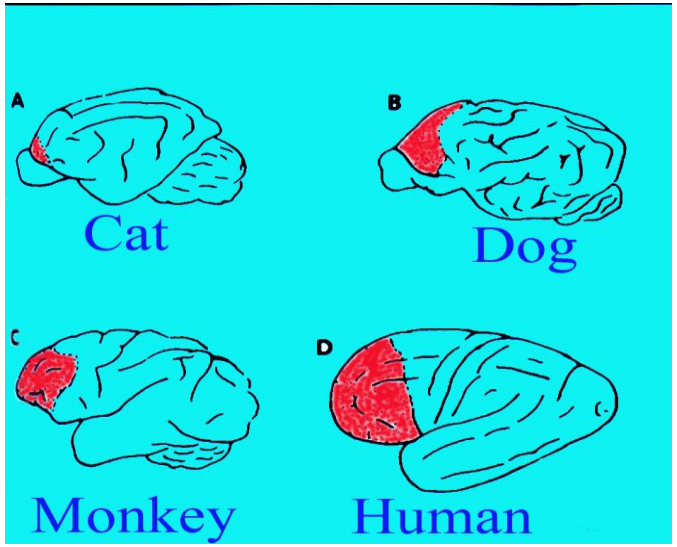
Frontal association area

- Executive function
  - Motor / behavioral
  - Cognitive

- Mostly developed in human



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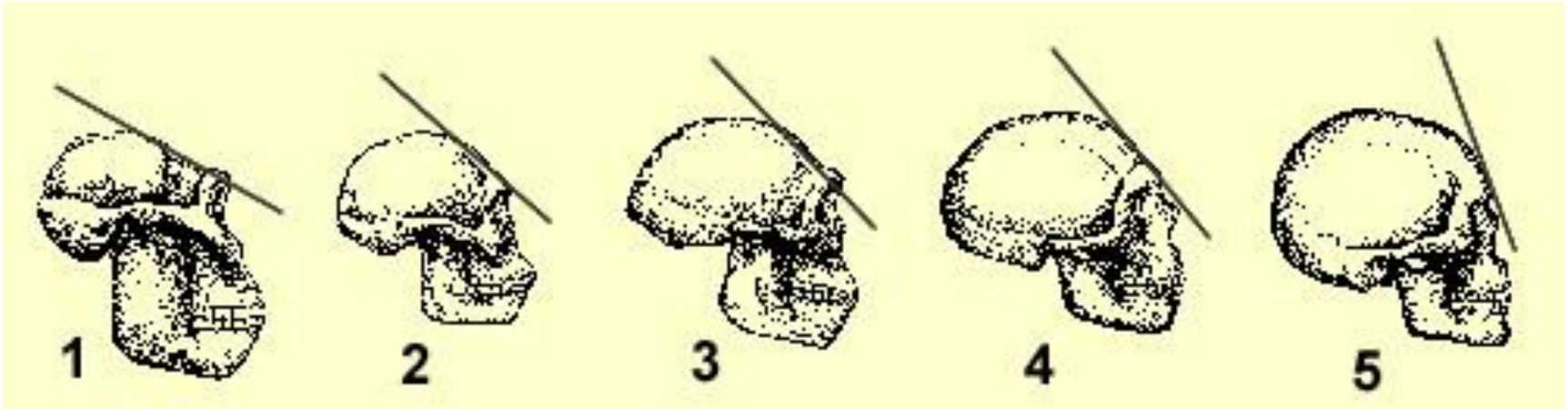
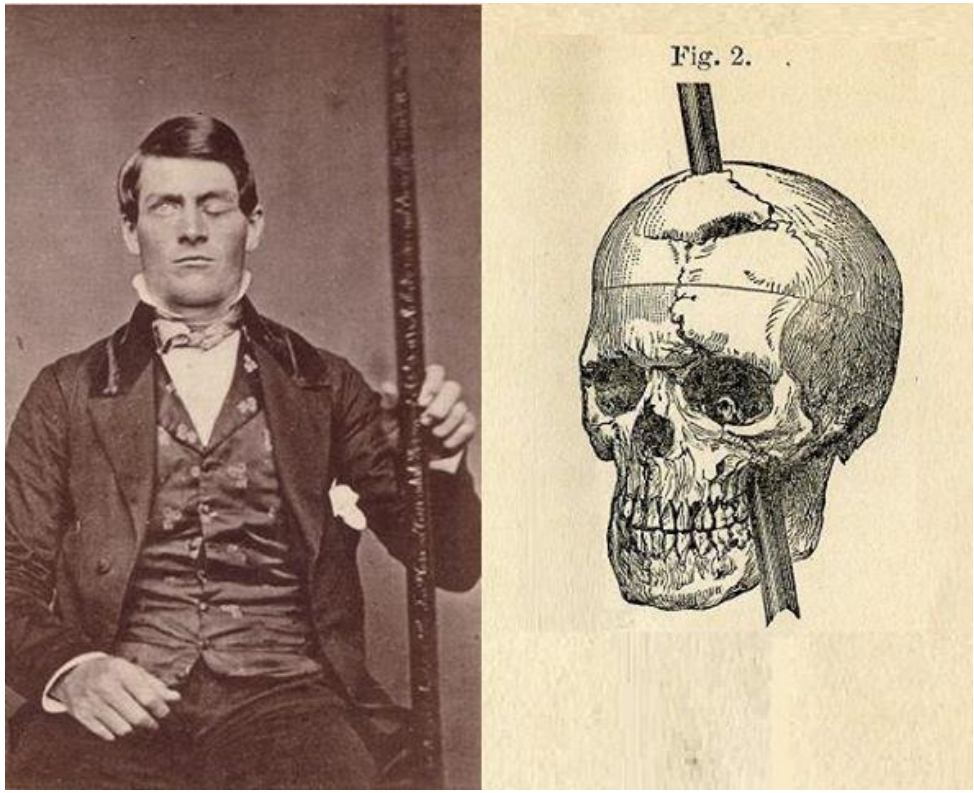


1. *Australopithecus robustus* 2. *Homo habilis* 3. *Homo erectus* 4. *Homo sapiens neanderthalensis* 5. *Homo sapiens sapiens*

Phinease Gage (1823 – 1860)

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



http://65.media.tumblr.com/553d3c3f3f579f57273b8598ec6739ab/tumblr_o11oqt0MUK1uaq7mqo1_1280.jpg

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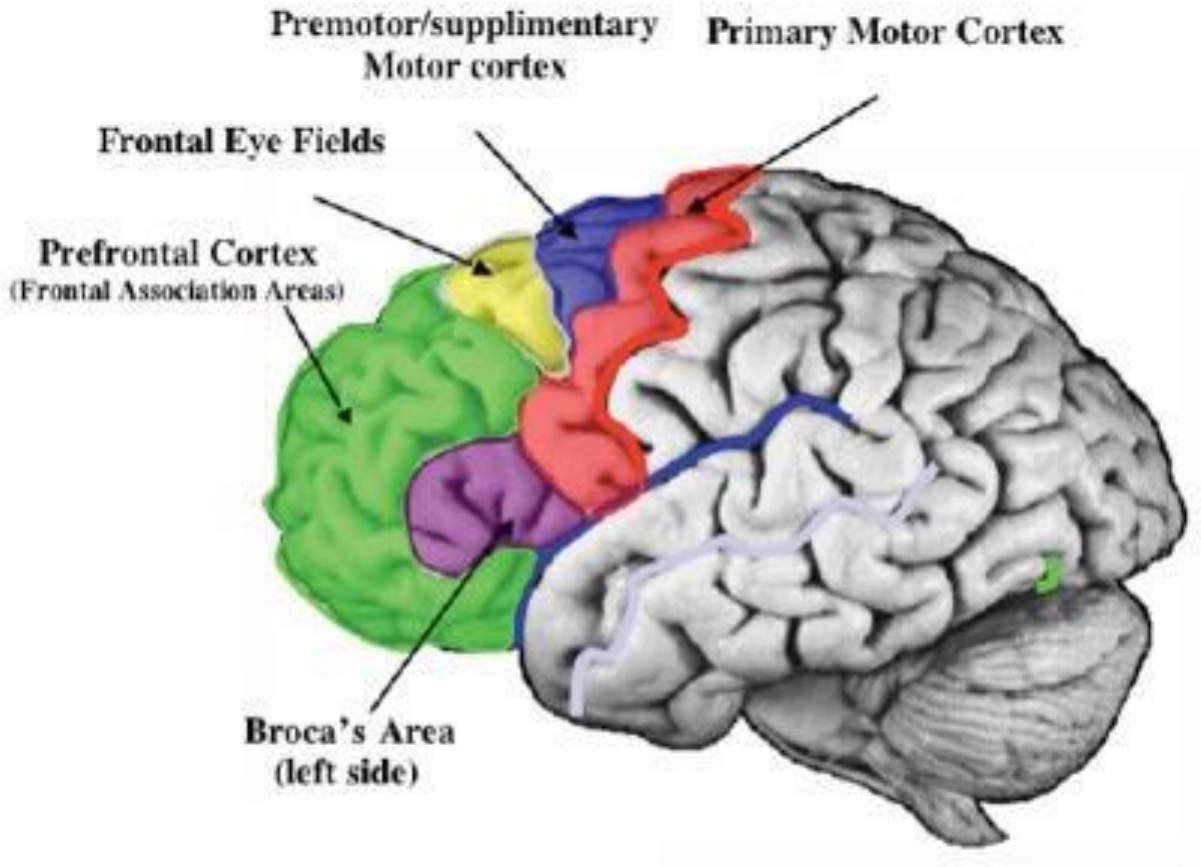
Frontal lobe



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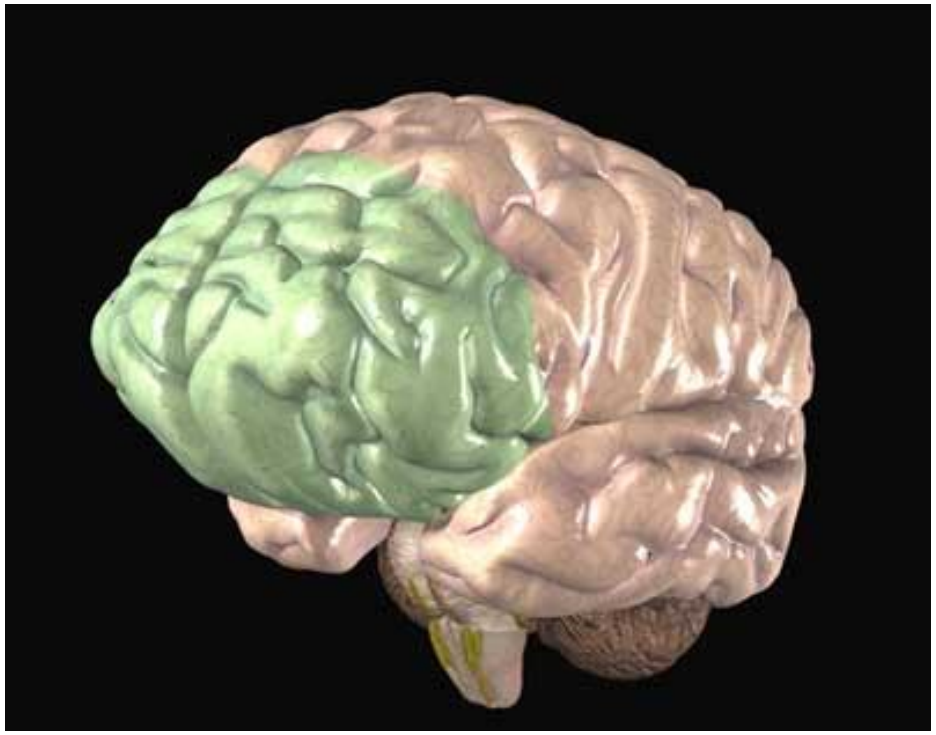
Frontal association area

- ~ 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?

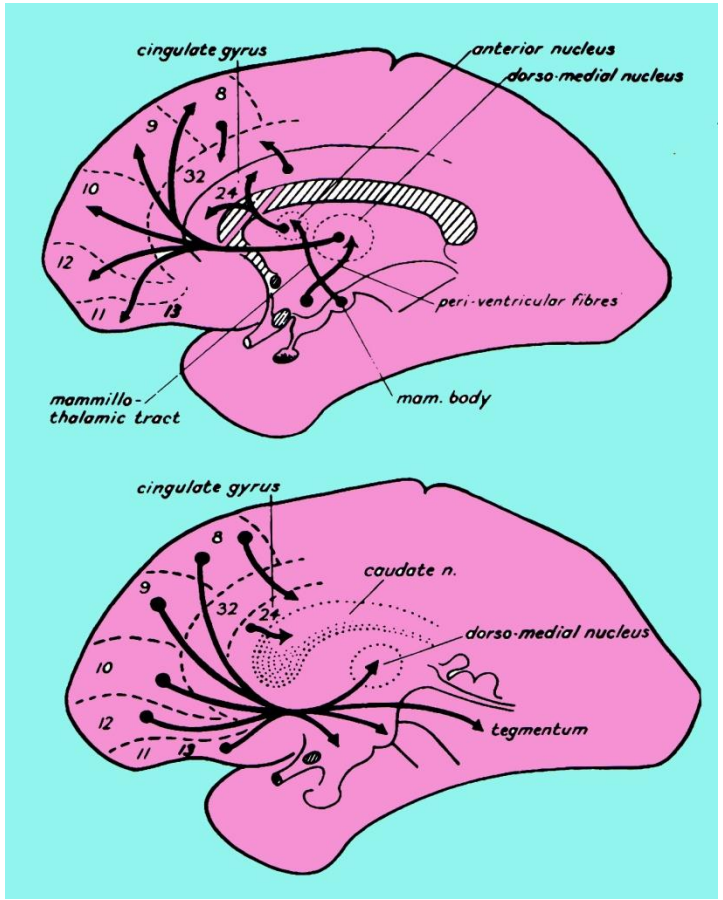


Frontal association area

- Input from association cortex
  - P-O-T association area
  - Limbic association area

- Reciprocal connections:
  - prefrontal processing modulates perceptual processing
  - „Loops“

- Input to premotor areas



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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

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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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