

Methods to study connective anatomy

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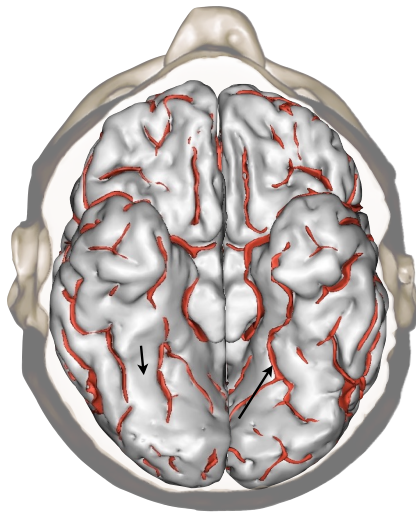
Radboud University

Nijmegen, the Netherlands

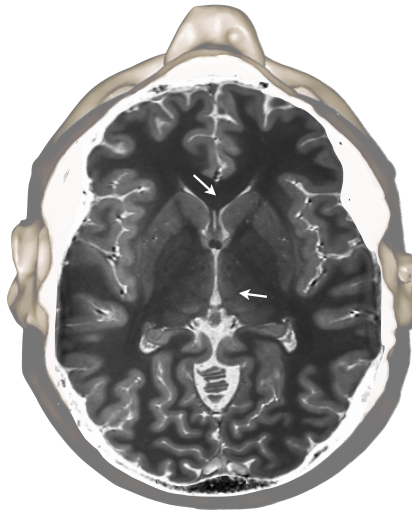


Studying Anatomy

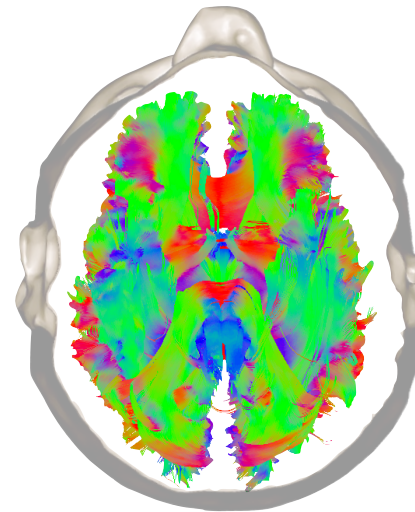
SURFACE ANATOMY



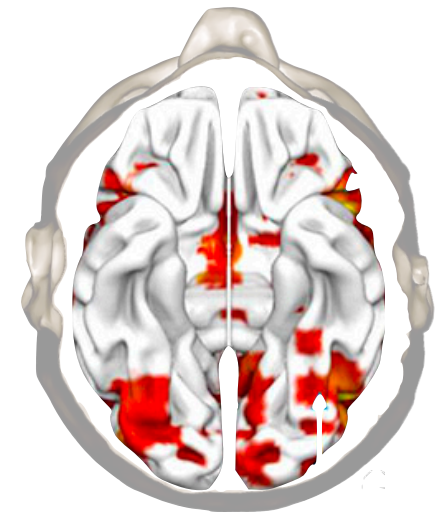
SECTIONAL ANATOMY



CONNECTIONAL ANATOMY



FUNCTIONAL ANATOMY



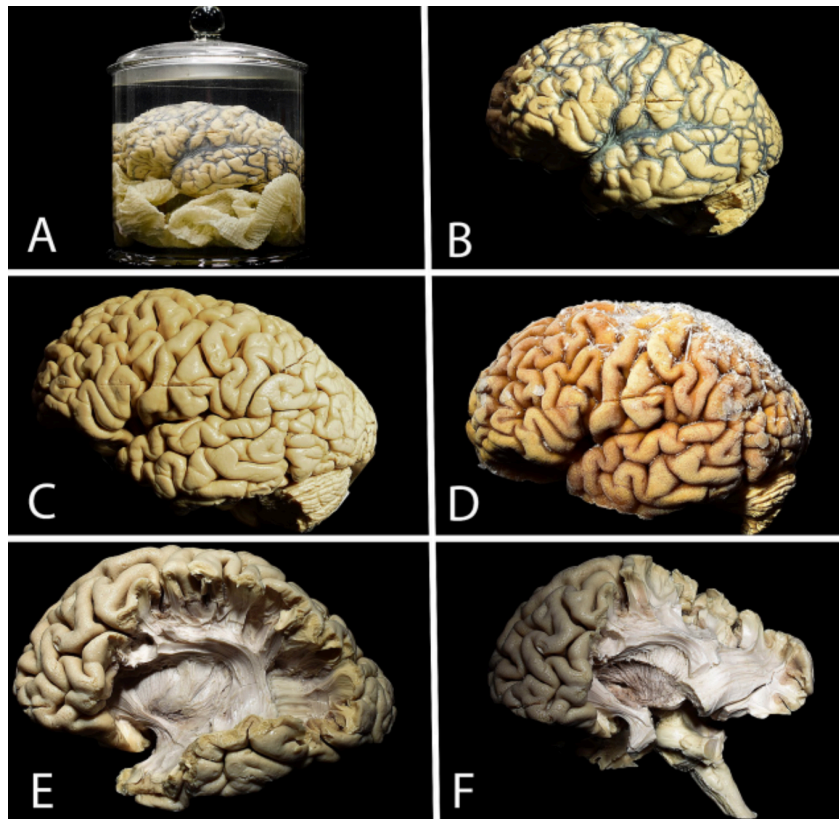
Catani & Thiebaut de Schotten, 2012

White matter dissection with the Klingler technique: a literature review

[Tomasz A. Dziejczak](#), [Artur Balasa](#), [Mateusz P. Jeżewski](#), [Łukasz Michałowski](#) & [Andrzej Marchel](#)

Brain Structure and Function **226**, 13–47(2021) | [Cite this article](#)

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A special technique developed by Joseph Klingler at the Institute of Anatomy in Basel, Switzerland in the 1930s.

Fixation, freezing, and thawing:

- 10% formalin
- Freezing time 8h to 2M
- Temperature -5 to -80 °C.

Klingler dissection technique: what is needed?



Specimen & patience

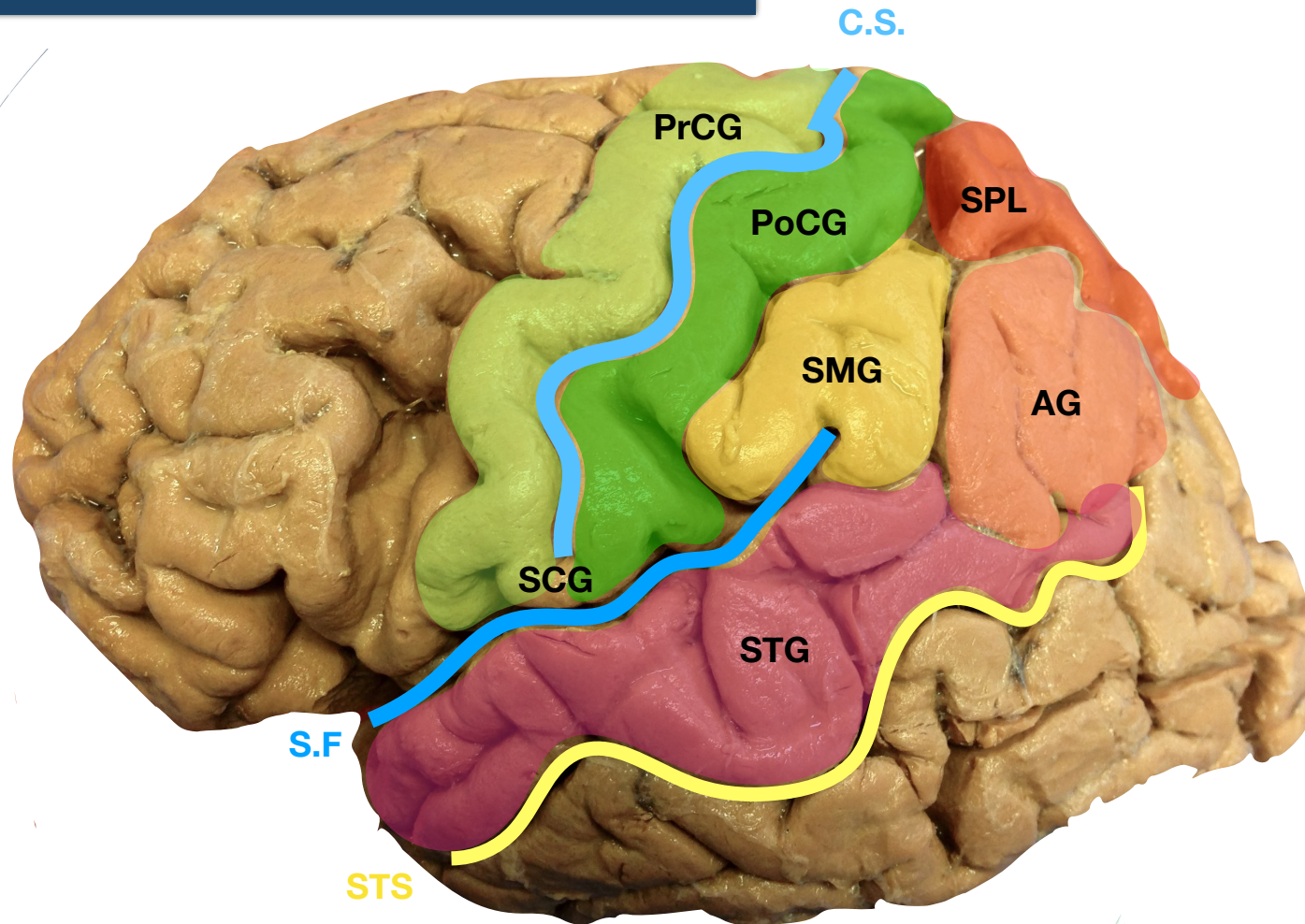


Instruments

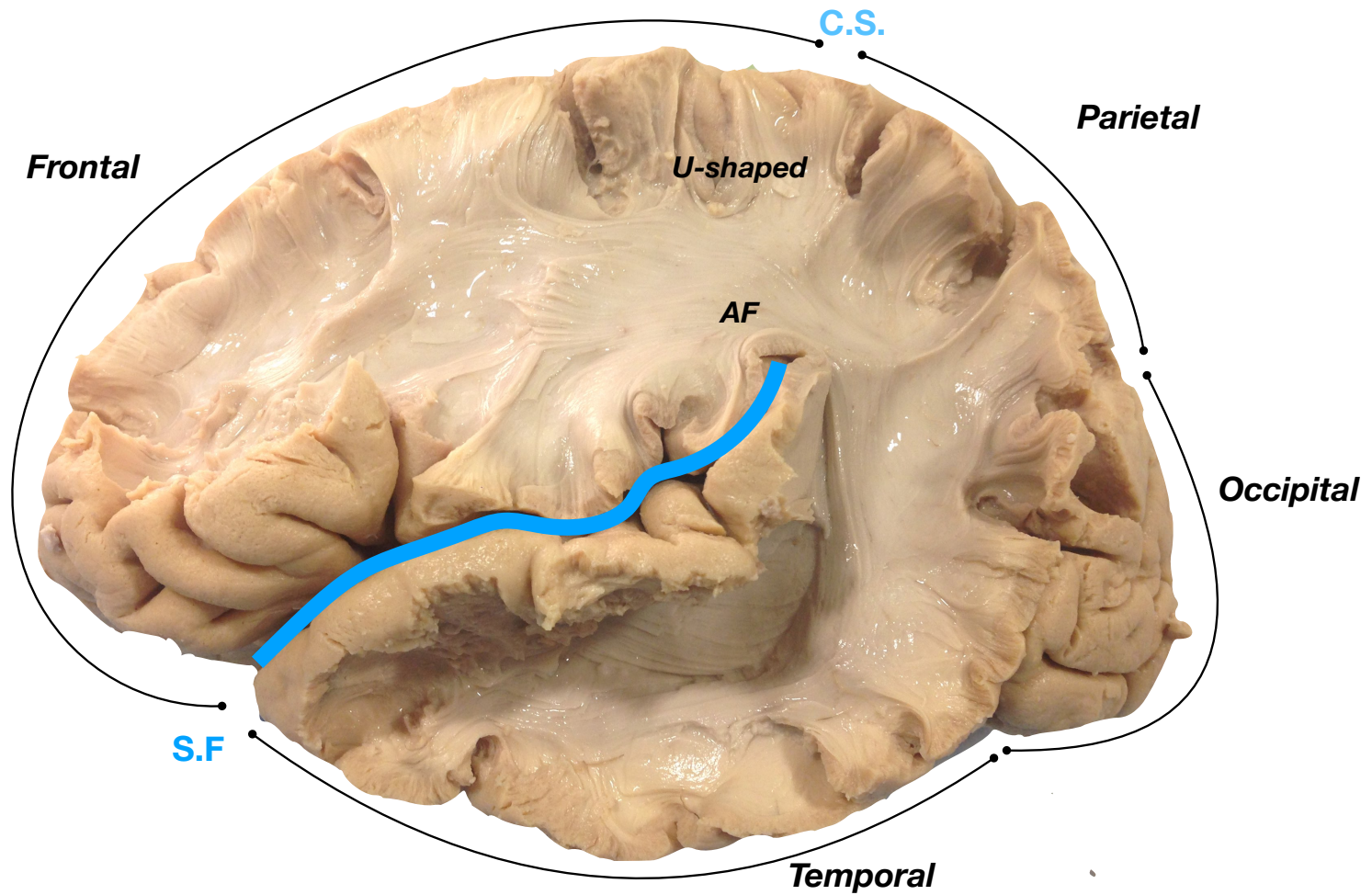


Microscope

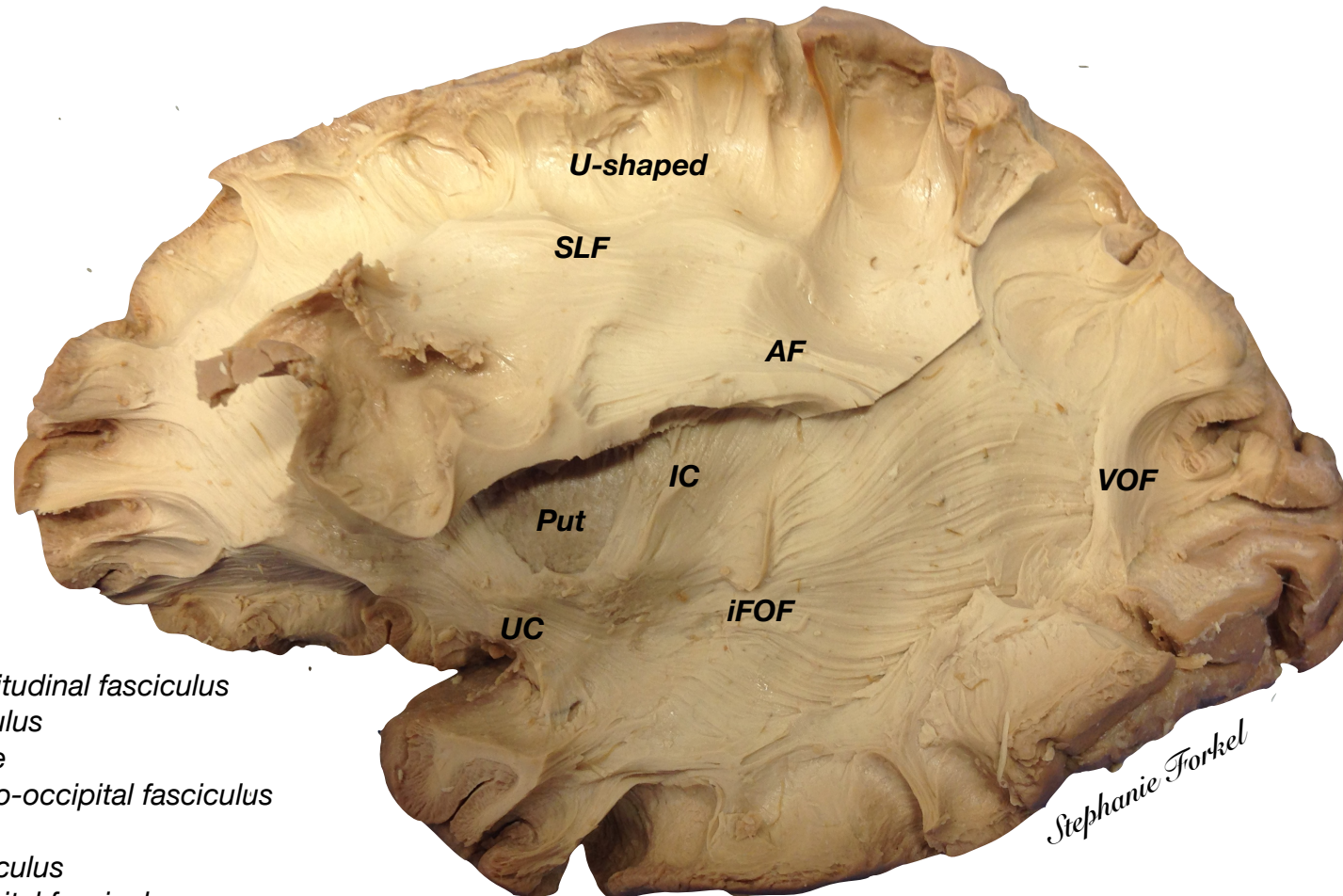
Lateral Aspect



Lateral Aspect

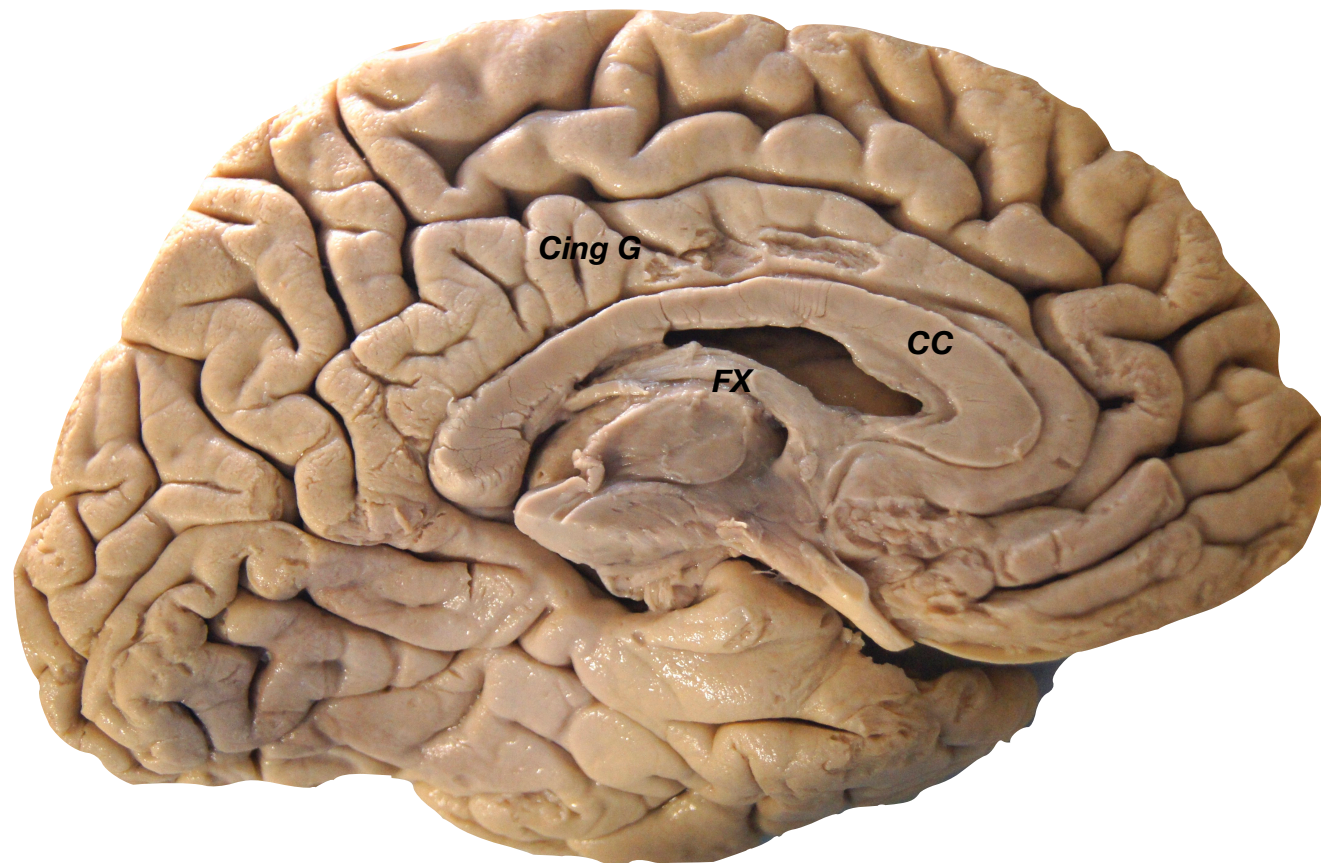


Lateral Aspect

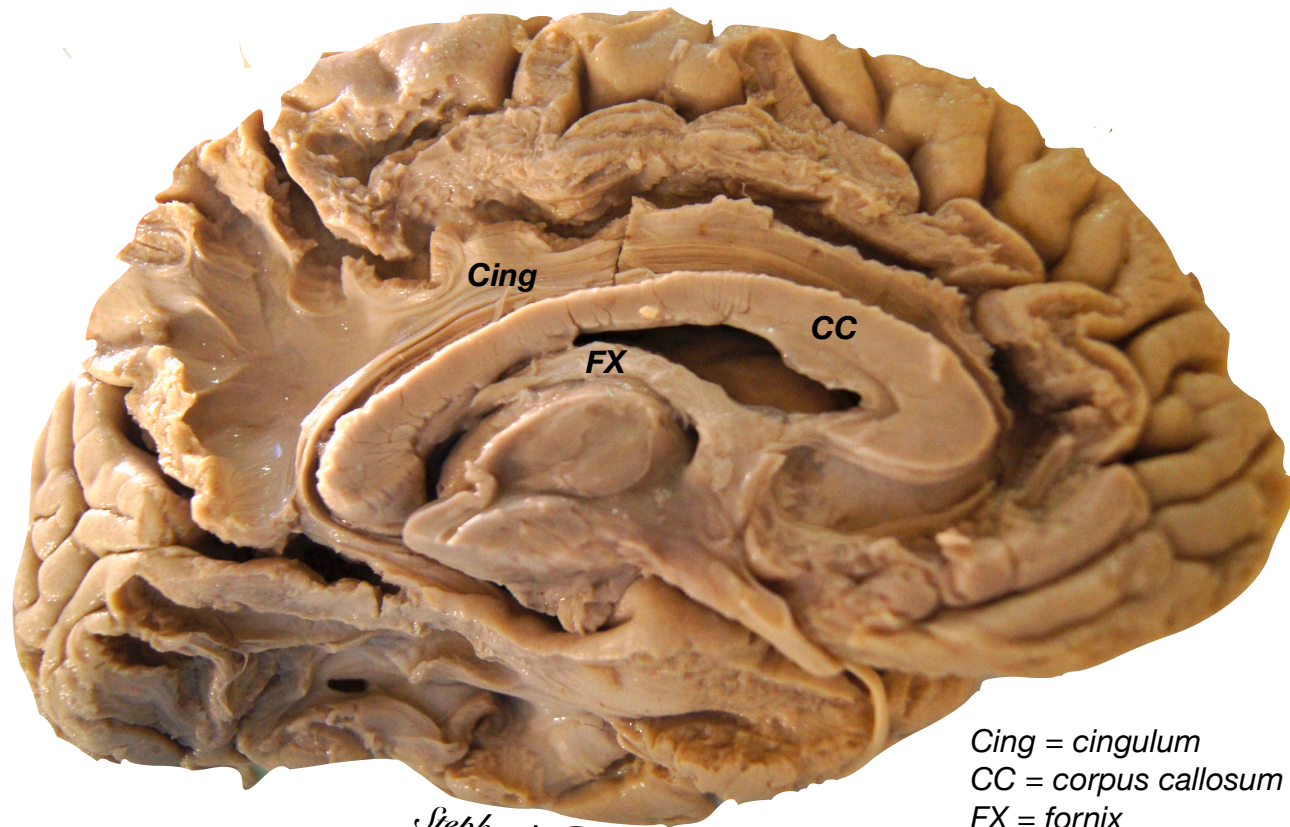


SLF = superior longitudinal fasciculus
AF = arcuate fasciculus
IC = internal capsule
IFOF = inferior fronto-occipital fasciculus
Put = putamen
UC = uncinata fasciculus
VOF = vertical occipital fasciculus

Medial Aspect



Medial Aspect



Stephanie Forkel

Cing = cingulum
CC = corpus callosum
FX = fornix

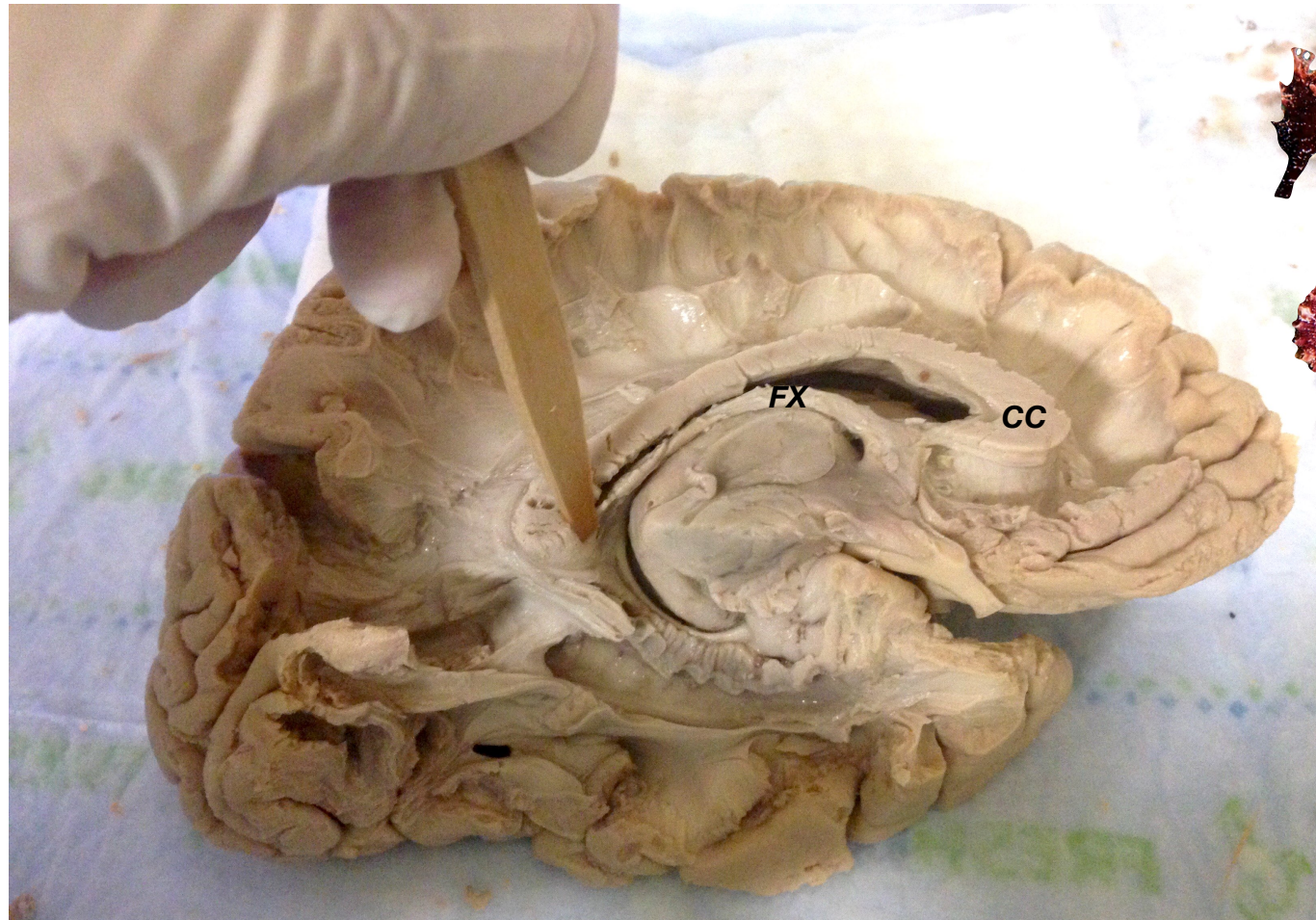
Medial Aspect



Medial Aspect



Medial Aspect



Klingler Dissection Summary

- invasive by nature
- time consuming procedure (prep + dissection)
- requires deep anatomical knowledge and skills
- difficult to determine cortical terminations
- freezing-thawing cycles might introduce artefacts

- excellent complementary research tool for neuroanatomical studies
- unparalleled method to improve understanding of the three-dimensional structures



Diffusion-weighted imaging

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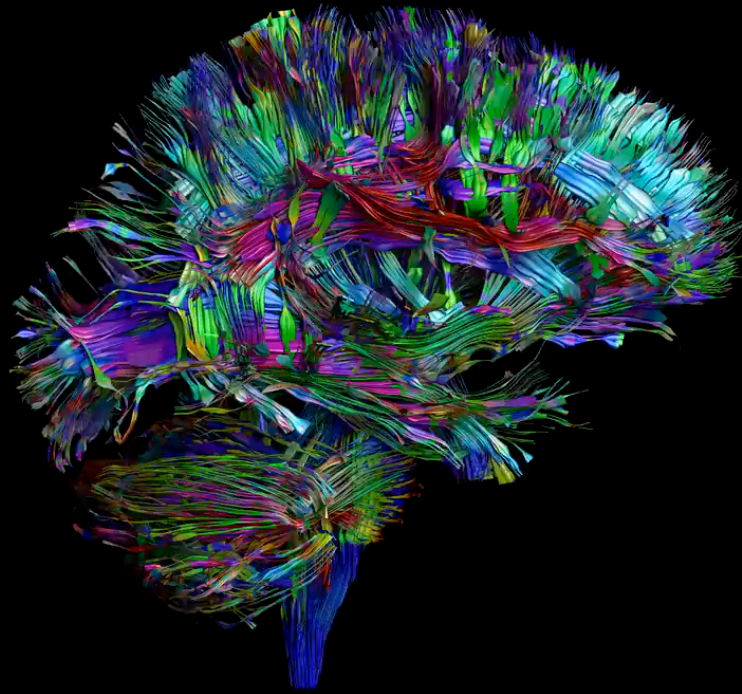


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Nijmegen, the Netherlands



Diffusion-weighted Imaging tractography



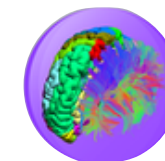
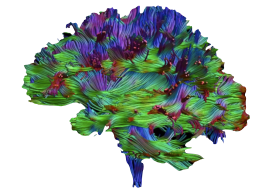
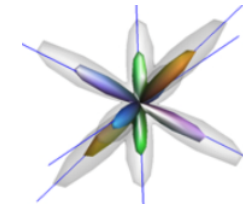
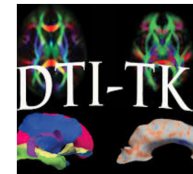
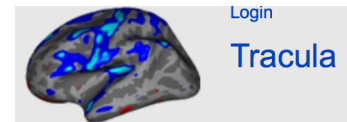
Courtesy Alexander Leemans

The method(s)

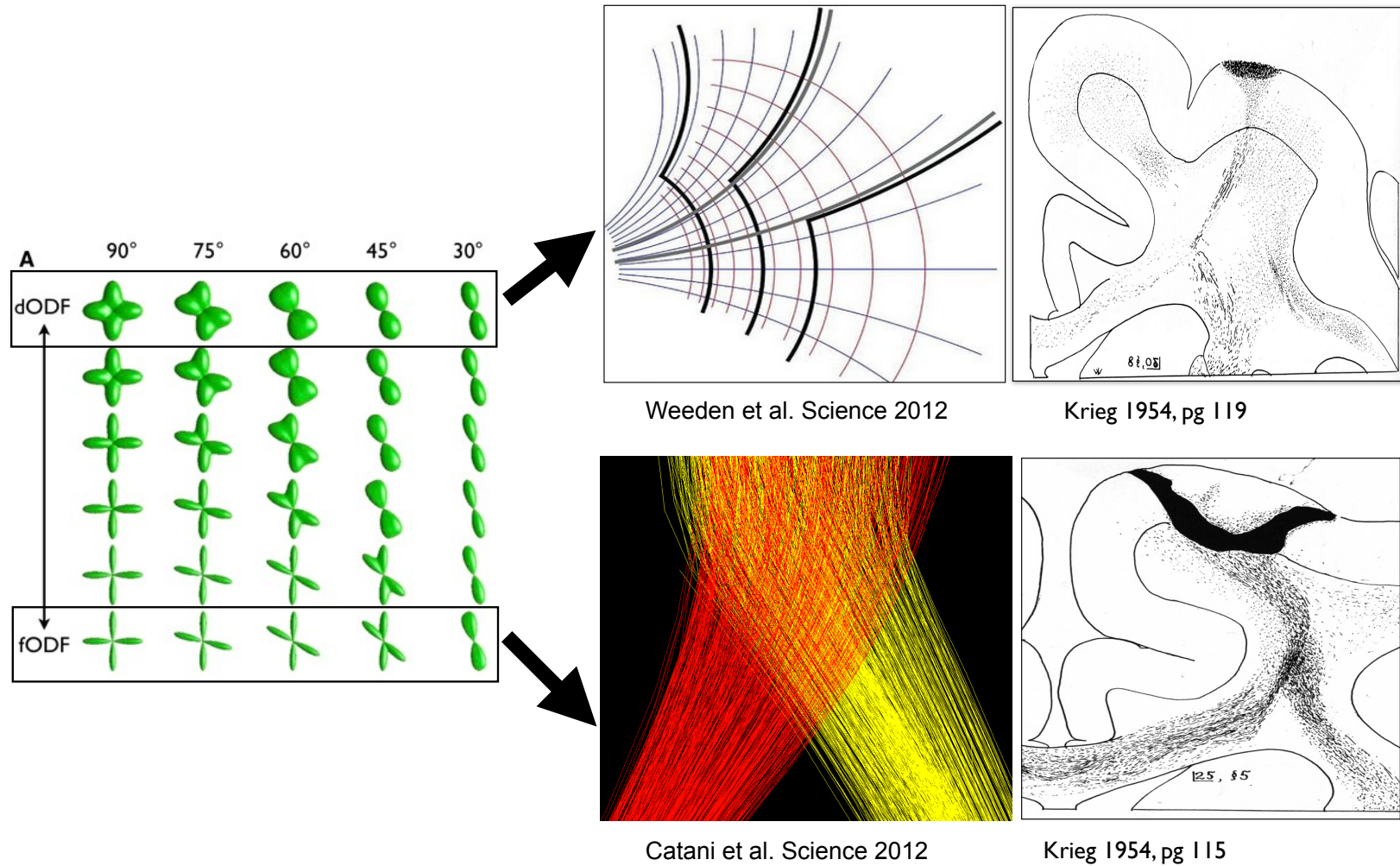
- + in vivo
- + non-invasive
- + whole brain
- + can address new questions
- low resolution (large bundles)
- indirect (diffusion path not axons)
- error-prone (MRI is noisy)
- difficult to interpret quantitatively



UCL Camino



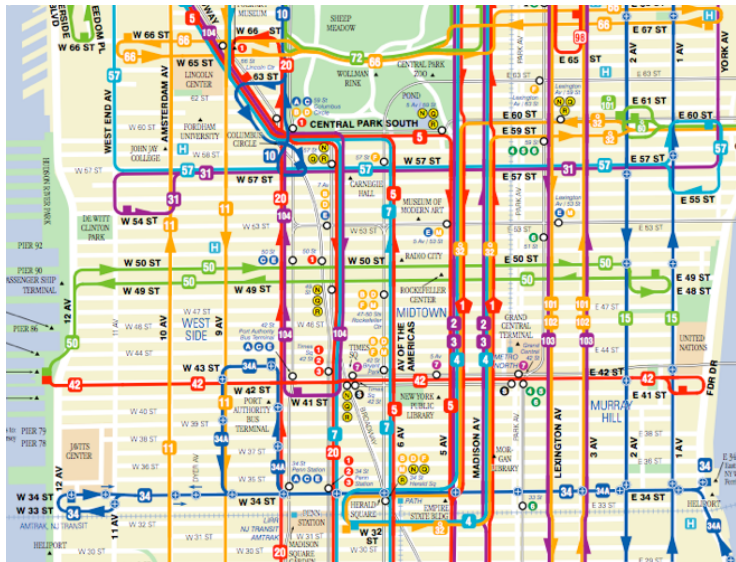
NON-TENSORIAL METHODS



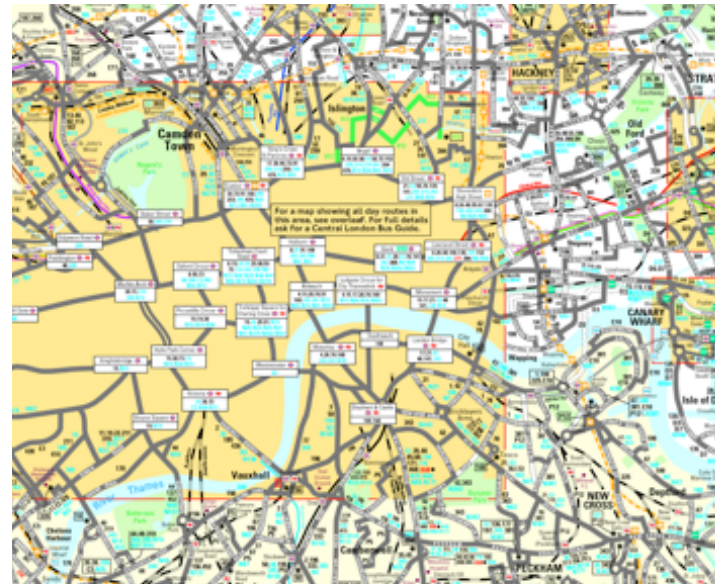
THE “GRID PATTERN” OF HUMAN CONNECTIVITY

Wedeen et al. have reported findings suggesting that the human brain is organized like a three-dimensional New York City street grid. We conclude that this view is biased by the limits of their technique and does not correspond to the real anatomy. To us, the architecture of the brain, seen through the lens of alternative diffusion methods, bears a closer resemblance to the intricate streets of Victorian London.

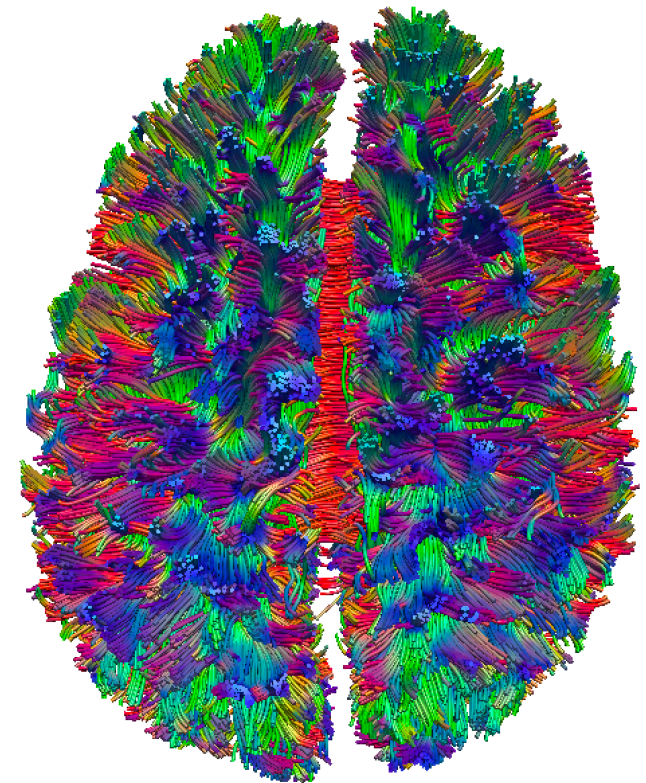
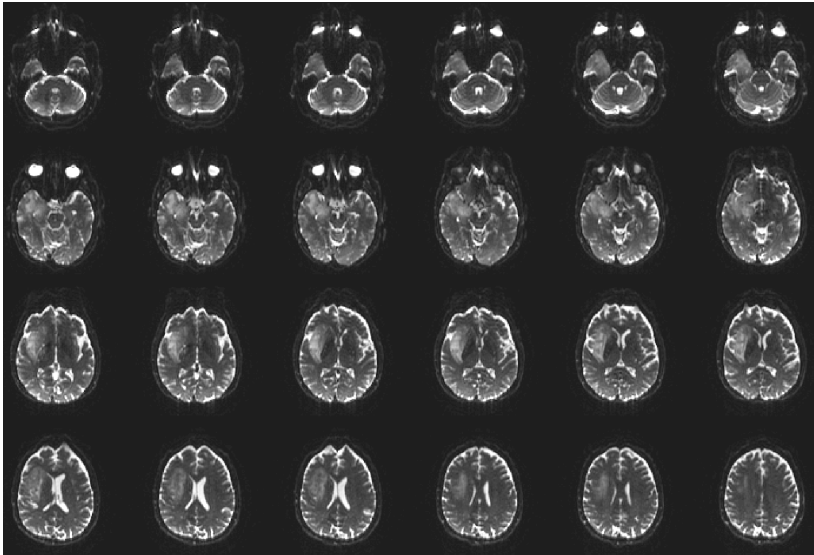
Manhattan



London

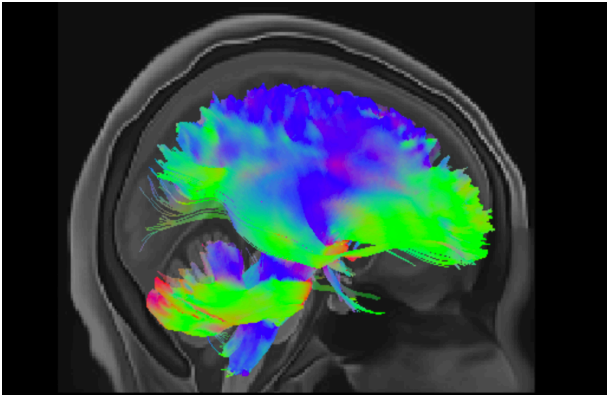


The method(s)

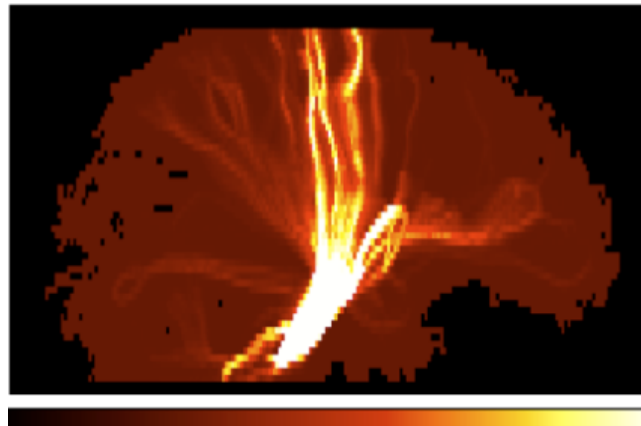


Types of tractography

Deterministic



Probabilistic

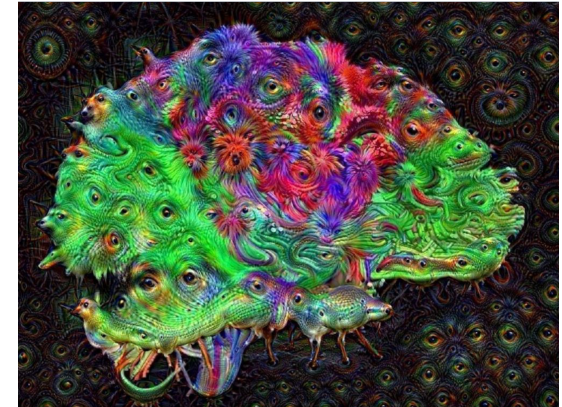


low

Reproducibility

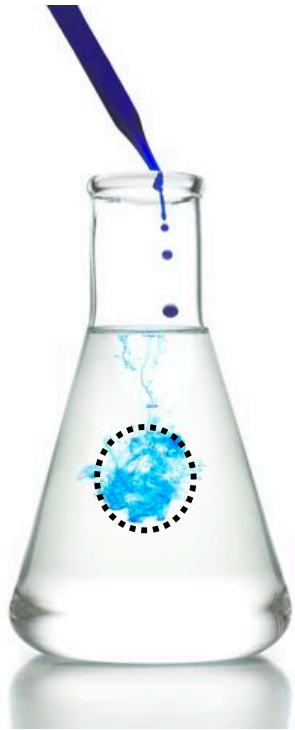
high

Fantastic



(BrainArt competition, Dr Etta Howells)

Principles of diffusion-weighted imaging



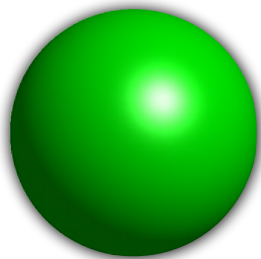
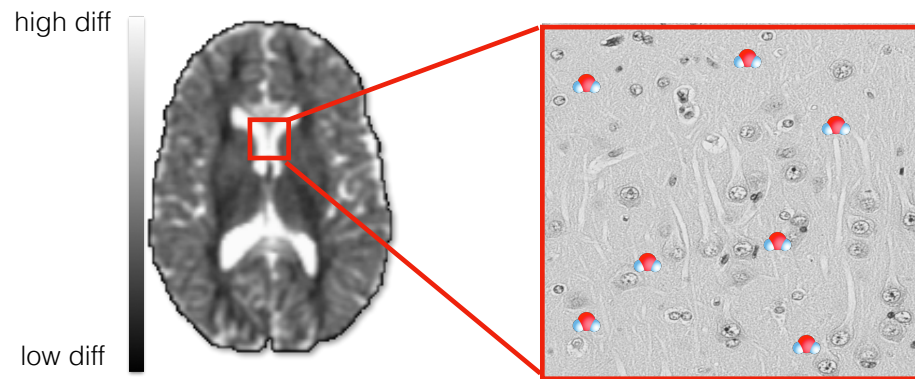
t_0 \rightarrow *time*

Diffusion is a random walk process
(e.g. Random motion of water molecules)

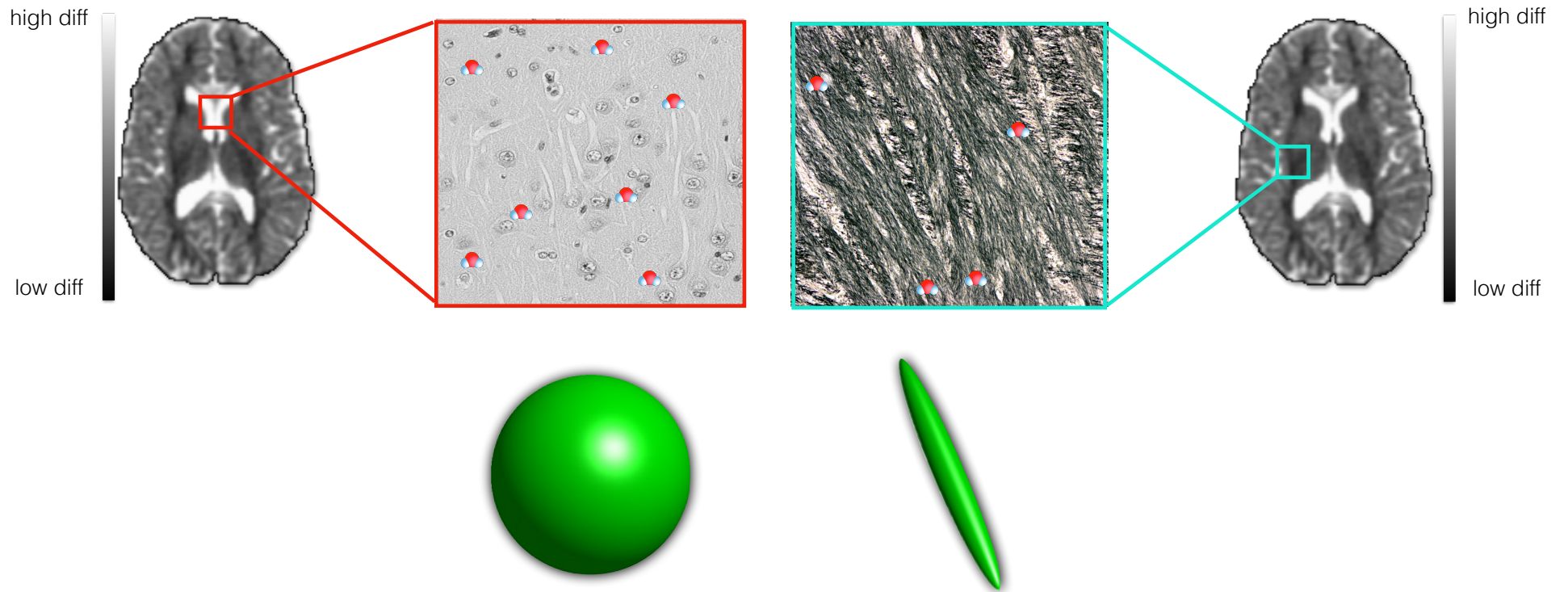
$$\langle R^2 \rangle = 6Dt$$

mean square displacement \uparrow \uparrow time
diffusion coefficient

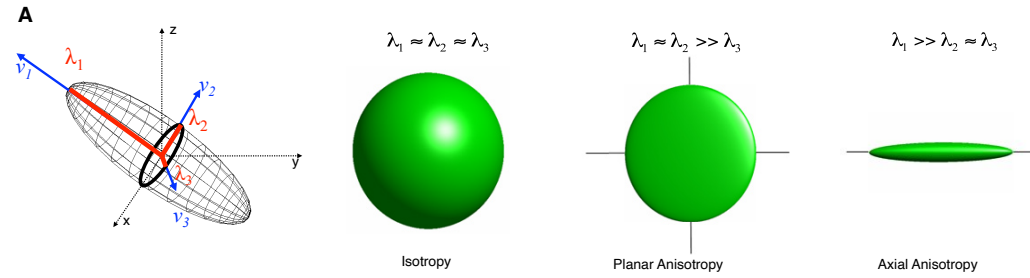
Principles of tractography



Principles of tractography



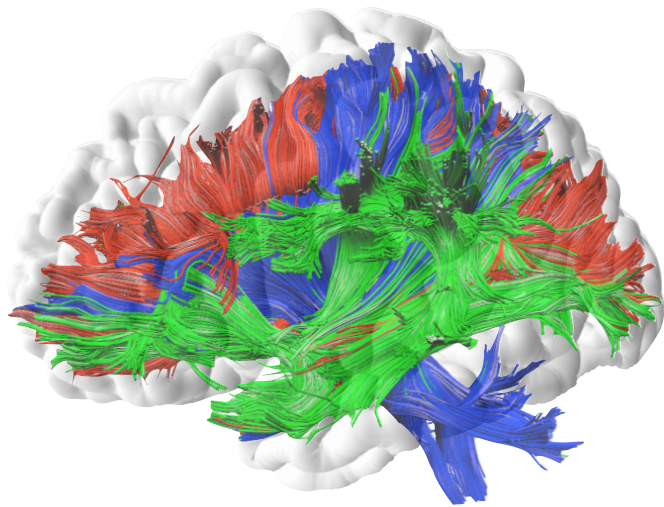
Diffusion Tensor Imaging (DTI)



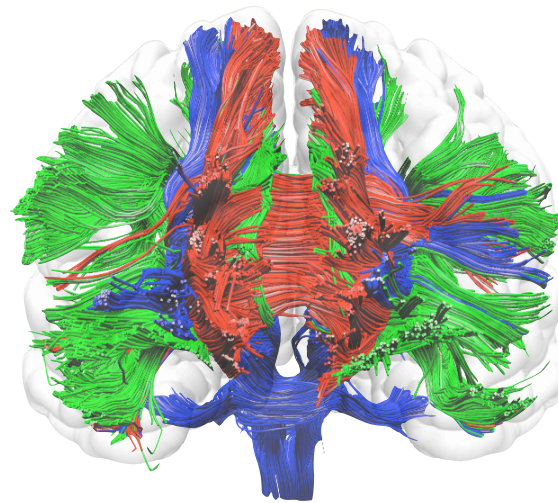





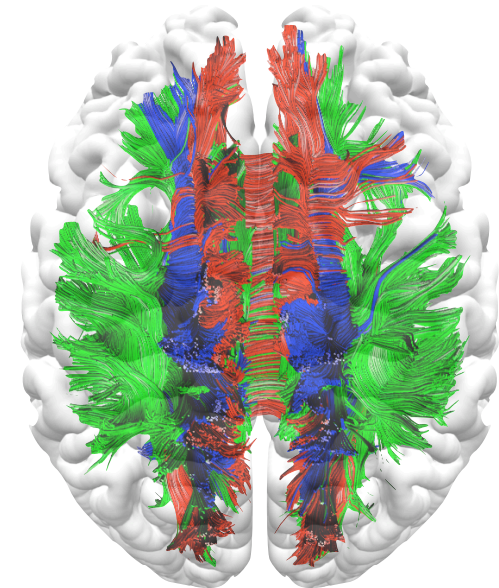
Tractography




 association pathways

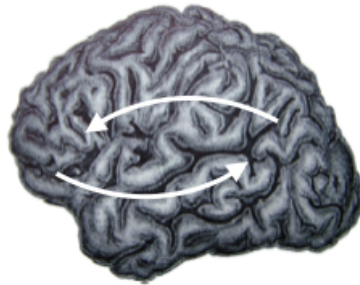


 projection pathways



 commissural pathways

White matter classification



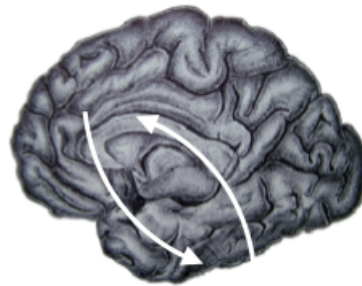
ASSOCIATION FIBERS



Theodor Meynert
(1833-1892)



COMMISSURAL FIBERS



PROJECTION FIBERS

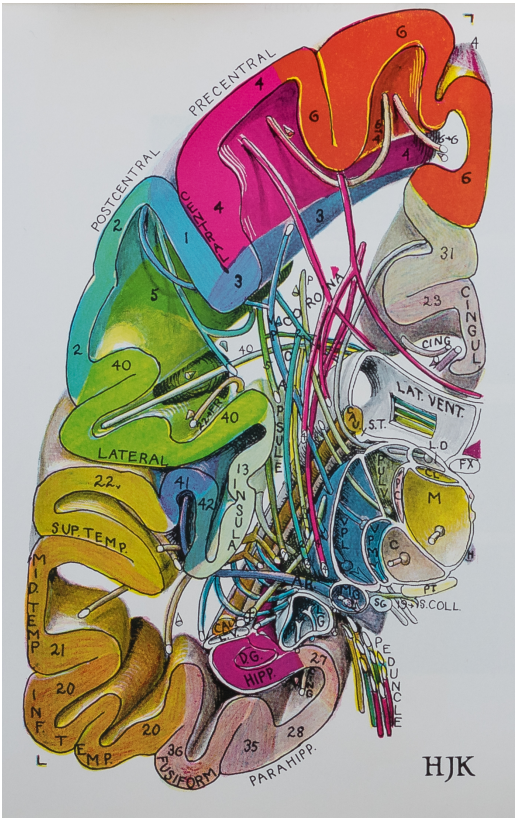
Catani, Forkel & Thiebaut de Schotten, 2010

White matter classification

Wendell Krieg

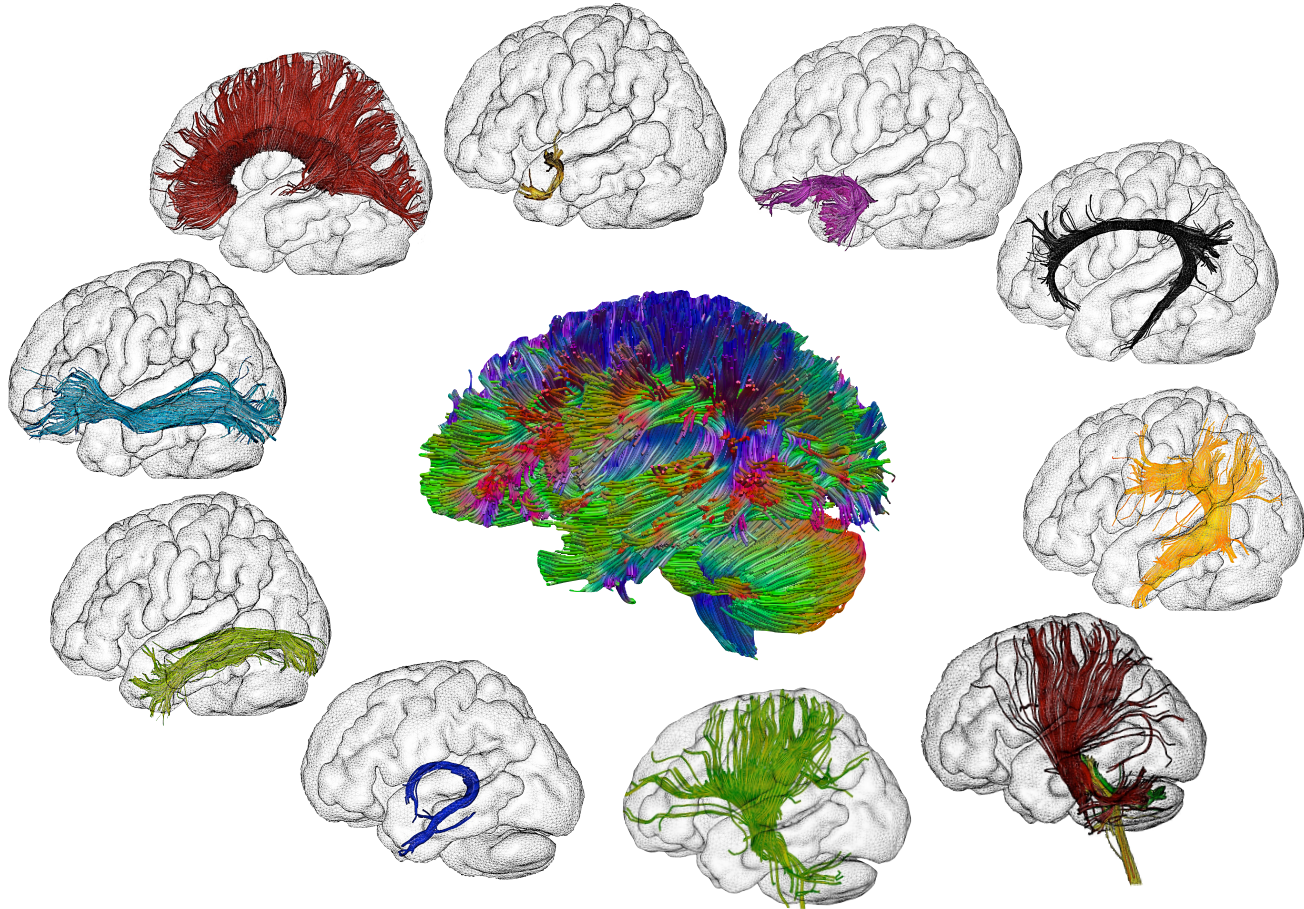


(1954)



NOT SHOWING INDIVIDUAL AXONS!

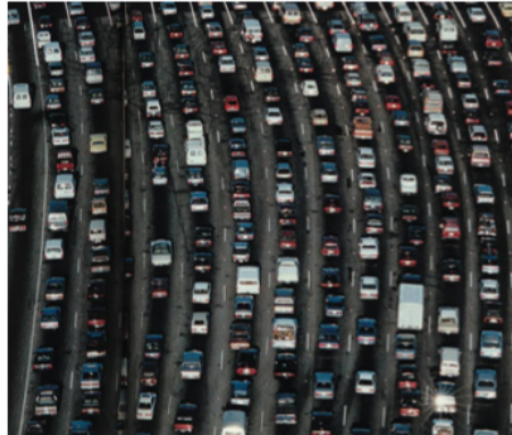
In vivo white matter dissections



courtesy Michel Thiebaut de Schotten

Tractography in a nutshell

“DTI”



“Crossing”



“Merging & Splitting”



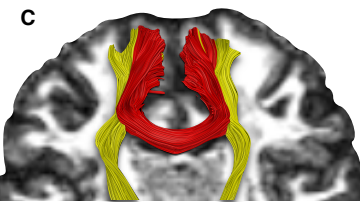
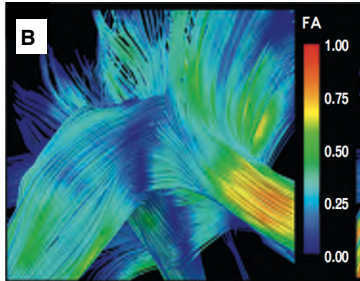
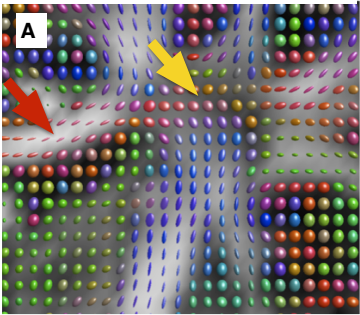
“...just a mess”



courtesy Flavio Dell'Acqua

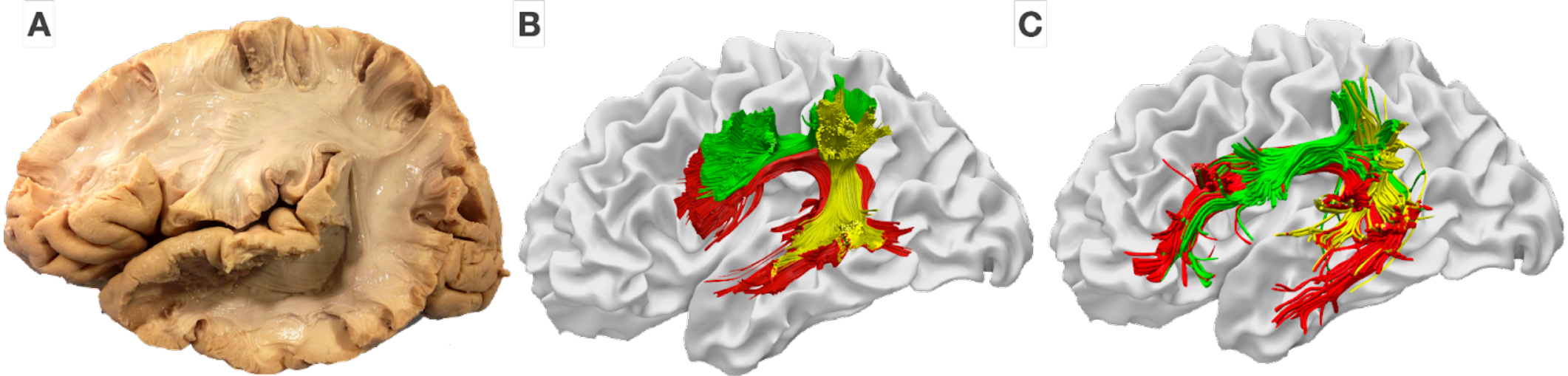
Advanced Tractography Models

Diffusion Tensor Imaging



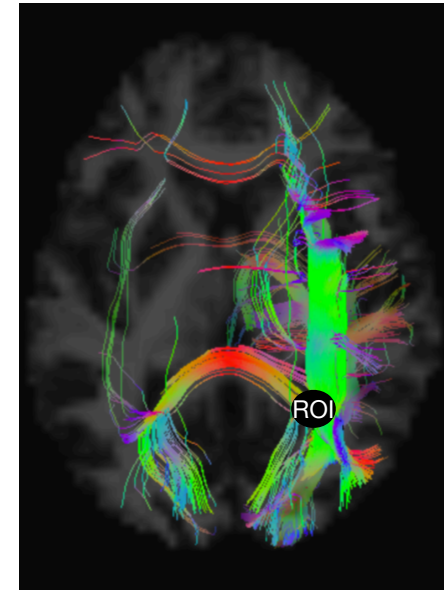
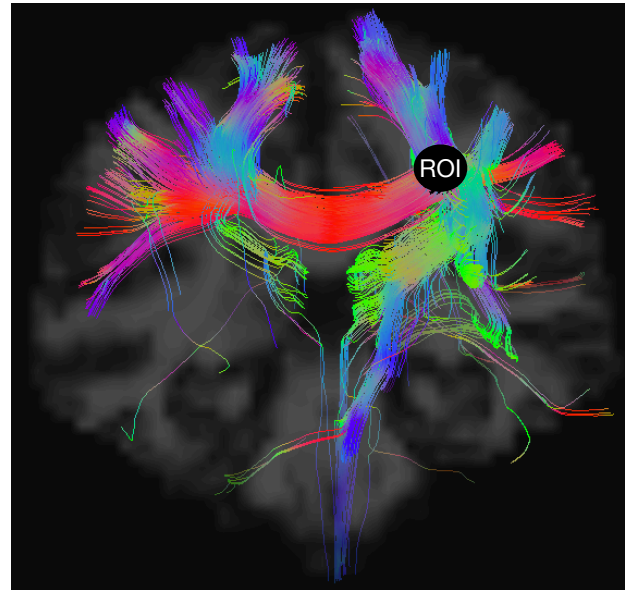
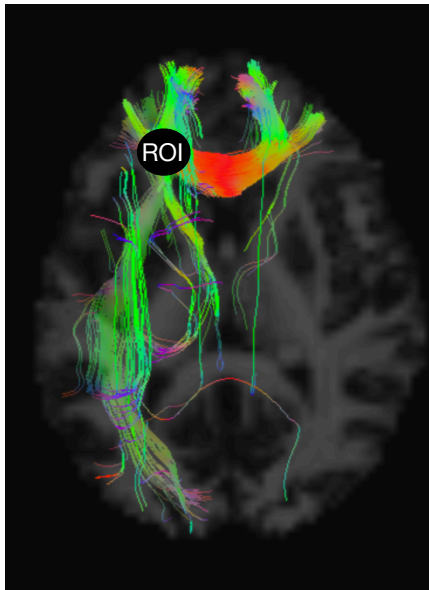
Forkel & Catani, OUP 2017

Advanced Tractography Models



Forkel et al, forthcoming

Advanced Tractography: the more the better?



**Advanced methods reconstruct
more fibre orientations**

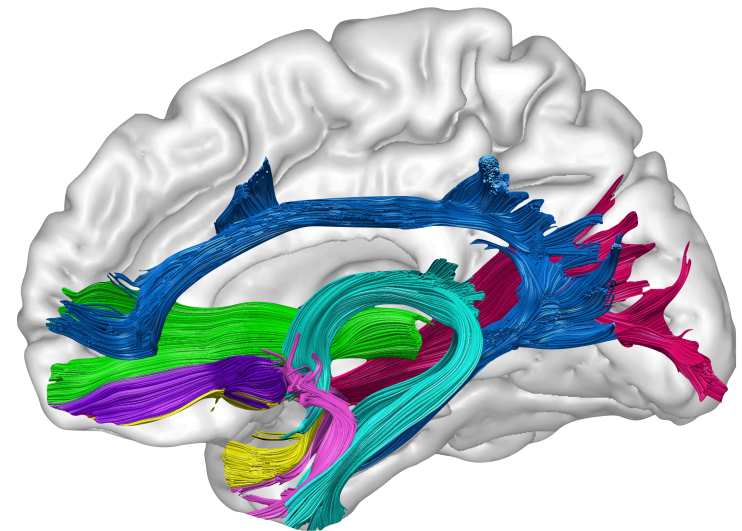


**More chances of getting it
wrong**

Diffusion-weighted Imaging tractography

- only method for **in vivo** white matter mapping
- time consuming procedure
- requires anatomical knowledge
- difficult to determine cortical terminations
- tracking algorithms might introduce artefacts

- excellent research tool for neuroanatomical studies
- understanding of the three-dimensional structure



Now it's your turn!



You will need the data and software:

- > download data
- > copy data on desktop
- > install Trackvis from this folder or
- > <http://trackvis.org/TrackVis.zip>
- > Send me your data :)