The normal EEG of the adult

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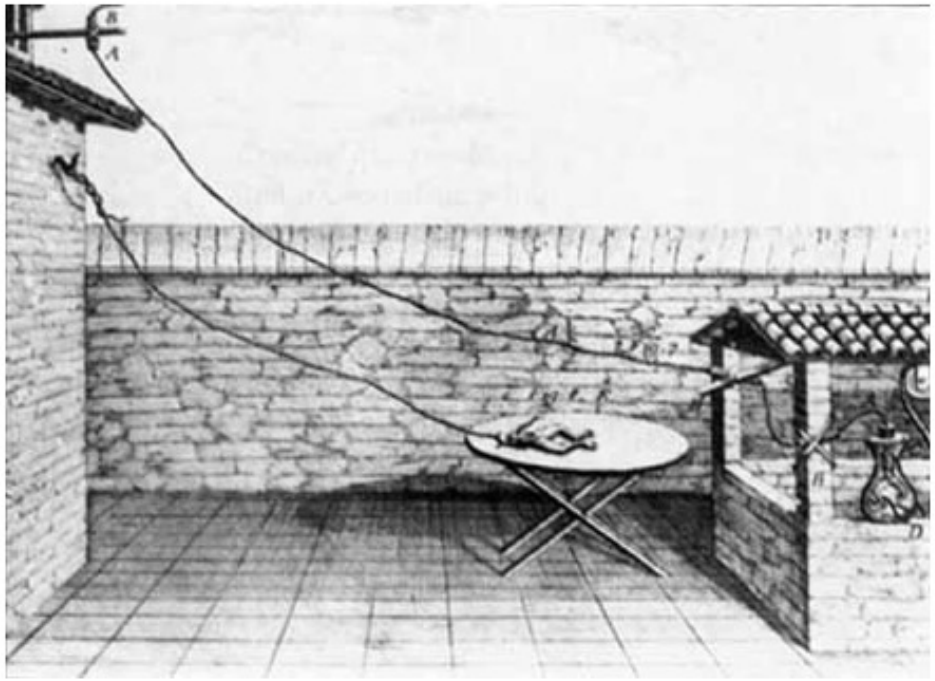
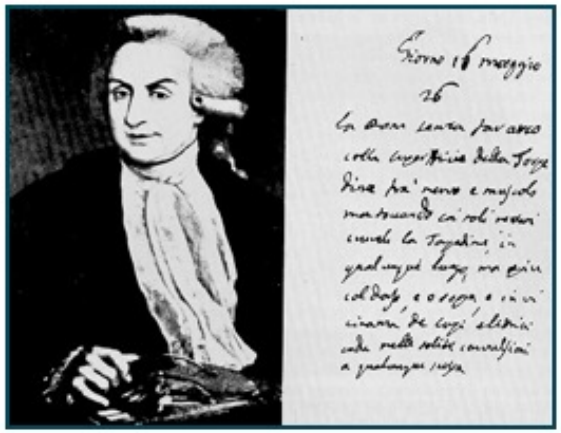
Experiments during lighthning

Italy ± 1750

Discovery of animal electricity



Galvani...



Luigi Galvani (1737 - 1798)

Volta...

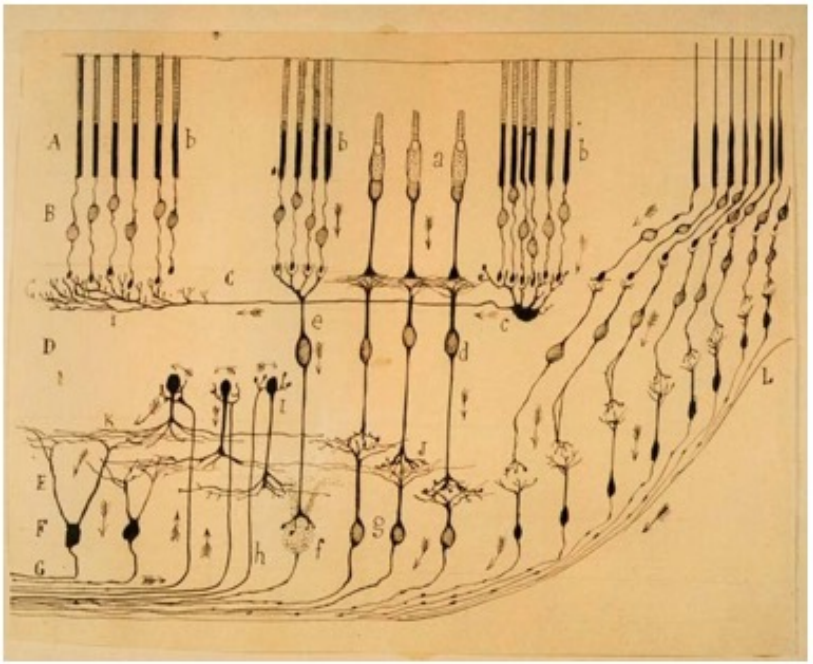
Alessandro Volta (1745 - 1827)

More than electricity..

Chemical Synapse

Santiago Ramón y Cajal: Nobel prize 1906

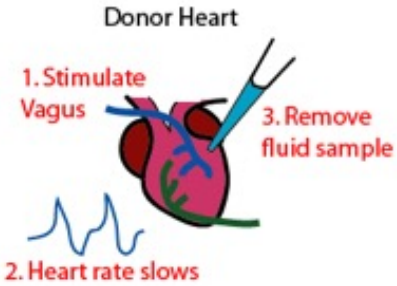
May 1, 1852 – October 17, 1934



Neurotransmitters

1873-1961

1921: Otto Loewi



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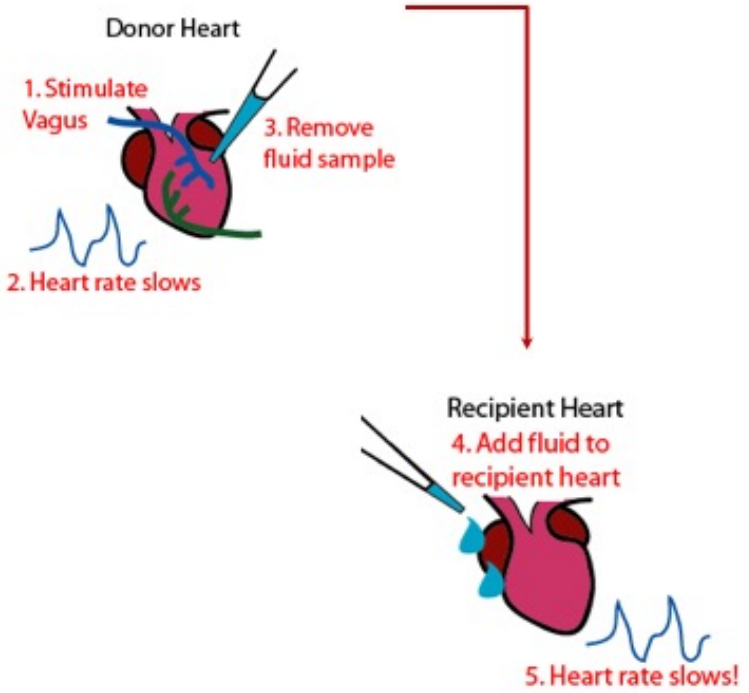

Neurotransmitters

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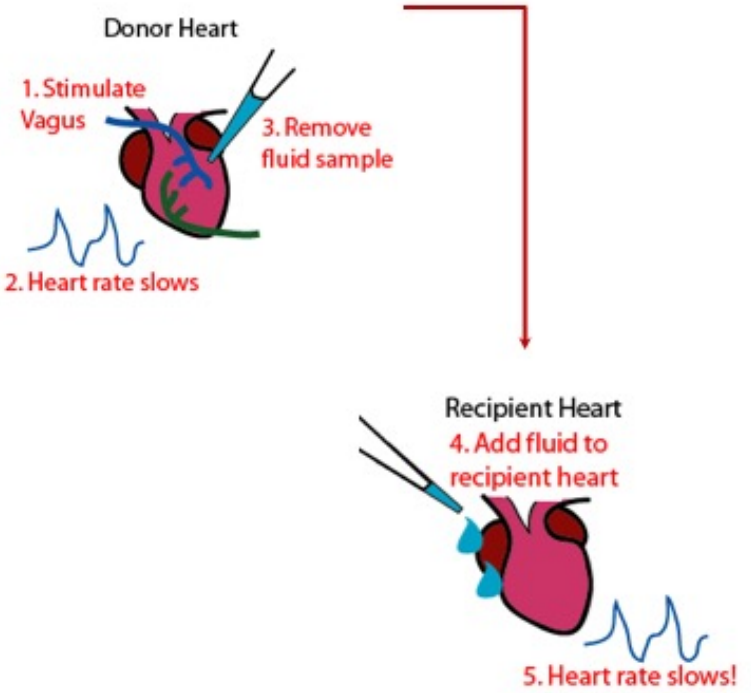
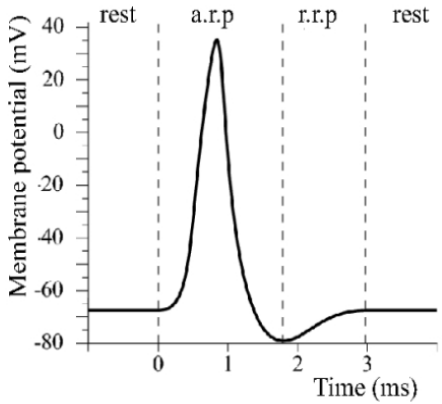


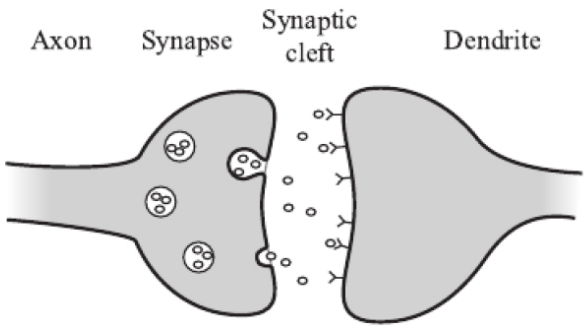
Nobel Prize 1936

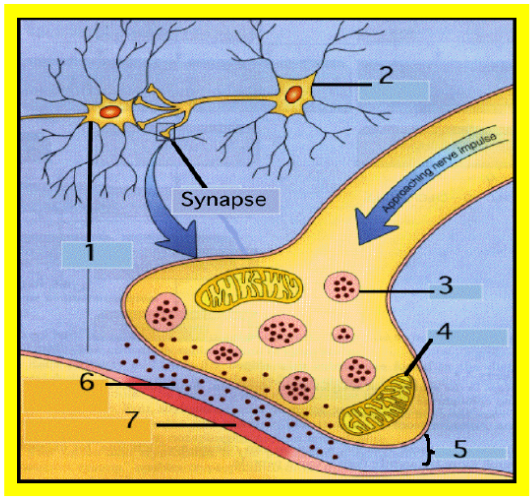
Neural information transport: electrochemical

Within Neurons: action potentials

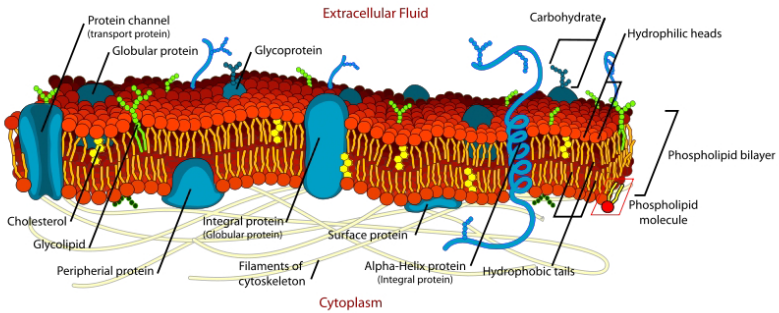


Between Neurons: Synapses



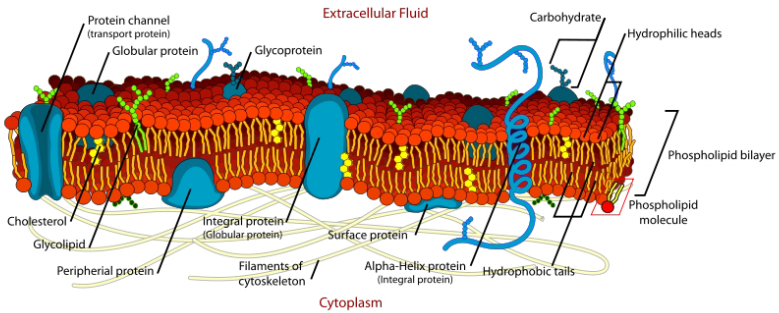


Membrane potential as basis for the EEG

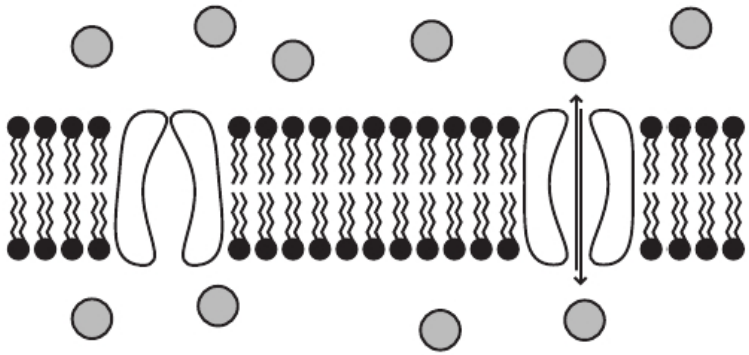


Complex biology..

Membrane potential as basis for the EEG

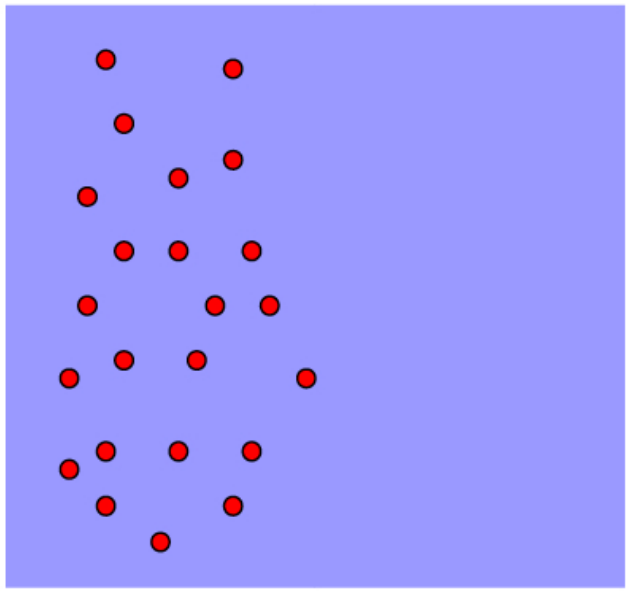


Complex biology..

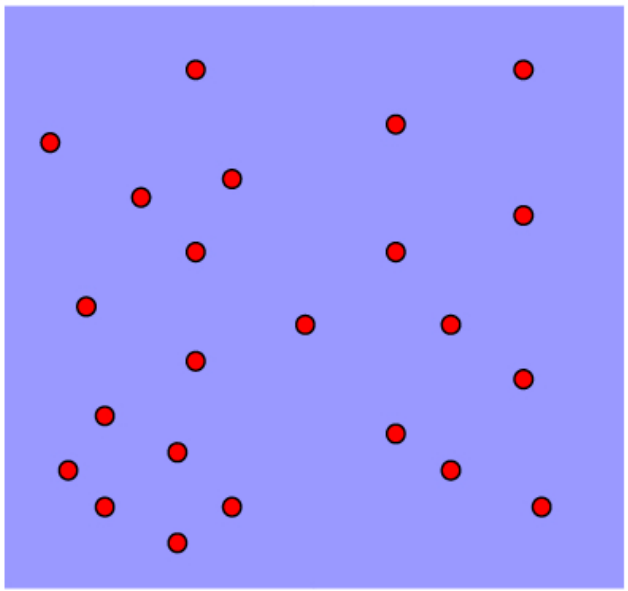


...to some essentials.

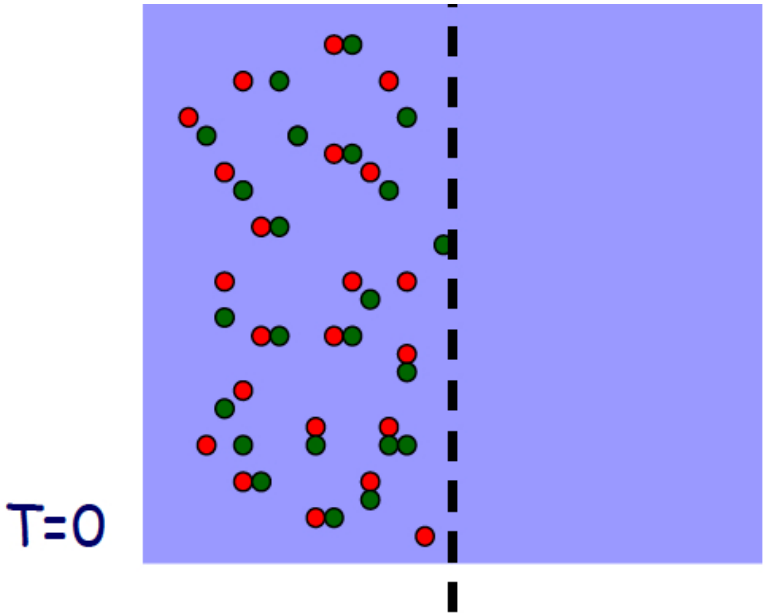
Diffusion



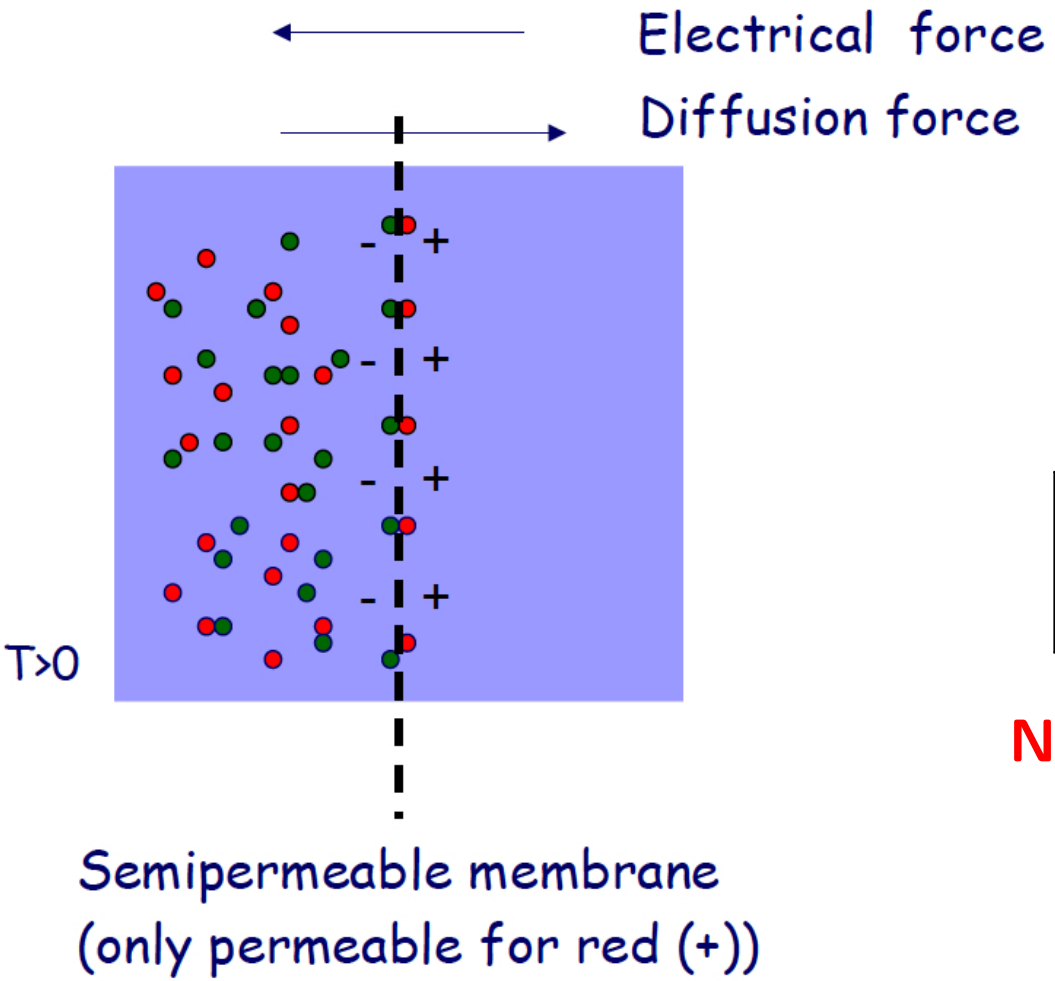
Diffusion



Semipermeable membranes and the membrane potential



Semipermeable membranes and the membrane potential

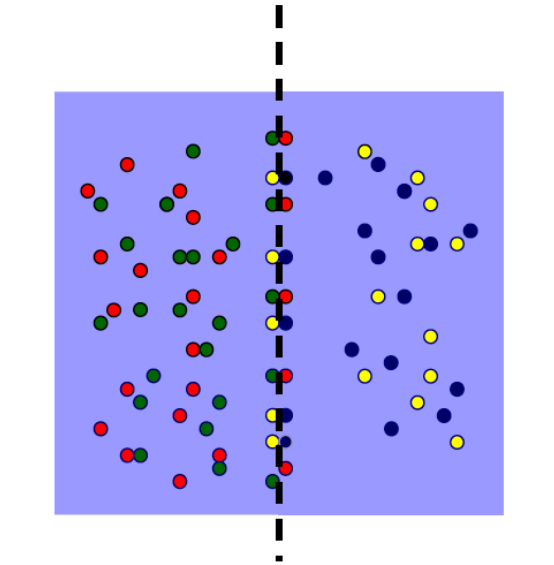


$$V = -\frac{kT}{q} \ln \frac{[K^+]_i}{[K^+]_o}$$

$$V = -61 \log_{10} \frac{[K^+]_i}{[K^+]_o} \text{ mV}$$

Nernst equation

Semipermeable membranes and the membrane potential



permeable for red and yellow

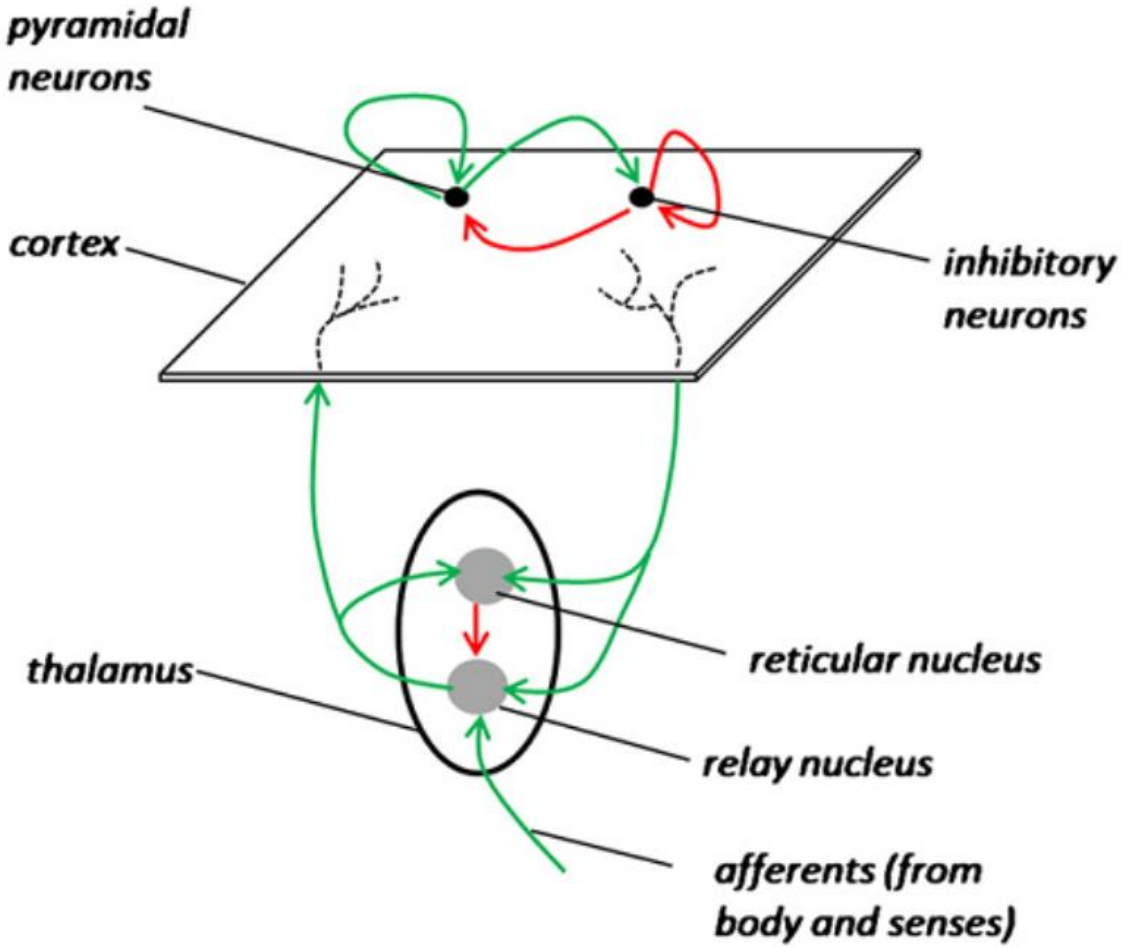
Twee equilibra, e.g. from Na and K ions.
What is the resulting voltage?

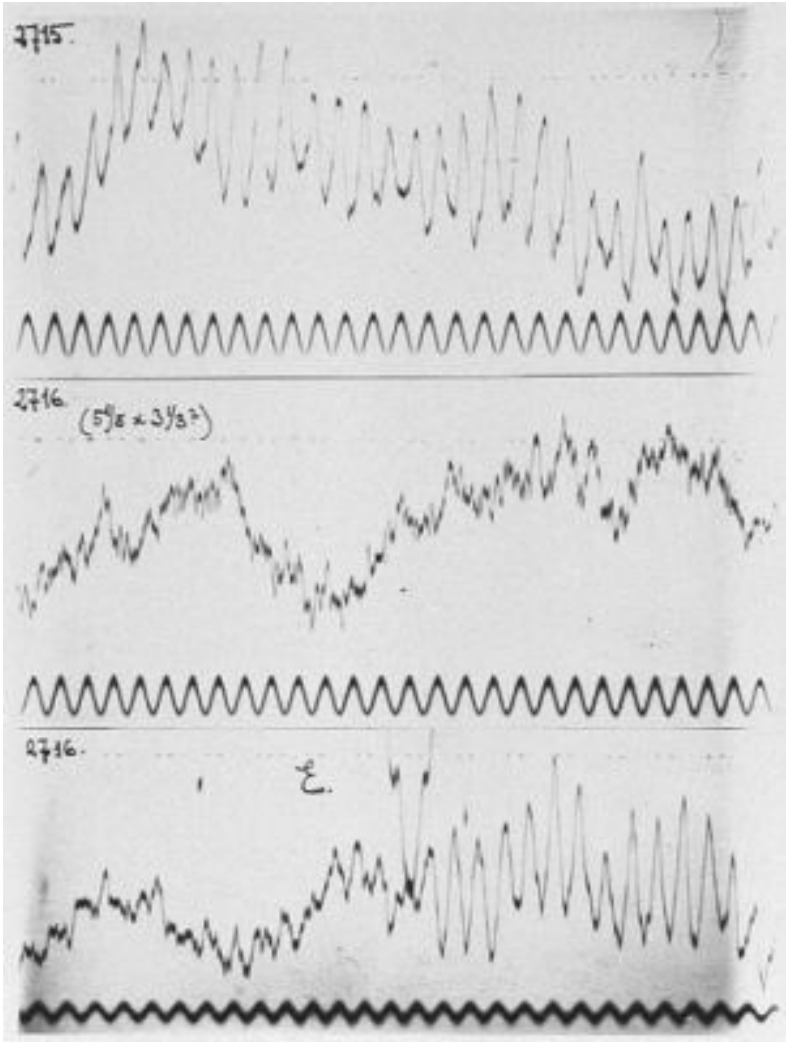
Goldman Hodgkin Katz (GHK) equation

$$V = -\frac{kT}{q} \ln \frac{P_k]K^+]_i + P_{\mathrm{Na}}[Na^+]_i + P_{\mathrm{Cl}}[Cl^-]_o}{P_k[K^+]_o + P_{\mathrm{Na}}[Na^+]_o + P_{\mathrm{Cl}}[Cl^-]_i}$$

- GHK simulator

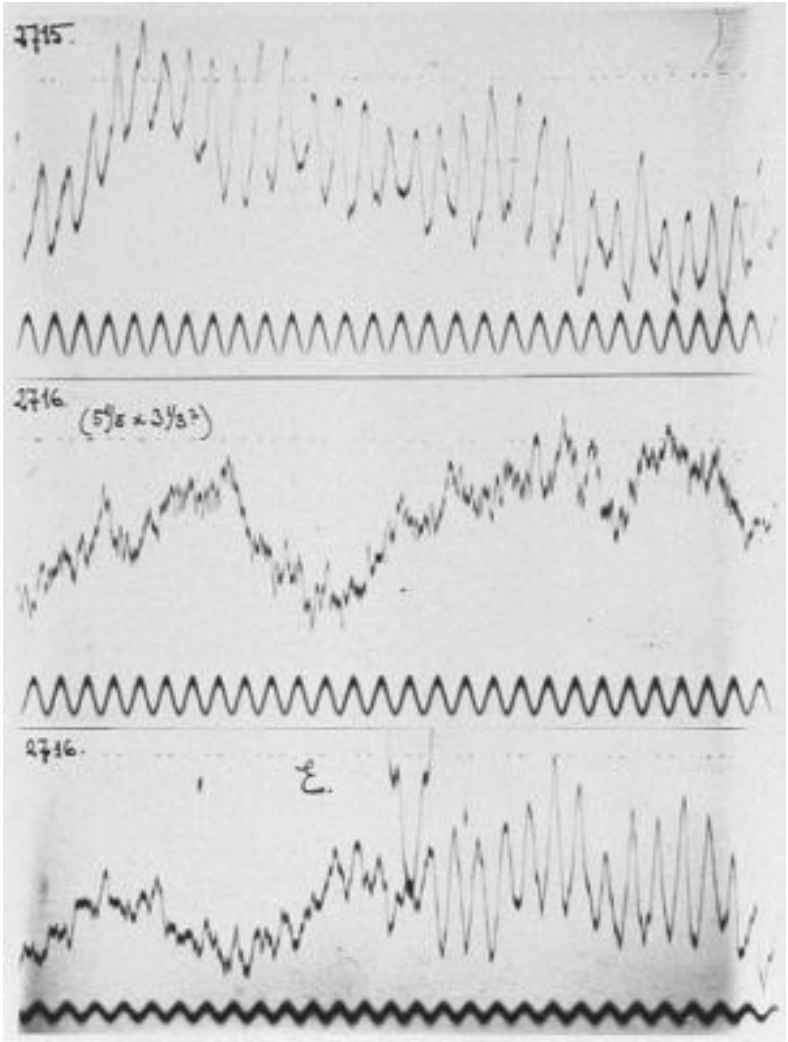
The thalamocortical system





One of the first EEG recordings by Hans Berger ($\sim$ 1924). The sine wave below each panel is a calibration signal.

- How was this recording obtained?



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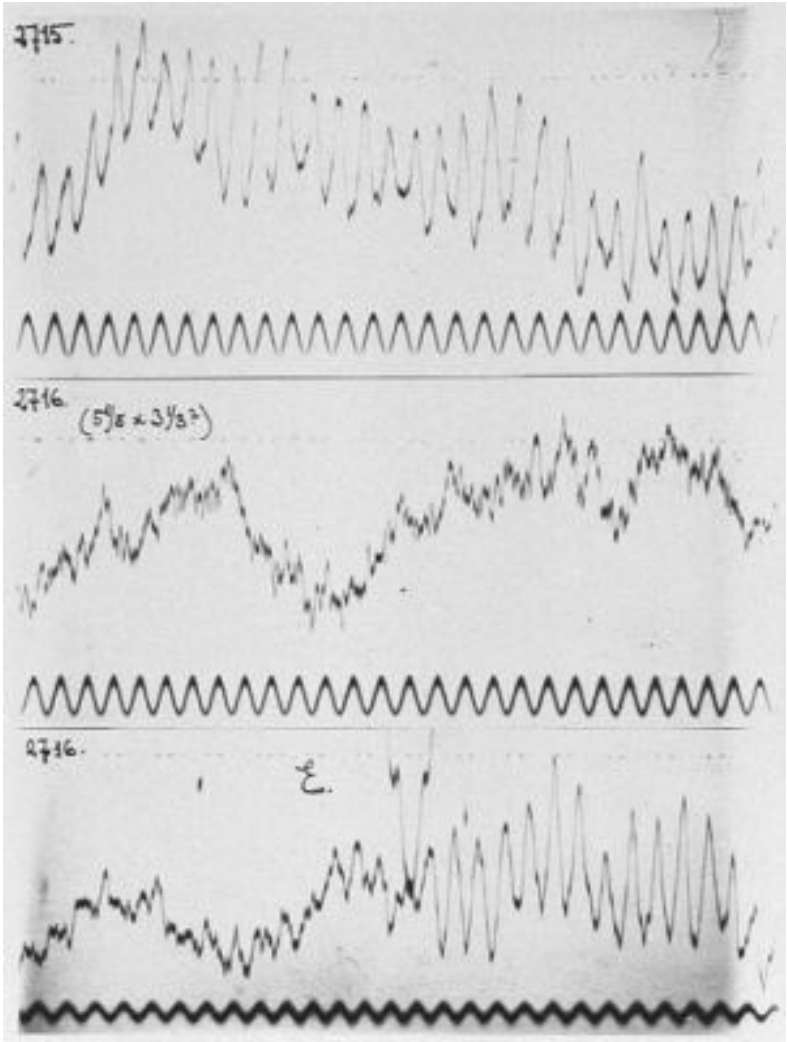
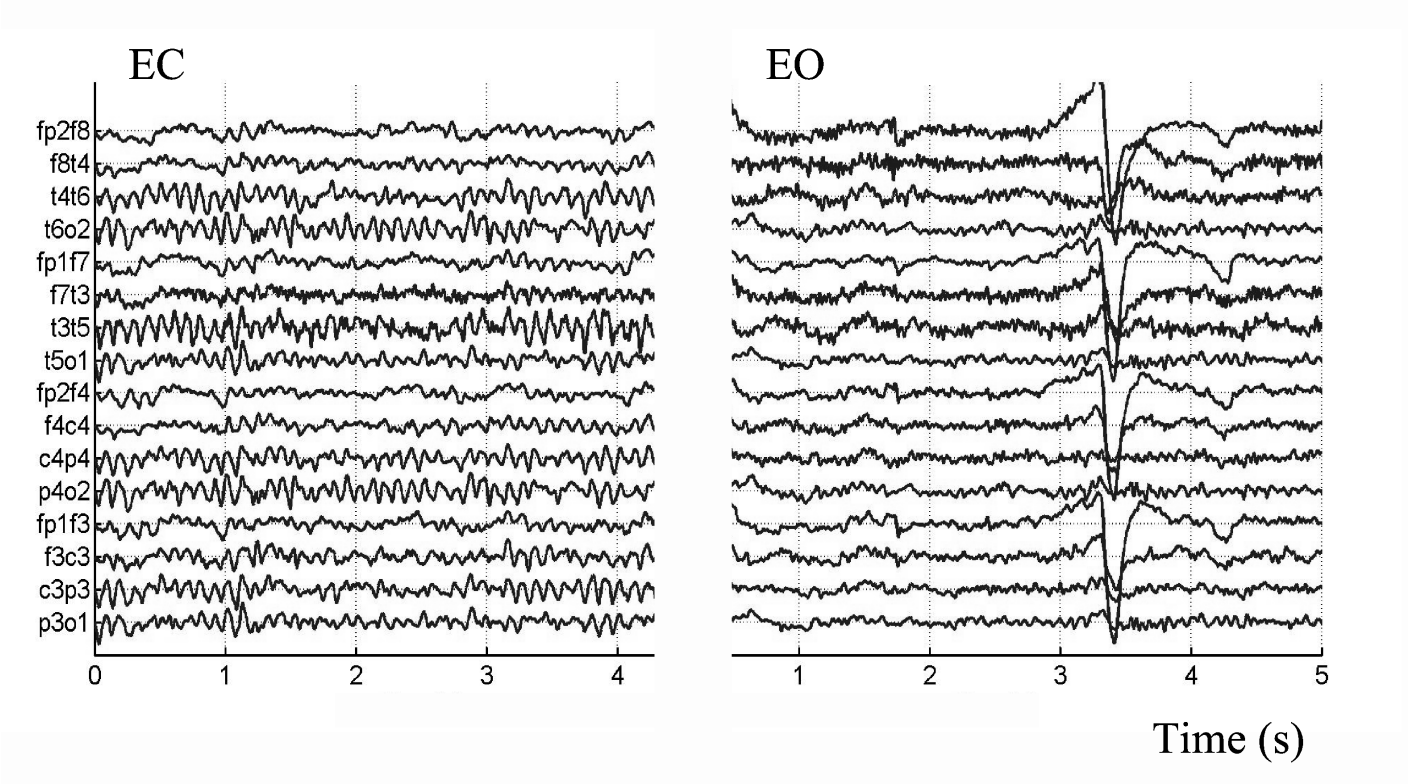
- How was this recording obtained?
- Which phenomenon is displayed here?

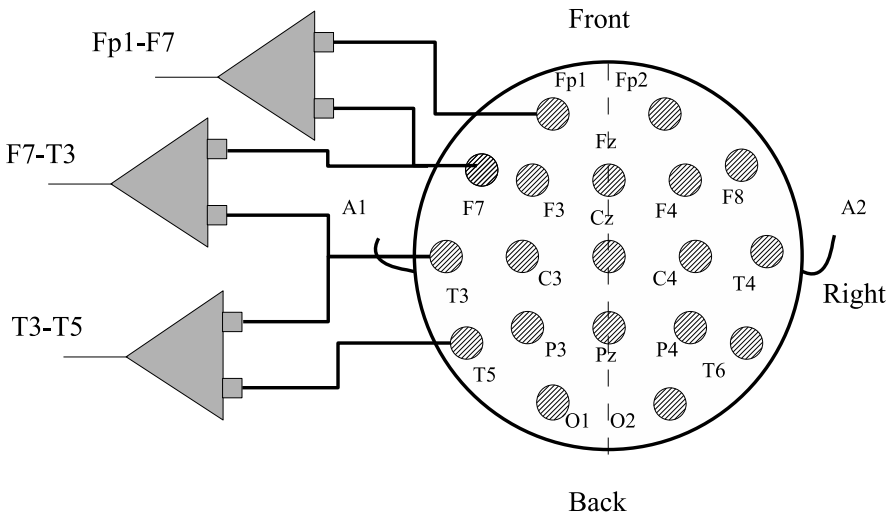


One of the first EEG recordings by Hans Berger ($\sim$ 1924). The sine wave below each panel is a calibration signal.

- How was this recording obtained?
- Which phenomenon is displayed here?
- How long did it take Berger to publish his results?



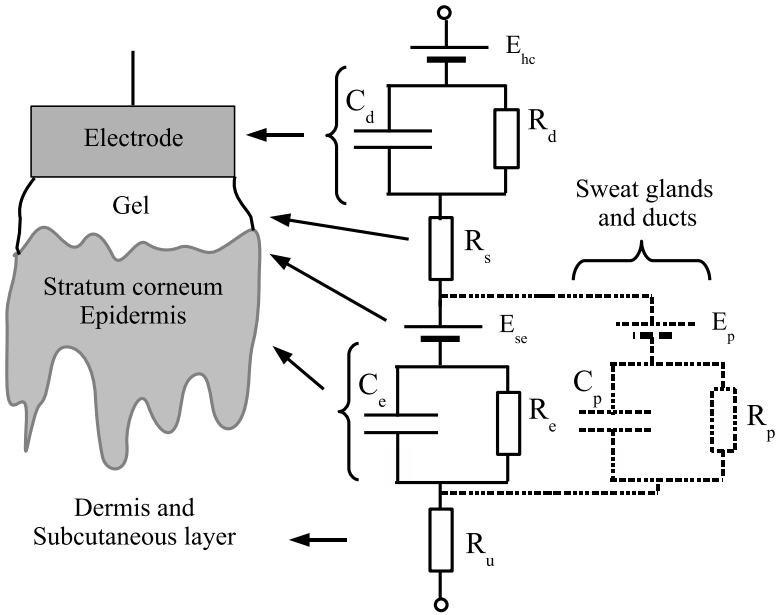
Left: EEG fragment, eyes closed (EC); at the right with eyes open (EO). The α rhythm is well visible at the left; at the right side, it is suppressed: *reactivity*.



The international 10/20 system

(from Van Putten, Essentials of Neurophysiology, Springer Verlag, 2009).

- even numbers refer to the right side
- odd numbers refer to the left side
- part of a bipolar montage is shown

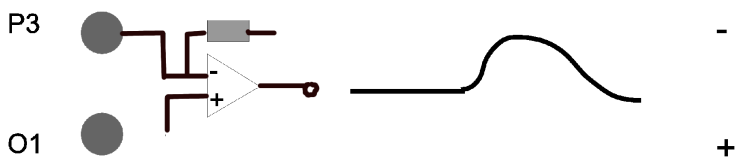


At the Interface.

(from Van Putten, Essentials of Neurophysiology, Springer Verlag, 2009).

From ionic to electronic currents

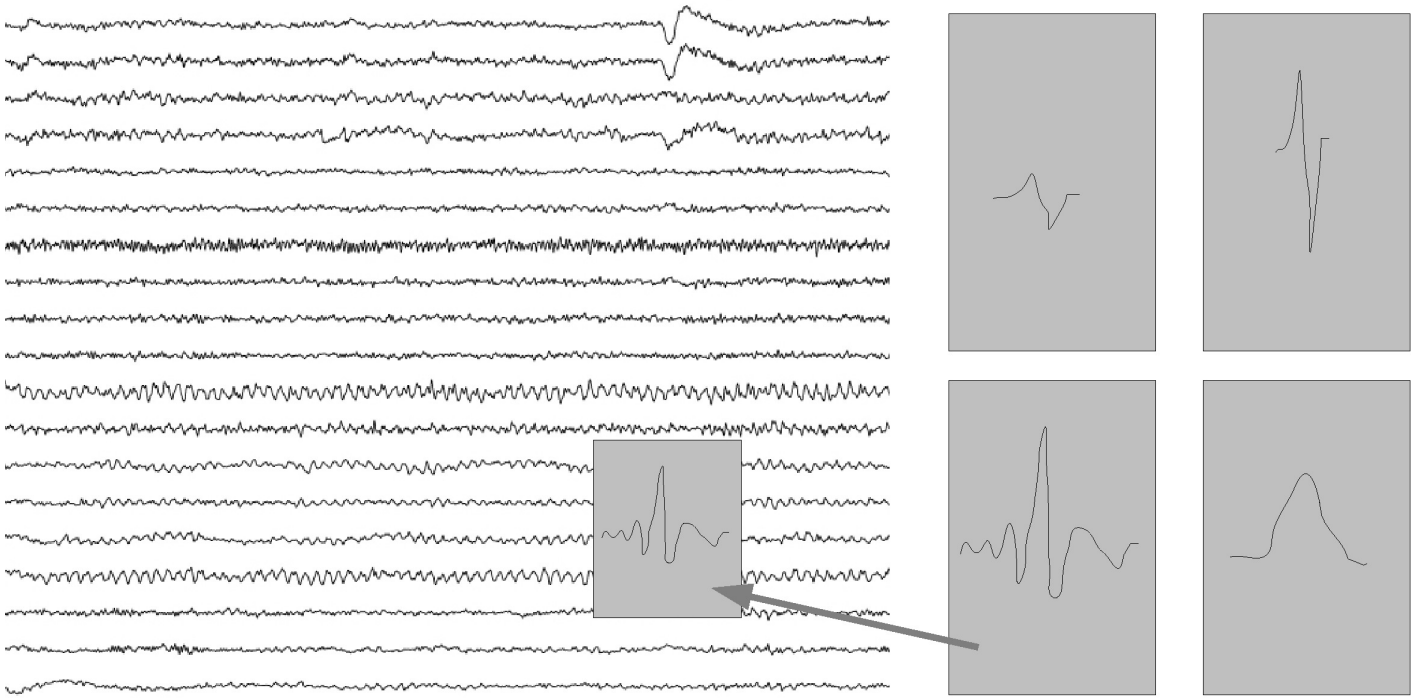
- Electrode material
- Frequency response
- Lab Tech is important here



P3-O1 recording. The deflection is “upwards”.

- Upward deflection means that electrode position to the left of the “-” is more negative.
- In this example, O1 is more positive than P3.
- what does this mean for the difference in extracellular concentration of ions?

Ground patterns and Transients



Nomenclature

Frequencies

- Delta 0-4 Hz
- Theta 4-8 Hz
- Alpha 8-13 Hz
- Beta 13-25 Hz
- Gamma 25-70 Hz

- Where are the rhythms
- When are they present
- Symmetry
- Relative amount
- Transients

The α-rhythm

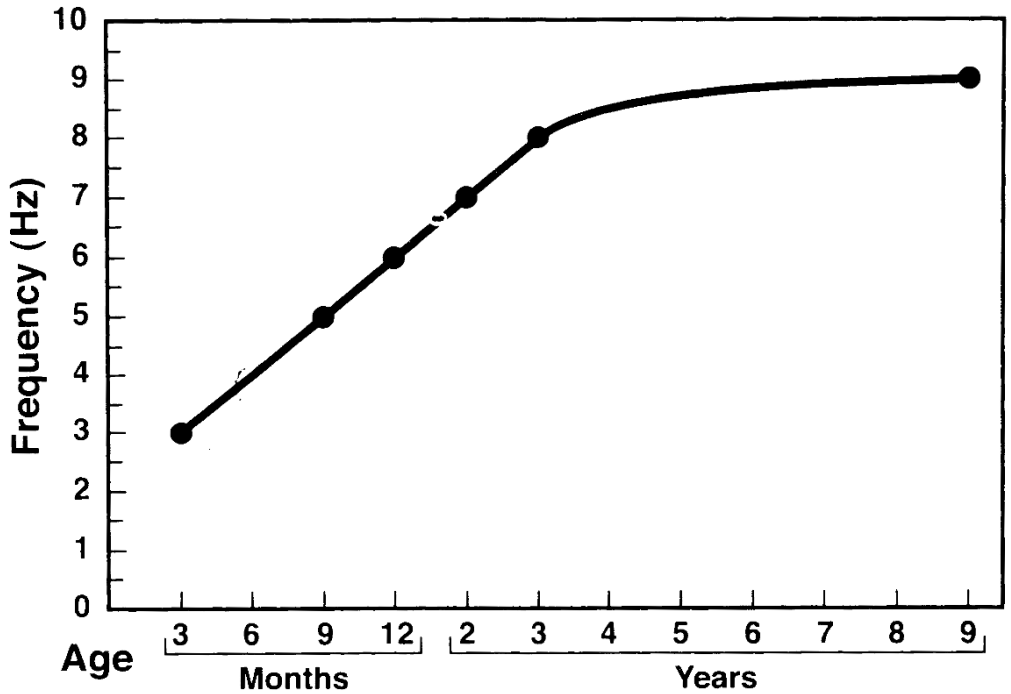
Features

- frequency between 8-13 Hz
- posterior dominant
- amplitudes between 20-70 µV
- reactive to eye opening

Amplitudes and Symmetry

- amplitude difference between left and right hemisphere $< 50\%$
- frequency difference < 0.5 Hz.
- variants

Appearance of alpha



From Levin and Lüders, Comprehensive Clinical Neurophysiology

70-y old female

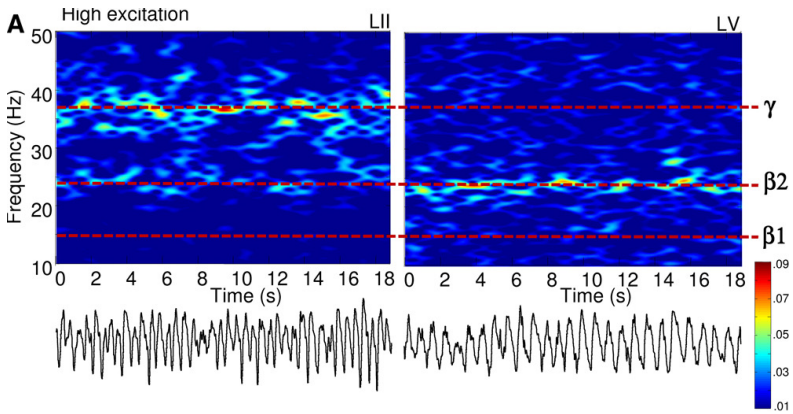
60-y old male


FP1 - F7
F7 - T3
T3 - T5
T5 - O1
FP1 - F3
F3 - C3
C3 - P3
P3 - O1
FZ - CZ
CZ - PZ
FP2 - F4
F4 - C4
C4 - P4
P4 - O2
FP2 - F8
F8 - T4
T4 - T6
T6 - O2
R EKG3 - L EKG2
FP1 - A1
L EYE - A1
FP2 - A2
R EYE - A2
20 mm

The β-rhythm

Features

- central dominant, 18-25 Hz
- normal $<$ 20 µV in 98% of normal adults.
- maximum: perirolandic and precentral
- Benzodiazepines and barbiturates $\rightarrow$ increase beta
- also $\uparrow$ by mental, lingual, or cognitive efforts



The θ-rhythm

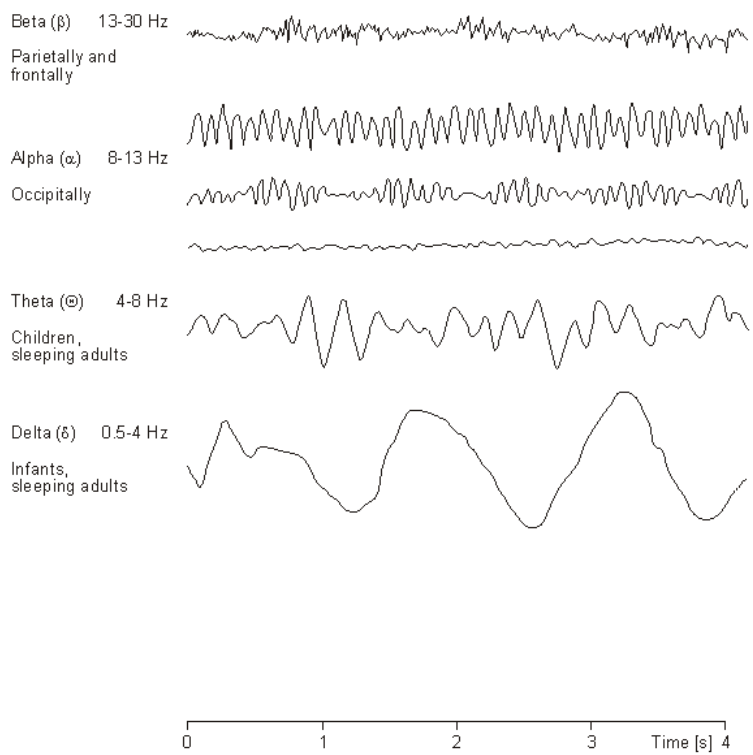
Features

- frequency between 4 and 7.5 Hz
- part of the normal EEG
- fronto-central regions
- temporal theta (in particular if age > 50), is not abnormal

The δ-rhythm

Features

- frequency between 0.5-4 Hz
- absent in healthy adults up to $\sim$ 65-y of age in wake state
- may occur sporadically in older individual
- focal delta activity is abnormal



The μ-Rhythm

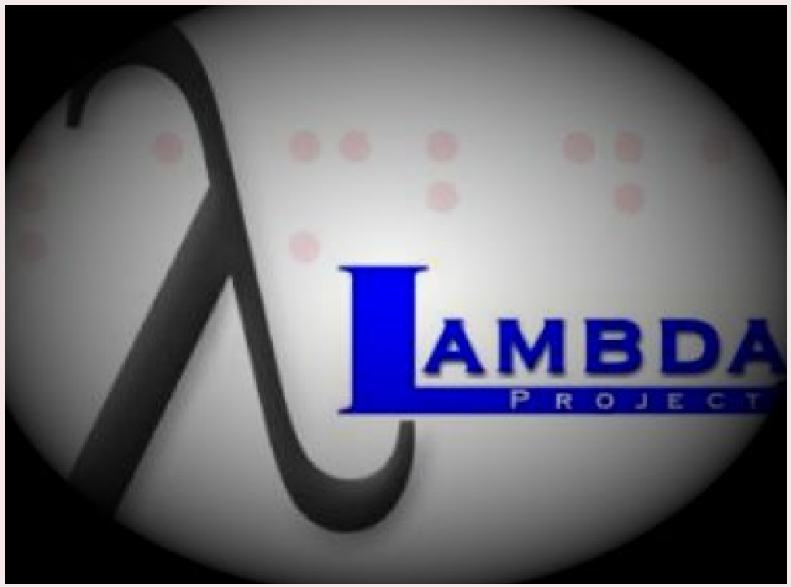
Features

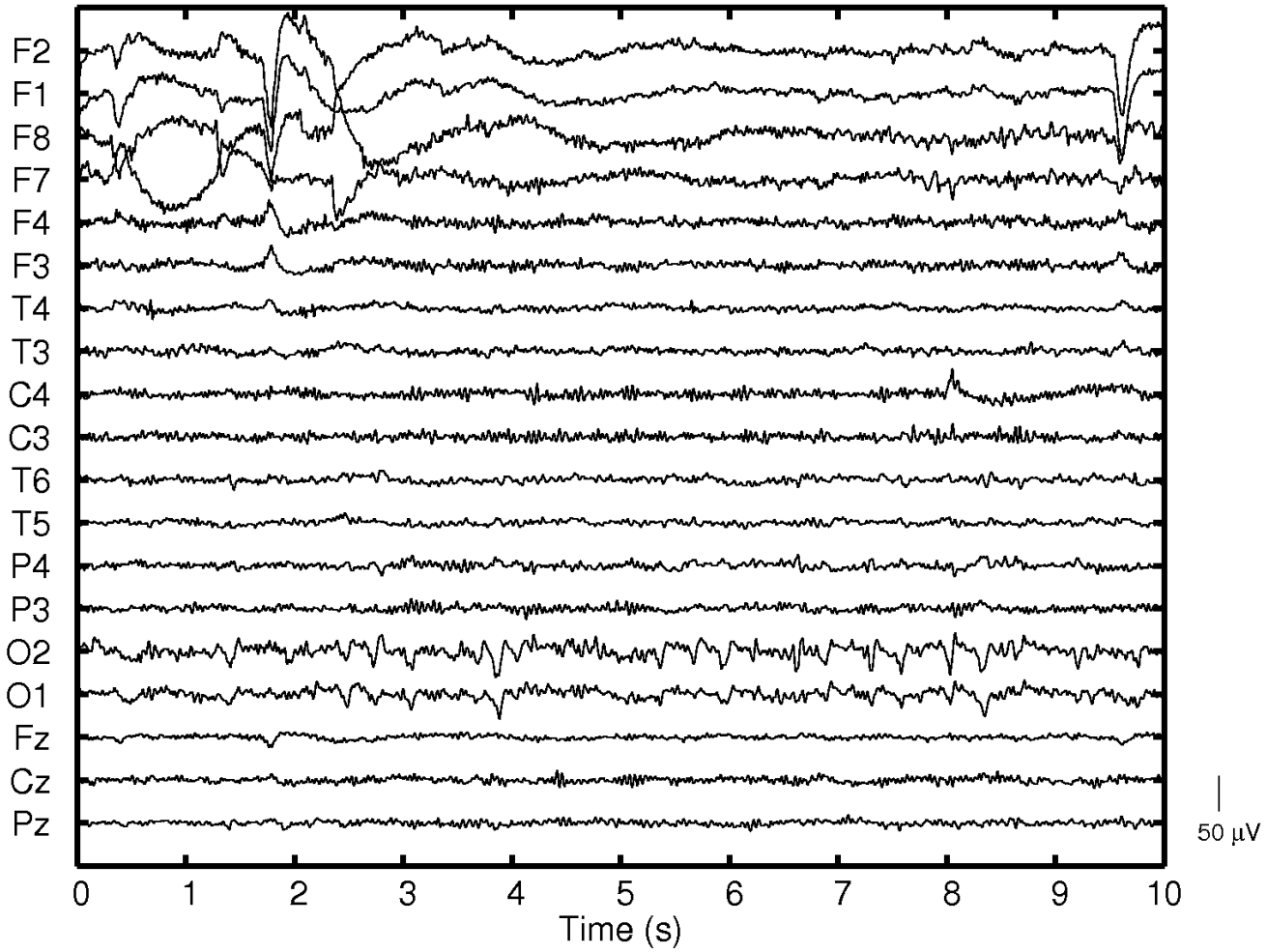
- comb-shaped
- central areas (C3 and C4)
- "idling of motor cortex"
- bilateral, but oftentimes unilateral
- blocked by contralateral movement, intention to move, or watching movement

λ-waves

Features

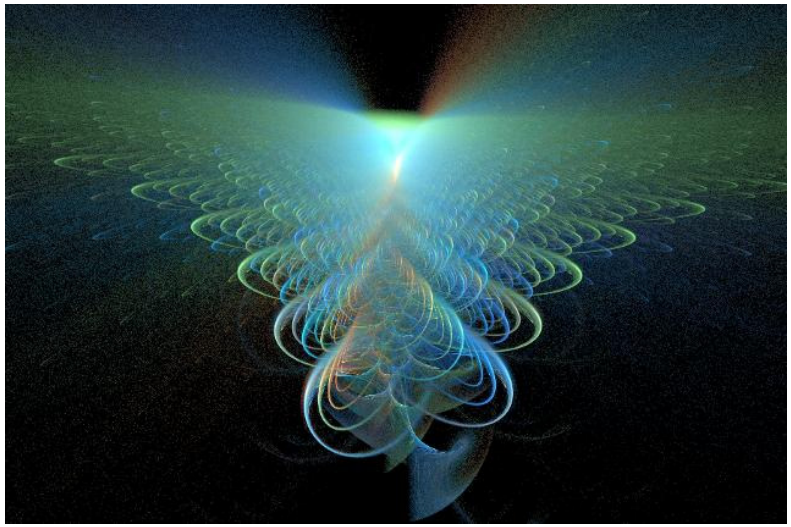
- shaped as capital Λ
- posterior areas
- scanning of the environment
- positive waves
- bilateral, but not always symmetrical




F2
F1
F8
F7
F4
F3
T4
T3
C4
C3
T6
T5
P4
P3
O2
O1
Fz
Cz
Pz
50 µV
0
1
2
3
4
5
6
7
8
9
10
Time (s)

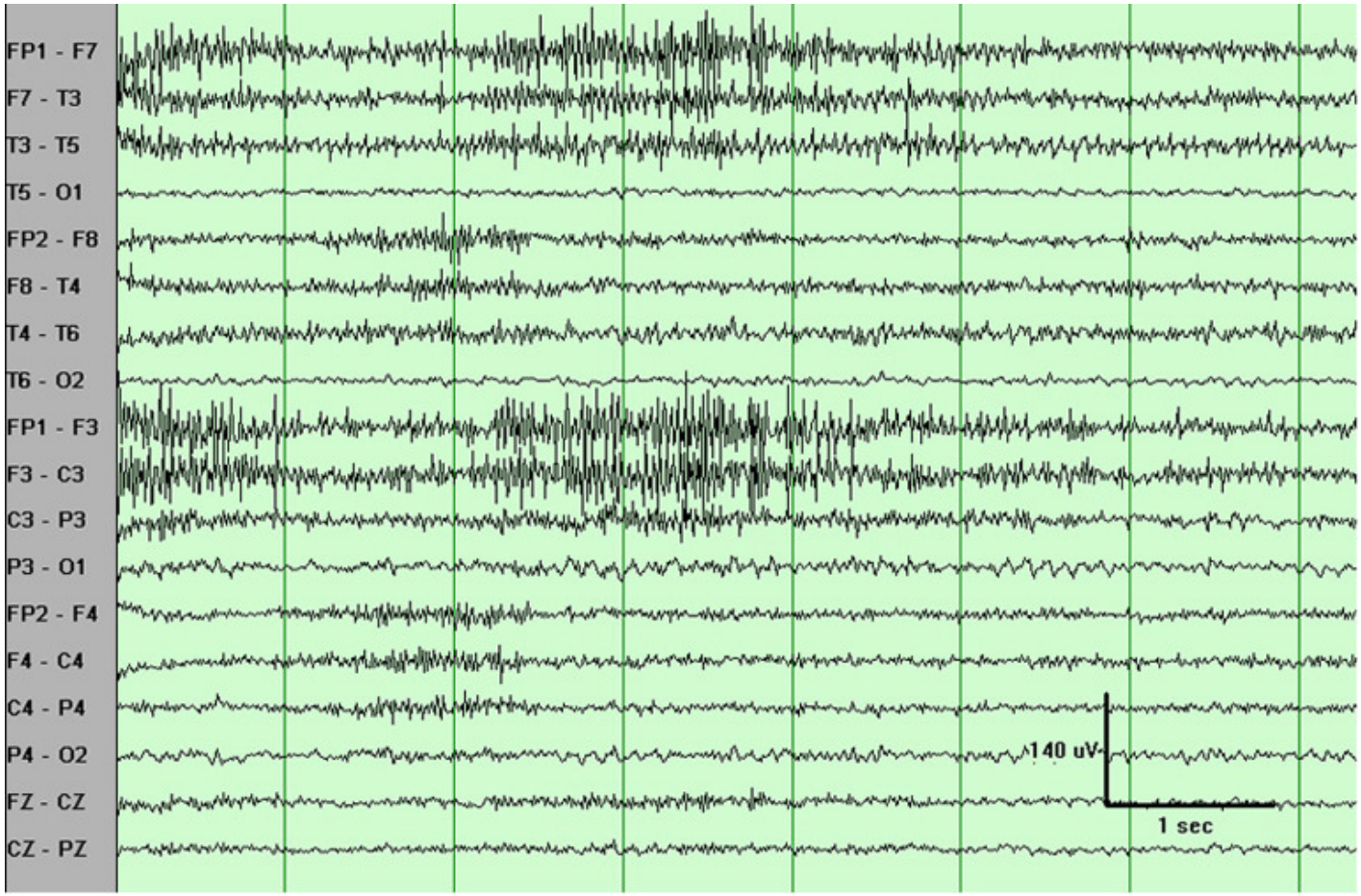
Midline theta

- frequency 4-7 Hz
- vertex (Cz)
- duration 2-10 s
- nonspecific clinical relevance

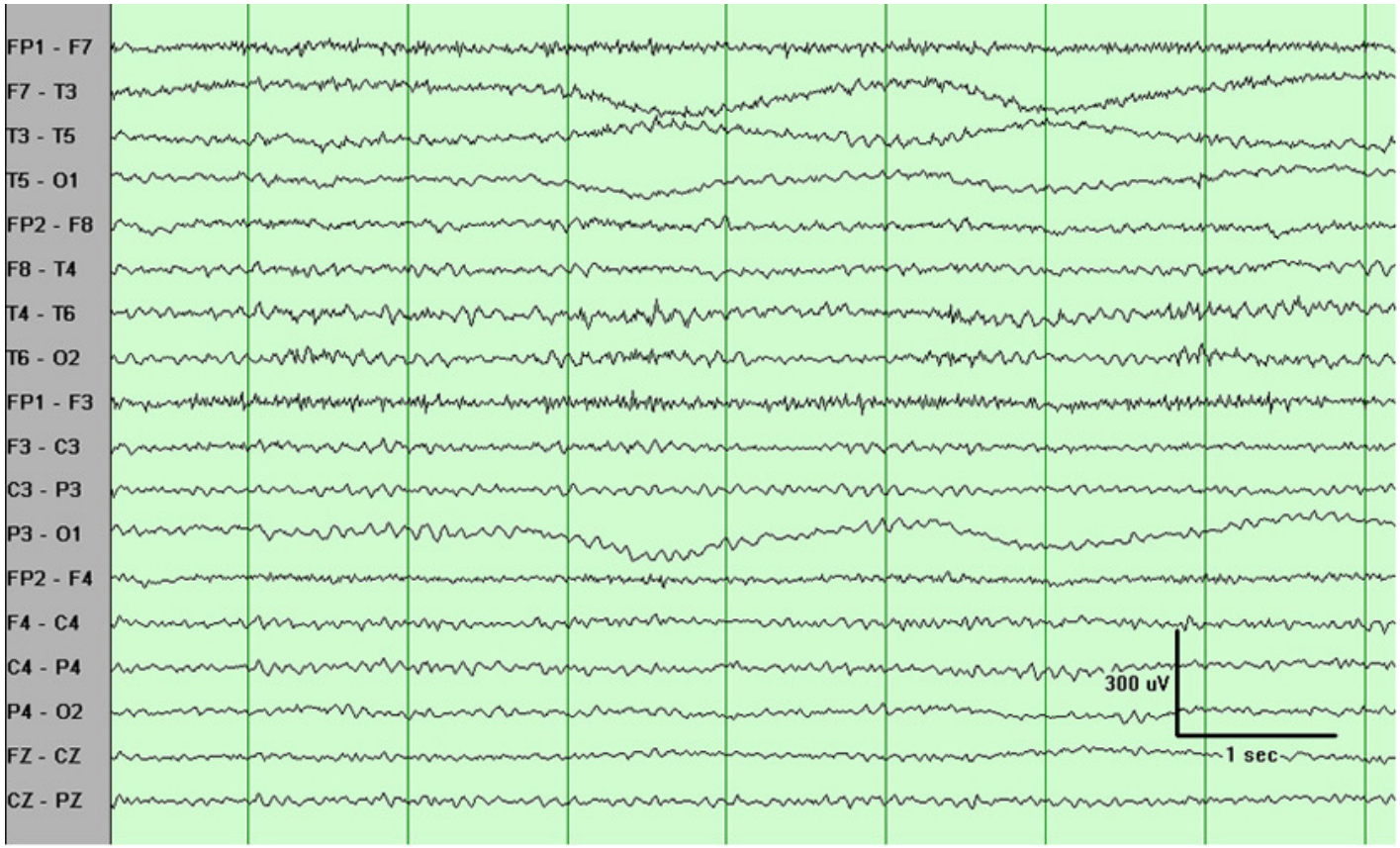


eye movement

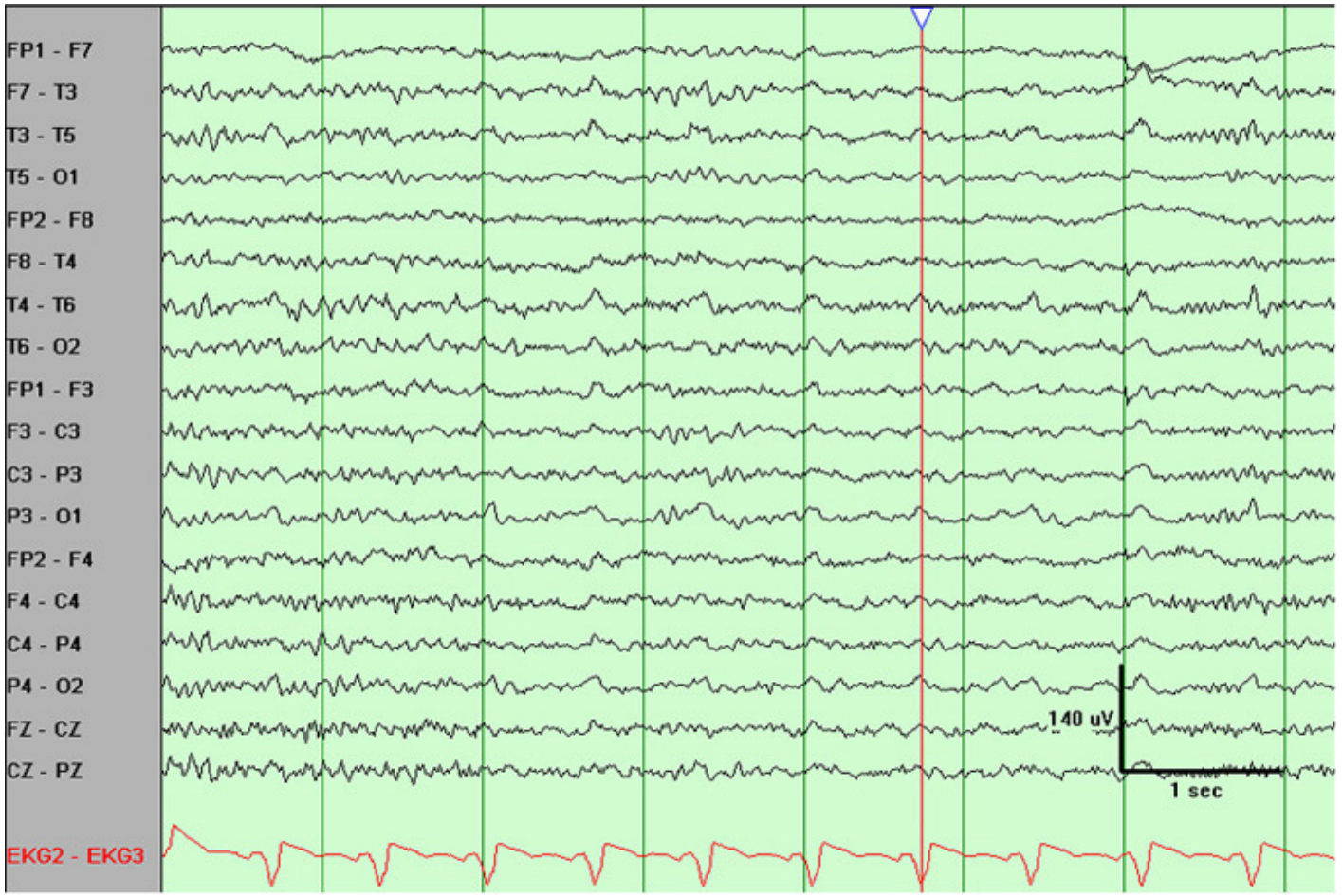
EMG


FP1 - F7
F7 - T3
T3 - T5
T5 - O1
FP2 - F8
F8 - T4
T4 - T6
T6 - O2
FP1 - F3
F3 - C3
C3 - P3
P3 - O1
FP2 - F4
F4 - C4
C4 - P4
P4 - O2
FZ - CZ
CZ - PZ
140 uV
1 sec

Sweat

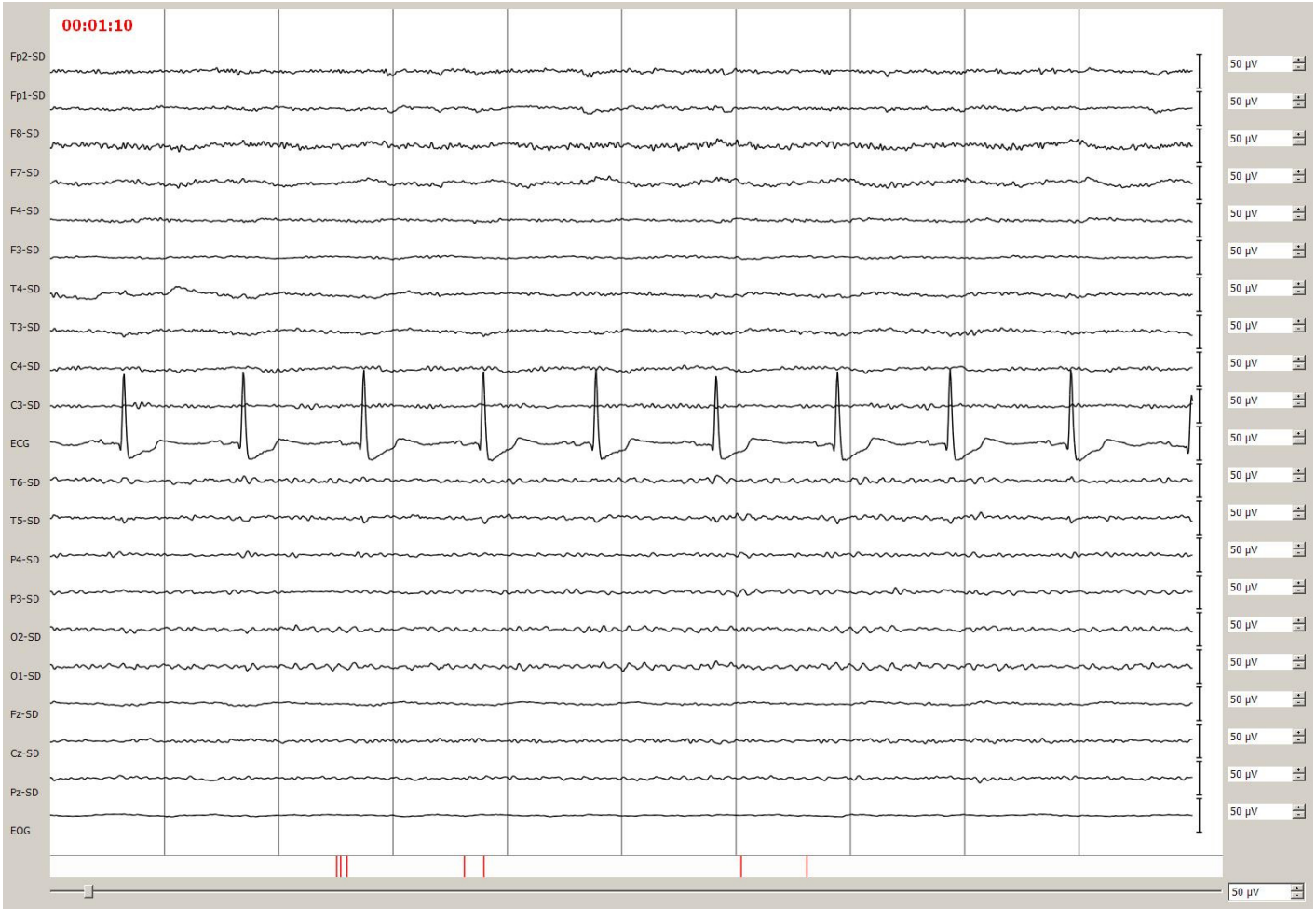

FP1 - F7
F7 - T3
T3 - T5
T5 - O1
FP2 - F8
F8 - T4
T4 - T6
T6 - O2
FP1 - F3
F3 - C3
C3 - P3
P3 - O1
FP2 - F4
F4 - C4
C4 - P4
P4 - O2
FZ - CZ
CZ - PZ
300 uV
1 sec

ECG

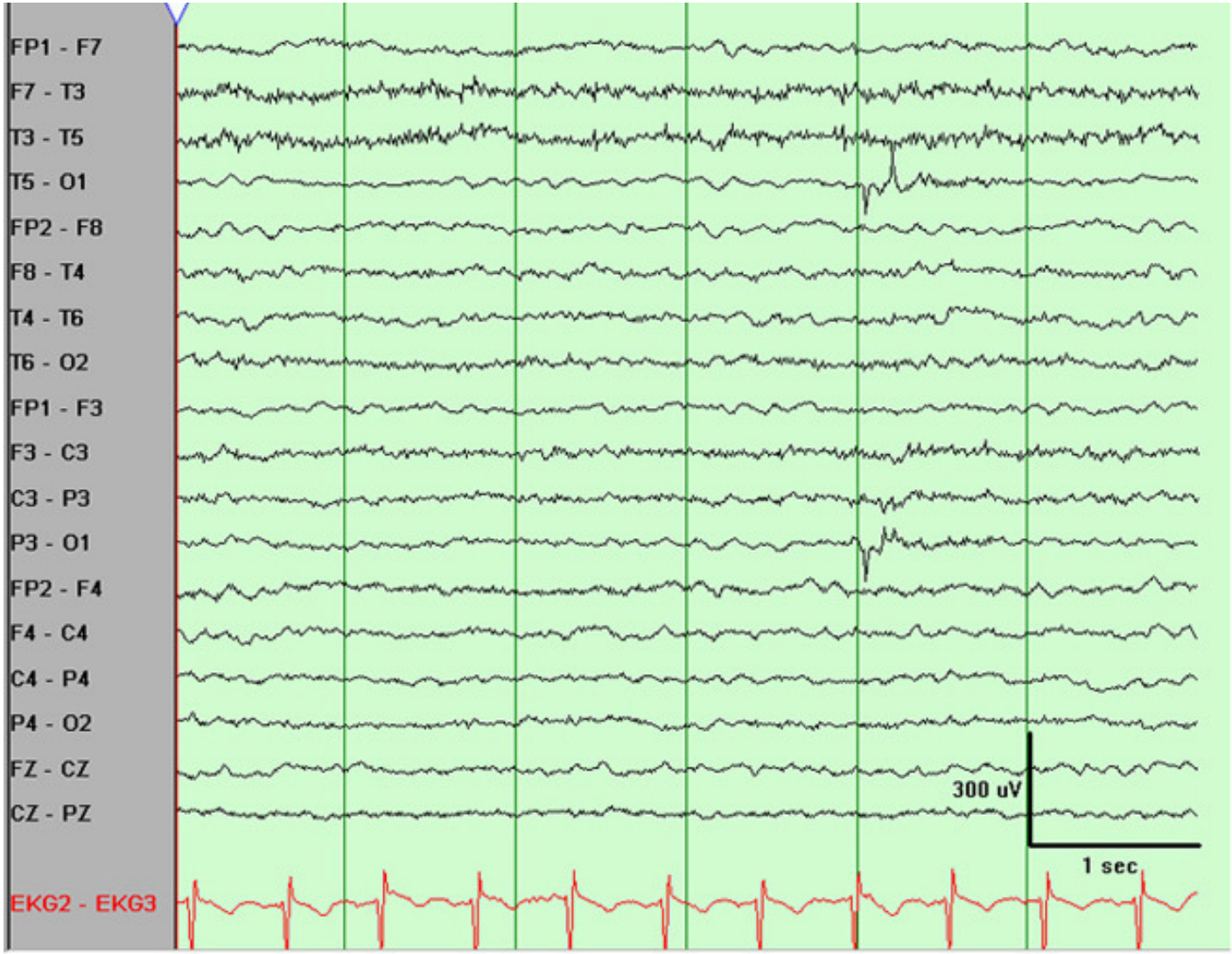

FP1 - F7
F7 - T3
T3 - T5
T5 - O1
FP2 - F8
F8 - T4
T4 - T6
T6 - O2
FP1 - F3
F3 - C3
C3 - P3
P3 - O1
FP2 - F4
F4 - C4
C4 - P4
P4 - O2
FZ - CZ
CZ - PZ
EKG2 - EKG3
140 uV
1 sec

Pulsation artefacts-I

Pulsation artefacts-II



Electrode artefact



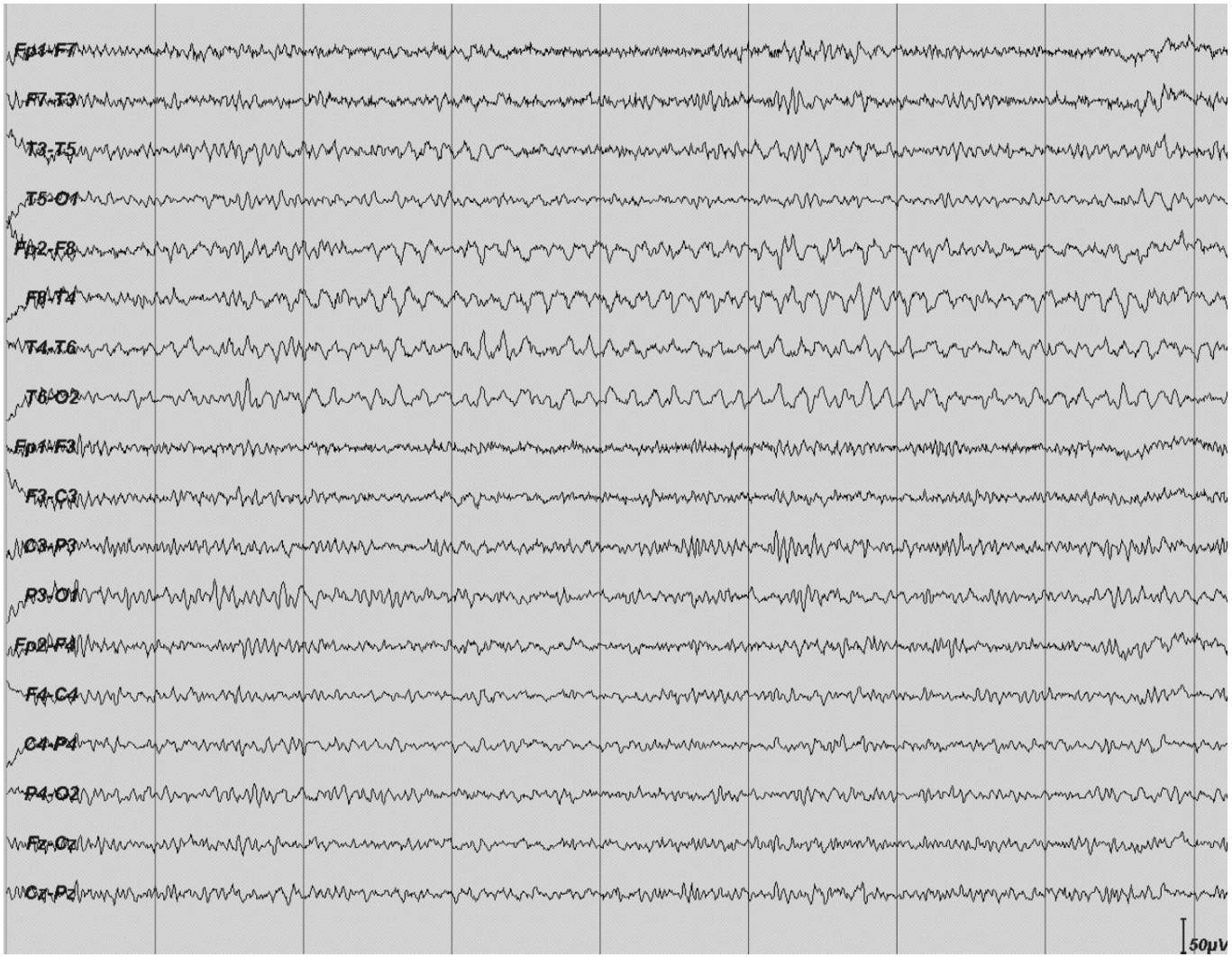
Overview of benign variants

- Rhythmic Temporal Bursts of Drowsiness
- SREDA
- Wicket waves
- Small Sharp Spikes of Sleep (SSS)
- 6 Hz phantom spike and waves
- Positive bursts of 14 and 6 Hz

Rhythmic temporal bursts of drowsiness

Features

- bursts of 5 to 7 Hz theta waves, sharp, flat, or notched
- maximum midtemporal, no spatial or temporal evolvement
- duration 10 s to 1 minute
- was known as psychomotor variant (Hughes and Cayaffa, 1973)
- 0.5-2% of adolescents and adults


Fp1-F7
F7-T3
T3-T5
T5-O1
Fp2-F8
F8-T4
T4-T6
T6-O2
Fp1-F3
F3-C3
C3-P3
P3-O1
Fp2-F4
F4-C4
C4-P4
P4-O2
Fz-Cz
Cz-Pz
50µV

Subclinical rhythmic EEG discharges of Adults

Features

- uncommon pattern, mainly in older persons (>50 y)
- at rest or during drowsiness; sharply contoured theta
- frequency is typically 5-6 Hz.
- Location is widespread or bilateral with a posterior maximum.
- Abrupt onset and termination
- duration 20 seconds to minutes (average 40-80 s)

Wicket waves

Features

- temporal area
- 5-7 Hz, notched appearance (mu-like)
- often unilateral
- short duration (0.5-2 s)

A8047. Wicket waves in a 90-y old male.

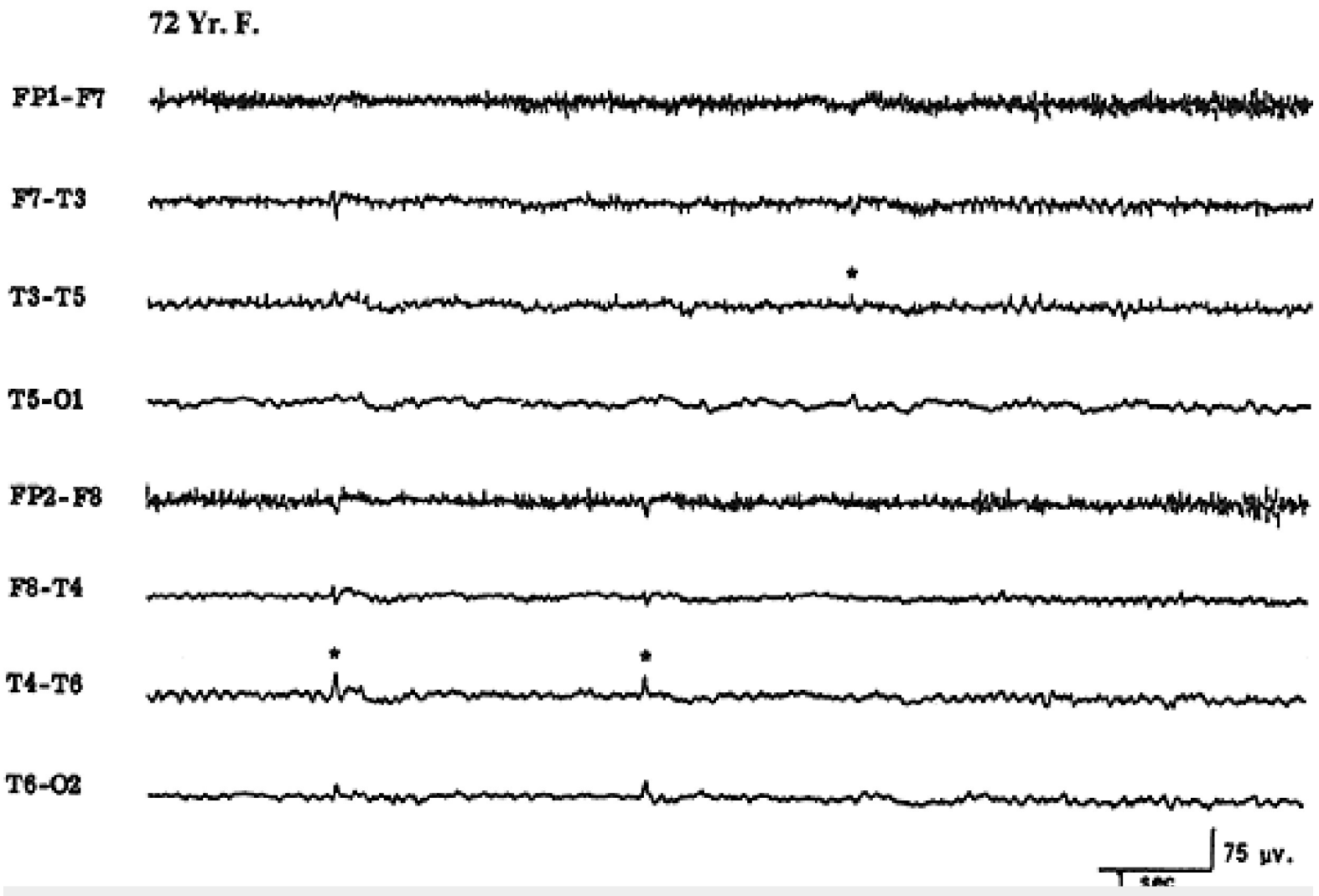
A8045. 74-y old female.

Small sharp spikes

Features

- during light sleep
- temporal, uni- or bilateral, independent
- monophasic
- short lasting (50 ms), small amplitude ($<$ 50 µV)

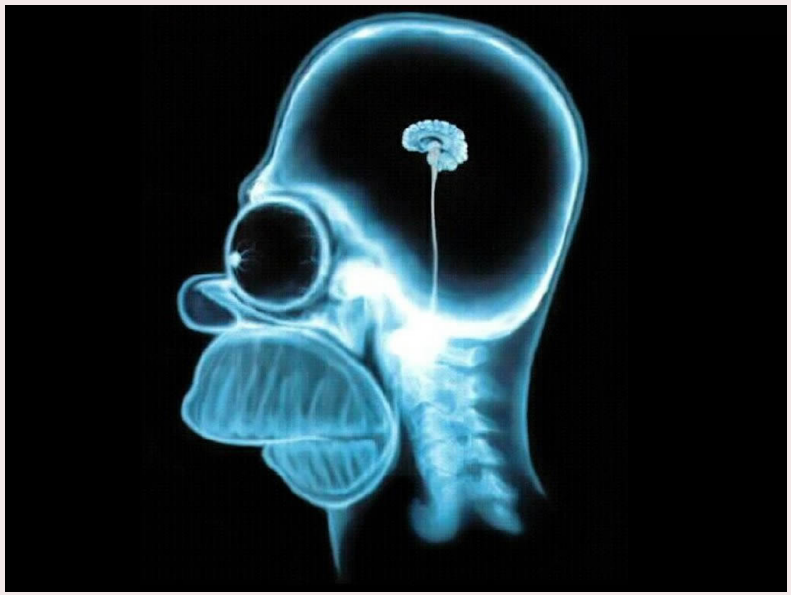
Small sharp spikes



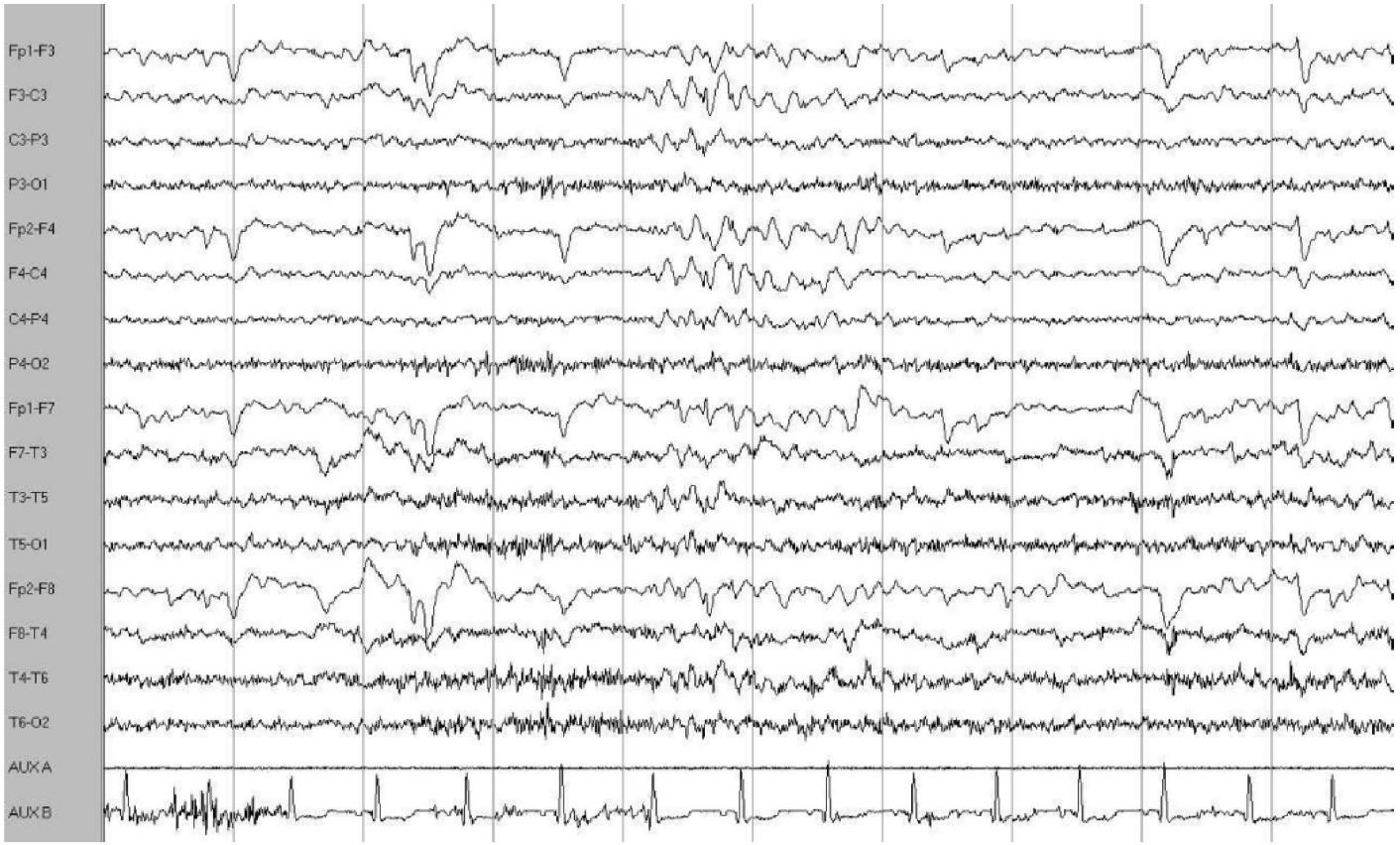
6 Hz phantom spike and waves

Features

- frequency: 5-7 Hz
- duration: 1-2 s
- phantom spike: not always visible
- in 2.5% adolescents and adults
- Bilateral synchronous, during light sleep

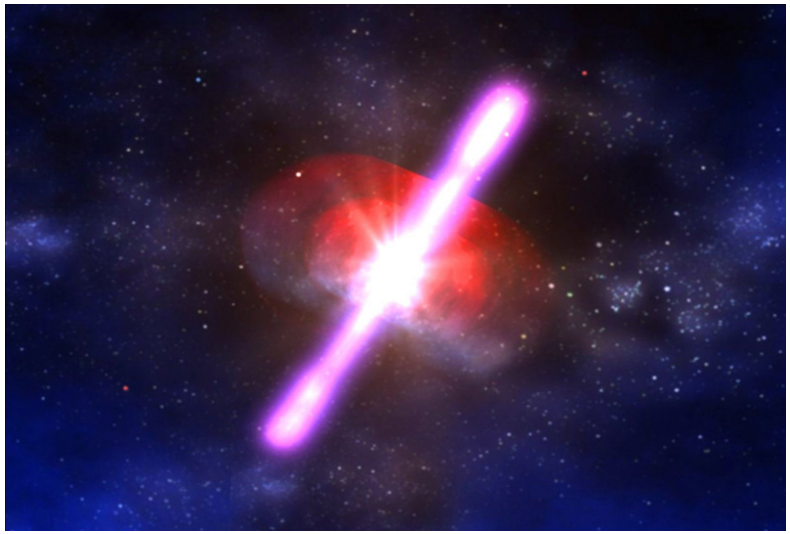


6 Hz phantom spike and wave



14 and 6 Hz positive bursts

- frequency 14 and 6 Hz
- duration $<$ 2 s, 20-60 µV
- temporal, unilaterally or bilaterally, monophasic
- awake and light sleep



Positive bursts of 14 and 6 Hz

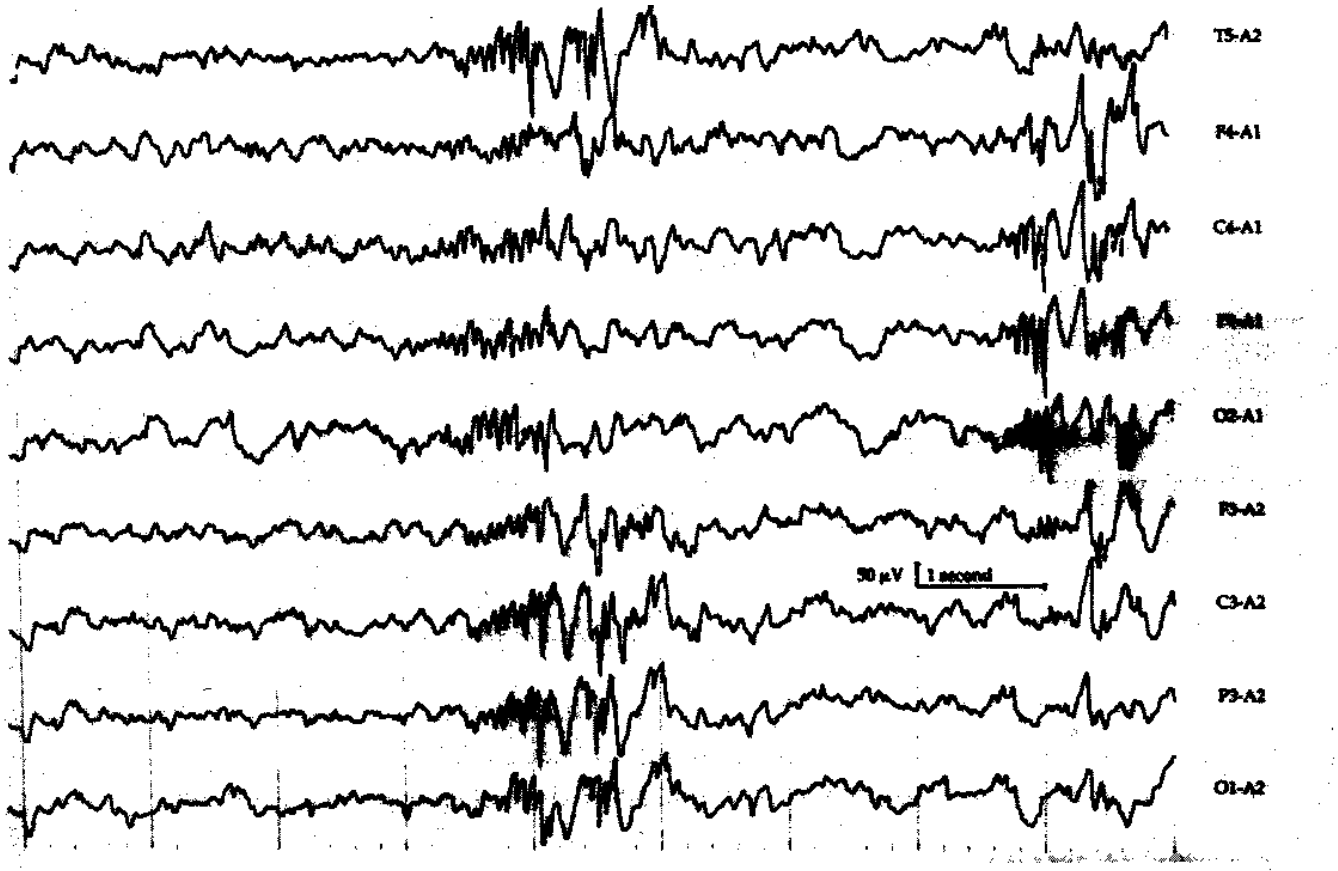


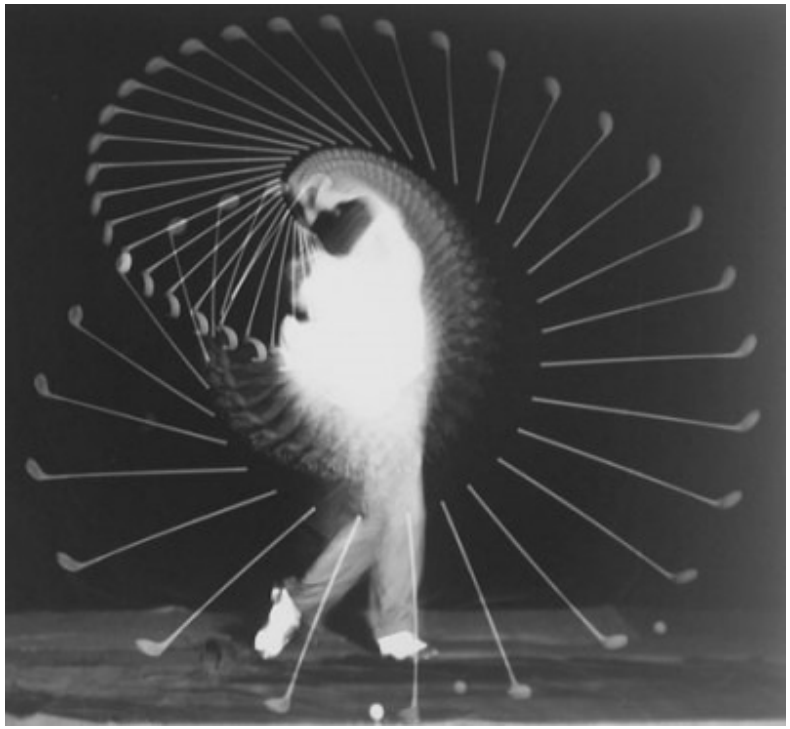
Fig. 4. Fourteen- and 6-Hz positive bursts. Note the bursts of spiky morphologies with surface positivity, here seen bilaterally with shifting laterality. They are best detected with long distance referential montages. Reprinted from Goldensohn et al., 1999 with permission.

Activation procedures

- eyes closed and eyes open: reactivity
- hyperventilation: *symmetric* increase in theta and delta
- photic driving

Photic Driving Responses

- photomyogenic
- photoconvulsive



This occurs during photic driving. What is the clinical significance?

Features of the routine EEG

- Background Pattern: PDR, frequency and symmetry. Temporal en parietal. Central. Frontal.
- Intermittent: epileptiform discharges? benign variants?
- HV: asymmetry? Epileptiform discharges?
- Photic Driving: response? Symmetry?
- ECG: regular?
- Conclusion

Quantitative EEG

Use at least:

- FFT for estimation of PDR
- symmetry (e.g. use the BSI)
- anterio-posterior gradient

More resources

- www.eegatlas-online.com
- www.eegteaching.org