# Medical Physics II

2nd semester

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# Lectures 3

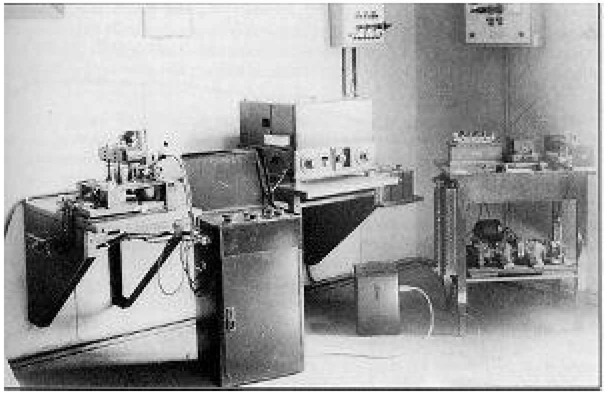
# Electrocardiogram

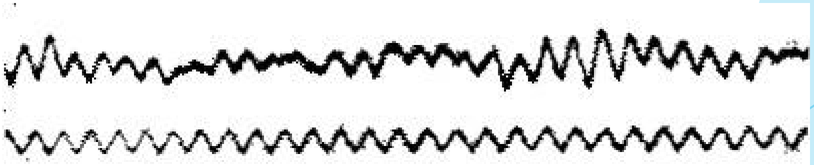
# Brief History of EEG

- Vladimirovich (1912): First animal EEG study (dog)
- Cybulski (1914): First EEG recordings of induced seizures
- Berger (1924): First human EEG recordings

- Invented the term **electroencephalogram (EEG)**
- American EEG Society formed in 1947
- Aserinsky & Kleitman (1953): First EEG recordings of REM sleep.

# Hans Berger (1924)





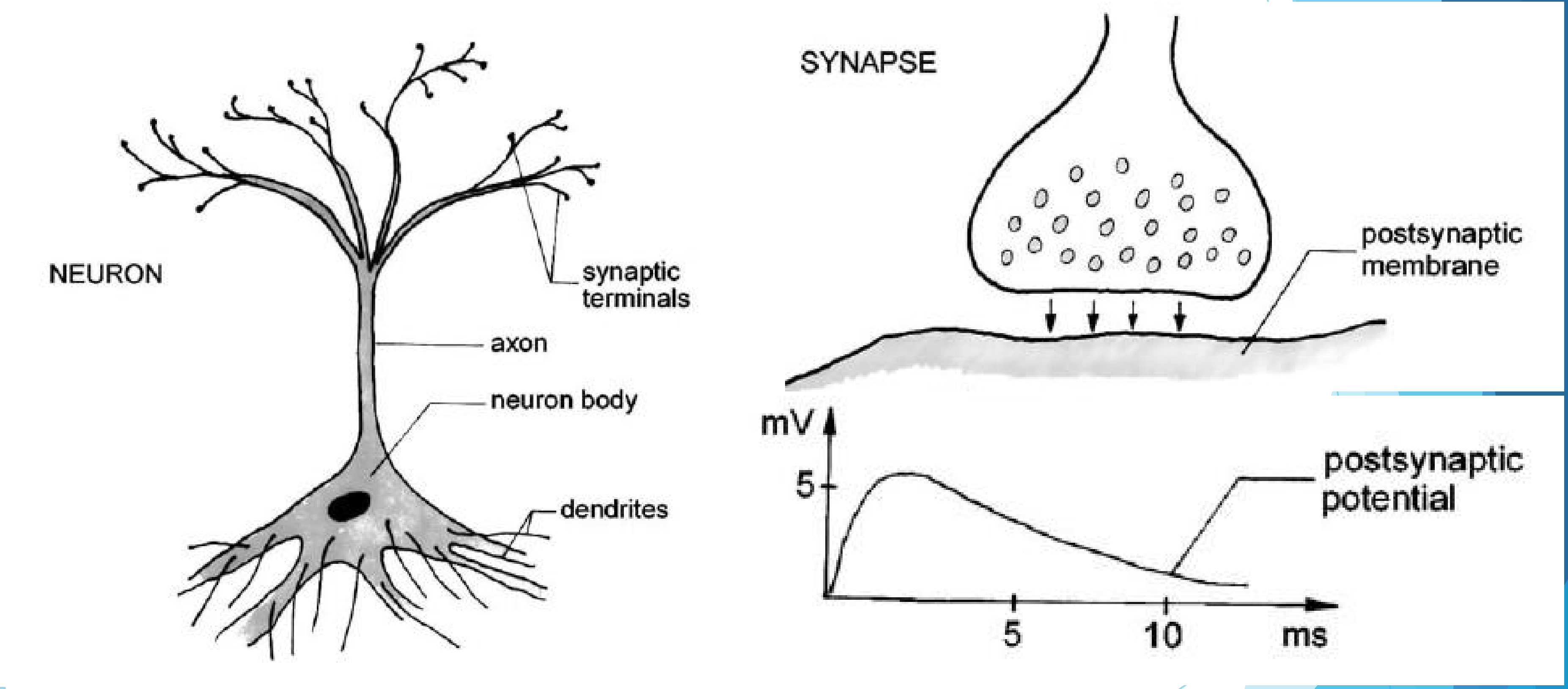
# What is Electroencephalogram (EEG)

- **Graphical** depiction of cortical **electrical activity**, usually **recorded** from the **scalp**.
- **Advantage** of **high temporal resolution but poor spatial resolution** of cortical disorders.
- **EEG** is the most important neurophysiological study for the **diagnosis**, **prognosis**, and **treatment of epilepsy**.
- Relatively **cheap** neuroimaging technique

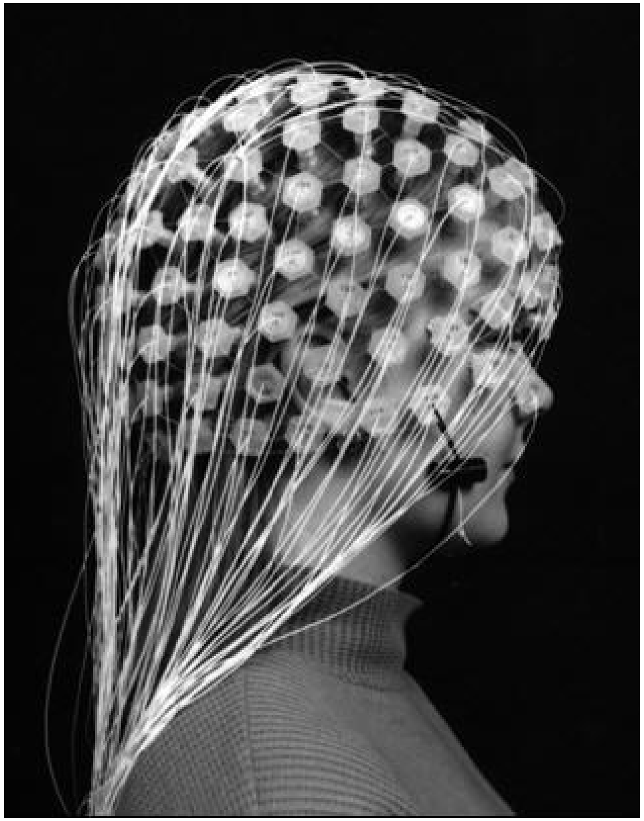
# Neurophysiological Basis of EEG

- **Single neuron activity** is too small to be picked up by EEG
- **EEG reflects** the summation of the synchronous activity of many neurons with similar spatial orientations.
- **Cortical pyramidal neurons** produce most of the EEG signal
- **Deep sources** (subcortical areas) are much more difficult to detect **than** currents near the skull.

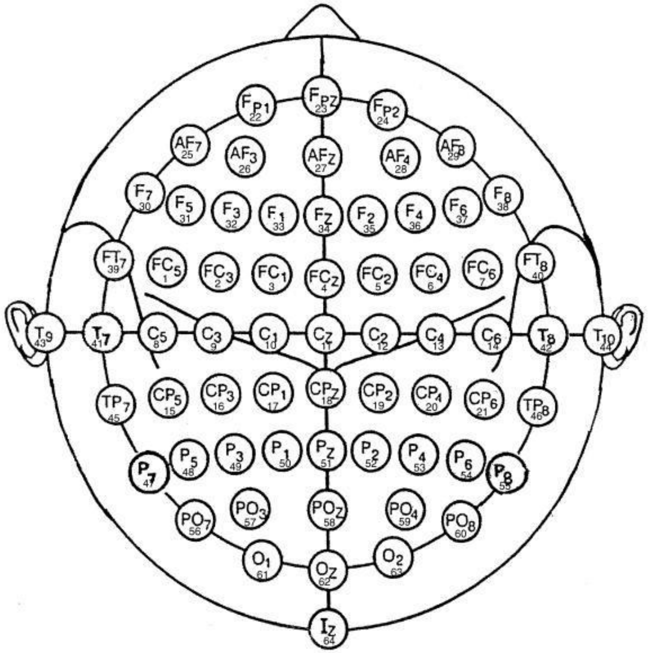
# Neurophysiological Basis of EEG



# Recording Standards



# Electrode Placement



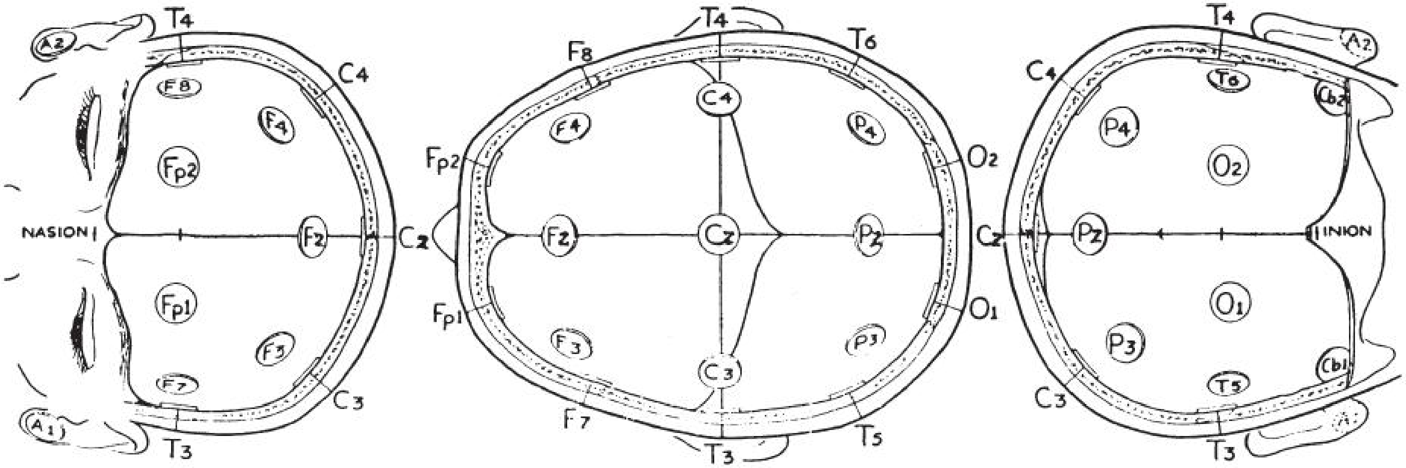
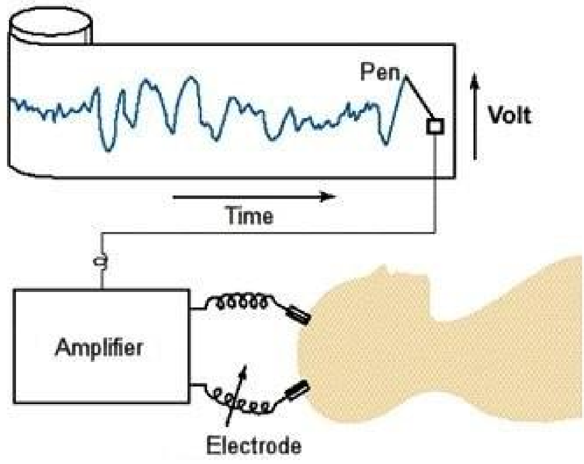




**Figure 3.** Electrodes placement in 10–20 system.

# Recording EEG Signals



# Why Measure the EEG ?

The greatest advantage of EEG is its temporal resolution. EEG can determine the relative strengths and positions of electrical activity in different brain regions.

**(1) Monitor alertness, coma and brain death.**

**(2) Locate areas of damage following head injury, stroke, tumor, etc.**

**(3) Test afferent pathways (by evoked potentials).**

**(4) Monitor cognitive engagement (alpha rhythm).**

**(5) Produce biofeedback situations, alpha, etc.**

**(6) Control anesthesia depth ("servo anesthesia").**

**(7) Investigate epilepsy and locate seizure origin.**

**(8) Test epilepsy drug effects.**

**(9) assist in experimental cortical excision of epileptic focus.**

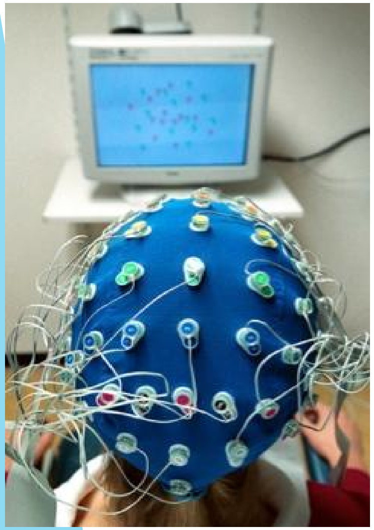
**(10) monitor human and animal brain development.**

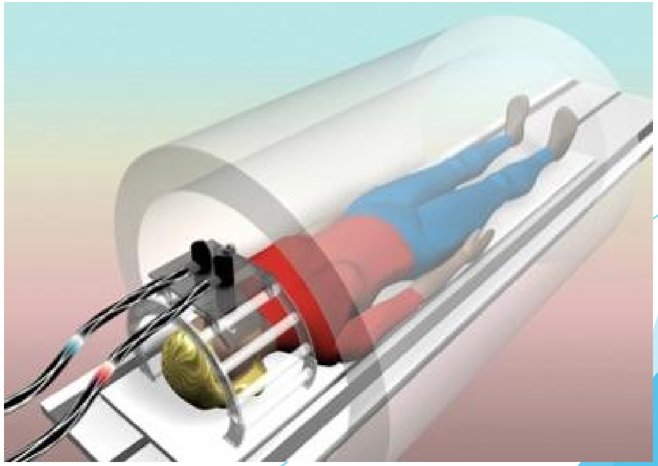
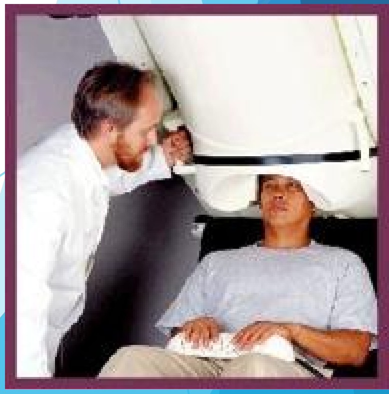
**(11) test drugs for convulsive effects.**

**(12) investigate sleep disorder and physiology.**

# Current Neuroimaging Modalities

- **In all modalities** **but EEG**, the sensors are heavy.
- **EEG** is the only modality not requiring the head/body to be fixed.
- EEG might enable monitoring of the brain functions of unconstrained participants performing normal tasks in the workplace and at home.

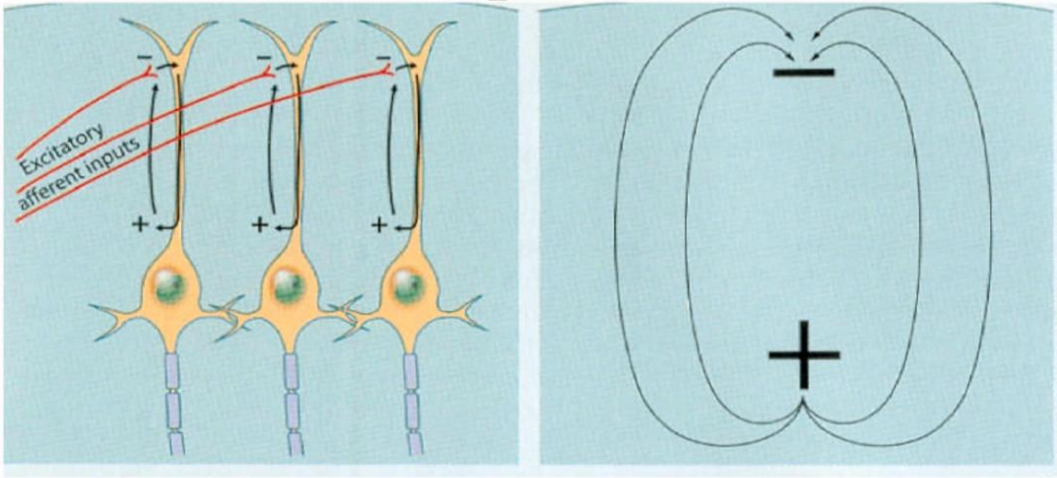


# Mechanism of EEG

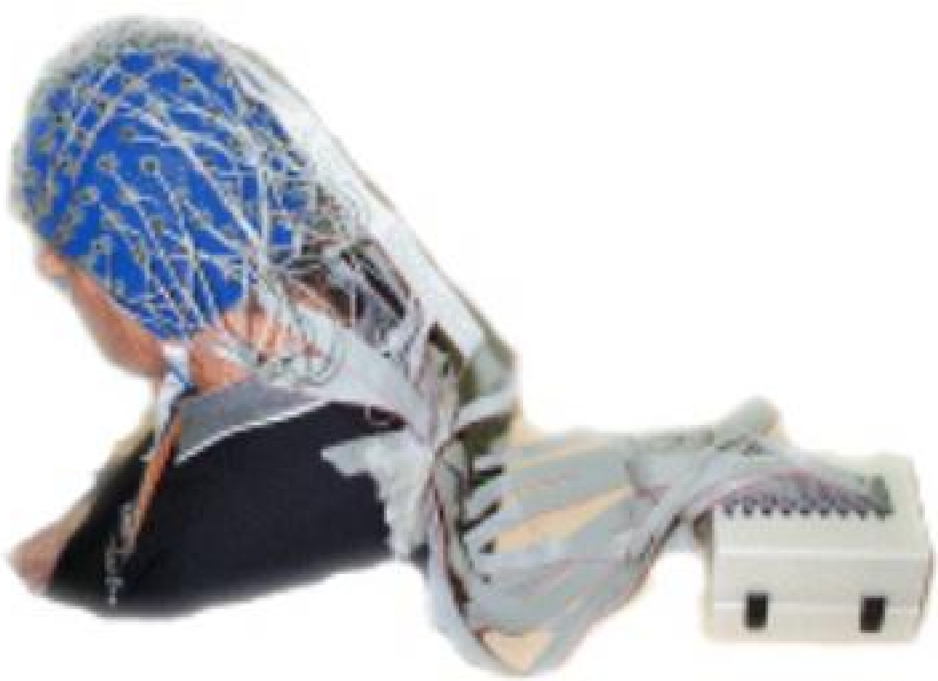
- **When neurons are activated, local currents** are produced.
- **EEG** measures the **current** that flow during the excitations of the dendrites of many pyramidal neurons in the cerebral cortex.
- **Potential differences** are caused by **summed postsynaptic**
- **Potentials from pyramidal cells create diploes between** soma and apical dendrites.
- **Necessary conditions**: Aligned neurons and synchronous activity.

Dipoles



# EEG Acquisition

- Electrode caps, conductive jelly, ruler, injection and aid for disinfection.
- EEG amplifier unit, PC/laptop

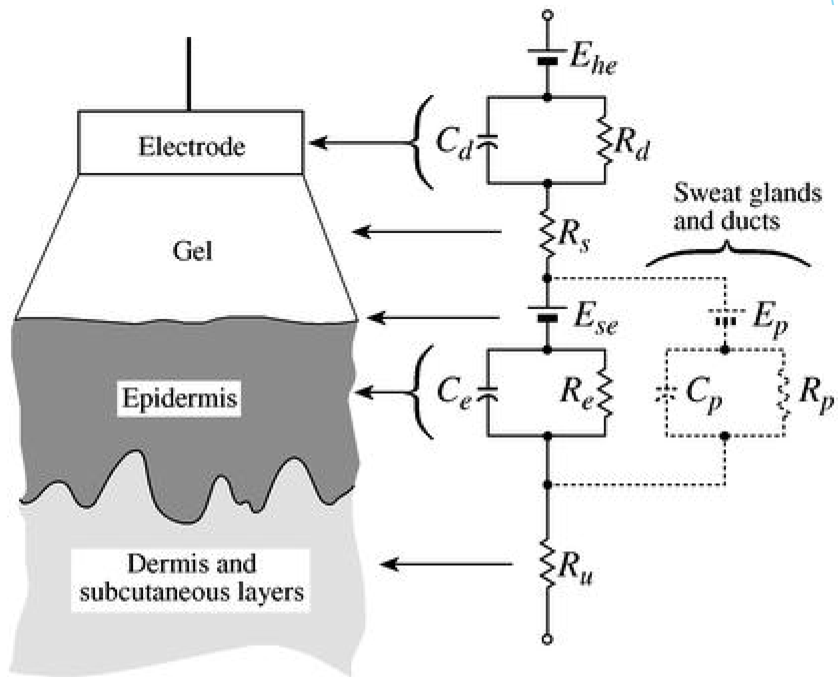



# EEG Electrodes

**EEG signals** are **measure** by an **electrode with** electrolyte gel **placed directly** on the **skin**.

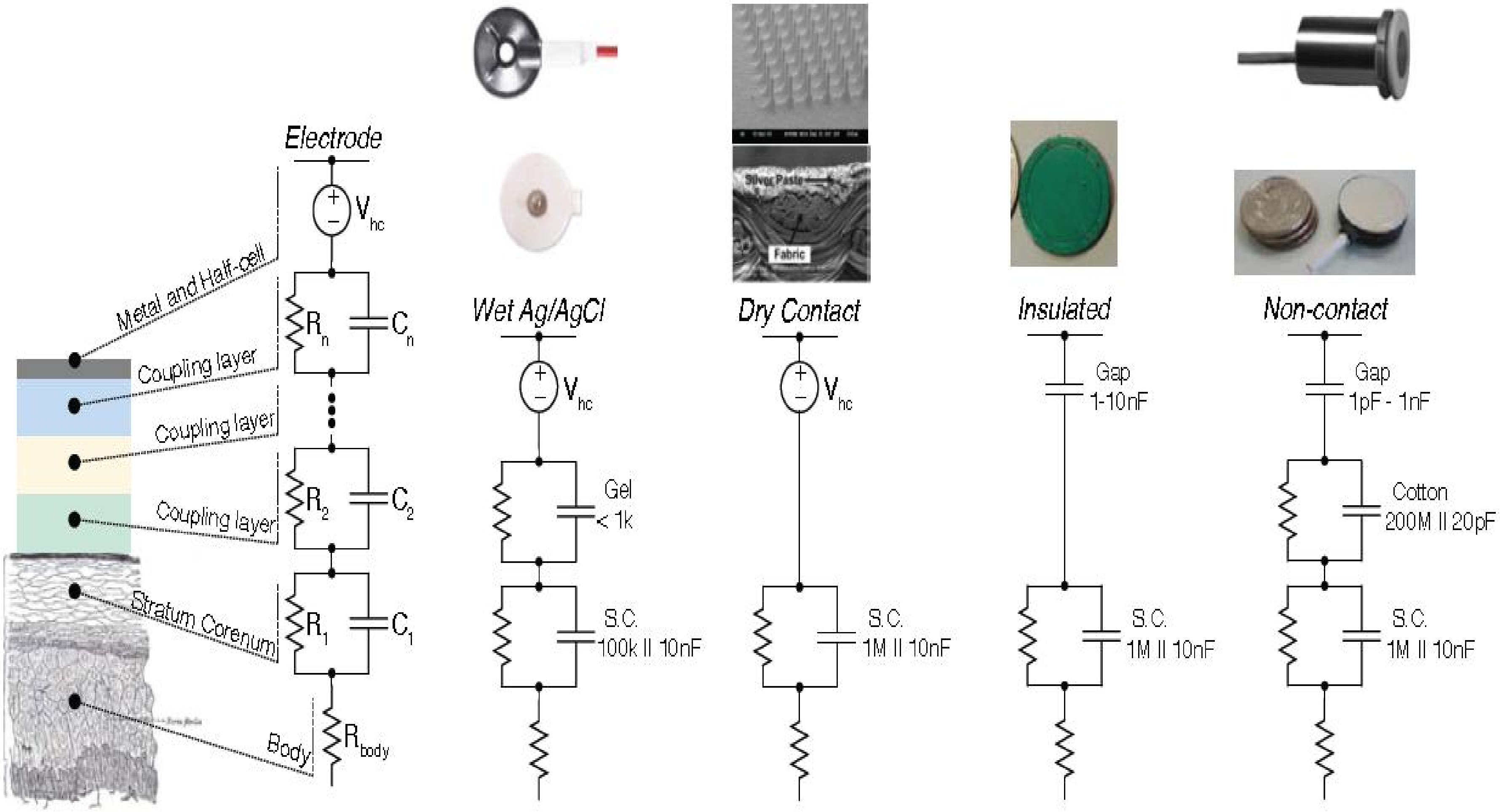
The **coupling** between skin and electrode can be described as a layered conductive and capacitive structure, with series combinations of parallel RC elements.

**Equivalent circuit**



# EEG Electrodes

Typically, one of the RC sections dominates and the electrical coupling may be simply represented as a **single element with conductance** gc **in parallel** with **capacitance** Cc , $Y_c(j\omega) = g_c + j\omega C_c$.



# Comparison for EEG Electrodes

- **Standard wet electrodes :** low skin impedance, and buffer the electrode against mechanical motion. **But**, they may be messy, time-consuming, irritating during preparation and cleaning, and the **signal quality degrades over time.**
- **Rigid metal electrodes:** subject to **motion artifacts.**
- **Dry foam electrode** (Gruetzmann et al., 2007): comfortable and stable with increased resistance to motion artifact, **but difficult** to assess hairbearing sites.
- **MEMS sensors:** low skin impedance, **but**, they may be irritating and difficult to penetrate the hairs.
- **Microprobe electrodes: sensitive** to motion artifacts.
- **Non-contact sensors: sensitive** to motion artifacts, poor settling times. **Friction between the electrode and insulation** can cause large voltage excursion at the sensitive input.
- **Epidermal electrodes** (Kim eta al., 2011): very comfortable and stable with increased resistance to motion artifact, **but difficult** to assess hair-bearing sites.

# Wearable EEG Devices

# What EEG/ERPs Can and Cannot Tell Us About Brain Functions

- **CAN**

Precise timing of neural activity

Sequence of mental operations

- **CANNOT**

Precise brain location of neural activity