

Modeling cortical activity: cortical columns

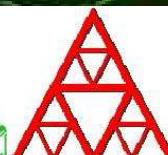
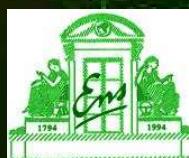
Séminaire ADSTIC

11 avril 2006

François Grimbert

Dir.: Olivier Faugeras

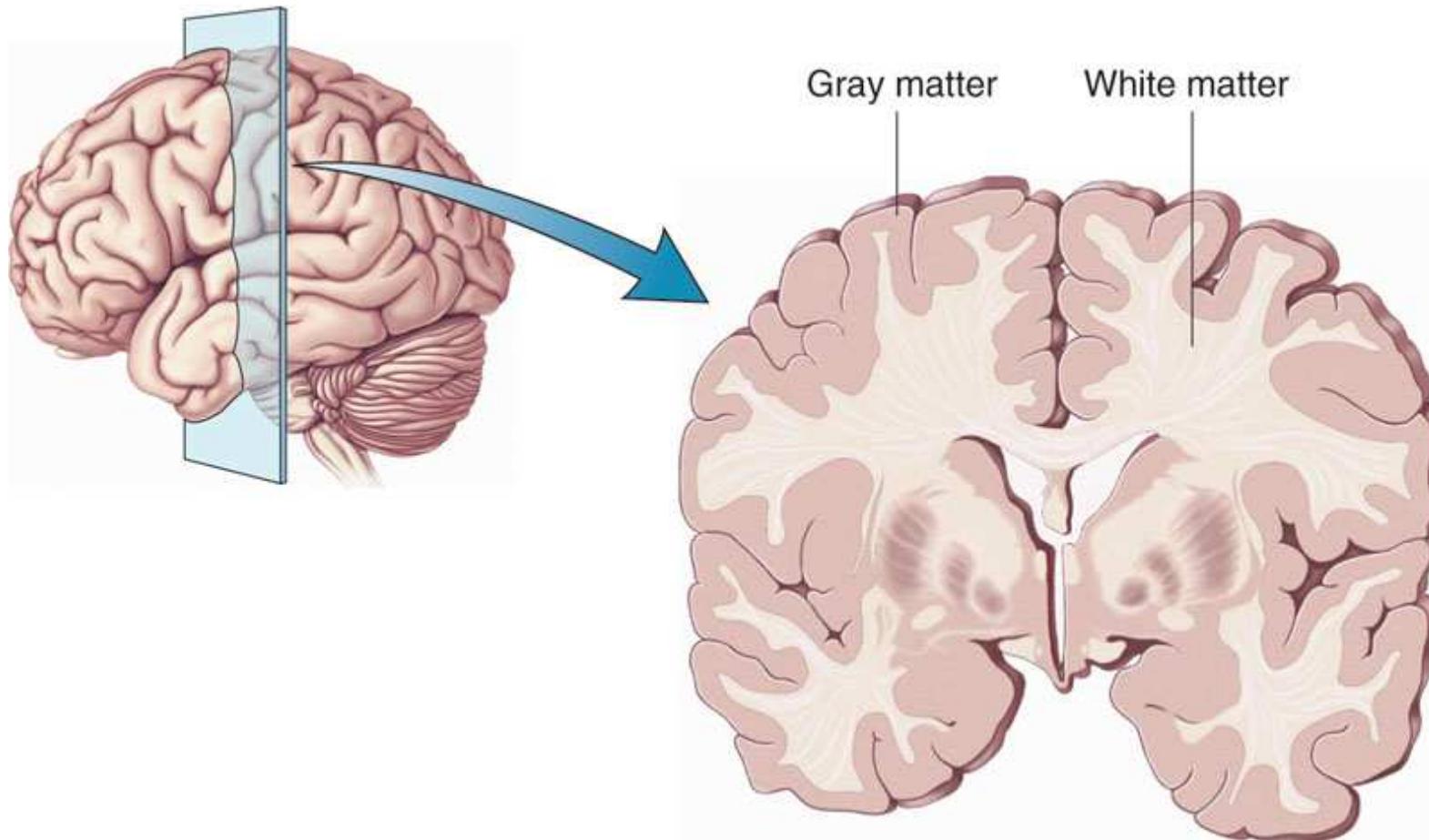
Projet Odyssée





Introduction

Cortex = gray matter

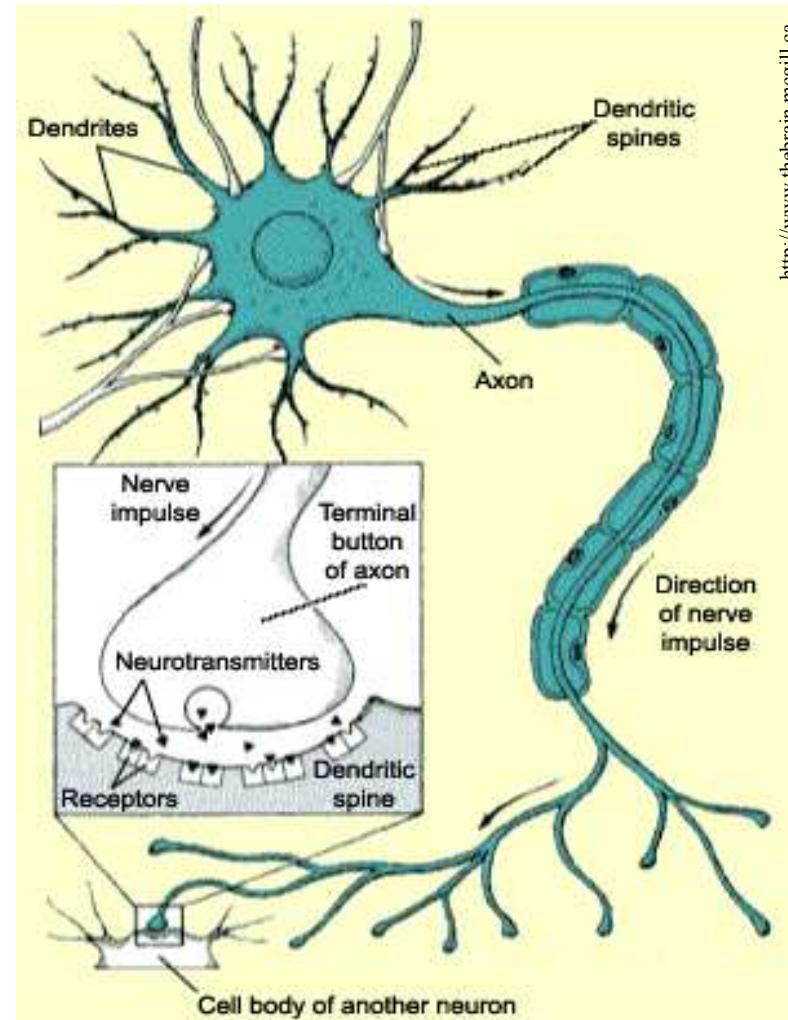


Gray Matter / White Matter

- Gray matter is a folded sheet of neurons (thickness: 2-4 mm).
- White matter contains the myelinated axons of neurons in gray matter.

Neurons

- Neurons receive input via their dendrites.
- They send output via their axon.
- Connexion is made by synapses where neurotransmitters are released.

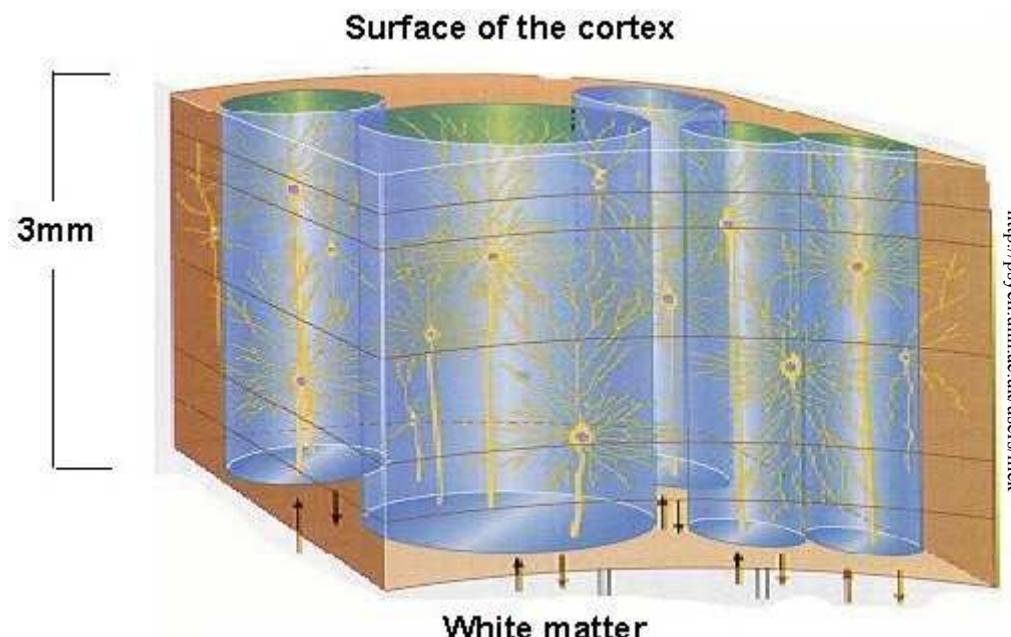


<http://www.thebrain.mcgill.ca>

Cortical columns

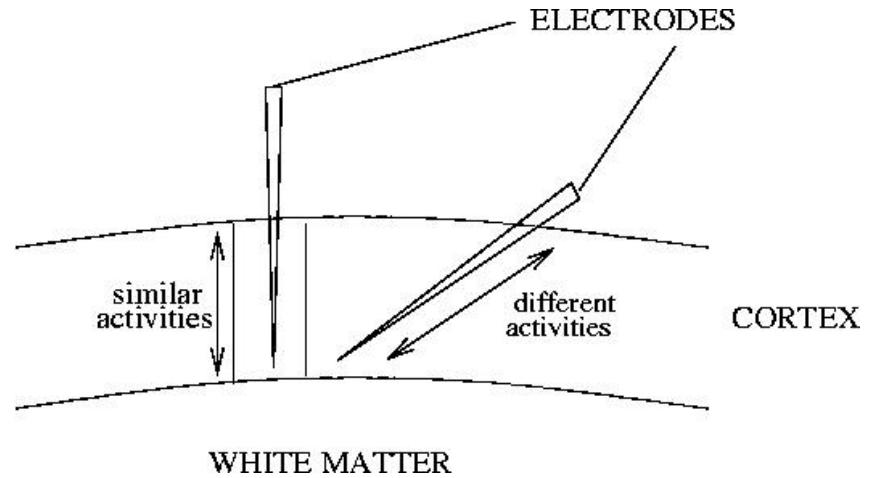
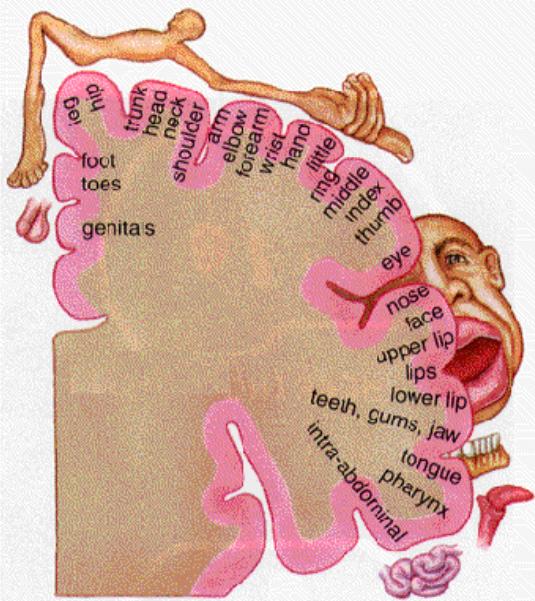
Cortical column?

- A small cylinder running across the depth of the cortex, with a diameter of 0.3-0.5 mm, containing about 10^5 neurons.



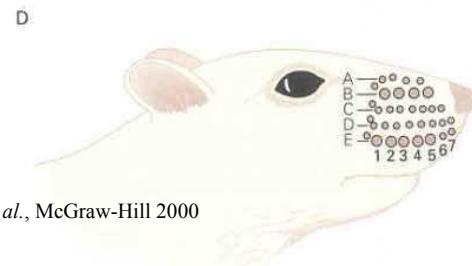
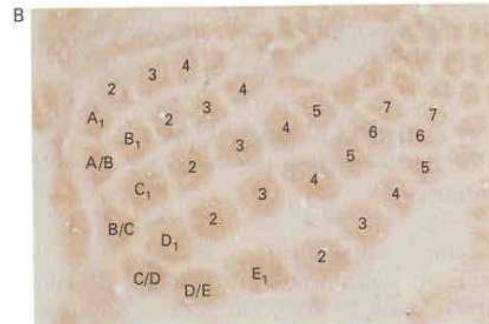
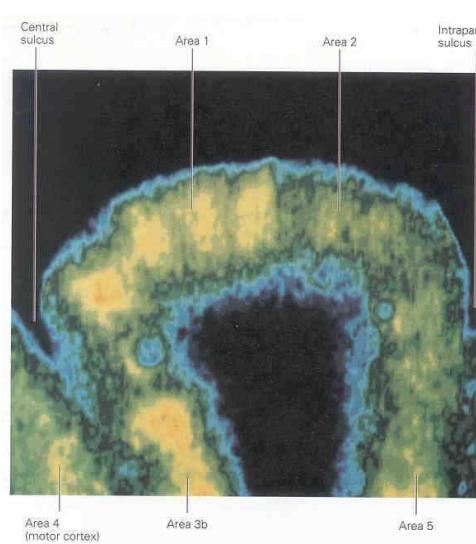
The discovery of cortical columns

Brown & Benchmark Introductory Psychology Electronic Image Bank copyright © 1995 Times Mirror Higher Education Group, Inc

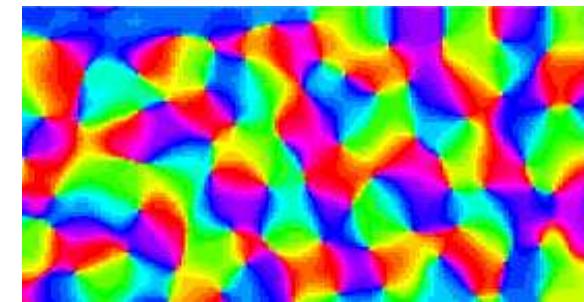


In 1957, Mountcastle discovers cortical columns from experiments on the somatotopy of the monkey.

Cortical columns as functional ensembles



From *Principles of Neural Science*, Kandel et al., McGraw-Hill 2000



Grinvald,
Weizmann Institute of Science

Problem: what spatial extension (discrete or continuous?) and what connectivity between columns?

Why modeling the brain by CCs?

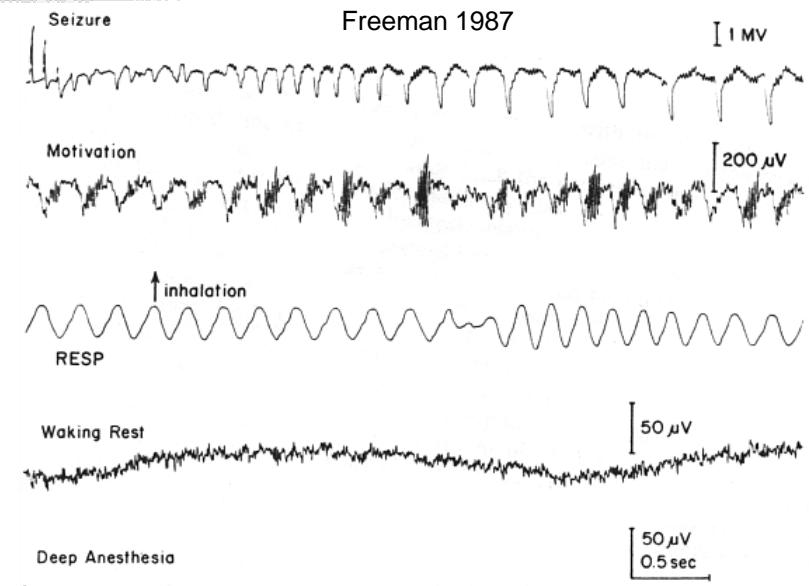
- Modeling the brain at the scale of the neuron is impossible (complexity, lack of information and technology).
- CC level is more appropriate to the resolution of measurement devices: EEG, MEG, MRI.
- Columns can be labeled by functions: cognitive and medical issues (epilepsy, vision, fingers...)



The goal is to understand MEEG signals:
origin and meaning

EEG and MEG

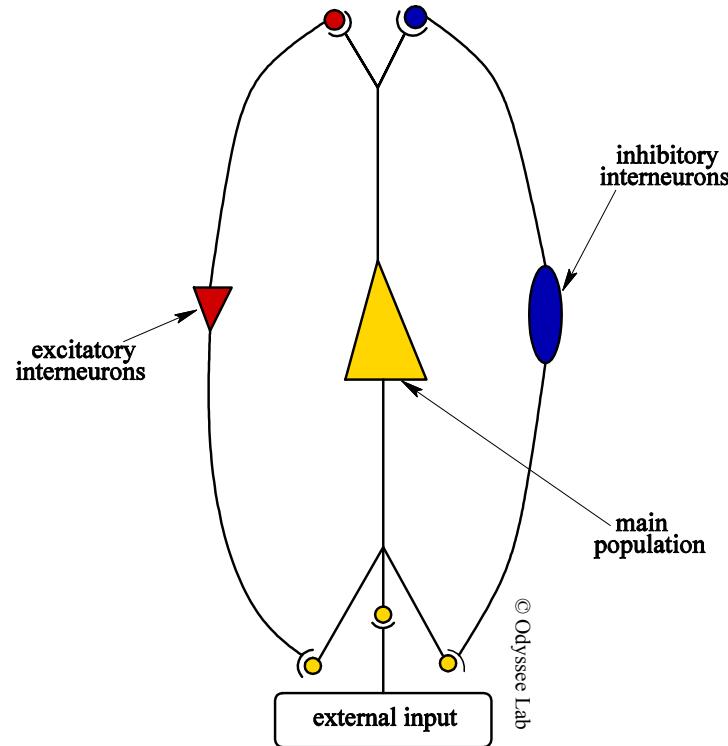
- EEG records the potential of the cortex through electrodes (deep or surface).
 - MEG records the currents in the cortex by magnetic induction.



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A model of CC

Model example: Jansen's neural masses model

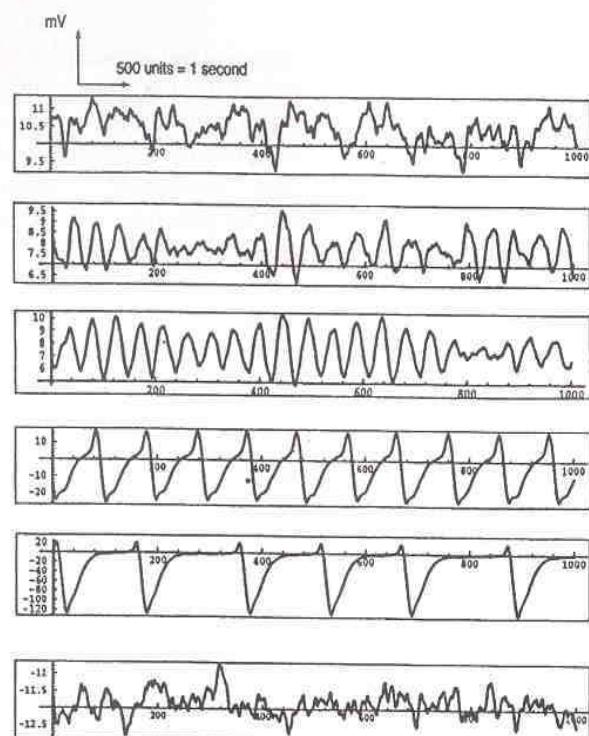


$$\begin{cases} y_0(t) = y_3(t) \\ y_3(t) = Aa\text{Sigm}[y_1(t) - y_2(t)] - 2ay_3(t) - a^2y_0(t) \\ y_1(t) = y_4(t) \\ y_4(t) = Aa\{p(t) + C_2\text{Sigm}[C_1y_0(t)]\} - 2ay_4(t) - a^2y_1(t) \\ y_2(t) = y_5(t) \\ y_5(t) = BbC_4\text{Sigm}[C_3y_0(t)] - 2by_5(t) - b^2y_2(t) \end{cases}$$

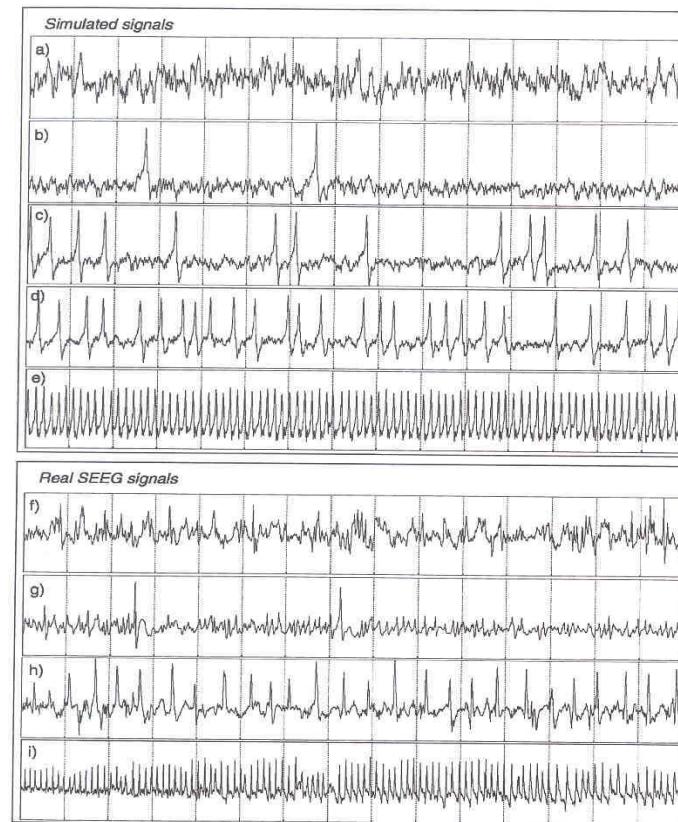
$y_1 - y_2$ is the electromagnetic activity of the cortical column
= synaptic activity of pyramidal neurons
= the signal recorded by MEEG

Activities Jansen's model can display

Alpha, beta,... activities, epilepsy seizures...



Jansen and Rit 95



Wendling, Bellanger et al. 00



Our work

We made a lot of mathematics...

- We made a mathematical analysis of Jansen's model (bifurcation theory) to understand how it can produce different activities.
- We are solving equations for a continuum of CCs and want to compare the results to real large scale recordings of cortical activity.

We need biology and validation

- We want to discuss with biologists more realistic models of one CC.
- We want to understand how CCs are connected.
- We will try to validate our work with MEG experimentations in Marseille.



THANK YOU!