Selected topics in cognitive science and biomodeling

L4: Anatomical Organization of Brains

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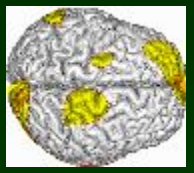
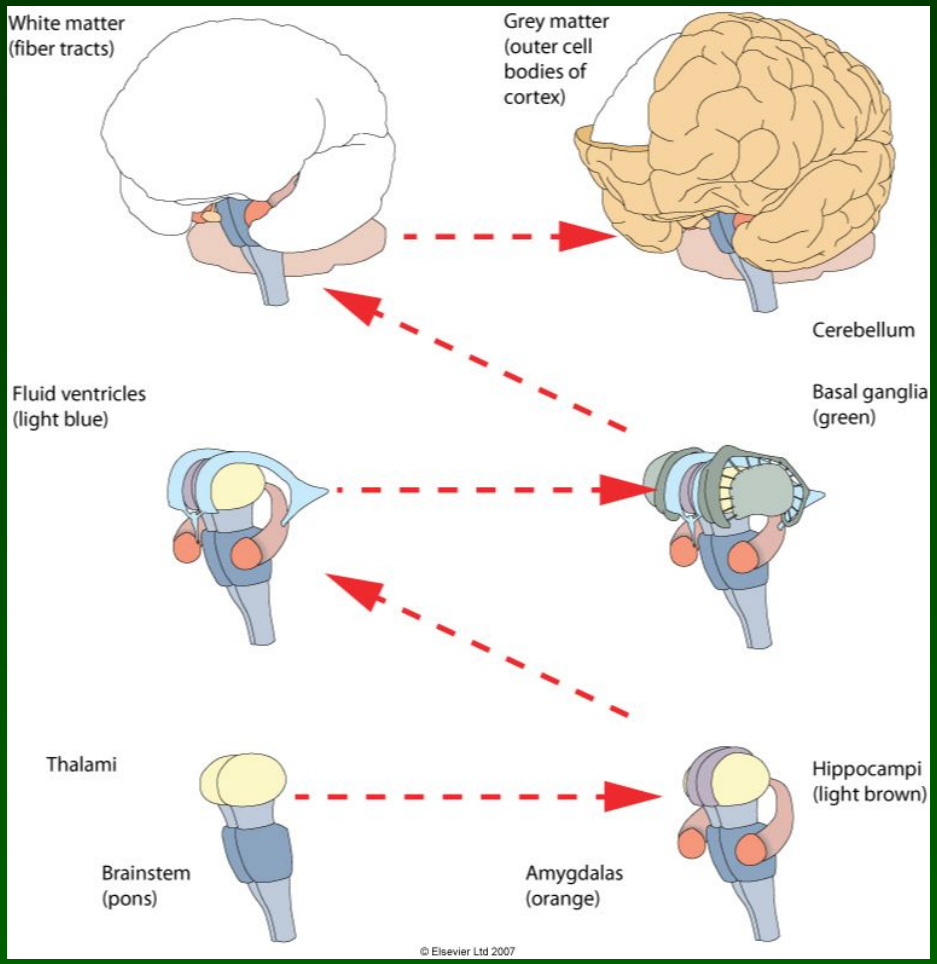
What it is about



1. Core ideas and cybernetic explanations.
2. Basic brain architecture.
3. Information flow in the brain.
4. Examples of communication breakdown.
5. Functions of the brain stem and states of consciousness.
6. Limbic system and emotions.

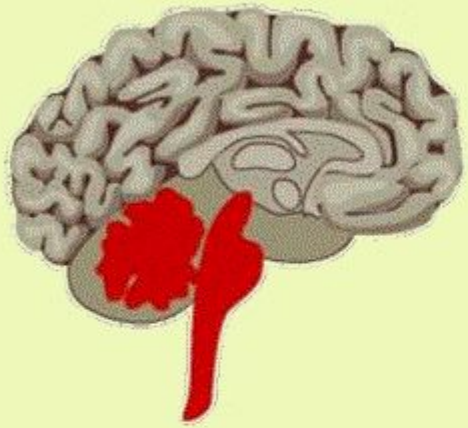
Growth of the brain

1. Starts with the brainstem enabling automatic homeostatic processes, and the thalamus, the major input hub collecting signals from all senses, including interoreception.
2. Hippocampal formation, major spatial orientation/episodic memory region.
3. Fluid ventricles are central to the brain's circulatory system, metabolic processes.
4. Basal ganglia are next (can be thought of as the output).
5. White matter (the interconnective material – myelin sheathed axons)
6. Last is the gray matter (outer body of the cortex).

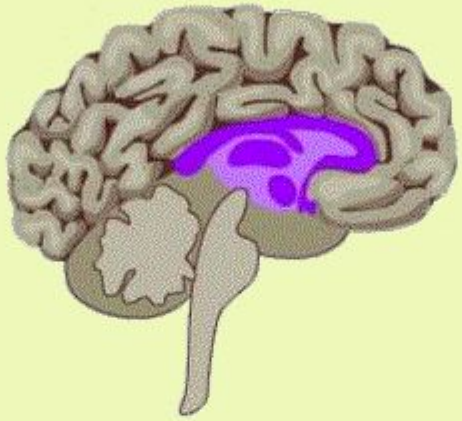


Triune brain

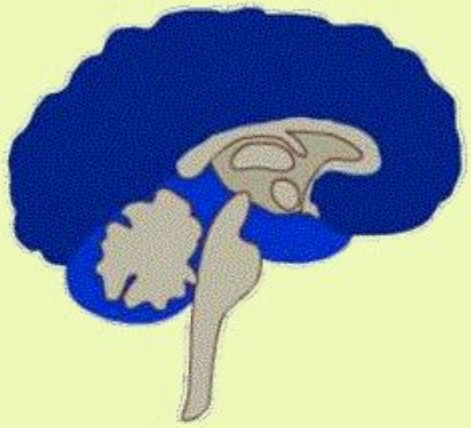
The Three-Parted Brain



Lizard Brain
(Brain stem and cerebellum)
Autopilot
Fight & Flight



Mammal Brain
(Limbic System)
Emotions
Memories
Habits
Attachments

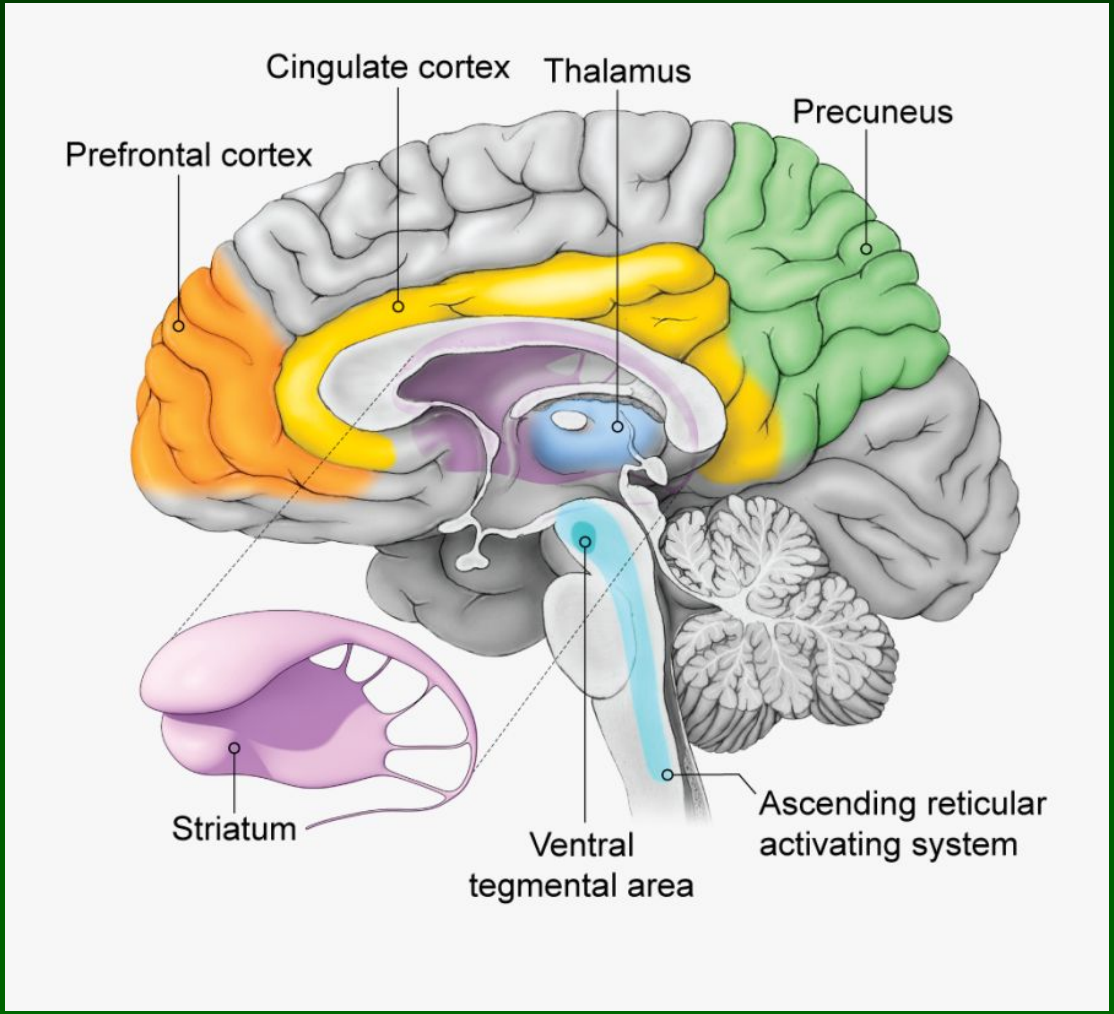


Human Brain
(Neo-Cortex)
Language, abstract thought, imagination, consciousness, reasoning, rationalising

(From Paul D. MacLean's model of the "Triune Brain")

Human brain

The outer, visible cortex is divided into four major lobes: prefrontal/frontal, parietal, occipital and temporal. The fifth lobe, cingulate cortex, is hidden in midline area deeper in the brain.



Major lobes, some hidden

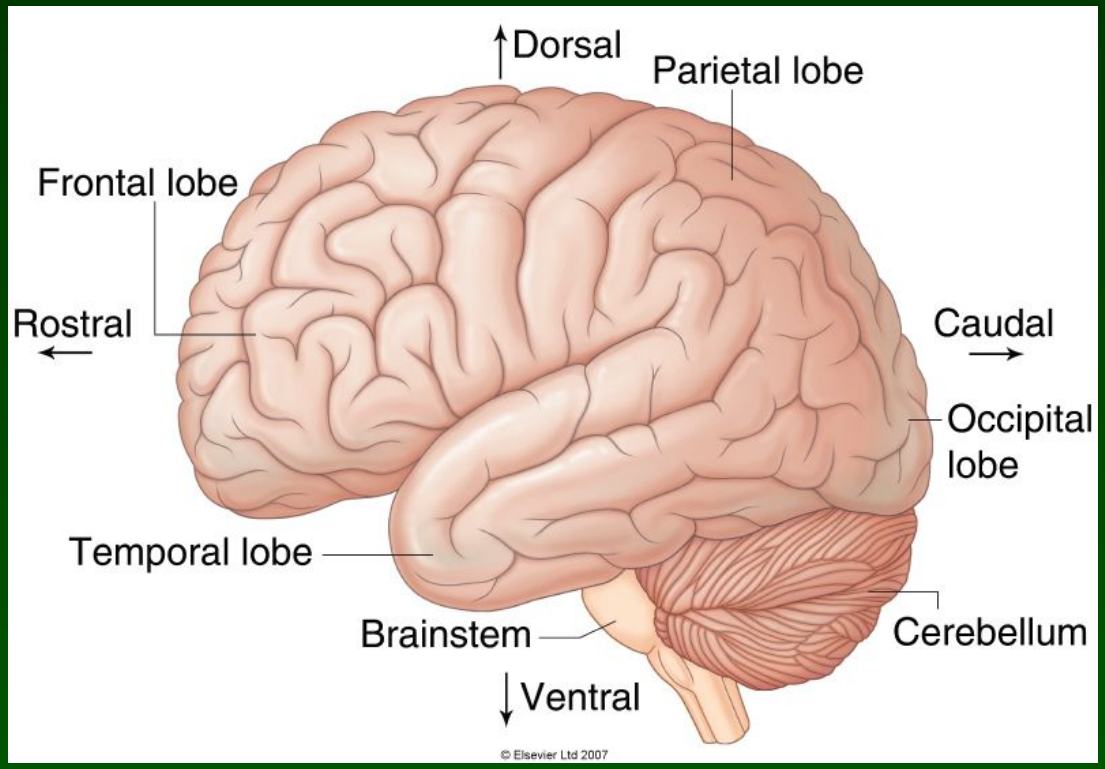
Four visible lobes:

- pre/frontal, parietal, temporal and occipital.

Hidden lobes:

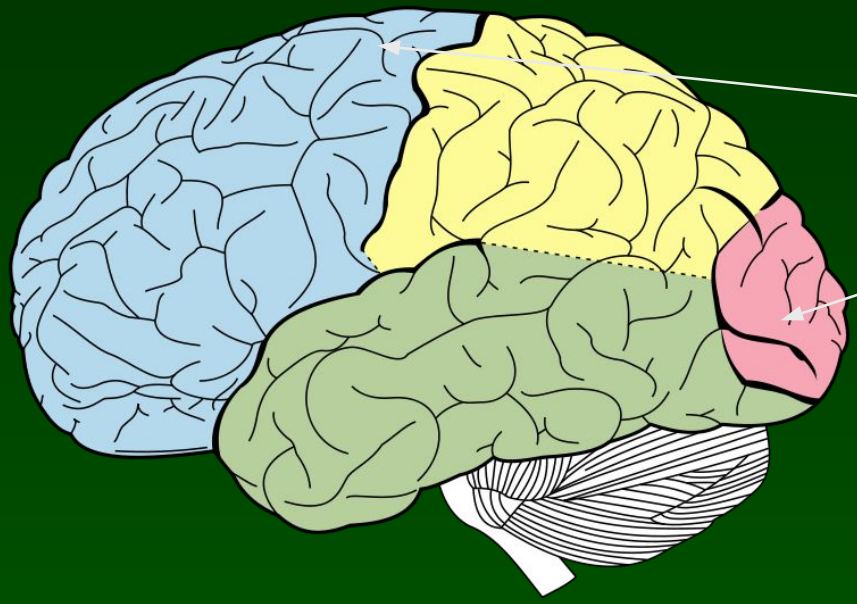
- Limbic lobe (cingulate)
- Insula
- Planum temporale

Medial temporal lobe is composed of limbic structures.



Brain directions: frontal – rostral, anterior;
back – caudal, posterior;
upper, top – dorsal, superior;
lower – ventral, inferior.

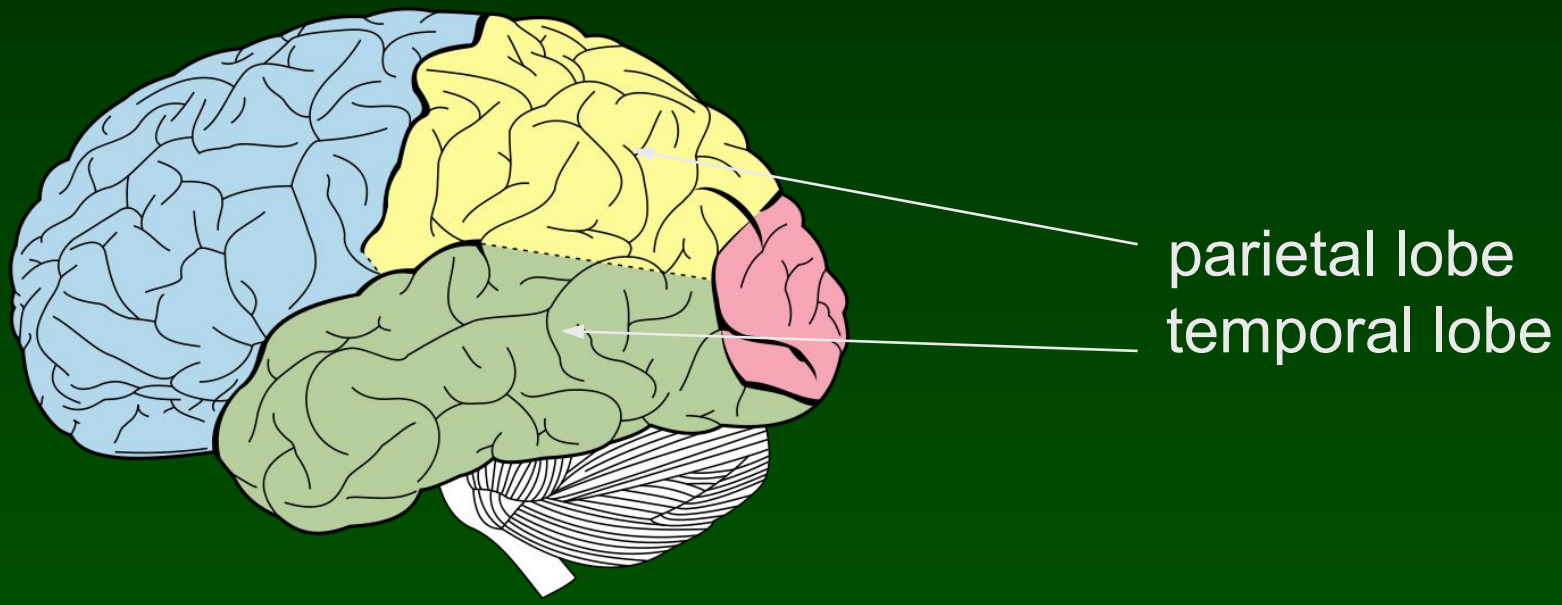
Major lobes – hidden and visible



Four visible lobes of the cortex:
frontal lobe
occipital lobe
parietal lobe
temporal lobe

The prefrontal lobe is responsible for: planning, thinking, memory, motivation, drive to act, decisions, evaluation of emotions and situations, predicting consequences of actions, social conformity, tact, feelings of serenity (reward system), frustration, anxiety and stress.
The frontal lobe: memory of learned motor actions, e.g. dance, mannerisms, specific patterns of behavior, face expression, plans of body movement.
The occipital lobe enables visual recognition, analyzing colors, motion, shape, depth, visual associations.

Major lobes – hidden and visible



The parietal lobe facilitates spatial orientation, motion recognition, feeling of touch, pain, temperature, spatial location of sensory stimuli, integration of motion and grasping, sensation and sight, understanding abstract concepts.

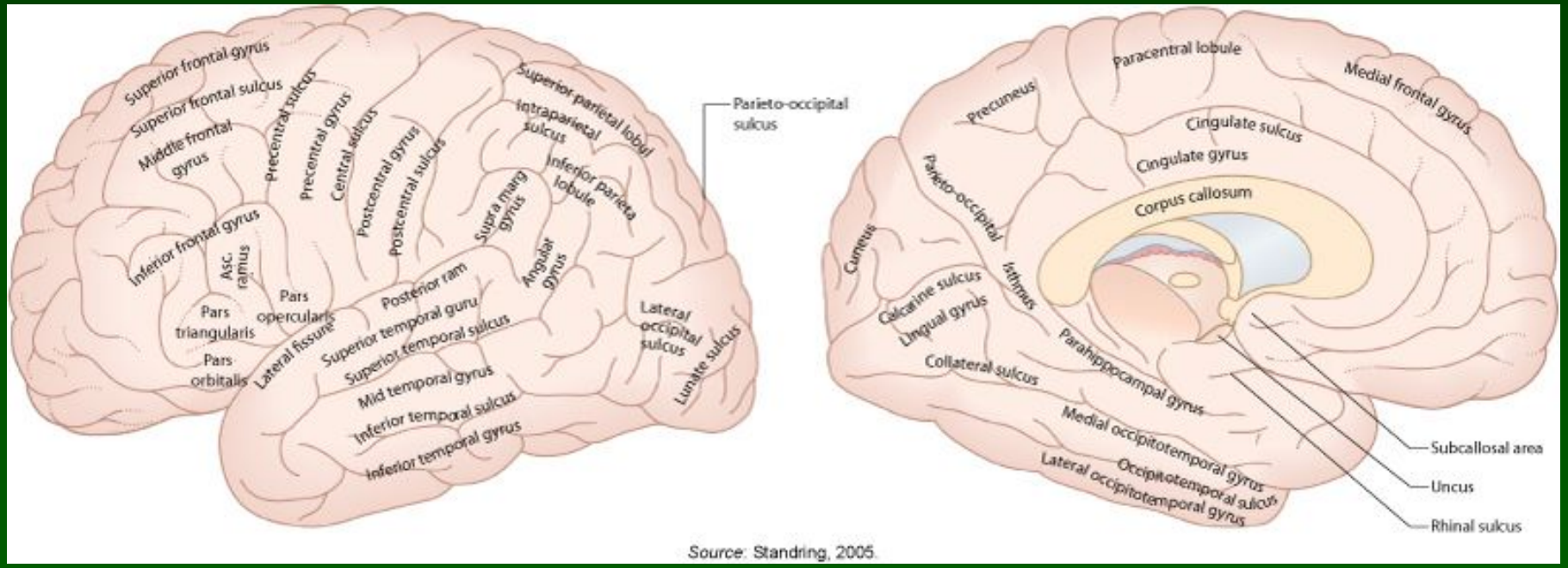
The temporal lobe enables speech, verbal memory, object recognition, hearing and aural impressions, scent analysis.

Lobes are separated by deep sulci, part of the cortex is always hidden there.

Regions of the brain

Human brains are roughly similar but individual variations of the size of gyri and sulci are significant, making life of neurosurgens hard …

Each gyrus has a name, is involved in many functions, and is separated from other gyri by sulci. Cortex can be parcelated into homogenous regions.



Lateral left panel and right Mid-sagittal view

Divisions

- Cortex is thin, 1.5-4 mm, but highly convoluted.
- It has about 2500 cm^2.
- Parts posterior to central sulcus and Sylvian fissure are primarily involved in sensory perception.
- Temporal lobe is separated by Sylvian fissure from frontal and parietal lobe.
- Occipital lobe is not separated clearly from parietal lobe.
- Lobes and hemispheres are contacted by fascicles and calossum fibers.
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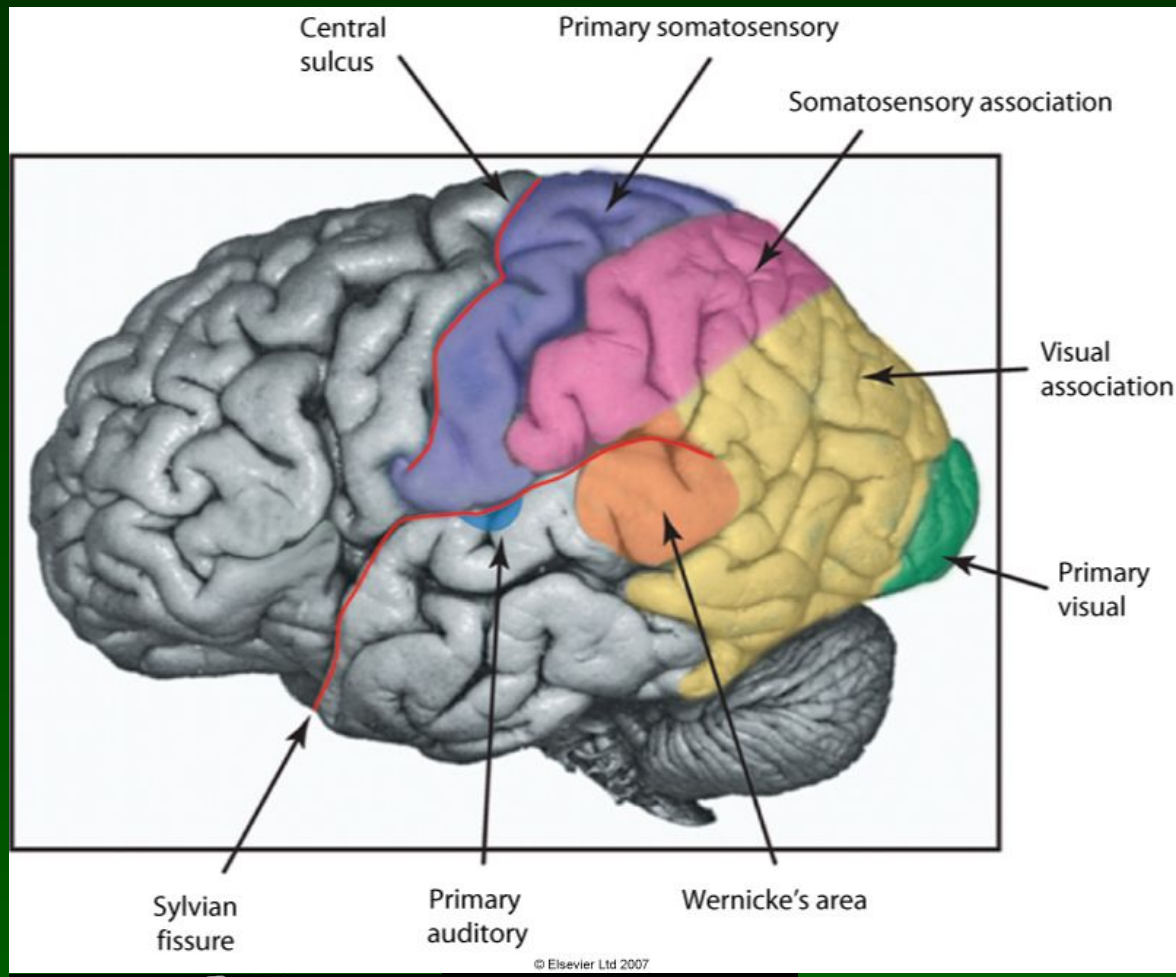
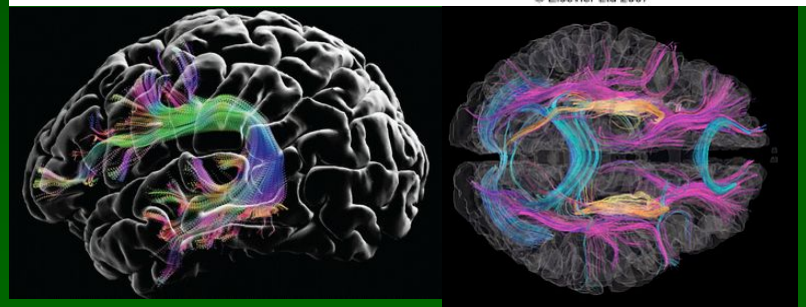
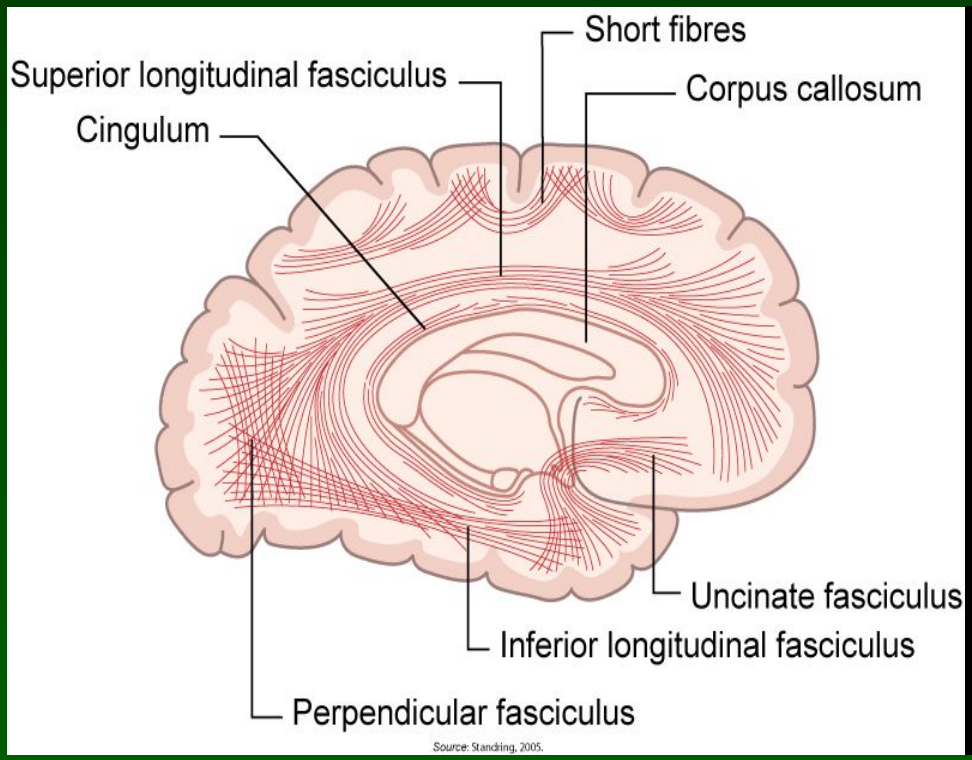
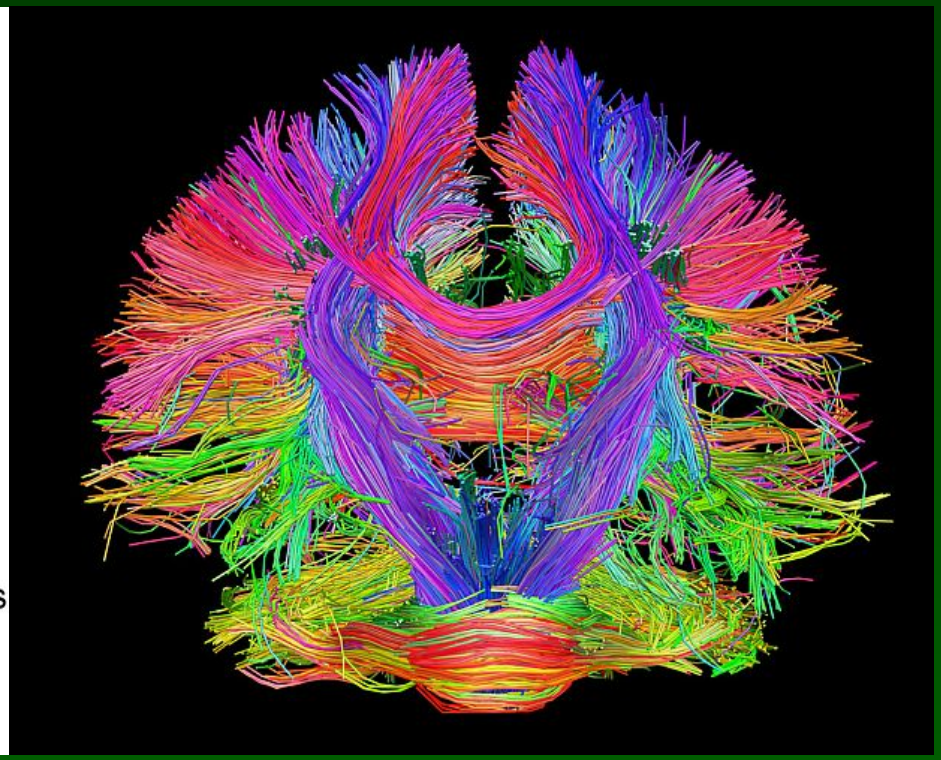




Major fiber patterns in the brain

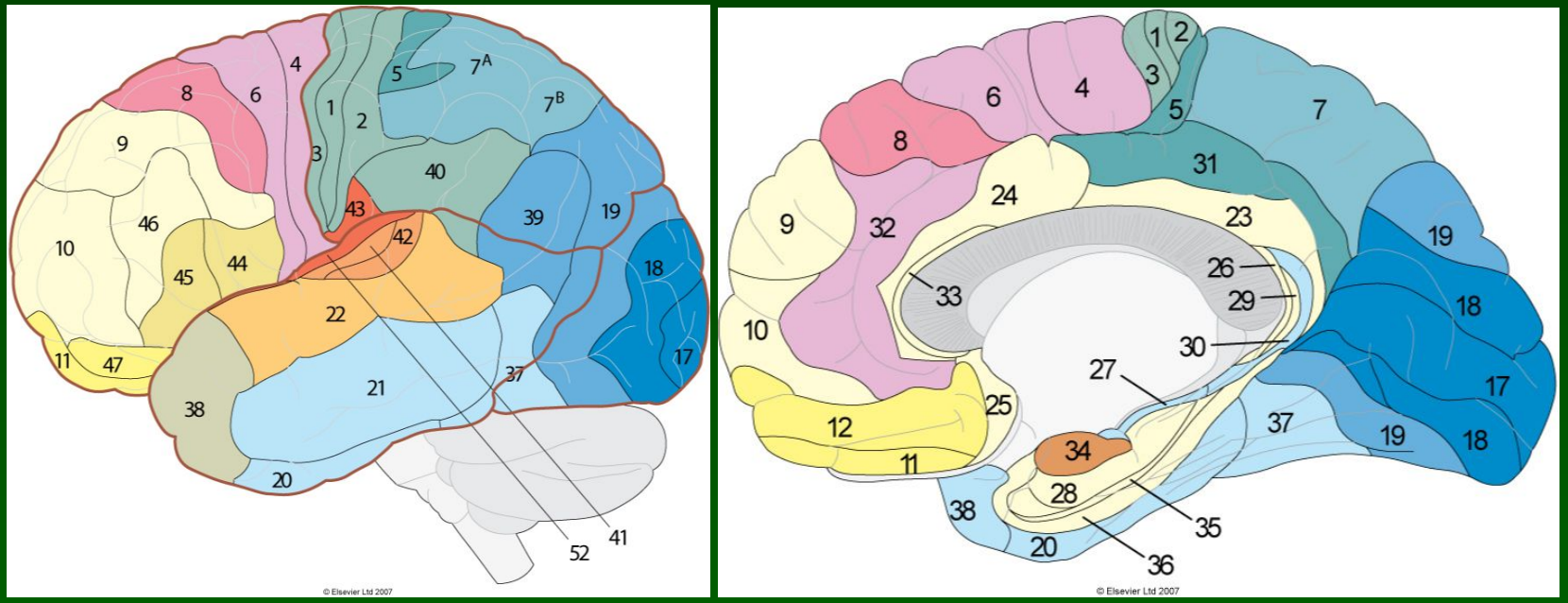
Fibers from cortical cells spread in every direction between hemispheres, thalamus, and other brain organs





Brodmann areas (1909)

- Broadman areas are the oldest attempt at parcelation of the cortex into 52 regions, based on the cytoarchitectural organization of neurons.
- New brain atlases recognize up to 300 specialized brain regions of interst (ROIs). Each may be involved in many functions: analysis of sensory signals, motor control, memory, associative thinking, planning, emotions.



Lateral left panel and right Mid-sagittal view

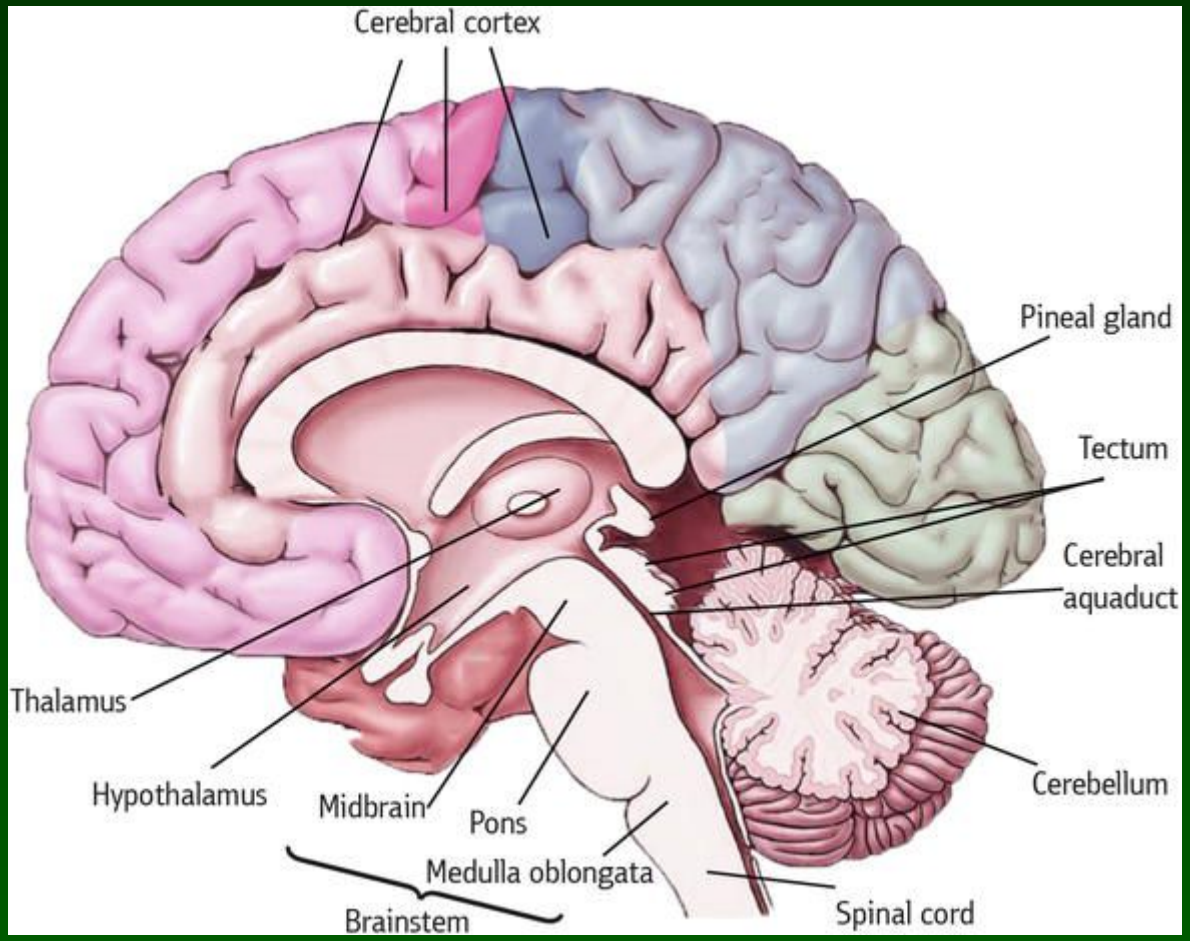
Subcortical areas

Brain stem:

Nuclei providing neurotransmitters, reticular formation activating cortex and consciousness.

Midbrain:

(mesencephalon): part of the ventral tegmental area (VTA): dopamine, value of action or observation.

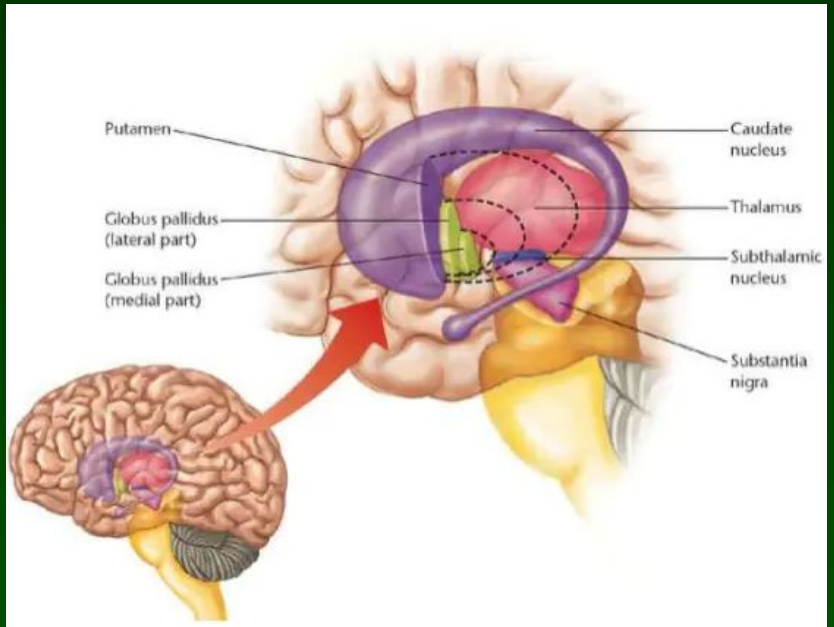


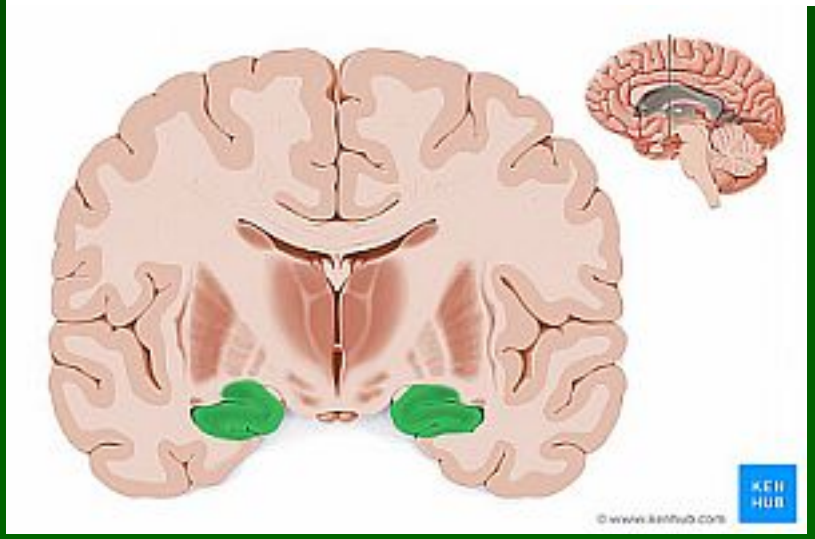
Thalamus: input of sensory signals, attention

Cerebellum: contains ¾ of all neurons, but only 10% synapses. Precise movements, sequences of motion.

Limbic areas

- Basal ganglia (striatum, globus pallidus, substantia nigra)
- Striatum nuclei initiate motor activities.
- Substantia nigra provides dopamine controlling learning.
- Amygdala: involved in emotional responses, affective associations.
- Basal ganglia: sequences of movements and motor control, modulation of prefrontal cortex activity, selection and initiation of new activity, anticipation.
- Hippocampus: fast learning, episodic and spatial memory, cognitive maps.



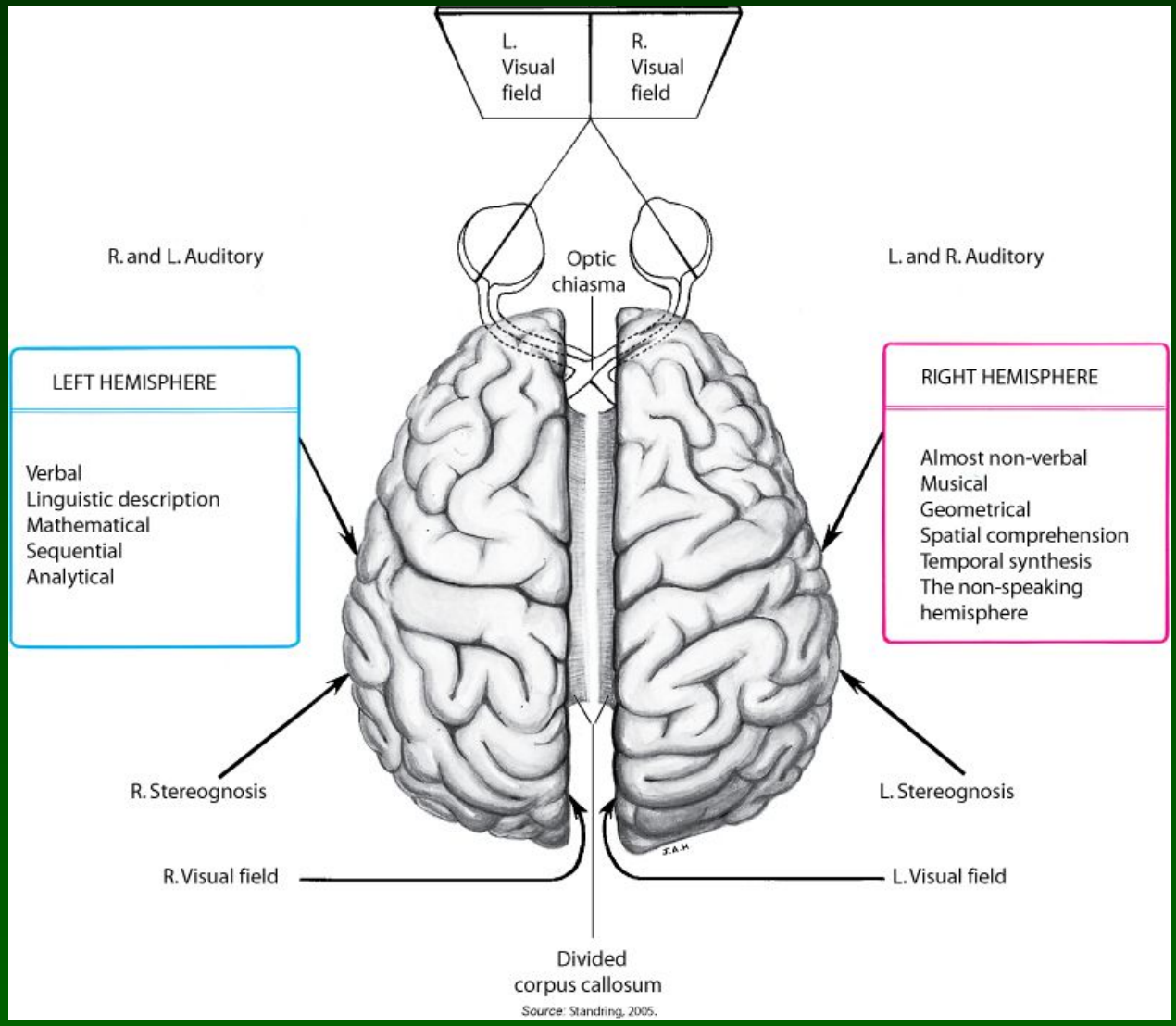


Corpus callosum

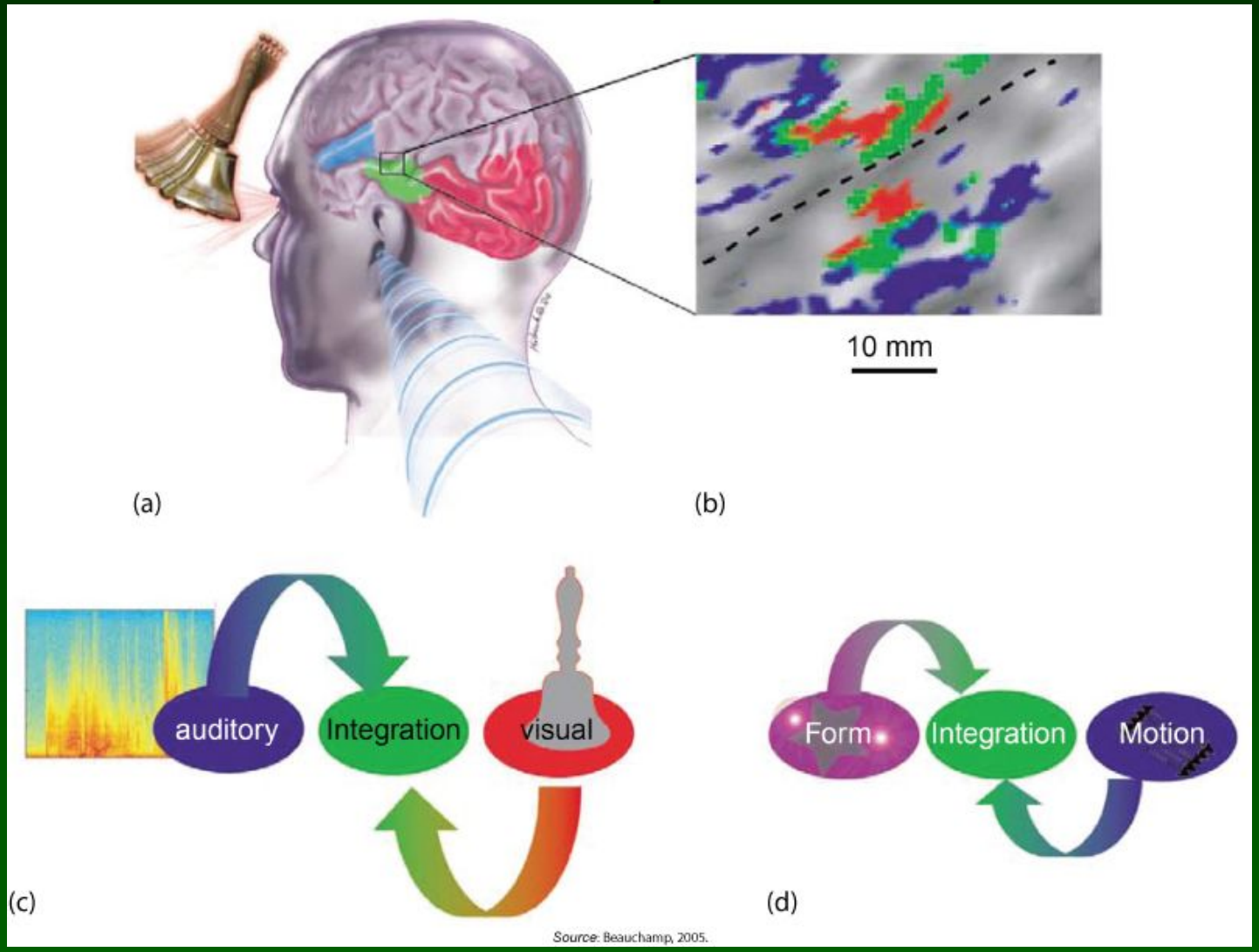
Many aspects of sensory and motor processing cross over information from left to right hemisphere.

200 mln axons transport information between hemispheres, enabling integration of their functions.
Specialization of functions is seen especially for language and math.

Only the (very old) olfactory nerve stays on the same side of the cortex.

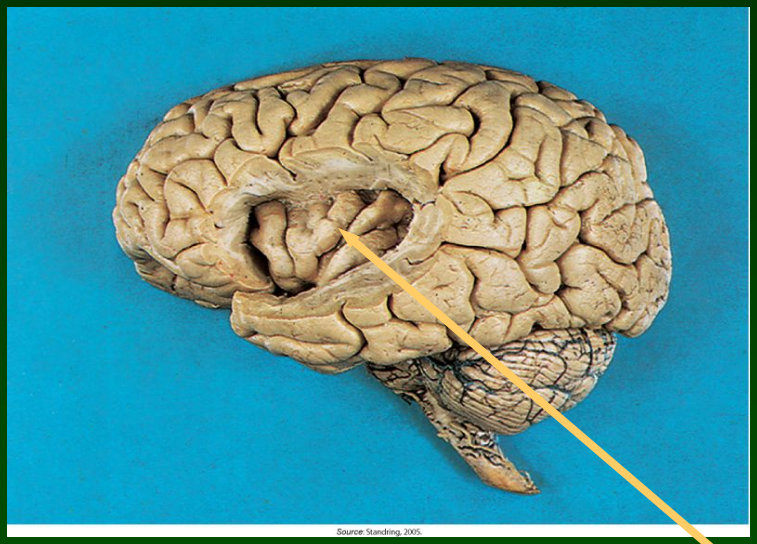


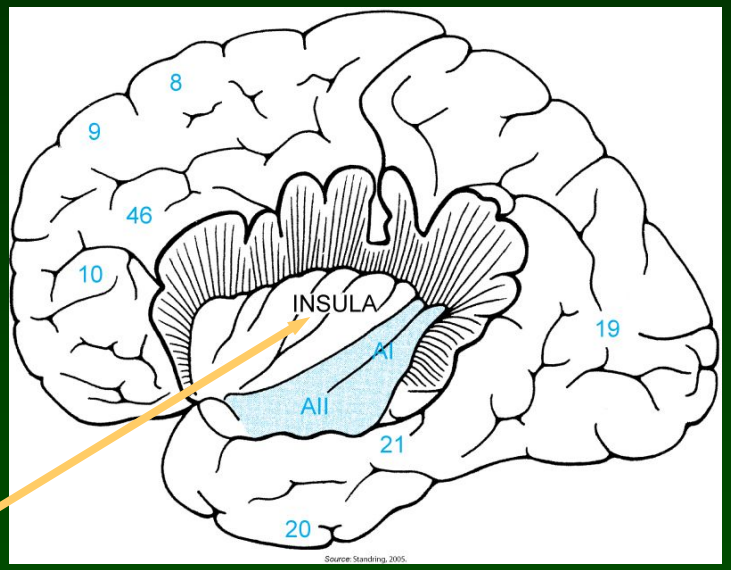
Functions of parietal lobe



Integrative multisensory function of the parietal lobe (tertiary association area).

Insula

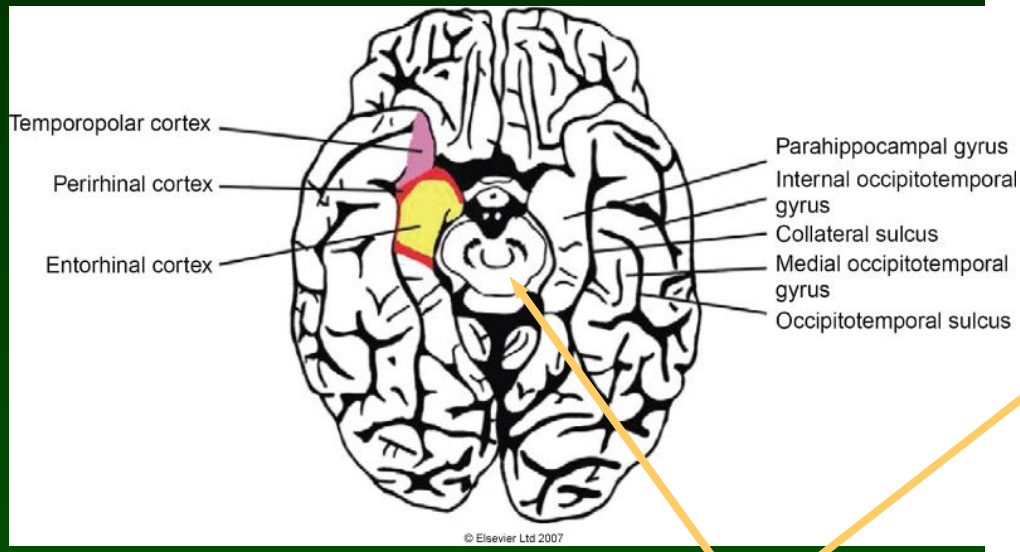


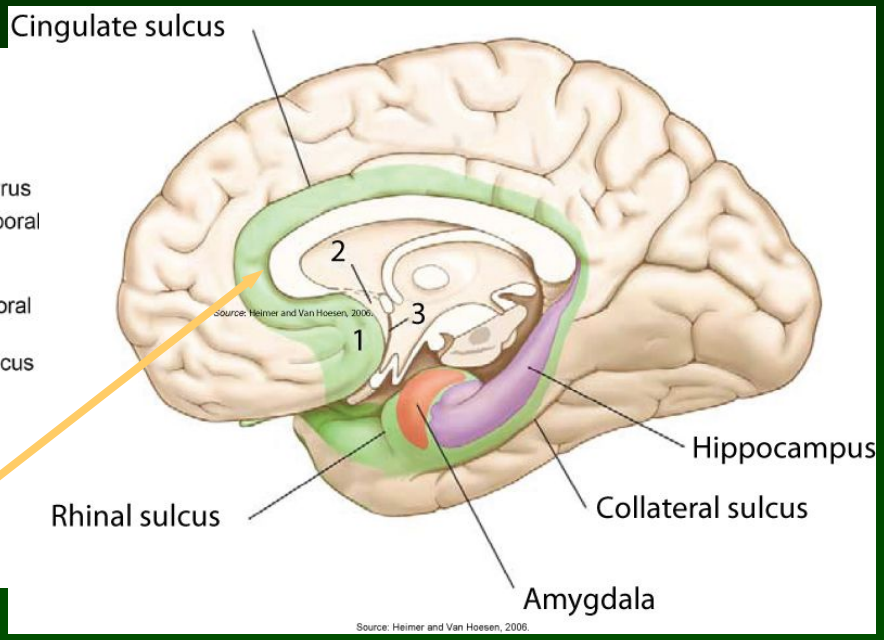


Insula and Sylvian fissure

- Insula is responsible for: 'gut feelings', the sense of nausea and disgust, interoception (feeling internal organs), emotional awarness.
- Sylvian fissure runs between parietal and temporal lobes horizontaly towards junction with occipital lobe. It contains supratemporal plane that hosts primary and secondary auditory cortex and part of Wernicke's area for speech comprehension.

Medial Temporal Lobe





medial temporal lobe

The medial temporal lobe is a part of temporal lobe. It contains:

- hippocampi and surrounding parahipocampal regions associated with the episodic memory;
- limbic system with cingulate sulcus involved in resolving conflicting situations and rhinal sulcus responsible for smell.

Some parts contain paleocortex with reduced number of layers.

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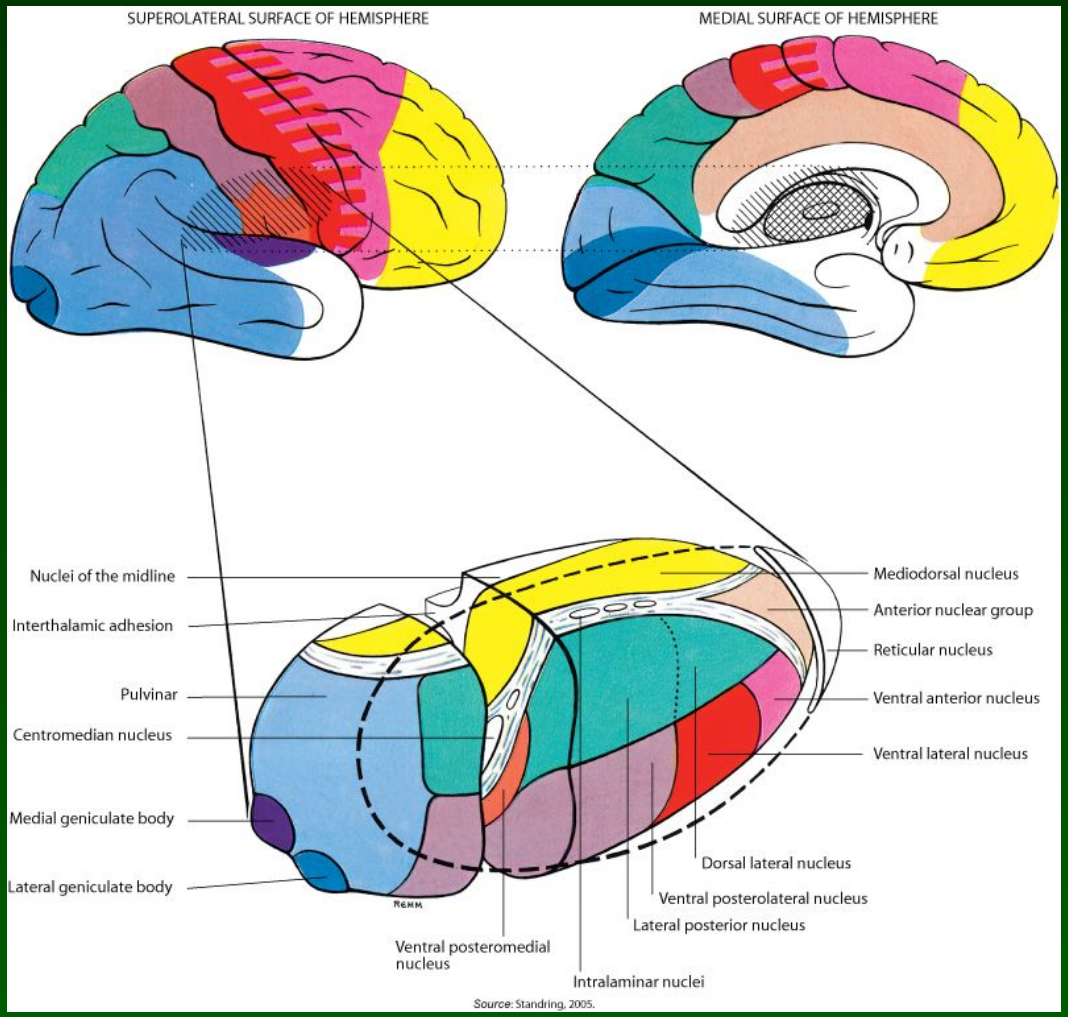
Cortico-thalamic loops

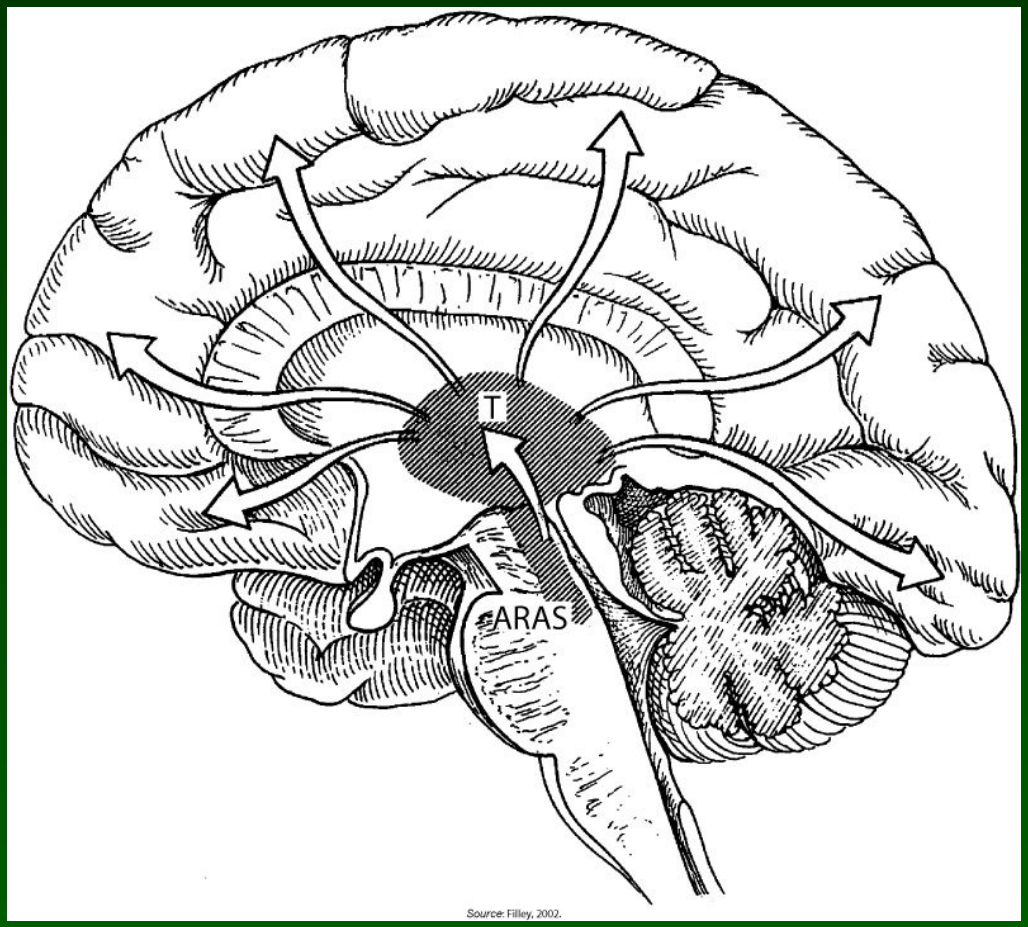


All inputs and outputs to the brain go through thalamus.

Mapping of the thalamic cortex to cortical regions is quite specific.

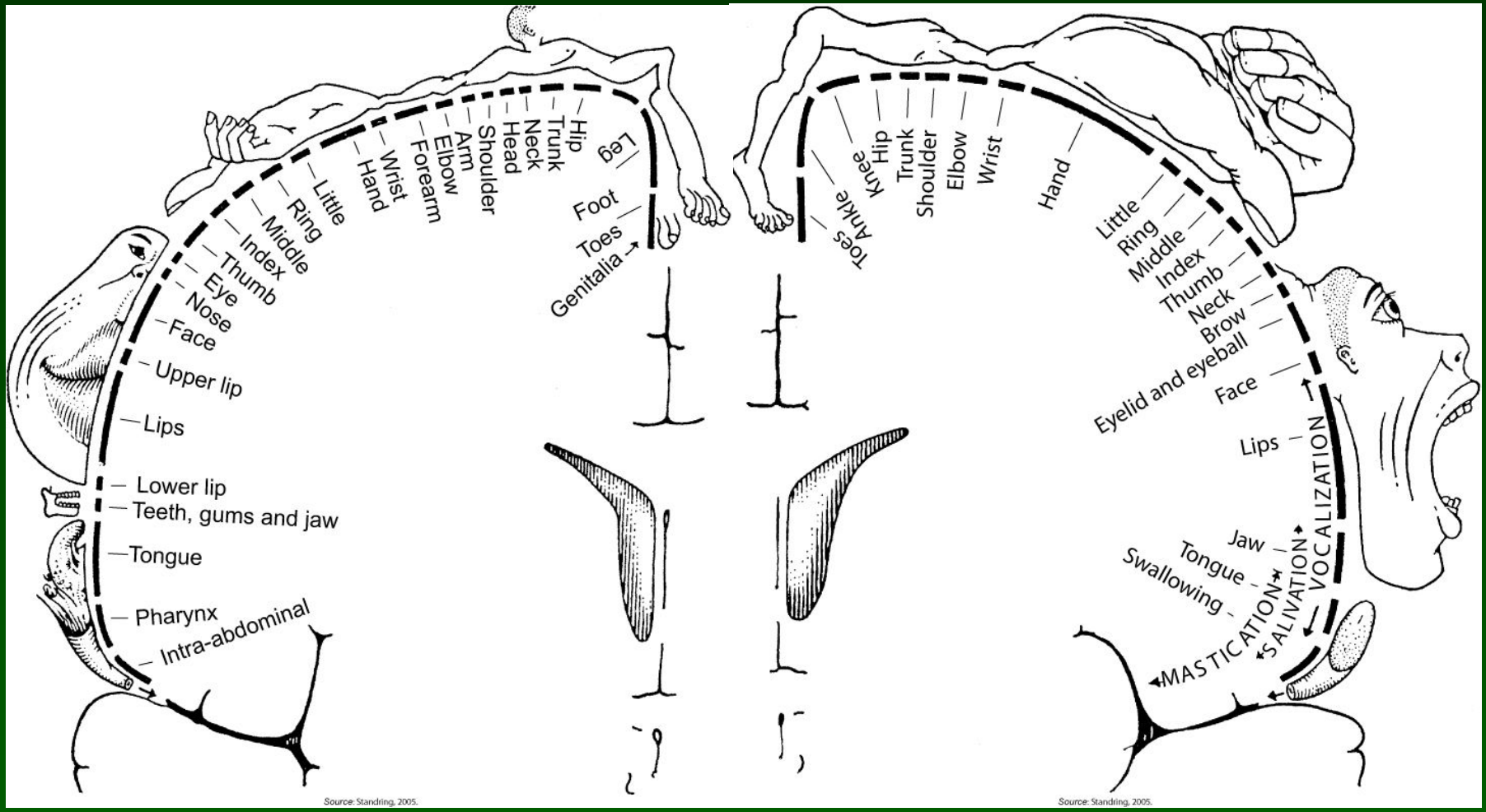
Reticular Activating System (ARAS)

- The ARAS and extended reticular-thalamic system (ERTAS) are thought to be required for the normal conscious waking state.
- Various sensory inputs converge in this region and compete.
- If an input prevails it becomes a global message distributed to other brain areas.
- Thus ERTAS underlies 'global broadcasting' function of consciousness of a selected sensory input.



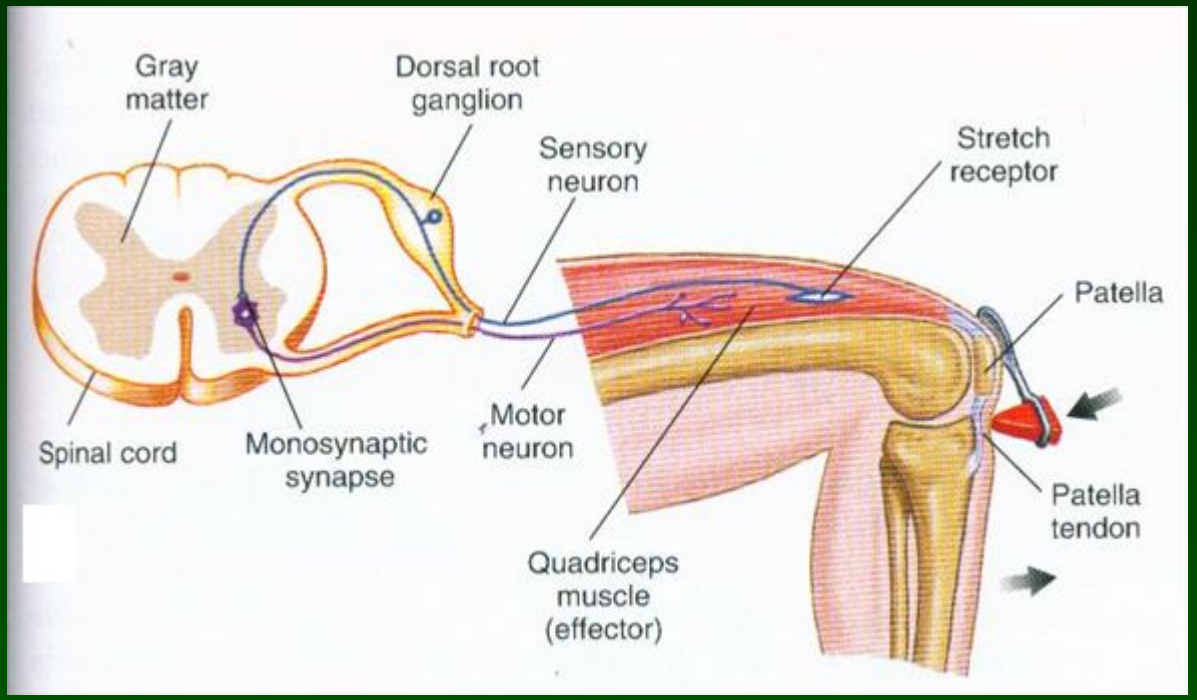
Source: Filley, 2002.

Homunculus around central sulcus



Sematosensory and motor cortex are next to each other on both sides of the central sulcus

A simple reflex circuit

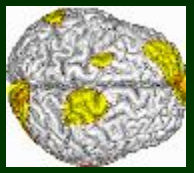


Not all behavior requires cortical conscious control. For example, we all know the knee-jerk reflex.

- Sensory neurons in muscles and tendons react to the sudden pressure transmitting signals to the spinal cord.
- An interneuron in the spine links the sensory impulses to motor neurons, bypassing higher level brain functions, contracting leg muscles.

This was known already 200 years ago, but reflexes in the brain were recognized only after Ivan Sechenov published “Reflexes of the brain” (1863).

What it will be about



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