1. Introduction to brain physiology and reasearch methods

Brain Physiology

- **Cortex**
  - Temporal lobe (Auditory processing)
  - Parietal lobe (Attention)
  - Frontal lobe (higher level cognition)
  - Occipital lobe (vision)
- **Subcortical structures**
  - Cerebellum (motor control)
  - Thalamus (sensory processing)
  - Hippocampus (memories)
  - Corpus Callosum (connects the two hemispheres)
- **Gray Matter**
  Perform Computations. Understanding the role of GM in the brain is essential for gaining insight into various neurological and psychiatric conditions.
- **White Matter**
  Consists mainly of long-range axon pathways that connects different regions of the brain.
- **Neuron**
  A neuron consists of dendrites, a cell body and an axon. Connections between neurons are called synapses (chemical, not electrical). A neuron will fire depending on the number of signals it receives on its dendrites and their strength, which are summed in the neuron's body. All-or-nothing signal.
- **Neuroplasticity**
  Network changes over time, to adapt to the environment. Synapses can be strengthened or pruned. Connections between neurons are constantly removed or created. An Hub neuron has more possibilities to survive.

Research Methods

The human brain can be studied at different levels of organization, from systems and pathways to synapses and membranes. Studying the brain at different scales provides insights into organization of function from the macroscopic to the microscopic level.

- **Resolution**
  Precision with research methods can capture brain activity or structure.
  - **Spatial Resolution**
    How much is small brain area that an instrument can distinguish.
  - **Temporal Resolution**
    Precision of the tool to distinguish brain activity that happens in different moments.
- **Experiment**
  An experiment or study is a systematic investigation of a research hypothesis that involves manipulating variables and measuring their effects on some outcome of interest.
- **Methods**
  - **Electroencephalography (EEG)**
    Study patterns of brain activity with high temporal resolution. It is sensitive to very subtle changes in electric potentials below the sensors, which are propagated to the scalp. These changes reflect alterations in the electrical environment of thousands of neurons that fire in synchrony. Each EEG sensor gives one **time series**. EEG also contains important informations in form of frequency characteristics (**Cycling rate**). Power plots can show the relative strength of each frequency, helping in frequency band interpretation.
    - **Event-Related Potential (ERP)**
      Quantifies electrical brain responses to events/stimuli based on time-locked EEG portions. This analysis can be used as the basis for more sophisticated analysis such as source localization.
    - **Noise**
      All noise artifacts have to be independently measured and then removed from the data. Noise reduction applies to each timepoint measured. The need for many repetitions can be challenging and time-consuming, but it is necessary for obtaining reliable and statistically significant results. In addition to repetition, other techniques such as filtering and artifact rejection can also help to reduce noise in EEG recordings.
  - **Structural Imaging**
    Collecting **3D images** of the brain. This images can provide information about: gray matter volume, density of gray matter in specific regions, cortical thickness and surface area of particular brain regions.
  - **Functional magnetic resonance imaging (fMRI)**
    Consists in observing which parts of the brain are involved in **metabolic activity** when we do things like thinking or perceiving. By analyzing the patterns of **proton** behavior, we can identify which brain areas are more active during certain tasks. With fMRI we get a time series for each voxel.
    The response measured by fMRI (called "**Hemodynamic**" because it is related to blood) is delayed since the blood requires time to flow. Notice this is not a simply shifted impulse response, as it is a smooth function. For this reason, fMRI tells us where the process takes place, but not when. Combining fMRI and EEG can be a solution.
  - **Diffusion Weighted Imaging (DWI)**
    Is used to examine the **structure** of white matter fibers. For each voxel, the preferred direction of diffusion and the strength of diffusion are estimated to determine white matter tracts. These connections are considered hardwired connections. They can be cross-referenced against functional connectivity.

Voxel: small region of the brain, 3x3x3 mm.