Lecture - 05

THE NERVOUS SYSTEM, EEG AND MEG

THE NERVOUS SYSTEM (NS)

The NS is formed of a big number of cells, which are of 2 types:

1. Nerve cells = Neurons
2. Supporting cells = Glial cells

NEURONS

- It is the basic structural unit of the NS.
- It generates electrical impulses → transmitted from one part of the body to another.
- In most neurons: electrical impulses → release of chemical messengers (**neurotransmitters**) to communicate with each other.
- Neurons are integrators: their output = the sum of the inputs they receive from thousands of other neurons that end on them.

STRUCTURE OF NEURON

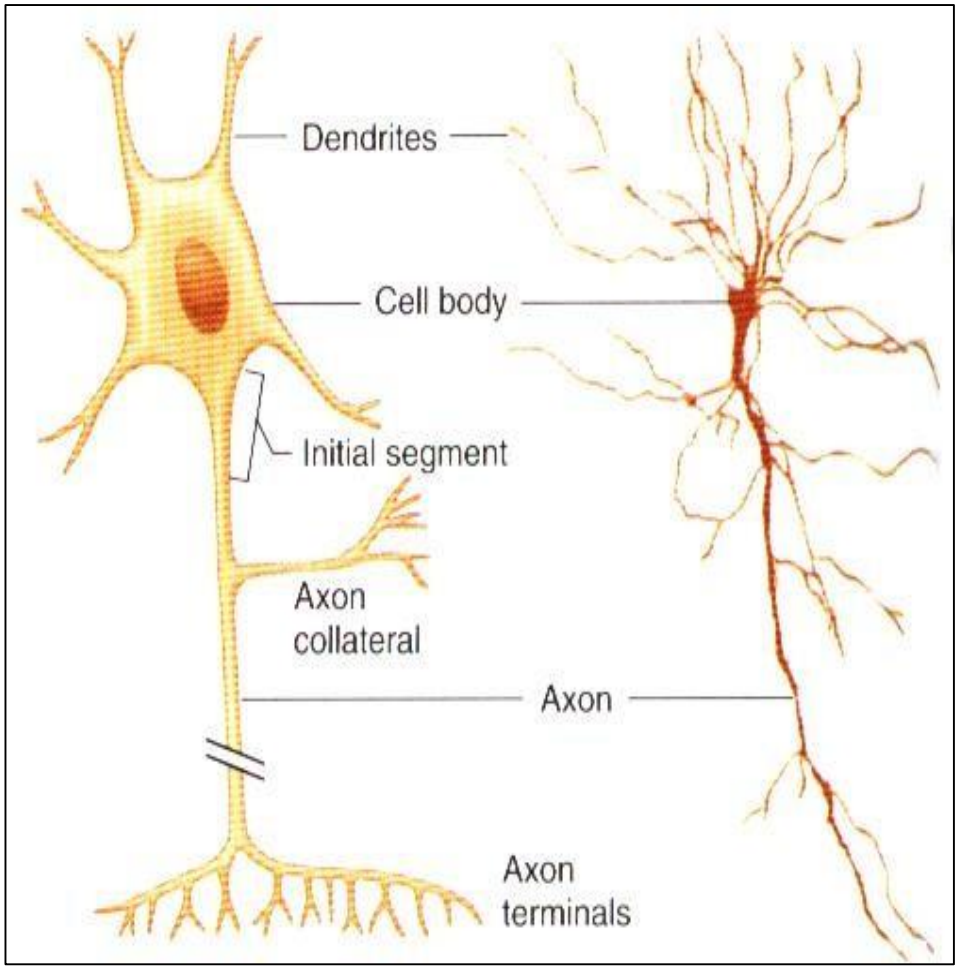
Neurons occur in a wide variety of shapes and sizes, but they share common features. They all possess 4 parts:

1. Cell Body = Soma: It contains:

- a nucleus
- ribosomes
- mitochondria & other organelles

2. Dendrites:

- Usually 5-7 processes
- Usually highly branched (up to 400,000)
- Together with cell body, dendrites receive most input.
- Transmit impulses toward cell body only.



STRUCTURE OF NEURON…

3. Axon = Nerve Fiber:

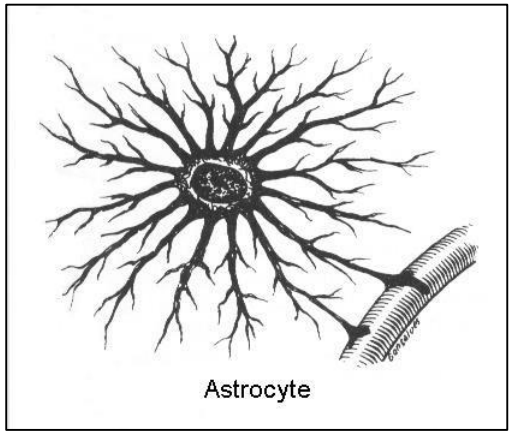
- Usually single & long (few µm to > 1m).
- Transmits impulses away from soma toward target cell.
- Axon hillock or initial segment (= beginning of axon + part of soma where axon joins it) is the trigger zone where electric signals are generated in most neurons. Signals are then propagated along axon.
- Axon may have branches = collaterals.
- Near its end the axon undergoes branching. The greater the no. of branches, the greater the sphere of influence of a neuron.

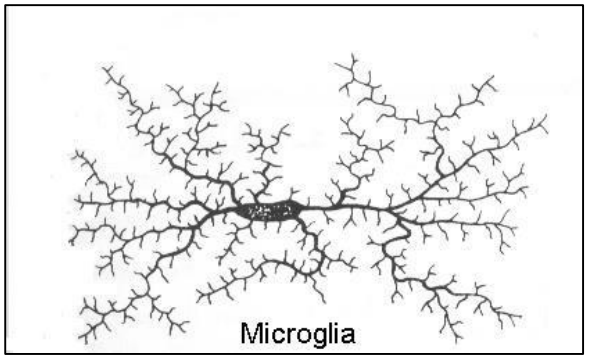
4. Axon Terminal = Terminal Button:

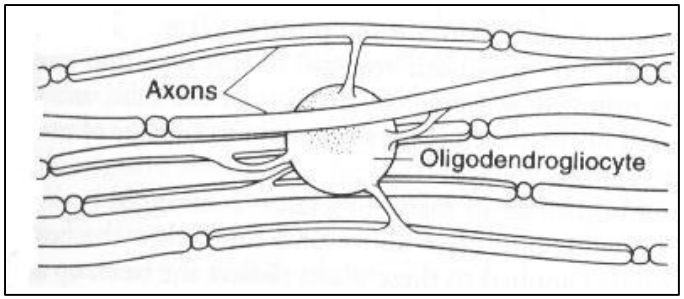
- Each branch of the axon ends in an axon terminal.
- Responsible for the release of neurotransmitters (NT) from axon. NT diffuse out of the axon terminal to next neuron or to a target cell.

GLIAL CELLS

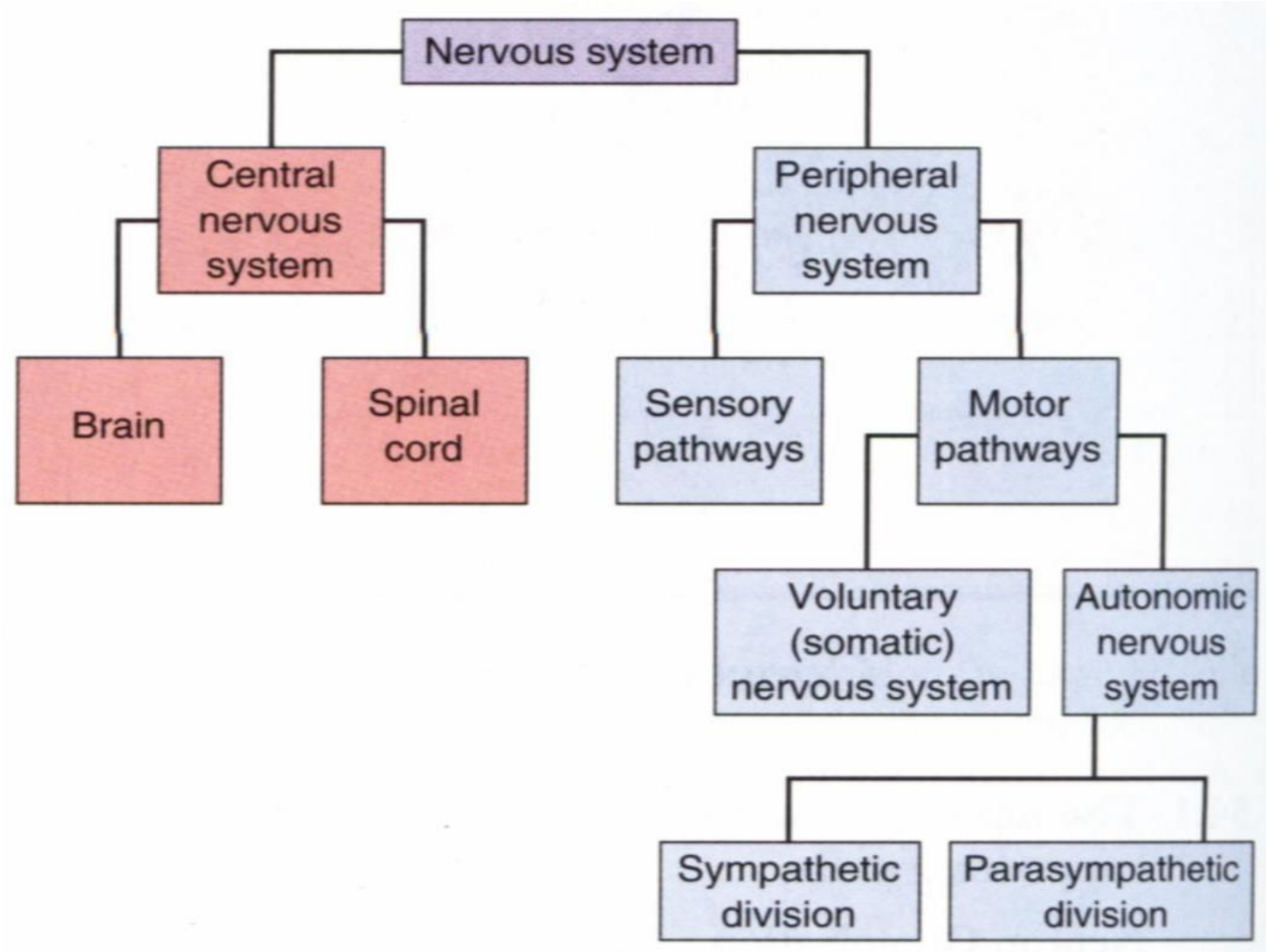
- Act as supporting cells (glia = glue)
- They surround neurons & support them physically & metabolically.
- They constitute 90% of cells in CNS.







ANATOMICAL ORGANIZATION OF NERVOUS SYSTEM



ANATOMICAL ORGANIZATION OF NERVOUS SYSTEM

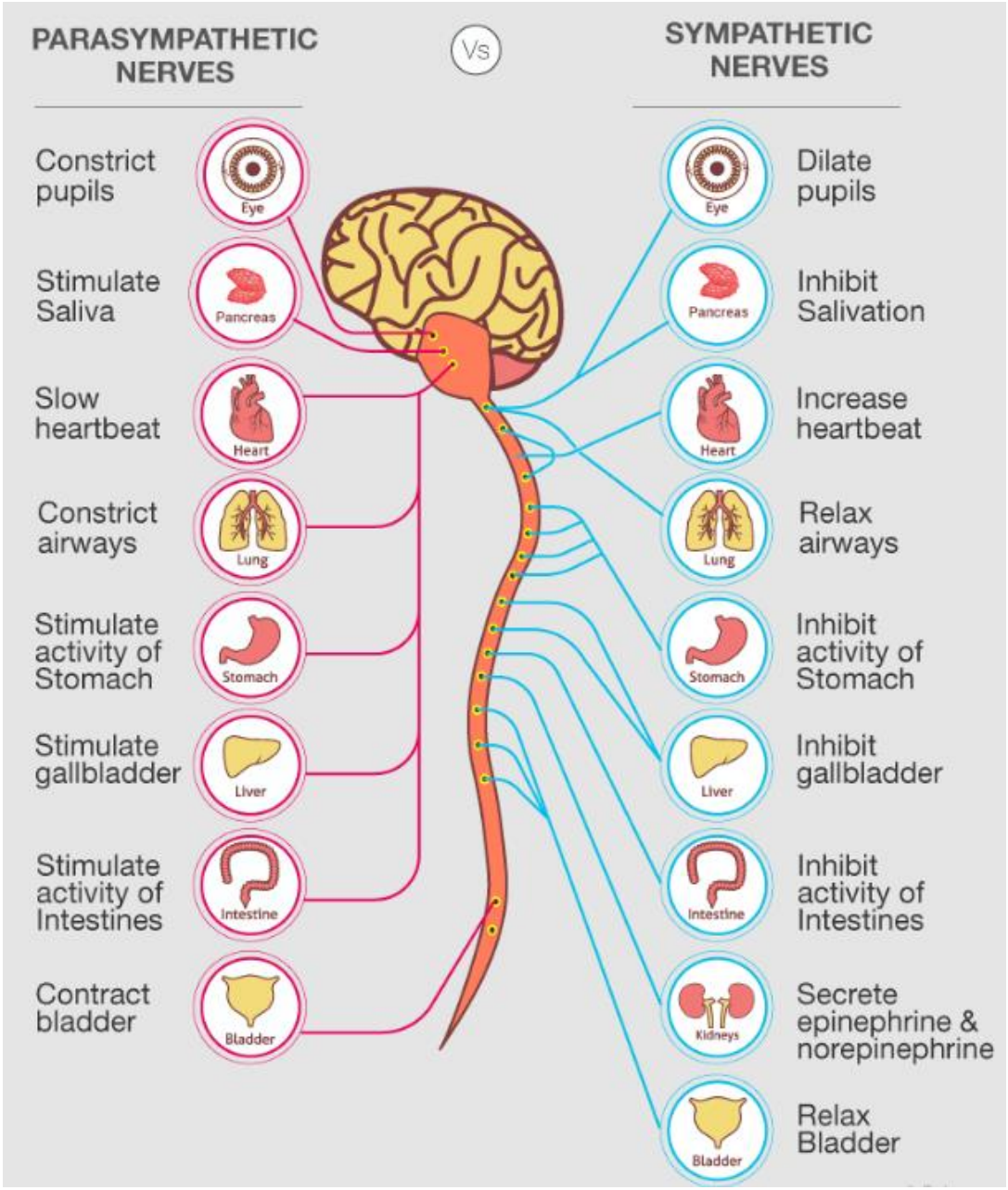
Central Nervous System (CNS):

- Brain & spinal cord
- Housed in bony structures: skull & vertebral column

Peripheral Nervous System (PNS):

- Transmits signals to & from CNS.
- Consists of nerves that extend between

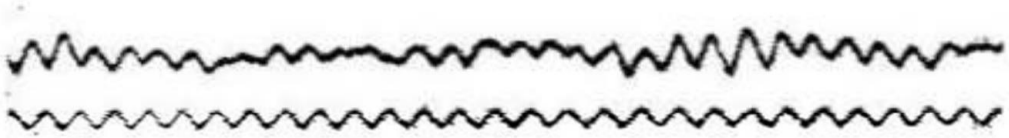
brain & spinal cord ⟷ skeletal, smooth & cardiac muscles and glands


PARASYMPATHETIC NERVES
Vs
SYMPATHETIC NERVES
Constrict pupils
Eye
Stimulate Saliva
Pancreas
Slow heartbeat
Heart
Constrict airways
Lung
Stimulate activity of Stomach
Stomach
Stimulate gallbladder
Liver
Stimulate activity of Intestines
Intestine
Contract bladder
Bladder
Dilate pupils
Eye
Inhibit Salivation
Pancreas
Increase heartbeat
Heart
Relax airways
Lung
Inhibit activity of Stomach
Stomach
Inhibit gallbladder
Liver
Inhibit activity of Intestines
Intestine
Secrete epinephrine & norepinephrine
Kidneys
Relax Bladder
Bladder

ELECTROENCEPHALOGRAM (EEG)

Introduction

- A medical imaging technique
- A measurement of the electrical activity of the brain.
- The recording of the brain's spontaneous electrical activity over a short period of time, usually 20–40 minutes, as recorded from multiple electrodes placed on the scalp.



ELECTROENCEPHALOGRAM (EEG)

- The first recordings were made by Hans Berger in 1929.

Über das Elektrenkephalogramm des Menschen.

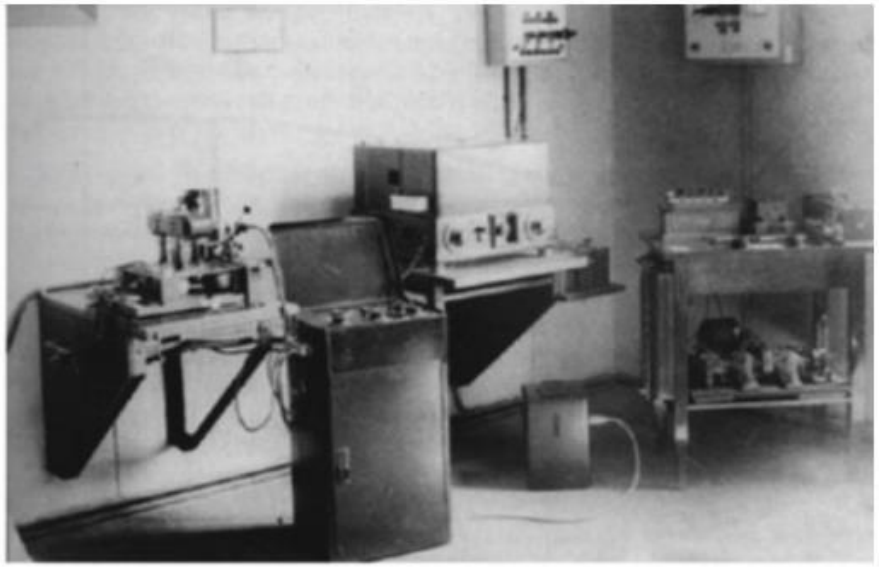
Von

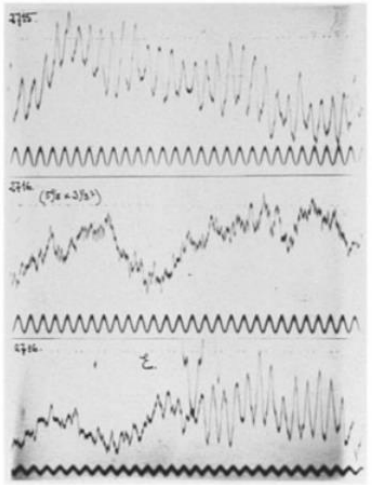
Professor Dr. **Hans Berger**, Jena.

(Mit 17 Textabbildungen.)

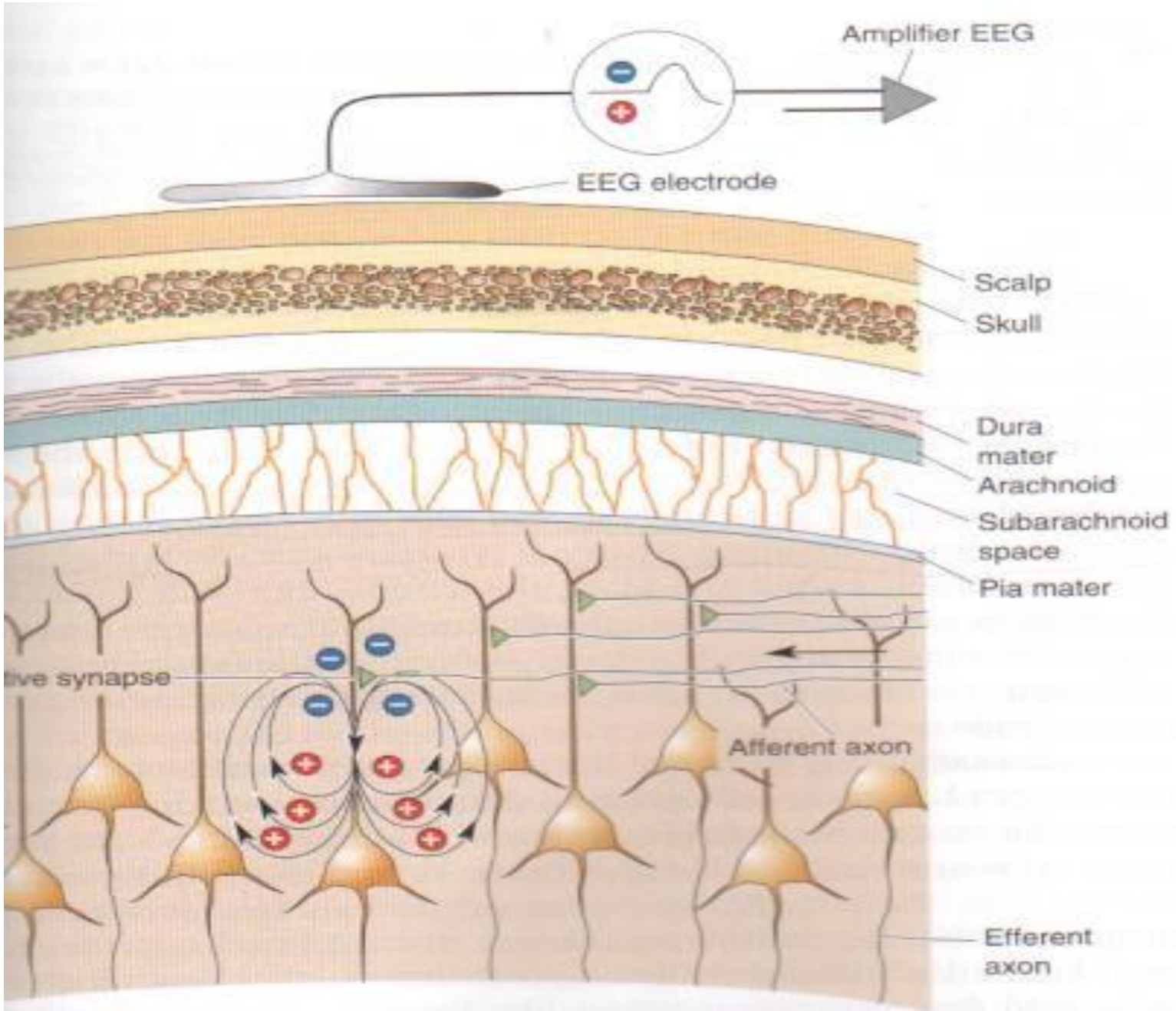
(Eingegangen am 22. April 1929.)

Wie *Garten* [1], wohl einer der besten Kenner der Elektrophysiologie, mit Recht hervorgehoben hat, wird man kaum fehlgehen, wenn man jeder lebenden Zelle tierischer und pflanzlicher Natur die Fähigkeit zuschreibt, elektrische Ströme hervorzubringen. Man bezeichnet solche Ströme als bioelektrische Ströme, weil sie die normalen Lebenserscheinungen der Zelle begleiten. Sie sind wohl zu unterscheiden von den durch Verletzungen künstlich hervorgerufenen Strömen, die man als Demarkations-, Alterations- oder Längsquerschnittsströme bezeichnet hat. Es war von vornherein zu erwarten, daß auch im Zentralnervensystem, das doch eine gewaltige Zellanhäufung darstellt, bioelektrische Erscheinungen nachweisbar seien, und in der Tat ist dieser Nachweis schon verhältnismäßig früh erbracht worden.



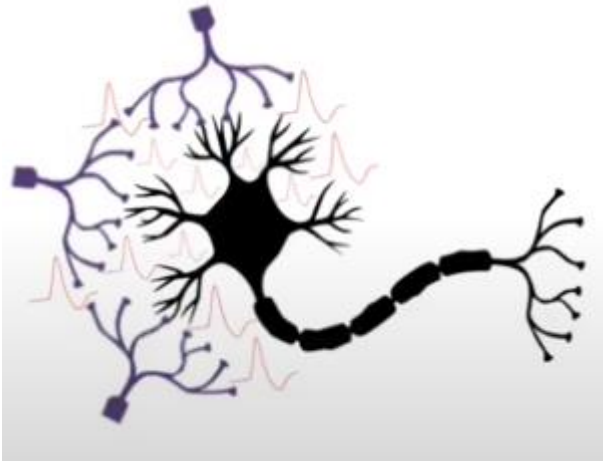


PHYSIOLOGICAL BASIS OF THE EEG



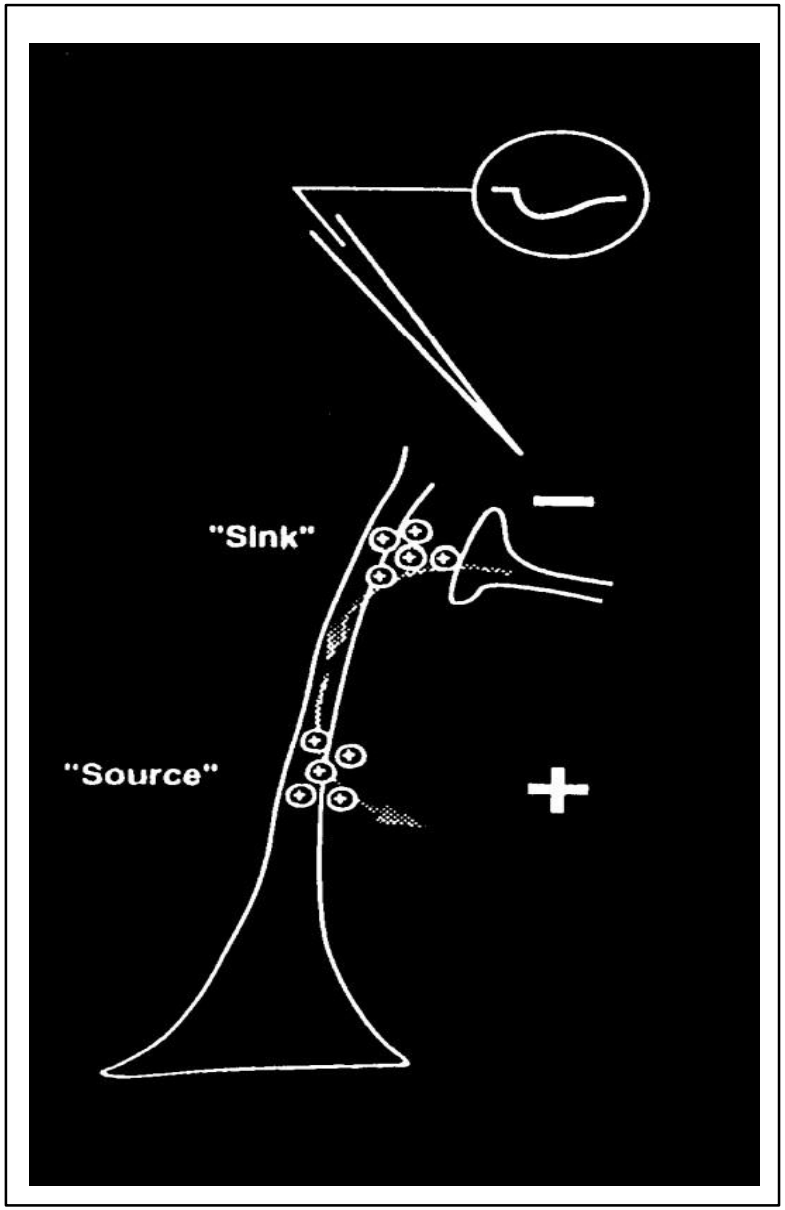
PHYSIOLOGICAL BASIS OF THE EEG

Pre-synaptic action potential



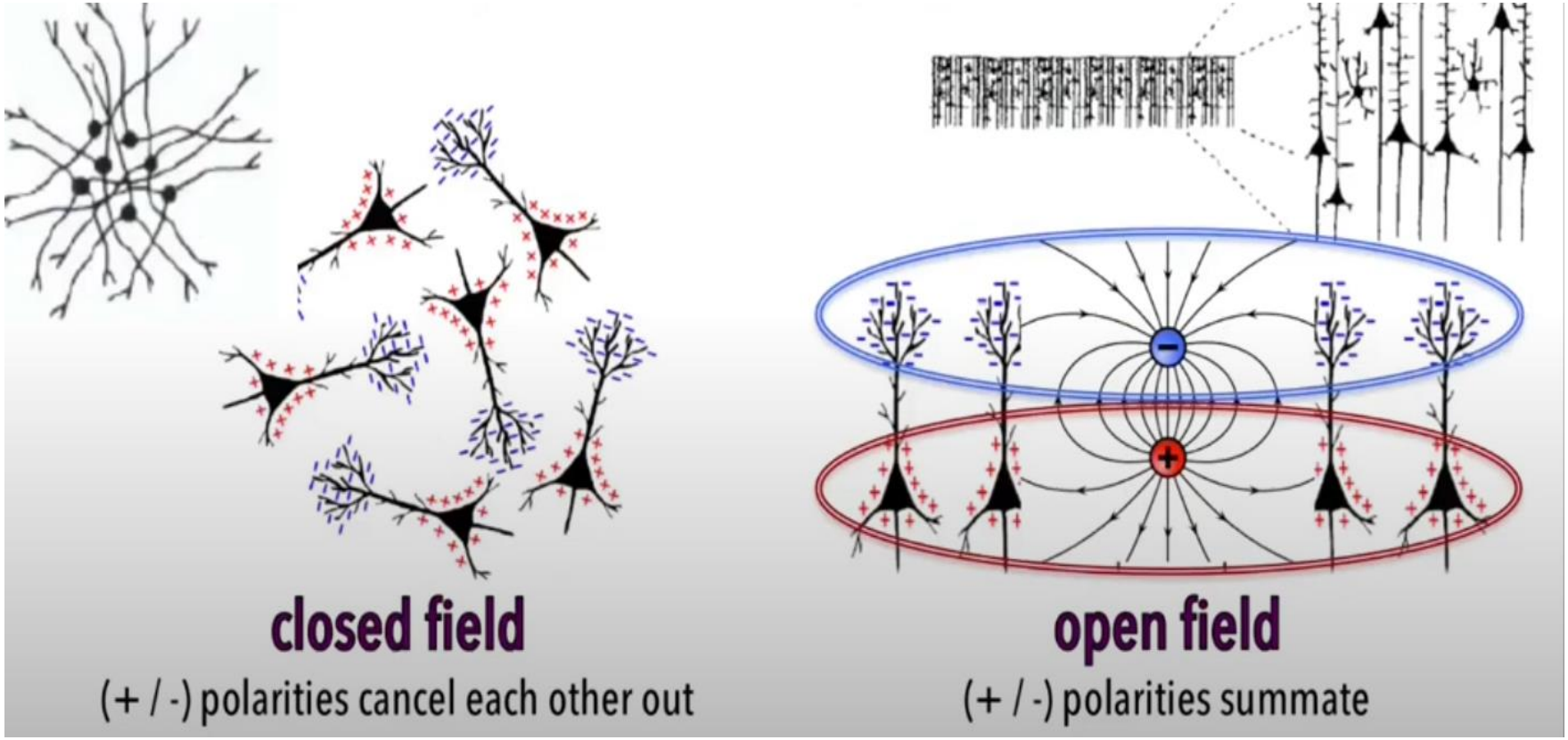
Post-synaptic action potential

PHYSIOLOGICAL BASIS OF THE EEG…

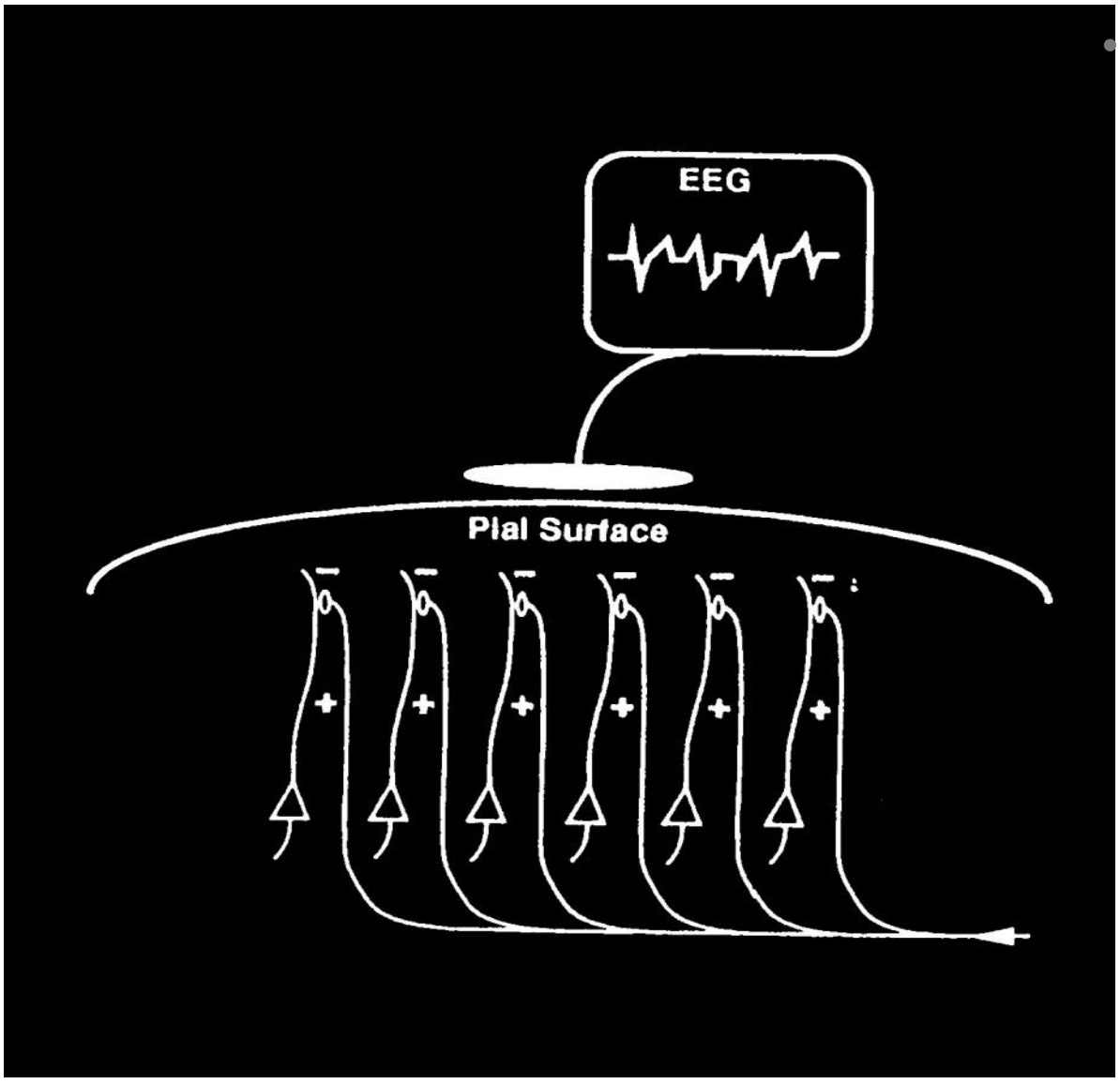


- Extracellular dipole generated by excitatory post-synaptic potential at apical dendrite of pyramidal cell

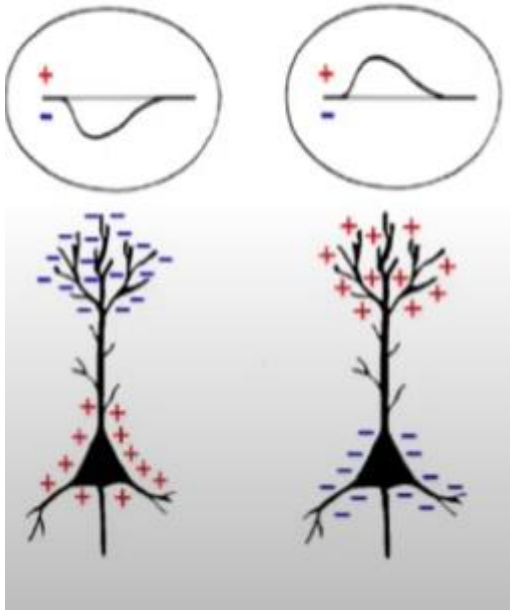
PHYSIOLOGICAL BASIS OF THE EEG



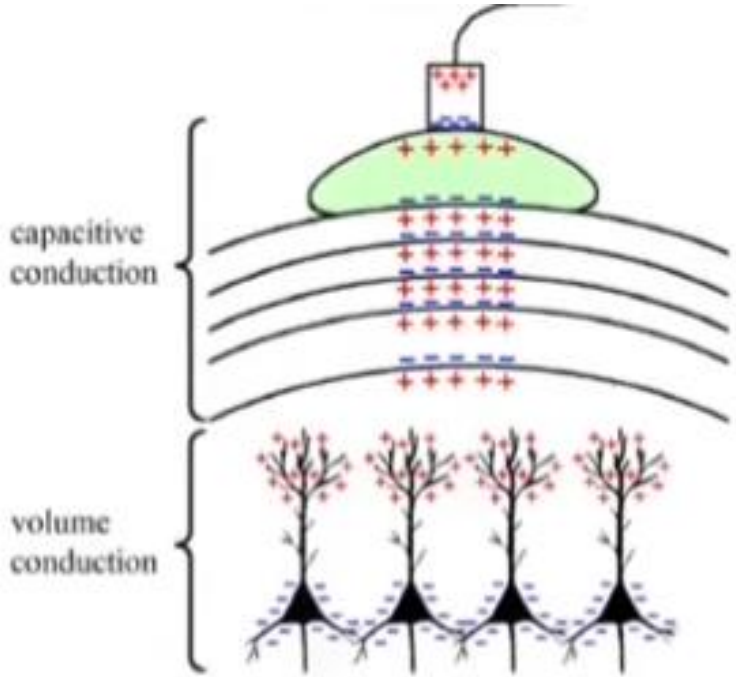
PHYSIOLOGICAL BASIS OF THE EEG…



Electrical field generated by similarly oriented pyramidal cells in cortex and detected by scalp electrode



PHYSIOLOGICAL BASIS OF THE EEG…



Applications

- Monitor alertness, coma and brain death
- Locate areas of damage following head injury, stroke, tumour, etc.
- Test afferent pathways (by evoked potentials)
- Monitor cognitive engagement (alpha rhythm)
- Produce biofeedback situations, alpha, etc.
- Control anaesthesia depth
- Investigate epilepsy and locate seizure origin
- Test epilepsy drug effects
- Assist in experimental cortical excision of epileptic focus
- Monitor human and animal brain development
- Test drugs for convulsive effects
- Investigate sleep disorder and physiology

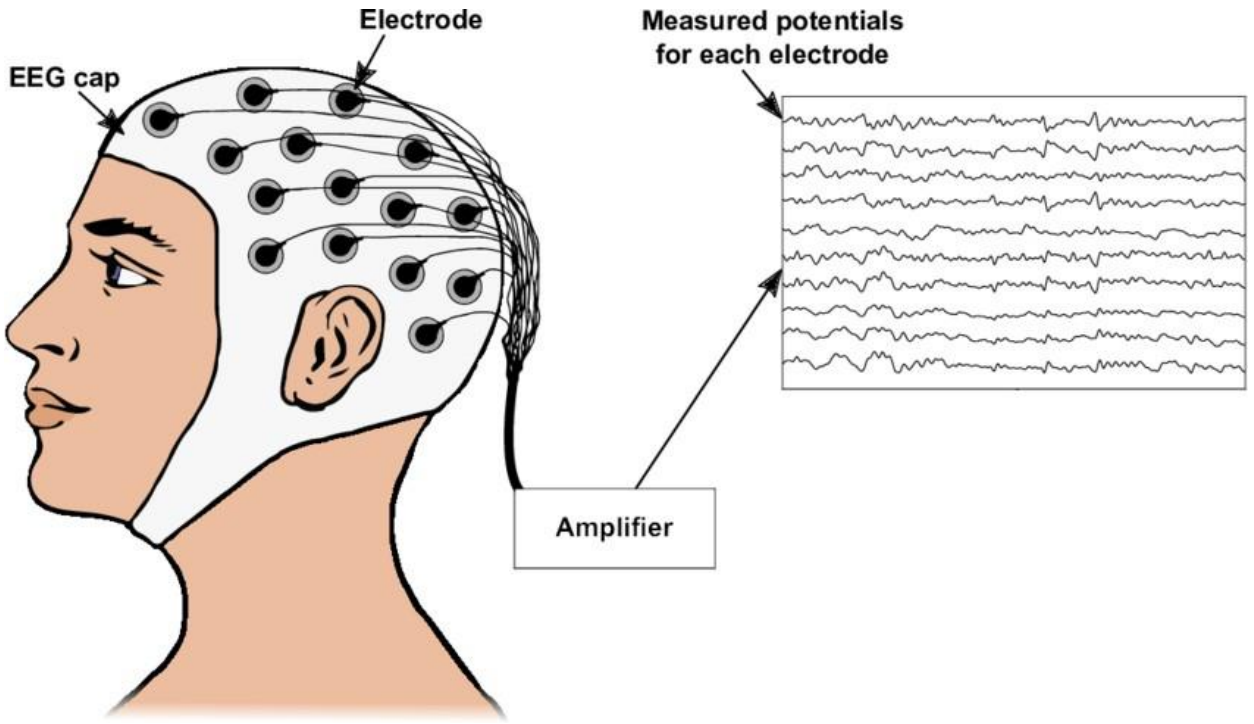
Methodology

- Non-invasive and painless
- To study the brain organization of cognitive processes such as perception, memory, attention, language and emotion in normal adults and children.
- Major components;

1. Electrodes with conductive media
2. Amplifiers with filters
3. A/D converter
4. Recording device

- Electrodes read the signal from the head surface, amplifiers bring the microvolt signals into the range where they can be digitalized accurately, converter changes signals from analog to digital form and personal computer stores and displays obtained data.

EEG ACQUISITION

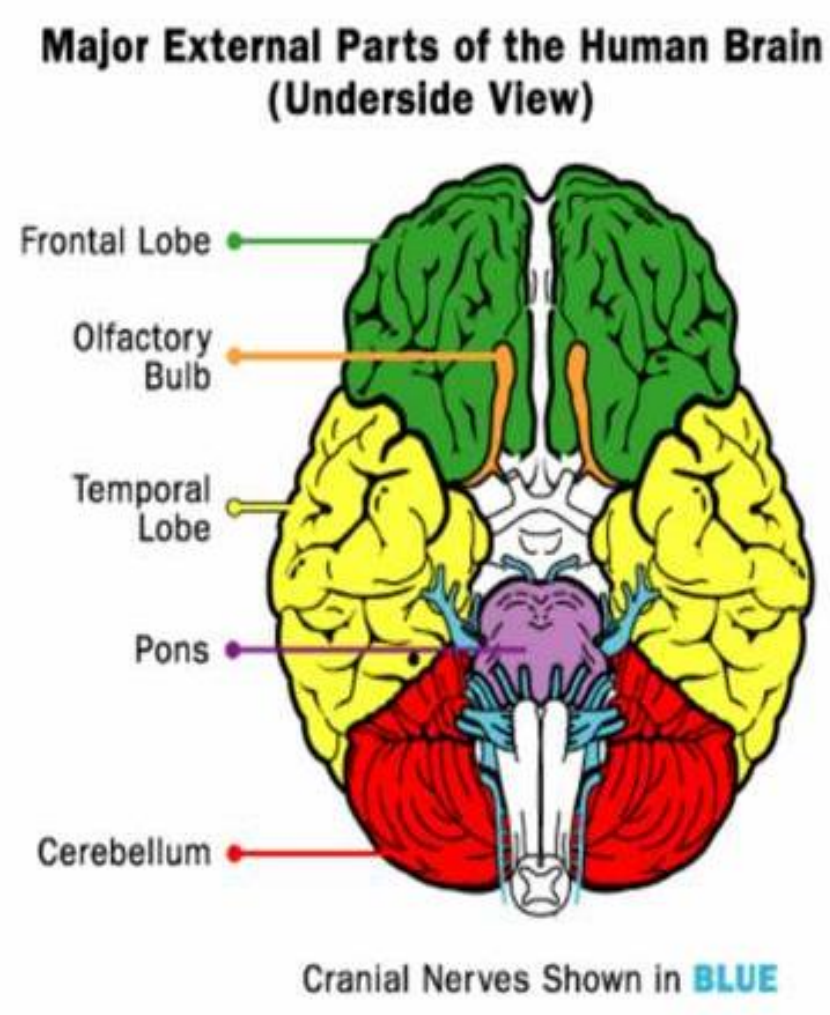


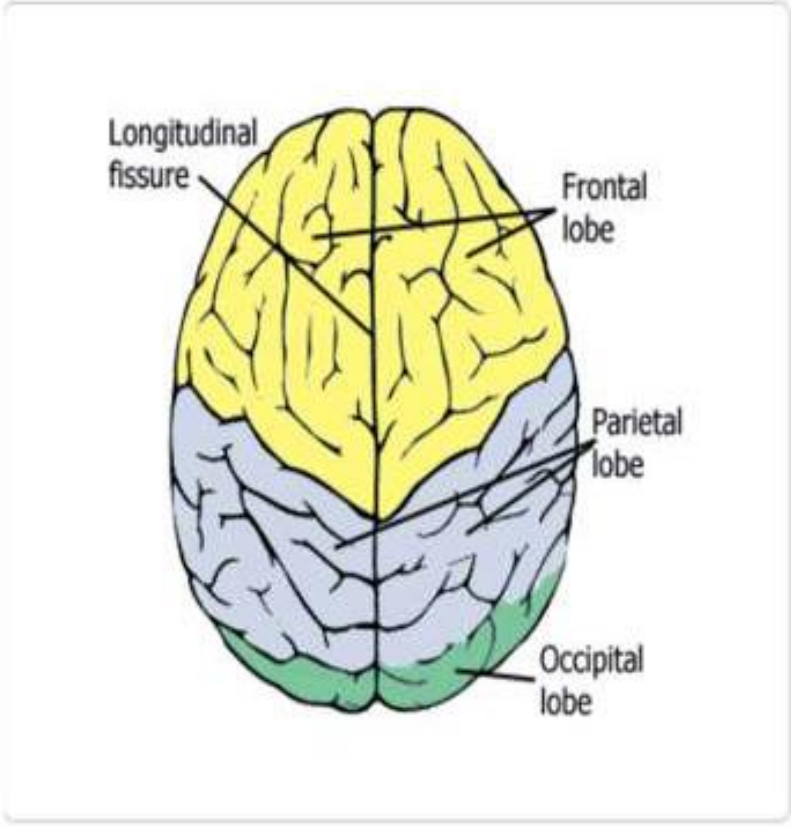
Recording electrodes

- Types of electrodes:

1. Disposable (gel-less, and pre-gelled types)
2. Reusable disc electrodes (gold, silver, s.s. or tin)
3. Headbands and electrode caps
4. Saline-based electrodes
5. Needle electrodes

- Electrode caps are preferred, with certain number of electrodes installed on its surface.
- Commonly used scalp electrodes consist of Ag-AgCl disks, 1 to 3 mm in diameter, with long flexible leads that can be plugged into an amplifier.
- Needle electrodes are used for long recordings and are invasively inserted under the scalp.


Major External Parts of the Human Brain
(Underside View)
Frontal Lobe
Olfactory Bulb
Temporal Lobe
Pons
Cerebellum
Cranial Nerves Shown in BLUE


Longitudinal fissure
Frontal lobe
Parietal lobe
Occipital lobe

- **The brain (cerebrum) is formed of two cerebral hemispheres, right and left.**

- **Each cerebral hemisphere is formed of four lobes:**

1- Frontal lobe: contains motor area.

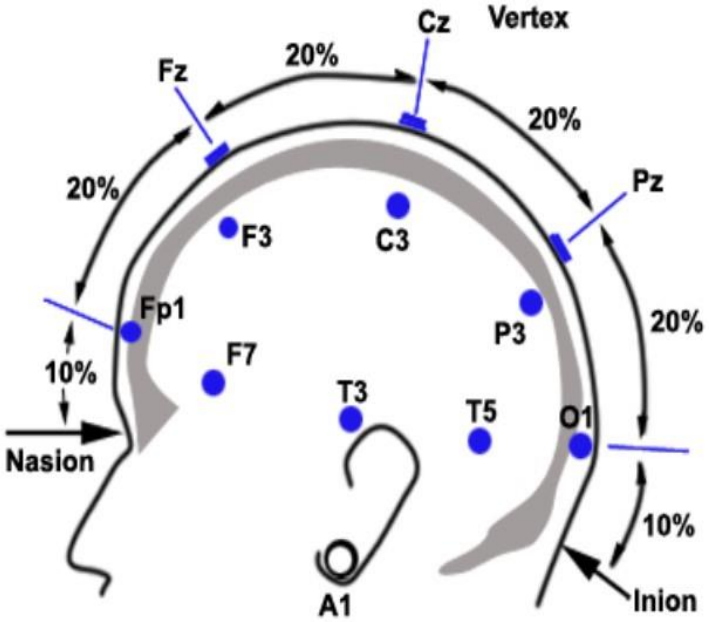
2- Parietal lobe: contains sensory area.

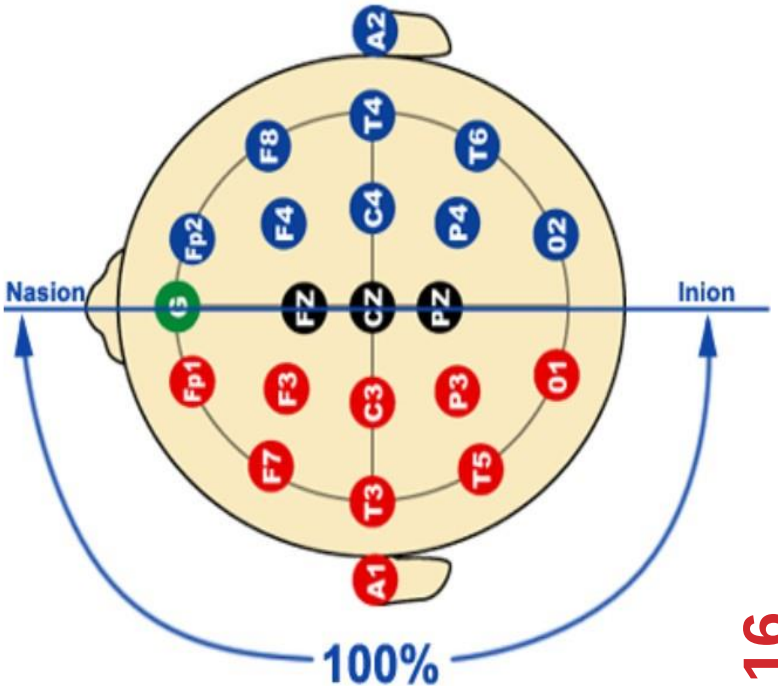
3- Temporal lobe: contains area of hearing & memory.

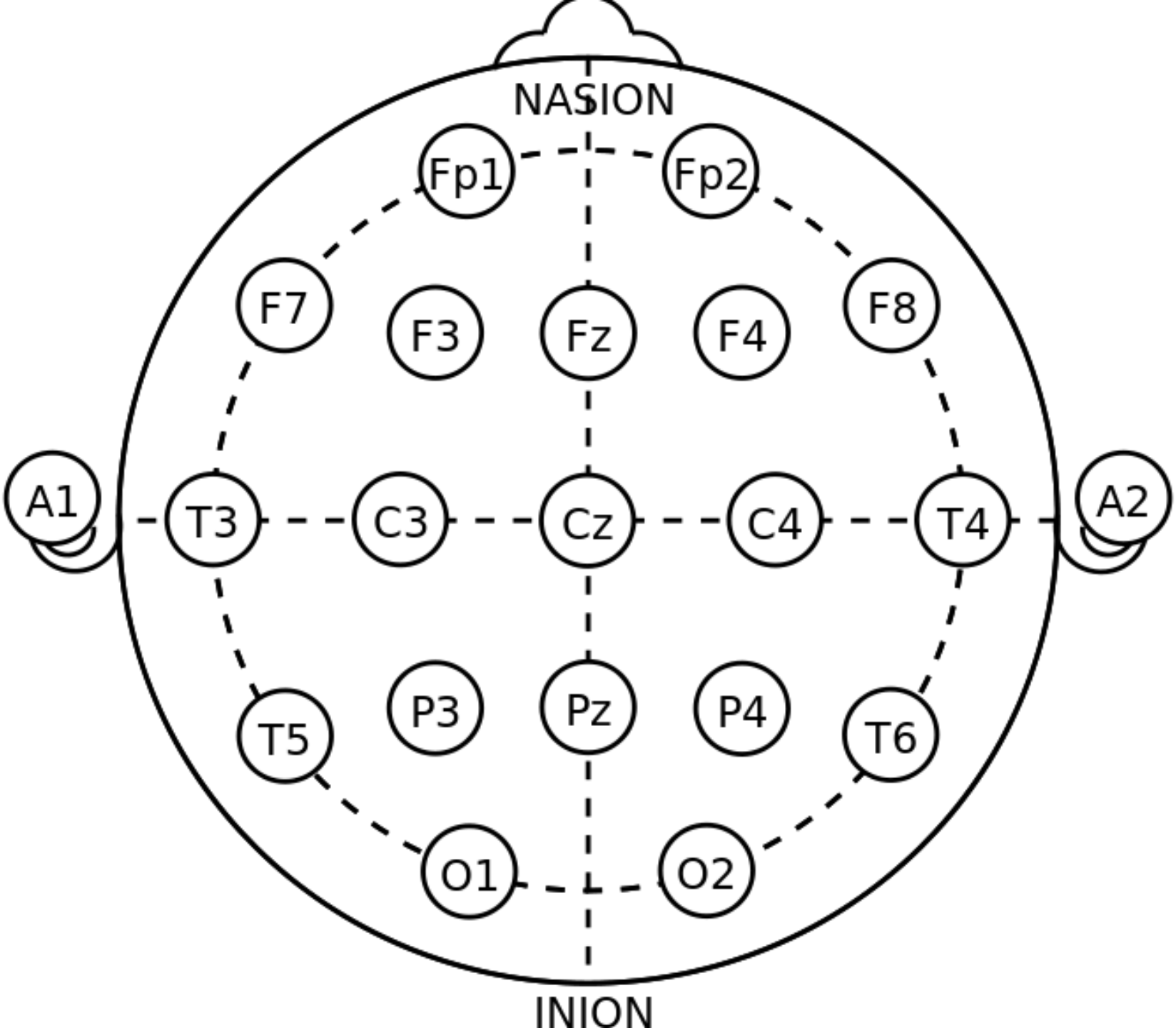
4- Occipital lobe: contains area of vision.

ELECTRODES POSITIONING

The standardized placement of scalp electrodes for a classical EEG recording has become common since the adoption of the 10/20 system. The essence of this system is the distance in percentages of the 10/20 range between Nasion-Inion and fixed points. These points are marked as the Frontal pole (Fp), Central (C), Parietal (P), occipital (O), and Temporal (T). The midline electrodes are marked with a subscript z, which stands for zero. The odd numbers are used as subscript for points over the left hemisphere, and even numbers over the right.

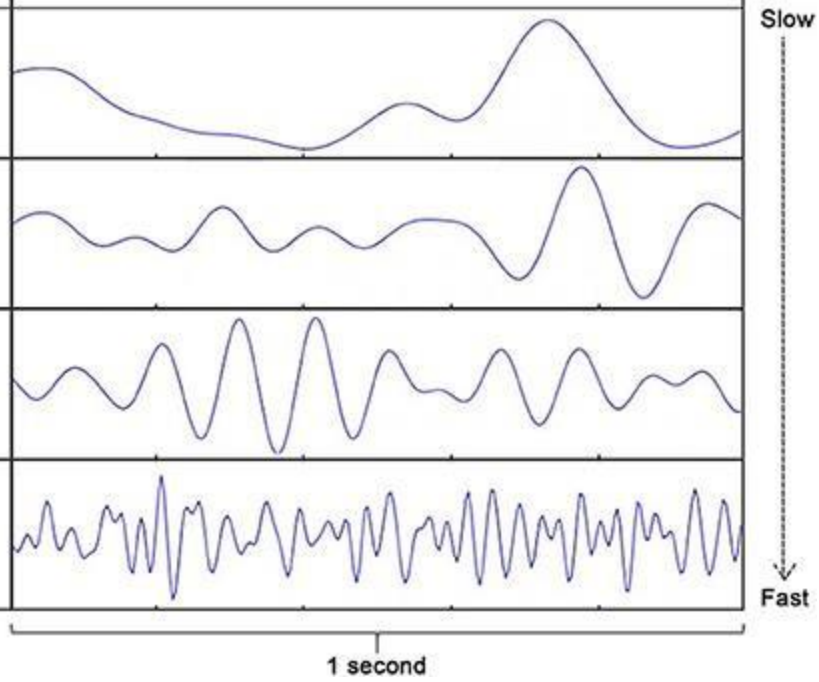





NASION
Fp1
Fp2
F7
F3
Fz
F4
F8
A1
T3
C3
Cz
C4
T4
A2
T5
P3
Pz
P4
T6
O1
O2
INION

EEG WAVES

Frequency band	Speed (Hz)	Mental state	Electroencephalography (EEG) recording
Delta	1-4	Deep sleep	
Theta	4-8	Drowsy	
Alpha	8-12	Relaxed	
Beta	12-30	Focused	



Artefacts

- Among basic evaluation of the EEG traces belongs scanning for signal distortions called Artefacts.
- The Artefact in the recorded EEG may be either patient-related or technical.

Patient related:

- Any minor body movements
- EMG
- ECG (pulse, pace-maker)
- Eye movements
- Sweating

Technical:

- 50/60 hz
- Impedance fluctuation
- Cable movements
- Broken wire contacts
- Too much electrode paste/jelly
- Low battery

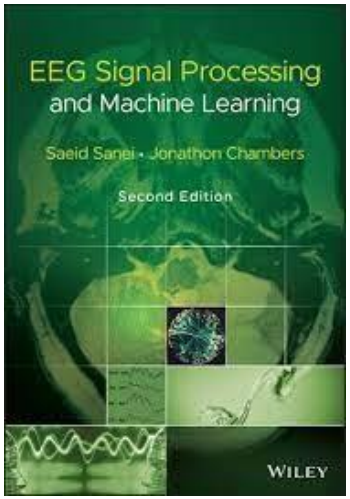
- Display of the EEG may be set up in one of several ways. The representation of the EEG channels is referred to as a *montage.*

1. Bipolar montage Each channel (i.e., waveform) represents the difference between two adjacent electrodes. The entire montage consists of a series of these channels.
2. Referential montage Each channel represents the difference between a certain electrode and a designated reference electrode.
3. Average reference montage The outputs of all of the amplifiers are summed and averaged, and this averaged signal is used as the common reference for each channel.
4. Laplacian montage Each channel represents the difference between an electrode and a weighted average of the surrounding electrodes.

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, hypoglycaemia, drugs
- Small or deep lesions might not produce an EEG abnormality
- May falsely localize epileptogenic zone

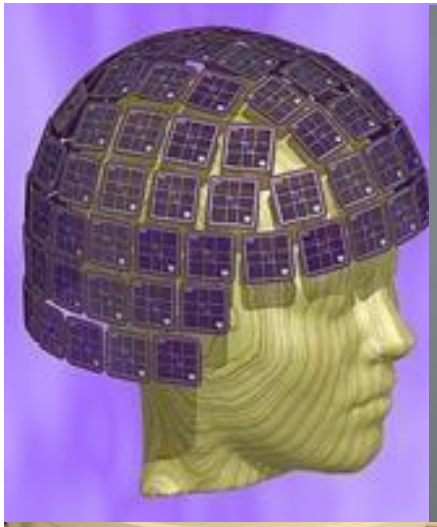
TEXTBOOK

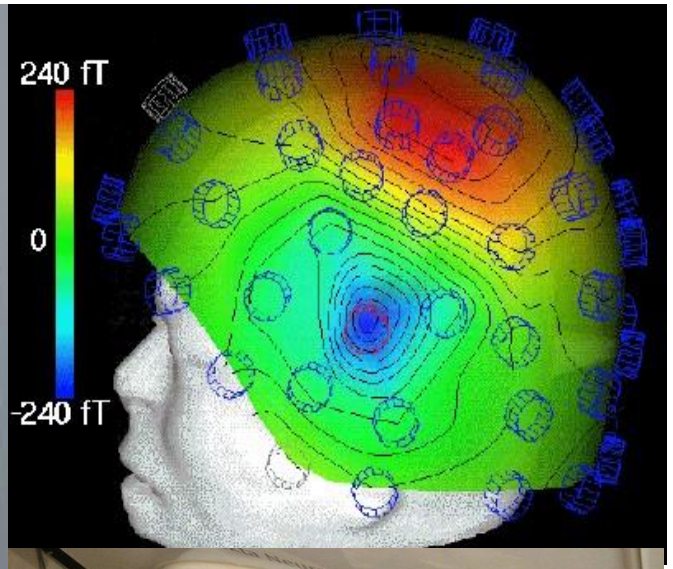


EEG Signal Processing and Machine Learning

Saeid Sanei
Imperial College London & Nottingham Trent University, UK

Jonathon A. Chambers
University of Leicester, UK

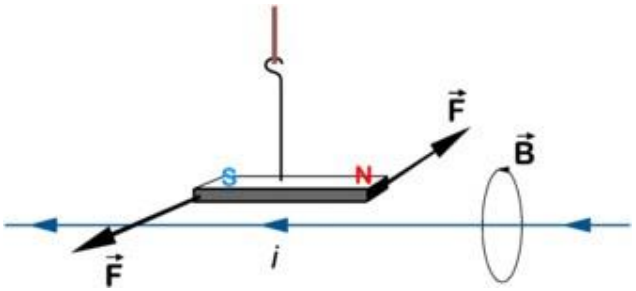




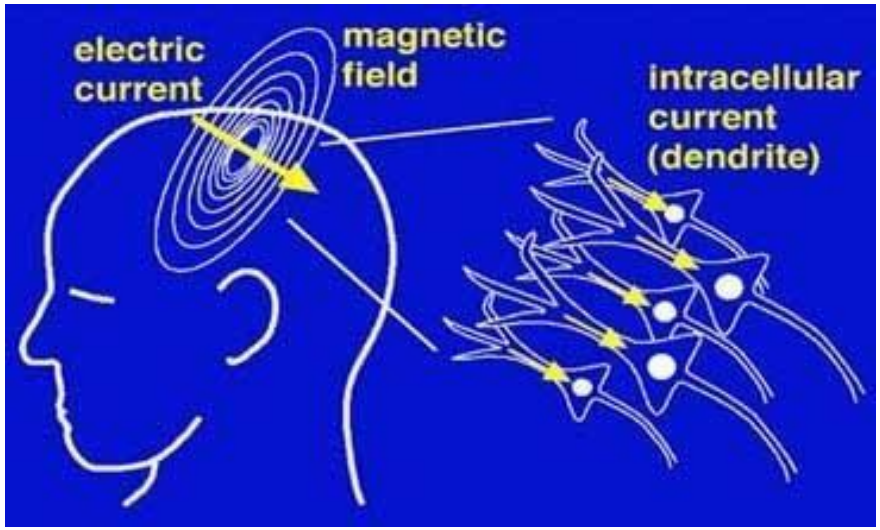
MAGNETOENCEPHALOGRAPHY (MEG)

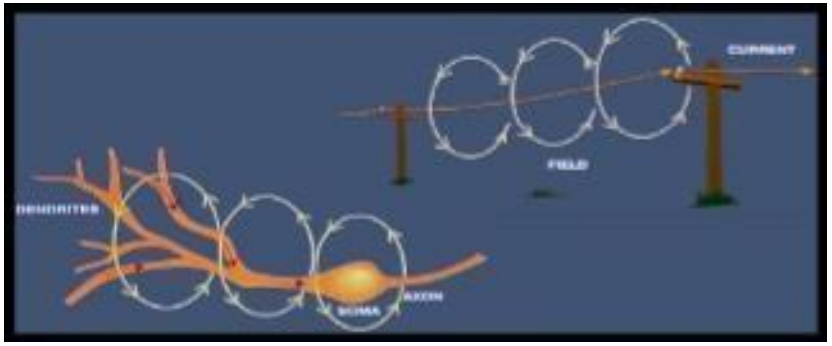
ELECTRICITY AND MAGNETISM

- The connection between electricity and magnetism was first discovered by Hans Christian Orsted in 1819.
- He demonstrated that a magnetic compass needle was affected by a current passing through a circuit.



MEG FUNDAMENTALS

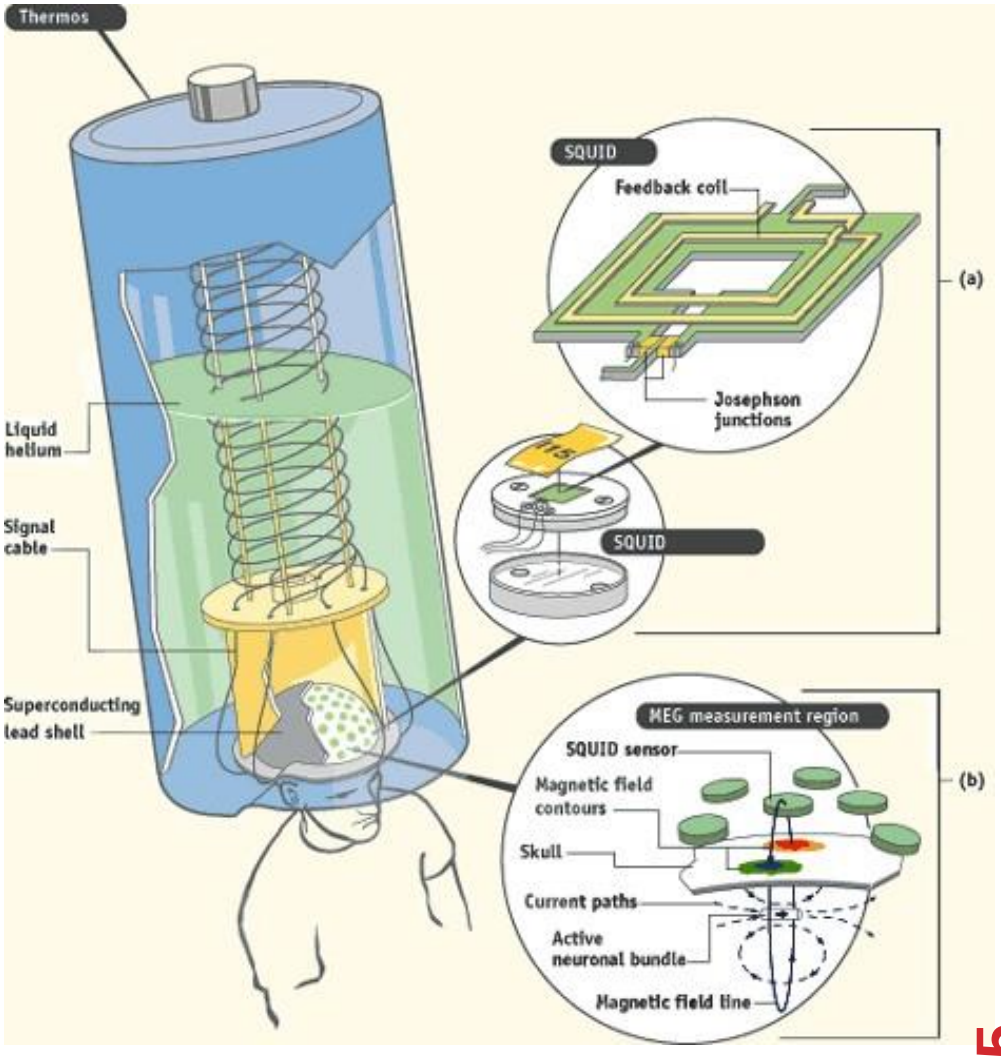




- The magnetic field is perpendicular to the current.
- If the current is running parallel to the scalp the magnetic field exits the head from one side of the dipole and re-enters on the other side and so can be measured.
- But if the current is perpendicular to the scalp the magnetic field does not leave the scalp and cannot be measured.

MEG FUNDAMENTALS…

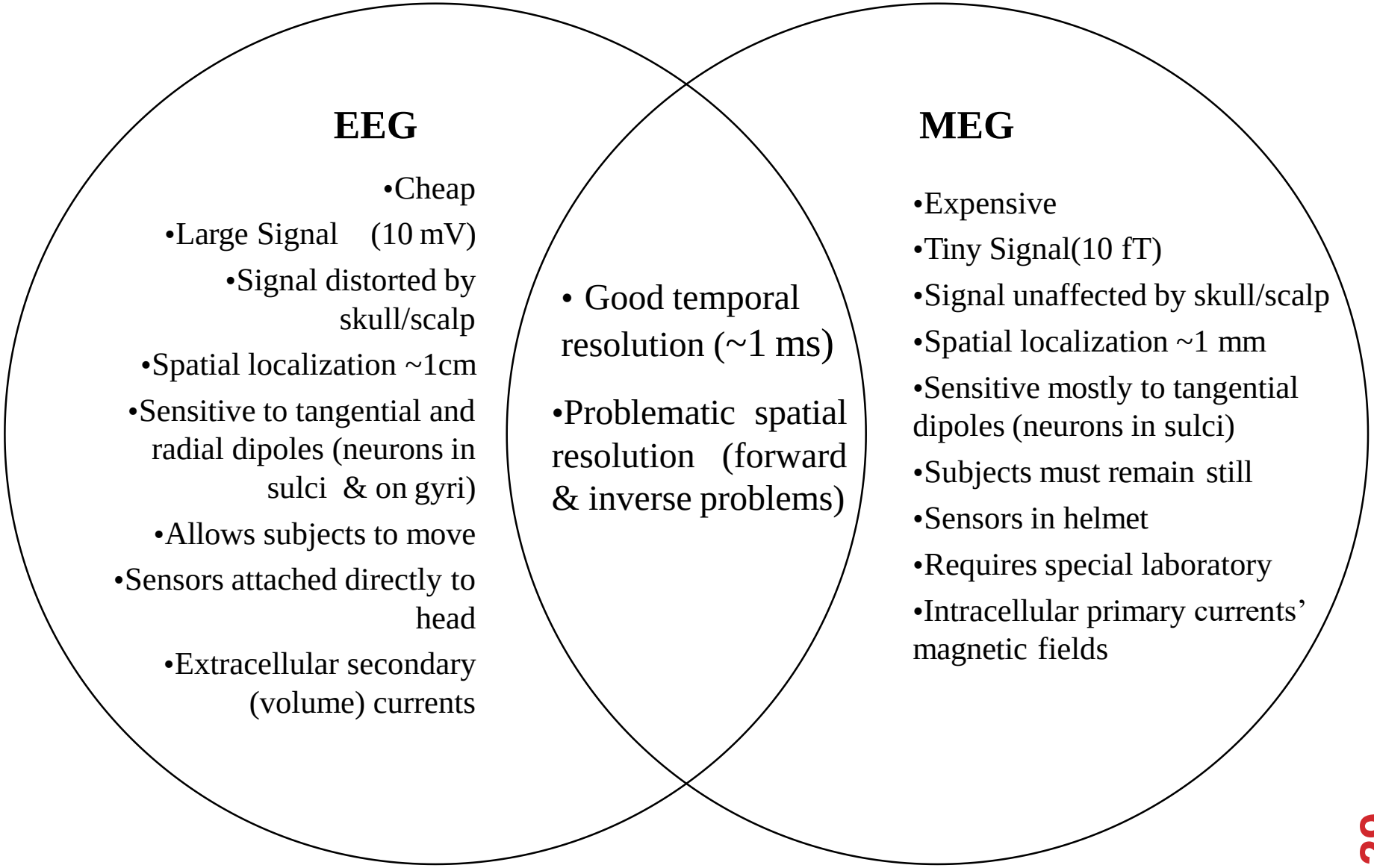
Since bio-magnetic fields are so small we need very sensitive equipment to detect them.



MEG FUNDAMENTALS…

- The sensors do not need to come into direct contact with the scalp. Unlike EEG, MEG does not mess up your hair!
- This cuts down preparation time and makes MEG more child-friendly.
- Helmets used today have as many as 300 sensors.

EEG VS. MEG


EEG
•Cheap
•Large Signal (10 mV)
•Signal distorted by skull/scalp
•Spatial localization ~1cm
•Sensitive to tangential and radial dipoles (neurons in sulci & on gyri)
•Allows subjects to move
•Sensors attached directly to head
•Extracellular secondary (volume) currents
• Good temporal resolution (~1 ms)
•Problematic spatial resolution (forward & inverse problems)
MEG
•Expensive
•Tiny Signal(10 fT)
•Signal unaffected by skull/scalp
•Spatial localization ~1 mm
•Sensitive mostly to tangential dipoles (neurons in sulci)
•Subjects must remain still
•Sensors in helmet
•Requires special laboratory
•Intracellular primary currents' magnetic fields


thank
you