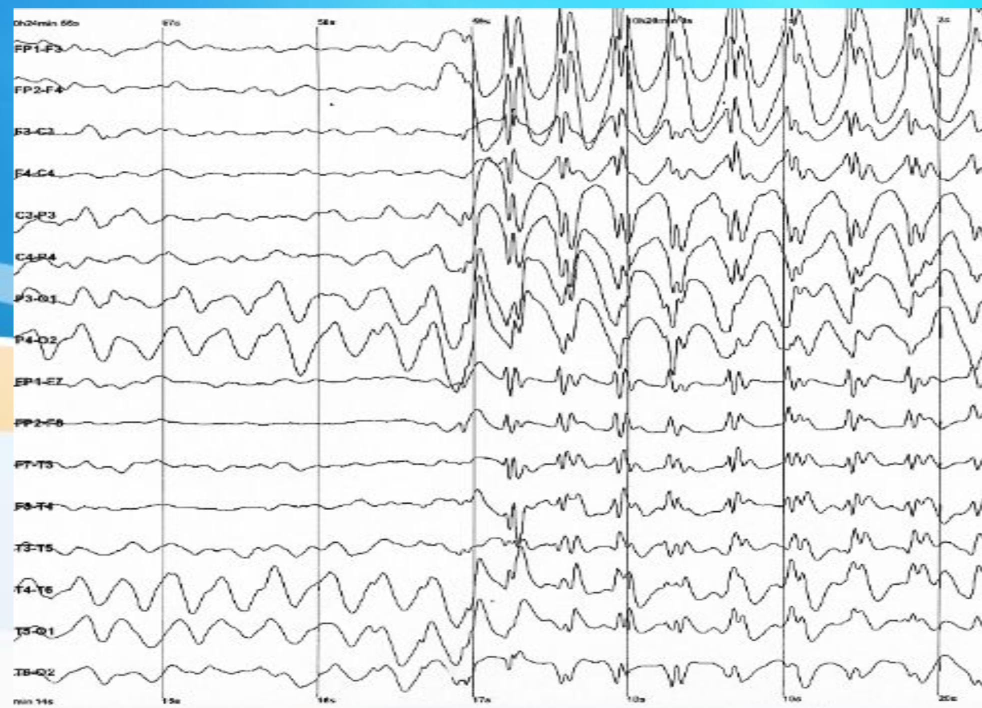
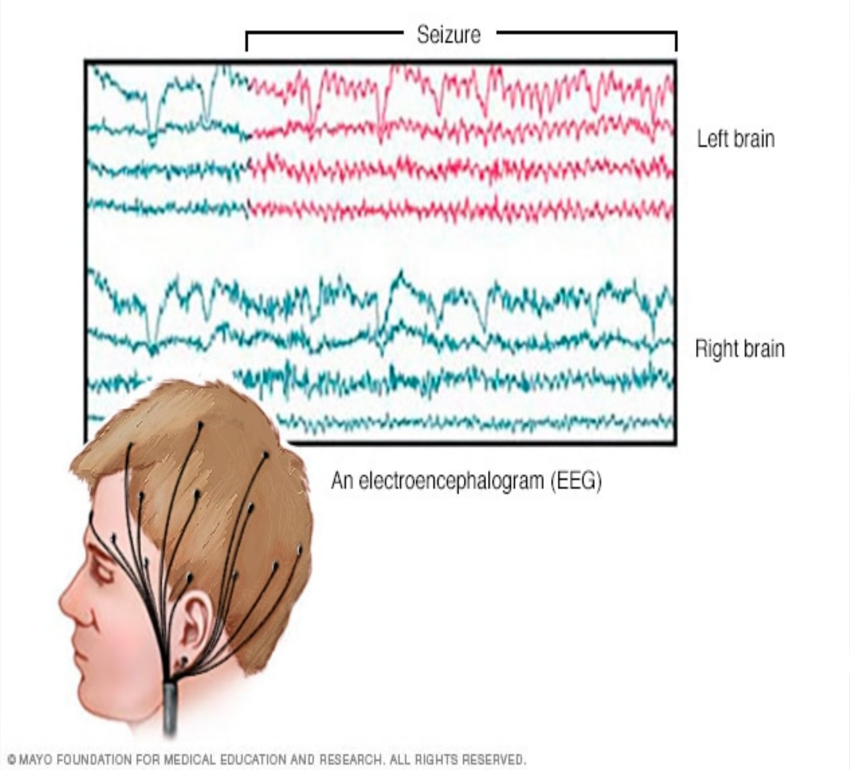
Electroencephalography (EEG)



- An electroencephalogram (EEG) is a test that measures electrical activity in the brain using small, metal discs (electrodes) attached to the scalp.
- Brain cells communicate via electrical impulses and are active all the time, even during asleep.
- This activity shows up as wavy lines on an EEG recording.
- An EEG is one of the main diagnostic tests for epilepsy and other brain disorders.



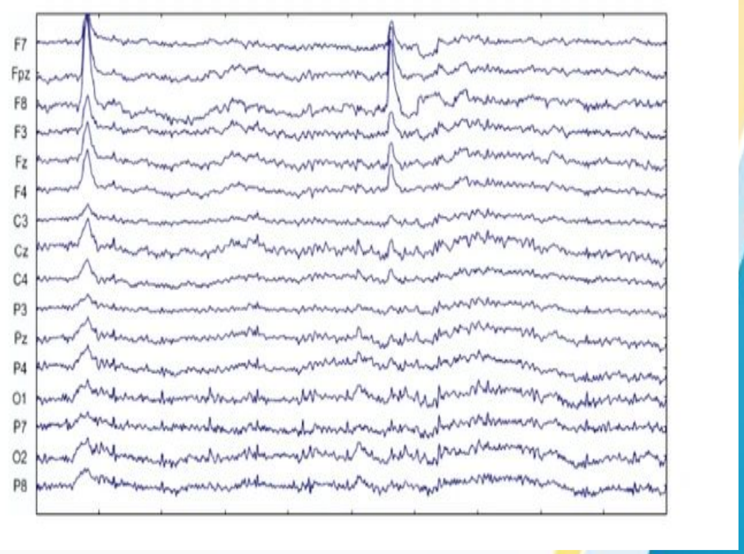
- The electroencephalogram (EEG) is a recording of the electrical activity of the brain from the scalp.
- 1st used in humans by Hans Berger in 1924 (the first report was published in 1929)
- A tracing of voltage fluctuations versus time recorded from electrodes placed over scalp in a specific array
- Represent fluctuating dendritic potentials from superficial cortical layers
- Required amplification

- It measures the activity of large numbers of neurons.
- EEG recordings are noninvasive, painless, do not interfere much with a human subject’s ability to move or perceive stimuli, are relatively low-cost.
- Electrodes measure voltage-differences at the scalp in the microvolt (µV) range.
- Voltage-traces are recorded with millisecond resolution – great advantage over brain imaging (fMRI or PET).

EEG Artifacts: The EEG signal amplitude is in the microvolts range and it is easily contaminated with noise, known as "artifacts", which need to be filtered from the neural processes to keep the valuable information we need for our applications.

- Biological artifacts
  - Eye artifacts (including eyeball, ocular muscles and eyelid)
  - ECG artifacts
  - EMG artifacts
  - Tongue movements

- External artifacts
  - Movement by the patient settling of the electrodes
  - Poor grounding of the EEG electrodes the presence of an IV drip

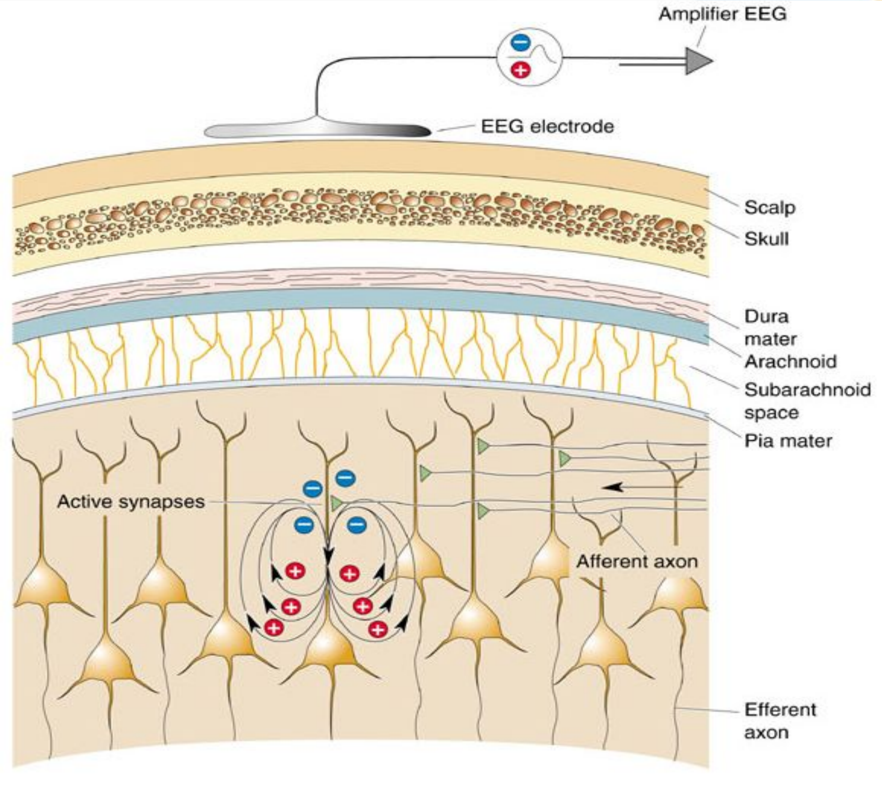


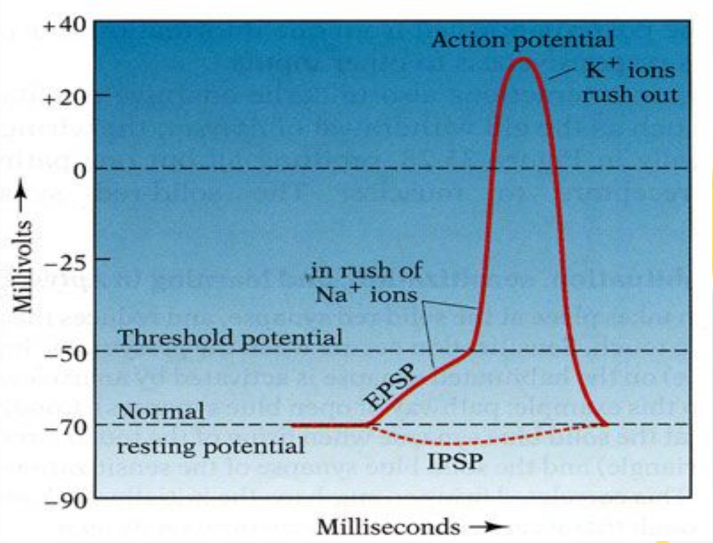
Types of EEG Recording

- Routine: analog, digital with computerized analysis & brain electrical activity mapping
- Long-term Monitoring

- The inside becomes less negative relative to the outside, a condition known as an excitatory postsynaptic potential (EPSP)

- The inside of the cell becomes even more negative relative to the outside, a condition known as an inhibitory postsynaptic potential (IPSP).





EEG MACHINE BLOCK DIAGRAM

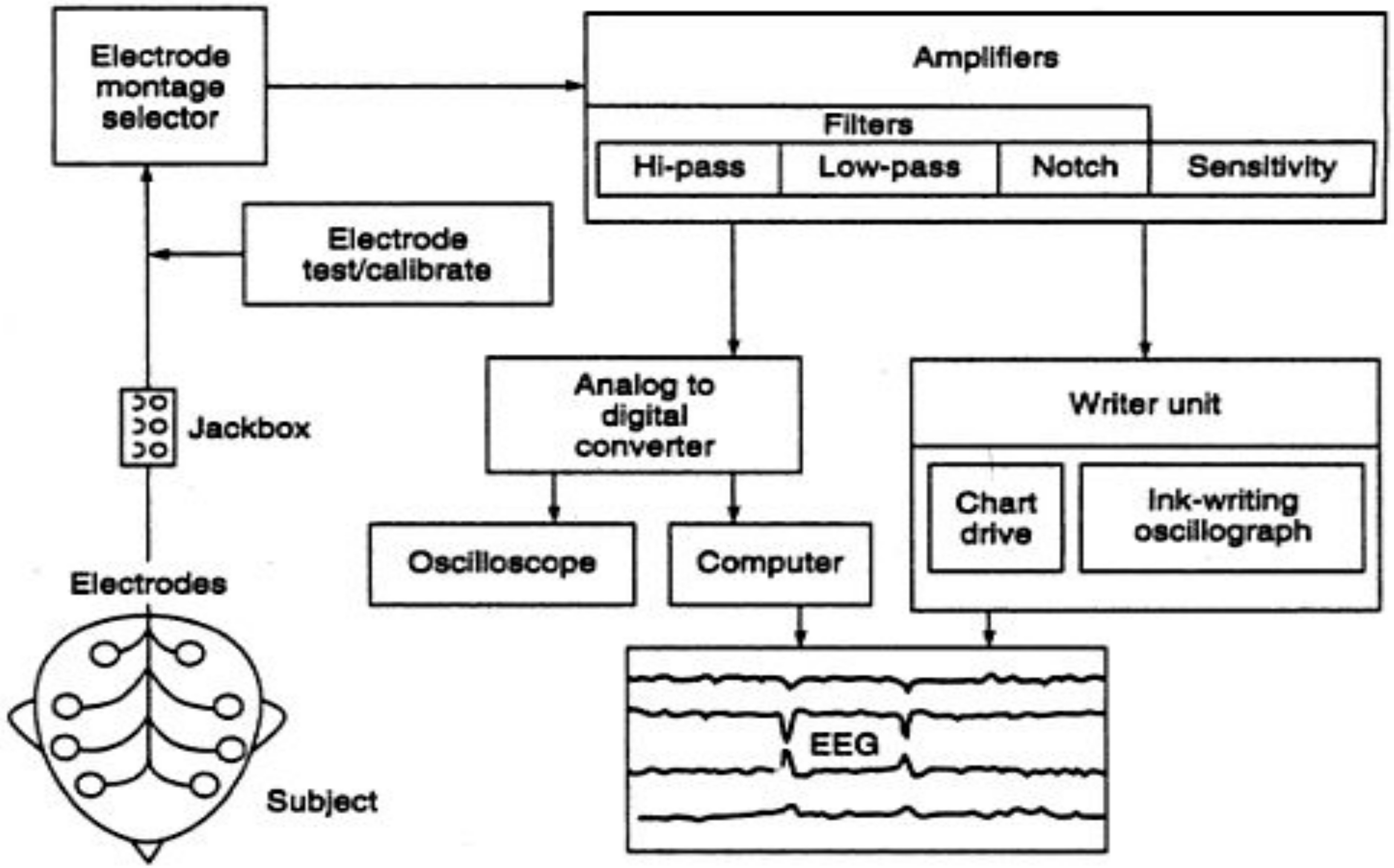
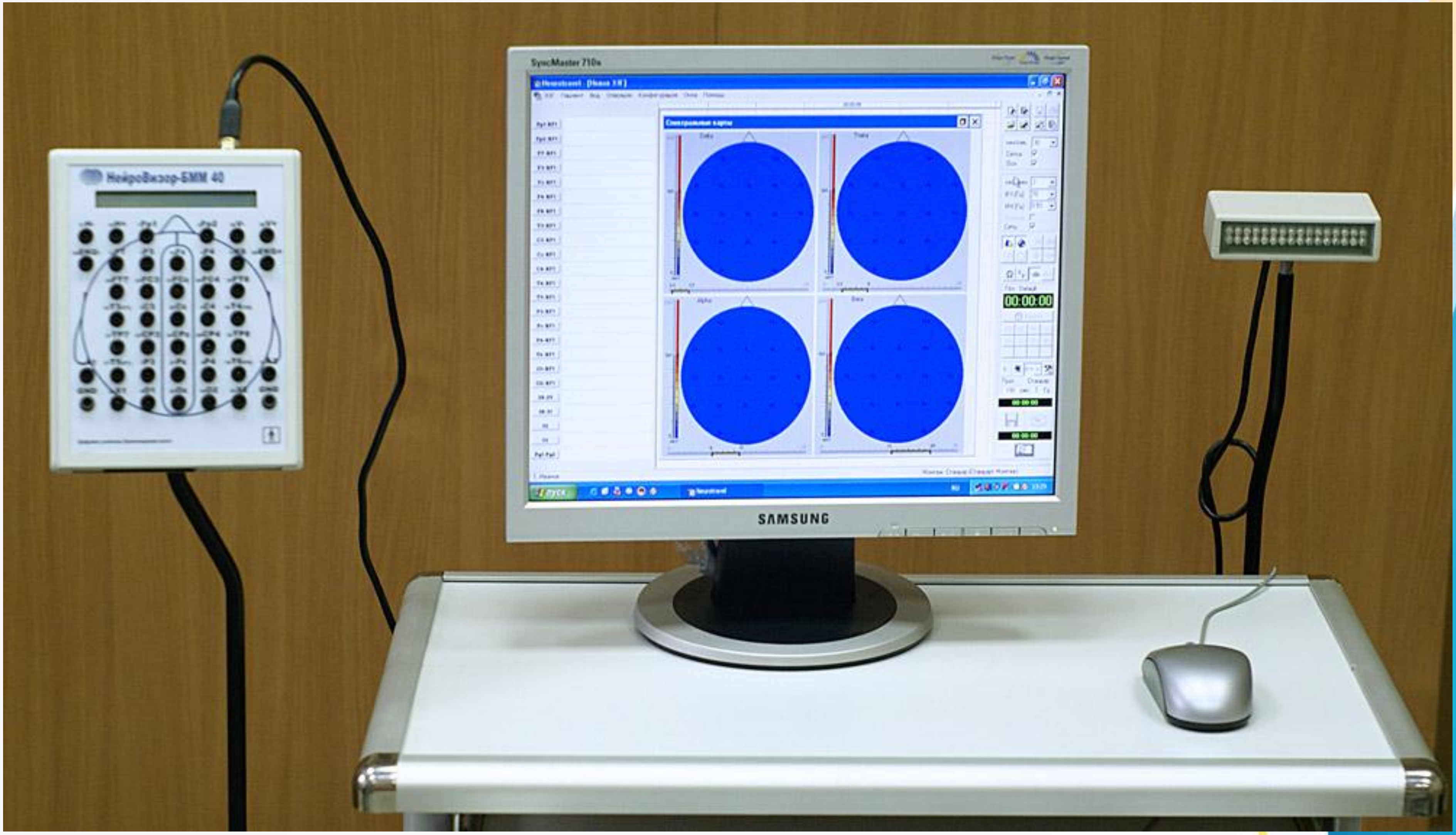


Fig. *Schematic diagram of an EEG machine (after Isley et al, 1998)*

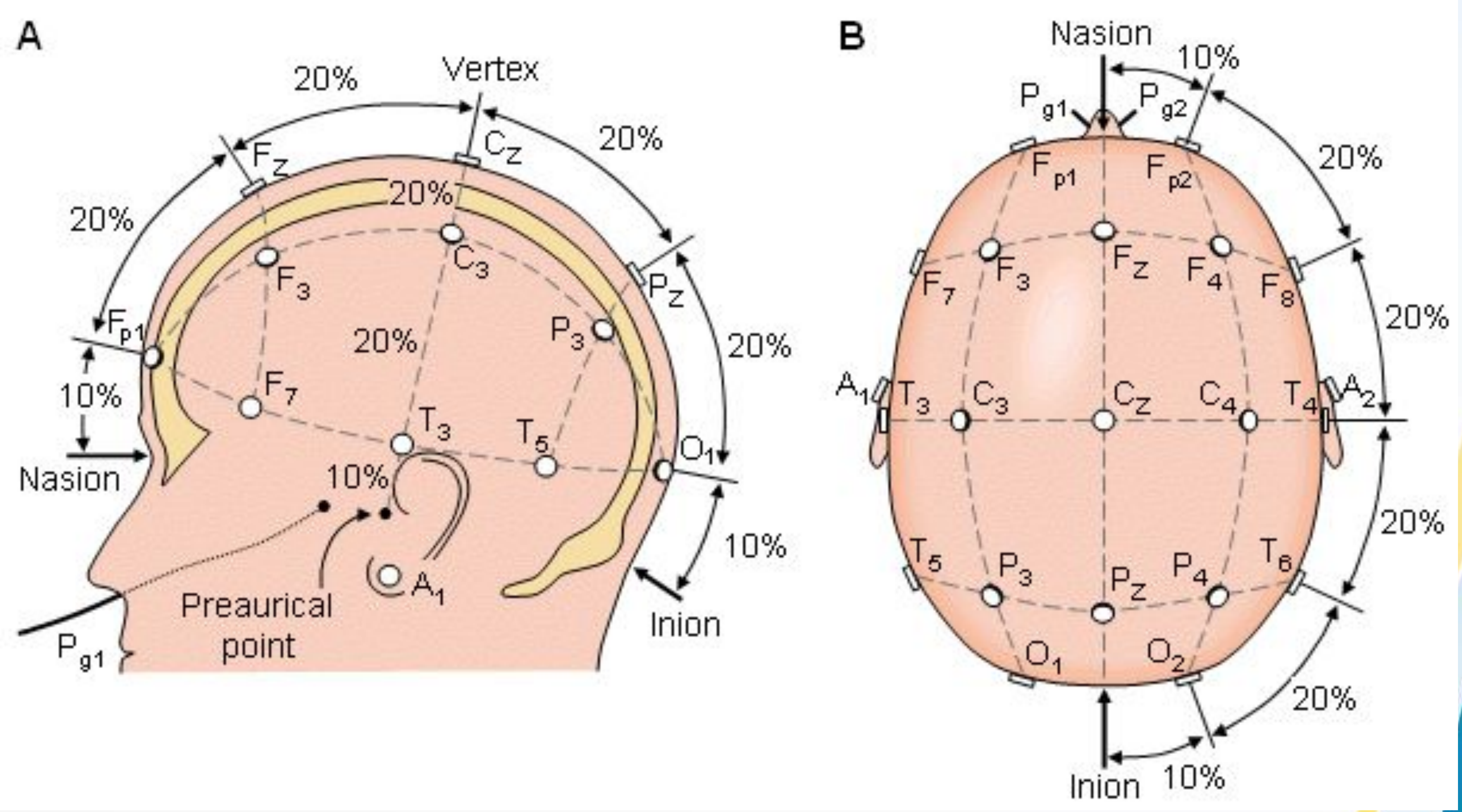
Computerized EEG Machine



Procedure of EEG recording

- A standard EEG makes use of 21 electrodes linked in various ways (Montage).
- Ask the subject to lie down in bed.
- Apply electrode according to 10/20% system.
- Check the impedance of the electrodes.
- Ask the subject to open eyes for 10 sec. and ask him/her to close eyes. (do this procedure for several times in each montage)

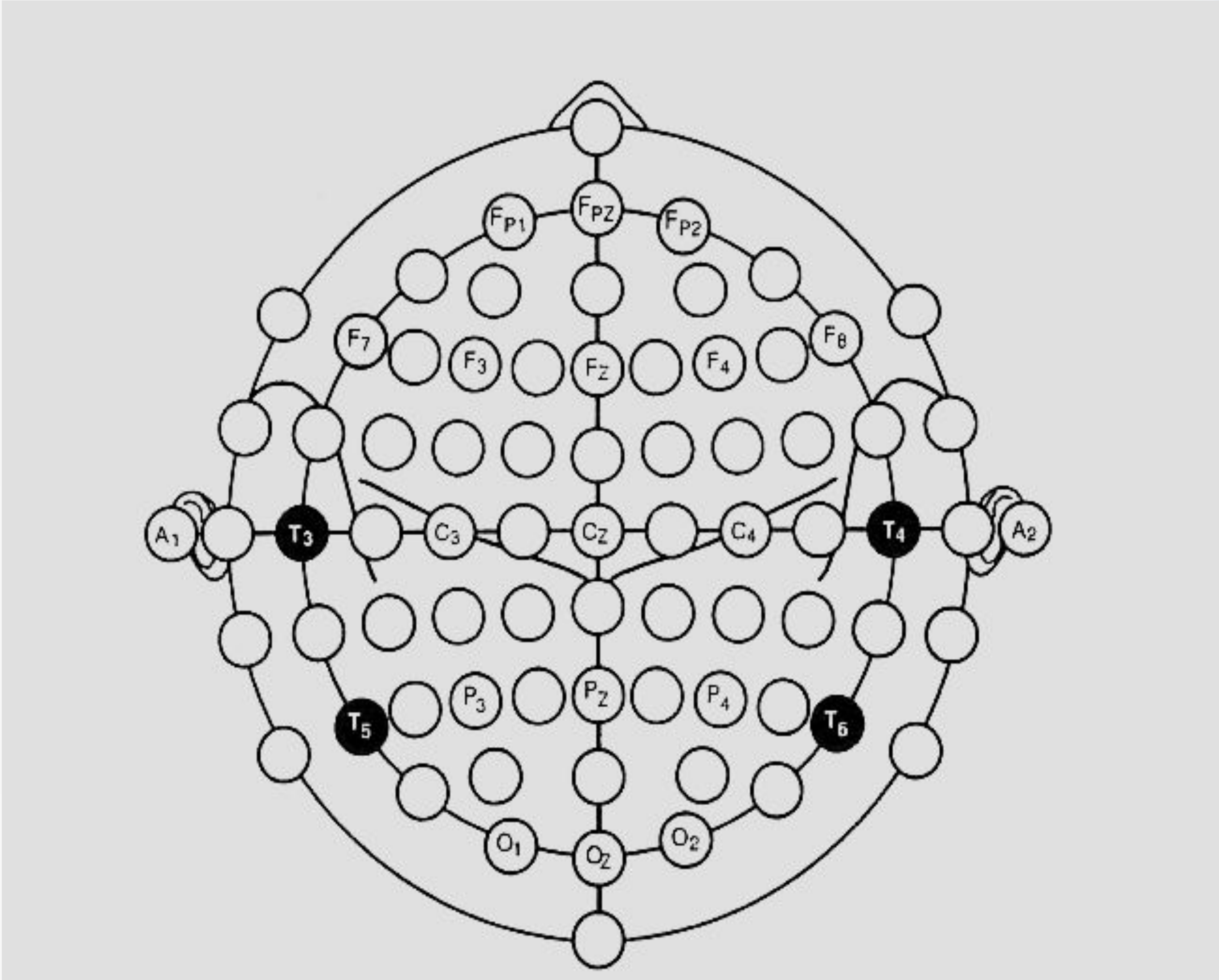
10 /20 % system of EEG electrode placement



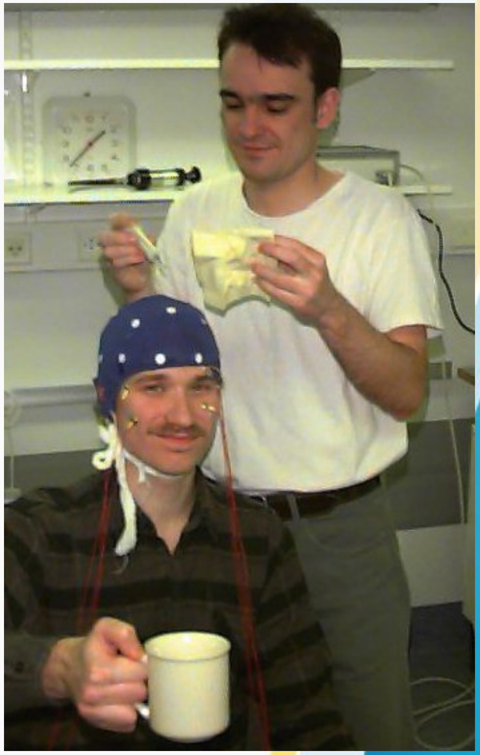
International 10-20 System of Electrode Placement

- Established in 1958
- Electrodes are spaced at 10% or 20% of distances between specified anatomic landmarks
- Use 21 electrodes, but others can be added
  - increase spatial resolution
  - record from specific areas
  - monitor other electrical activity (e.g. ECG, eye movements)
- Odd number electrodes over left and even number over right hemisphere

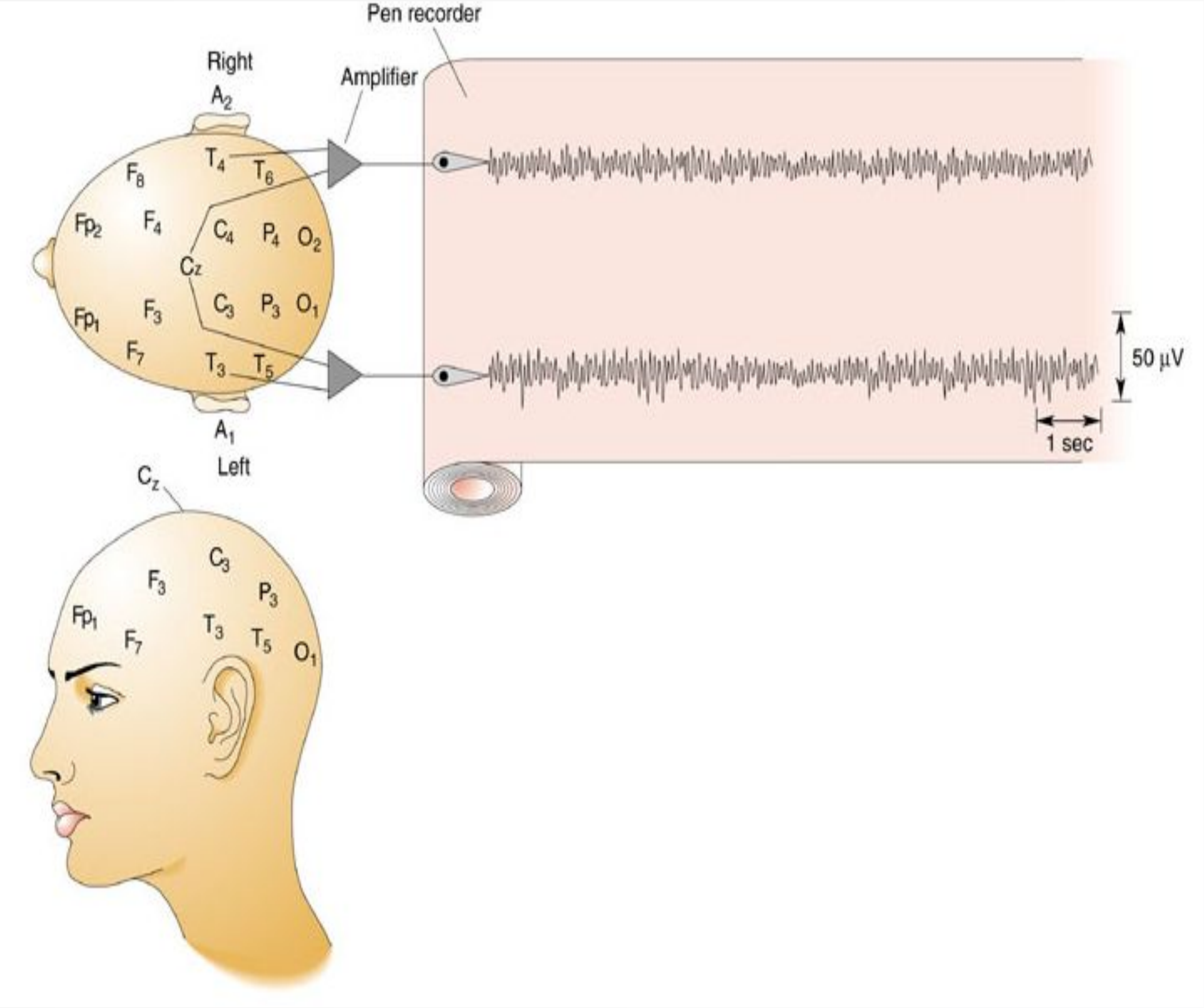
10-20 System Of Electrode Placement



EEG



EEG



Standard placements of electrodes on the human scalp: A, auricle; C, central; F, frontal; Fp, frontal pole; O, occipital; P, parietal; T, temporal.

Two types of recording

- Bipolar – both the electrodes are at active site
  - Bipolar montage are parasagital montage.
- Unipolar – one electrode is active and the other is indifferent kept at ear lobe.
    - Always watch for any abnormal muscle activity.
    - Ask the subject to open eyes for 10 sec. then ask them to close the eyes.

- Each electrode site is labeled with a letter and a number.
- The letter refers to the area of brain underlying the electrode

e.g. F - Frontal lobe and T - Temporal lobe.

- Even numbers denote the right side of the head and
- Odd numbers the left side of the head.

Routine EEG Techniques

- 20-min or longer sampling of brain activity
- Written out or recorded directly on magnetic tape or digitally by computer
- Disc electrodes are applied according to 10-20 system of electrode placement
- Montages: referential, bipolar, changeable with digital recording

Objectives of EEG recording

- Familiarize with the principles of techniques involved
- Count frequencies and measure the amplitudes of the record obtained.
- Categories the records into appropriate rhythms – α, β, θ,and δ.
- Identify and describe changes produced by provocation tests.

e.g. eye opening & closing, intermittent photic stimulation (IPS) clapping sound, induce thinking & hyperventilation.

- Appreciate clinical uses of EEG

- Normally classified into 5 categories: Rhythms occur in distinct frequency ranges:

  Gamma: 20-60 Hz (“cognitive” frequency band)

  Beta: 14-20 Hz (activated cortex)

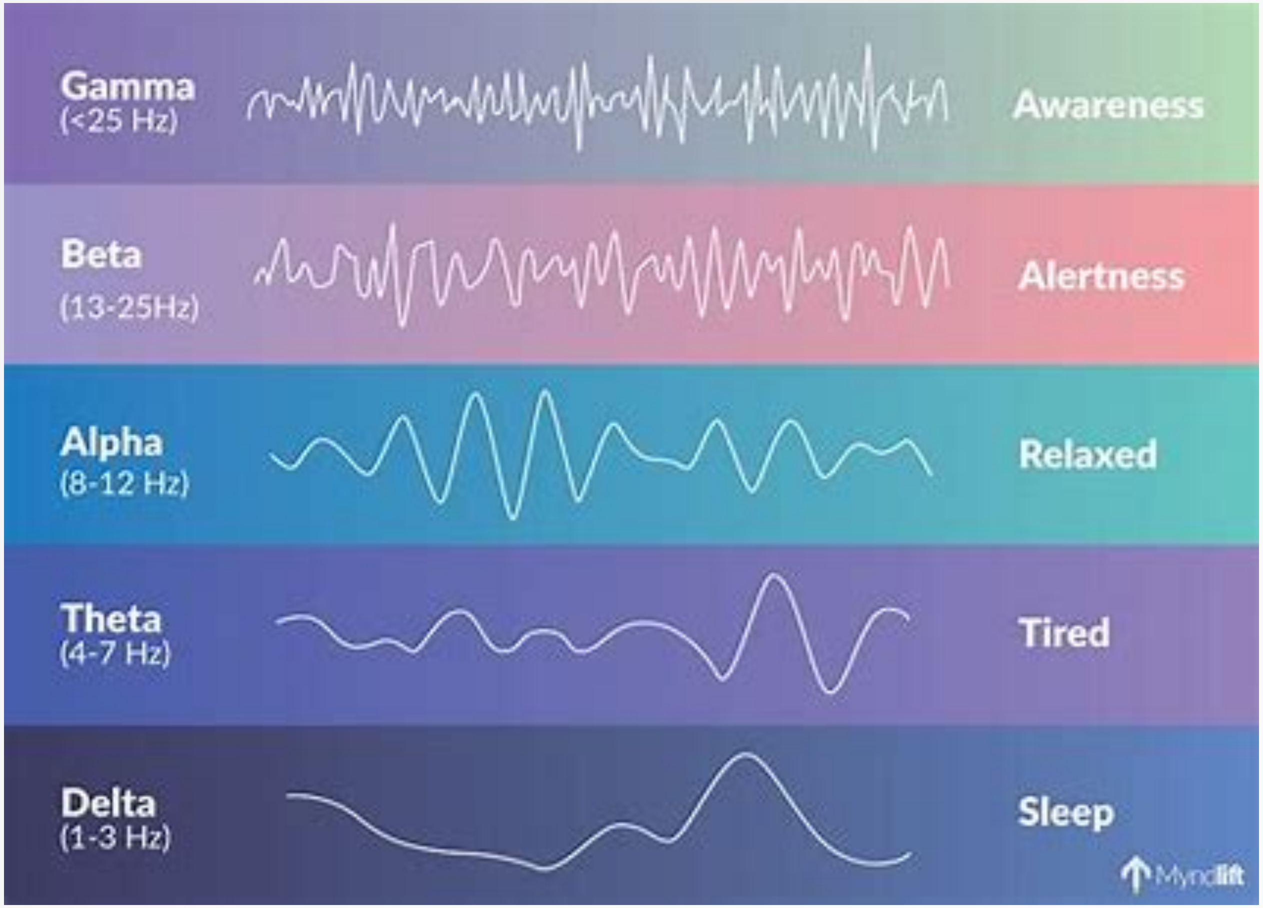
  Alpha: 8-13 Hz (quiet waking)

  Theta: 4-7 Hz (sleep stages)

  Delta: less than 4 Hz (sleep stages, “deep sleep”)

- Higher frequencies: active processing, relatively de-synchronized activity (alert wakefulness, dream sleep).
- Lower frequencies: strongly synchronized activity (nondreaming sleep, coma)

Different types of brain waves in normal EEG



EEG amplitude & Frequency Bands

- EEG signal voltage amplitude range from about 1 to 100 μV peak-to-peak at low frequencies (0.5 to 100Hz) at the cranial surface
- At the surface of cerebrum, signal may be 100 times stronger
- At brain stem about 0.25 μV (100-3000Hz)
- EEG rhythms correlate with patterns of behavior (level of attentiveness, sleeping, waking, seizures, coma)

- EEG potentials often display rhythmic patterns at characteristic frequencies.

- It shows dramatic changes to the 5 stages of sleep: drowsiness, light sleep, moderately sleep, deep sleep, & REM

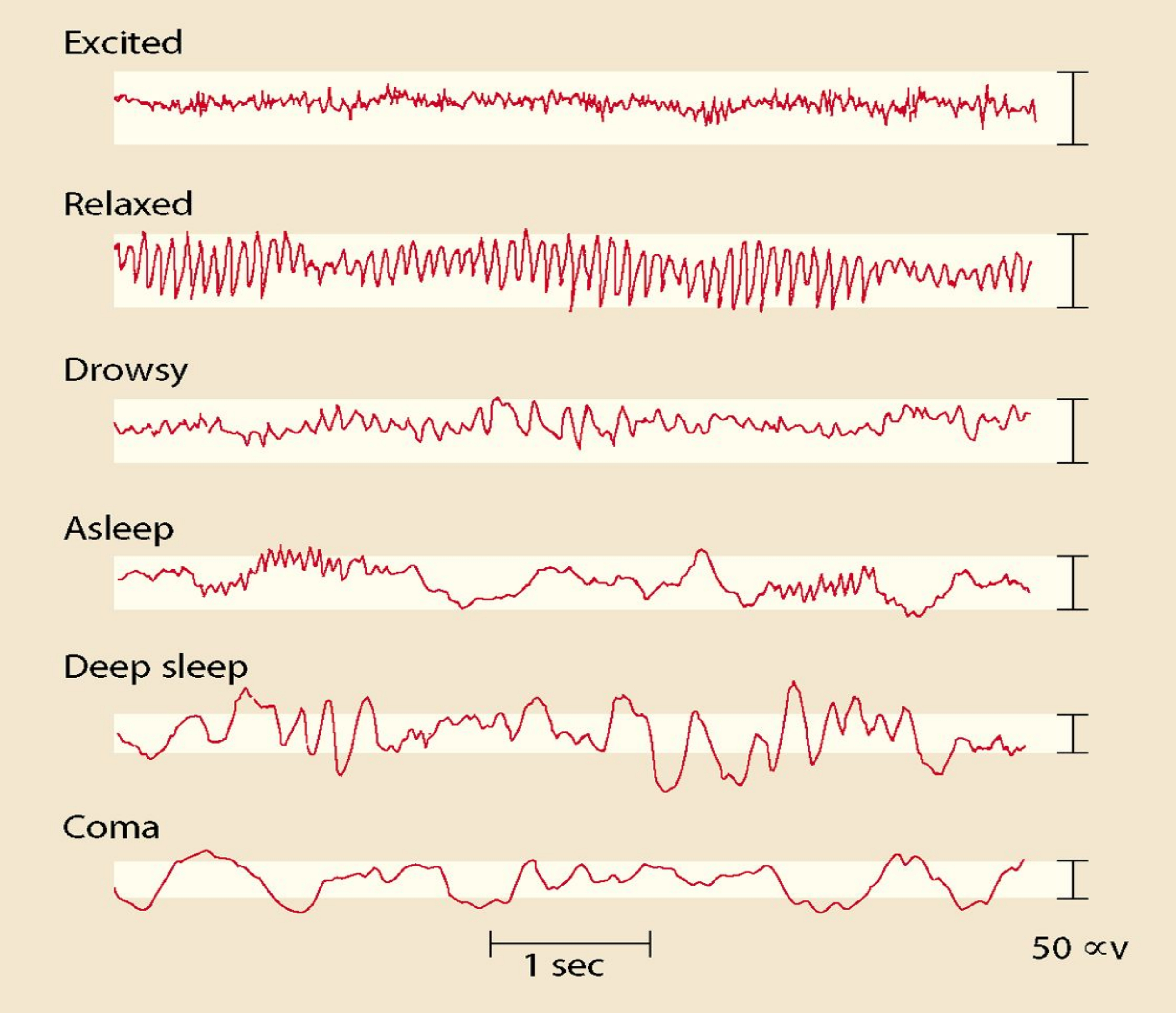
Sleep Disorders

- Insomnia: lack of adequate sleep
- Chronic hypersomnia: excessive sleep or sleepiness

- Sleep paralysis: inability to move during apparent full consciousness

- Nightmare: night terrors revealed by sudden scream and arousal

Frequency spectrum of EEG



EEG Recording From Normal Adult Male

Different types of brain waves in normal EEG

Rhythm	Frequency (Hz)	Amplitude (uV)	Recording & Location
Alpha(α)	8 – 13	50 – 100	Adults, rest, eyes closed. Occipital region
Beta(β)	14 - 30	20	Adult, mental activity Frontal region
Theta(θ)	5 – 7	Above 50	Children, drowsy adult, emotional distress Occipital
Delta(δ)	2 – 4	Above 50	Children in sleep

- Evoked potential amplitudes tend to be low, EEG, EMG, and ECG.

- Usually the term "evoked potential" is reserved for responses involving either recording from, or stimulation of, central nervous system structures.

- I t is compound motor action potentials (CMAP) or sensory nerve action potentials (SNAP) as used in nerve conduction studies (NCS)

- ERPs are brain responses that are time-locked to some “event”, such as a sensory stimulus.

Visual evoked potential (VEP) VEP Stimuli

- In 1934, Adrian and Matthew noticed potential changes of the occipital EEG can be observed under stimulation of light.
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- It is beneficial to use this type of stimulus when testing infants or individuals with poor visual acuity.

Auditory evoked potential

- Auditory evoked potentials (AEPs) are a subclass of event-related potentials (ERP)s. For AEPs, the "event" is a sound.

- AEPs (and ERPs) are very small electrical voltage potentials originating from the brain recorded from the scalp in response to an auditory stimulus, such as different tones, speech sounds, etc.

Strength and Advantages of EEG

- Is a measure of brain function; supplement neuroimaging studies
- Provides direct rather than indirect evidence of epileptic abnormality
- May be the only test that shows abnormalities in epileptic patients
- Provides some spatial or localization information
- Low cost
- Low morbidity
- Readily repeatable
- Portable / ambulatory

Limitations and Disadvantages Of EEG

- Detects cortical dysfunction but rarely discloses its etiology
- Relatively low sensitivity and specificity
- Subject to both electrical and physiologic artifacts
- Influenced by state of alertness, drugs
- Small or deep lesions might not produce an EEG abnormality
- Limited time sampling (for routine EEG) and spatial sampling
- May falsely localize epileptogenic zone

Uses of EEG in the Management of Seizure Disorders

- To support a clinical diagnosis of epilepsy
- To help to classify seizures
- To help localize epileptogenic focus, especially in presurgical candidates
- To quantify seizures
- To aid in the decision of whether to stop AED treatment
- Not a good guide to the effectiveness of treatment, except in absence seizures

Analysis

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

Factor influencing EEG

- Age
  - Infancy – theta, delta wave
  - Child – alpha formation.
  - Adult – all four waves.
- Level of consciousness (sleep)

NORMAL EEG CHANGES

Sleep studies

- The EEG is frequently used in the investigation of sleep disorders especially sleep apnoea (loud snoring) .

- Polysomnography (PSG, recording of the biophysiological changes that occur during sleep): EEG activity together with
  - heart rate,
  - airflow,
  - respiration,
  - oxygen saturation and
  - limb movement

Epilepsy

- Epilepsy (from the Ancient Greek verb meaning "to seize, possess, or afflict") is a group of long-term neurological disorders characterized by epileptic seizures.

- About 1% of people worldwide (65 million) have epilepsy, and nearly 80% of cases occur in developing countries.

- In most cases the cause is unknown, although some people develop epilepsy as the result of brain injury, stroke, brain cancer, and drug and alcohol misuse, among others.

- Epileptic seizures are the result of excessive and abnormal cortical nerve cell activity in the brain.

- About 5-10% of all people will have an unprovoked seizure by the age of 80 and the chance of experiencing a second seizure is between 40 and 50%.
- Epilepsy cannot be cured, but seizures are controllable with medication in about 70% of cases.
- In those whose seizures do not respond to medication, surgery, neurostimulation or dietary changes may be considered.

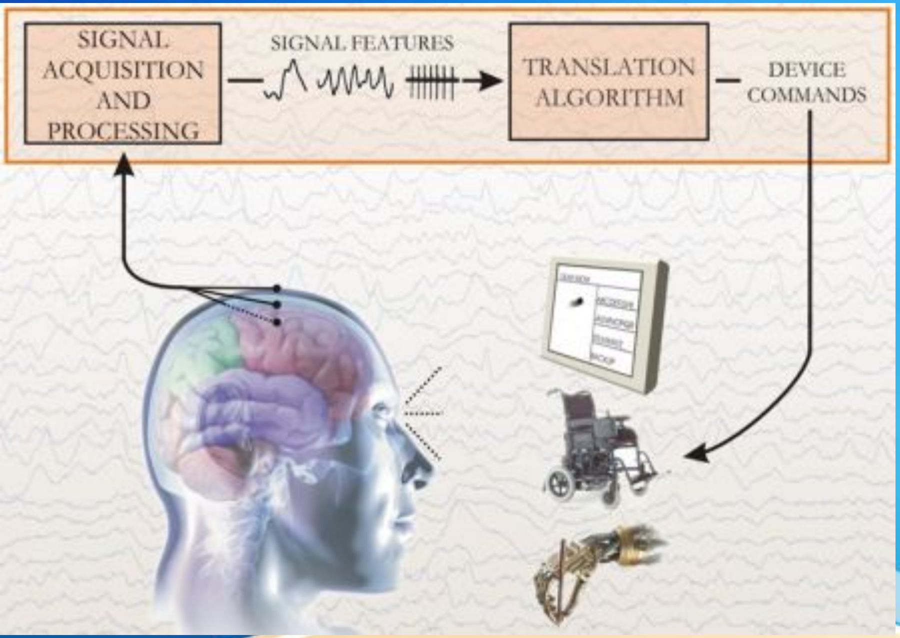
- Grand mal seizure: also known as a tonic-clonic seizure-features a loss of consciousness and violent muscle contractions.

- Petit mal seizure

  - It is most commonly called an absence seizure.

  -It is a brief (usually less than 15 seconds) disturbance of brain function due to abnormal electrical activity in the brain.

  - It is associated with small muscle movement and temporary loss of consciousness.



BCI applications