INSTR/EEE F432: Nervous System and EEG

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Introduction

- The task of controlling the various functions of the body and coordinating them into an integrated living organism is not simple.

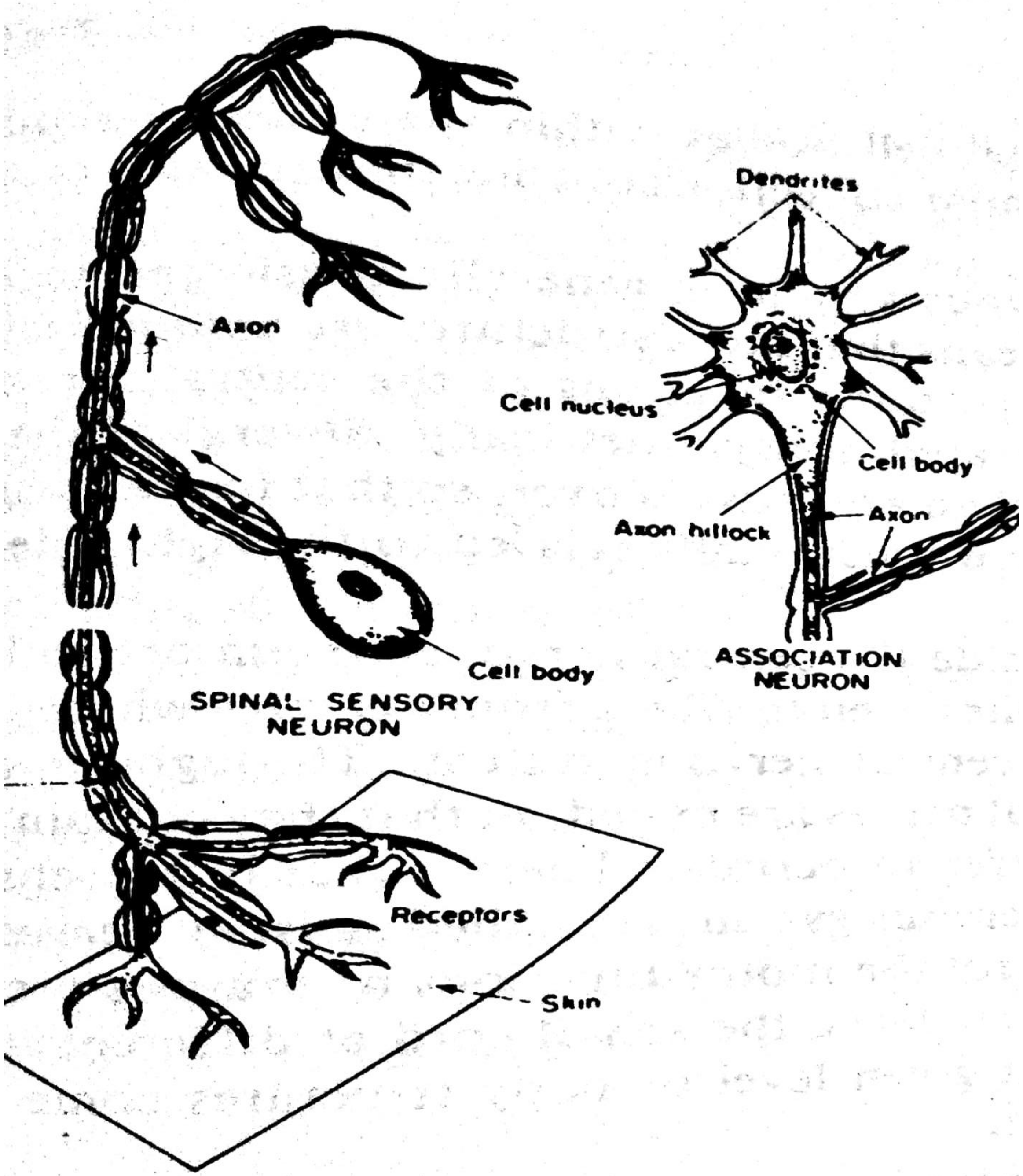
- Consequently, the nervous system, which is responsible for this task, is the most complex of all systems in the body and also one of the most interesting.

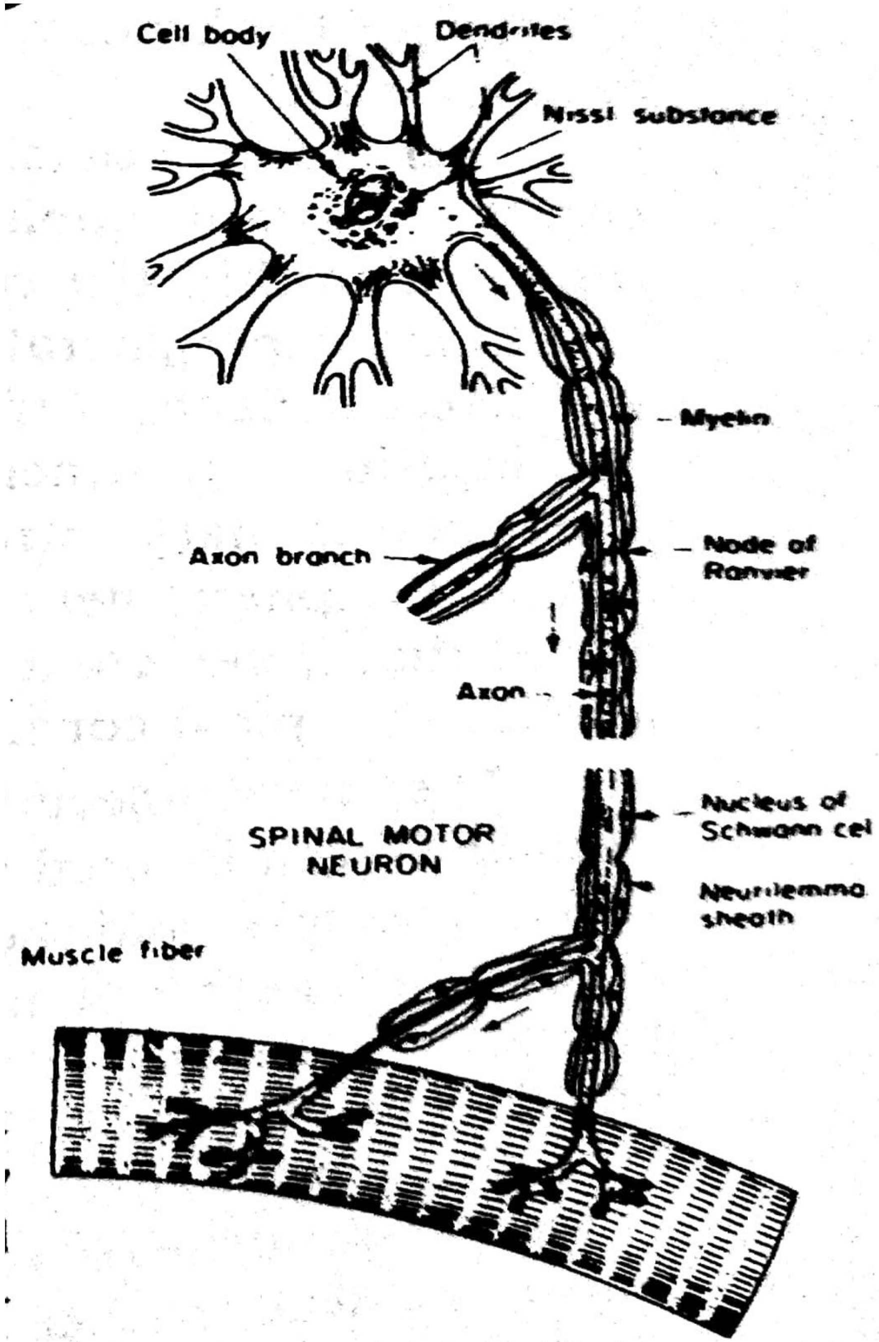
- Composed of the brain, numerous sensing devices, and a high-speed communication network that links all parts of the body.

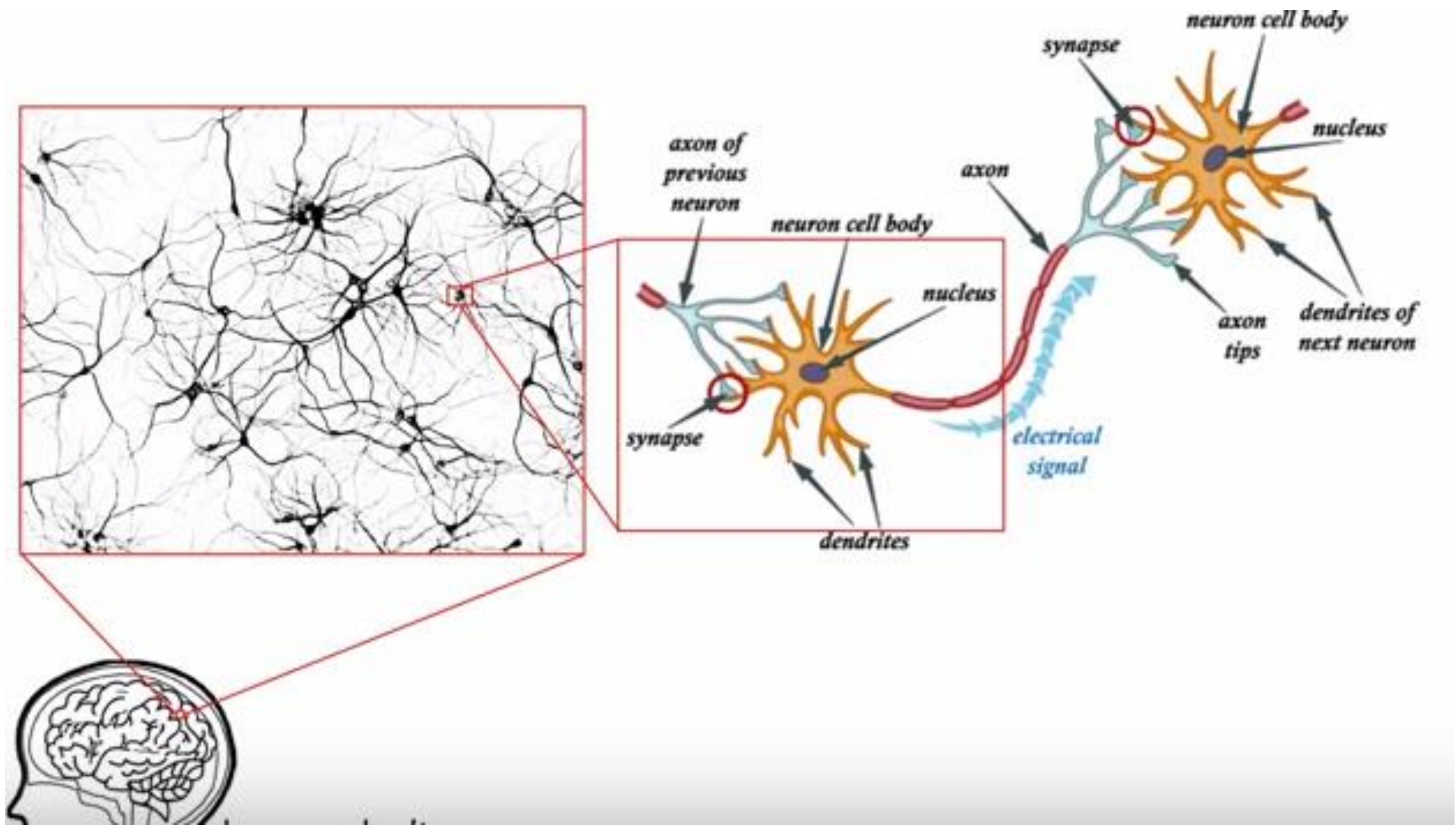
- The nervous system not only influences all the other systems but is also responsible for the behavior of the organism.

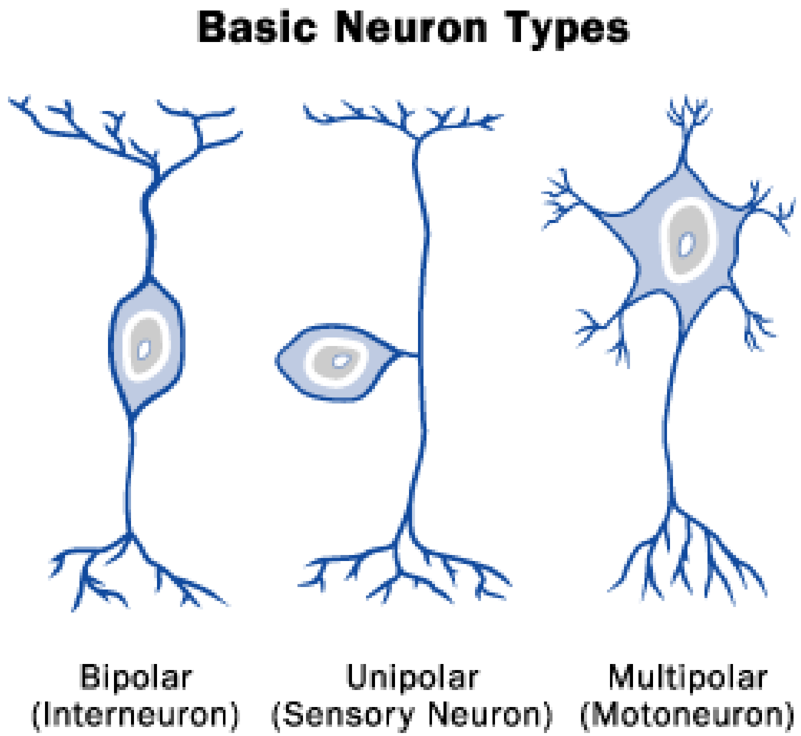
Neuron

- The basic unit of the nervous system is the neuron.
- A neuron is a single cell with a cell body, sometimes called the soma, one or more input fibers called dendrites, and a long transmitting fiber called the axon.
- The portion of the axon immediately adjacent to the cell body is called the axon hillock. This is the point at which action potentials are usually generated.
- Branches that leave the main axon are often called collaterals.
- Certain types of neurons have axons or dendrites coated with a fatty insulating substance called myelin. The coating is called a myelin sheath and the fiber is said to be myelinated.


Axon
Dendrites
Cell nucleus
Cell body
Axon hillock
Axon
ASSOCIATION NEURON
Cell body
SPINAL SENSORY NEURON
Receptors
Skin


Cell body
Dendrites
Nissl substance
Myelin
Axon branch
Node of Ranvier
Axon
Nucleus of Schwann cel
SPINAL MOTOR NEURON
Neurilemma sheath
Muscle fiber


axon of
previous
neuron
neuron cell body
nucleus
synapse
dendrites
axon
electrical
signal
synapse
neuron cell body
nucleus
axon
tips
dendrites of
next neuron


Basic Neuron Types
Bipolar
(Interneuron)
Unipolar
(Sensory Neuron)
Multipolar
(Motoneuron)

Neuron

- In some cases, the myelin sheath is interrupted at rather regular intervals by the nodes of Ranvier, which help speed the transmission of information along the nerves.

- Outside of the central nervous system, the myelin sheath is surrounded by another insulating layer, called the neurilemma.

- This layer, thinner than the myelin sheath and continuous over the nodes of Ranvier, is made up of thin cells, called Schwann cells

- some neurons have long dendrites, whereas others have short ones. Axons of various lengths can also be found throughout the nervous system.

- In appearance, it is difficult to tell a dendrite from an axon. The main difference is in the function of the fiber and the direction in which it carries information with respect to the cell body.

Nervous system

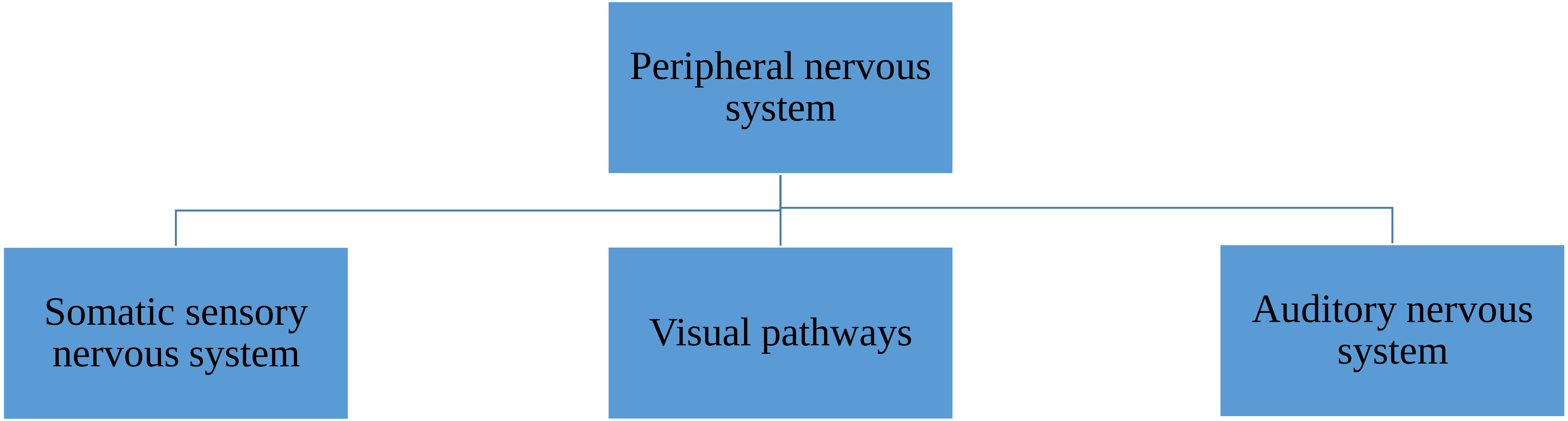
- Nervous system
  - Central nervous system (CNS)
  - Peripheral nervous system (PNS)

- The CNS is composed of Brain and Spinal chord where as the PNS is composed of spinal nerves that branch out from the spinal chord and the cranial nerves that branch out from the brain.

- In addition to the large number of neurons of many varieties, the CNS also contain a number of large fatty cell bodies called glial cells.

Peripheral nervous system

- Nerve fibers outside the central nervous system are called peripheral nerves.
- Afferent peripheral nerves that bring sensory information into the central nervous system are called sensory nerves.
- Efferent peripheral nerves that control the motor functions of muscles are called motor nerves.



Contd..

- Autonomic nervous system
  - Sympathetic nervous system
  - Parasympathetic nervous system

➢ Autonomic nervous system involves with emotional responses and controls smooth muscles in various parts of the body, heart muscle and in the secretion of a number of glands.

➢ Sympathetic nervous system tends to mobilize the body for emergencies whereas Parasympathetic nervous system tends to conserve and store bodily resources.

Brain

innovate achieve lead

- Most complex organ of the body, as it contains memory, computational power, decision making capability etc.

- 1300 – 1400 grams or approx. 3 pounds.

- The brain receives information through five senses: sight, smell, touch, taste and hearing often many at one time.

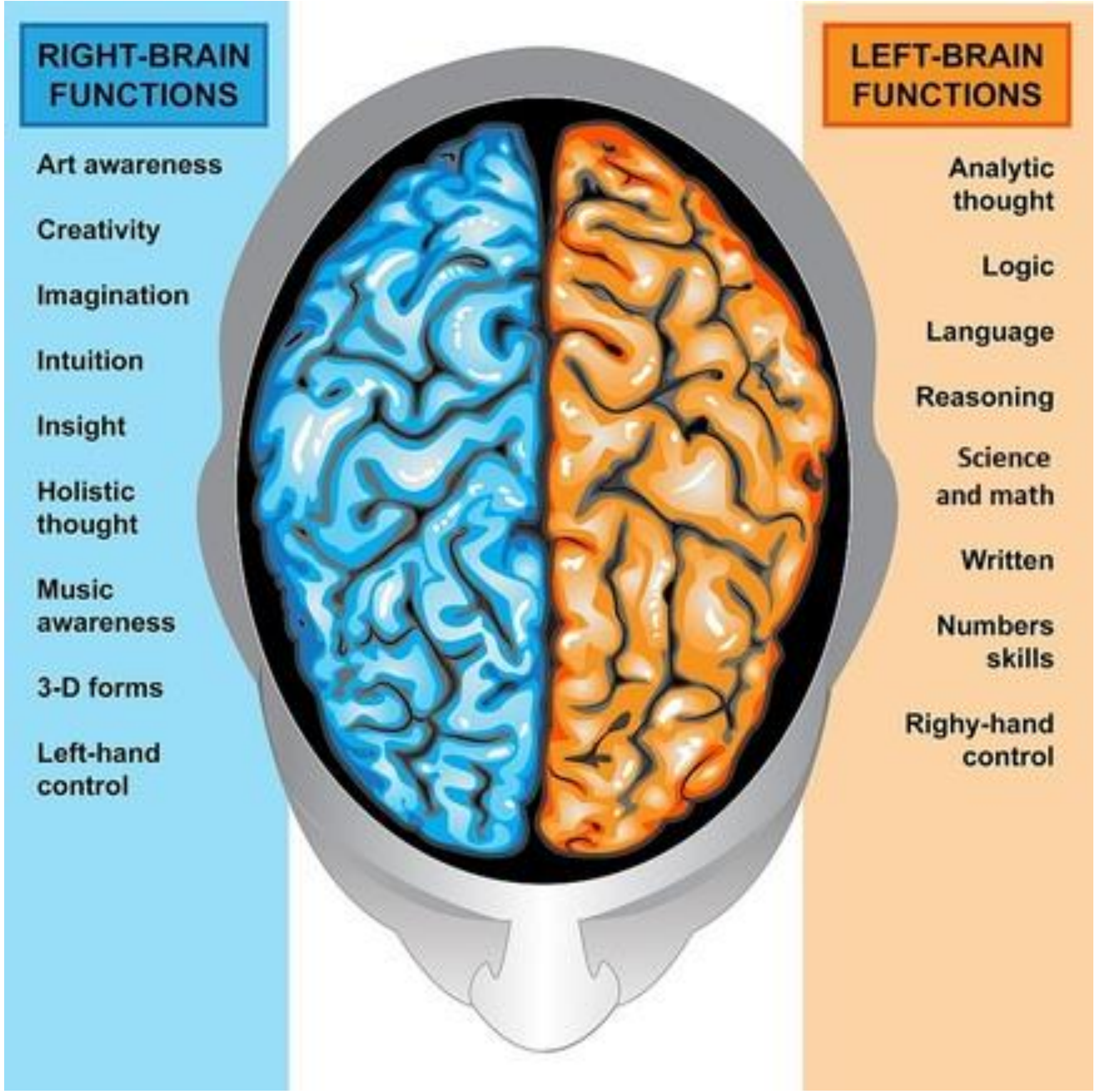
- It controls our thoughts, memory, speech, movement of arms and legs and functions of many organs of the body.

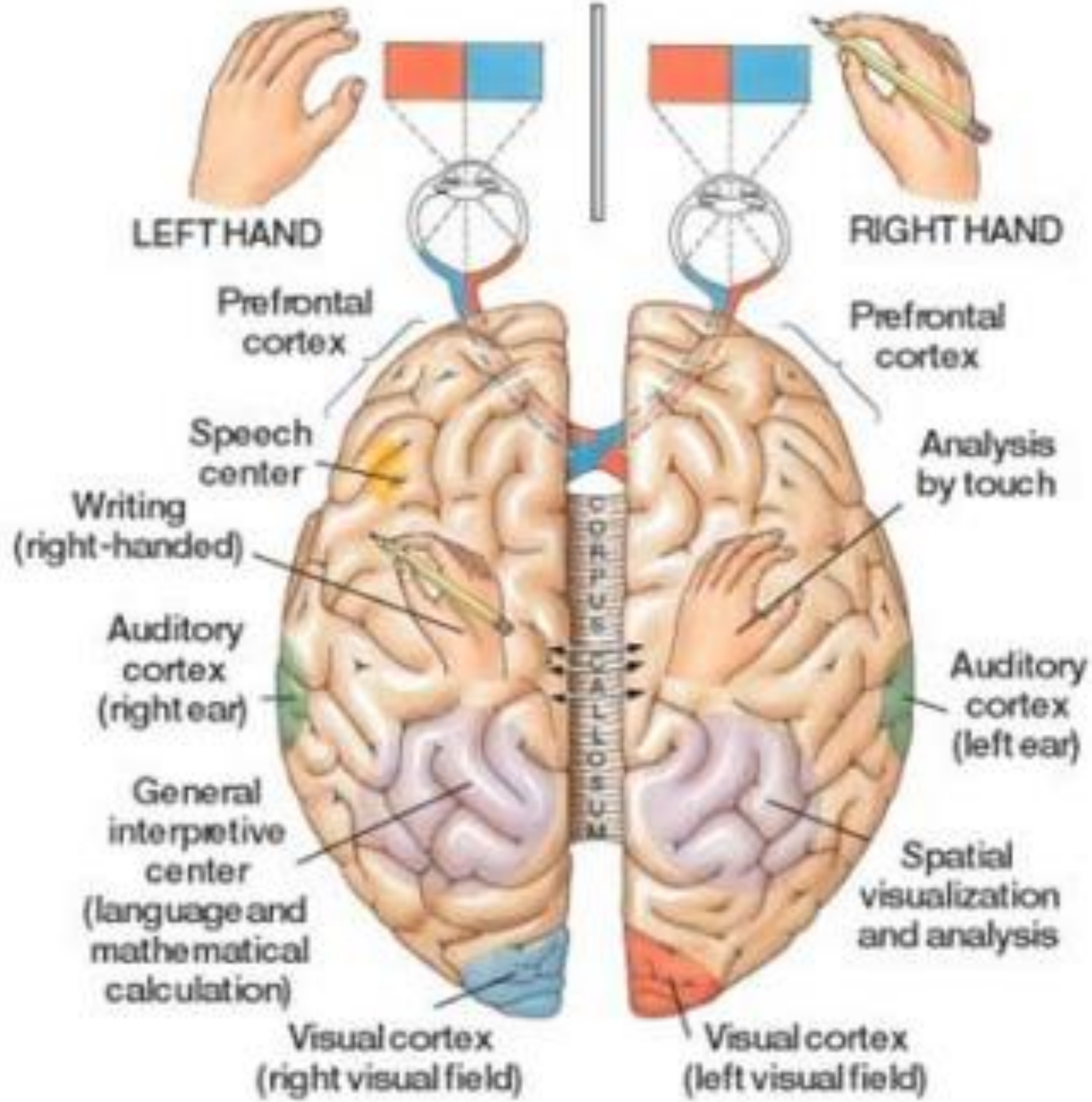
- It also determines how to respond to stressful situations by regulating our heart and breathing rate.

- There are two hemispheres: Right and Left.

- **Right hemisphere**: Responsible for control of the left side of the body, and is the more artistic and creative side of the brain.

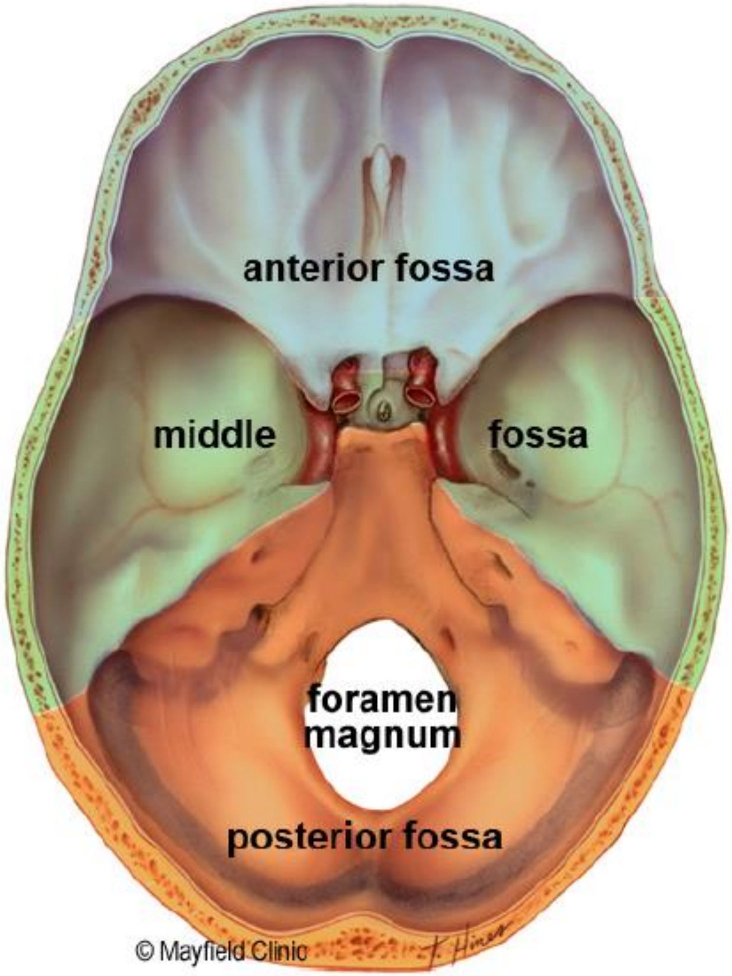
- **Left hemisphere**: Responsible for control of the right side of the body, and is more for logical thinking, analytic thoughts, computation.




LEFT HAND
RIGHT HAND
Prefrontal cortex
Prefrontal cortex
Speech center
Analysis by touch
Writing (right-handed)
CORPUS CALLOSUM
Auditory cortex (right ear)
Auditory cortex (left ear)
General interpretive center (language and mathematical calculation)
Spatial visualization and analysis
Visual cortex (right visual field)
Visual cortex (left visual field)

Skull

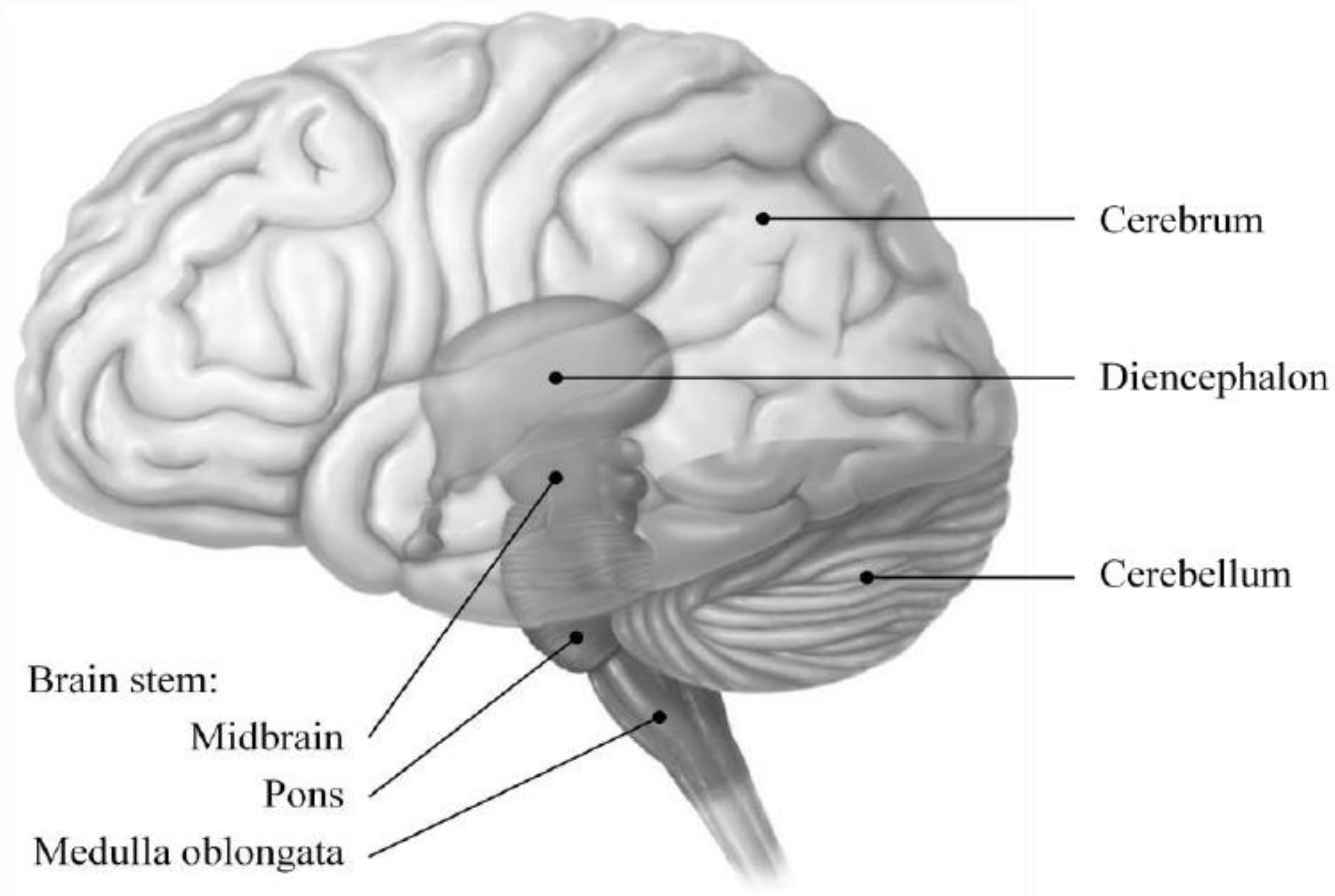
- The skull is formed of 8 bones that fuse together along suture lines. The face is formed by 14 paired bones.
- Suture lines are those lines where the bony plates of the skull join together.
- Skull has three different areas: Anterior fossa, Middle fossa and Posterior fossa.
- All the arteries, veins and nerves exit the base of the skull through holes called foramina.
- The big hole in the middle called foramen magnum, where the spinal chord exists.



Brain anatomy

- The **Cerebrum** is the forward-most portion and largest part of the human brain. It is generally associated with higher brain functions such as conscious thought, action selection and control.

- It consists of two hemispheres which are not directly connected. Right and left hemisphere instead communicate indirectly through long-range connections via corpus callosum.



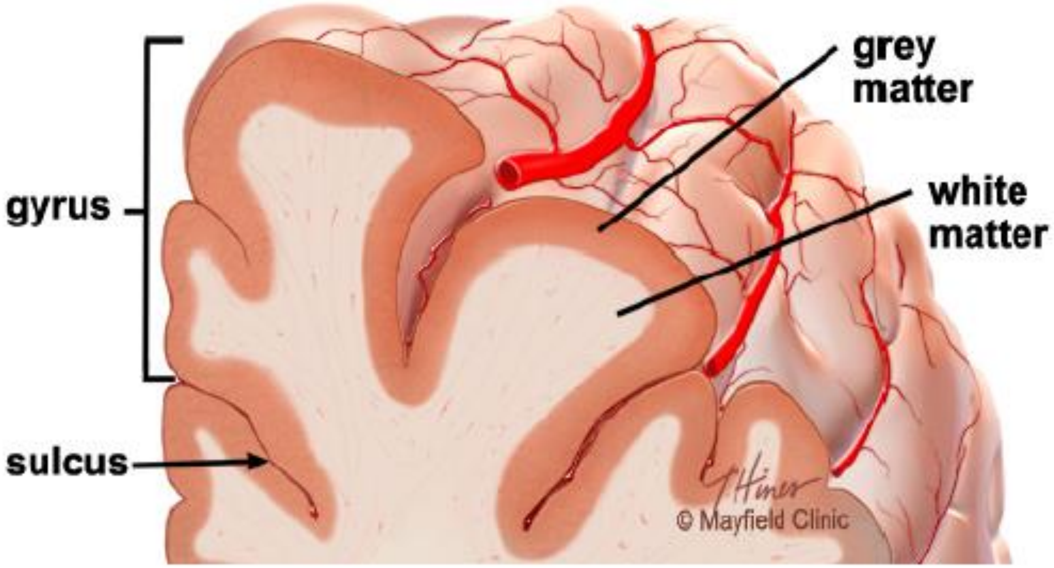
Cerebral cortex

- The surface of the cerebrum has a folded appearance called the cortex and cortex contains about 70% of the 100 billion nerve cells.

- The nerve cell bodies color the cortex grey brown giving its name grey matter.

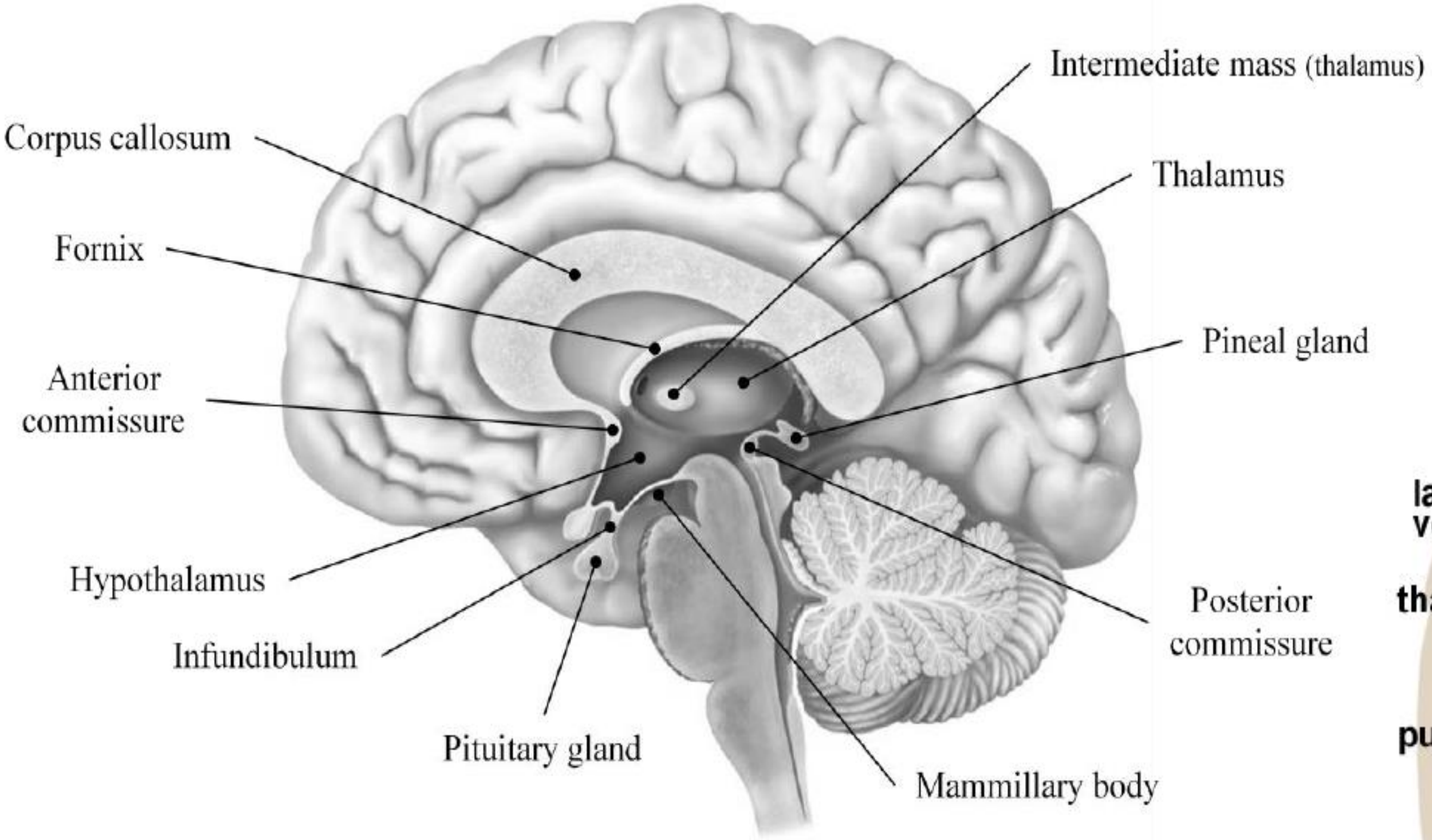
- Beneath the cortex are long connecting fibers between neurons called axons, which make up the white matter.

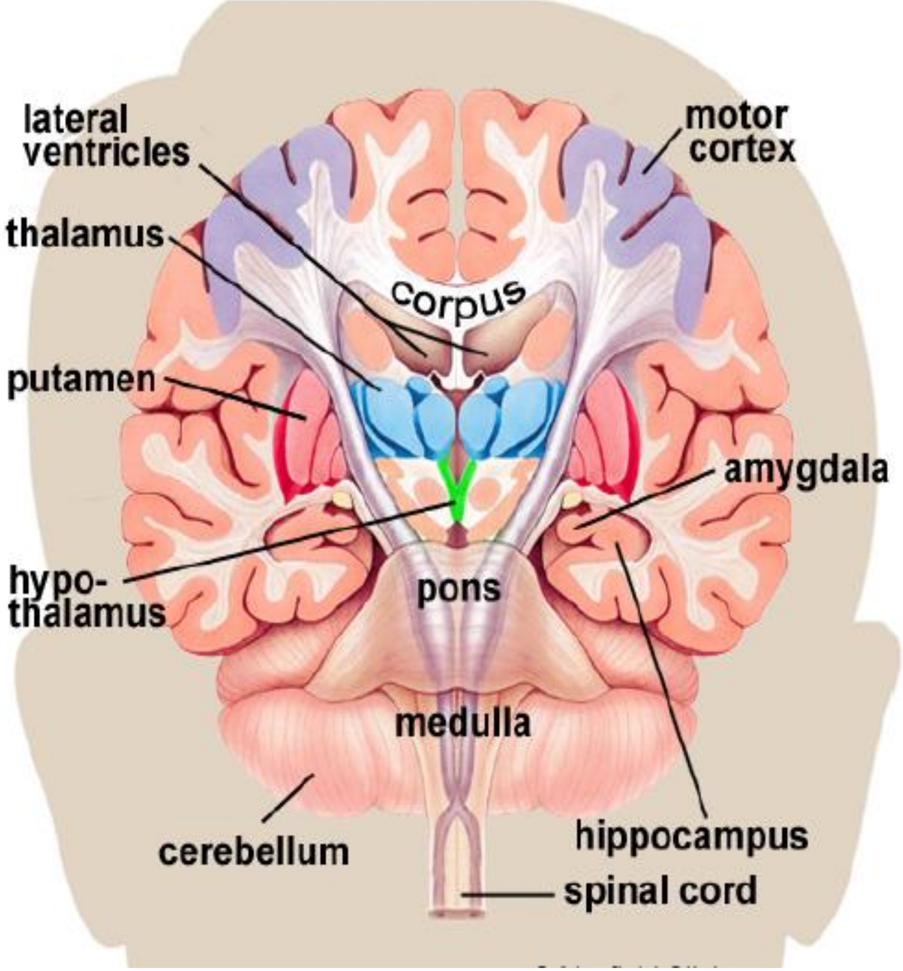
- Each fold is called a gyrus and each groove between the folds is called a sulcus.



Brain anatomy

- The **Cerebellum** or “little brain“ has two hemispheres which have highly folded surfaces.
- The cerebellum is responsible for regulation and control of fine movements, posture and balance.
- The **Brain Stem** is the lower part of the brain, comprising the midbrain, pons and medulla.
- Often called the reptilian brain, it controls autonomic body processes such as heartbeat, breathing, bladder function and sense of equilibrium.
- The **diencephalon** forms the central core of the brain. Consisting of largely of three structures, the thalamus, hypothalamus, and epithalamus, the diencephalon plays a vital role in integrating conscious and unconscious sensory information and motor commands.


Intermediate mass (thalamus)
Corpus callosum
Thalamus
Fornix
Pineal gland
Anterior commissure
Hypothalamus
Posterior commissure
Infundibulum
Pituitary gland
Mammillary body


lateral ventricles
motor cortex
thalamus
corpus
putamen
amygdala
hypo-thalamus
pons
medulla
cerebellum
hippocampus
spinal cord

Contd..

- **Hypothalamus** is located on the floor of the third ventricle and is the master control of the autonomic system. It plays a major role in controlling behaviors such as hunger, thirst and sleep. Regulates the body temperature, blood pressure, emotions and secretions of hormones.

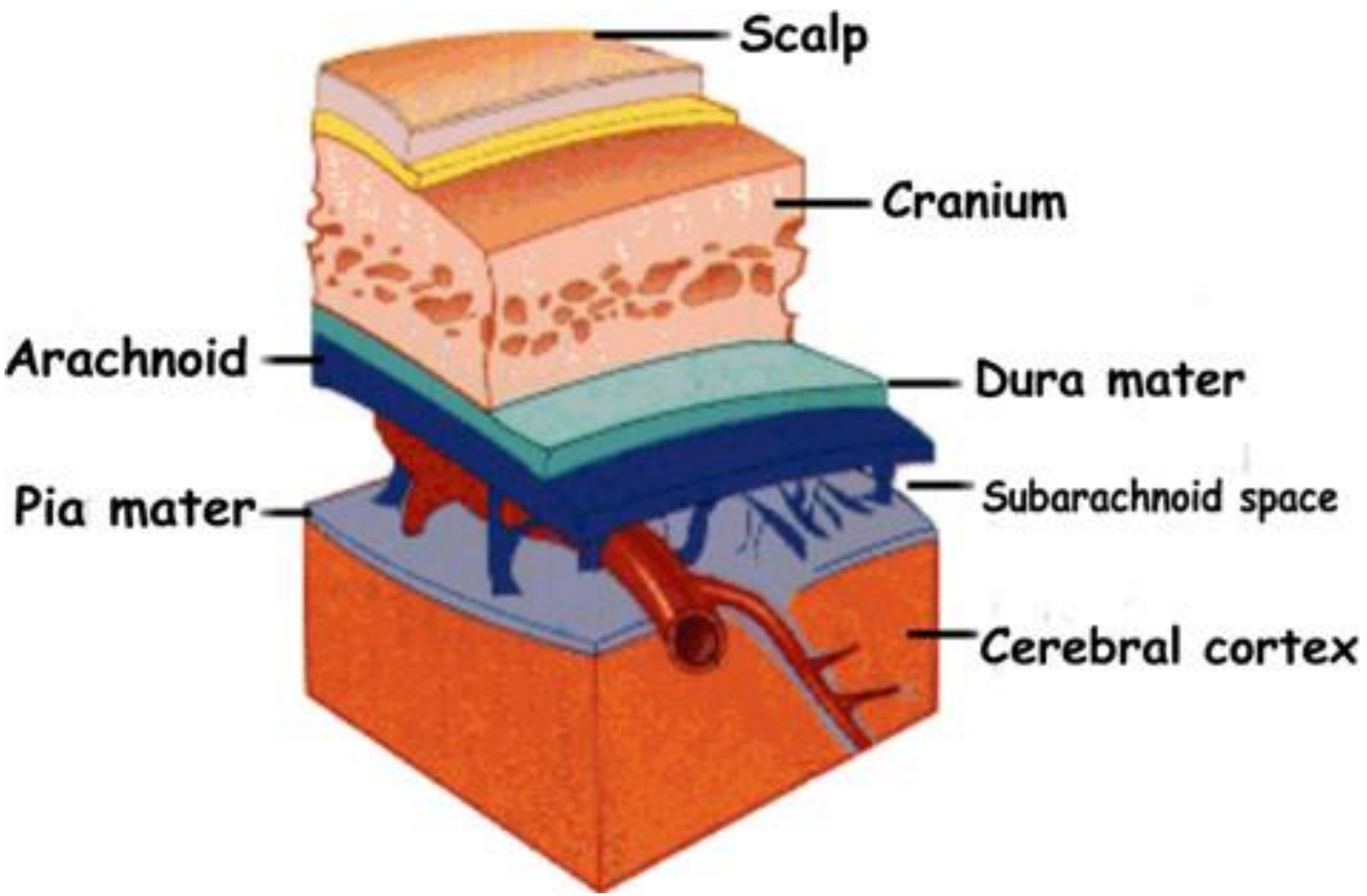
- **Thalamus** serves as a relay station for almost all information that comes and goes out to the cortex.

- The **pituitary gland** is called as a master gland, as it controls the other endocrine glands in the body. This gland is connected to the hypothalamus of the brain by a pituitary stalk.

- **Pineal gland** is located behind the third ventricle. It helps to regulate the body internal clock and circadian rhythms by secreting melatonin.

- **Lumbic system** is the center of our emotions, learning and memory. It includes hypothalamus, amygdala and hippocampus (memory).

Meninges


Scalp
Cranium
Arachnoid
Dura mater
Pia mater
Subarachnoid space
Cerebral cortex

Ventricles

- The brain has hollow filled cavities called ventricles. Inside the ventricles a ribbon like structures called the choroid plexus that makes the clear colorless cerebrospinal fluid (CSF).

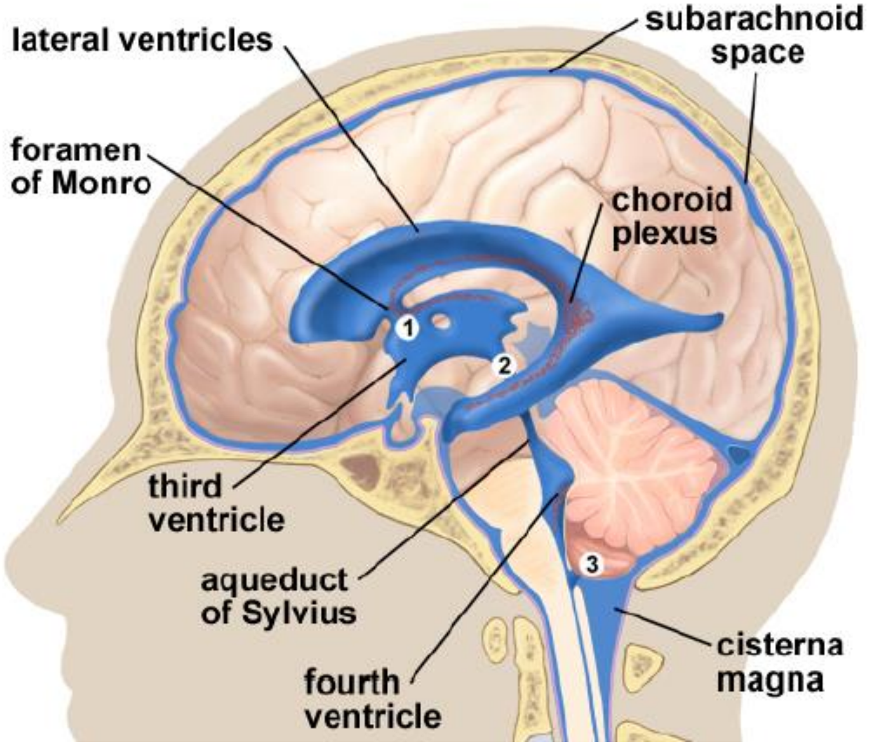
- There are two ventricles deep within the cerebral hemispheres called the lateral ventricles.

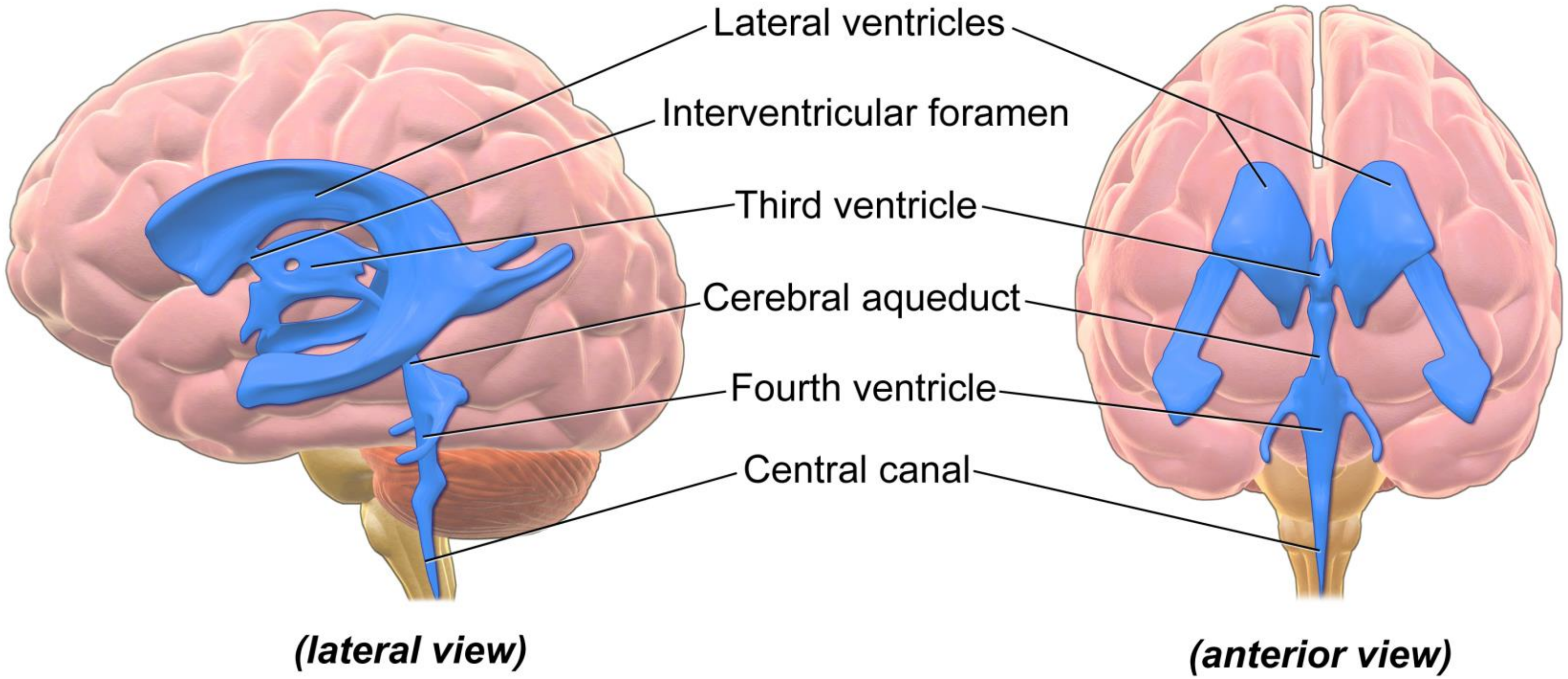
- The two lateral ventricles connected to the third ventricle through a separate opening called the foramen of monro.

- The third ventricle is connected to the fourth ventricle through a long narrow tube called the aqueduct of sylvius.

- From the fourth ventricle, CSF flows into the subarachnoid space where it circulates and cushions the brain.

- A balance is to be maintained between the amount of CSF that is absorbed and the amount that is produced.


lateral ventricles
subarachnoid space
foramen of Monro
choroid plexus
1
2
3
third ventricle
aqueduct of Sylvius
fourth ventricle
cisterna magna


Lateral ventricles
Interventricular foramen
Third ventricle
Cerebral aqueduct
Fourth ventricle
Central canal
(lateral view)
(anterior view)

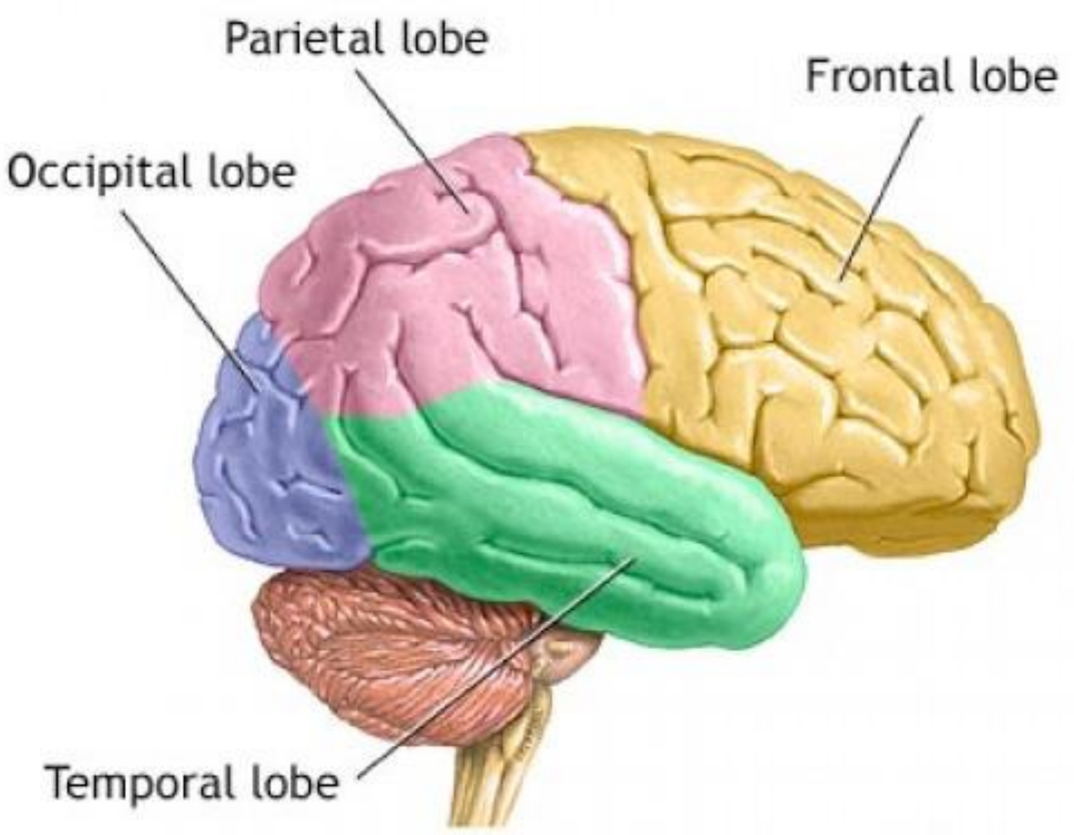
Lobes of Cerebrum

- All sensory inputs from various parts of the body reaches the cortex, where certain regions relate specifically to certain modalities of sensory information.

- For example: hearing, vision, emotions, thinking.

- There are four lobes (or divisions)

- Frontal lobe
- Temporal lobe
- Parietal lobe
- Occipital lobe

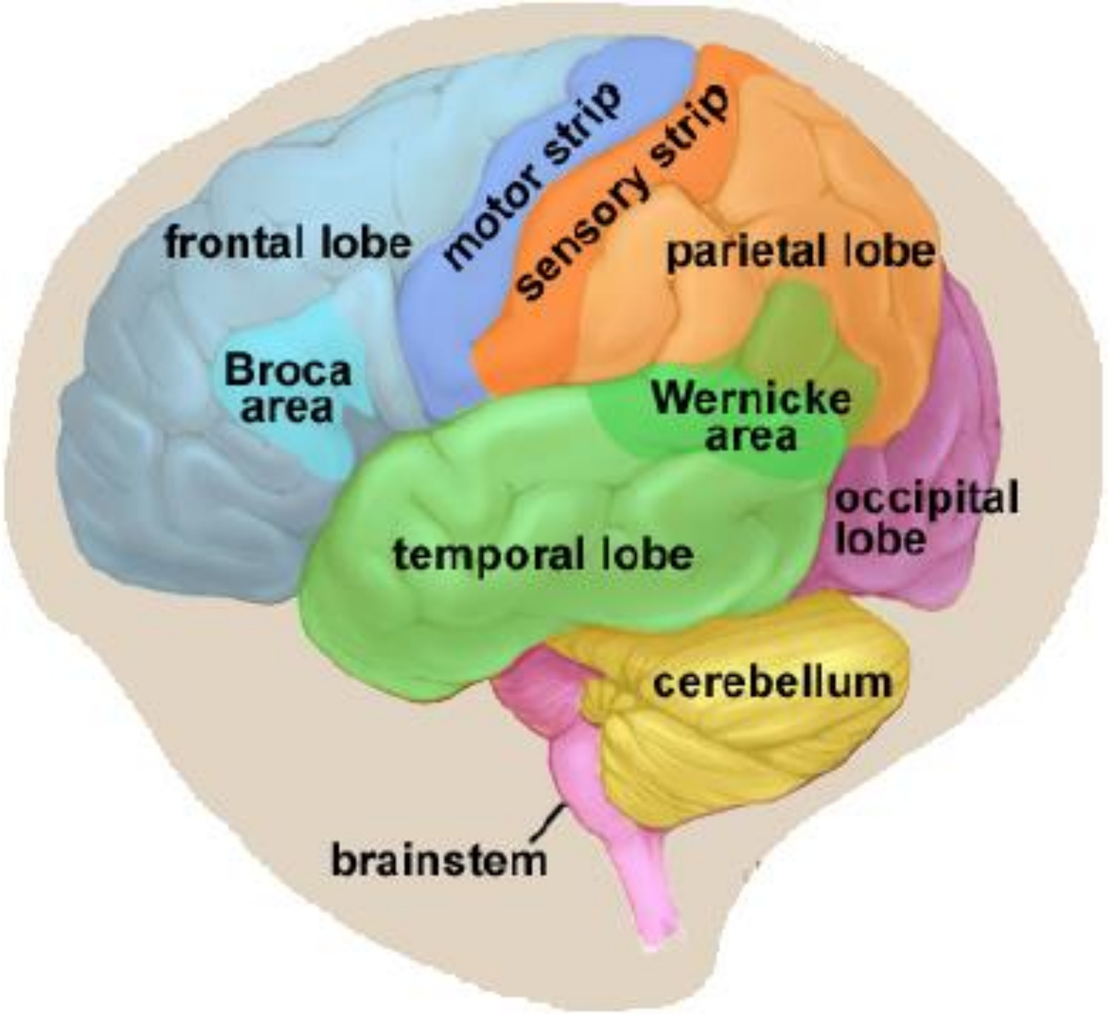


Frontal lobe

- Largest among the lobes.
- Located at the front of both hemispheres.
- The frontal lobe is thought to be involved in complex functioning of the brain including problem solving, personality, emotions, judgment, insight, reasoning, abstract thinking and self evaluation.
- The frontal lobe includes working memory especially the ability to plan and initiate any activity.
- **Broca's area**: Located in the left hemisphere of the frontal lobe and is responsible for speech production and meaningful sentences.

Temporal lobe

- Located at the side of both hemispheres.
- The temporal lobe is responsible hearing, feeling, language understanding, memory.
- **Wernicke's area**: Located in the left hemisphere of the temporal lobe and is responsible for speech understanding.
- **Hippocampus**: particularly long-term memory.



Parietal & Occipital lobe

Parietal Lobe

- Located behind the frontal lobes and above the temporal lobes.
- Contains **somatosensory cortex**: important for processing touch sensation.
  For example: helps to identify the object by touch.
- Identify the location of touch sensation.
- Other functions: attention, Spatial visualization.

Occipital Lobe

- Rearmost portion of the cerebrum.
- Important for visual processing.

- The **corpus callosum** is a thick band of nerve fibers that divides the cerebral cortex lobes into left and right hemispheres.
- It connects the left and right sides of the brain allowing for communication between two hemispheres.

Frontal lobe

- Personality, behavior, emotions
- Judgment, planning, problem solving
- Speech: speaking and writing (Broca's area)
- Body movement (motor strip)
- Intelligence, concentration, self awareness

Parietal lobe

- Interprets language, words
- Sense of touch, pain, temperature (sensory strip)
- Interprets vision, hearing, sensory and memory
- Spatial and visual perception

Occipital lobe

- Interprets vision (color, light, movement)

Temporal lobe

- Understanding language (Wernicke's area)
- Memory
- Hearing
- Sequencing and organization

Brain stem

- The brain stem begins inferior to the thalamus and runs approximately 7cm before merging into the spinal cord.
- The brain stem centers produce the rigidly programmed, automatic behaviors necessary for survival.
- Positioned between the cerebrum and the spinal cord, the brain stem also provides a pathway for fiber tracts running between higher and lower brain centers.
- **Mid brain** is the region of the brain stem between diencephalon and pons.
- **Cerebral peduncle**: Bulge located on the ventral aspect of the midbrain; contains fiber tracts running between the cerebrum and spinal cord.

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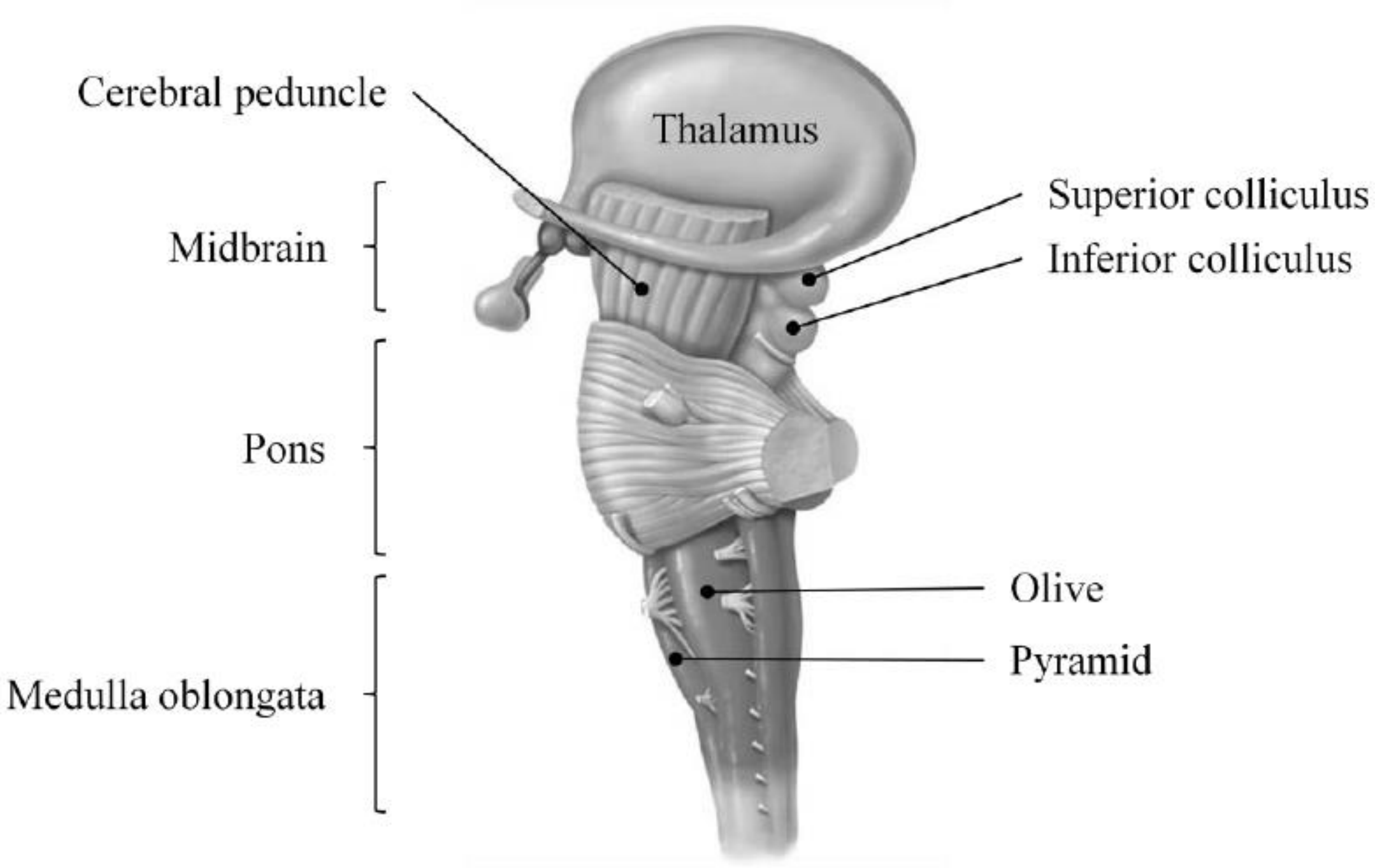


Cerebral peduncle
Thalamus
Midbrain
Superior colliculus
Inferior colliculus
Pons
Olive
Pyramid
Medulla oblongata

Contd..

- **Superior and inferior colliculus**: Part of midbrain; contains nerve reflex centers involved in coordinated eye movements, focusing, and papillary responses.

- **Pons**: Region of brain stem between the midbrain and medulla oblongata; serves as the bridge (connection) between the two regions, and the cerebellum.

- **Medulla oblongata**: The most inferior portion of the brain stem; contains the cardiac, vasomotor, and respiratory centers.

- **Pyramid**: Longitudinal ridge mid-line of the medulla oblongata; contains fiber tracts running between the cerebrum and spinal cord.

- **Olive**: Located lateral to the pyramid of the medulla oblongata; regulates impulse propagation from the cerebrum and midbrain to the cerebellum.

Cerebellum

- Located on the lower dorsal aspect of the brain, the cerebellum accounts for ~ 11% of the total brain mass.

- Like the cerebrum, the cerebellum has two major hemispheres with an outer cortex made up of gray matter with an inner region of white matter.

- The cerebellum is located dorsal to the pons and medulla and it protrudes under the occipital lobes of the cerebral hemispheres, from which it is separated by the transverse fissure.

- Cerebellar activity occurs subconsciously, we have no awareness of it.

Electroencephalogram(EEG)

Introduction

- Not all electrical fields generated by the brain are strong enough to spread all the way through tissue, bone and skull towards the scalp surface.

- Research indicates that it is primarily the synchronized activity of pyramidal neurons in cortical brain regions which can be measured from the outside.

- Their name stems from the pyramidal/triangular shape of their cell body.

- Pyramidal cells can be found in all cortical areas (occipital, temporal, parietal, frontal cortices), where they are always oriented perpendicular to the cortical surface.

- The cell body is heading away from the surface, while their dendrite is heading towards the surface.

EEG

- To record electrical activity generated by the brain, EEG researchers don't have to open skulls to place sensors.

- Thankfully, it‘s much easier than that - they simply record the electrical data from sensors placed on the scalp surface with the help of electrodes.

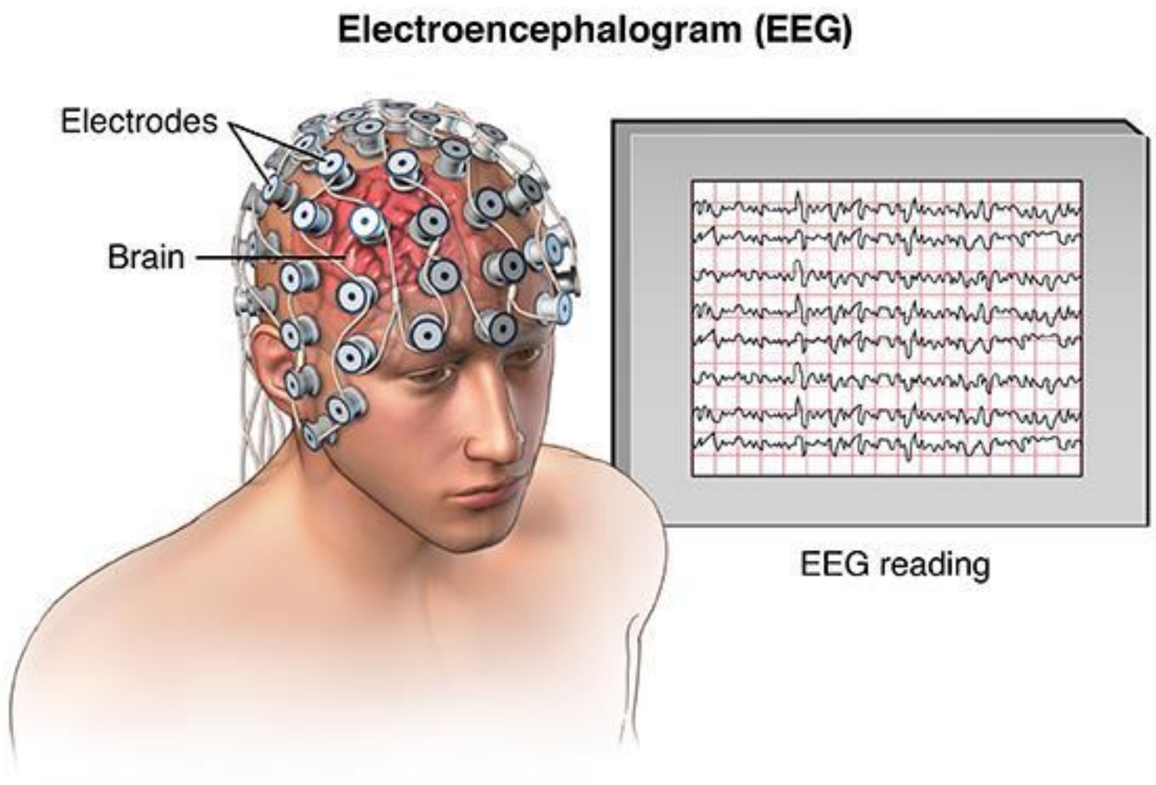
- Applied first to humans in the 1920s by German neurologist Hans Berger, EEG is a non-expensive, non-invasive and completely passive recording technique.

- The most central benefit of EEG is its excellent time resolution, that is, it can take hundreds to thousands of snapshots of electrical activity across multiple sensors within a single second.

- This renders EEG an ideal technology to study the precise time-course of cognitive and emotional processing.

EEG

➢ In contrast to other physiological recordings, EEG recordings are done with electrode arrays, comprising various sensor numbers ranging from 10 to 500 electrodes, depending on the scope of the experiment.

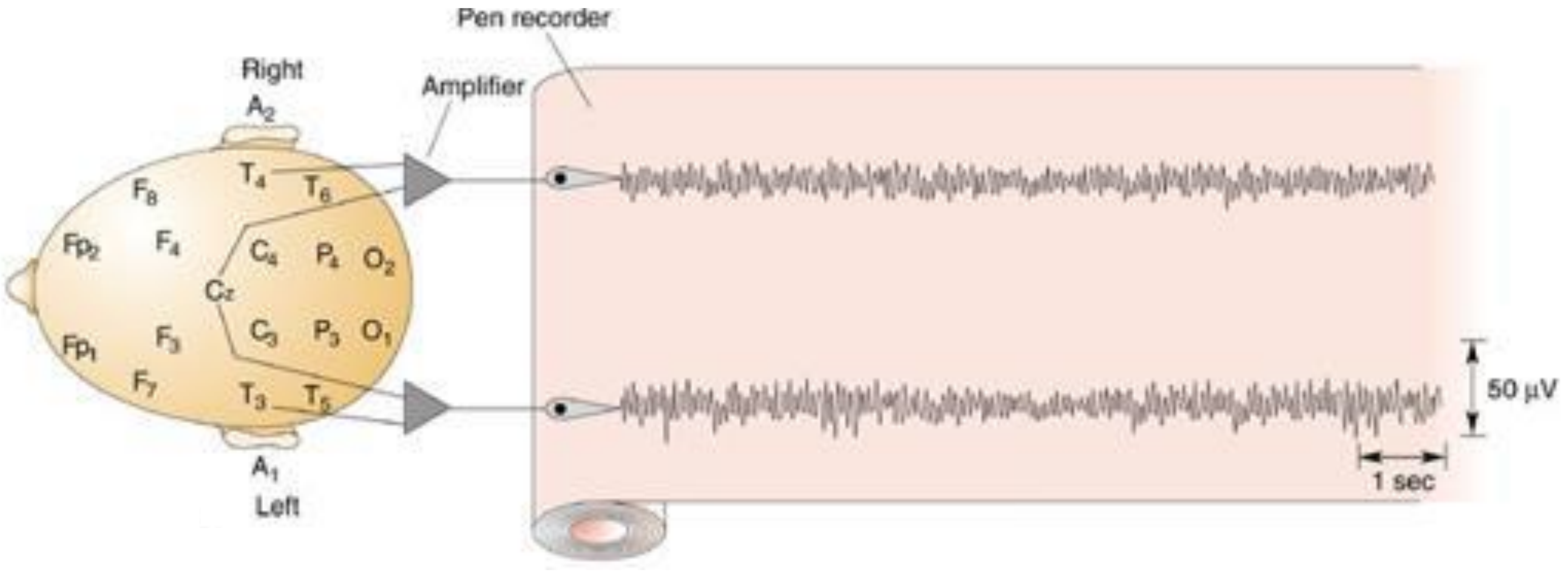


EEG: Data acquisition

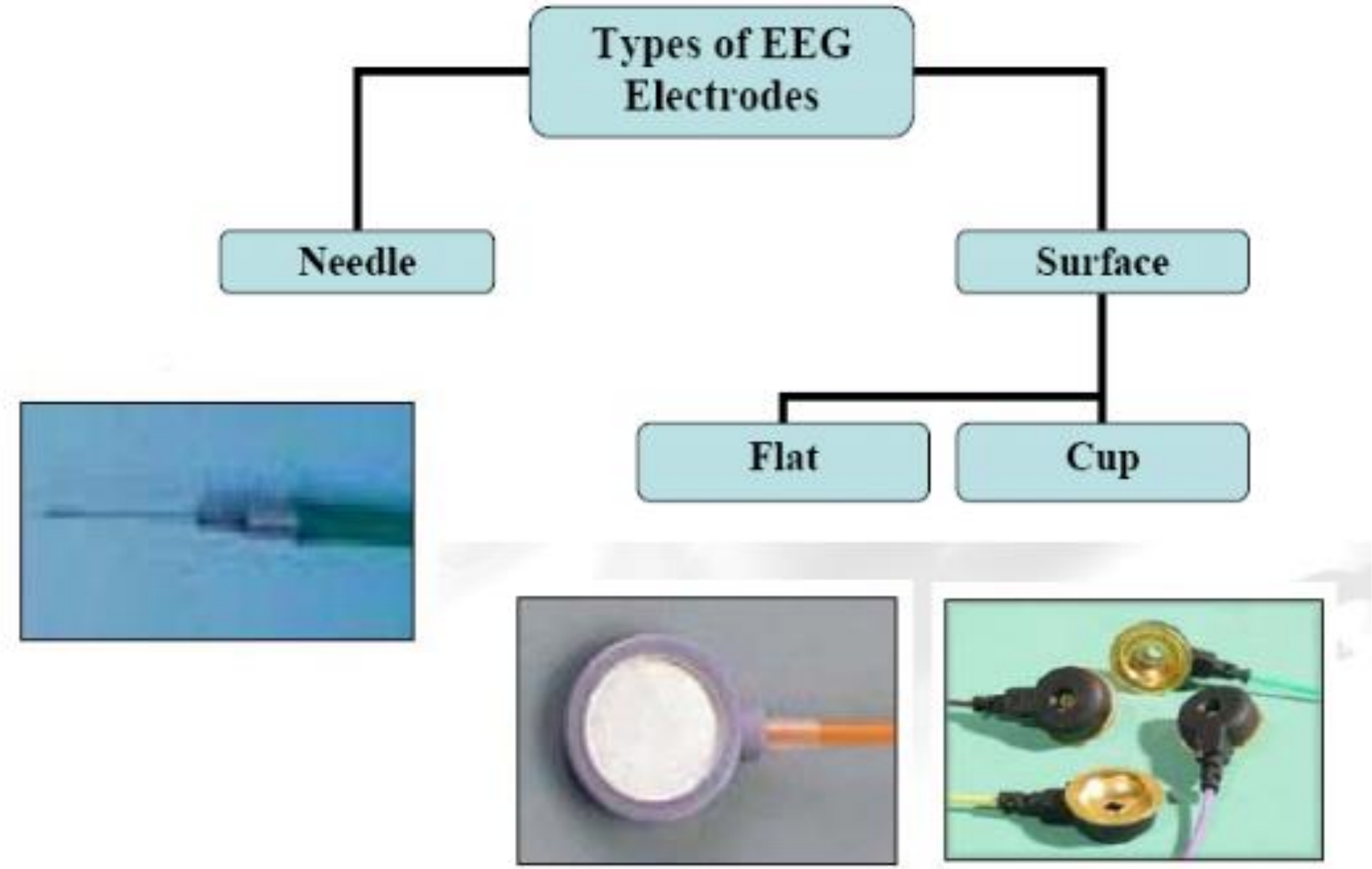
Electrodes and their placement scheme:

- Surface electrode: Ag/Ag-Cl.
- To get a good contact between electrode and skin surface, the skin may have to be cleaned for dirt removal.
- Electrodes are placed on the scalp using a conductive gel or paste.
- International Federation of Societies for Electroencephalography and Clinical Neurophysiology has recommended the 10-20 system of electrode placement for clinical recording.
- Differential Amplifier: The amplifier amplifies the difference in voltage between these two electrodes (usually between 1000 and 100000 times).

EEG Diff amplifier



EEG electrodes



EEG:10-20 electrode placement

- An internationally recognized method that allows EEG electrode placement to be standardized.

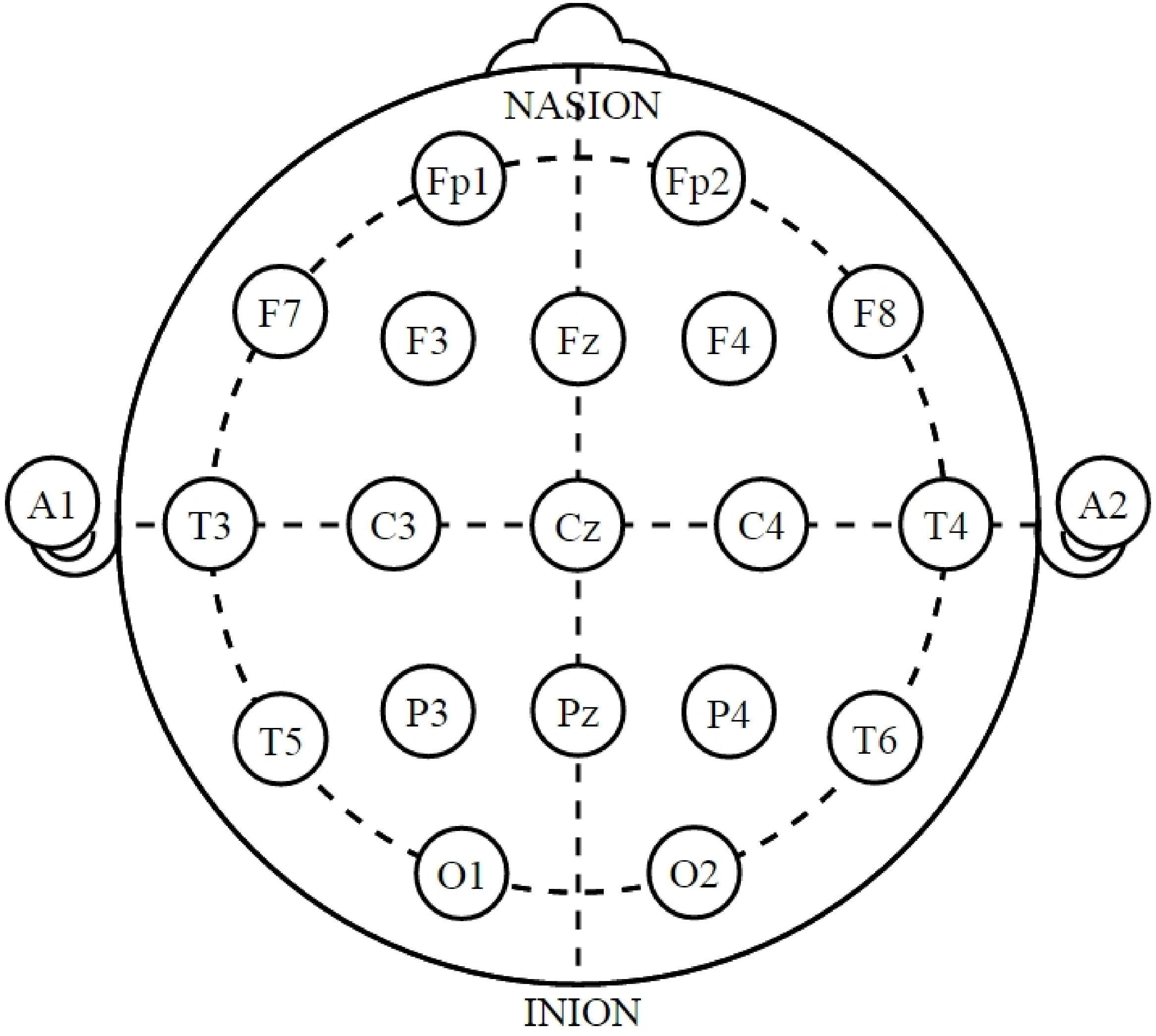
  - Ensures inter-electrode spacing is equal
  - Electrode placements proportional to skull size & shape

Covers all brain regions

F = Frontal T = Temporal
P = Parietal O = Occipital

Numbering system

Odd = left side, Even = right side, Z = midline



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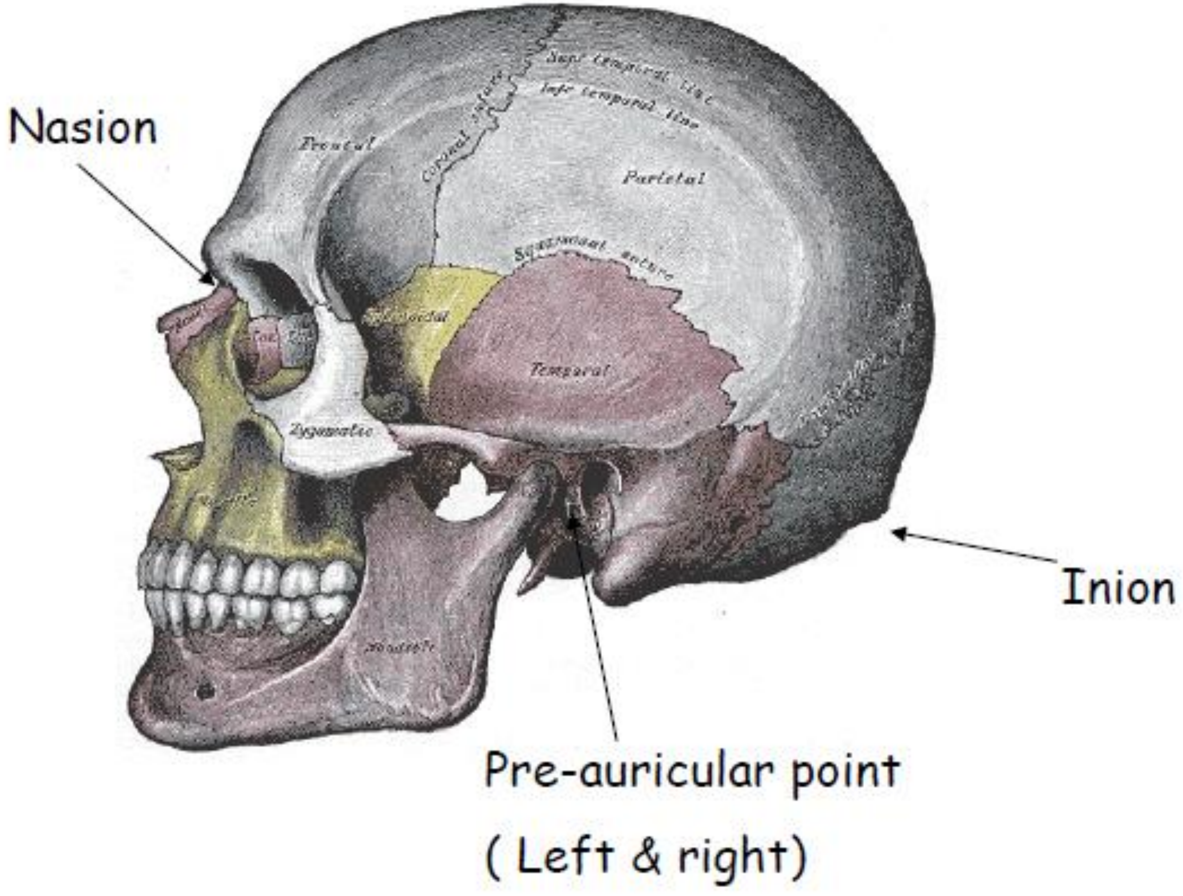
Four skull landmarks:

- **Nasion**: Point between the forehead and nose.
- **Inion**: bony region behind the head.
- Left Pre-auricular point
- Right Pre-auricular point.



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- The vertical line connecting nasion (front) and inion (back) as well as the horizontal line connecting left and right pre-auricular points are now divided into ten equal sections.
- Electrode names begin with one or two letters indicating the general brain region or lobes where the electrode is placed (Fp = fronto-polar; F = frontal; C = central; P = parietal; O = occipital; T = temporal).
- Each electrode name ends with a number. Odd numbers are used in the left hemisphere, even numbers in the right hemisphere.
- Larger numbers indicate greater distances from the midline, while electrodes placed at the midline are labeled with a “z” for zero.

Step 1:

- Measure the distance from the nasion to inion.
- Mark 10% of the total distance up from the nasion as F_{pz} and inion as Oz along the line joining them.
- Mark the halfway point between nasion and inion as Cz.
- Mark 20% of the total distance from Cz in front as Fz and back as Pz along the line joining the nasion and inion.

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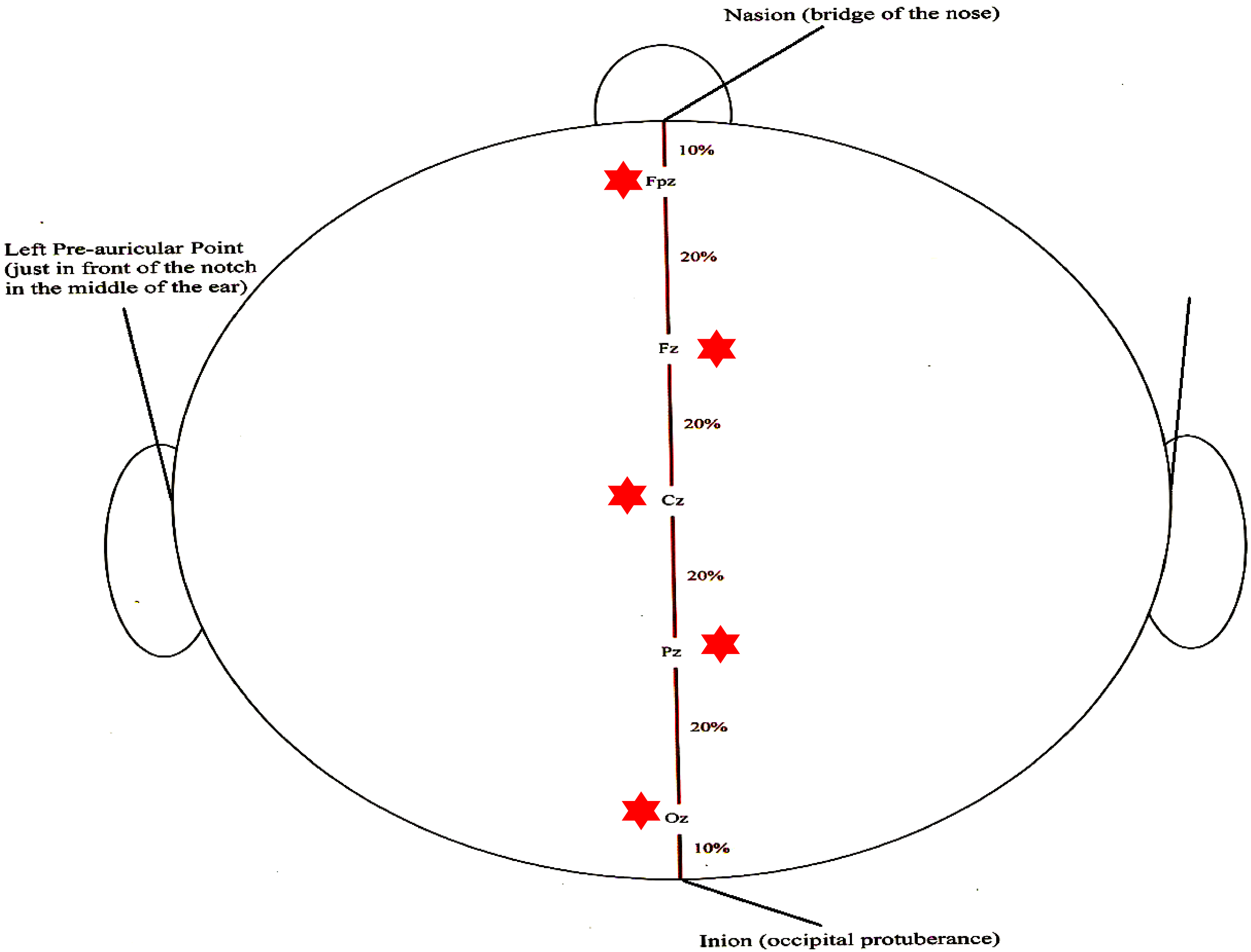


Nasion (bridge of the nose)
10%
Fpz
20%
Fz
20%
Cz
20%
Pz
20%
Oz
10%
Left Pre-auricular Point
(just in front of the notch
in the middle of the ear)
Inion (occipital protuberance)

Contd..

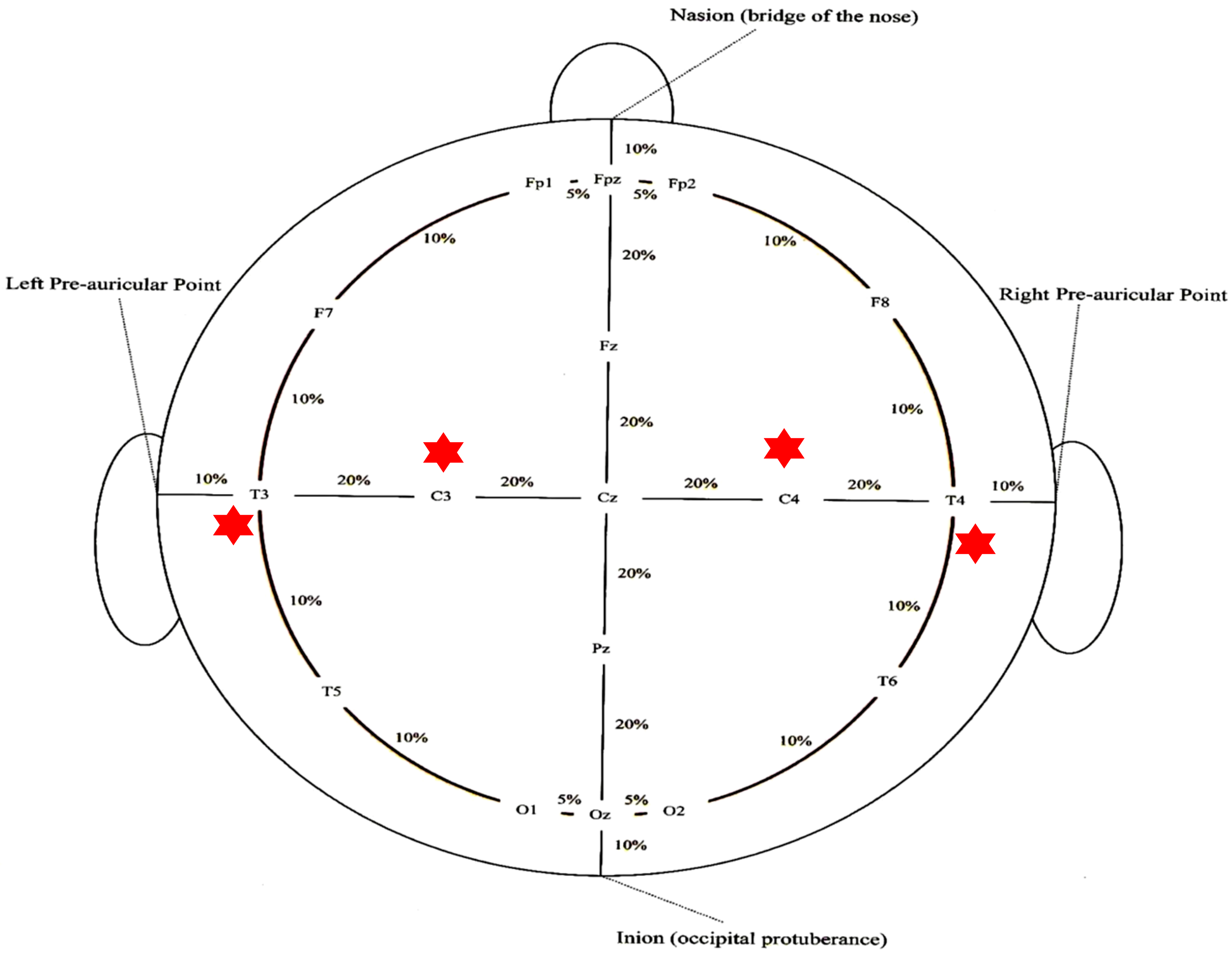
Step 2:

- Measure the distance from the left pre-auricular point to the right pre-auricular point, with the tape passing through the halfway mark between nasion and inion.

- Mark 10% of this distance up from the left as T3 and right preauricular points as T4.

- From Cz mark 20% of this distance on left as C3 and right as C4 side on the line joining the left and right preauricular points.

Contd..



Nasion (bridge of the nose)
10%
Fp1
Fpz
Fp2
5%
5%
10%
10%
20%
Left Pre-auricular Point
Right Pre-auricular Point
F7
F8
Fz
10%
10%
20%
10%
T3
20%
C3
20%
Cz
20%
C4
20%
T4
10%
20%
10%
10%
Pz
T5
T6
20%
10%
10%
O1
5%
Oz
5%
O2
10%
Inion (occipital protuberance)

Contd..

Step 3:

- Measure the circumference of the head such that the tape should pass through all the 10% up marks.
- 50% of this measurement should coincide with Oz at the back and Fpz in the front.
- Mark 5% of the circumference on the left and right of Fpz (Fp1 and Fp2) and Oz (O1 and O2)
- Mark 10% of the circumference to the left of Fp1 as F7 and right of Fp2 as F8.
- Mark 10% of the circumference to the left of O1 as T5 and right of O2 as T6.

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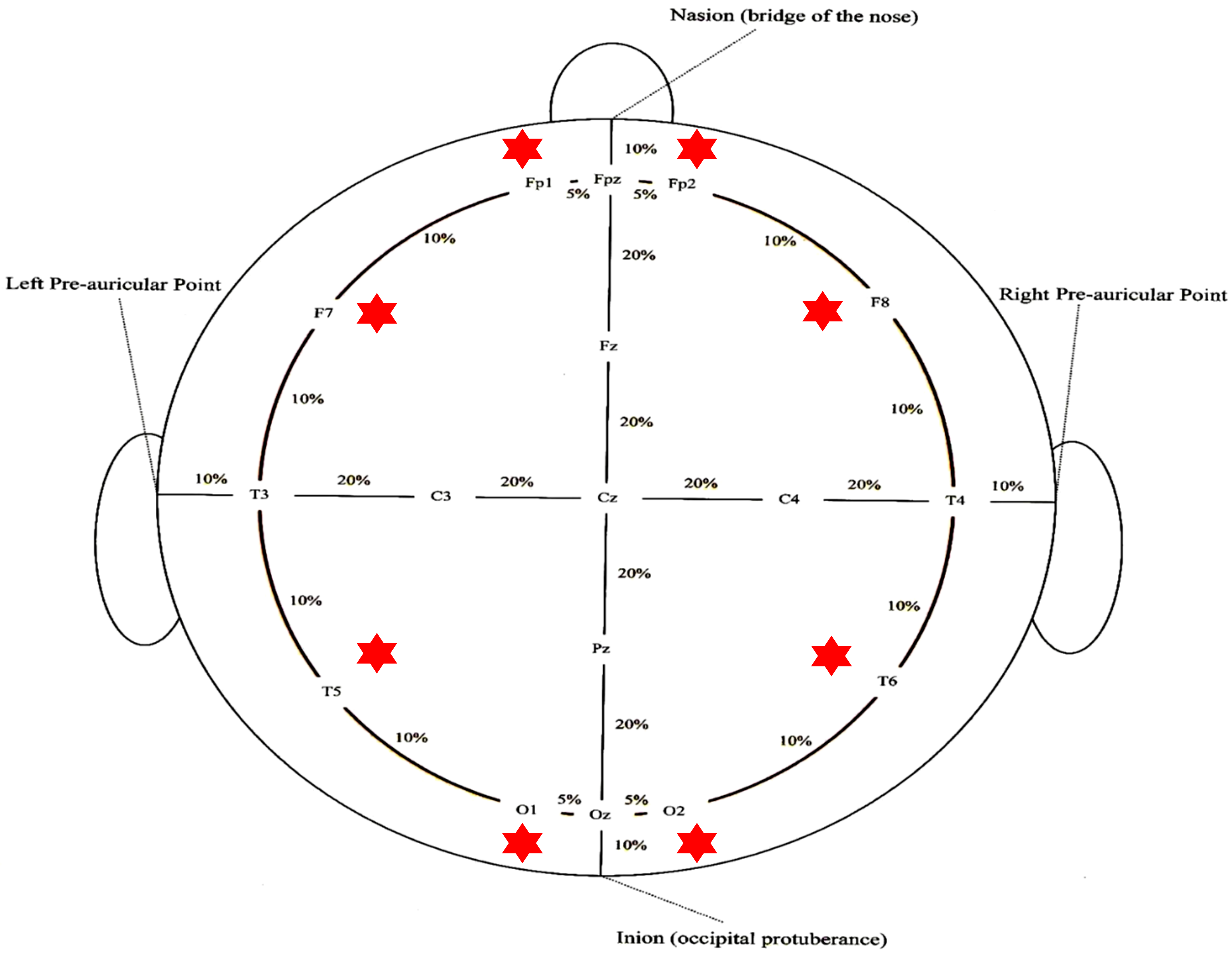

Nasion (bridge of the nose)
Left Pre-auricular Point
Right Pre-auricular Point
Inion (occipital protuberance)
Fp1
Fpz
Fp2
F7
Fz
F8
T3
C3
Cz
C4
T4
T5
Pz
T6
O1
Oz
O2
10%
5%
20%

Step 4:

- Measure from Fp1 to O1 passing through C3
- Mark 50% of this distance and it should intersect the 20% mark on the left of Cz. This is the exact location of C3.
- Mark 25% of this distance on the line joining Fp1 and C3. This is the first mark for F3.
- Do the same on the right side to find C4 and the first mark for F4.

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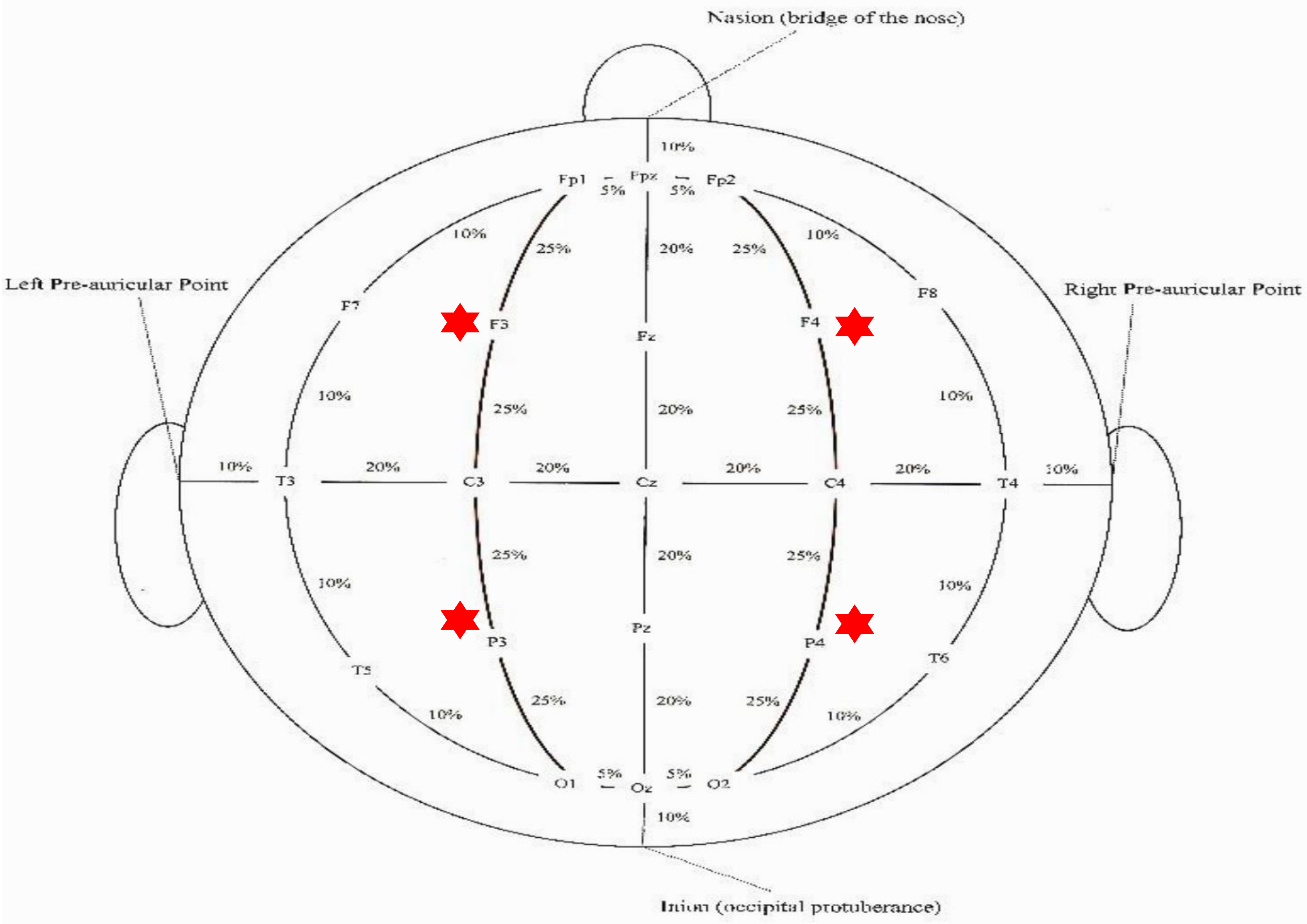
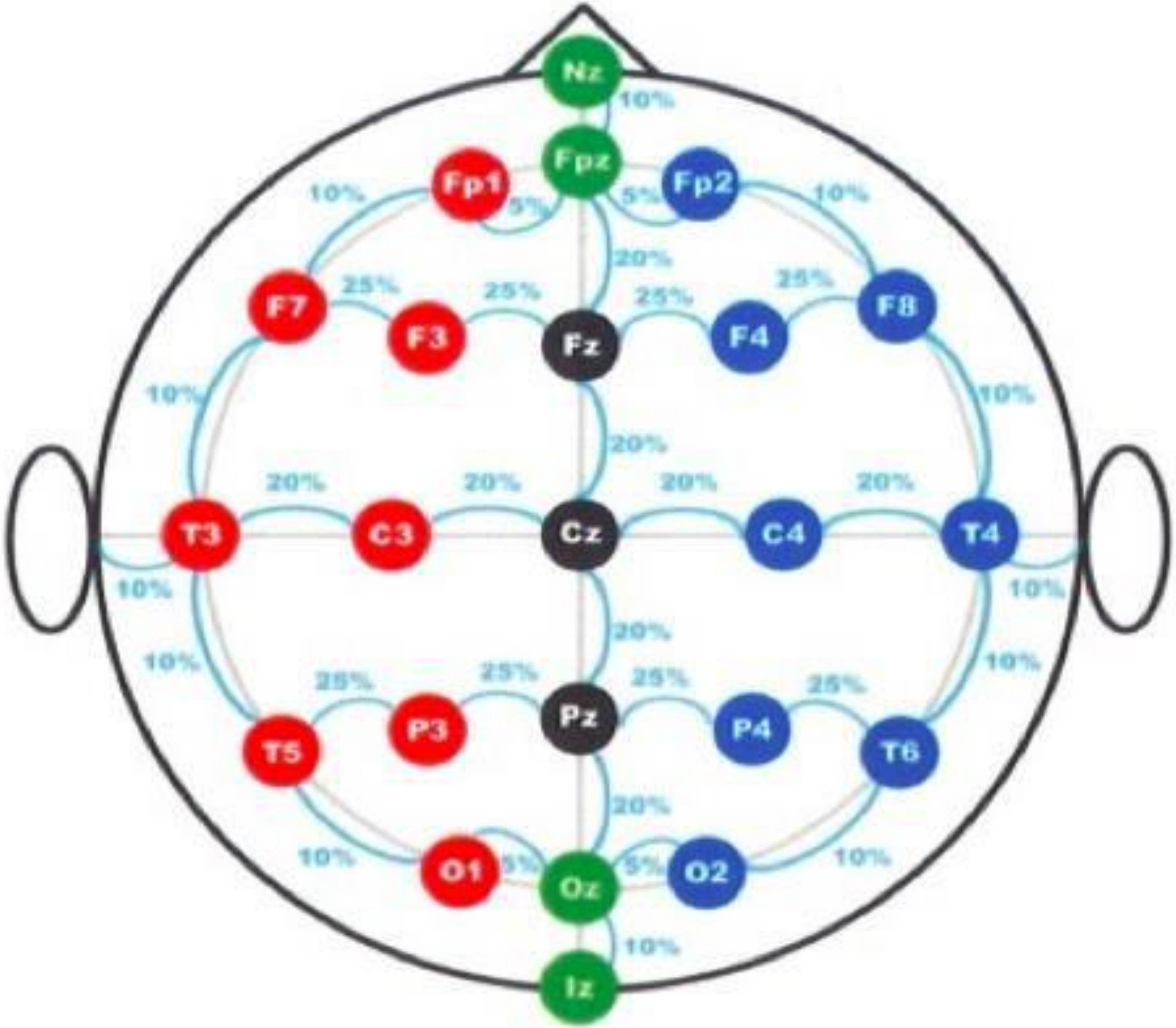


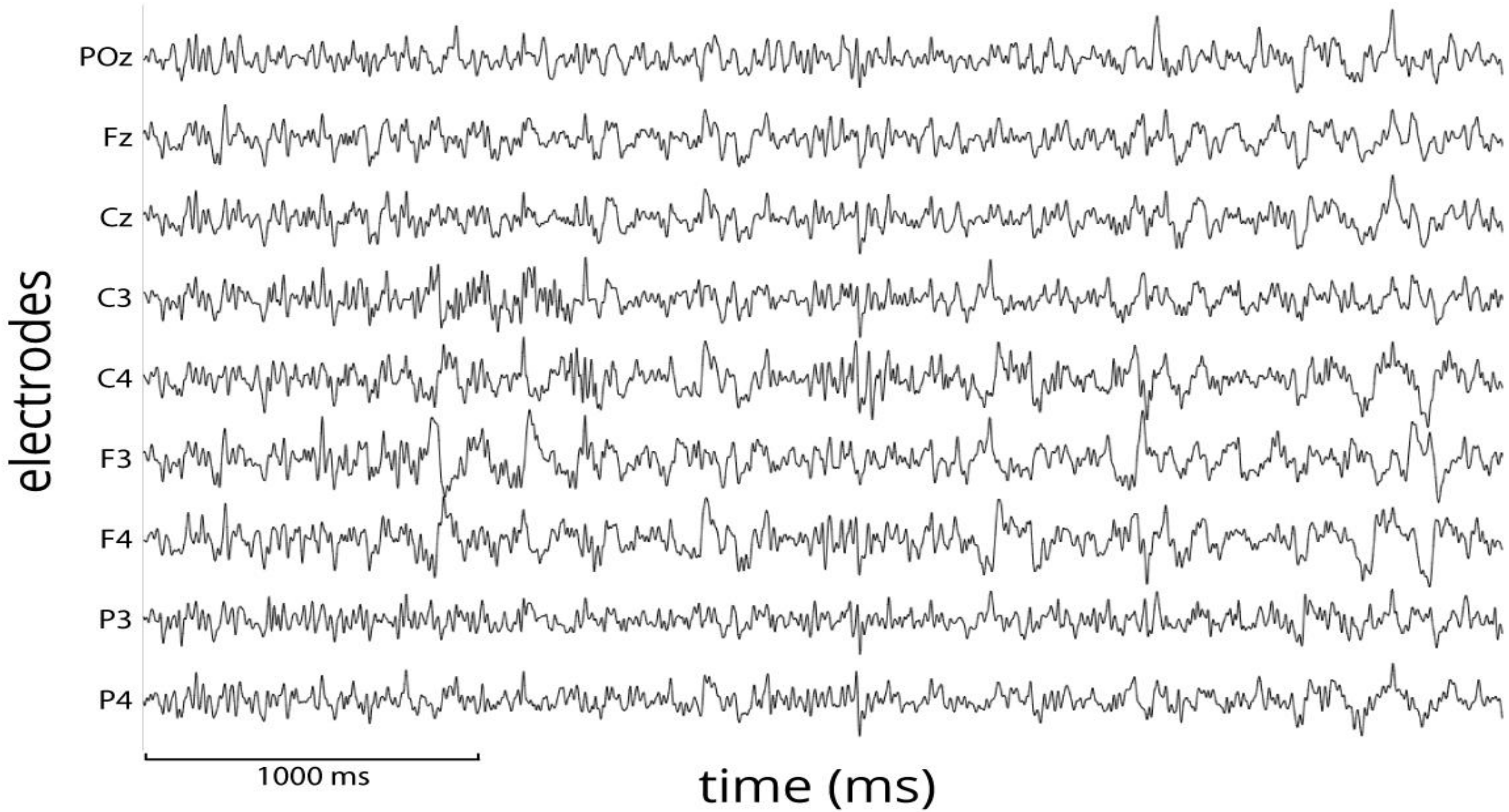
Nasion (bridge of the nose)
10%
Fp1
Fpz
Fp2
5%
5%
10%
25%
20%
25%
10%
Left Pre-auricular Point
Right Pre-auricular Point
F7
F3
Fz
F4
F8
10%
25%
20%
25%
10%
10%
T3
20%
C3
20%
Cz
20%
C4
20%
T4
10%
25%
20%
25%
10%
10%
P3
Pz
P4
T5
T6
25%
20%
25%
10%
10%
O1
5%
Oz
5%
O2
10%
Inion (occipital protuberance)

Contd..



Nz
10%
Fpz
Fp1
Fp2
5%
5%
10%
10%
20%
F7
F3
Fz
F4
F8
25%
25%
25%
25%
10%
10%
20%
20%
20%
20%
20%
T3
C3
Cz
C4
T4
10%
10%
20%
10%
10%
25%
25%
25%
25%
T5
P3
Pz
P4
T6
20%
10%
10%
O1
5%
Oz
5%
O2
10%
Iz

EEG signal (8 electrodes)



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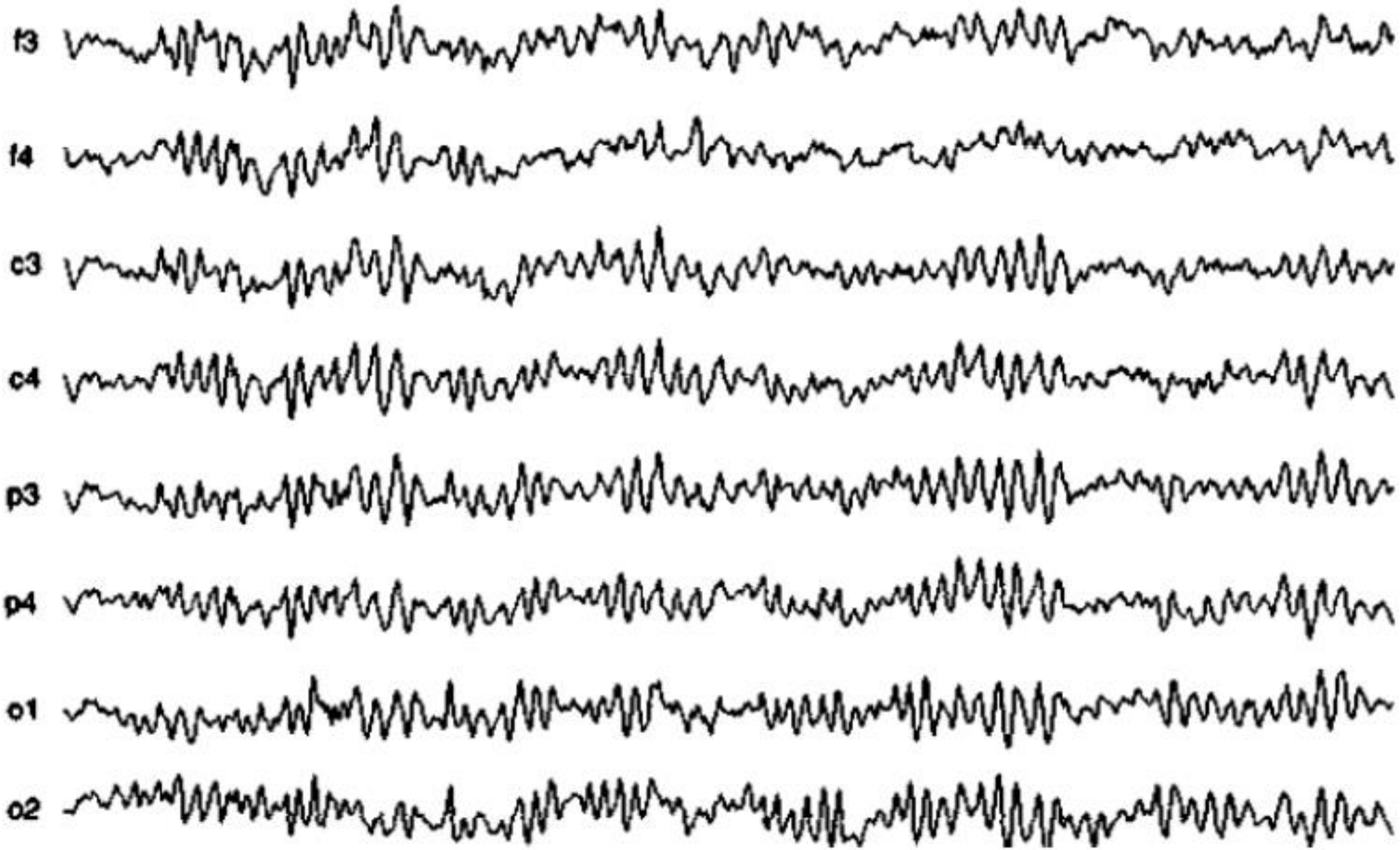


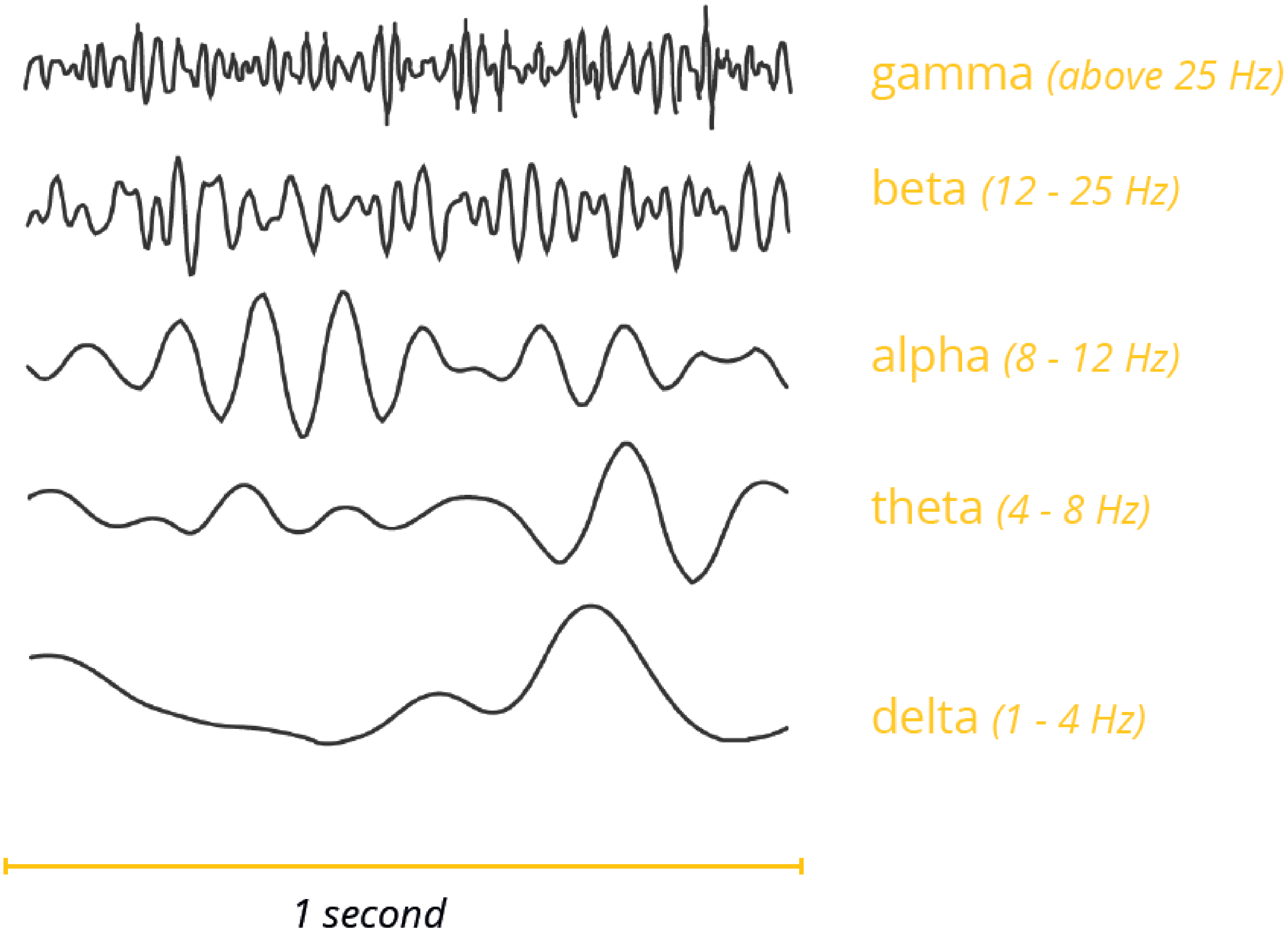
Classification of EEG waves

- However, the signal is always a mixture of several underlying base frequencies, which are considered to reflect certain cognitive, affective or attentional states.

- Because these frequencies vary slightly dependent on individual factors, stimulus properties and internal states, research classifies these frequencies based on specific frequency ranges, or frequency bands:

Delta band (1 – 4 Hz)
Theta band (4 – 8 Hz)
Alpha band (8 – 12 Hz)
Beta band (13 – 25 Hz)
Gamma band (> 25 Hz)

Contd..


gamma (above 25 Hz)
beta (12 - 25 Hz)
alpha (8 - 12 Hz)
theta (4 - 8 Hz)
delta (1 - 4 Hz)
1 second

Delta waves

<u>Delta band (1 - 4 Hz):</u>

- Being the slowest and highest amplitude brainwaves, oscillations in 1 – 4 Hz range are characterized as delta waves.

- Delta waves are only present during deep non-REM sleep, also known as slow-wave sleep (SWS).

- In sleep labs, delta band power is examined to assess the depth of sleep. The stronger the delta rhythm, the deeper the sleep.

- Delta frequencies are stronger in the right brain hemisphere and the sources of delta are typically localized in the thalamus.

Theta waves

Theta band (4 - 8 Hz):

- Brain oscillations within 4 – 8 Hz frequency range are referred to as theta band.

- Studies consistently report frontal theta activity to correlate with the difficulty of mental operations

for example: during focused attention and information uptake, processing and learning or during memory recall.

- Theta frequencies become more prominent with increasing task difficulty. This is why theta band is generally associated with brain processes underlying mental workload or working memory.

Alpha waves

Alpha band (8 - 12 Hz):

- First discovered by Hans Berger in 1929, alpha is defined as rhythmic oscillatory activity within the frequency range of 8 – 12 Hz.
- Alpha is generated in posterior cortical sites, including occipital, parietal and posterior temporal brain regions.
- Alpha waves have several functional correlates reflecting sensory, motor and memory functions. You can see increased levels of alpha band power during mental and physical relaxation with eyes closed.
- By contrast, alpha power is reduced, or suppressed, during mental or bodily activity with eyes open.

Beta waves

Beta band (12- 25 Hz):

- Oscillations within the 12 – 25 Hz range are commonly referred to as beta band activity.
- This frequency is generated both in posterior and frontal regions.
- Active, busy or anxious thinking and active concentration are generally known to correlate with higher beta power.
- Over central cortex (along the motor strip), beta power becomes stronger as we plan or execute movements, particularly when reaching or grasping requires fine finger movements and focused attention.

Gamma waves

<u>Gamma band (above 25 Hz):</u>

- At the moment, gamma frequencies are the black holes of EEG research as it is still unclear where exactly in the brain gamma frequencies are generated and what these oscillations reflect.

EEG can be used to diagnose:

- Sleep disorder
- Anesthetic
- Coma
- Brain death
- Epileptic seizures: A disorder in which electrical activity of the neurons in the brain is disturbed.

For example: Temporary confusions, loss of consciousness or awareness, uncontrollable jerking movements of the arms and legs.

EEG: Frequency analysis

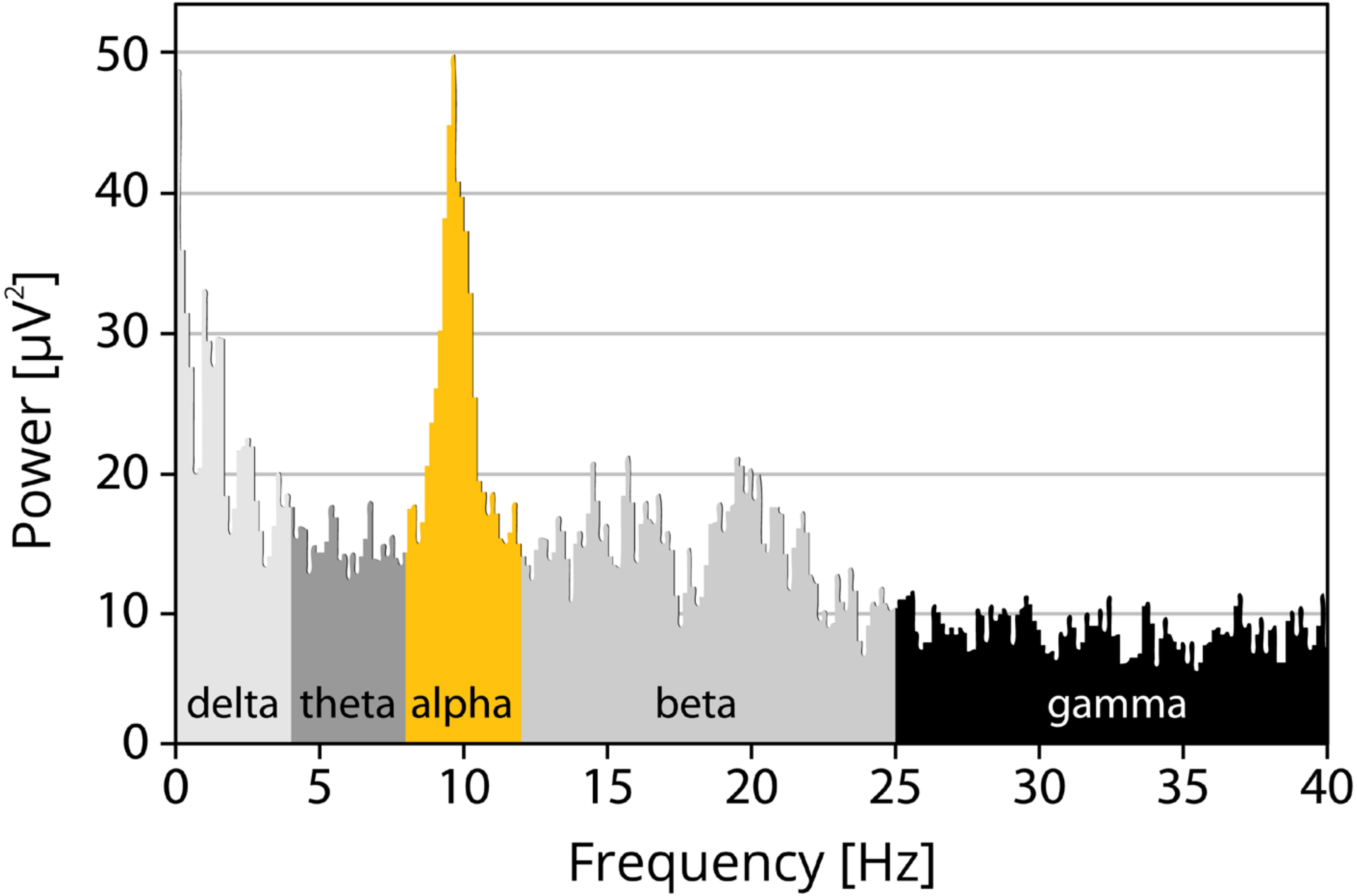
- The raw EEG signal is a time-course of voltages – it is a time-domain signal. If you plot the data, time is on the x-axis and voltage is on the y-axis.

- The Fast Fourier Transform (FFT) transforms the EEG signal into the frequency domain. If you plot this data, frequency is on the x-axis and voltage is on the y-axis.

- Some of the most widely used terms in frequency analysis is power, which reflects the strength of a specific frequency in the signal.

- Higher power means that the EEG signal contains a specific frequency to a larger extent. You could also say that the EEG signal is driven by a specific frequency.

Contd..



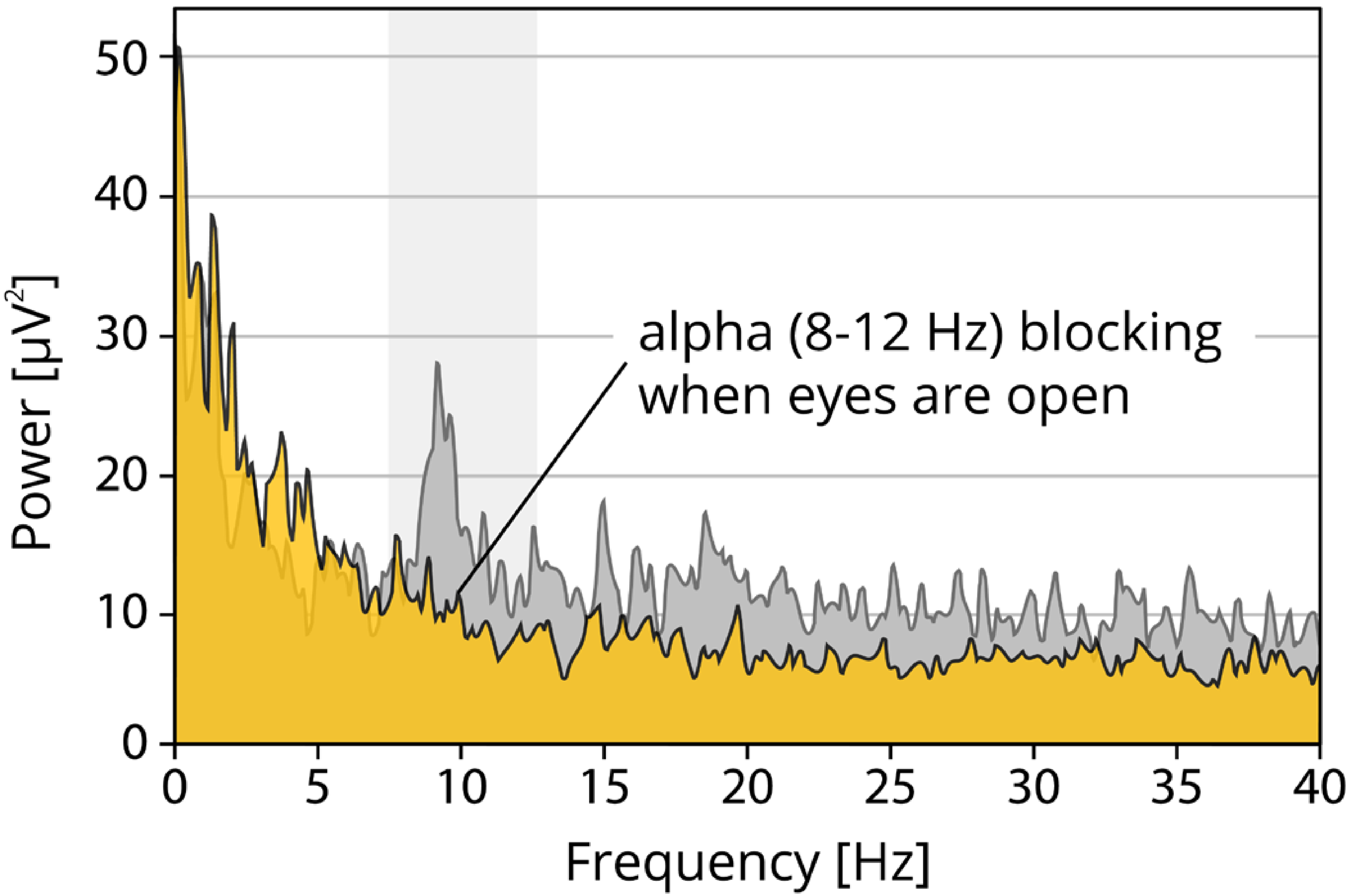
Power [μV²]
50
40
30
20
10
0
delta
theta
alpha
beta
gamma
0
5
10
15
20
25
30
35
40
Frequency [Hz]

Contd..

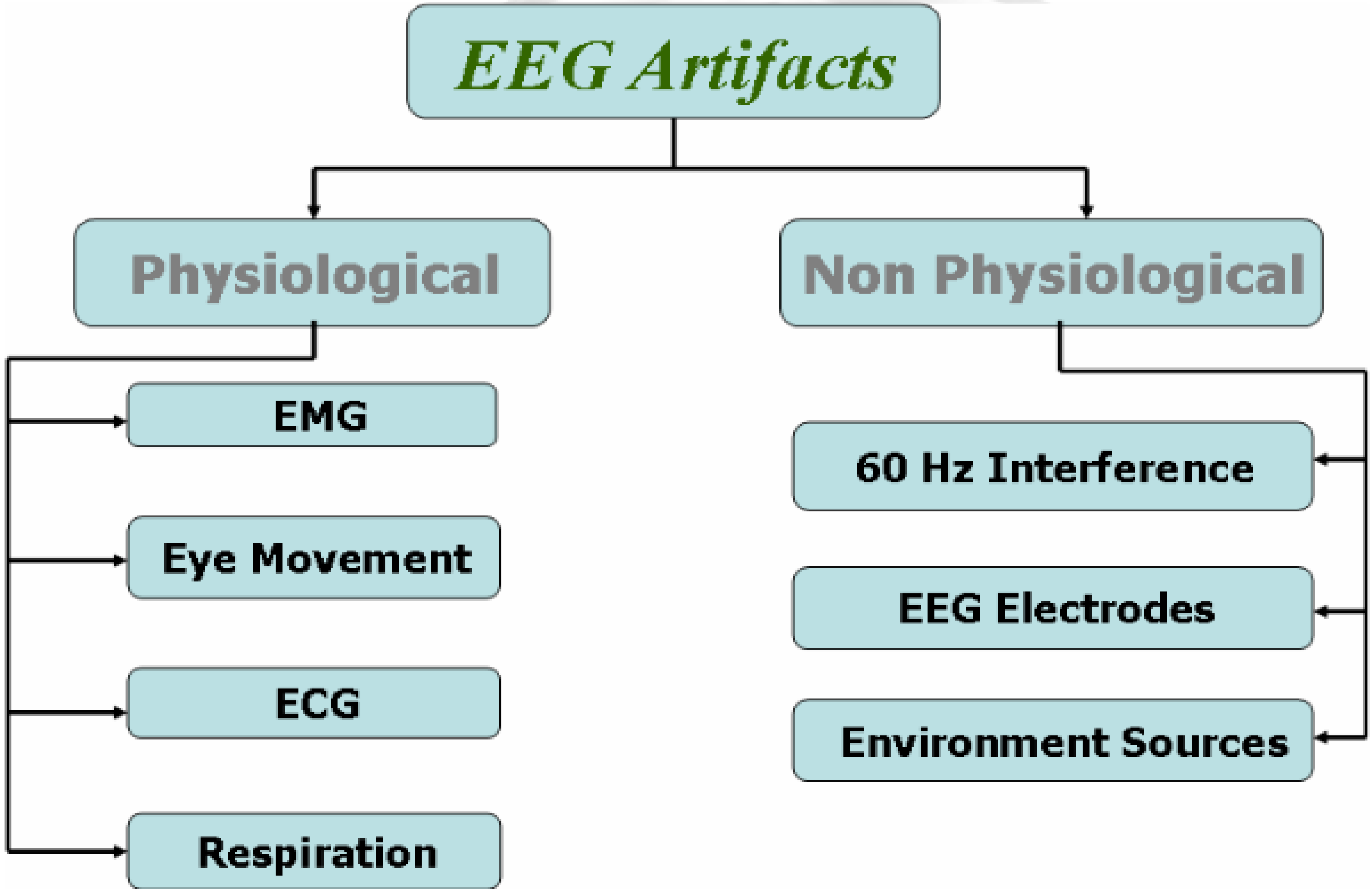
Consider an example:

- Record EEG data for 2 minutes from respondents and simply instruct them to keep their eyes open (they are certainly allowed to blink).
- Record EEG data for another 2 minutes and instruct respondents to close their eyes and focus on their inner thoughts and mental images.
- When you analyze both conditions separately with an FFT and extract the frequencies underlying the spontaneous EEG data, you will notice that the condition eyes closed shows much higher frequency power in the alpha band (8 – 12 Hz) as compared to the condition eyes open.
- This effect of reduced alpha power when opening the eyes is called alpha blocking and has been initially described by Hans Berger in 1929.

Contd..


Power [μV²]
50
40
30
20
10
0
alpha (8-12 Hz) blocking
when eyes are open
0
5
10
15
20
25
30
35
40
Frequency [Hz]

EEG artifacts

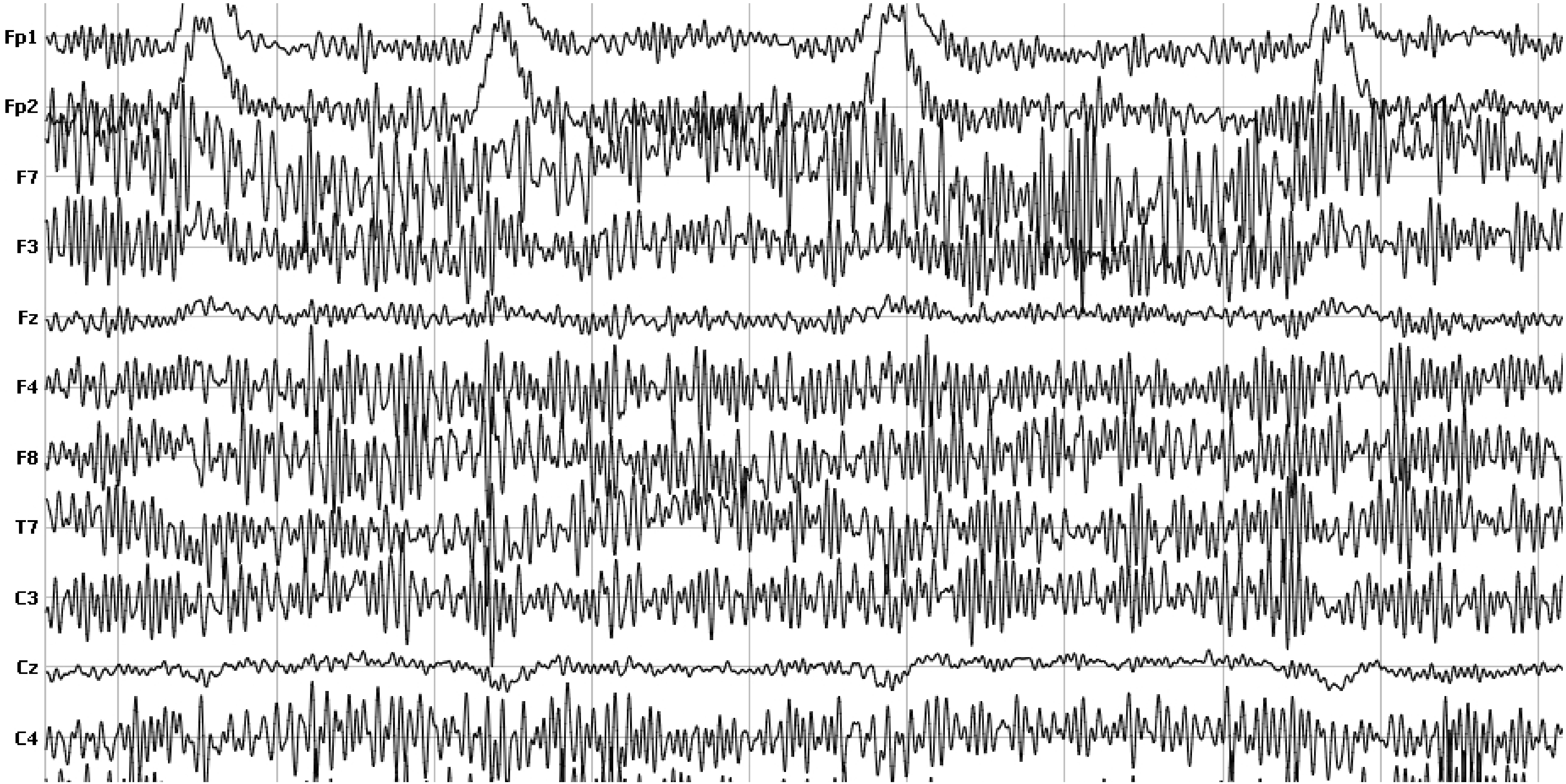


EMG & ECG

- Muscle activity (EMG) generates electric currents that are picked up by the electrodes. The closer the muscles are to the electrodes, the stronger their impact on the recording will be.

- Particularly the activity of facial muscles (forehead, cheek, mouth), neck muscles and jaw musculature has severe effects on EEG recordings.

- Since the heart is muscle, it also affects EEG data quality. Since hearts cannot be simply instructed to stop, you have to rely on signal decontamination procedures to remove ECG noise from EEG recordings.

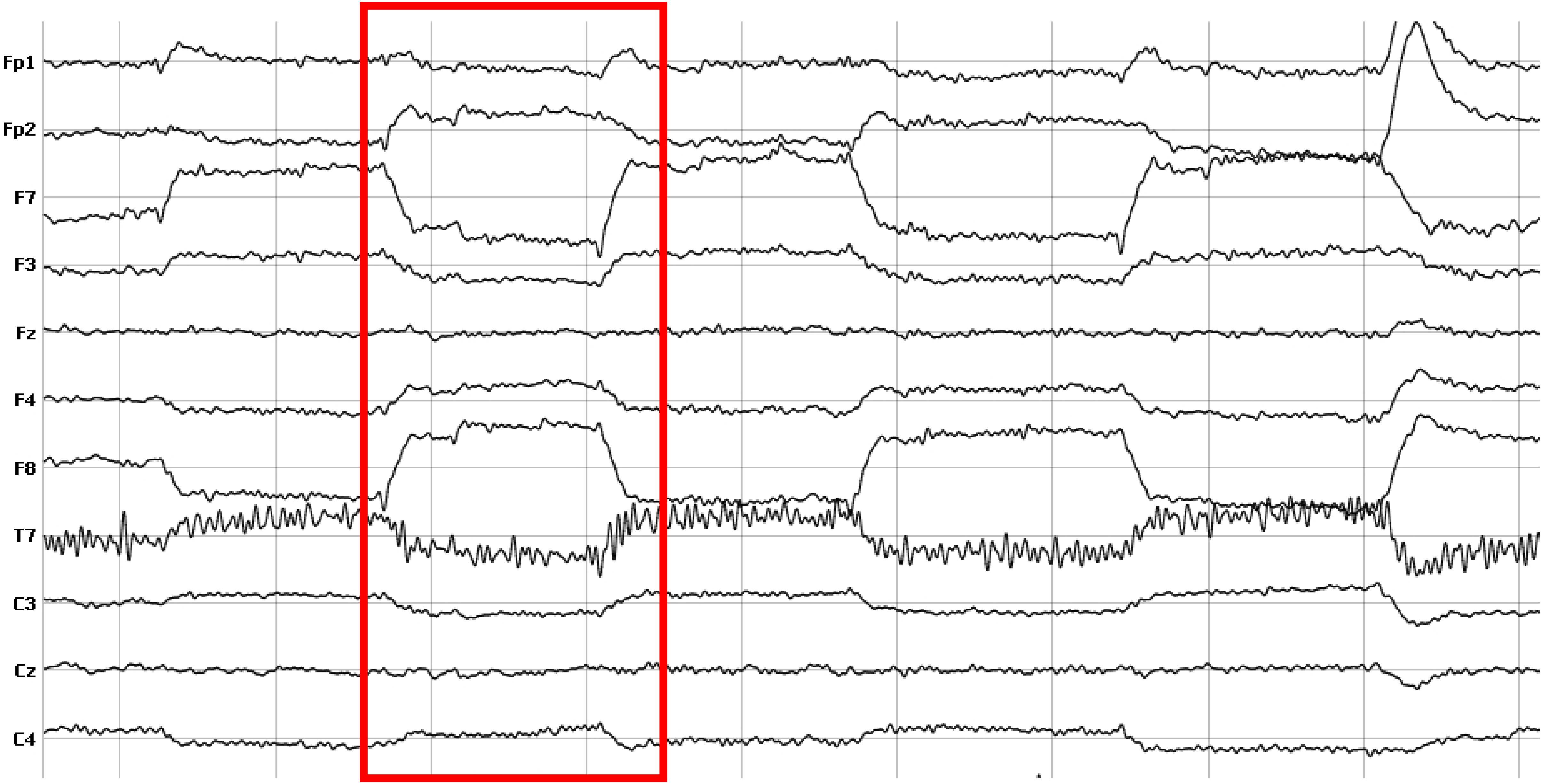


Fp1
Fp2
F7
F3
Fz
F4
F8
T7
C3
Cz
C4

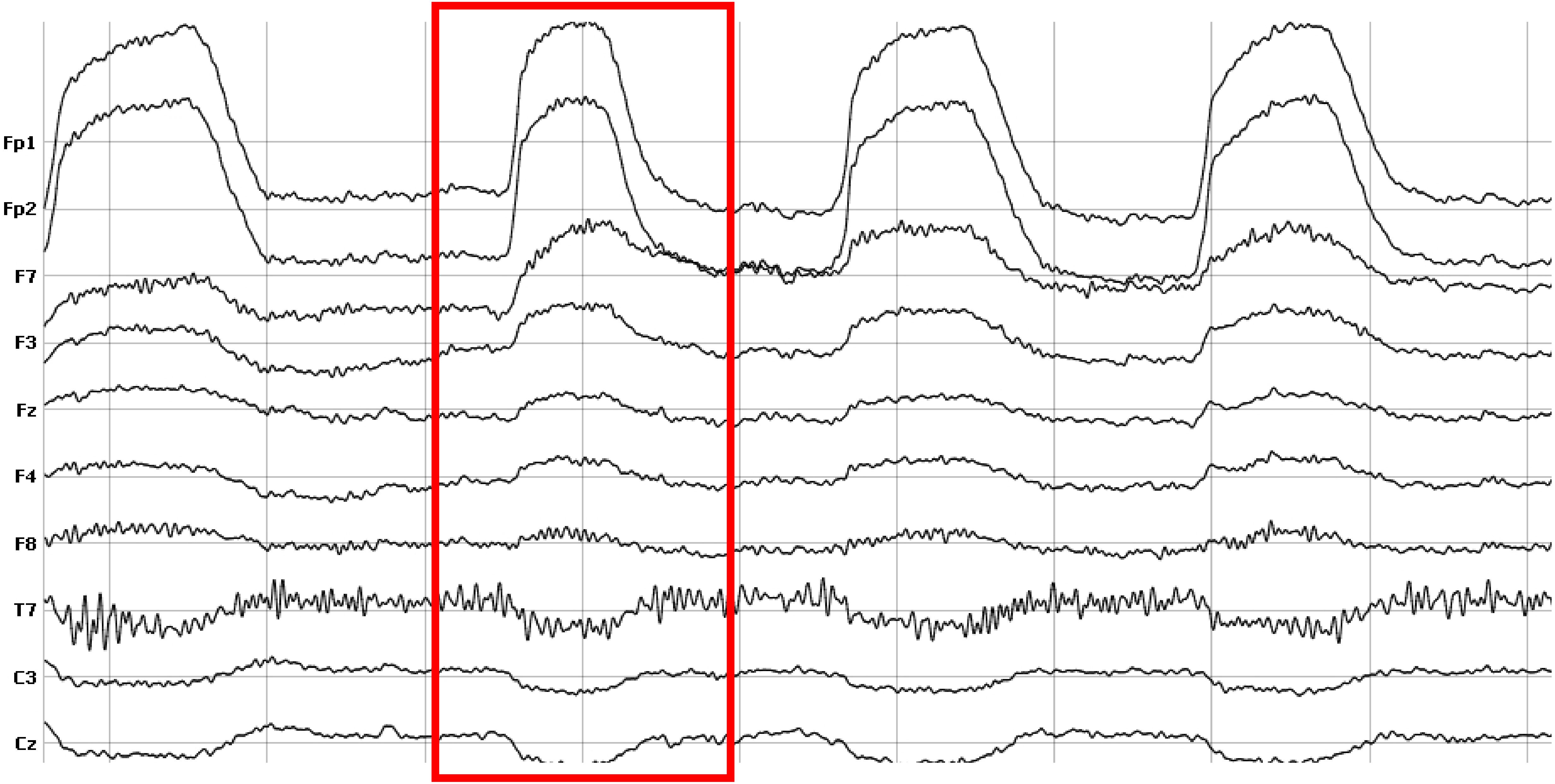
Eye movements & blinks

- Eye movements (horizontal and vertical) affect the electrical fields picked up by the electrodes.
- Vertical eye movements (up-down) look more sinusoidal, while horizontal eye movements (right-left) look more box-shaped.
- It's recommended to record eye movements using eye trackers or by placing additional EEG electrodes surrounding the eyes.
- Similar to eye movements, blinking interferes with brain signals quite a bit. If respondents blink while a certain stimulus is shown on screen, the EEG might not reflect the cortical processes of seeing the stimulus.
- As an EEG expert, you might tend to exclude this trial from the analysis since the EEG data does not contain relevant information

Eye movement



Eye blinking

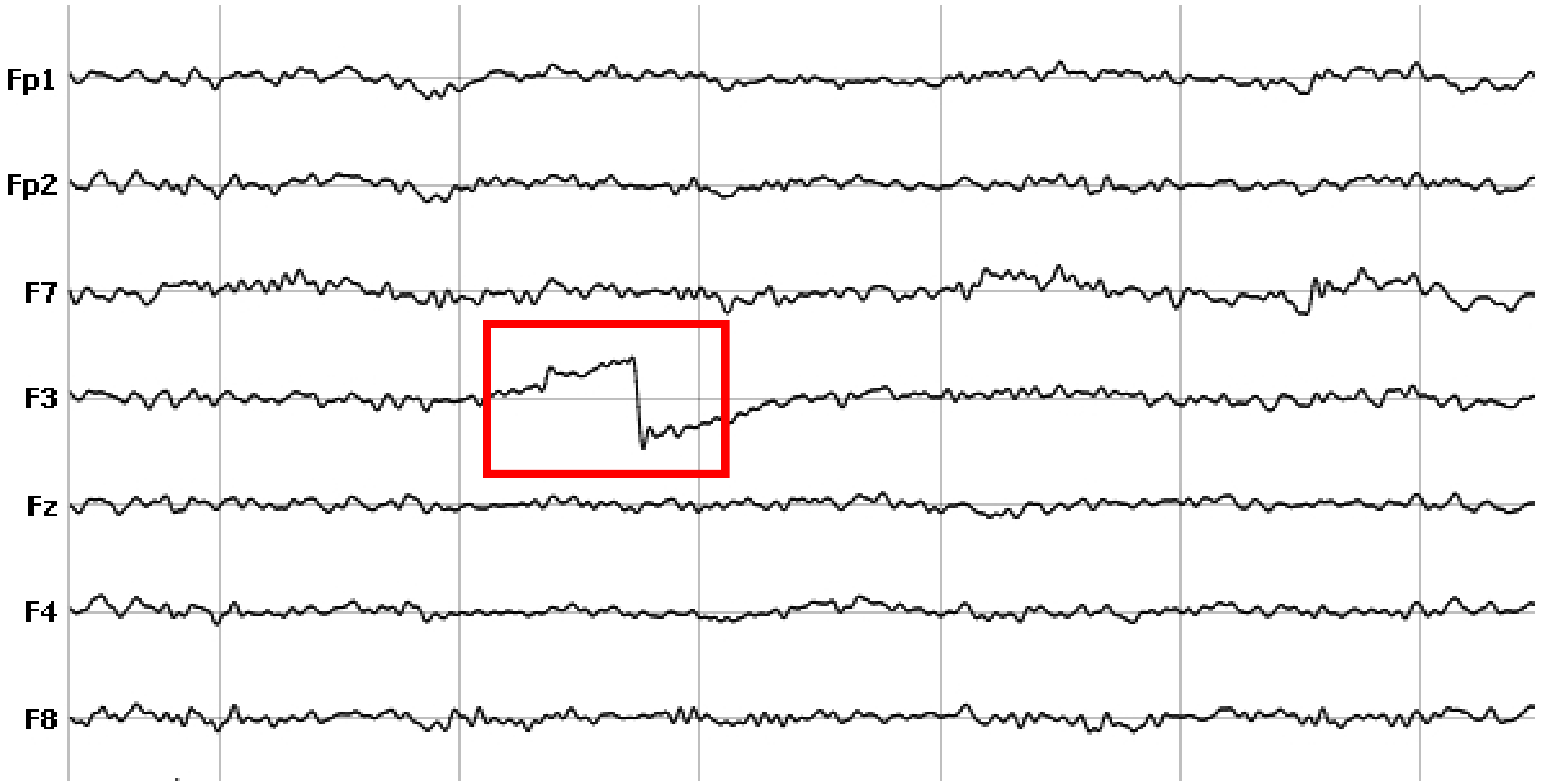


External sources of artifacts

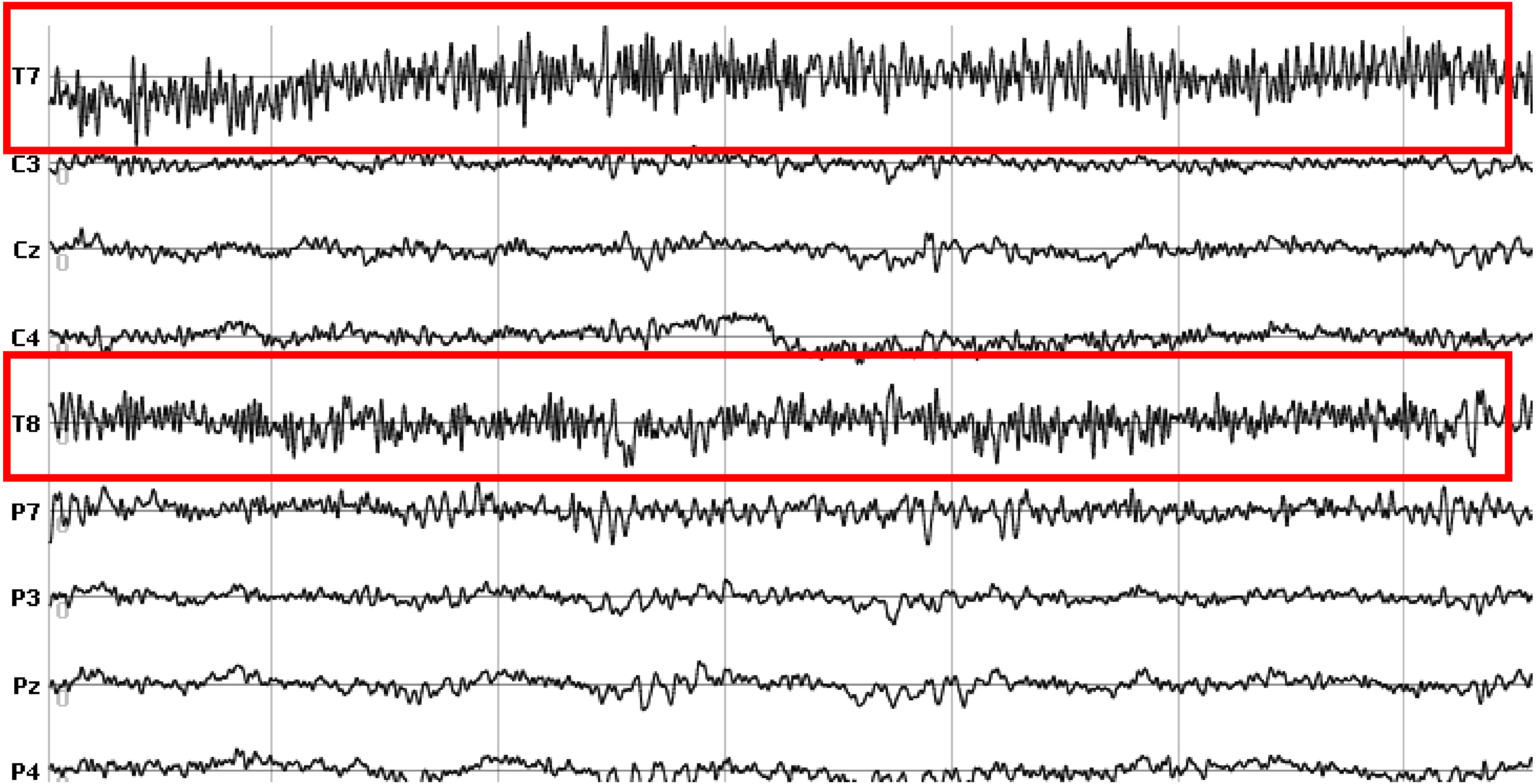
- Movement of an electrode or headset movements can cause severe artifacts that are visible in the affected channel or in all channels.
- The EEG headset becomes loose, an electrode loses contact with the socket. It's always recommended to make sure that the headset sits snug on the head, and that all electrodes are securely attached to the skin.
- Line noise (50 Hz in the US, 60 Hz in the EU) can have strong artifacts on the electrode recording
- If the reference electrode is affected, the captured line noise is propagated to all other electrodes.
- Glad fully, the cognitive frequencies of the brain are well below the 50 or 60 Hz range, allowing you to filter your data accordingly or focus on the frequencies of interest.

EEG headset with electrodes

Movement of an electrode



Line noise

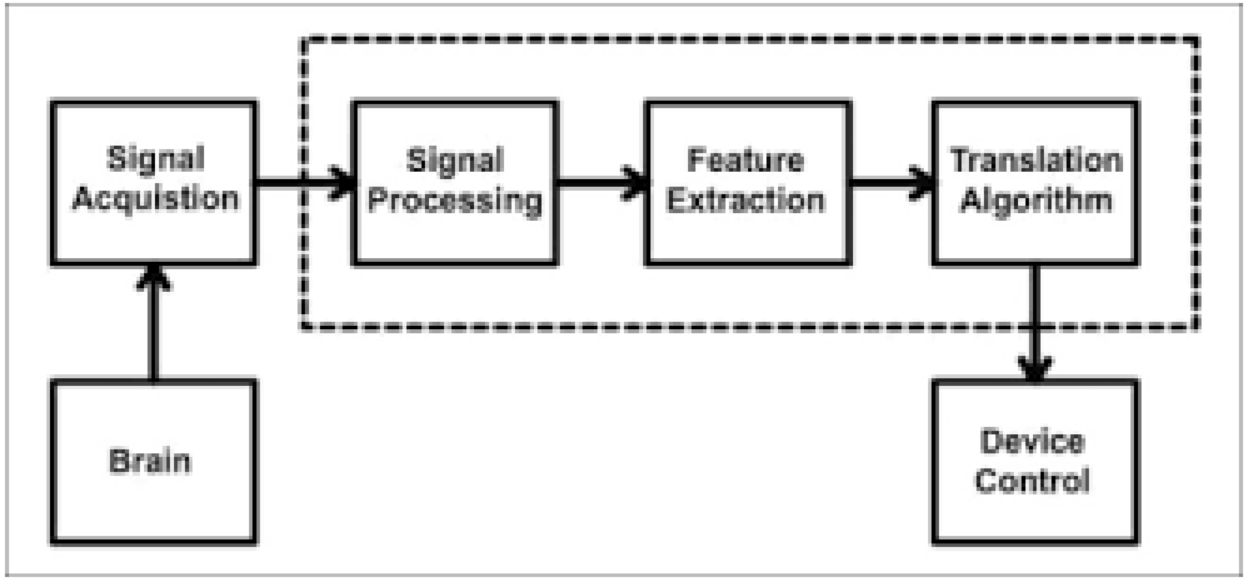


Application of EEG:BCI

- A Brain-Computer Interface (BCI) is a technology which allows a human to control a computer, or other electronic device with thought.

- In other words, a system which connects the human brain to an external device.

- BCI acquire EEG signal from the human brain, recognizes and translates the specific brain signal patterns into a device control command through the signal processing algorithm.



Event Related Potentials (ERPs)

- The goal of event-related EEG paradigms is to collect those brain processes which are triggered by external stimuli.
- There’s strong ongoing EEG activity and random noise completely unrelated to the onset of a stimulus. Think of this as your inner “default activity“ (your ongoing thoughts and mental states).
- When you present a stimulus, you trigger stimulus-related EEG activity.
- Here is one example: Showing the picture of a face (stimulus) triggers brain processes related to face perception. These processes are much smaller compared to the ongoing activity.

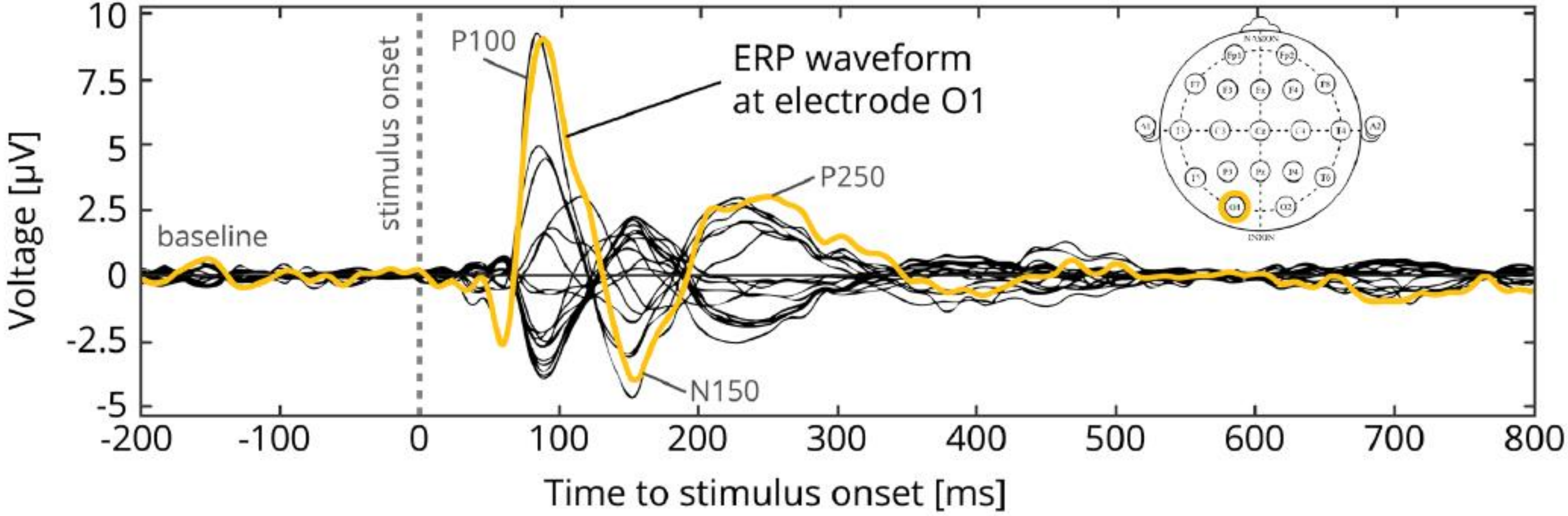
Contd..

- In order to uncover the stimulus-related EEG data from the unrelated ongoing data, the stimulus is shown several times - 50 times or more.

- At the end of the data collection, you will have 50 trials, which are data portions time-locked to stimulus-onset and typically range from about 200 ms prior to stimulus onset to 1000 ms after stimulus onset.

- Each trial is a time-course of data at each electrode. The selection of data portions from the continuous EEG recording is called epoching or segmentation.

Contd..



10
7.5
5
2.5
0
-2.5
-5
Voltage [μV]
baseline
stimulus onset
P100
ERP waveform
at electrode O1
P250
N150
-200
-100
0
100
200
300
400
500
600
700
800
Time to stimulus onset [ms]

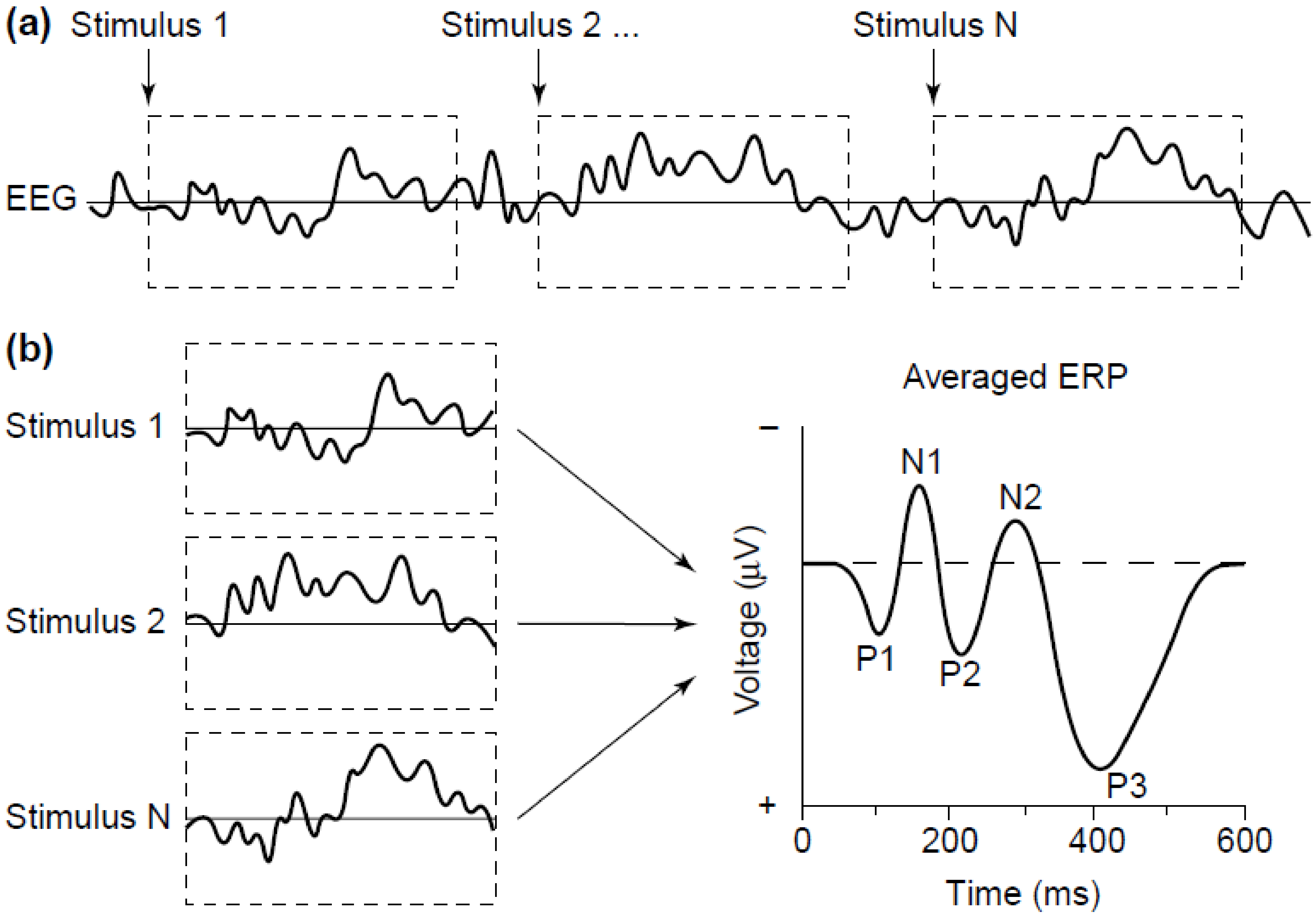
Contd..

- After the exclusion of epochs containing artifacts (or the correction of data due to blinking, for example), the remaining epochs are averaged sample by sample, resulting in an average time-course of EEG data.

- By averaging the EEG time-courses of all trials, only the stimulus-related EEG activity survives while the unrelated random background noise is attenuated (the more repetitions you complete, the cleaner the event-related EEG data will be).

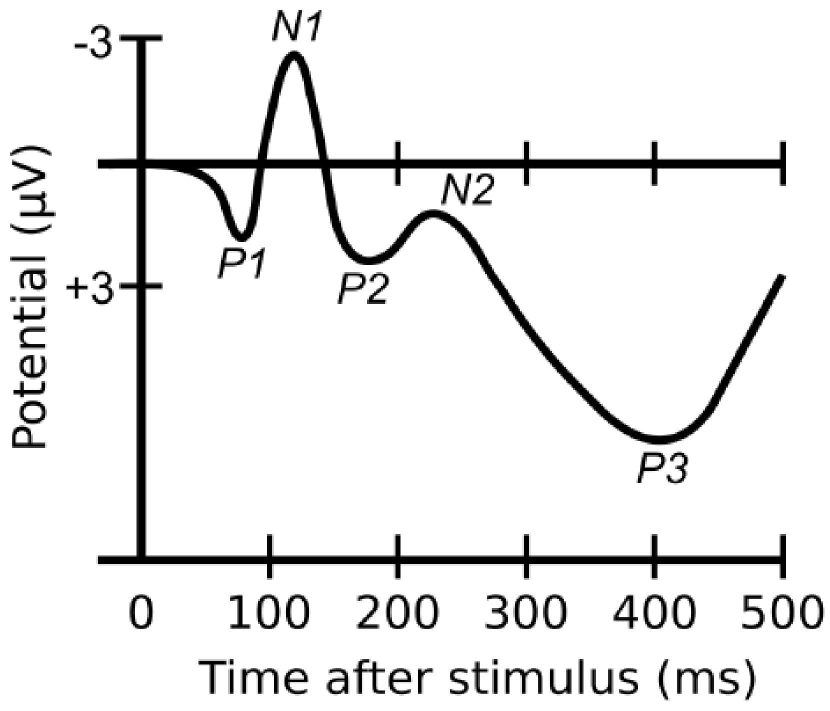
- The remaining average EEG waveform is the event-related potential, which reflects the average stimulus-related EEG activity as triggered by a specific stimulus.

- Research has identified ERPs for all sensory modalities - vision, touch and sound, olfaction and haptic stimuli.

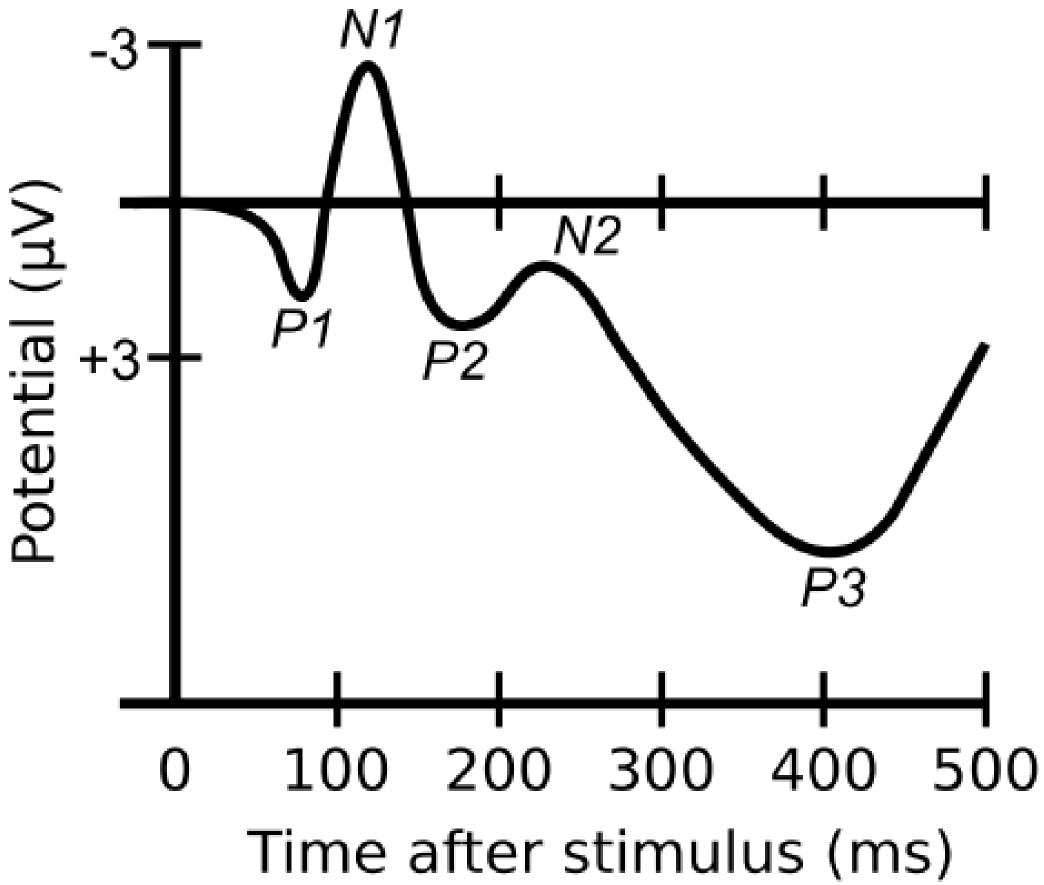

(a)
Stimulus 1
Stimulus 2 ...
Stimulus N
EEG
(b)
Stimulus 1
Stimulus 2
Stimulus N
Averaged ERP
−
+
Voltage (μV)
N1
N2
P1
P2
P3
0
200
400
600
Time (ms)

ERP measurements

- **Amplitude**: Voltages
- **Latency**: from the time of the stimulus to the time of the peak.
- Peaks at a particular latency are called as **components**.
- **Early wave** (before 100 ms): sensory reaction to physical characteristics. Which part of the brain is encoding this information?
- **Late wave** (after 100 ms): cognitive interpretation of the stimulus.



ERP components



Significance of ERP components

- **P1 (P100):** A positive deflection peaking around ~ 100 ms. Responsible for Initial Perception.
- **N1 (N100):** A negative deflection peaking between ~ 90 and 200 ms after the onset of the stimulus. Responsible for Perception and attention.
- **P2 (P200):** A positive deflection peaking between ~ 100 - 250 ms after the onset of the stimulus. Responsible for Interpretation.
- **N2 (N200):** A negative deflection peaking between ~ 190 and 300 ms after the stimulus onset. Responsible for classification.
- **P3 (P300):** A positive deflection peaking between ~ 300 and 400 ms after the stimulus onset. Cognitive processing (e.g., Memory updating).

Contd..

- **P50**:occurs approximately 50 ms (between 40 and 75 ms) after the presentation of a stimulus (e.g., auditory clicks). Used to measure sensory gating.

- Sensory gating (gating or filtering) describes neurological processes of filtering out redundant or unnecessary stimuli in the brain from all possible environmental stimuli.

- Sensory gating prevents an overload of irrelevant information in the higher cortical areas of the brain by paying attention largely to the target stimulus.

- **N300:**Recent finding, related to semantics.

- **N400** and **P600**: Language processing.

Pathological conditions from ERPs

Phobia: Produces a significant larger amplitude in P300.

Panic disorder: longer latency of P300.

Anxiety disorder: larger amplitude of P300.

Posttraumatic stress disorder: Reduced P50, P300

Depression: Reduced P300

Alcohol consumption: reduced N1, P2, and P3 amplitudes, increase in latency of N200.