Foundations of Psychophysiology

Part 8.1: Electrocortical activity

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NEUROADAPTIVE HUMAN-COMPUTER INTERACTION

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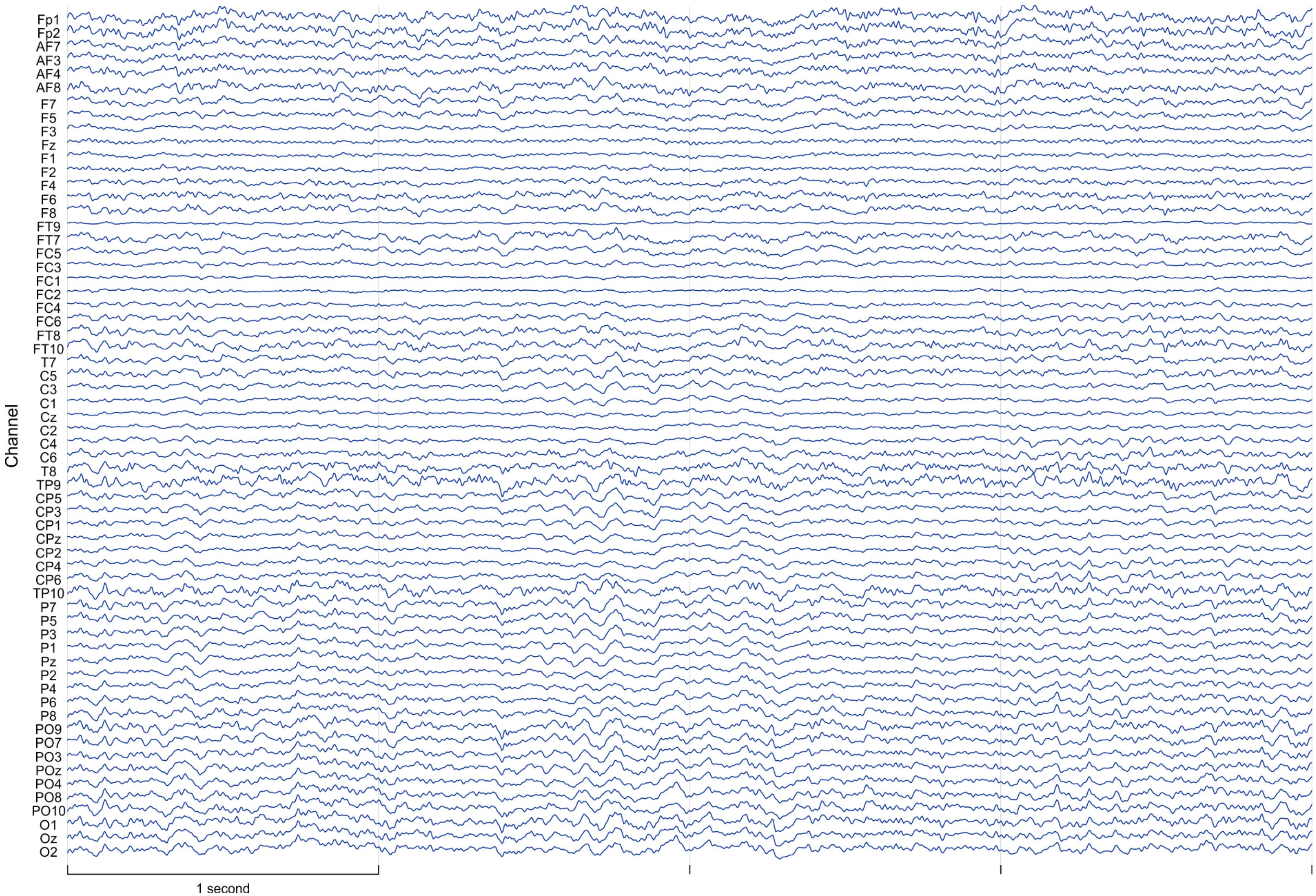
The electroencephalogram



Electrocortical activity

Brief history of EEG

Physiological origins

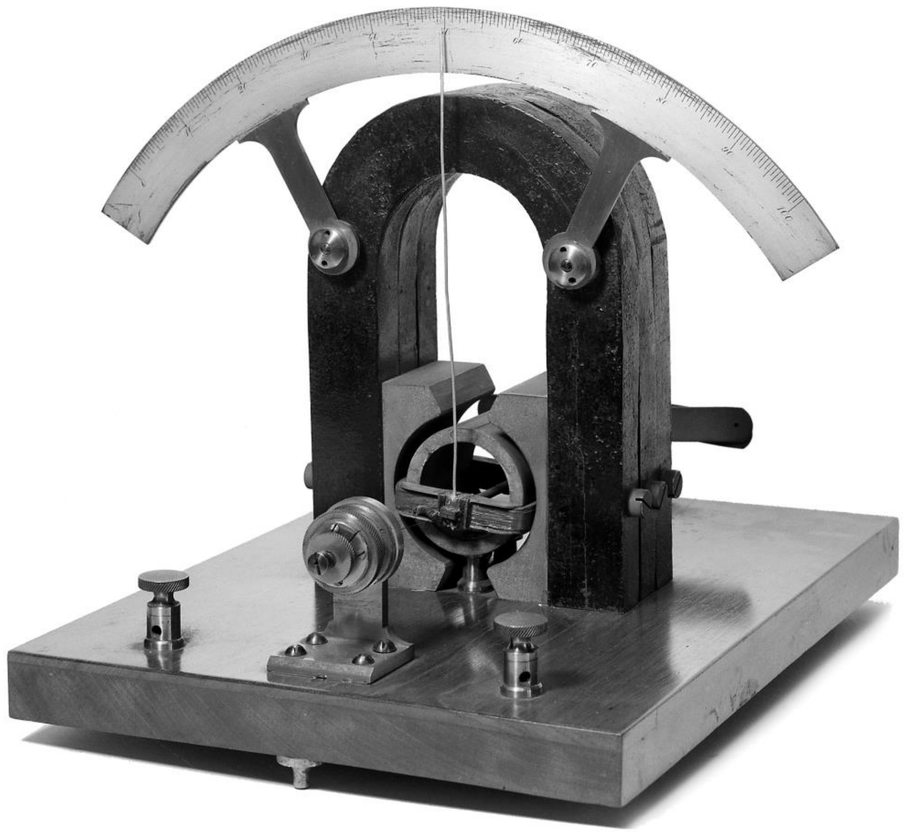
EEG versus other modalities

Brief history of EEG

Physiological measurement

Richard Caton used a galvanometer to observe electrical impulses from the surface of living rabbit and monkey brains.

"… currents ... were found to be … influenced by stimulation of the ... retina by light."

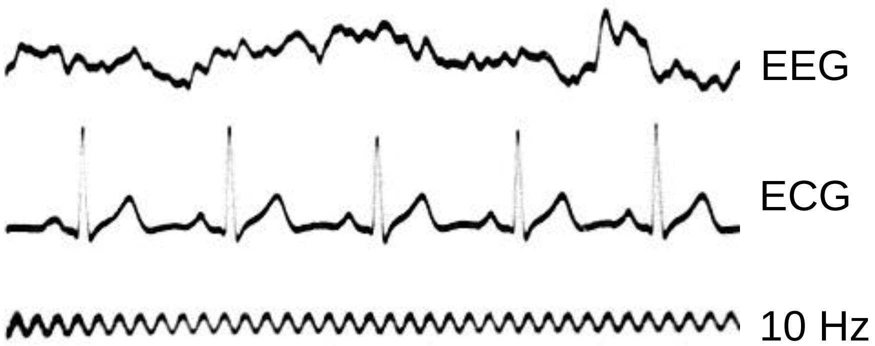


Caton, R. (1875). The electric currents of the brain. *British Medical Journal, 2*(765), 278.

Physiological measurement

On July 6th, 1924, Hans Berger performed the first measures on a living human brain.

Later measurements, which Berger conducted on his own son, revealed first indications that different intensities of mental activity led to visible changes in the recorded curves.



Berger, H. (1929). Über das Elektrenkephalogramm des Menschen. *Archiv für Psychiatrie und Nervenkrankheiten, 87*, 527–570.

Electrocerebrogram?

"Ich glaube in der Tat, daß die von mir hier ausführlich geschilderte cerebrale Kurve im Gehirn entsteht und dem Elektrocerebrogramm der Säugetiere von *Neminski* entspricht.

Da ich aus sprachlichen Gründen das Wort 'Elektrocerebrogramm', das sich aus griechischen und lateinischen Bestandteilen zusammensetzt, für barbarisch halte, möchte ich für diese von mir hier zum erstenmal *beim Menschen* nachgewiesene Kurve in Anlehnung an den Namen 'Elektrokardiogramm' den Namen 'Elektrenkephalogramm' vorschlagen."

– Berger (1929)

Berger, H. (1929). Über das Elektrenkephalogramm des Menschen. *Archiv für Psychiatrie und Nervenkrankheiten, 87*, 527–570.

The electroencephalogram

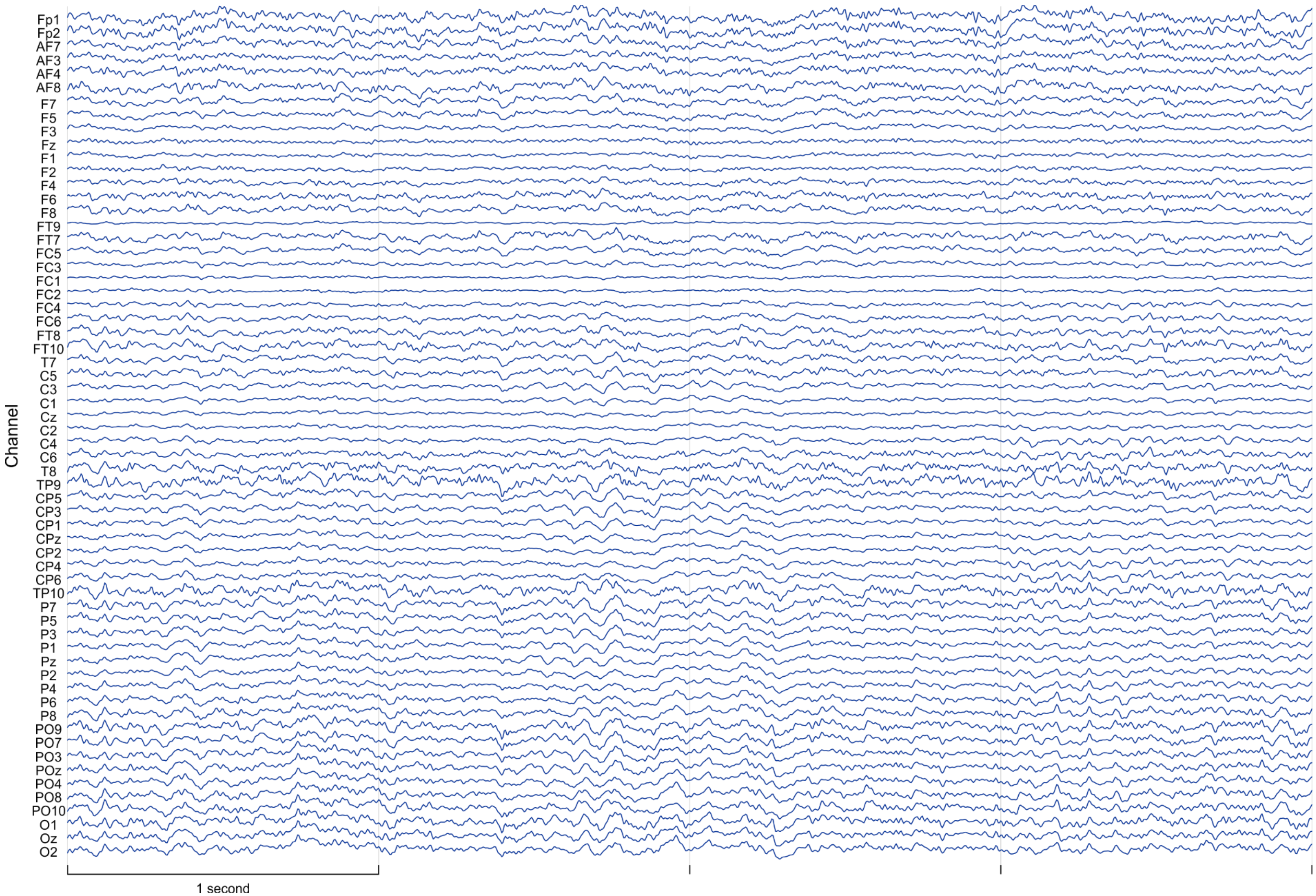
= the “**graphical**” representation of the **electrical** activity of the brain (Greek: **encephalon**)

Electroencephalo**graphy** refers to the method.

The abbreviation **EEG** can refer to either electroencephalogram or electroencephalography.

Using EEG, brain activity is usually recorded at the scalp.

The electroencephalogram



Recap: Electricity

- Current

  The flow of charged particles through a conductor, measured in ampere (A).

- Voltage

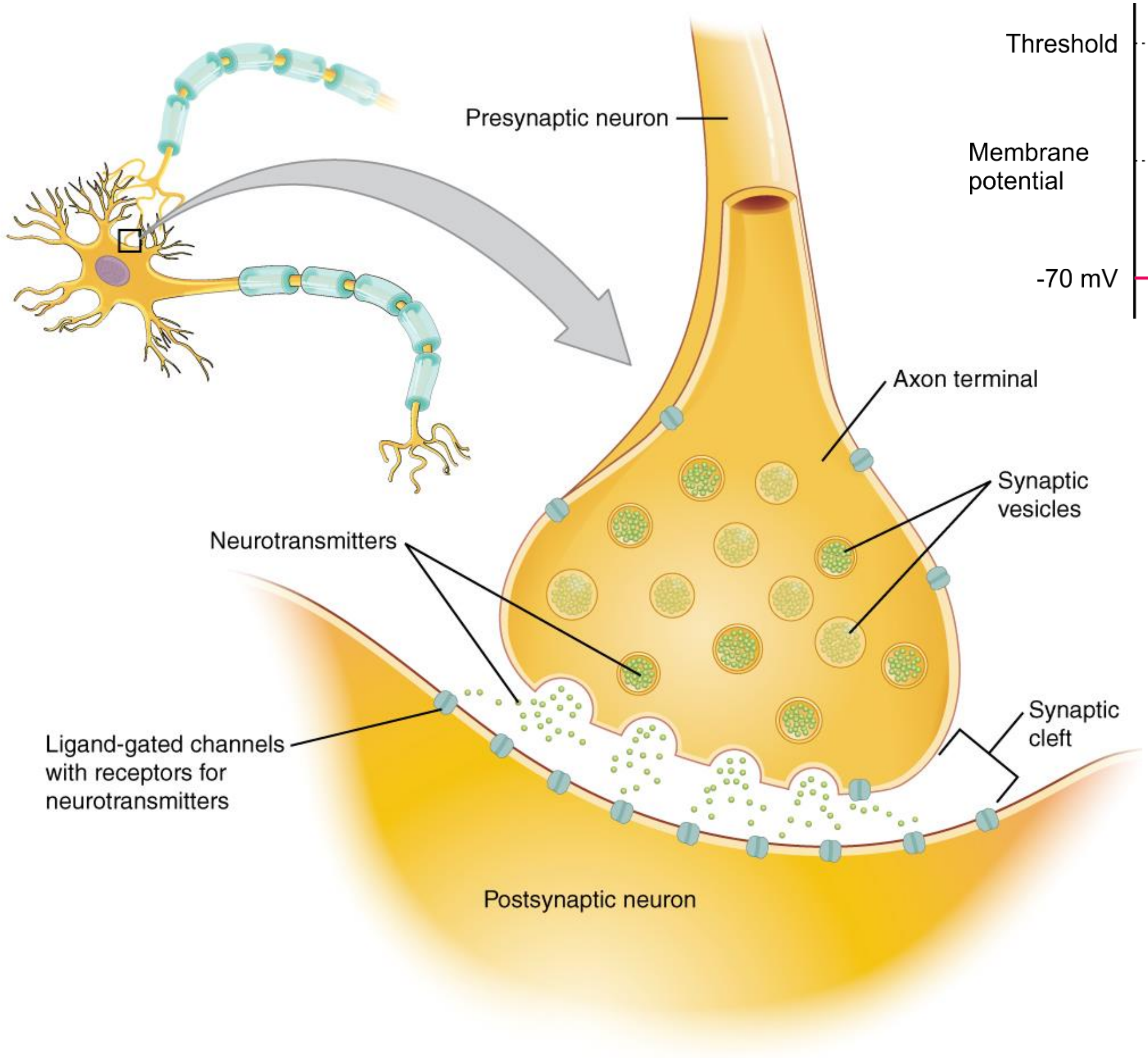
  The potential for current to flow from one place to another, measured in volt (V).

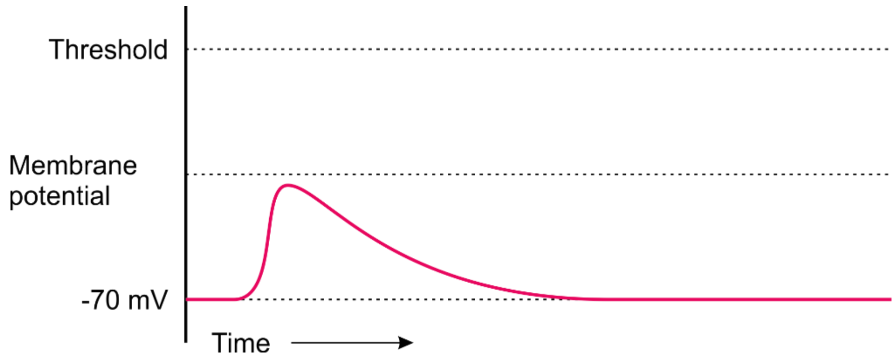
- Resistance

  A substance’s ability to resist the flow of current, measured in ohm (Ω).
  Impedance is resistance for alternating currents.

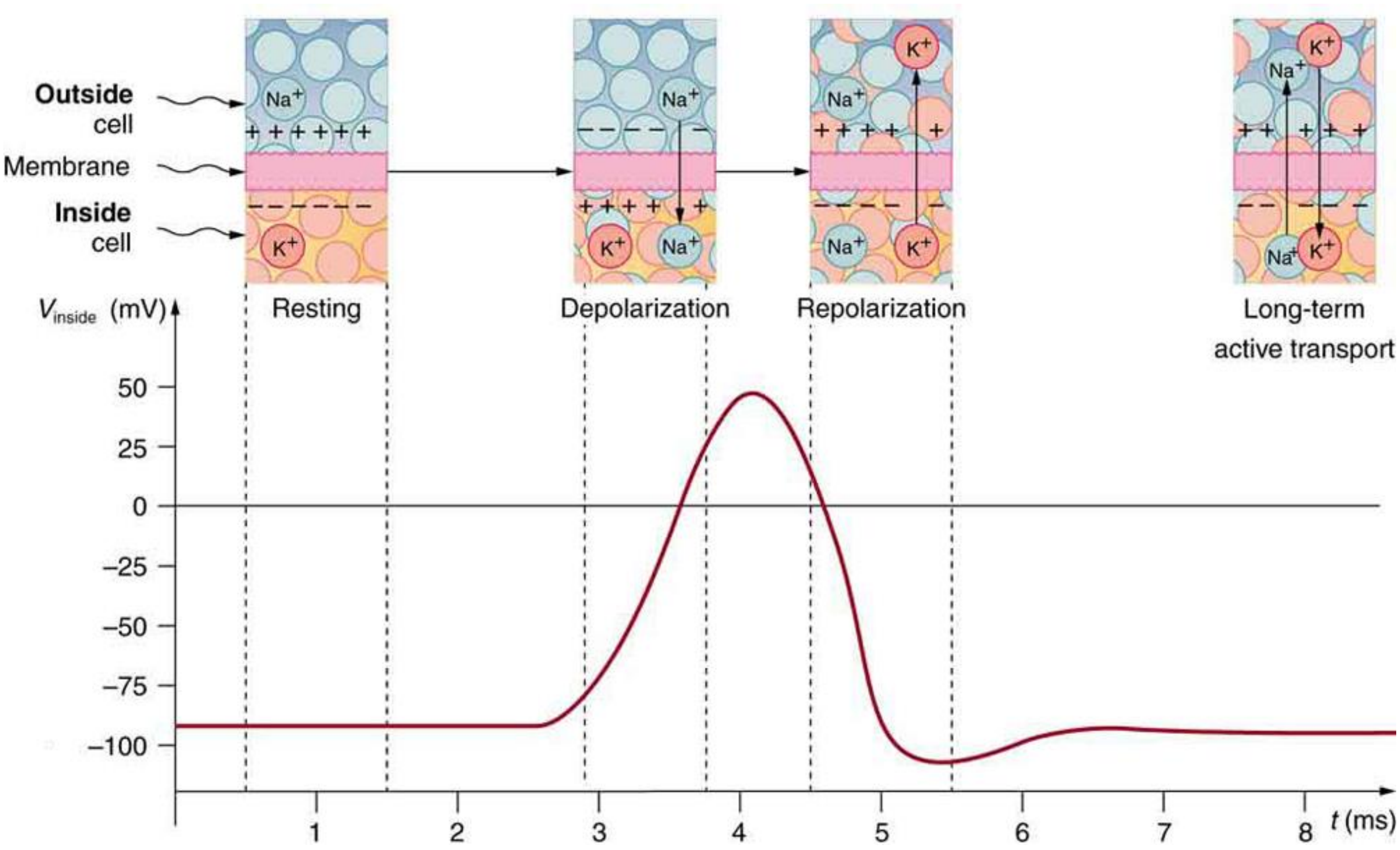
Physiological origins

Recap: Postsynaptic potential





Recap: Action potential



Microelectrodes versus scalp measures

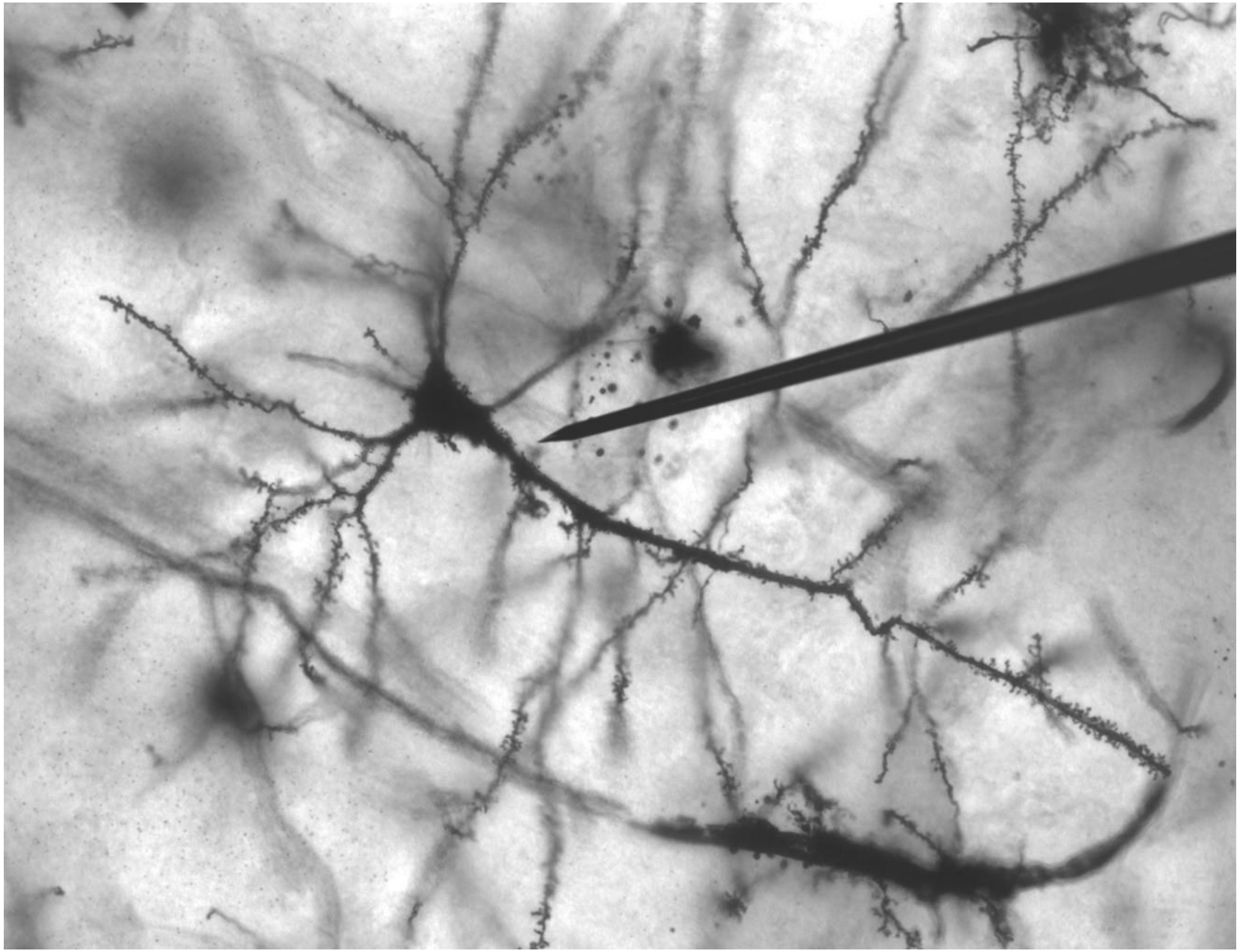
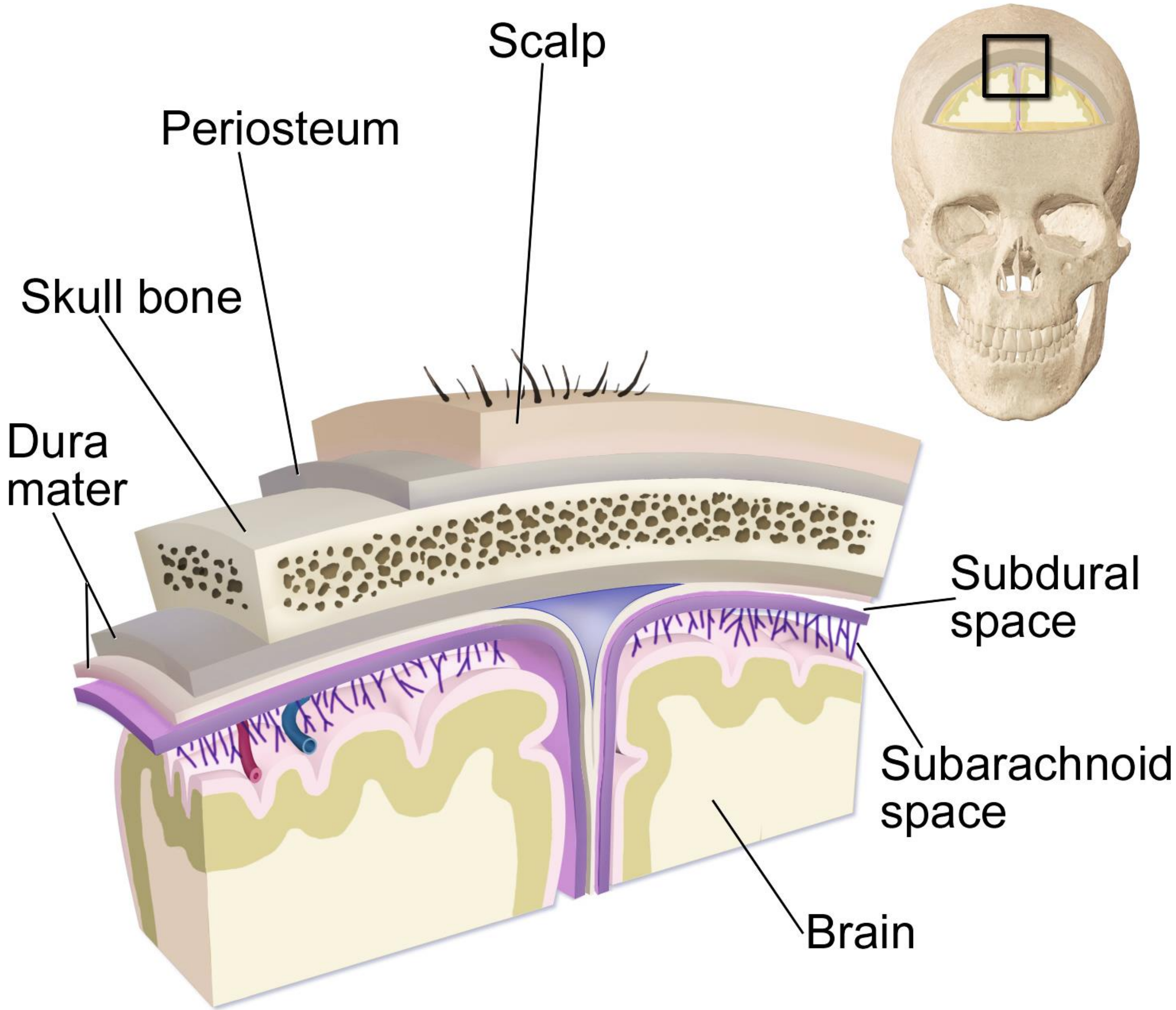


Figure: “Pyramidal hippocampal neuron 40x” by MethoxyRoxy is licensed under CC BY-SA 2.5 / Added electrode

Barriers between brain and scalp electrodes



Barriers between brain and scalp electrodes

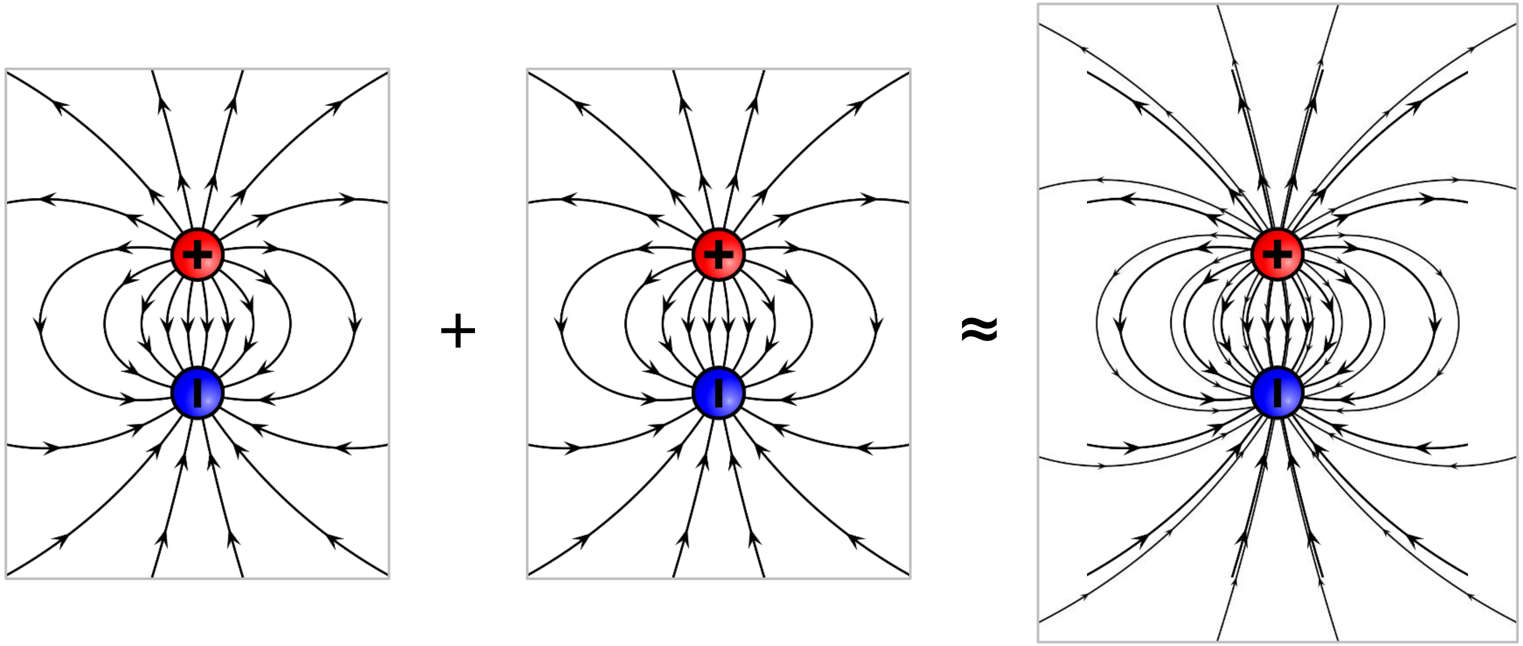
Not only are there barriers between the electrical activity of the neuron and the scalp electrode, they are also just far away.

Therefore, synchronous activity of larger cell populations is needed for a large enough electrical effect to be measurable at the scalp.

In fact, both **temporal synchrony** *and* an appropriate **spatial organisation** is required for this.

Electrical interference

Synchronous, equally oriented currents add up.



Electrical interference

Differently oriented currents may cancel out.

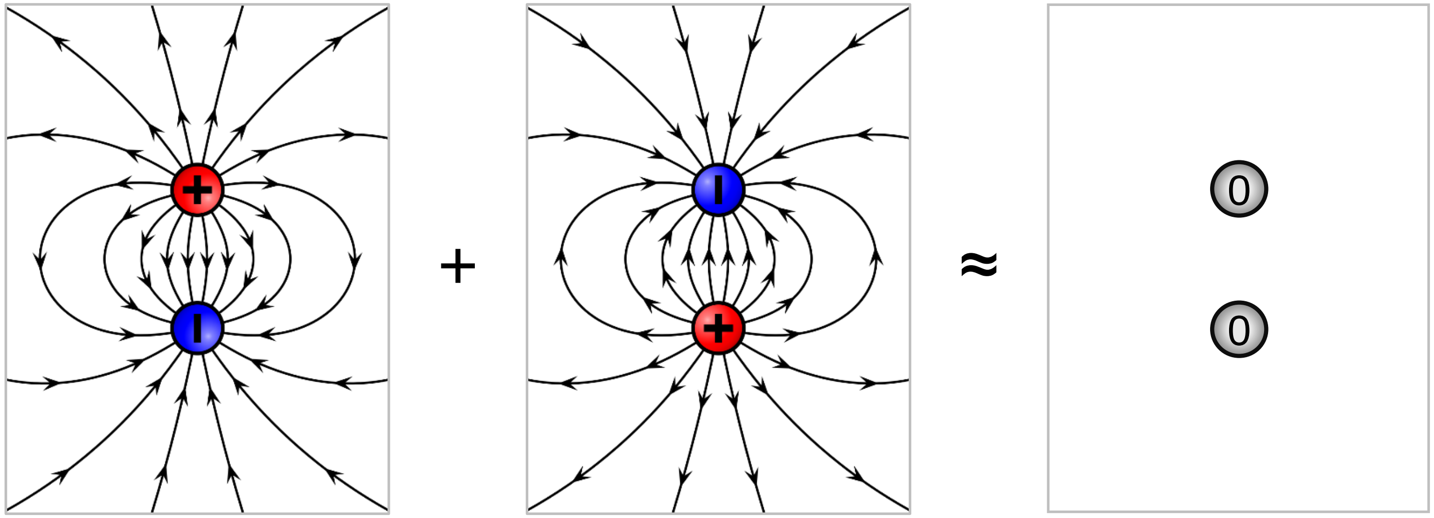


Figure: “VFPt charges plus minus thumb” by Geek3 is licensed under CC BY-SA 3.0

Neuronal electrical activity in the EEG

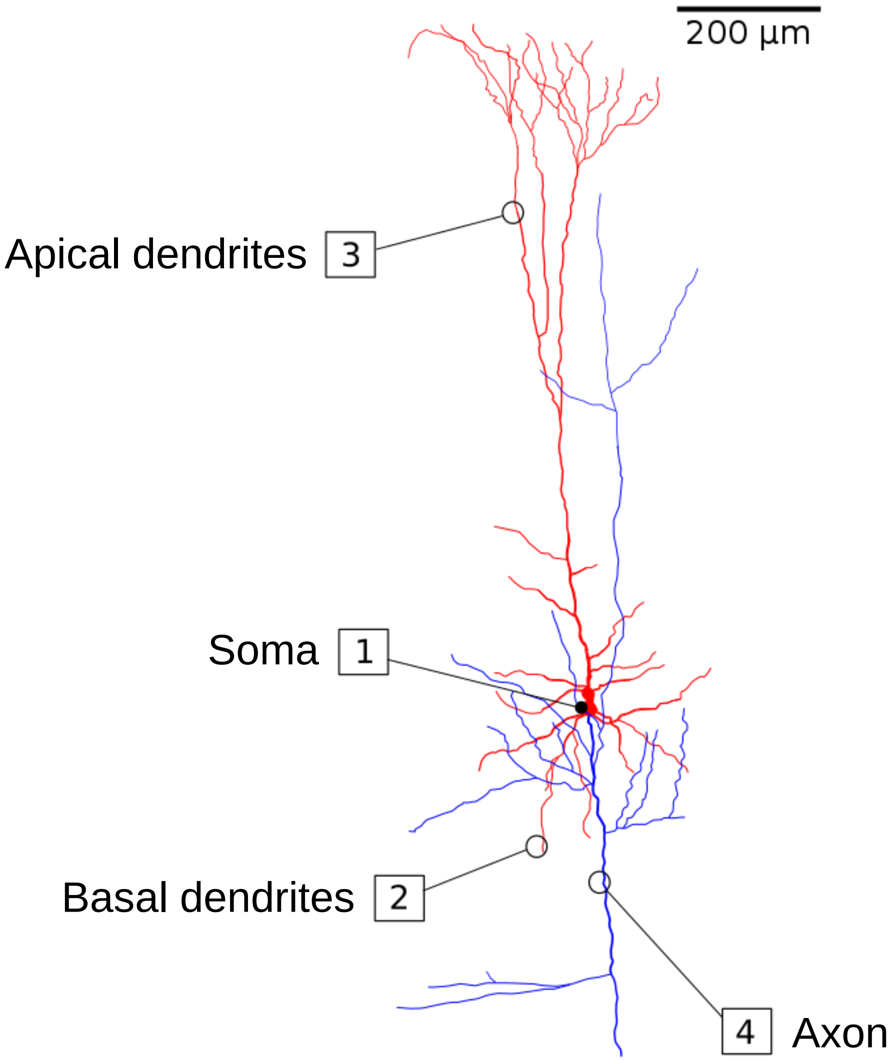
In almost all cases, action potentials are too fast (1-2 ms) to be synchronous over large populations.

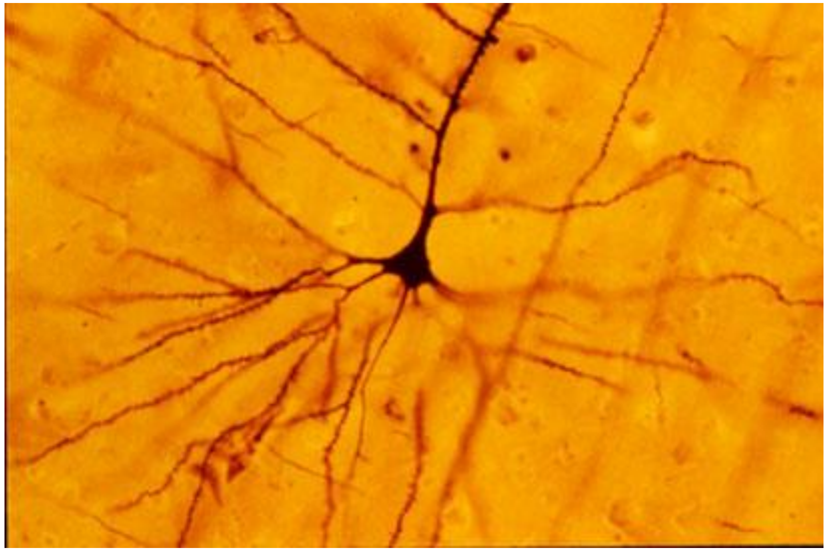
Postsynaptic potentials last longer (10-250 ms), allowing their synchronous activity to summate to be measurable at the scalp.

Aside from temporal synchrony, this requires a physical arrangement of the neurons that does not cancel out the synchronous electric fields.

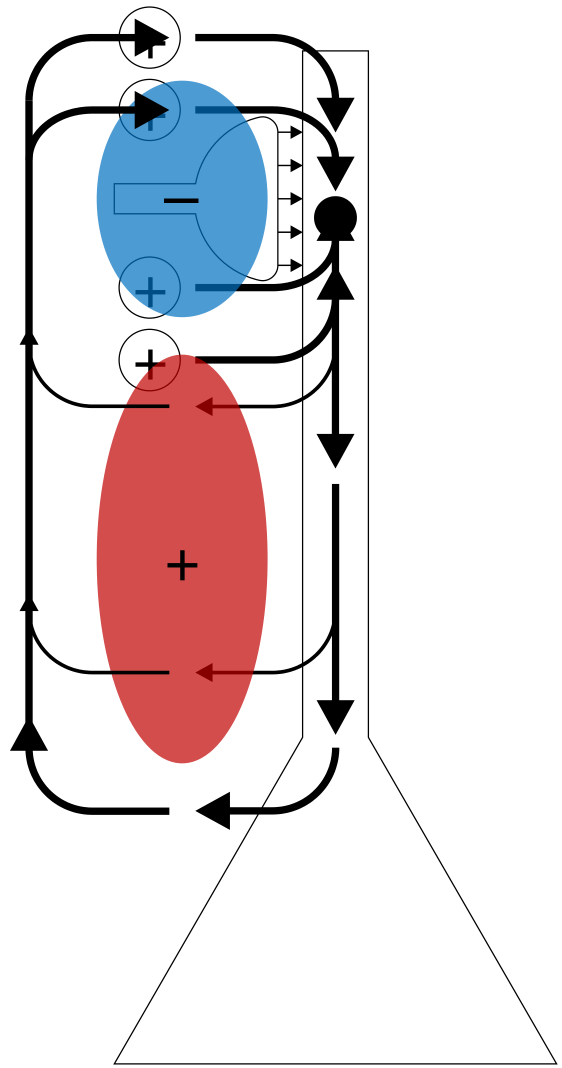
This is the case for the pyramidal cells in the cerebral cortex.

Cortical pyramidal cells





Cortical pyramidal cells



Cortical pyramidal cells

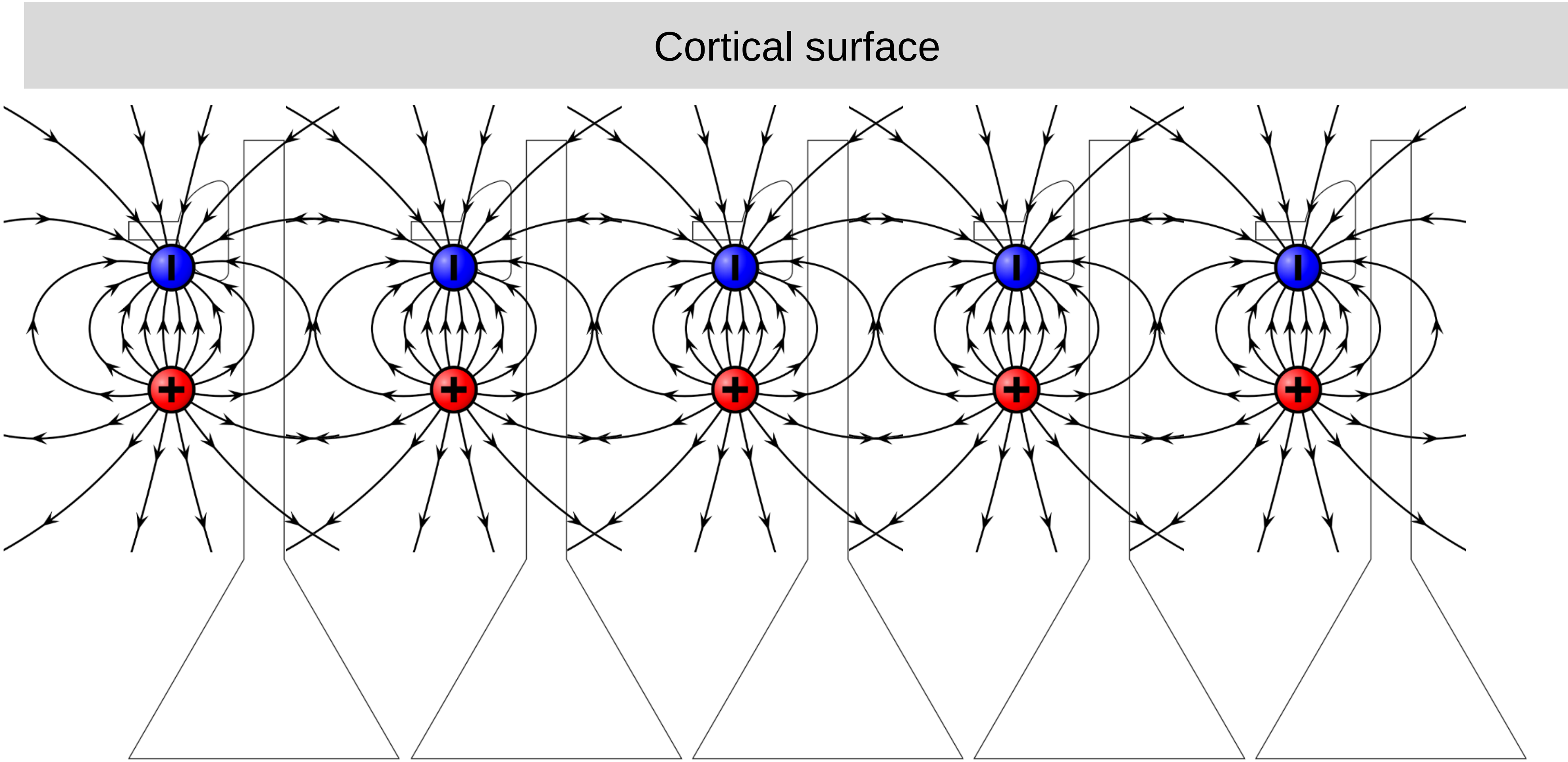


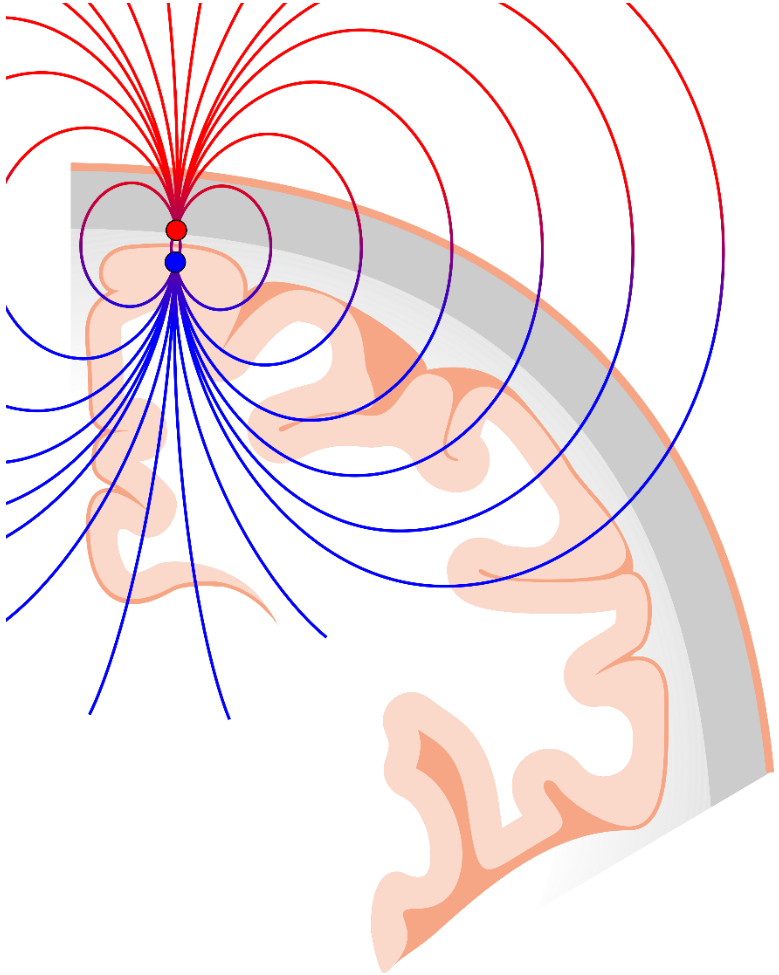
Figure: “VFPt charges plus minus thumb” by Geek3 is licensed under CC BY-SA 3.0

Physiological origins of EEG

A single EEG electrode records the activity of *at least* 10 million neurons, possibly up to 1000 million.

EEG, therefore, has relatively low spatial resolution.

This is due to the previous requirements, as well as volume conduction.



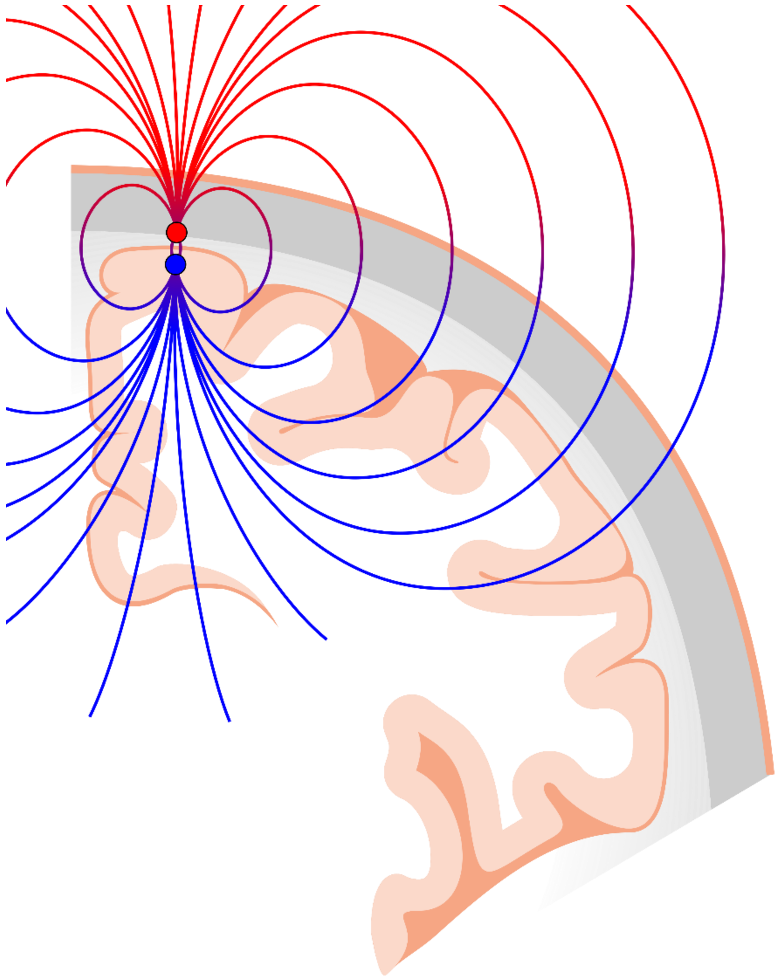
Numbers from
Nunez, P. L., & Srinivasan, R. (2006). *Electric fields of the brain: the neurophysics of EEG*. New York, NY, USA: Oxford University Press.

Volume conduction

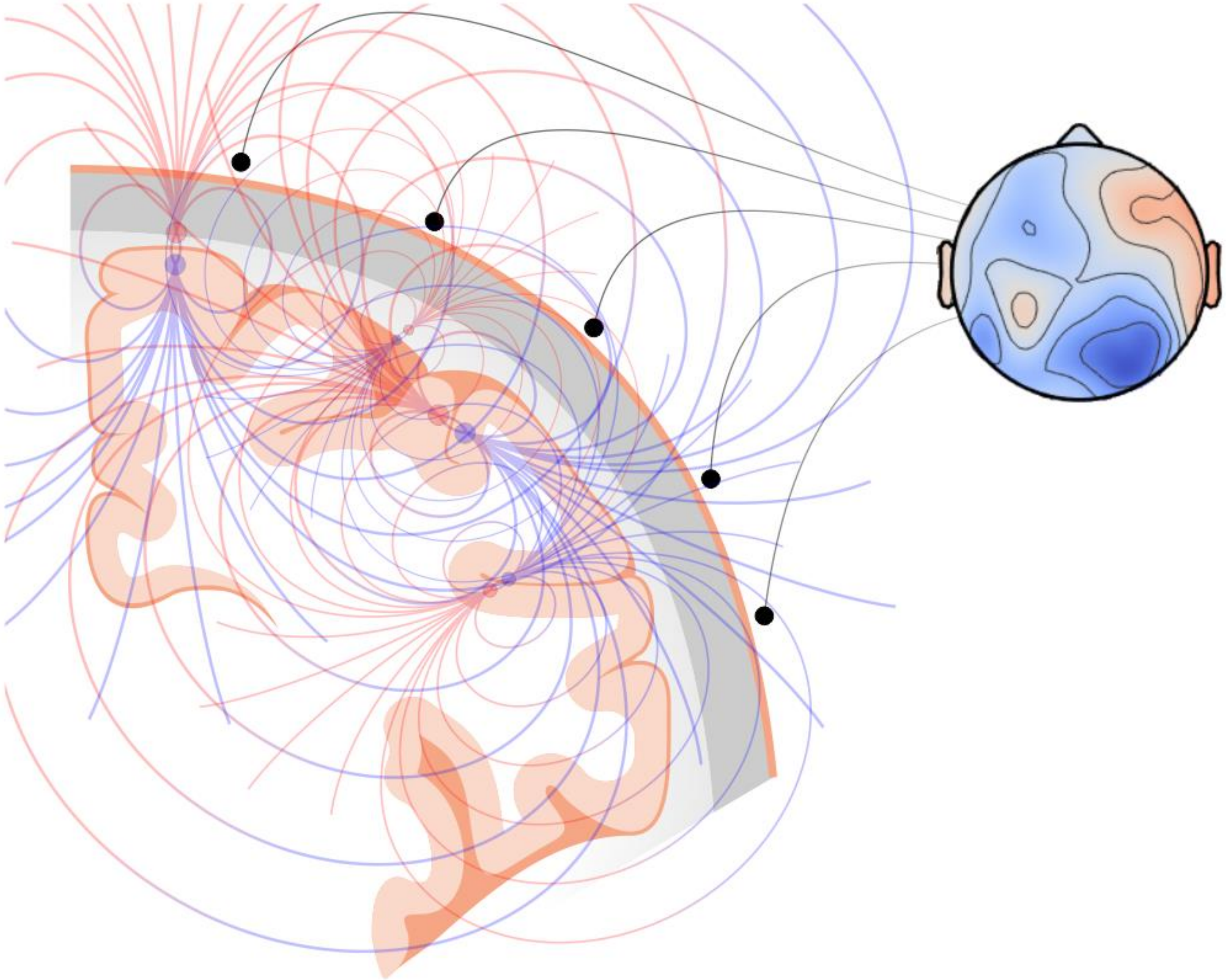
Through volume conduction, the spread of the electric (voltage) fields is instantaneous and reaches the scalp surface everywhere at once.

(Remember: No neutral reference.)

The dipolar nature of the activity means that for any dipole, both positive *and* negative voltage changes arrive simultaneously on different areas at the scalp.



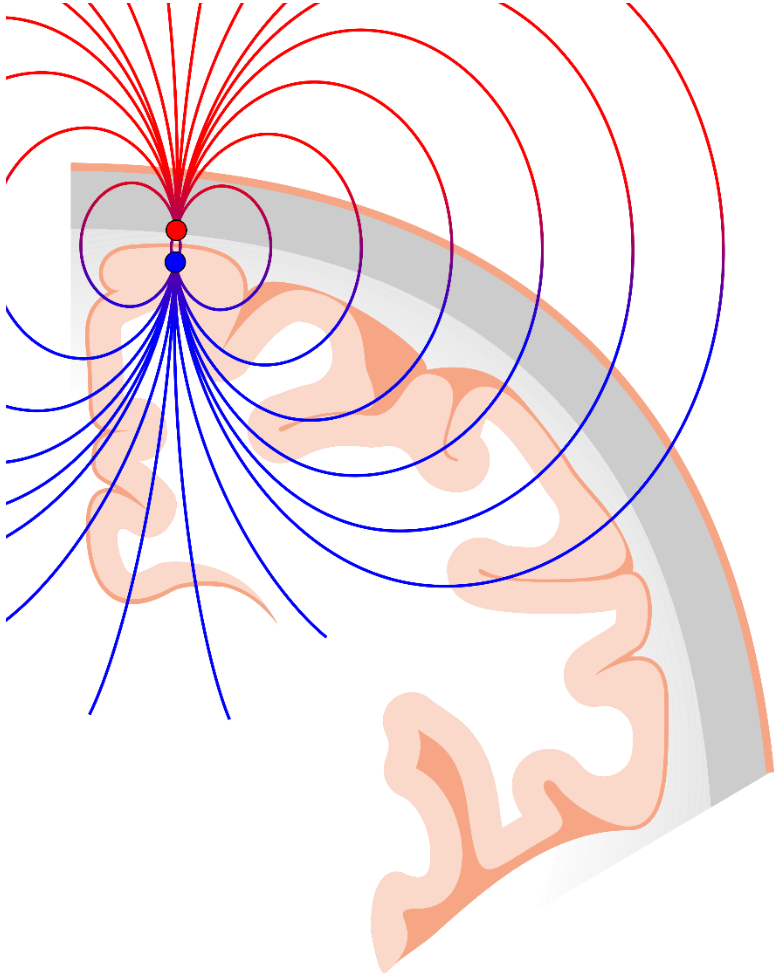
Volume conduction



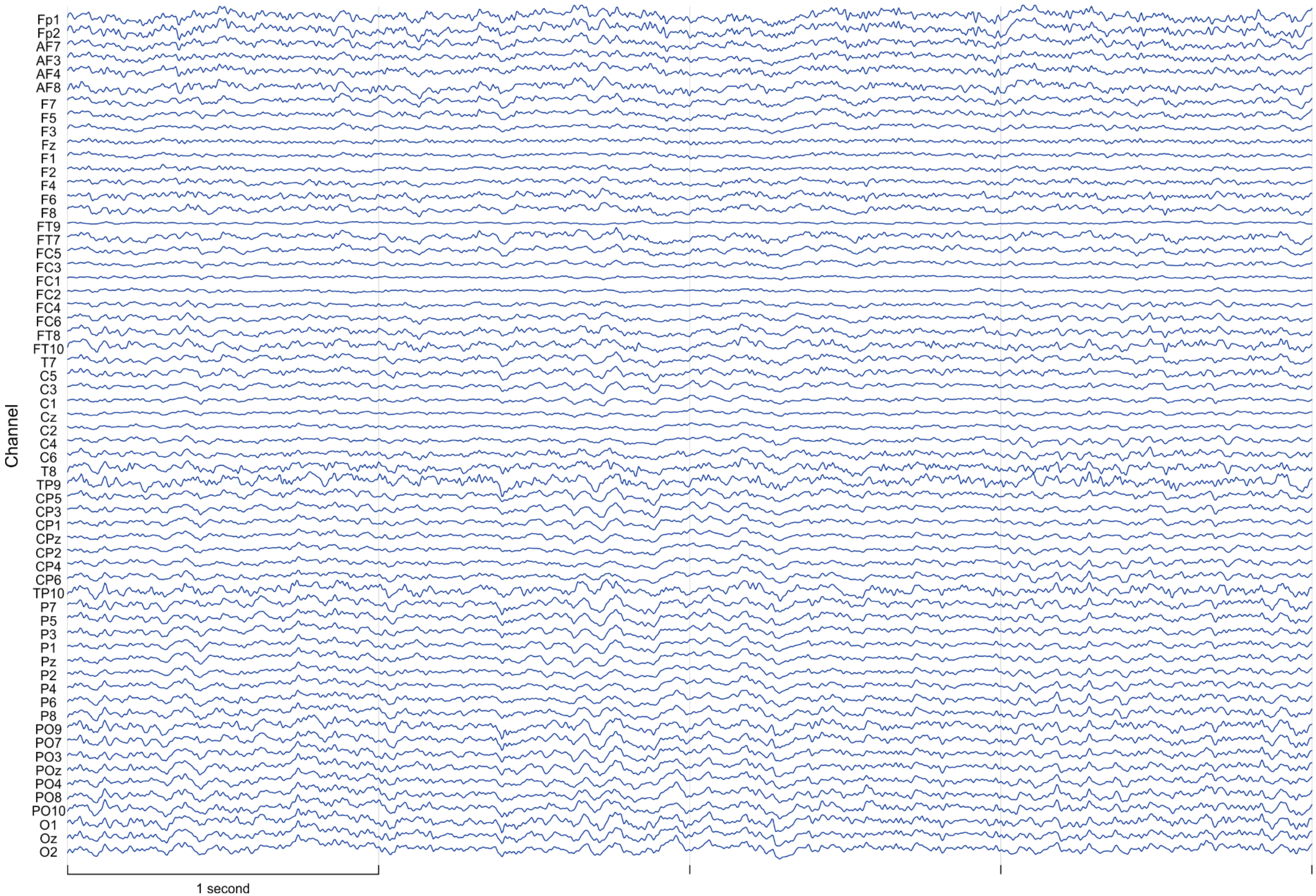
Physiological origins of EEG

EEG is thought to originate from

- the **synchronous activity**
- of **postsynaptic potentials**
- at the **apical dendrites**
- of **large populations**
- of **pyramidal cells**
- in the **cortical surface**.



The electroencephalogram



EEG versus other modalities

Electroencephalography (EEG)

Advantages:

- High temporal resolution
- Relatively inexpensive
- Noninvasive
- Mobile

Disadvantages:

- Low spatial resolution
- No activity from deeper brain structures
- Complex signal that can interfere with itself

Magnetoencephalography (MEG)

MEG records brain activity by measuring the magnetic fields produced by electrical currents in the brain.

MEG signals originate from the same physiological processes as EEG signals.

Magnetoencephalography (MEG)

Advantages:

- High temporal resolution
- Better spatial resolution because the skull and scalp are transparent to magnetism
- Noninvasive
- Reference-free

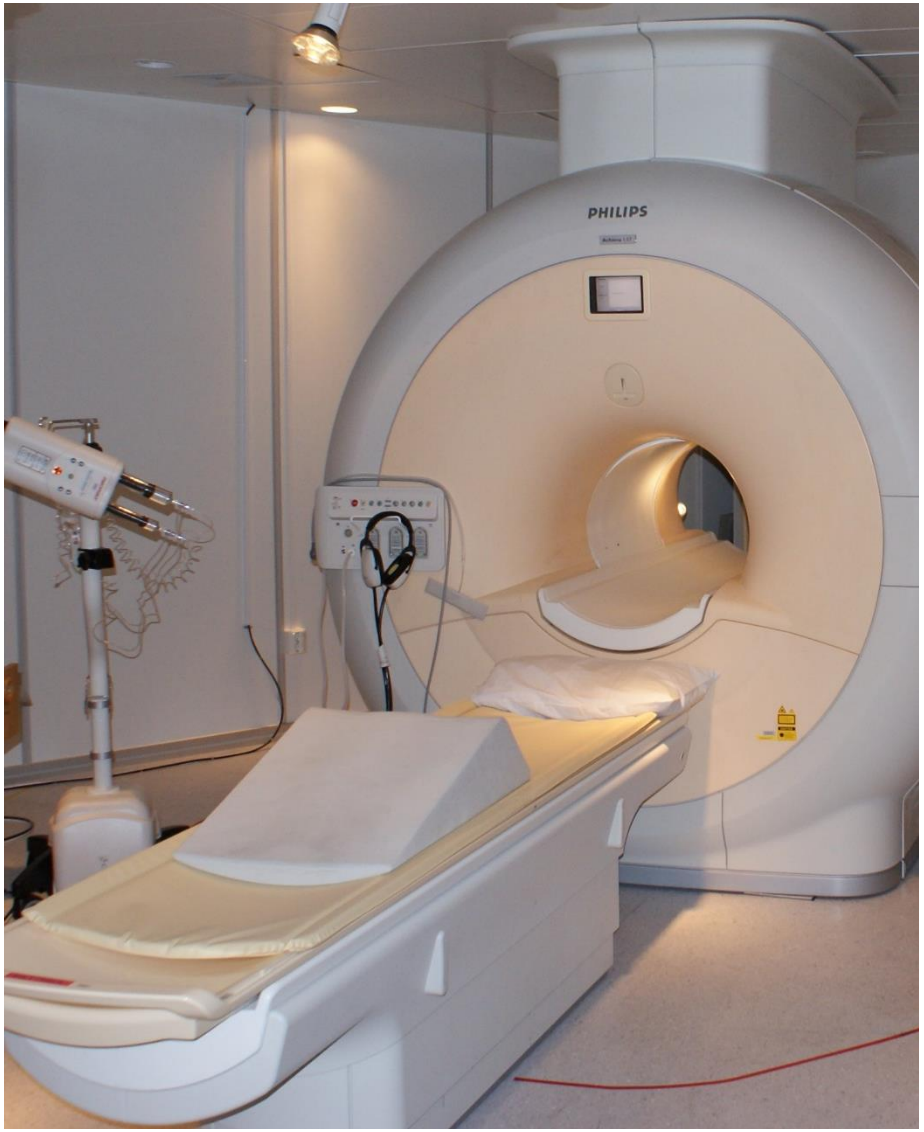
Disadvantages:

- No activity from deeper brain structures
- Expensive
- Stationary

Functional Magnetic Resonance Imaging (fMRI)

fMRI indirectly records brain activity by detecting changes in blood oxygenation levels using magnetic fields.

Neural activity requires energy, resulting in an increase in oxygen in the blood near active neural tissue.



Functional Magnetic Resonance Imaging (fMRI)

Advantages

- High spatial resolution
- Can reach deeper brain structures
- Noninvasive

Disadvantages

- Low temporal resolution
- Expensive
- Stationary (lying down)

Functional Near-Infrared Spectroscopy (fNIRS)

fNIRS indirectly records brain activity by detecting changes in blood oxygenation levels.

The reflection of near-infrared light, rather than magnetic fields, is used to detect this.

Functional Near-Infrared Spectroscopy (fNIRS)

Advantages

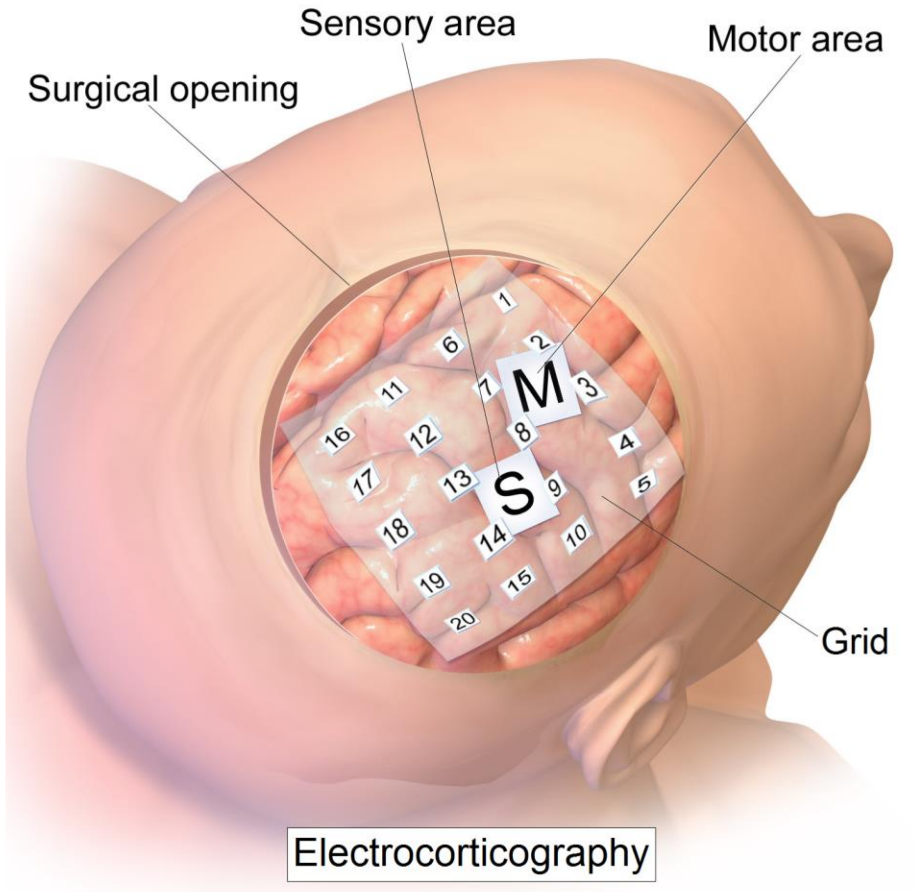
- Clear spatial localisation of activity
- Relatively inexpensive
- Noninvasive
- Mobile

Disadvantages

- Low temporal resolution
- Low spatial resolution

Electrocorticography (ECoG)

ECoG measures the electrical activity from the cerebral cortex with electrodes placed directly on the cortical surface.



Electrocorticography (ECoG)

Advantages

- High temporal resolution
- High spatial resolution
- High signal-to-noise ratio

Disadvantages

- Highly invasive: requires surgery
- Usually limited to select areas of the brain

Psychophysiology
Part 8.1: Electrocortical activity

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