

Neuroimaging and mathematical modelling

Nivedita Agarwal, MD

Nivedita.agarwal@apss.tn.it

Nivedita.agarwal@unitn.it

What will I teach you? (12 hours)

1. Brain anatomy (2hours)
 - a. Structure
 - b. Function
 - c. Chemistry

2. MRI (data acquisition)
 - a. Structural imaging and volumetric analysis (2 hours.)
 - b. Diffusion tensor imaging (DTI) and Diffusion weighted imaging (DWI) (3hours)
 - i. Basic anatomy
 - ii. Pathology related anatomy

 - c. Functional MRI (fMRI) (3 hours)
 - i. Resting state
 - ii. Cognition evoked fMRI

 - d. Magnetic resonance spectroscopy (MRS) (2 hours)
 - a. Normal spectrum
 - b. Techniques (single-voxel and chemical shift imaging)

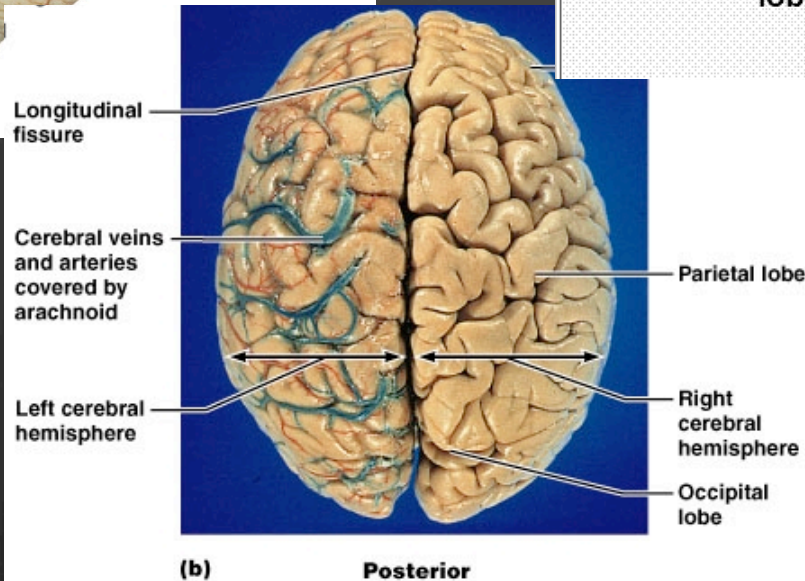
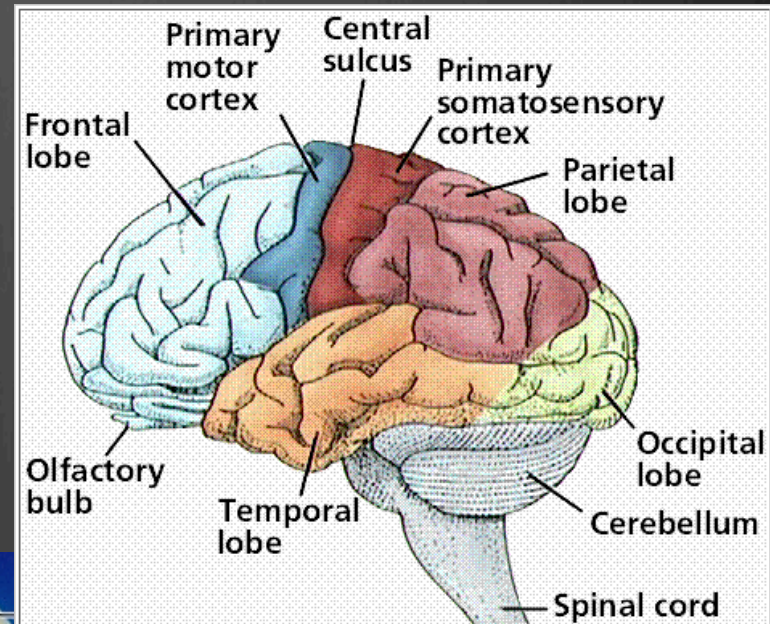
BRAIN ANATOMY

GROSS ANATOMY

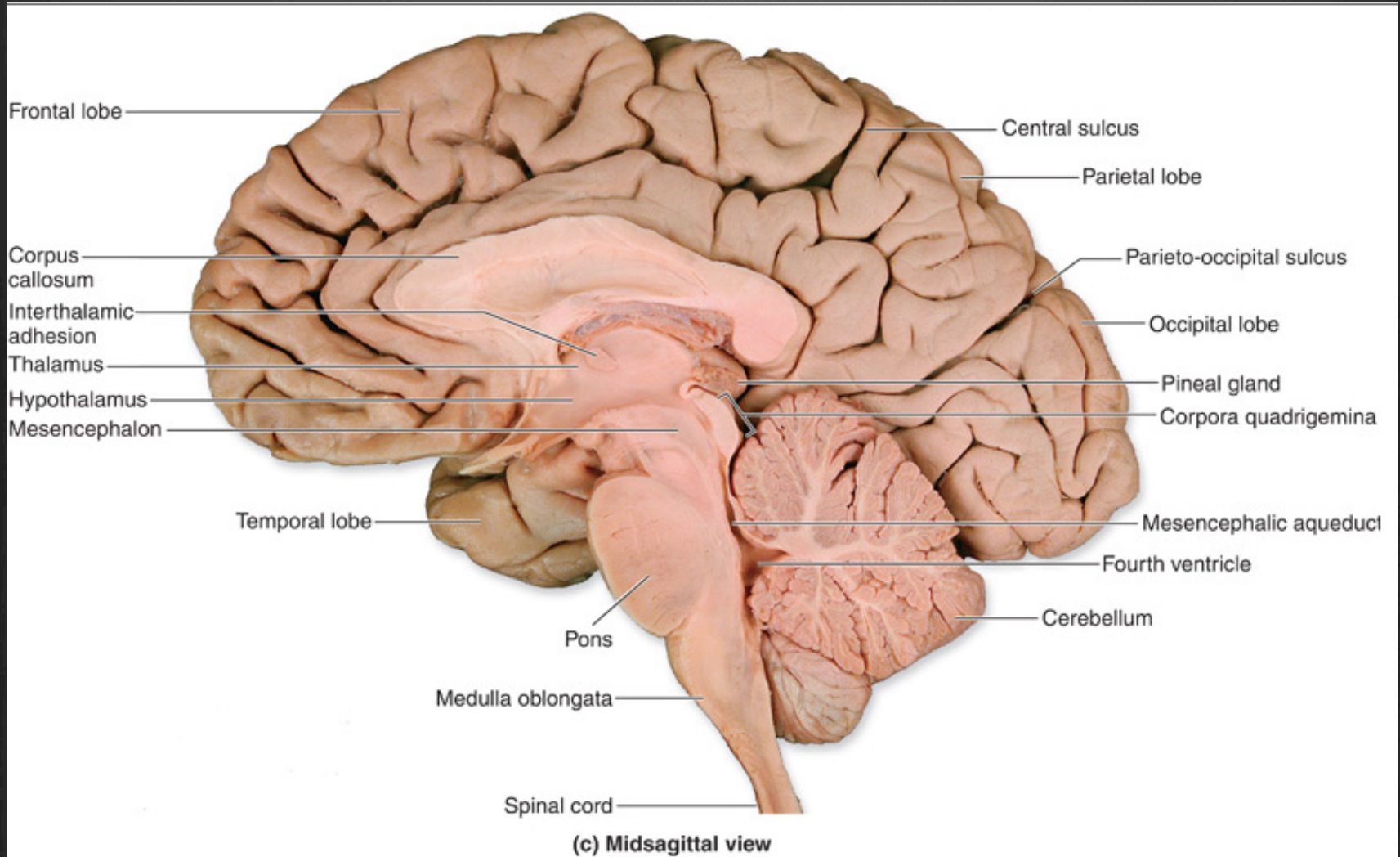
HISTOLOGICAL ANATOMY

FUNCTIONAL ANATOMY

GROSS ANATOMY

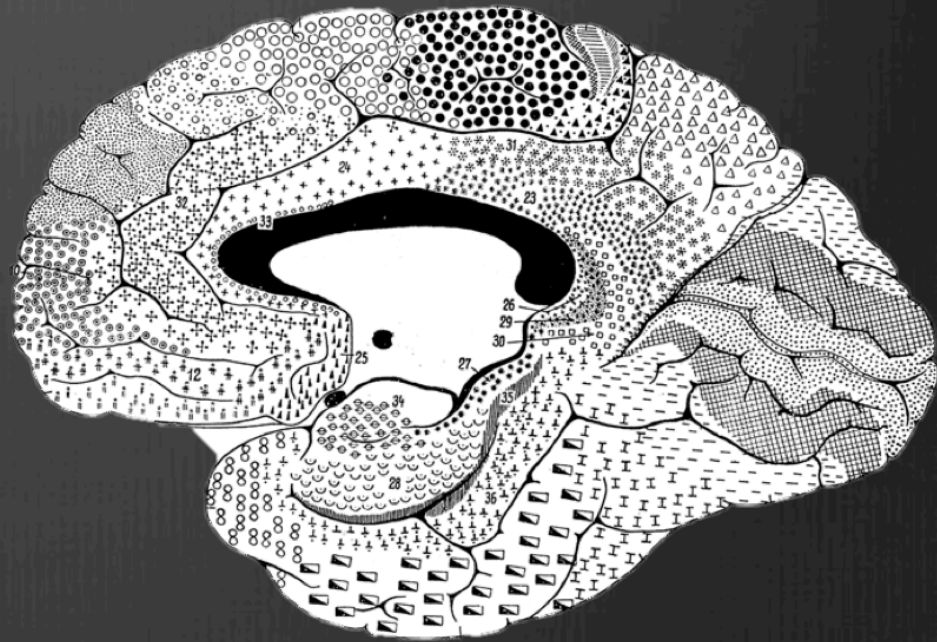
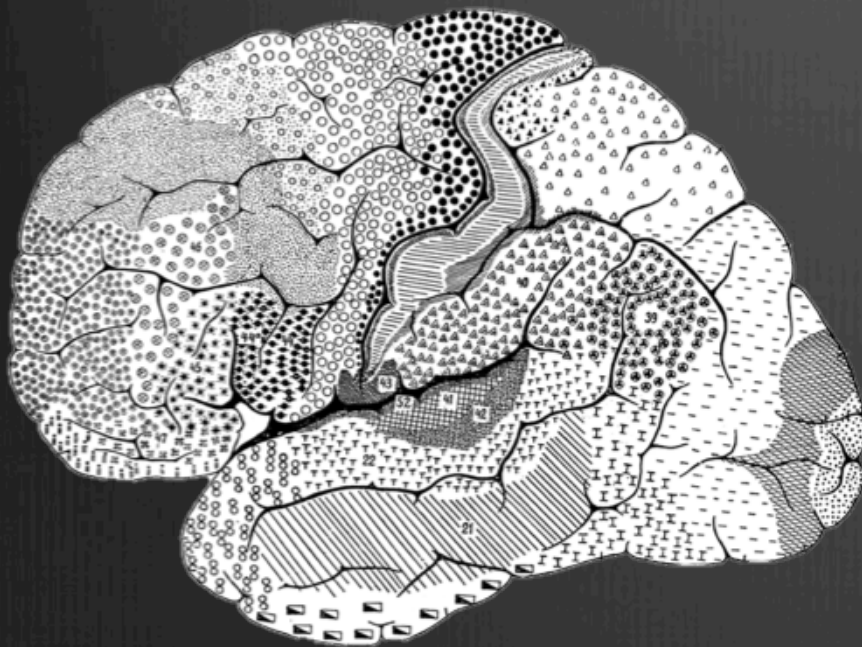


GROSS ANATOMY



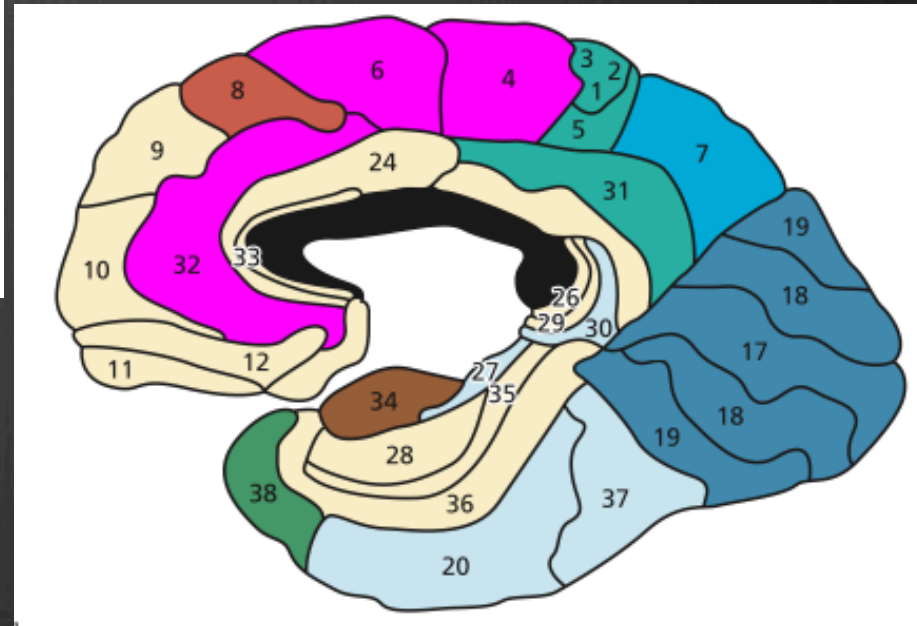
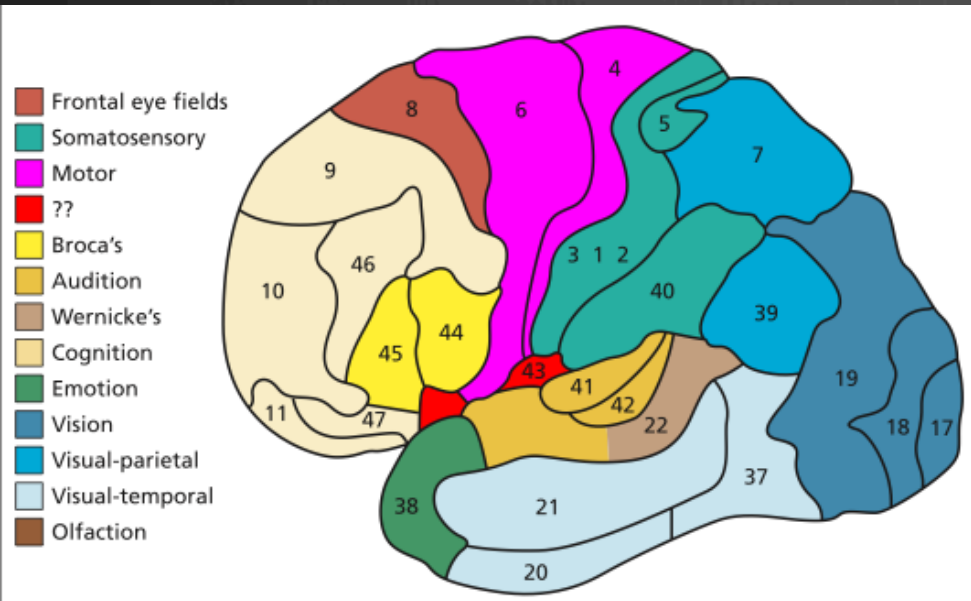
Telencefalo: neocortex

🎯 Citoarchitecture (BRODMANN's areas)



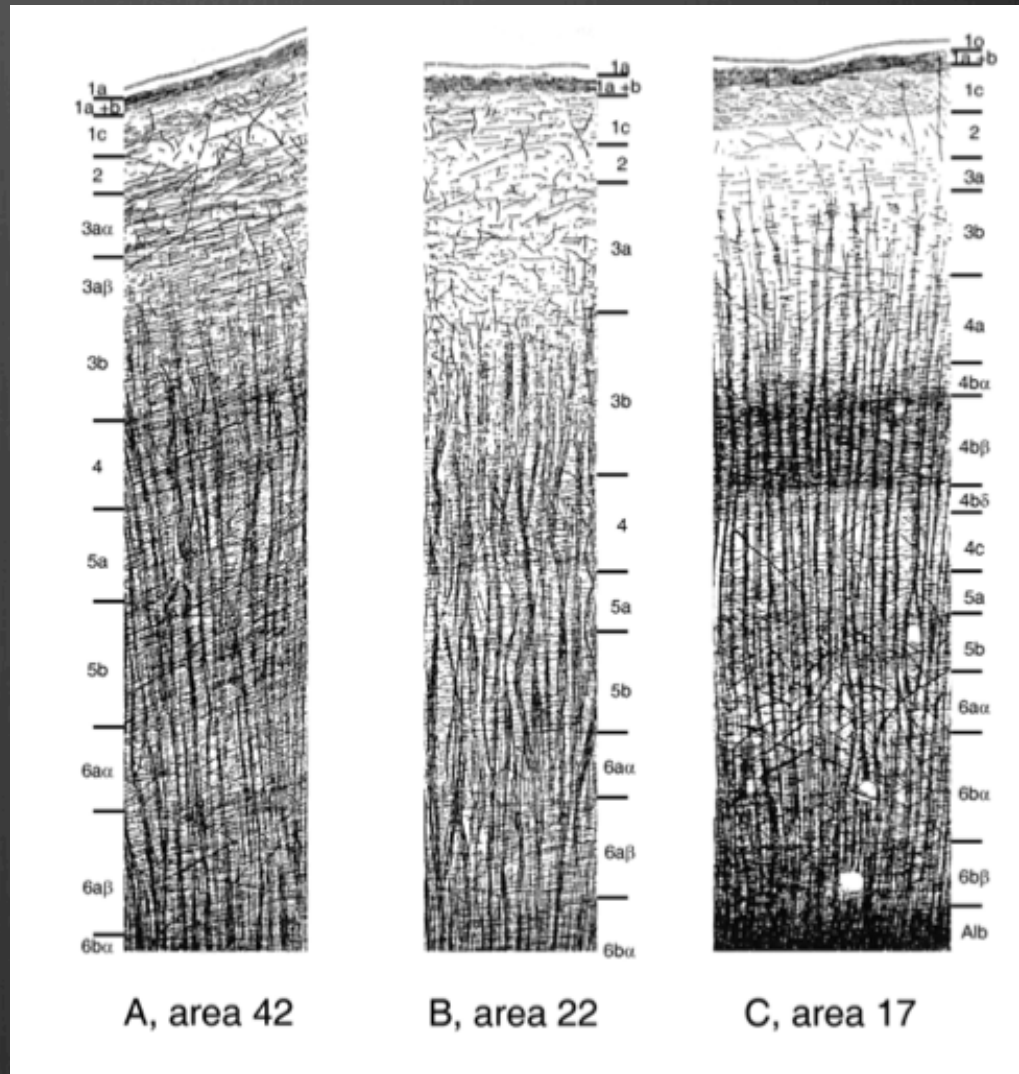
Telencefalo: neocortex

🎯 Citoarchitecture (AREA DI BRODMANN)



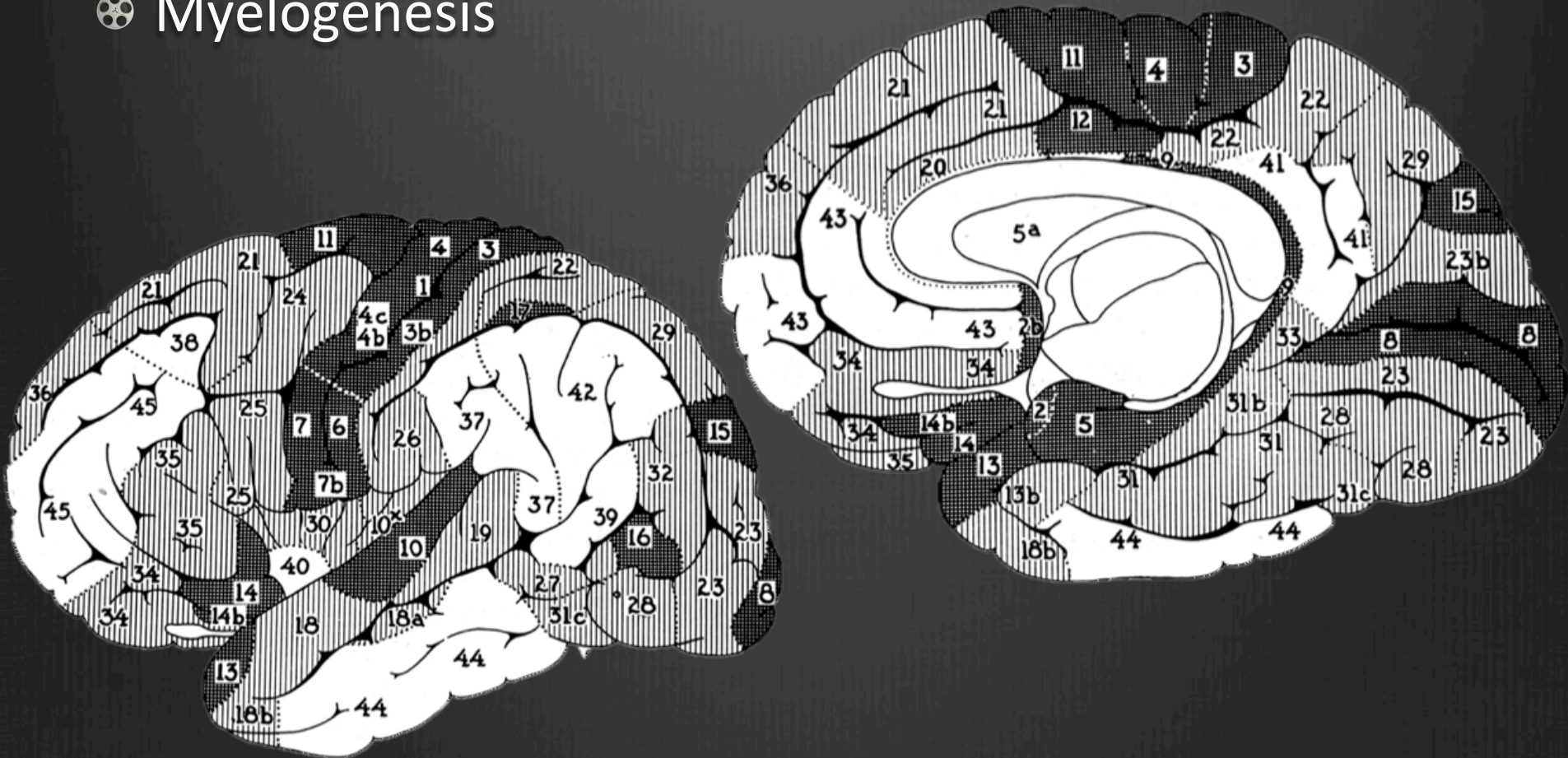
Telencefalo: neocortex

🎯 Myeloarchitecture

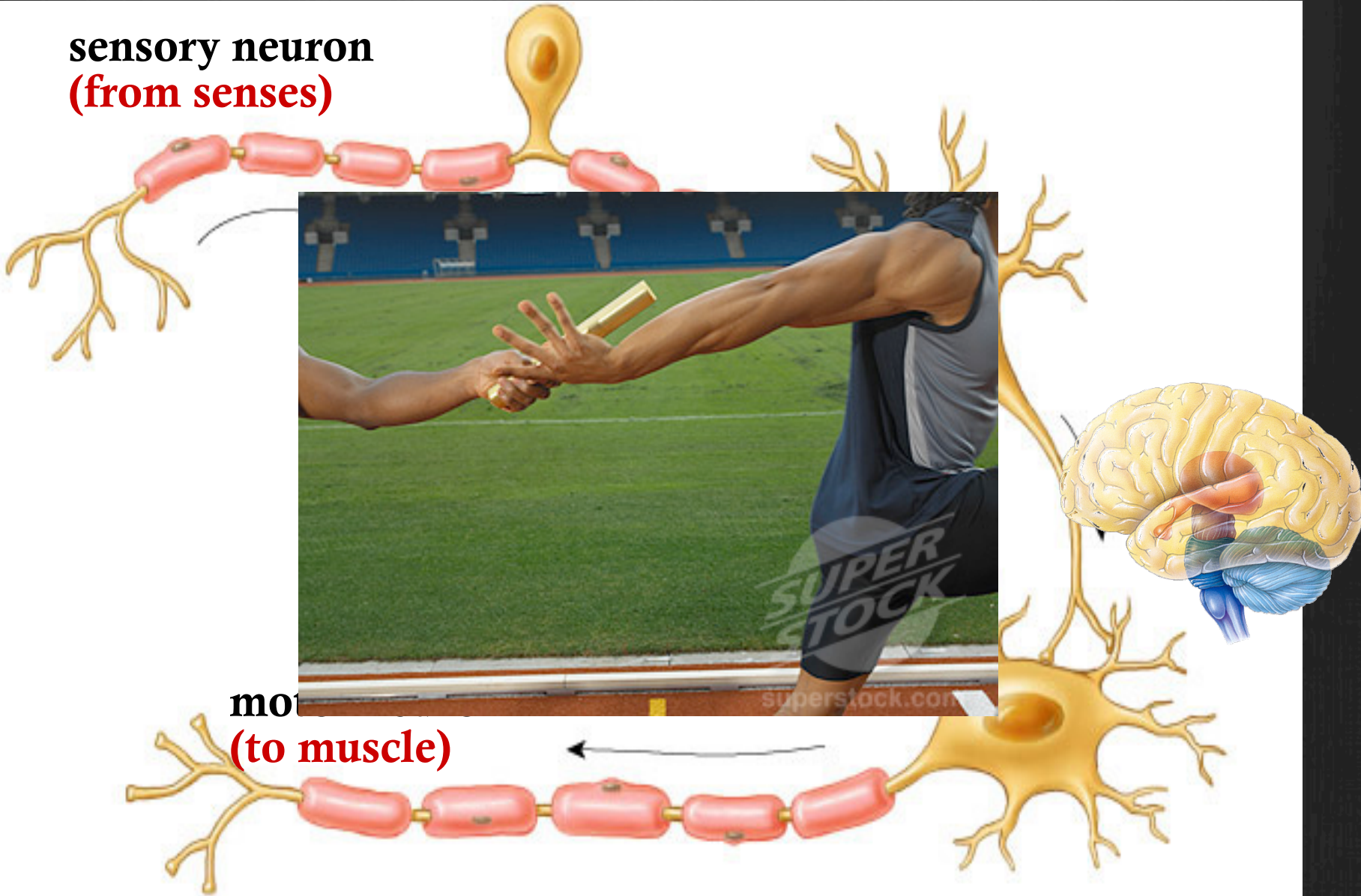


Telencefalo: neocortex

🎯 Myelogenesis



sensory neuron
(from senses)



motor neuron
(to muscle)

Volume and surface morphometry

Brain volume

White matter

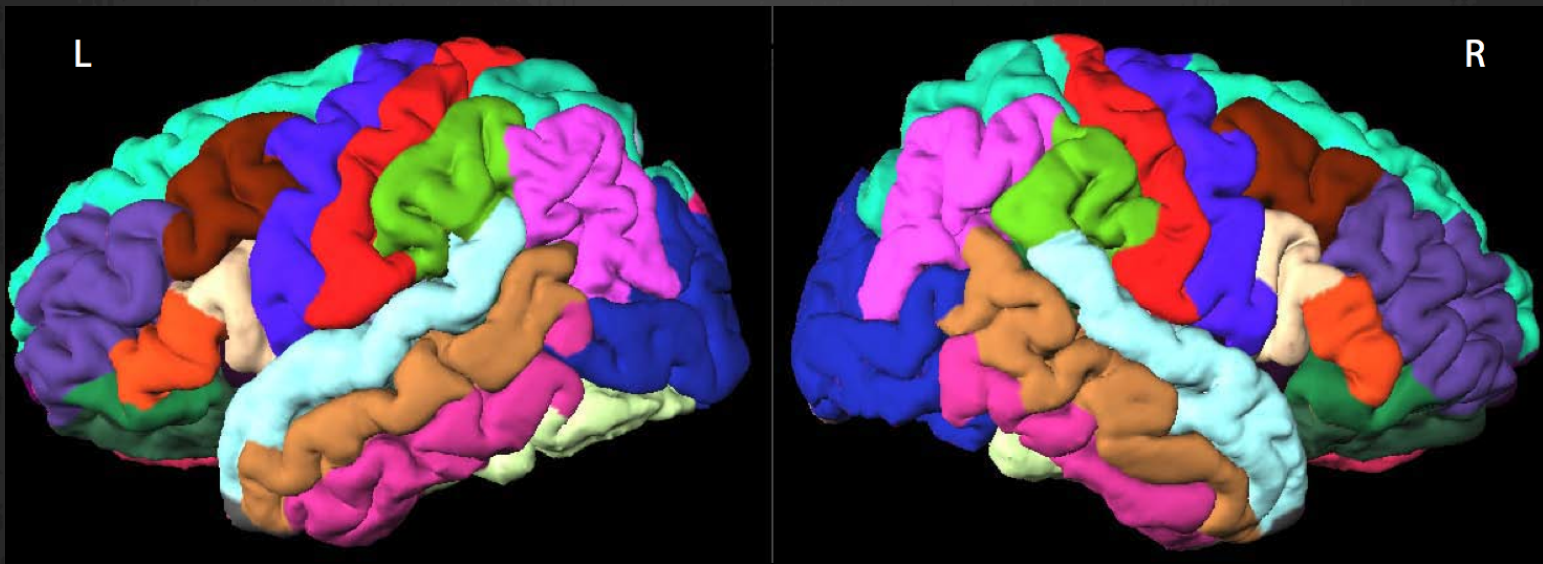
Grey matter

Volume of specific brain structures

hippocampus (Alzheimer's disease, memory loss states)

frontal lobe (intelligence!, analytical brain)

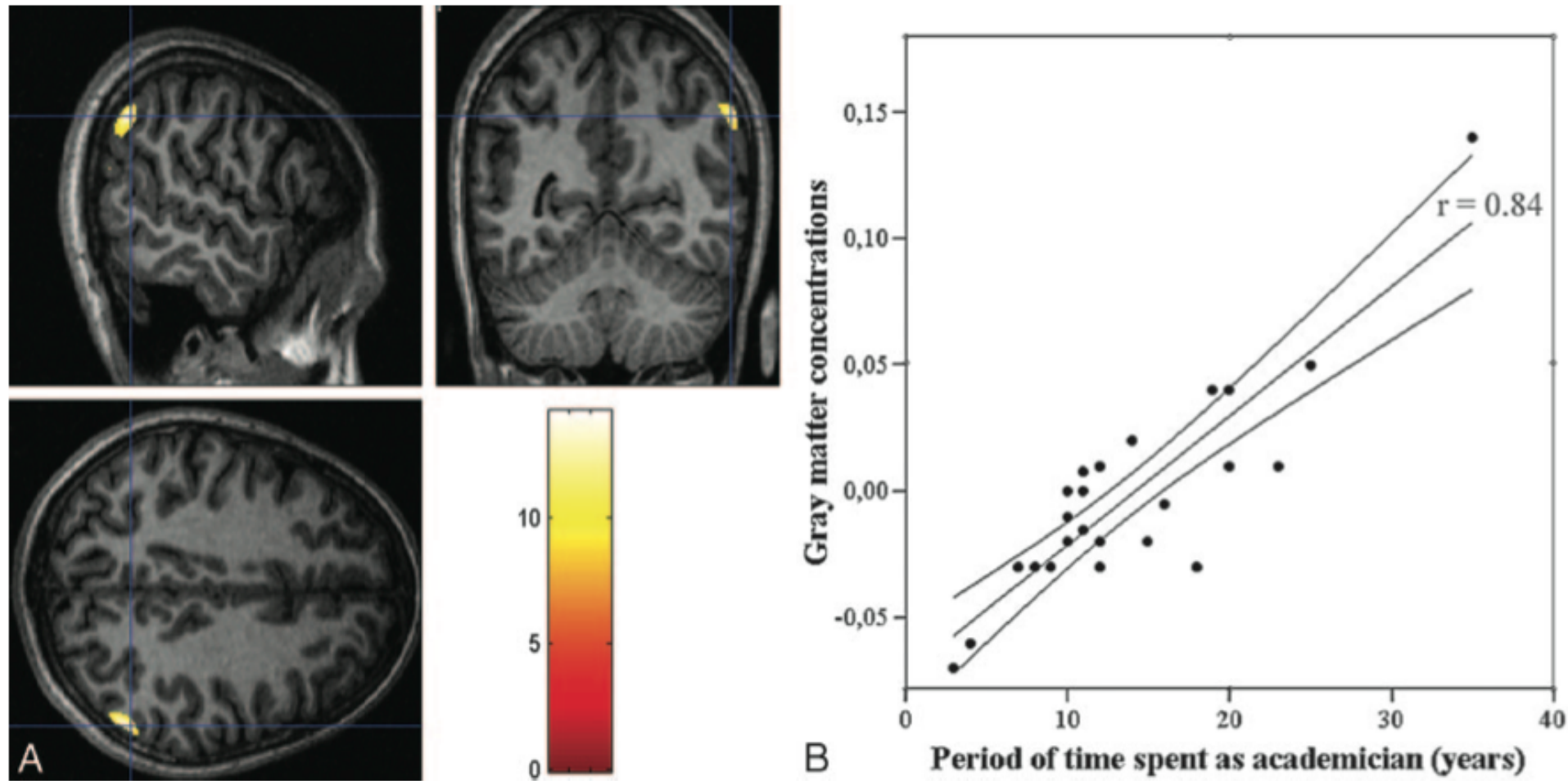
basal ganglia (Parkinson's disease, metabolic disorders)



Examples applications of VBM

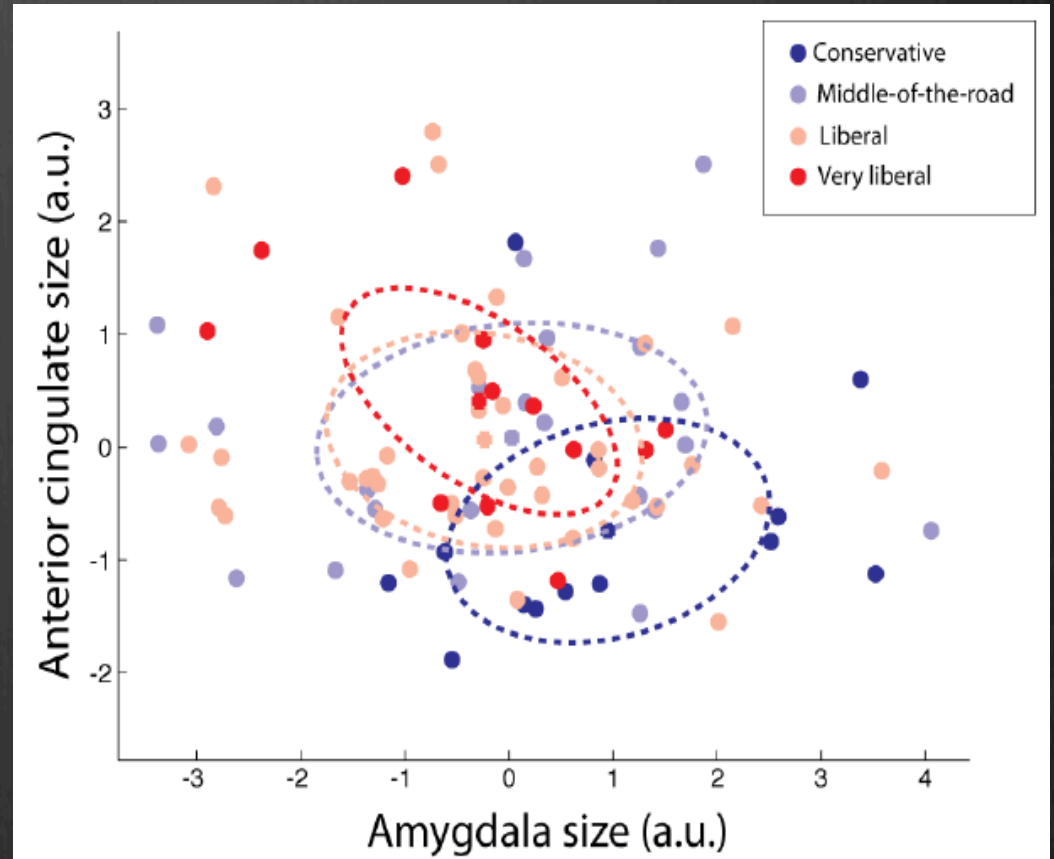
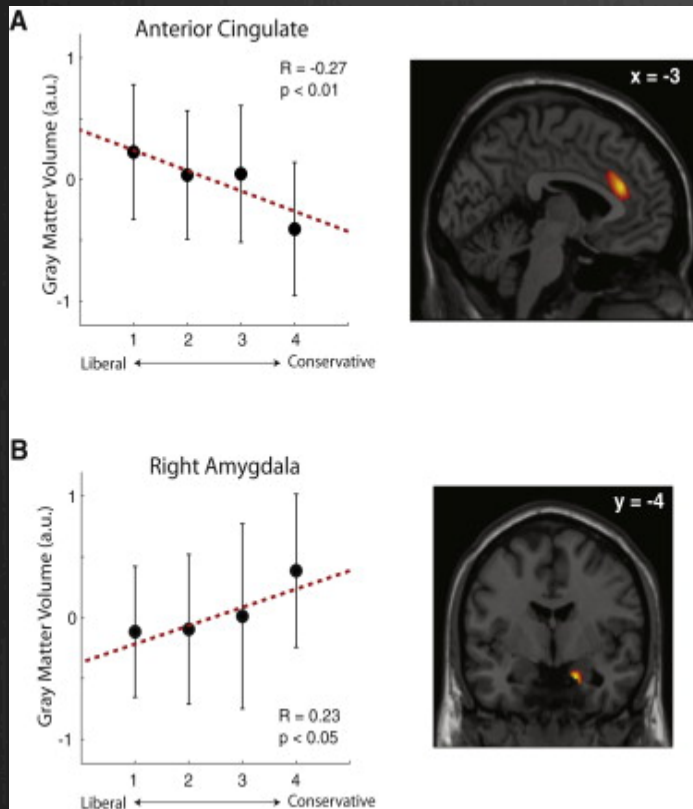
- ⊗ Many scientifically or clinically interesting questions might relate to the local volume of regions of the brain
- ⊗ For example, whether (and where) local patterns of brain morphometry help to:
 - ⊗ Distinguish groups (e.g. schizophrenics and healthy controls)
 - ⊗ Explain the changes seen in development and aging
 - ⊗ Understand plasticity, e.g. when learning new skills
 - ⊗ Find structural correlates (scores, traits, genetics, etc.)

Examples applications of VBM

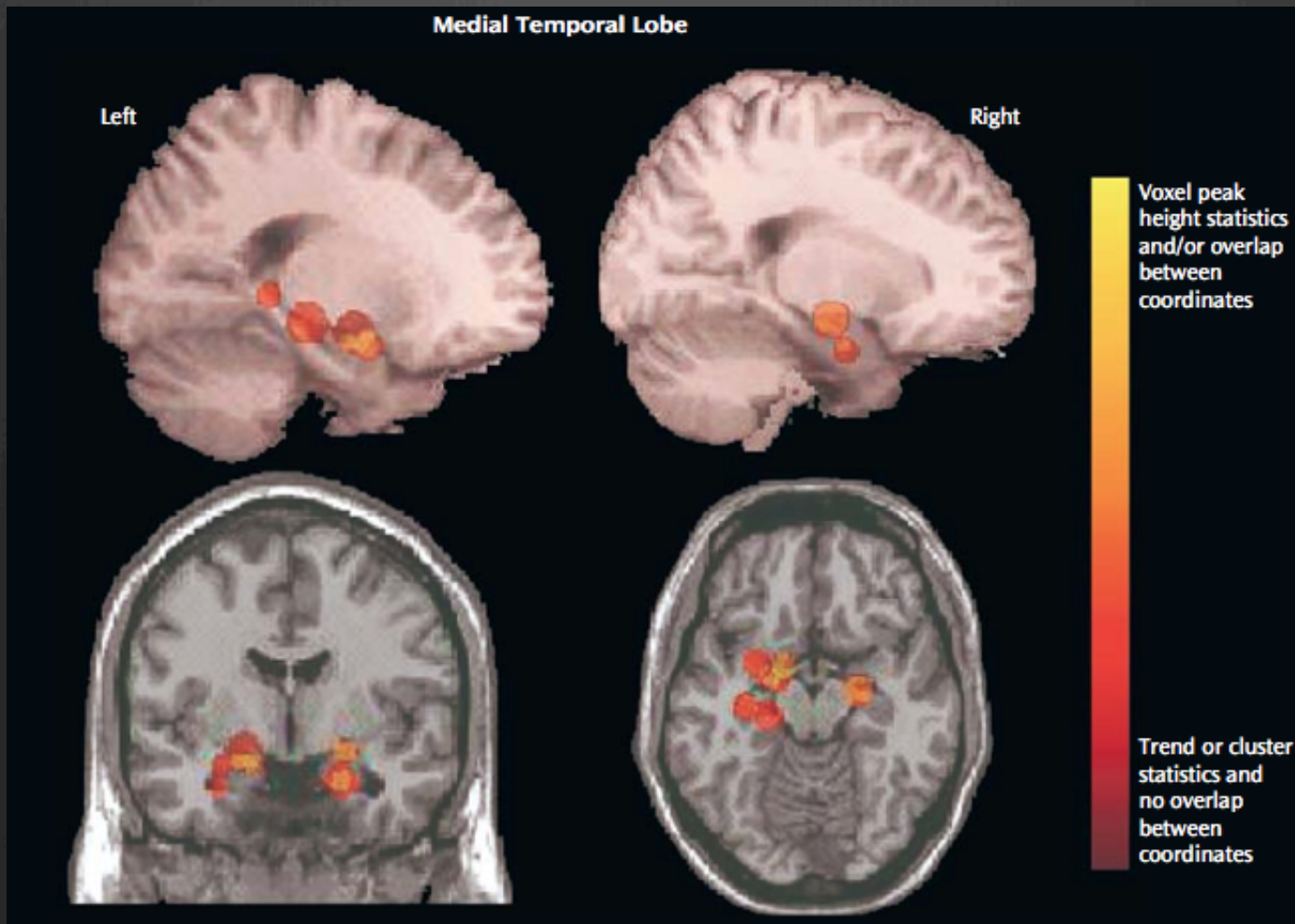


VBM and political orientation

- 🌀 Ryota Kanai, Tom Feilden, Colin Firth, Geraint Rees
- 🌀 *Political Orientations Are Correlated with Brain Structure in Young Adults.*



Volume and surface morphometry



Schizophrenia vs. healthy controls

Volume and surface morphometry

This is where mathematicians and physicists come in to the scene!

Lots of online free tools to study volume of brain structures and identify surface anatomy

<http://surfer.nmr.mgh.harvard.edu/fswiki/FreeSurferAnalysisPipelineOverview>

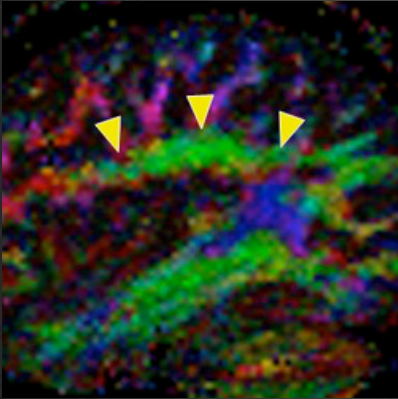
<http://surfer.nmr.mgh.harvard.edu/fswiki/Slicer>

<http://afni.nimh.nih.gov/>

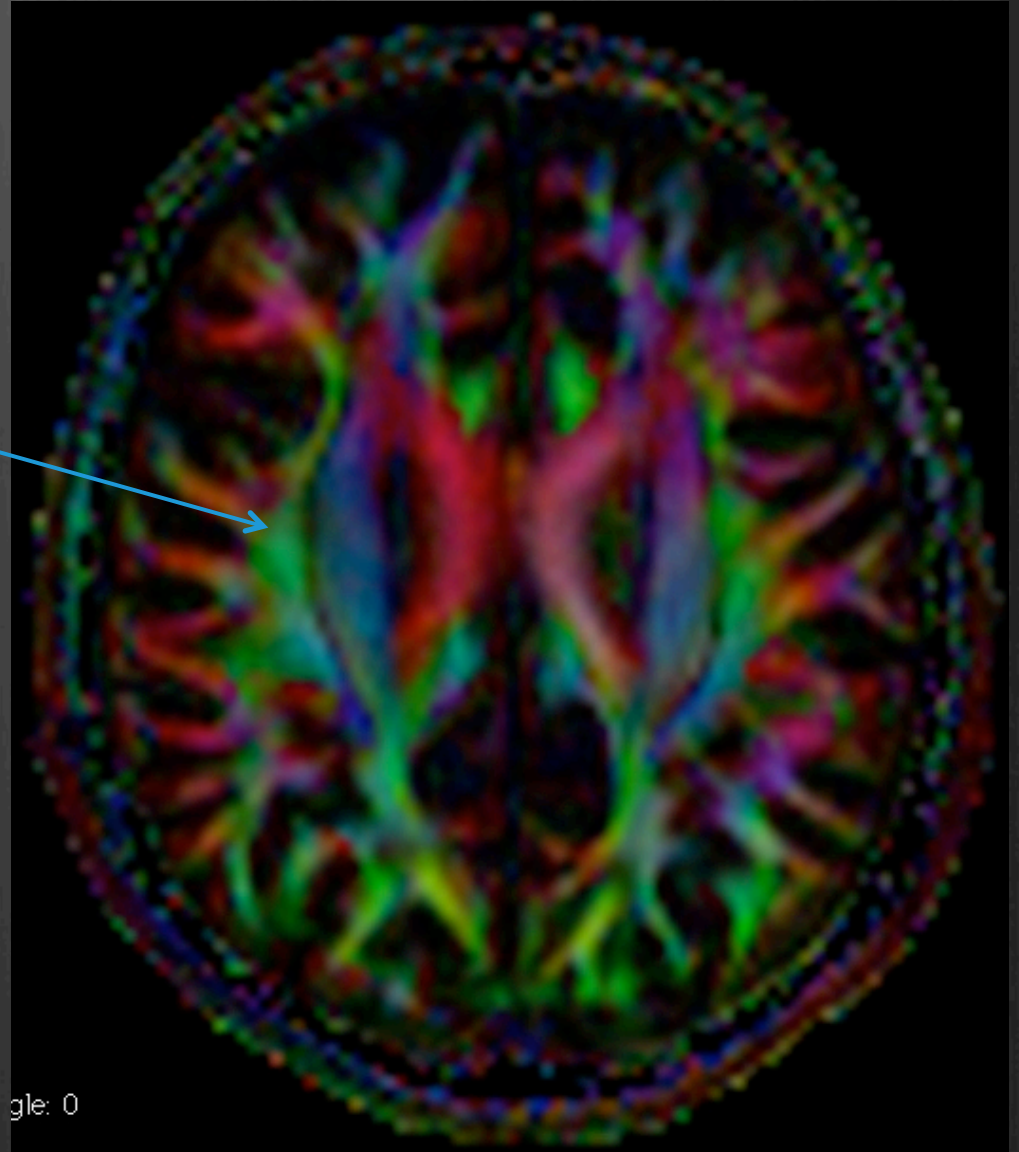
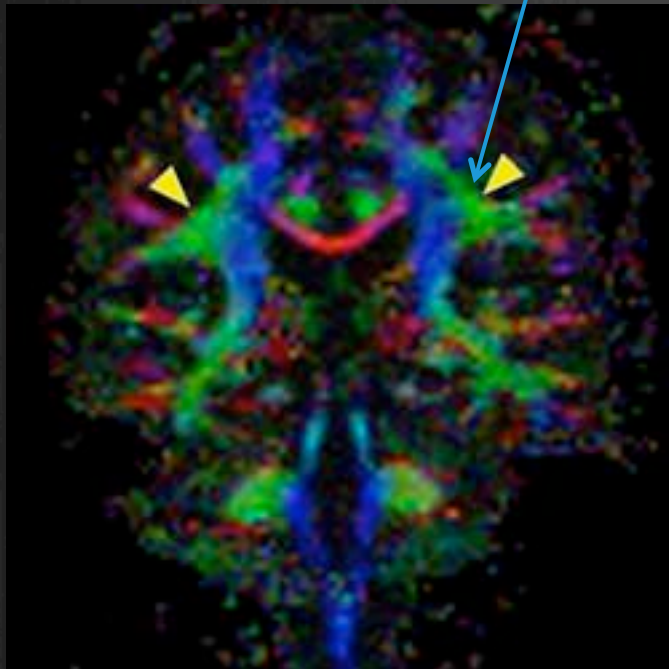
White matter



Diffusion tensor imaging (DTI)



SLF



Inferior longitudinal fasciculus

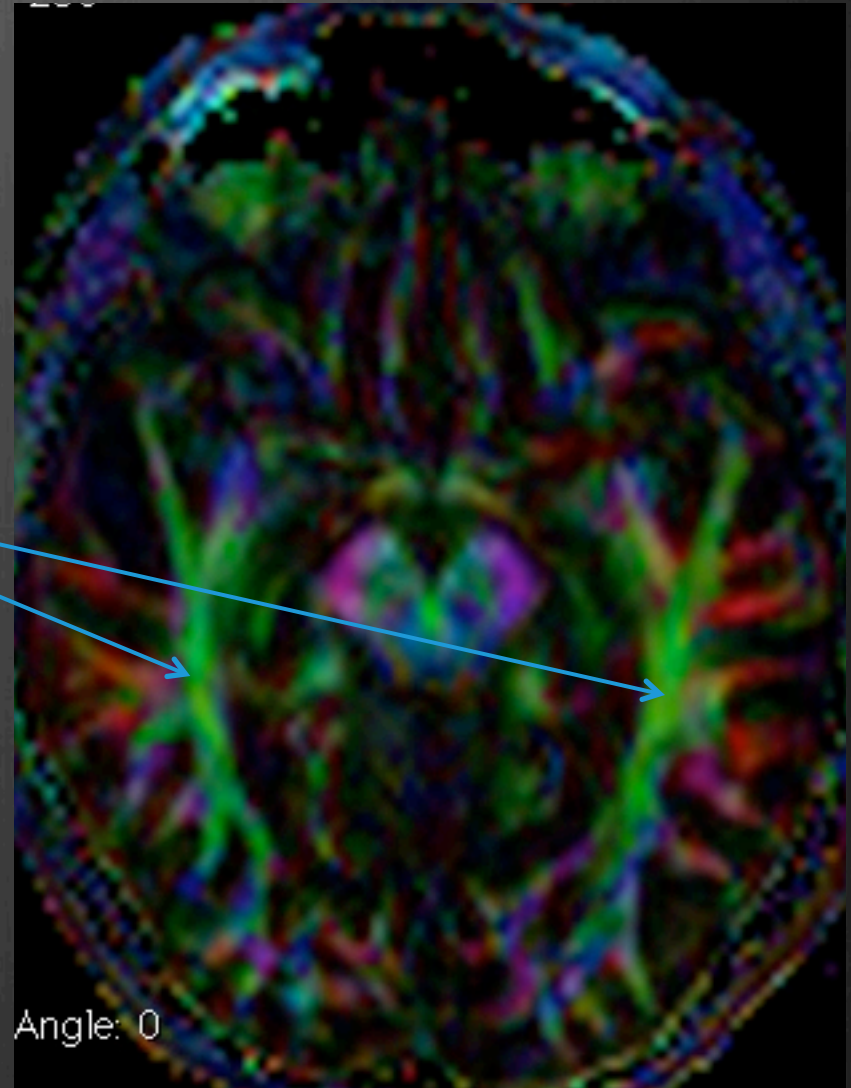
Connette il lobo occipitale al lobo temporale.

Importante nella **via visiva ventrale**
riconoscimento degli oggetti e delle faccie.

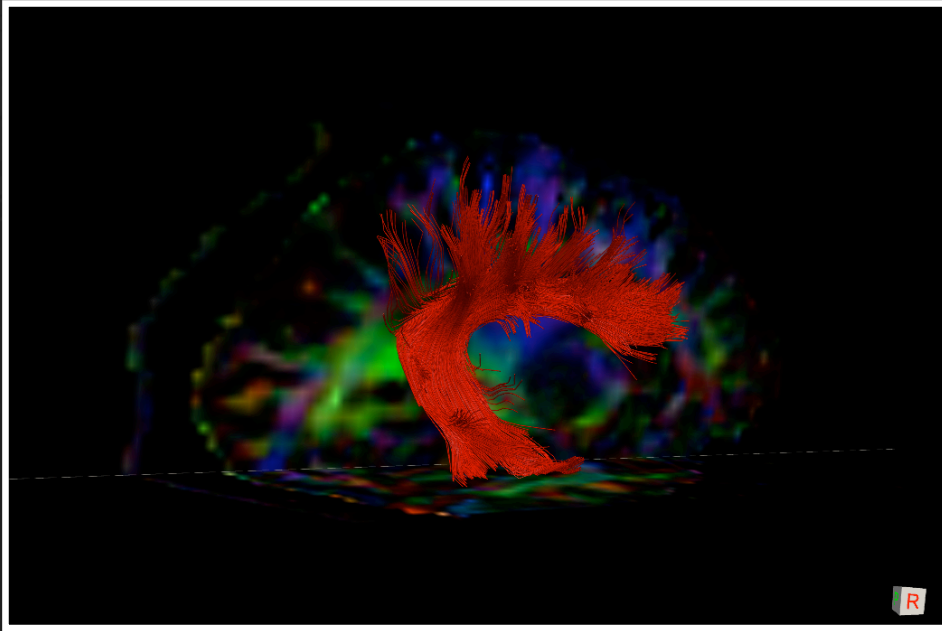
Semantic processing.
Visual object recognition

Lesioni possono dare agnosia

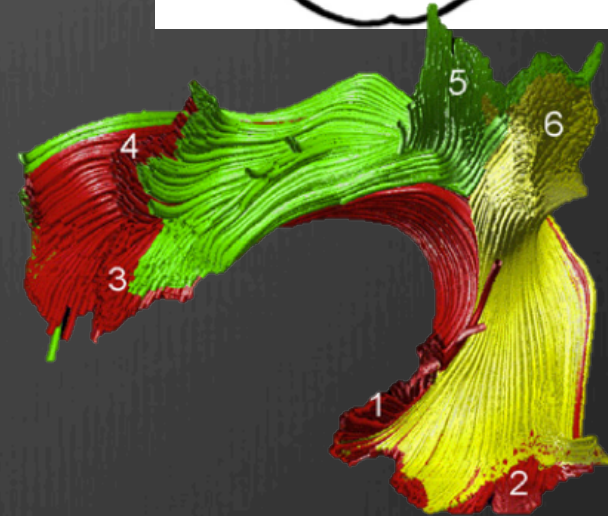
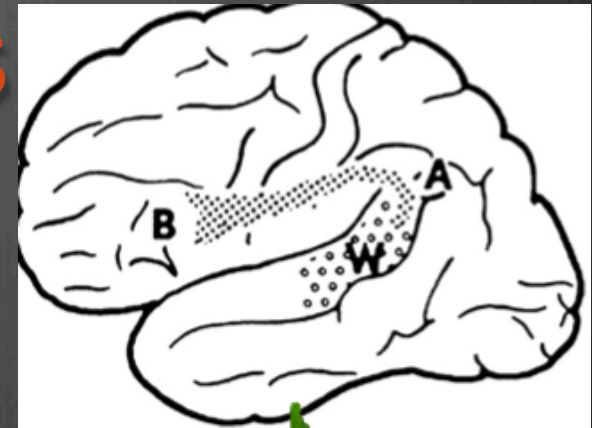
ILF



Arcuate fasciculus



Function: Conduction aphasia



AF connects superior temporal gyrus (spatial localization of sounds) and caudal areas of the prefrontal cortex (spatial attention and working memory).

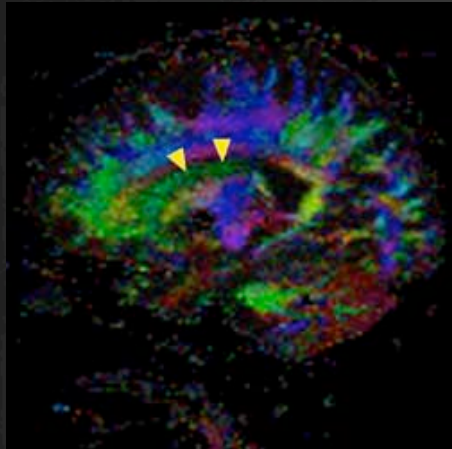
AF is important in the localization of sounds and words.

Occipito-frontal superior fasciculus

Connects DLPFC areas (frontal eye fields)

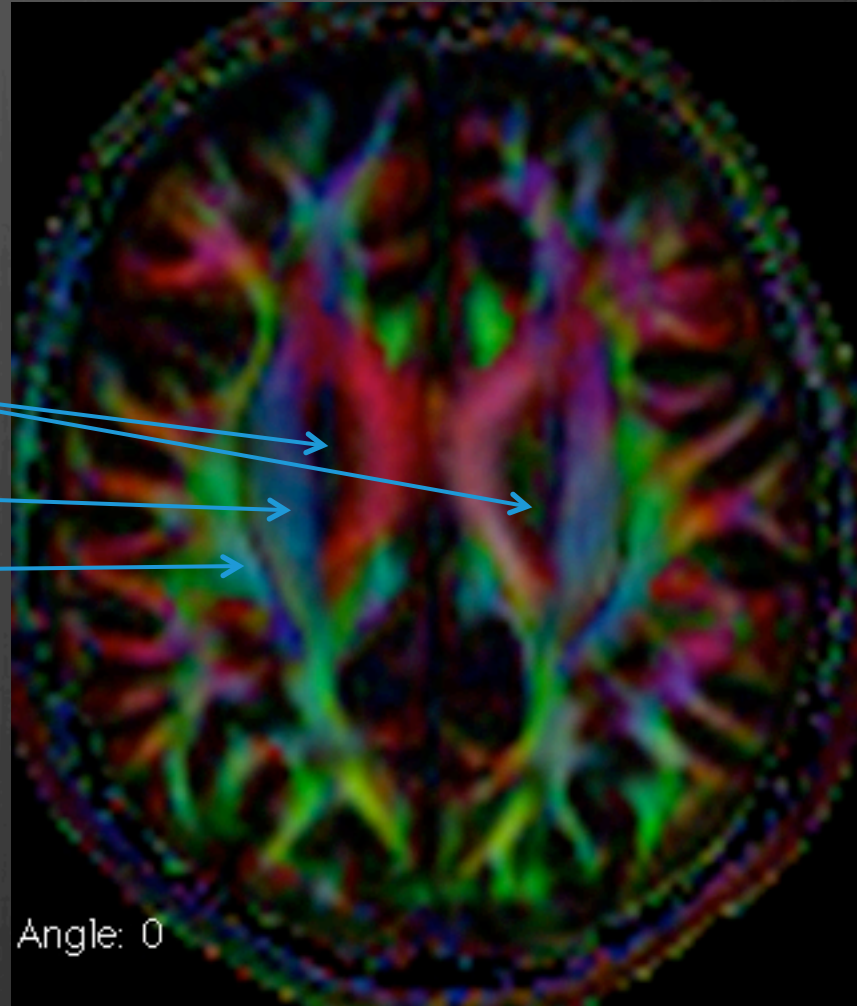
Spatial visual processing.

Corona radiata



SOF

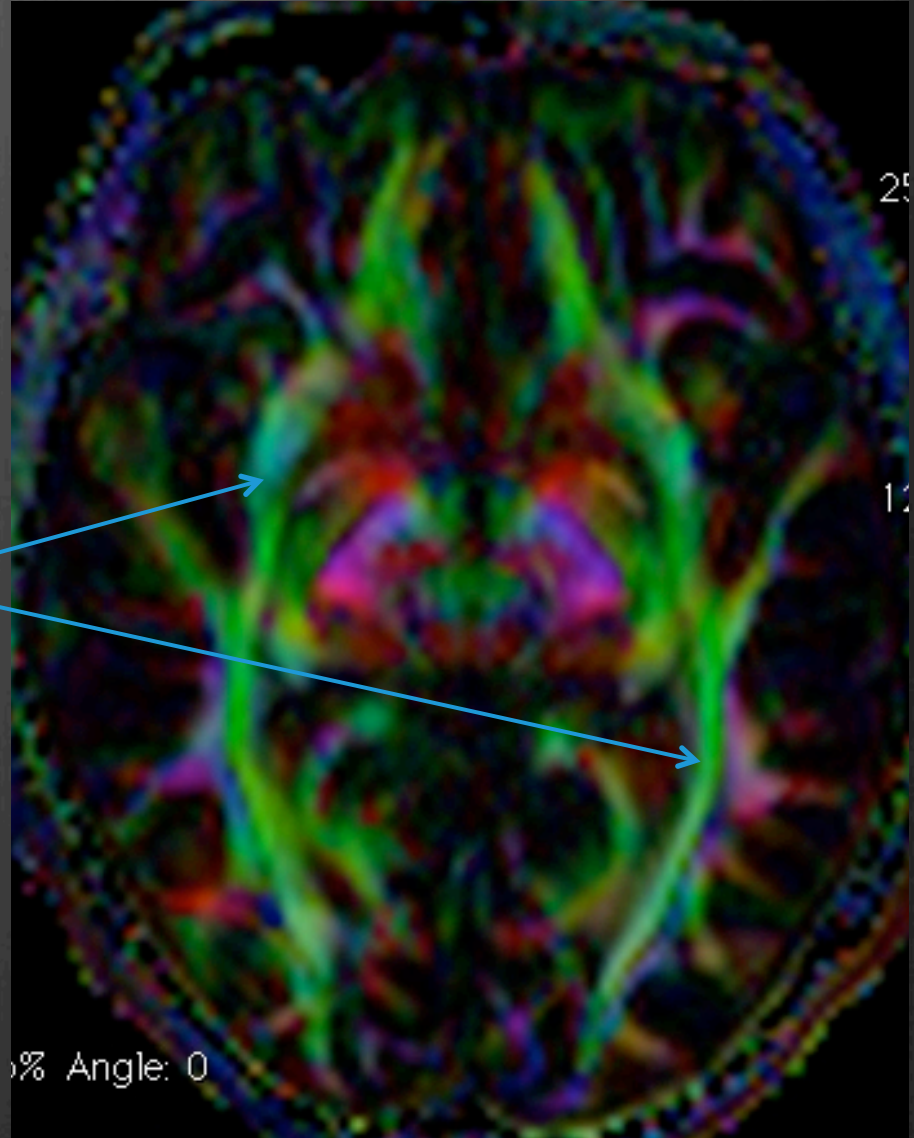
SLF



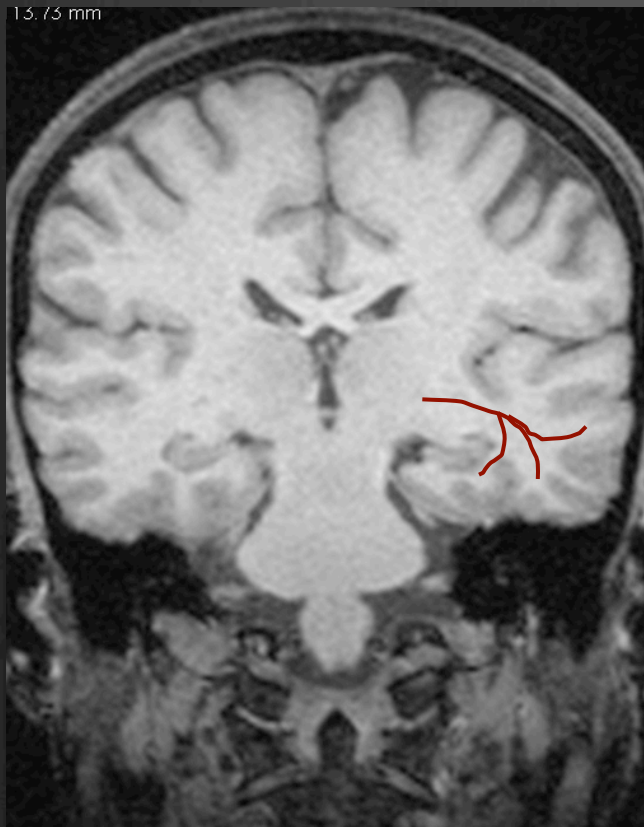
Occipito-frontal inferior fasciculus

Connects auditory and visual areas
to the frontal areas

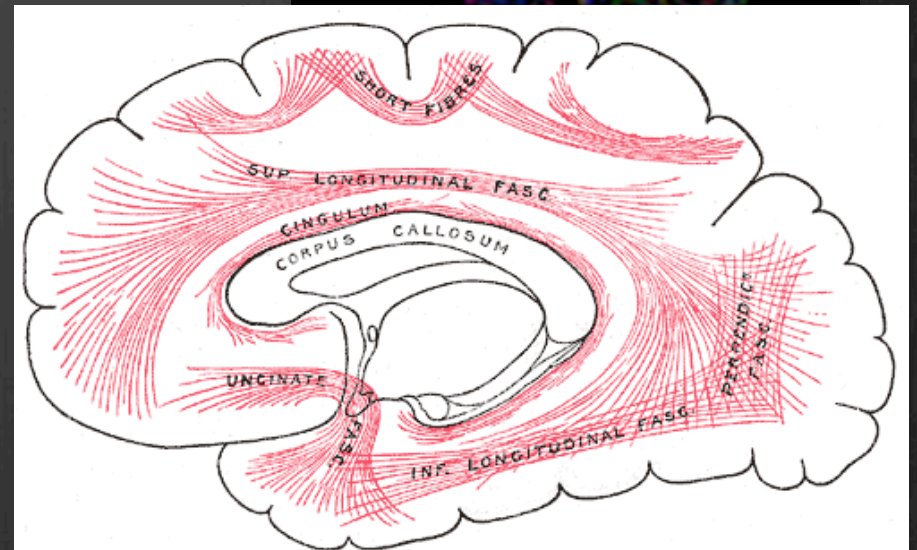
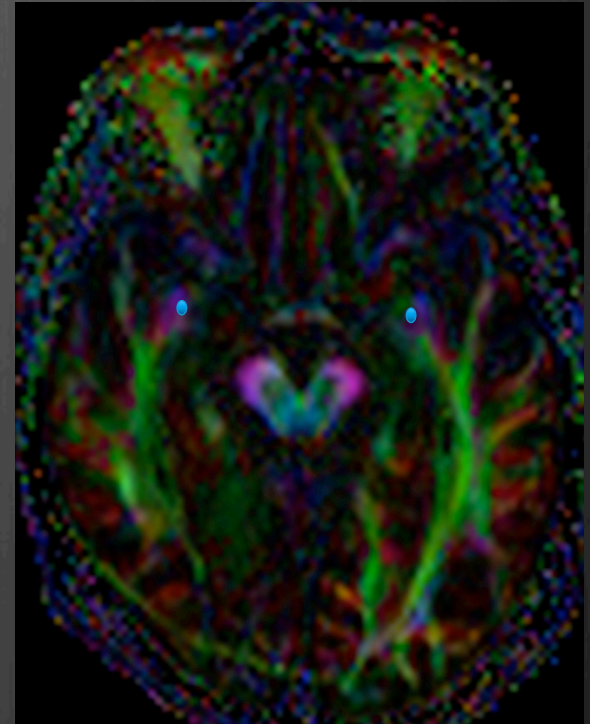
IFOF



Uncinate fasciculus



Temporal lobe



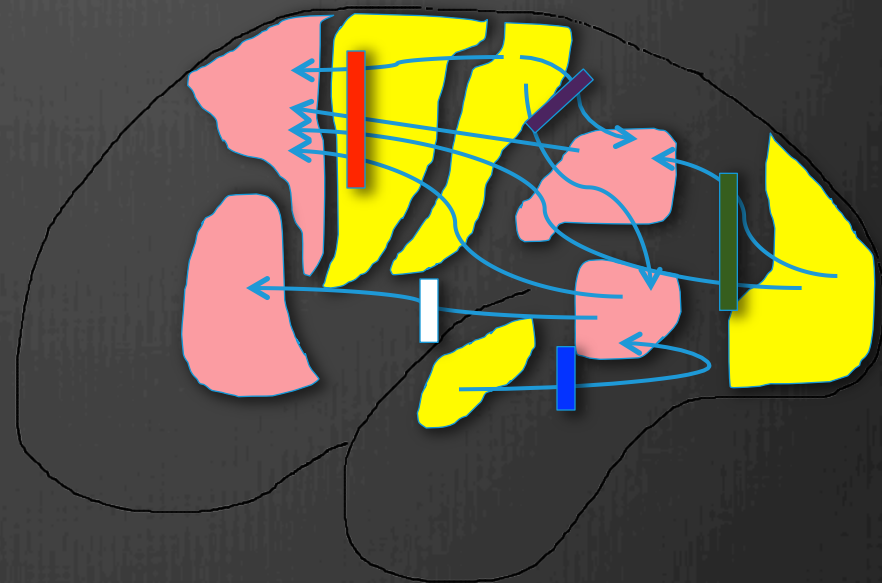
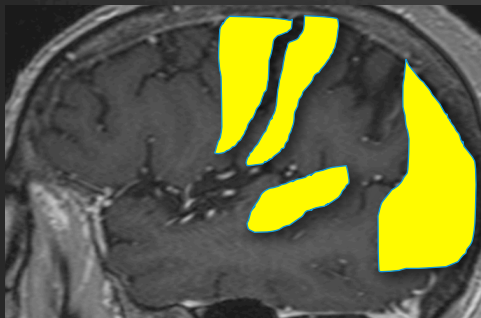
Major white matter tracts

⊗ Unimodal areas

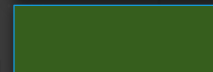
- ⊗ Somatosensory
- ⊗ Motor
- ⊗ Visual
- ⊗ Auditory

⊗ Heteromodal areas

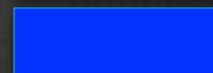
- ⊗ Parieto-temporal
- ⊗ Medial temporal
- ⊗ Prefrontal



apraxia



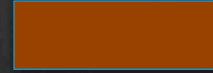
Visual agnosia, pure alexia



Pure hearing loss for words

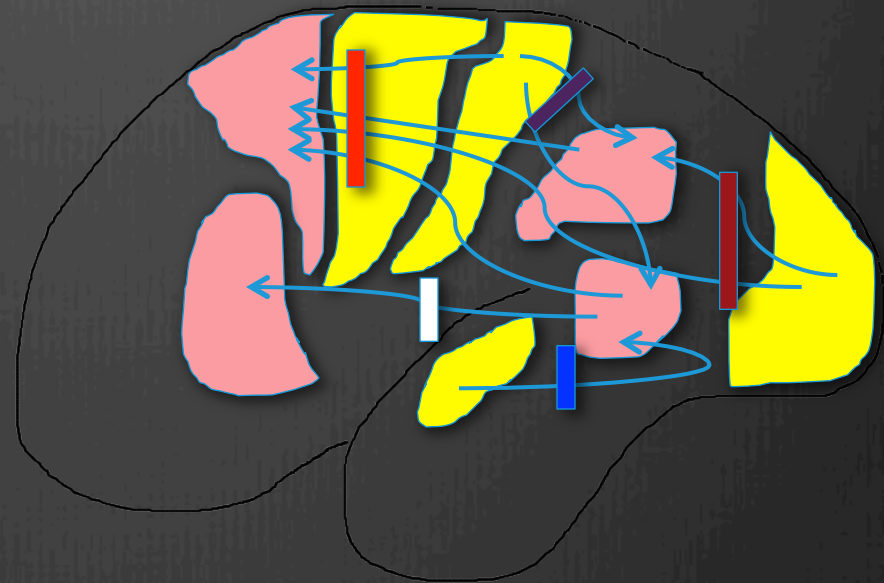
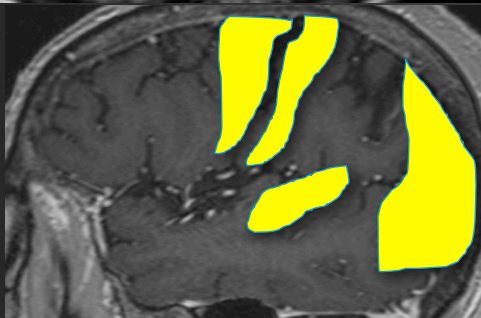
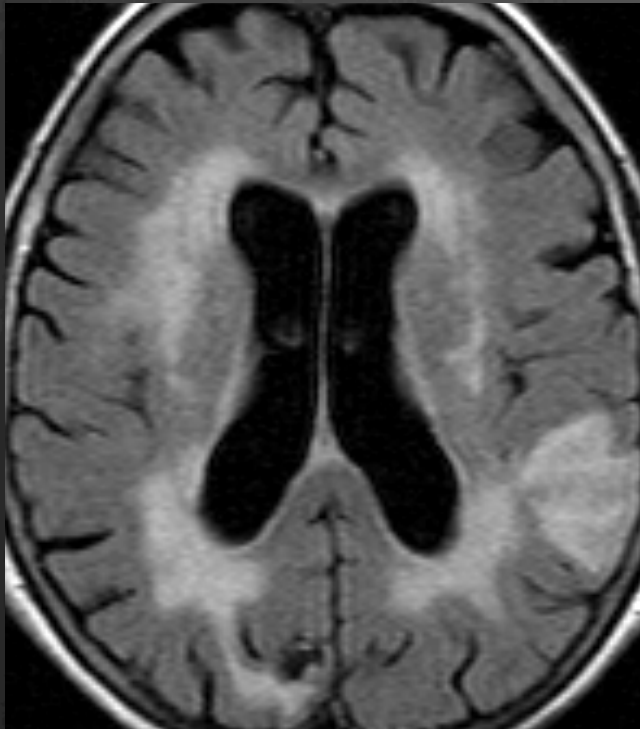


Conduction aphasia



Tactile agnosia

Major white matter tracts



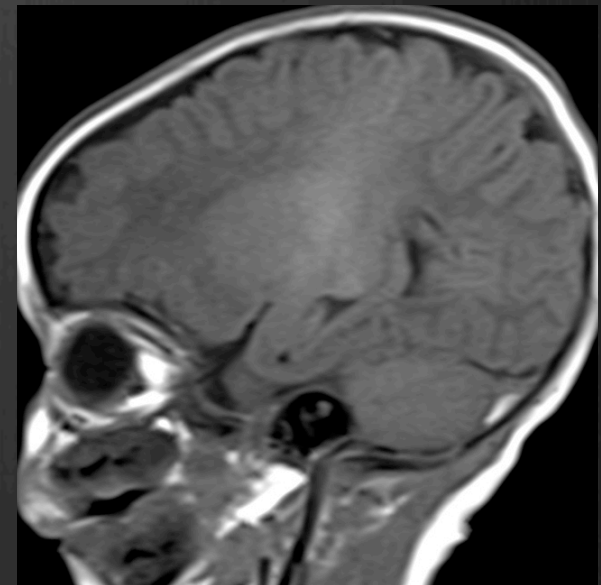
- apraxia
- Visual agnosia, pure alexia
- Pure hearing loss for words
- Conduction aphasia
- Tactile agnosia

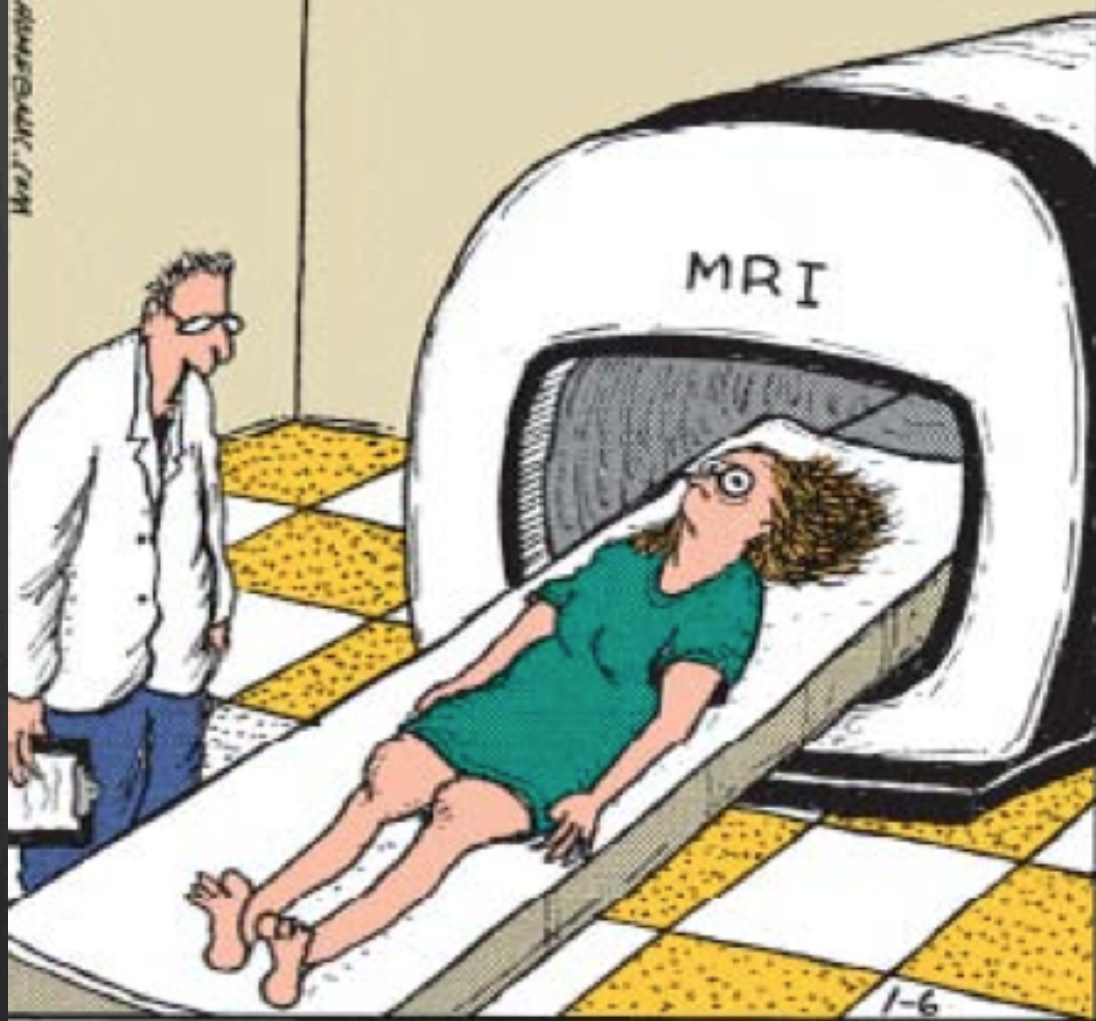
Embryology: development of major tracts.

- Corticospinal tract
- The fornix
- Spinothalamic tract
- Optic radiation
- The arcuate fasciculus
- Longitudinal fasciculi
- Anterior arm of the internal capsule
- The cingulum



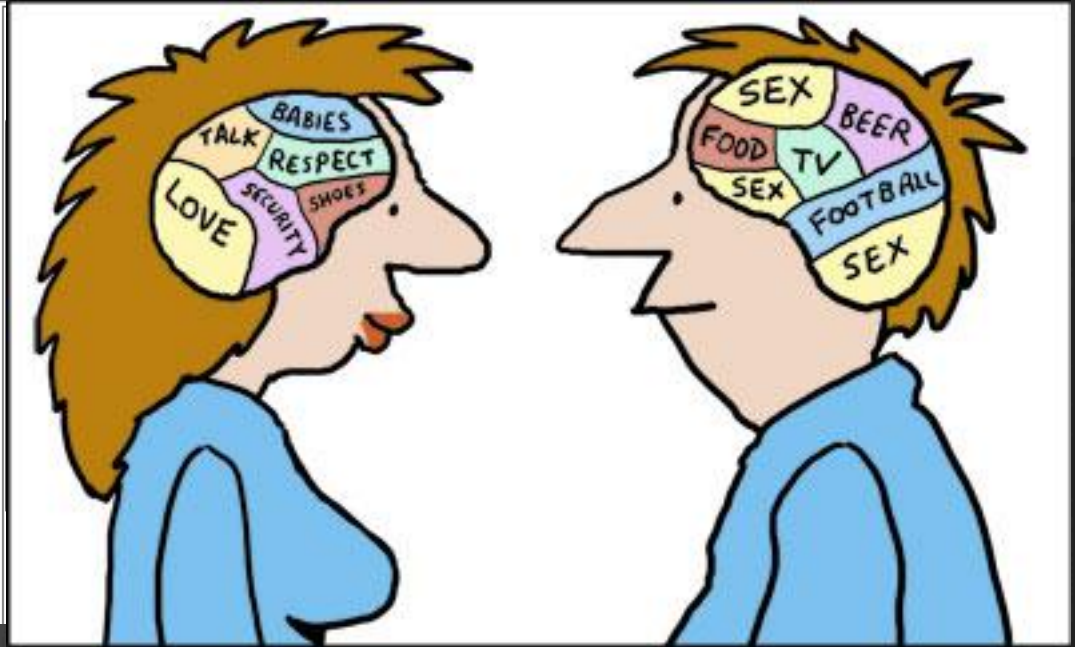
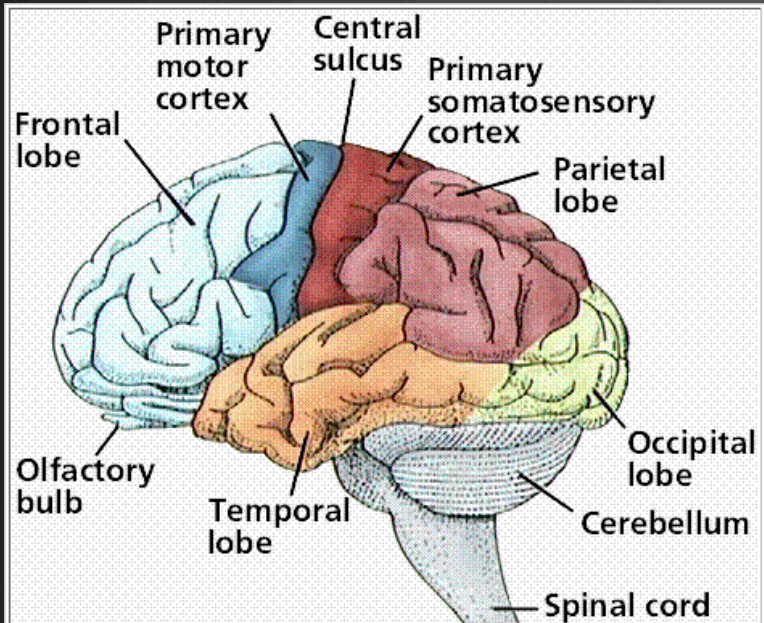
MYELINIZATION





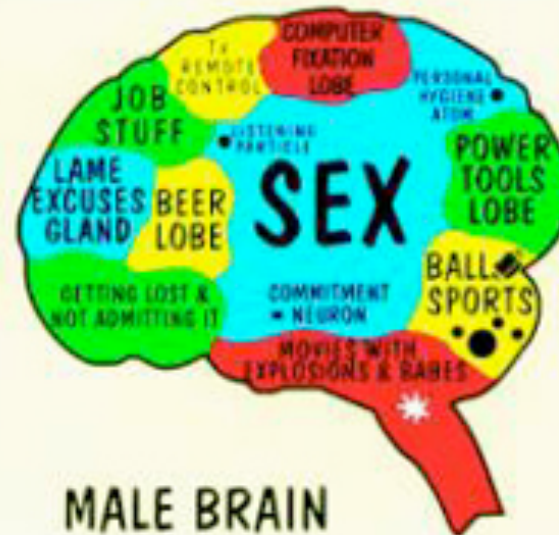
"OK, Mrs. Dunn. We'll slide you in there, scan your brain, and see if we can find out why you've been having these spells of claustrophobia."

Functional anatomy



Functional anatomy

So that explains it.



Functional anatomy

Review articles

Sexual dimorphism in the human brain: evidence from neuroimaging

Julia Sacher^{a,b,*}, Jane Neumann^{a,c}, Hadas Okon-Singer^a, Sarah Gotowiec^a, Arno Villringer^{a,b}

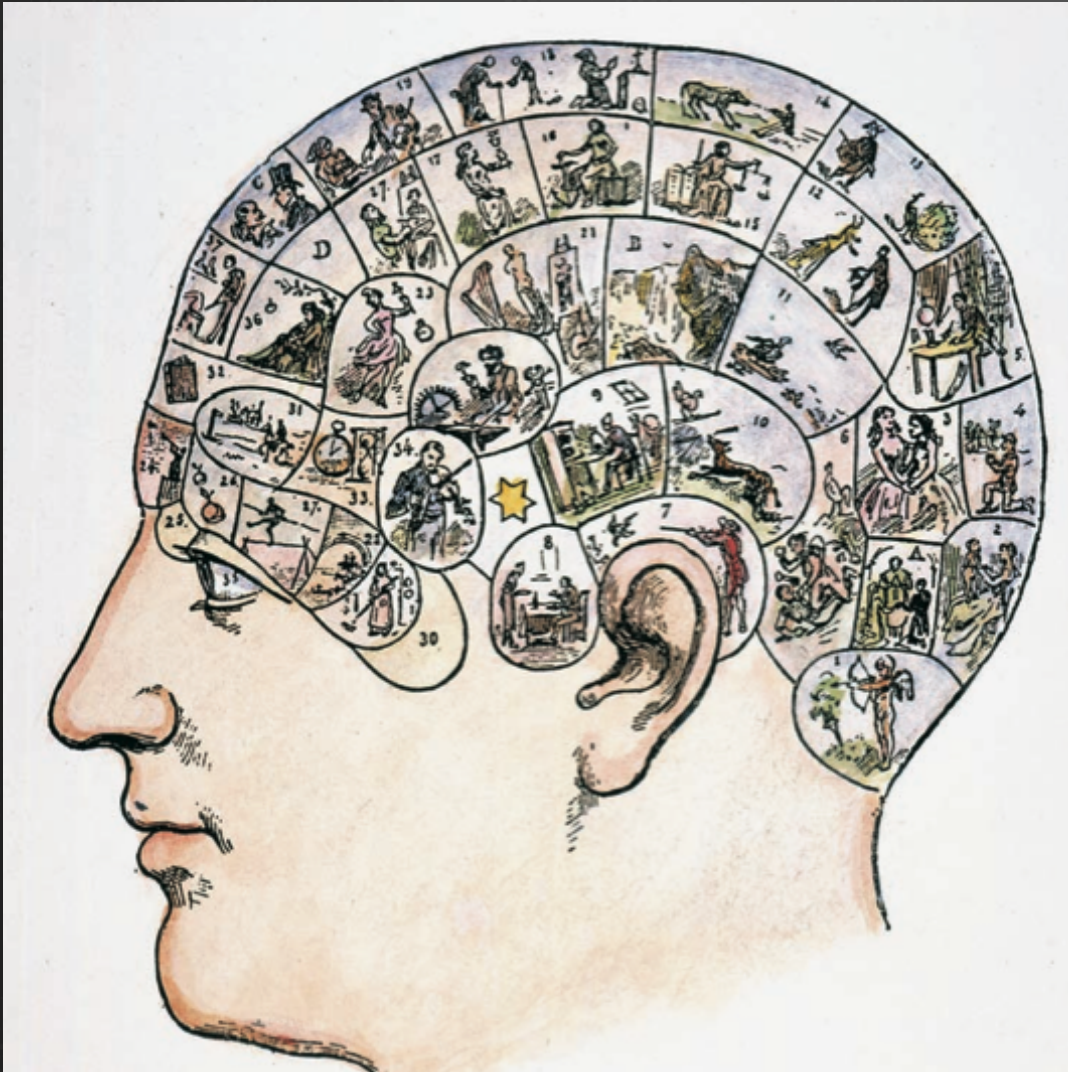
^a *Max-Planck-Institute for Human Cognitive and Brain Sciences, Stephanstr, 1A, Leipzig, Germany*

^b *Clinic of Cognitive Neurology, University of Leipzig, Liebigstr, 16, Leipzig, Germany*

^c *Leipzig University Medical Center, IFB Adiposity Diseases, Leipzig, Germany*

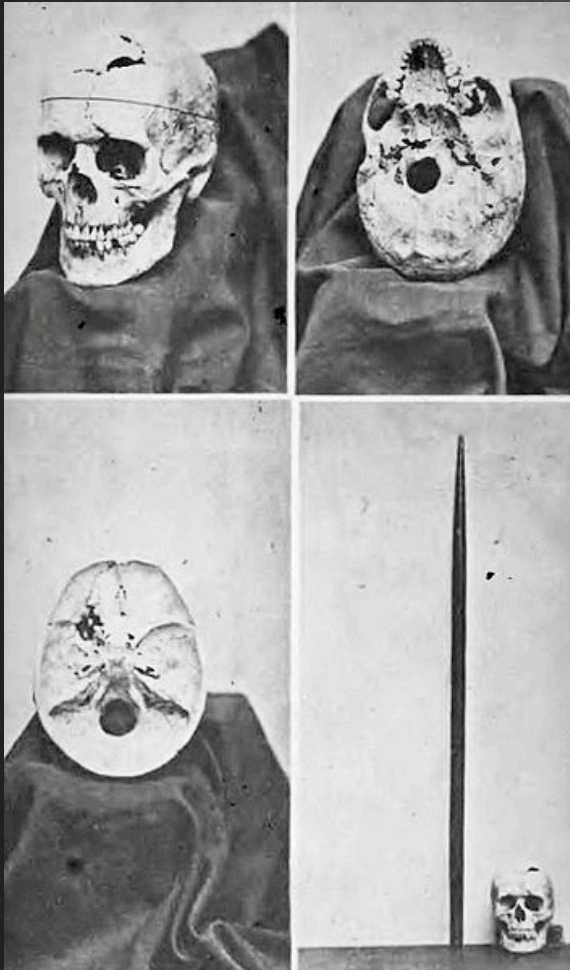
Magnetic Resonance Imaging 31 (2013) 366-375

History of functional brain maps



This phrenological chart was created by French in the 19th century

Functional anatomy



The case of Phineas Gage

1848

Functional anatomy

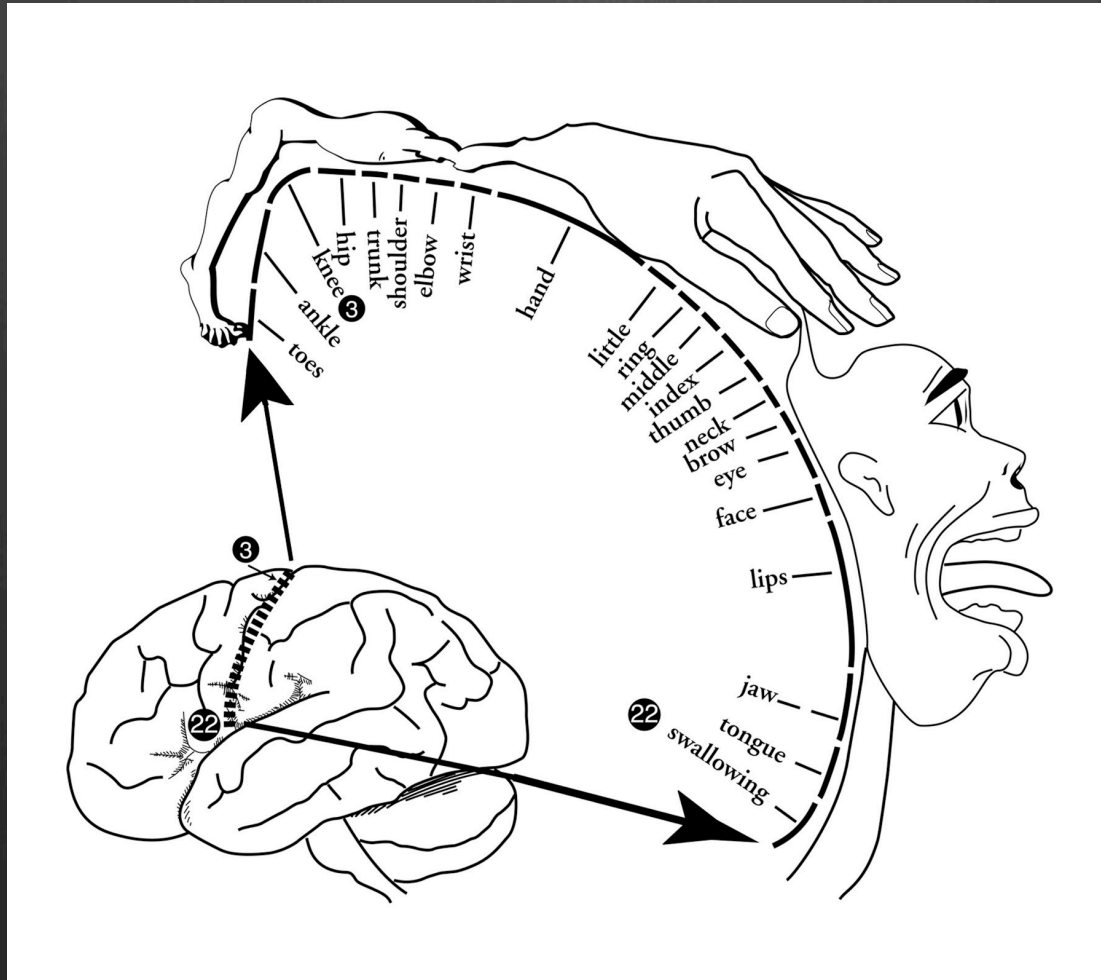


Motor homunculus



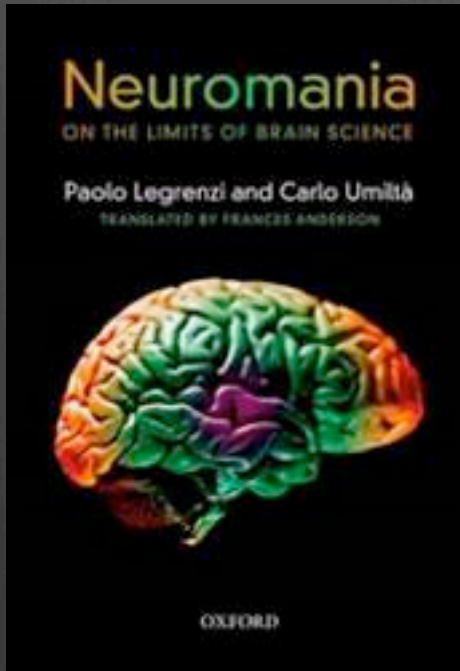
Sensory homunculus

Functional anatomy



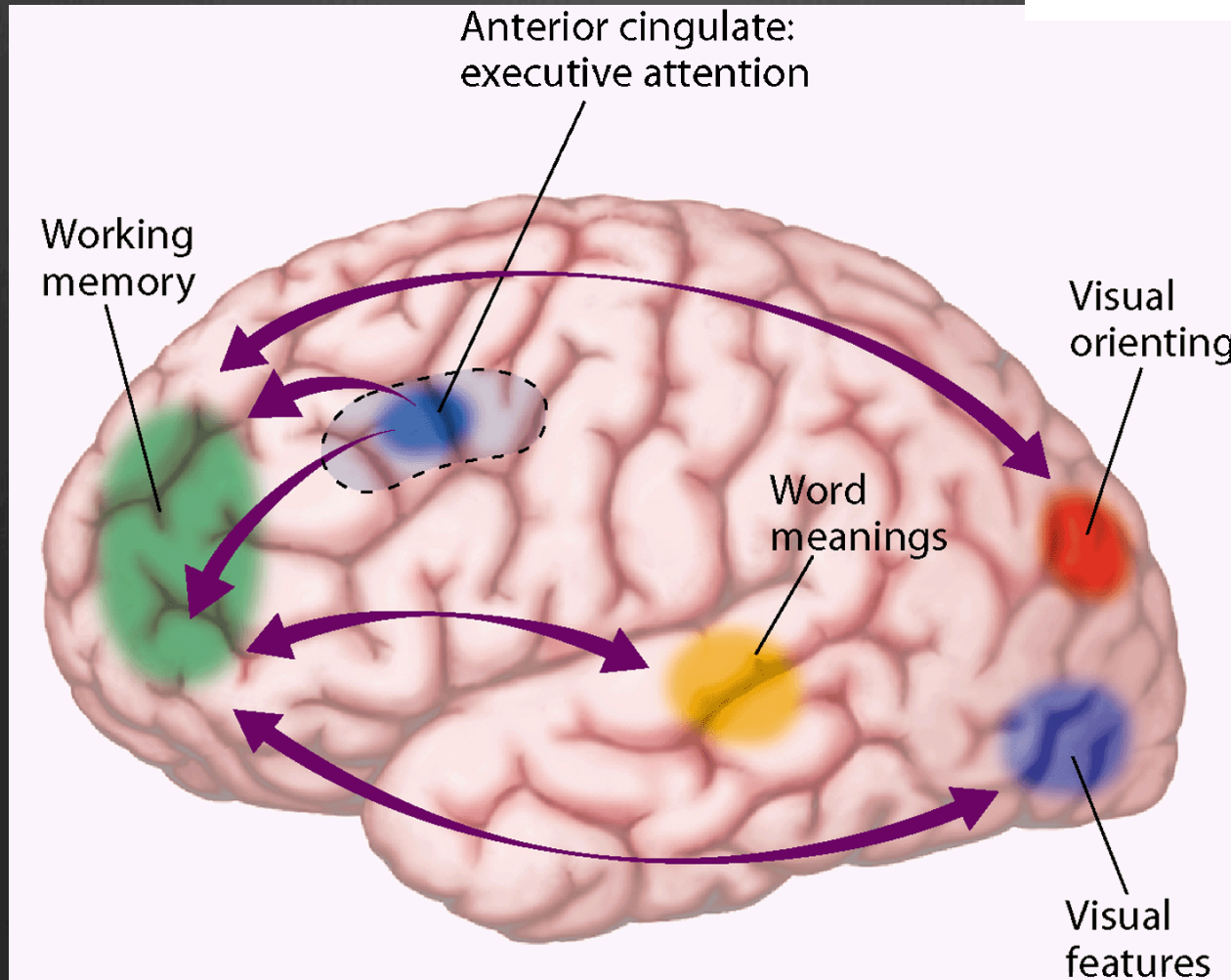
Motor homunculus

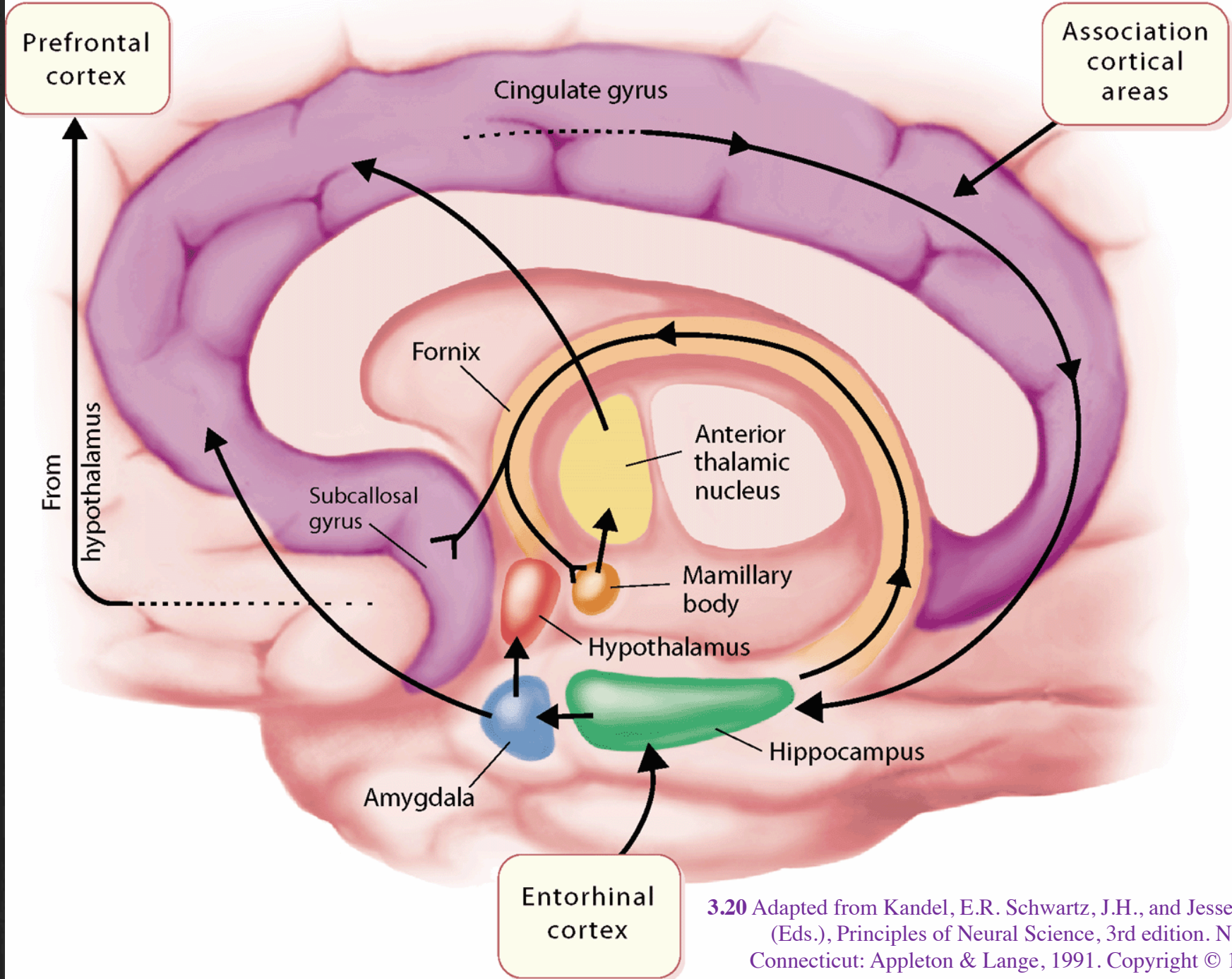
Functional anatomy



Neuroeconomics, Neuromarketing, Neurotheology, Neuroaesthetics, Neuropolitics

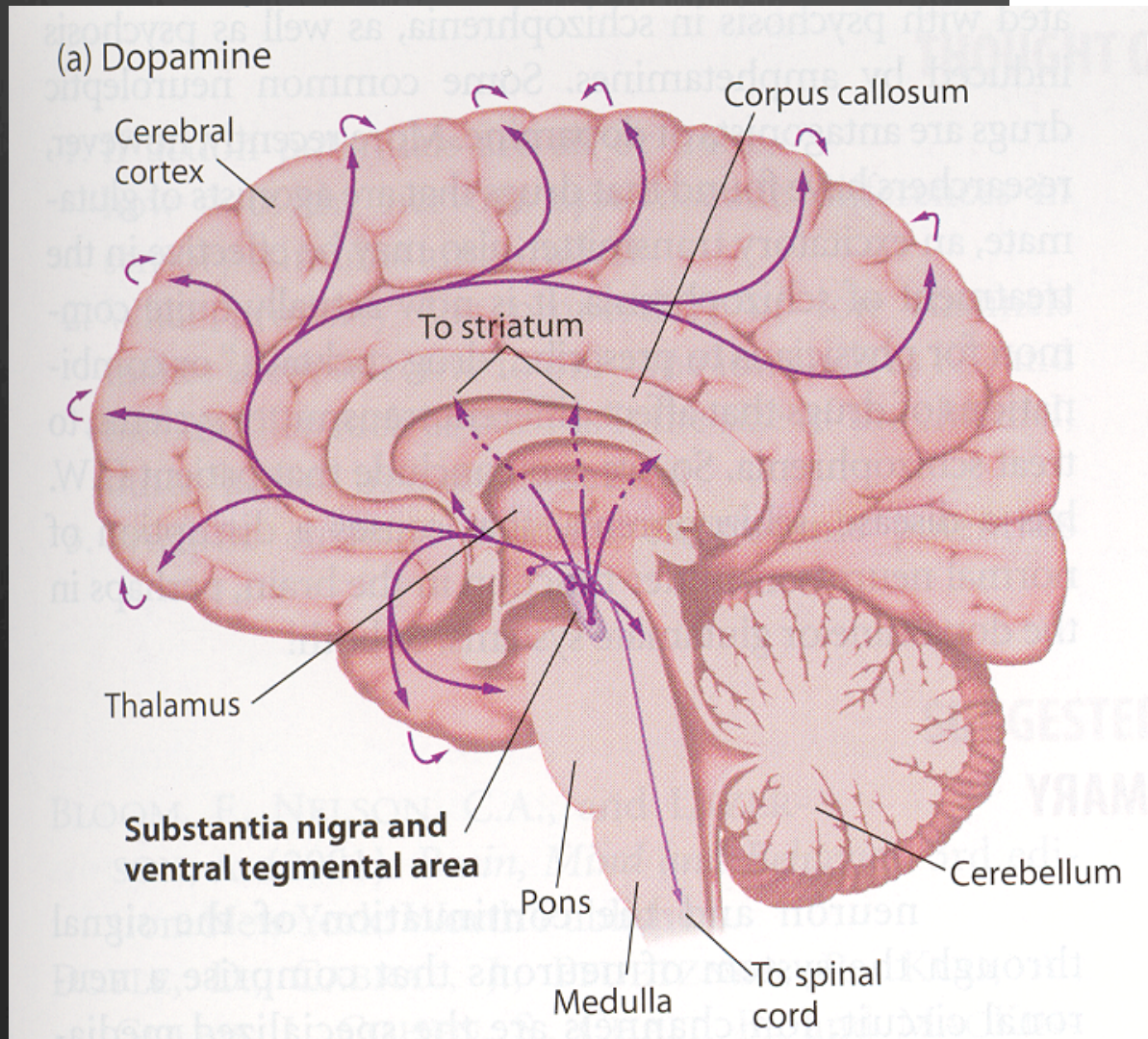
Working Memory



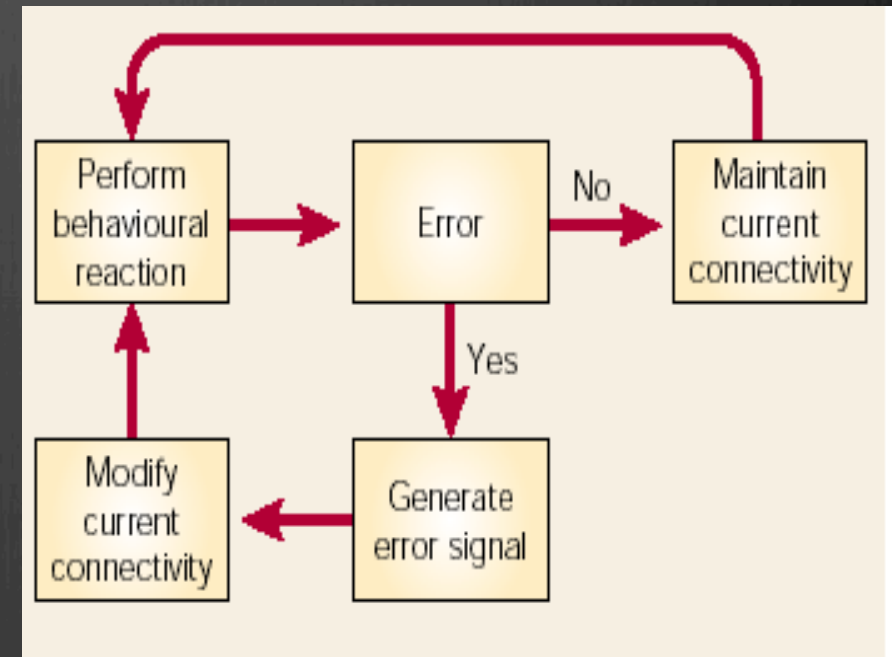
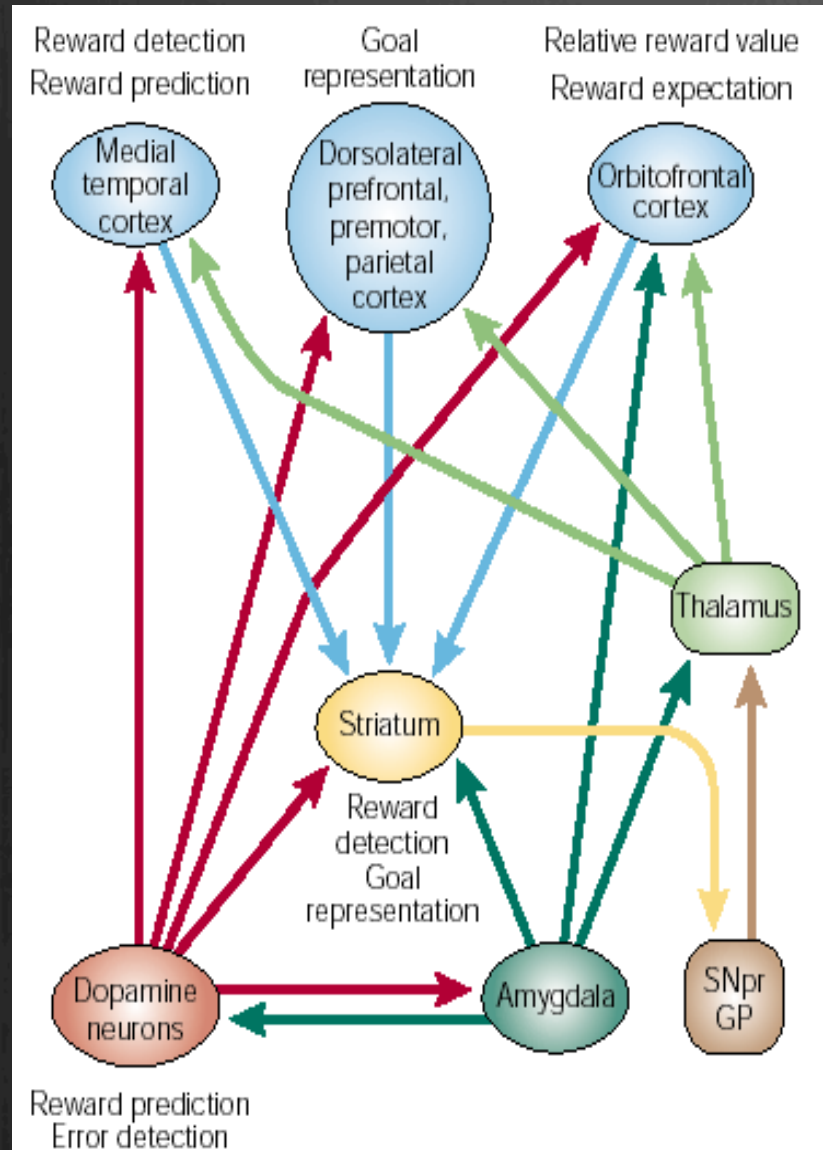


3.20 Adapted from Kandel, E.R. Schwartz, J.H., and Jessell, T.M. (Eds.), *Principles of Neural Science*, 3rd edition. Norwalk, Connecticut: Appleton & Lange, 1991. Copyright © 1991 by

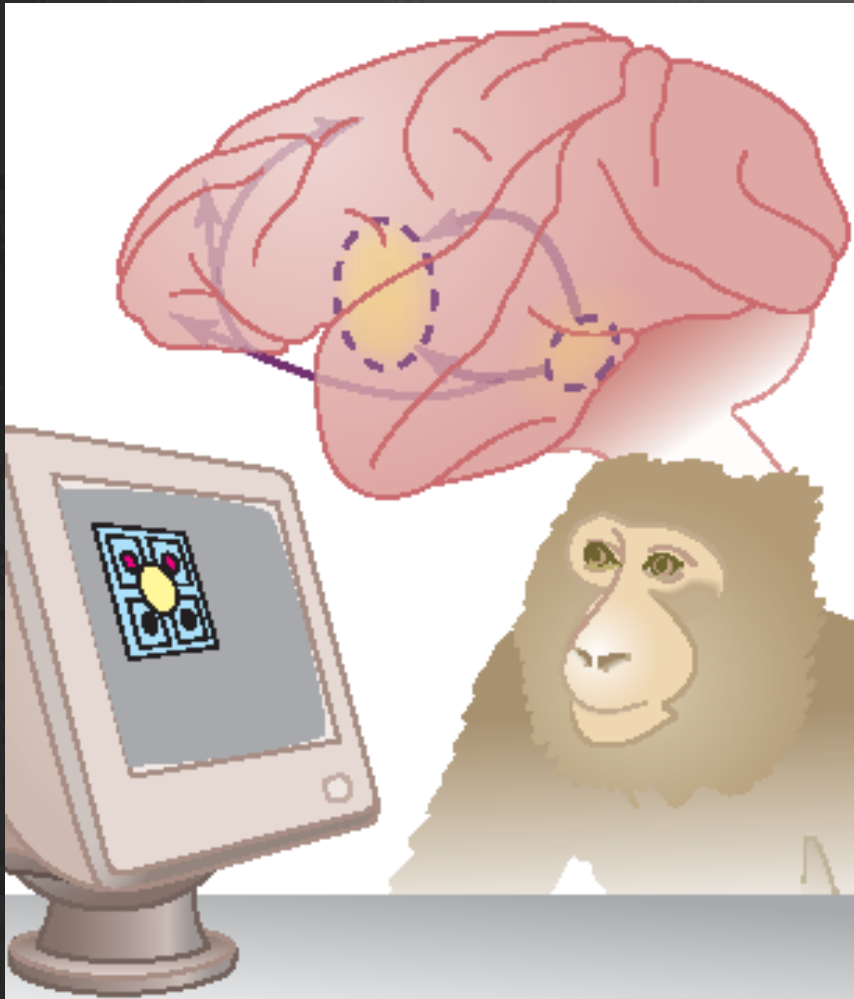
The Dopamine System



Role of the Dopamine System



Reward and Uncertainty



The new concept: brain areas interconnected structurally and functionally

- Human brain mapping using fMRI e DTI data.
- Brain connectivity changes in paraphysiologic and pathological states.
 - HOW THE BRAIN WORKS!

End of the first lecture!

Next time (26 Nov. 2013):
Get into some details regarding VBM!

<http://www.fil.ion.ucl.ac.uk/spm/>