EEG
**EEG**

- The **electroencephalogram (EEG)** is a recording of the electrical activity of the brain from the scalp.

- When measured directly from the cortical surface is called **electrocorticogram** while when using depth probes it is called **electrogram**.
EEG

- electroencephalographic reading is a completely non-invasive procedure that can be applied repeatedly to patients, normal adults, and children with virtually no risk or limitation.

The first recordings were made by Hans Berger in 1929.
Principle

Neural electrical activity
- Currents of the action potential
- Postsynaptic cellular currents
Neural electrical activity

- **Action potential** - short lasting depolarisation, which eventually moves along the axon
- **Postsynaptic potentials** - formed at the postsynaptic level, they may be:
  - **Excitatory** = depolarisation - Na+, Ca2+ channels
  - **Inhibitory** = hyperpolarisation - Cl-, K+ channels
EEG- sources of scalp potentials

- Neurons
  - Post-synaptic potentials – excitatory, from functional synaptic units, are major contributors
  - No Action Potentials – short lasting, axon is further away from the scalp

- Which neurons?
Which neurons and how?

- The dipoles make the major contribution to the scalp potential.
- When neurons are activated, local currents are produced.
- EEG measures the currents that flow during the excitations of the dendrites of many pyramidal neurons in the cerebral cortex.
- Potential differences are caused by summed postsynaptic potentials from pyramidal cells that create dipoles between soma and apical dendrites.
Pyramidal neuron

- triangular shaped soma
- a single axon
- a large apical dendrite
- multiple basal dendrites
- dendritic spines
Necessary conditions: Aligned neurons and synchronous activity

- Neurons which are radially symmetric, randomly oriented or asynchronously activated do not produce externally observable electrical fields.
• Neurons which are non-radially symmetric, spatially aligned and synchronously activated add up to produce externally observable electric fields.
Many neurons need to sum their activity in order to be detected by EEG electrodes. The timing of their activity is crucial. Synchronized neural activity produces larger signals.
Currents due to:
1) the parallel array of pyramidal cells
2) synaptic currents, lasting 10-100's of milliseconds.

By convention, downward deflections of the EEG are positive. Generally speaking, depolarization (excitation) of deeper layers of the cortex and hyperpolariz...
EEG recording techniques

- Encephalographic measurements employ recording system consisting of:
  - electrodes with conductive media
  - amplifiers with filters
  - A/D converter
  - recording device.

- Electrodes read the signal from the head surface, amplifiers bring the microvolt signals into the range where they can be digitalized accurately, converter changes signals from analog to digital form, and computer / other device stores and displays obtained data.
Requirements

- EEG machine (8/16 channels).
- Silver cup electrodes/metallic bridge electrodes.
- Electrode jelly.
- Rubber cap.
- Quiet dark comfortable room.
- Skin pencil & measuring tape.
Electrodes

Sliver Electrodes  Electrodes Cap
Electrode placement

- in 1958, International Federation in Electroencephalography and Clinical Neurophysiology adopted standardisation for electrode placement called **10-20 electrode placement system**
- Based on the relationship between the location of an electrode and the underlying area of cerebral cortex.
  - Nasion - point between the forehead and nose.
  - Inion - Bump at back of skull
- The "10" and "20" refer to the 10% or 20% interelectrode distance.
Electrode positioning 10-20 system

- Each point indicates a possible electrode position.
- Each site has a letter (to identify the lobe) and a number or another letter to identify the hemisphere location.
- The letters F, T, C, P, and O stand for Frontal, Temporal, Central, Parietal and Occipital.
  (Note that there is no "central lobe", but this is just used for identification purposes)
- Even numbers (2, 4, 6, 8) refer to the right hemisphere and odd numbers (1, 3, 5, 7) refer to the left hemisphere.
- The z refers to an electrode placed on the midline. Also note that the smaller the number, the closer the position is to the midline.
Two types of recording

- **Bipolar**
  Each channel (i.e., waveform) represents the difference between two adjacent electrodes. The entire montage consists of a series of these channels. For example, the channel "Fp1-F3" represents the difference in voltage between the Fp1 electrode and the F3 electrode. The next channel in the montage, "F3-C3," represents the voltage difference between F3 and C3, and so on through the entire array of electrodes.

- **Unipolar**
  Each channel represents the difference between a certain electrode and a designated reference electrode (inactive). There is no standard position for this reference; it is, however, at a different position than the "recording" electrodes.
Montage

- Different sets of electrode arrangement on the scalp by 10–20 system is known as montage.
- 21 electrodes are attached to give 8 or 16 channels recording.
Analysis

- Electrical activity from the brain consist primarily of rhythms.
- They are named according to their frequencies (Hz) and amplitude in microvolts (μv).
- Different rhythms at different ages and different conditions (level of consciousness)
- Usually one dominant frequency (background rhythm)
Influencing EEG

- **Age**
  - Infancy – theta, delta wave
  - Child – alpha formation.
  - Adult – all four waves.
- **Level of consciousness (sleep)**
- **Hypocapnia (hyperventilation):** slow & high amplitude waves.
- **Hypoglycemia**
- **Hypothermia**
- **Low glucocorticoids**
EEG waves

- Brain patterns form wave shapes that are commonly sinusoidal.
- Usually, they are measured from peak to peak and normally range from 0.5 to 100 μV in amplitude, which is about 100 times lower than ECG signals.
- Individual’s brain wave patterns are unique.
- In some cases, it is possible to distinguish persons only according to their typical brain activity.
- For example, subjects who regard themselves as rational types or as holistic/intuitive types may demonstrate certain higher activity in their frontal left and frontal right hemisphere respectively.
Waves

- Frequency between 0.5-30 Hz, divided into types based on frequency
  - delta (0-3 Hz),
  - theta (3-8 Hz),
  - alpha (8-13 Hz)
  - beta (>13-30 Hz).
- gama (> 30 Hz) (during learning activity)
- Amplitude varies with every type
Alpha

- 8 – 13 Hz, 50-100 uV
- in all age groups but are most common in adults
- occur rhythmically on both sides of the head but are often slightly higher in amplitude on the nondominant side, especially in right-handed individuals
- tend to be present posteriorly (parietooccipital) more than anteriorly and are especially prominent with closed eyes and with relaxation.
- alpha activity disappears normally with attention (eg, mental arithmetic, stress, opening eyes) → alpha block/ desynchronisation
- in most instances, it is regarded as a normal waveform.
- an abnormal exception is alpha coma, most often caused by hypoxic-ischemic encephalopathy of destructive processes in the pons (eg, intracerebral hemorrhage). In alpha coma, alpha waves are distributed uniformly both anteriorly and posteriorly in patients who are unresponsive to stimuli.
Eye opening

- Alpha rhythm changes to beta on eye opening (desynchronization / α-block)
Beta

- 13-30Hz (>13)
- Beta waves are observed in all age groups.
- They tend to be small in amplitude and usually are symmetric and more evident anteriorly (frontal and parietal).
- Mental activities (calculus, thinking, eyes opened)
- Rythm of rapid activity, frequency and amplitude of beta vary greatly
Thinking

- Beta waves are observed
**delta and theta rhythms**

**theta rhythm:**
- 4 – 7 Hz
- Slow activity
- Generalized distribution
- Normal: children under 13 (parietal & temporal) and adults in 2nd sleep stage
- Pathologic: focal in subcortical lesions and diffuse in profound lesions, diffuse cortical lesions or metabolic encephalopathies
- Exp. recorded from hippocampus

**delta rhythm:**
- Under 3-4 Hz
- Normal and dominant in 3 and 4 sleep stages and in infancy
- Occurs in the cortex indep. of lower brain regions activities
- Pathologic: focal in subcortical lesions and diffuse in profound lesions, diffuse cortical lesions or metabolic encephalopathies
EEG interpreting

Change in background activity
Note frequency and amplitude

Wave morphology

Compare symmetry
left vs. right

Localisation
Parieto-occipital

Reactivity

Syncronous activity

Continuity
Sleep studies

• The EEG is frequently used in the investigation of sleep disorders especially sleep apnoea.

• Polysomnography: EEG activity together with
  • heart rate,
  • airflow,
  • respiration,
  • oxygen saturation and
  • limb movement
Sleep patterns of EEG

- There are two different kinds of sleep:
  - Rapid eye movement sleep (REM-Sleep)
  - Non-REM sleep (NREM sleep)/ slow wave sleep

- NREM sleep is again divided into 4 stages (I to IV). The EEG pattern in sleep is given in the following table:
Sleep investigation methods

- Electroencephalogram (EEG) = Brain Waves
- Electrooculogram (EOG) = Eye Movements
- Electromyogram (EMG) = Muscle Tension
Standard somnographic montage

- 3 EEG leads:
  C3-A2, C4-O1, O2-A1

- 2 EOG leads

- 2 EMG leads
Awakefulness

AWAKE

EEG
EOG
EOG
EMG
Stage 1

- Brain activation level reduced: low voltage EEG, diminished
- alpha activity, reduced frequency activity (theta) 3-7 Hz
- EOG – Slow eye movement, low muscular activity
- EMG moderate – reduced
Stage 2

- low voltage EEG, mixed activity frequency, 12-14 Hz
- sleep spindles associated with K complexes (diphasic waves, > 0.5 s)
- EOG – slow, rare eye movements
- EMG moderate – reduced muscular activity
Stage 3

- EEG – delta waves, 0.5-2 Hz & amplitude >75mV; covering around 20-50% from the analyzed epoch.
- EOG – rare eye movements
- EMG moderate – reduced muscular activity
Stage 4

- EEG delta activity covering >50% from the epoch
- EOG – rare eye movements
- EMG moderate - reduced
REM Stage

- EEG low voltage, rhythm with rapid activity and mixed frequencies (desynchronized sleep), aspect close to stage 1
- EOG – REM, mirror aspect
- EMG – muscular activity absent
Changes in brain waves during different stages of sleep & wakefulness
Stage 3 sleep

Stage 4 sleep

REM sleep

Delta activity

Theta activity

Beta activity

Seconds
Clinical applications

(1) monitor alertness, coma and brain death;
(2) locate areas of damage following head injury, stroke, tumour, etc.;
(3) test afferent pathways (by evoked potentials);
(4) monitor cognitive engagement (alpha rhythm);
(5) produce biofeedback situations, alpha, etc.;
(6) control anaesthesia depth (“servo anaesthesia”);
(7) investigate epilepsy and locate seizure origin;
(8) test epilepsy drug effects;
(9) assist in experimental cortical excision of epileptic focus;
(10) monitor human and animal brain development;
(11) test drugs for convulsive effects;
(12) investigate sleep disorder and physiology.
Artifacts

- **Muscle artifact**
  - No gum!
  - Use headrest
  - Measure EMG and reject/correct for influence

- **Eye movements**
  - Eyes are dipoles
  - Reject ocular deflections including blinks
  - Computer algorithms for EOG correction
Chewing
Vertical eye roll
Talking and moving the head
Blink and
Triple blink
EEG abnormal activity

- Abnormal activity can broadly be separated into epileptiform and non-epileptiform activity. It can also be separated into focal or diffuse.

- Focal epileptiform discharges represent fast, synchronous potentials in a large number of neurons in a somewhat discrete area of the brain.

- Generalized epileptiform discharges often have an anterior maximum, but these are seen synchronously throughout the entire brain. They are strongly suggestive of a generalized epilepsy.

- Focal non-epileptiform abnormal activity may occur over areas of the brain where there is focal damage of the cortex or white matter. It often consists of an increase in slow frequency rhythms and/or a loss of normal higher frequency rhythms. It may also appear as focal or unilateral decrease in amplitude of the EEG signal.
EEG indicating focal abnormality (right temporal).
EEG discharges

Epileptiform EEG discharges, during epileptic attack, used in epilepsy diagnosis:
1. spikes (20-70ms);
2. sharp waves (70-200 ms);
3. a spike and wave complex (spike or sharp wave followed by a slower wave).

Activation/trigger procedures in a suspected case of epilepsy/ in the interictal period:
- hyperventilation for 3-5 min (most used)
- intermittent photic stimulation: bright light flashes (1-30/sec)
- delivered for 10 sec. (most effective)
spikes
Spike-wave complex
Sharp waves
Absence seizure

- Absence seizures are one of several kinds of seizures. These seizures are sometimes referred to as petit mal seizures (from the French for "little illness").
- Absence seizures are brief (usually less than 20 seconds), generalized epileptic seizures of sudden onset and termination. They have two essential components:
  - clinically, the impairment of consciousness (absence)
  - EEG shows generalized spike-and-slow wave discharges.
Grand mal seizures

- Tonic–clonic seizures (formerly known as grand mal seizures) are a type of generalized seizure that affects the entire brain. Tonic–clonic seizures are the seizure type most commonly associated with epilepsy and seizures in general, though it is a misconception that they are the only type.
Steps of a grand mal seizure

• Aura – may feel a sense of strong *déjà vu*, lightheadedness and/or dizziness, unusual emotions, intense feelings of discomfort or premonition, altered vision and hearing (+/- hallucinations). This is actually a simple partial seizure.

• Tonic phase - quickly lose consciousness, and the skeletal muscles will suddenly contract

• Clonic phase - muscles will start to contract and relax rapidly, causing convulsions.
Tonico-clonic generalised discharges