




Biological DIFFUSION

MP/NTP 651
Fall 2020



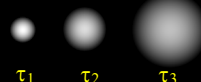


1

Diffusion


- Random 'Walk' of Water Molecules

$$\overline{\Delta x^2} = 2nD\tau$$

$$D = \frac{\overline{\Delta x^2}}{2n\tau}$$

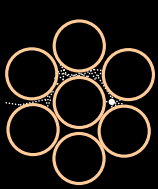
[mm²/s]



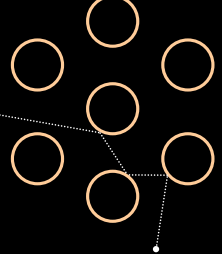
2

Diffusion probes tissue microstructure


ADC = Apparent Diffusion Coefficient





More barriers
ADC low



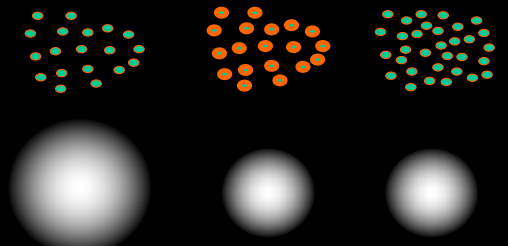

Fewer barriers
ADC high



3

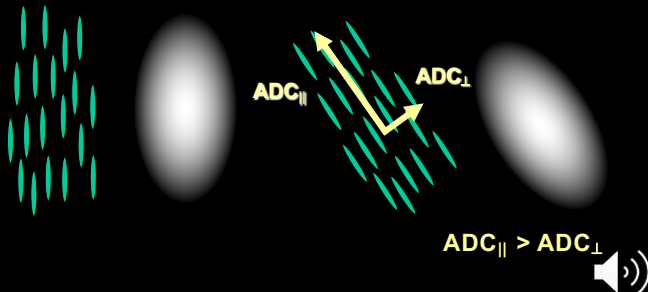
Diffusion Probes Microstructure - e.g. Density of Membranes

4

Anisotropic Diffusion

- E.g. Fibrous tissues (white matter, muscle)
- Diffusion has angular dependence



5



Factors that influence diffusion of water in CNS



- Temperature
- Cellular membranes and cytoskeleton
- Cellularity
- Myelin
- Water Content (hydration, edema, inflammation)
- Fibrous tissue (WM – anisotropic)
- Perfusion (pseudo-diffusion, IVIM)



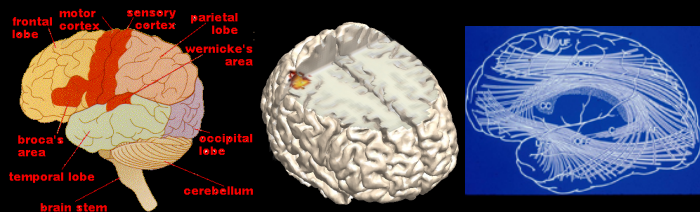
6



Functional Brain Tissues



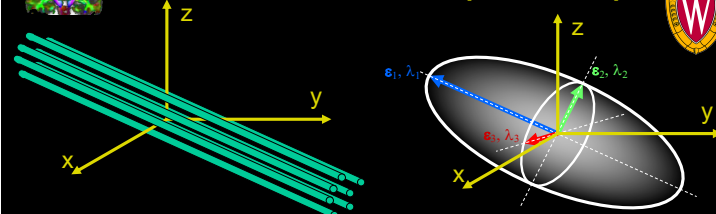
- Gray Matter – “Processing Centers”
- White Matter – “Interconnections”



7



Diffusion Probability Density





Multivariate Normal

$$p(x | x_0, \tau) = \frac{1}{\sqrt{(4\pi\tau)^3 |\underline{D}|}} \exp \left(-\frac{(x - x_0)^T \underline{D}^{-1} (x - x_0)}{4\tau} \right)$$

- Ellipsoid
- iso-probability of diffusion distribution



8


JOURNAL OF MAGNETIC RESONANCE, Series B 103, 247-254 (1994)

Estimation of the Effective Self-Diffusion Tensor from the NMR Spin Echo



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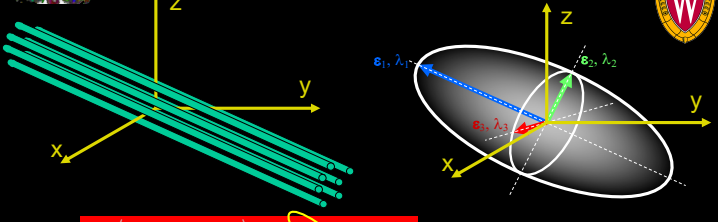
DT-MRI Alexander



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The Diffusion Tensor




$$D = \begin{pmatrix} D_{xx} & D_{xy} & D_{xz} \\ D_{yx} & D_{yy} & D_{yz} \\ D_{zx} & D_{zy} & D_{zz} \end{pmatrix} = E^T \begin{pmatrix} \lambda_1 & 0 & 0 \\ 0 & \lambda_2 & 0 \\ 0 & 0 & \lambda_3 \end{pmatrix} E$$



Diffusion Tensor Eigenvalues Matrix of 3 eigenvectors

$D_{ii} > 0$
 $D_{ij} = D_{ji}$

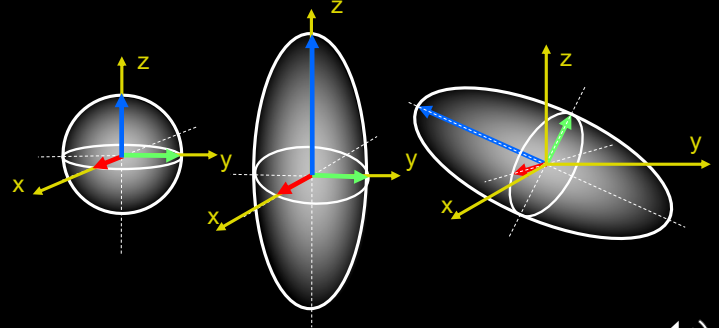
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10

Diffusion Displacement Densities



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