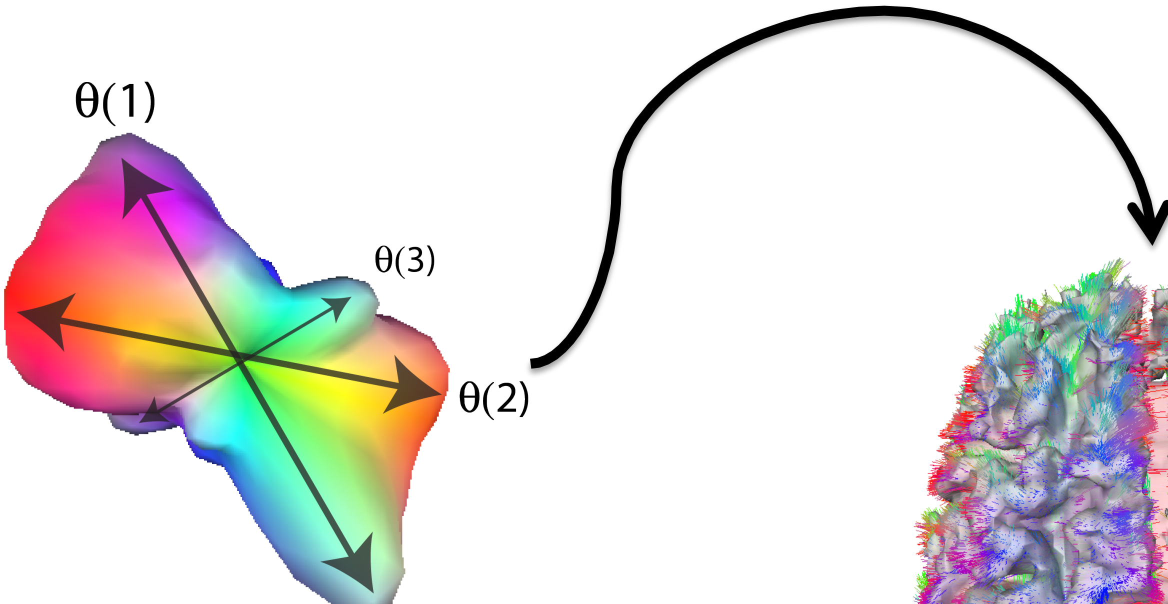
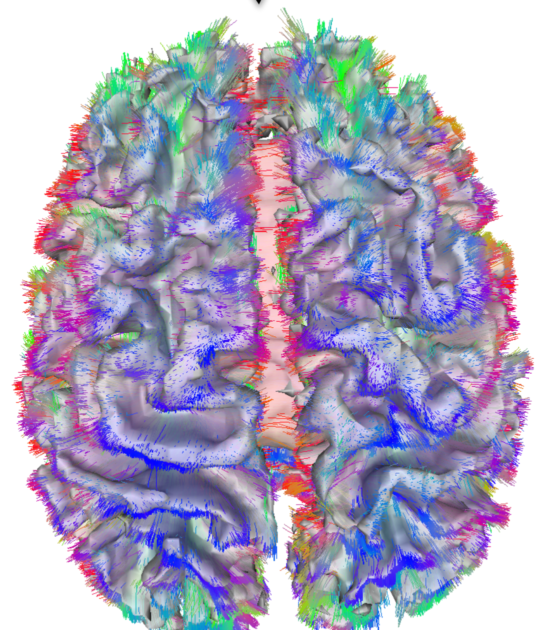
Basic Principles of Fiber Tractography:





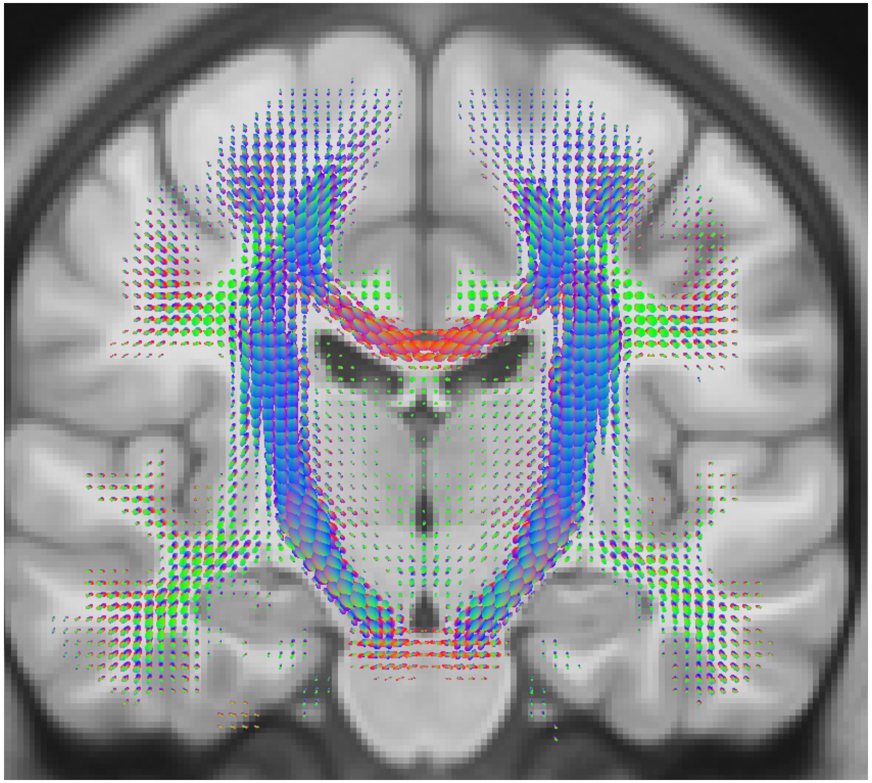
Virtual Neuroanatomy

Lecture Date: 09/04/2014

Learning Goals

- What are the two different classes of fiber tractography algorithms?
- What can you (or can't you) infer with tractography?

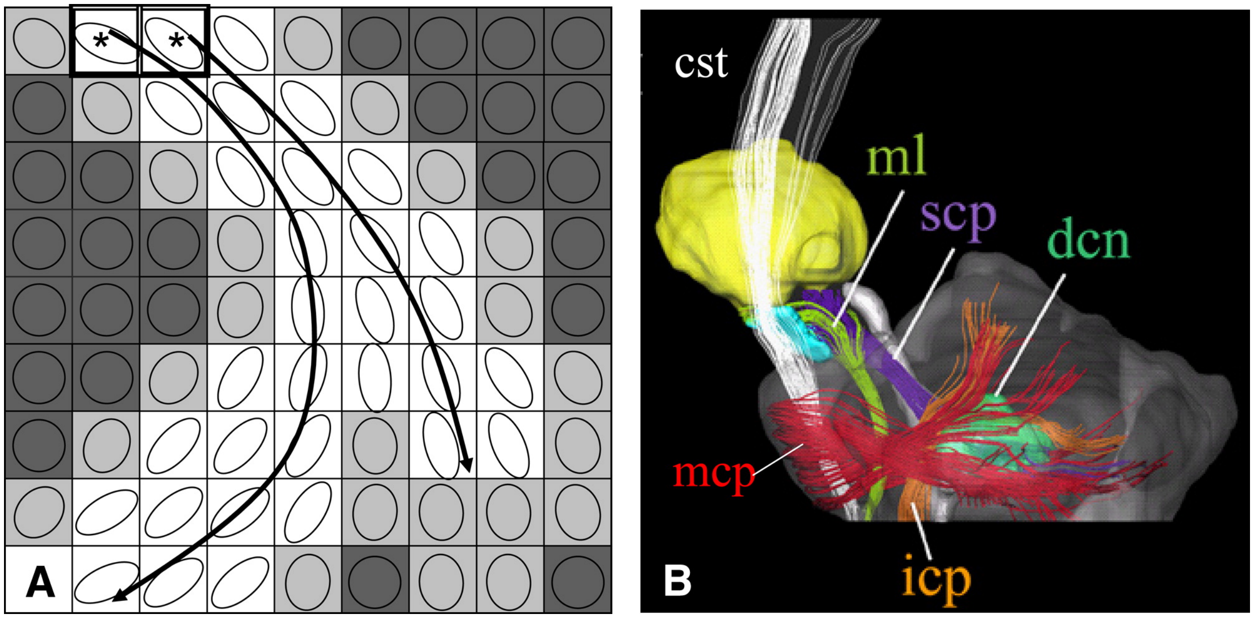
Remember voxelwise reconstruction



How do you get from this map of voxel models to visualizing structural connectivity?

Principles of fiber tractography

Basic idea of fiber tracking



Use the underlying directional diffusion information to map out connections between areas.

Mori & Zhang, Neuron 51: 527-539

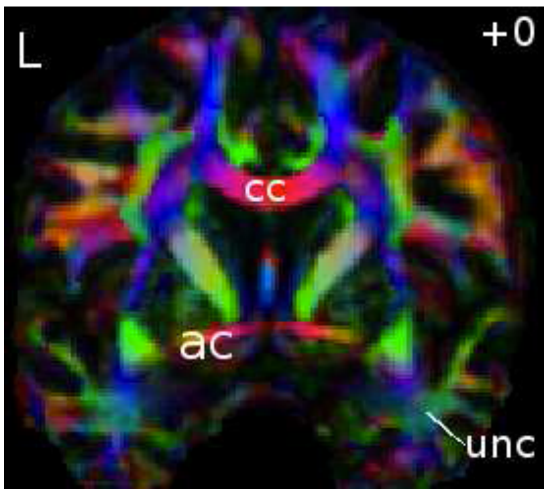
Two General Approaches to Tractography

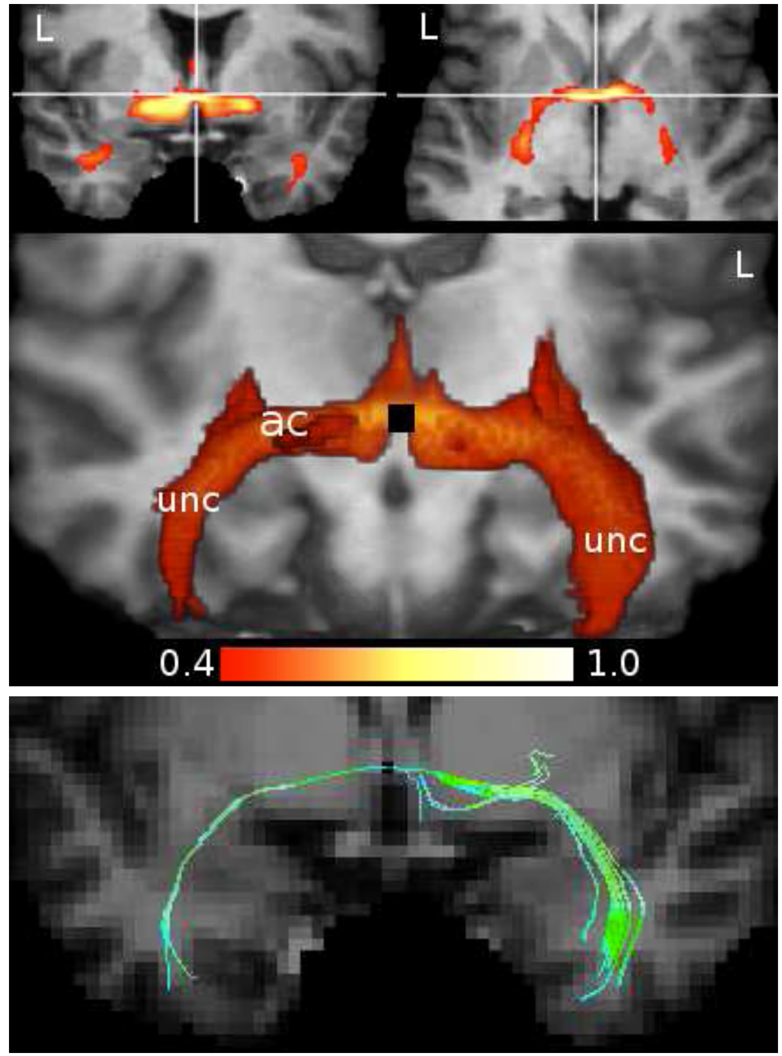
- **Deterministic**: Line reconstructed paths (e.g., *fiber streamlines*) between regions based on stochastic sampling methods.

- **Probabilistic**: Probabilistic estimate that any two voxels are connected based on the ODF/Tensor information of the adjoining voxels

Two General Approaches to Tractography

Tensor Image



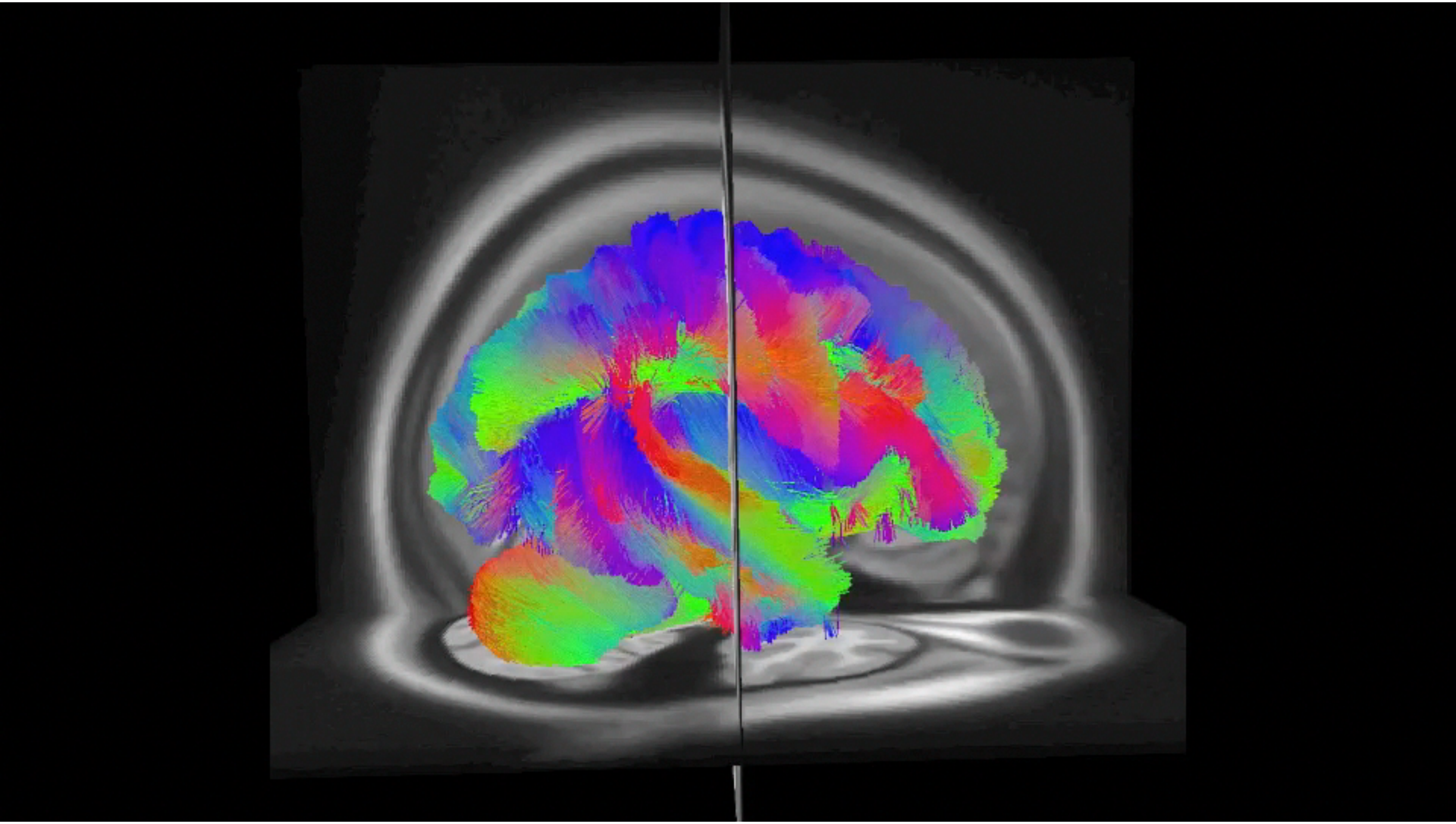


Probabilistic

Deterministic

Descoteau et al. 2007, IEEE: Med Imaging, 28: 269-286

Example of whole-brain deterministic tractography

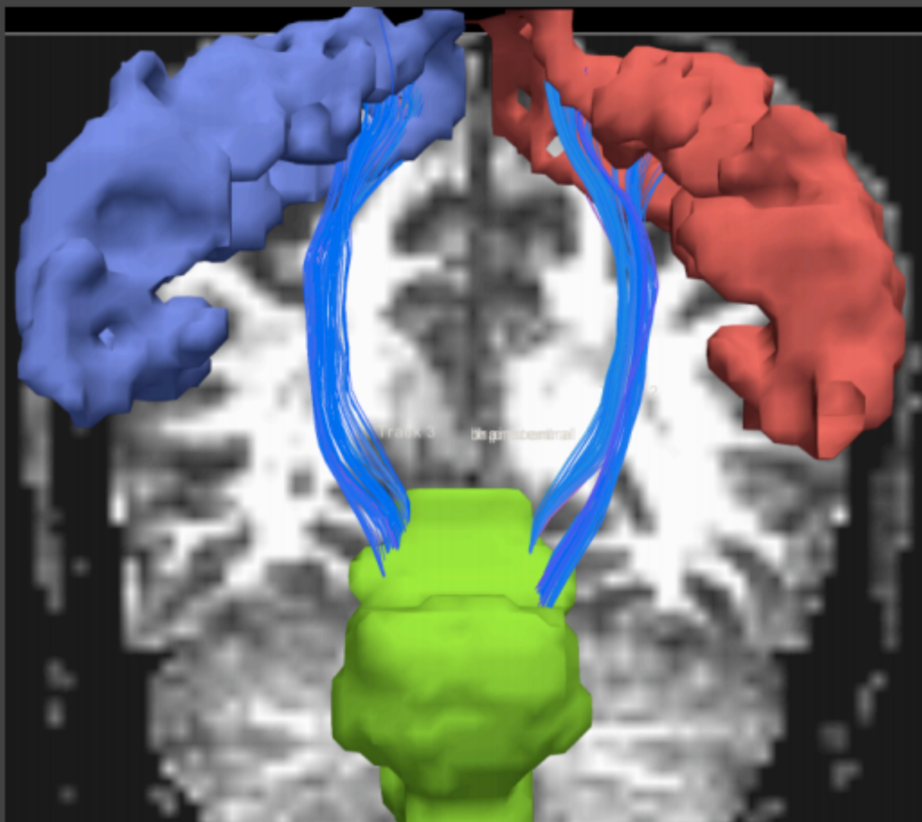


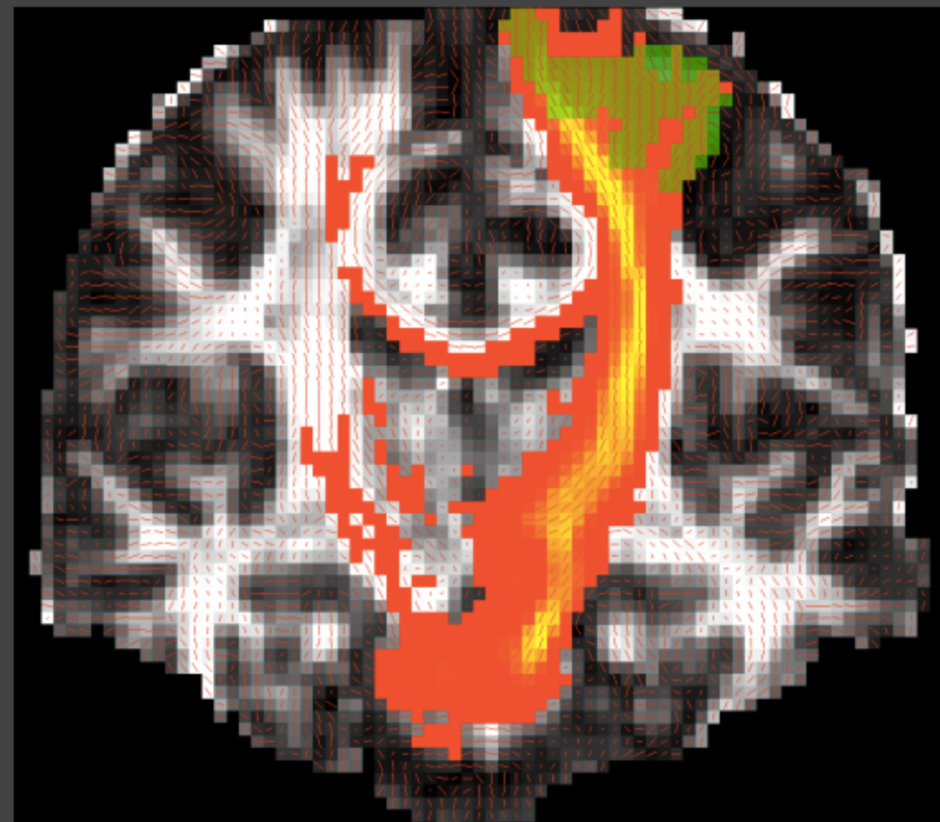
Deterministic:

One streamline per seed voxel

Probabilistic:

A probability distribution
(sum of all streamline samples from all seed voxels)





(courtesy of Anastasia Yendiki)

Pros & Cons

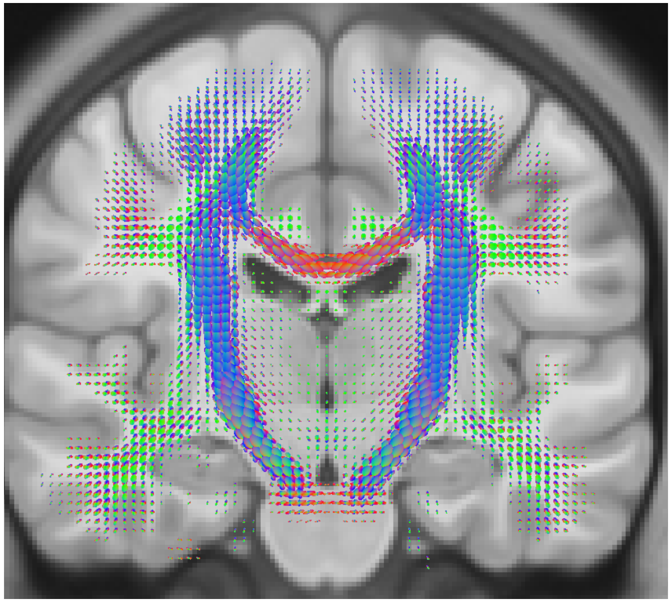
- **Deterministic**:
  - Pro: Visualize the streamline paths below the voxel resolution
  - Con: Cannot determine uncertainty of individual streamlines

- **Probabilistic**:
  - Pro: Easy interpretation of estimates of connectedness
  - Con: Resolution limited to voxel-level

Utility of structural connectivity

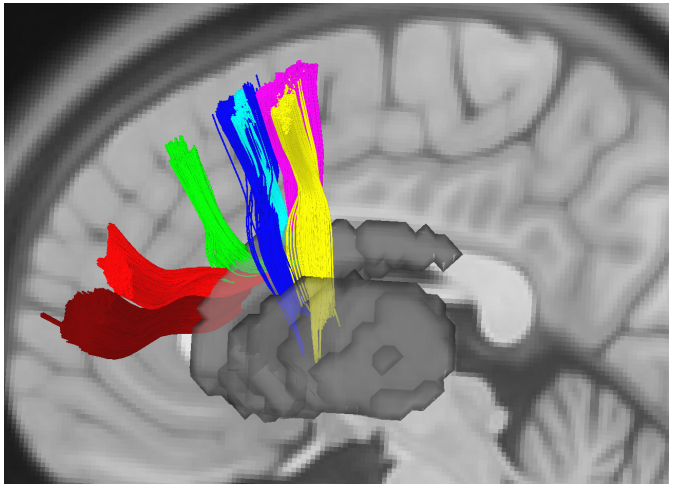
Pros:

- Measure of direct connections.
- Known signal source.



Cons:

- High Type-II Error.
- Spatial bias (long range).
- Gyral bias.
- Poor estimate of *degree* of connectivity.



Applications of tractography

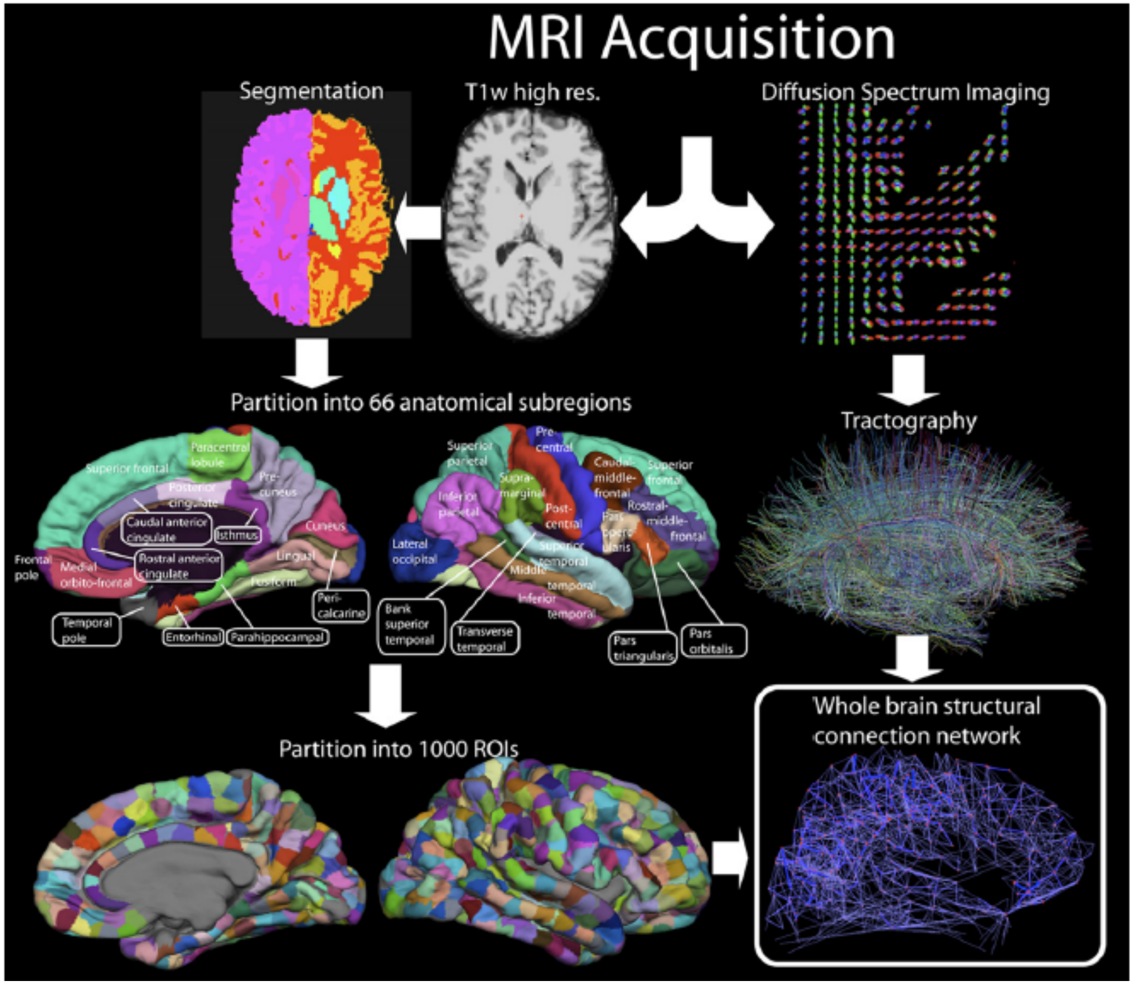
General Applications of Tractography

1. Network Mapping

2. Topography

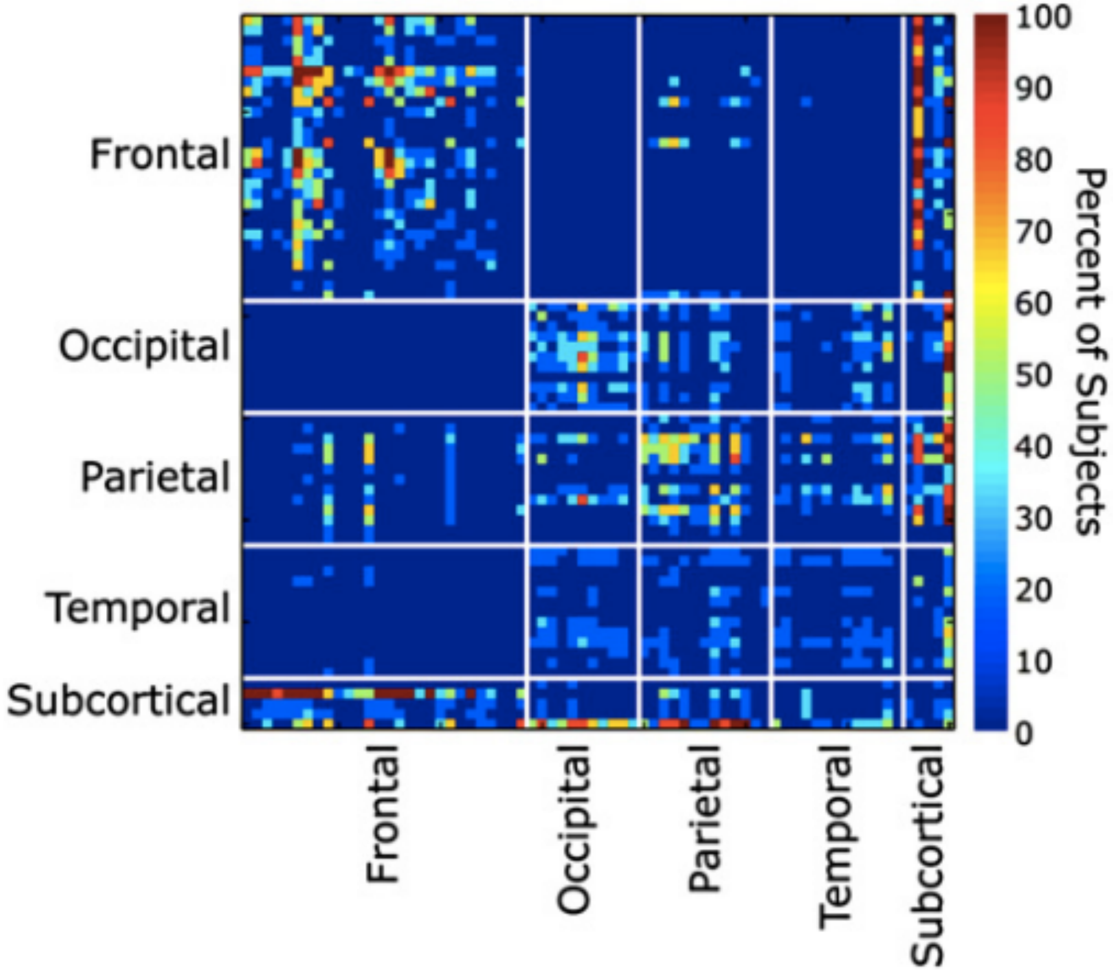
3. Integrity

Network Mapping



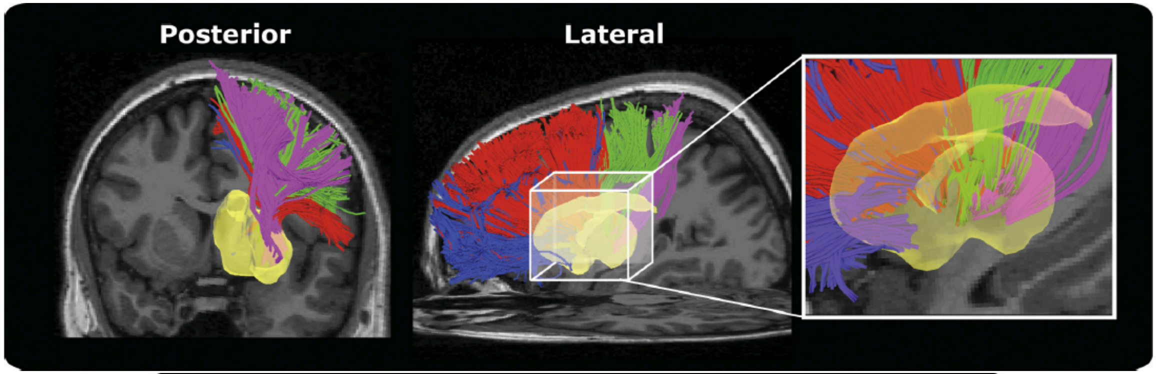
Typically gray matter areas are segmented and the physical connections between these segmented regions is measured.

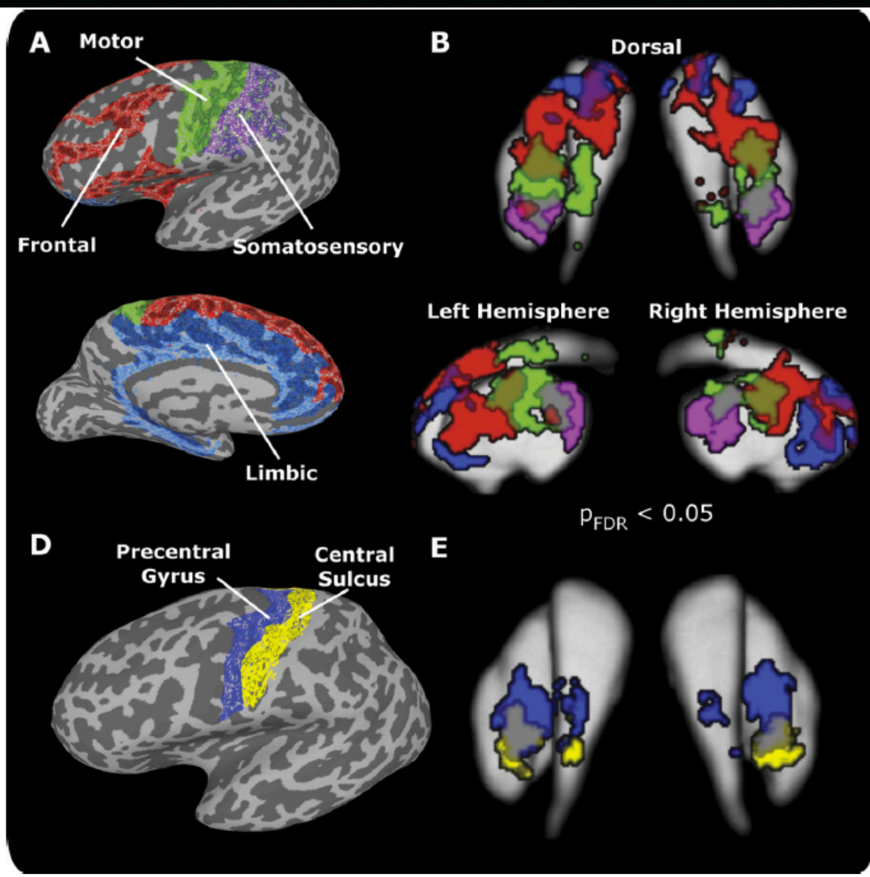
Network Mapping



Typically gray matter areas are segmented and the physical connections between these segmented regions is measured.

Topography

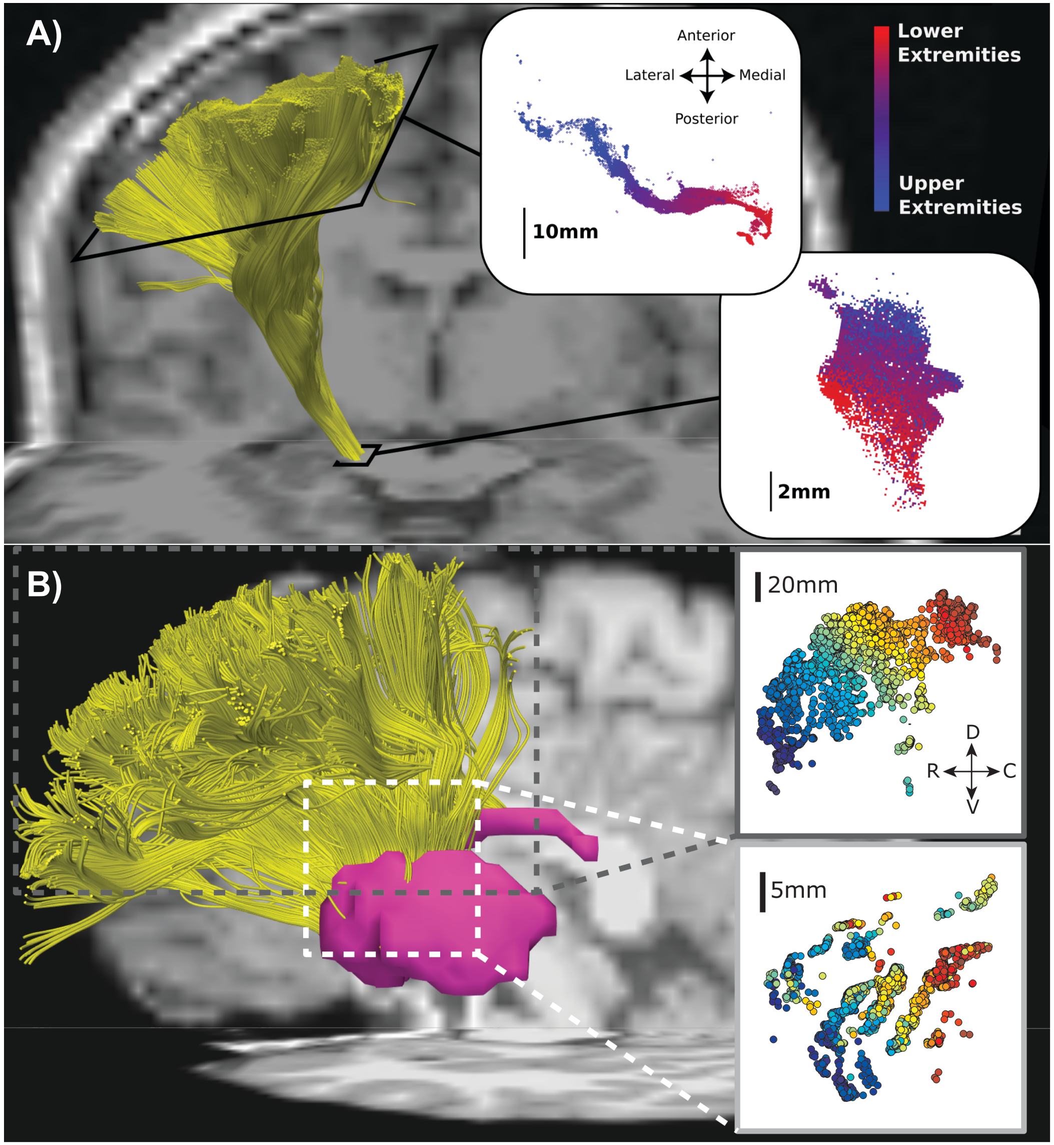




By mapping across individuals you can find areas that consistently connect to each other

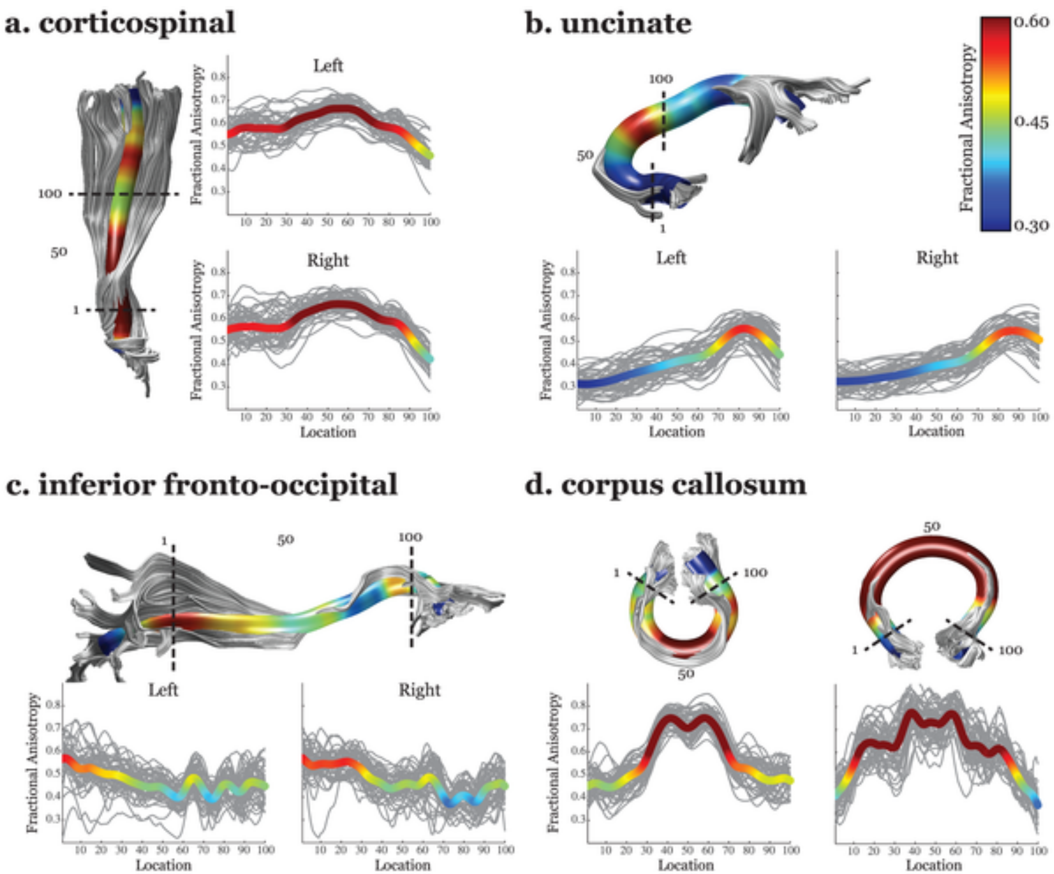
Verstynen et al. J. Neurophys 2012

Topography



Verstynen et al. J. Neurophys 2011; 2012

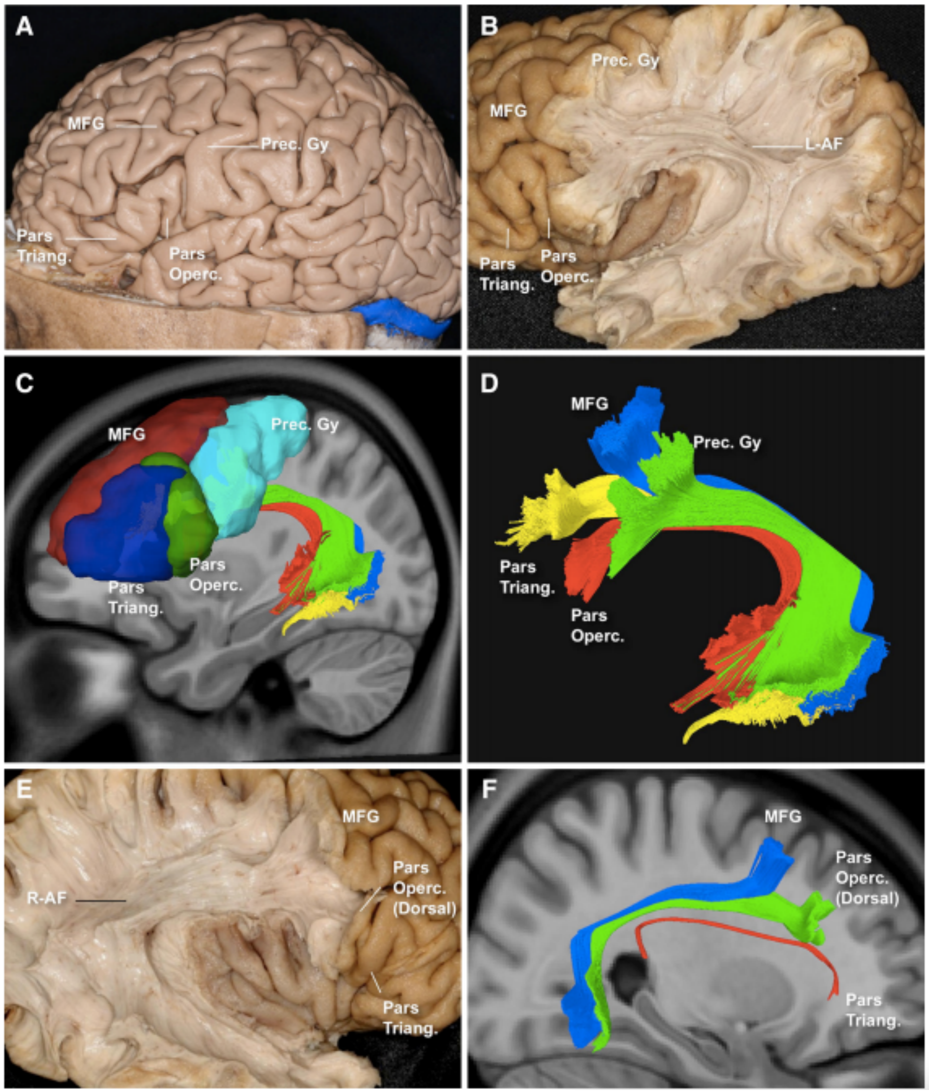
Integrity



Rather than measure FA at individual voxels, you can measure it along the entire tract.

Yeatman et al. PLoS One, 2012

"How do I know what I'm looking at is real?"



You <u>can't</u> using <u>only</u> DWI:

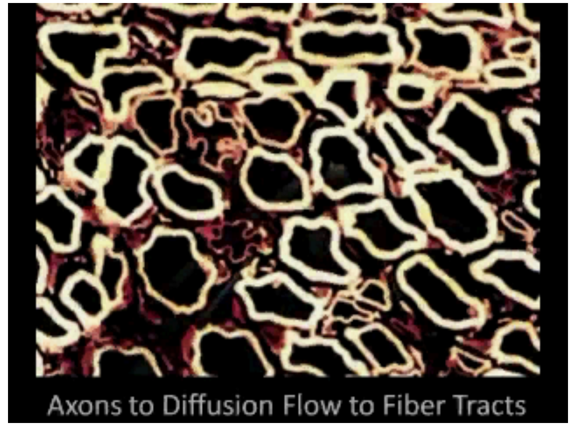
Confirmation of neuroanatomical patterns can only be validated against direct histological validation.

<u>**However**</u>: It doesn't mean we can't indirectly infer patterns (e.g., same problem with fMRI and neural activity)

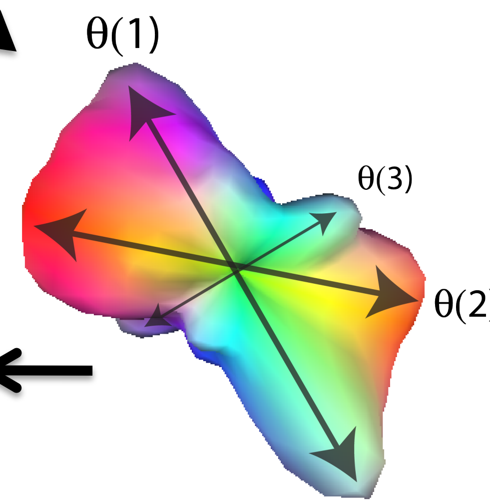
Summary

Water Diffusion

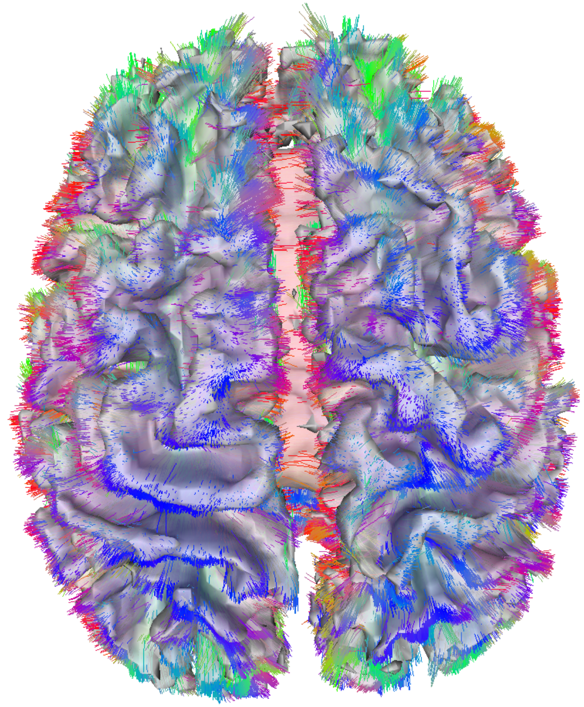
Microtubules



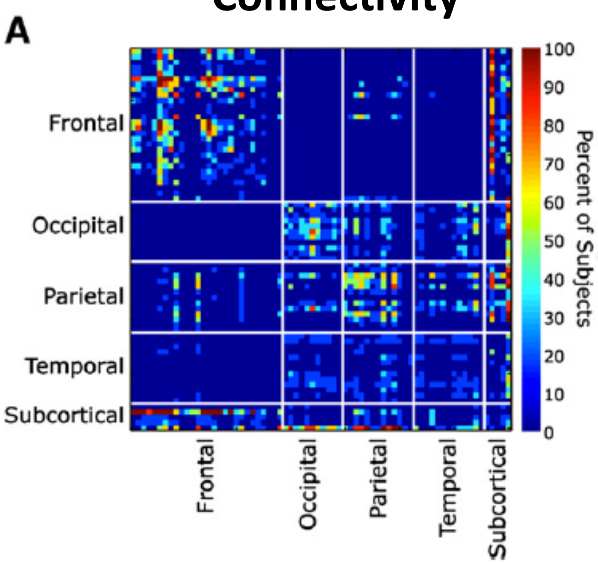
3D Diffusion Models



Tractography



Connectivity



Learning Goals

- What are the two different classes of fiber tractography algorithms?
- What can you (or can't you) infer with tractography?

Putting it all together

1. Reconstruct single subject data
2. Compare three reconstruction approaches:
   a. Diffusion Tensor Imaging
   b. QBI
   c. GQI
3. Visualize a complex fiber pathway.

Homework

Take a snapshot of the left centrum semiovale and highlight differences between the three methods you reconstructed today.