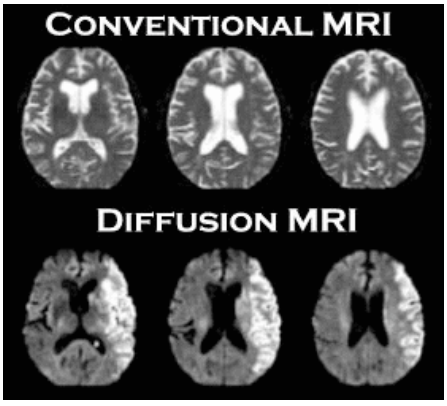
Bioengineering 278
Magnetic Resonance Imaging

Winter 2009
Lecture 9

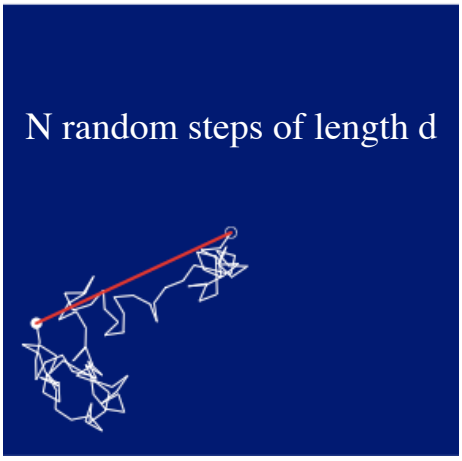
- Diffusion Imaging
  - Diffusion Basics
  - Diffusion in a Gradient Field
  - Anisotropic Diffusion
  - Fiber Tract Mapping

Diffusion Imaging

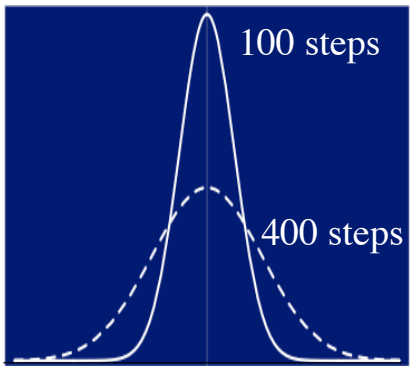
- Quantitative measure of local self diffusion coefficient
- Measurement in multiple directions gives information on diffusion anisotropy and fiber orientation
- Uses:
  - Clinical applications in stroke and white matter disease
  - White matter fiber tract mapping (anatomical connectivity)



Diffusion



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



In brain:
$D \cong 0.001\ mm^2/s$
For T=100 msec,
$\Delta x \cong 15\ \mu$

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Signal Attenuation by Diffusion

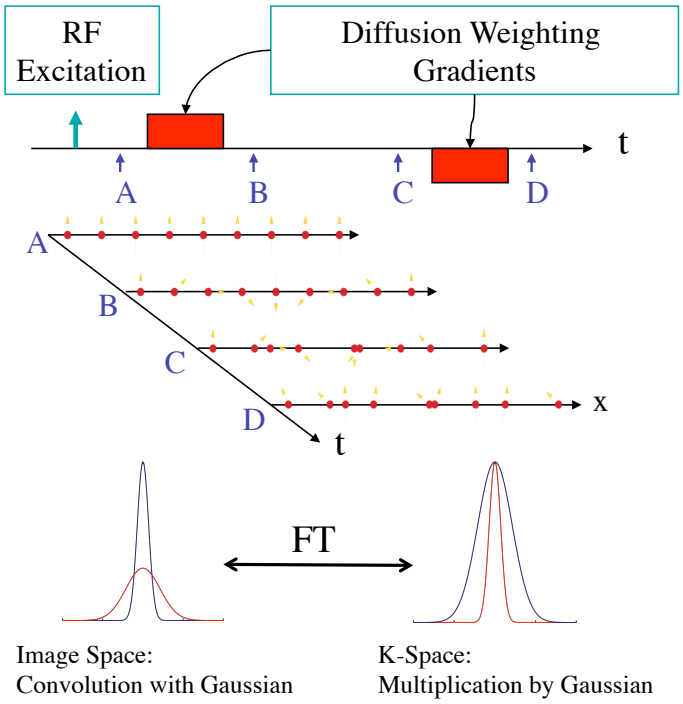
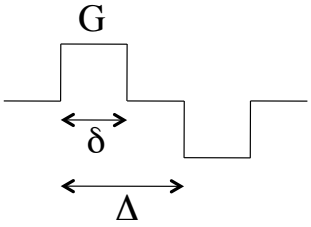


Image Space:
Convolution with Gaussian

K-Space:
Multiplication by Gaussian

<u>Bipolar Gradient:</u>



$$S = S_0 e^{-bD}$$

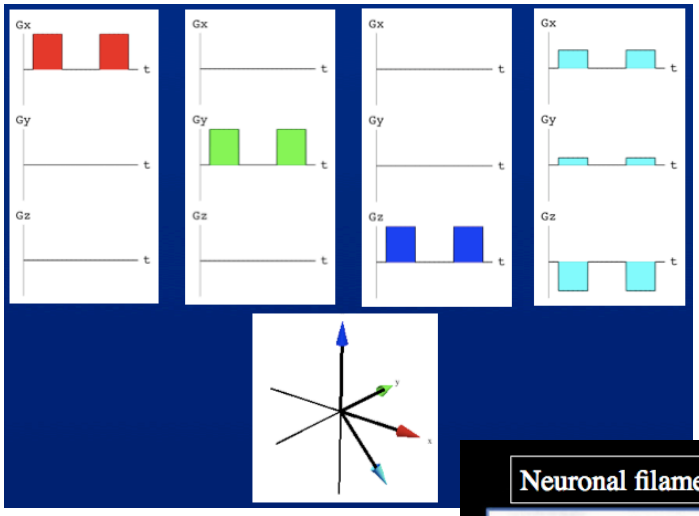
$$b = \gamma^2 G^2 \delta^2 (\Delta - \delta/3)$$

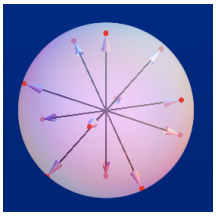
<u>In General:</u>

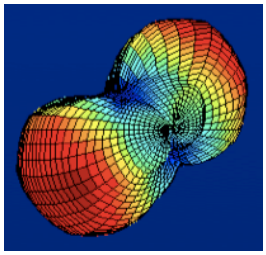
$$S(t) = S_0 e^{-\int_0^t k(t')\cdot D\cdot k(t')dt'}$$

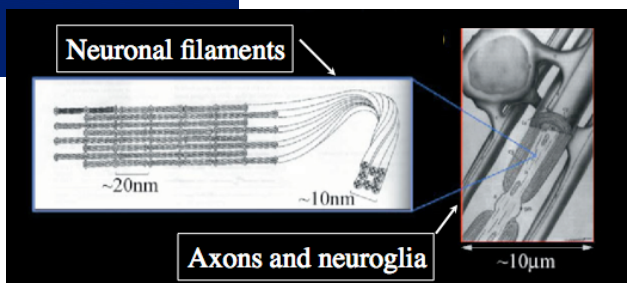
$$k(t) = \gamma \int_0^t G(t')dt'$$

Anisotropic Diffusion









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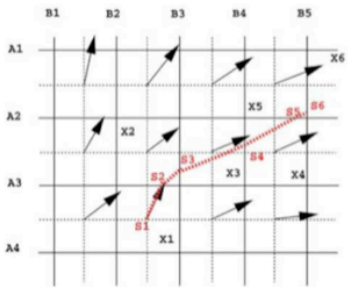
Anisotropic Diffusion



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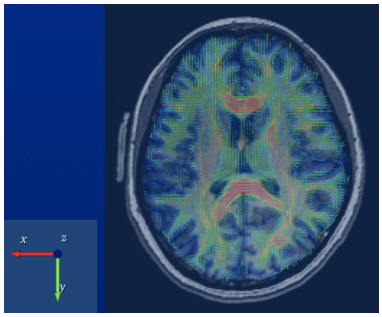
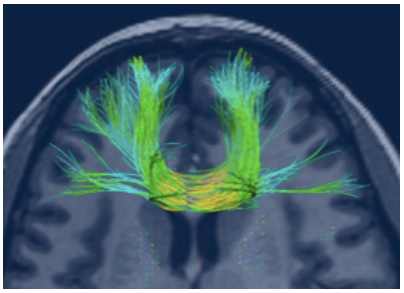
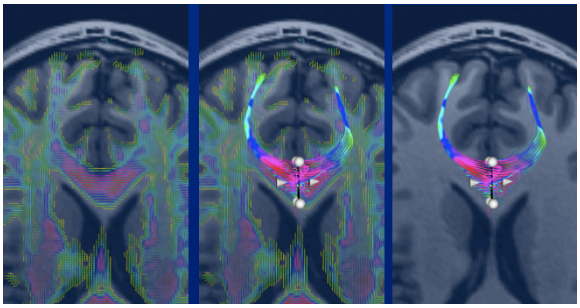
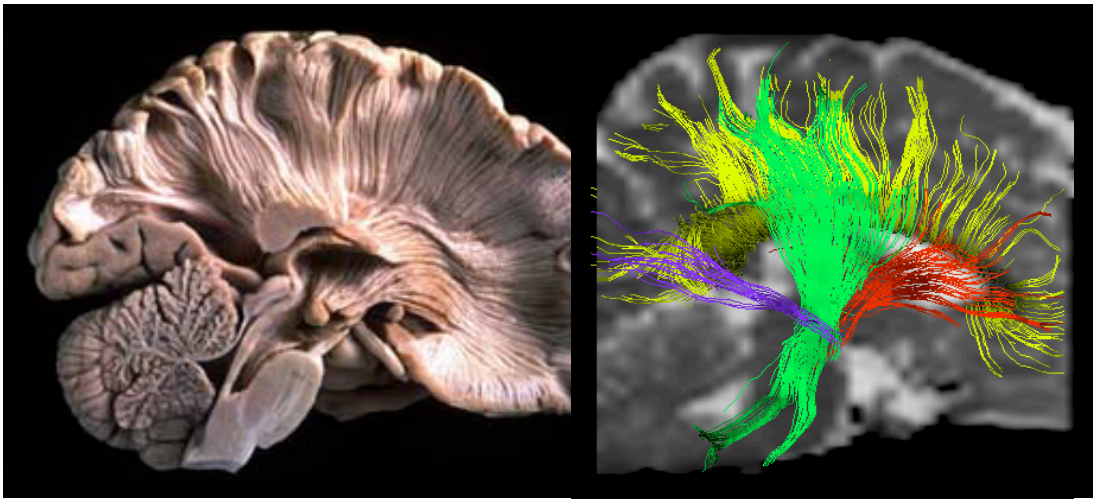
- Reconstruct a 3D trajectory by starting from a seed point and always proceeding in the direction of the principal eigenvector, which corresponds to the largest eigenvalue.
- Black arrows: principal eigenvector field.
- Red dashed route: generated fiber track.







Comparison with anatomical preparation



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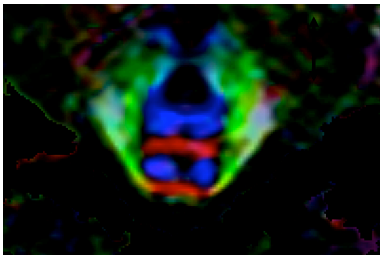
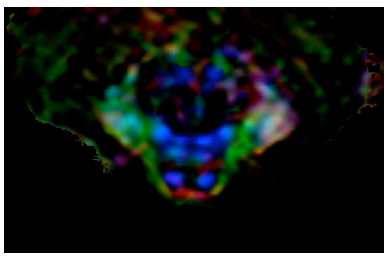
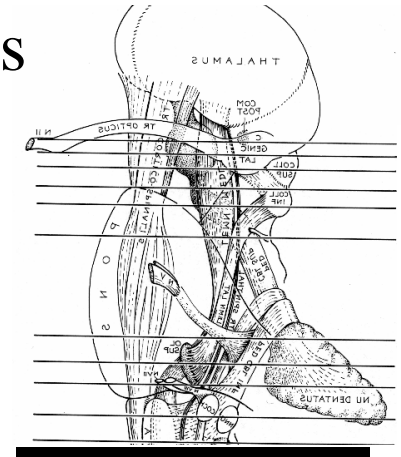
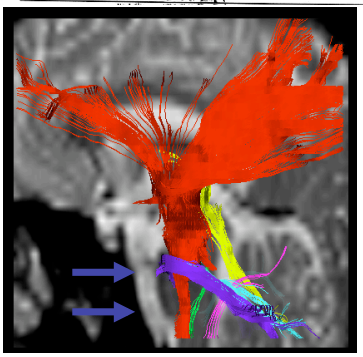
Detail fiber structures









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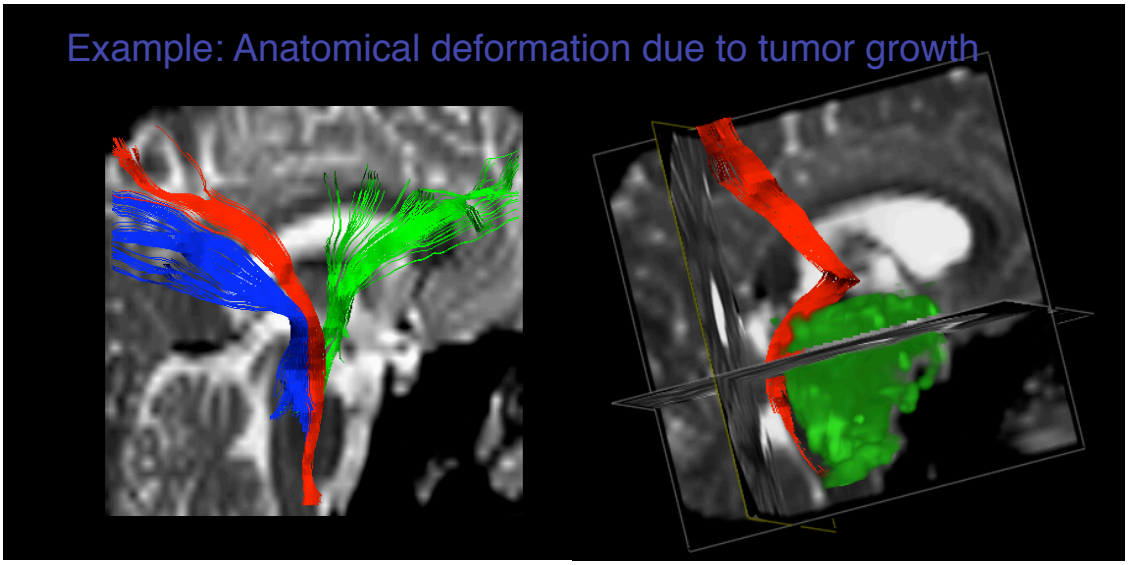
Anatomical guidance:



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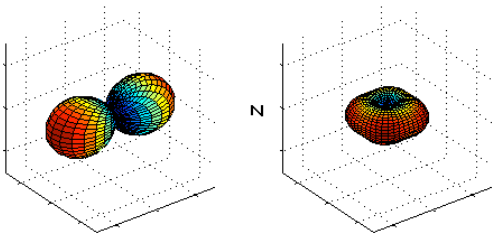
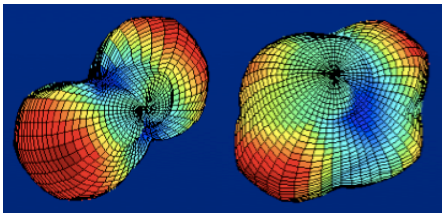
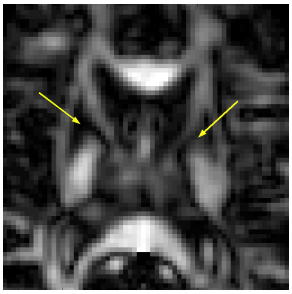
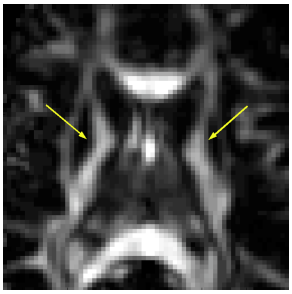
Diffusion - Fiber Crossings





Corpus Callosum Corona Radiata





Relative Anisotropy Directional Variance

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