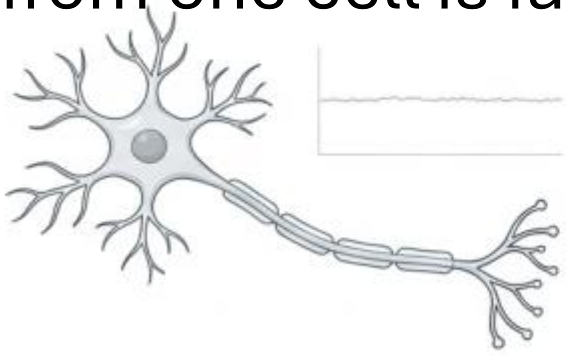
Electroencephalogram (EEG)

Introduction:

- An Electroencephalogram, or EEG, is a test designed to detect and record the electrical activity of the brain.
- The procedure uses small, flat metal discs called electrodes, which are attached to the scalp to pick up the faint electrical signals produced by brain cells.
- The resulting recording of these brain waves, visualized as a series of lines, is the electroencephalogram itself.
- This technology provides a direct look into the real-time activity of the brain.
- But what exactly are these signals, and how does a machine listen in on the brain's constant electrical chatter?

The Source of the Signal

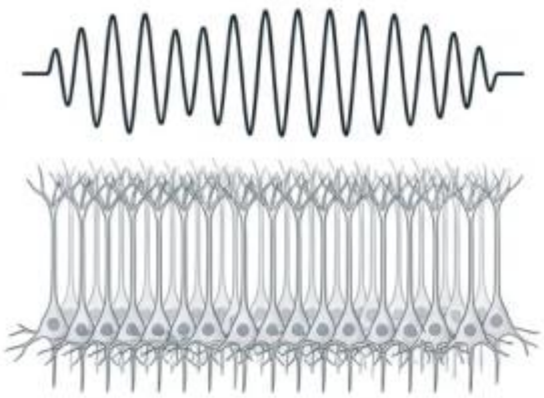
- Normal brain function relies on the continuous generation of electrical potentials, or nerve impulses.
- These impulses are created by millions of brain cells communicating with each other.
- This process is active all the time, even when you are asleep.
- A crucial insight into EEG is that it does not detect the electrical activity of a single neuron; the signal from one cell is far too small to be measured from the scalp.



Single Neuron Potential. Too small to be detected through the skull.

The Source of the Signal

- Instead, an EEG measures the **summation of the synchronous activity** of thousands or millions of neurons firing together in similar orientations.
- These collective, detectable electrical signals are called **brain waves**.
- They specifically indicate the activity of the cerebral cortex and are strong enough to pass through the skull easily, which allows them to be recorded non-invasively from the outside.
- Understanding the source of these waves is the first step in appreciating how we can capture and analyze them.

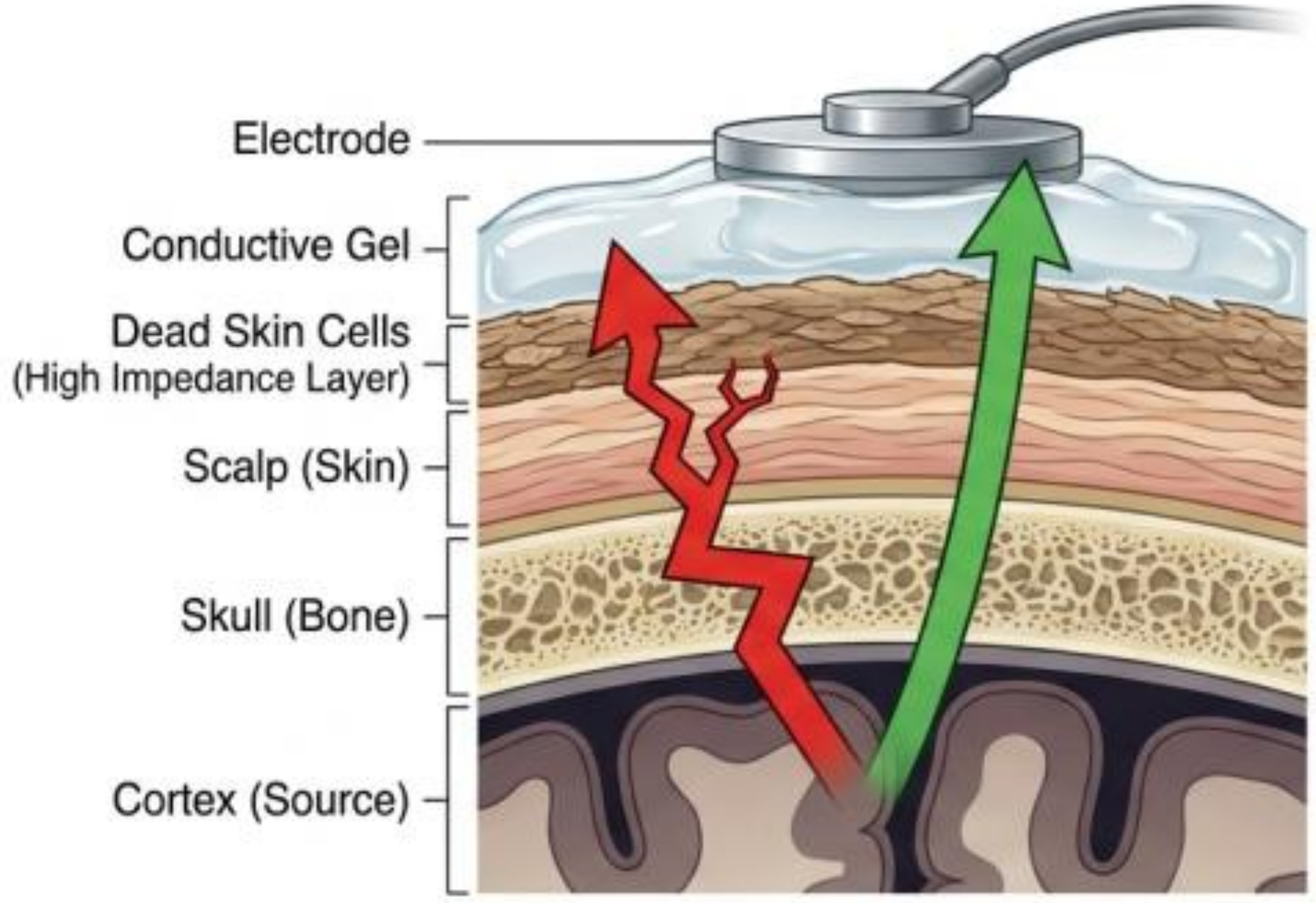


Summation. The synchronous activity of millions of neurons creates a signal strong enough to bridge the skull.

The Step-by-Step EEG Procedure

- The process of recording brain waves is a standardized procedure designed to ensure an accurate and reliable measurement.
- It involves several key steps from preparation to recording.
  1. **Scalp Preparation** To get a clear signal, the scalp area is first prepared with a light abrasion. This helps reduce electrical impedance caused by dead skin cells, ensuring a clean and strong connection between the scalp and the electrode.
  2. **Electrode Placement** Next, electrodes are carefully placed on the scalp using a conductive gel or paste. In most clinical applications, a total of 21 electrodes are used: 19 for recording brain activity, one to act as a ground, and one to serve as a common system reference.

The Step-by-Step EEG Procedure



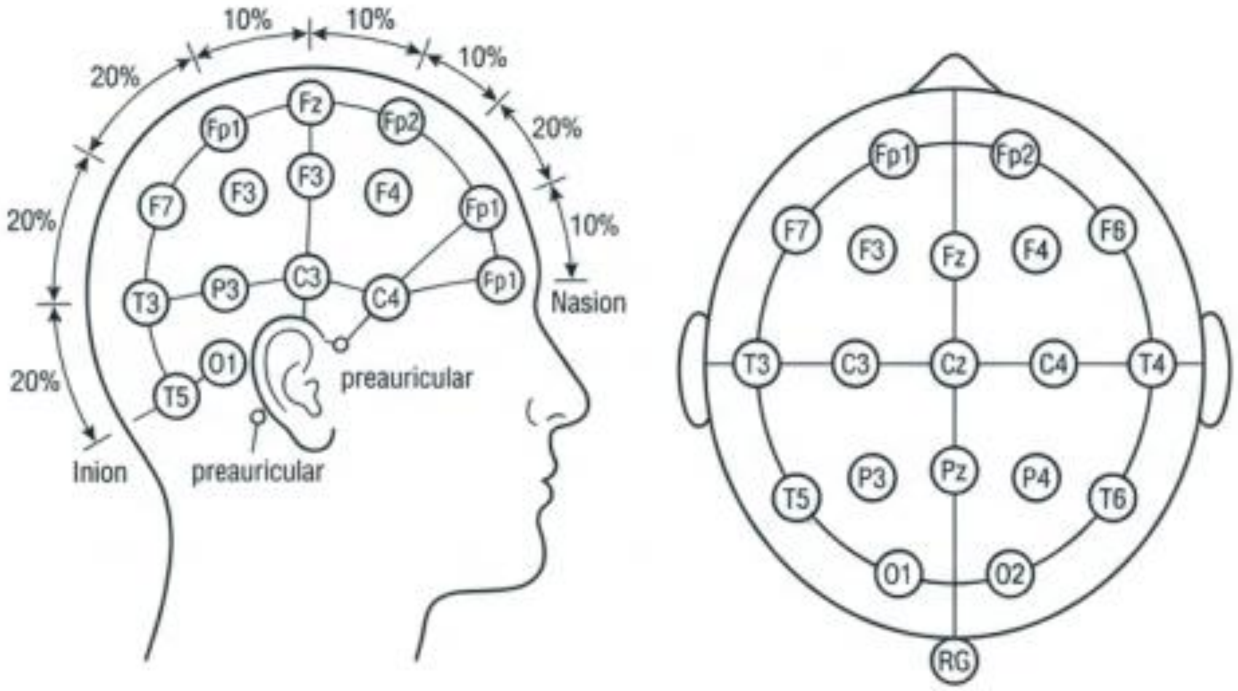
1. **Abrasion:** The scalp is lightly abraded to remove **dead skin cells** that create resistance.

2. **Conduction:** Electrodes are applied using a thick conductive paste to bridge the gap between scalp and sensor.

The Step-by-Step EEG Procedure

Configuration:
21 Total Electrodes

Breakdown:
19 Recording,
1 Ground,
1 Common
Reference



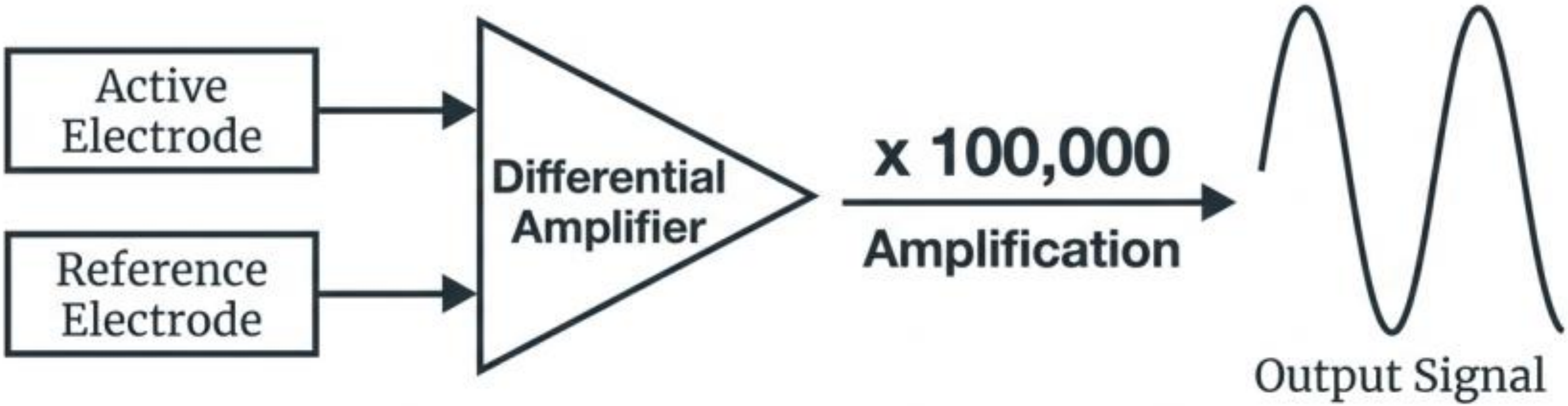
Logic:
Standardized placement to measure potential differences between specific cortical areas.

The Step-by-Step EEG Procedure

3. Amplification Each electrode is connected to an input of a differential amplifier. The brain's electrical signals are incredibly weak by the time they reach the scalp. This device magnifies the tiny voltage differences between the electrodes by about 100 to 100,000 times, making them strong enough to be recorded.
4. Recording The amplified voltage fluctuations are sent to an apparatus that records them as a series of wavy lines. A typical recording session for the brain's spontaneous electrical activity lasts for 20 to 40 minutes.

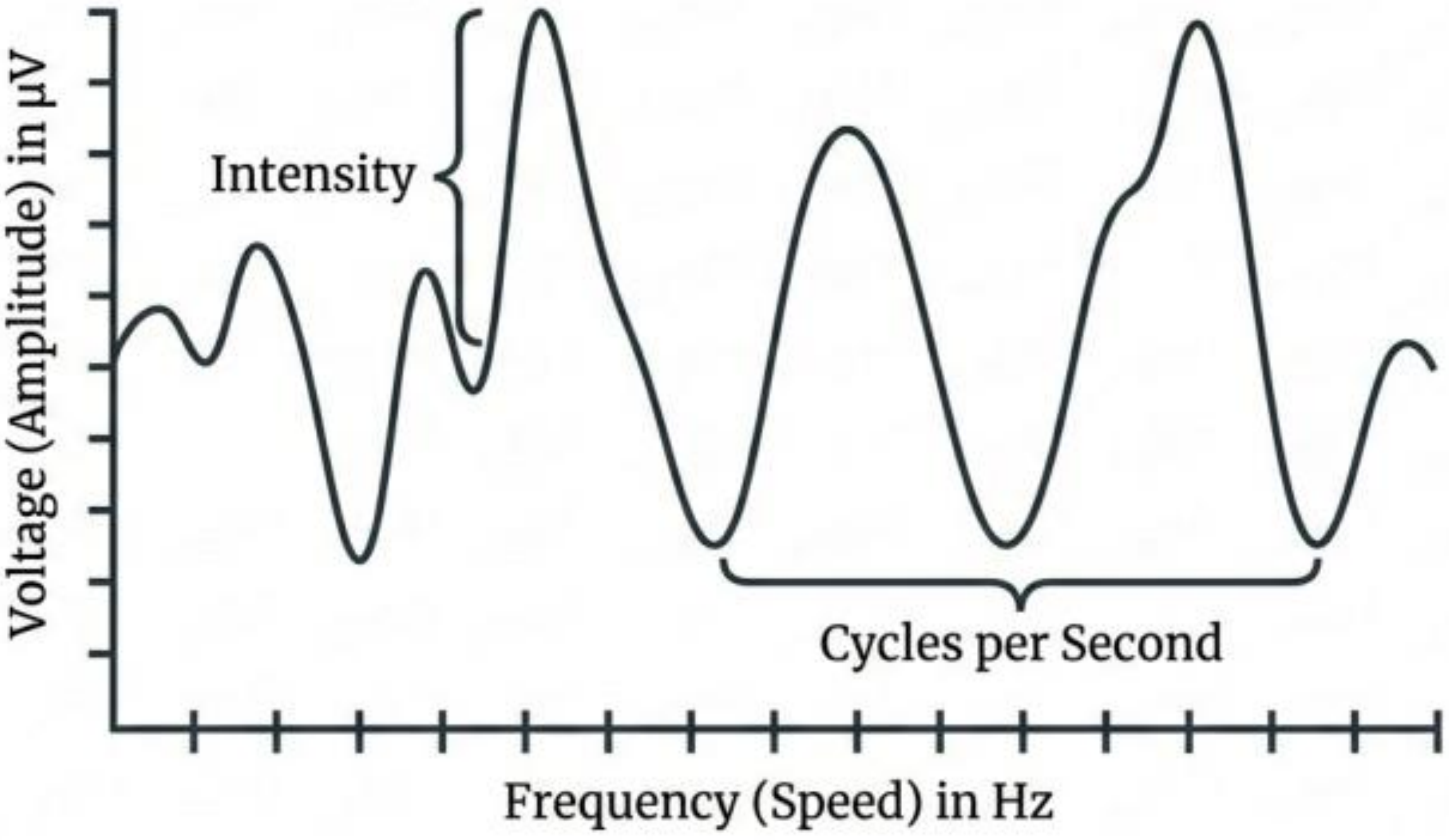
- Once the recording is complete, the data can be analyzed. The next step is to decode these complex squiggles into meaningful information about the brain's state.

The Step-by-Step EEG Procedure



The amplifier measures the voltage difference between the active and reference electrodes, multiplying the micro-volt biological whisper into a readable data signal.

The Step-by-Step EEG Procedure



The Inverse Rule:

Active Brain = Low Amplitude, High Frequency (Alert).

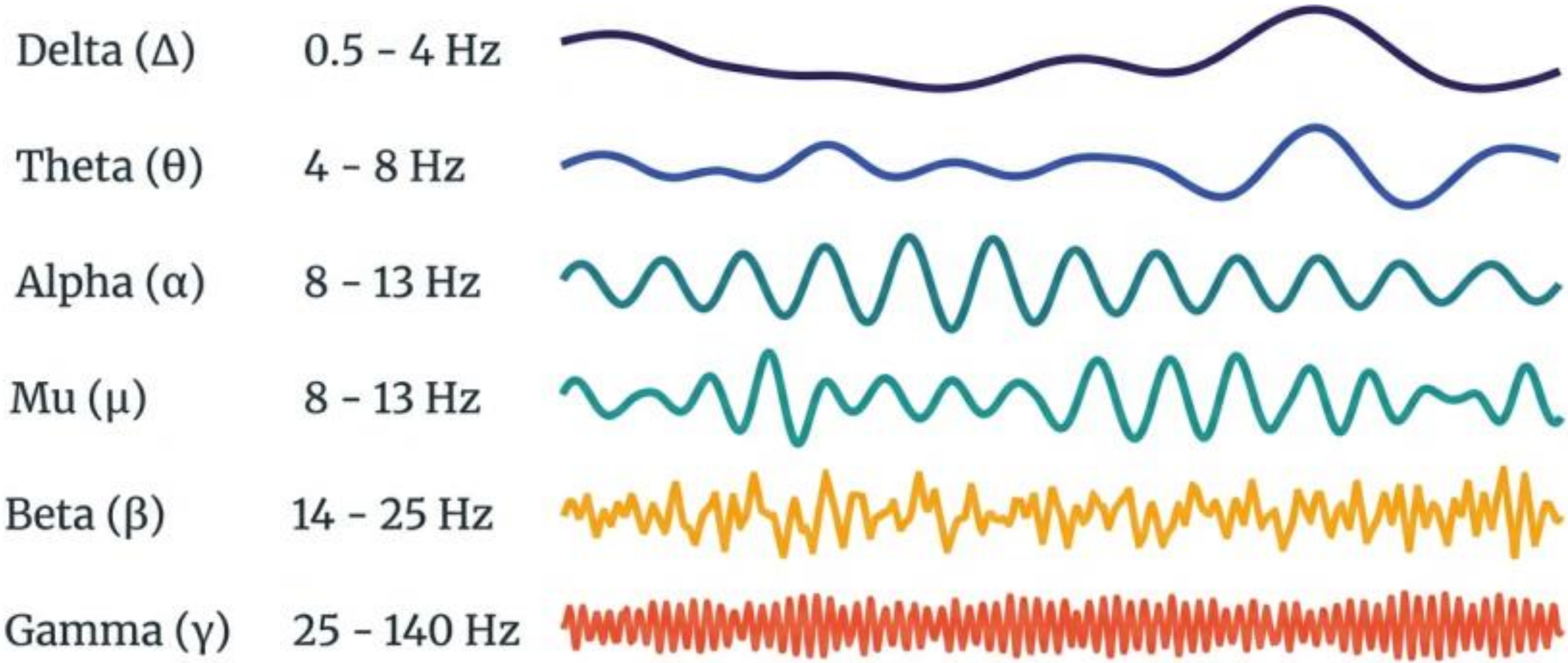
Inactive Brain = High Amplitude, Low Frequency (Sleep).

Amplitude reflects the number of neurons firing in sync.

Decoding the Signals:

- Brain waves are patterns of electrical activity defined by their frequency and amplitude.
- While a person's brain produces waves at all frequencies simultaneously, the dominant pattern changes depending on their mental state.
- Each of us has a pattern of brain waves that is unique as our fingerprints.
- These patterns are classified into distinct types, each associated with different states of consciousness and cognitive functions.

Decoding the Signals:



Decoding Delta (Δ) Signals:

- **Frequency:** 0.5 - 4 Hz
- **State:** Deep dreamless sleep, unconsciousness.
- **Mechanism:** Generated when the Reticular Activating System (RAS) is dampened.
- **Function:** Stimulates immune system and healing. Acts as a ‘filter,’ allowing the brain to ignore sensory input (like a ringing phone) unless critical.

Decoding Theta (θ) Signals:

- **Frequency:** 4 - 8 Hz
- **State:** Dreaming (REM), deep meditation, and 'Autopilot' mode.
- **Characteristics:** More irregular than Alpha. Governs the layer between conscious and unconscious.
- **Context:** Associated with memory, deep emotions, and trance states (e.g., highway hypnosis or children immersed in play).

Decoding Alpha (α) Signals:

Frequency: 8 - 13 Hz

State: Wakeful relaxation with closed eyes.

Also Known As: Berger's Wave (after Hans Berger, 1929).

Reactivity: Prominent when eyes are closed and mind is resting. Vanishes immediately upon opening eyes or engaging in mental tasks.

Decoding Mu (μ) Signals:

Frequency: 8 - 13 Hz (Same as Alpha)

Location: Sensorimotor Cortex (band across the top of the head), distinct from Alpha's Visual Cortex origin.

Key Distinction: Does NOT react to opening eyes. Reacts to physical movement or the intent to move.

Function: Associated with motor neurons at rest and social mirroring.

Decoding Beta (β) Signals:

Frequency: 14 - 25 Hz

State: Conscious alertness, active thinking, anxiety.

Activity: Problem-solving, logic, critical reasoning.

Context: The dominant wave of modern life. High Beta levels are associated with stress, stress, tension, and "busyness." Minimal during relaxation.

Decoding Gamma (γ) Signals:

- **Frequency:** 25 - 140 Hz
- **State:** Hyper-focus, peak performance, spiritual emergence.
- **Mechanism:** The ‘Binding’ wave—connects information from different brain areas simultaneously.
- **The 40 Hz Mystery:** A specific frequency associated with a significant increase in brain power, altruism, and higher virtues.

Decoding Signals:

- You might notice that Alpha (α) and Mu (μ) waves share the same frequency range. The key distinction lies in their location and behavior.
- Mu rhythms are found over the sensorimotor cortex (the part of the brain that controls voluntary movement) and are not affected by opening or closing the eyes.
- Alpha rhythms, in contrast, are typically found over the resting visual cortex at the back of the scalp and are significantly reduced or eliminated when the eyes are open.
- As a general principle, when the brain is active, the brain waves are complex, and it has a low amplitude and high frequency, which indicates a state of alert. But when the brain is inactive, the brain waves have high amplitudes and low frequencies, which indicates that the brain is inattentive, with less responsive behavior, such as in a sleep state.

Clinical Uses of EEG

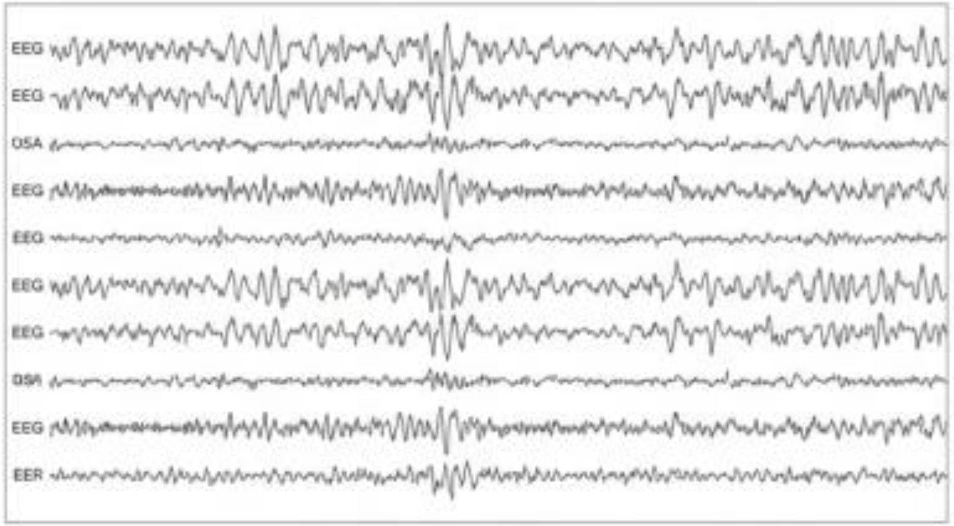
- Understanding these normal brainwave patterns is the key to identifying when something is wrong.
- A primary and powerful use of EEG is to detect abnormal brain wave patterns. These irregularities can help in the diagnosis and localization of various diseases and conditions affecting the nervous system.

Clinical Uses of EEG

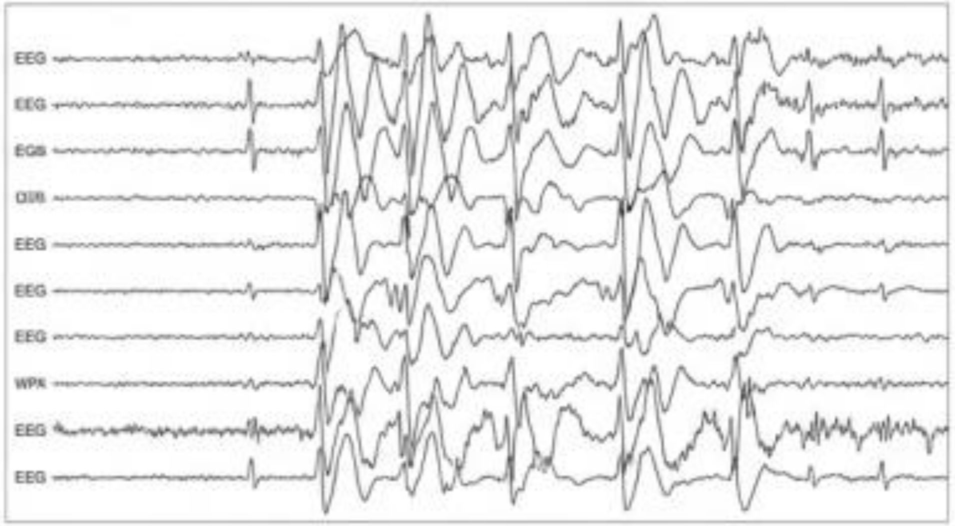
- An EEG can help detect and monitor a wide range of conditions, including:
  - Tumors
  - Seizures and epilepsy
  - Infarctions (tissue death due to lack of blood supply)
  - Blood clots and hemorrhage
  - Regions of dead tissues
  - High or low blood sugar
  - The absence of brain waves, a condition known as a "flat EEG," is considered clinical evidence of brain death.

Clinical Uses of EEG

Normal EEG Awake



Abnormal: Epilepsy



- Epilepsy and Seizures (Spike and Wave patterns)
- Tumors and Lesions (Focal slowing)
- Brain Death (Flat EEG / Absence of signal)
- Sleep Disorders