Bioelectric Signals

for

Biomedical Applications

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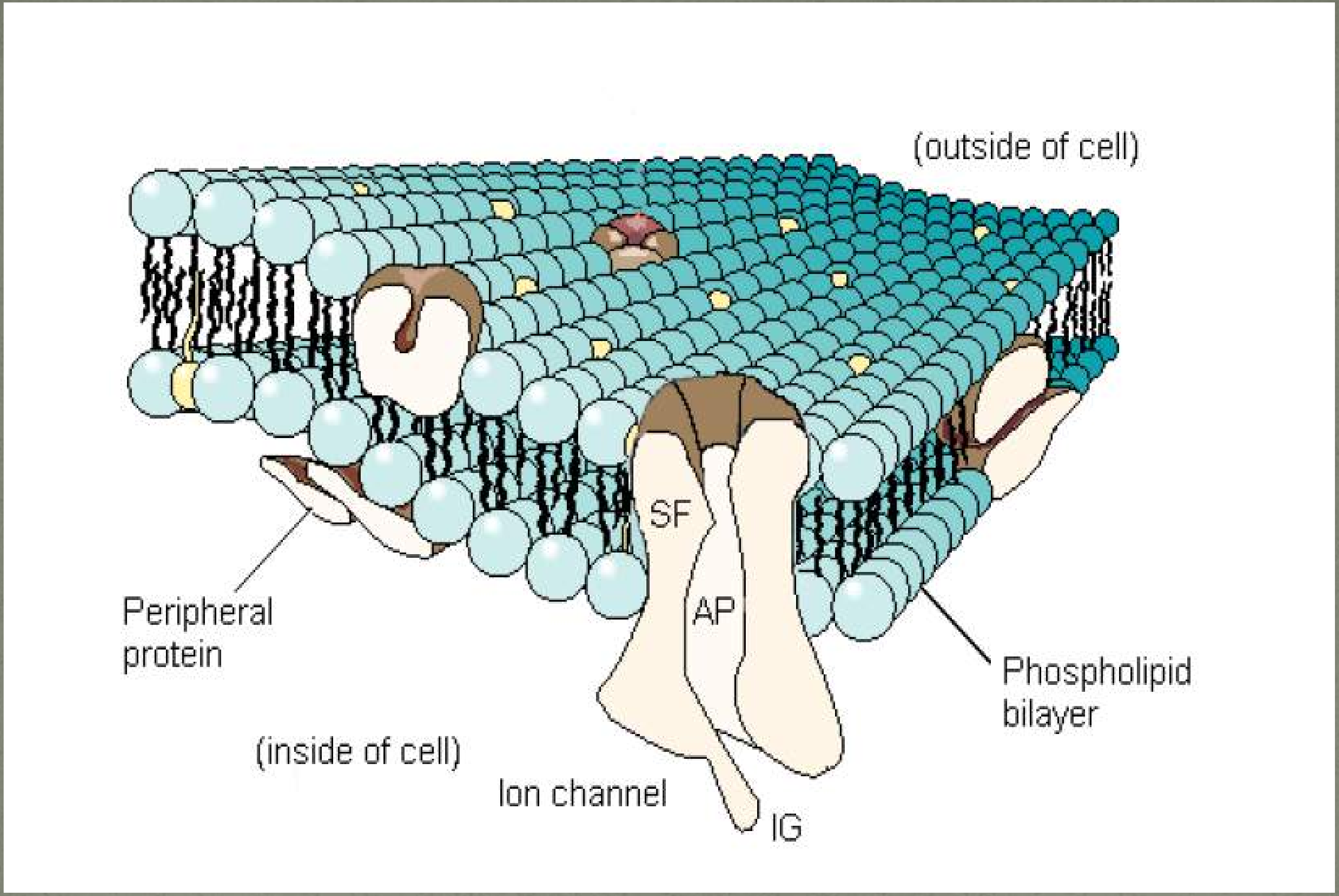
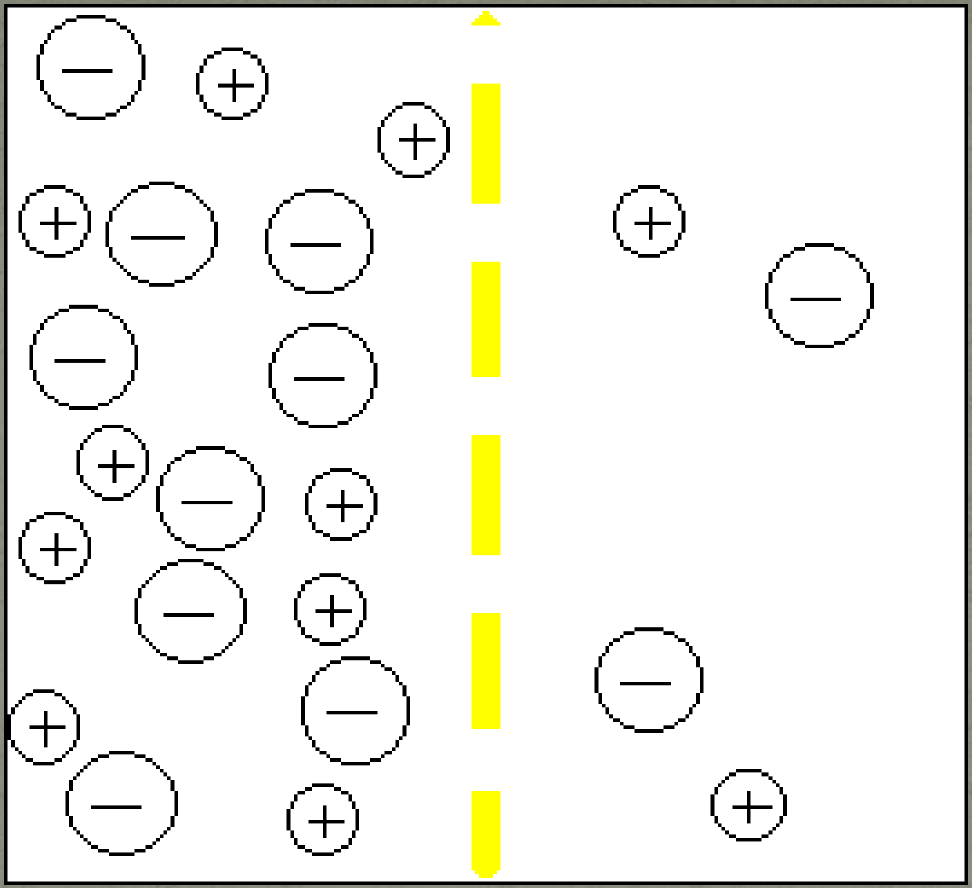
Origin of Bioelectric Signals

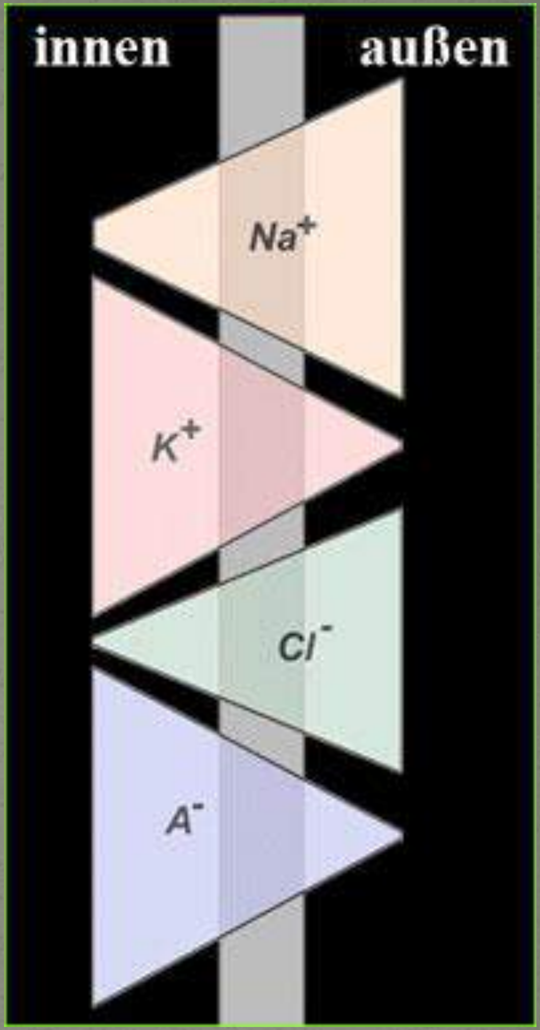


Cell membrane, channel proteines



Electrical and chemical gradients at the semi-permeable cell membrane

Iones	Intracel.	extracel.
potassum K^+	400	20
Sodium Na^+	50	440
Chlorid Cl^-	108	560
organic Aniones	460	0

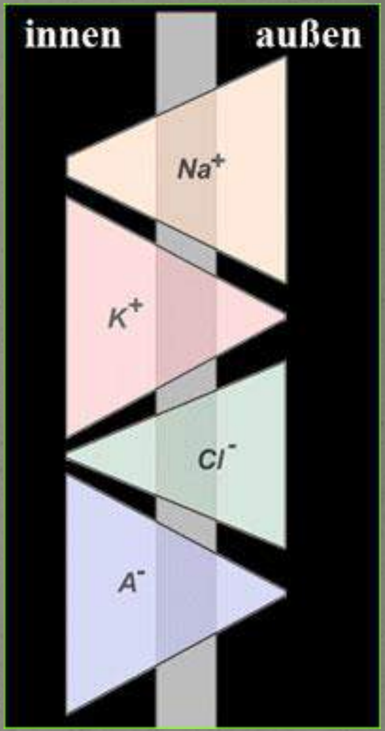


Electrical and chemical gradients at the semi-permeable cell membrane

Nernst – equation (chemical potential):

$$\Delta G = \mathrm{R} \cdot T \cdot \ln \frac{c(A_i)}{c(A_a)}$$

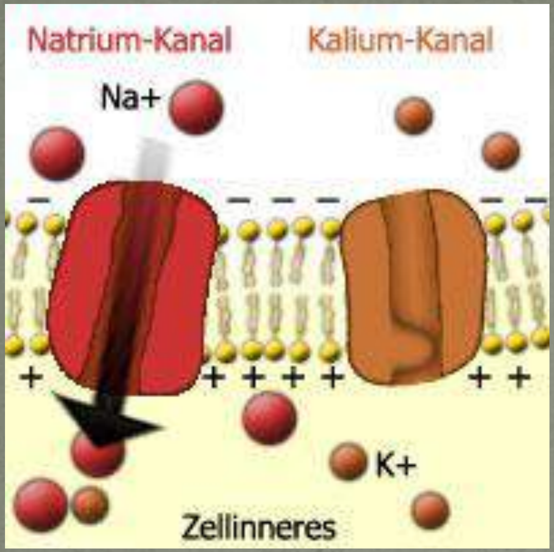
R … Gas-Constant = 8,3143 J / (mol·K)
T … Temperature (Kelvin)



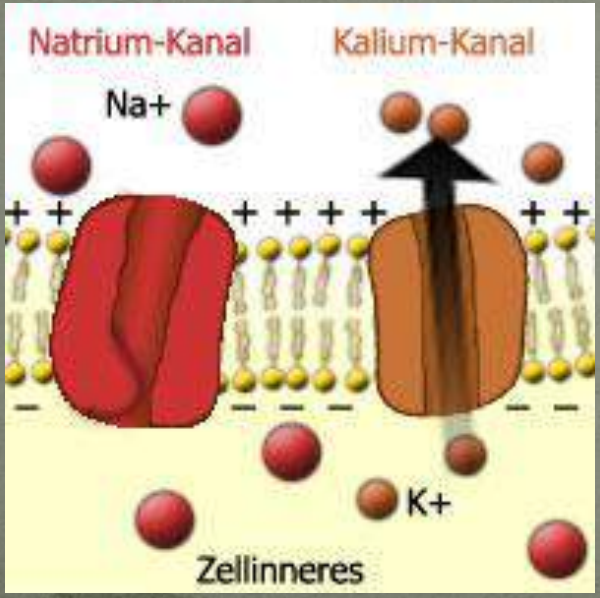
Goldman – equation (for different ions):

$$\Delta\Psi = \frac{\mathrm{R}T}{\mathrm{F}} \cdot \ln \frac{\Sigma[P_{ka} \cdot c_{ka-a}] + \Sigma[P_{an} \cdot c_{an-a}]}{\Sigma[P_{ka} \cdot c_{ka-i}] + \Sigma[P_{an} \cdot c_{an-i}]}$$

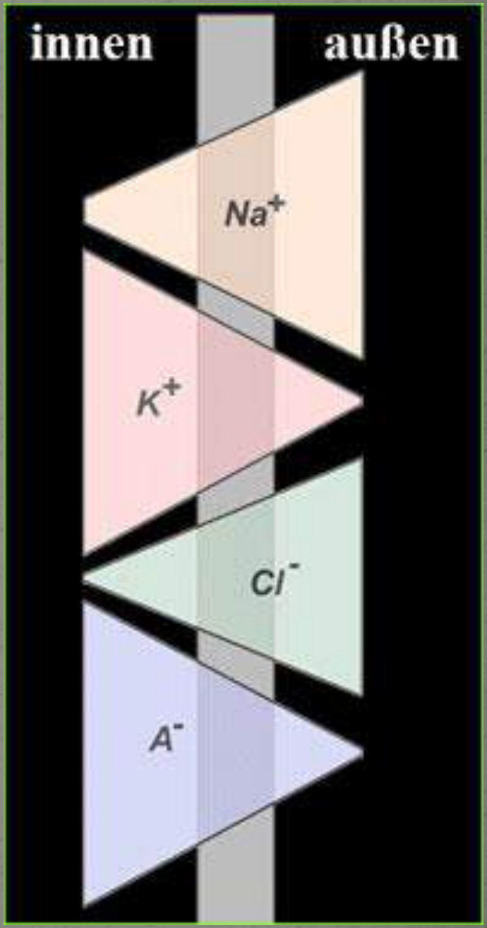
As a result, we get a membrane resting potential of about -70mV

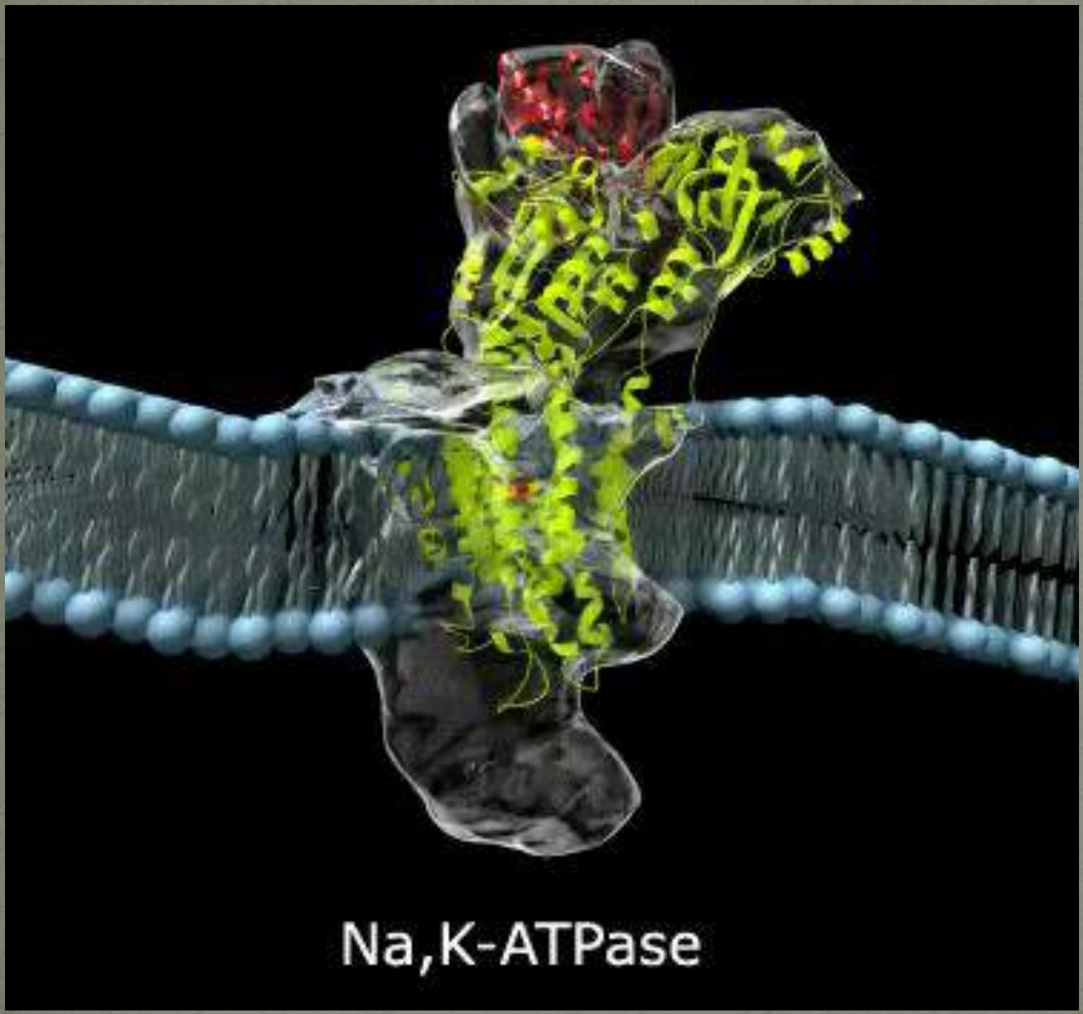


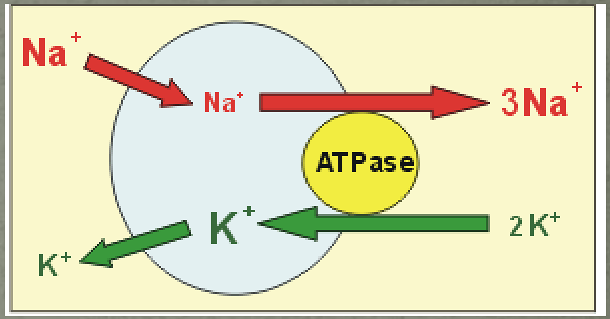
Depolarization
Sodium Cations
rush in



Hyperpolarization
Potassom Cations
rush out



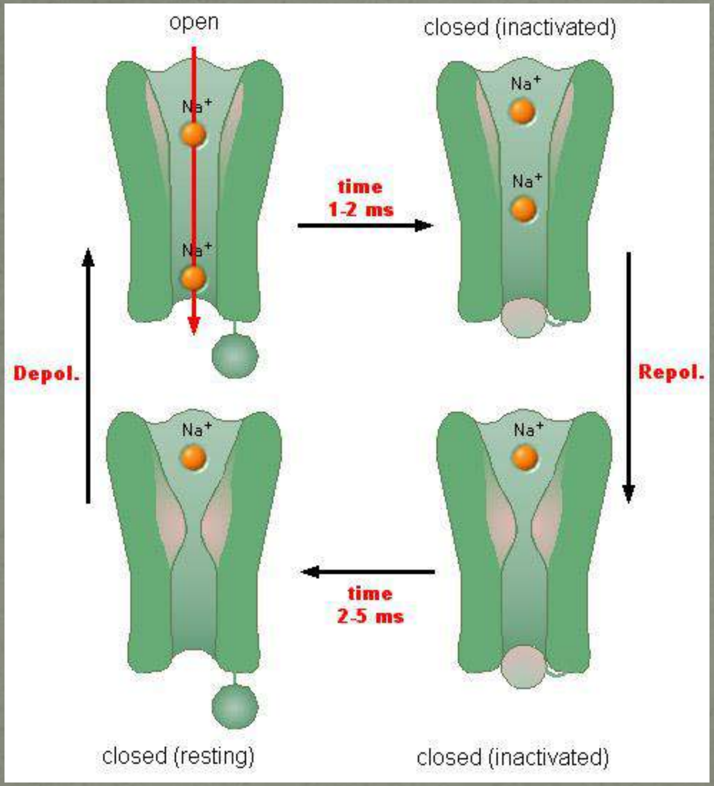


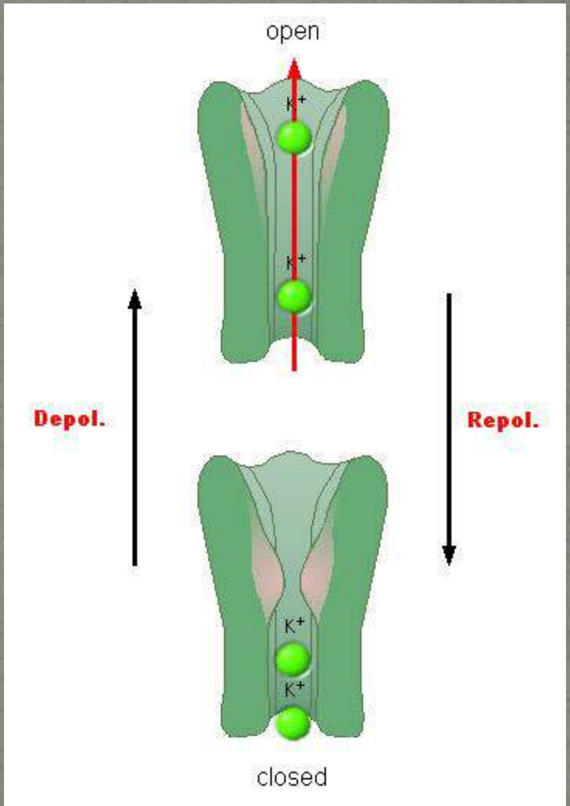


Maintaining the Resting potential

Sodium/potassum Ion pump

Voltage- and Time dependent activation of Ion Channels: the physiological basis for action potentials

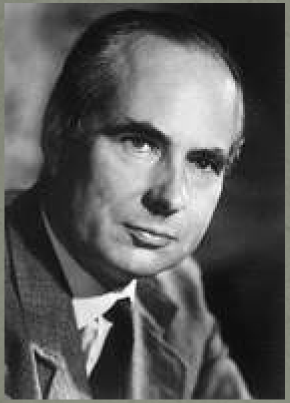




Sodium-Channel

Potassum- Channel

Alan Hodgkin

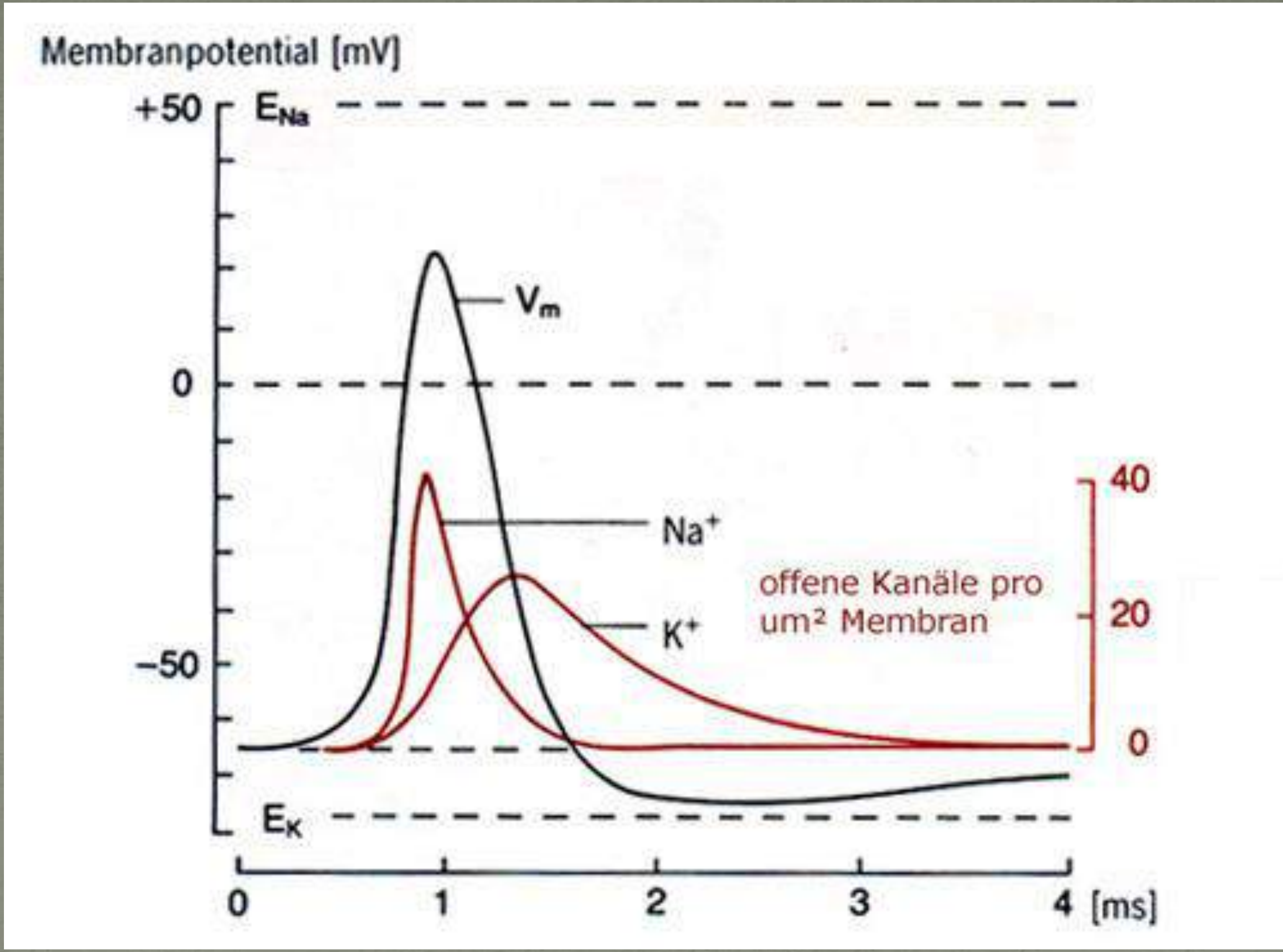


Andrew Huxley

Hodgkin - Huxley Model (1952)

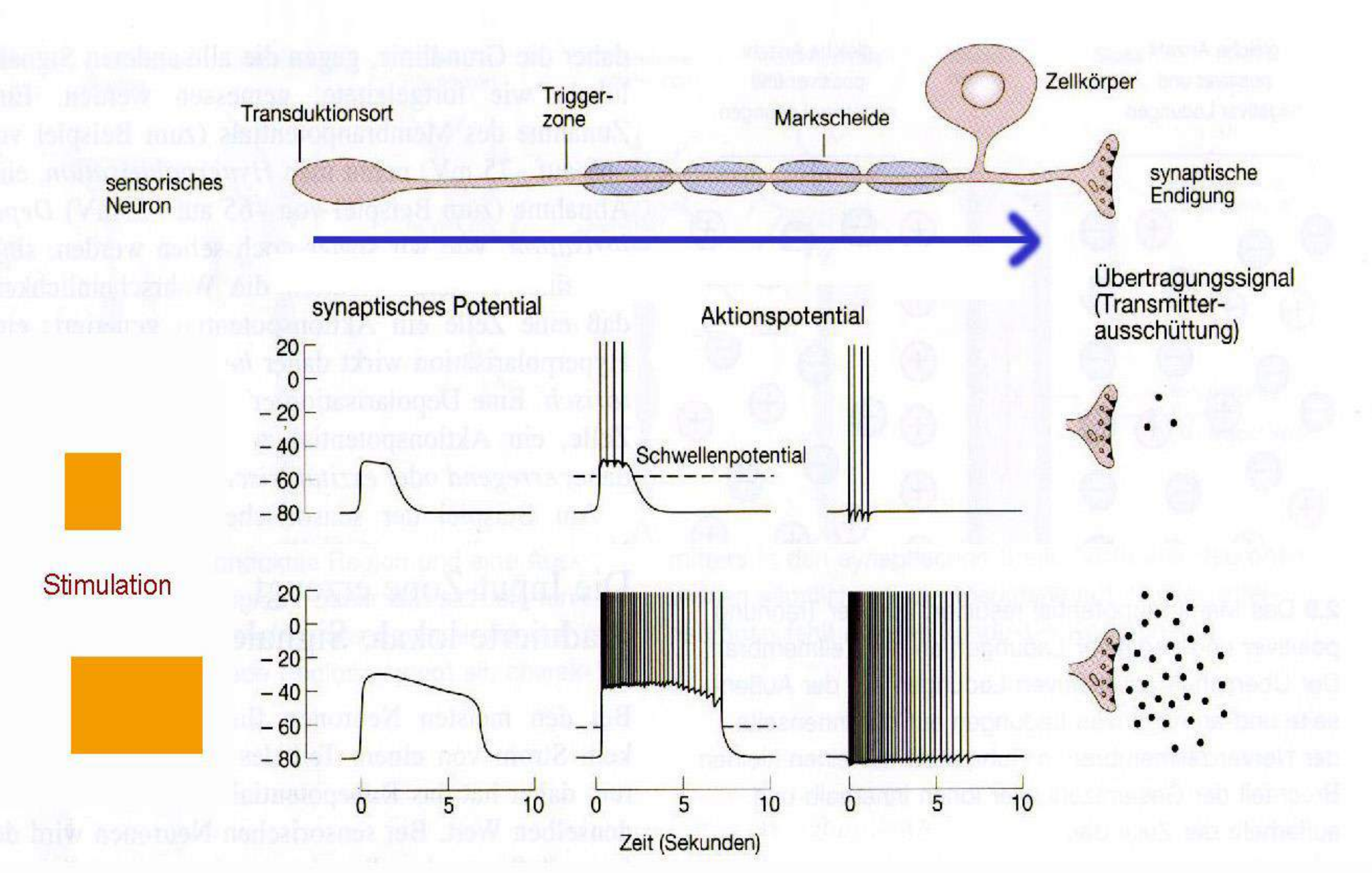
- Researched the Giant Squid-Axon
- Used the Voltage-Clamp technique
  -> Isolation of channel currents of
  Na und K
- Developed a model for the function
  of the channel proteines

$$C_m \frac{dV}{dt} = \overline{G}_{Na} m^3 h (E_{Na} - V) + \overline{G}_K n^4 (E_K - V) + G_m (V_{rest} - V) + I_{inj}(t)$$



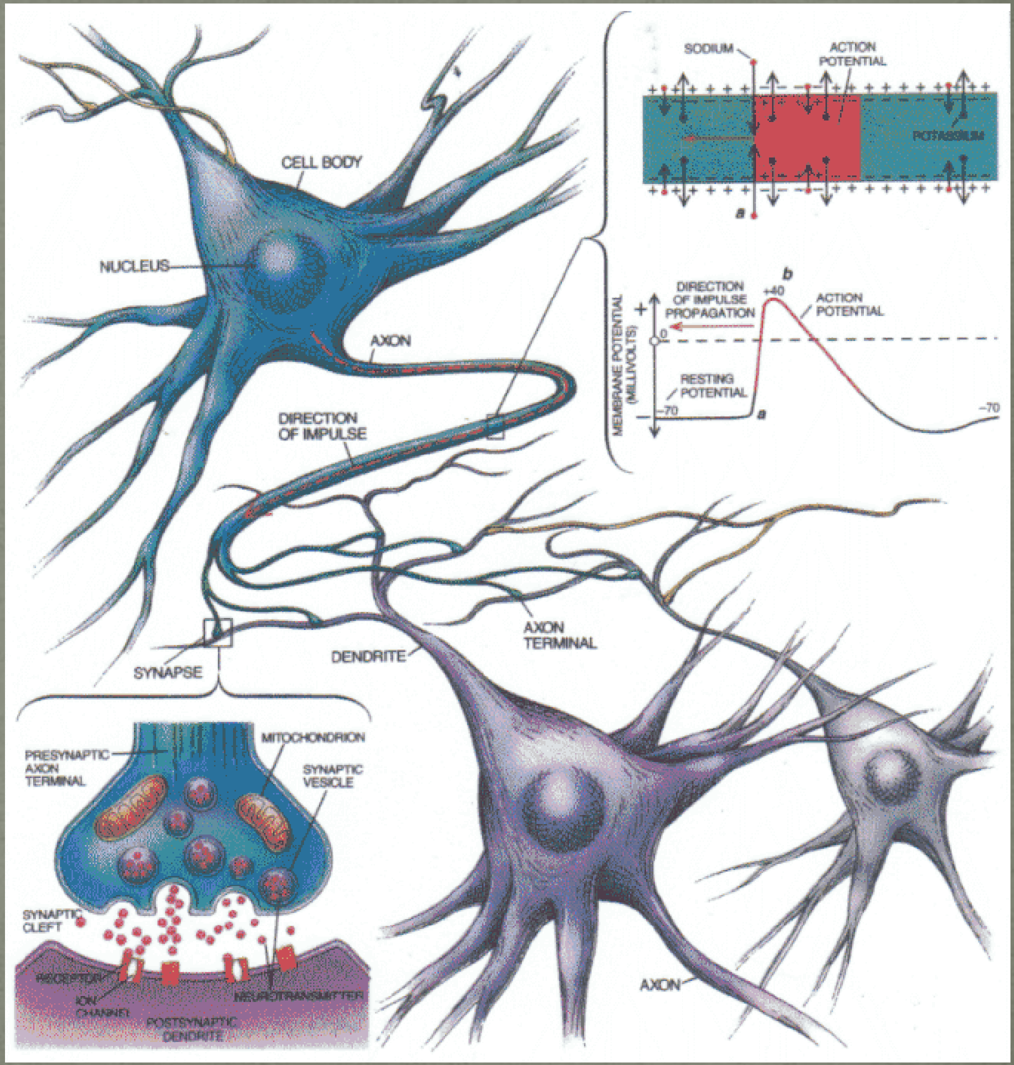
Action potential: the result of Na and K Ion movement through the membrane

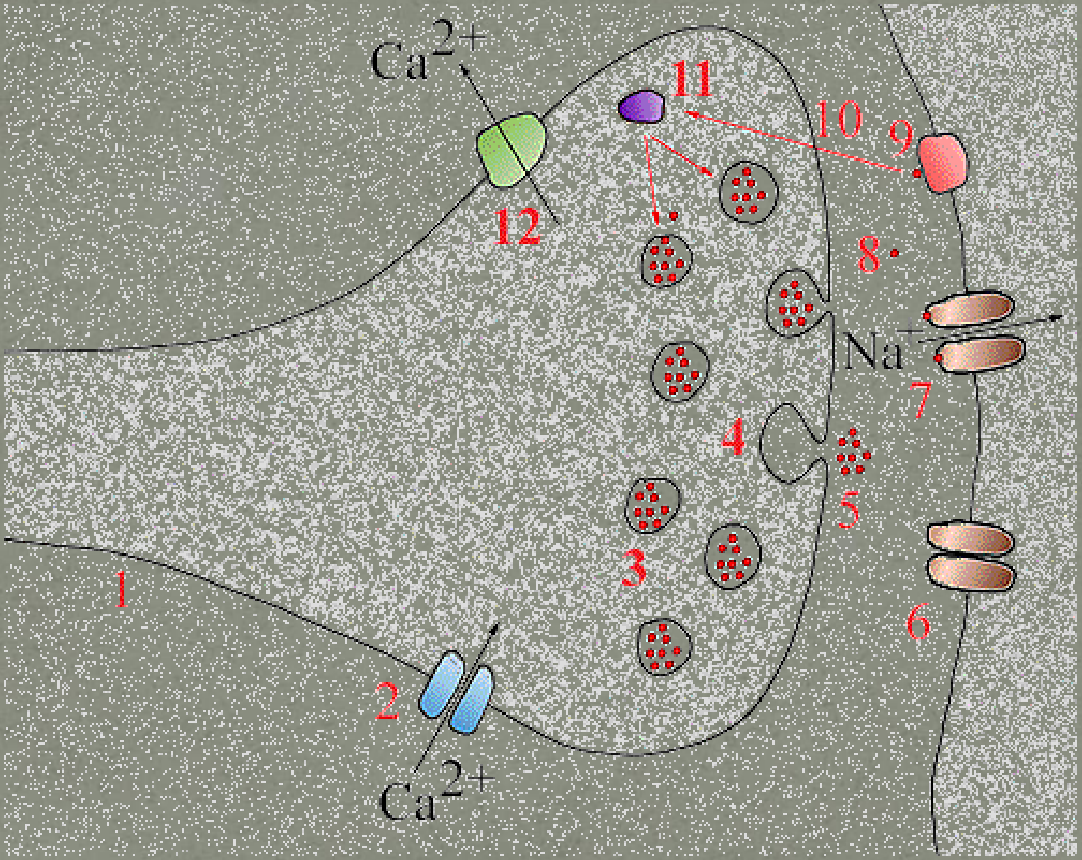
Action Potentials



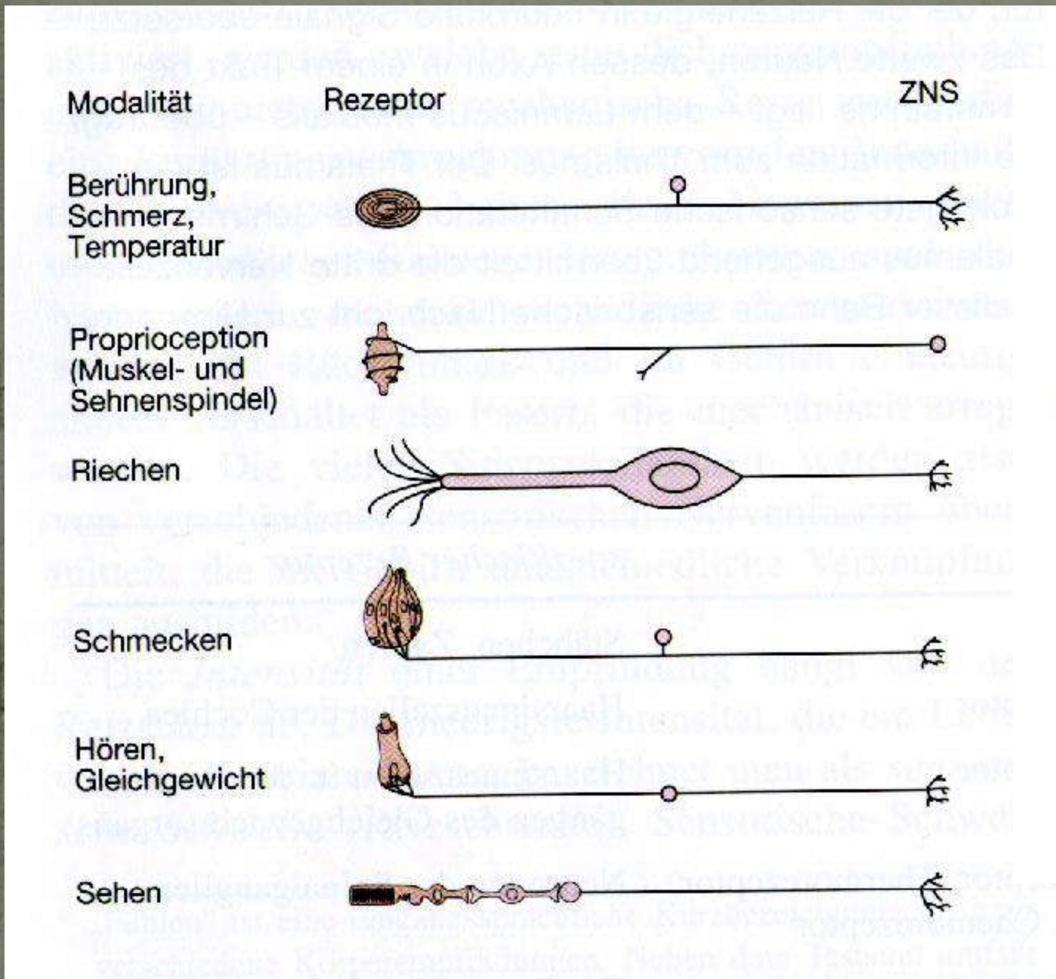
Axo-dendritic transmission of action potentials,

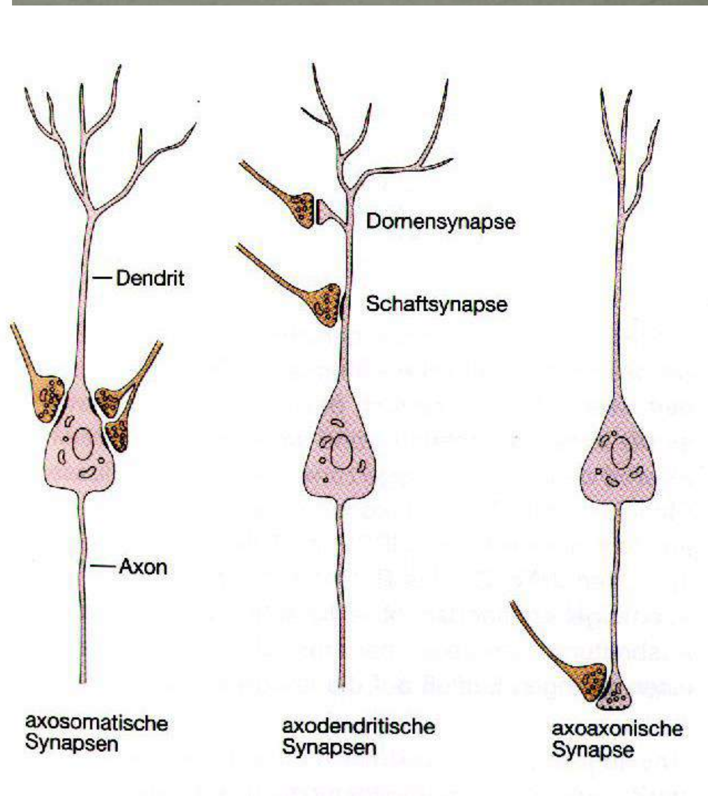
Synaptic transduction



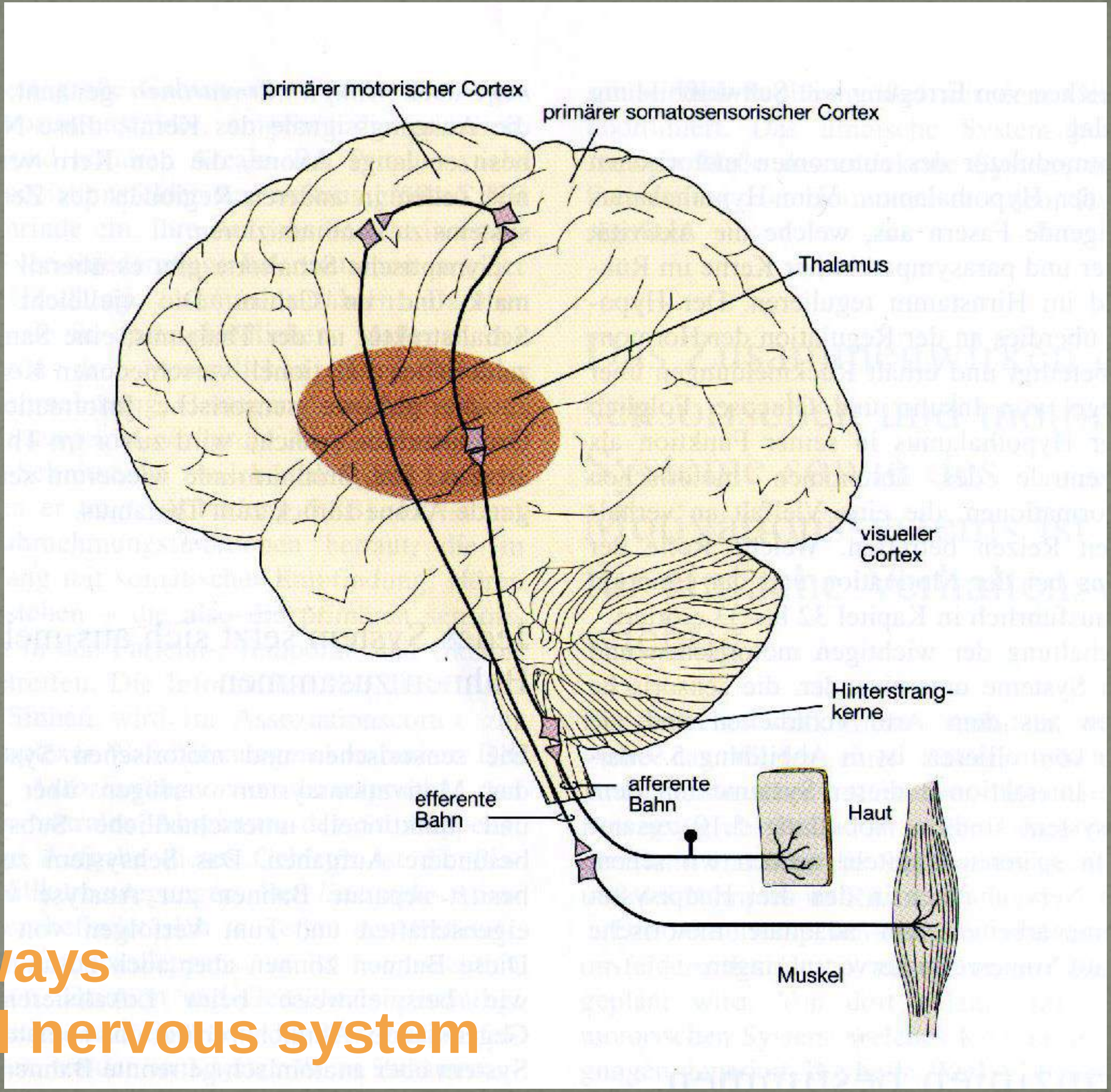


Synaptic coupling, release and uptake of neurotransmitters





Types of nerve cells, Synaptic coupling



Signal Pathways in the central nervous system

Bioelectric Signals

ECG Electro-Cardiogram, Heart activity
EMG Electro-Myogram, Muscle movement
EOG Electro-Oculogram, Eye movement
EEG Electro-Encephalogram
GSR Galvanic Skin Response

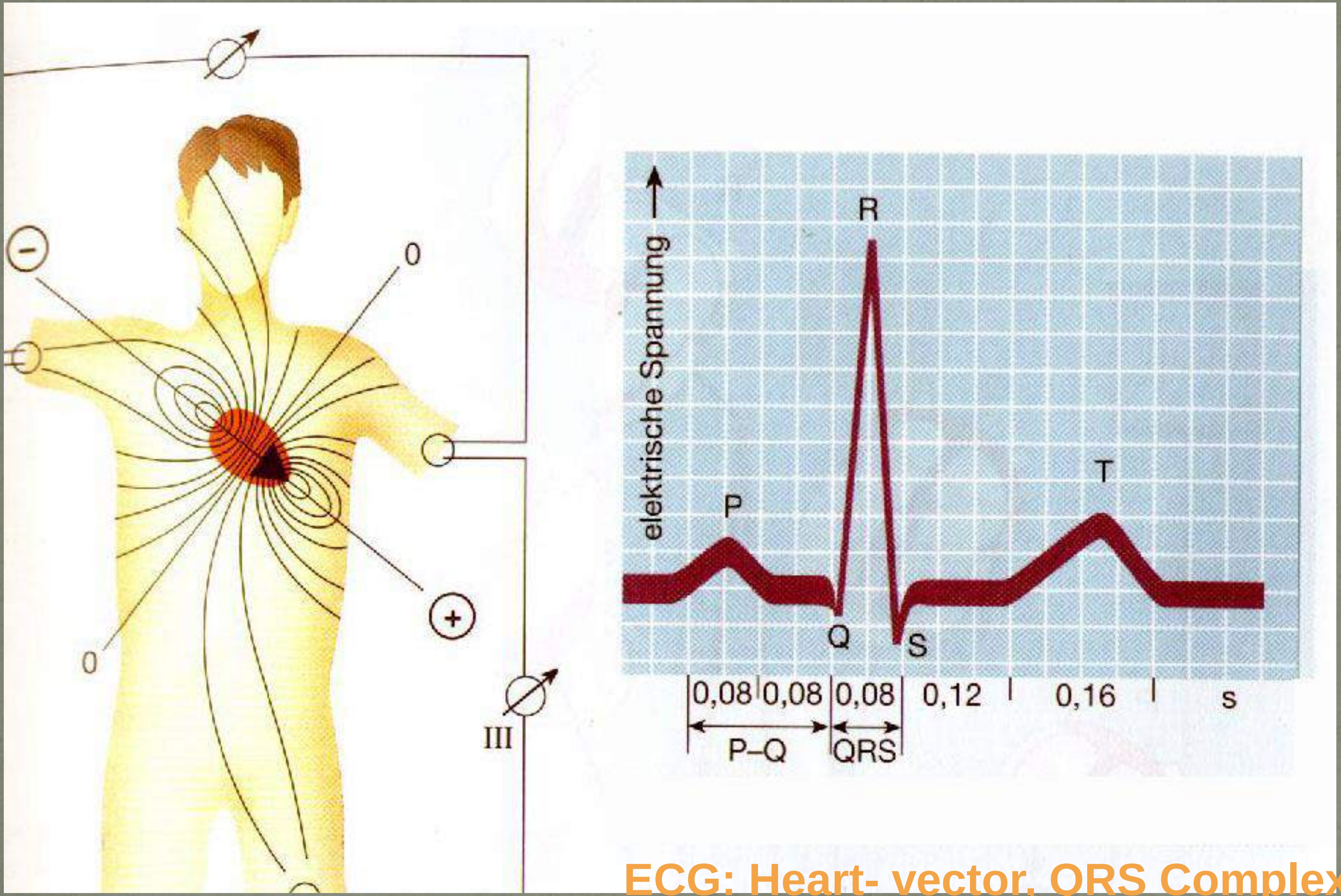
- Measured with electrodes:
  skin-electrode interface: Ions <--> Electrodes

Breathing, temperature, movement etc.

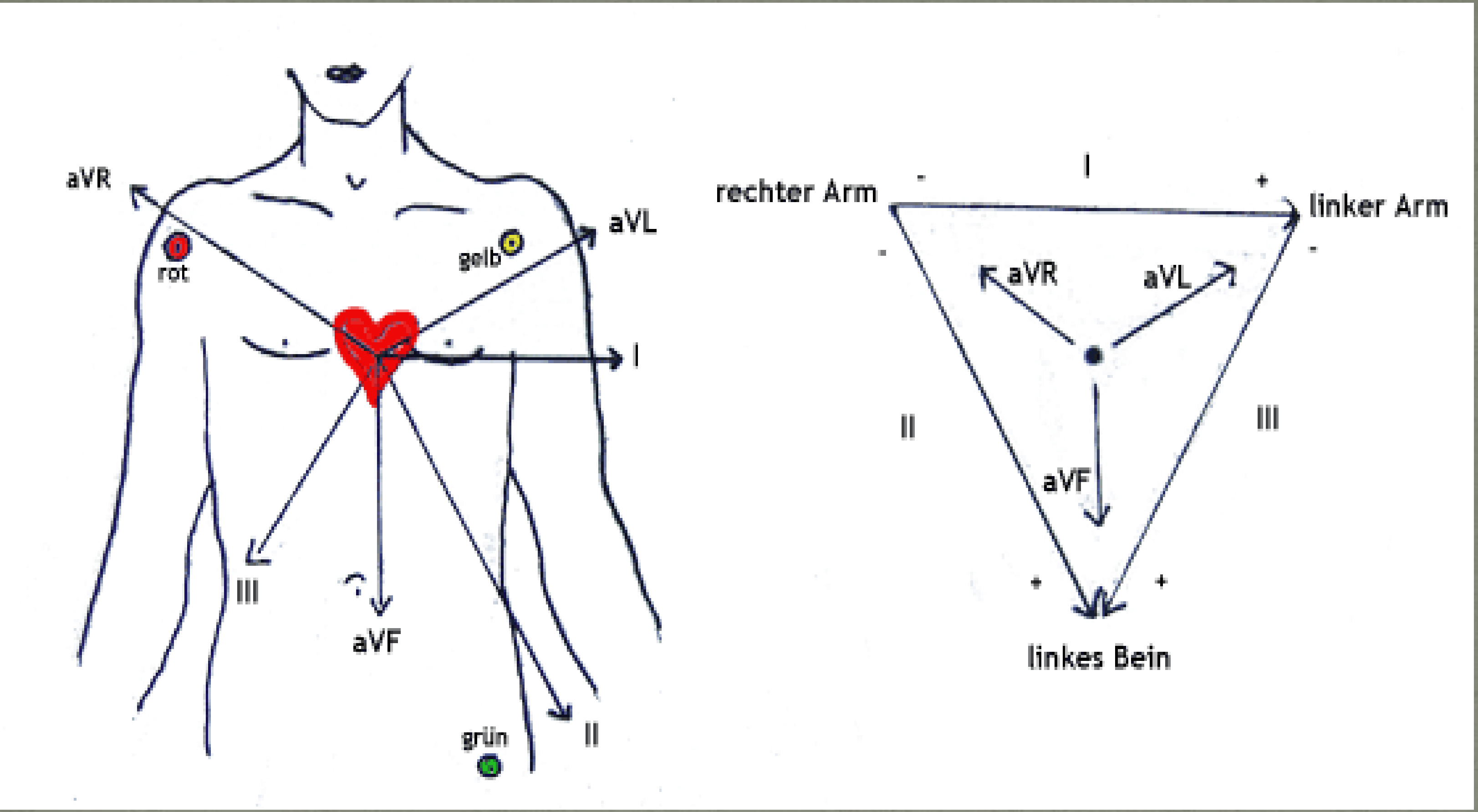
- Measured with other sensors / transducers:

NTC, LDR, piezo-crystal, hall-sensor,
Accelerometer, Goniometer, …

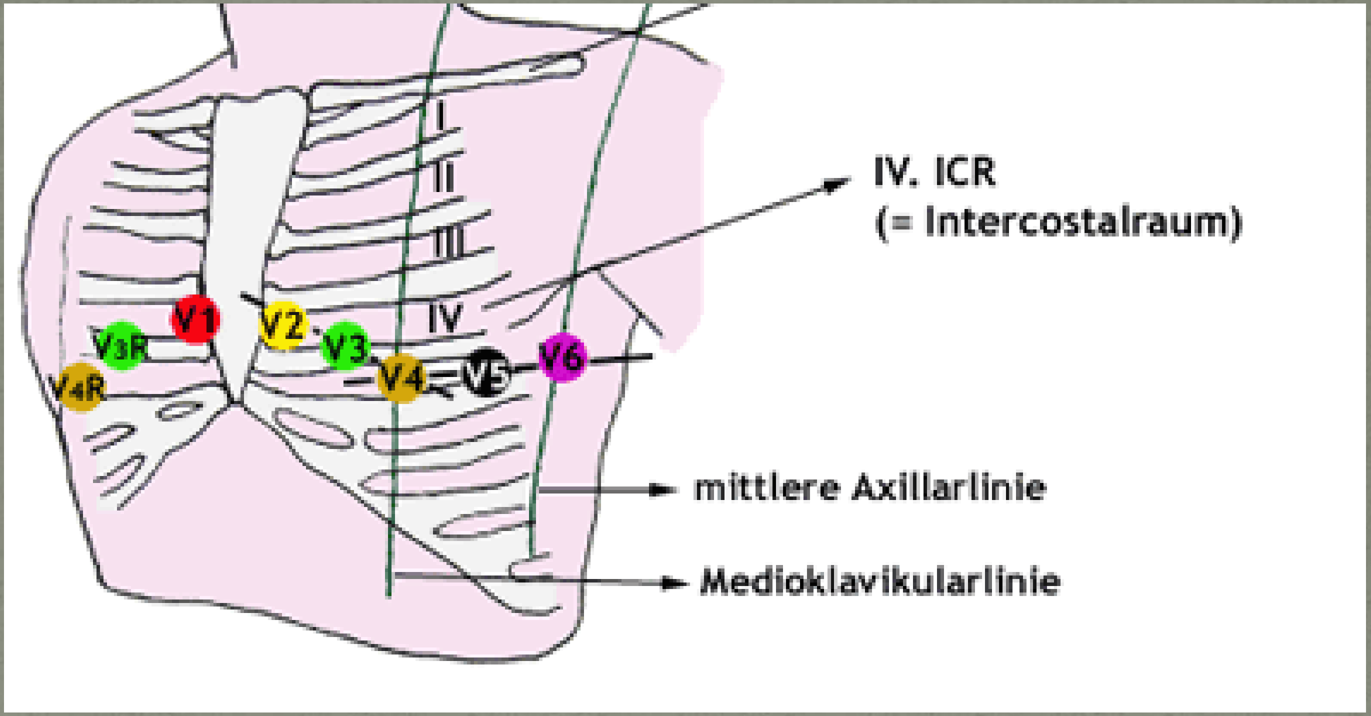
ECG - Electrocardiogram



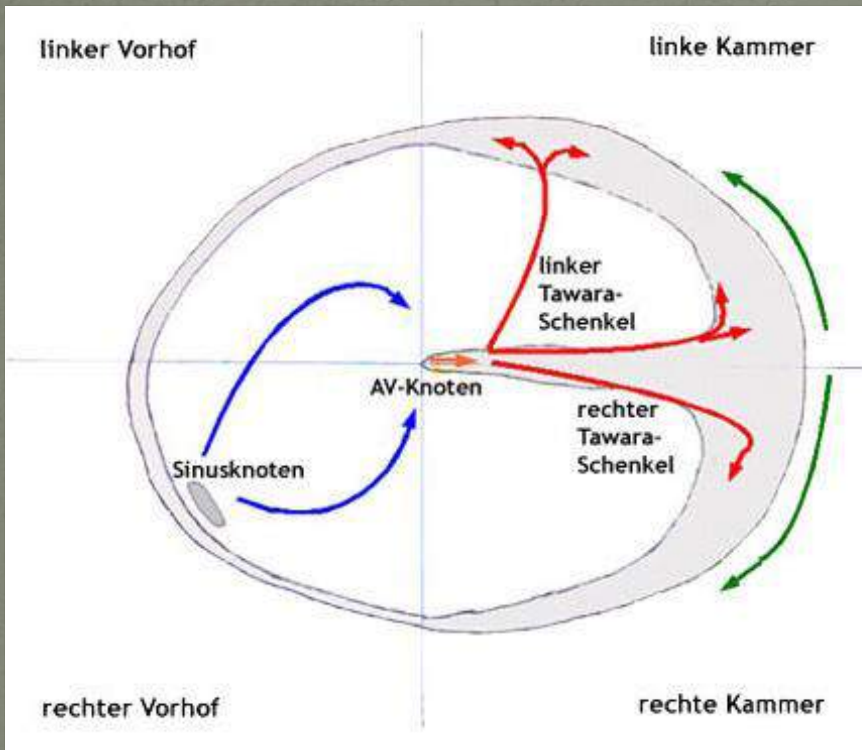
ECG: Heart- vector, QRS Complex

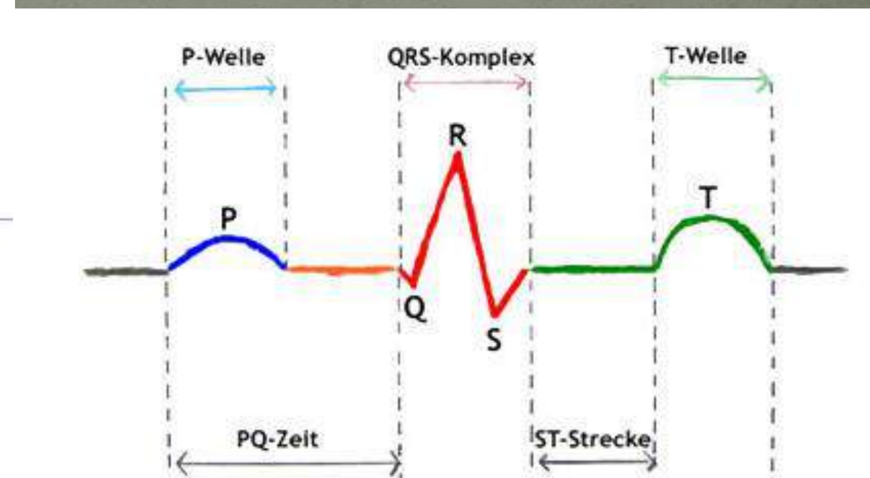


ECG measurement: Goldberger (left) and Einthoven (right)



ECG measurement: Wilson



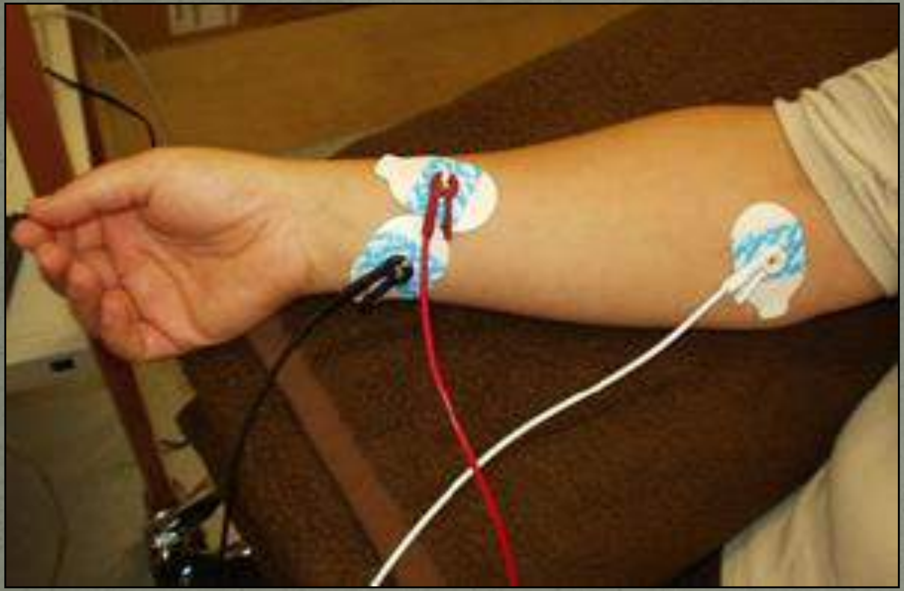


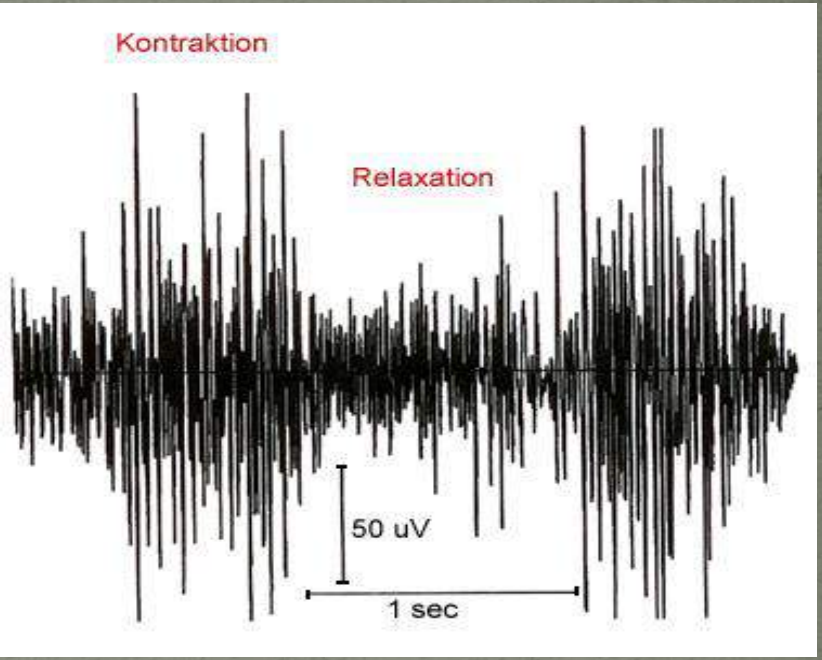
Origination of the QRS - Signal

ECG - applications

- Diagnostics
- Functional analysis
- Implants (pace maker)
- Biofeedback (Heartrate variability, HRV)
- Peak Performacne Training, Monitoring

EMG - Electromyogram



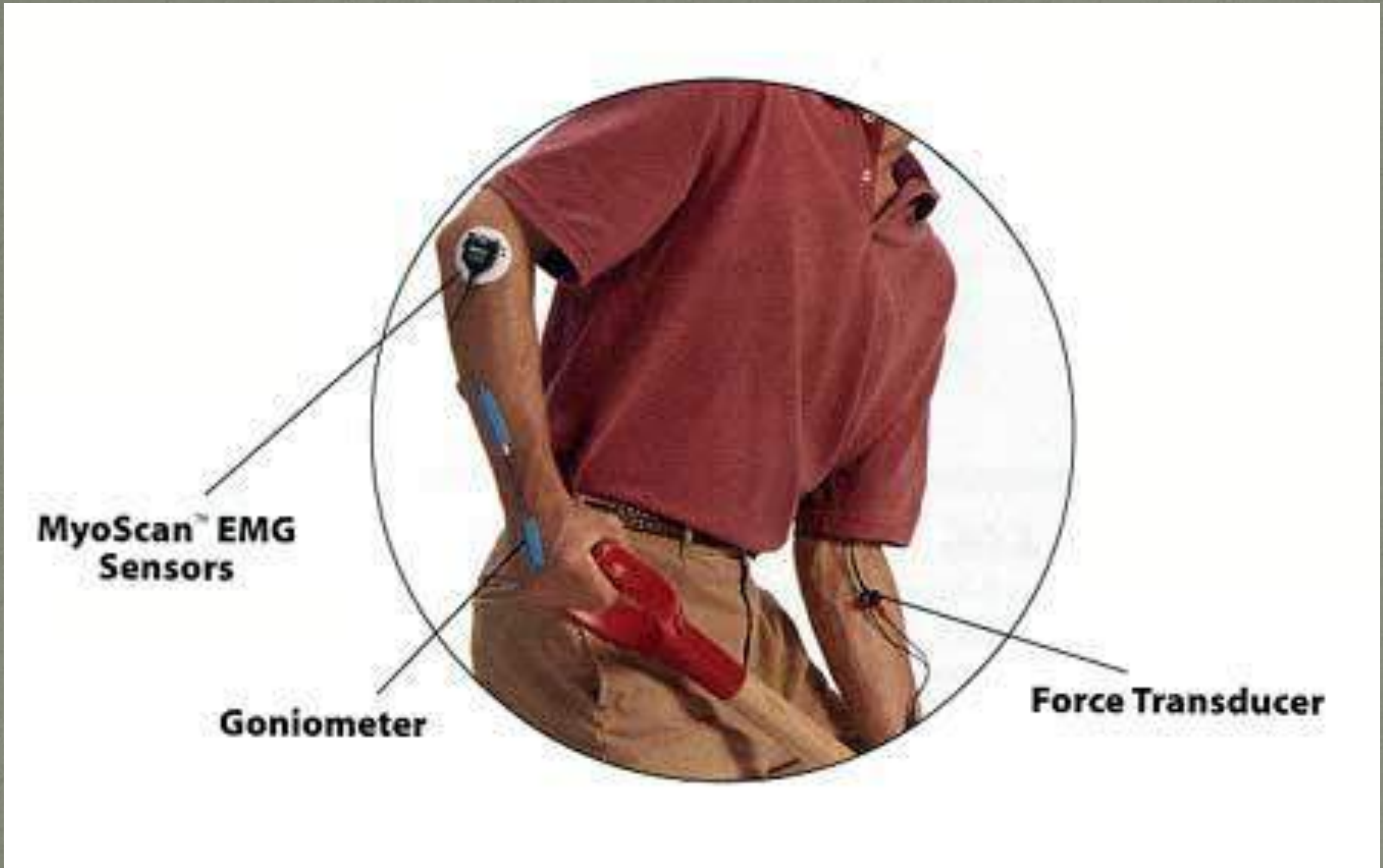


EMG surface (glue-) electrodes

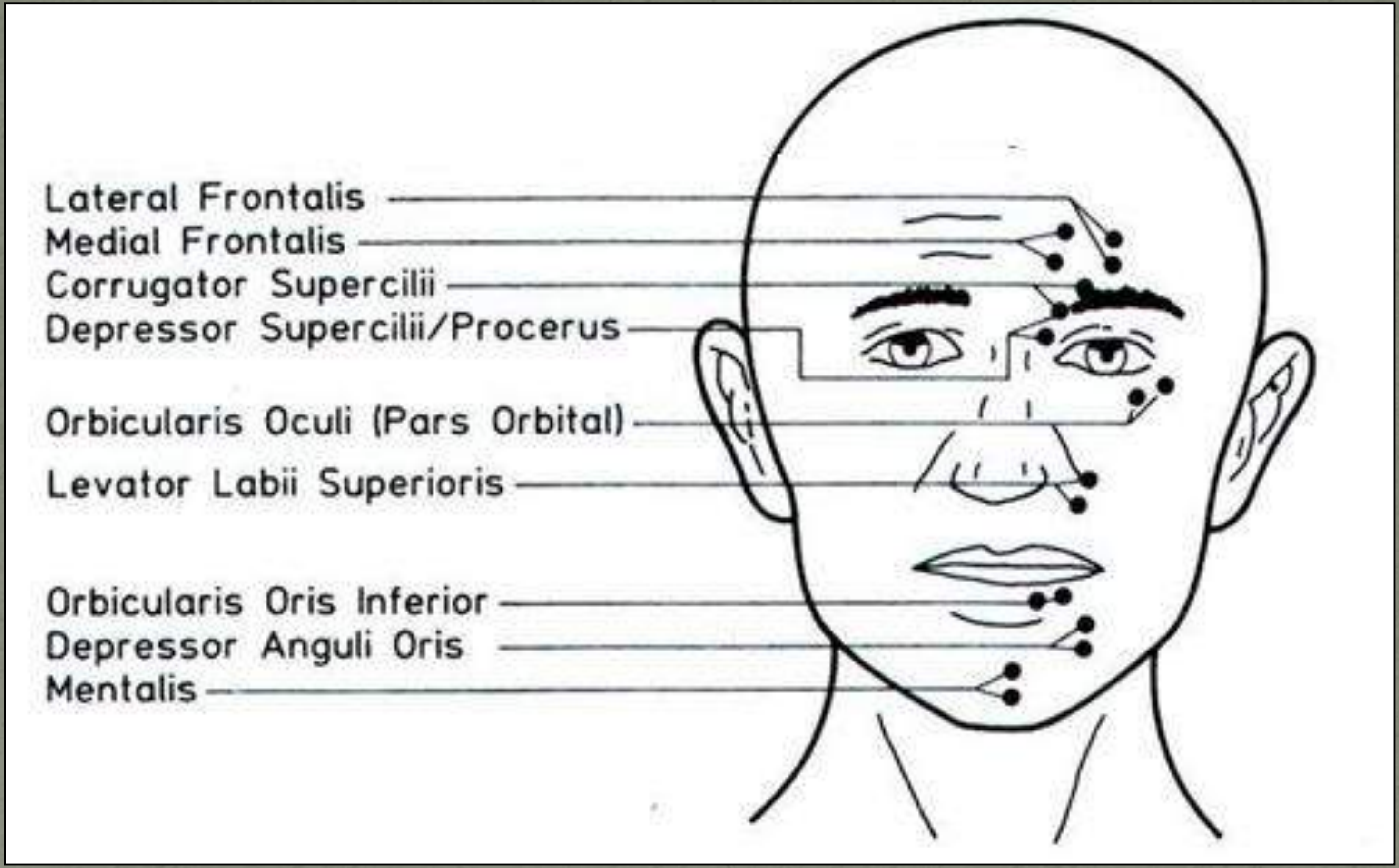
EMG - signal (up to 3mV, 1kHz)

EMG electrodes (passive)

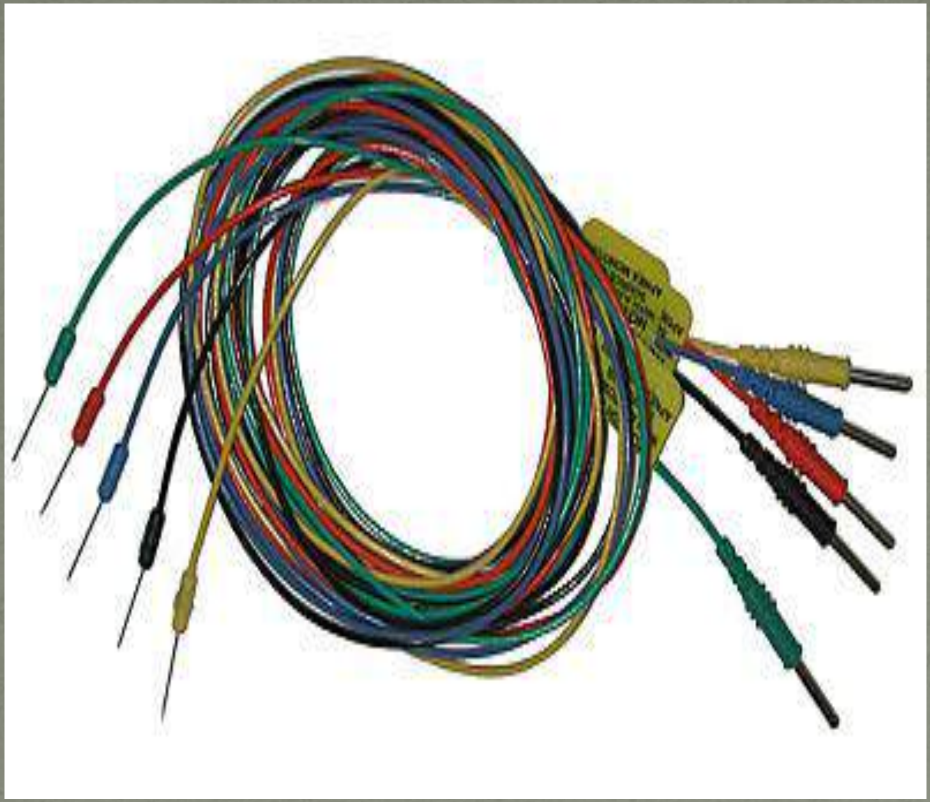
EMG electrodes (active)



EMG electrodes (active)



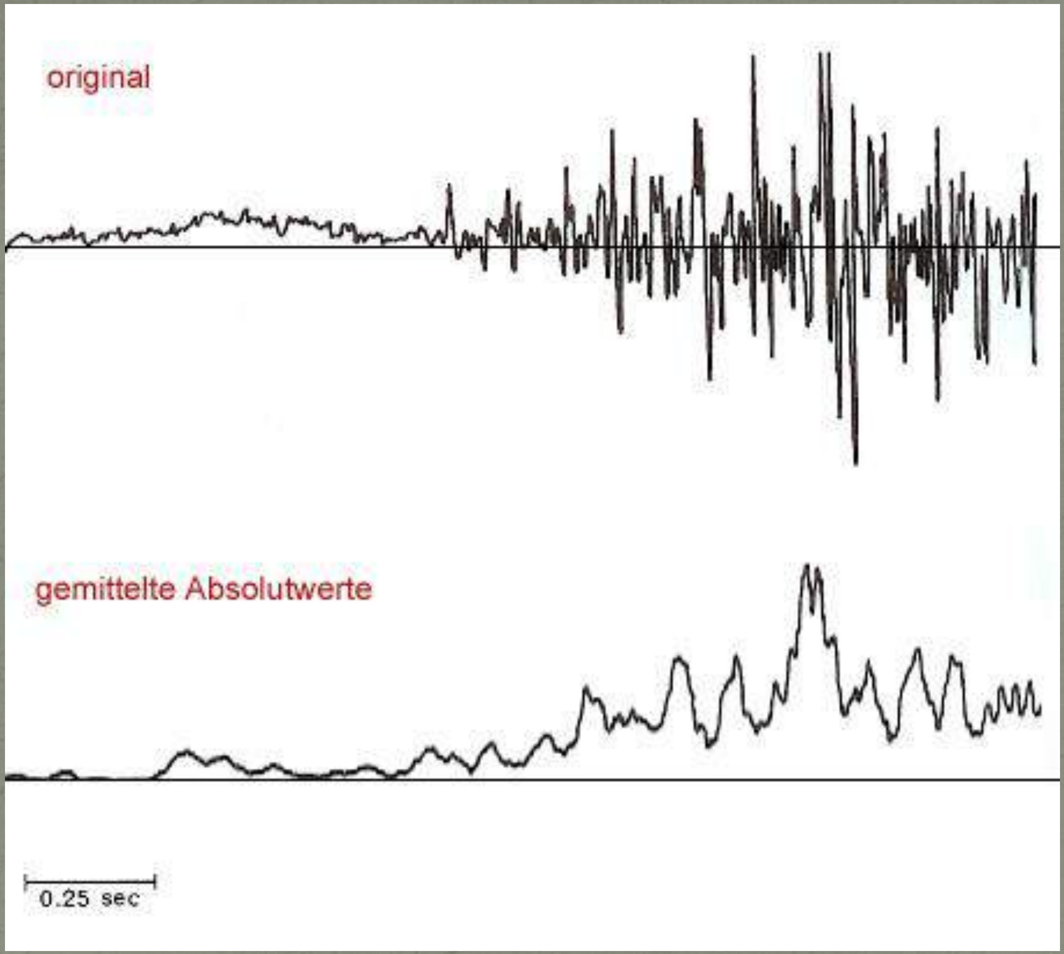
Recording locations for facial EMG



Needle electrodes

adhesive electrode

Vagina / rectal electrodes / pelvic floor training

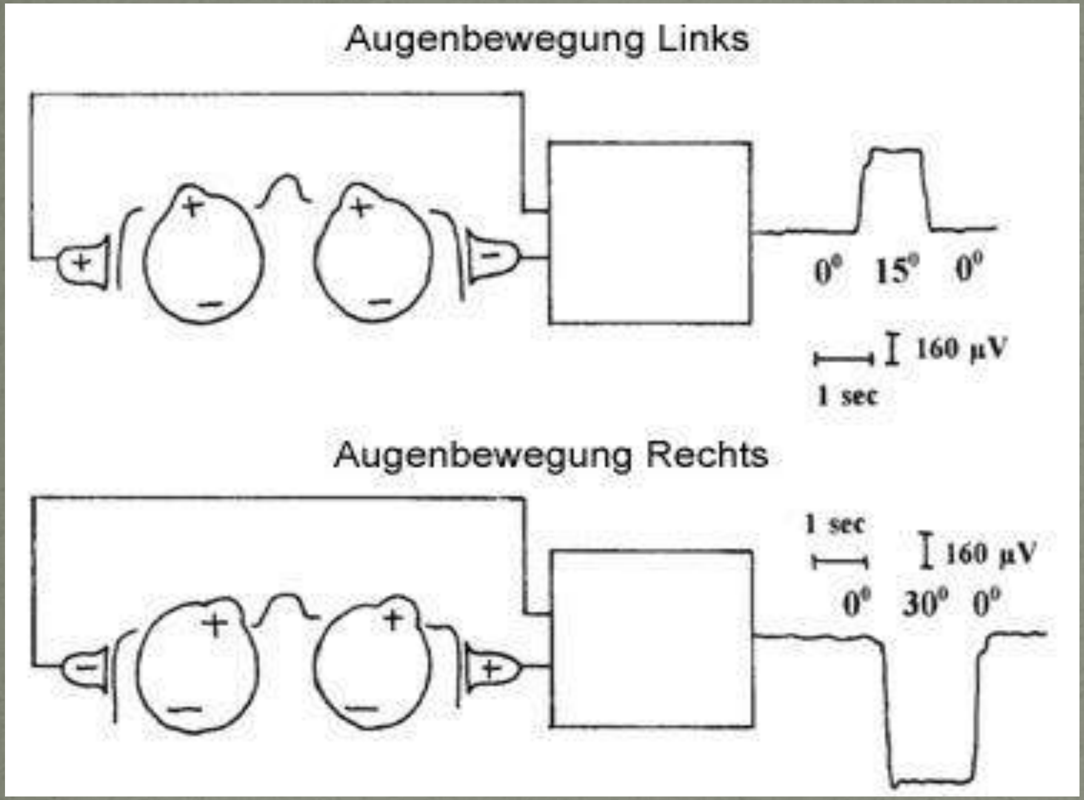


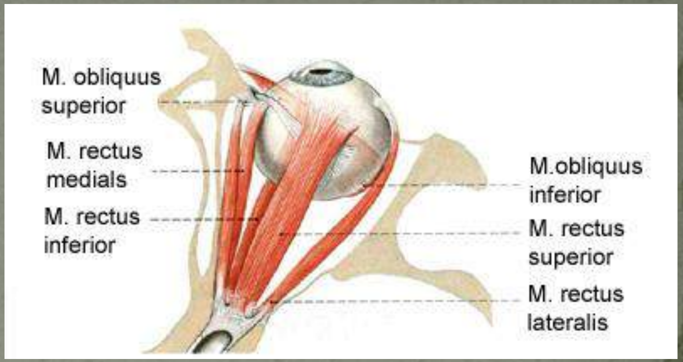
EMG activity: averaging absolute vaues

EMG - applications

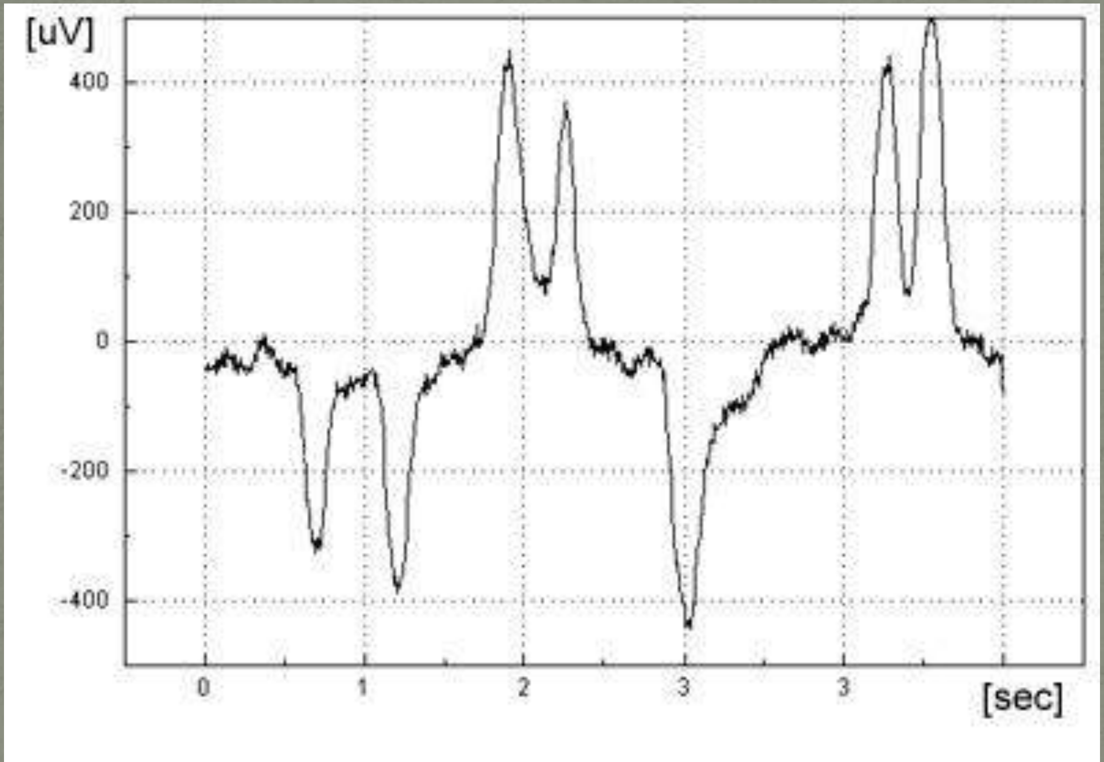
- Rehabilitation
- Functional analysis
- active Prothetics, Orthesis
- Biomechanics, Sports medicine

EMG - Electrooculogram





Electrooculogram (EOG), Eye Dipole

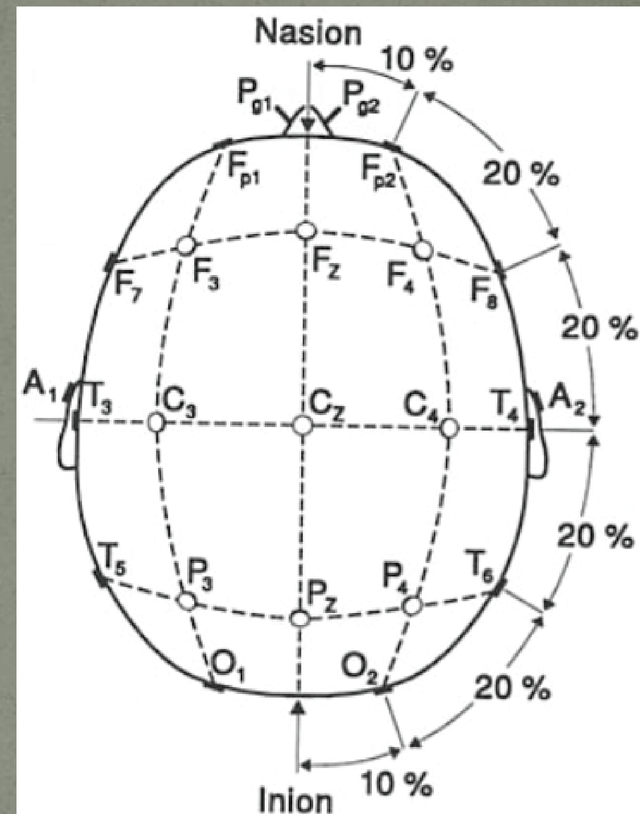


Saccadic eye movements to the left and right

EOG - applications

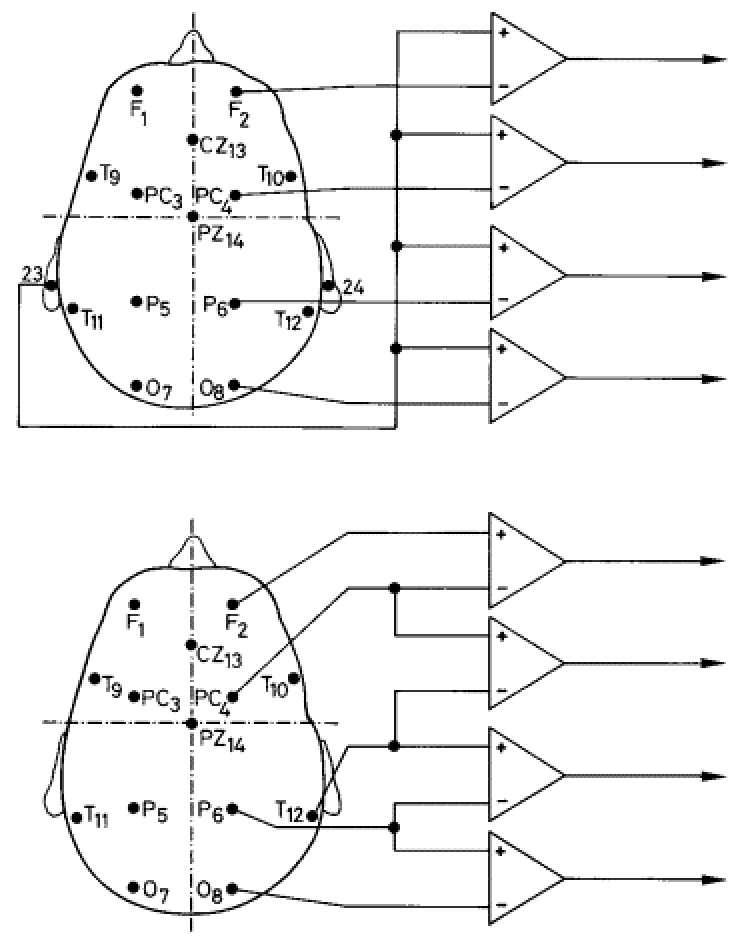
- Diagnostics
- Functional analysis
- Human Computer Interfaces

EEG - Electroencephalogram



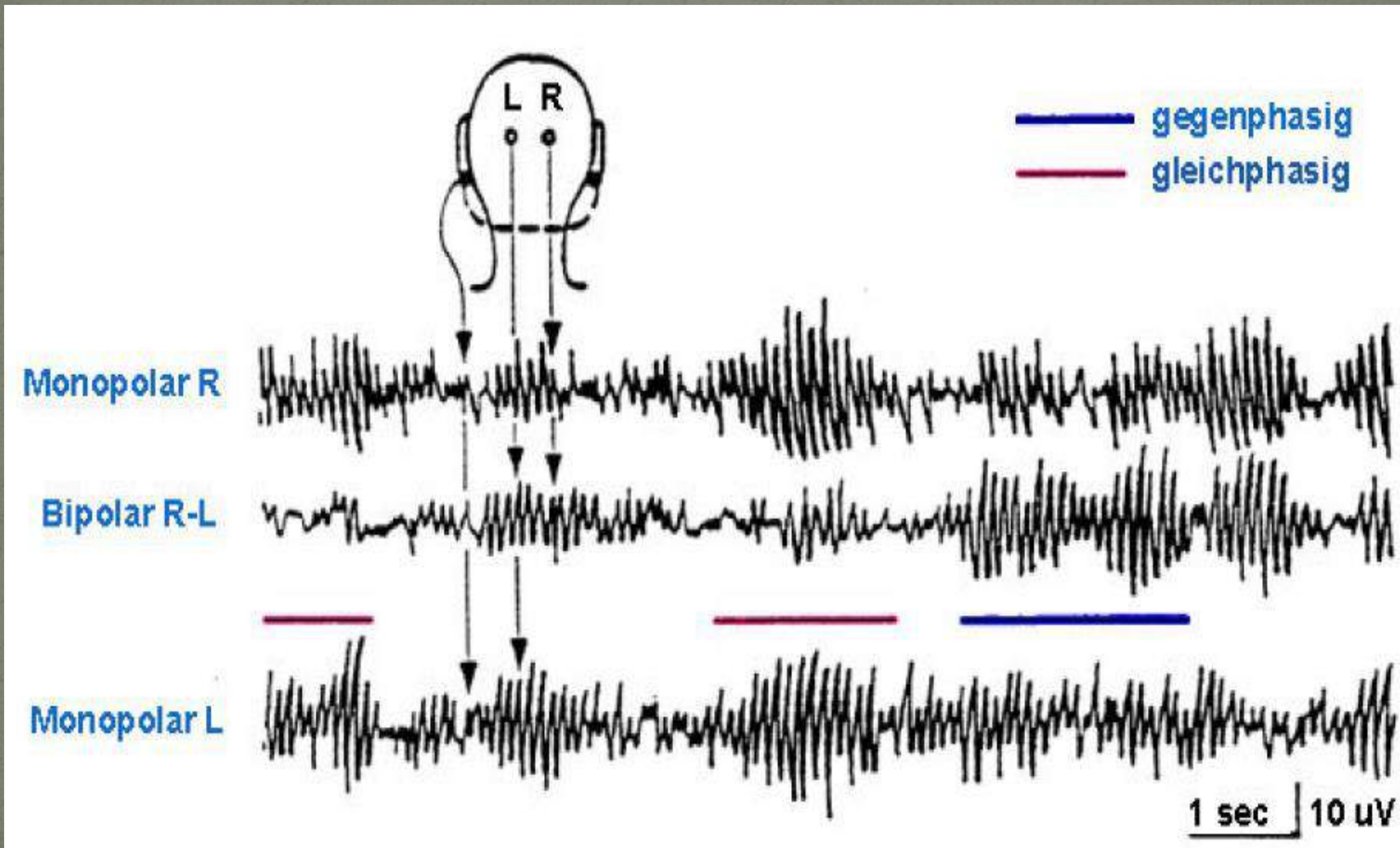
EEG Electrode – cap

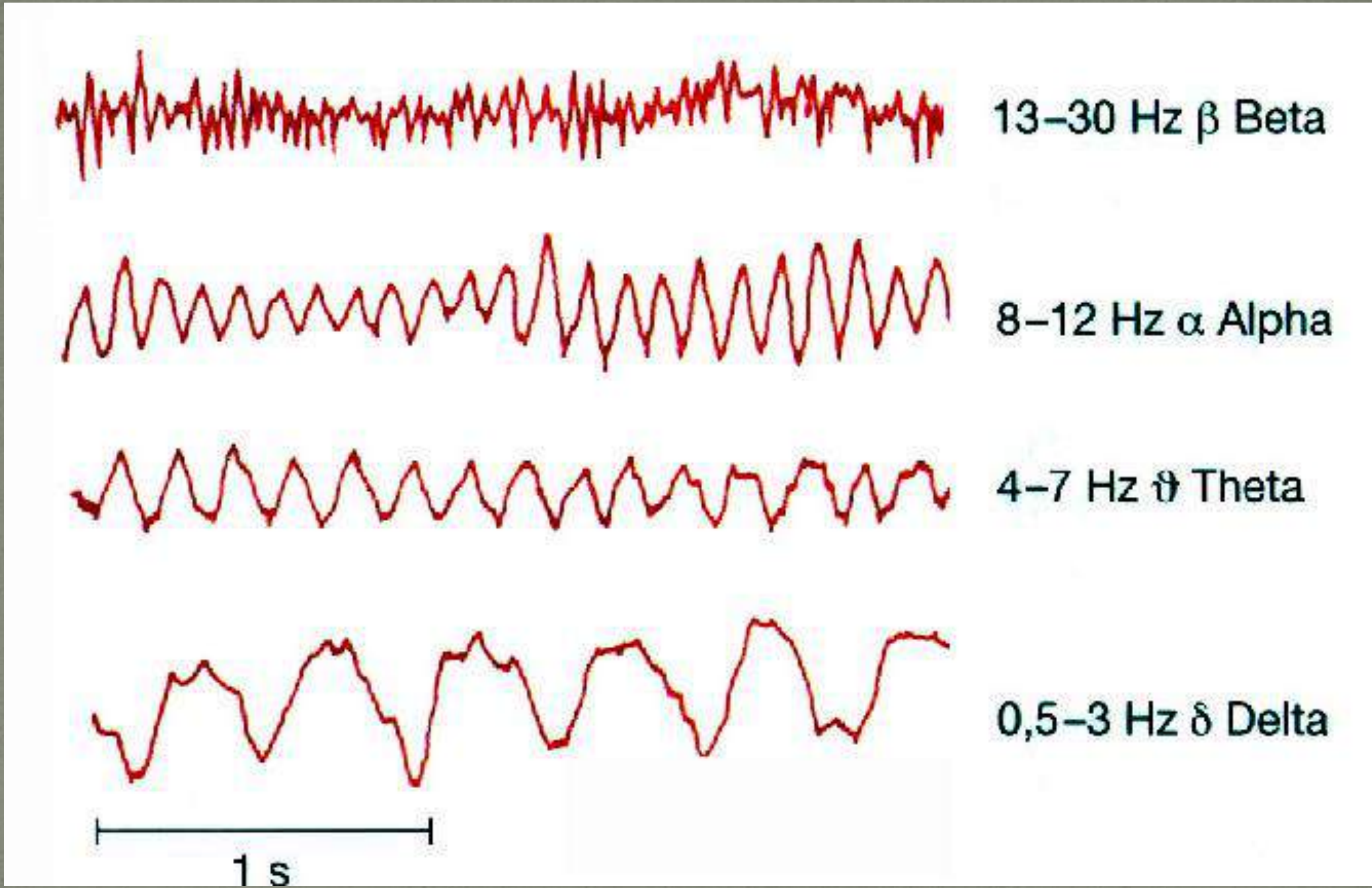
locations of the 10/20 system



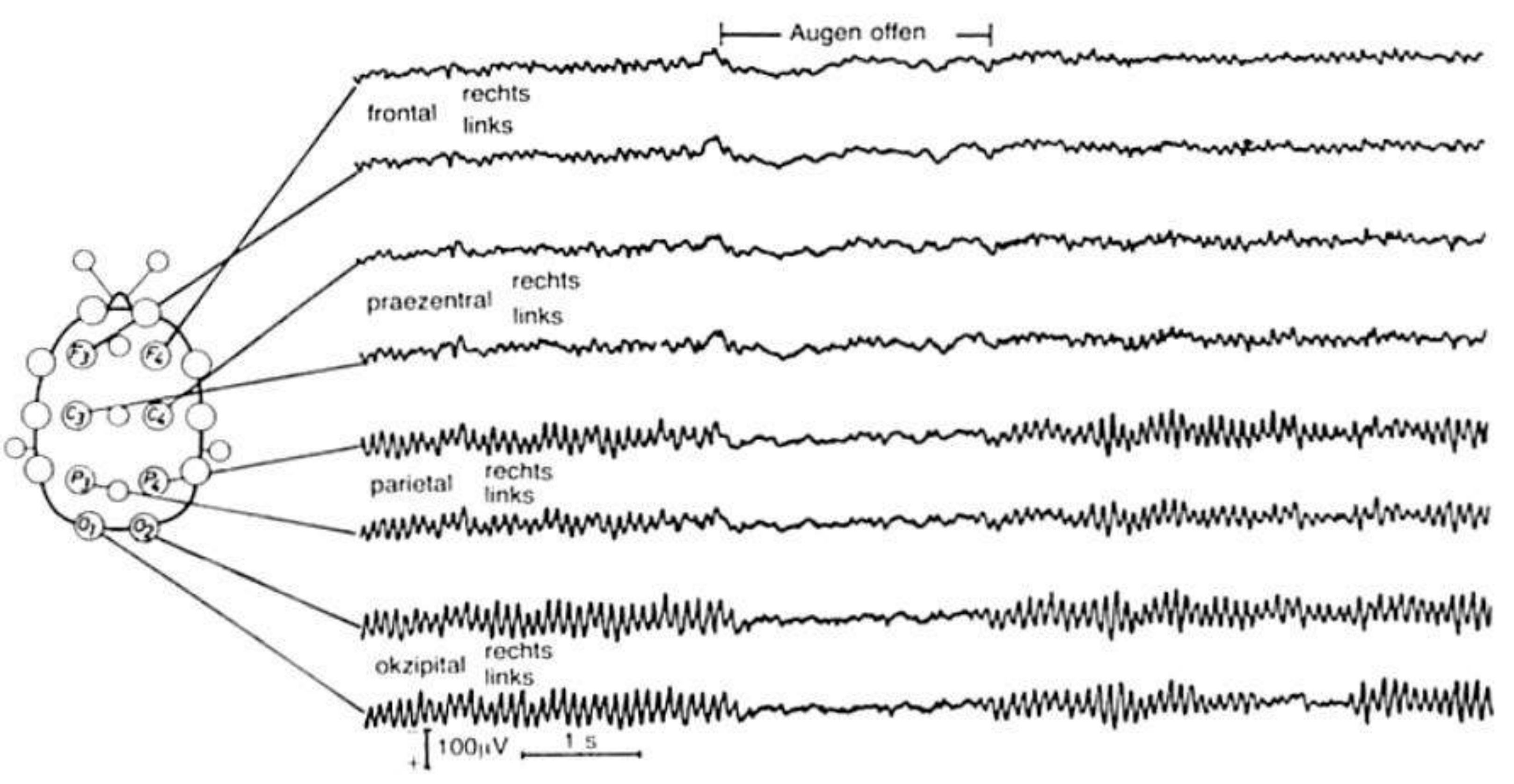
Unipolar measurement (indifferential right ear electrode)

Bipolar measurement

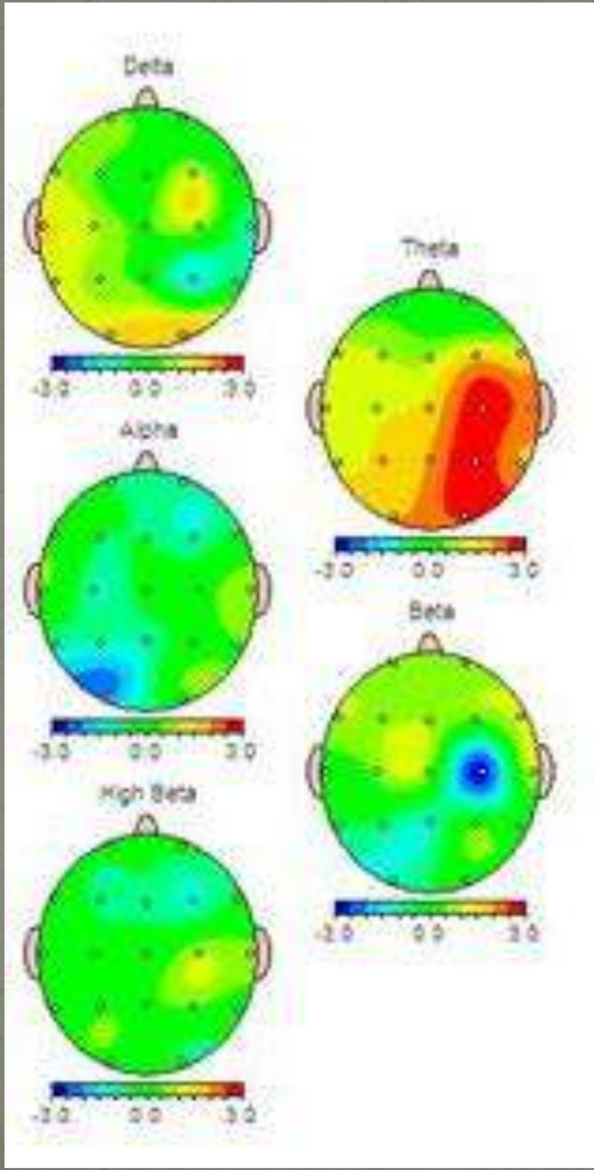

L R
gegenphasig
gleichphasig
Monopolar R
Bipolar R-L
Monopolar L
1 sec
10 uV



EEG, dominant frequencies, < 300 uV

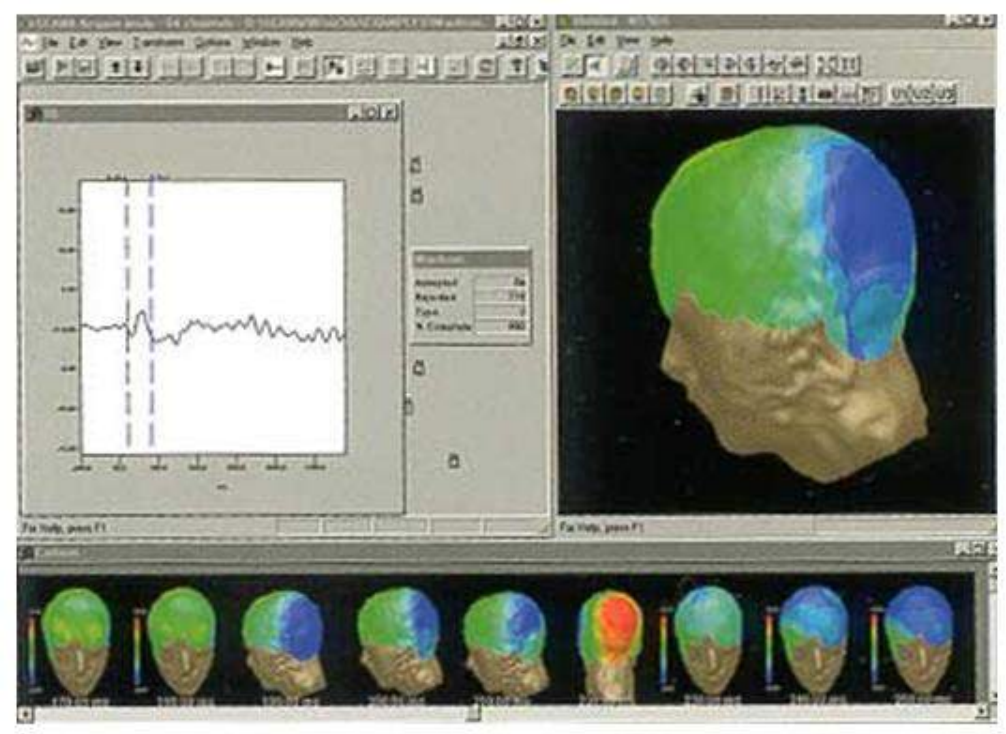


EEG, Alpha bursts when eyes closed,
alpha desynchronisation when eyes opened



Quantitative EEG (QEEG),

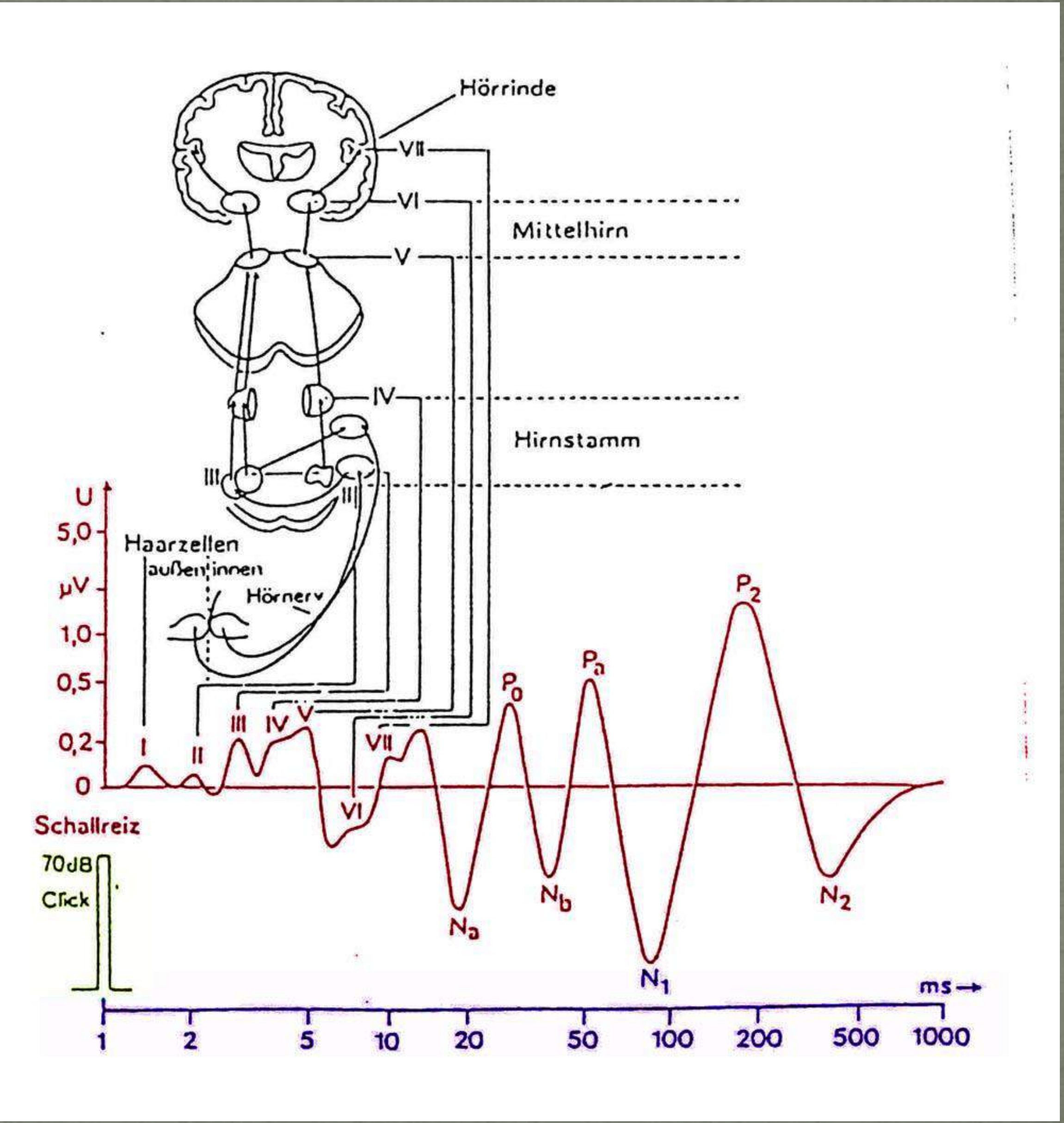
many EEG channels (up to 256)
source / dipole localisation

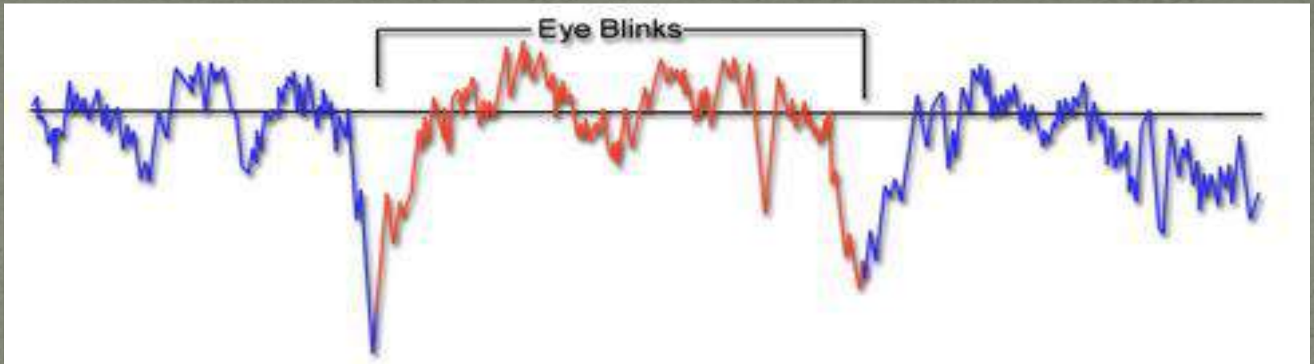


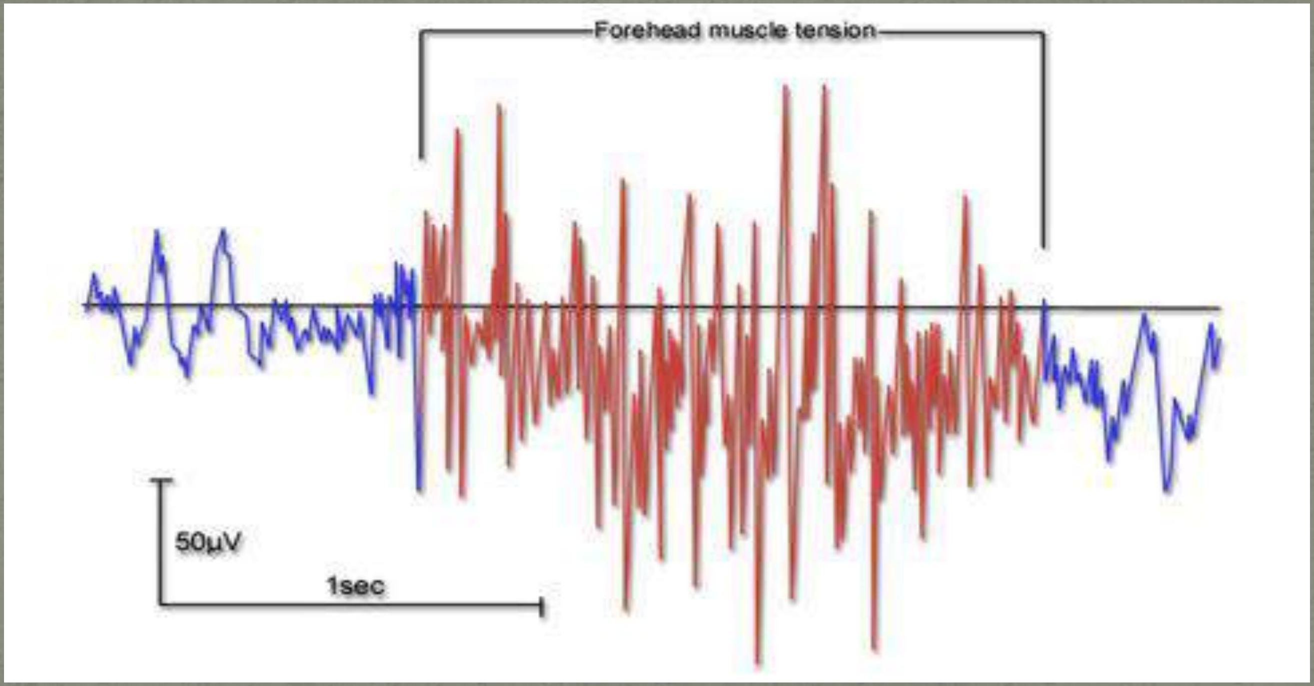
Auditory Evoked Potentials (AEP)

Trial averaging

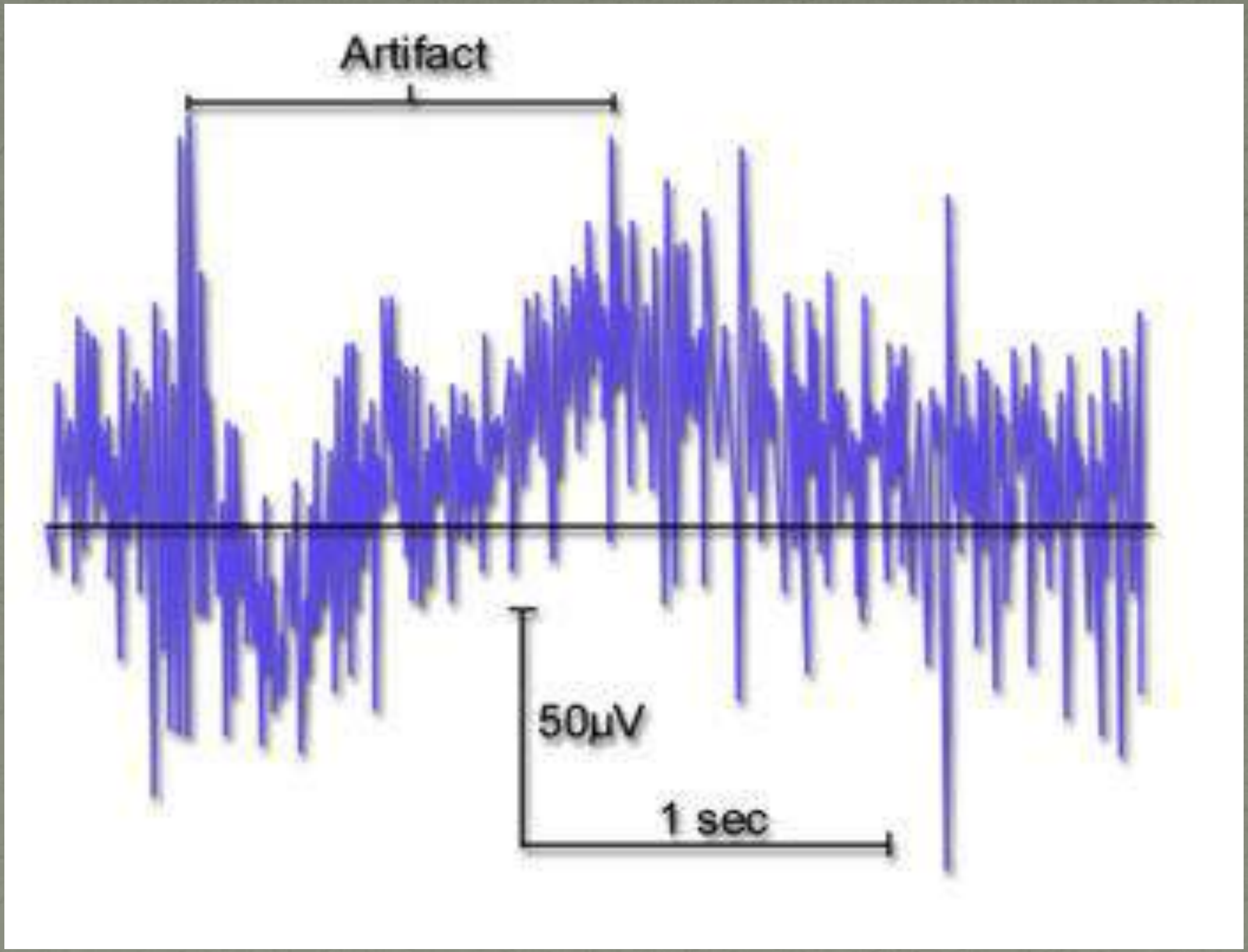
Also:
VEP
SSEP



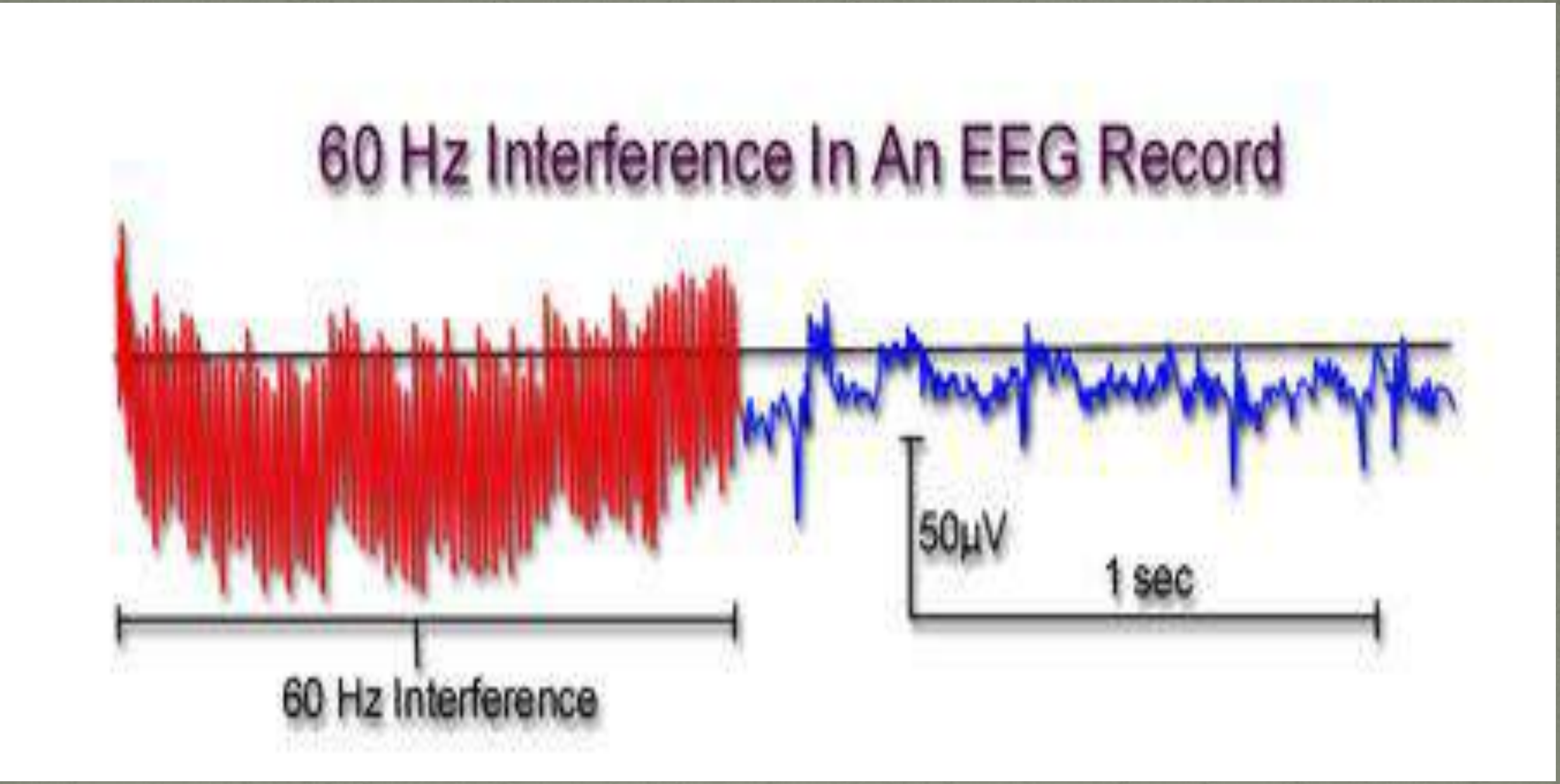




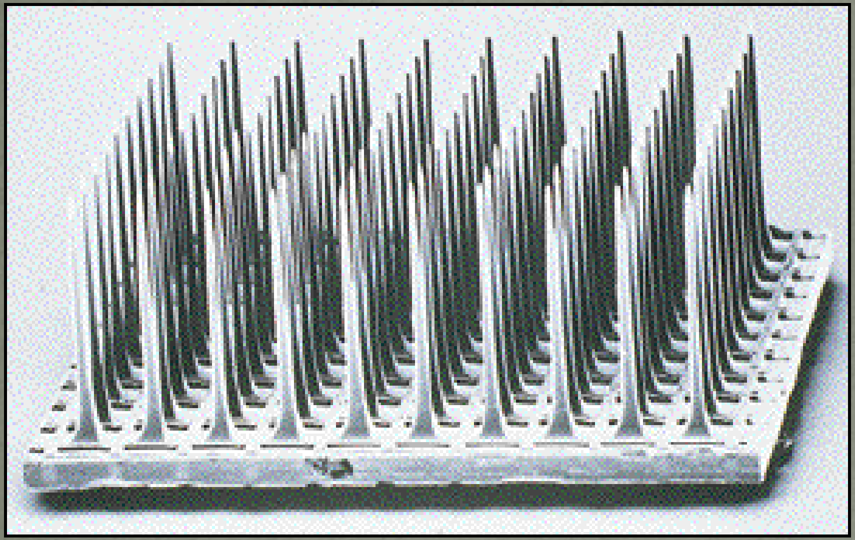
EEG artifacts: Eye blinks, muscle tension

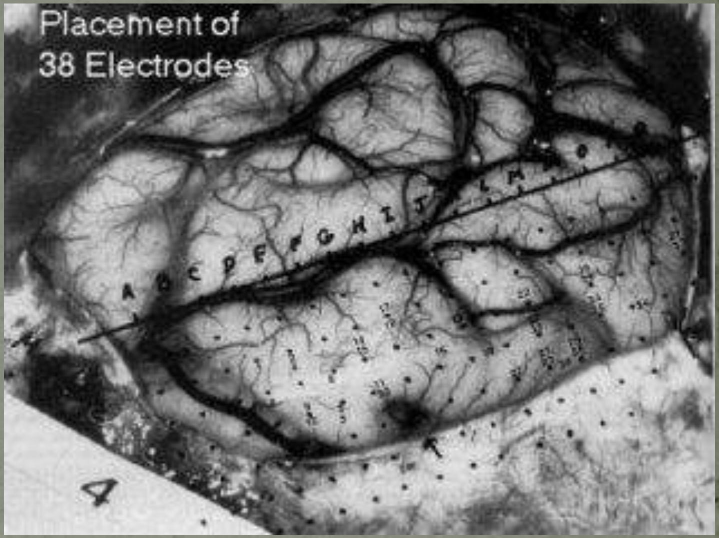


EEG artifacts: movement, electrode drifting

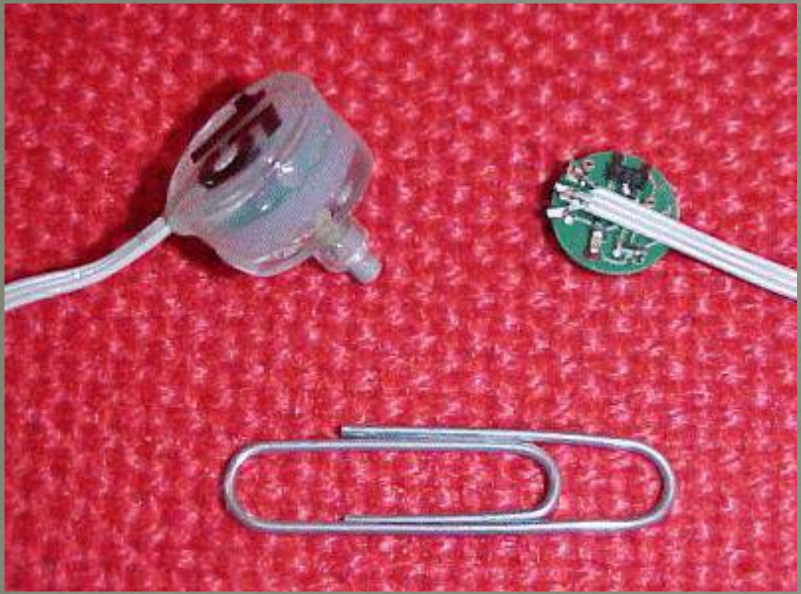


EEG artifacts: mains interference, 50/60Hz noise

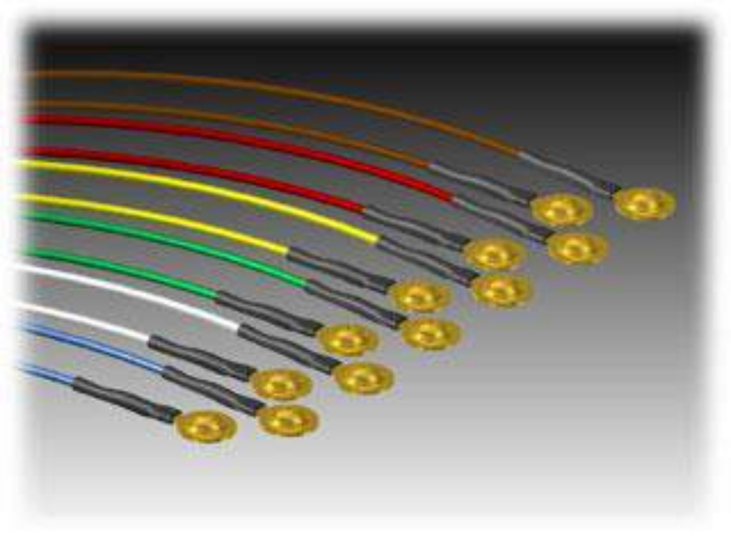




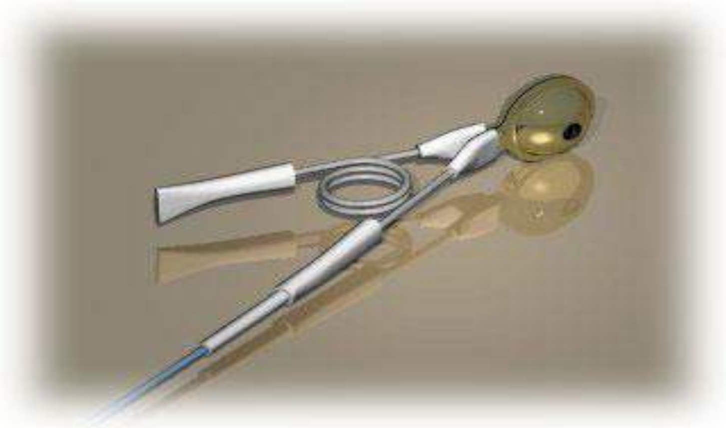
Intracortical / chronical electrodes



Active EEG- electrode



Singe disk gold plated electrodes



Ear clip electrode

EEG - applications

- Diagnostics (Epilepsy, Oncology, ..)
- Cognitive Sciences
- Sleep Analysis
- Human Computer Interfaces (BCIs)
- Pharmacology
- Intensive Care, Monitoring

Summary bioelectric signals

	Frequency	Amplitude (mV)
ECG	0,2 – 300	0,1 - 3
EEG	DC – 100	0,005 - 0,2
EEG (cortical)	10 – 100	0,015 - 0,3
EMG	10 – 1000	0,1 - 5
EMG (needle)	10 – 10000	0,05 - 5
EOG	0 – 30	0,1 - 2
Intracell.	0 – 10000	50 .. 130