

# Metodi di “immagine” del sistema nervoso centrale

**Statici:** permettono di visualizzare la **struttura** del SNC

Radiografia

Tomografia assiale computerizzata (TAC)

Risonanza magnetica (NMR-MRI)

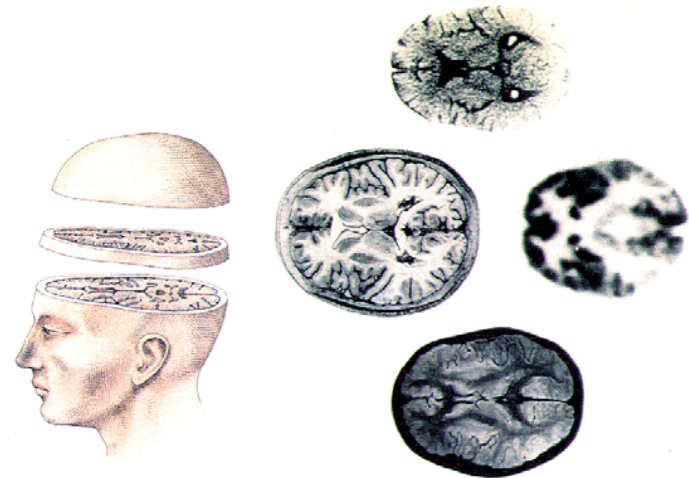
**Dinamici:** permettono di studiare la **funzione** cerebrale

EEG

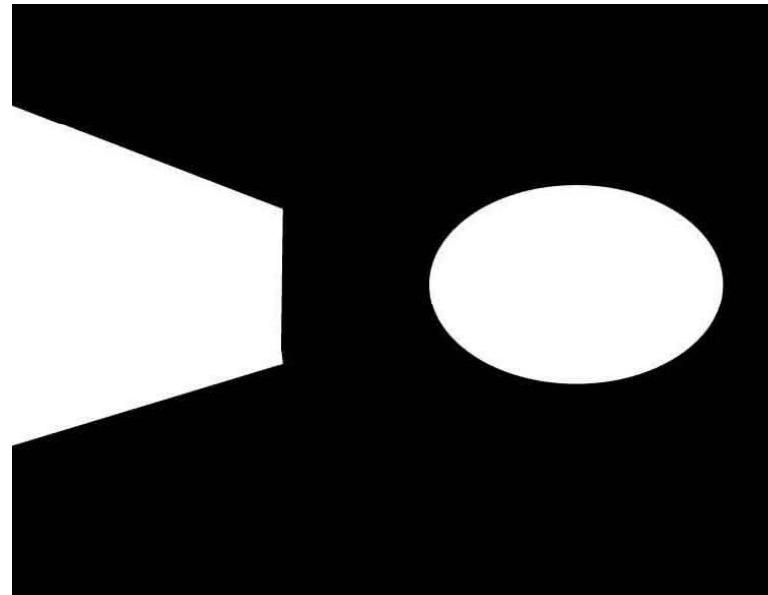
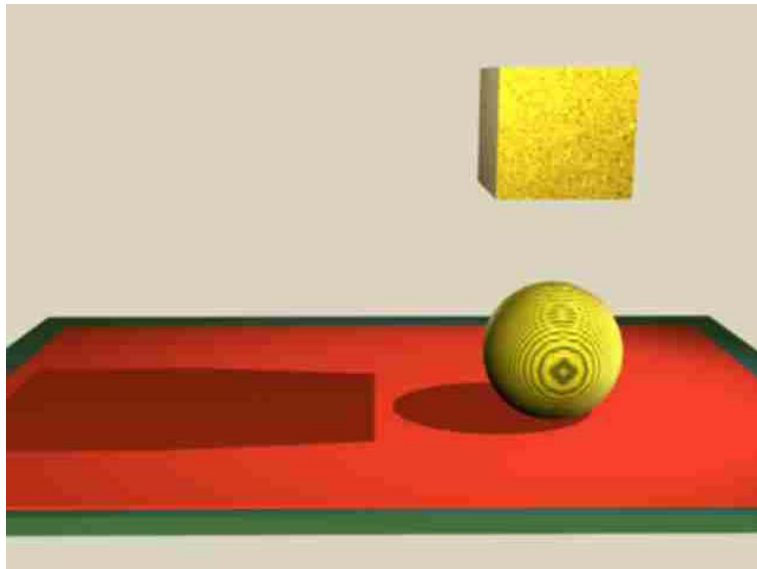
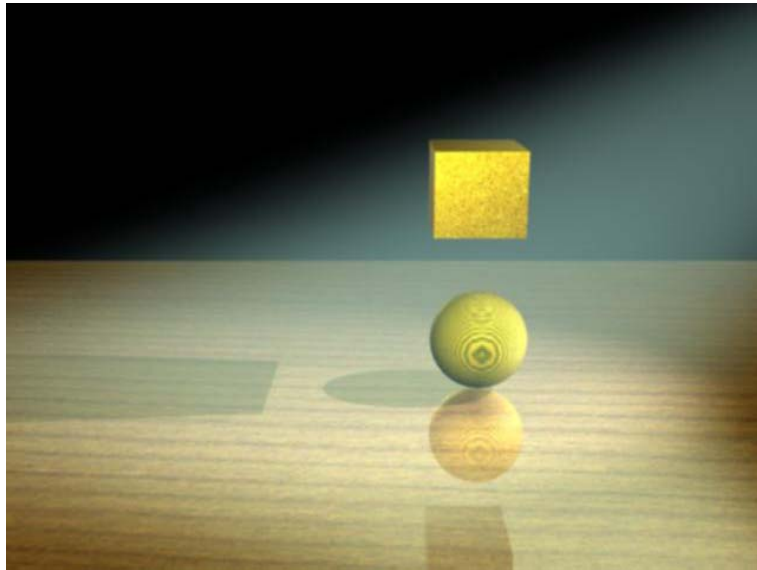
potenziali evocati (ERP)

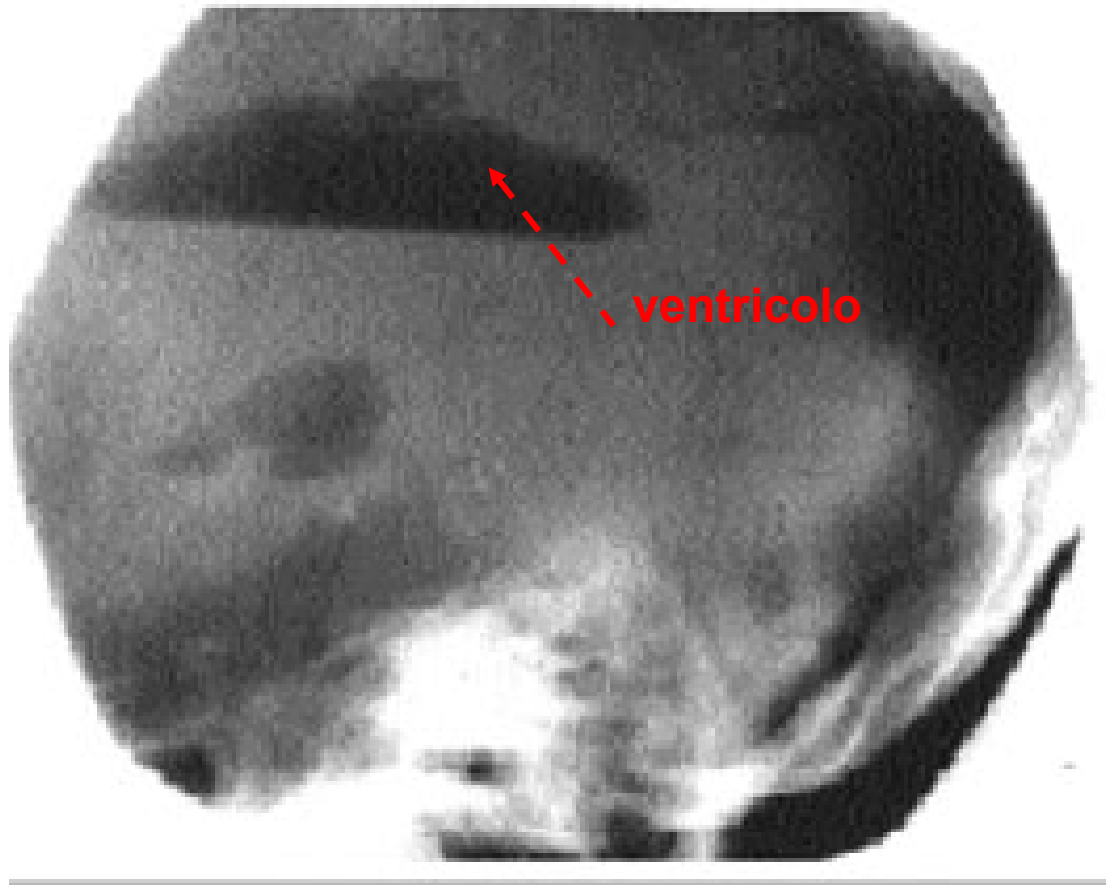
Tomografia ad emissione di positroni (PET)

Risonanza magnetica funzionale (fMRI)



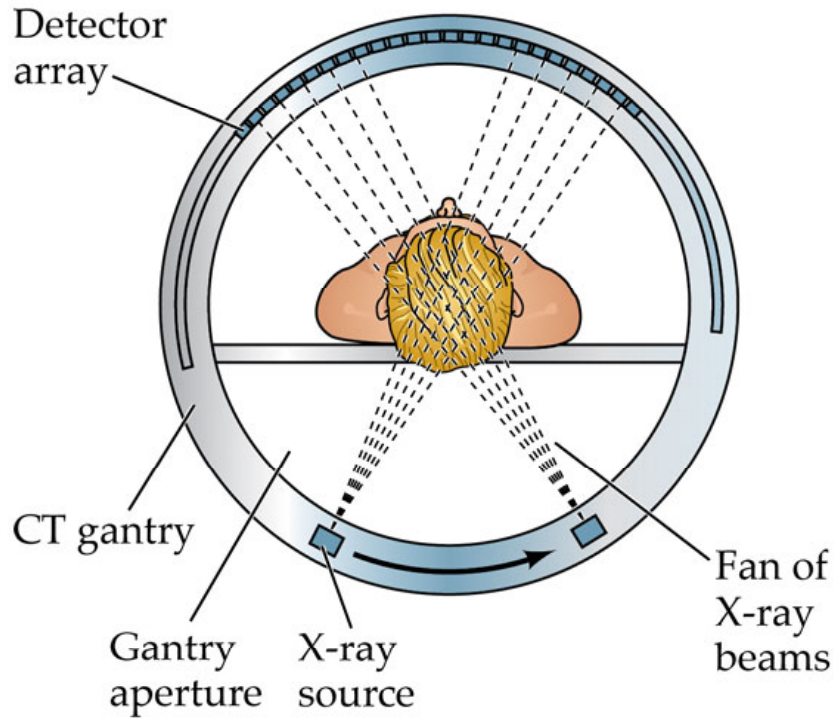
# RADIOGRAFIA



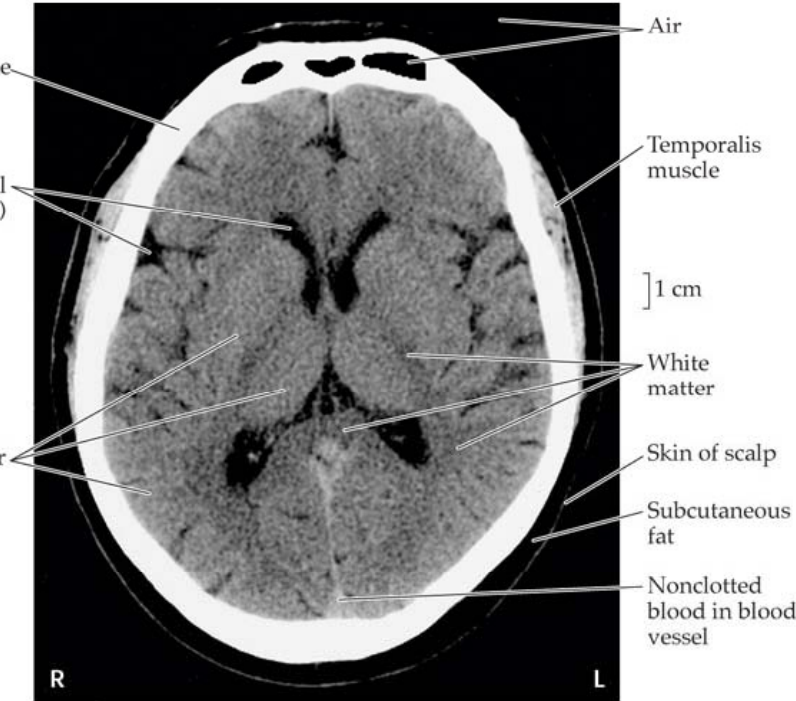
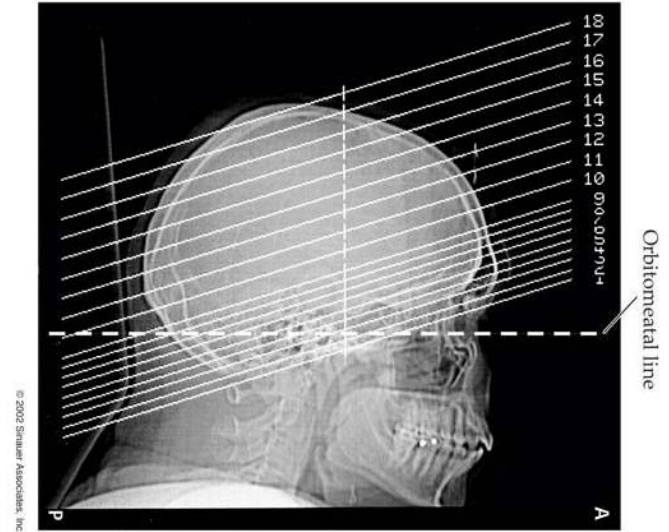


**Il tessuto nervoso è scarsamente radio-opaco**

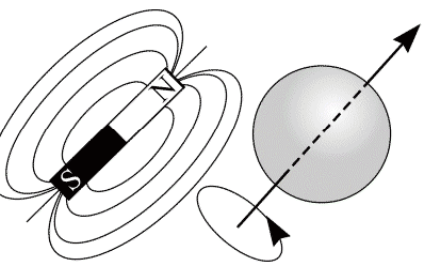
# Tomografia Assiale Computerizzata - TAC



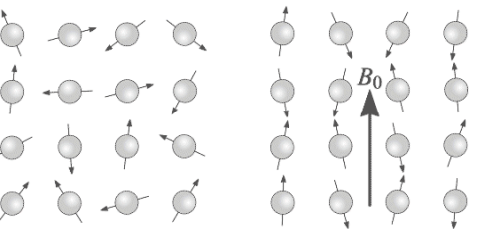
© 2002 Sinauer Associates, Inc.



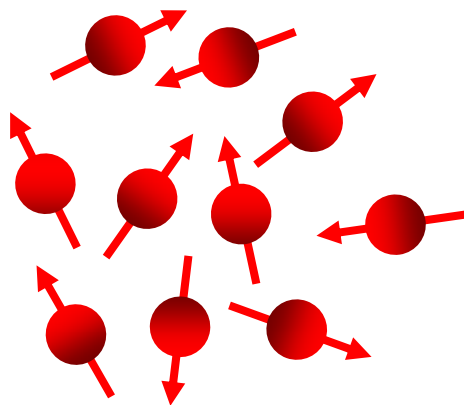
# Risonanza Magnetica Nucleare - NMR



Protoni  
nuclei di atomi di idrogeno -  $H_2O$ )

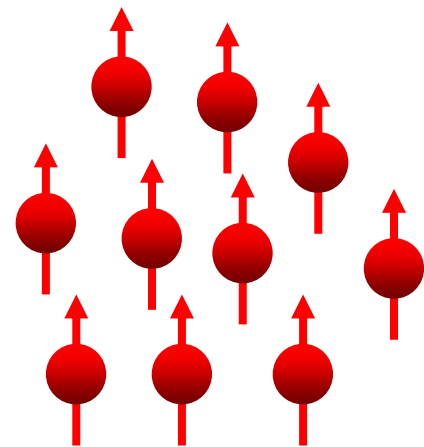


1



2

campo magnetico verticale ↑



accoppiamento  
paramagnetico

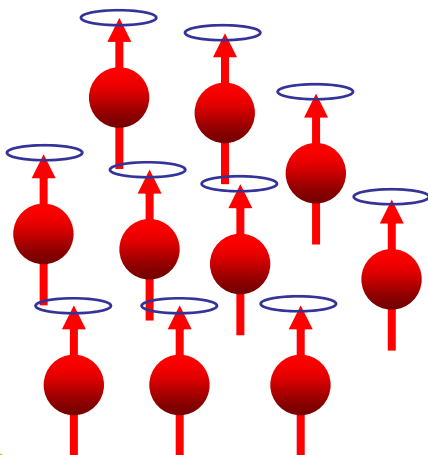
3

campo magnetico verticale ↑



pulso di radiofrequenza  
(campo magnetico orizzontale)

precessione

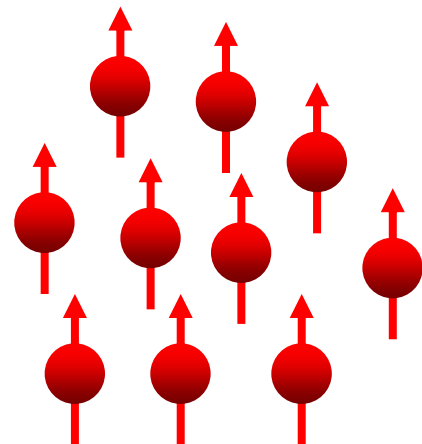


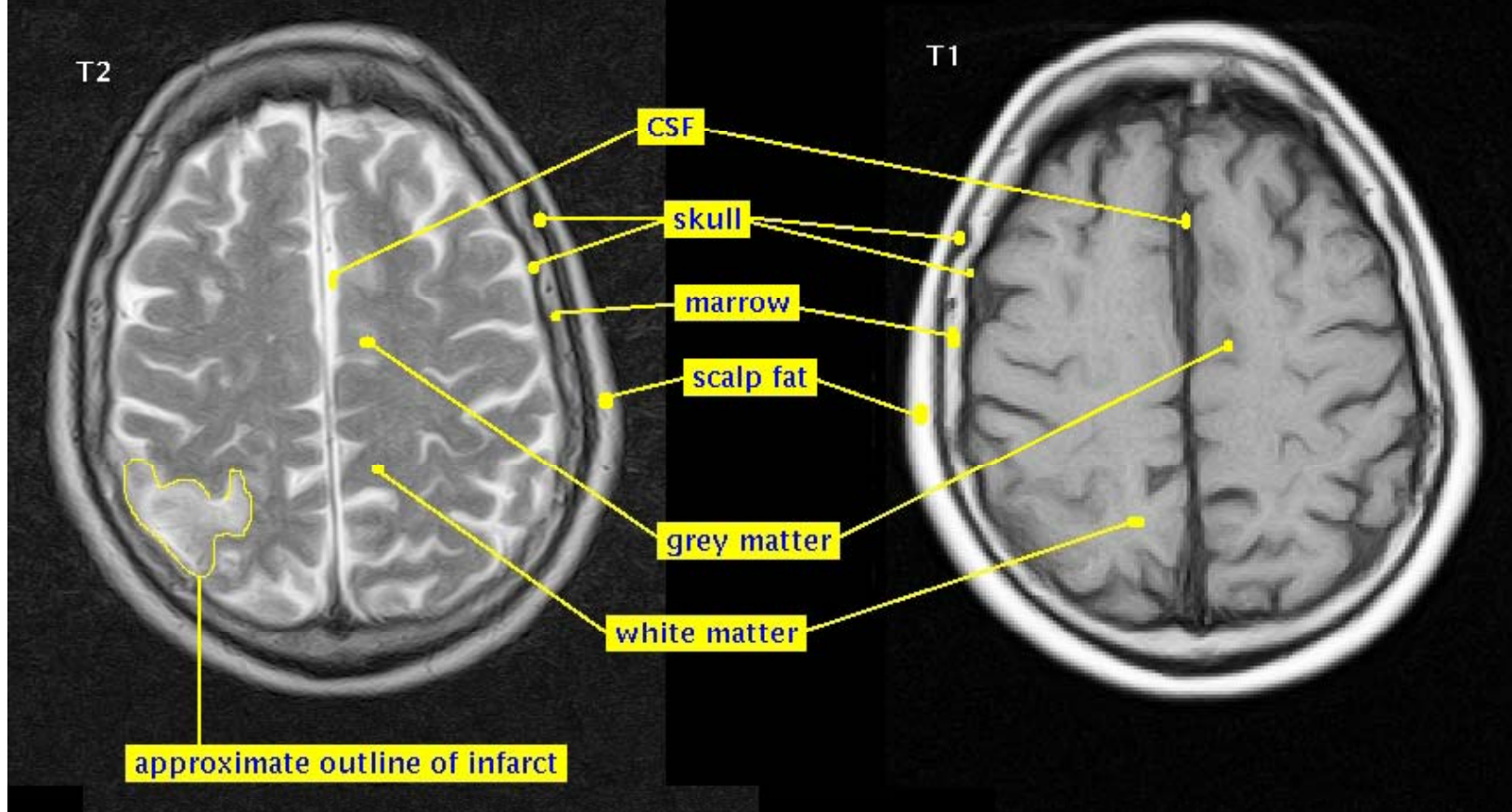
4

rilassamento

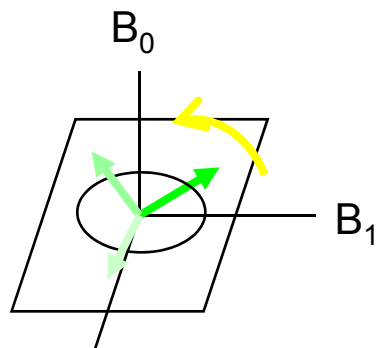


campo magnetico verticale ↑



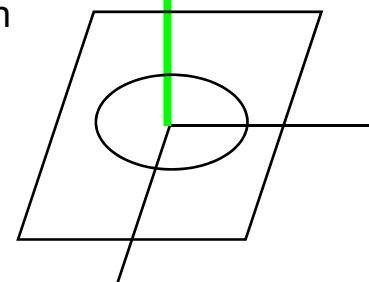


Transverse magnetization

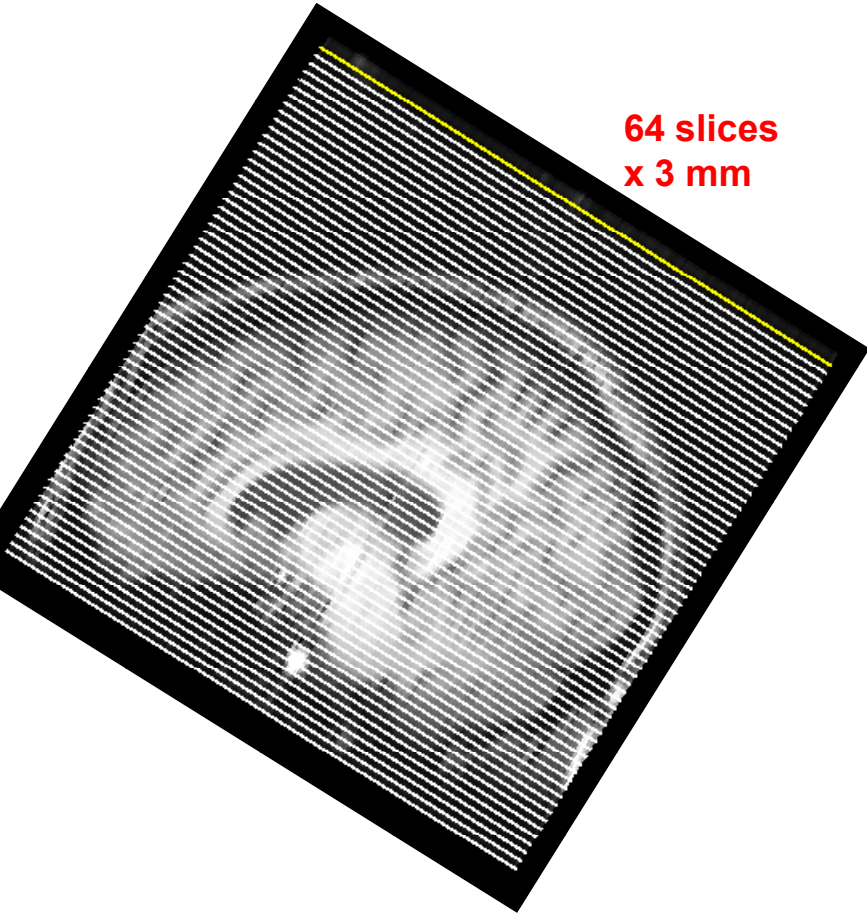


Longitudinal magnetization

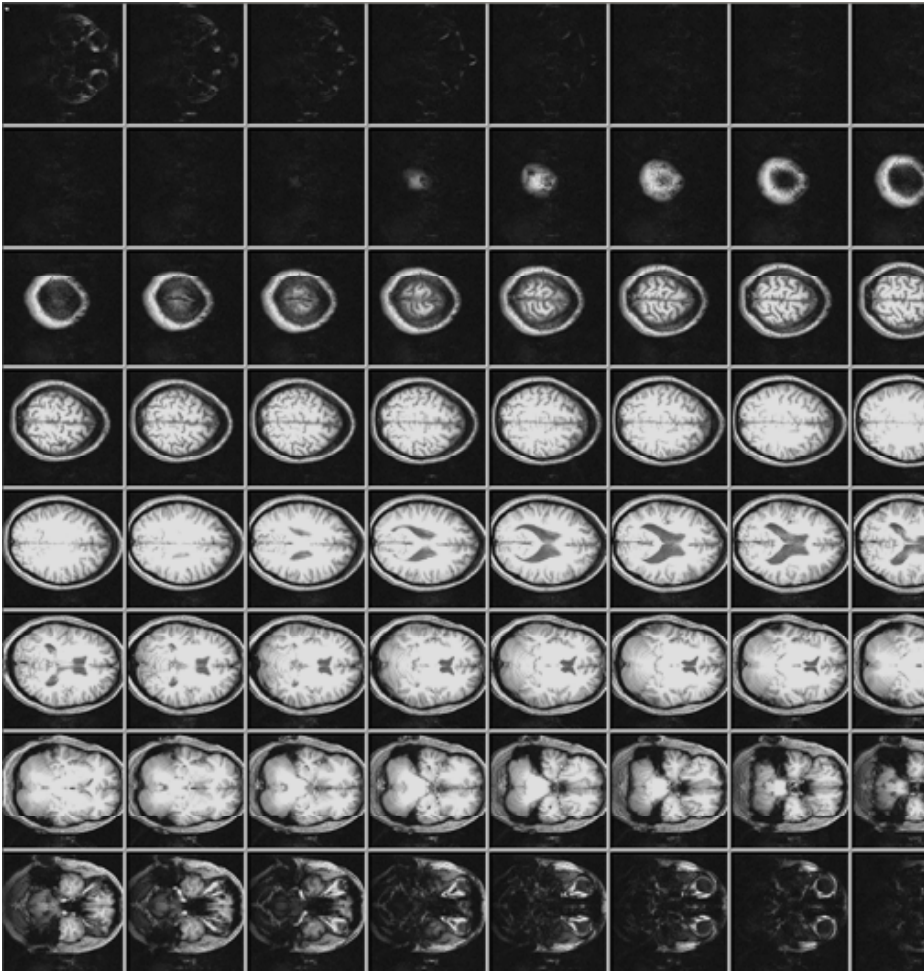
longitudinal axis

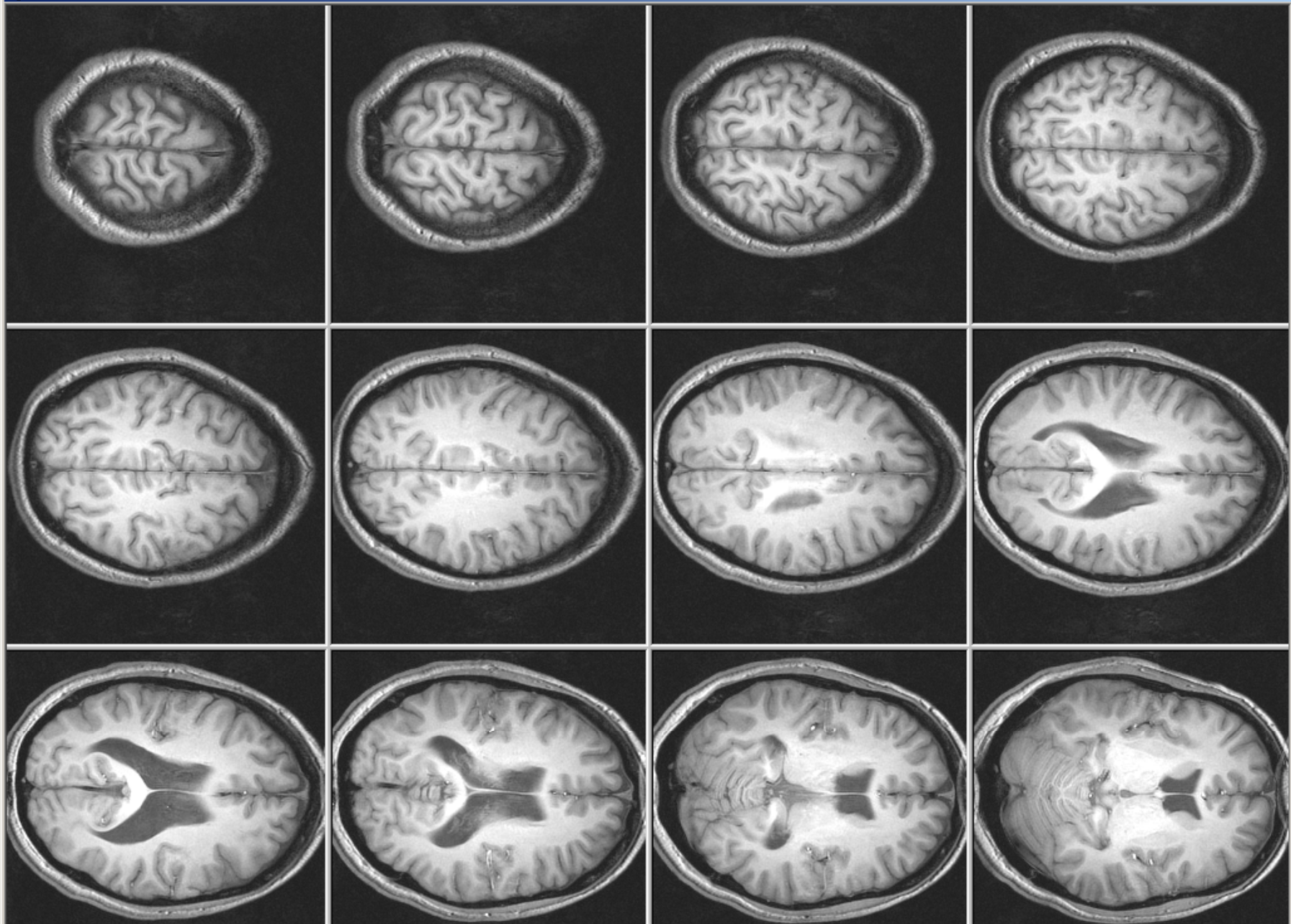


# NMR

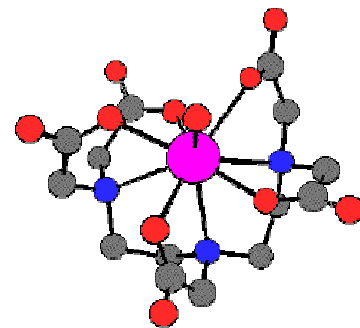
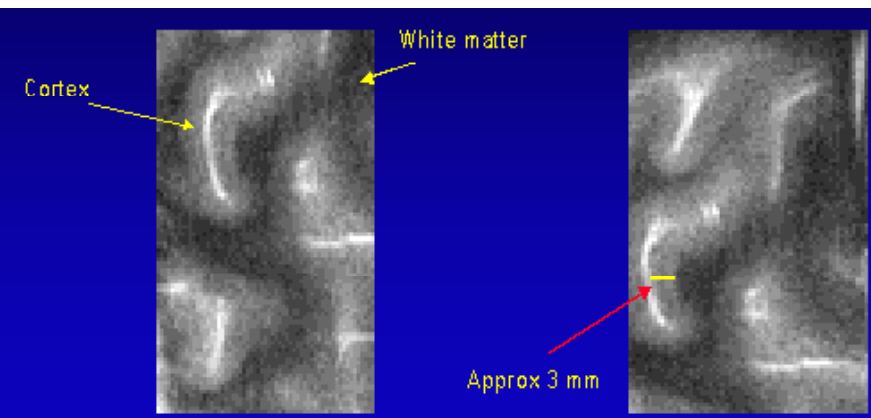
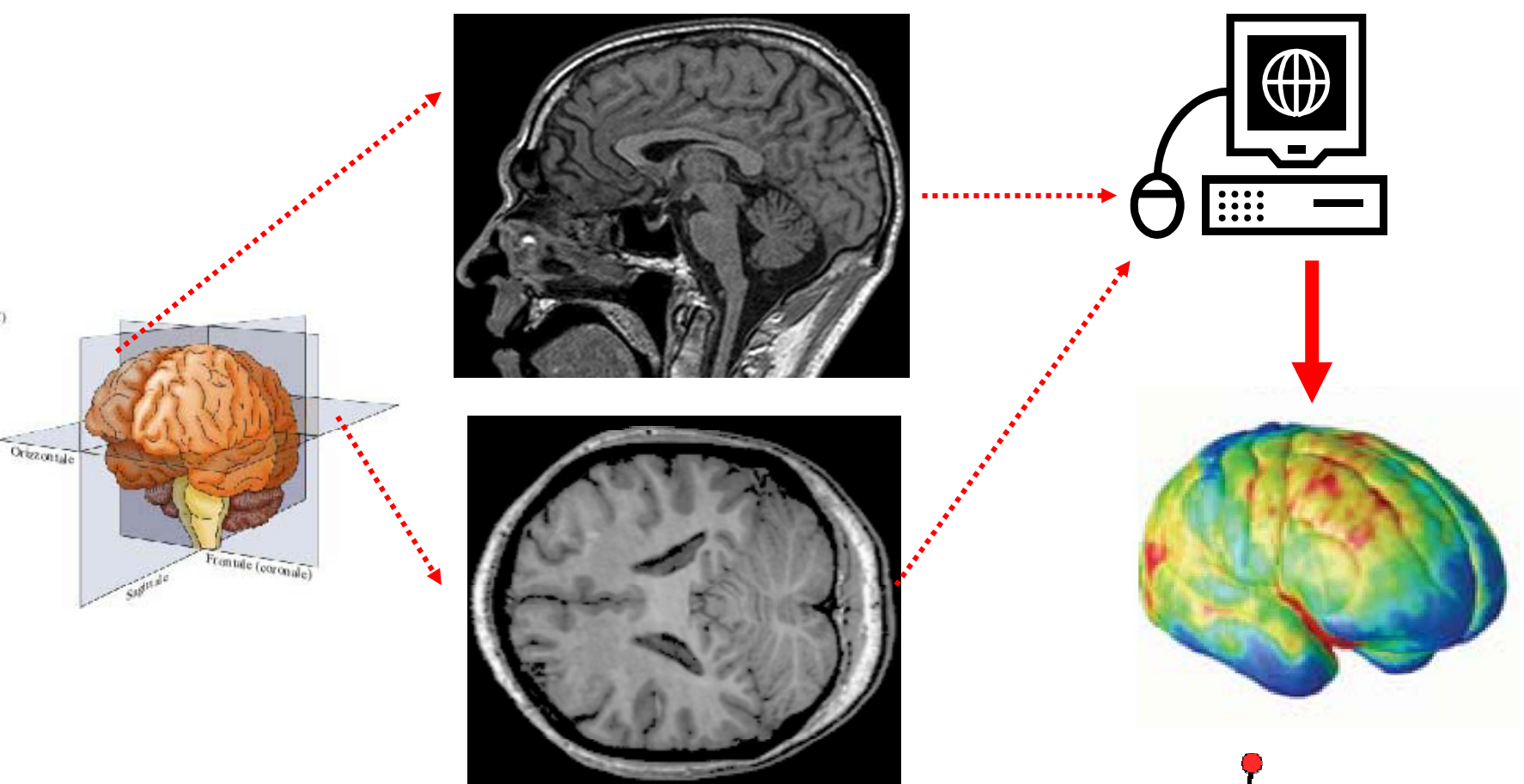


64 slices  
x 3 mm









**Gadolinio: aumenta le proprietà paramagnetiche del tessuto**

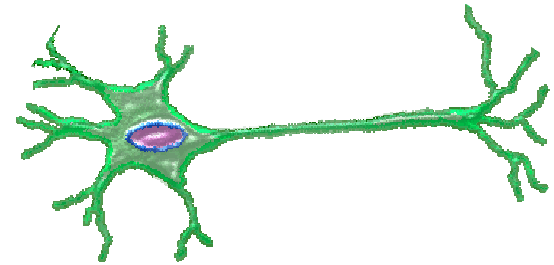
# Metodi di indagine funzionale del sistema nervoso

## Misure dirette – Attività elettrica

Singole unità

EEG

ERP



## Misure indirette

Variazioni di flusso sanguigno

Variazioni attività metabolica

(consumo di O<sub>2</sub>/glucosio)

PET

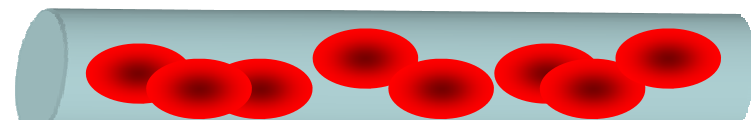
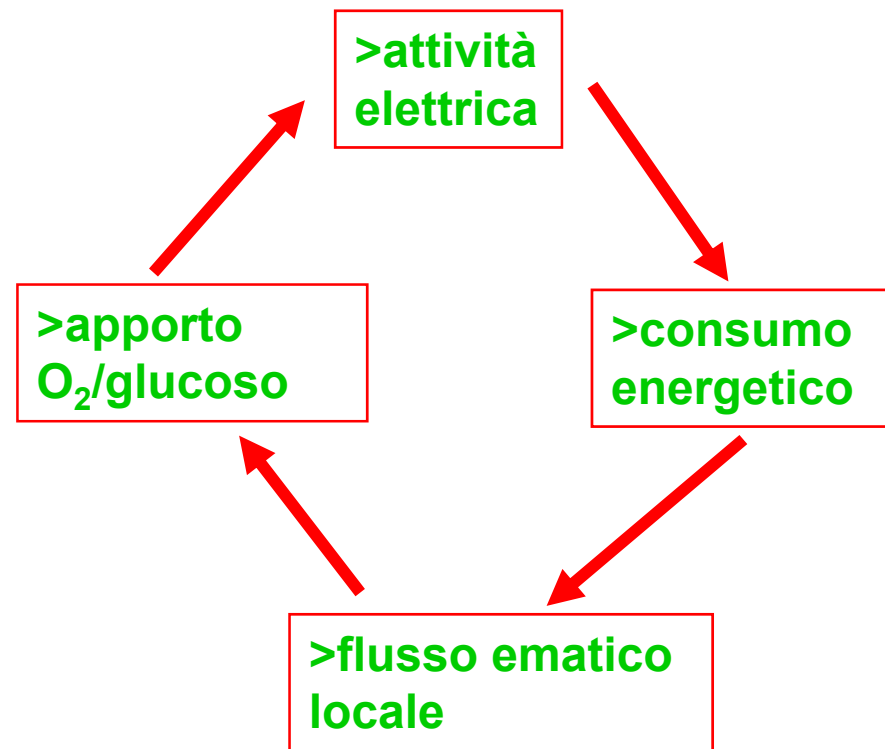
SPECT

fMRI

Altre misure funzionali (binding, ecc..)

PET

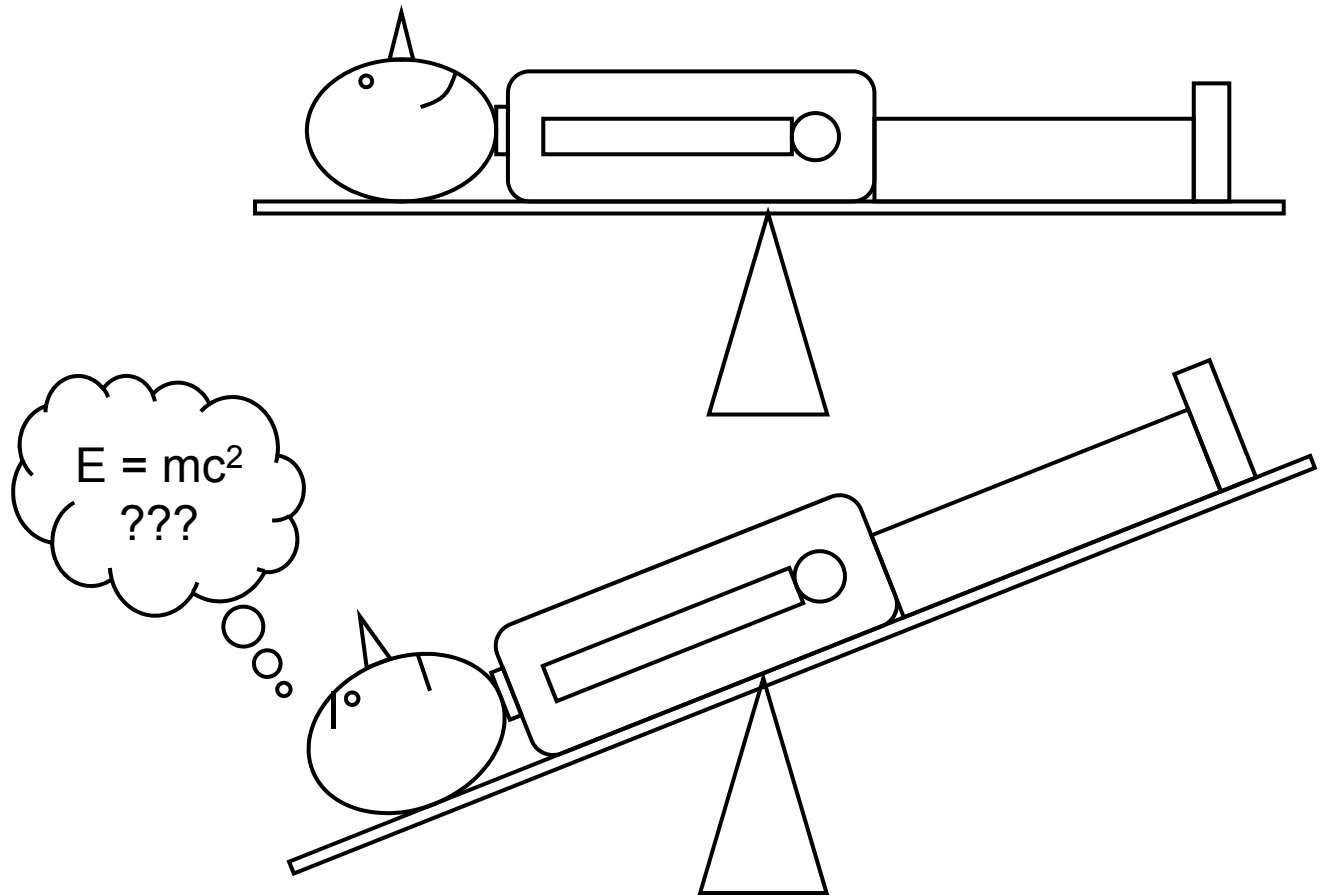
SPECT



# Il primo esperimento di brain imaging funzionale



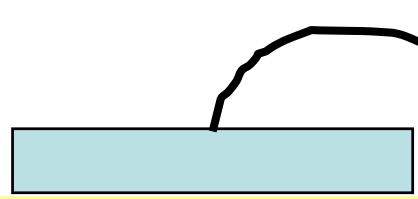
**Angelo Mosso**  
(1846-1910)



[In Mosso's experiments] the subject to be observed lay on a delicately balanced table which could tip downward either at the head or at the foot if the weight of either end were increased. The moment emotional or intellectual activity began in the subject, down went the balance at the head-end, in consequence of the redistribution of blood in his system."

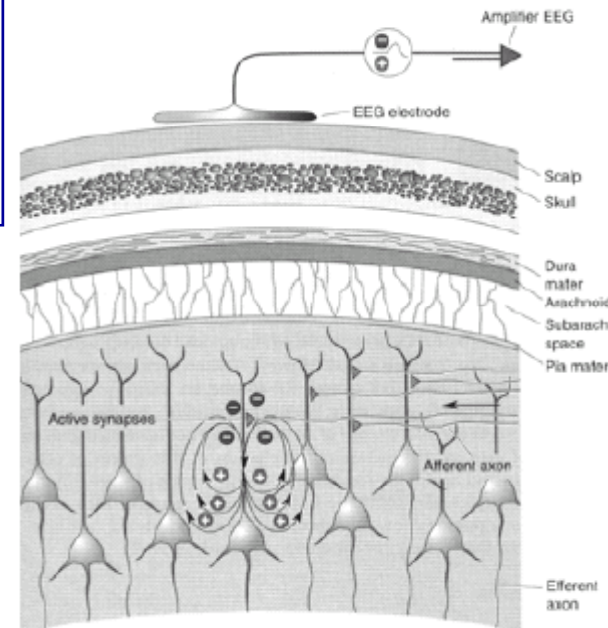
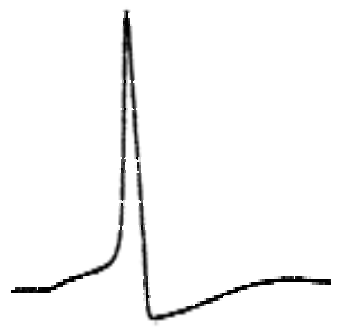
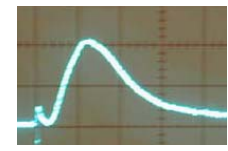
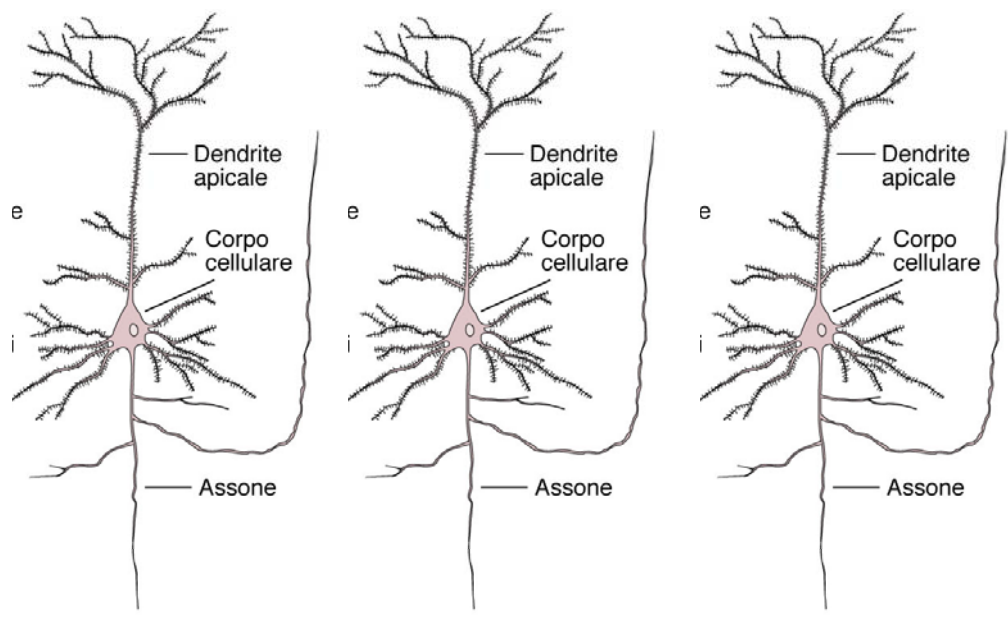
-- William James, *Principles of Psychology* (1890)

# EEG



cranio

meninge



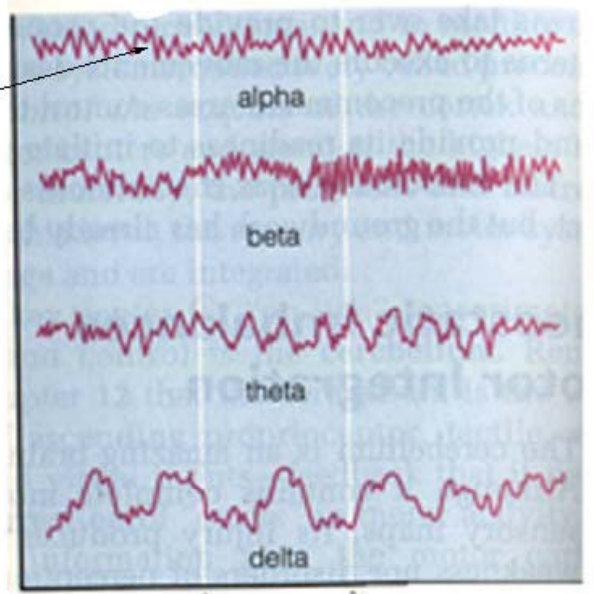


Relaxed Wake/  
Stage I/REM  
"sawtooth"  
Awake, Alert

Stage 2

Stage 3/4

(a)



(b)

1 second interval

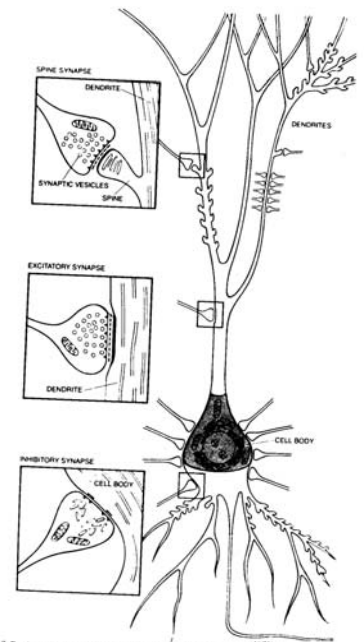
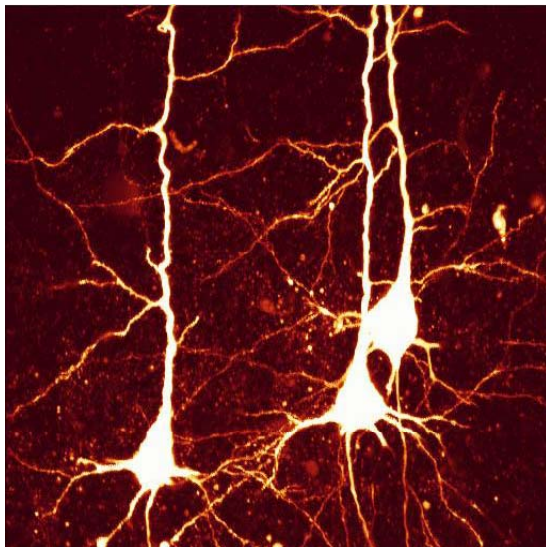
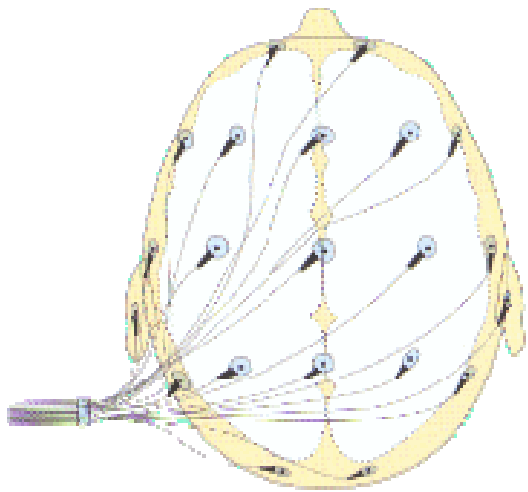
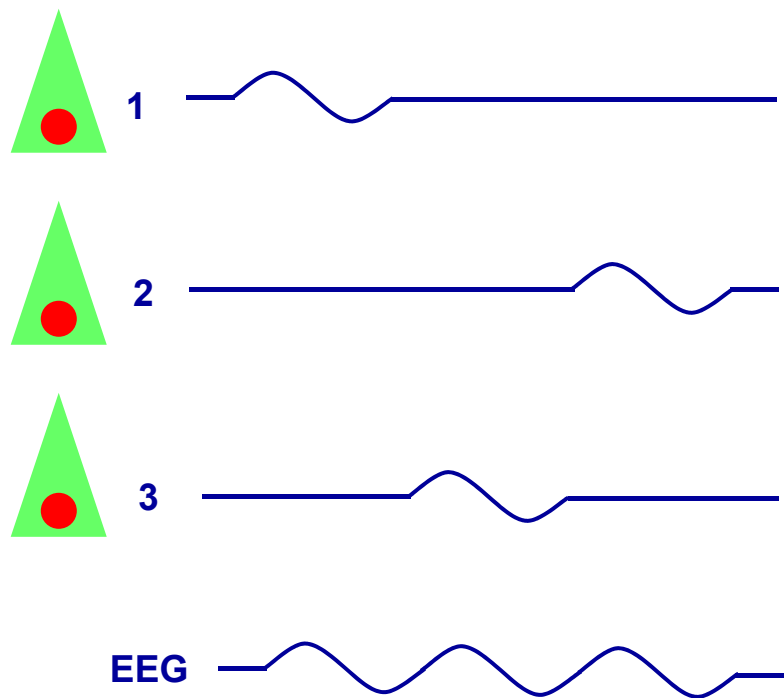


Fig. 3-5. A pyramidal cell and several synapses.



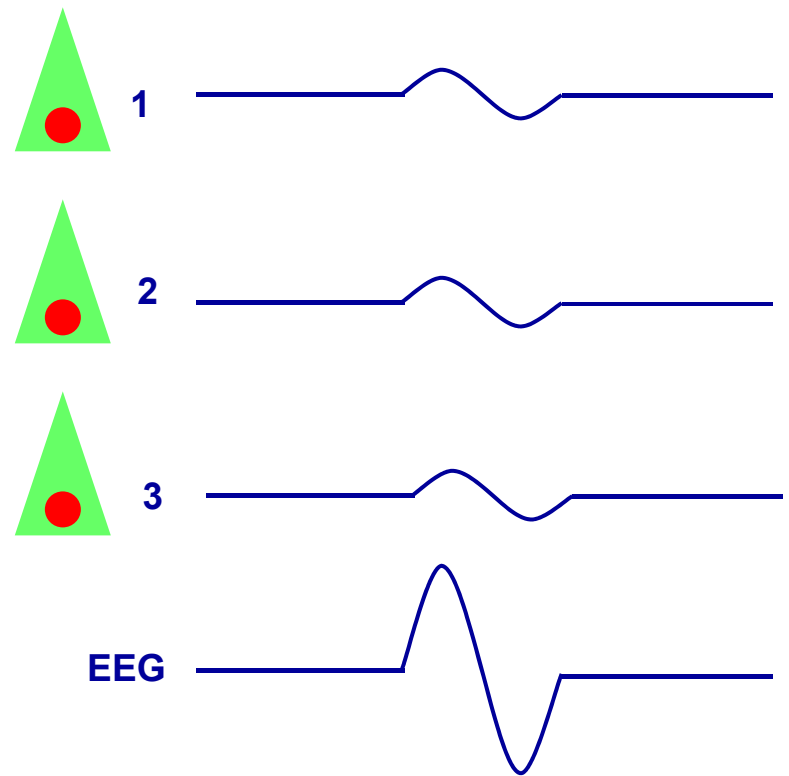
**attività corticale desincronizzata**

**EEG:**

**alta frequenza**

**bassa ampiezza**

Awake: low voltage-random, fast



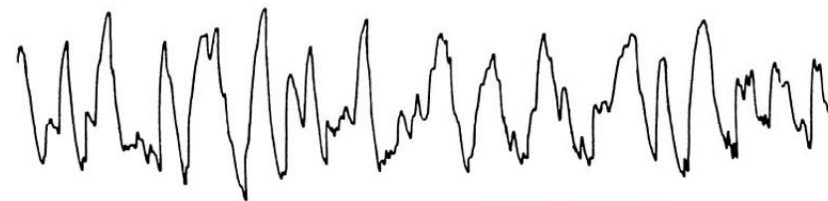
**attività corticale sincronizzata**

**EEG:**

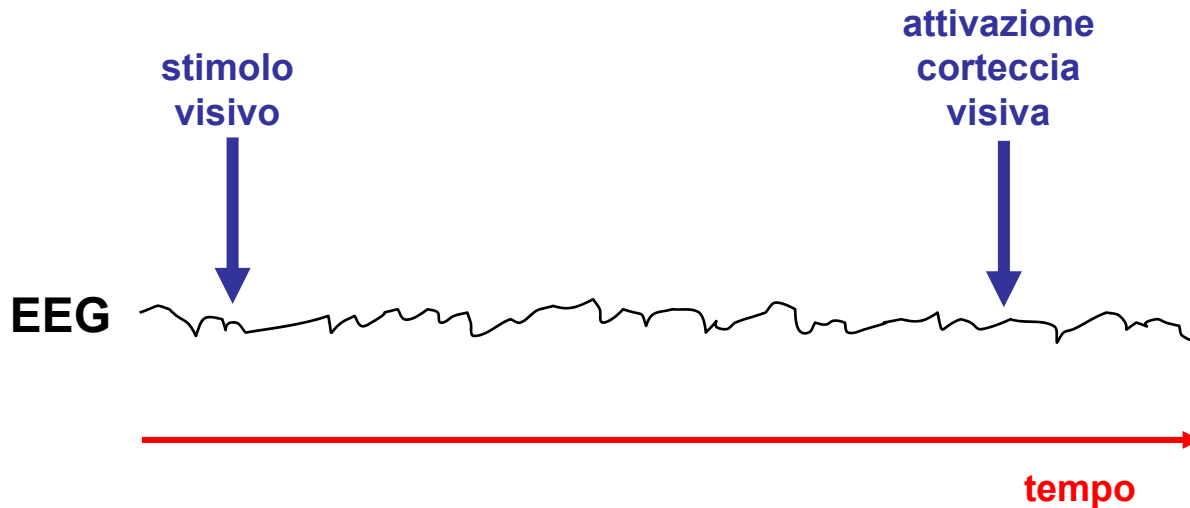
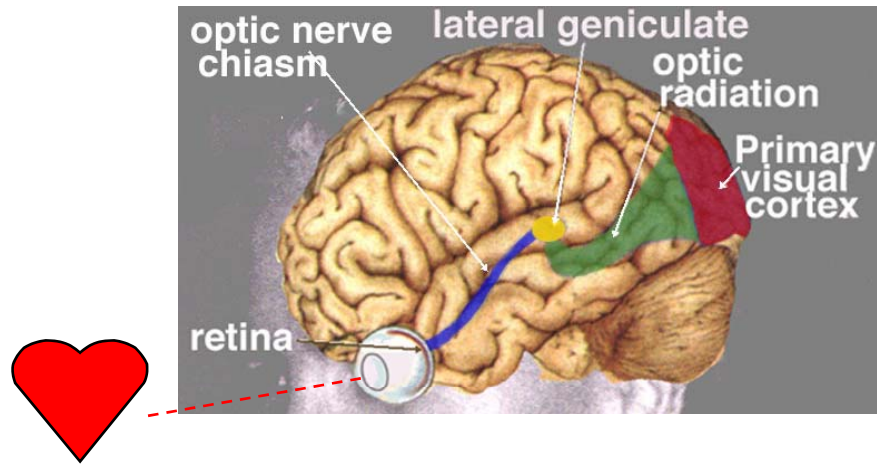
**bassa frequenza**

**alta ampiezza**

Deep sleep: 1/2 to 2 cps- delta waves >75  $\mu$ V

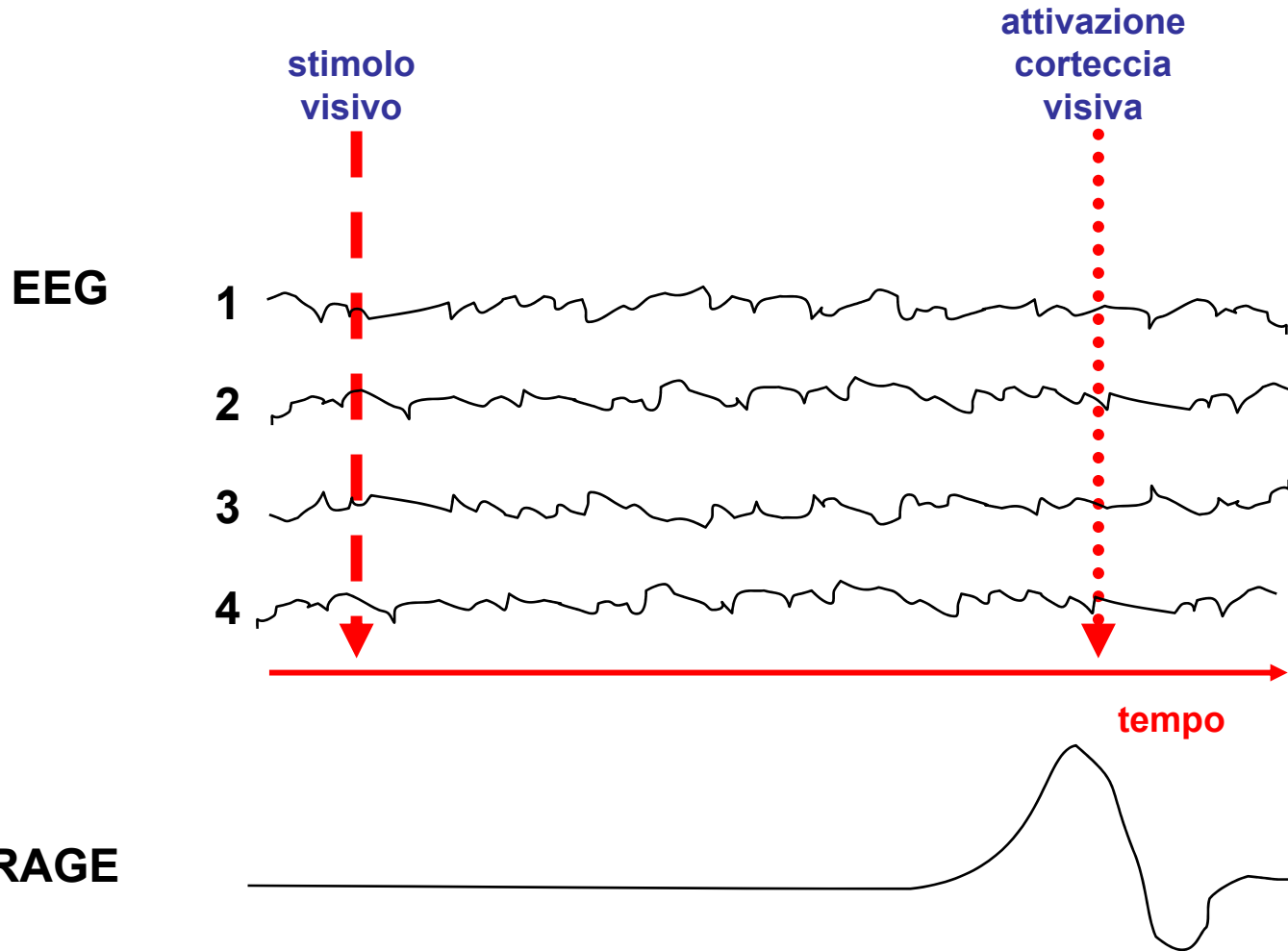


# Potenziali evocati e event-related potentials /ERP



Sul tracciato EEG non si rileva l'attività indotta dallo stimolo (è troppo piccola rispetto al rumore di fondo)

# Potenziali evocati e event-related potentials /ERP -- AVERAGING

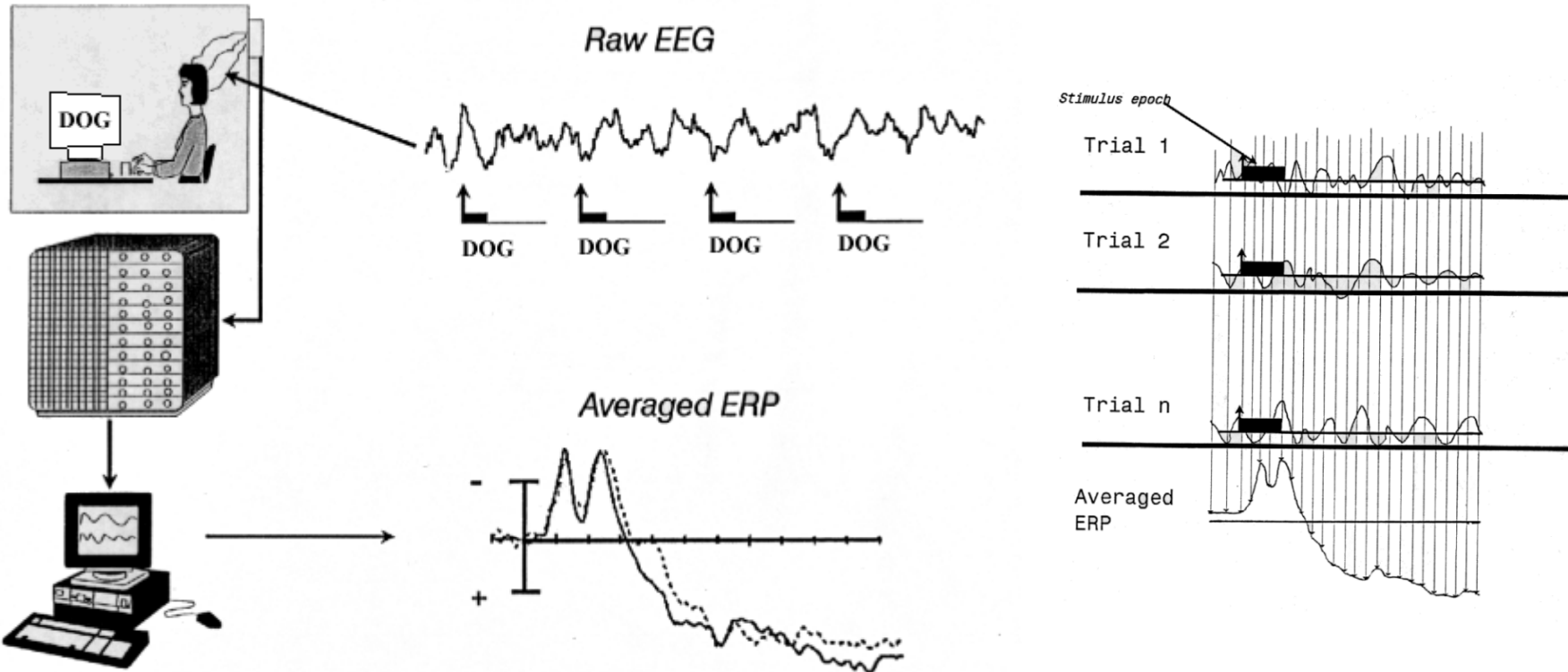


Gli eventi distribuiti casualmente tendono ad elidersi da un trial all'altro. Quelli in relazione temporale con lo stimolo tendono a sommarsi



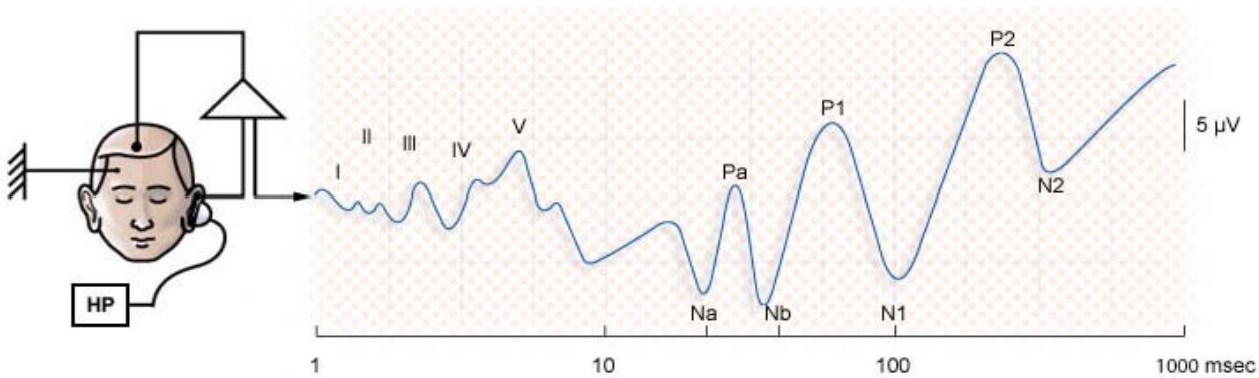
# Potenziali evocati e event-related potentials /ERP -- AVERAGING

## Event-Related Potential Technique



**L'averaging si utilizza tutte le volte che si deve aumentare il rapporto segnale/rumore**

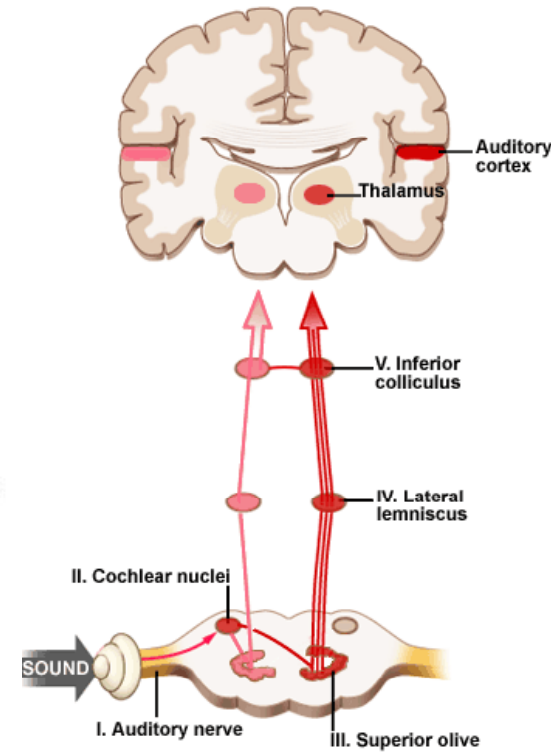
# Potenziali evocati uditivi



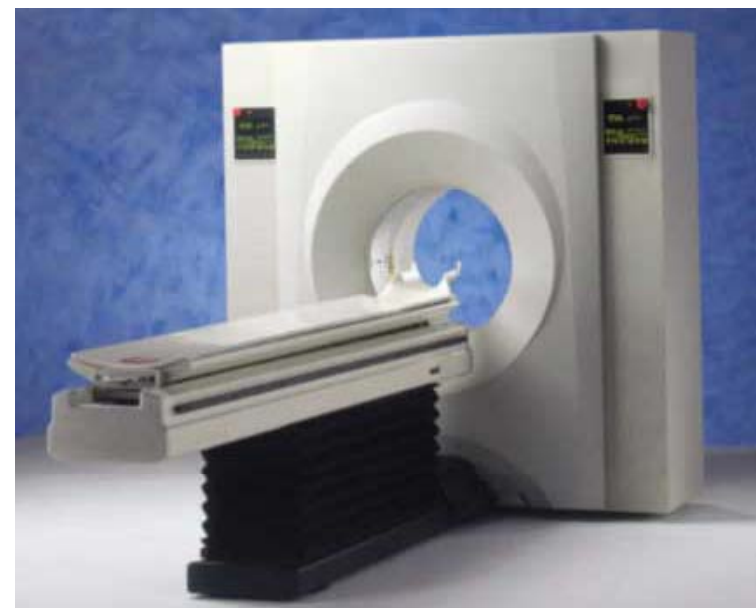
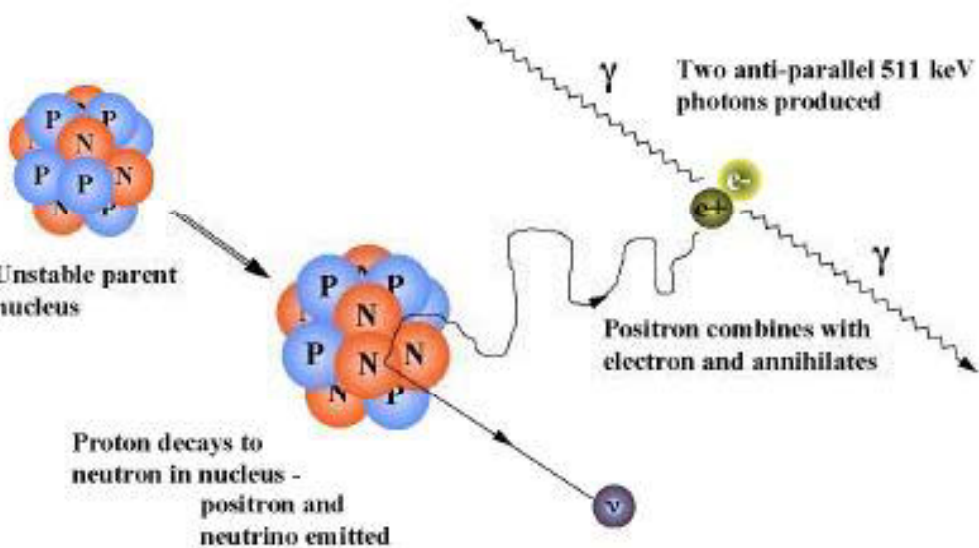
tronco enc.

talamo

corteccia



# Tomografia ad emissione di positroni (PET)



## Isotopi che emettono positroni:

**15O**

**11C**

**18F**

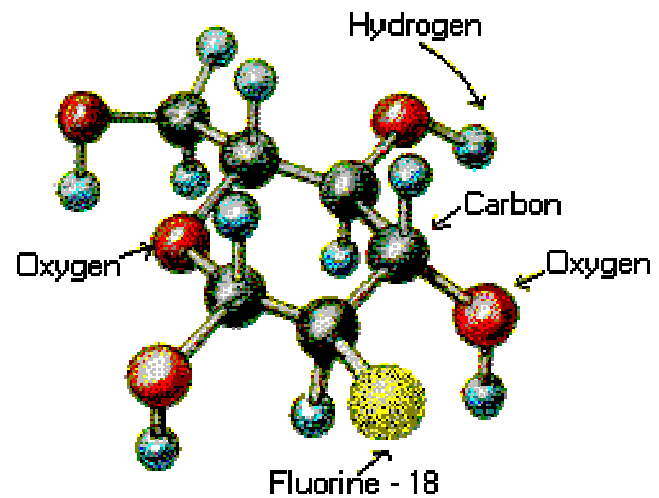
**SPECT (Tc99m)**

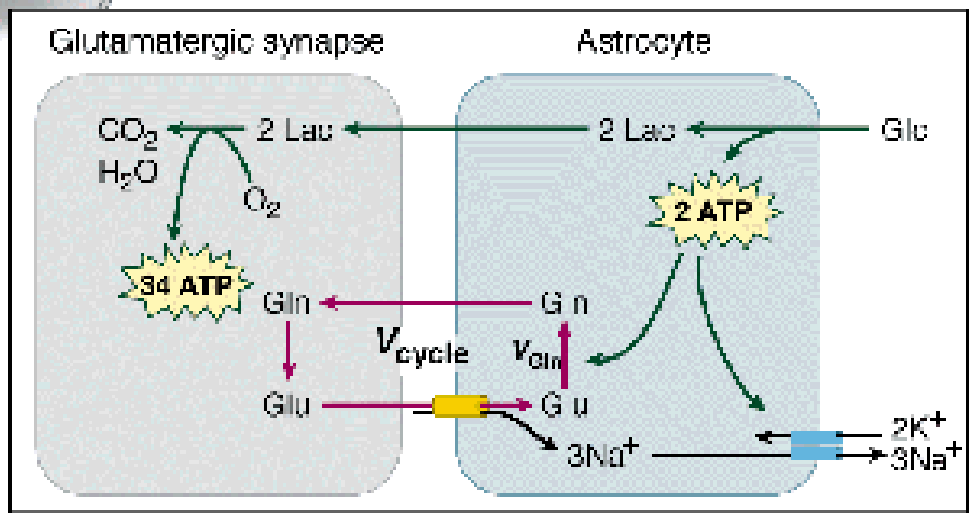
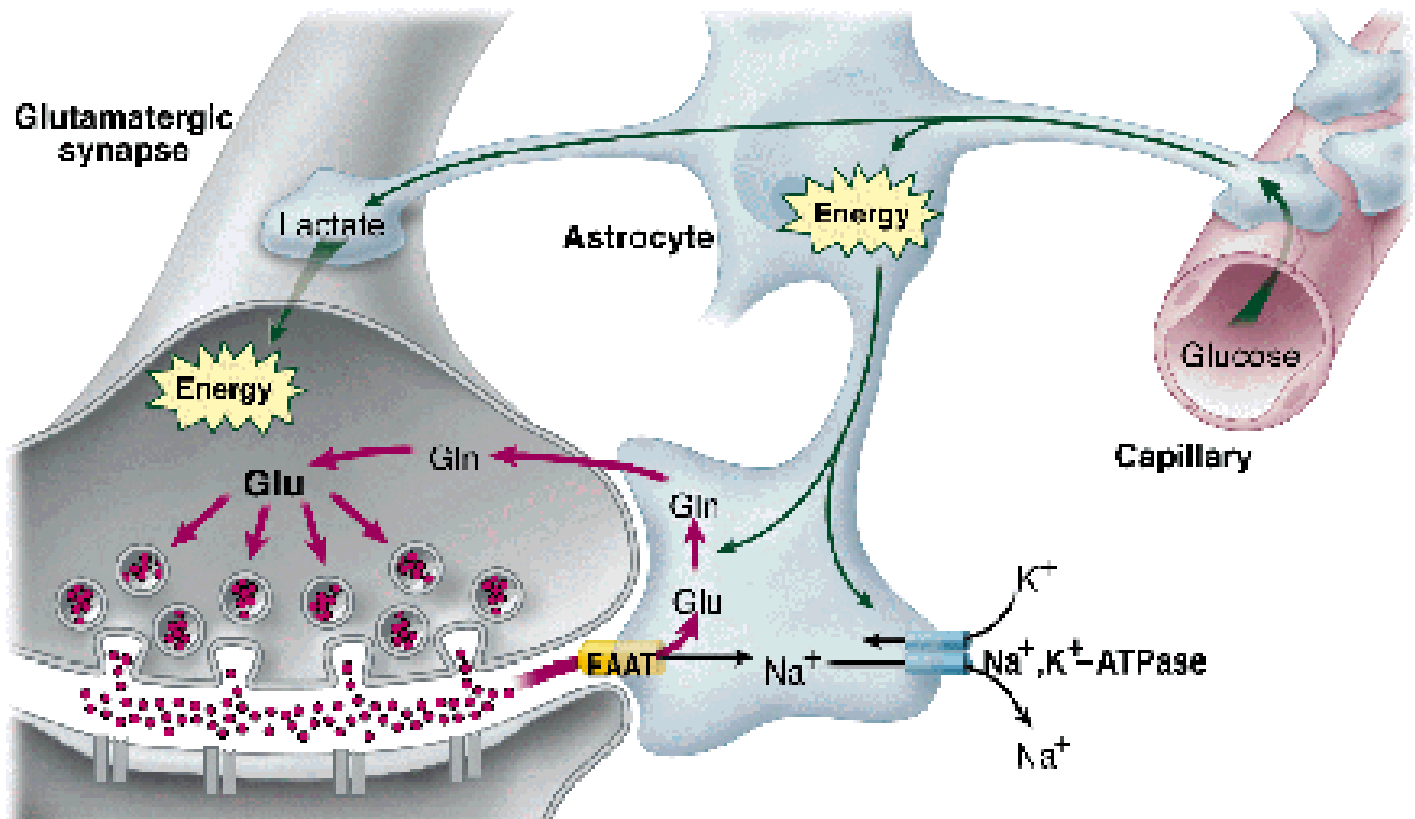
**1cm - min**

**PET**

**5mm - 30s**

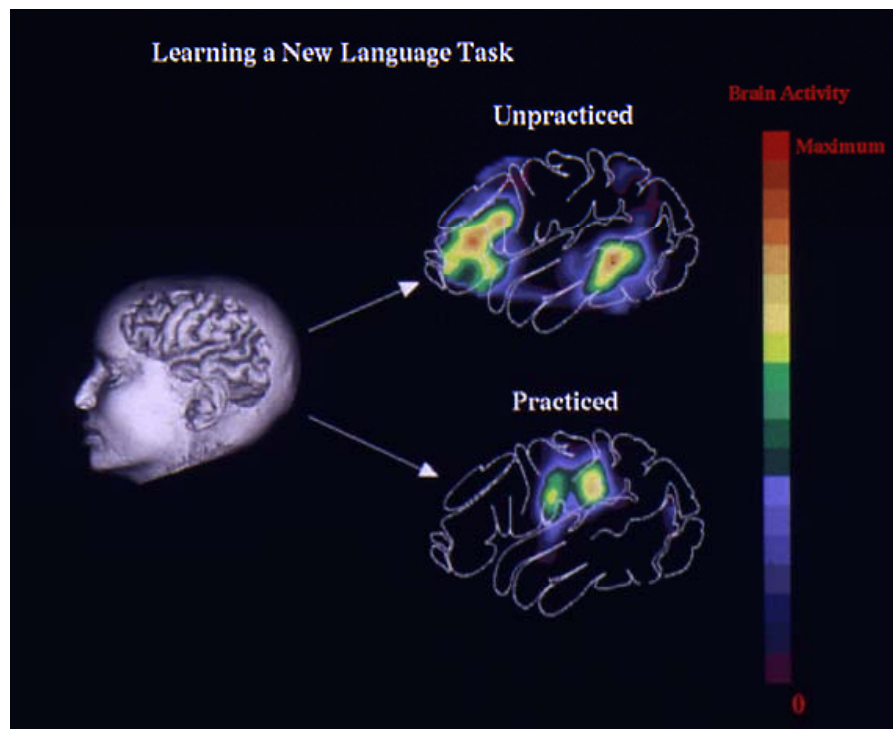
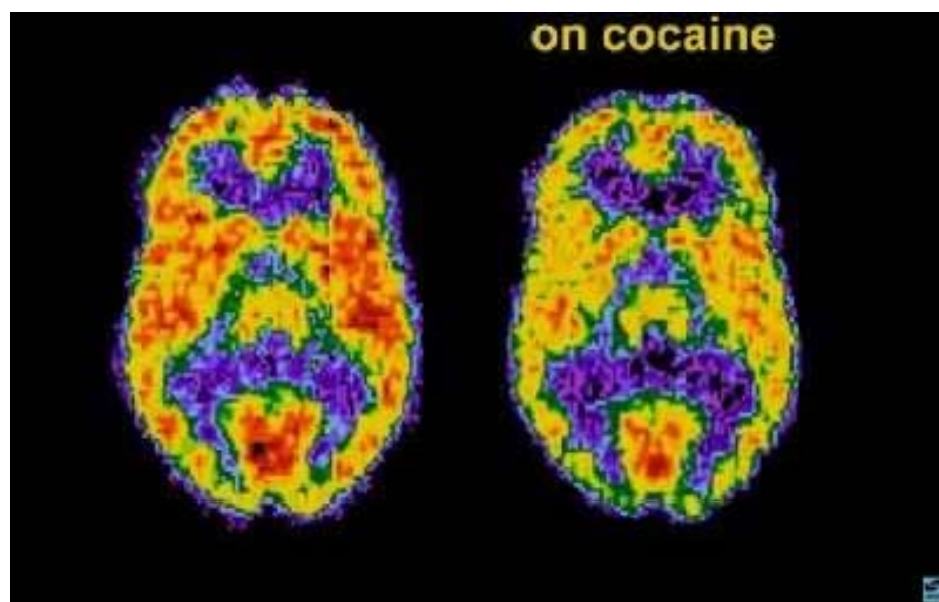
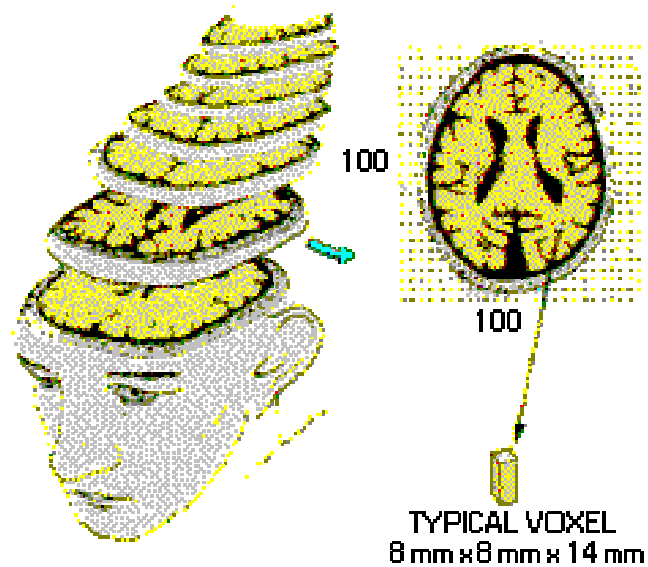
## 2-fluoro-2-deoxy-D-glucose "FDG"





# PET – variazioni di flusso o del metabolismo energetico

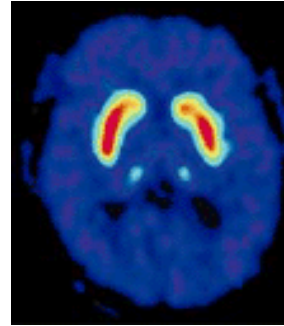
## Typical “Slice”



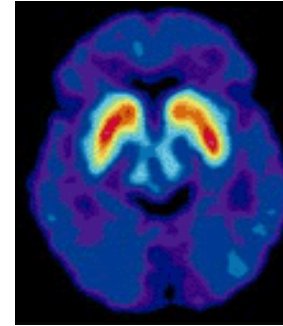
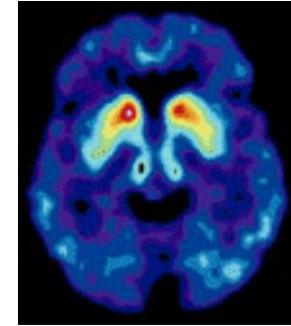
# PET – localizzazione di sostanze

## Analisi funzionale molecolare

individuo normale



paziente parkinsoniano



prima del trapianto

un anno dopo il trapianto

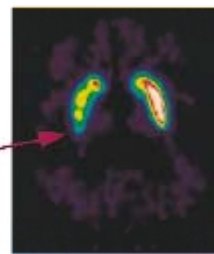
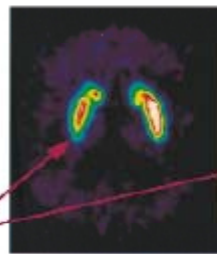
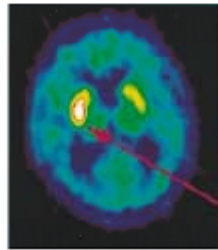
[<sup>18</sup>F]-Dopa

[<sup>11</sup>C]-Raclopride

saline

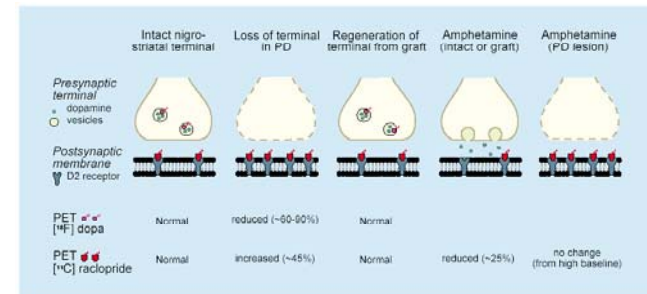
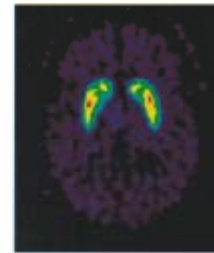
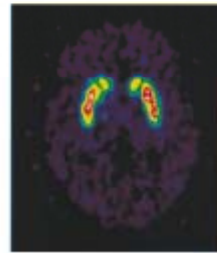
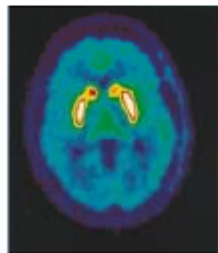
methamphetamine

PD patient



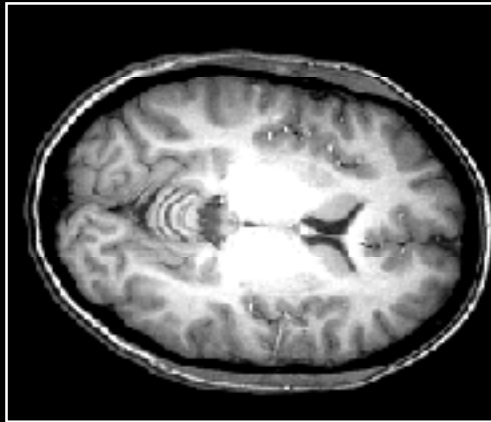
graft

Normal subject



# MRI vs. fMRI

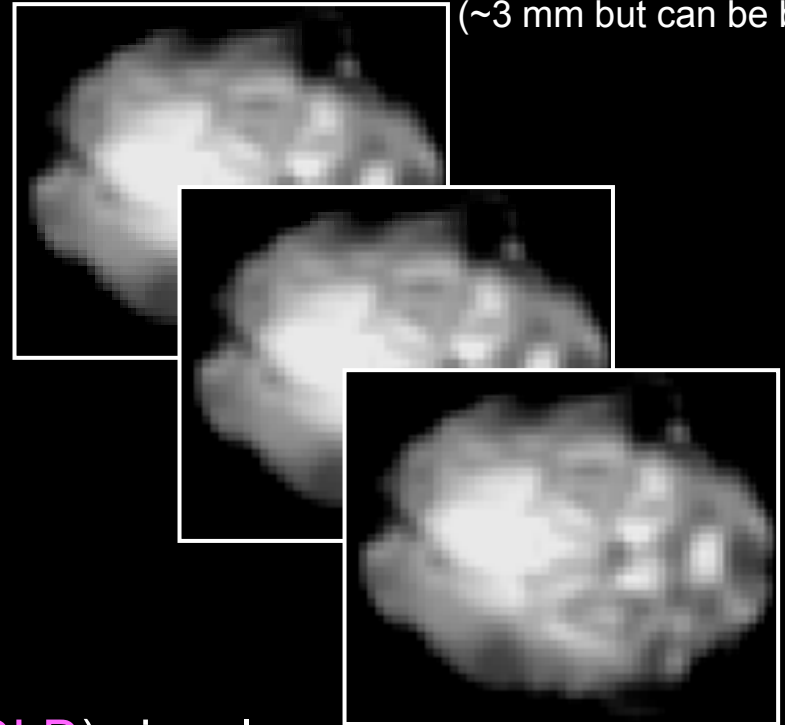
high resolution  
(1 mm)



one image

low resolution

(~3 mm but can be better)



many images

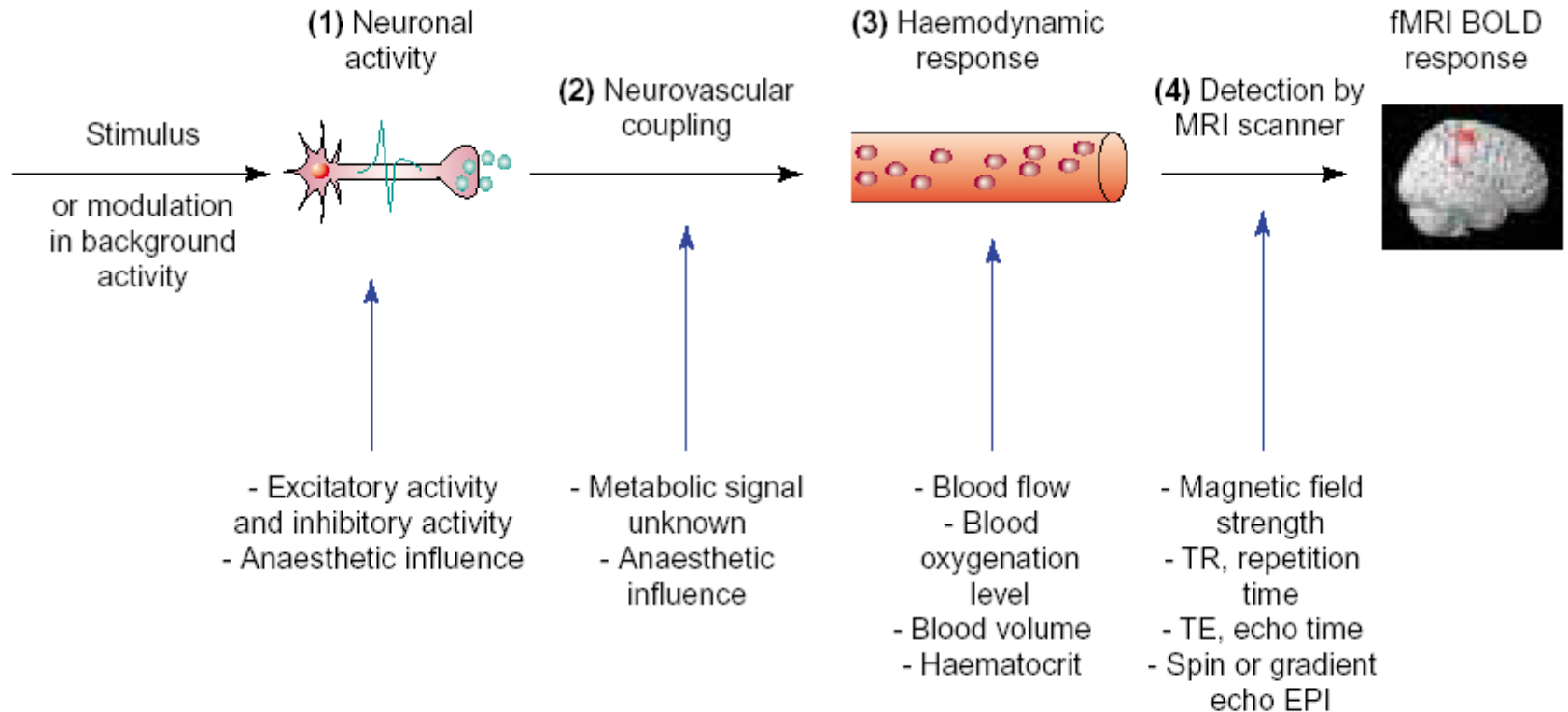
(e.g., every 2 sec for 5 min)

fMRI  
Blood Oxygenation Level Dependent (BOLD) signal  
indirect measure of neural activity

↑ neural activity → ↑ blood oxygen → ↑ fMRI signal

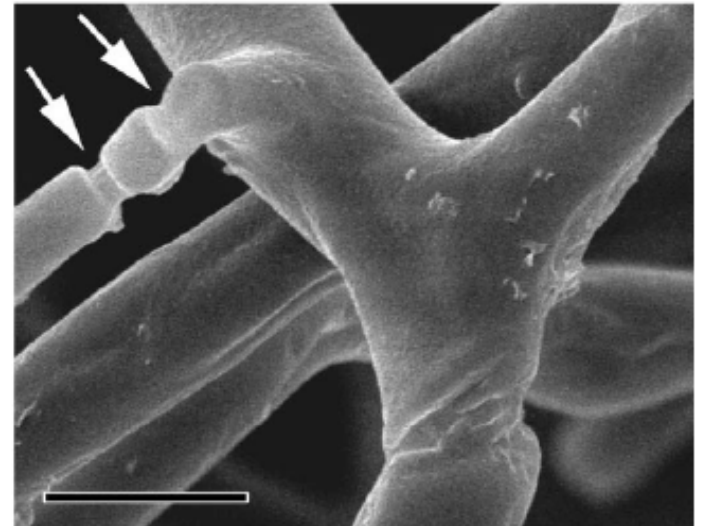
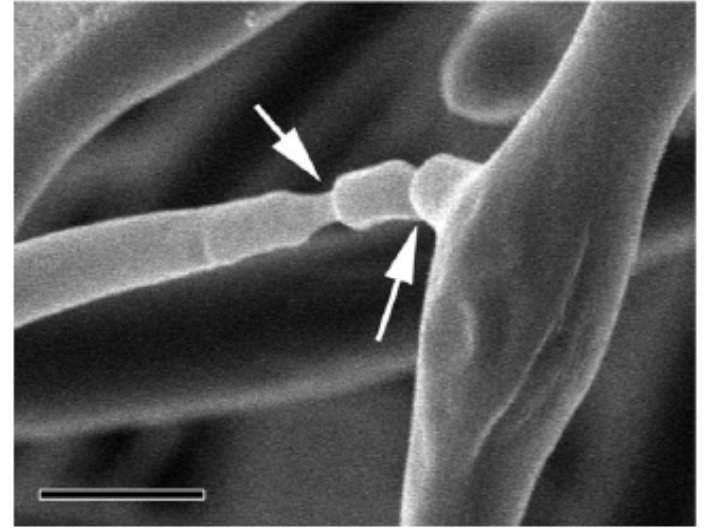
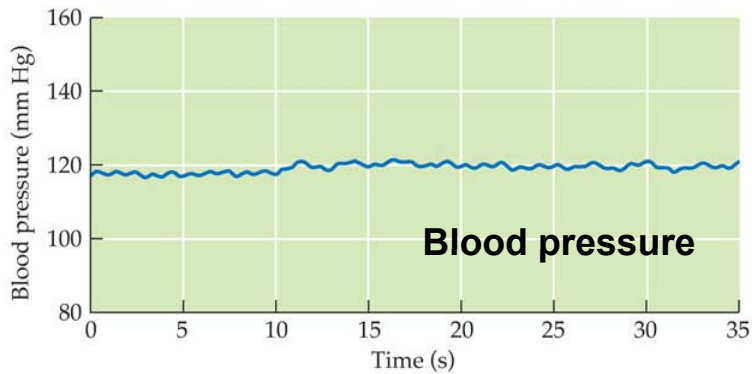
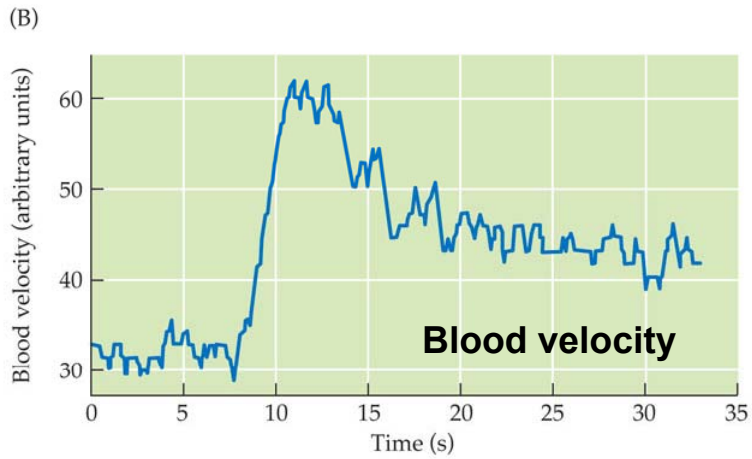
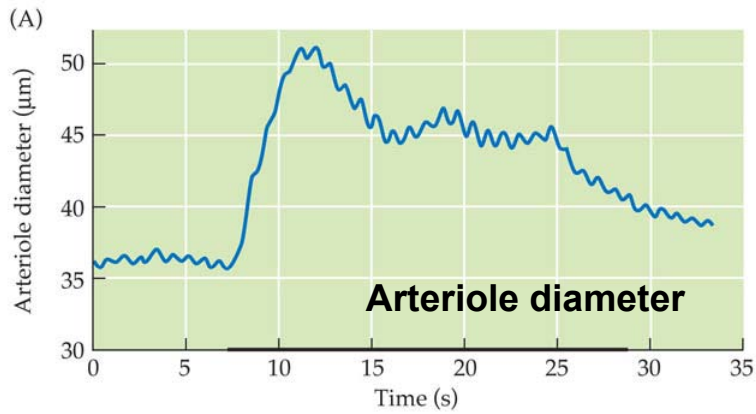


# Stimulus to BOLD

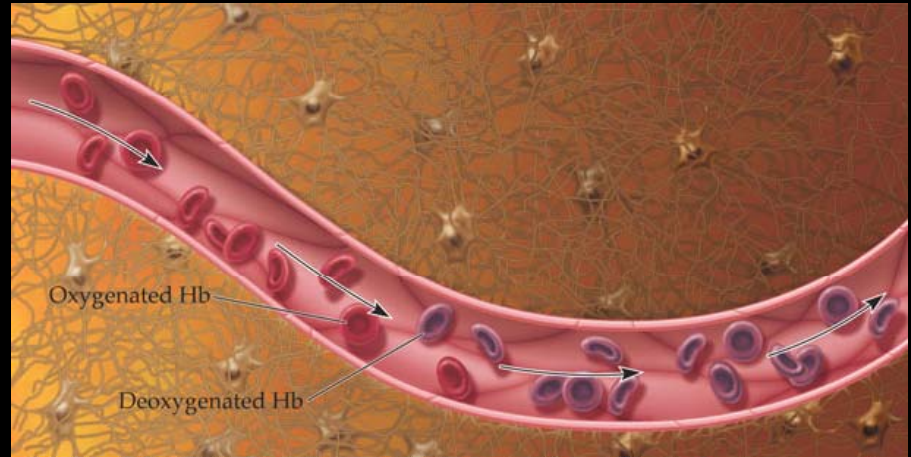
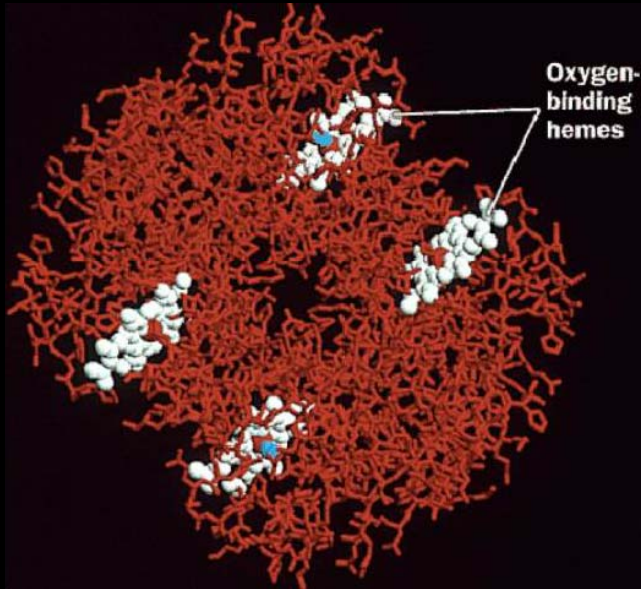




## sensory stimulation leads to increased blood flow

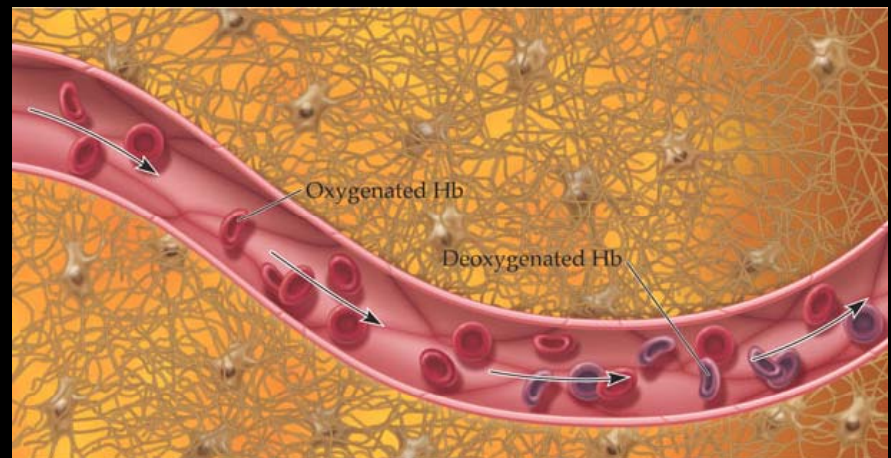


# Hemoglobin



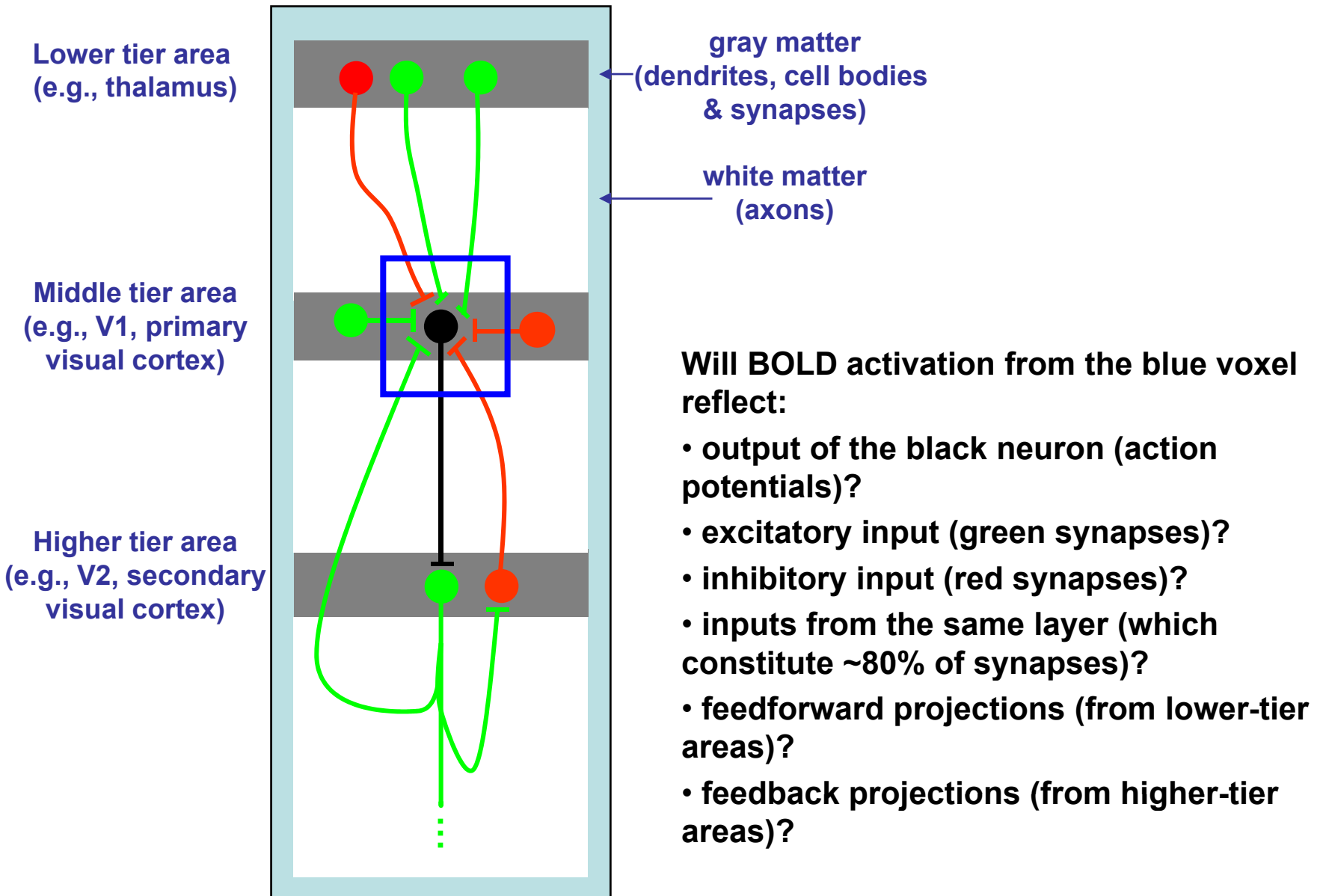
**riposo**

**Lo stato di ossigenazione dell'Emoglobina ne modifica le proprietà paramagnetiche e quindi il segnale MRI**

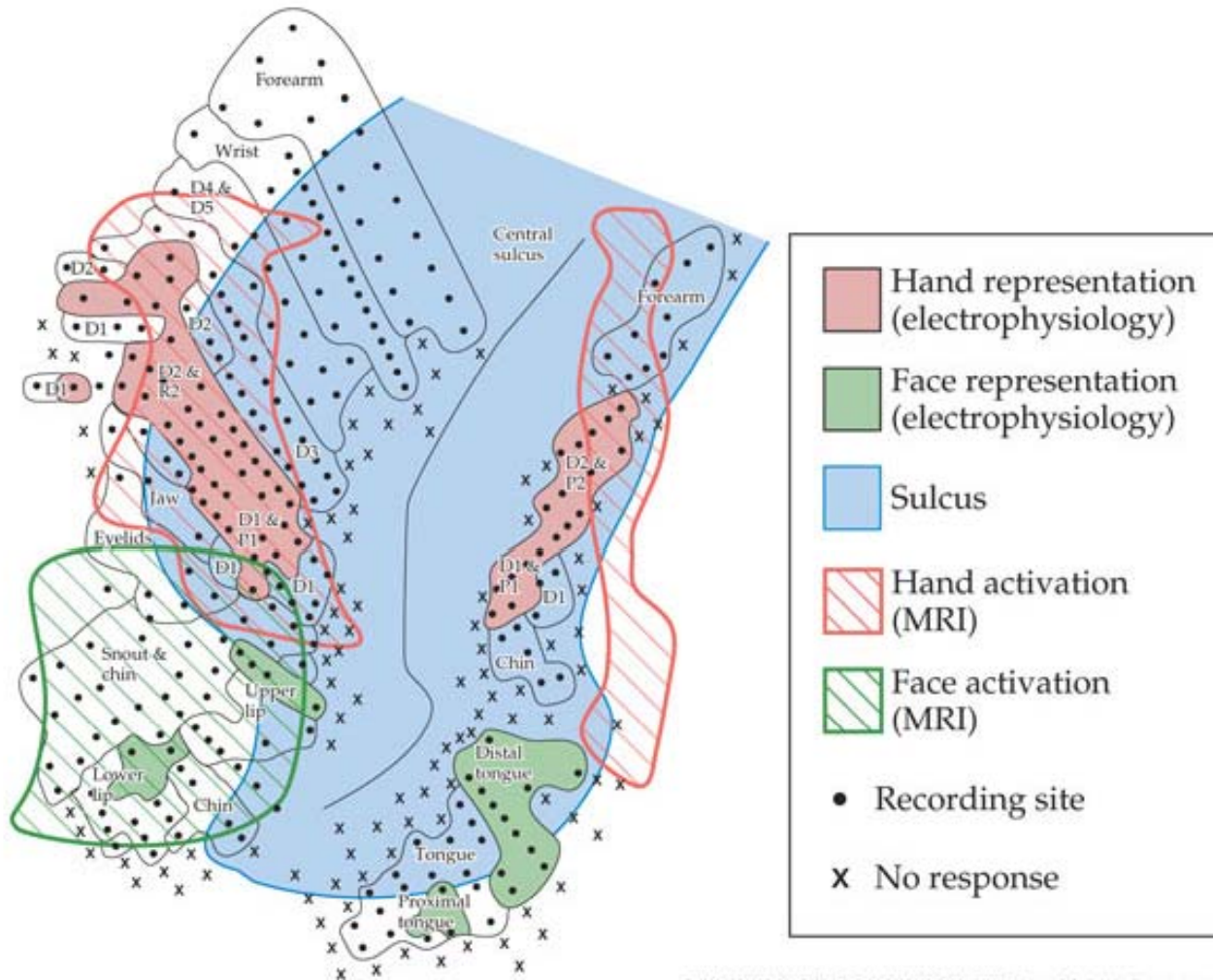


**attivo**

# Even Simple Circuits Aren't Simple



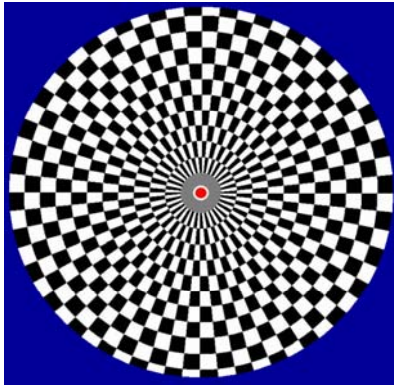
# Comparing Electrophysiology and BOLD



FUNCTIONAL MAGNETIC RESONANCE IMAGING, Figure 8.4 © 2004 Sinauer Associates, Inc.

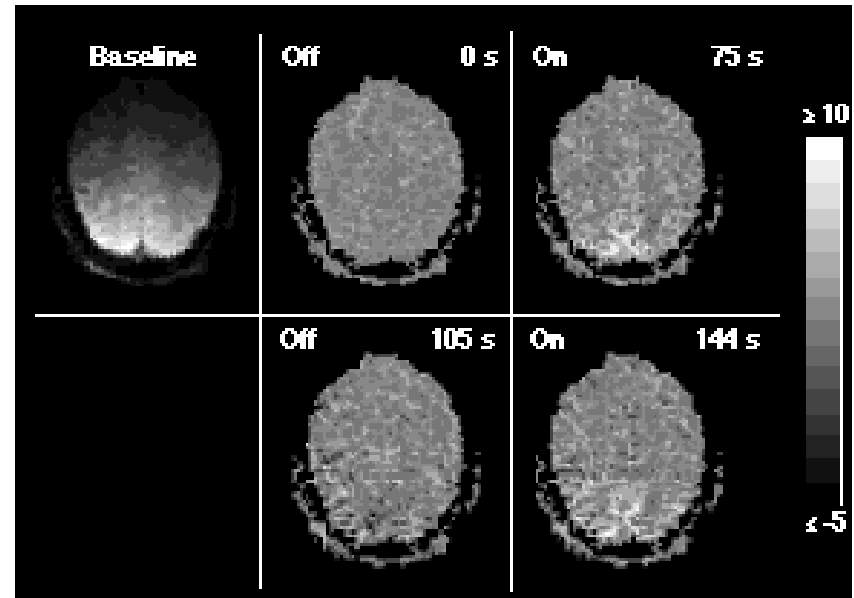
Logothetis et al. (2001) combined BOLD fMRI and electrophysiological recordings; found that BOLD activity is more closely related to local field potentials (EEG) than multiple unit activity (MUA)

# fMRI Activation

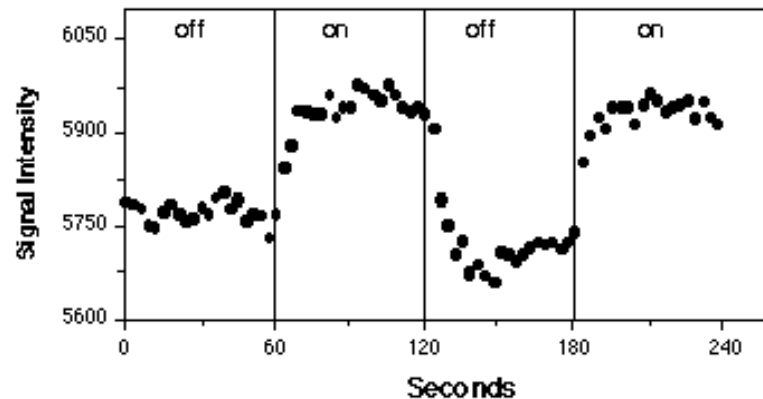


**Flickering Checkerboard**

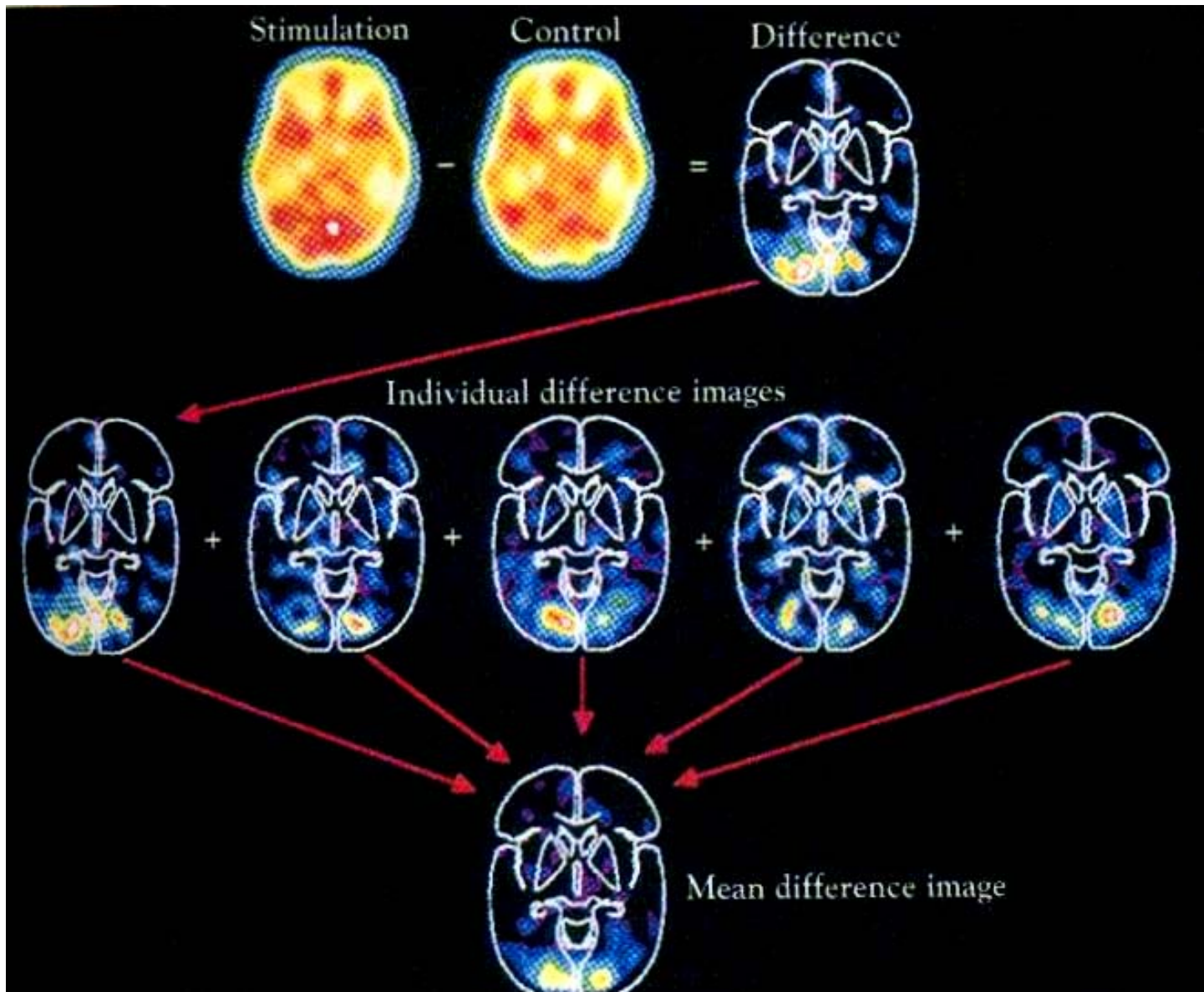
OFF (60 s) - ON (60 s) - OFF (60 s) - ON (60 s) - OFF (60 s)  
stimolo



**Brain  
Activity**

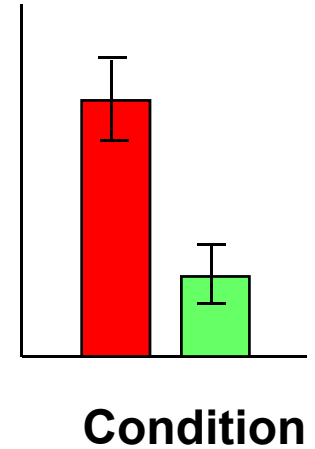
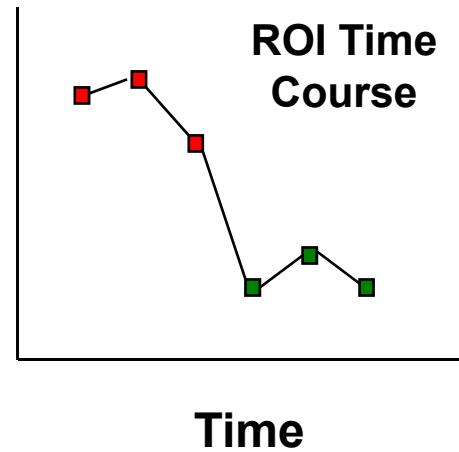
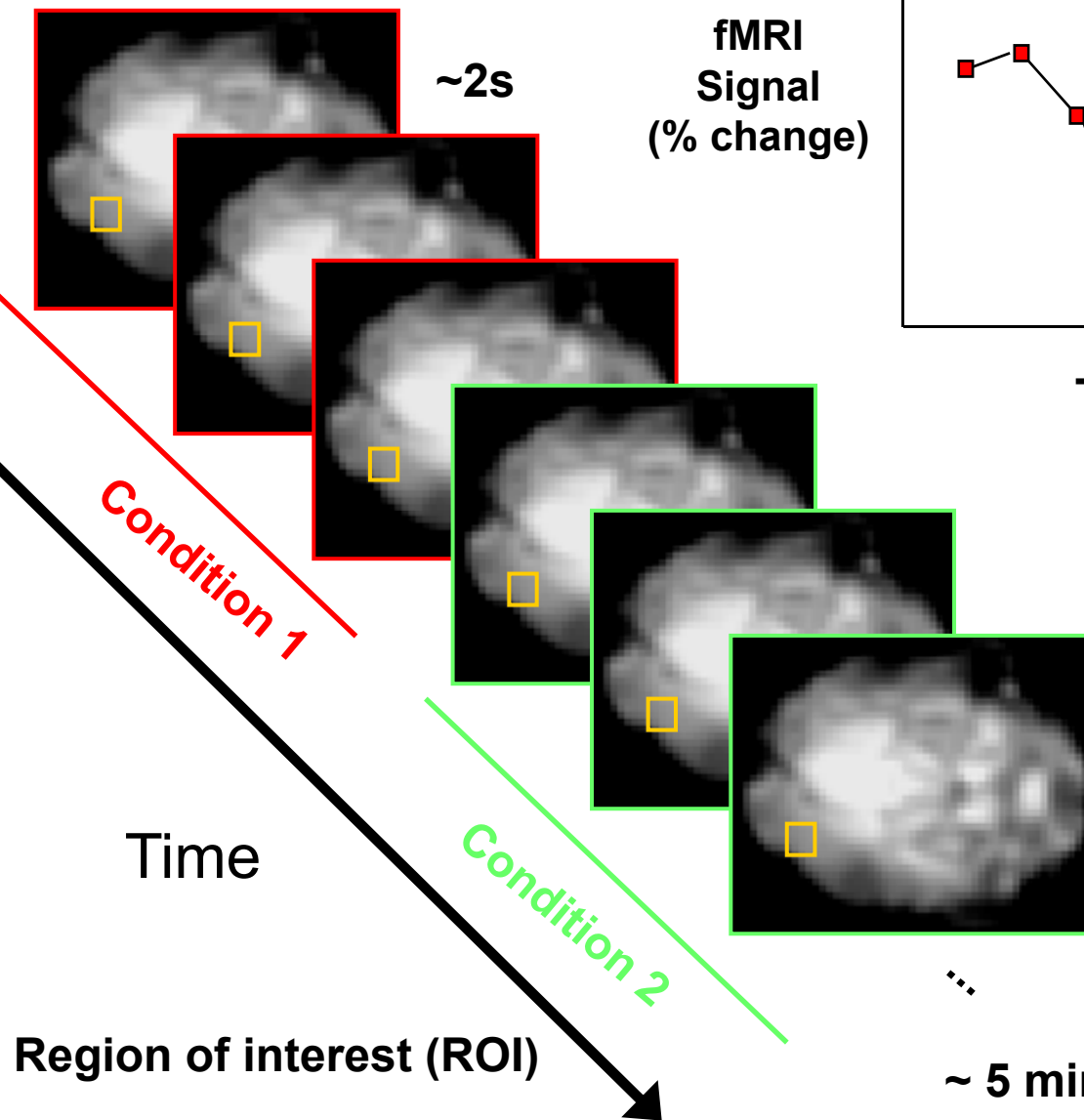


# PET and fMRI Activation

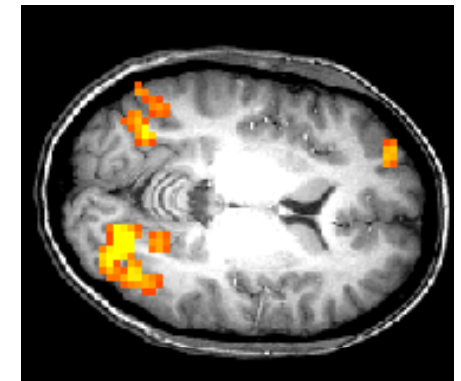


# Activation Statistics

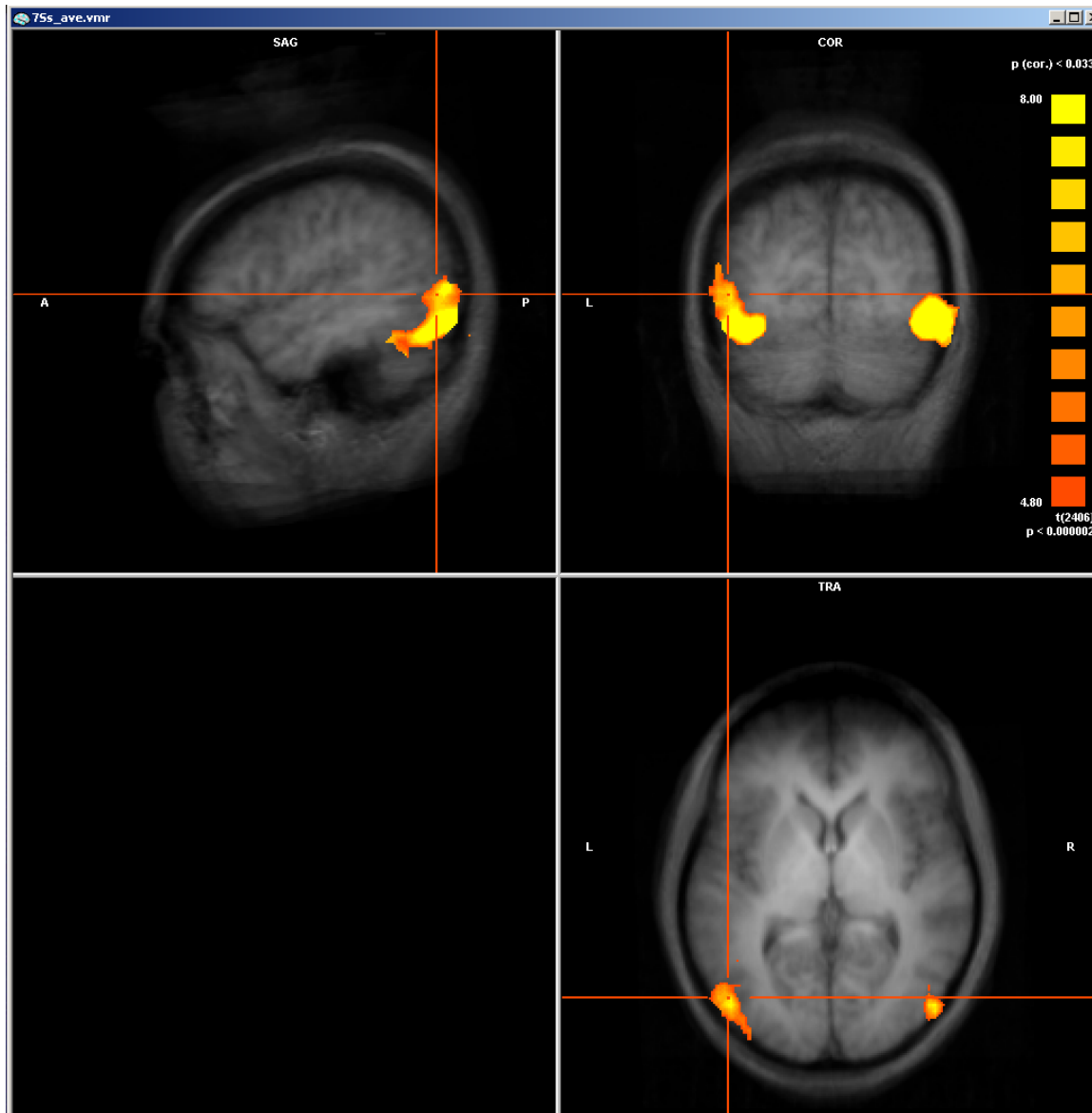
## Functional images



**Statistical Map**  
superimposed on  
anatomical MRI image

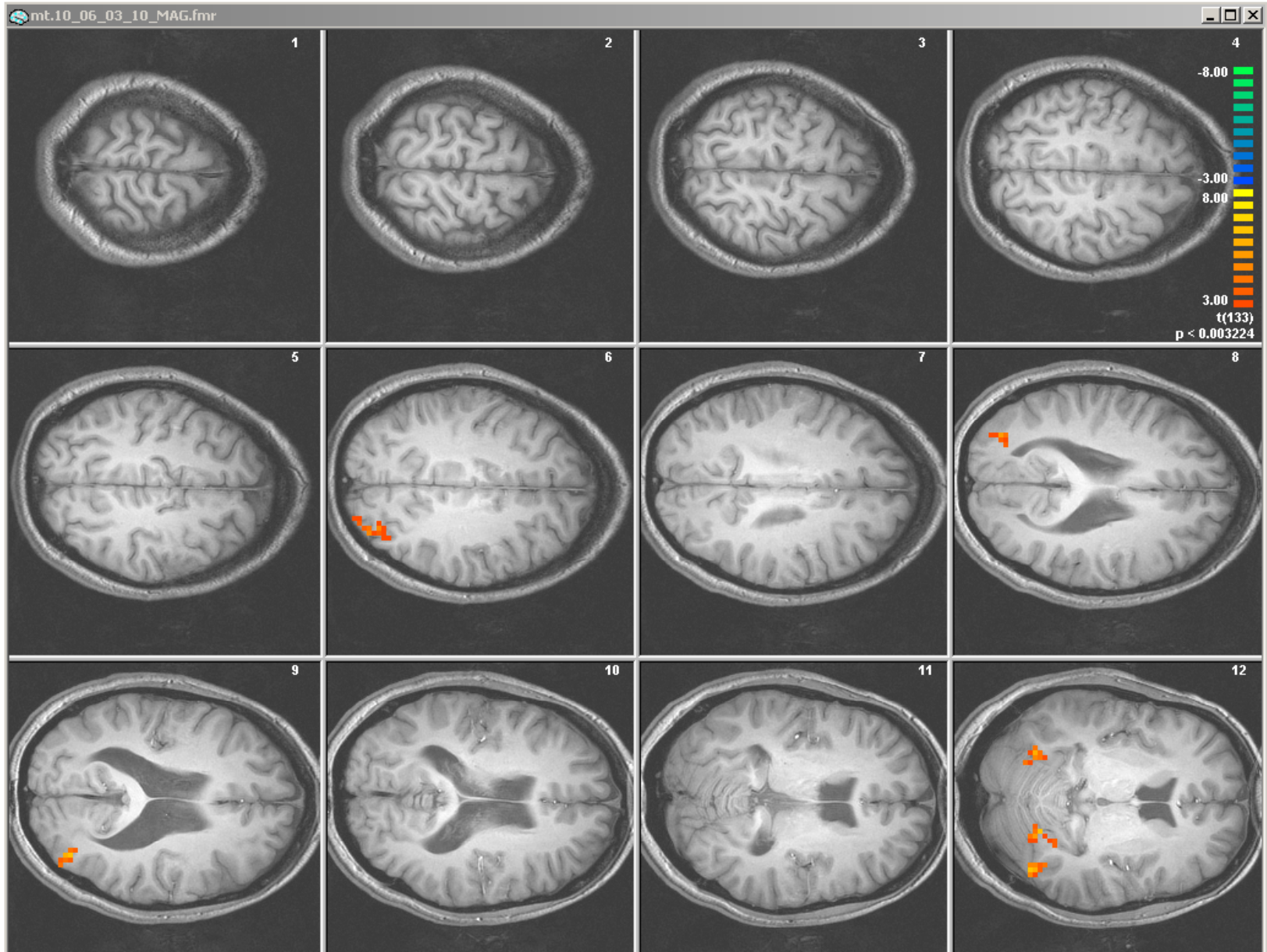


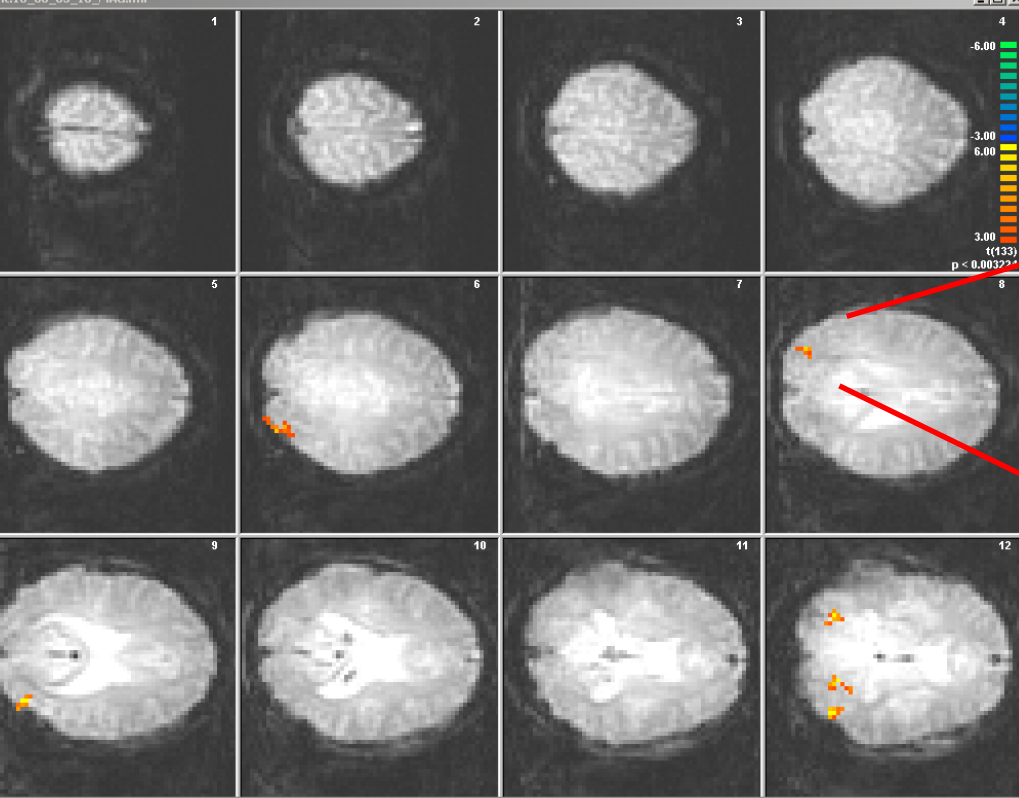
# Averaging



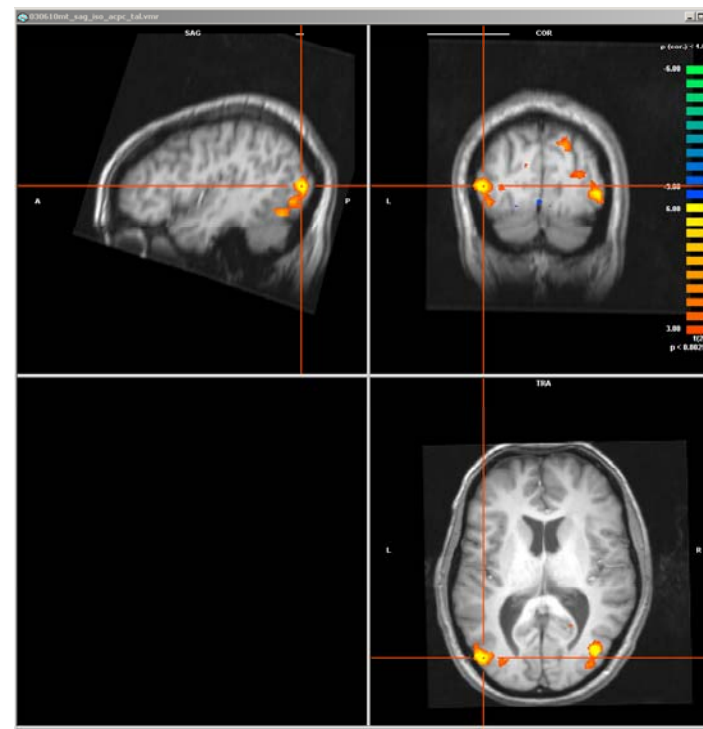
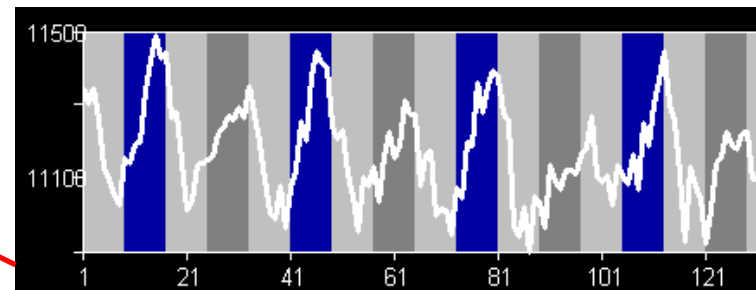


# Statistical map on anatomical map

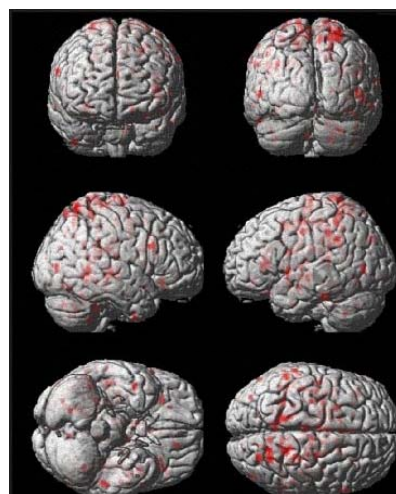




# Statistical Maps & Time Courses



2D → 3D



# fMRI

**Acquisizioni multiple**

**Differenza esperimento-controllo**

**Averaging**

**Localizzazione - mappa statistica (bassa risoluzione)  
sovrapposta a mappa anatomica (alta risoluzione)**

**2D – 3D**

**Time course**

# Tomografia Assiale Computerizzata - TAC

