
Corso di laurea in Fisica

A.A. 2017-2018

# Diagnostica per Immagini

# Imaging di Diffusione - DTI

# Diffusion

- The migration of water in extracellular tissue space can be visualized…
- In the presence of a gradient field the diffusion can be expressed as

$$\frac{\partial \mathbf{M}}{\partial t} = D\nabla^2\mathbf{M}$$

where D is the diffusion coefficient

# Diffusion

Re-writing the Bloch equations to include diffusion terms…

$$\frac{\partial M_x}{\partial t} = \frac{-M_x}{T_2} + \gamma \mathbf{Gr} M_y + D\nabla^2 M_x$$

$$\frac{\partial M_y}{\partial t} = \frac{-M_y}{T_2} + \gamma \mathbf{Gr} M_x + D\nabla^2 M_y$$

$$\frac{\partial M_{xy}}{\partial t} = \frac{-M_{xy}}{T_2} + i\gamma \mathbf{Gr} M_{xy} + D\nabla^2 M_{xy}$$

# Diffusion

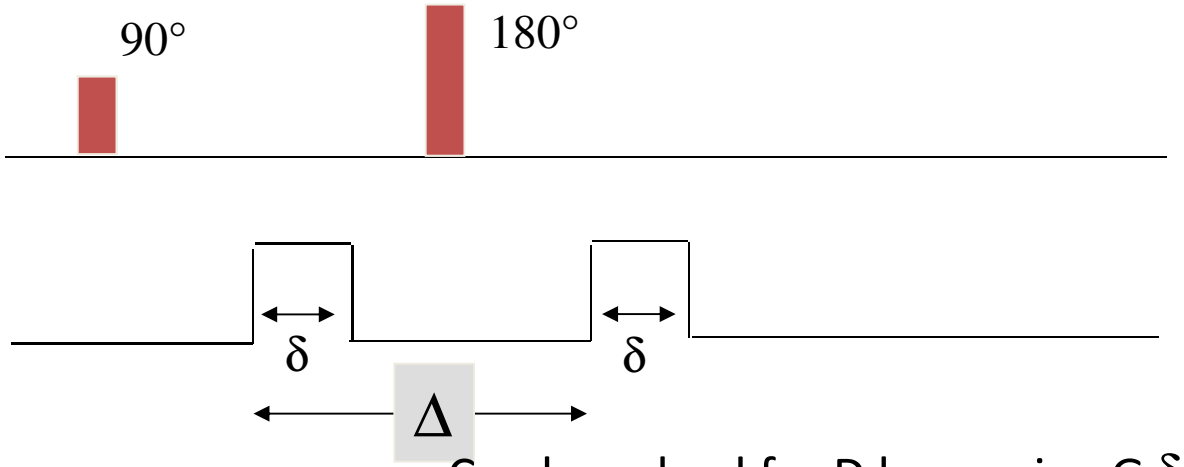
Solving for the transverse magnetization, with integrals of the gradient over time

$$M_{xy} = M_{xy}(0)e^{\left(-t/T_2 + i\gamma G_z zt - D\gamma^2 G_z{}^2 t^3/3\right)}$$

# Diffusion

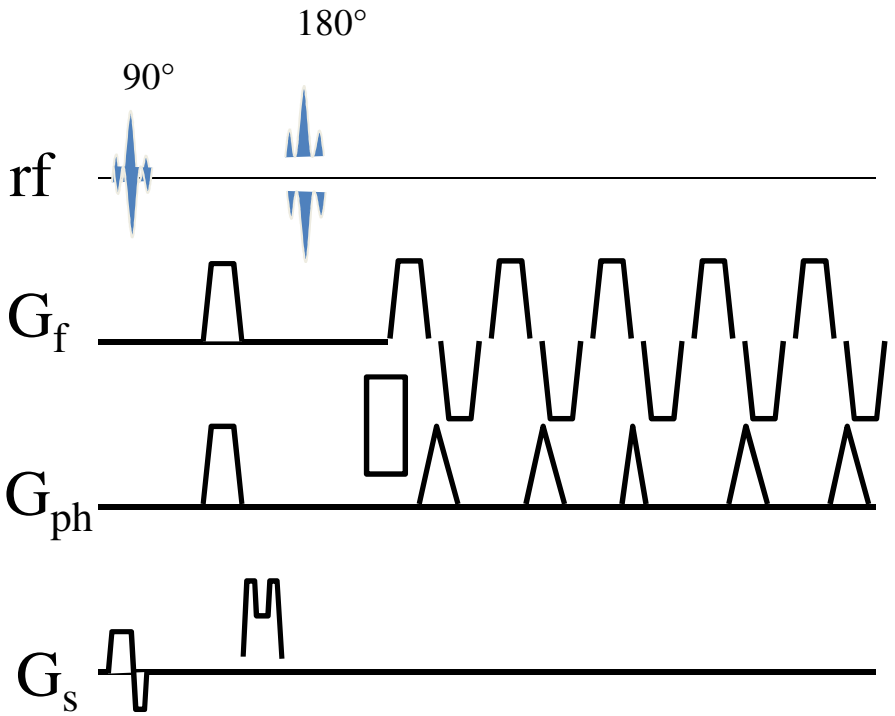
Stejskal-Tanner sequence

$$S(TE) = S(0)e^{\left(-TE/T_2 - D\gamma^2 G^2 \delta^2 (\Delta - \delta/3)\right)}$$



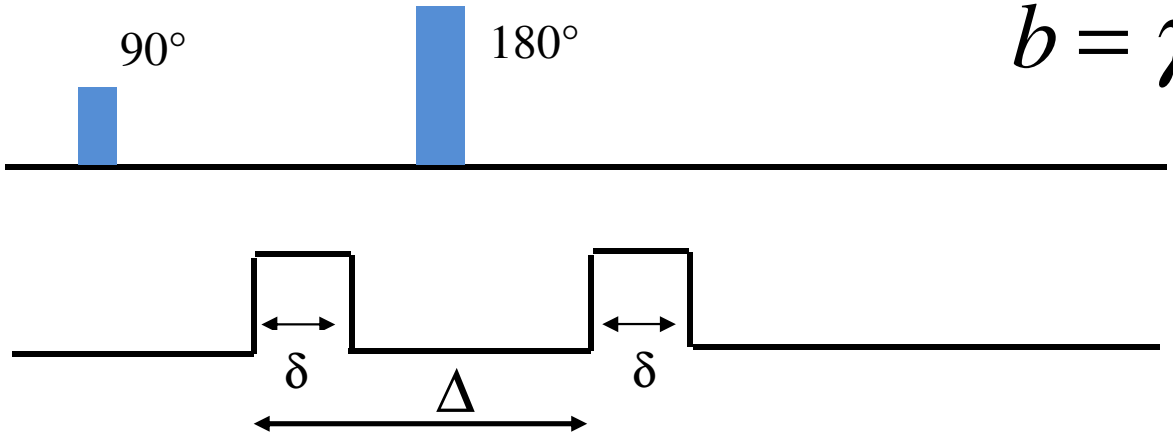

Can be solved for D by varying G δ or Δ

# DWI-EPI Sequence



# What do diffusion images mean?

- Diffusion represents small translational motion (i.e. across a cell membrane)
- In MRI, diffusion is complicated by the perfusion of blood through microscopic blood vessels, therefore, the measurement of diffusion in MRI is known as the *apparent diffusion coefficient* (ADC)

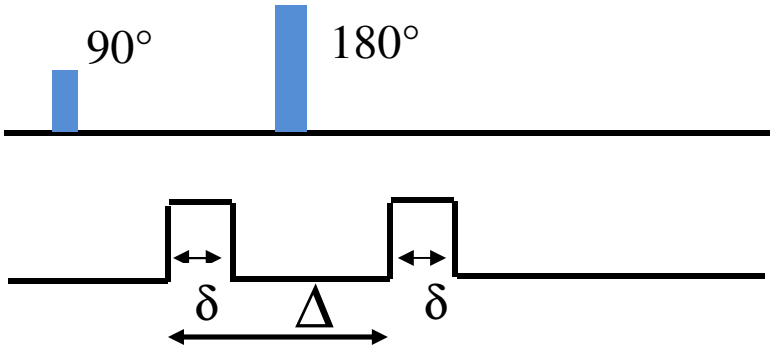



$$b = \gamma^2 G^2 t^2 \left(\Delta - \delta/3\right)$$

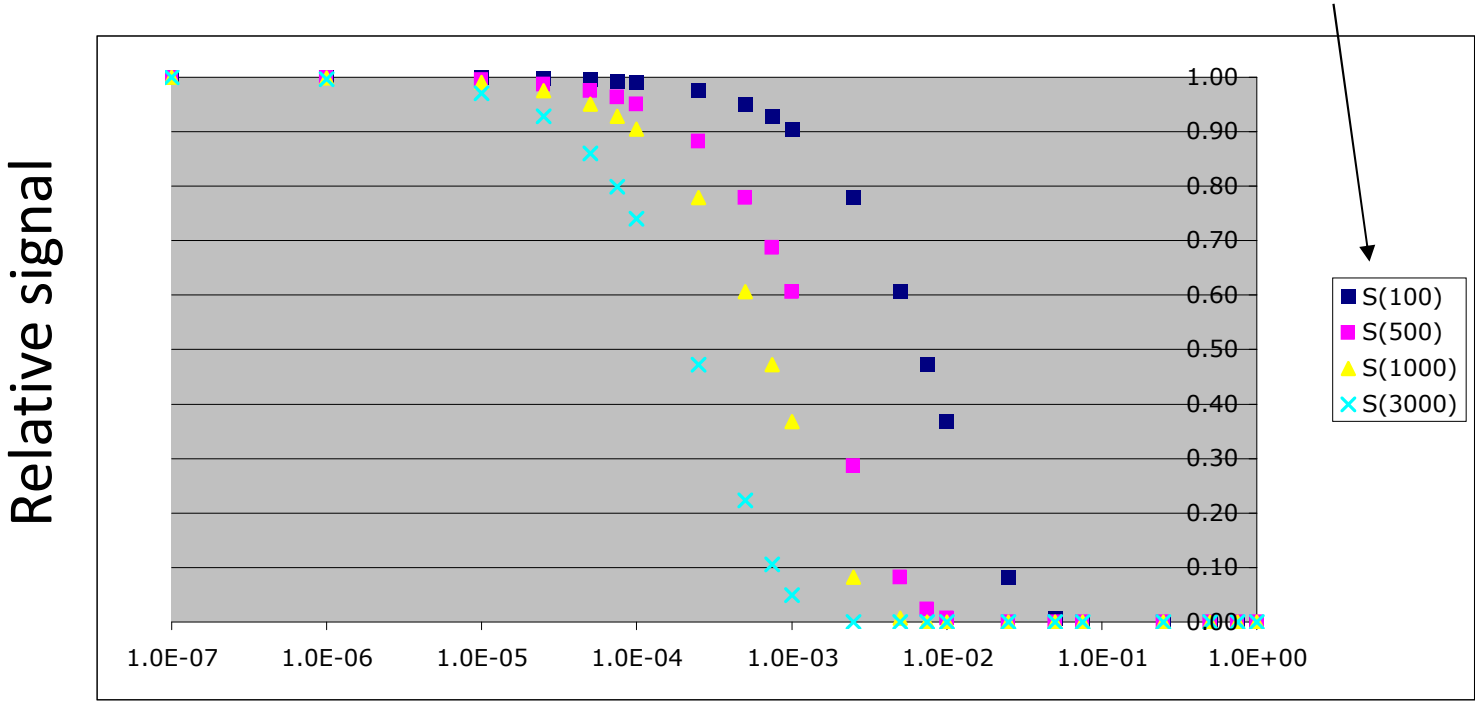
$$S(TE) \propto \exp[-TE/T_2] * \exp[-bD']$$

Moving spins experience unequal effects from the gradient pulses and therefore do not rephase at the echo time TE. Thus, there is a signal loss for "diffusing" spins. The larger the b-value, the larger the signal loss. Spins that are impeded from diffusion by lack of blood flow, cellular exchange, etc. do not lose as much signal. These areas look brighter on the diffusion coefficient images.

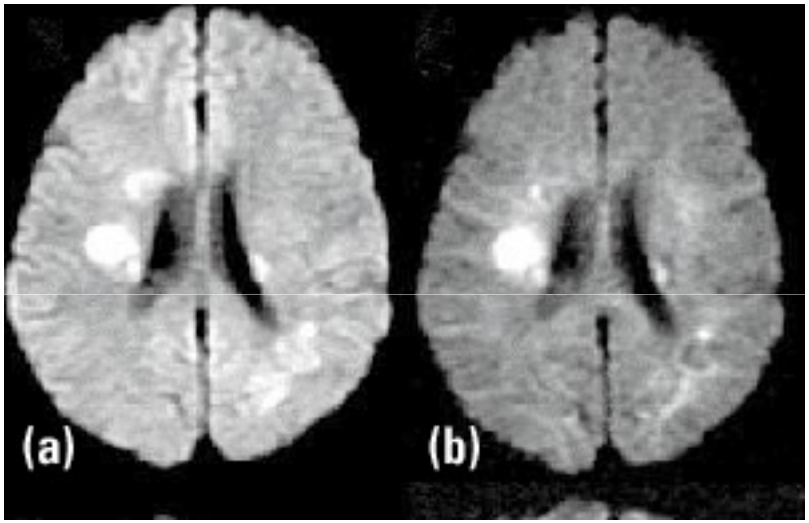
$$b = \gamma^2 G^2 t^2 (\Delta - \delta/3)$$



Varying b-values



# Diffusion Imaging Example



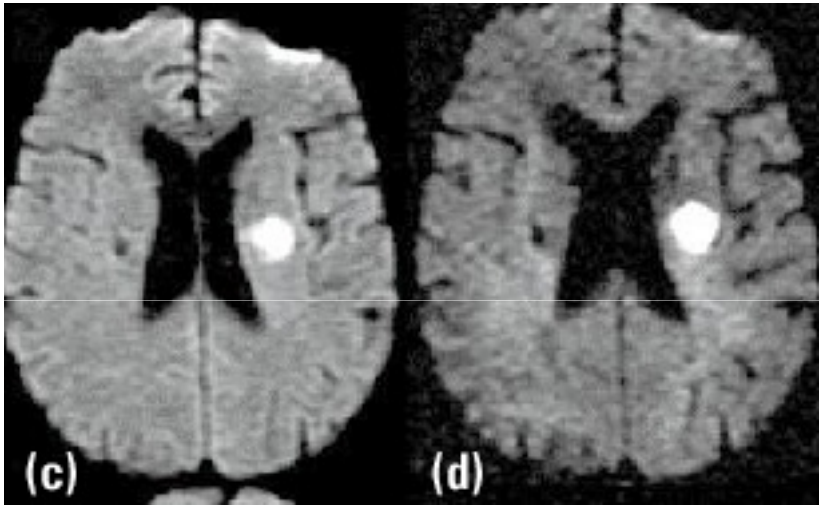
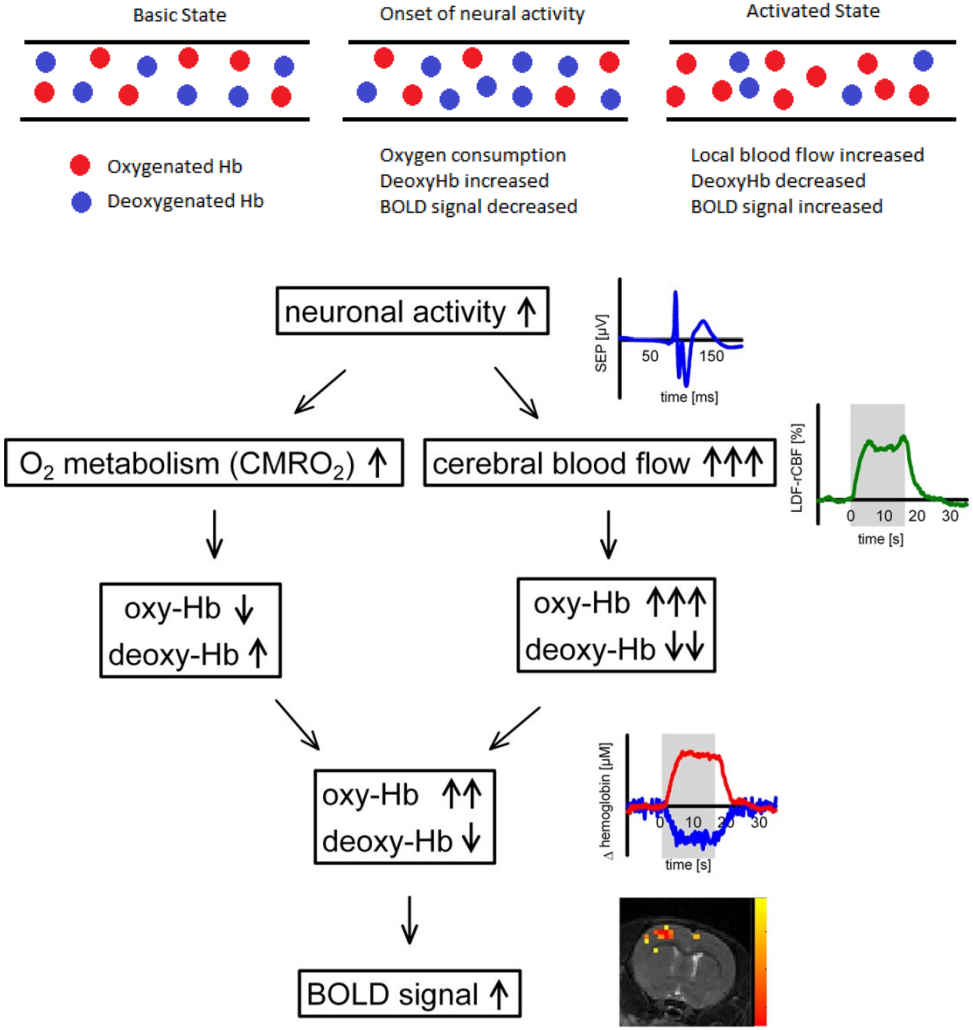
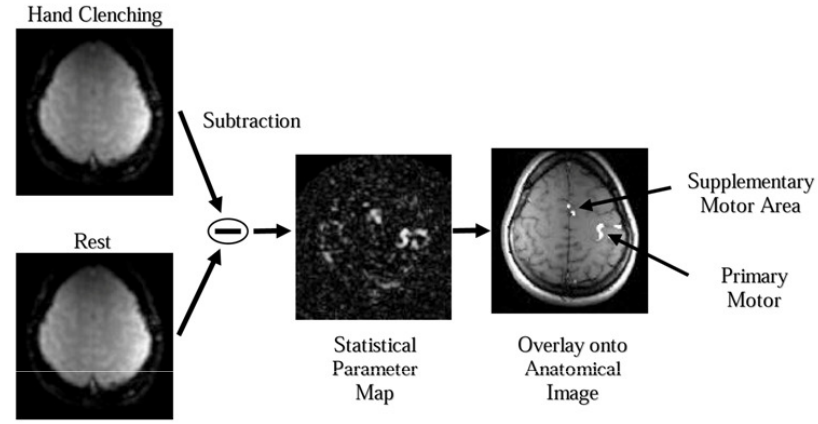




Figure 12 : Multiple Sclerosis: isotropic diffusion-weighted image with (a) b = 1000 s/mm$^2$ and (b) b = 3000 s/mm$^2$. The high b-value DWI may show the active regions of MS with higher contrast-to-noise ratio (CNR) from that of the inactive regions of MS.

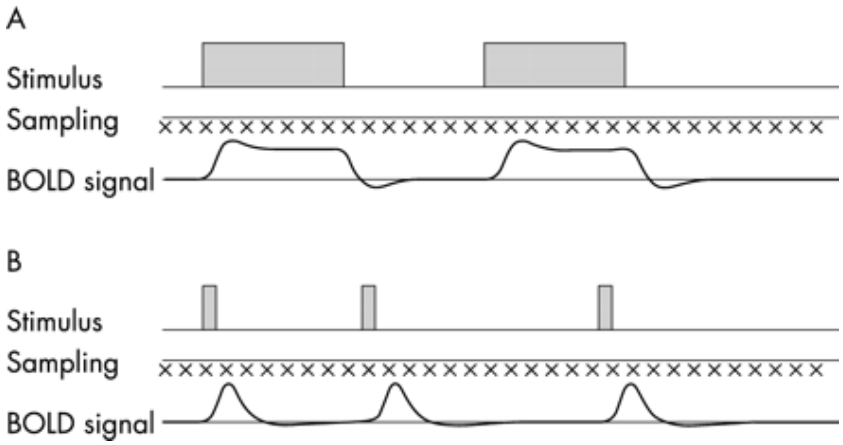
Acute Stroke: (c) b = 1000 s/mm$^2$ and (d) b = 3000 s/mm$^2$. The high b-value DWI demonstrates the region of acute stroke with higher CNR than the DWI with b = 1000.

Brighter areas indicate less mobility of spins - e.g. tissue under stress

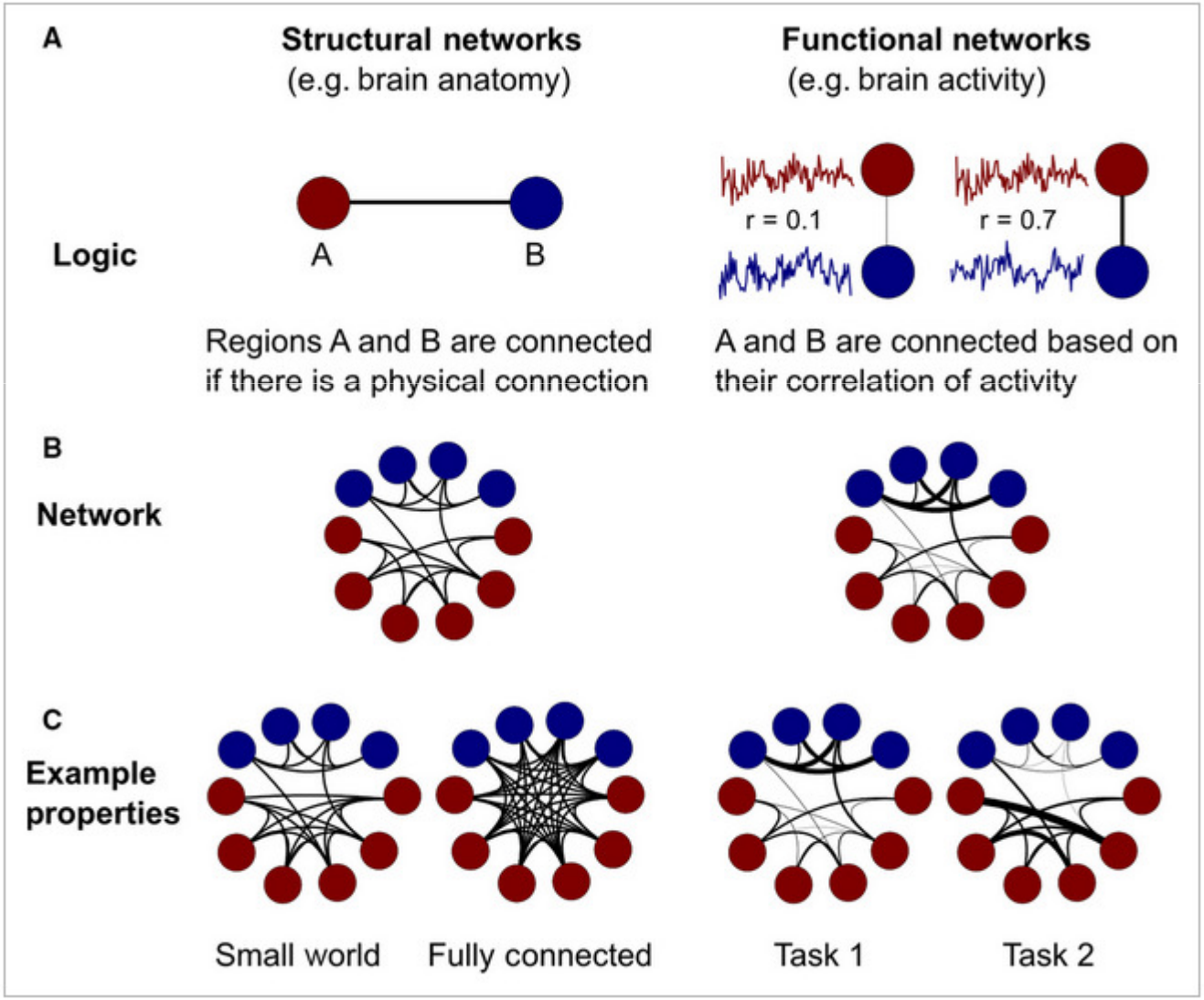



A) Metodo block design
B) Metodo event related

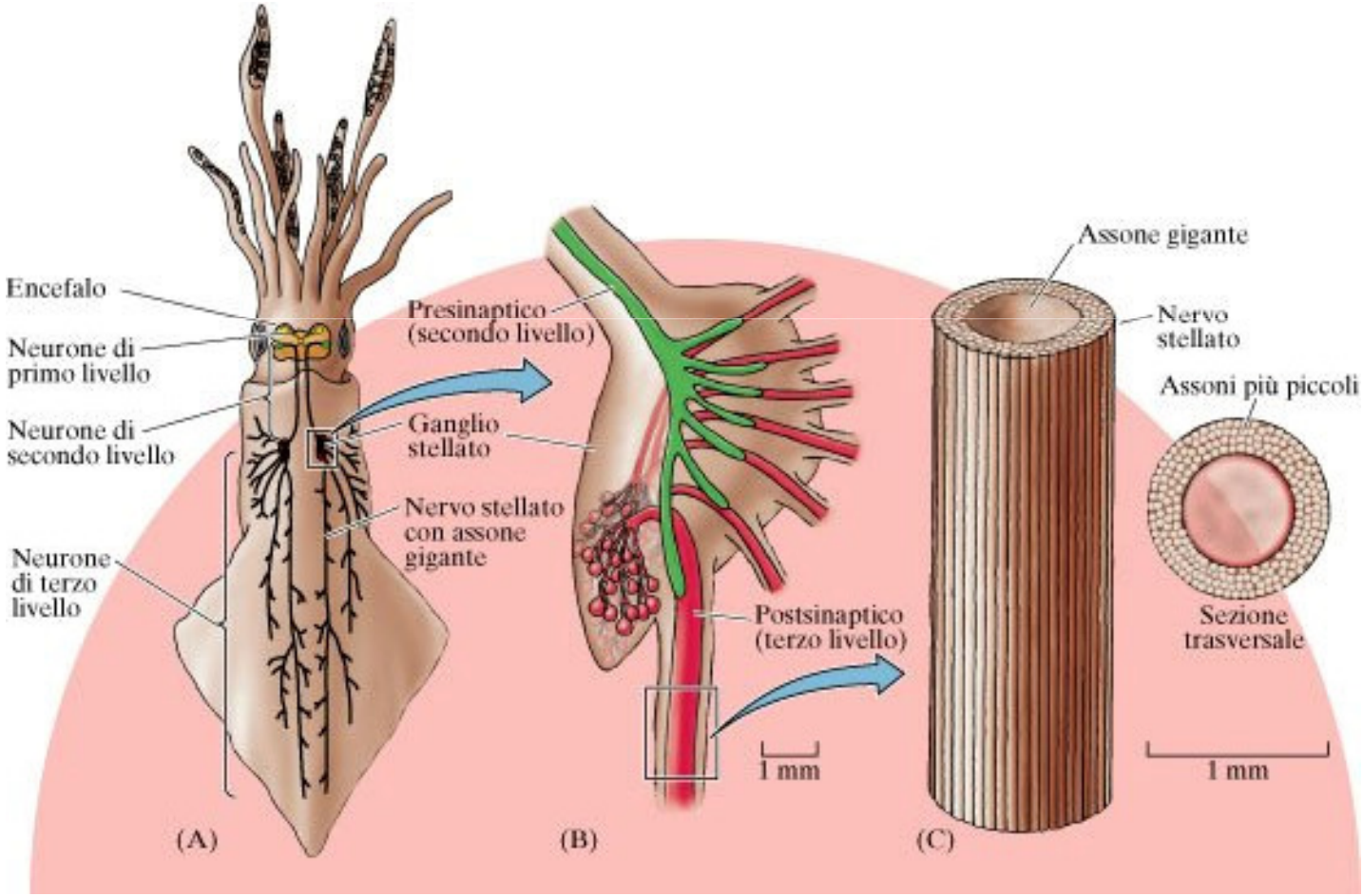


# Connessioni di reti neurali



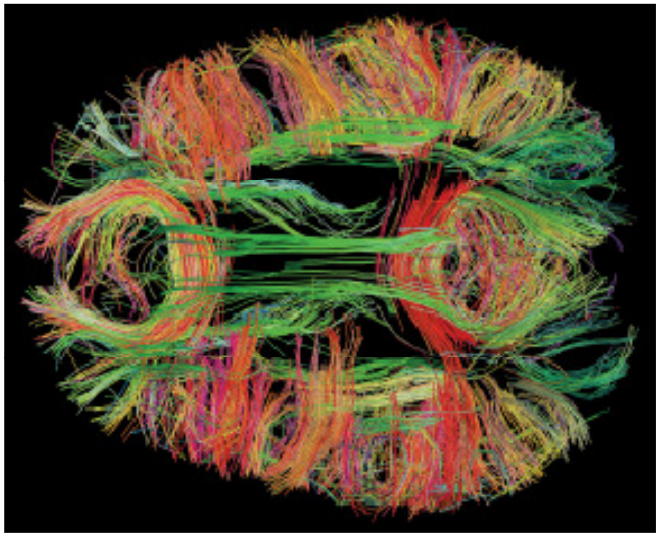
# L’assone gigante del calamaro

L'assone gigante del calamaro rappresenta la cellula nervosa più grande che si conosca del regno animale. Può raggiungere fino a 1mm di diametro e quasi un metro di lunghezza.



# DTI – Imaging del Tensore di Diffusione

- E’ una modalità di imaging sensibile al percorso compiuto dalle molecole di acqua (non coordinata) durante il tempo della misura in una particolare direzione scelta per mezzo di un gradiente di campo magnetico.
- Le molecole d'acqua nella cellula hanno una diffusione limitata; se la cellula ha una struttura anatomica omogenea sviluppata in una direzione, come ad esempio sono i fasci di fibre nervose, il moto in quella direzione ha caratteristiche diverse rispetto alle altre direzioni e può essere rivelato con una sequenza DTI applicando un gradiente di campo magnetico nella stessa direzione.
- Si ottengono così mappe tridimensionali delle fibre di sostanza bianca (trattografia) che consentono di esplorare in vivo la connettività anatomica del cervello umano.



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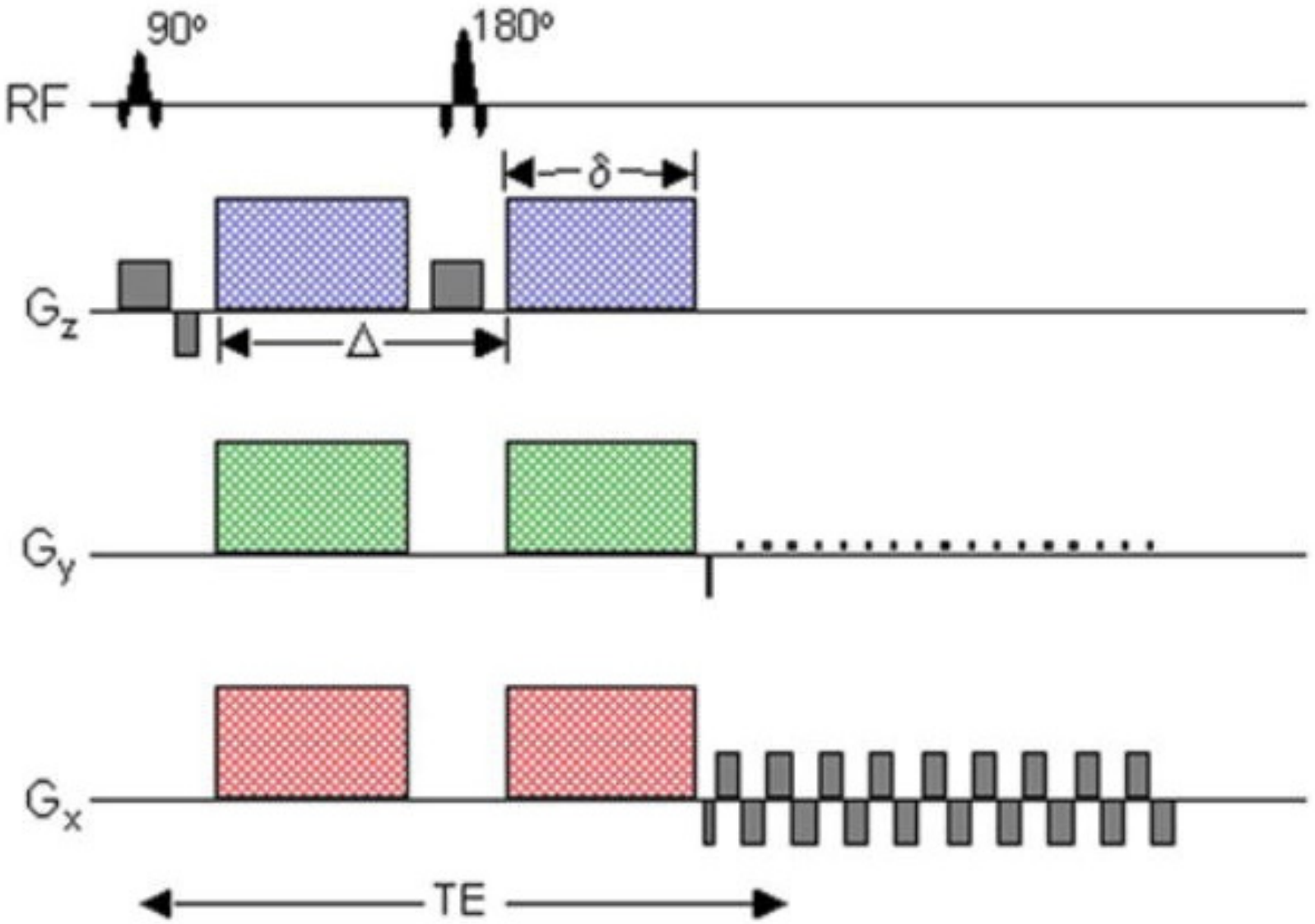

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