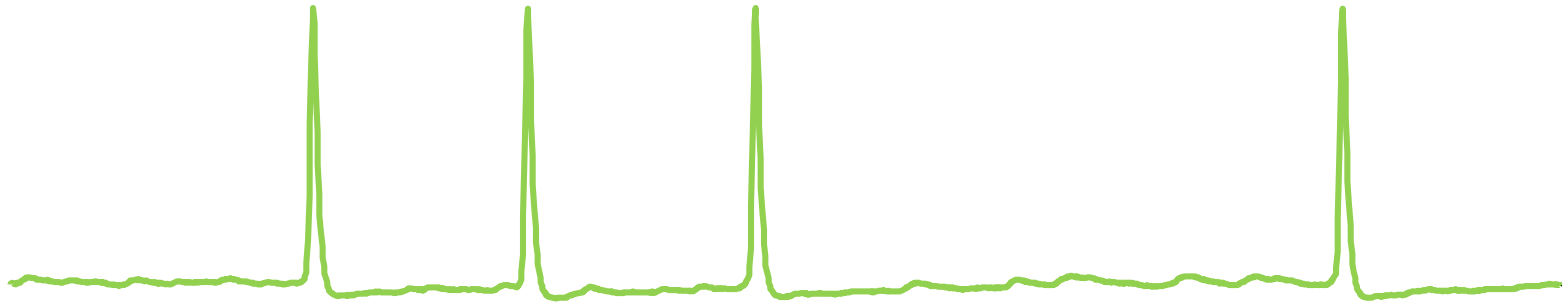


Methods in Behavioral Physiology -Electrophysiology-

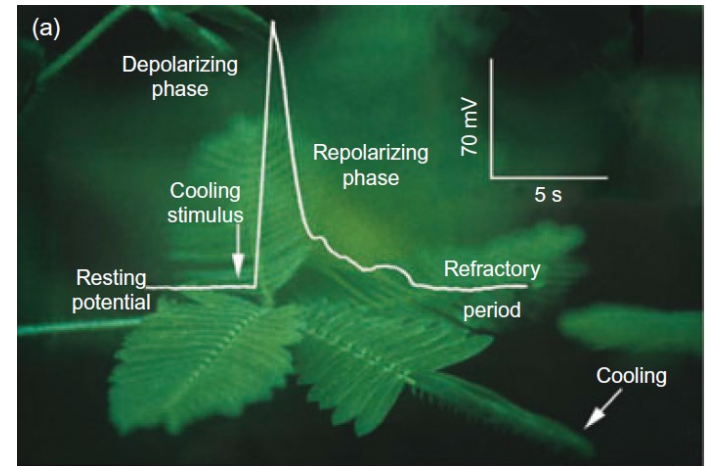
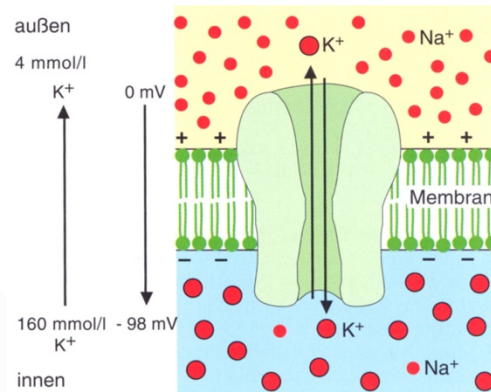
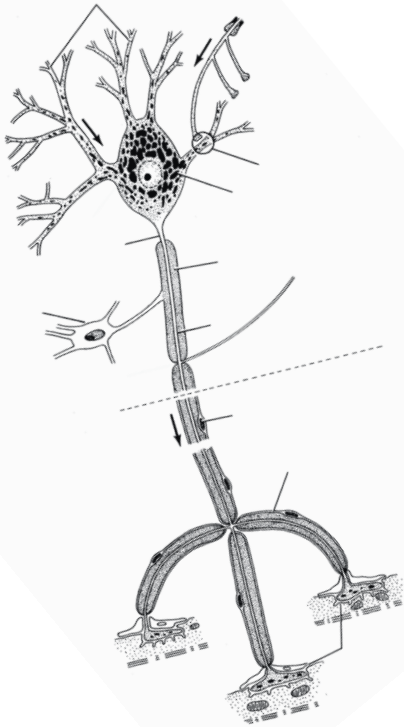


International MSc Program “Fokus Life Sciences” - Methods in Life Sciences

Prof. Keram Pfeiffer
Behavioral Physiology & Sociobiology (Zoology II)

What is electrophysiology

Elektrophysiologie ist die Studie der elektrischen Eigenschaften von tierischen und pflanzlichen Zellen und Geweben.



Fromm and Lautner 2007: Plant, Cell and Environment 30:249–257

Elektrophysiologie from tissues to channels

Entire
organs/tissues

summed potentials

EMG: electro**myo**gram

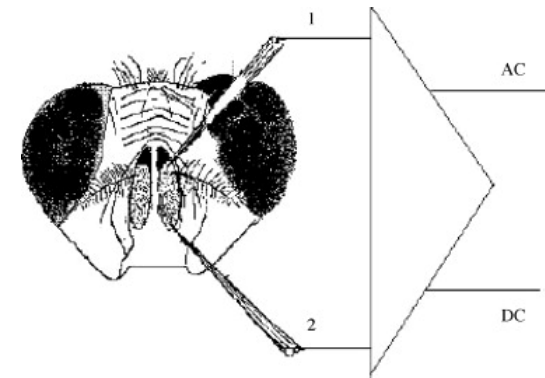
EOG: electro**oculo**gram

ECG: electro**cardio**gram

EEG: electro**encephalo**gram

EAG: electro**antenn**ogram

ERG: electro**retino**gram



Huotari M 2007: Sensors and Actuators B 127:284–287.

Elektrophysiologie von Gewebe zu Kanälen

Entire organs/tissues

Multiple cells

Single cells

Single channels

Summed potentials

extracellular

extracellular

patch clamp

EEG
EKG

multielectrode recordings

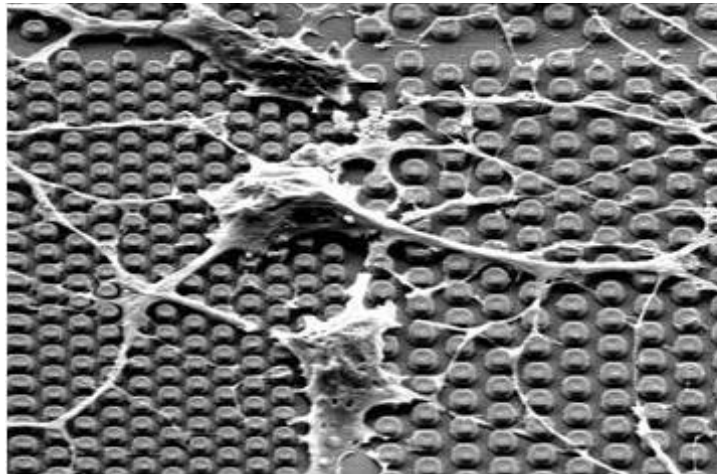
intracellular

EOG

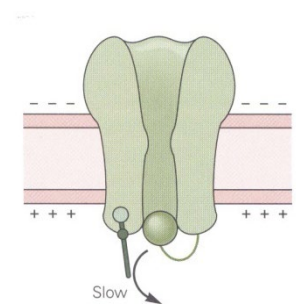
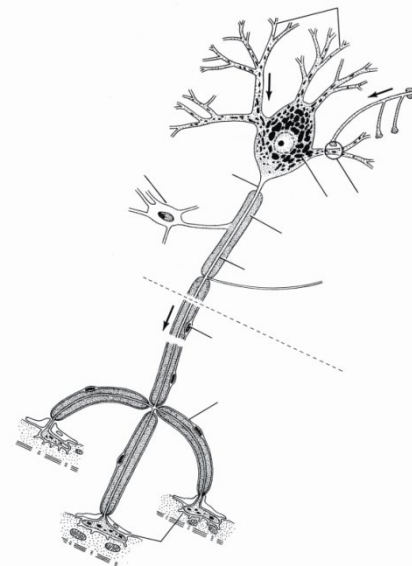
EAG

EMG

ERG



www2.imec.be



Kandel et al. 2000

Electrophysiology equipment 1

**electrical
contact with
specimen**

recording
electrode



reference
electrode

**filtering/
amplification**

filter
amplifier



**visualisation/
recording**

chart recorder

oscilloscope



analog-digital-
converter/Computer



Electrophysiology equipment 2

audio monitor



50 mV

2 s

Electrophysiology equipment 3

vibration isolation
table

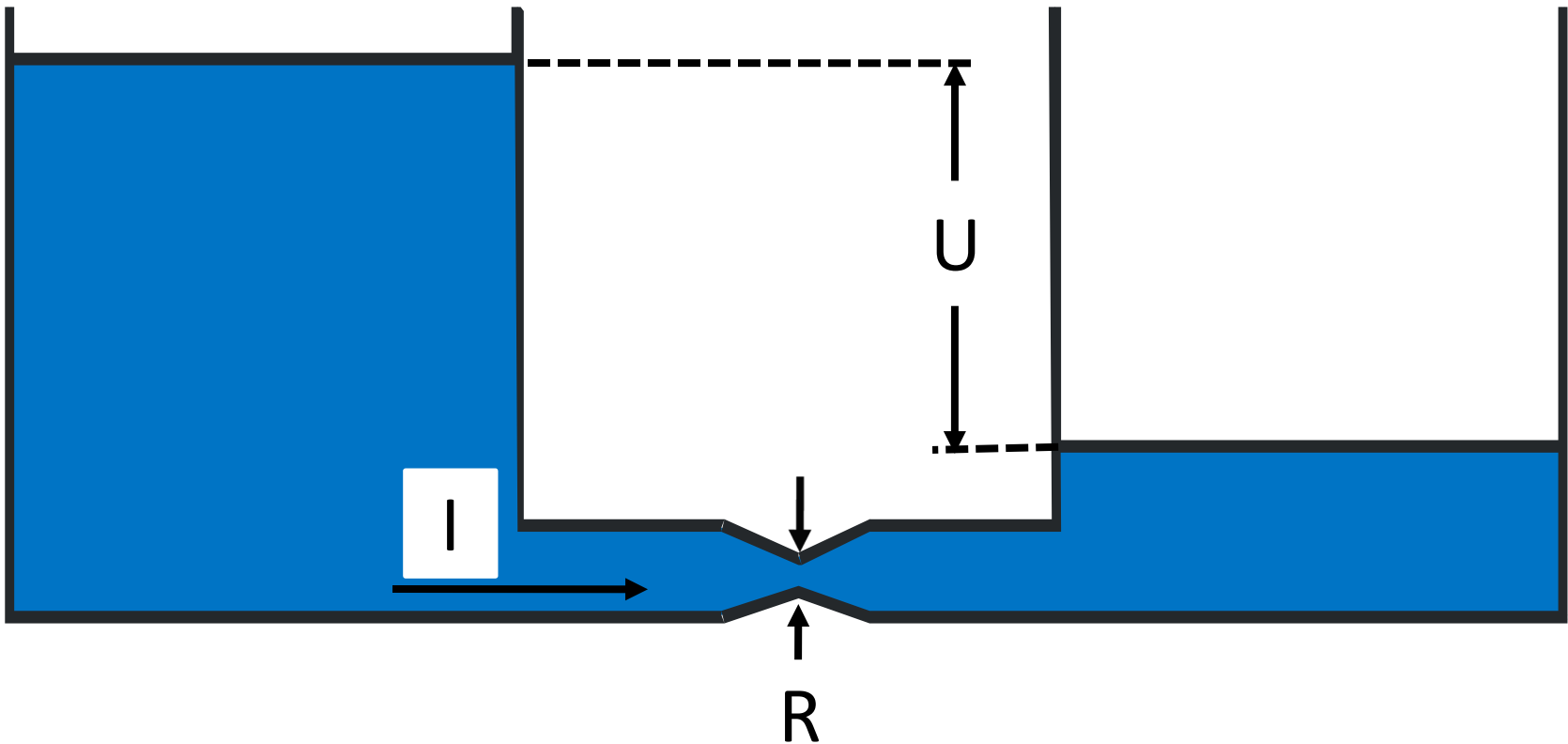


micromanipulator



Ohm's law

$$U = R * I$$



Electrophysiology equipment 1

**electrical
contact with
specimen**

recording
electrode



reference
electrode

filtering/
amplification

filter
amplifier



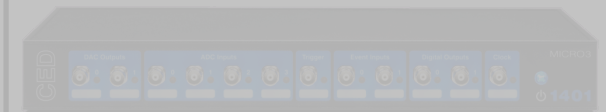
visualisation/
recording

chart recorder

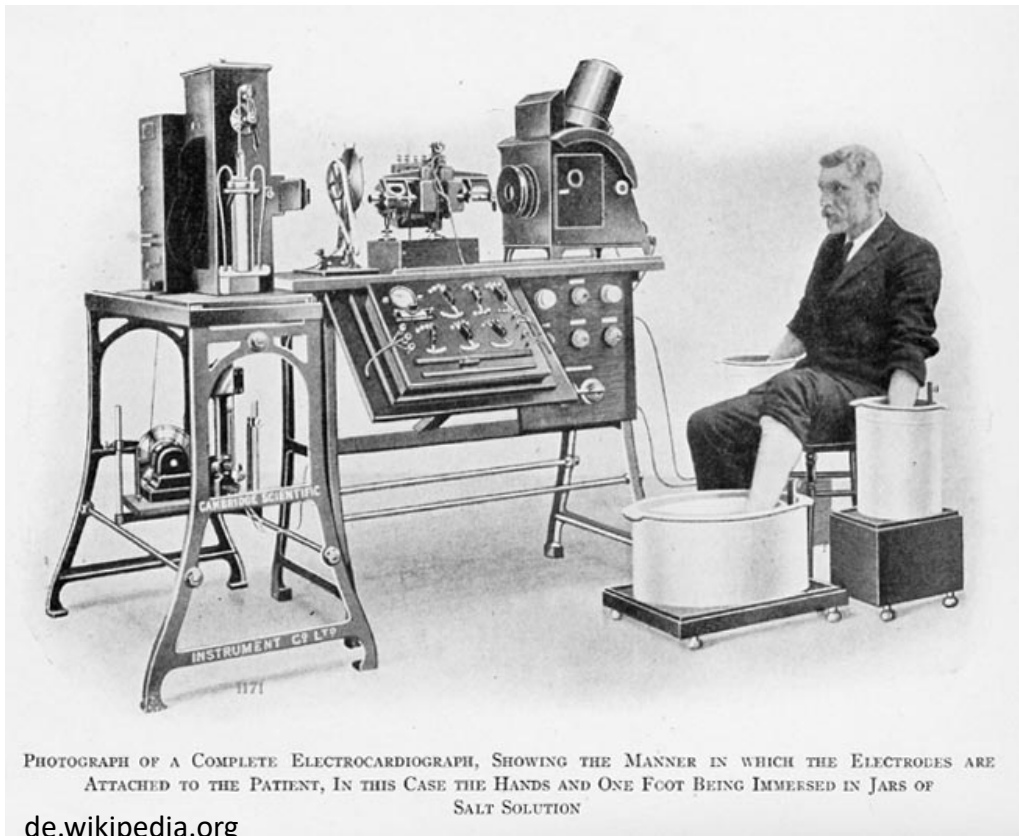
oscilloscope



analog-digital-
converter/Computer

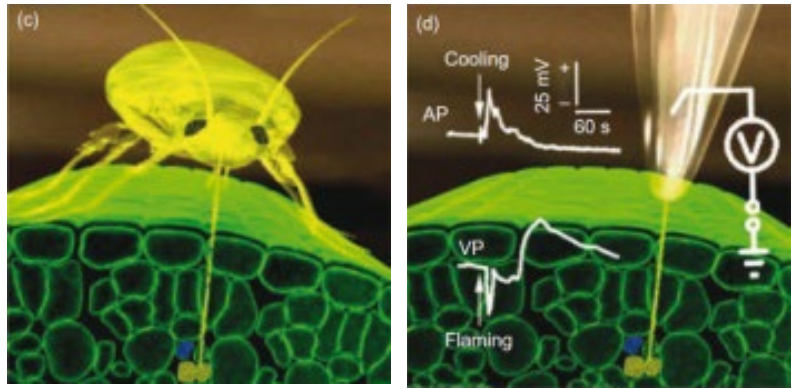


Electrodes 1

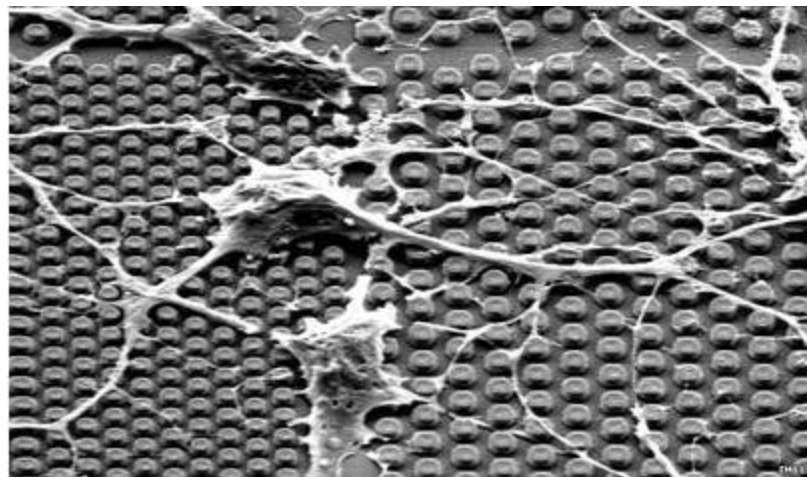


PHOTOGRAPH OF A COMPLETE ELECTROCARDIOGRAPH, SHOWING THE MANNER IN WHICH THE ELECTRODES ARE ATTACHED TO THE PATIENT, IN THIS CASE THE HANDS AND ONE FOOT BEING IMMERSED IN JARS OF SALT SOLUTION

de.wikipedia.org



Fromm and Lautner 2007: Plant, Cell Environ 30:249–257



www2.imec.be

electrodes 2

extracellular

etched metal rods
(tungsten or
platinum/iridium)

copper wires

suction electrodes

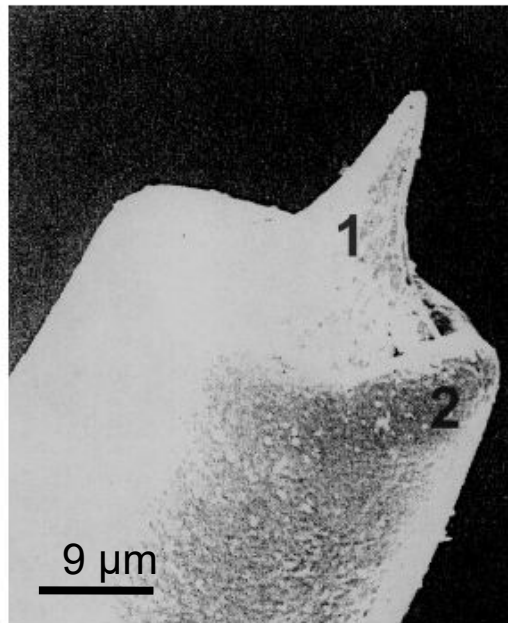
glass micro cappillaries

intracellular

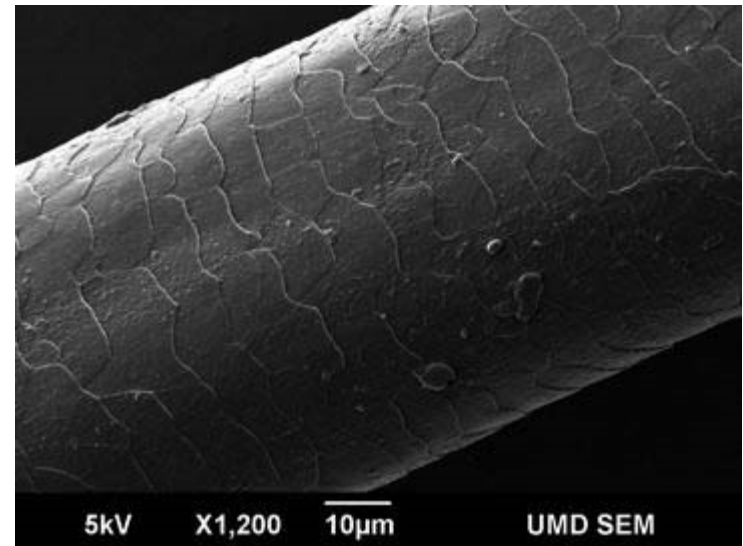
glass micro electrodes
(impedance ca. 100 M Ω)

patch clamp

glass micro electrodes
(impedance ca. 5–15 M Ω)

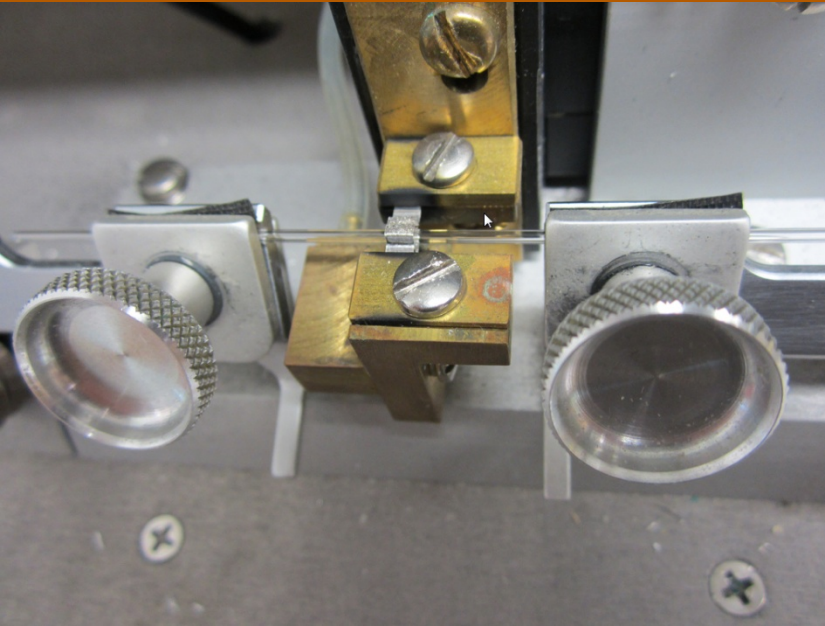


Modified from Scharmann 1996

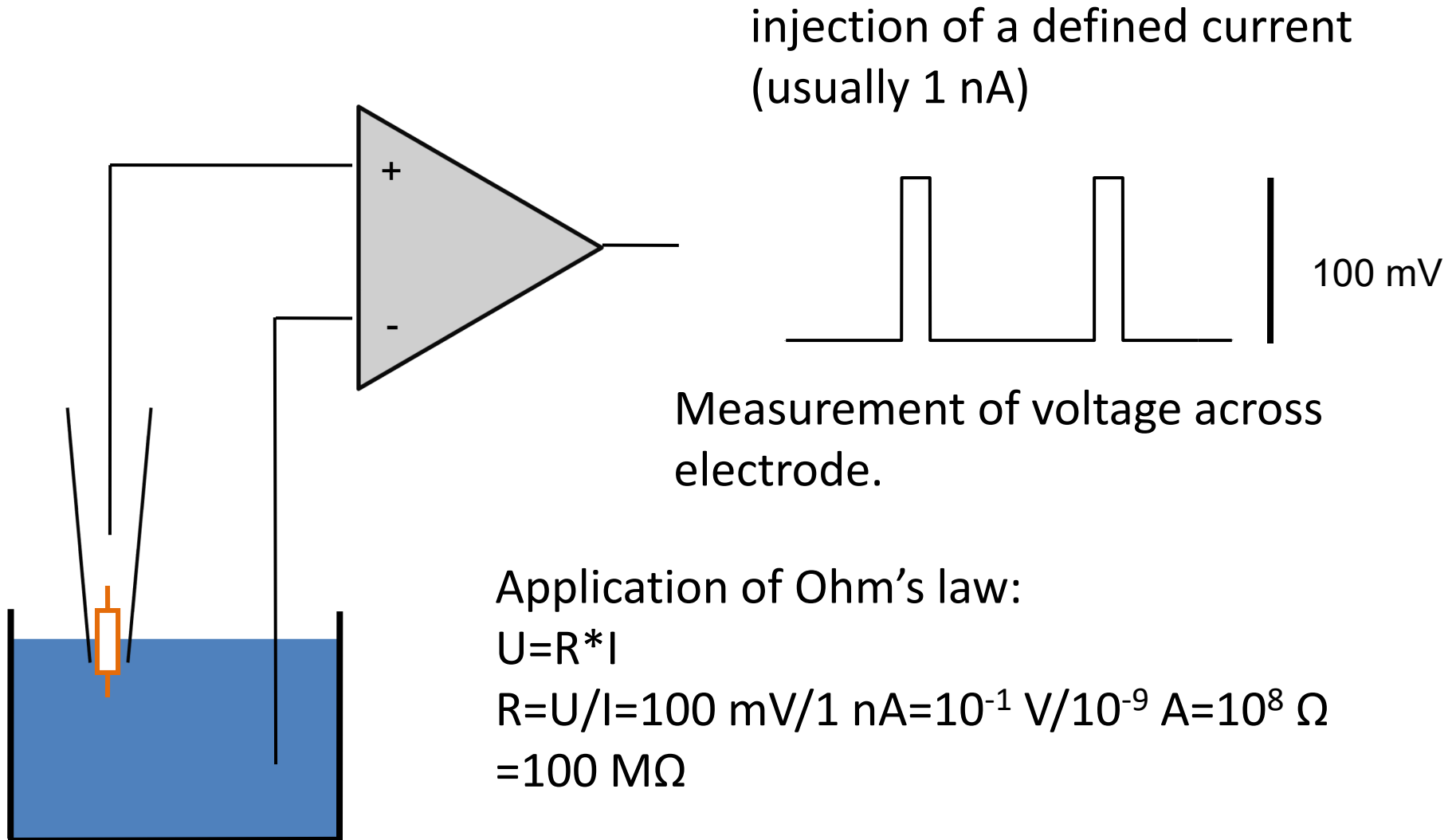


www.d.umn.edu/news/2008/August/Human_hair.jpg

electrode puller



Measurement of electrode resistance



injection of a defined current
(usually 1 nA)

100 mV

Measurement of voltage across
electrode.

Application of Ohm's law:

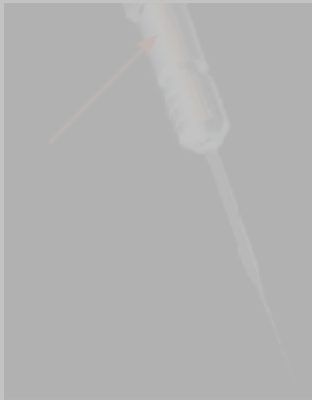
$$U=R \cdot I$$

$$R=U/I=100 \text{ mV}/1 \text{ nA}=10^{-1} \text{ V}/10^{-9} \text{ A}=10^8 \Omega$$
$$=100 \text{ M}\Omega$$

Electrophysiology equipment 1

electrical
contact with
specimen

recording
electrode



reference
electrode

**filtering/
amplification**

filter
amplifier



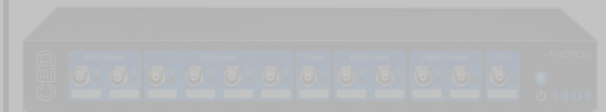
visualisation/
recording

chart recorder

oscilloscope



analog-digital-
converter/Computer



Why filter?

Removing of unwanted frequency bands, e.g.:

- noise

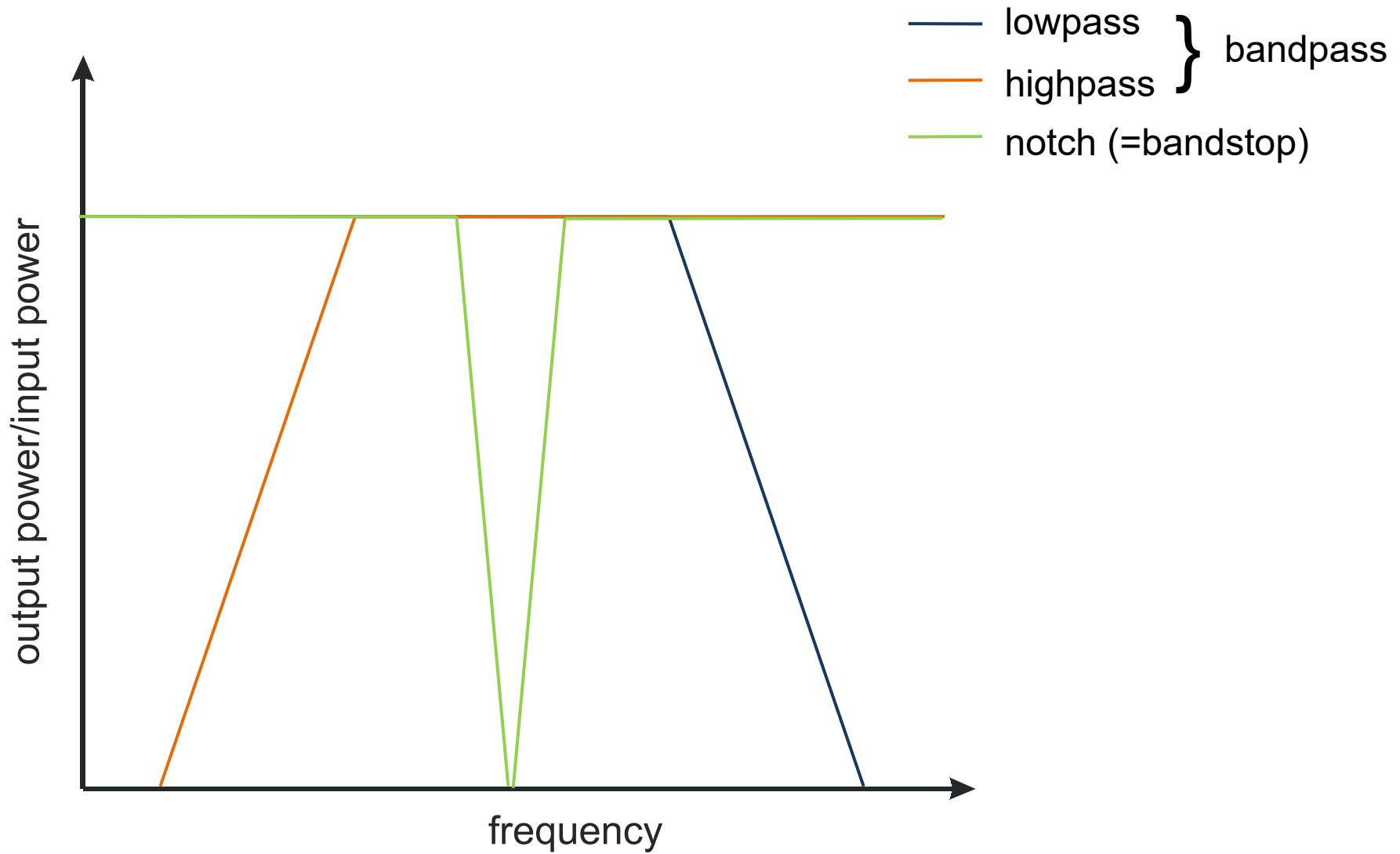
- offset/drift

- 50 Hz or 60 Hz hum

avoidance of aliasing

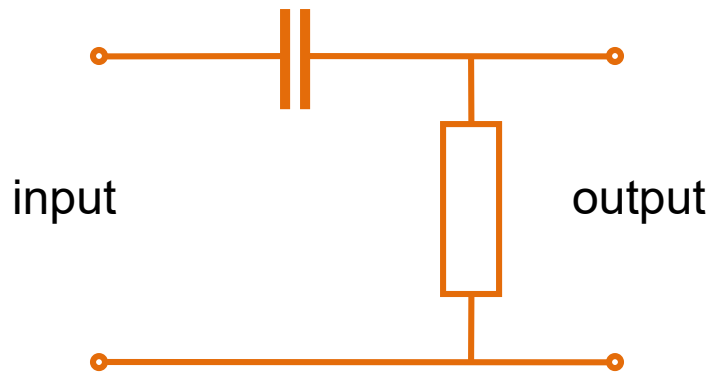


Transfer functions of filters

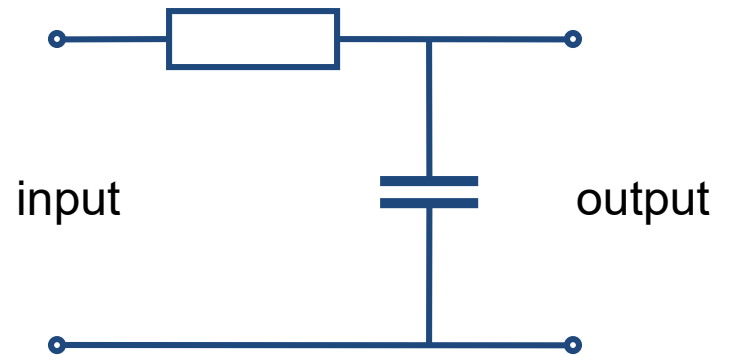


RC-circuit

high pass filter



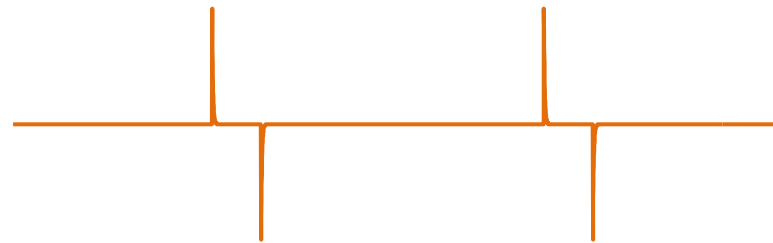
low pass filter



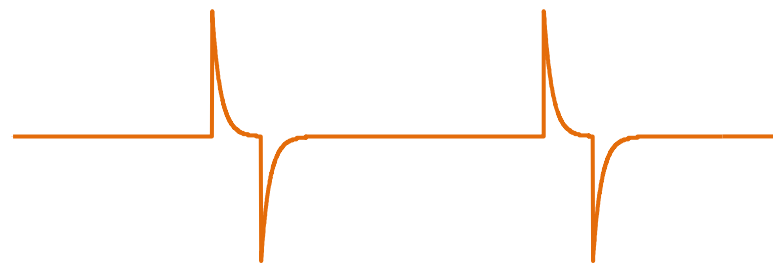
effects of high pass filters

input signal

output signal



500 Hz HP



50 Hz HP

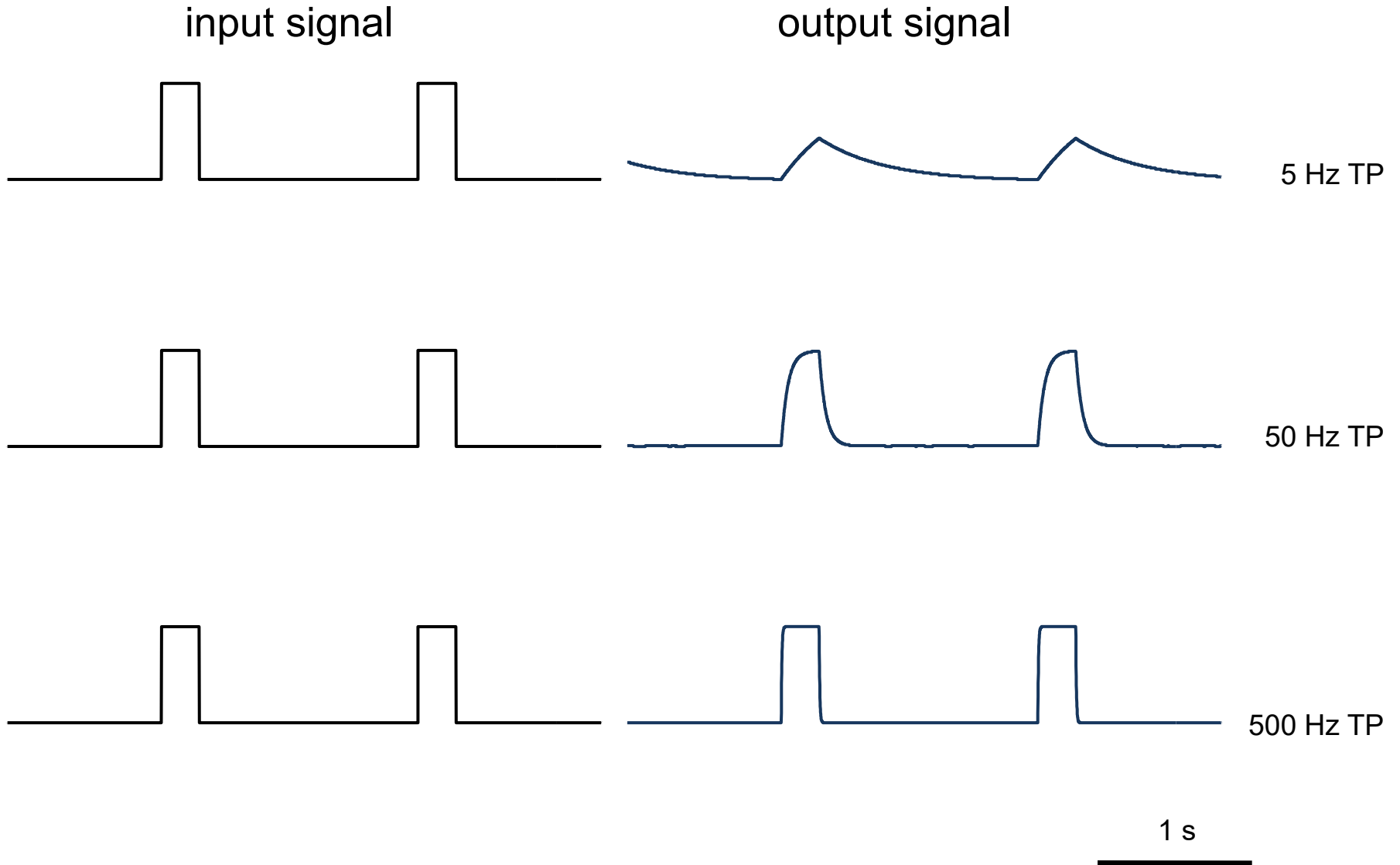


5 Hz HP

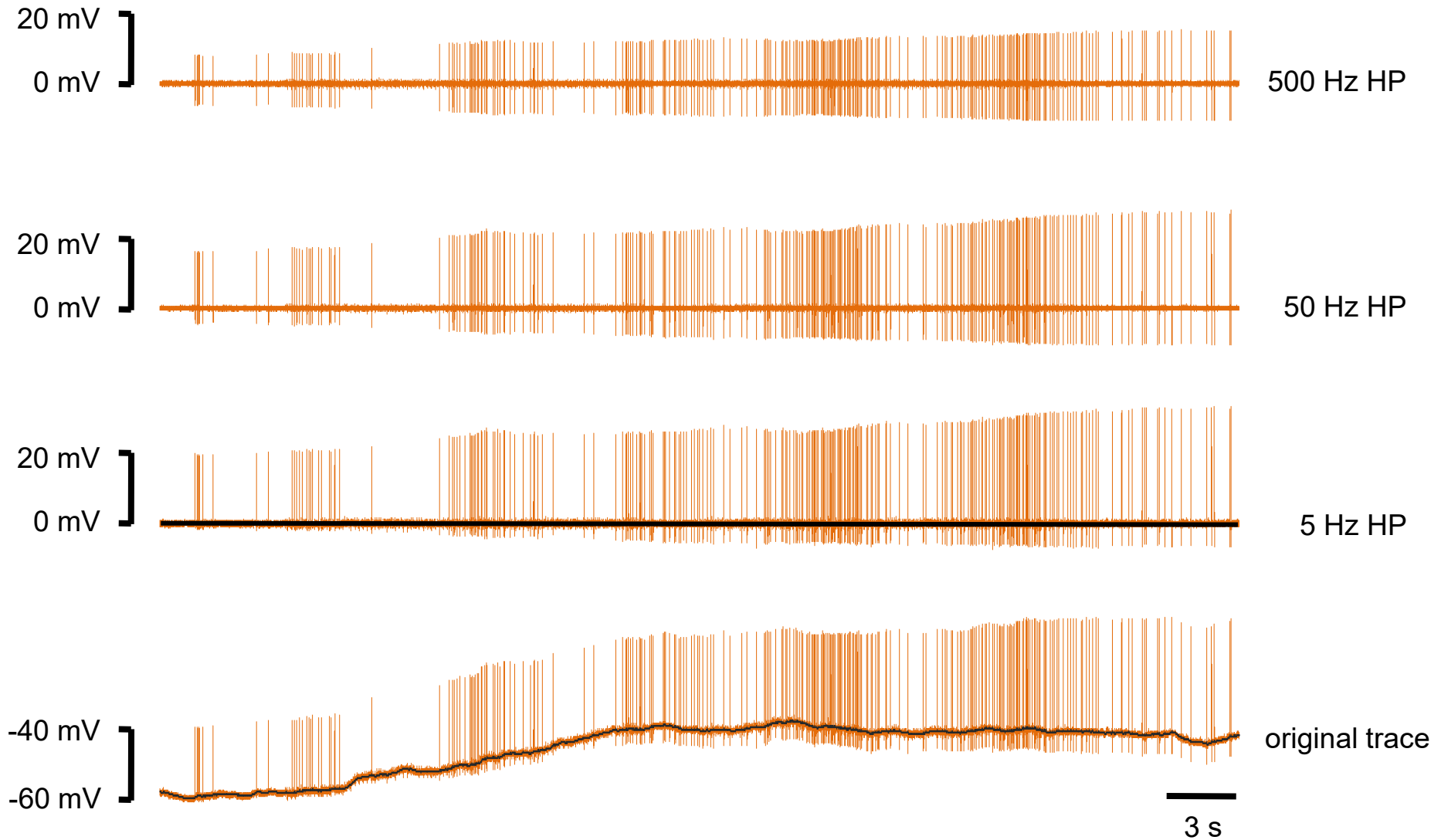
1 s



effects of low pass filters



effects of high pass filters



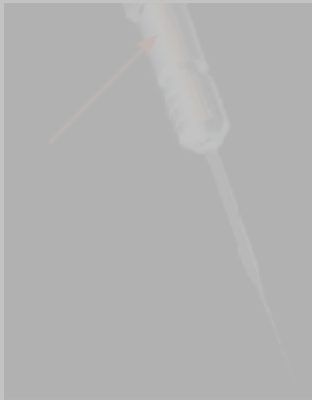
effects of low pass filters



Electrophysiology equipment 1

electrical
contact with
specimen

recording
electrode



reference
electrode

filtering/
amplification

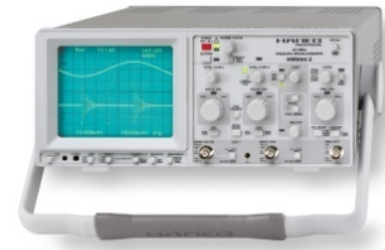
filter
amplifier



**visualisation/
recording**

chart recorder

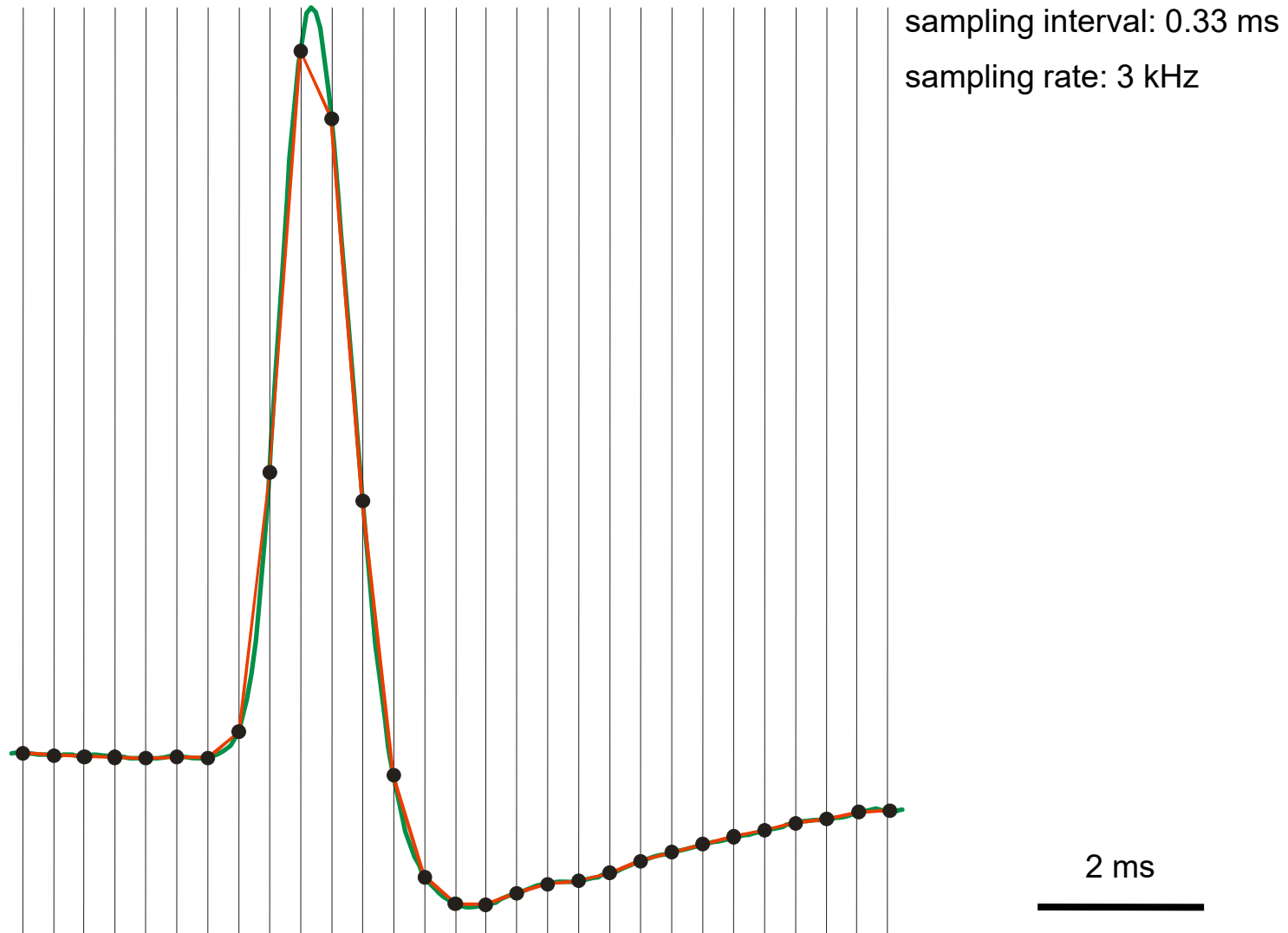
oscilloscope



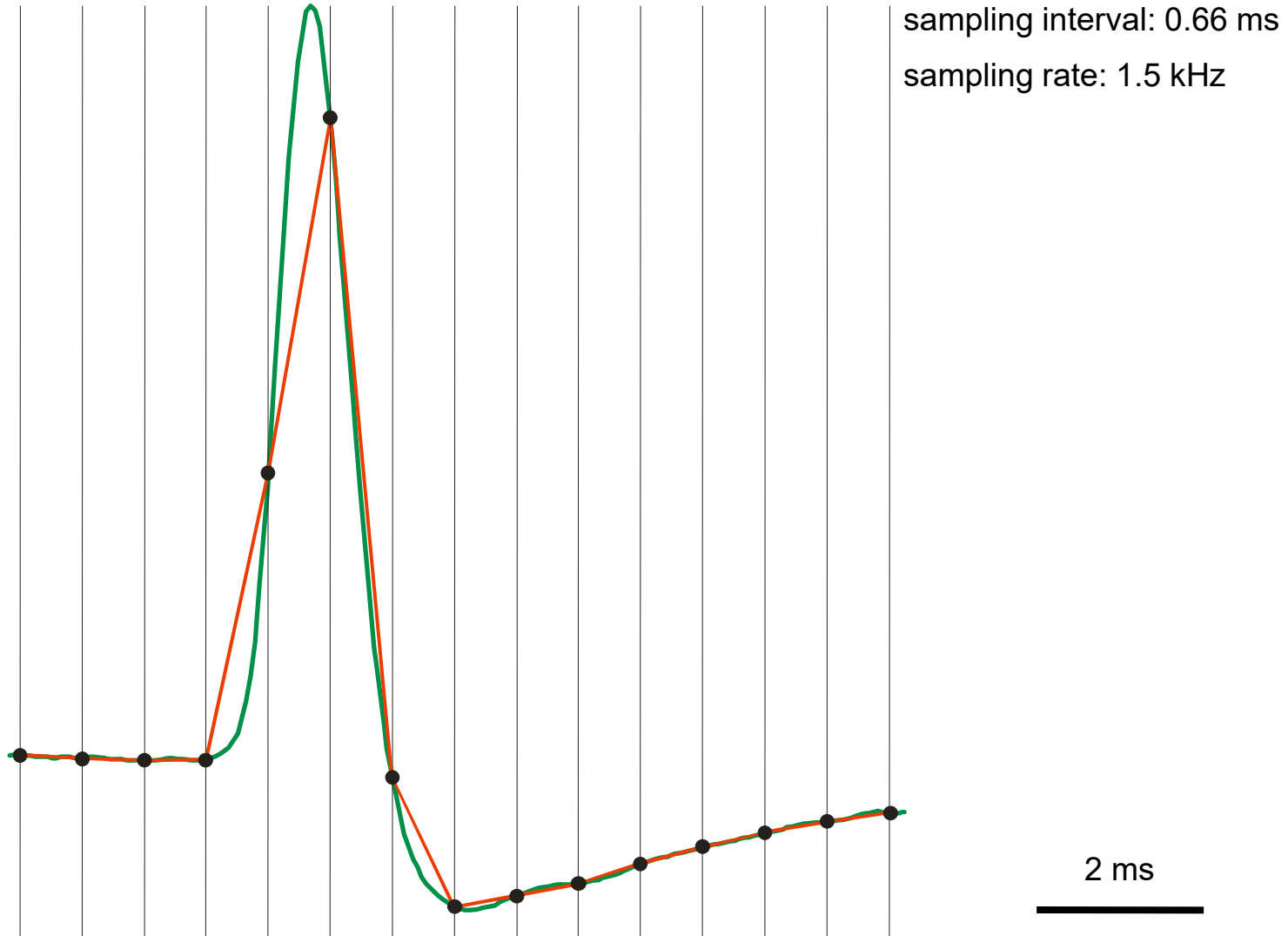
analog-digital-
converter/Computer



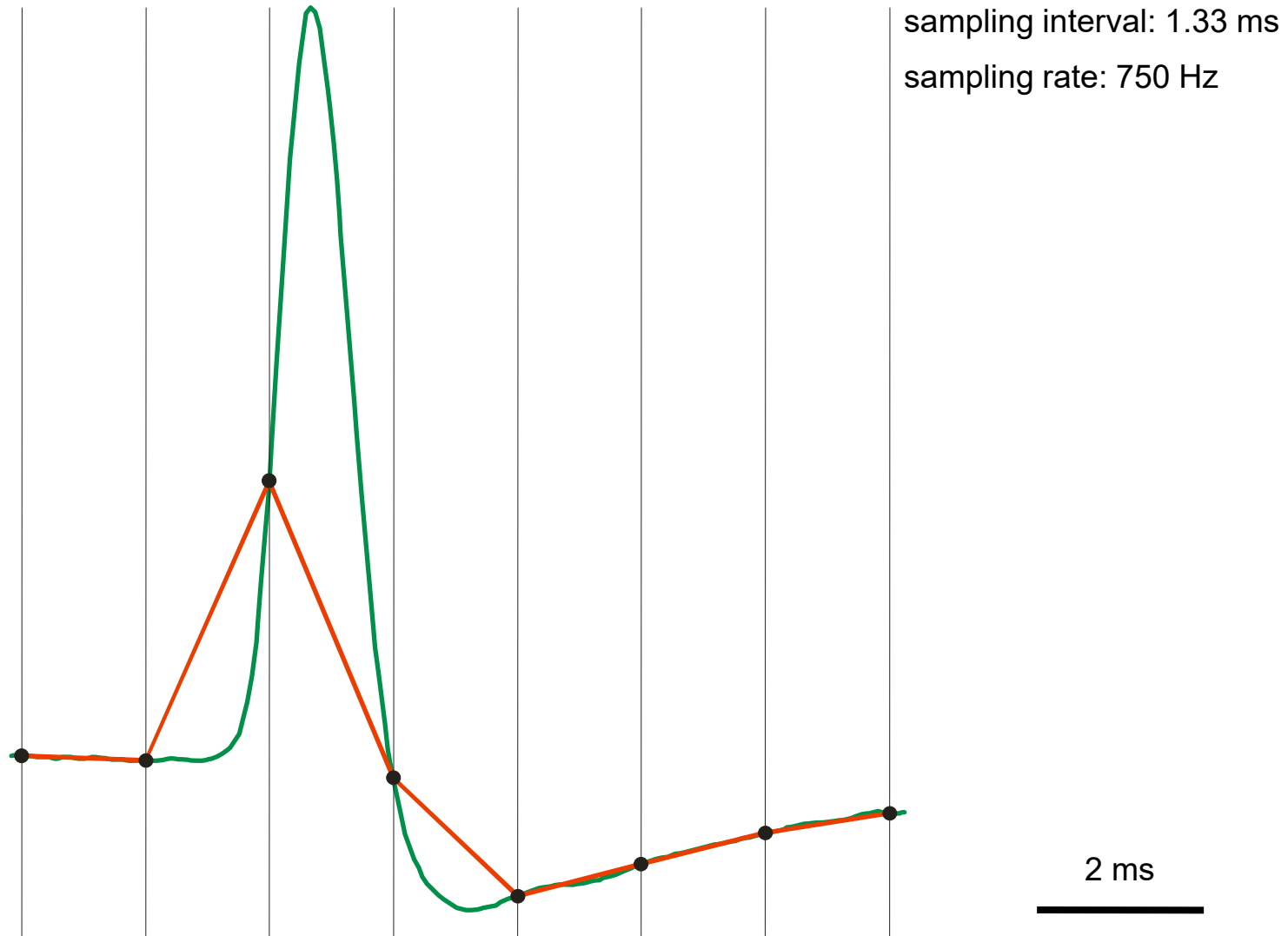
Digitization of analog signals



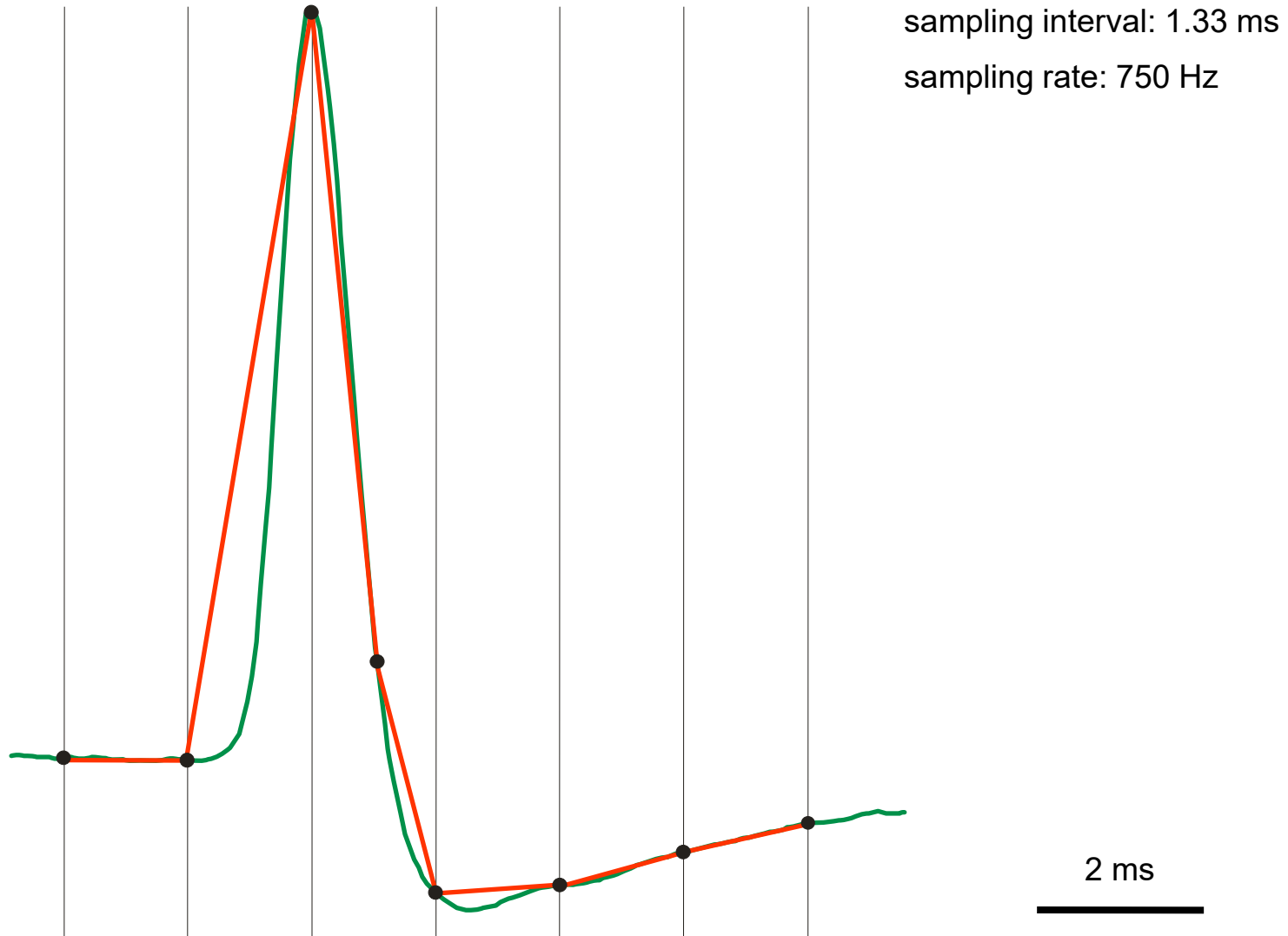
Digitization of analog signals



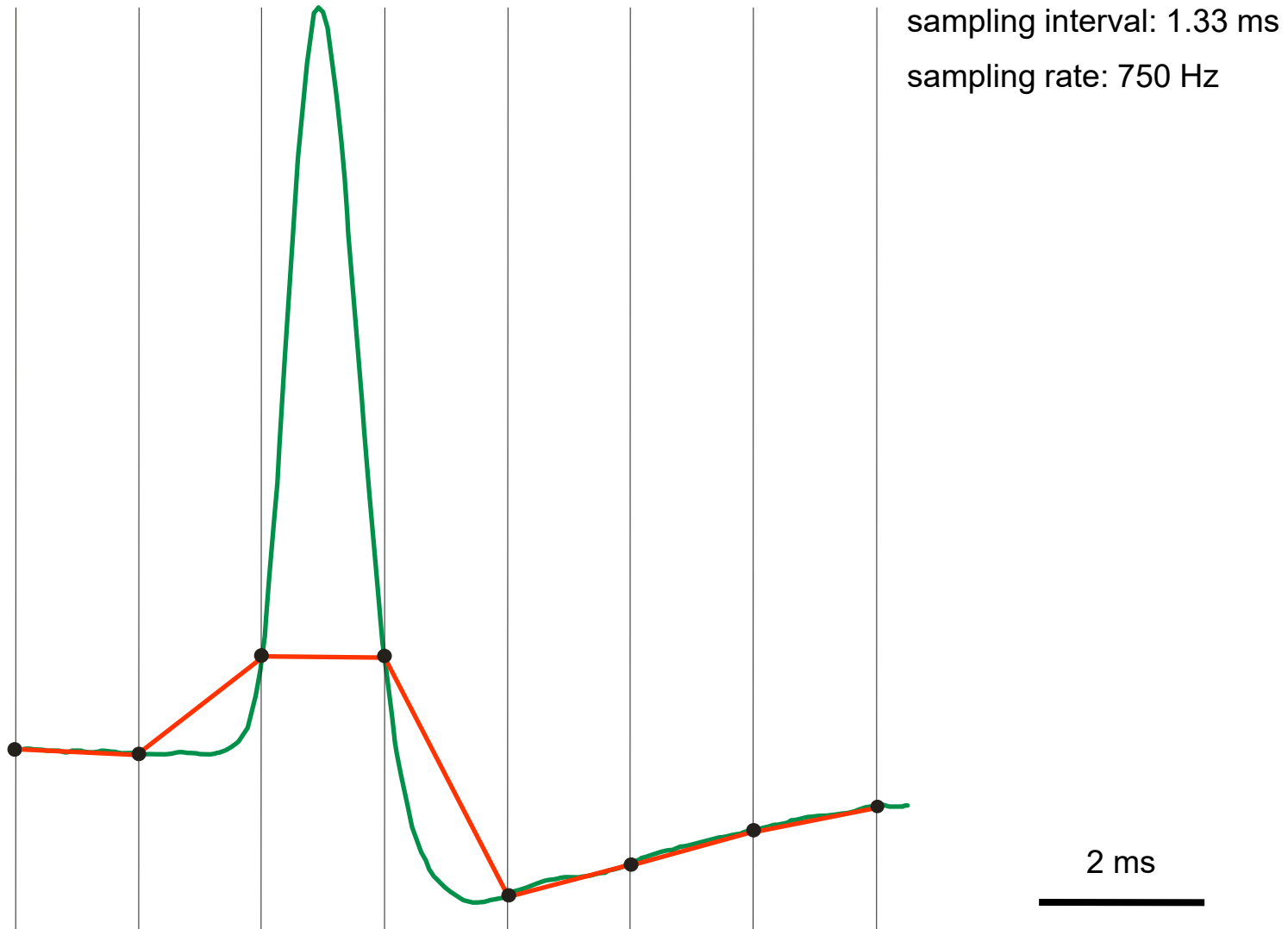
Digitization of analog signals



Digitization of analog signals

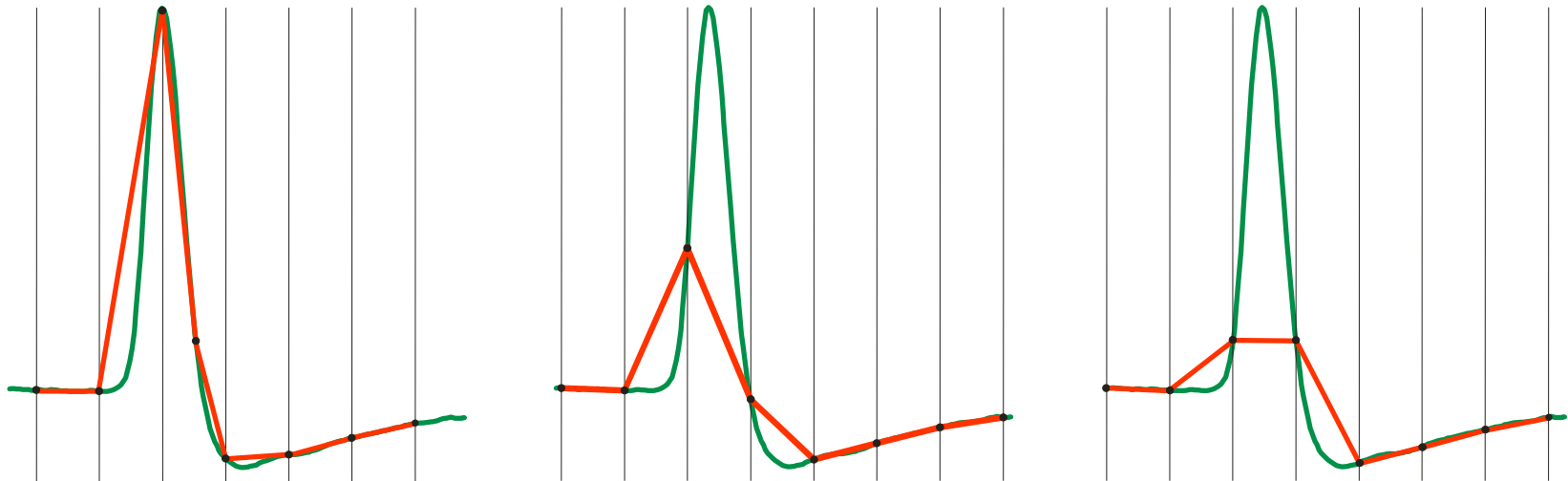


Digitization of analog signals



Digitization of analog signals

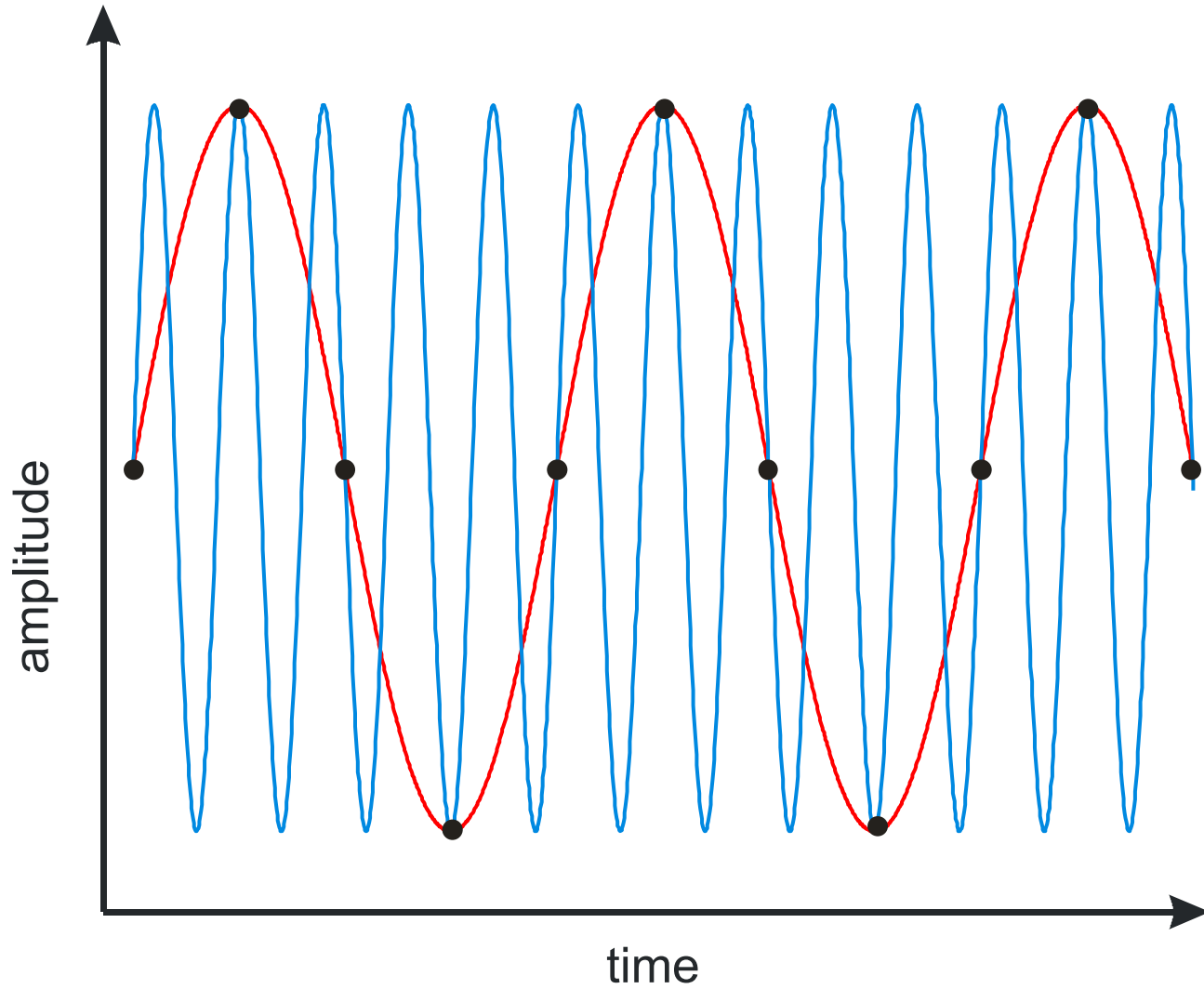
sampling interval: 1.33 ms
sampling rate: 750 Hz



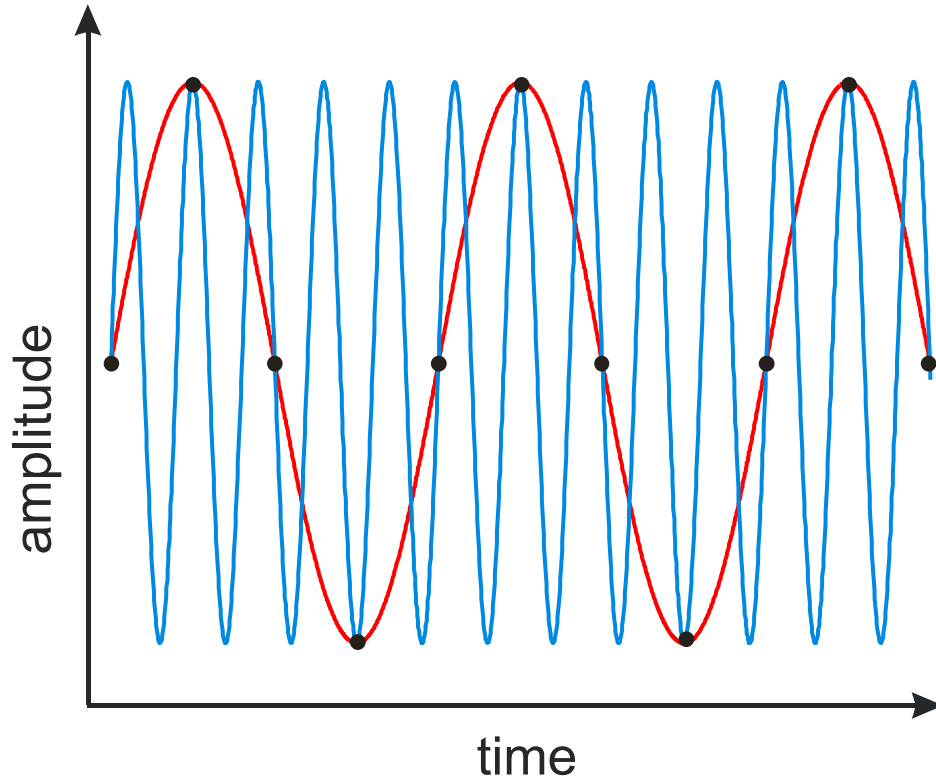
2 ms



Aliasing



Nyquist-Shannon theorem



The sampling frequency has to be at least 2 times that of the highest frequency in the signal.

Elektrophysiologie von Gewebe bis zu Kanälen

Alle
Organe/Gewebe

Mehrere Zellen

Einzelne Zellen

Einzelne Kanäle

Summierte Potentiale

extrazellulär

extrazellulär

patch clamp

EEG
EKG

multielektroden
Aufzeichnungen

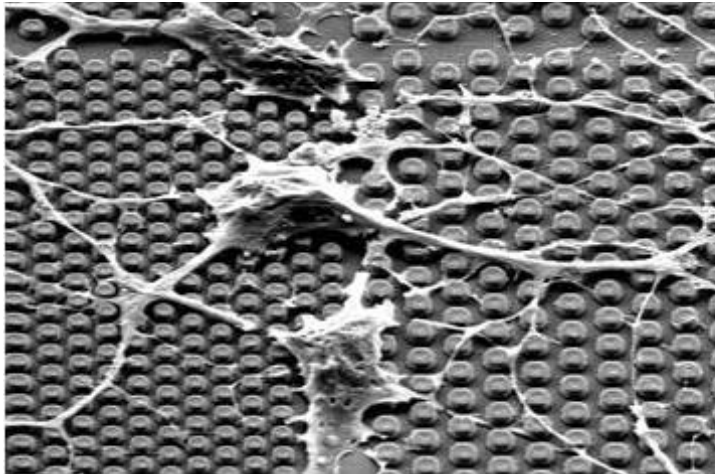
intrazellulär

EOG

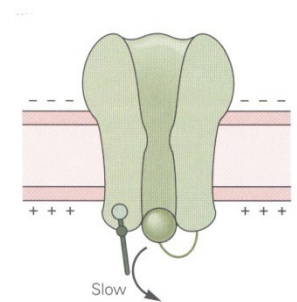
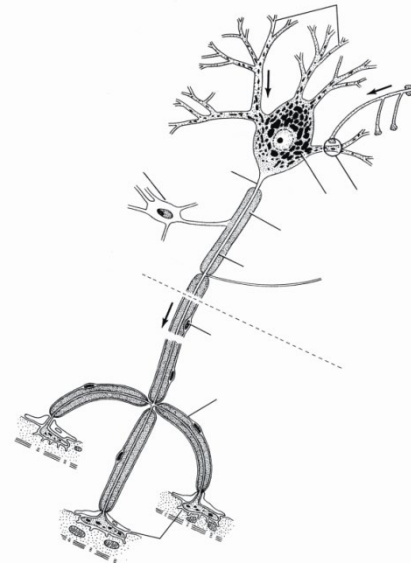
EAG

EMG

ERG

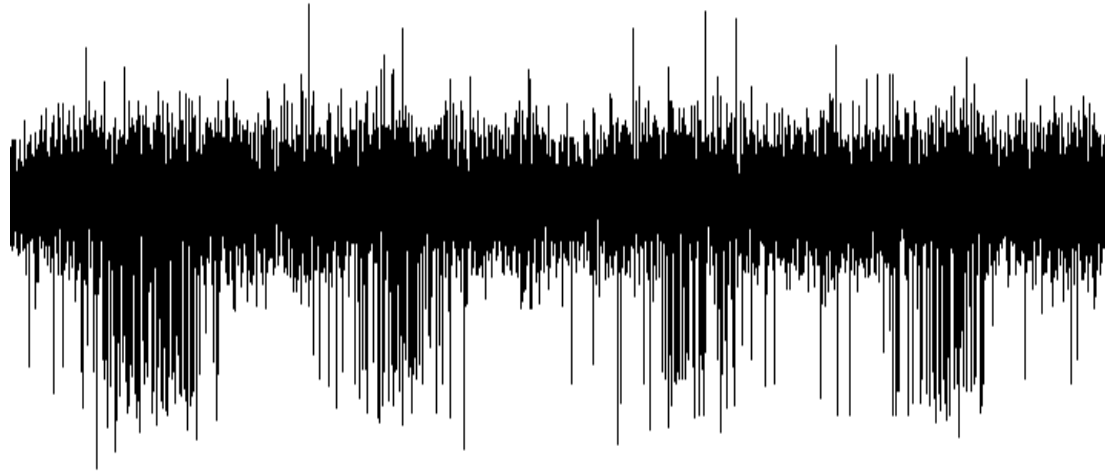


www2.imec.be

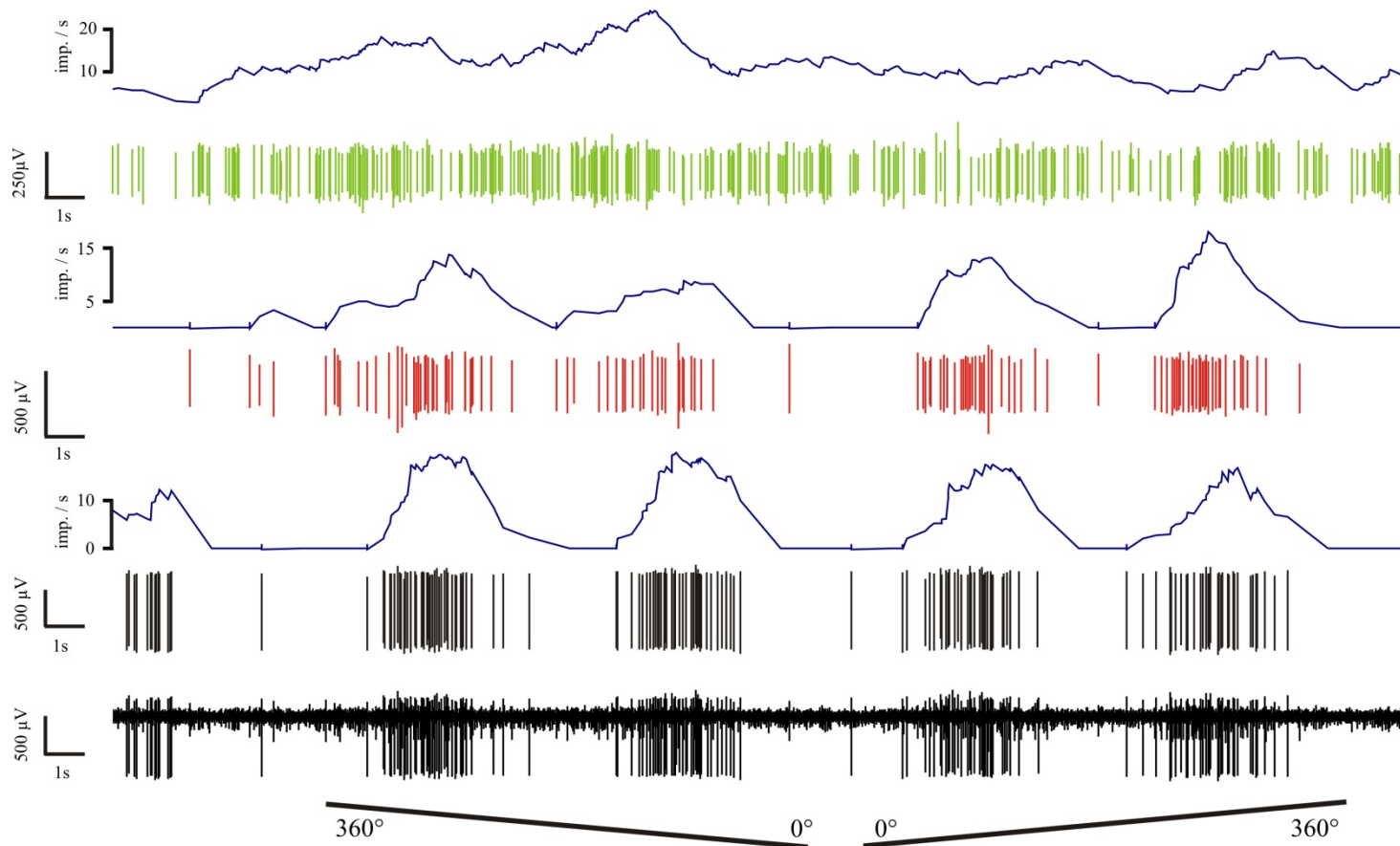


Kandel et al. 2000

Spike sorting



Multi unit recording



Elektrophysiologie von Gewebe zu Kanälen

Entire organs/tissues

Multiple cells

Single cells

Single channels

Summed potentials

extracellular

extracellular

patch clamp

EEG
EKG

multielectrode recordings

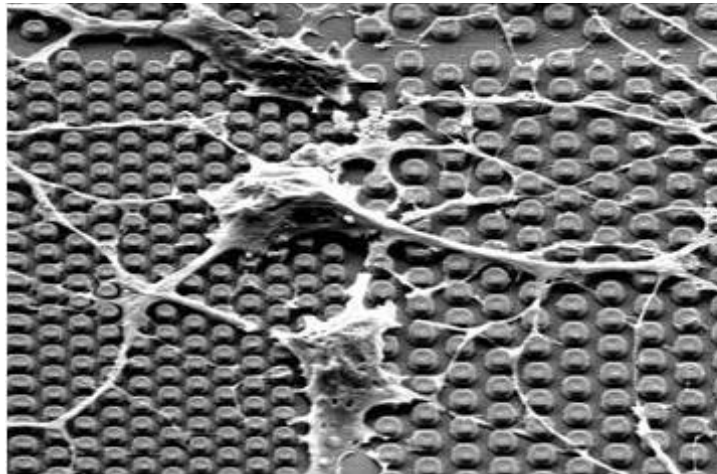
intracellular

EOG

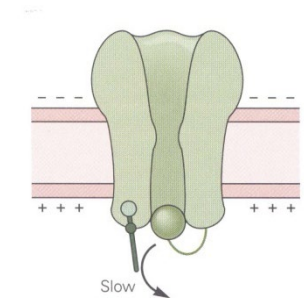
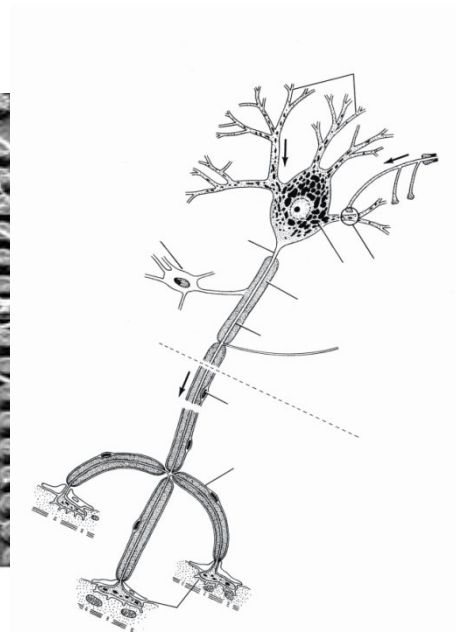
EAG

EMG

ERG

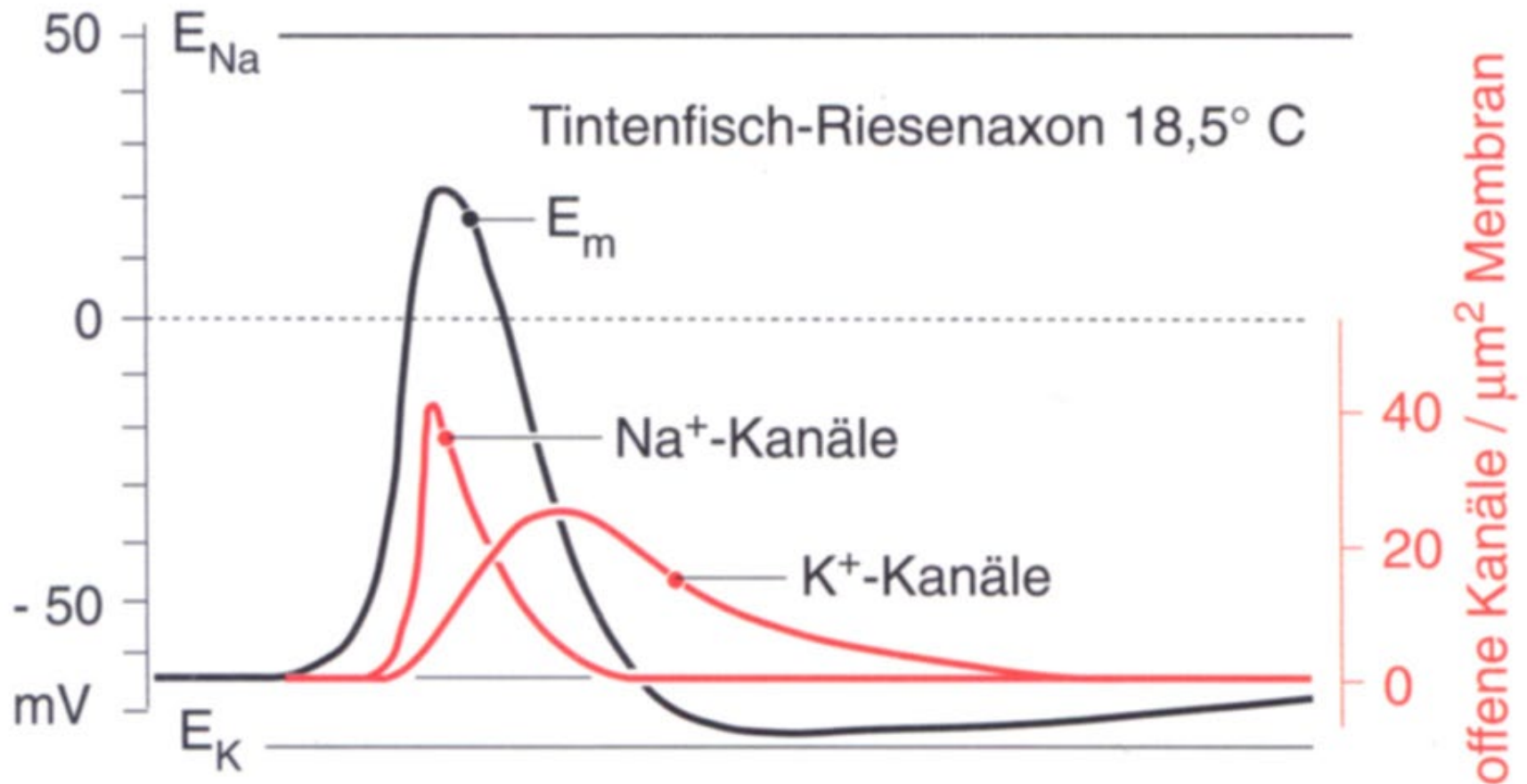


www2.imec.be



Kandel et al. 2000

Action potential



Intracellular recording

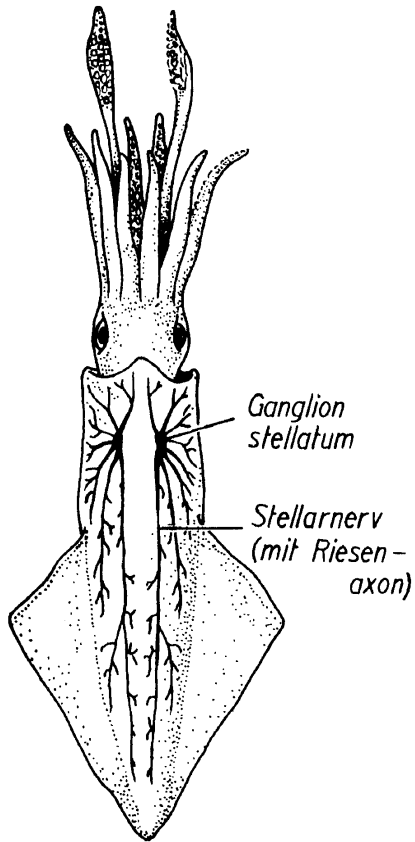


Fig. 1.
MICROGRAPH OF ELECTRODE INSIDE GIANT
AXON. 1 SCALE DIVISION = 33 μ .

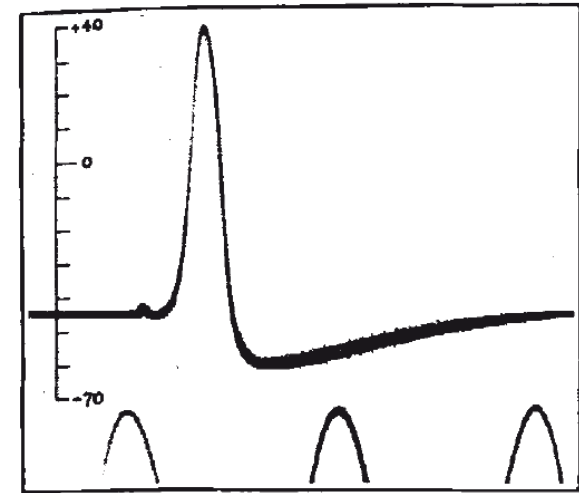


Fig. 2.

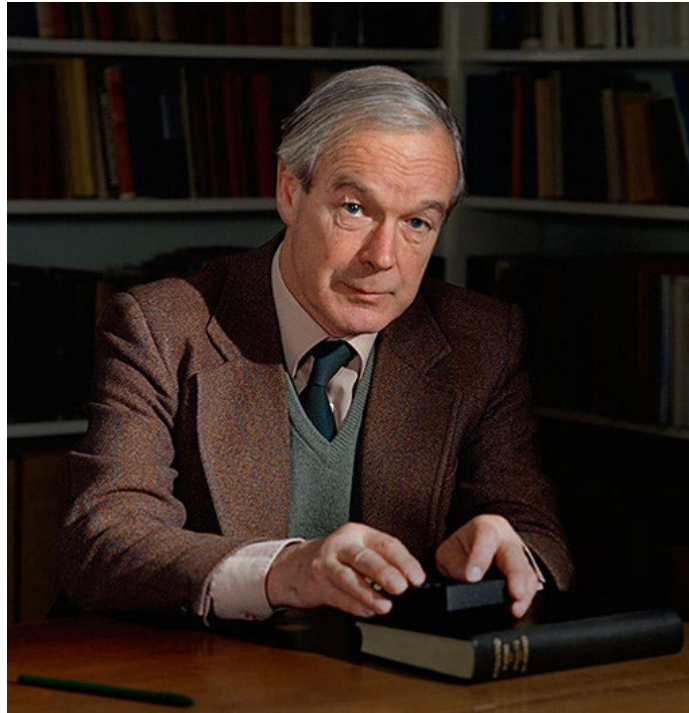
ACTION POTENTIAL RECORDED BETWEEN INSIDE AND OUTSIDE OF AXON. TIME MARKER, 500 CYCLES/SEC. THE VERTICAL SCALE INDICATES THE POTENTIAL OF THE INTERNAL ELECTRODE IN MILLIVOLTS, THE SEA WATER OUTSIDE BEING TAKEN AT ZERO POTENTIAL.

Nobel Prize Medicin/Physiology 1963

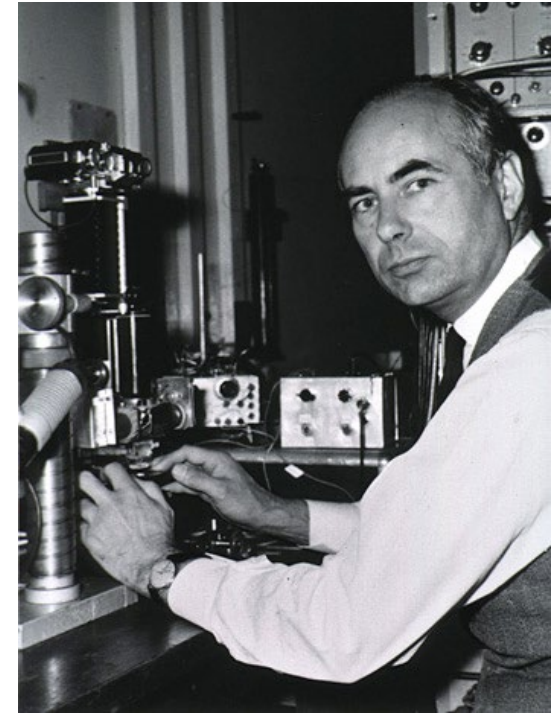
John Carew Eccles



Alan Lloyd Hodgkin

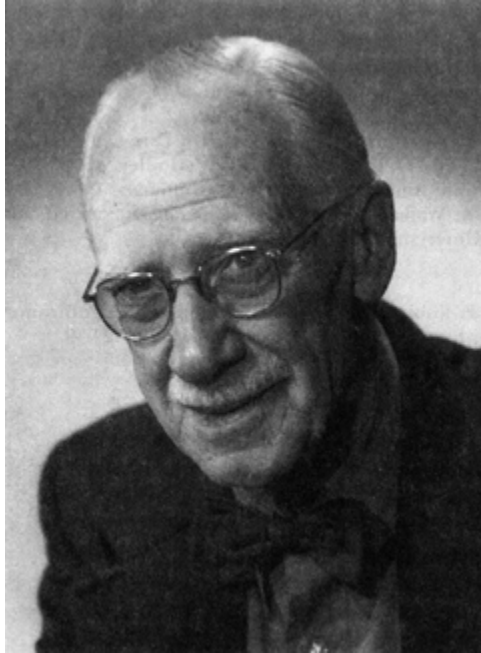


Andrew Fielding Huxley

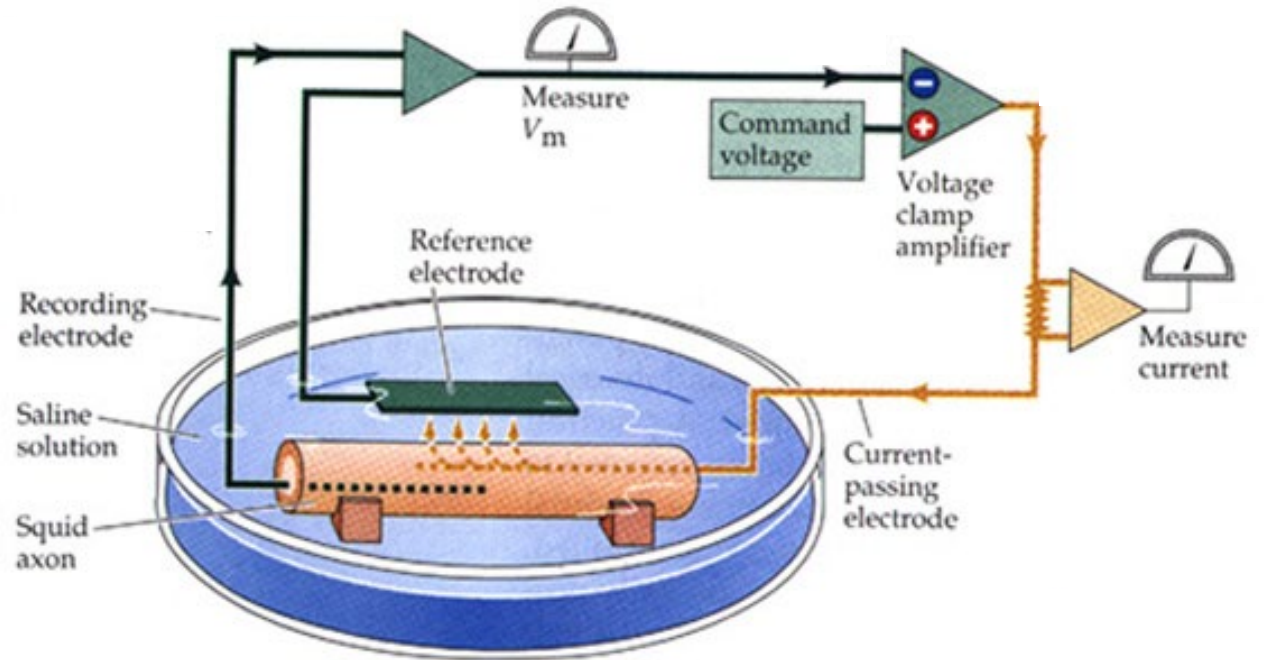


“for their discoveries concerning the ionic mechanisms involved in excitation and inhibition in the peripheral and central portions of the nerve cell membrane”

Voltage clamp



Kenneth Cole
1900-1994



Elektrophysiologie von Gewebe zu Kanälen

Entire organs/tissues

Multiple cells

Single cells

Single channels

Summed potentials

extracellular

extracellular

patch clamp

EEG
EKG

multielectrode recordings

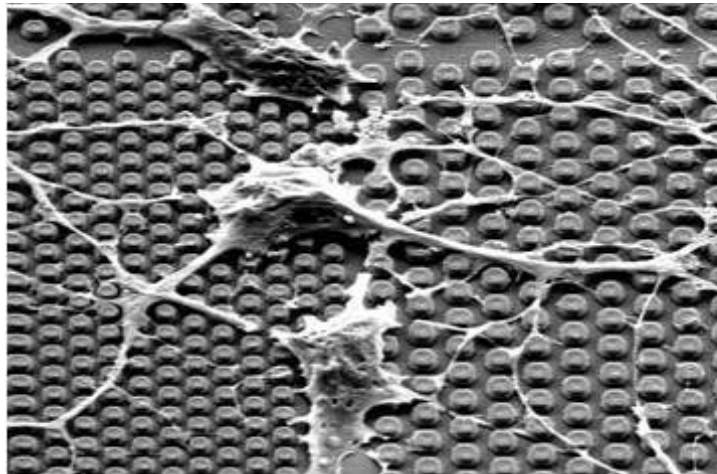
intracellular

EOG

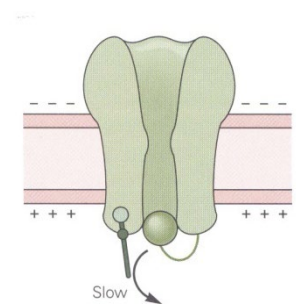
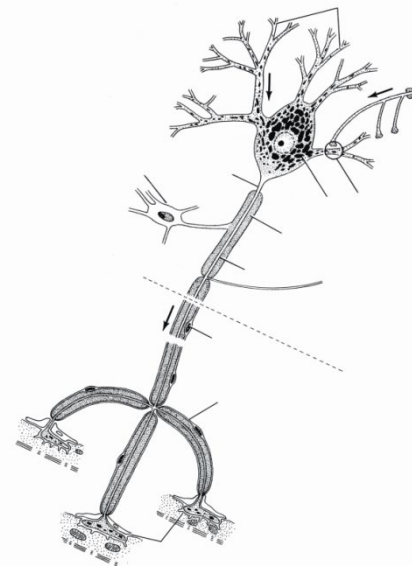
EAG

EMG

ERG

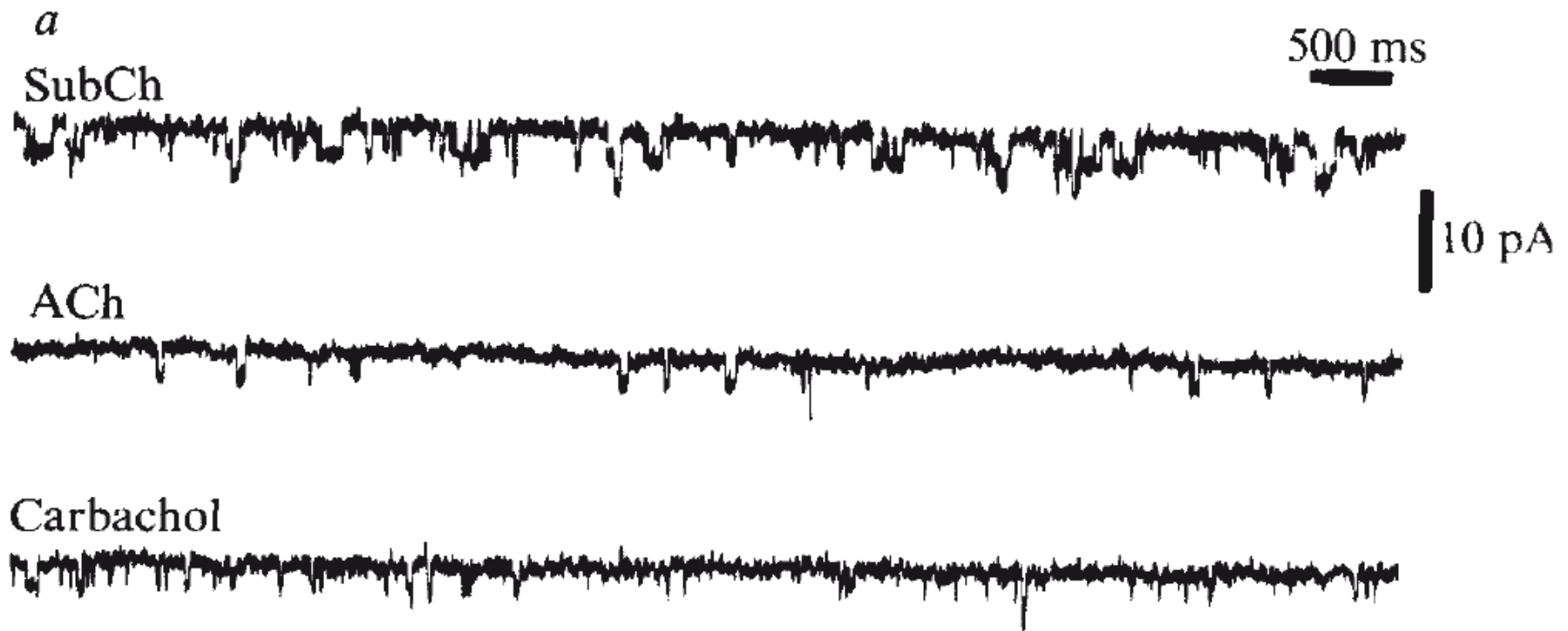


www2.imec.be

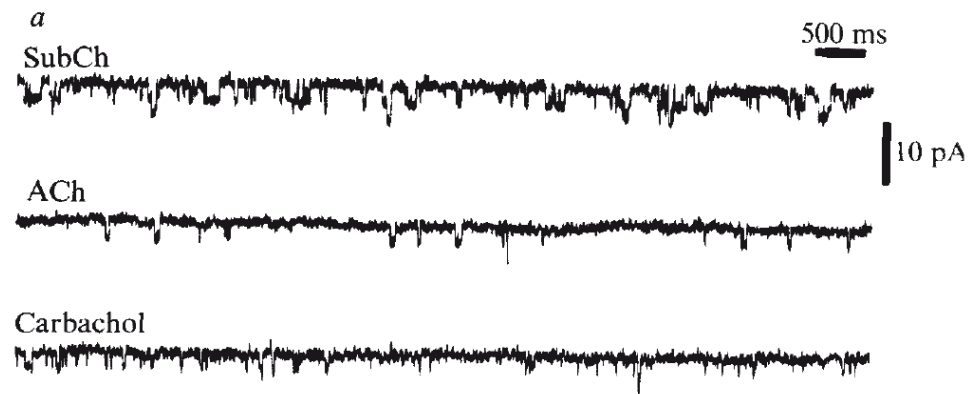
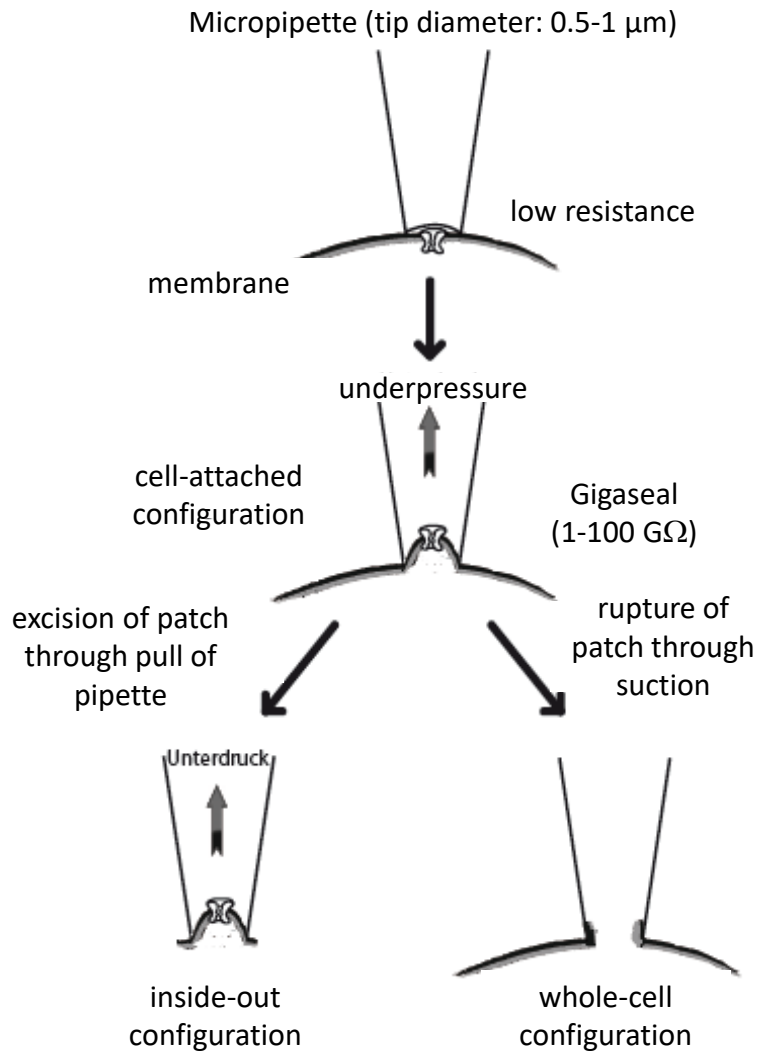


Kandel et al. 2000

Single channel recording



Patch Clamp Technique



Neher E, Sakmann B 1976: Nature 260: 799-802

Nobel Prize Medicine/Physiology 1991

Erwin Neher



Bert Sakmann



"for their discoveries concerning the function of single ion channels in cells"

Summary

Choose your tools according to the questions you want to answer

Know which filters you are using and why

Know the Shannon-Nyquist theorem and choose your sampling frequency accordingly