PD233: Design of Biomedical Devices and Systems

(Lecture-7 Biopotentials 2)

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Course Website:
http://cpdm.iisc.ac.in/utsaah/courses/

Electromyogram (EMG)

Skeletal muscles are organized functionally on basis of ***motor unit***

Motor unit is smallest unit that can be by activated by volitional effort and all muscle fibers in that unit are activated synchronously.

In a single firing of motor unit extracellular field 20-2000µV for duration of 3-15ms.

Frequency of discharge varies from 6-30 per second.

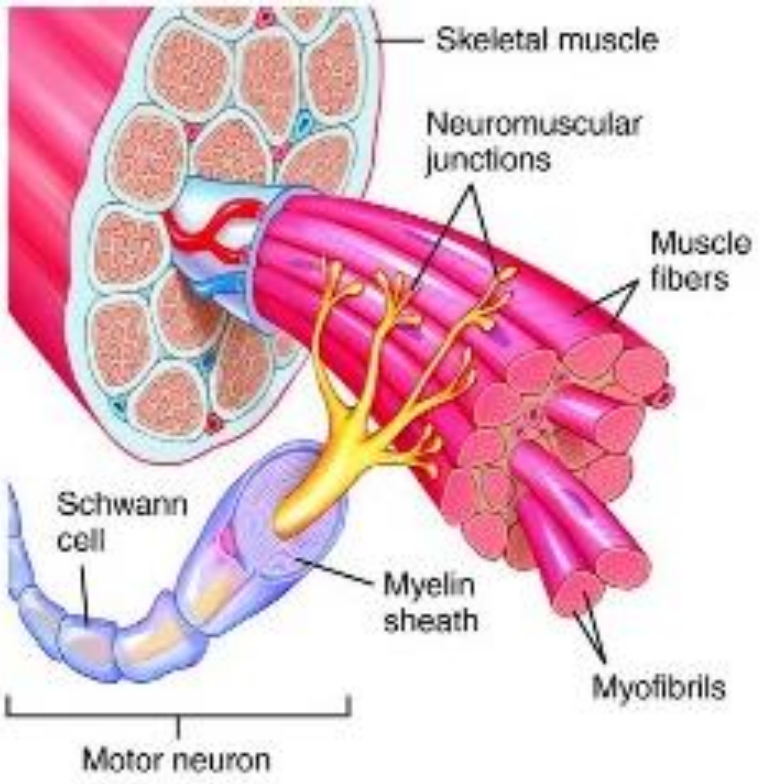
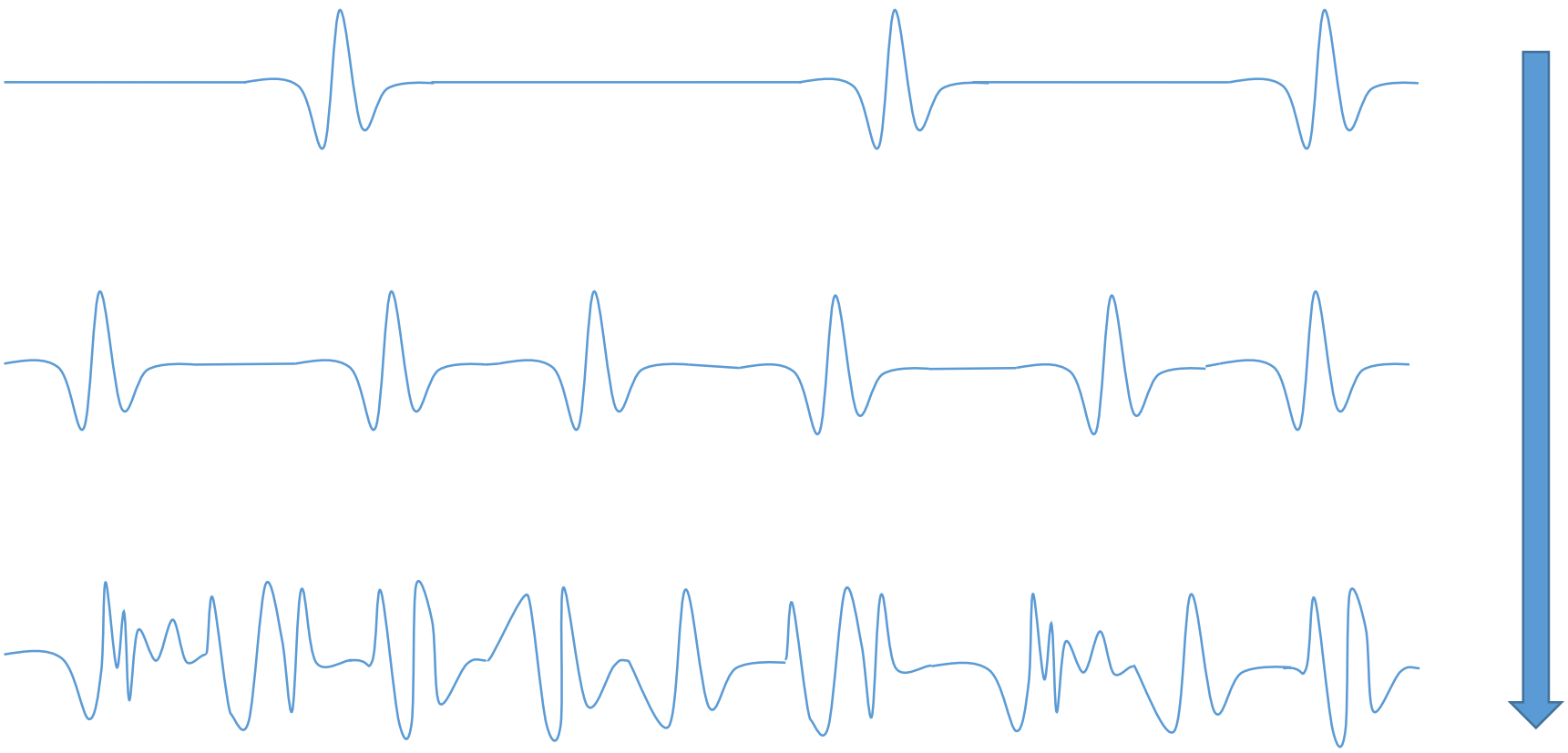
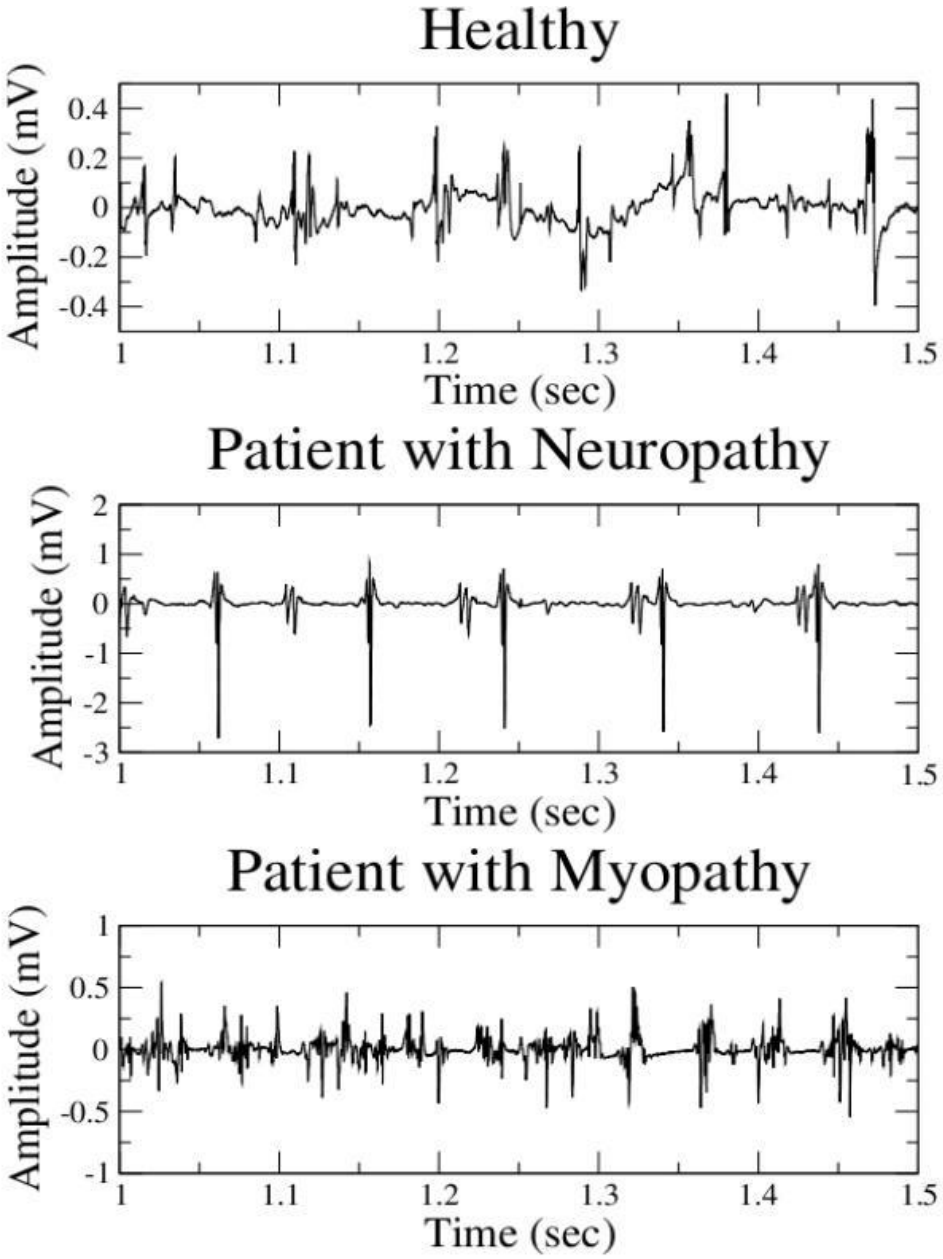


Image source: Mosby's Medical Dictionary, 8th edition

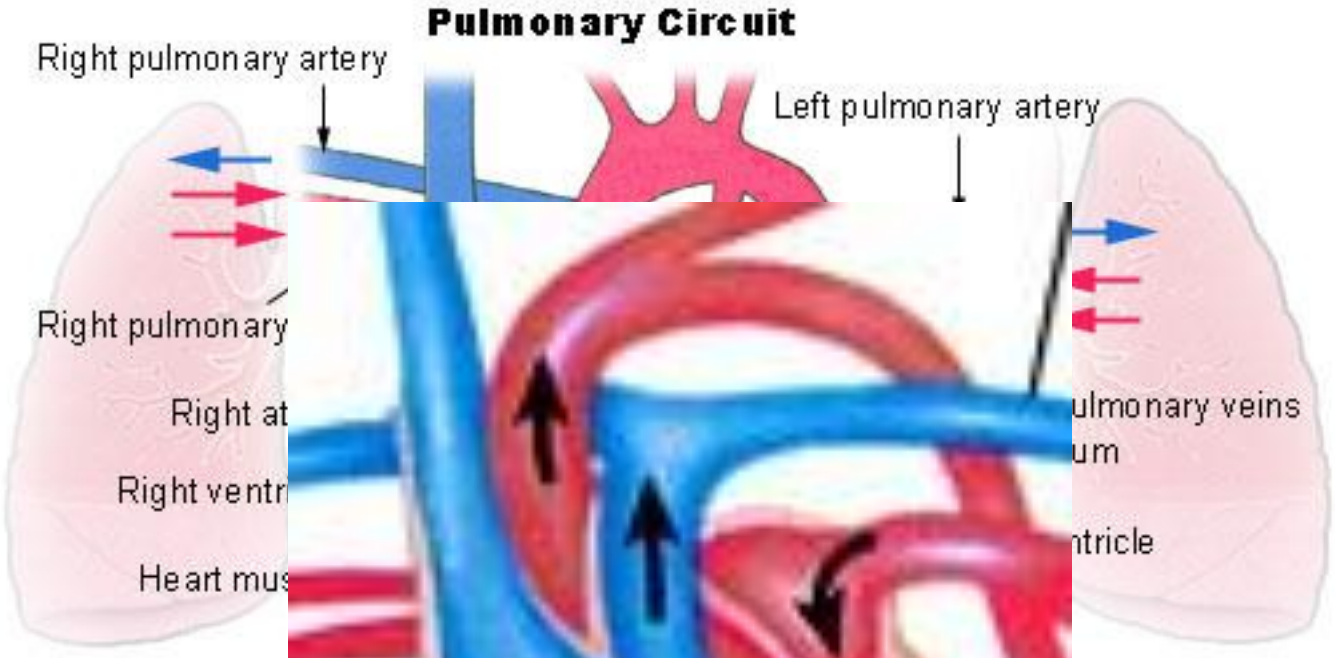
Normal EMG with increasing effort





Zennaro D, *et al*. IEEE Trans Biomed Eng, 50(1):58–69, 2003

Anatomy and Function of Heart



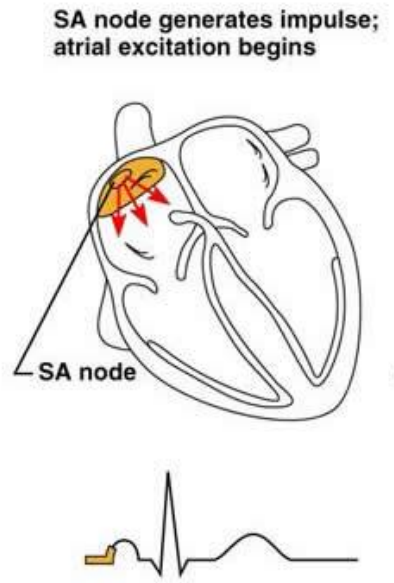
Heart in humans is four chambered pump of circulatory system.

Filling phase : ***Diastole***
Active/contractile phase: ***Systole***

Well coordinated electrical activity leads smooth rhythmic contractions of atria and ventricles

Image Source: Wikimedia.org

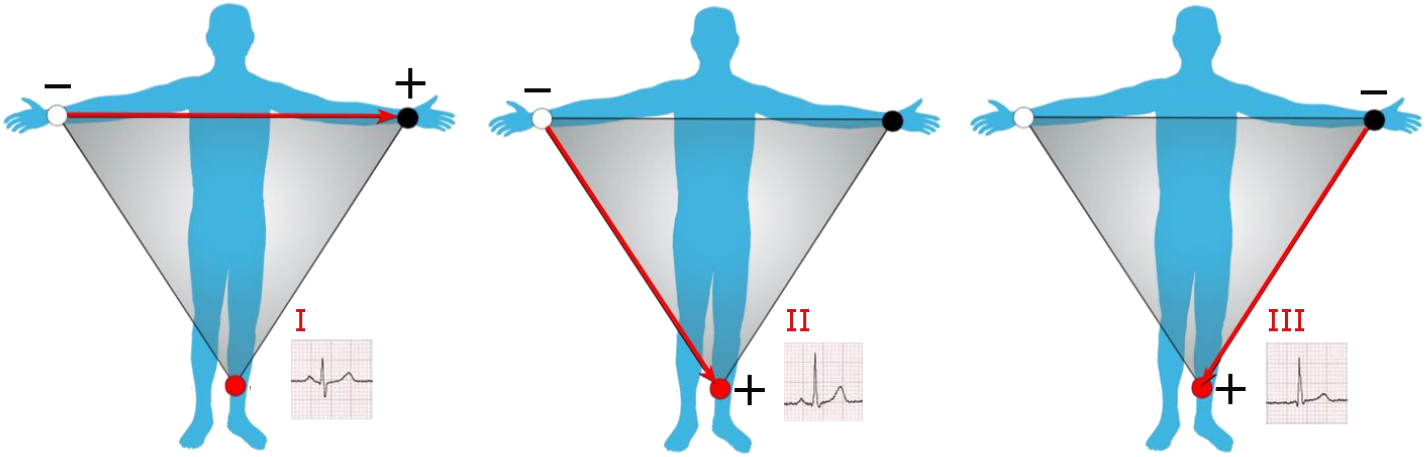
Electrical activity of heart



Heart muscles have resting potential of about -90mV
During electrical systole heart muscles ***first rapidly depolarized*** (at 150V/s) originating at **Sinoartrial (SA)** node and then ***gradually repolarize*** over 200-300ms
This depolarization and repolarization happens in spatially co-ordinated manner

Image credit: http://classes.midlandstech.edu/carterp Dr. Perry Carter

ECG measurements (3 lead system)



I = LA - RA

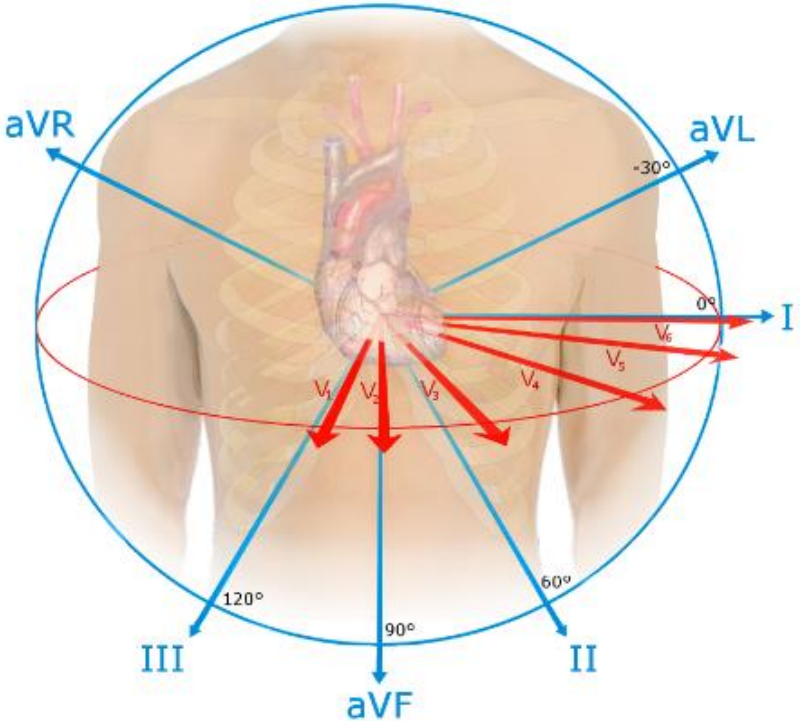
II = LL - RA

III = LL - LA

Three lead configuration uses three surface electrodes:
Note: Leads do not mean electrodes –
Lead refers voltage difference between two electrodes

Three lead configuration gives component of ***polarization vector*** in the vertical (coronal plane)

ECG measurements (other leads)



Wilsons terminal: V_w= (RA+LA+LL)/3

Augmented limb leads

aV_R= 2/3(RA- V_w)

aV_L= 2/3(LA- V_w)

aV_F= 2/3(LL- V_w)

V_1-V_6 are precordial lead which give projection polarization vector in ***horizontal plane***

Wilsons terminal is used as negative electrodes for precordial leads.

Normal and Abnormal Heart Rhythms

Bradycardia : slow down on heart rate (e.g. during sleep)

Tachycardia : faster than normal heart rate (e.g. due to exercise, emotions or fever)

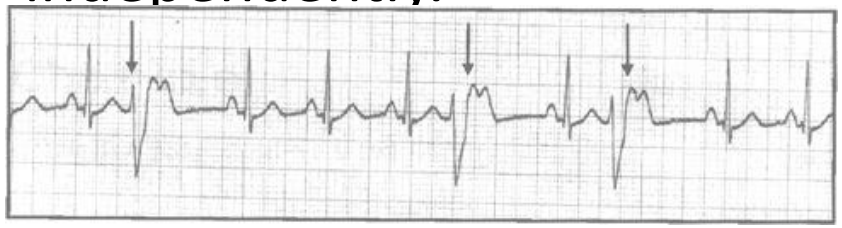
Complete Heart Block: electrical activity does not pass to ventricles (Problem with bundle of His)

First degree Heart Block: longer transmission time to ventricles, P-R interval in prolonged

Second Degree Heart Block: not all atrial pulse are conducted

Normal and Abnormal Heart Rhythms

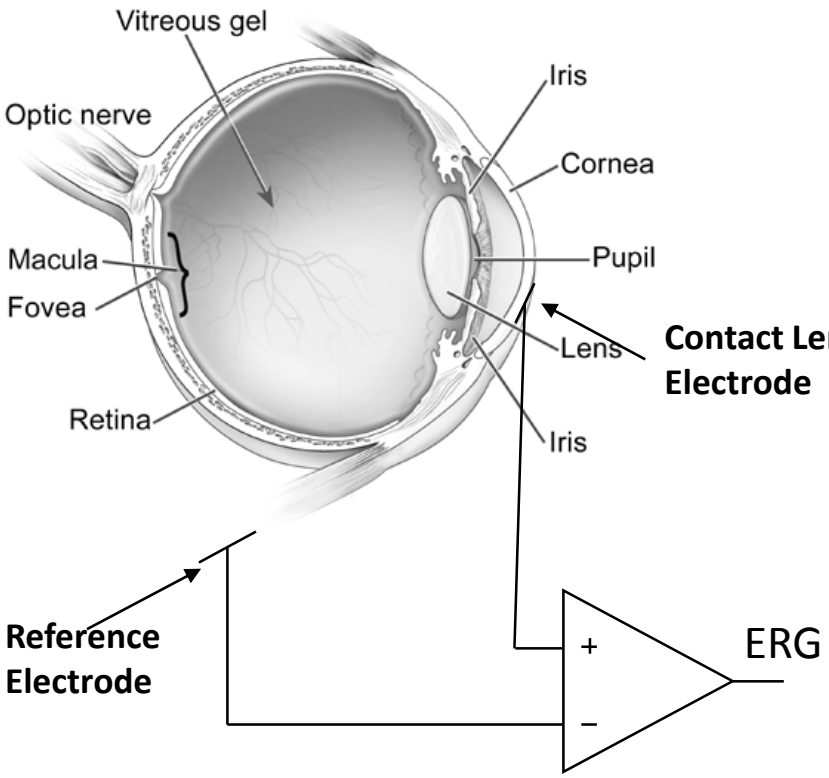
Ectopic focus: A portion of myocardium node is irritable and can 'fire' independently.



Paroxymal Tachycardia
Atrial Flutter
Atrial fibrillation
Ventricular Fibrillation

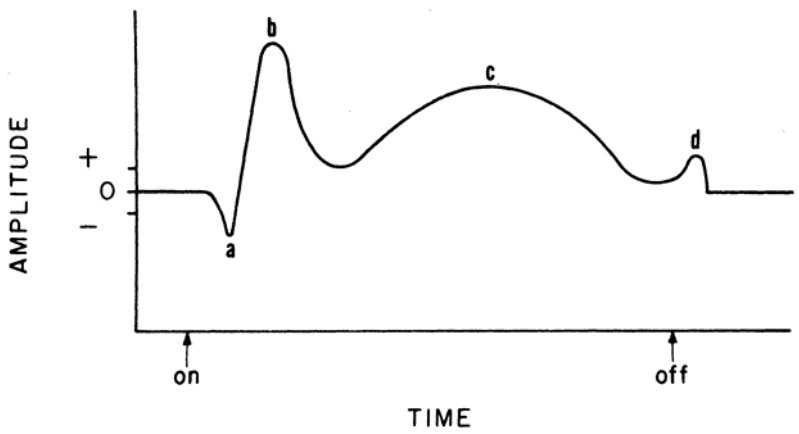
Myocardial Infarction (MI): Blood flow stops to part of the cardiac muscle.

Electroretinogram (ERG)



Rod and ***Cone*** are specialized (photosensitive) nerve cells present in the ***Retina***

Temporal changes in potential between retina and reference location in response to exposure to light.



Electro-oclulogram (EOG)

- Steady potential between retina and cornea (i.e. DC measurement)
- Can be used for eye gaze tracking – horizontal and verticle
- Linear relationship between angle of gaze and EOG

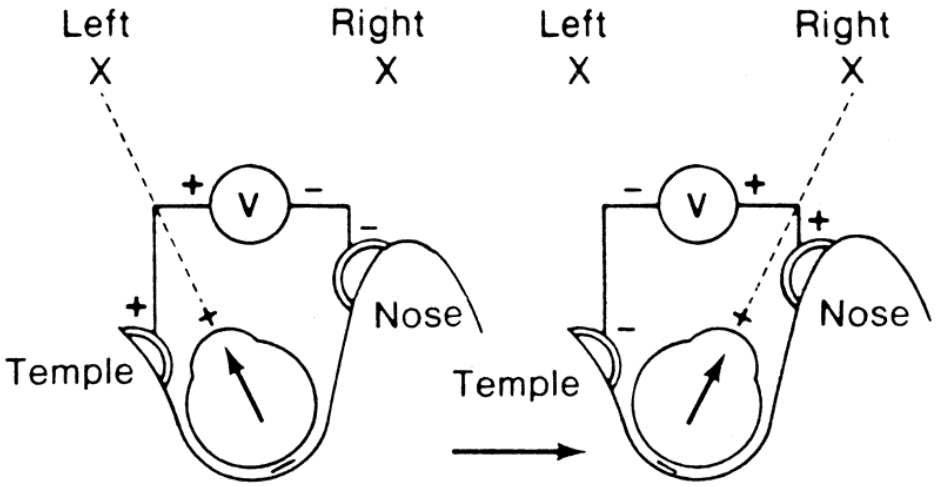


Image credit : http://www.oculist.net

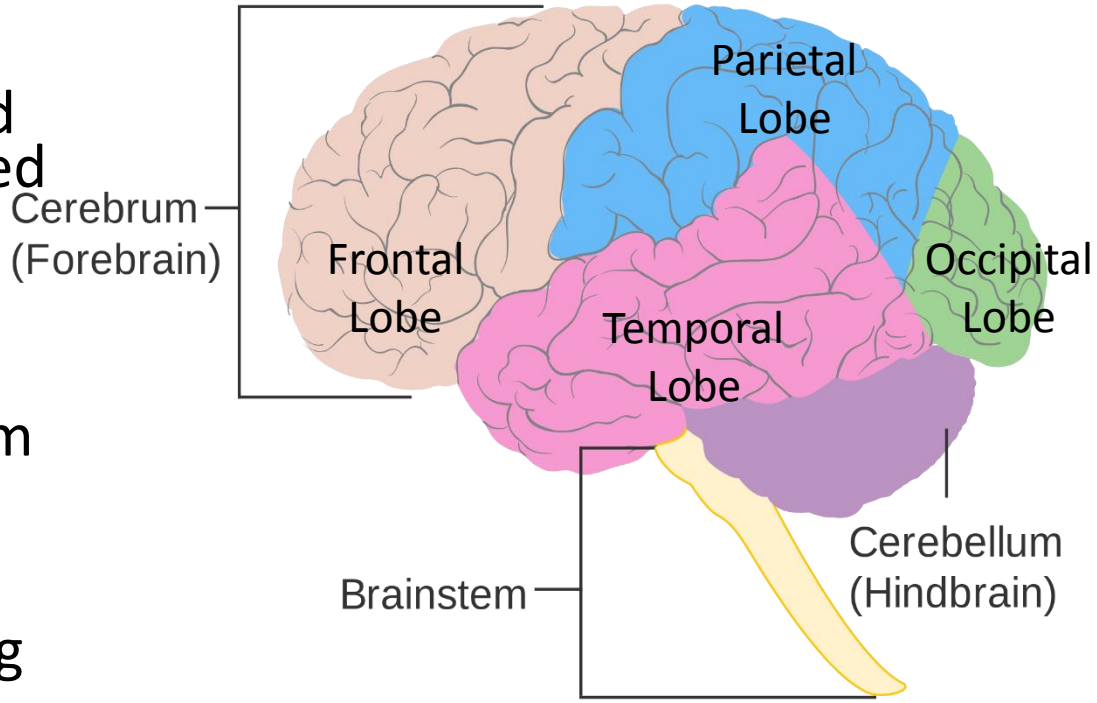
Electroencephalogram (EEG)

In the nervous system information is transmitted using frequency modulated impulse.

EEG measures potential fluctuations recorded from the brain.

EEG can be recorded using

- scalp electrodes
- cortical electrodes
- depth electrodes



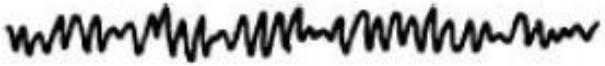
Main parts of the brain
Image credit: CRUK

Resting EEG

Cortical or depth EEG recording can be as large as 10mV but scalp EEG recoding are order 100µV, and are result of **synchronous** action of a region in the brain.

Resting stage EEG is divided into:

Alpha 8-13 Hz



(Relaxation)

Evoked Reponses Potentials (ERP)

EEG response can be gathered in response to certain stimuli, e.g.

Auditory evoked response (AER)

-Response to clicks (100µs) and tones (100ms pulses) can be used to check auditory circuit of the brain.

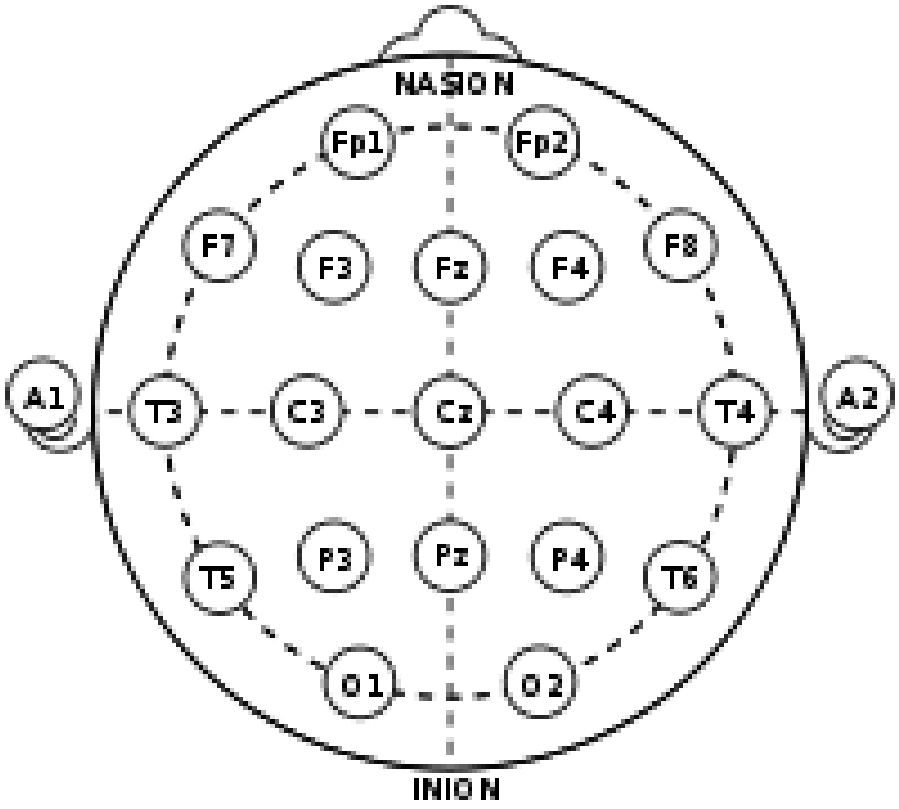
Visual evoked response (VER)

-Reponses to visual stimuli

Cognition potentials

-Response to cognitive function (recognising known object, odd sound etc.)

10-20 electrode system



Standardized system for EEG Electrode placement.

Epilepsy

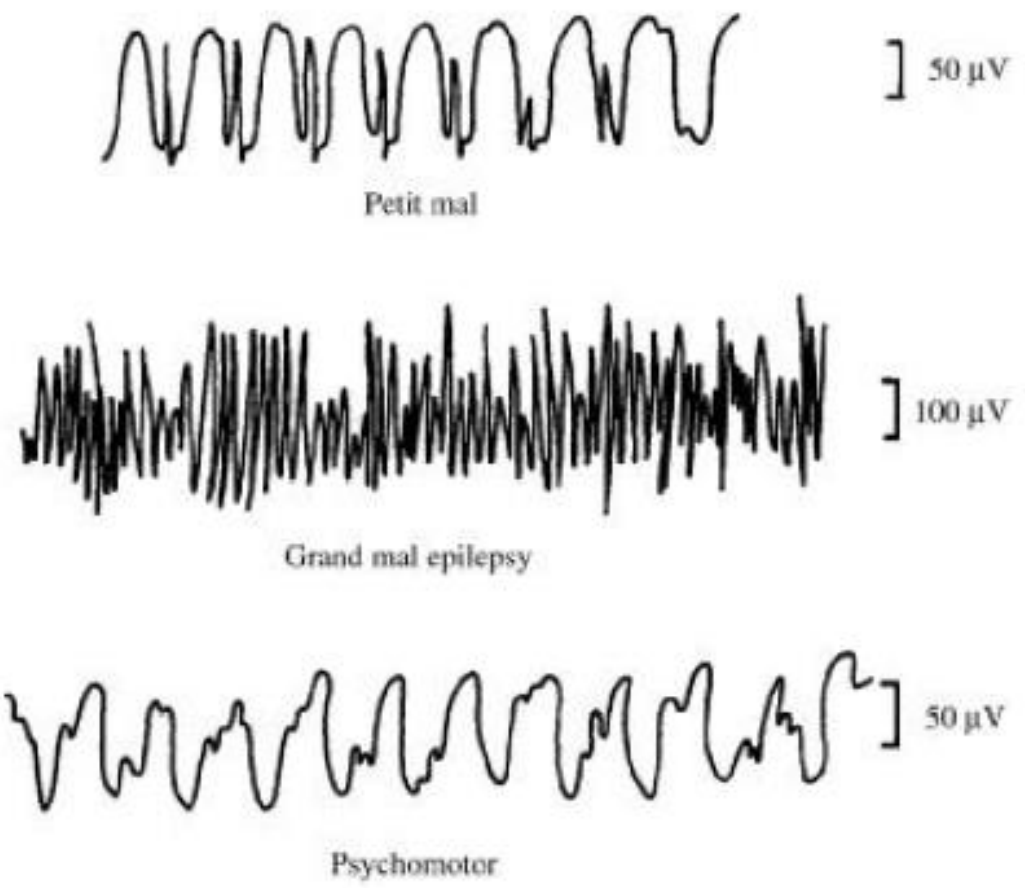
Neurological disease characterized by seizures

EEG is used as tool to characterized Epilepsy

Convulsive seizures occur in 60% of the cases, but 40% cases may not have show convulsion.

Abnormal EEG patters in Epilepsy

- Generalized
- Partial
- Focal



Electrode-electrolyte interface

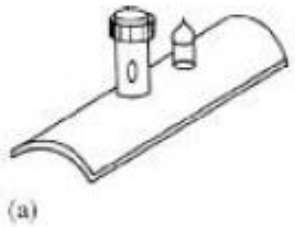
Biopotenatial electrodes are also transducers

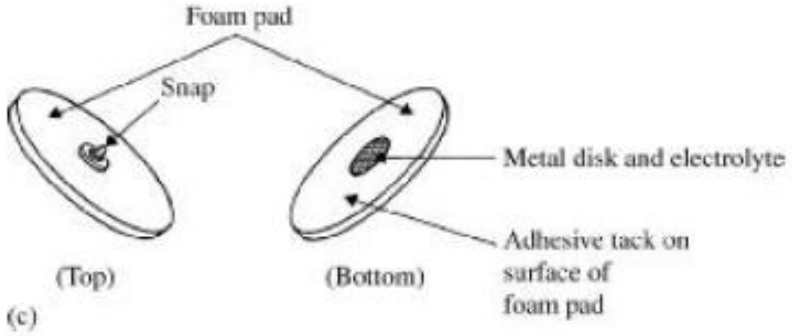
- they convert ionic currents to electron flow in the lead wires.

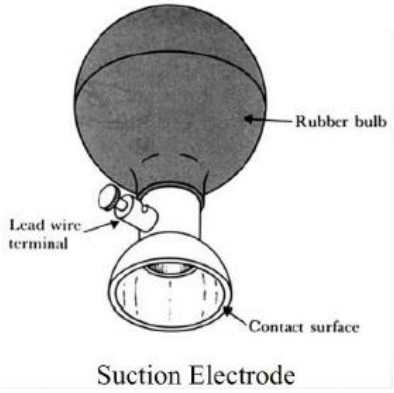
The electrochemistry of electrode materials governs their characteristics

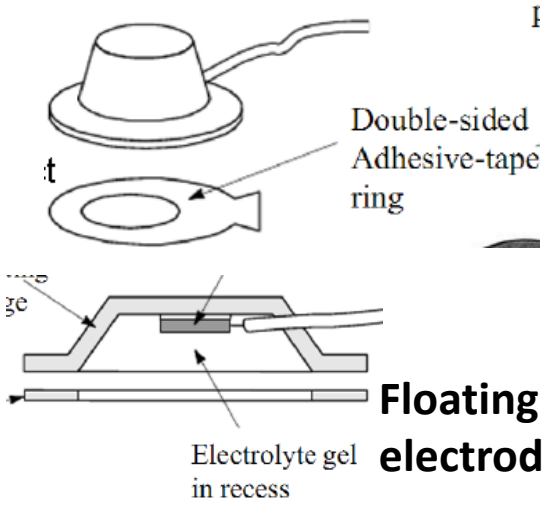
Types of electrodes:

- Polarizable electrodes (noble metals, Au, Pt)
- Non-polarizable electrode (Ag/AgCl)









Floating electrodes

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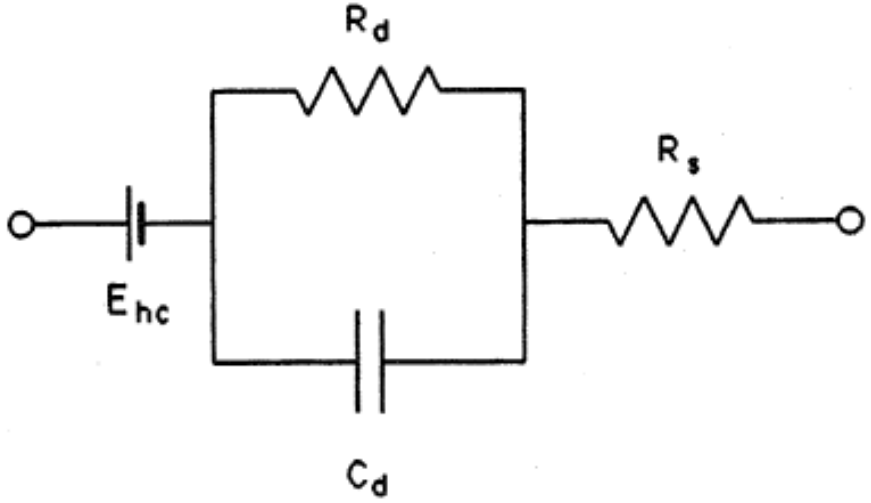
Equivalent circuit of electrode

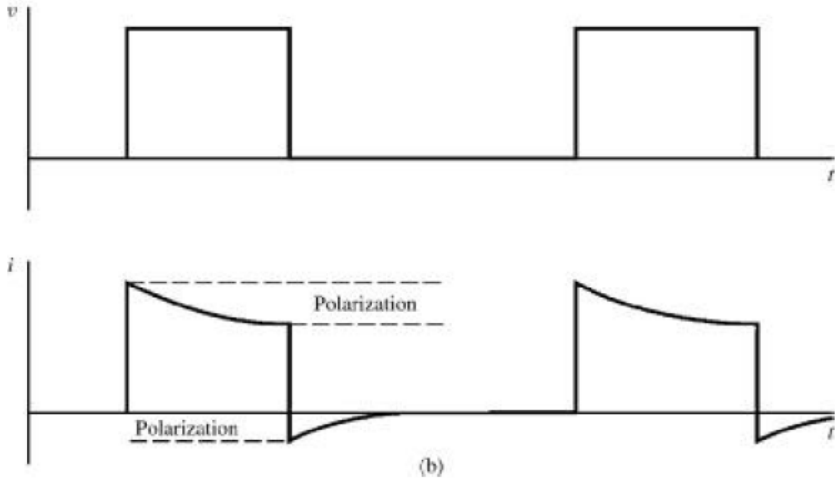


E_{hc} = Half cell potential

R_d , C_d = impedances associated with electrode-electrolyte systems

R_s = Series resistance

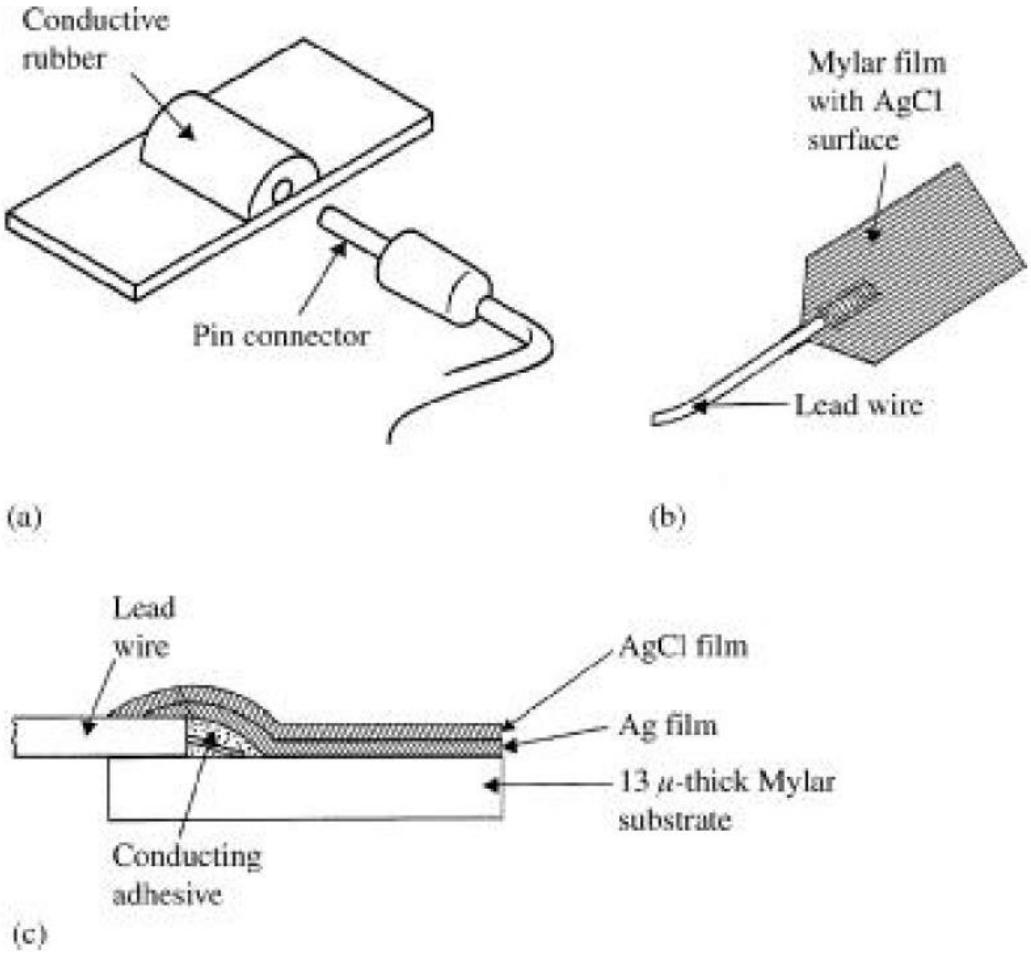
Effect of Polarization of Electrical Stimulation



Constant Voltage Stimulation

Constant Current Stimulation

Flexible electrodes



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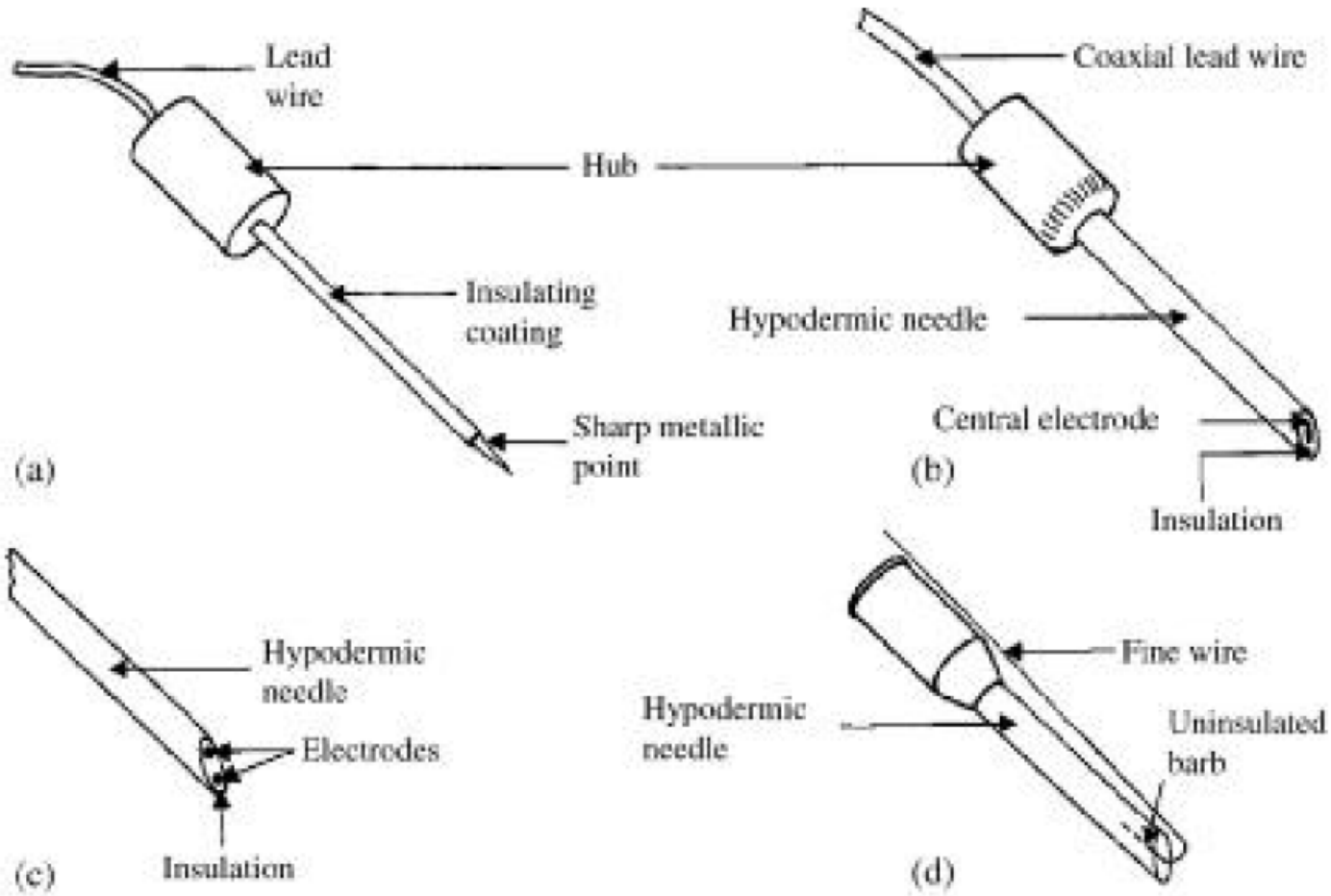
Needle electrodes



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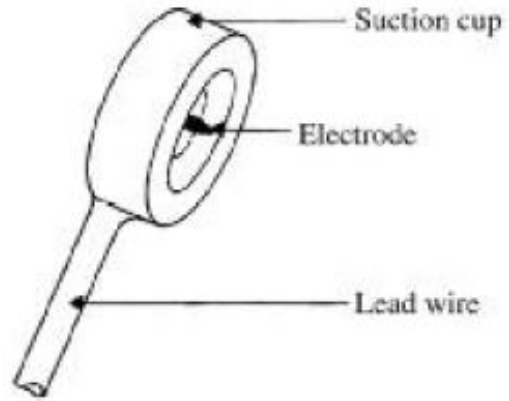
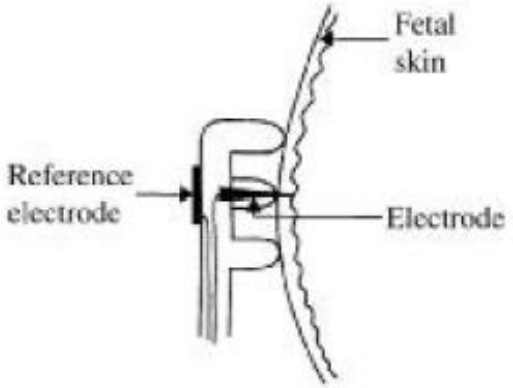
Foetal Electrode



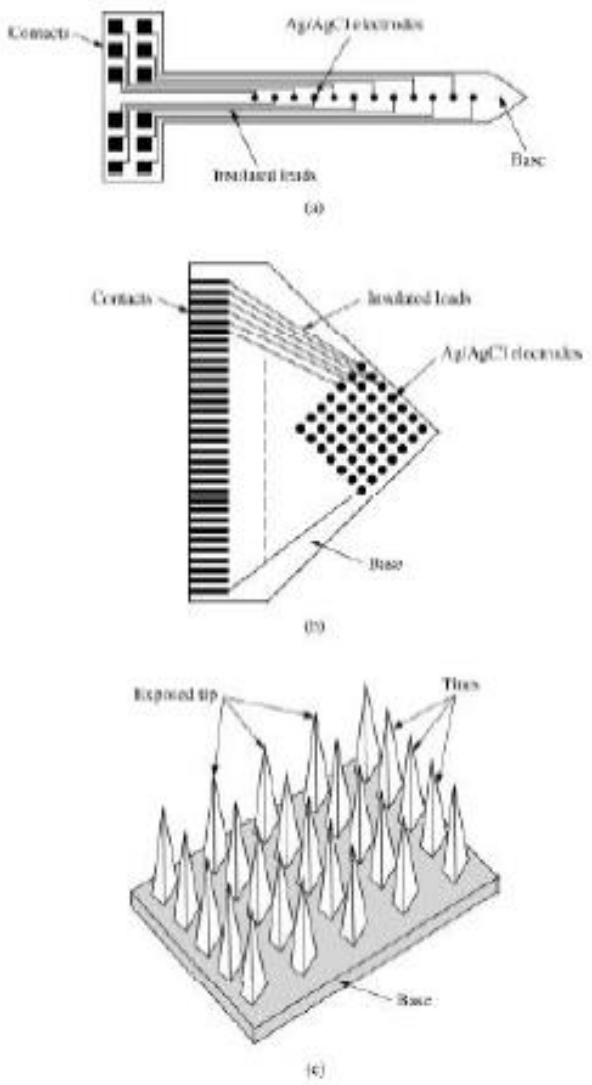
(a)

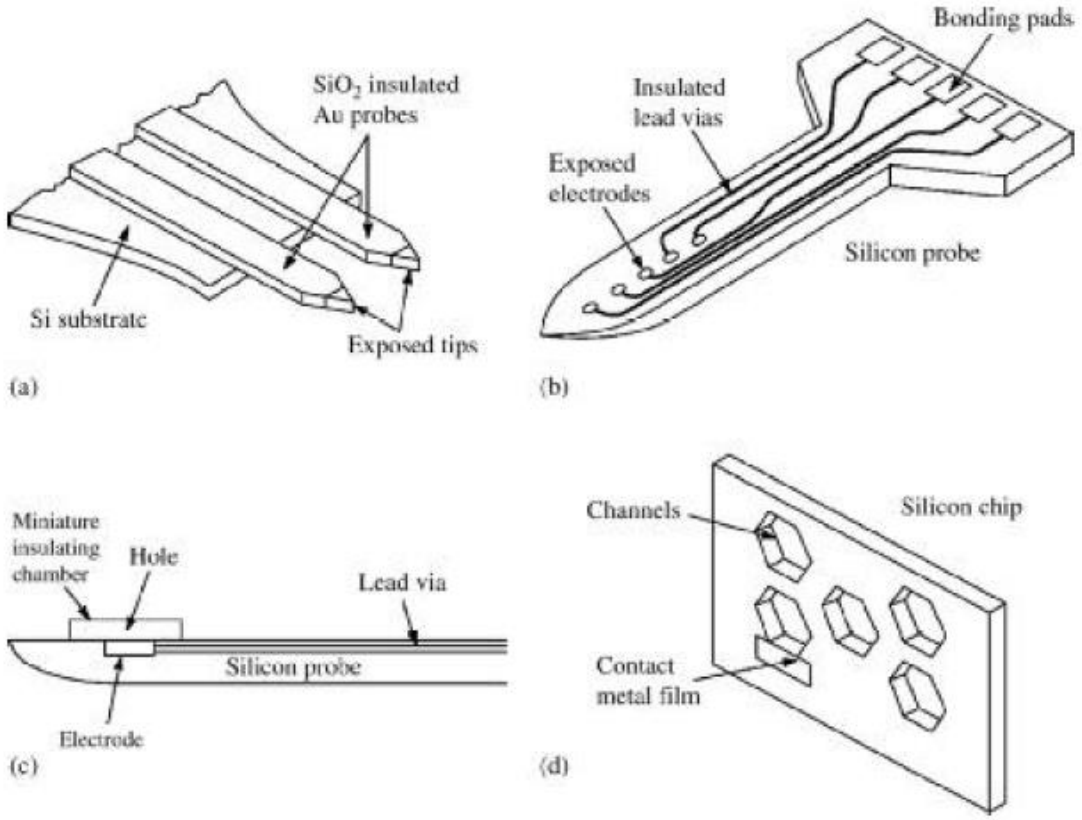
(c)



(b)

Microelectrode Arrays



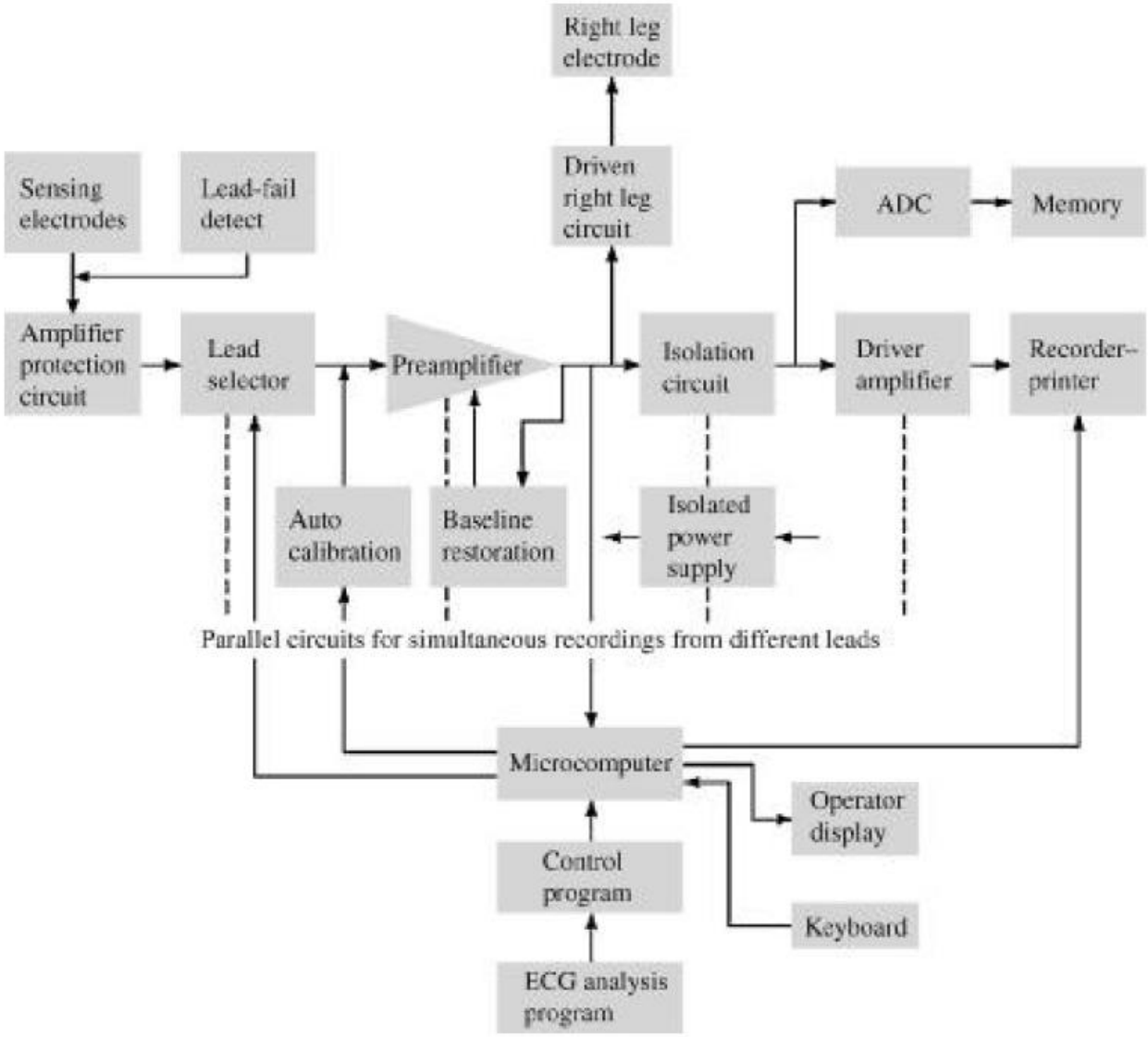


Microfabricated electrode array

Biopotential Amplifiers Requirements

- High input impedance
- Input protection
- High Gain
- Differential Input
- High Common Mode Rejection
- Calibration possibility

Electrocardiogram (ECG)



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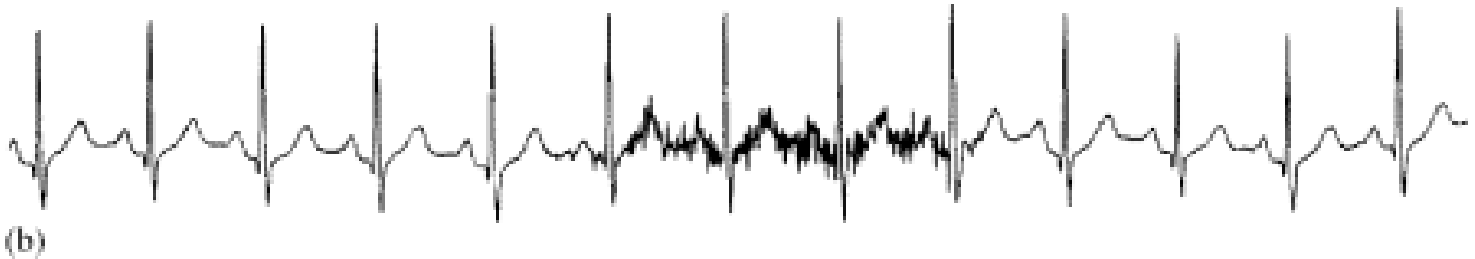
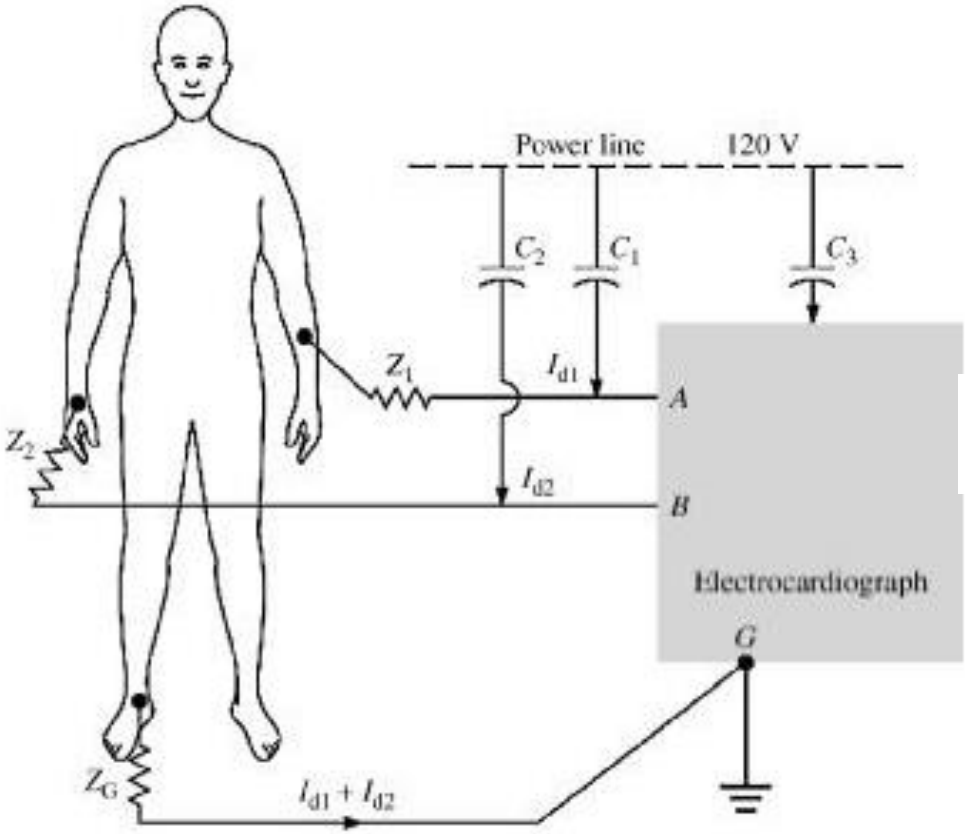
Electrical Interference

Power Line Pickup



Myogenic interference

Interference voltage



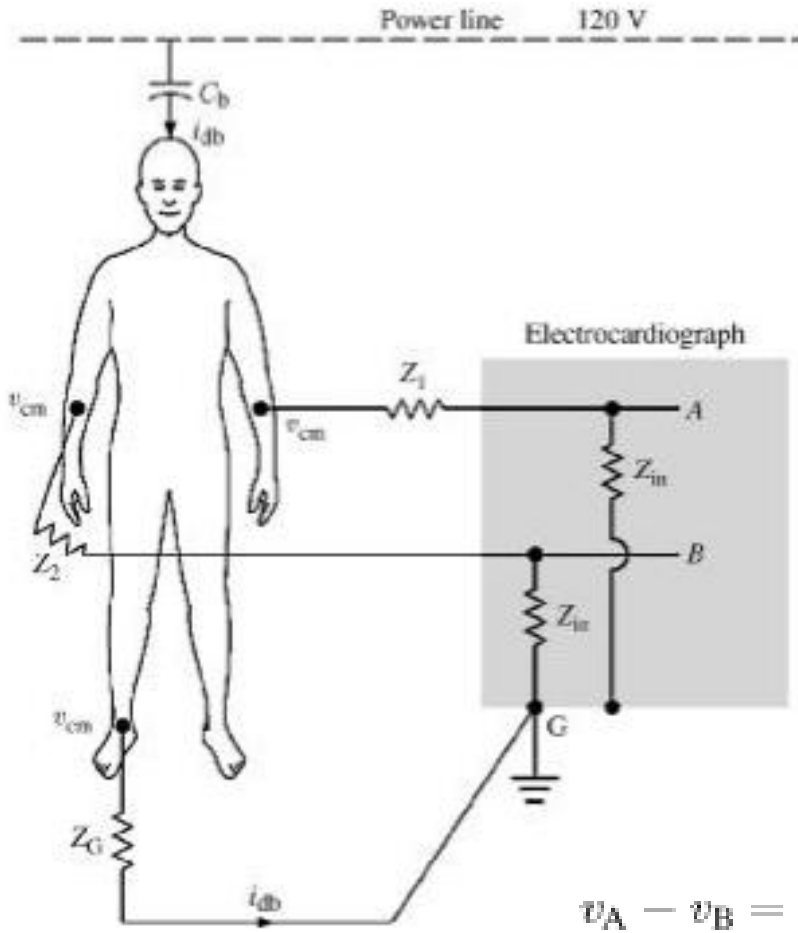
Shielding of cable
Lower skin-electrode Impedance

$$v_A - v_B = i_{d1}Z_1 - i_{d2}Z_2$$

$$v_A - v_B = i_{d1}(Z_1 - Z_2)$$

$$v_A - v_B = (6\,\text{nA})(20\,\text{k}\Omega) = 120\,\mu\text{V}$$

Common mode interference



$$v_{cm} = i_{db} Z_G$$

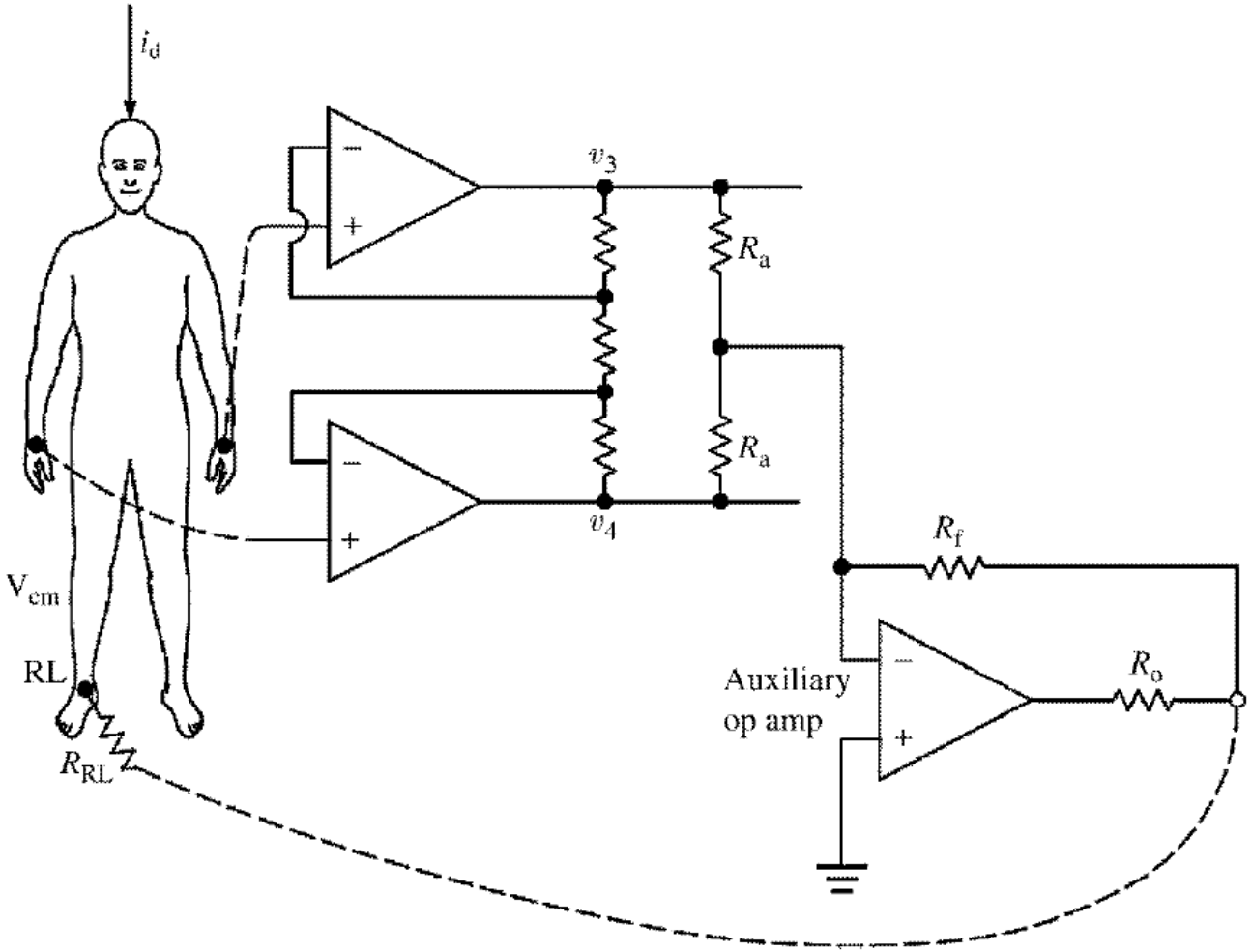
$$v_{cm} = (0.2\,\mu A)(50\,k\Omega) = 10\,mV$$

$$v_A - v_B = v_{cm}\left(\frac{Z_{in}}{Z_{in} + Z_1} - \frac{Z_{in}}{Z_{in} + Z_2}\right)$$

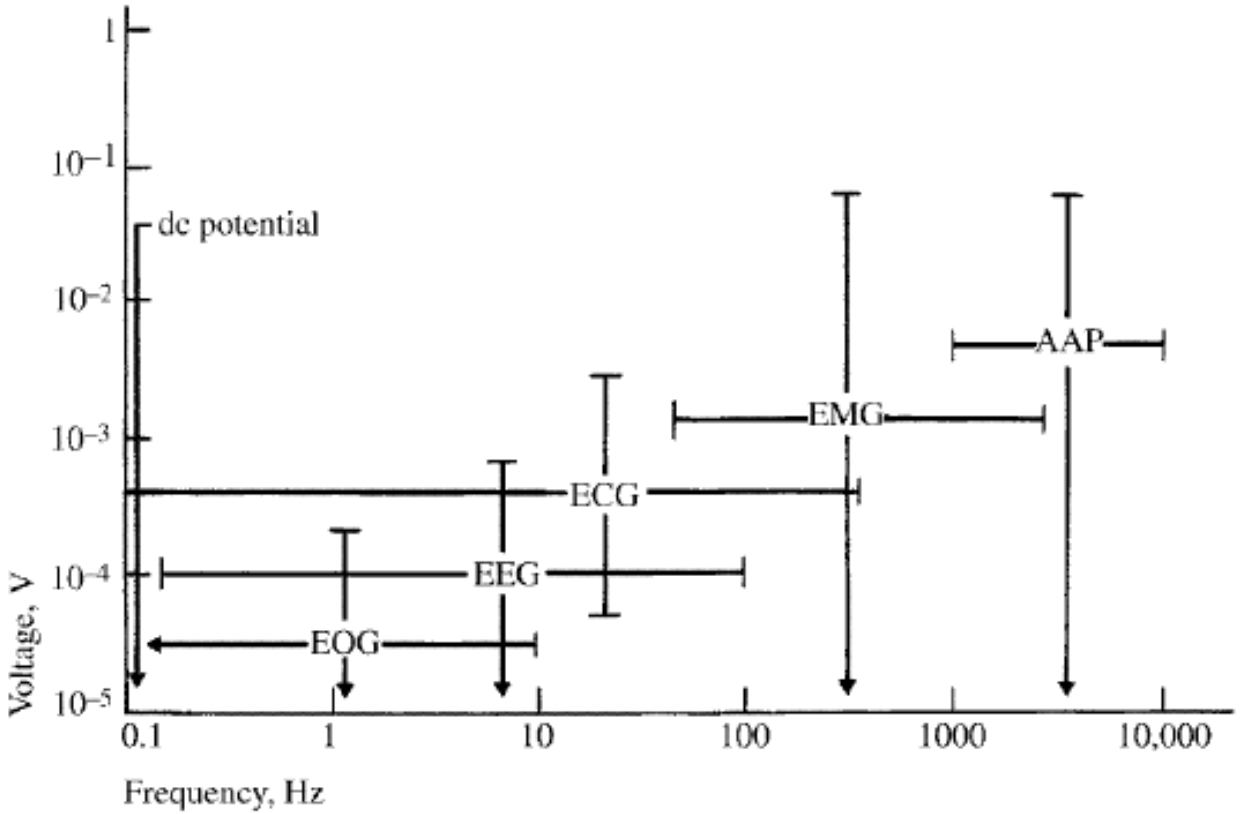
$$v_A - v_B = v_{cm}\left(\frac{Z_2 - Z_1}{Z_{in}}\right)$$

$$v_A - v_B = (10\,mV)(20\,k\Omega/5\,M\Omega) = 40\,\mu V$$

Driven Right Leg



Other Biopotential Amplifier



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