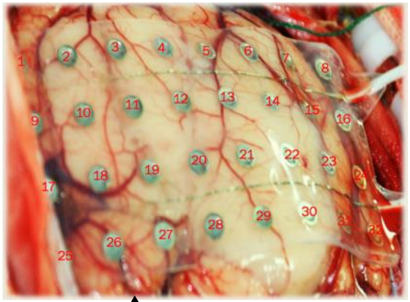
Methods for Neural signal recording

Brandenburgische Technische Universität Cottbus - Senftenberg

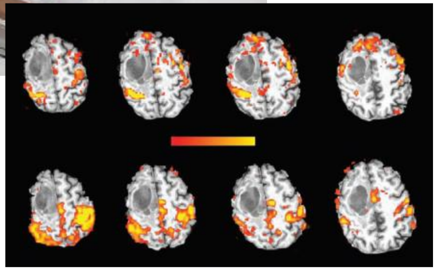
Electroencephalography

Magnetoencephalography

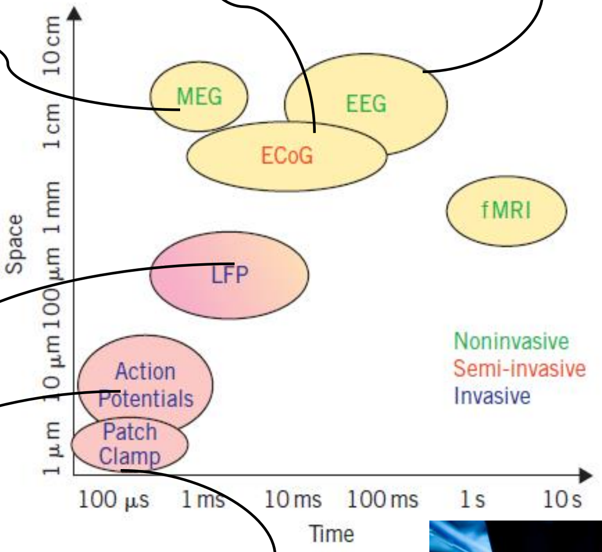
Electrocorticography

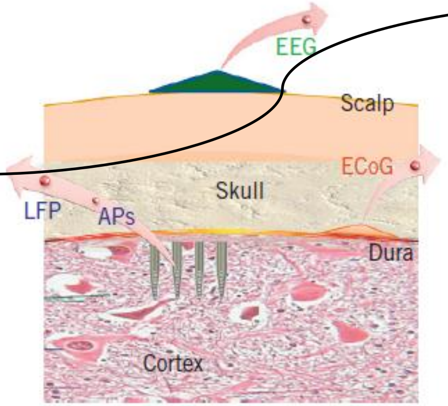


Functional magnetic resonance imaging

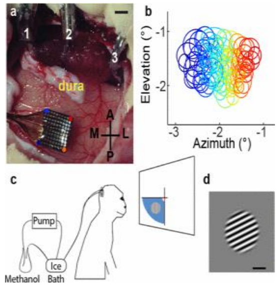


This technique relies on the fact that cerebral blood flow and neuronal activation are coupled

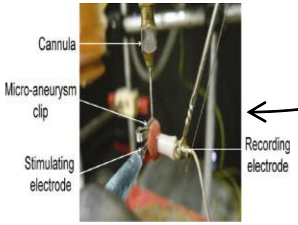




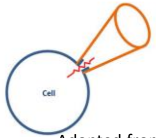
Till S. Hartmann, 2019, Fig1



Extracellular electrical potentials

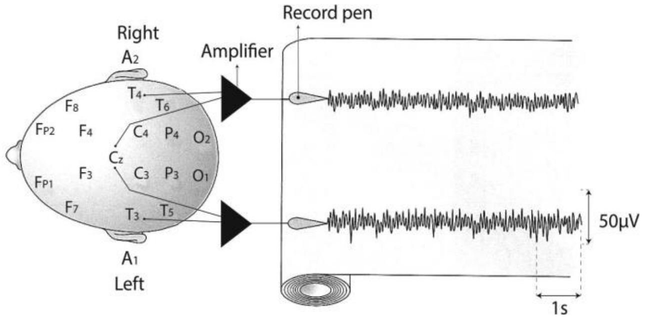


Gary Tse ,Fig2, 2016

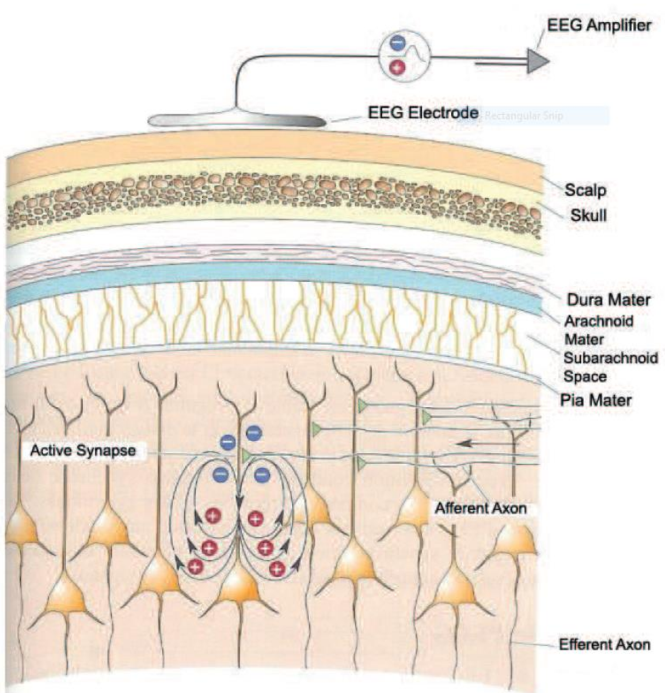


Adopted from Fig1.1 of Statistical Signal Processing for Neuroscience and Neurotechnology Edited by Karim G. Oweiss

Origin of EEG



Bastos-Filho, Teodiano Freire, ed. *Introduction to Non-invasive EEG-based Brain-computer Interfaces for Assistive Technologies*. CRC Press, 2020.



M. F. Bear, B. W. Connors, and M. A. Paradiso. Neuroscience: Exploring the Brain.

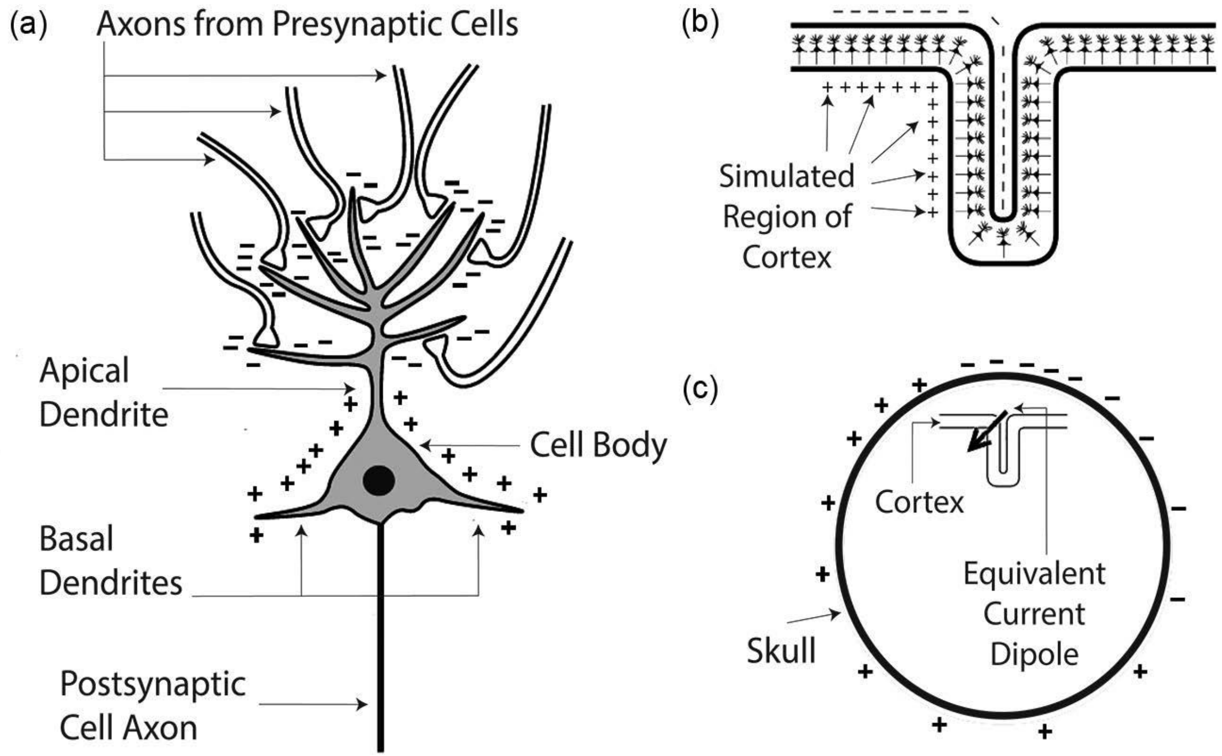
The EEG mainly records the extracellular currents that arise as a consequence of synaptic activity in dendrites of neurons in the cerebral cortex.

The extracellular electric field is mainly generated by the postsynaptic potential (PSP) that may be excitatory postsynaptic potential (EPSP) or inhibitory postsynaptic potential (IPSP).

When the AP reaches postsynaptic dendrites, it causes a current flow that enters through the synapse to the postsynaptic dendrites of the next neuron.

Pyramidal cells (mostly excitatory) are main contributors to the formation of the electrical field lead to EEG are spatially aligned perpendicularly to the cortex.

Origin of EEG …



The dipole of an individual neuron is impossible to be measured by electrodes on the scalp; however, under specific conditions, the dipoles of many neurons are added, generating a resulting field that can be measured on the scalp.

(a) Bipolar configuration of the electric field of pyramidal neuron during a PSP.
(b) bipolar configuration of the electric field of a pyramidal neurons of an active cortical region.
(c) equivalent current dipole of the active cortical region

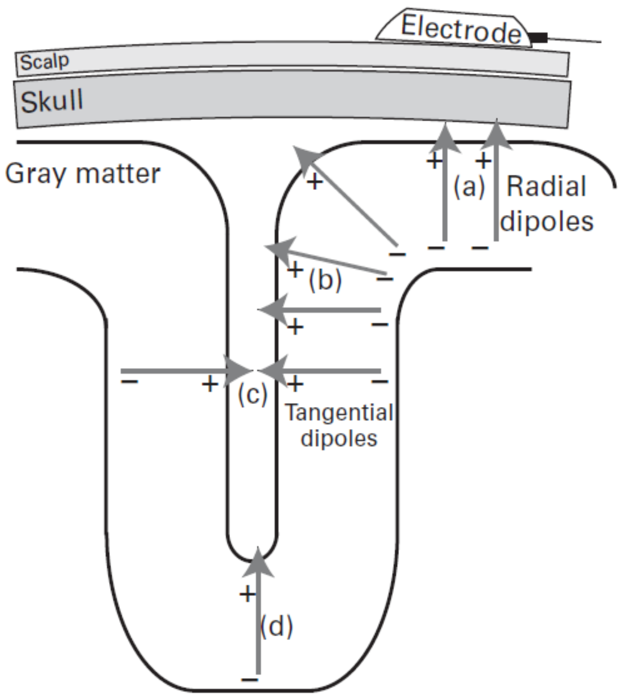
Origin of EEG …

Illustration of dipoles in different orientations with respect to the skull.

(a) These dipoles will contribute the strongest signal to EEG.

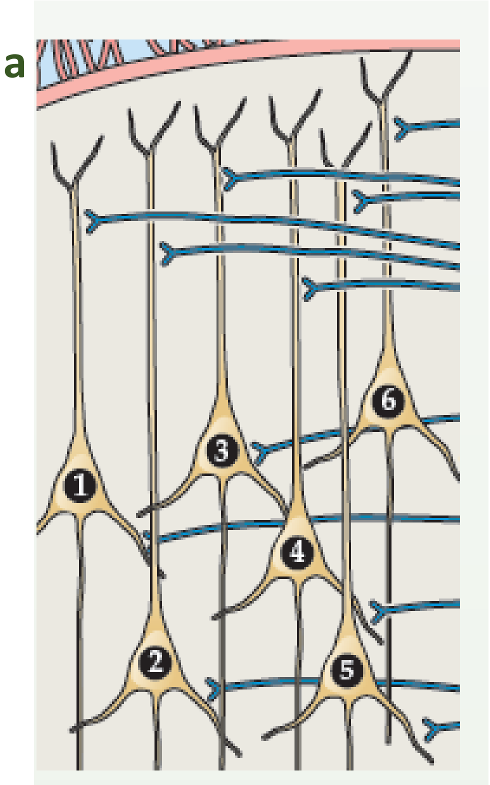
(b,C) These dipoles are unlikely to be measured because the dipoles on opposing sides of the sulcus produce electrical fields that are likely to cancel each other.

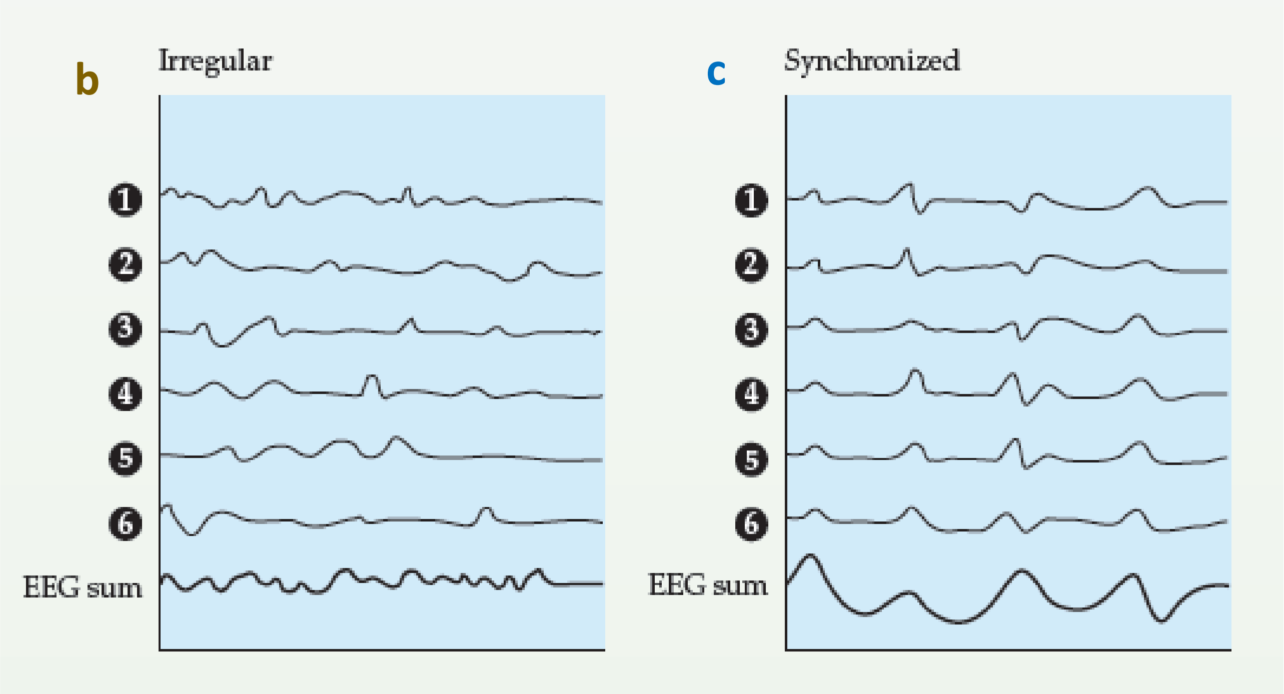
(d) These dipoles will make a smaller contribution to EEG than dipole (a) because it is further away from the electrode.



inspired by figure 1 of Scherg 1990

Origin of EEG …





(a) six pyramidal neurons wherein the PSP is measured between a pair of sensors at their extremities (gray triangles).

(b) The neurons are activated in irregular time intervals and the summed PSP activity of all six neurons has small amplitude.

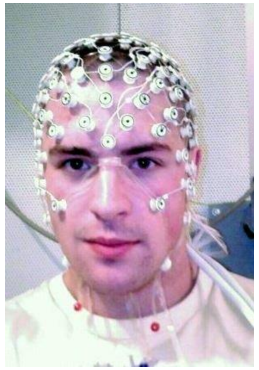
(c) The neurons are activated synchronously; thus, the summed PSP activity of all six neurons has high amplitude.

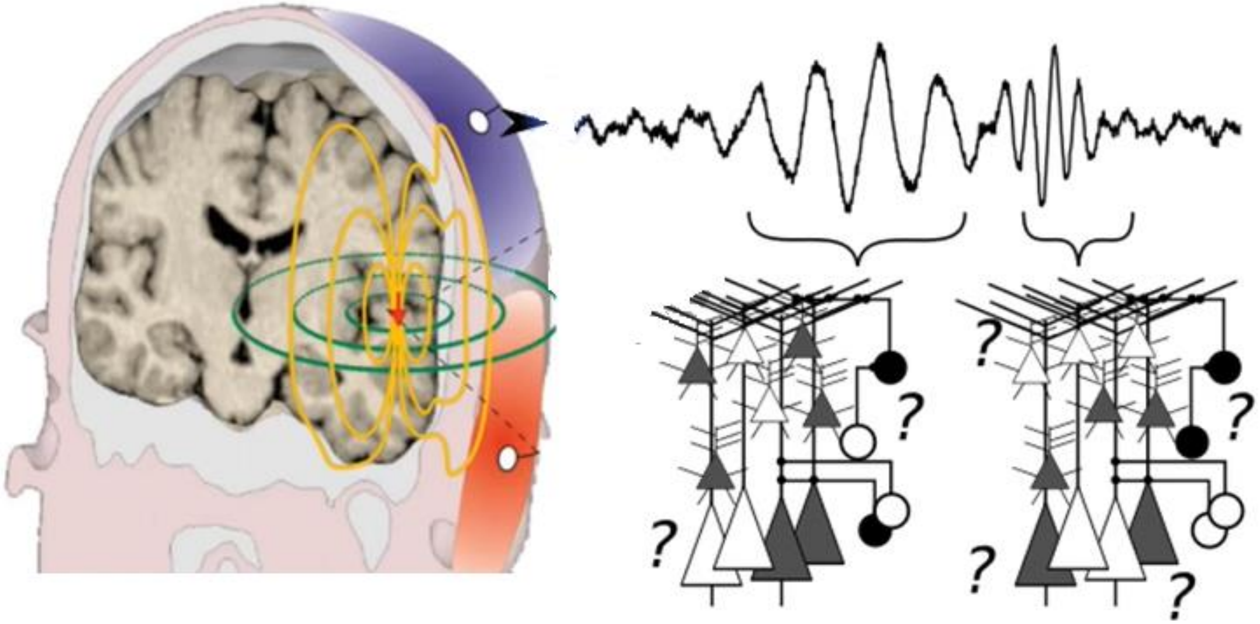
If the neurons are randomly oriented, the positivity of a dipole would be canceled by the negativity of the adjacent dipole.

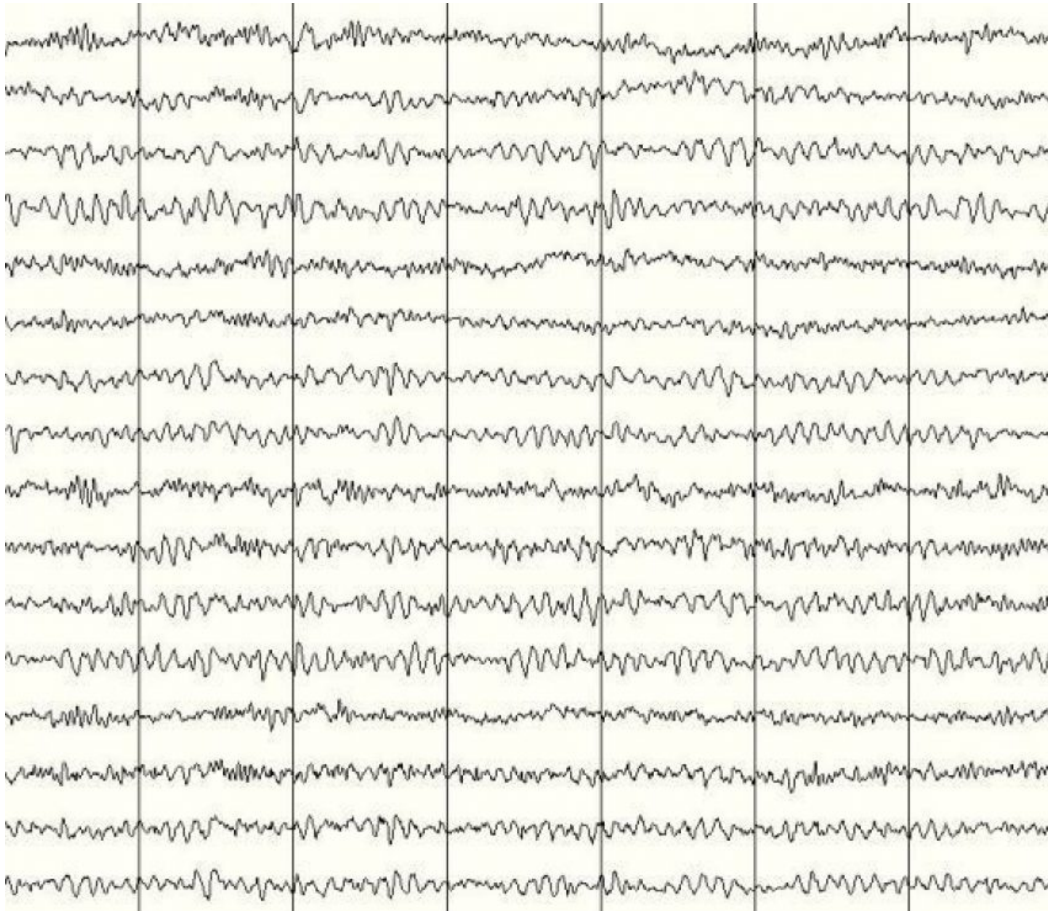
if a neuron is stimulated by an excitatory neurotransmitter, and an adjacent neuron is stimulated by an inhibitory neurotransmitter, the dipoles will have opposite orientations and cancel each other.

If many neurons having similar orientations and the same type of neurotransmitter are stimulated at approximately the same moment, then the dipoles will be added and their activity may be measured on the scalp

Content of EEG ???







Why EEG

The use of EEG in practical applications has steadily increased and is expected to continue to increase. Indeed, EEG has many advantages over the other methods to study brain functions, as follows:

- EEG is perfectly noninvasive, without any exposure to radiation or high magnetic field
- EEG is direct measure of electrical brain activity
- EEG devices can be made small and portable
- EEG has high temporal resolution (The temporal resolution match the speed of cognition).
- EEG has very rich information allow for physiologically inspired analysis (Oscillation, synchronization, connectivity ,….)
- EEG can be recorded in an open environment
- EEG is economical

Chapter 2

EEG recording

Data Acquisition

- Most acquisition systems can be subdivided into **analog and digital** components.
- Observing a biological process normally starts with the connection of a **transducer or electrode pair** to pick up a signal.
- The next stage is amplification. In most cases the amplification takes place in two steps using a separate preamplifier and amplifier.
- Then signal is usually filtered to attenuate undesired frequency components (band pass filtering and/or by notch filtering).
- A critical step is to attenuate frequencies that are too high to be digitized by the ADC. This operation is performed by the **antialiasing filter**.
- Finally, the sample-and-hold (S/H) circuit samples the analog signal and holds it to a constant value during the ADC process.

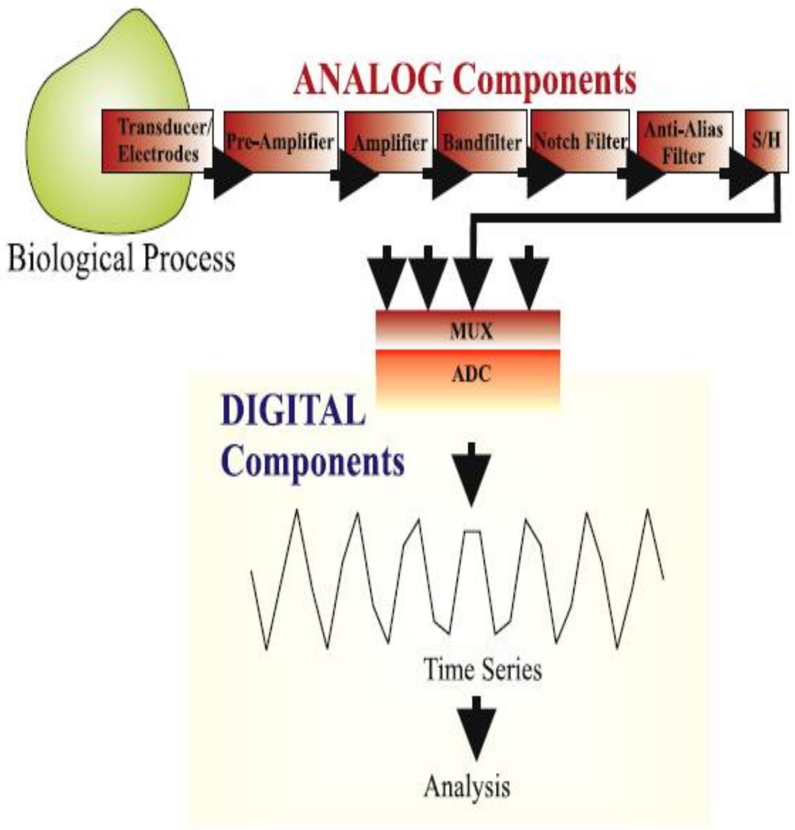


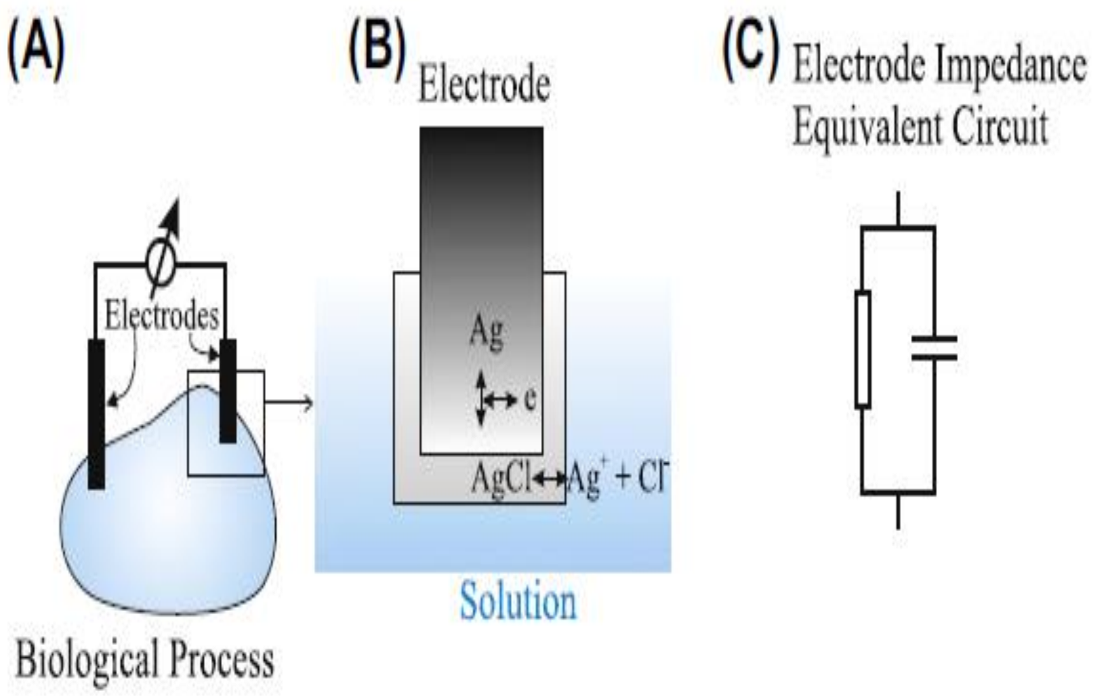
Figure2.1 , Signal processing for Neuroscientist, second edition by Wim van Drongelen

Electrodes

Metal electrodes are often used to measure potentials which must be bathed in an **ionic solution**. A fundamental problem with such direct measurements of electricity in solutions is the interface between the metal and solution.

This boundary generates an electrode potential that is material and solution Specific. The electrode potential is usually not a problem when bio potentials are read from electrode pairs made of the same material.

One widely used electrodes are silver electrode with a silver chloride coating. This facilitates the transition from ionic (**Ag or Cl)** to electronic conduction, reducing the electrode capacitance at the solution interface, and consequently facilitating the recording of signals with low-frequency components.

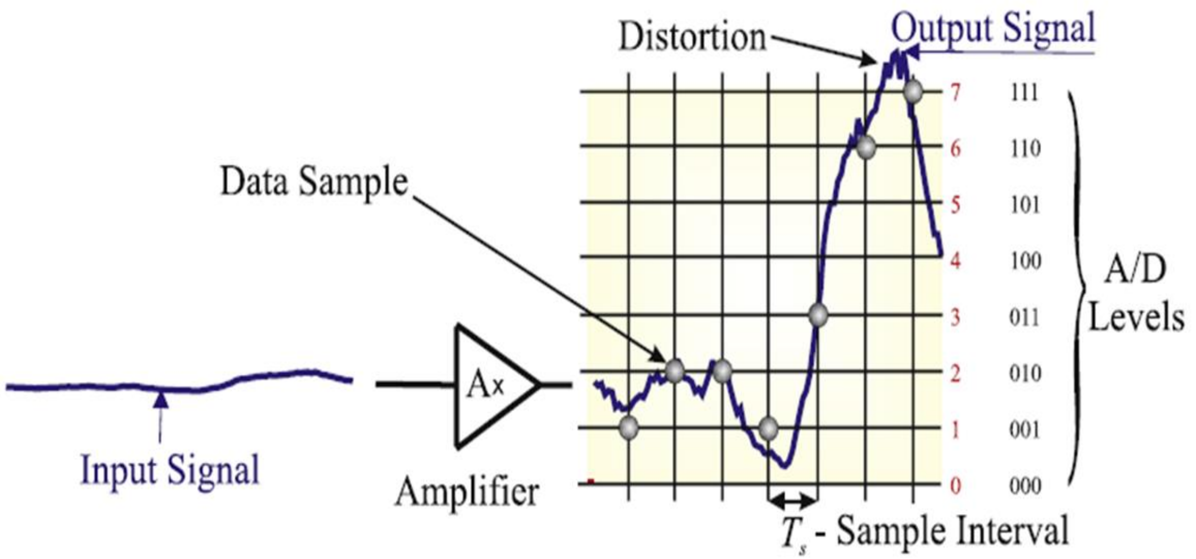


(A) A setup with silver- silver chloride electrodes with
(B) a detail of the chloride layer and
(C) a simplified electronic equivalent circuit.

Figure2.3 , Signal processing for Neuroscientist, second edition by Wim van Drongelen

Analogue to digital conversion

- The nature of biomedical signals is analog: i.e., continuous both in amplitude and time. Modern data acquisition and analysis frequently depends on digital signal processing, and therefore the signal must be converted into a discrete representation. The time scale is made discrete by sampling the continuous wave at a given interval; the amplitude scale is made discrete by an analog-to-digital converter (A/D converter or ADC), which can be thought of as a truncation or rounding of a real-valued measurement to an integer representation.
- An important characteristic of an ADC is its amplitude resolution, which is measured in **bits.**



Analog-to-digital conversion (ADC). An example of an analog signal that is amplified A and digitized showing seven samples (marked by the dots) taken at a regular sample interval Ts, and a 3-bit A/D conversion. There are $2^3 = 8$ levels (0-7) of conversion. The decimal (0-7) representation of the digitizer levels is in red, the 3-bit binary code (000-111) in black. Note that, in this example, the converter represents the amplified signal values as integer values based on the signal value rounded to the nearest discrete level

Figure1.6 , Signal processing for Neuroscientist, second edition by Wim van Drongelen