Brain Dynamics on the Connectome
Sinergia Summerschool 2021

UNIVERSITÉ DE GENÈVE
FACULTÉ DE MÉDECINE

HUG Hôpitaux Universitaires Genève

# Lecture 1.3
# EEG basics

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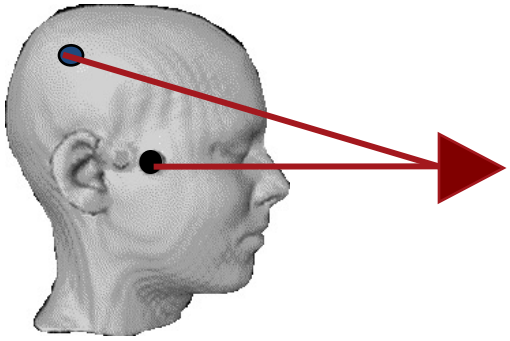
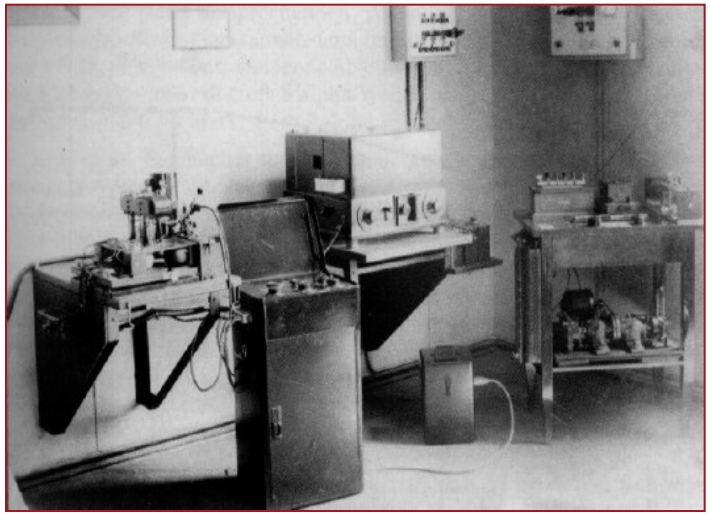
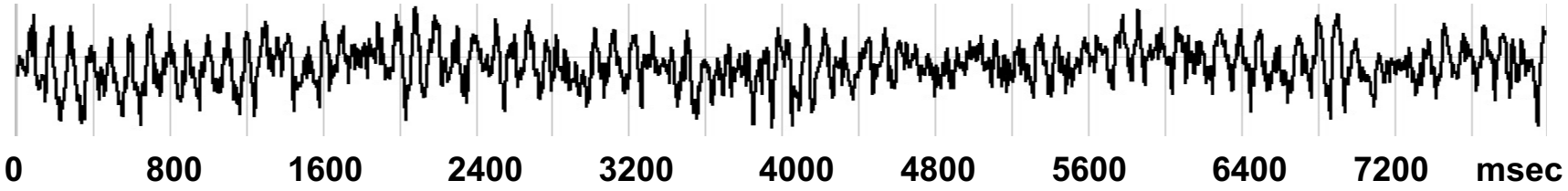
Service de Neurologie HUG

# Electroencephalography (EEG)





**Hans Berger (1926)**




Rythme alpha

# Applications ?

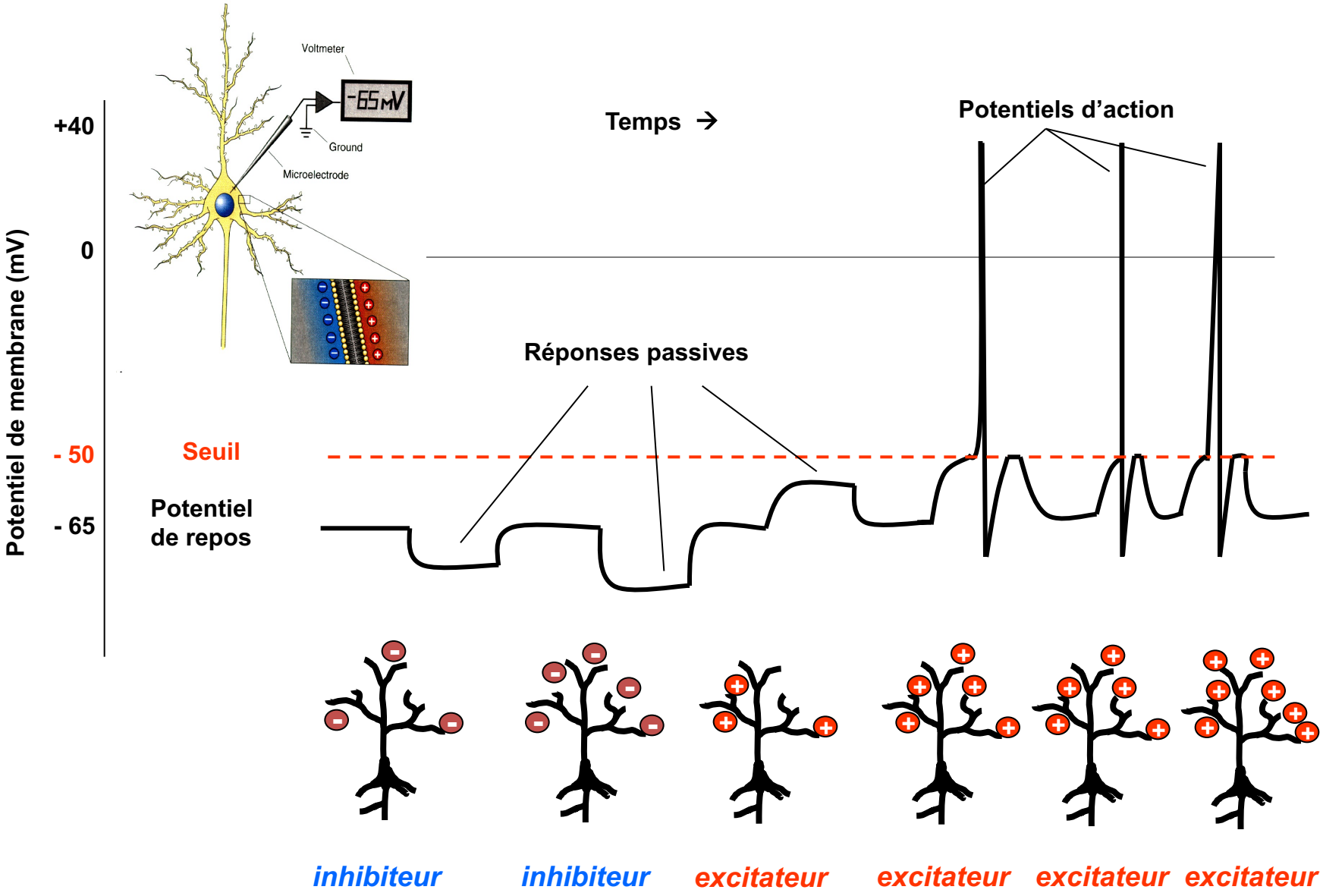
**Clinical diagnosis, monitoring and prognosis**

- Epilepsy
- Sleep disorders
- Coma
- Cognitive disorders

**Brain mapping tool (”resting state”, tasks) :**

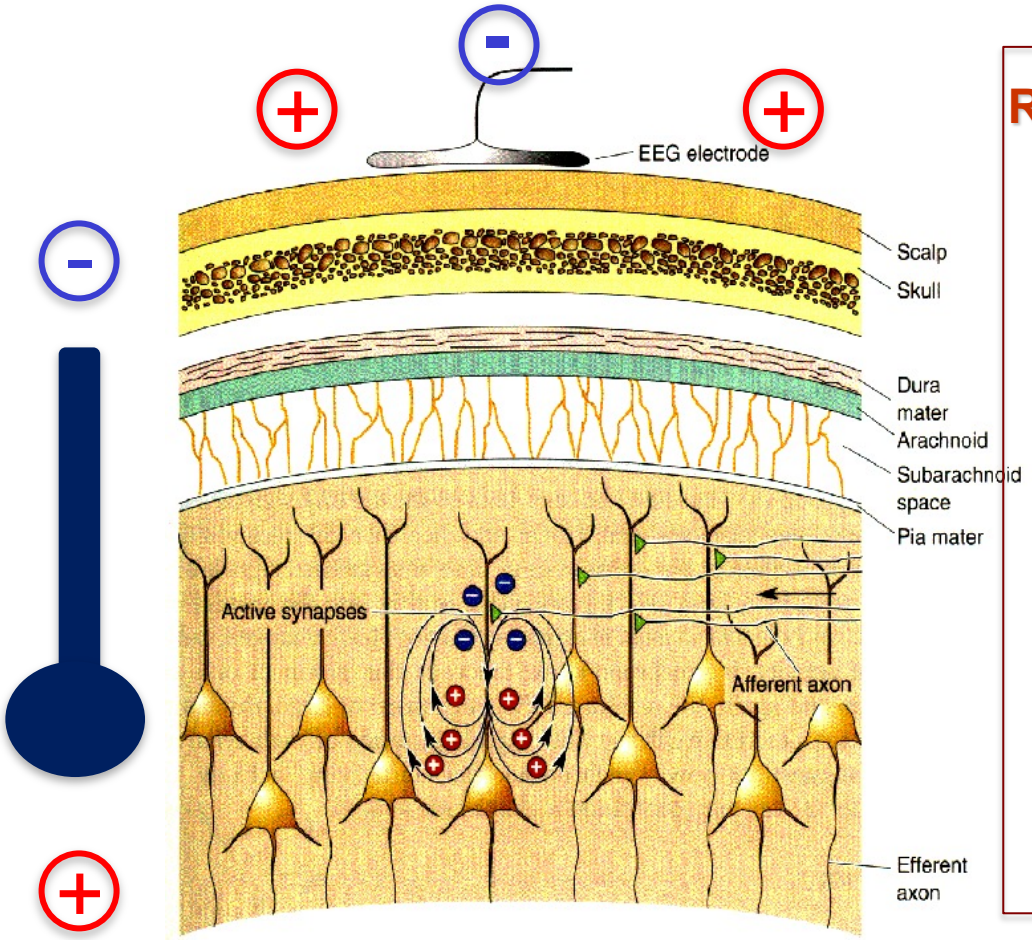
- High temporal resolution → brain dynamics
- no irradiation, repeatable, long duration possible

# Single cell: Action potentials

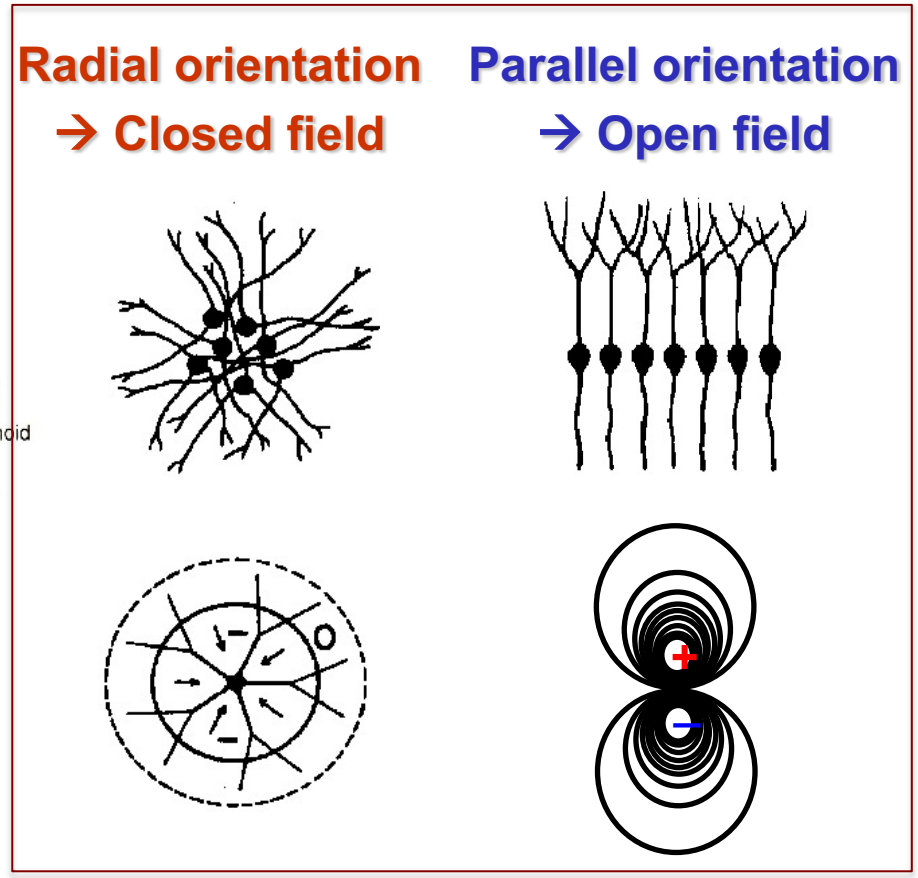


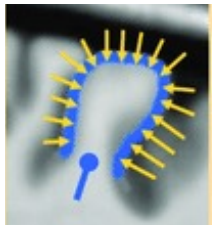
# Scalp EEG recording: extracellular post-synaptic potentials

## Large distance between electrode and neurons




Local dipole model

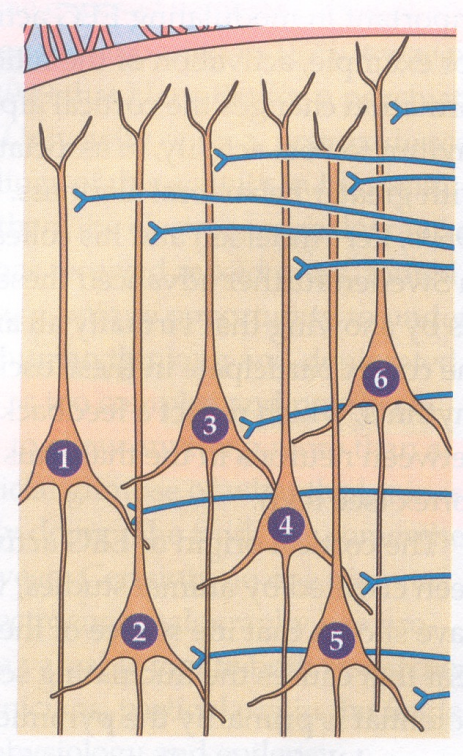


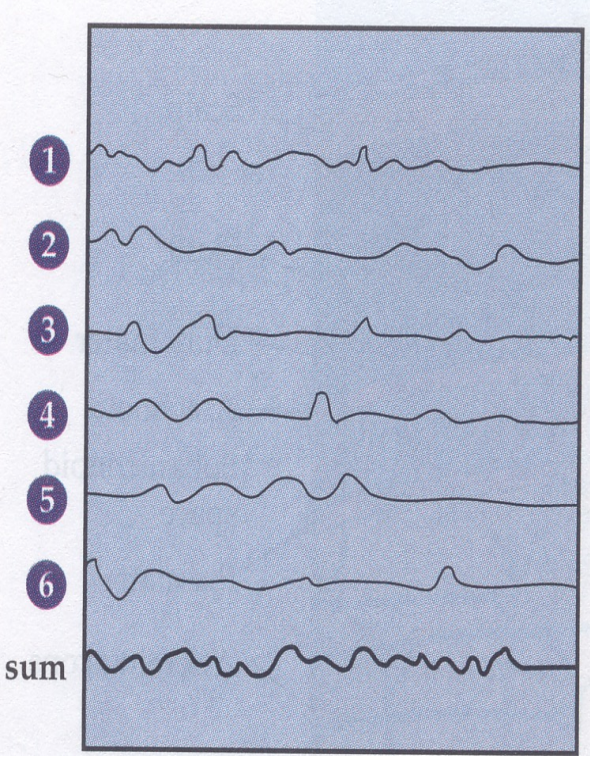



Problem of sulci & subcortical regions

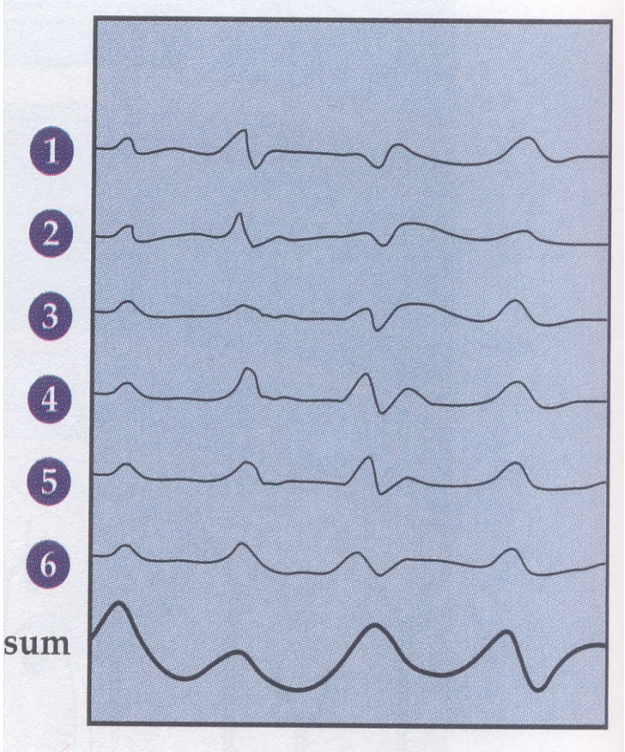
# Neuronal synchrony

Signals must co-exist in time in order to sum up



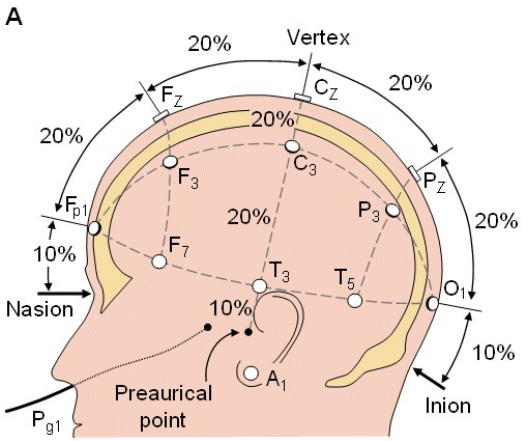

Weak synchronisation
→ irregular signal
→ high frequency
→ low amplitude

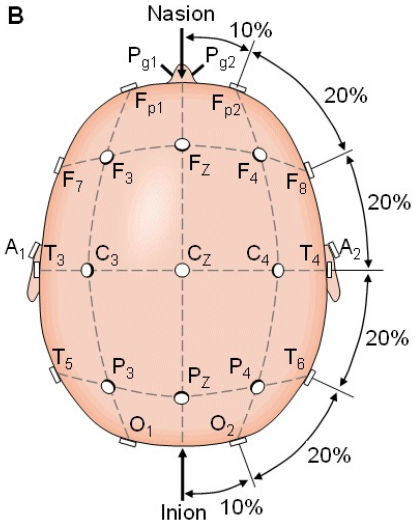


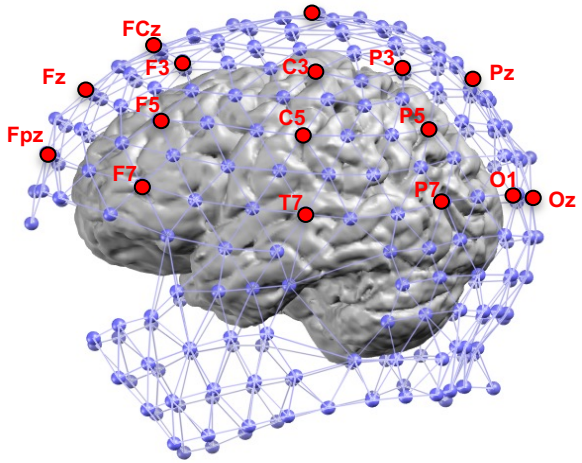

Strong synchronisation
→ regular signal
→ Low frequency
→ high amplitude

# Recording

## Convention for electrode locations: 10-20 International montage



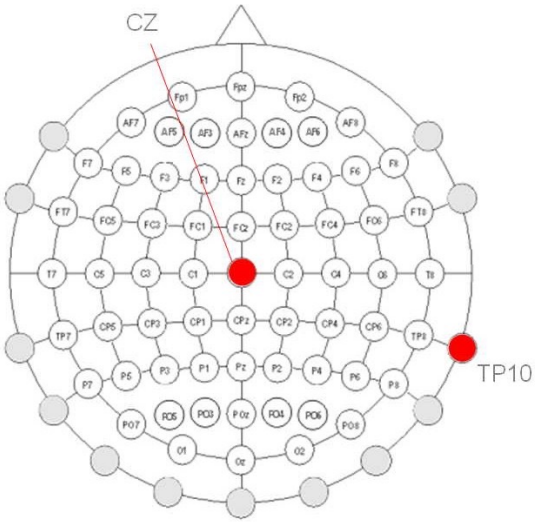




## Different recordings techniques and durations

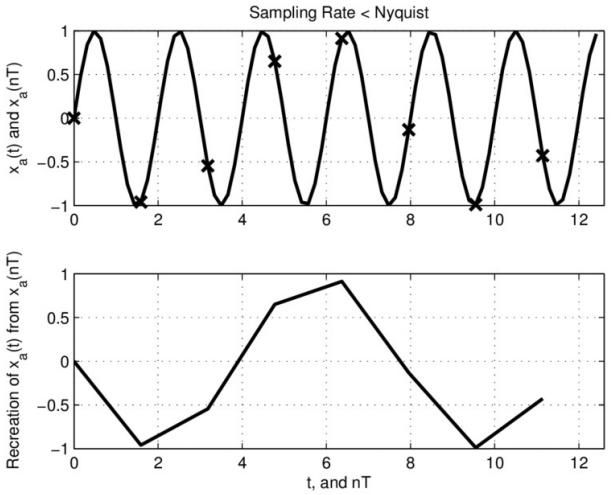
# Recording

Low amplitude signal: → 20-200 microV → AMPLIFICATION
→Low impedance needed (conductive paste/solution)

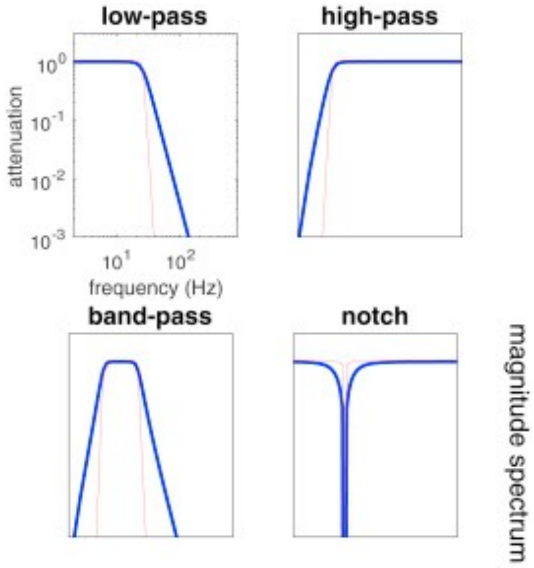
## Recording settings




Reference



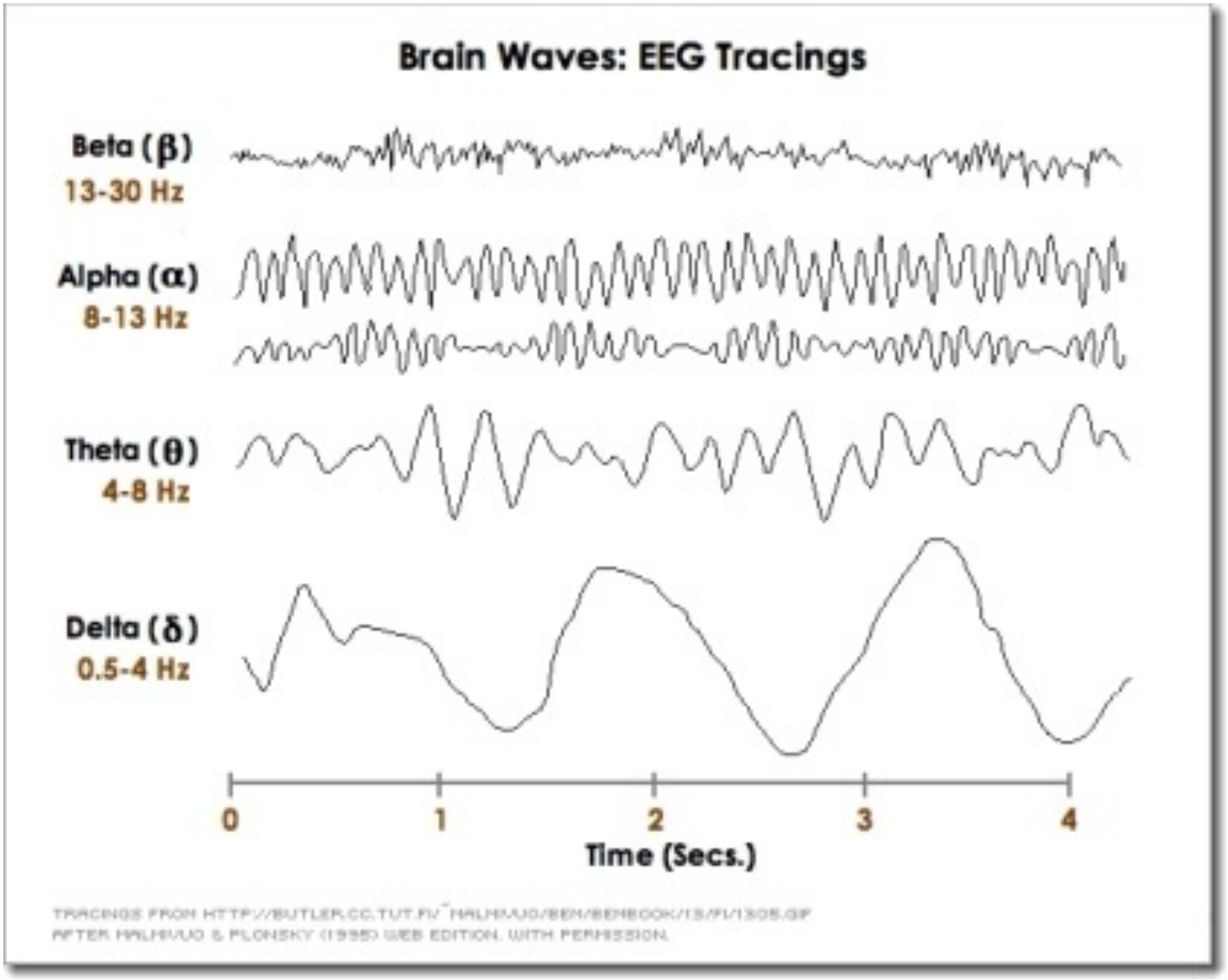

Frequency sampling



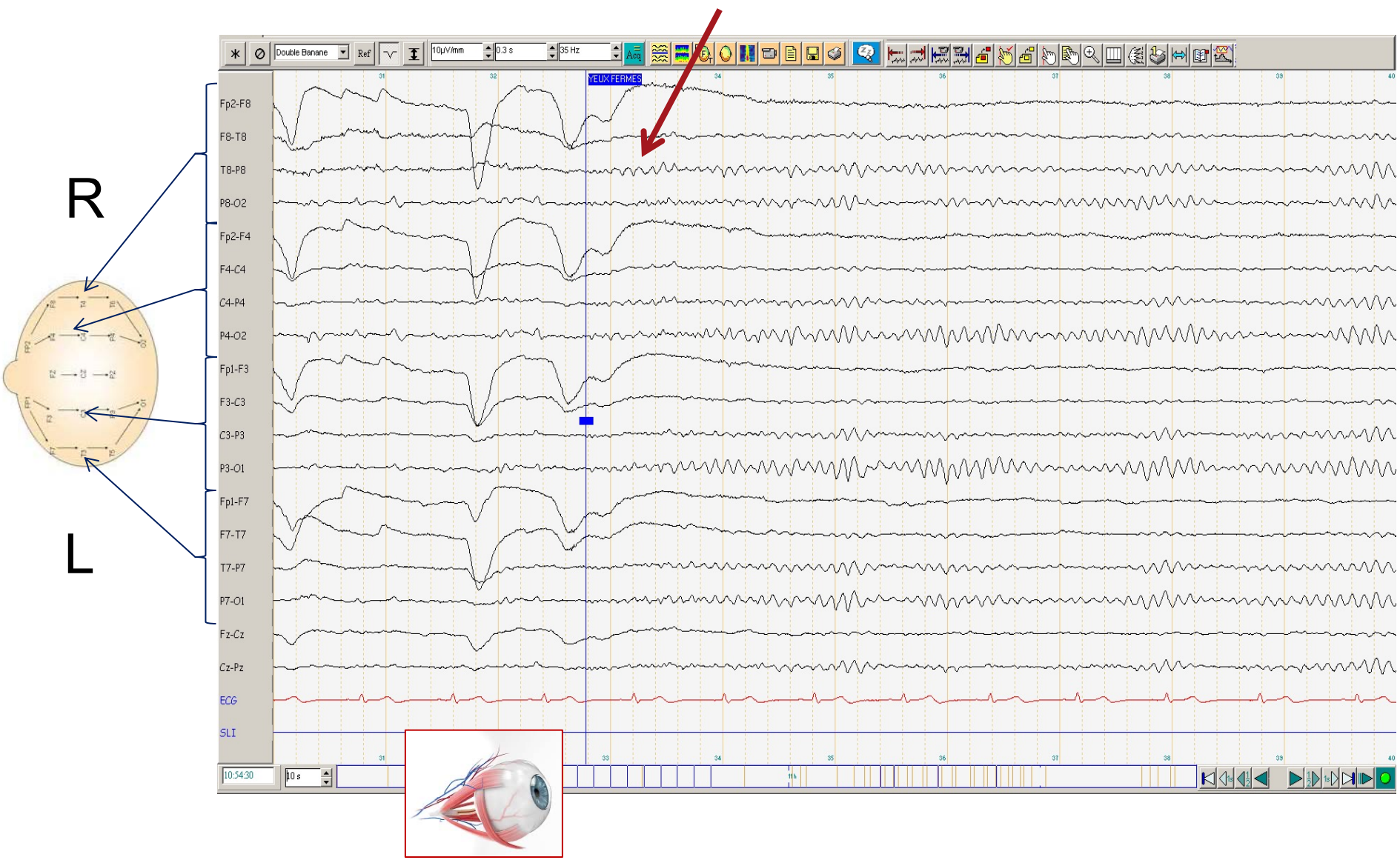

Frequency filters

*Sources: science.org, eeglab wicki*

# Rythmes EEG


Brain Waves: EEG Tracings
Beta (β)
13-30 Hz
Alpha (α)
8-13 Hz
Theta (θ)
4-8 Hz
Delta (δ)
0.5-4 Hz
0
1
2
3
4
Time (Secs.)

# What is a normal EEG ?



# Sleep

**NREM= slow-wave sleep**

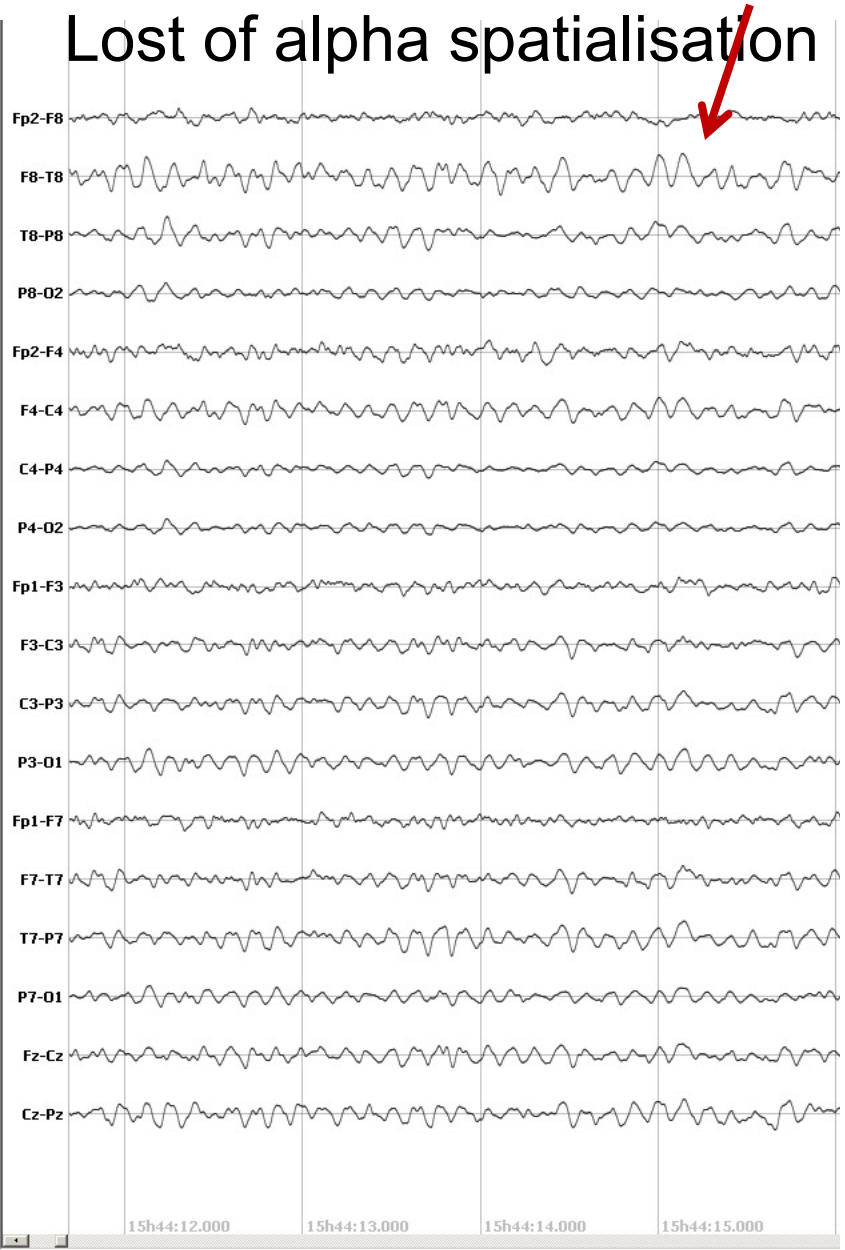
- Stage 1: drowsiness
- Stage 2: light sleep
- Stage 3: deep sleep

**REM sleep**

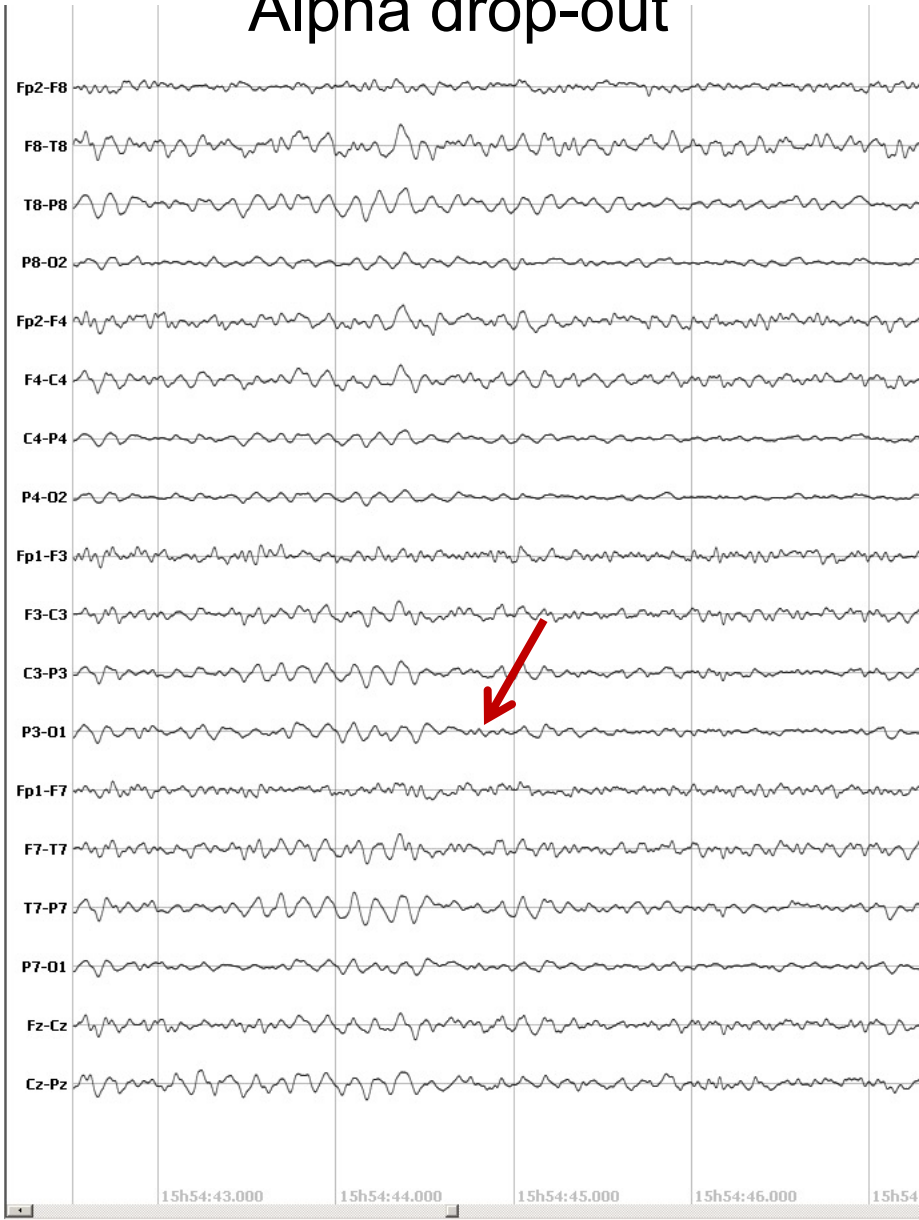
- EEG similar as wakefulness but with Rapid Eye Movements and muscular atonia (except eyes and respiratory muscles)

# Stade 1

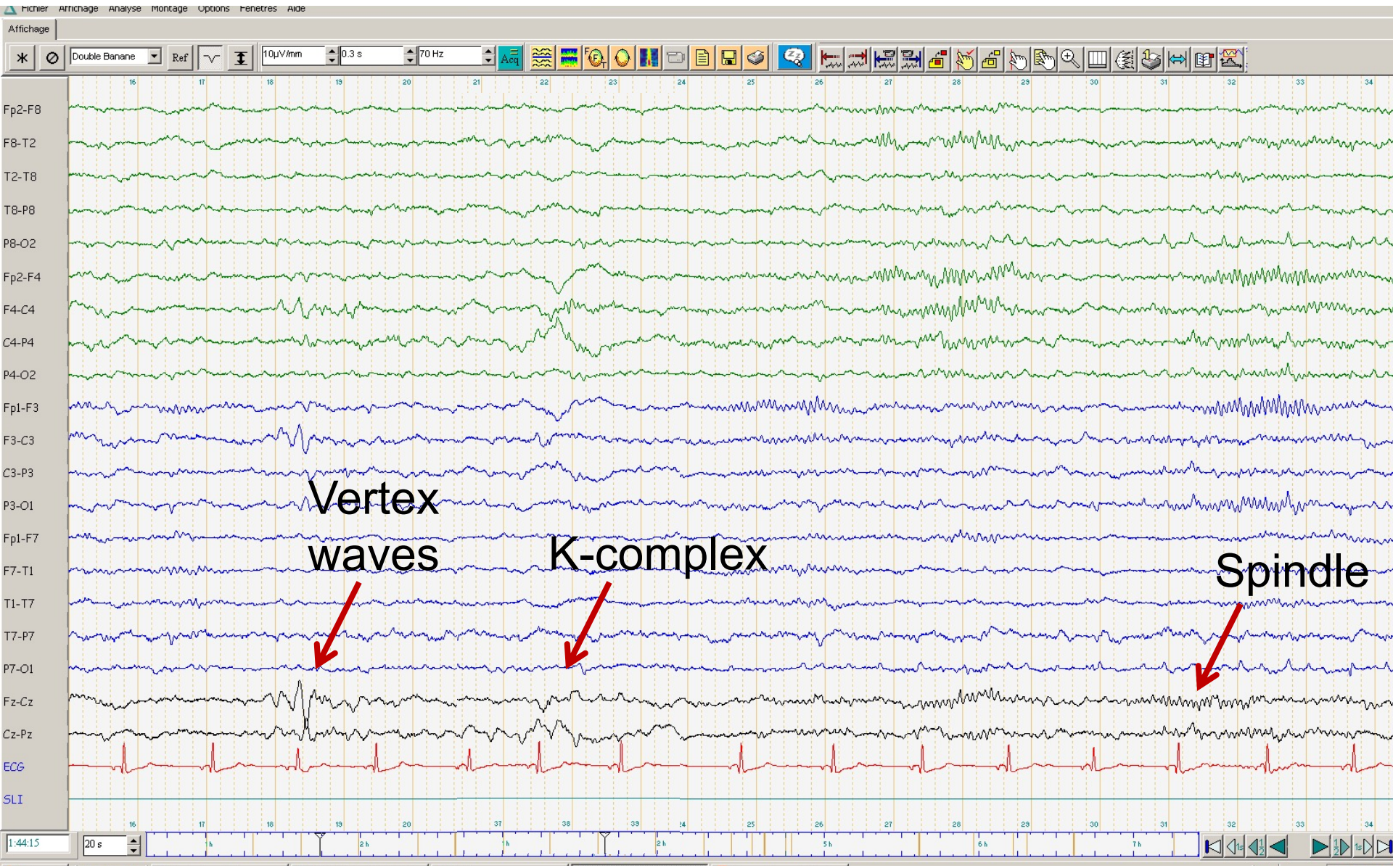
## Lost of alpha spatialisation




## Alpha drop-out



# Stade 2

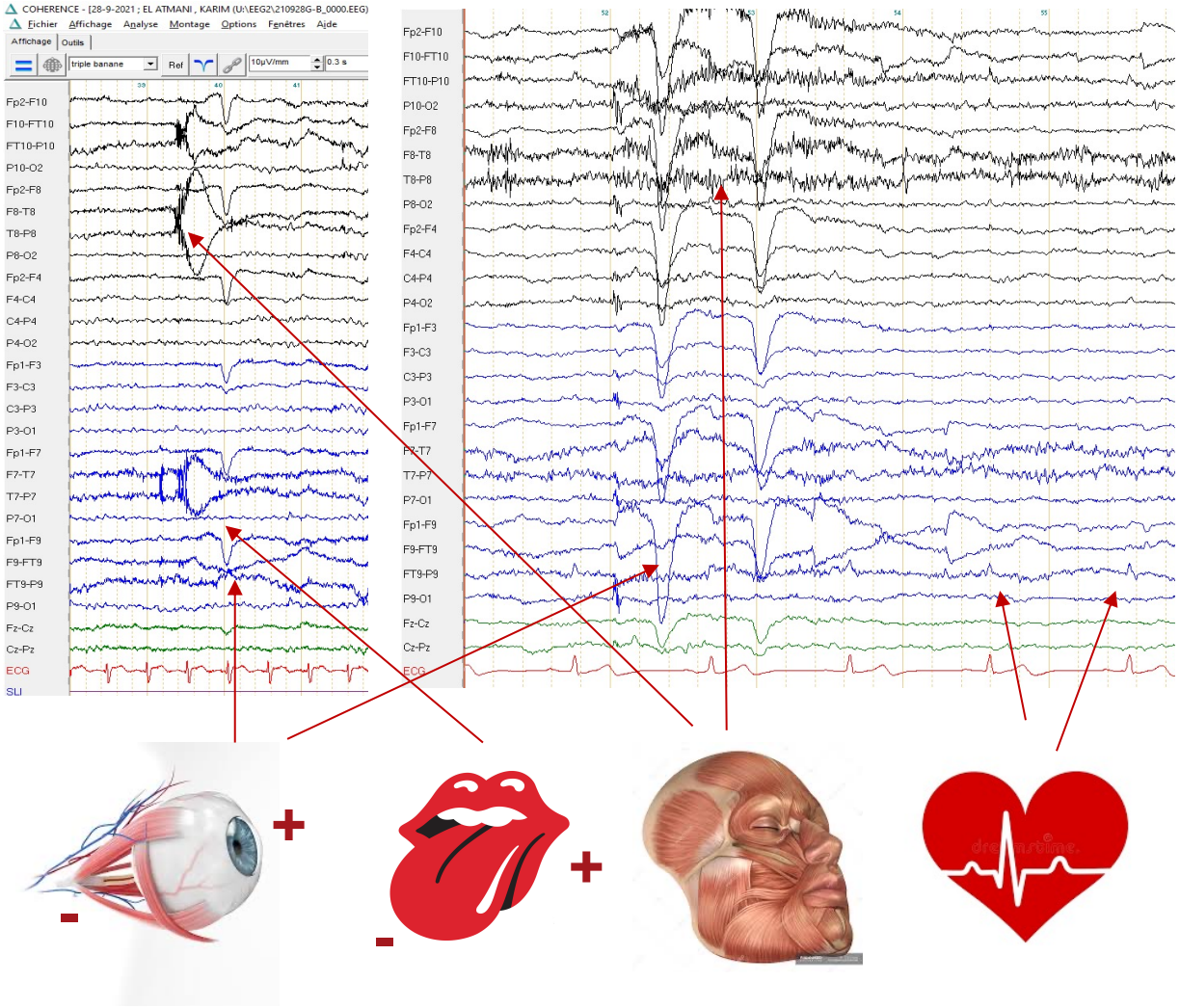

Fichier Affichage Analyse Montage Options Fenêtres Aide
Affichage
Double Banane
Ref
10µV/mm
0.3 s
70 Hz
Acq
Fp2-F8
F8-T2
T2-T8
T8-P8
P8-O2
Fp2-F4
F4-C4
C4-P4
P4-O2
Fp1-F3
F3-C3
C3-P3
P3-O1
Fp1-F7
F7-T1
T1-T7
T7-P7
P7-O1
Fz-Cz
Cz-Pz
ECG
SLI
Vertex waves
K-complex
Spindle
1:44:15
20 s

# Stade 3

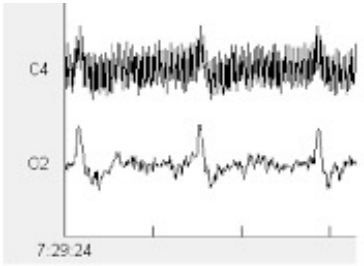

Very slow waves (delta range) with some spindles on top

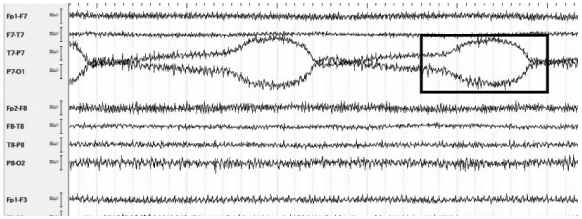
# Artefacts

## Biological artefacts



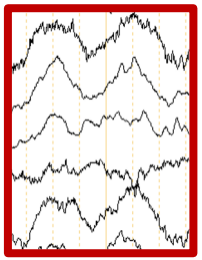
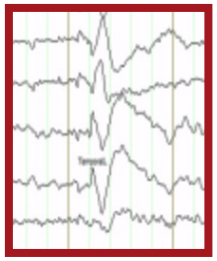

## Technical artefacts:

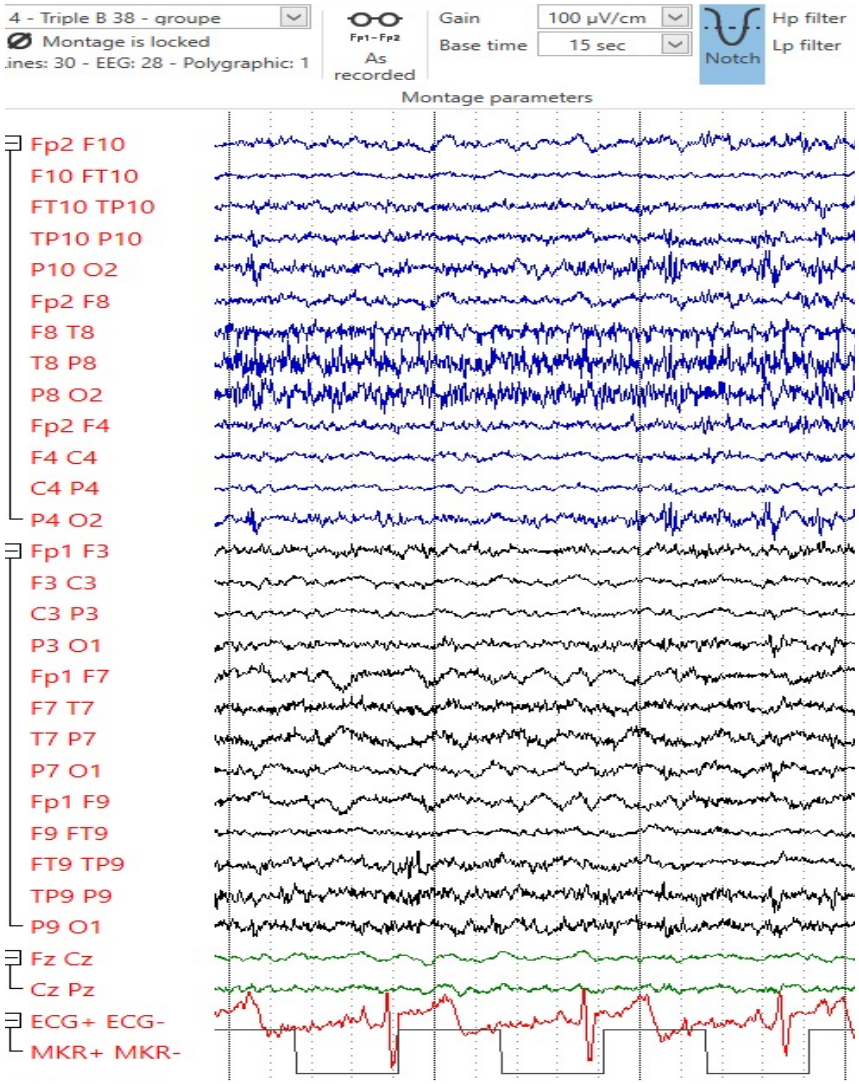


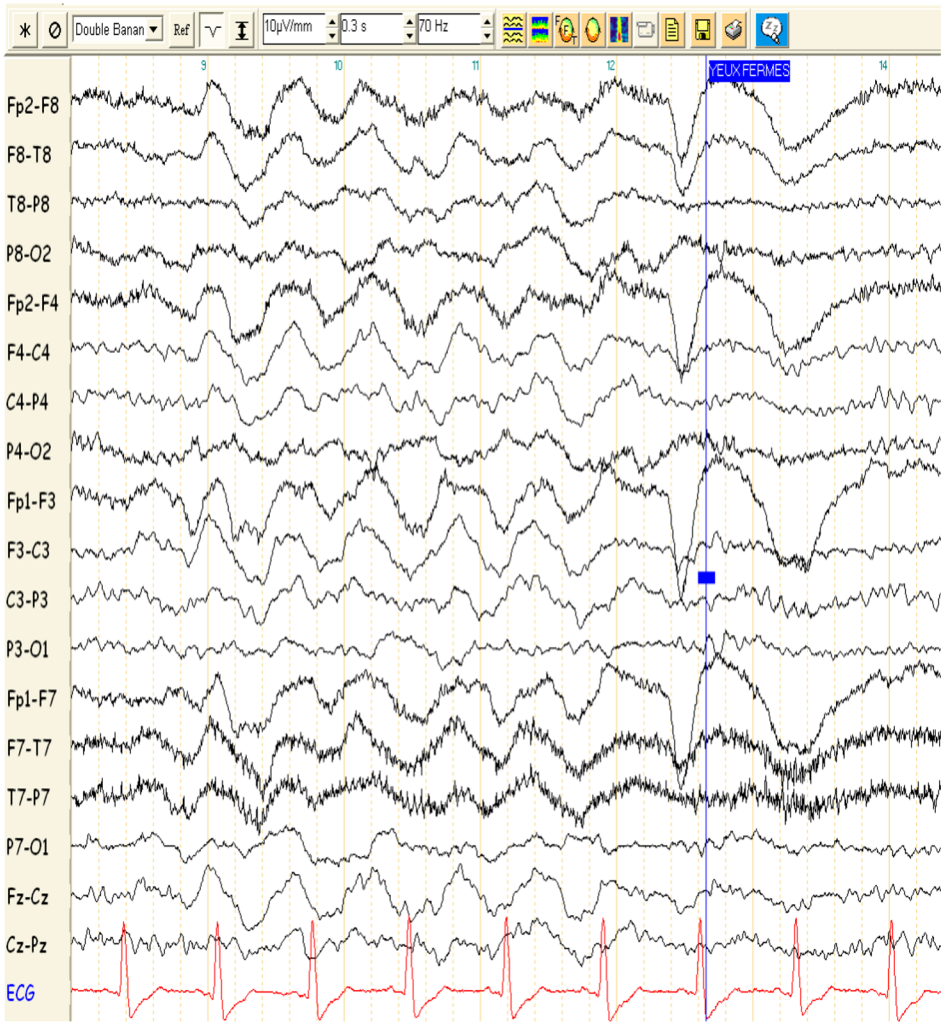
Line noise 50Hz
« bad » electrode

# Clinical studies: Pathological activities

| | Focalisé(e) | Generalised /Diffuse |
|---|---|---|
| **Slowing**  | **Focal dysfunction:**<br><br>Structural lesion ? | **Sleep ?**<br>**Encephalopathy ?**<br>**Coma ?** |
| **Epileptiform**  | **Focal epileptic activity:**<br>**Ictal vs interictal ?**<br><br>Structural cause ? | **Generalised epilepsy ?**<br>**Ictal vs interictal ?** |




Focal slow activity

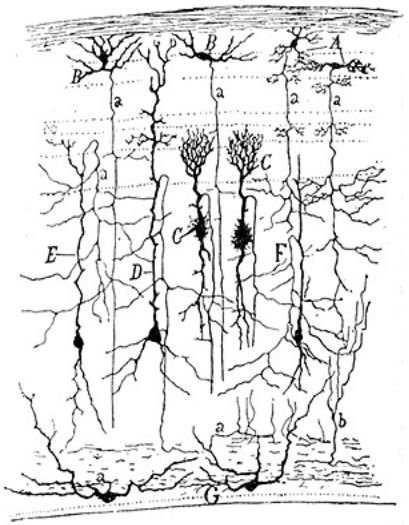



Generealised slow activity

# Epilepsy

## Epileptic seizures :

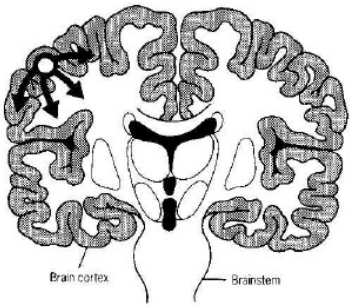
Transient symptoms caused by **excessive and synchronous activity** of a neuronal population.



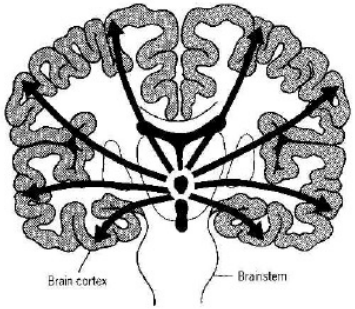
## Epilepsy :

Enduring predisposition of the brain to generate seizures.

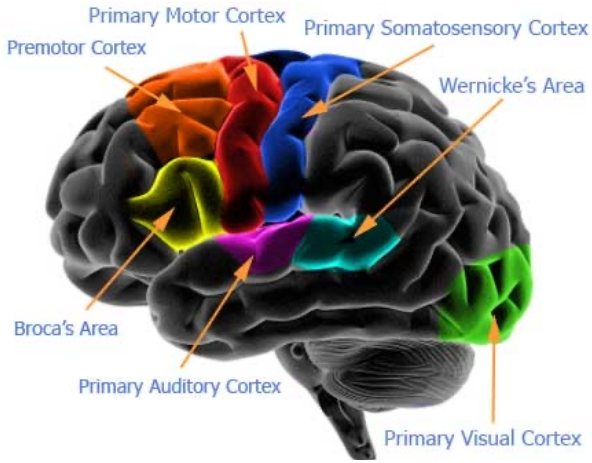
*Fisher et al, Epilepsia 2005*




**Focal seizures**

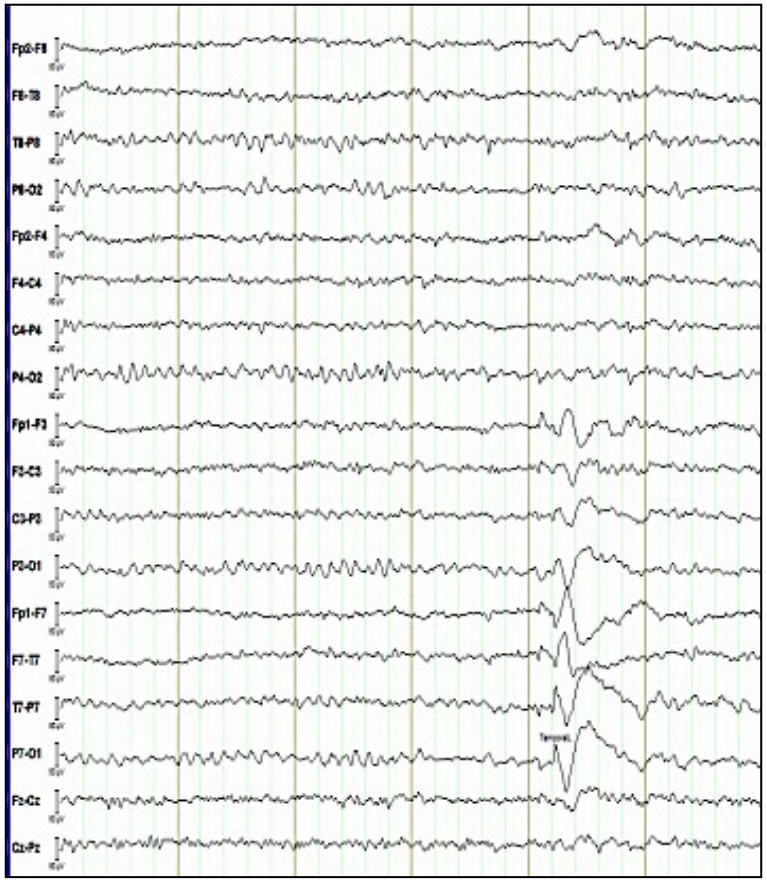



**Generalised seizures**

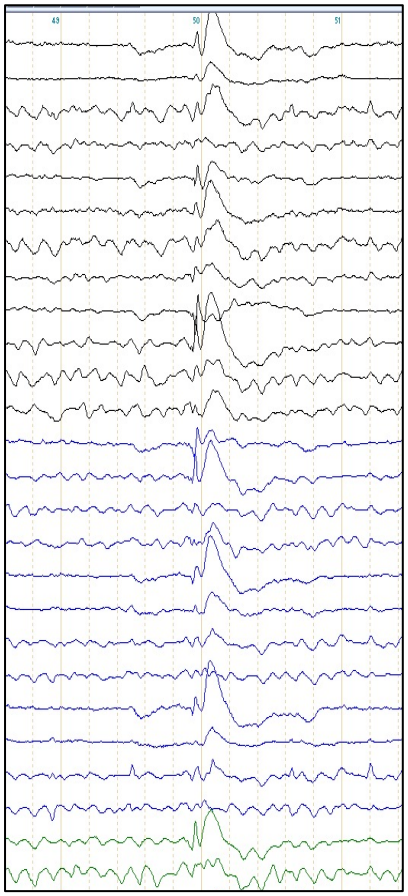


# Focal vs generalised epileptic activity

Between seizures (interictal state):
EEG markers of epilepsy. Diagnostic and prognostic info.

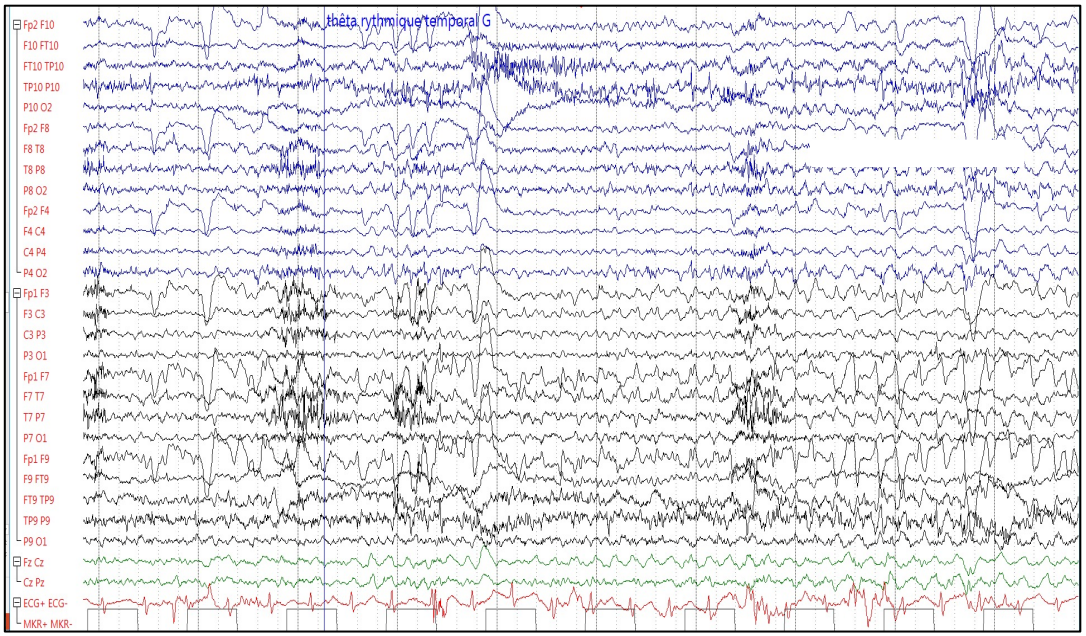



Focal spike



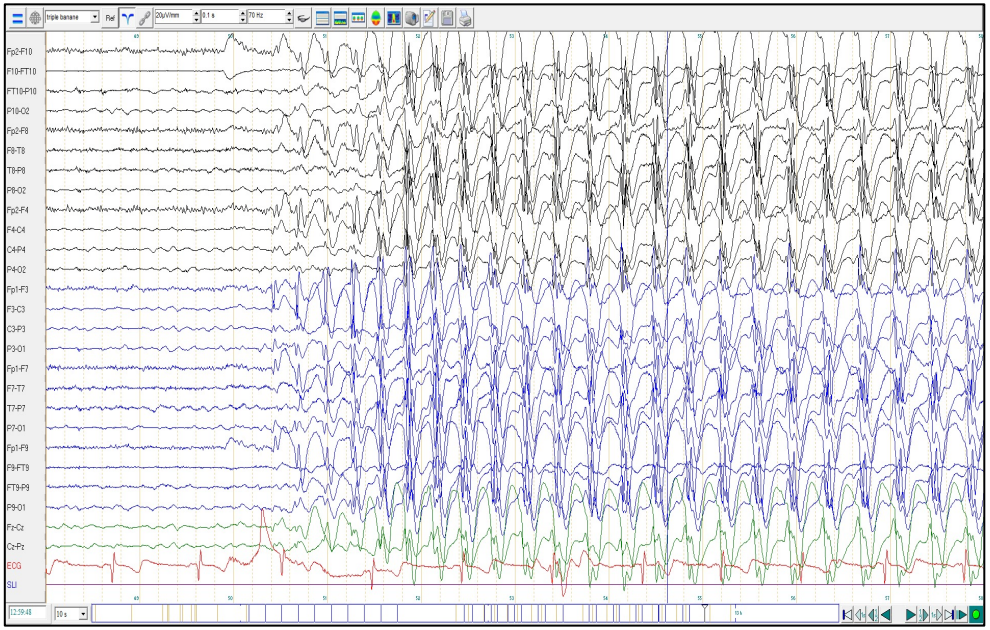
Generalised spike

# Seizures: sustained rythmic pattern: Focal vs generalised




Focal

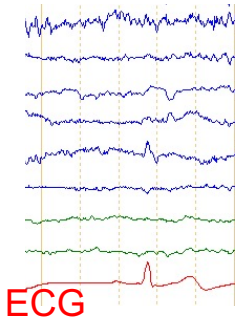
Generalised



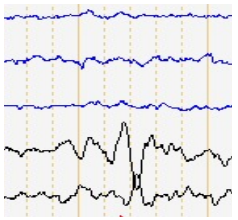
# EEG = sum of different components

- **Artefacts**
- **Physiological rhythms and sharp transients (e.g. sleep transients)**
- **Norm variants (sharp transients, rhythms)**

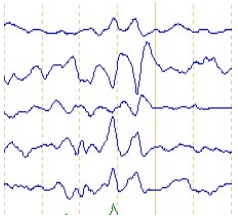
  can « mimick » pathological activity
- **Pathological activity**



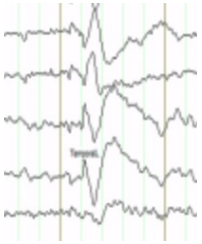

ECG artefact



Sleep Vertex wave



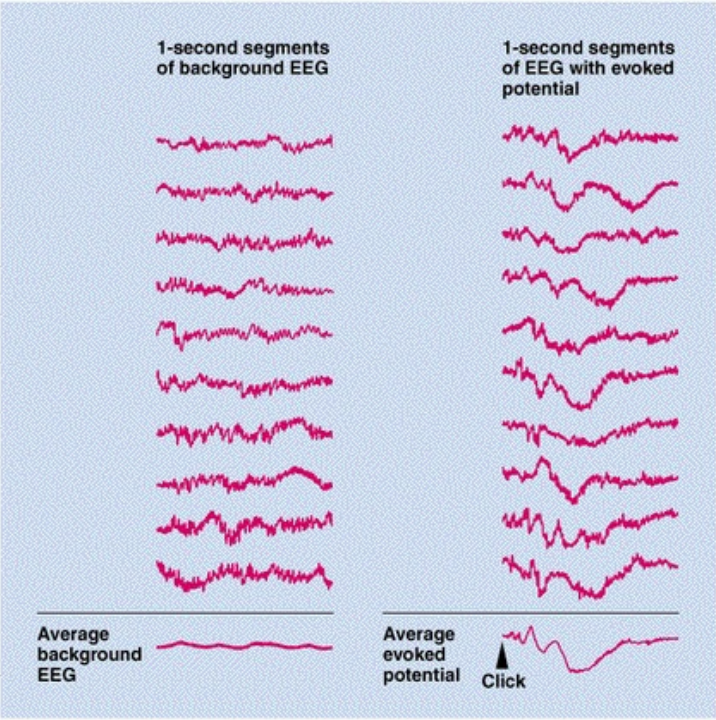
Norm variant (wicket spike)

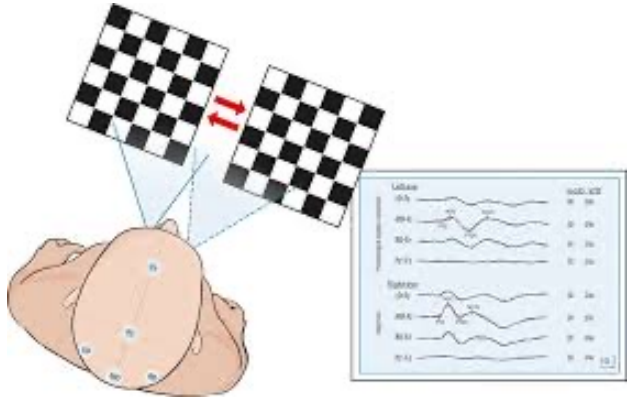


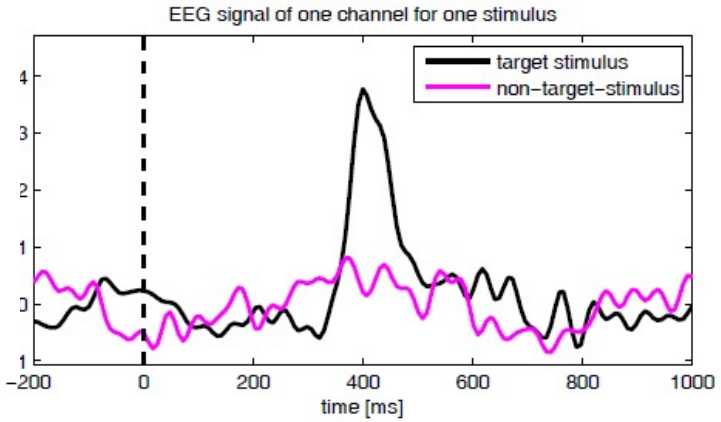
epileptic spike

# Evoked potentials

Testing specific neural circuits using the electrophysiological responses to a physical or cognitive stimulus

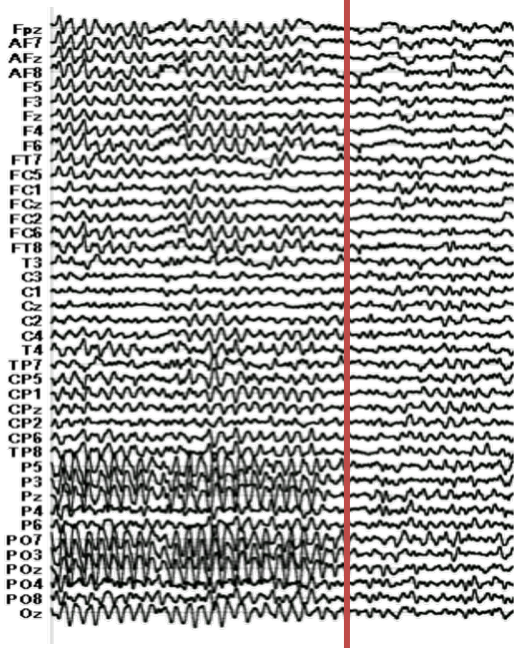


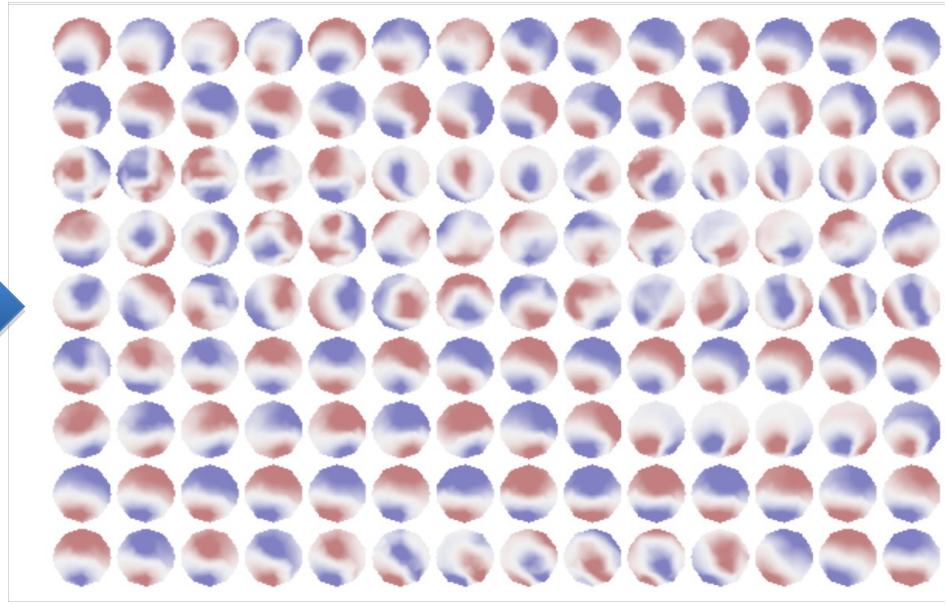





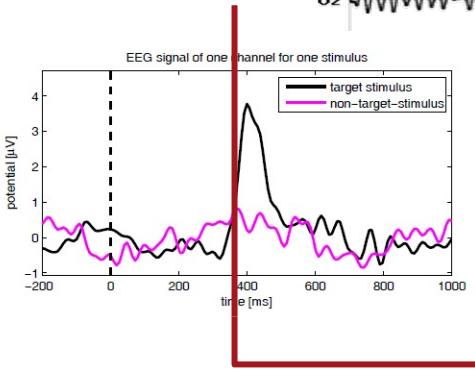

- Stimulus repetition (visual, auditory, …)
- Averaging to remove background fluctuations
- Analysis: differences between conditions/groups: e.g. P300, Oddball

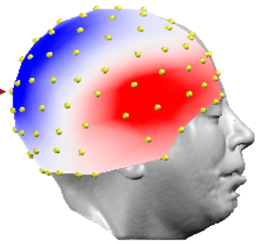
# Perspectives: EEG analysis

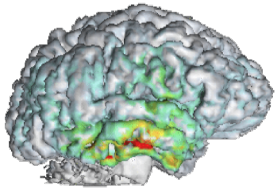


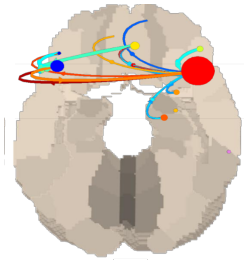



*Michel et al 2004*







Voltage maps

Electric sources

Connectivity

# Take home message

- Many EEG signals don’t come from the brain !
- Importance of good recording conditions/settings
  (artefacts, reference, filters)
- Identify/exclude « influencers » of your signal:
  artefacts, arousal states, normal/pathological transient activities
- Enjoy your next analysis !

# Quizz

- Lecture 1.3 - Question 1
- Which sentence is correct ?

a) The scalp EEG signal is generated by the action potentials in the cortical neurons

b) Low frequencies represent highly synchronised neuronal activity

c) There is more theta and delta activity in wake compared to sleep

- Lecture 1.3 - Question 2
- Which sentence is correct ?

a) The scalp EEG signal does not depend from the localisation of the reference electrode

b) Artefacts can affect only EEG high frequencies

c) Movements/activity of the tongue, eyes, muscles and heart can alter the EEG signal