

# Bioengineering 208 Magnetic Resonance Imaging

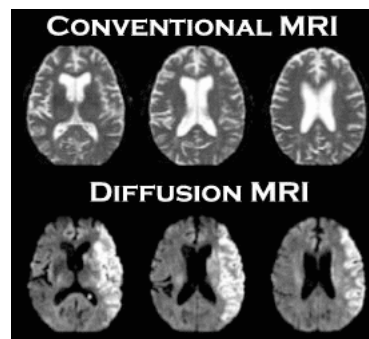
Winter 2008  
Lecture 10

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

E. Wong, BE208, UCSD Winter 2008

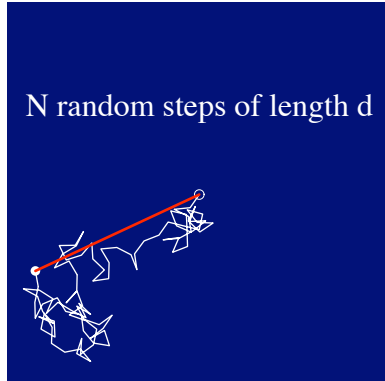
## Diffusion Imaging

- 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)

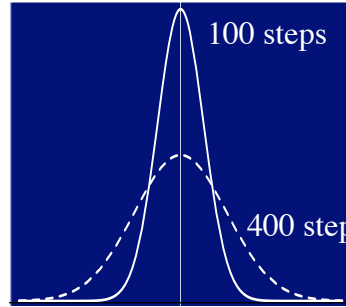


E. Wong, BE208, UCSD Winter 2008

# Diffusion



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

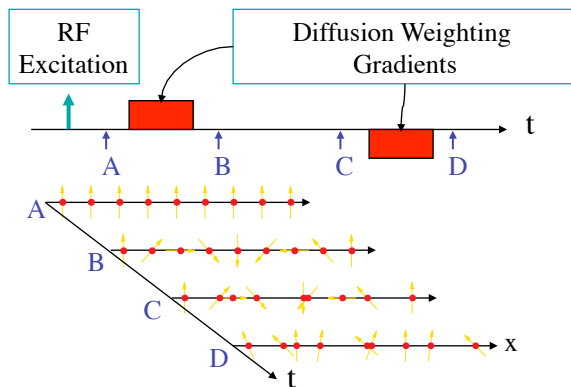


In brain:  
 $D \approx 0.001 \text{ mm}^2/\text{s}$   
 For  $T=100 \text{ msec}$ ,  
 $\Delta x \approx 15 \mu$

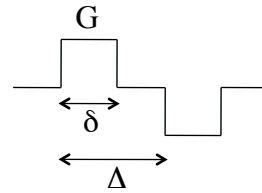
Slide credit: L. Frank

E. Wong, BE208, UCSD Winter 2008

# Signal Attenuation by Diffusion



## Bipolar Gradient:



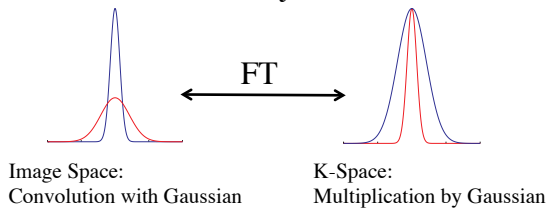
$$S = S_0 e^{-bD}$$

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

## In General:

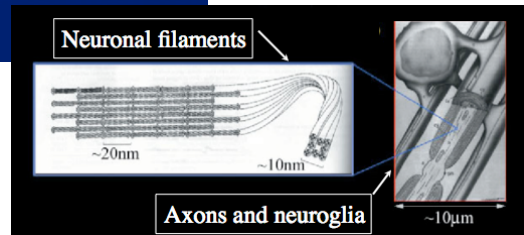
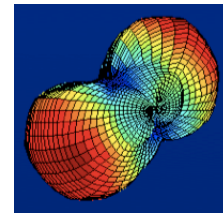
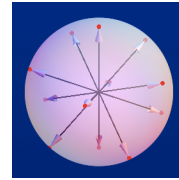
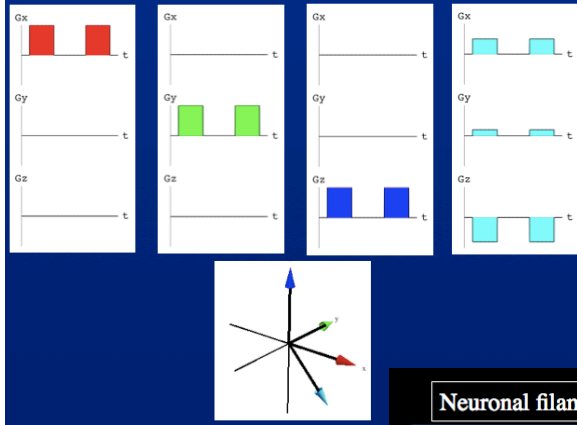
$$S(t) = S_0 e^{-\int_0^t k(t') \cdot D \cdot k(t') dt'}$$

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



E. Wong, BE208, UCSD Winter 2008

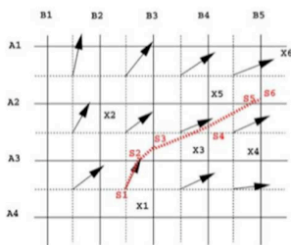
# Anisotropic Diffusion



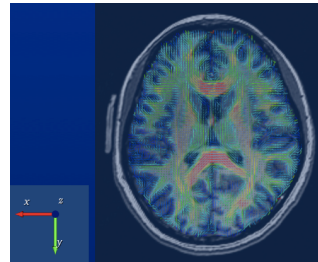
Slide credit: L. Frank

E. Wong, BE208, UCSD Winter 2008

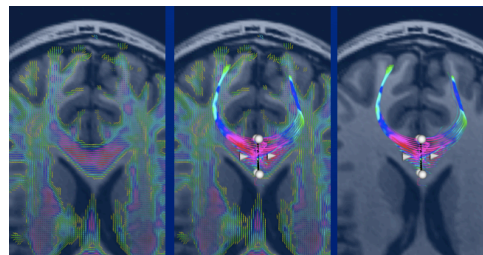
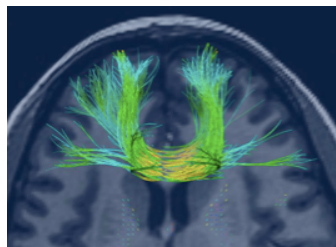
# Anisotropic Diffusion



- 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.

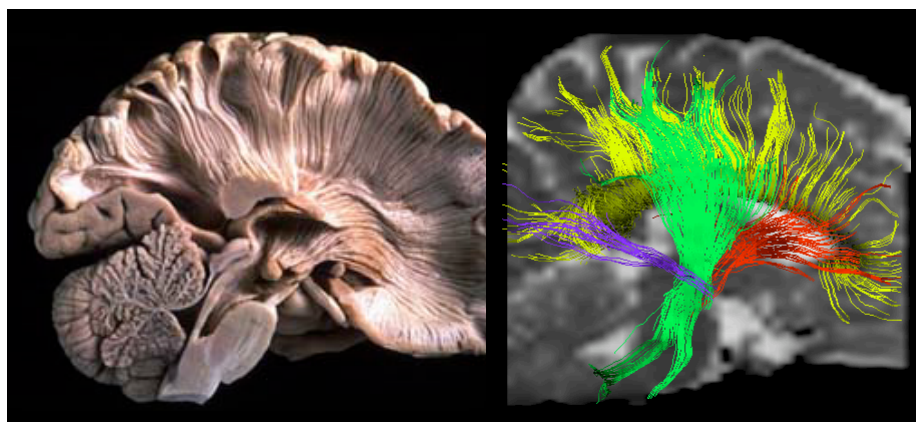


Slide credit: L. Frank



E. Wong, BE208, UCSD Winter 2008

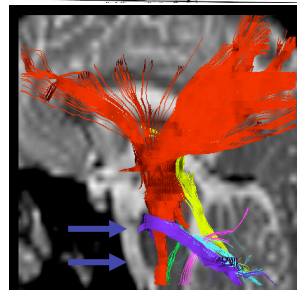
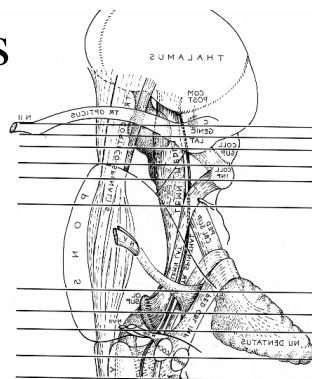
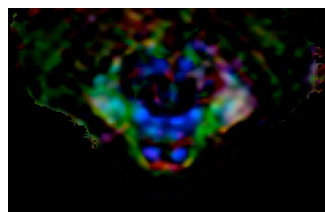
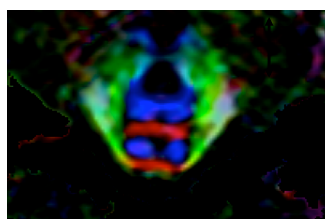
## Comparison with anatomical preparation



S. Mori - JHU

E. Wong, BE208, UCSD Winter 2008

## Detail fiber structures

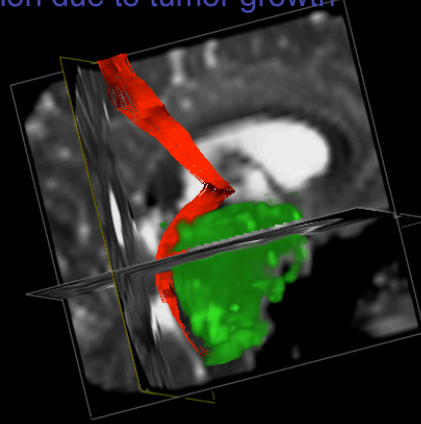
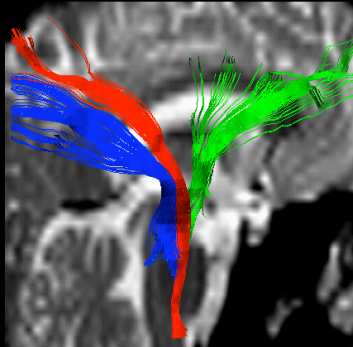


S. Mori - JHU

E. Wong, BE208, UCSD Winter 2008

# Anatomical guidance:

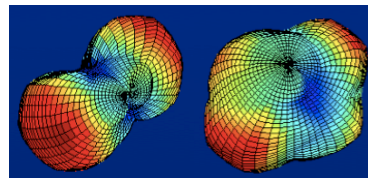
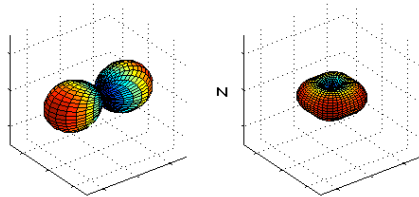
Example: Anatomical deformation due to tumor growth



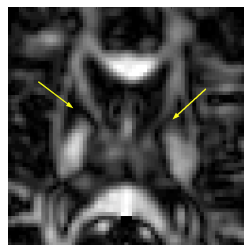
S. Mori - JHU

E. Wong, BE208, UCSD Winter 2008

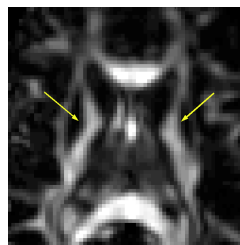
## Diffusion - Fiber Crossings



Corpus Callosum Corona Radiata



Relative Anisotropy



Directional Variance

E. Wong, BE208, UCSD Winter 2008

Slide credit: L. Frank