ELECTROENCEPHALOGRAPHY
EEG

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The recording machine, the **electroencephalograph** produces a 16-channel ink-written record of brain waves, called the **encephalogram .**

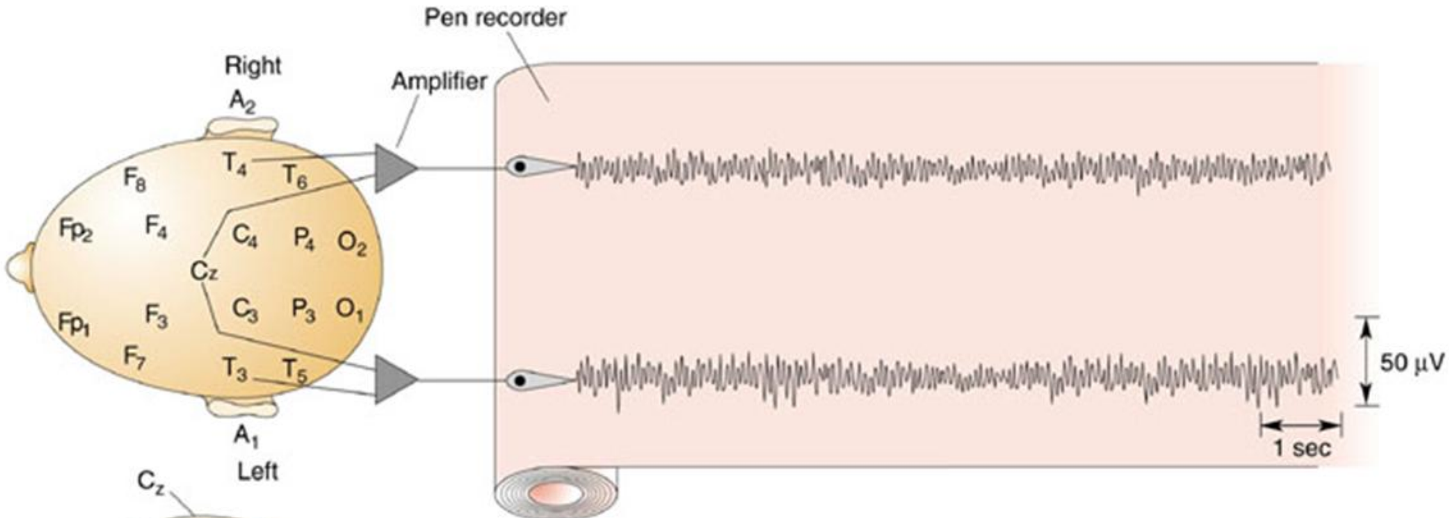
used to:

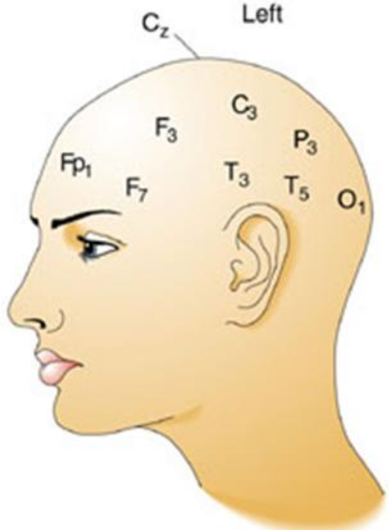
(1) monitor alertness, coma and brain death;
(2) locate areas of damage following head injury, stroke, tumour, etc.;
(3) test afferent pathways (by evoked potentials);
(4) monitor cognitive engagement (alpha rhythm);
(5) produce biofeedback situations, alpha, etc.;
(6) control anaesthesia depth (“servo 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.

- **The electroencephalogram (EEG)** is a recording of the electrical activity of the brain from the scalp (it may be recorded from electrodes placed directly on or in the brain itself) The recorded waveforms reflect the cortical electrical activity.

- The EEG is considered to be a macroscopic phenomenon, i.e. it results from activity of large populations of neurons.

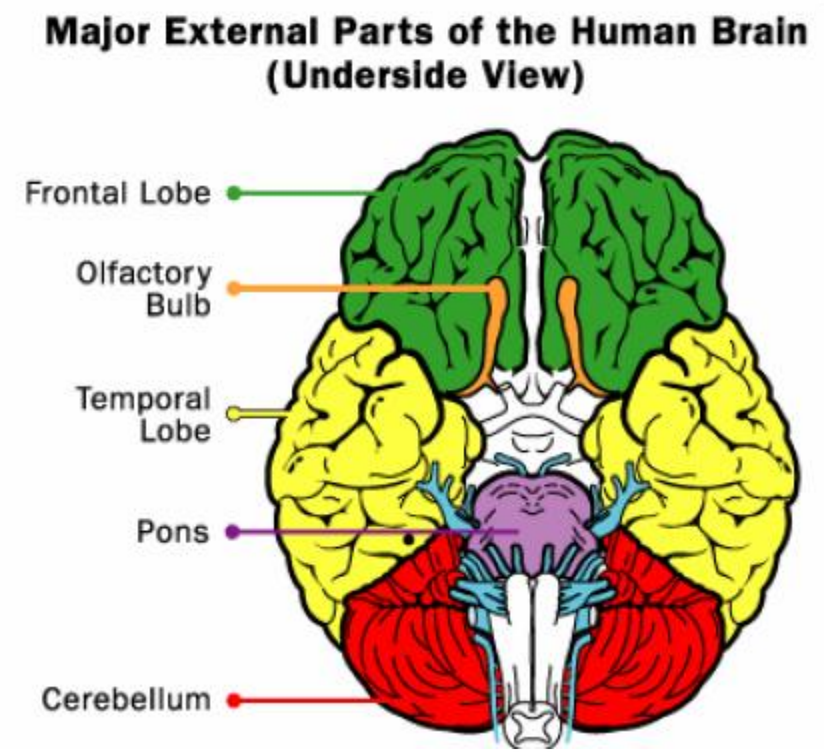
Dr. Hans Berger, an Austrian psychiatrist was the **first to record electroencephalographs from humans**. **Berger found the regular waves at about 10 cycles per second** that he named the **Alpha waves** because they were the first waveforms he isolated in the human EEG. **Berger published a paper in 1929** based on the research he had done five years earlier with his son Klaus as a subject. He made 73 recordings, which became the **first published EEGs of humans**.

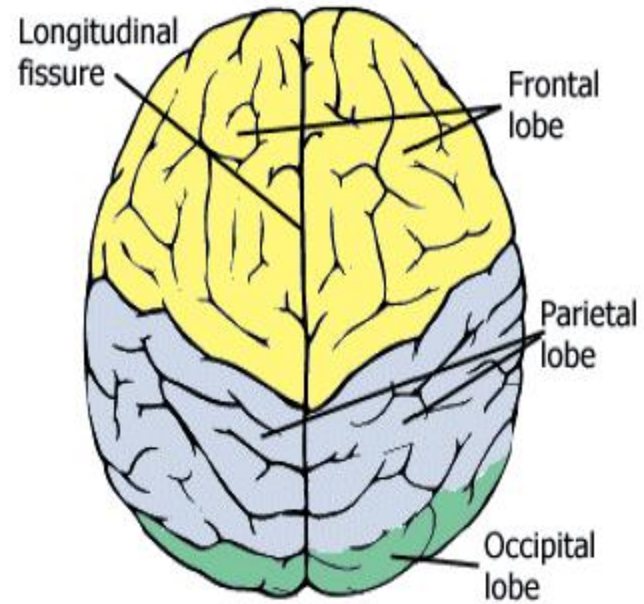




20 equally spaced electrodes are pasted to the surface of the scalp (standard positions adopted by the International Federation of EEG) , and is called the 10/20 system.

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





1- Frontal lobe: contains motor area.

2- Parietal lobe: contains sensory area.

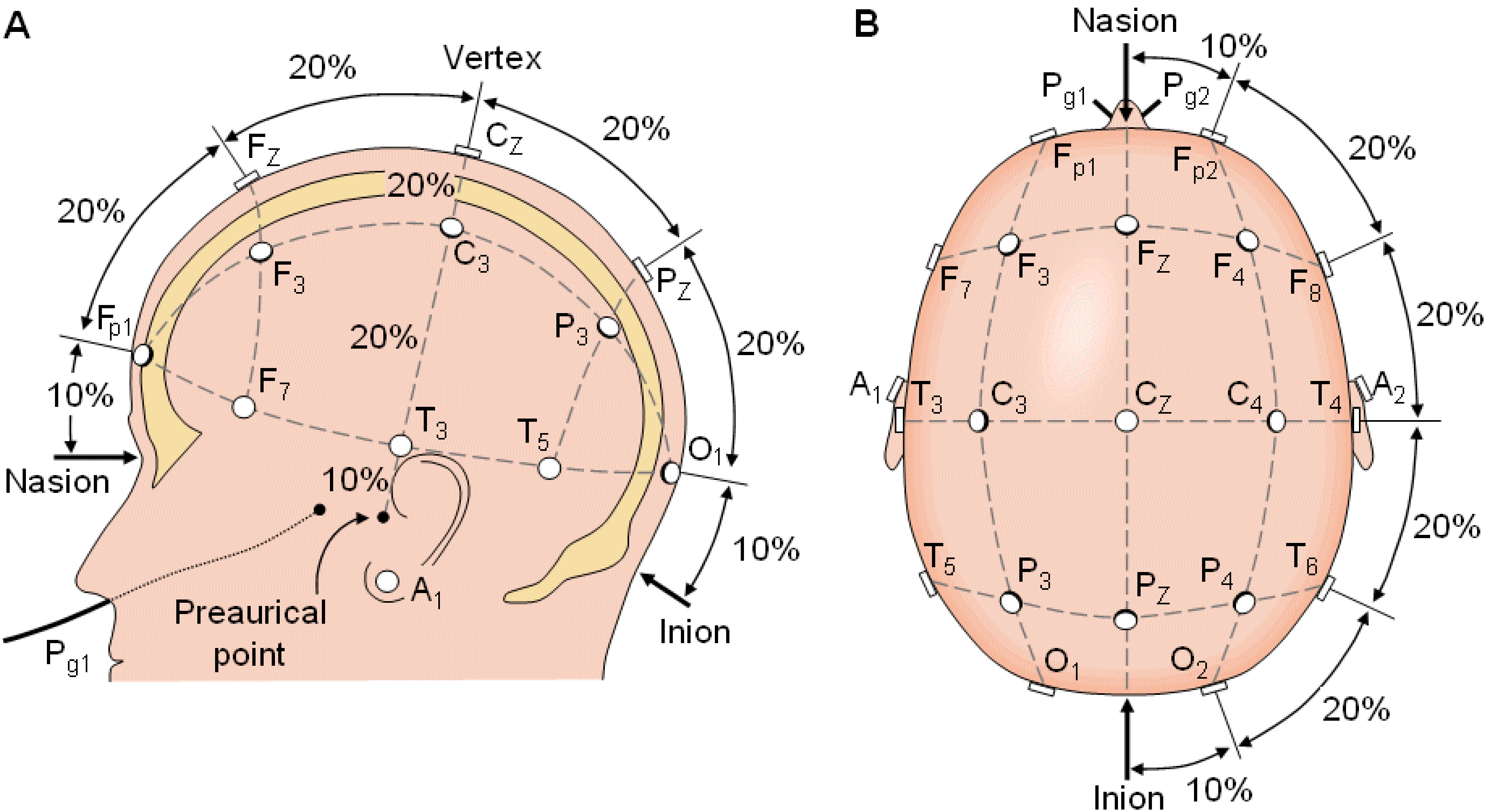
3- Temporal lobe: contains area of hearing & memory.

4- Occipital lobe: contains area of vision.

EEG system covers all parts of brain by placing electrode on all part of head.

- **There are two system of electrode placement:**
- **10-20 international system: includes 21 electrodes.**
- **10-10 international system: includes 64 electrodes.**

Electrodes are placed according to their percentage distance to several defined landmarks such as naison, inion, and left and right prearicular points.



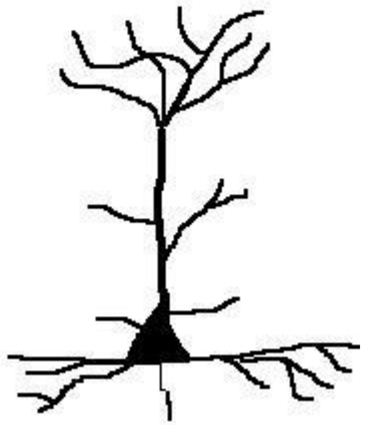
A
Vertex
20%
20%
20%
20%
20%
10%
Nasion
Fz
Cz
Fp1
F3
C3
F7
T3
T5
P3
Pz
O1
10%
10%
Preauricular
point
A1
Pg1
Inion
B
Nasion
10%
Pg1
Pg2
20%
Fp1
Fp2
F3
Fz
F4
F7
F8
20%
A1
T3
C3
Cz
C4
T4
A2
20%
T5
P3
Pz
P4
T6
O1
O2
20%
Inion
10%

The Basis of EEG

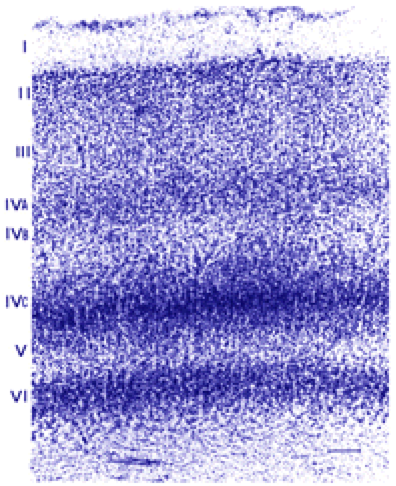
For brain electrical activity to be detectable through skull,
The signal must be strong enough

Synchronized neuronal activity from hundreds of thousands or millions of neurons acting together form the electrical patterns on the surface of the brain (brain waves).
Neurons responsible of EEG signals are the pyramidal cells.

Pyramidal neurons are characterized by their distinct apical and basal dendritic trees and the pyramidal shape of their soma.
The existence of dendritic domains with distinct synaptic inputs, excitability, modulation and plasticity appears to be a common feature.

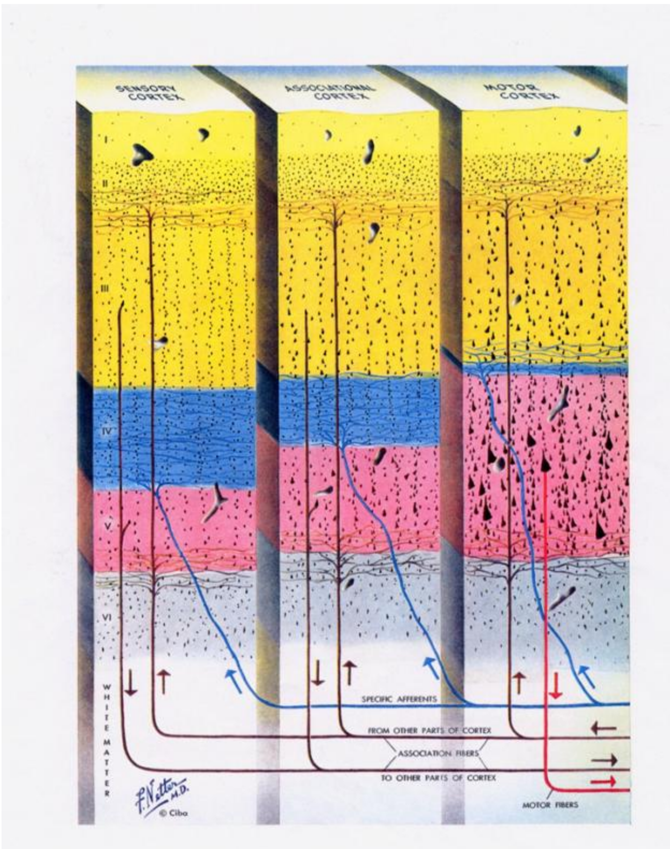


The cerebral cortex is approximately 3-6 mm thick and neuroanatomists have observed that the cortical neurons appear to be organized in columns. Cortical columns oriented perpendicular to the cortical surface, with length spanning the 3-6 mm depth



Dendrites of pyramidal cells branch profusely in layer I
Output connections are excitatory
Those of layers V and VI project to the thalamus and other subcortical structures

Pyramidal Cell Orientation in Cortex



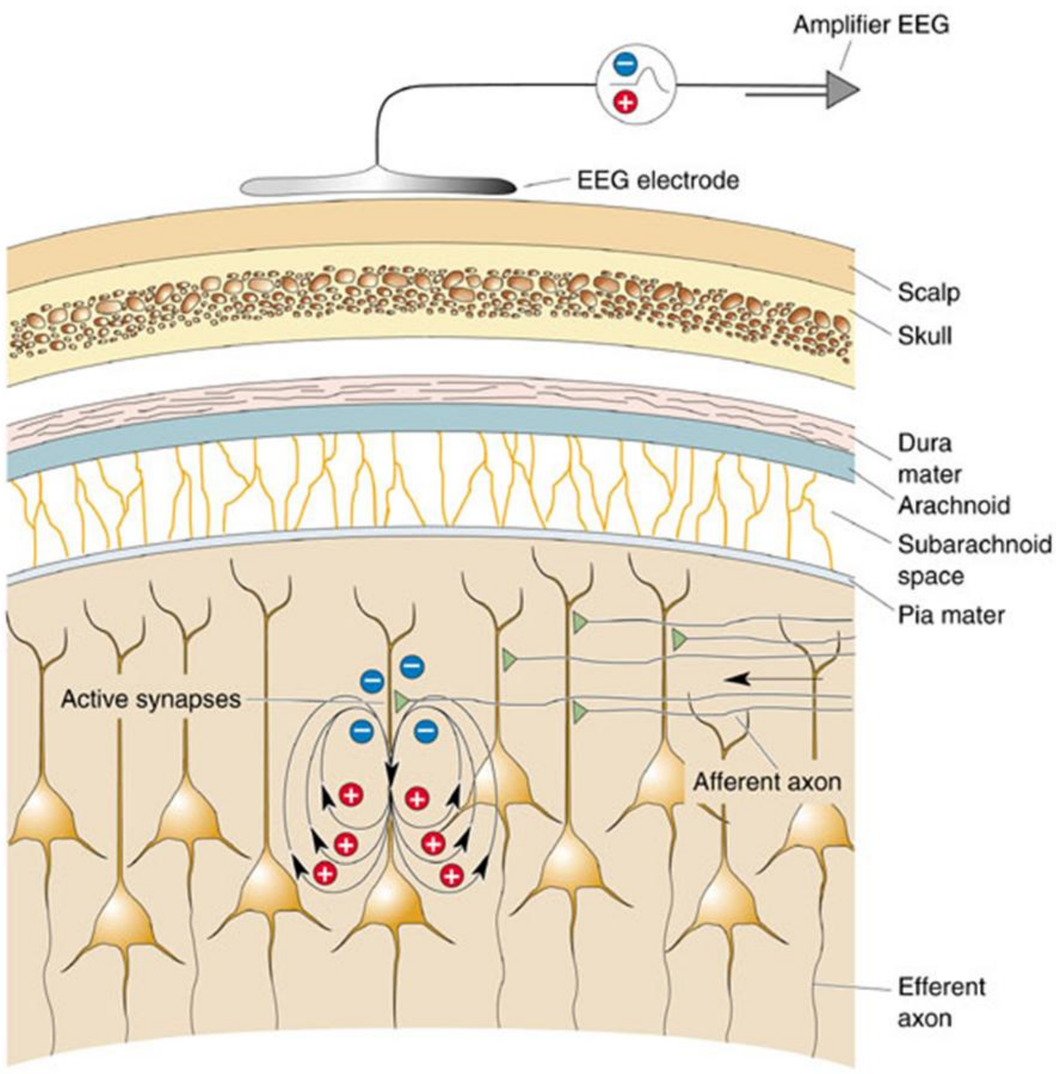
-Pyramidal cells extend through all layers of cortex , are vertically oriented and paralell to each other

- One afferent axon may contact thousands of cortical neurons, so the potential they create sums up (= spatial summation)

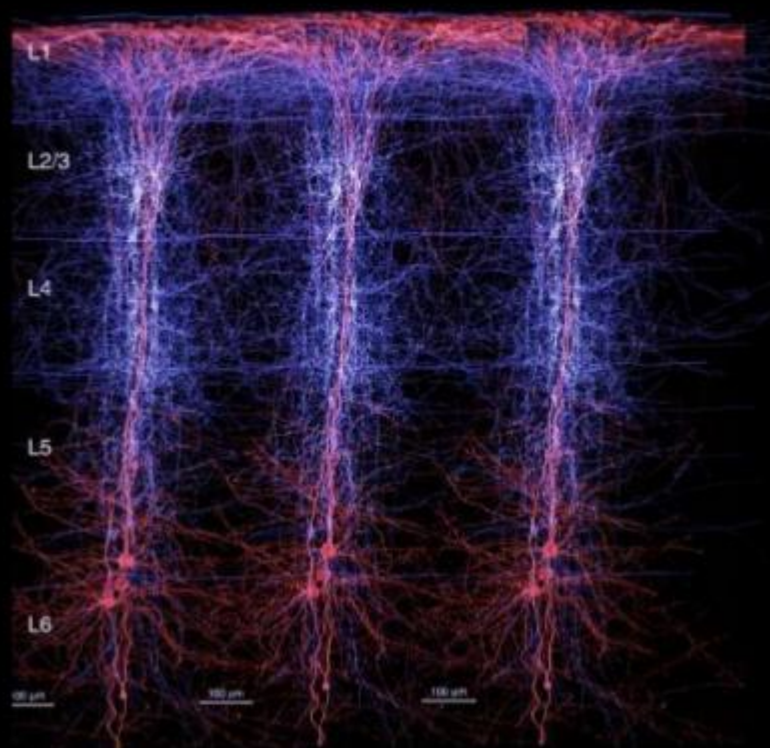
-A single pyramidal cell receives about 30,000 excitatory inputs and 1700 inhibitory inputs.

-The current generated by these neurons sum up in the extracellular space and form the EEG signals.

The electrical signals in EEG arise mainly from cortical nerve cells. Thousands of pyramidal cells with inhibitory or excitatory postsynaptic potential act in synchrony and form the EEG signal.



Parallel configuration



Pyramidal neurons are spatially aligned perpendicular to the cortical surface.

Creates a dipole layer or dipole sheet in the cortex.

Thus, EEG represents mainly the postsynaptic potentials of pyramidal neurons close to the recording electrode.

The amplitude of the EEG signal depends on how synchronous the activity of neurons are.

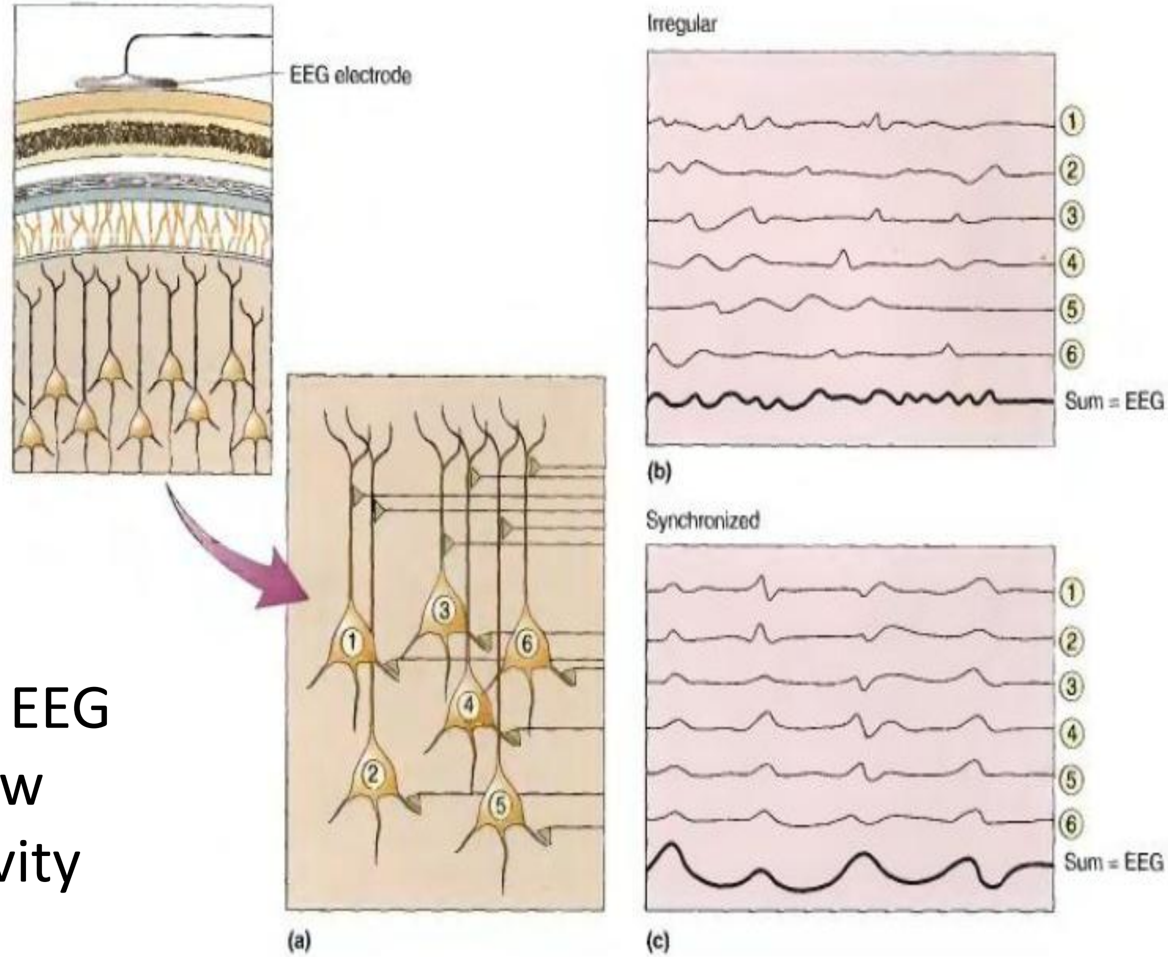


FIGURE 19.4

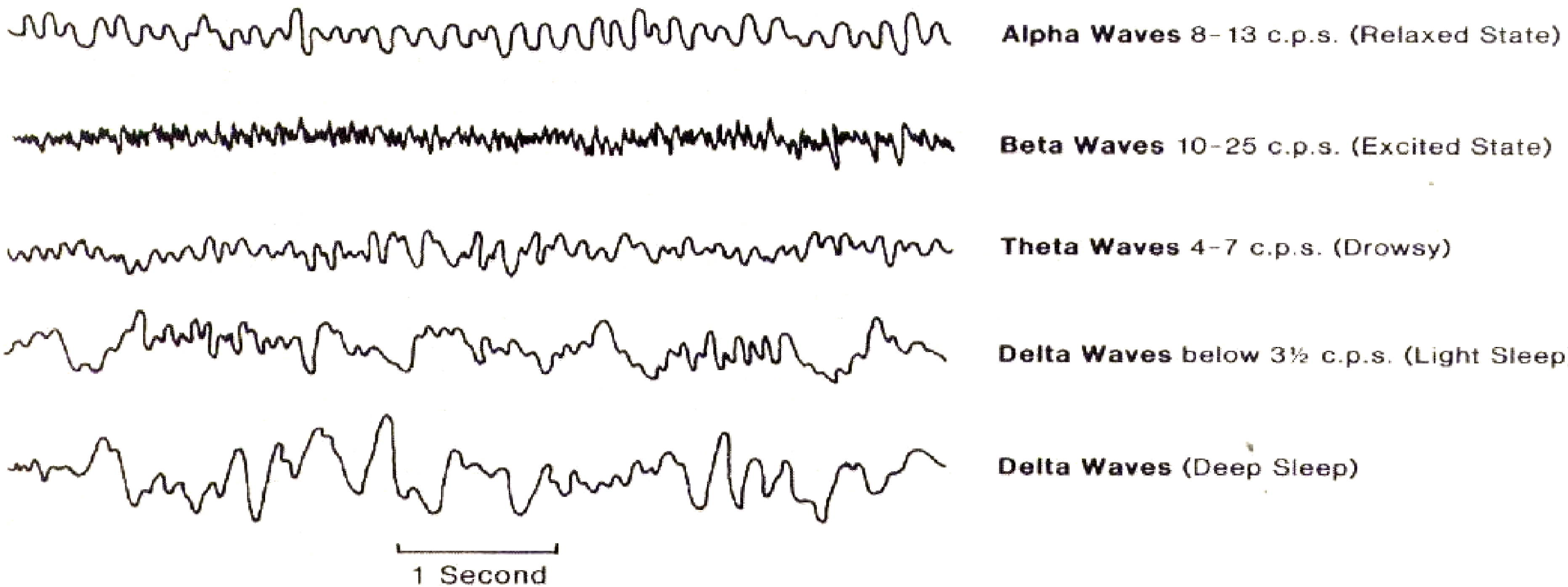
The generation of large EEG signals by synchronous activity. (a) In a population of pyramidal cells located under an EEG electrode, each neuron receives many synaptic inputs. **(b)** If the inputs fire at irregular intervals, the pyramidal cell responses are not synchronized, and the summed activity detected by the electrode has a small amplitude. **(c)** If the same number of inputs fire within a narrow time window so the pyramidal cell responses are synchronized, the resulting EEG is much larger.

Rhythms occur in distinct frequency ranges:

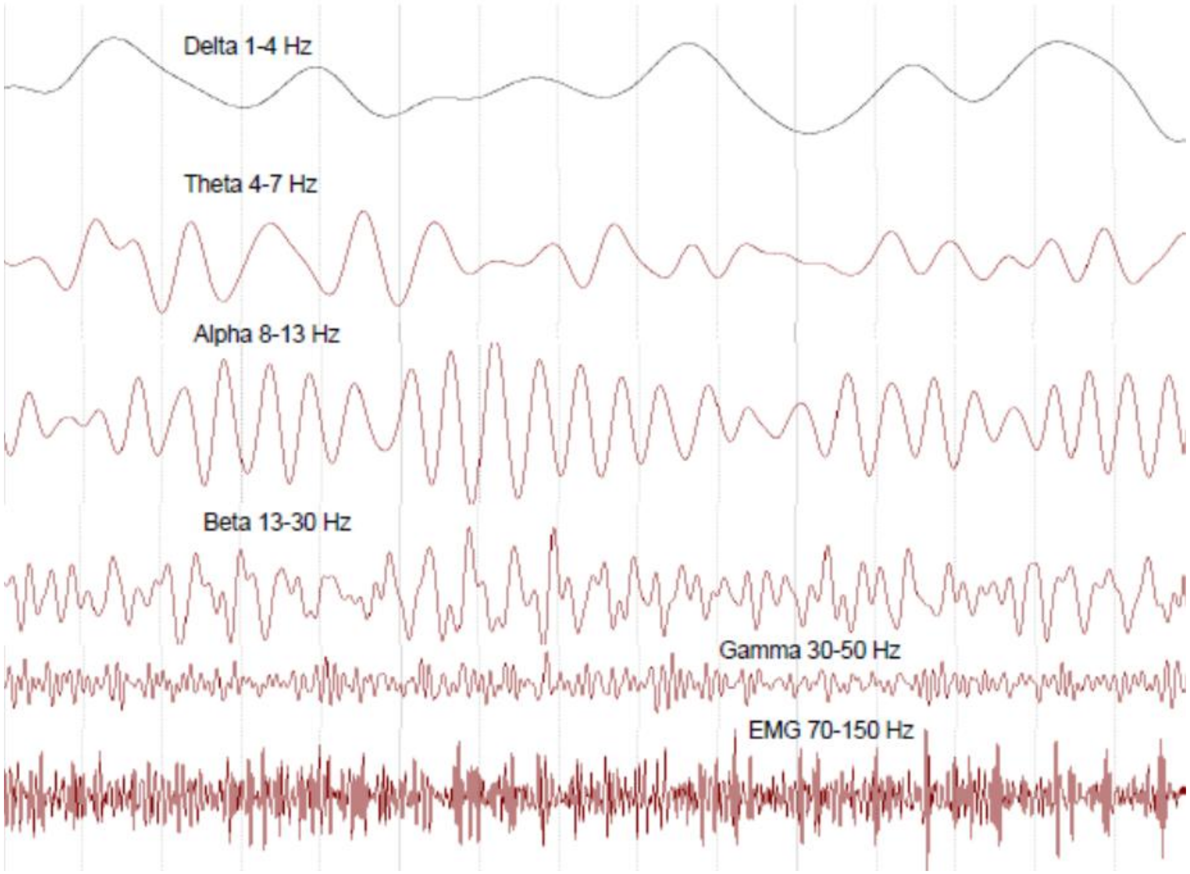
Gamma:	20-60 Hz ("cognitive" frequency band)
Beta:	14-20 Hz (activated cortex)
Alpha:	8-13 Hz (quiet waking)
Theta:	4-7 Hz (sleep stages)
Delta:	less than 4 Hz (sleep stages, especially "deep sleep")

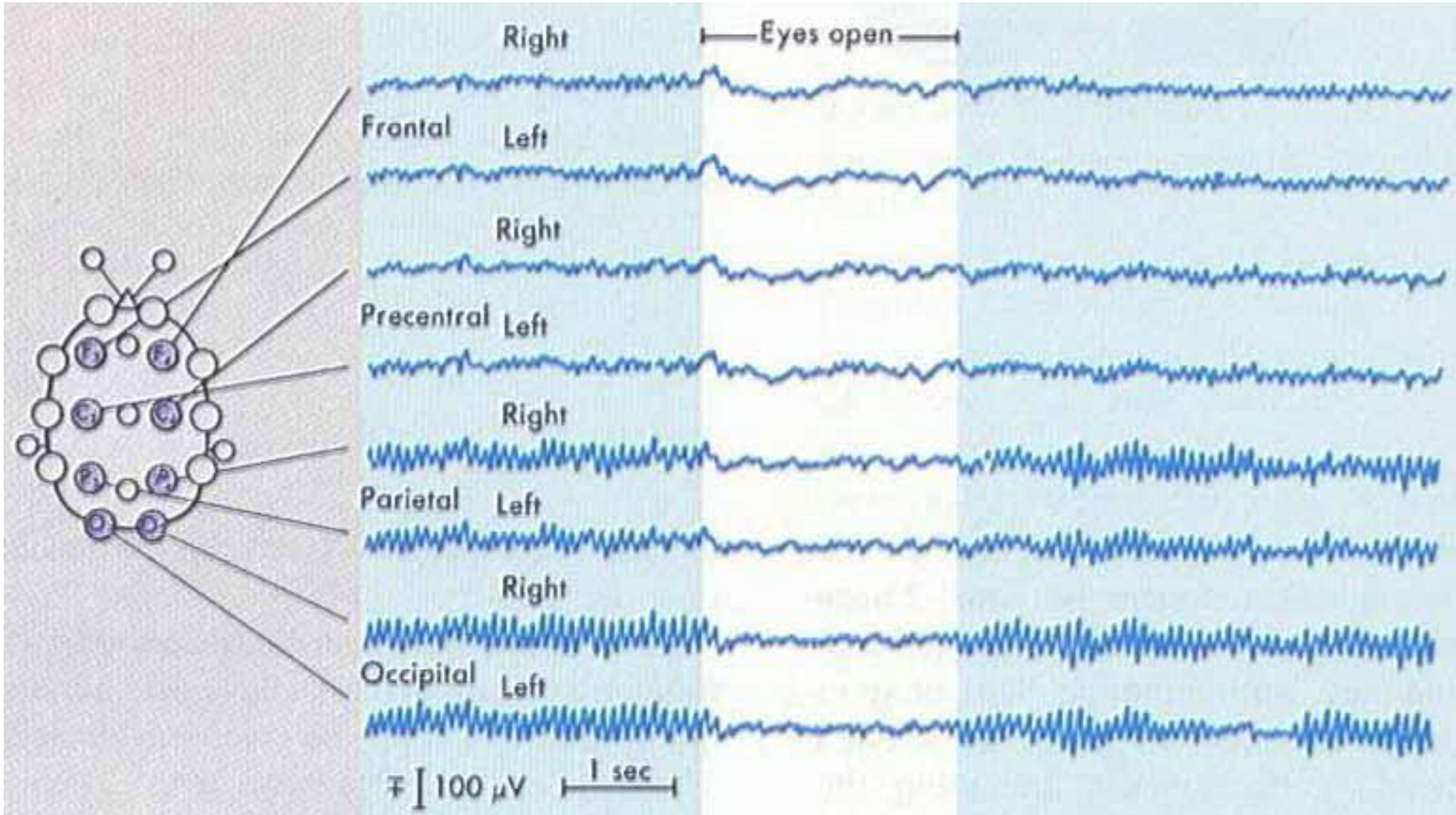
Higher frequencies: active processing, relatively de-synchronized activity (alert wakefulness, dream sleep).

Lower frequencies: strongly synchronized activity (nondreaming sleep, coma).



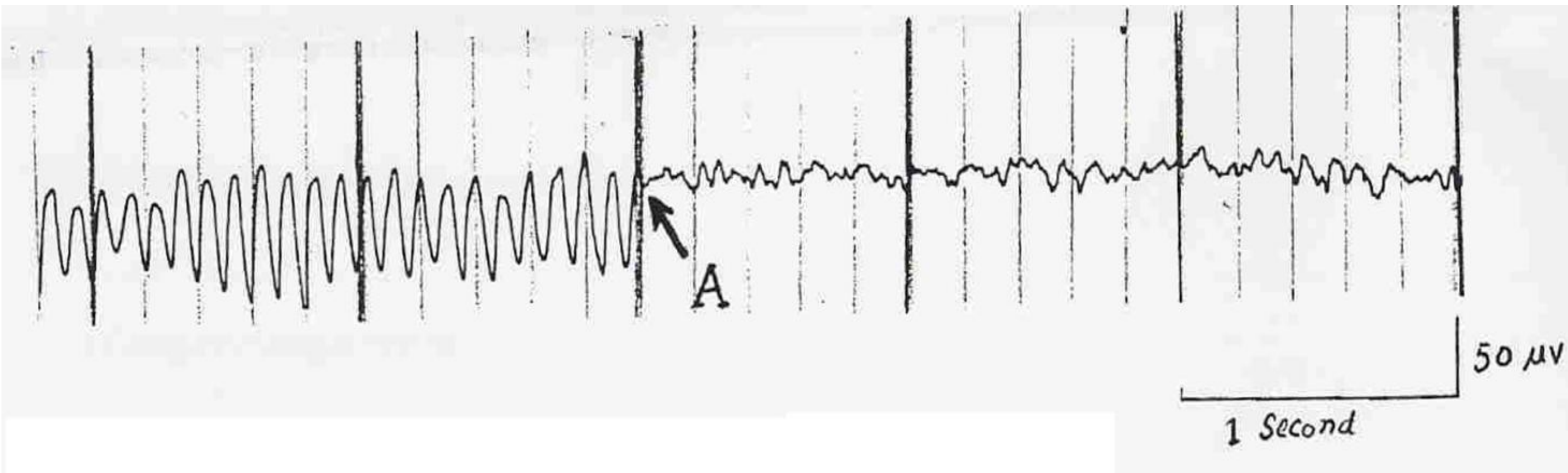
Alpha Waves 8-13 c.p.s. (Relaxed State)
Beta Waves 10-25 c.p.s. (Excited State)
Theta Waves 4-7 c.p.s. (Drowsy)
Delta Waves below 3½ c.p.s. (Light Sleep)
Delta Waves (Deep Sleep)
1 Second


Delta 1-4 Hz
Theta 4-7 Hz
Alpha 8-13 Hz
Beta 13-30 Hz
Gamma 30-50 Hz
EMG 70-150 Hz



Here you can see **"alpha block"** or desynchronization of alpha waves

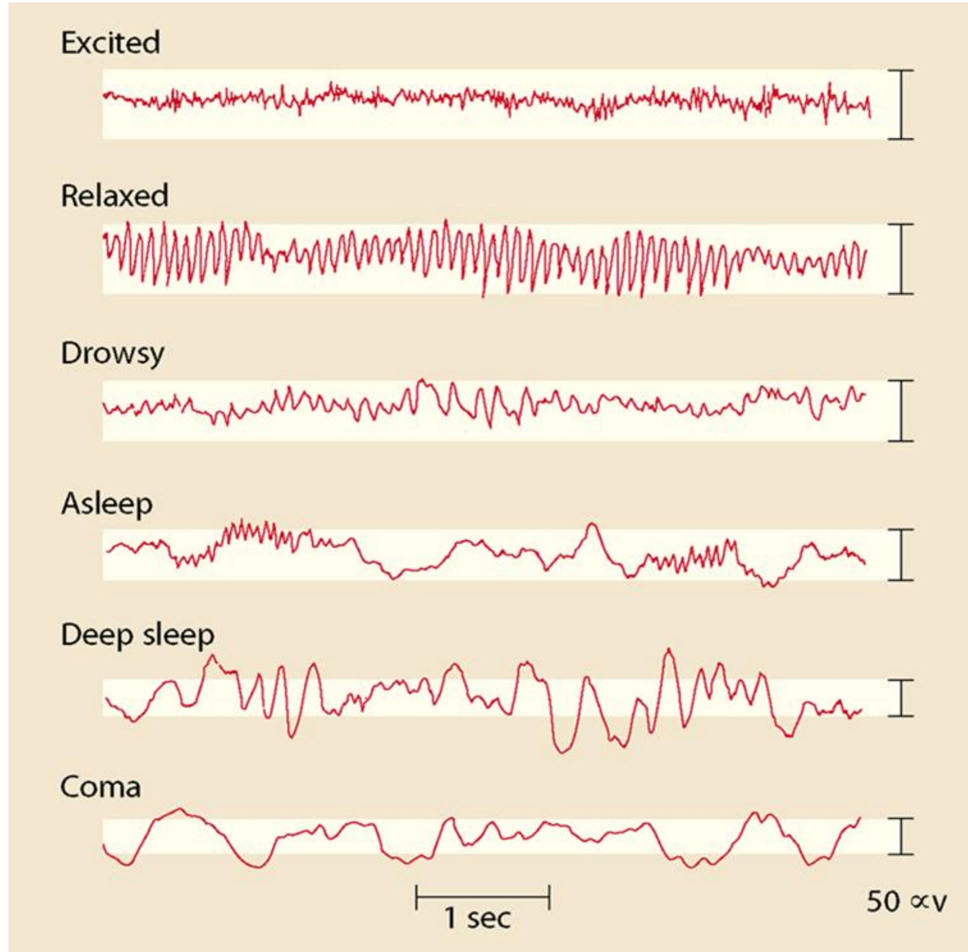
Desynchronization or Alpha block



Cause:

Eyes opening (after closure)
Thinking by the subject (mathematical calculation)
Sound (clapping)

Characteristic EEG rhythms during several states of consciousness.
During deep sleep, you see delta waves.
When someone's drowsy, you see theta waves.
Alpha is characteristic of a relaxed but alert state with eyes closed.
Beta is characteristic of a more excited, or actively attentive state.



ALPHA WAVES

Alpha is usually best detected in the frontal regions of the head, on each side of the brain.

Alpha has been linked to extroversion, creativity (creative subjects show alpha when listening and coming to a solution for creative problems), and mental work.

When your alpha is within normal ranges we tend to also experience good moods, see the world truthfully, and have a sense of calmness.

Alpha is one of the brain's most important frequency to learn and use information taught in the classroom and on the job.

THETA WAVES

Theta can indicate drowsiness, daydreaming, the first stage of sleep or 'indirect' imagination/thinking.

Theta activity is not often seen in awake adults (unless engaged in a meditative practice), but is perfectly normal in alert children up to 13 years and in most sleep.

Theta is believed to reflect activity from the limbic system and hippocampal regions.

Theta is observed in anxiety, behavioral activation and behavioral inhibition. When the theta rhythm appears to function normally it mediates and/or promotes adaptive, complex behaviors such as learning and memory.

DELTA WAVES reveals deep sleep or slow-wave 'background' thinking.

The highest in amplitude and the slowest waves. Certain frequencies, in the delta range, have been shown to trigger the body's healing and growth mechanisms.

We increase Delta waves in order to decrease our awareness of the physical world.

We also access information in our unconscious mind through Delta.

Peak performers decrease Delta waves when high focus and peak performance are required. The inappropriate Delta response often severely restricts the ability to focus and maintain attention.

It is as if the brain is locked into a perpetual drowsy state.

BETA WAVES are characteristic of an engaged mind, which is highly alert and well focused.

Beta activity dominates the normal waking state of consciousness when attention is directed towards the outside world.

Typically detected in the **frontal lobes** on both sides of the brain.

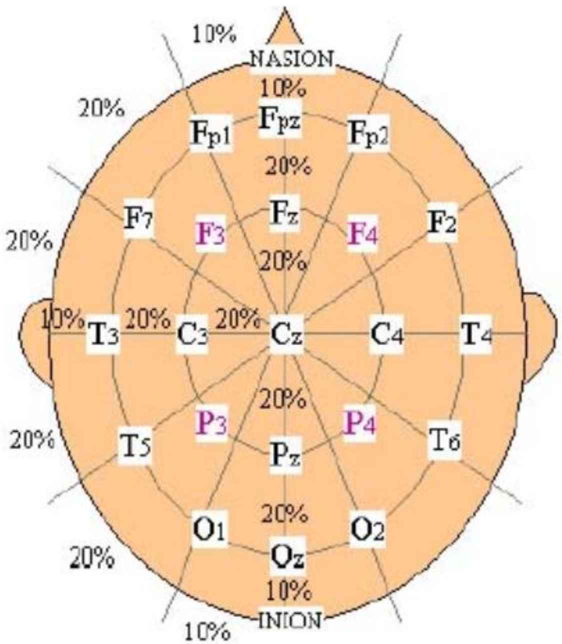
It may be absent or reduced in areas of brain damage.

Tends to be the dominant rhythm in those who are alert, anxious or have their eyes open.e.g. converstaion that needs full attention, public speaking, teaching!!, complex problem solving

Band	Frequency (Hz)	Location	Normally	Pathologically
Delta	up to 4	frontally in adults, posteriorly in children; high-amplitude waves	• adult slow wave sleep • in babies • Has been found during some continuous-attention tasks	• subcortical lesions • diffuse lesions • metabolic encephalopathy hydrocephalus • deep midline lesions
Theta	4 – 7	Found in locations not related to task at hand	• young children • drowsiness or arousal in older children and adults • idling • Associated with inhibition of elicited responses (has been found to spike in situations where a person is actively trying to repress a response or action).[39]	• focal subcortical lesions • metabolic encephalopathy • deep midline disorders • some instances of hydrocephalus
Alpha	7 - 14	posterior regions of head, both sides, higher in amplitude on non-dominant side. Central sites (c3-c4) at rest	• relaxed/reflecting • closing the eyes • Also associated with inhibition control, seemingly with the purpose of timing inhibitory activity in different locations across the brain.	• coma
Beta	15 - 30	both sides, symmetrical distribution, most evident frontally; low-amplitude waves	• alert, eyes open • active, busy, or anxious thinking, active concentration	• benzodiazepins
Gamma	30 – 100+	Somatosensory cortex	• Displays during cross-modal sensory processing (perception that combines two different senses, such as sound and sight) • Also is shown during short-term memory matching of recognized objects, sounds, or tactile sensations	• A decrease in gamma-band activity may be associated with cognitive decline, especially when related to the theta band; however not proven for use as a clinical diagnostic measurement

EEG Recording

EEG is recorded using electrodes (diameter 0.4 to 1.0 cm) held in place on the scalp with special pastes, caps or nets. In clinical applications 19 recording electrodes are placed uniformly over the scalp (the **International 10-20 System**). In addition, one or two reference electrodes (often placed on ear lobes) and a ground electrode (often placed on the nose) to provide amplifiers with reference voltages are required.



The head is divided into proportional distances from prominent skull landmarks (nasion, preauricular points, inion) to provide adequate coverage of all regions of the brain.

Label 10-20 designates proportional distance in percents between ears and nose where points for electrodes are chosen.

Electrode placements are labelled according adjacent brain areas: F (frontal), C (central), T (temporal), P (posterior), and O (occipital).

The letters are accompanied by odd numbers at the left side of the head and with even numbers on the right side

In **referential recordings**, potentials between each recording electrode and a fixed reference are measured over time. The reference should not pick up signals which are not intended to be recorded, like heart activity. Reference electrodes are placed at some distance from recording electrode (the ear-lobes, the nose, or the mastoids (i.e. the bone behind the ears).
With multi-channel recordings (e.g. >32 channels), it is common to compute the "average reference", i.e. to subtract the average over all electrodes from each electrodes for each time point.

Bipolar recordings measure potential differences between adjacent scalp electrodes.

Electrode placements and the different ways of combining electrode pairs to measure potential differences on the head constitute the **electrode montage**.

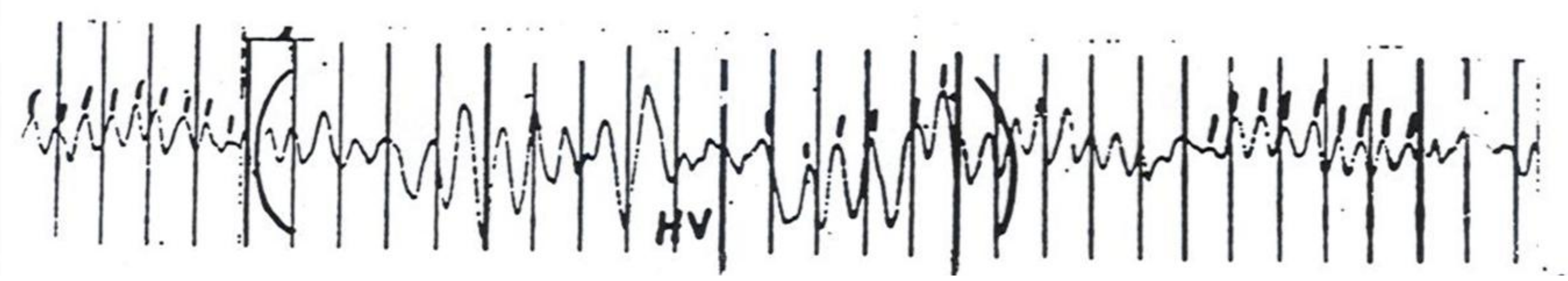
Provocation test

Intermittent photic stimulation

Increase rate & decrease amplitude

Hyperventilation

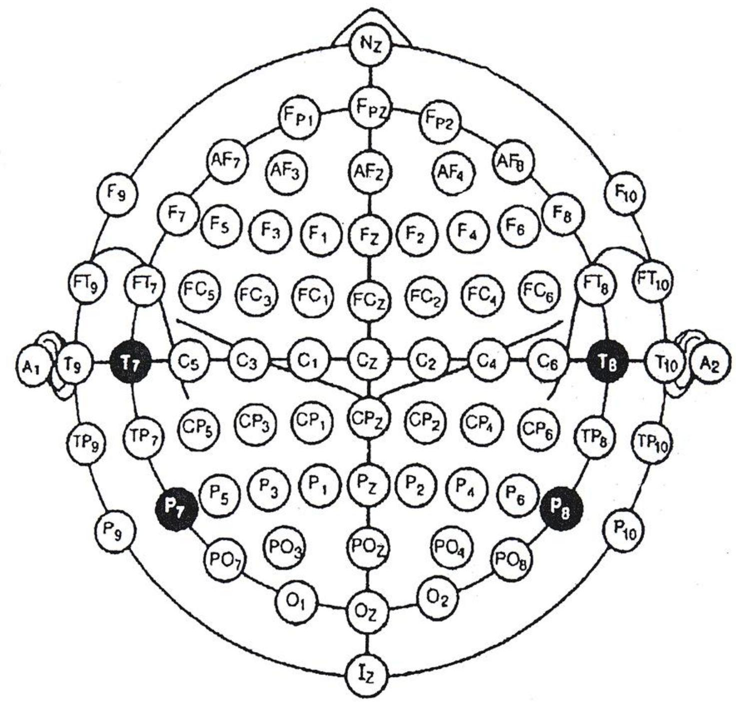
Decrease rate & increase in amplitude

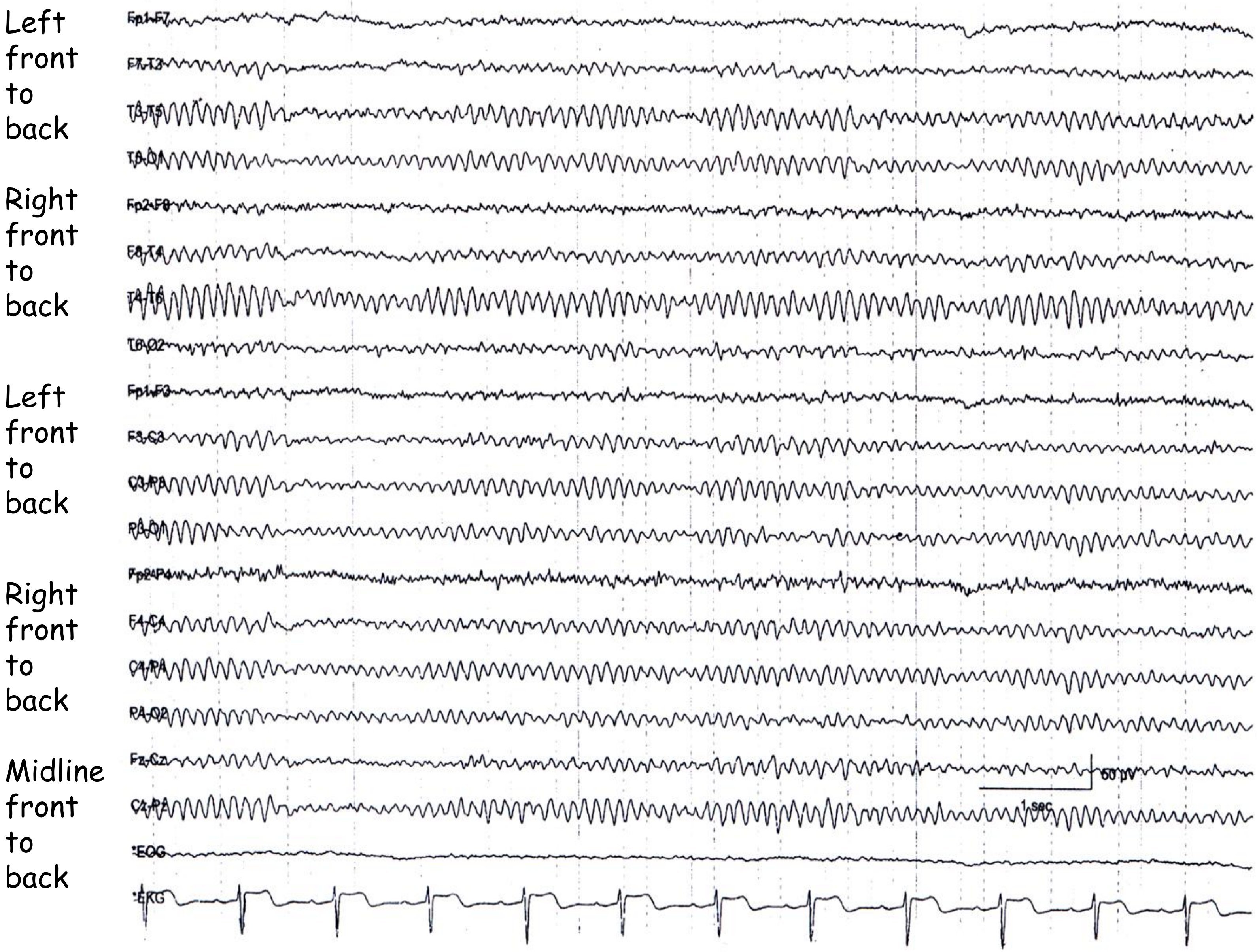


Often 64 to 131 recording electrodes or more are used in research.

When large numbers of electrode are employed, potential at each location may be measured with respect to the average of all potentials (the ***common average reference***),

"10 - 10" Electrode Location Naming Convention
(Sharbrough et al, 1991)





A-1 Normal adult. This is a 55-year-old man who is awake with eyes closed. There is a well-developed alpha rhythm at 10 Hz, prominent in the posterior head regions. The sinusoidal waves constitute the major and nearly only finding in this record. Little if any beta activity is present.

Factor 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