BENEFRI Workshop 2019

Methods in Experimental Neurosciences:
From Animal Models to Humans

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fMRI in Neuroscience

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roadmap

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9:15-10:00 **Basic concepts of functional Neuroimaging**

fMRI Signal, task-dependent fMRI, resting state fMRI, Functional Network Analysis, processing pipeline, statistical testing, Random Effects, General Linear Model and MRI physics.

10:15-11:00 **Basic concepts of structural Neuroimaging**

Voxel Based Morphometry, Cortical Thickness, Cortex based inter-subject alignment, Diffusion Tensor Imaging, Tract-Based Spatial Statics.

11:15-12:00 **Advanced Neuroimaging Methods in Neurosciences**

Non-BOLD fMRI, Cerebral Blood flow (CBF), calibrated fMRI, Multimodal Imaging.

Cytoarchitecture „von Economo“ 1927

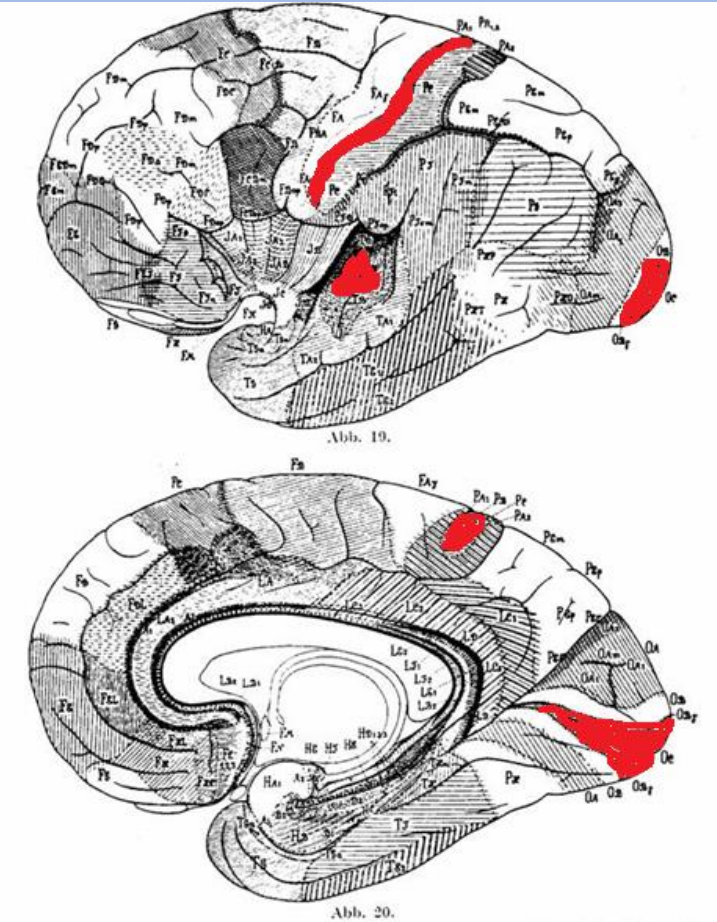
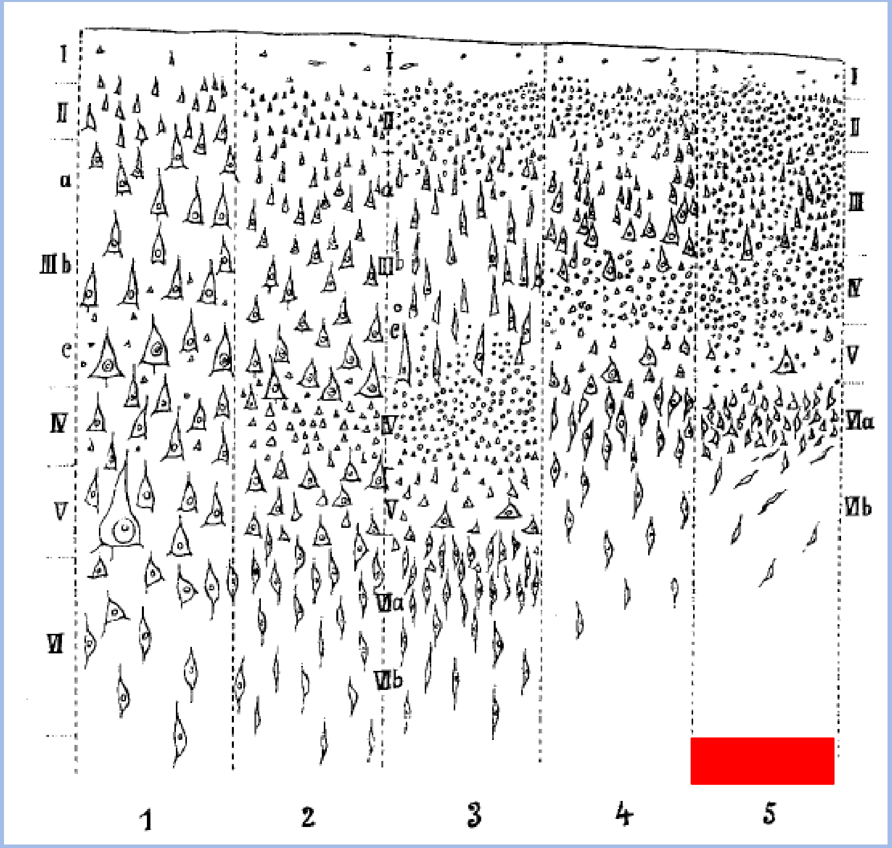
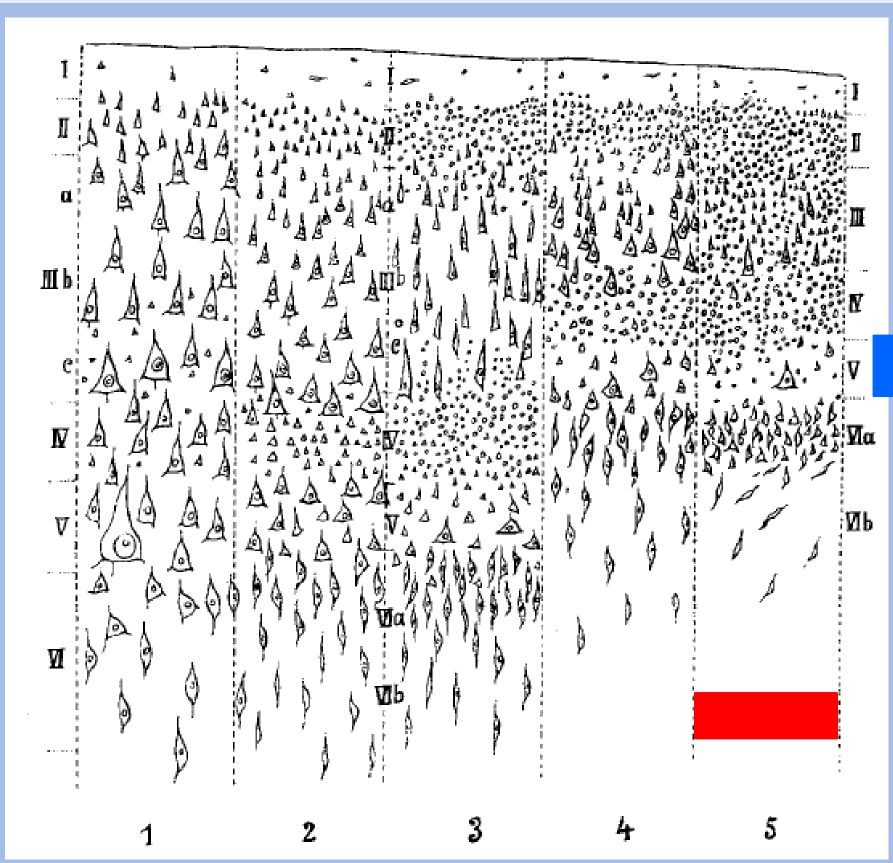


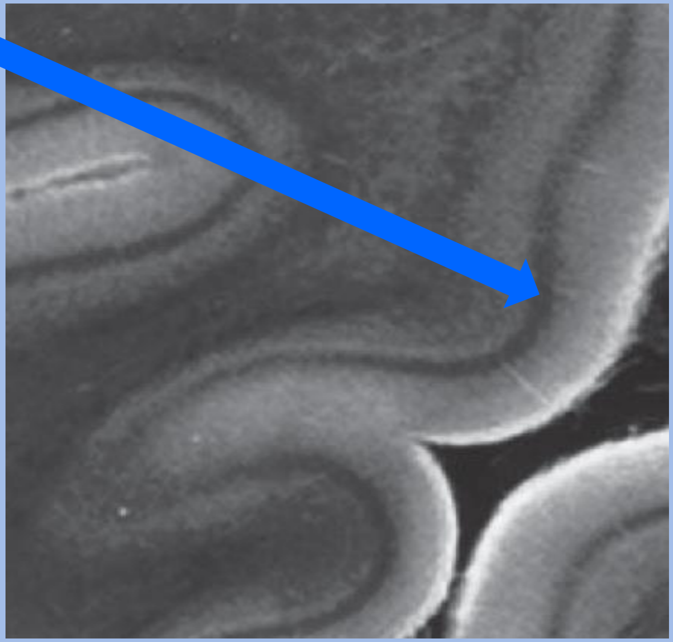
Abb. 19 und 20. Unsere cytoarchitektonische areale Hirnkarte, Abb. 19 der Konvexität, Abb. 20 der Medianfläche des menschlichen Großhirns (s. S. 206 und Abb. 92—95).



Primary sensory Cortex



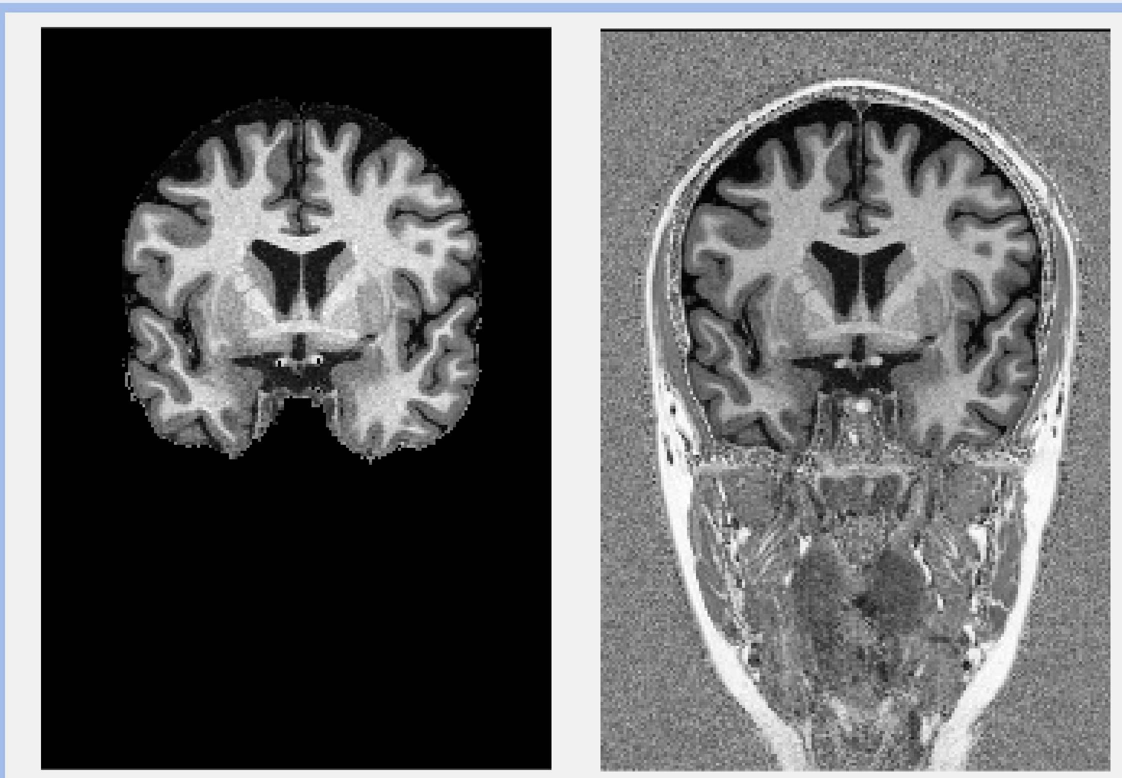
- Primyry sensory Cortex
- Granular Cells
- Reduced Thickness
- High Celldensity

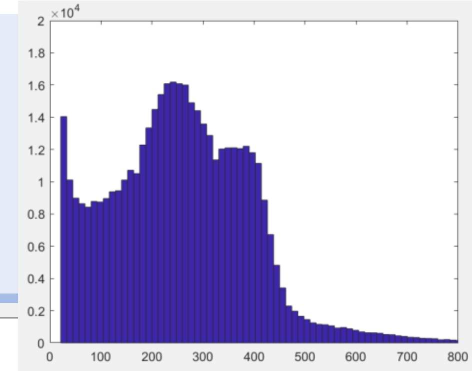


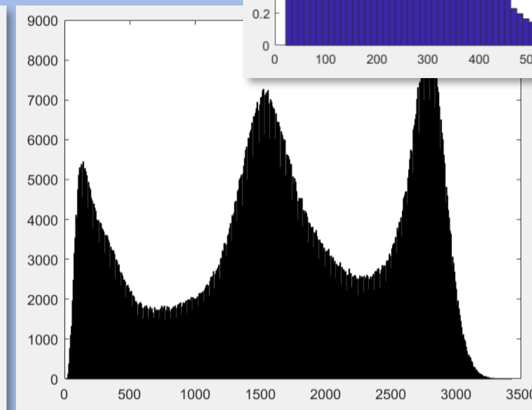
Von Economo, C., 1927

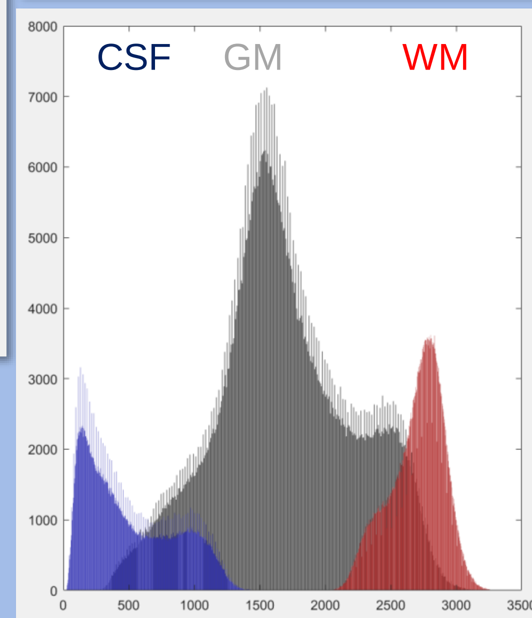
Fatterpekar, G.M., 2002

mp2rage: segmentation



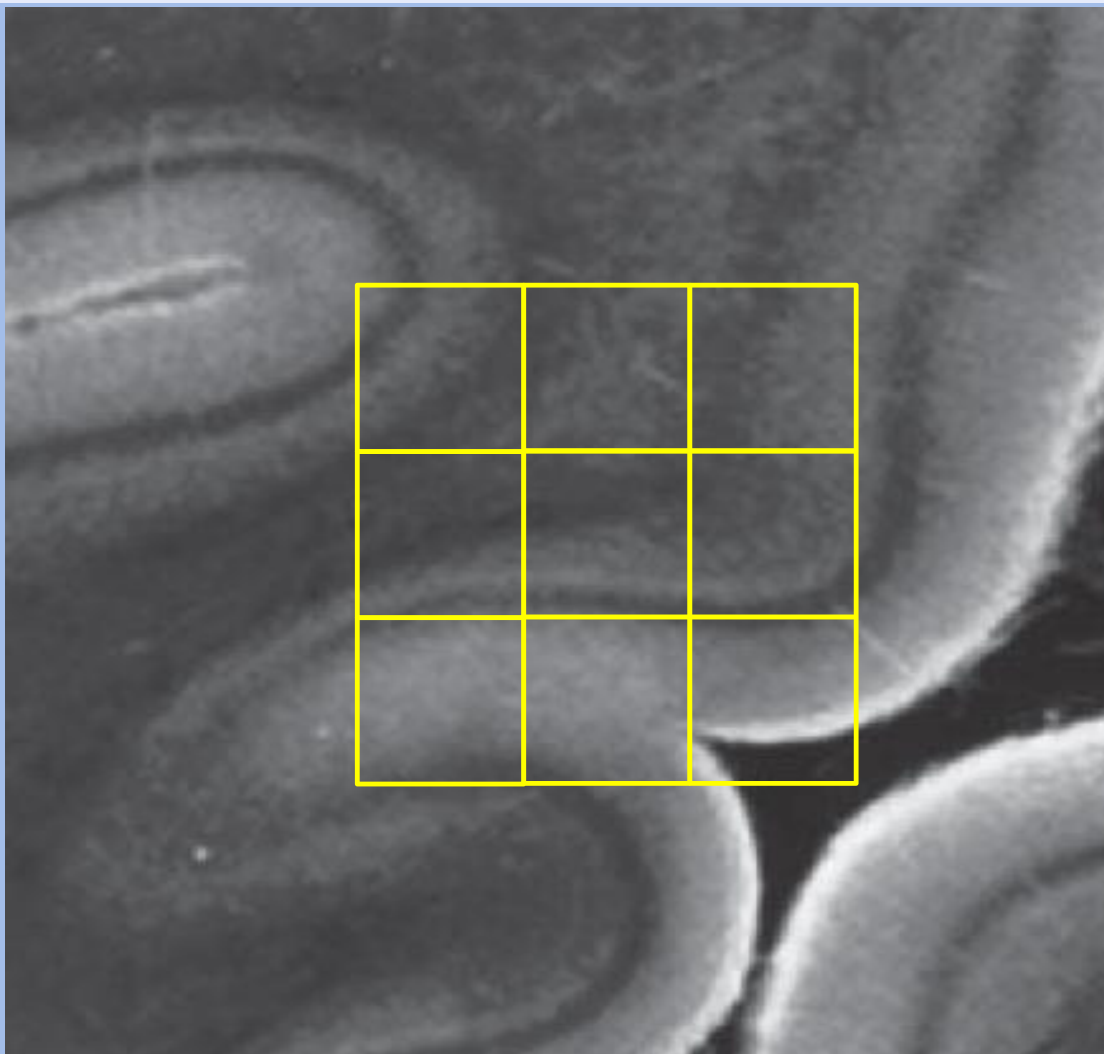




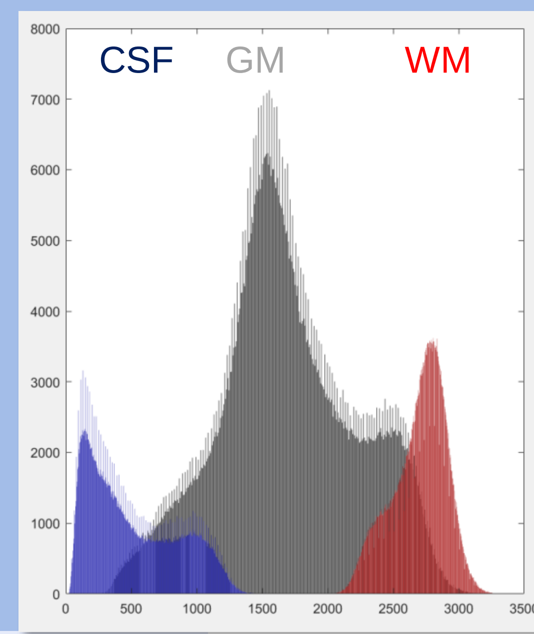


Improved segmentation;
optimal CNR;
homogeneous tissue

Tissue type within one voxel?

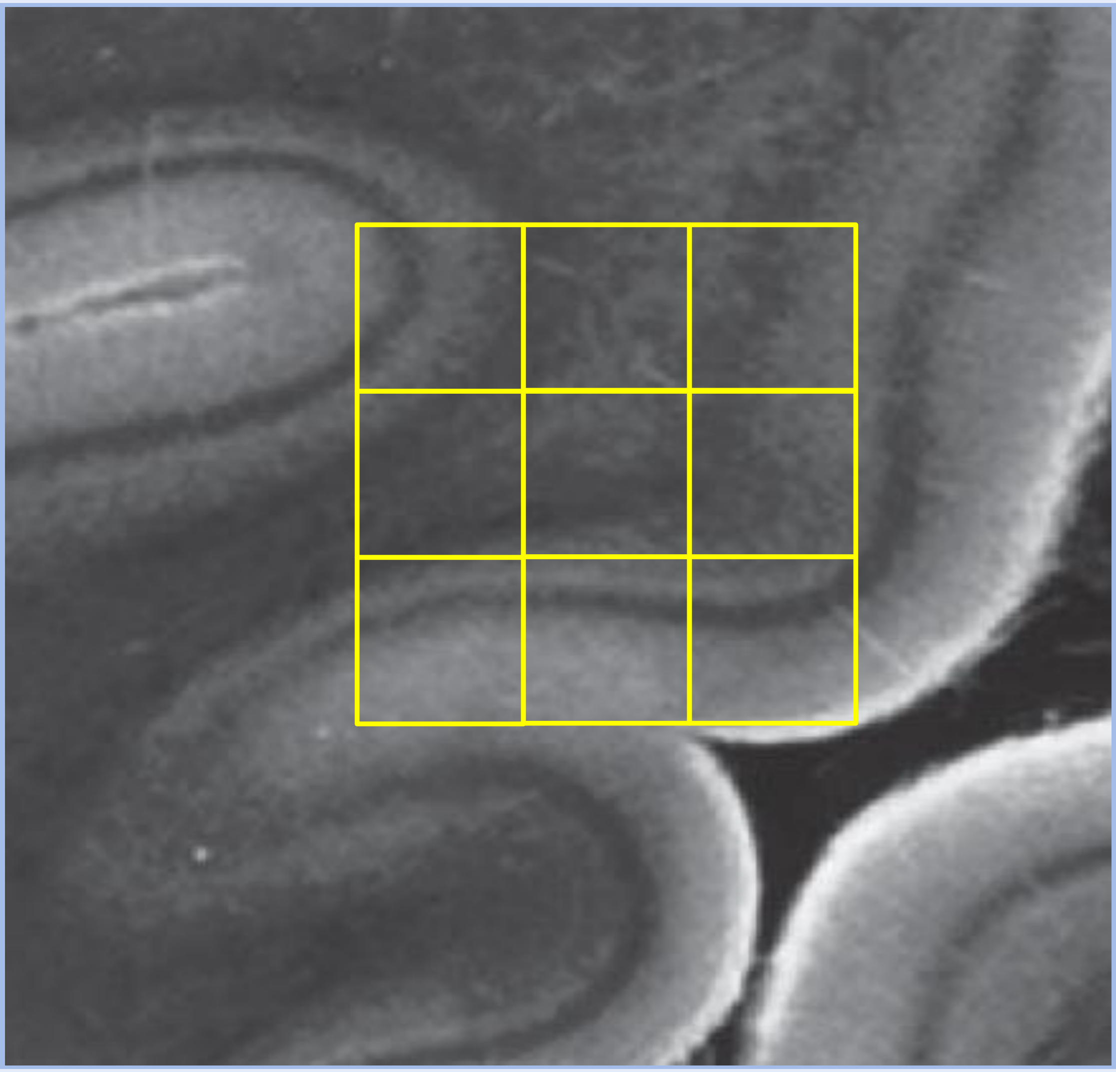


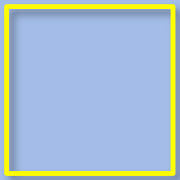
MR voxel Dimension:



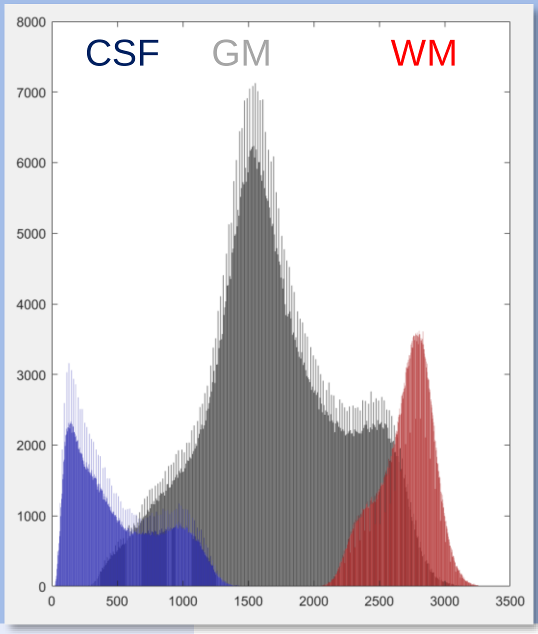
Fatterpekar, G.M., 2002

Tissue type within one voxel?



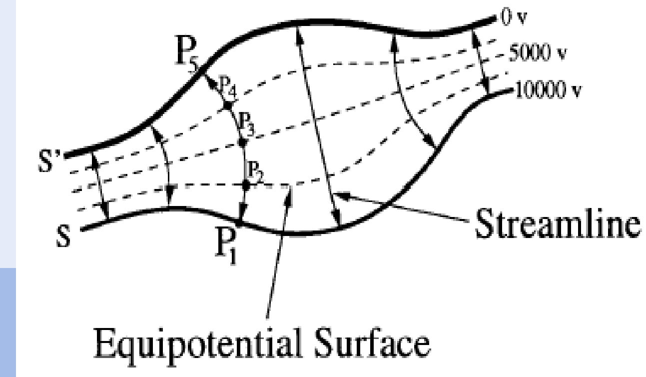


MR voxel Dimension:

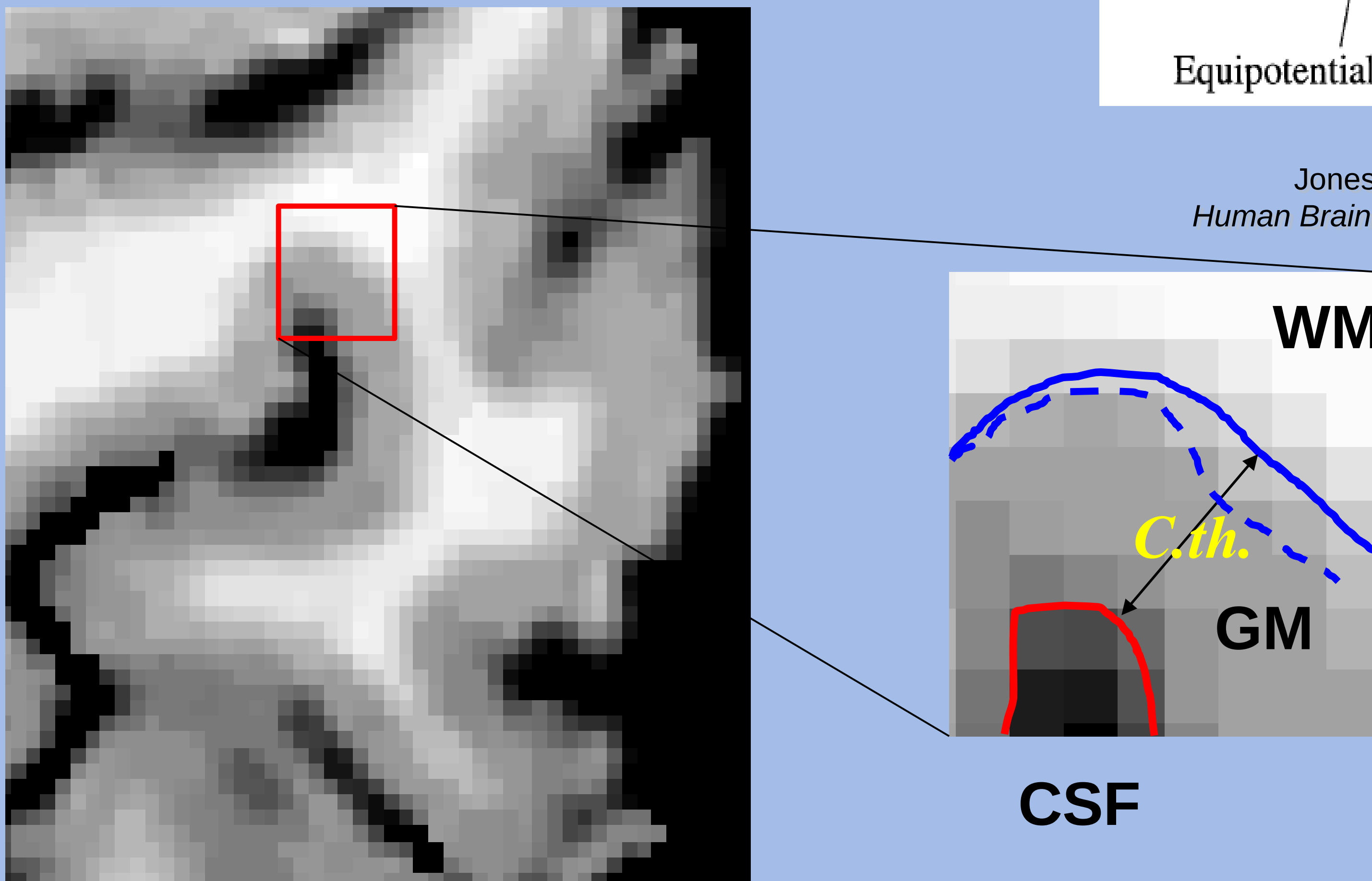


Fatterpekar, G.M., 2002

Segmentation: Problem

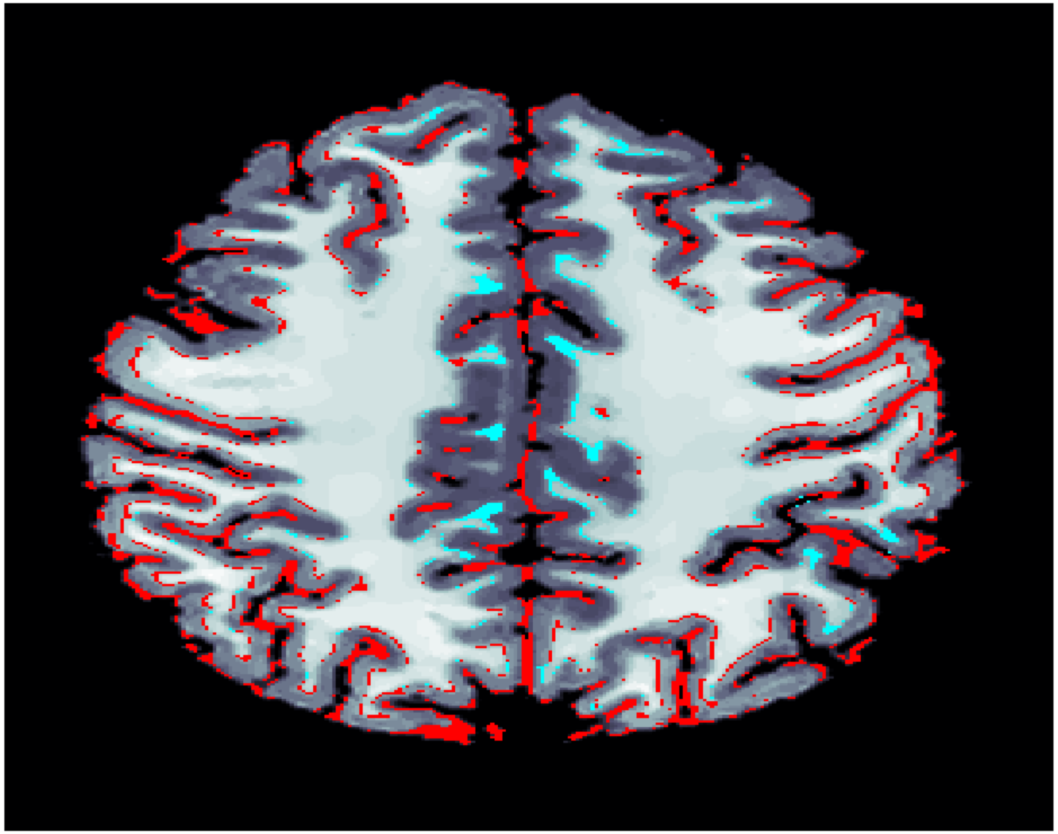


Jones et al. (2000)
Human Brain Mapping, 11, 12-32.

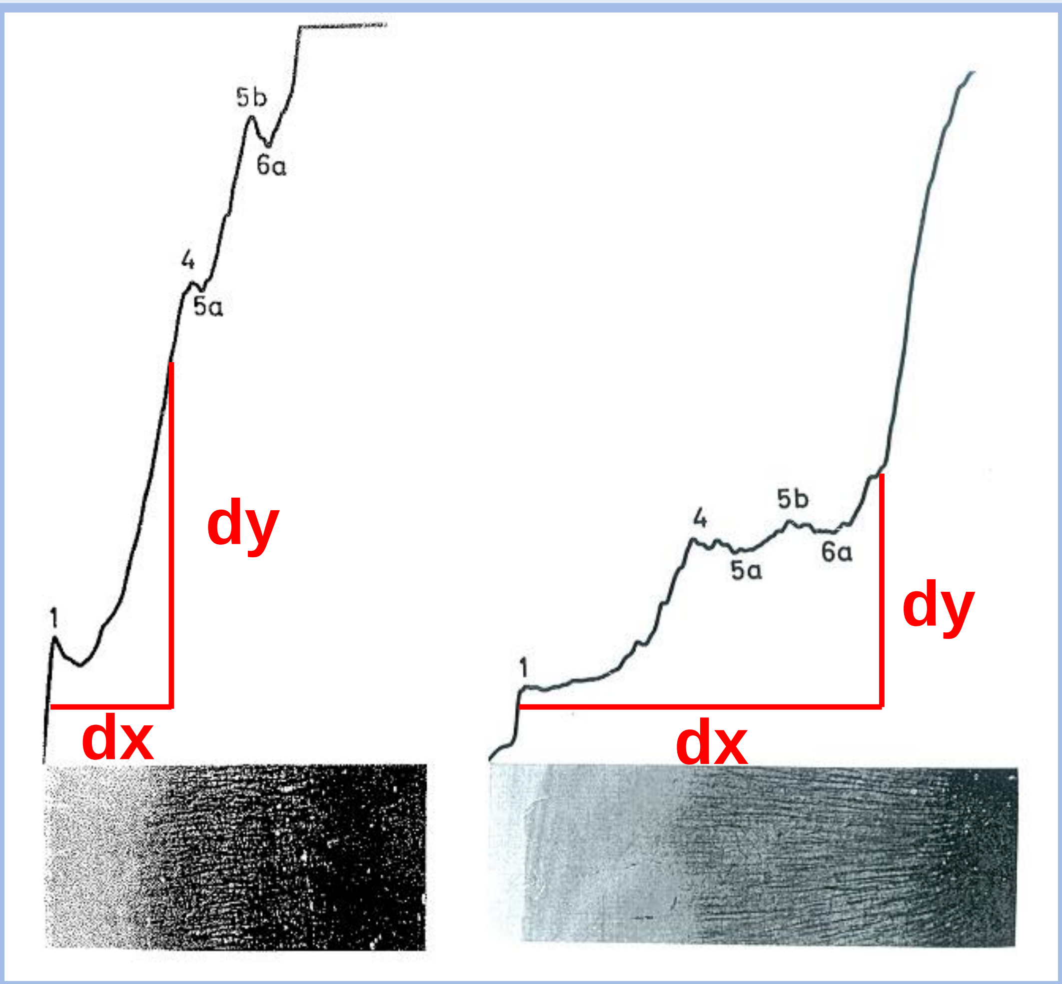


$$2 * \sqrt{2} \leq C.th. \leq 3 * \sqrt{2}$$

Partial Volume Correction (PVE)



Gradient

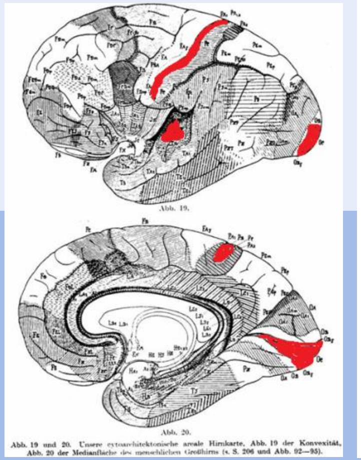


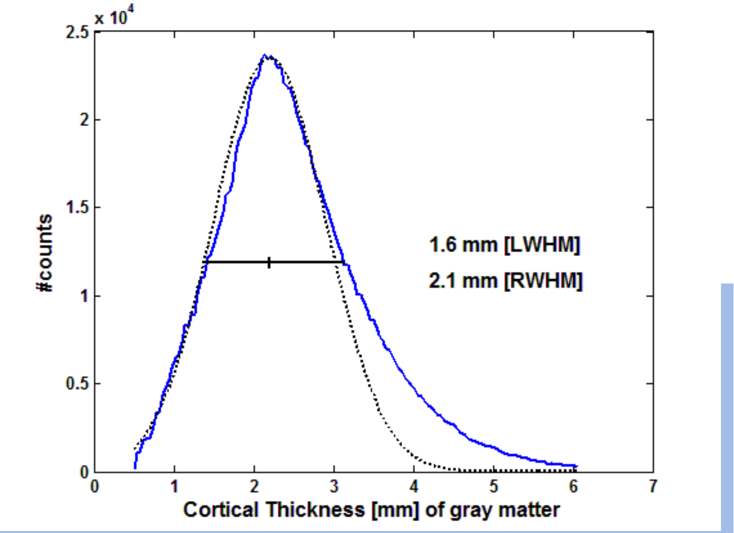
Gradient:

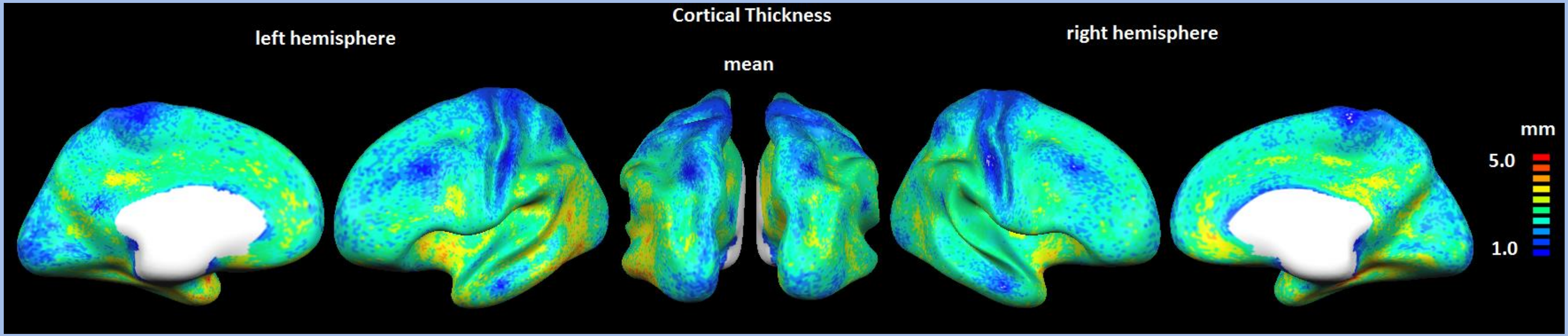
- Direction of the steepest change

- The higher the Gradient is, the better you can define borders between different tissues

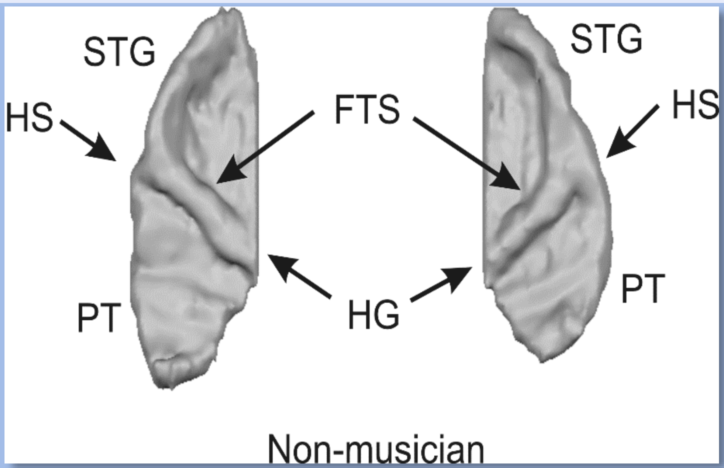
Cortical Thickness

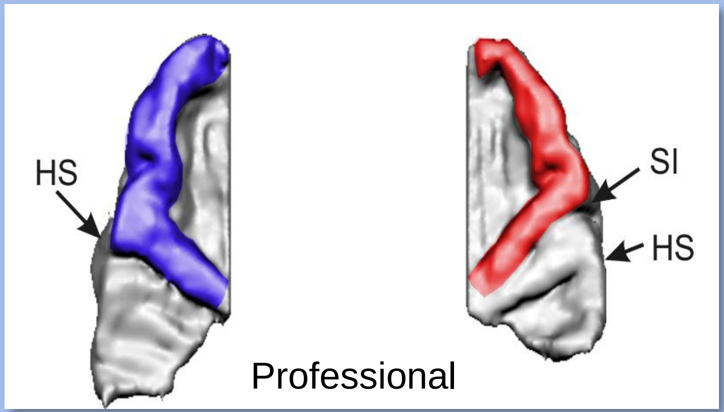


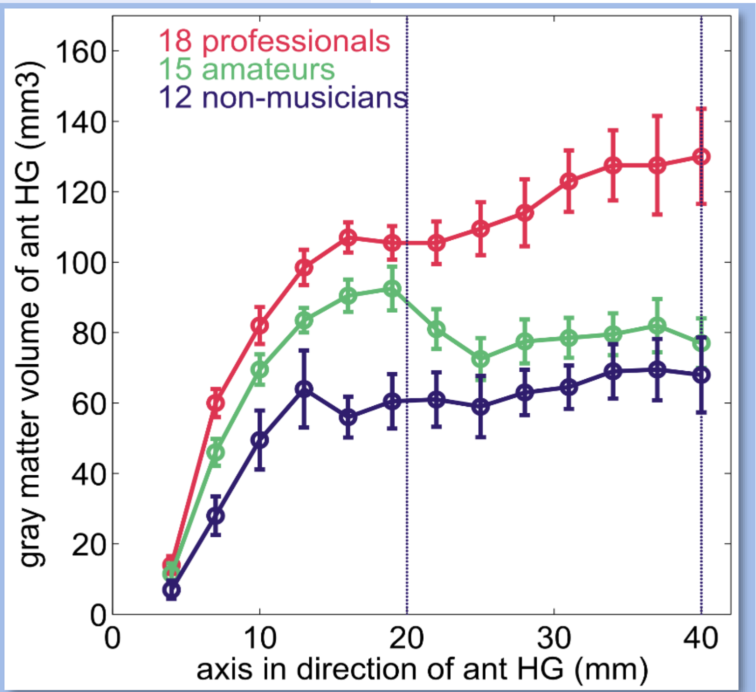




Gray matter volume: Heschel's Gyrus



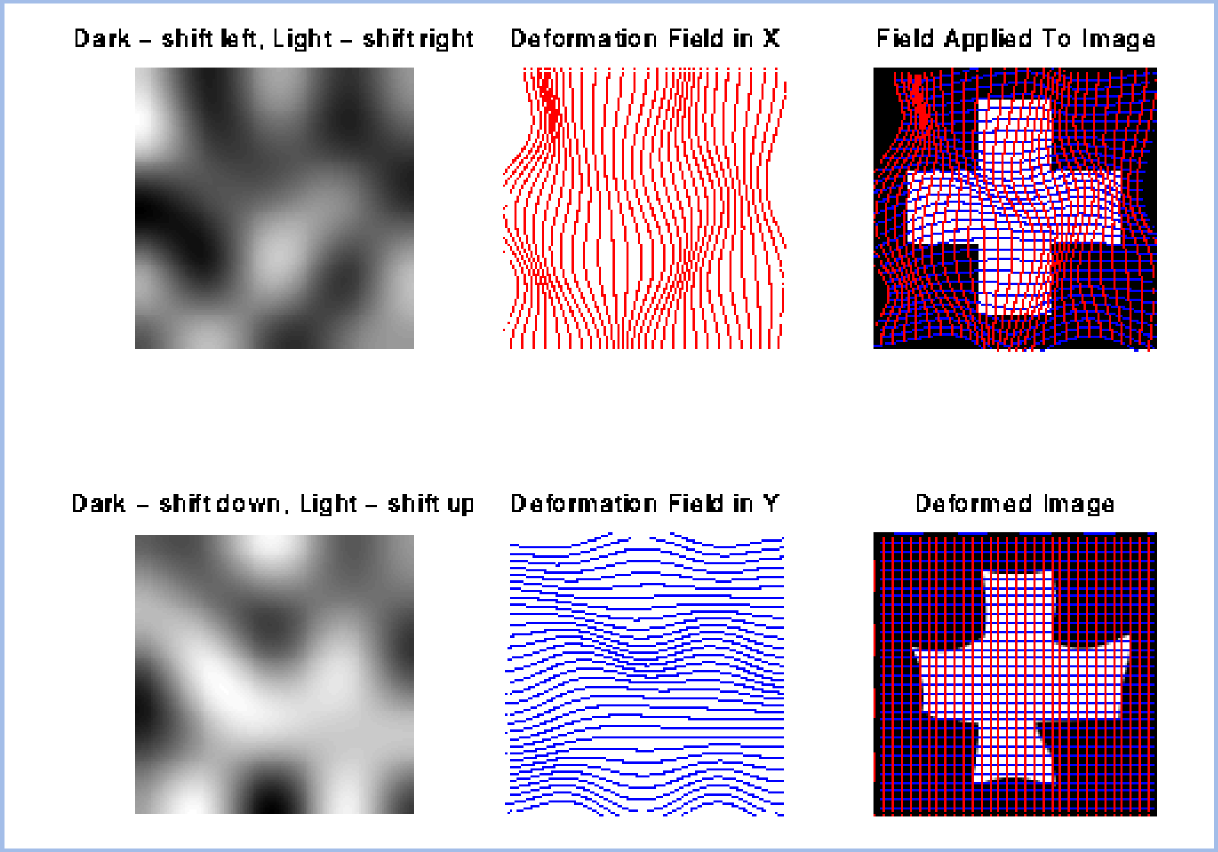


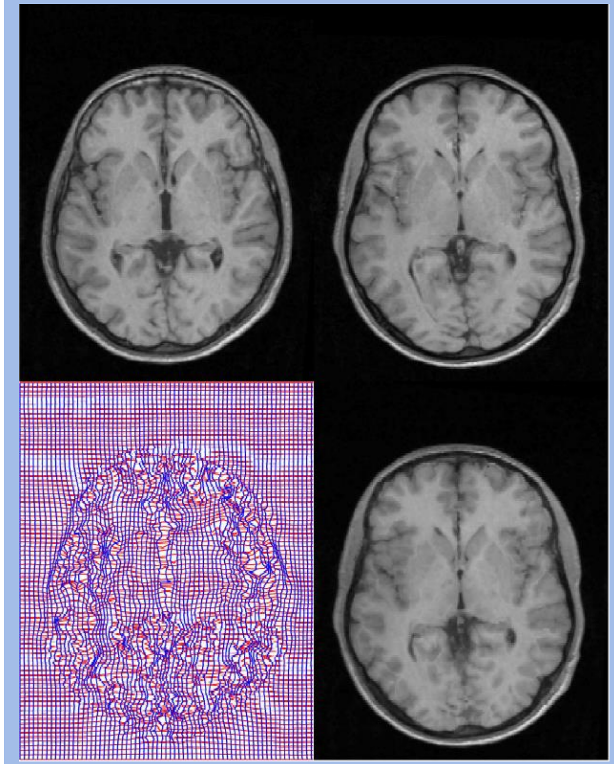


VBM/Cort.th. “roadmap” with SPM

- Coregistration (3D anatomy $t_1 \rightarrow$ 3D anatomy t_2)
- Segmentation (3D anatomy)
- Normalisation (3D anatomy)
  Warp subject’s image to a Template
- Parcellation (3D anatomy)

Step 2: Non-linear Registration





- The model for defining nonlinear warps uses deformations consisting of a linear combination of low-frequency periodic basis functions.

Talairach Space

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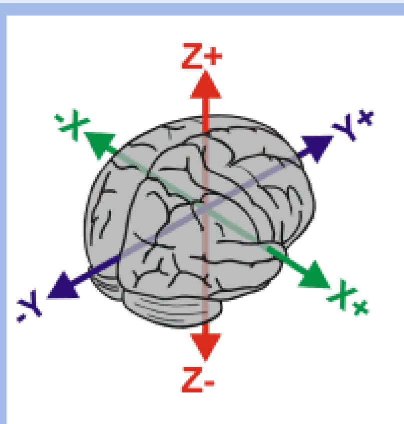
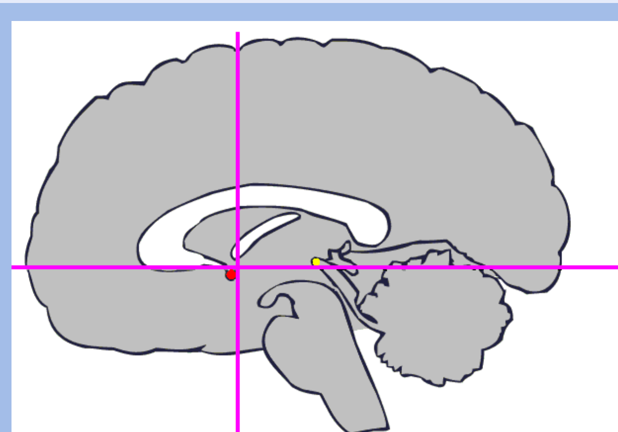
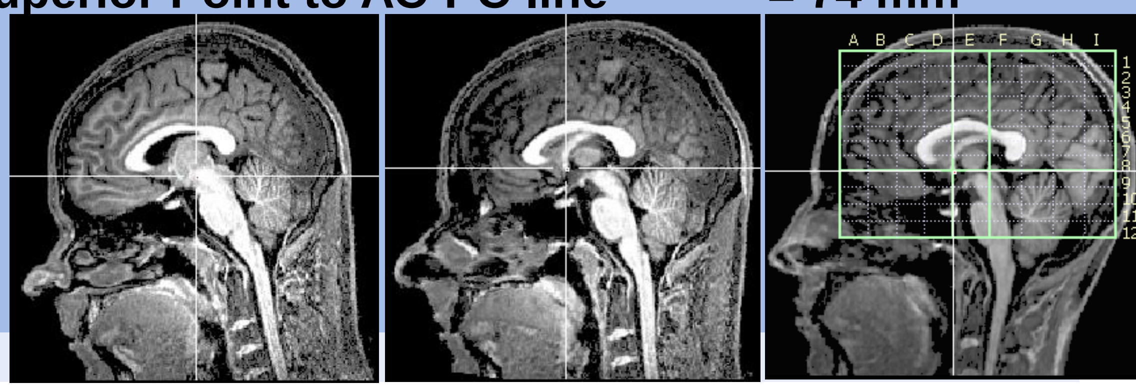




X-axis: AC-PC line to left Point = 68 mm
X-axis: AC-PC line to right Point = 68 mm
Y-axis: AC to PC = 23 mm
Y-axis: Anteror Point to Point AC = 70 mm
Z-axis: Inferior Point to AC-PC line = 42 mm
Z-axis: Superior Point to AC-PC line = 74 mm



Standardized Spaces

> **Talairach space** (proportional grid system)
- From atlas of Talairach and Tournoux (1988)
- Based on single subject (60y, Female, Cadaver)
- Single hemisphere
- Related to Brodmann coordinates

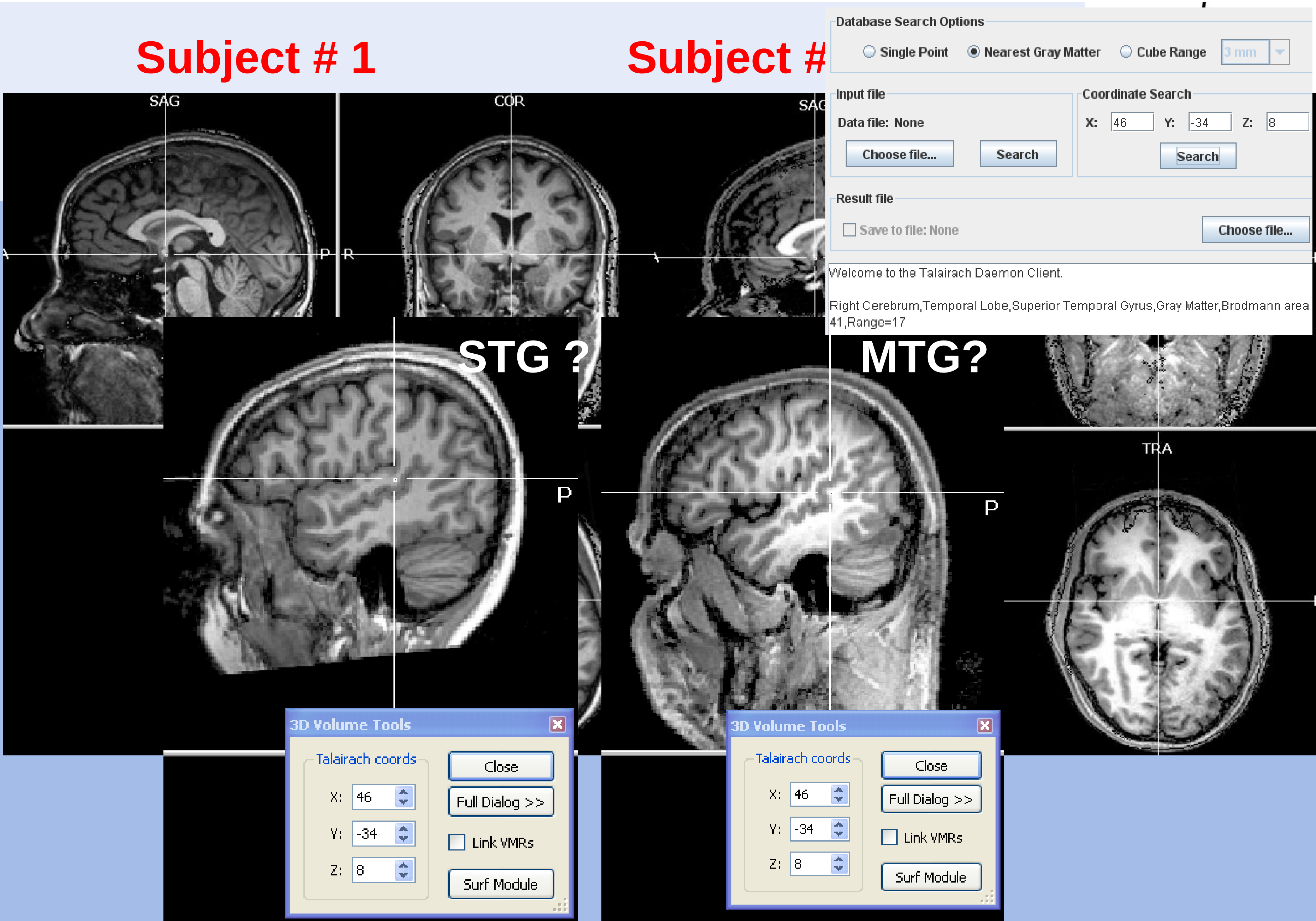
8 Parameter

> **Montreal Neurological Institute (MNI) space**
- Combination of many MRI scans on normal controls
  - All right-handed subjects
- Approximated to Talaraich space
  - Slightly larger
  - Taller from AC to top by 5mm; deeper from AC to bottom by 10mm
- Used by SPM, National fMRI Database, International Consortium for Brain Mapping

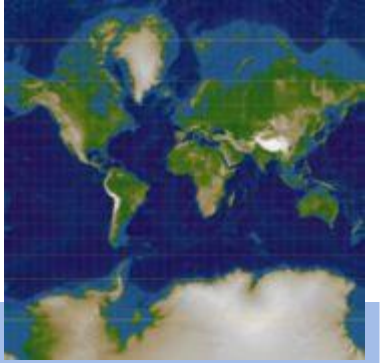
12 Parameter Affine Transformations

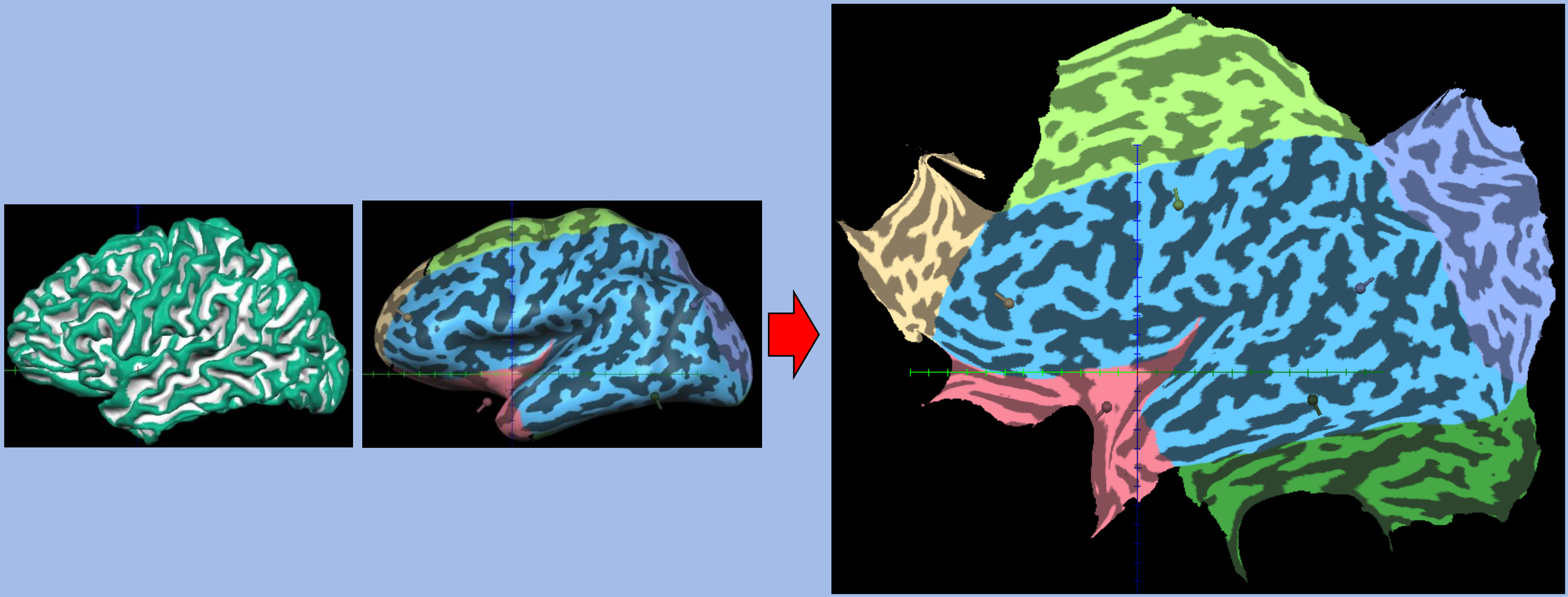
Subject # 1

Subject



2D area on 3D sphere?

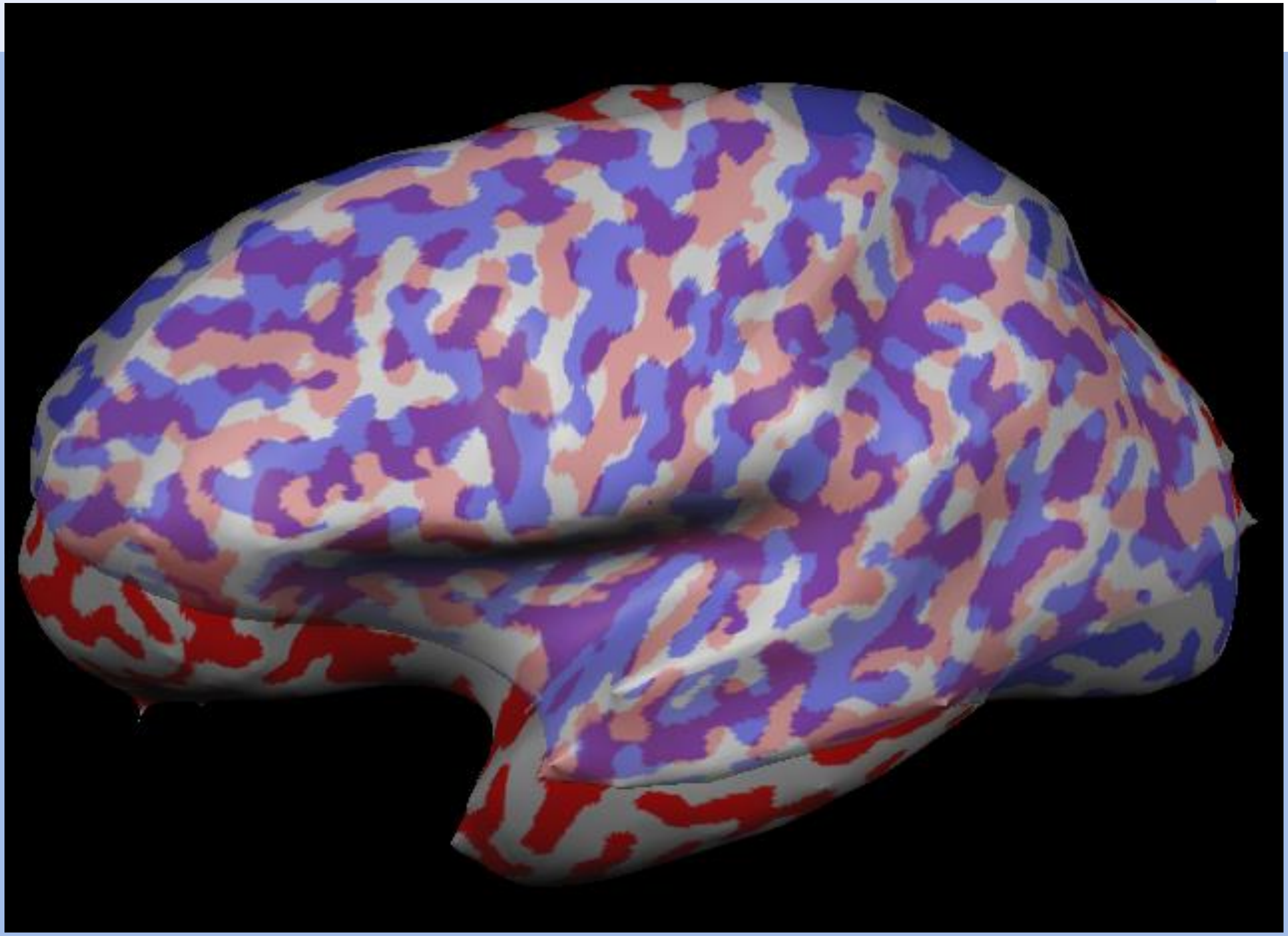




No distance-preserving Mapping of 3D Sphere :→ 2D curved

Therefore: angle-distortions or area-distortions !

Subject # 1 Subject # 2
Talairach-Normalized on 2D



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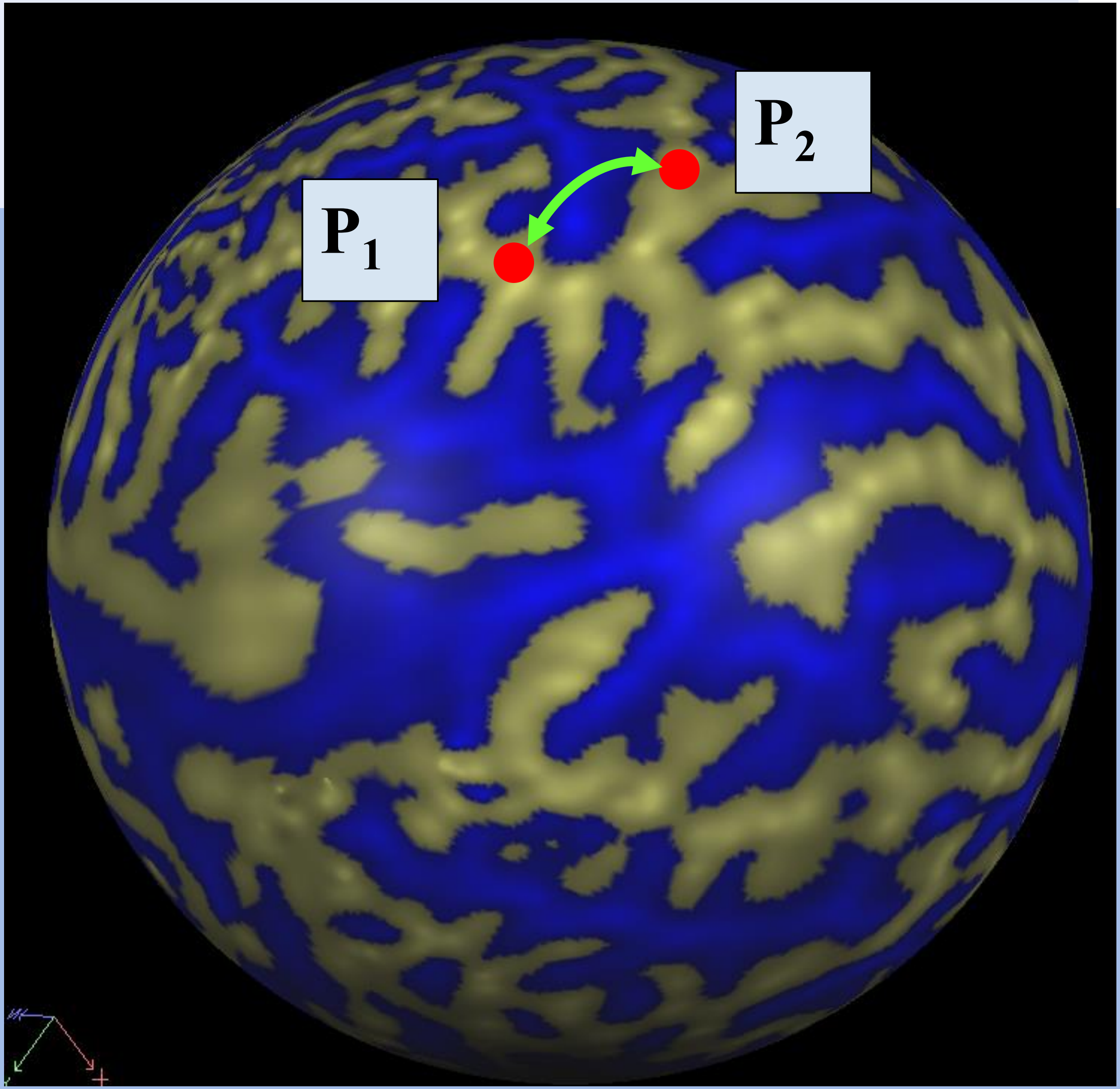

P1
P2

Cortex based intersubject alignment

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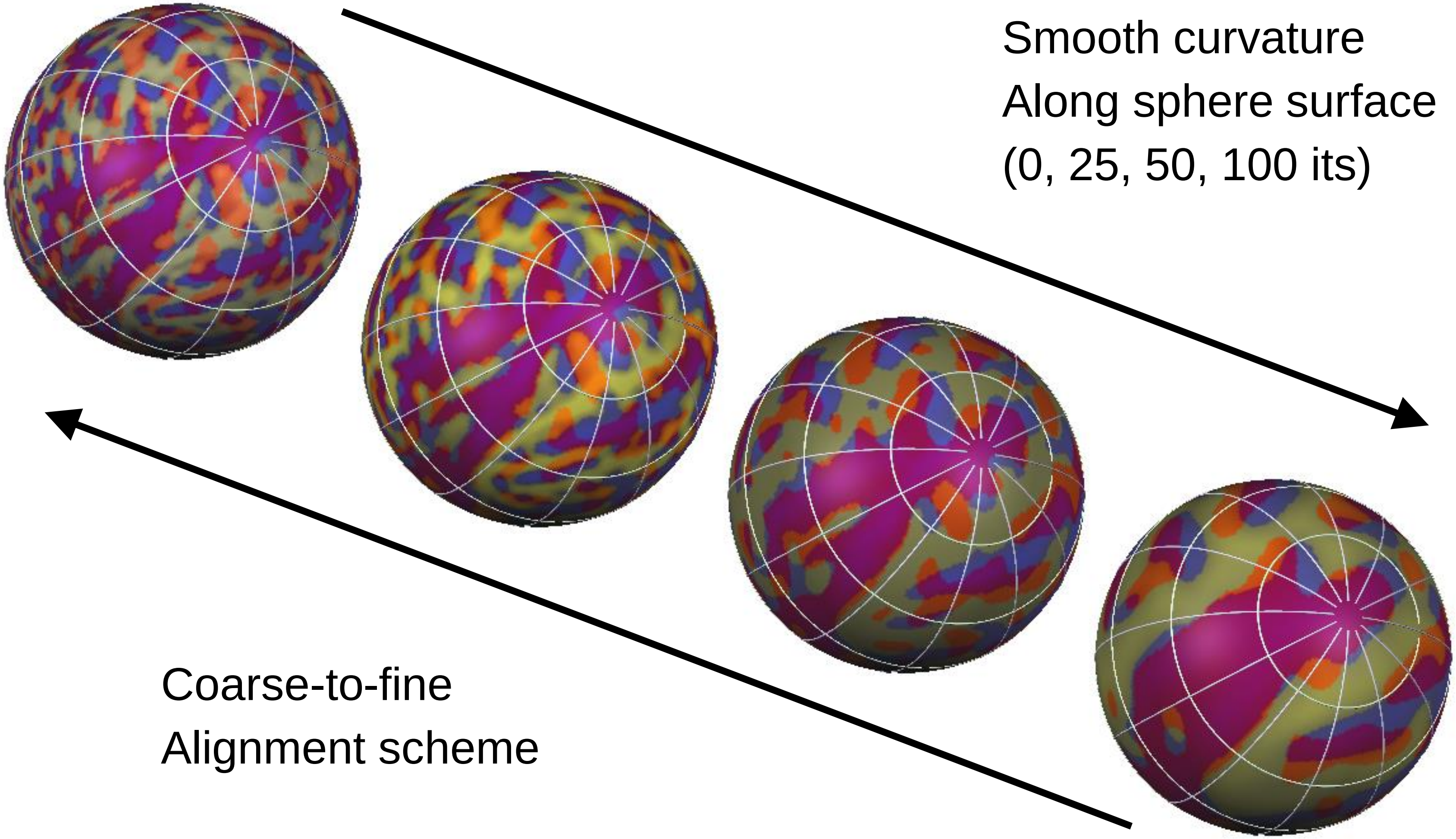
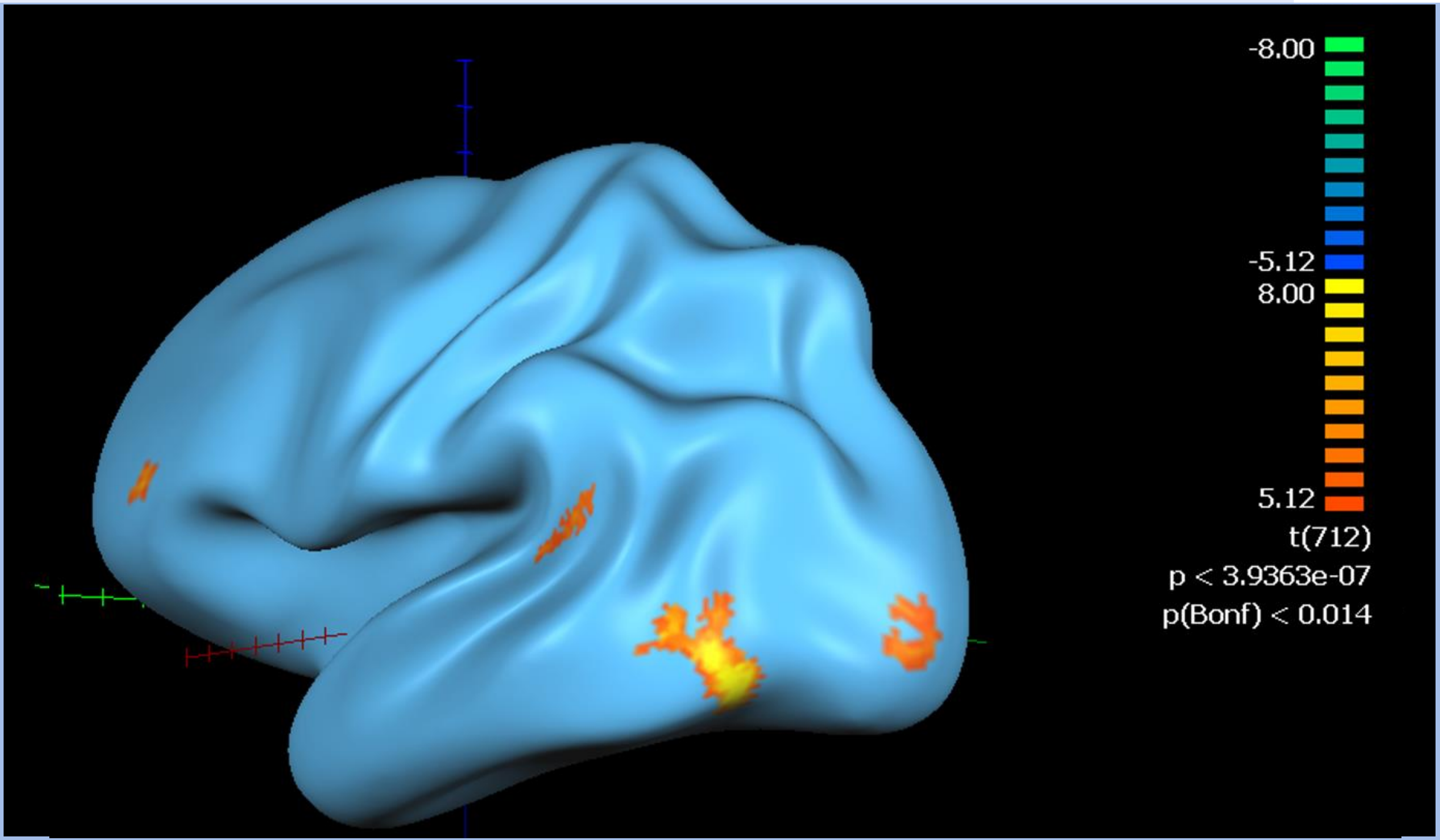


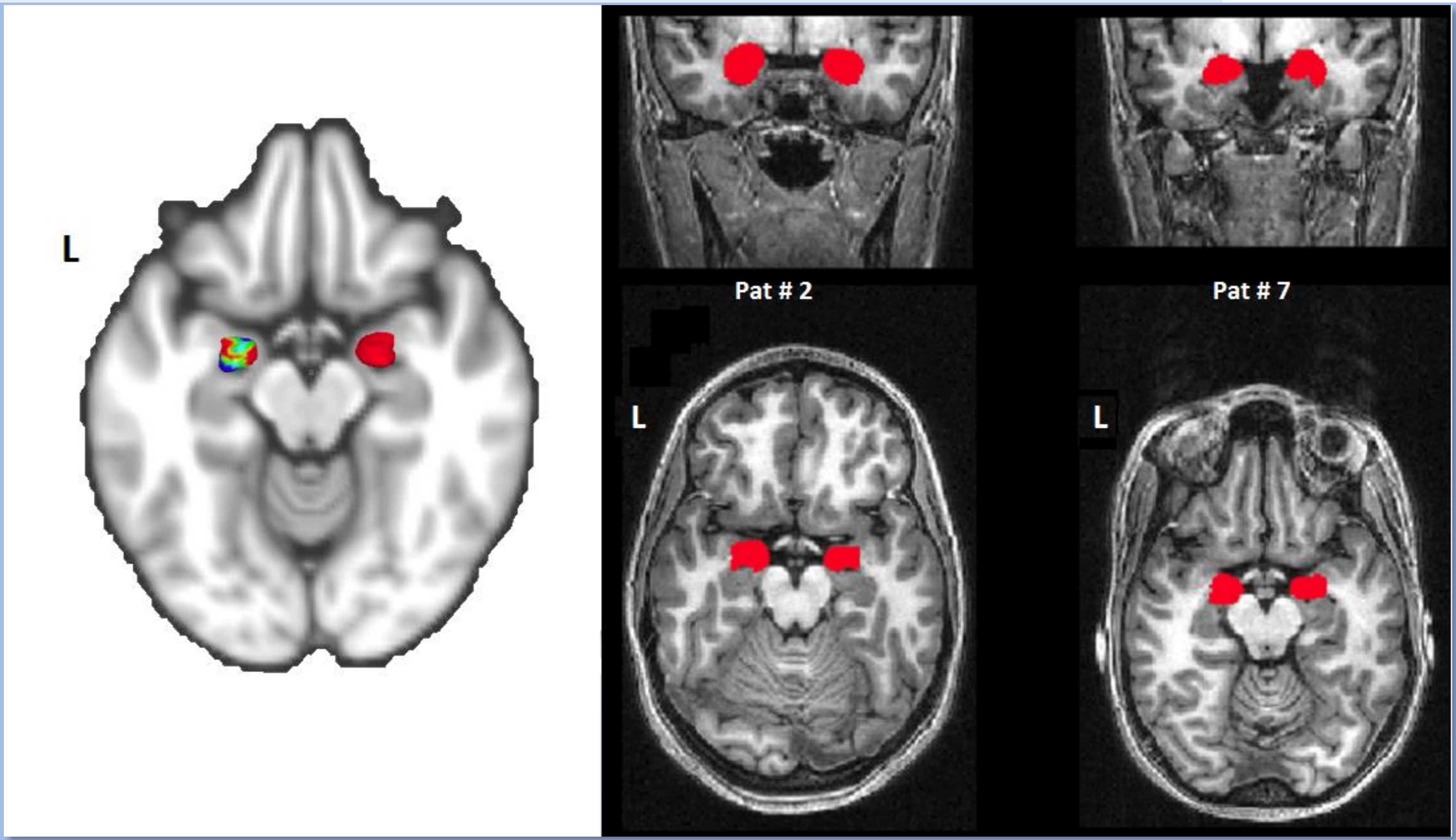
Smooth curvature
Along sphere surface
(0, 25, 50, 100 its)

Coarse-to-fine
Alignment scheme

Talairach statistics vs CBA statistics



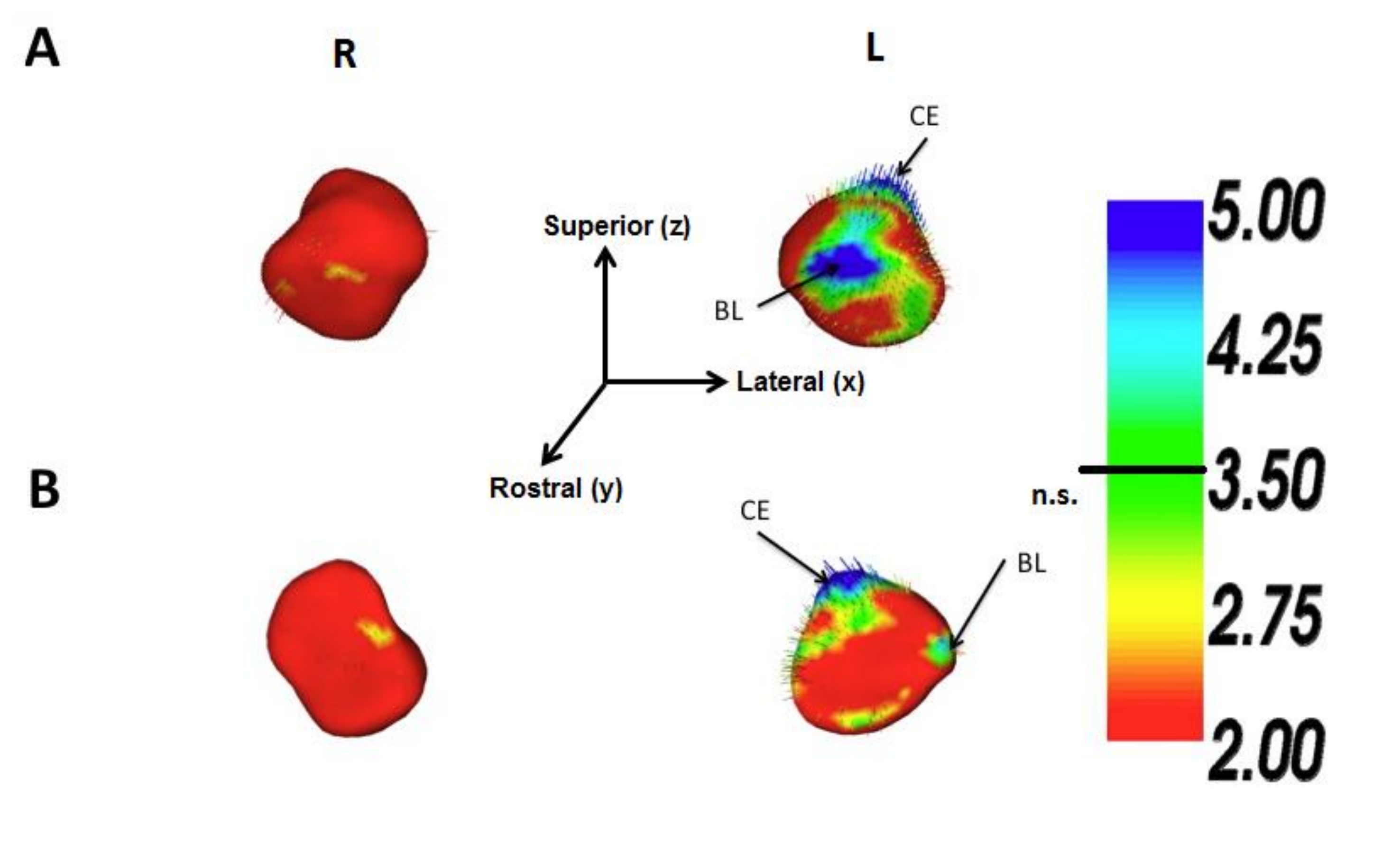
Shape analysis



Fisler M.S. Federspiel A. et al., *BMC psychiatry* 13:70. doi: 10.1186/1471-244X-13-70

Shape analysis

Left Amygdala in Spider Phobia patients stat.sig. smaller as compared to controls



FSL FIRST; http://fsl.fmrib.ox.ac.uk/fsl/fslwiki/

Diffusion Tensor Imaging (DTI)

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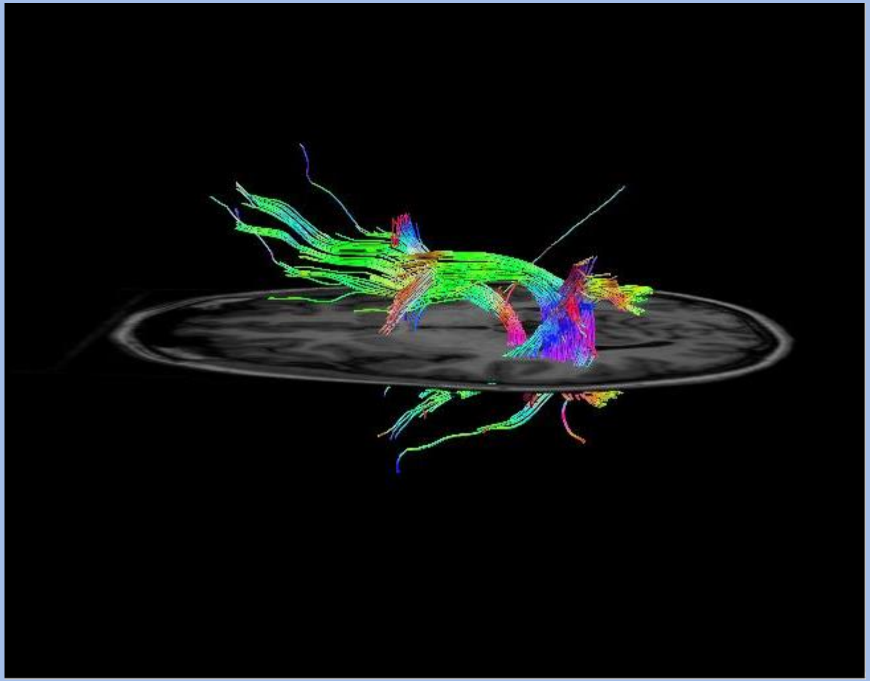
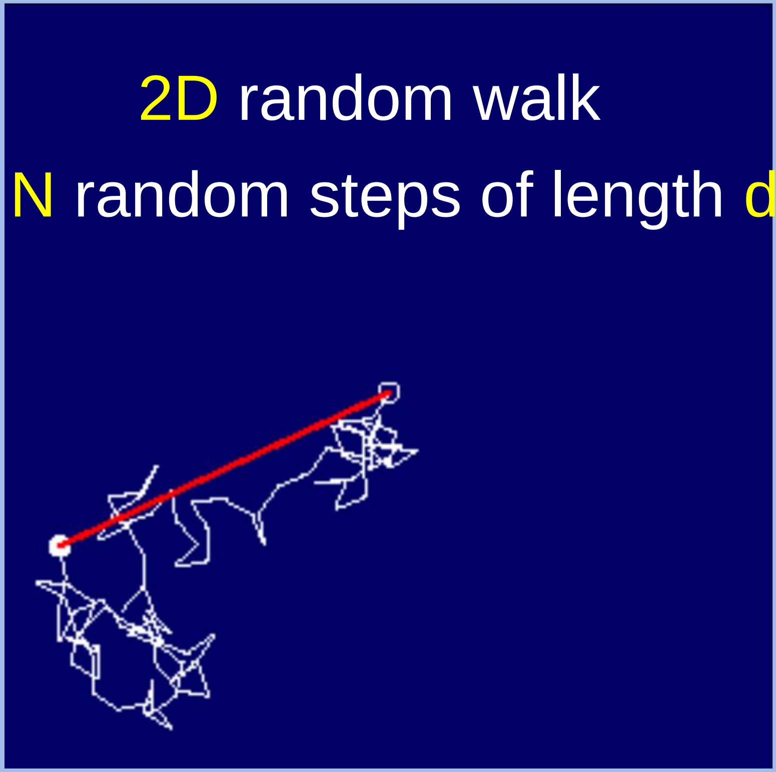
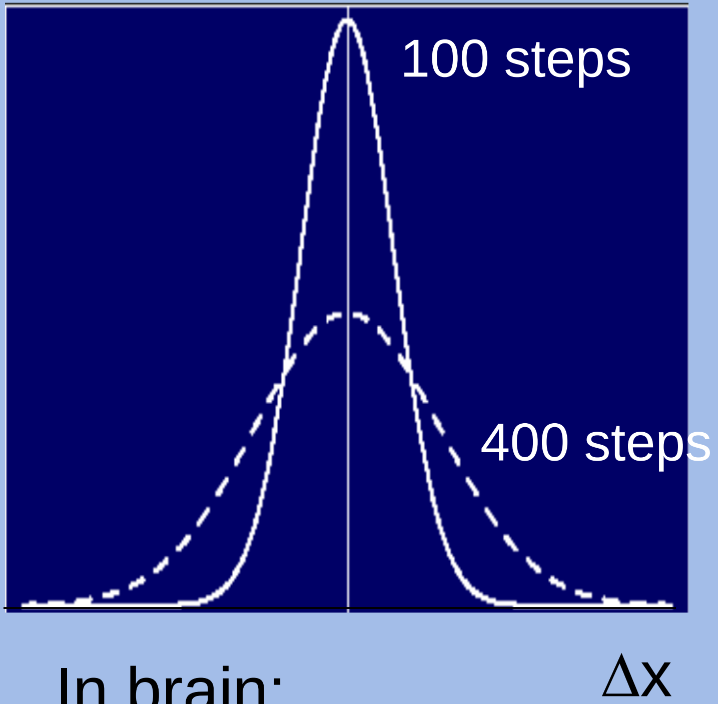
White Matter structure



Diffusion



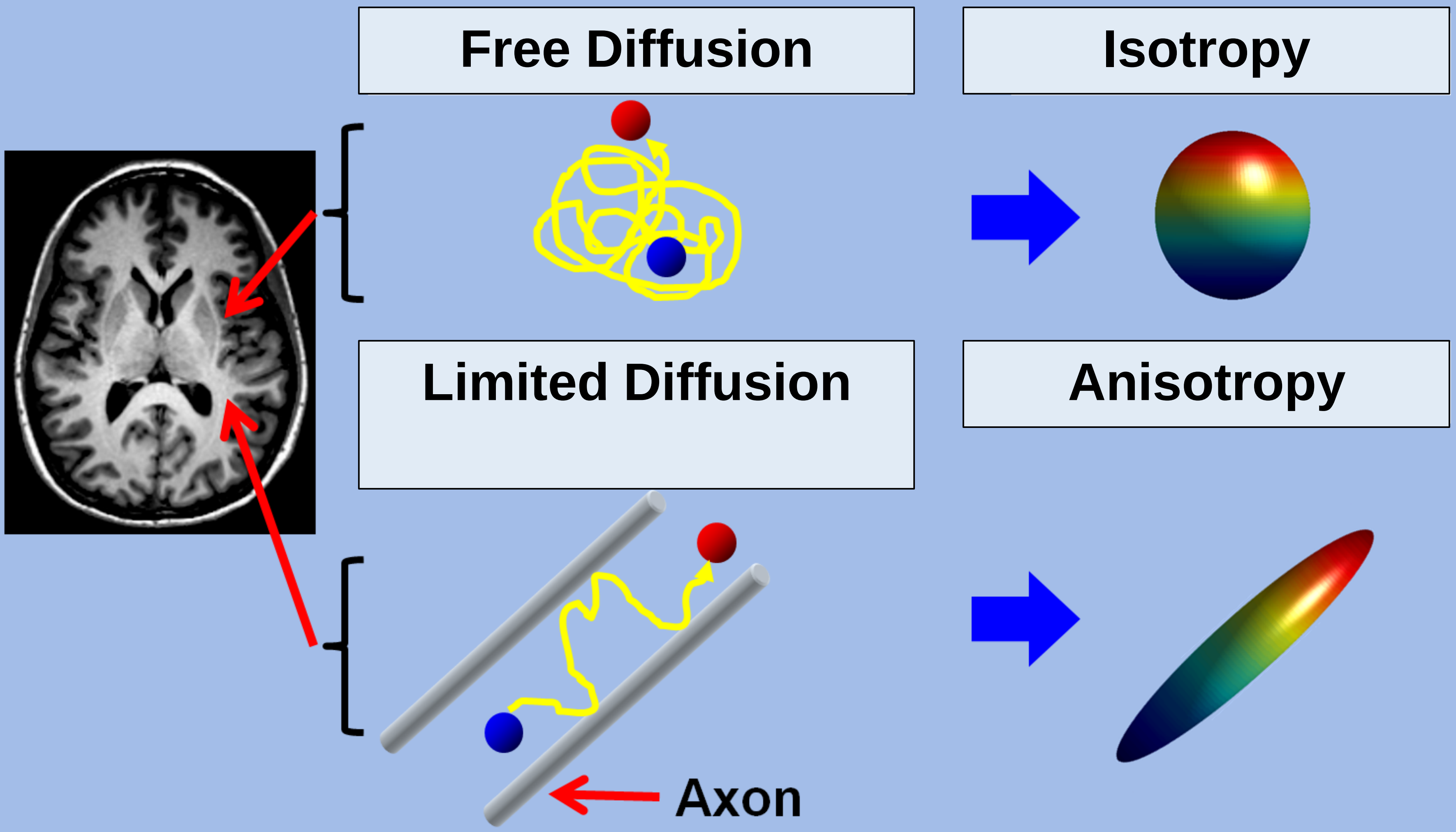


$$\overline{\Delta x^2} = Nd^2 = 2DT$$

In brain:
$D \cong 0.00112\ mm^2/s$
For T=100 msec,
$\Delta x \cong 15\ \mu$

Einstein Diffusion Equation D [mm^2/s]

Anisotropy of the white Matter

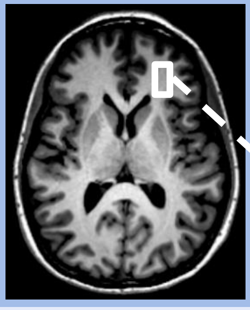


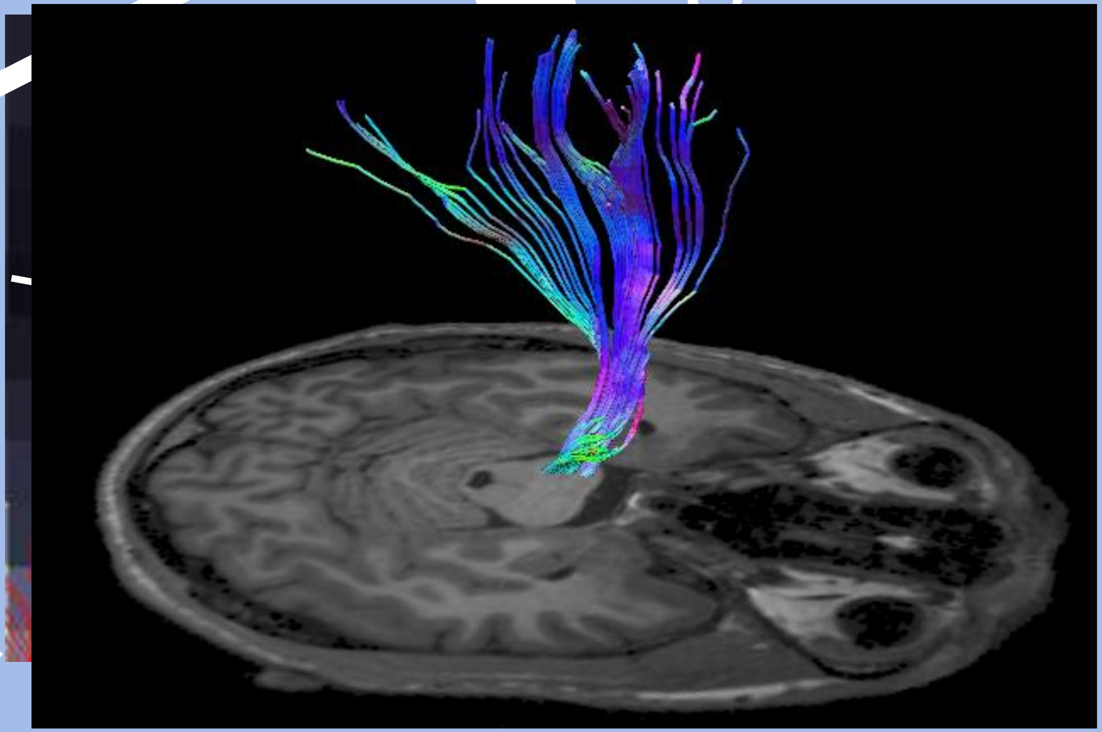
Diffusion Tensor Imaging (DTI)

$$D_{Diffusion\ Tensor} \times \vec{V} = \lambda \times \vec{V}$$

Eigenvector

Eigenvalue

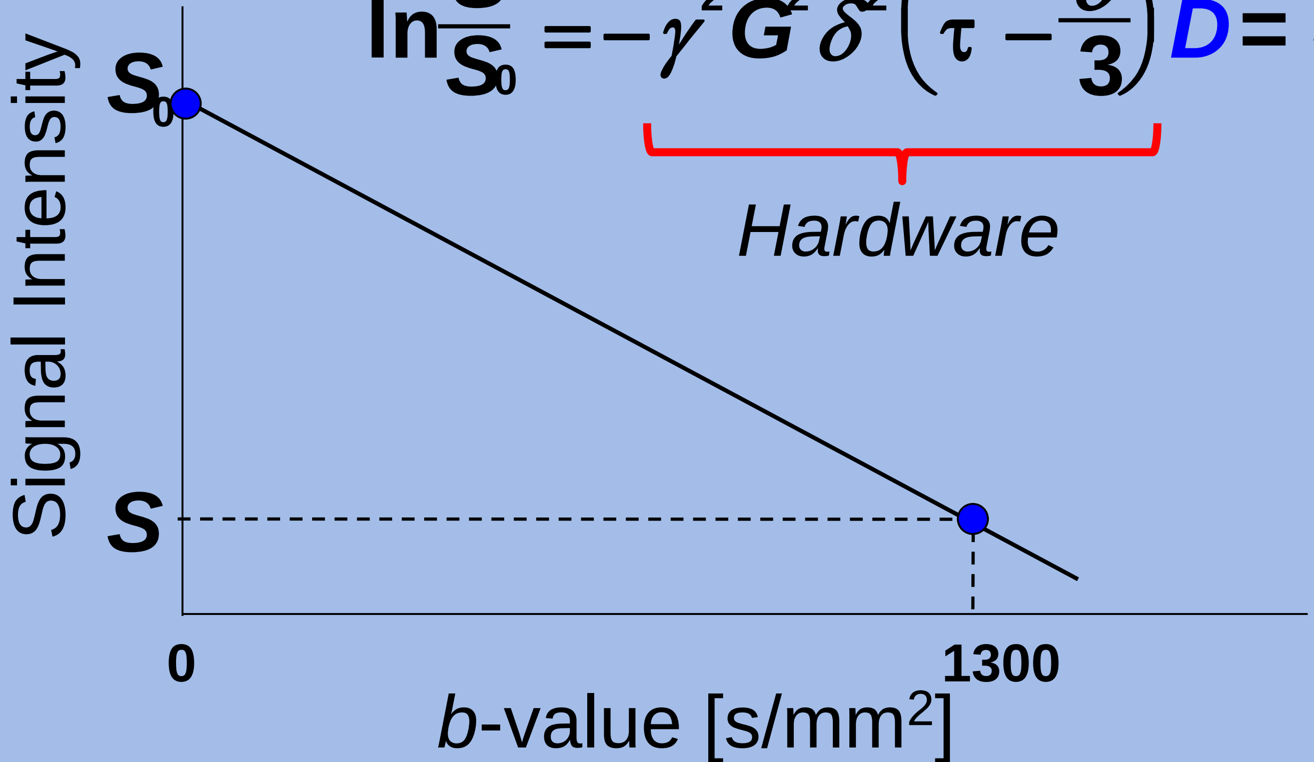




Steyskal Tanner Equation

$$\ln\frac{S}{S_0} = -\gamma^2 G^2 \delta^2 \left(\tau - \frac{\delta}{3}\right) D = -bD$$

Hardware



D: diffusion coefficient
δ: gradient width
τ: diffusion time
γ: gyromagnetic ratio
G: gradient amplitude

D: diffusion coefficient
δ: =24.5 ms
τ: =64.65
γ: =42.58 MHz*3 T
G: =40mT/m

Diffusion Tensor

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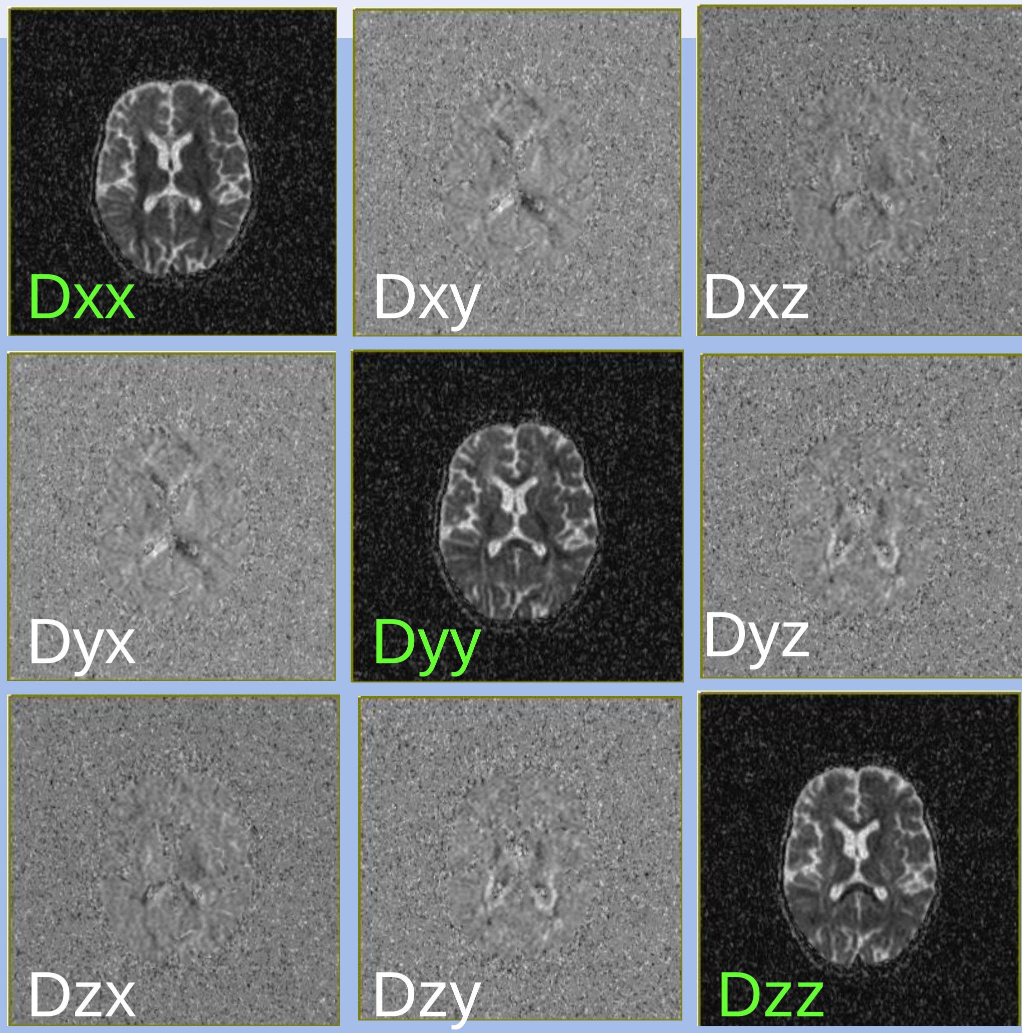

$$FA = \frac{\sqrt{3}}{\sqrt{2}} \frac{\sqrt{(\lambda_1 - \lambda)^2 + (\lambda_2 - \lambda)^2 + (\lambda_3 - \lambda)^2}}{\sqrt{\lambda_1^2 + \lambda_2^2 + \lambda_3^2}}$$

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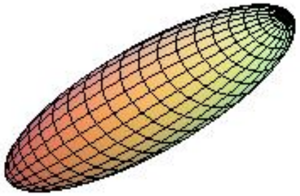
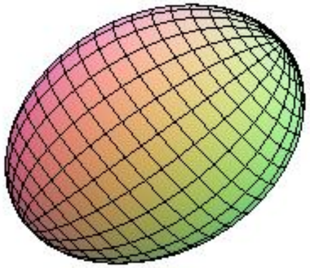
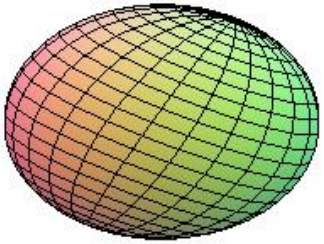


$\lambda_1 >> \lambda_2 ; \lambda_3=0$ FA~1



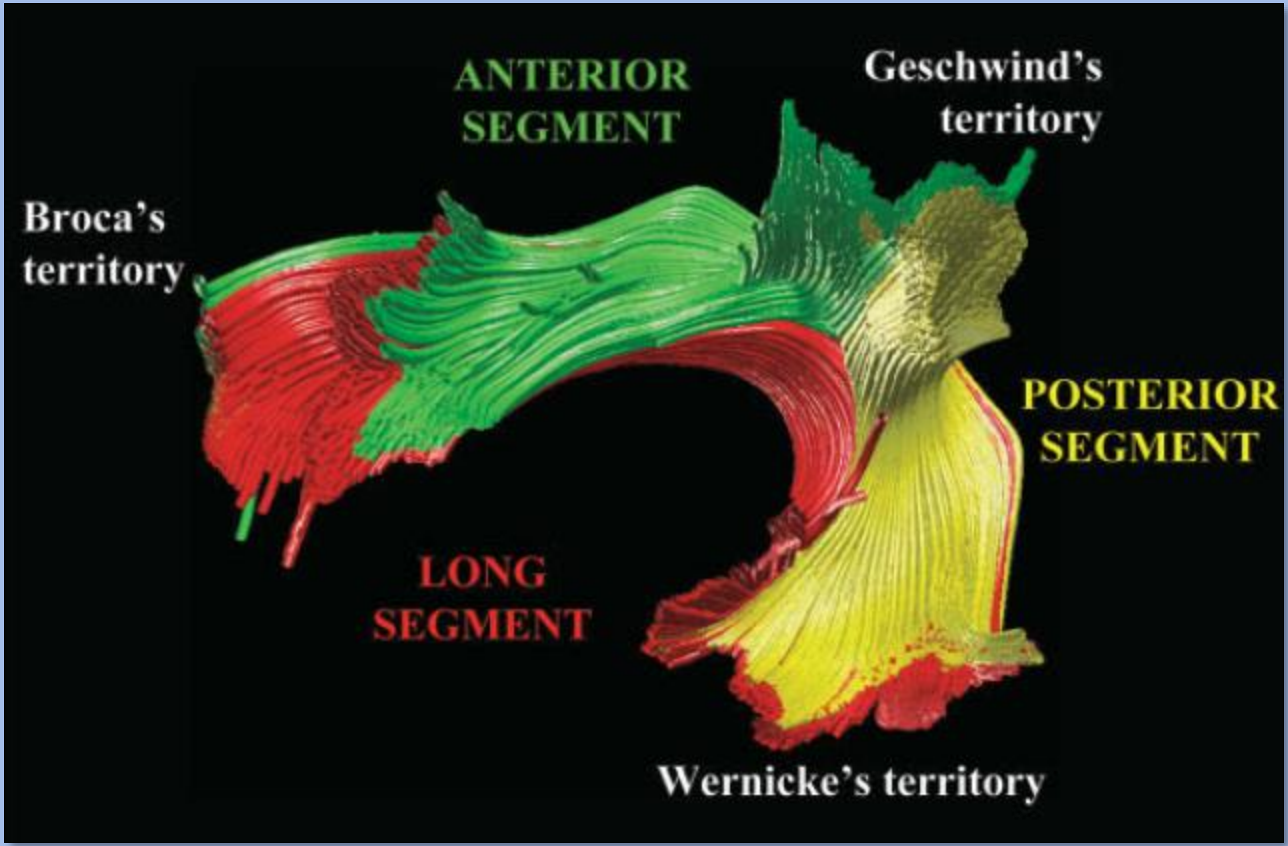
$\lambda_1 > \lambda_2 ; \lambda_3 \sim 0$ FA<<1



$\lambda_1 = \lambda_2 = \lambda_3$ FA=0

Path of language processing

Indirect pathway

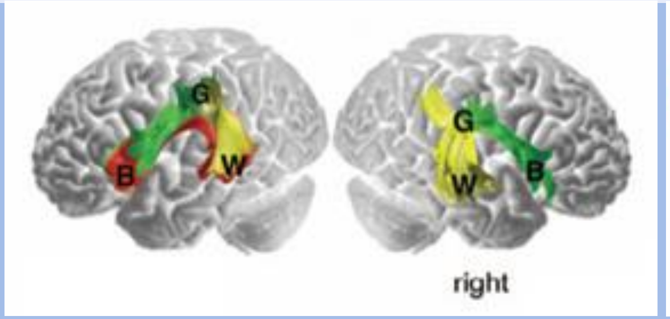


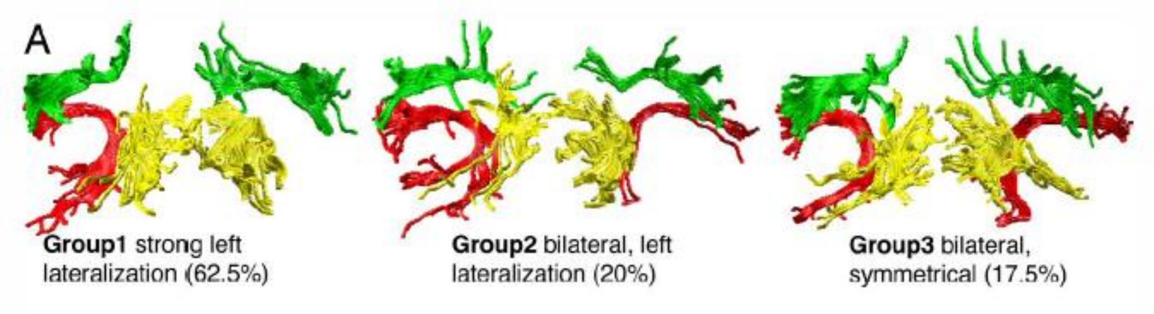
Direct pathway

Indirect pathway

Catani M et al., Ann Neurol 2005; 57:8-16

Lateralization of Language Regions

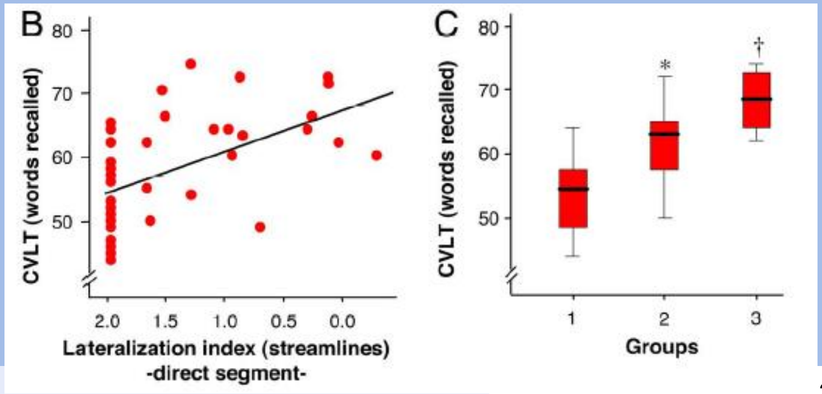




Anatomy of White Matter different in hemispheres.

Pattern of Lateralization is heterogeneous.

Bilateral Language Network favors the learning of words.



Catani M. et al. *PNAS 2007* 104(43):17163-68.

Axonal diameter (with DWI)

Mean R [mm]			
G1	0.0080	B2	0.0096
G2	0.0088	B3	0.0114
B1	0.0105	S1	0.0097
		S2	0.0073

Tab.1: mean regional estimated R