I. NEURAL BASES OF EEG

EEG-TRAINING

OUTLINE OF EEG-TRAINING COURSE

- I. Neural basis of EEG
- II. Signal pre-processing
- III. Time-domain analysis
- IV. Frequency domain analysis
- V. Statistical testing

REFERENCES THROUGHOUT THE COURSE

In each chapter, references will be listed at the end of the course materials and in the respective notebooks. However, from now there are a couple of books that you can explore if you are directing yourself more seriously towards neuroscience with EEG as a tool:

- Kandel, Eric R., John D. Koester, Sarah H. Mack, et Steven A. Siegelbaum, éd. *Principles of neural science*. 6e éd. New York: McGraw Hill, 2021.
- Cohen, Mike X. *Analyzing neural time series data: theory and practice*. Issues in clinical and cognitive neuropsychology. Cambridge, Massachusetts: The MIT Press, 2014.

OUTLINE

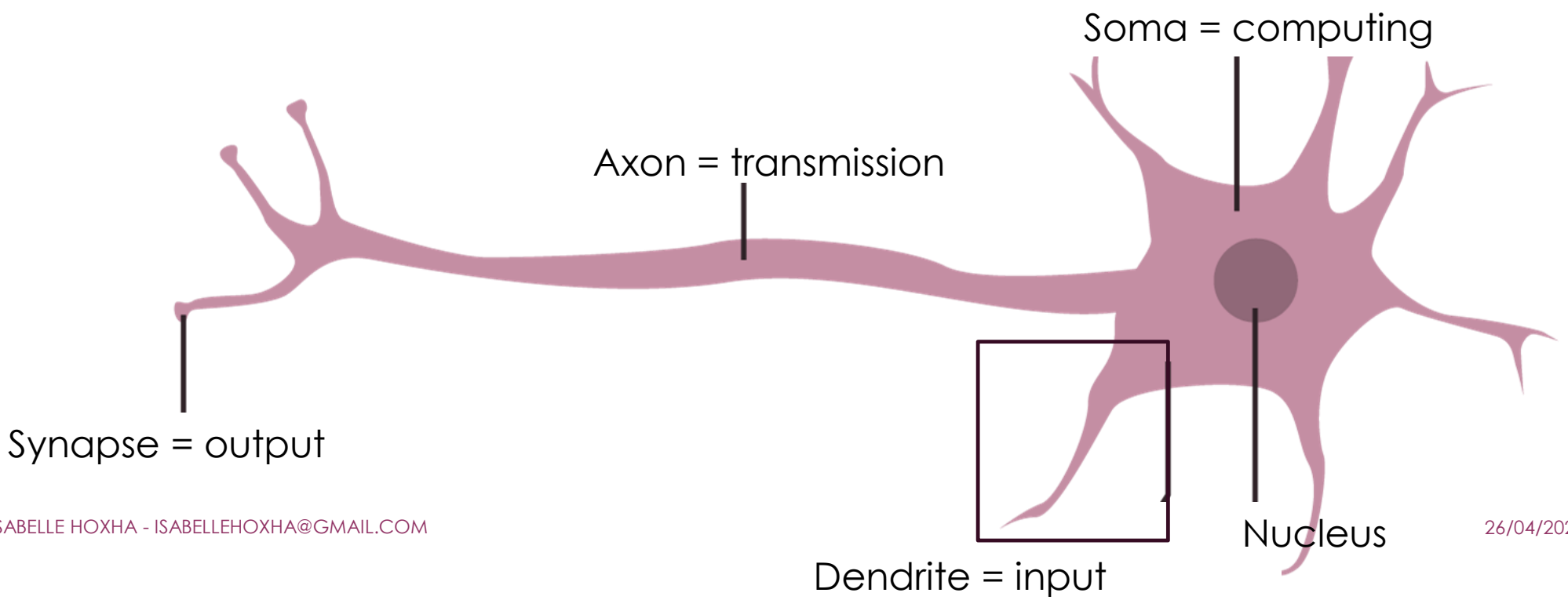
1. Origins and meaning of EEG signals
    1. Some history
    2. Neurophysiology notes
2. The EEG system
    1. Experiment setup
    2. About the EEG cap
    3. Recording parameters
3. Advantages and drawbacks

1) SOME HISTORY

- The question is how to study the live brain in function, while not having to perform surgery
- 1797: Luigi Galvani formulates the hypothesis of an « animal electricity », which he defined as a fluid produced by the brain and that decharges when a nerve is linked to metal
- From then: what is this electricity? What is its functions? Does it exist on its own or is it an epiphenomena of the metal? How can we record it?
- 1924: Hans Berger recorded EEG signals for the first time (what will be later called the alpha rhythm: sinusoidal oscillations of frequency ~10Hz)

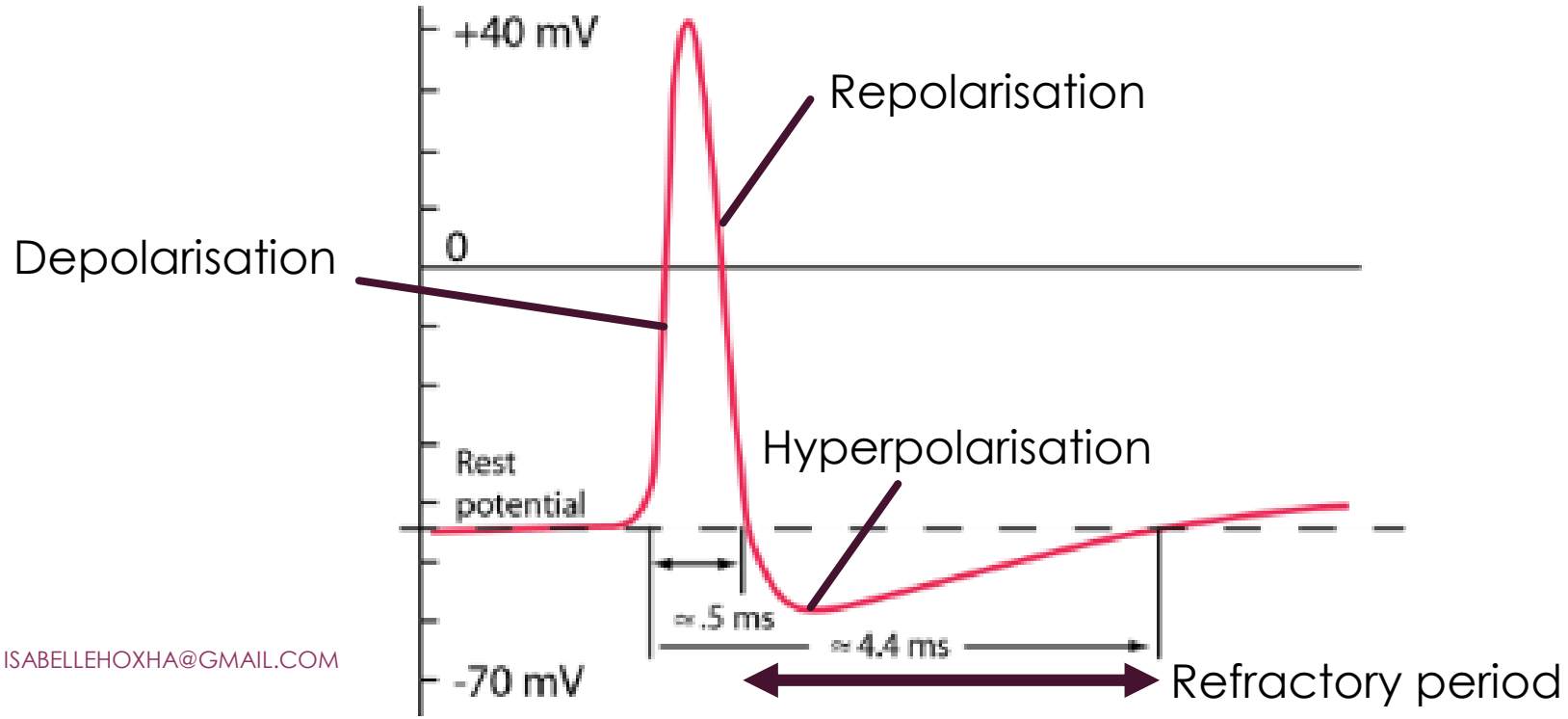
1) NEURAL BASES

- Neurons are the computing units of the brain (in a human brain, ~80 billion neurons)



1) NEURAL BASES

- Inputs arriving from the dendrites are summed by the soma. When the sum is big enough, an action potential is triggered and sent down the axon



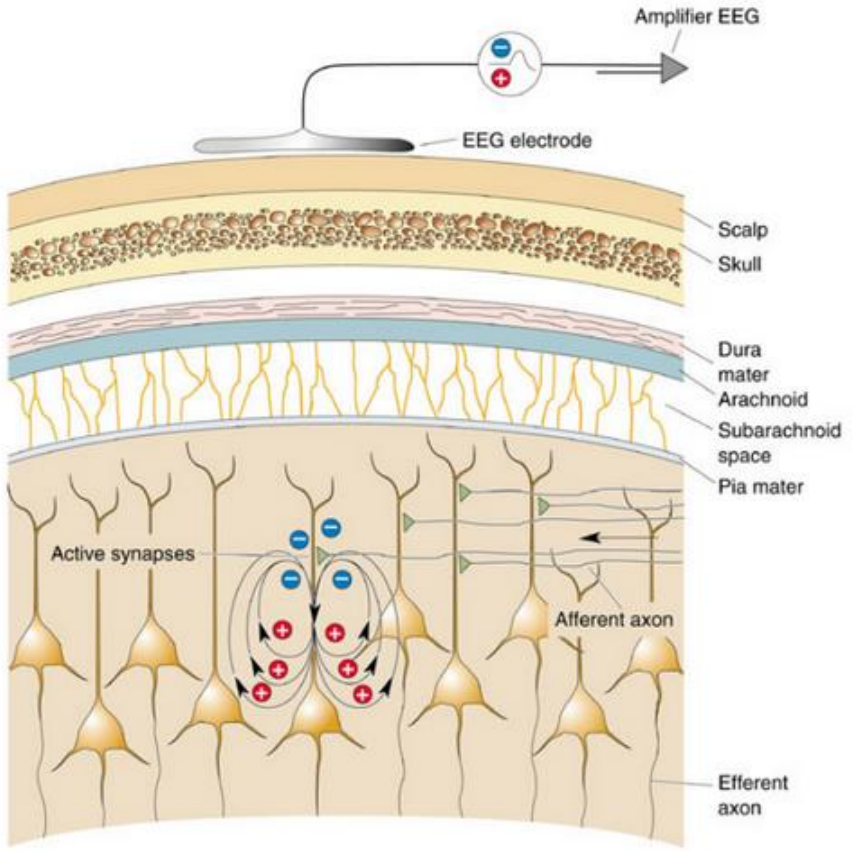
Adapted from http://hyperphysics.phy-astr.gsu.edu/hbase/Biology/actpot.html

1) NEURAL BASES

- Action potentials are needed by one cell (the **pre-synaptic** neuron) to commuicate to another (the **post-synaptic** neuron)
- In the post-syaptic neuron, the action potentials generale small potentials called **post-syaptic potentials**
- These can be **excitatory** (ie tend to depolarize the cell) or **inhibitory** (ie tend to repolarize the cell): **Excitatory Post-Synaptic Potentials (EPSP)** and **Ihibitory Post-Synaptic Potentials (IPSP)**

1) NEURAL BASES

- The summation of E/IPSP of a big number of neurons with parallel geometric orientation generate signals recorded through EEG
- EEG signal mostly cortical because of the strong atténuation with distance to the scalp



From https://www.slideshare.net/kj_jantzen/biophysical-basis-of-eeg

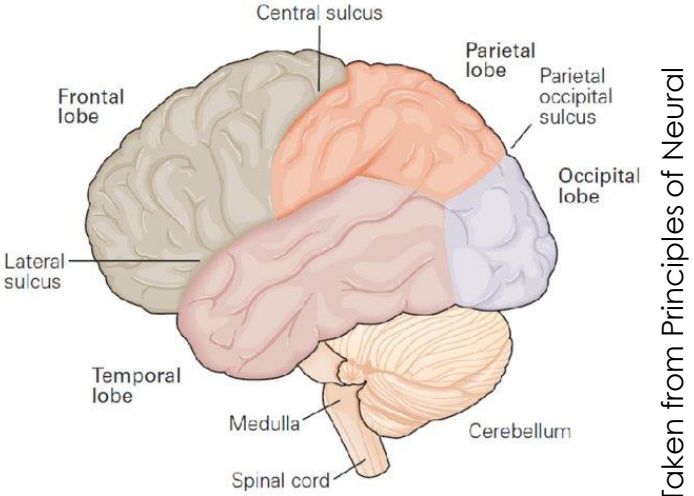
2) EXPERIMENT SETUP

Here is a list of what equipment is most often needed in EEG experiments:

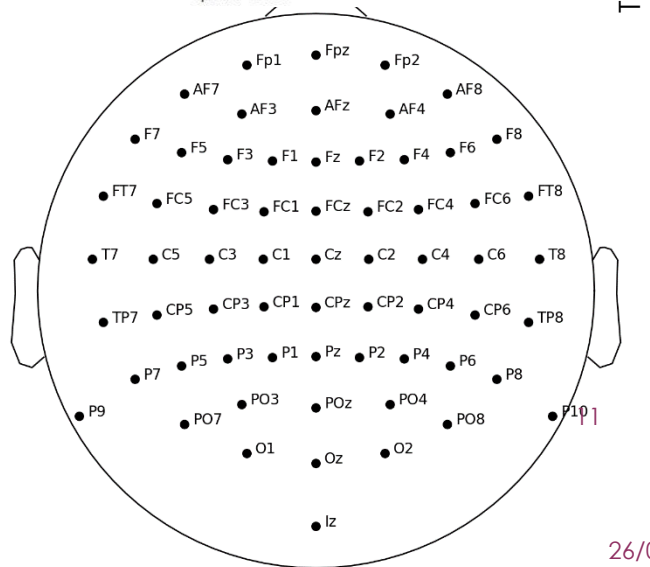
- Stimulation device (screen, sound system, vibrotactile stimulation)
- Response device (to track the participant's responses)
- Electrodes and EEG cap (to record brain activity)
- Amplifyiers (to help remove noise from EEG and convert to a format that is readable by the computer)
- Recording computer (to which EEG data is sent, whose role is to save acquired data and which will match the EEG data with time markers)
- Analysis computer (analyses can be done offline, ie after the experiment, or online, with active decoding of brain states)

2) ABOUT THE EEG CAP

- The electrodes are placed following certain rules (to ensure readability through common practices)
- Reference points: the nasion (point of the beginning of the nose, the inion (gap in the bone of the back of the skull near the junction with the neck), and the periauricular points (gap near the ears towards the mastoids)
- A letter or two and a number name each electrode
  - Letter: linked to brain area (eg: F=frontal, T=temporal, CP: central parietal,…)
  - Number: even numbers for electrodes to the right, odd numbers for electrodes to the left, z in the midline, numbered from medial to lateral positions



Taken from Principles of Neural Science, 5th edition (Kandel et al., 2000)



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2) RECORDING PARAMETERS AND UNITS

- EEG signals are in the range of a few tens of microvolts (μV)
- The sampling rate (ie the number of samples recorded at each second) can be set. The higher the better, but also a high sampling rate means high memory requirements (usually, 1000 or 2000Hz enough, some applications may require only 250Hz or less)
- The number of electrodes will have an impact on the spatial resolution (more electrodes: better resolution, but also more time to setup)

Everything is a matter of compromise!

3) ADVANTAGES AND DRAWBACKS

Advantages:

- Direct reflection of the brain activity (as opposed to fMRI for example, that records metabolic changes)
- High temporal resolution possible
- Non-invasive, fairly safe
- Fairly non-bulky

3) ADVANTAGES AND DRAWBACKS

Drawbacks:

- Spatial resolution lower than other recording techniques (MEG, fMRI)
- Prone to noise, low signal-to-noise ratio (SNR)

Main sources of noise:

- Eye movements (EOG)
- Sweat artifacts
- Muscle contractions
- Line noise: from the electricity running in the building!

CONCLUSION

- EEG is an appreciated recording technique thanks to its non-invasiveness, portability and high temporal resolution
- Noise can be a major problem and ruin recording sessions
- In the next sessions we will see how to get rid of parts of the noise
- In the tutorial for this session, we will explore visualization techniques using MNE on Python