EEG, Brain Waves, Seizures and Sleep
Electroencephalography (EEG)

- **Electro**: relating to electricity.
- **Encephalo**: relating to the brain.
- **Graphy**: writing or representation produced in a specified manner.

Therefore, EEG produces a graphed representation of the electrical activity occurring in a person’s brain.
Origin of EEG waves

EEG is the record of electrical activity of brain (superficial layer i.e. the dendrites of pyramidal cells) by placing the electrodes on the scalp.
EEG Electrode Placement
Classifying EEG brain waves

- **Frequency**: the number of oscillations/waves per second, measured in Hertz (Hz)
  - reflects the firing rate of neurons
  - alpha, beta, theta, delta

- **Amplitude**: the magnitude of brain waves, measured in millivolts (mV), gives an indication of the wave’s “power”.
  - The number of neurons firing in synchrony & the distance between the neurons and the recording electrode
Delta Waves

- Slowest frequency waves: 1 – 3 Hz
- Associated tasks & behaviors:
  - deep, dreamless sleep, not moving, not attentive, sleeping
Theta Waves

- **Slow wave frequency**: 4 – 8 Hz

- **Associated tasks & behaviors**:  
  - State between wakefulness and sleep  
    “Drowsy”  
  - during sleep, meditation, internal focus, and prayer; subconsciouness.
**Alpha Waves**

- **Mid wave frequency:** 8 - 13 Hz
- **Parietal and occipital lobes**
- **Associated tasks & behaviors:**
  - Relaxing, watching television, light reading (e.g., novel), eyes closed.
Beta Waves

- High wave frequency: 12 - 35 Hz
  - The “normal” dominant rhythm
  - mostly on temporal and frontal lobe

- Associated tasks & behaviors:
  - listening and thinking during analytical problem solving, judgment, decision making, processing information,
EEG Waveforms

- **Alpha**
  - 8-13 Hz
  - Parietal and occipital prominent
  - Relaxed wakeful

- **Beta**
  - 13-30 Hz
  - Frontal prominent
  - Intense mental activity

- **Delta**
  - 0.5-4 Hz
  - Drowsiness/early SWS

- **Theta**
  - 4-7 Hz
  - Drowsiness/early SWS
Seizure

- Abnormal electrical discharge.
- Initially synchronous
- May have no motor component
Convulsion

- Indicative of seizure activity
- Motoric output of synchronous neuronal firing.
Primary (Idiopathic) Seizure Disorders

- No identifiable cause
- Not the result of overt disease or injury
- In short, a guess.
Secondary (Symptomatic) Seizure Disorders

- Associated with or secondary to disease or injury
- e.g. trauma, neoplasm, or infection.
Epilepsy

- Seizures and/or convulsions can be acute and isolated...
- ...they can be associated with a treatable organic disorder...
- When seizures/convulsions are chronic and of undefined origin...
- ...the condition is described as epilepsy.
Generalized Seizure Disorders

May be convulsive or not and include...

- Absence
- Myoclonic
- Clonic
- Tonic-Clonic (Grand mal)
- Atonic
Normal vs. Tonic-Clonic

![Graph showing normal EEG and generalised seizure EEG (tonic-clonic type) with different sites: frontal, temporal, and occipital. The graph indicates phases: normal record, onset of tonic phase, clonic phase, and post-convulsive coma.](CNSforum.com)
Normal vs. Absence

NORMAL EEG

Frontal site
Temporal site
Occipital site

1 sec

GENERALISED SEIZURE EEG
(absence seizure type)

Frontal site
Temporal site
Occipital site

3 sec

'Spike and wave' discharge

1 sec

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Partial Seizure Disorders

Focal, localized seizures including...

- **Simple**
  - No impairment of consciousness.

- **Complex**
  - Consciousness impaired or disturbed.

- **Secondarily generalized**
Normal vs. Partial

normal EEG

frontal site

temporal site

occipital site

1 sec

partial seizure EEG

frontal site

temporal site

occipital site

synchronous abnormal discharges in frontal and temporal regions

1 sec

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Scheme of Seizure Spread

Simple (Focal) Partial Seizures

Contralateral spread

From M.I. Davila-Garcia, Howard Univ., 2003
Seizure Pathophysiology

- Altered ionic conductance (increased excitability) of neuron.
- Reduced inhibitory neuronal (primarily GABAergic) control.
- Increased excitatory neuronal (primarily glutamatergic) control.
- Probable mechanisms tend to overlap.
Cellular and Synaptic Mechanisms of Epileptic Seizures

- Abnormal voltage-operated channels:
  - Focal epileptogenesis

- Abnormal receptor-operated channels:
  - Decreased inhibition
  - Increased excitation
  - Synchronization

- Alterations in extracellular ionic environment:
  - Propagation

- Recruitment of normal neurons via anatomical circuits

Seizure Sequence
Sleep
Why Do We Need Sleep?

Adaptive Evolutionary Function
- safety
- energy conservation/efficiency

Restorative Function
- body rejuvenation & growth

Brain Plasticity
- enhances synaptic connections
- memory consolidation
The ascending arousal system promotes wake

A.

B.

Modified from Fuller et al., J Biol Rhythms, 2006
Hypocreatin (orexin)
Hypocretin

GABA

Sleep (ventrolateral preoptic area)

Norepinephrine
Histamine
Dopamine
Serenotonin
Acetylcholine

Wake

GABA

Norepinephrine
Serotonin
Narcolepsy VS Insomnia
Melatonin: Produced by pineal gland, released at night-inhibited during the day (circadian regulation); initiates and maintain sleep; treat symptoms of jet lag and insomnia
SCN and sleep

Wild type animal with period of ~24h

SCN lesioning

A

SCN lesioning abolishes circadian rhythm

B

SCN lesioning

C

Transplanting SCN of donor with ~20-h period

Wild type animal acquires period of donor (~20h)

Tau mutant with period of ~20h

Modified from Ralph and Lehman, Trends Neuro 1991
Coffee

Do Stupid Things Faster with More Energy
Coffee

- During waking, brain consume ATP
Coffee

- During waking, brain consume ATP
- ↑ adenosine
Coffee

- During waking, brain consume ATP

  \[ \text{adenosine} \]

- Adenosine bind to A1 receptor

- Inhibit acetylcholine neurons
Coffee

- During waking, brain consume ATP
- ↑ adenosine
- Adenosine bind to A1 receptor
- Inhibit acetylcholine neurons
- Caffeine and Theophylline are A1 antagonist
Sleep stages

- Awake
- Stage 1
- Stage 2
- Stage 3
- Stage 4

Slow wave sleep
Sleep stages

- Awake
- Stage 1
- Stage 2
- Stage 3
- Stage 4
- Rapid eye movement sleep (REM)

Slow wave sleep (NREM)
Types and Stages of Sleep: NREM

- Stage 1 – eyes are closed and relaxation begins; the EEG shows alpha waves; one can be easily aroused
- Stage 2 – EEG pattern is irregular with sleep spindles (high-voltage wave bursts); arousal is more difficult
–Stage 3 – sleep deepens; theta and delta waves appear; vital signs decline; dreaming is common

–Stage 4 – EEG pattern is dominated by delta waves; skeletal muscles are relaxed; arousal is difficult
REM Sleep

- Presence of beta activity (desynchronized EEG pattern)
- Physiological arousal threshold increases
  - Heart-rate quickens
  - Breathing more irregular and rapid
  - Brainwave activity resembles wakefulness
  - Genital arousal
- Loss of muscle tone (paralysis)
- Vivid, emotional dreams
- May be involved in memory consolidation
SLEEP AND WAKE THROUGHOUT HUMAN LIFE

HOURS PER DAY

REM SLEEP

NREM SLEEP

WAKING

1-15 days
1.5 mos
6-23 mos
2-3 yrs
3-5 yrs
5-9 yrs
10-13 yrs
14-18 yrs
19-30 yrs
33-45 yrs
50 yrs
60 yrs

REM Dreaming

“vivid and exciting”
~3 per night
- Longer, more detailed
- Fantasy world
- Nightmares

NREM Dreaming

“just thinking”
Shorter, less active
Logical, realistic
Sleep Disorders

- insomnia
- sleep walking, talking, and eating
- nightmares and night terrors
- narcolepsy
- sleep apnea