EXERCISES – BIOLOGICAL SIGNALS

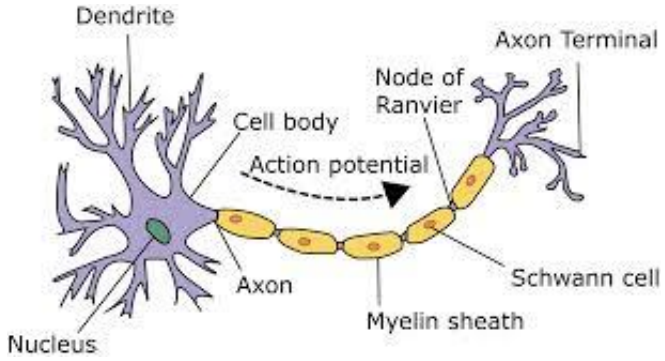
Exercise 7 - SS 2014 – Michel Kana

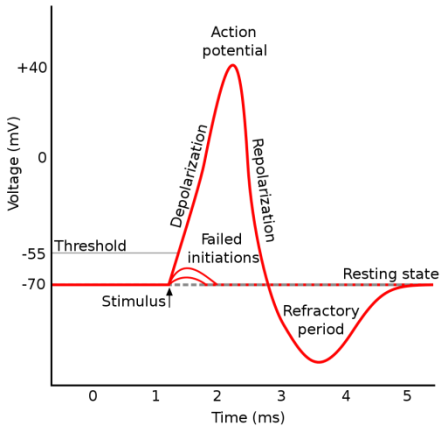
What will we do today?

1. **The physiology behind EEG**
2. **Structure of the EEG Signal**
3. **EEG measurement with BIOPAC**
4. **Summary**

The physiology behind EEG

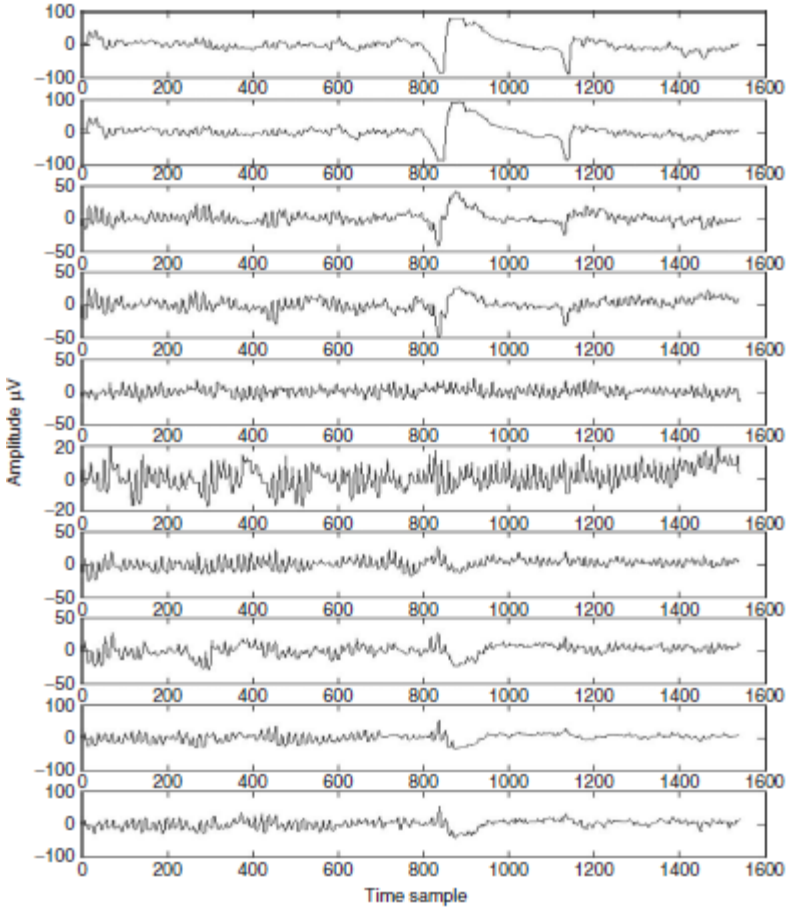
- The nervous system is composed of neurons and glial cells
- Neurons are excitable cells that generate and carry electrical signals that are called action potentials
- The electrical activity spreading through the head and reaches the scalp
- The resulting voltage differences can be recorded as the electroencephalogram (EEG)
- EEG reflects the summation of synchronous activity of many neurons with similar spatial orientations
- EEG offers a good millisecond temporal resolution, however with limited spatial resolution





Structure of the EEG Signal

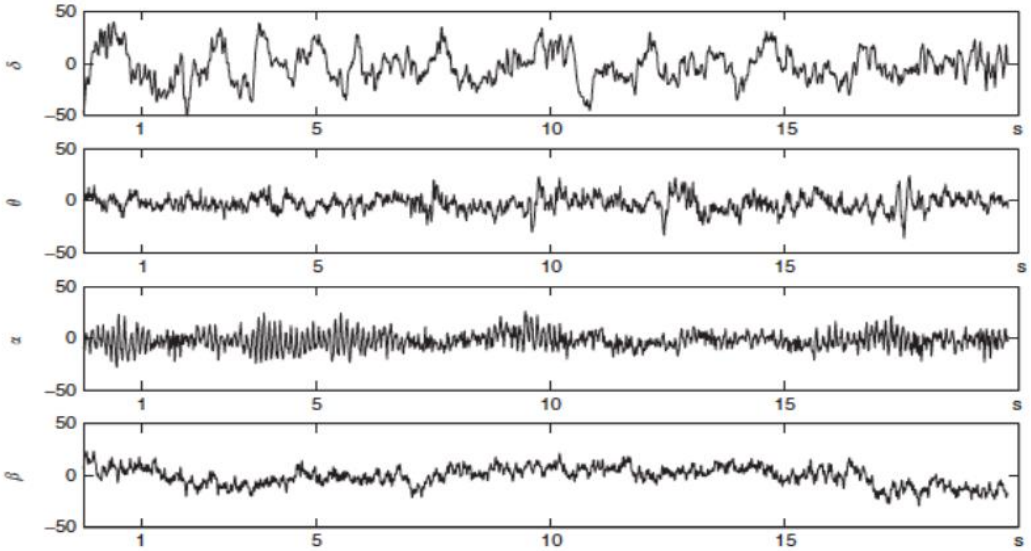
- **Characteristics of the EEG signal**
  - Frequency components up to 300 Hz.
  - Amplitude in order to μvolts.



Structure of the EEG Signal

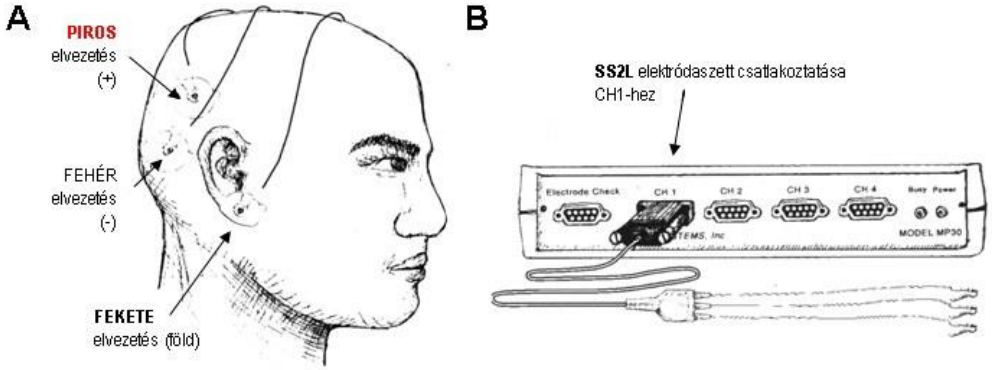
- **Characteristics of the EEG signal**
  - Frequency components up to 300 Hz.
  - Amplitude in order to μvolts.
- **Waves in the EEG signal**
  - **Delta wave:** high amplitude neural oscillations in the frequency range of 0.5 – 4 Hz. They are primarily associated with deep sleep.
  - **Theta wave:** neural oscillations in the frequency range of 4 – 8 Hz. They have been associated with access to unconsciousness, creative inspiration and deep meditation.
  - **Alpha wave:** neural oscillations in the frequency range of 8 – 13 Hz. They are associated to a relaxed awareness without any attention or concentration. They should be reduced or eliminated by opening the eyes, by hearing unfamiliar sounds, by anxiety, mental concentration or attention.
  - **Beta wave:** neural oscillations in the frequency range of 13 – 30 Hz. They are associated with active thinking, active attention, focus on the outside world, or solving concrete problems.
  - **Gamma wave:** neural oscillations in the frequency range of 30 – 90 Hz. They are suggested to be related to consciousness.

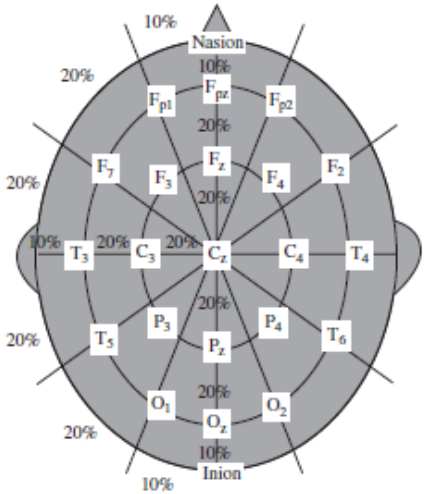
Structure of the EEG Signal



- **Parameters in the EEG signal**
  - **Standard deviation (STD):** measure of activity in the brain wave
  - **Average Value (AVG):** measure of mean amplitude
  - **Cycle Count (CC):** measure of central frequency

EEG Measurement

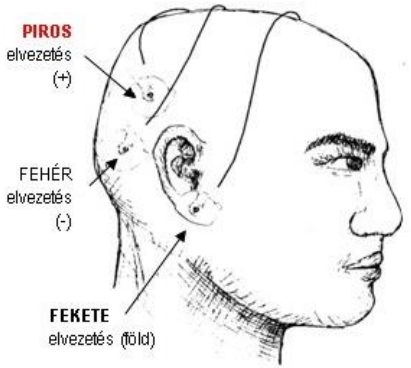




- **Operational configuration**
  - Multichannel recording with an electrodes cap using 10 to 20 Ag–AgCl disks.
    - For example, C3 and C4 can be used to record the right and left finger movement related signals
  - 1-Channel recording.
  - Differential or referential electrodes setup.
- **Noise sources**
  - Muscle movement artifact (0 to 1000 Hz)
  - Motion artifact from electrode movements (0 to 20 Hz)
  - Power line interference (60 or 50 Hz)

Exercice 1: EEG measurement with BIOPAC

- **Biopac MP35 measurement system**
  - EEG is recorded using Biopac SS2L wires plugged in the third channel.
  - Electrodes are attached as depicted, avoiding hair between scalp and electrodes.



- **Biopac Student Lab PRO software**
  - The acquisition is set up at a sampling rate of *500 Hz*.
  - Analog Channel CH1 should have the preset *Electroencephalogram EEG (.5-100Hz)*
  - Calculation Channel C1 should have the preset *EEG alpha (8-13Hz)*
  - Calculation Channel C2 should have the preset *EEG beta (13-30Hz)*
  - Calculation Channel C3 should have the preset *EEG delta (0.5-4Hz)*
  - Calculation Channel C4 should have the preset *EEG theta (4-8Hz)*
  - Calculation Channel C5 should have the preset *EEG gamma (30-90Hz)*
- **EEG parameters calculation**
  - Estimate the STD, AVG and CC of each of the five brain waves

Exercice 2: Relaxed with eyes open without blinking

- **Procedure**
  - Subject is instrumented for EEG measurement with Biopac.
  - The subject should be seated with legs fully relaxed and keep eyes open, staring at the computer screen without blinking during min 10 seconds.
- **Evaluation**
  - Estimate the STD of the all brain waves

Exercice 3: Relaxed with eyes closed

- **Procedure**
  - Subject is instrumented for EEG measurement with Biopac.
  - The subject should be seated with legs fully relaxed and eyes closed during 120 seconds.
- **Evaluation**
  - Estimate the STD, AVG and CC of the alpha wave
  - Verify the following assertions:
    - Females tend to have higher mean frequency of alpha waves
    - Alpha amplitude tend to be higher in outgoing subjects

Exercice 4: Mental math with eyes closed

- **Procedure**
  - Subject is instrumented for EEG measurement with Biopac.
  - The subject should be seated with legs fully relaxed and eyes closed.
  - After 60 seconds of baseline measurement at rest, the subject should mentally find the reminder of 12345 divided by 12 during another 60 seconds.
- **Evaluation**
  - Estimate the STD, AVG and CC of the alpha and beta waves
    - By how much did the amplitude of alpha waves changed?
    - Are there changes in the beta waves?

Exercice 5: Hyperventilation with eyes closed

- **Procedure**
  - Subject is instrumented for EEG and PPG measurement with Biopac.
  - The subject should be seated with legs fully relaxed and eyes closed.
  - The subject should increase breathing rate to 60 cycles per minute while breathing deeply during 120 seconds.
- **Evaluation**
  - Estimate the STD, AVG and CC of the alpha wave
    - It is expected that carbon dioxide levels fall, pH increases, blood pressure decreases, overall brain activity increases, alpha rhythms increase. Can you verify?

Team Projects

- **Project 1: Cardiovascular Signal Analyzer**
  - Digital filtering of a raw PPG signal
  - Extraction of PH (pulse height) and PP (peak-to-peak) values from a filtered PPG signal
  - MAP estimation using PH
  - Fourier transform of PP intervals and estimation of HF and LF
  - Implementation in Matlab, if possible with an interactive GUI
    - User should be able to import the raw signal import from a Biopac text export
    - User should be able to enter the sampling frequency, signal type (ECG or PPG or both) and channel numbers
    - User should be able to filter the raw signal
    - User should be able to execute PP, PH, MAP, LF, HF computation
    - User should be able to display plots of the raw signal for a given start and end timestamp
    - User should be able to display plots of PP, PH, MAP over the time for a given start and end timestamp and display the value of LF and HF

Team Projects

- **Project 2: Nervous Activity Analyzer**
  - Digital filtering of a raw EEG signal
  - Extraction of alpha, beta, theta, delta waves from a filtered EEG signal
  - Computation of STD, AVG and CC
  - Implementation in Matlab, if possible with an interactive GUI
    - User should be able to import the raw signal import from a Biopac text export
    - User should be able to enter the sampling frequency
    - User should be able to filter the raw signal
    - User should be able to execute alpha, beta wave, theta, delta wave computation using Fourier or Wavelet transform or digital filtering
    - User should be able to execute STD, AVG, CC computation
    - User should be able to display plots of the raw signal for a given start and end timestamp
    - User should be able to display plots of alpha, beta wave, theta, delta waves over the time for a given start and end timestamp and display the values for STD, AVG and CC

Team Projects

- **Project 3: Muscle Activity Analyzer**
  - Digital filtering of a raw EMG signal
  - Computation of rectified EMG from a filtered EMG signal
  - Computation of the spectrum of the filtered EMG signal using Fourier transform
  - Computation of RMS, ARV
  - Implementation in Matlab, if possible with an interactive GUI
    - User should be able to import the raw signal import from a Biopac text export
    - User should be able to enter the sampling frequency
    - User should be able to filter the raw signal
    - User should be able to execute rectified EMG computation
    - User should be able to execute Fourier transform of the rectified EMG for a given start and end timestamp
    - User should be able to execute RMS, ARV computation for a given start and end timestamp
    - User should be able to display plots of the raw EMG, rectified EMG, EMG Fourier transform for a given start and end timestamp
    - User should be able to display the values for RMS, ARV for a given start and end timestamp