

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 activated by volitional effort and all muscle fibers in that unit are activated synchronously.

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

Frequency of discharge varies from 6-30 per second.

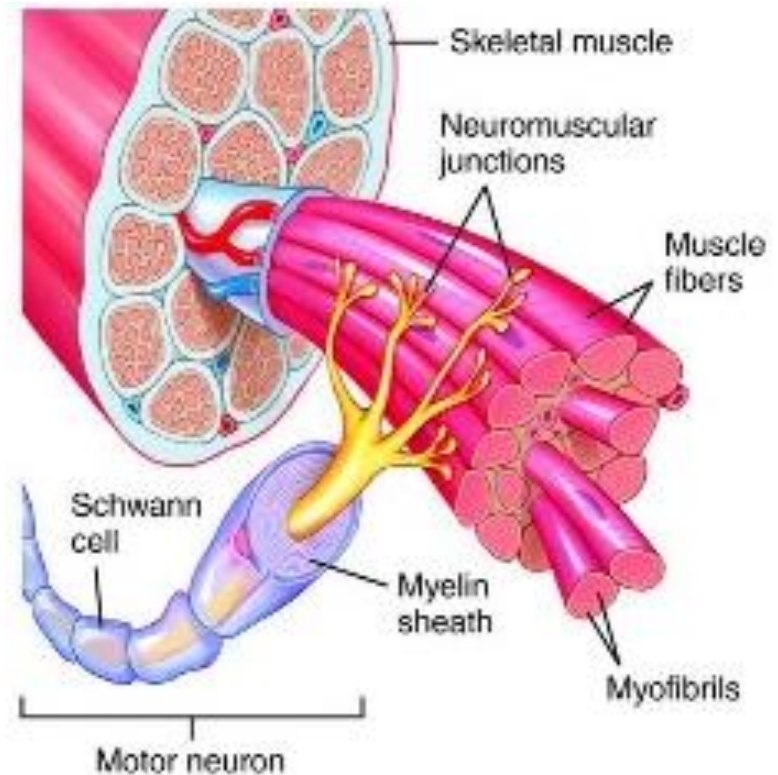
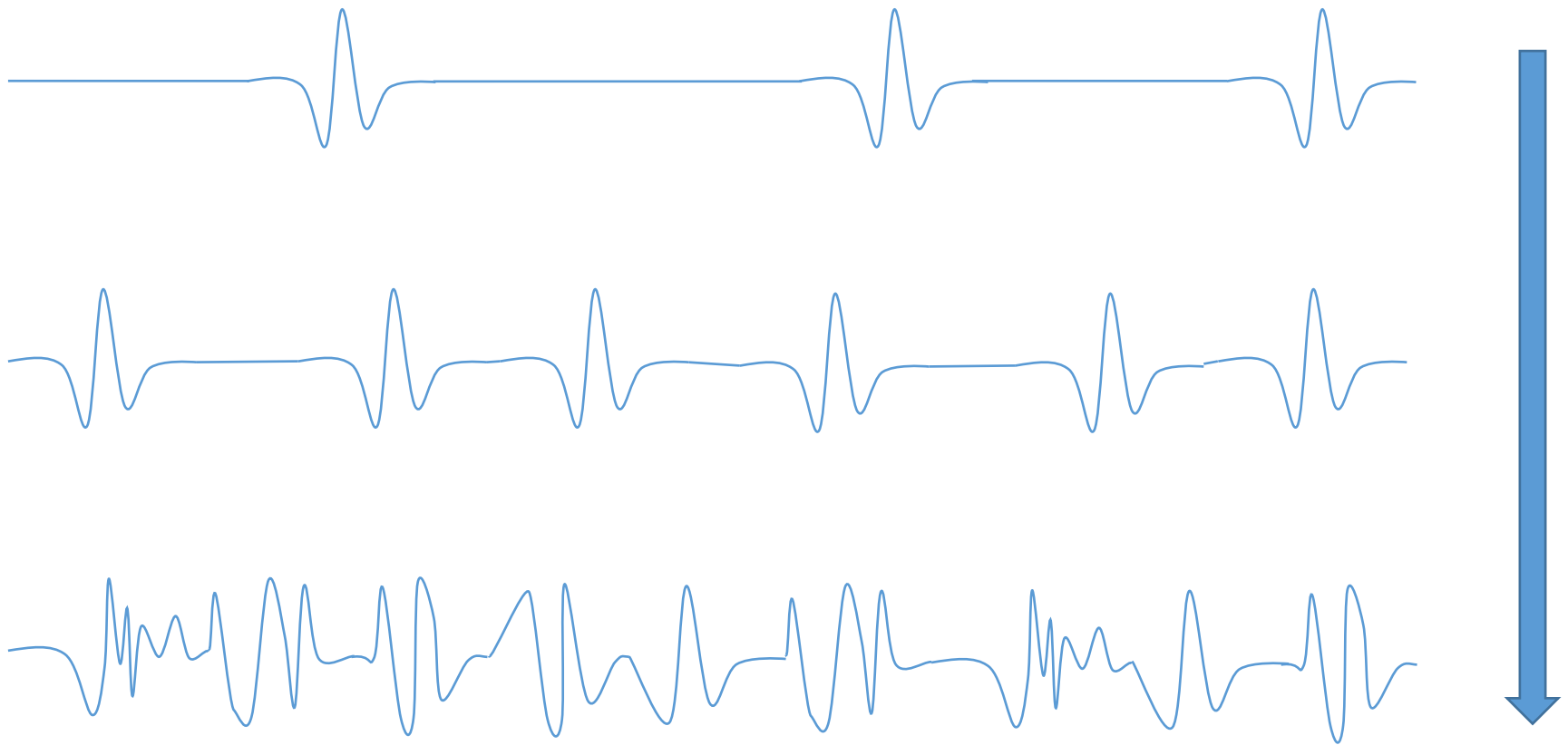
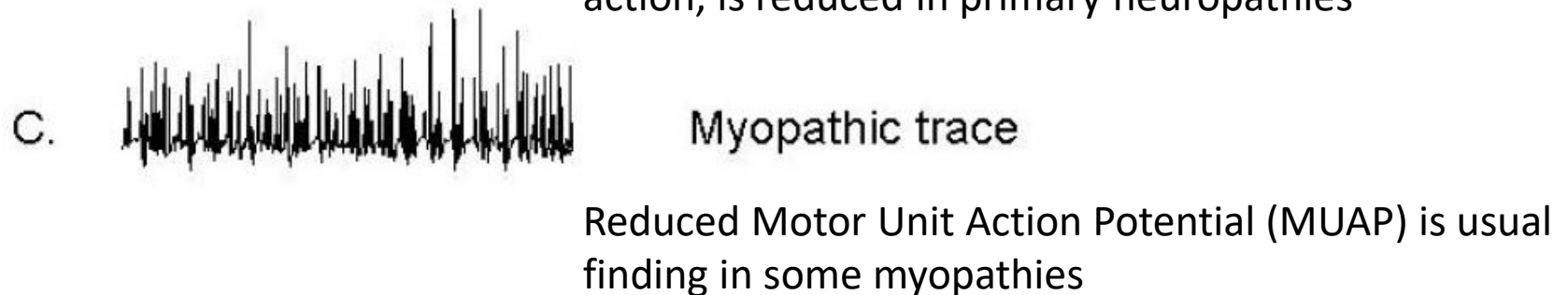
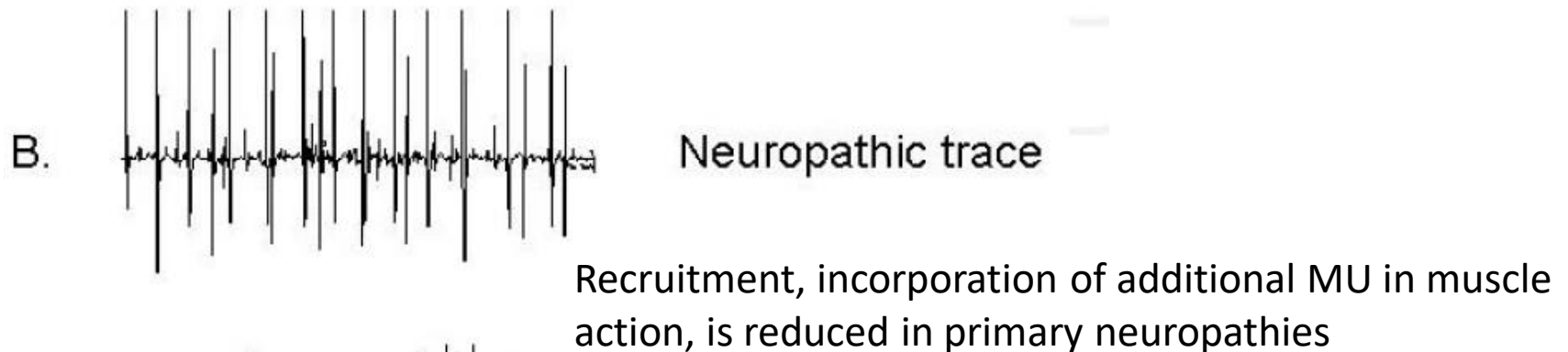
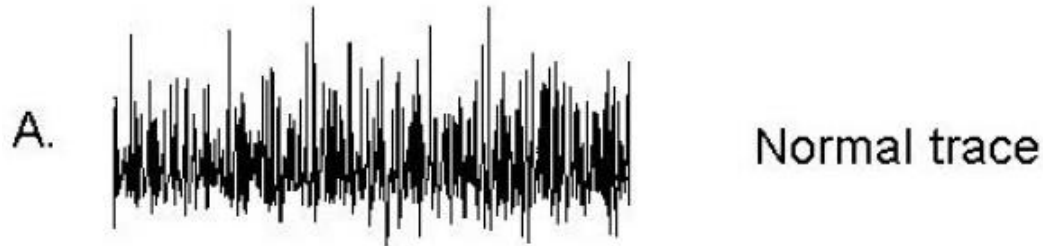


Image source: Mosby's Medical Dictionary, 8th edition

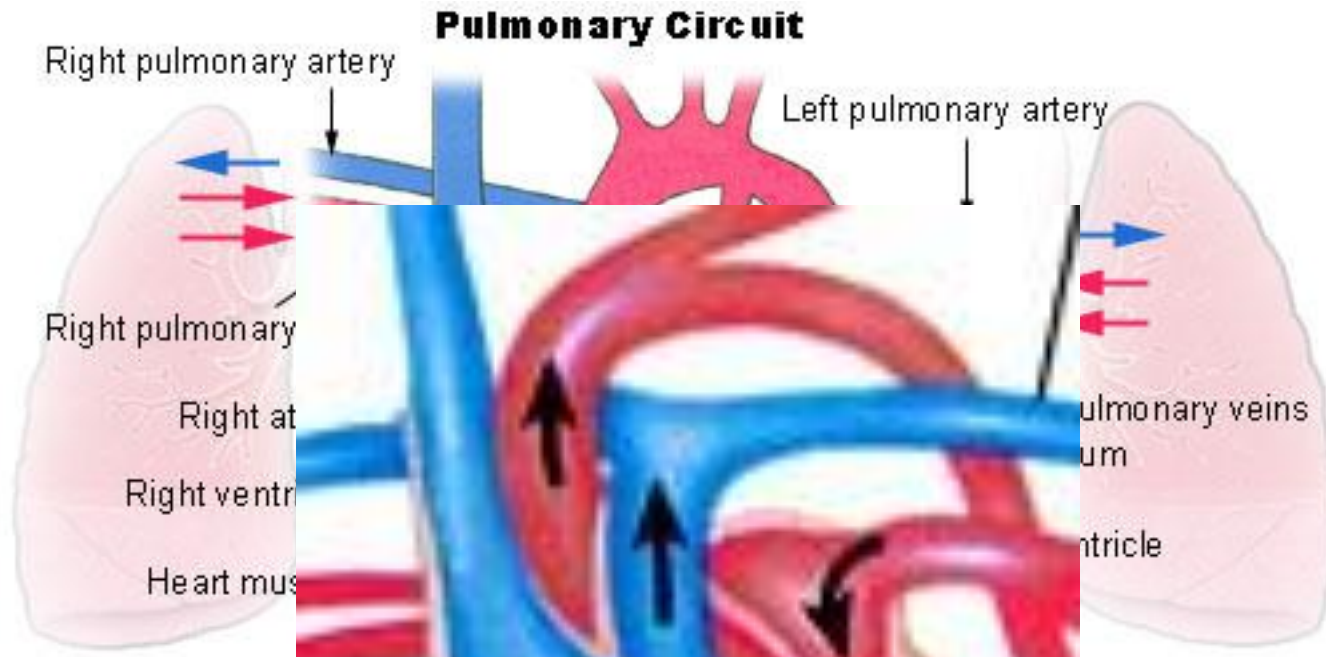
Normal EMG with increasing effort



Clinical use of EMG



Anatomy and Function of Heart



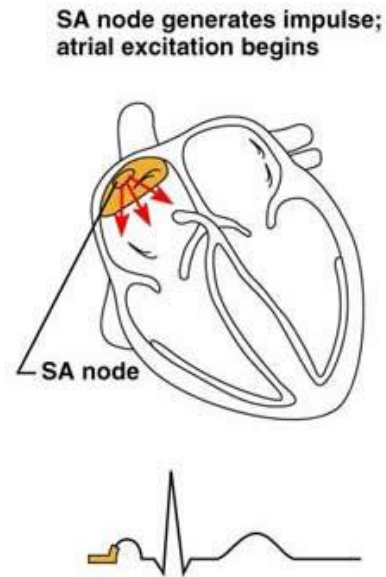
Heart in humans is four chambered pump of circulatory system.

Filling phase : ***Diastole***

Active/contractile phase: ***Systole***

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

Electrical activity of heart



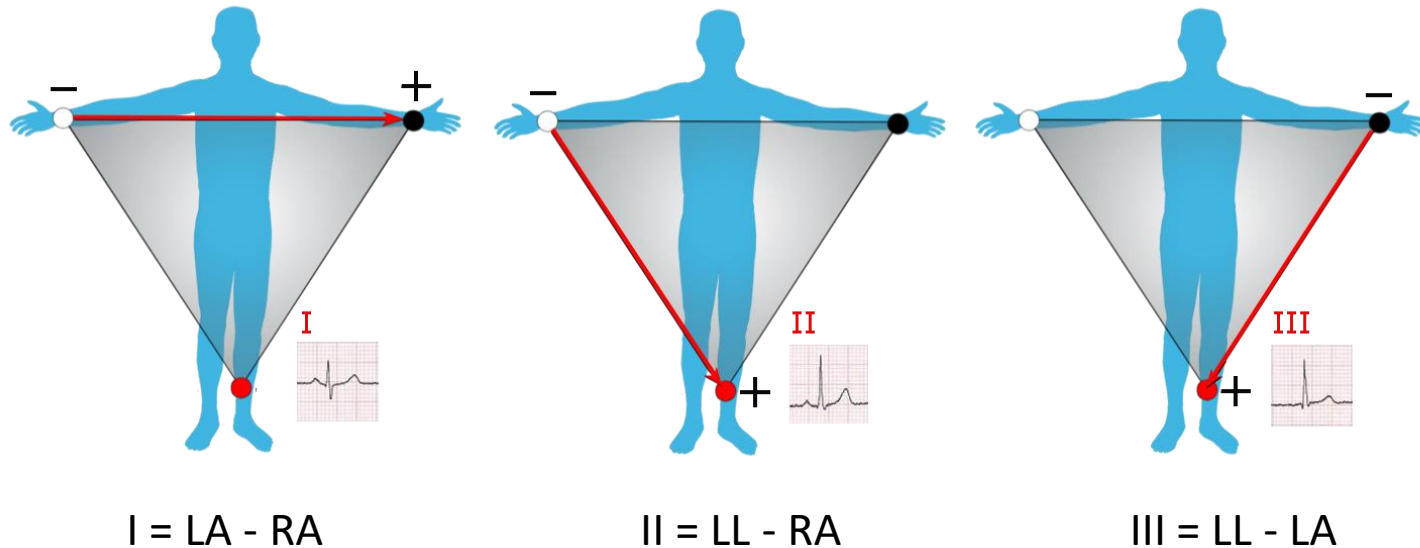
Heart muscles have resting potential of about -90mV

During electrical systole heart muscles ***first rapidly depolarized*** (at 150V/s) originating at **Sinoatrial (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)

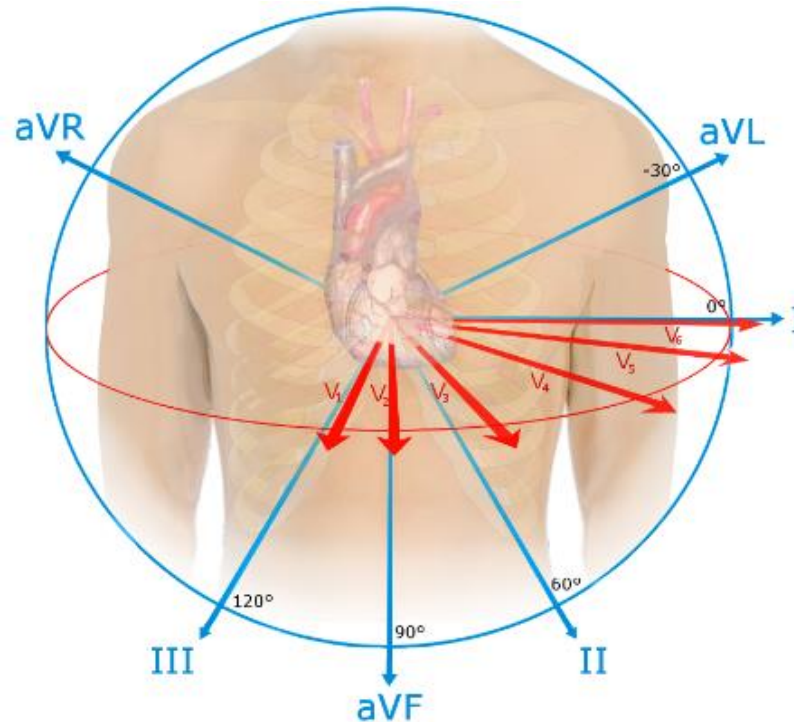


Three lead configuration uses three surface electrodes:

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)



Wilson's 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 leads which give projection polarization vector in **horizontal plane**

Wilson's 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 is 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

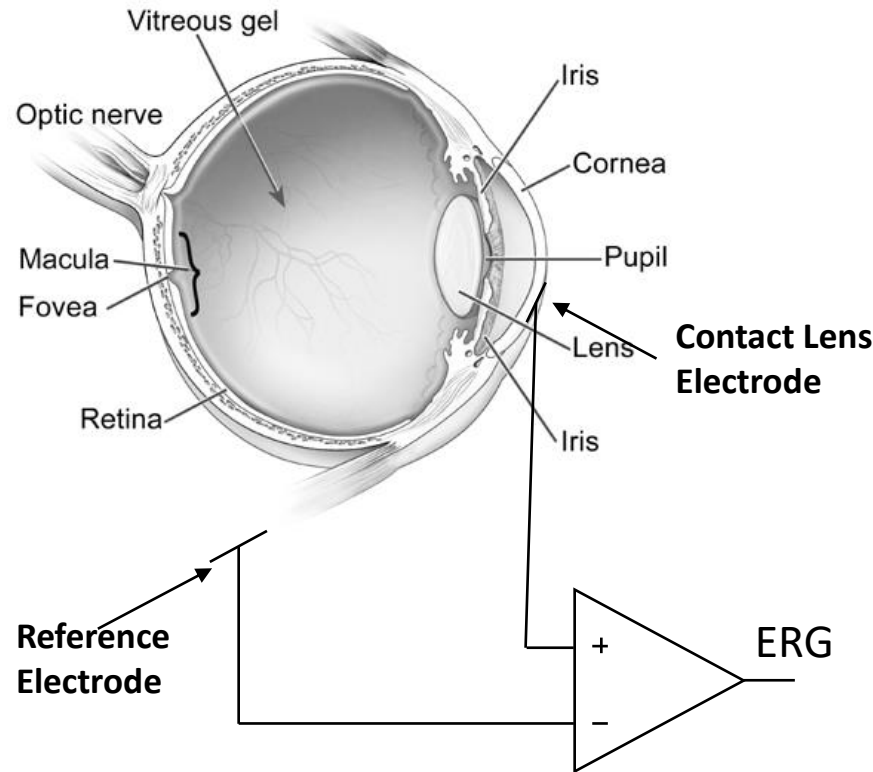
Atrial Flutter

Atrial fibrillation

Ventricular Fibrillation

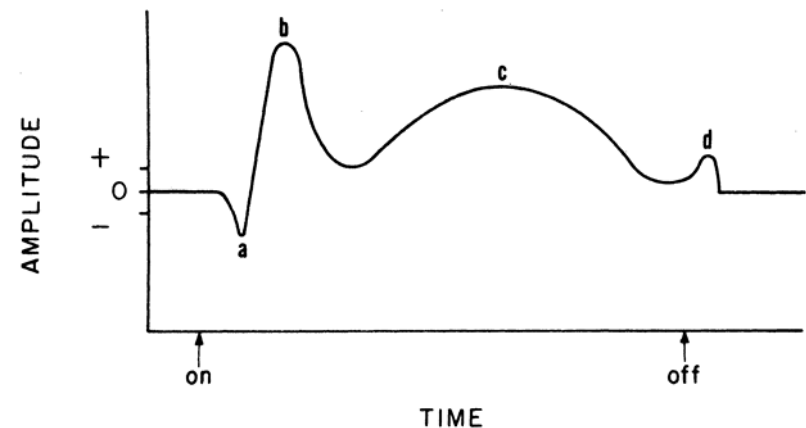
Myocardial Infarction (MI): Blood flow stops to part of the cardiac muscle.

Electro-retinogram (ERG)



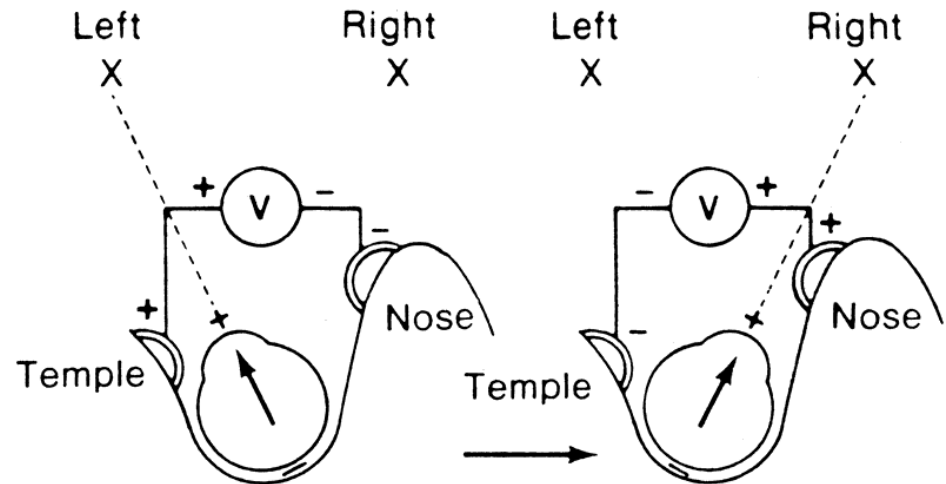
Rod and **Cone** are specialized (photosensitive) nerve cells present in the **Retina**

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



Electro-oculogram (EOG)

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



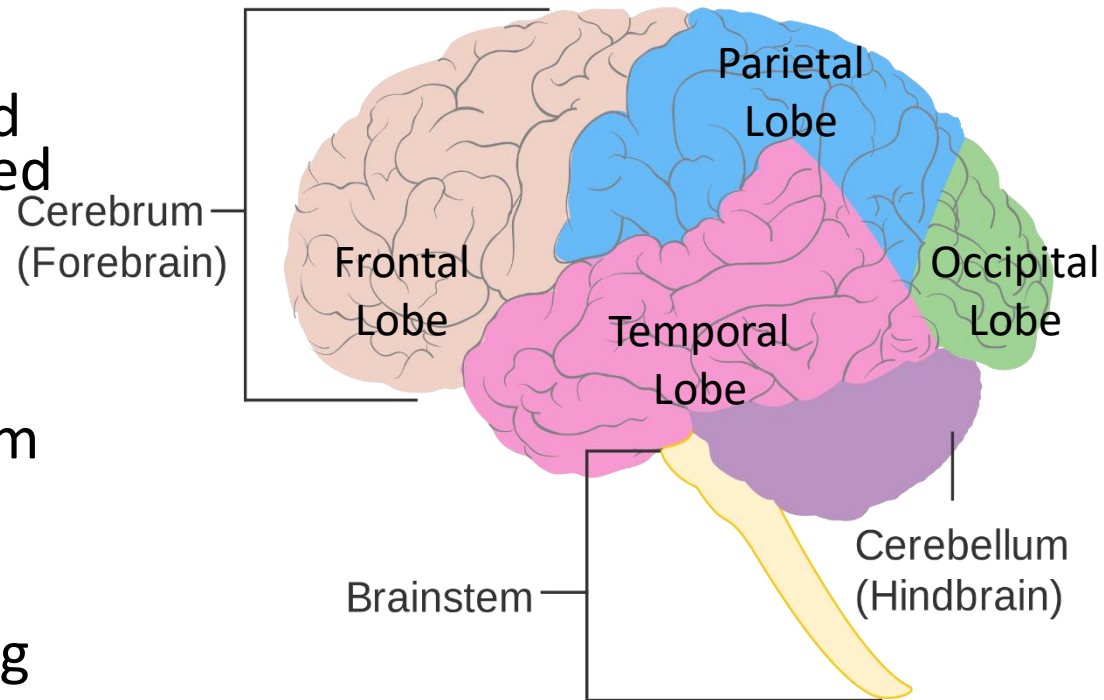
Electroencephalogram (EEG)

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 recording are order 100 μ V, and are result of **synchronous** action of a region in the brain.

Resting stage EEG is divided into:

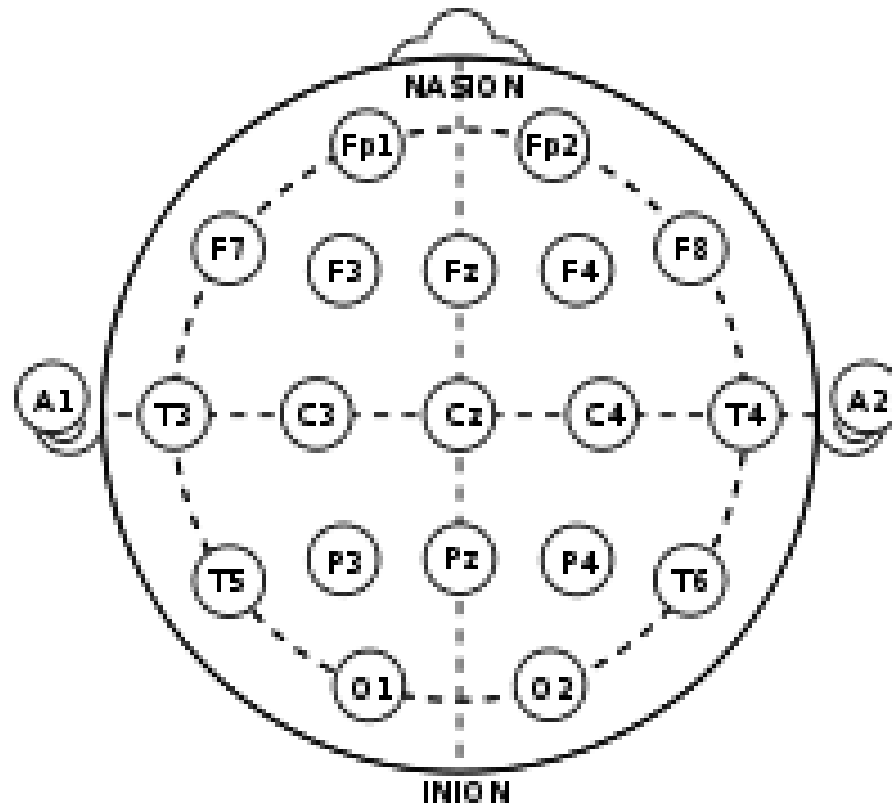
Alpha 8-13 Hz

(Relaxation)



1 s

10-20 electrode system



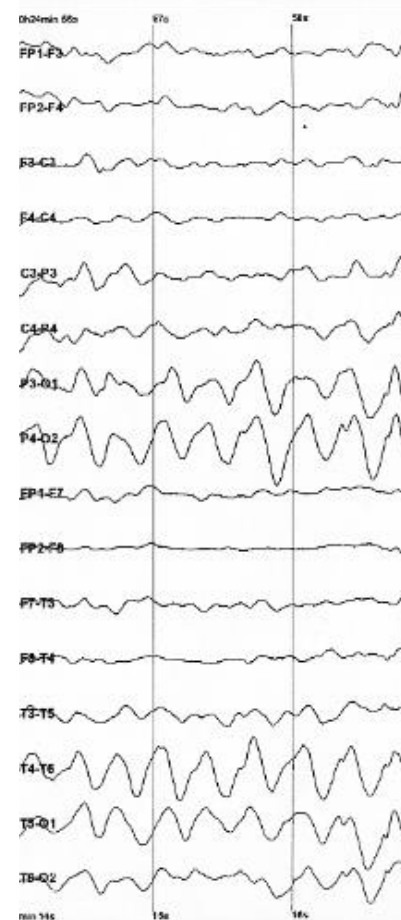
Standardized system for EEG Electrode placement.

Epilepsy

Neurological disease
characterized by seizures

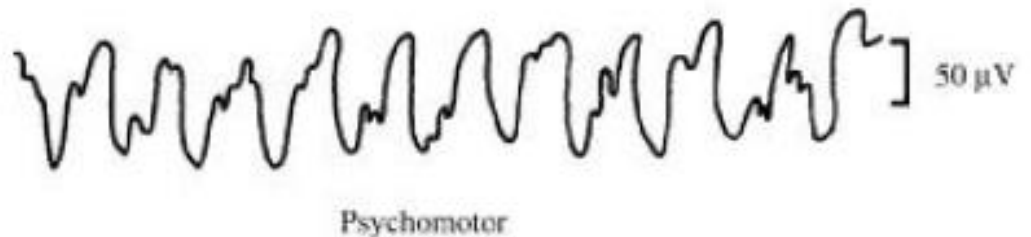
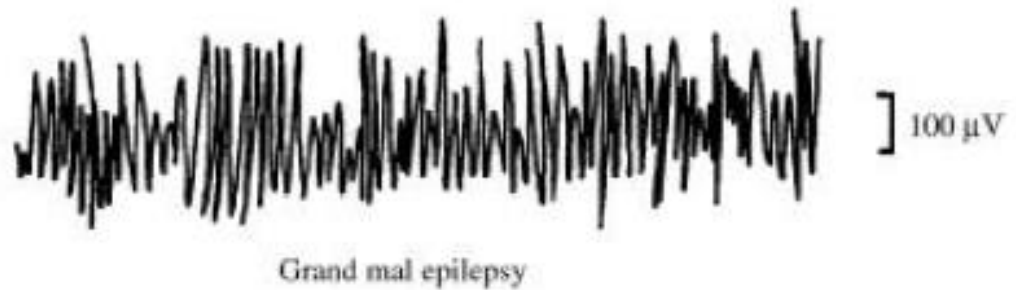
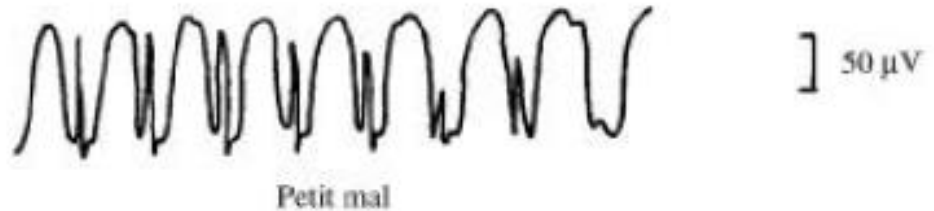
EEG is used as tool to
characterized Epilepsy

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



Abnormal EEG patterns in Epilepsy

- Generalized
- Partial
- Focal



Evoked Responses Potentials (ERP)

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

Auditory evoked response (AER)

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

Visual evoked response (VER)

-Responses to visual stimuli

Cognition potentials

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

Electrode-electrolyte interface

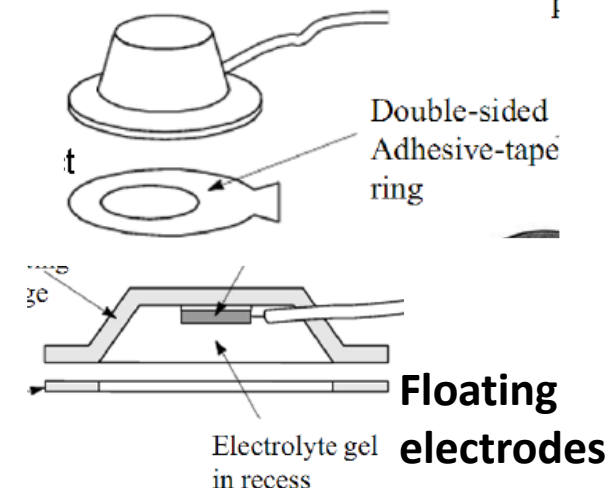
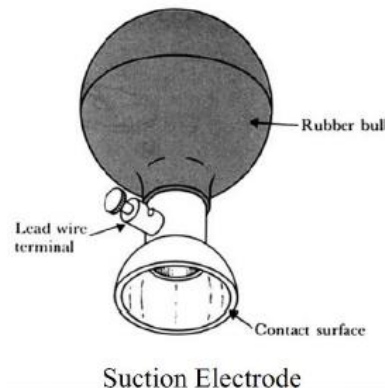
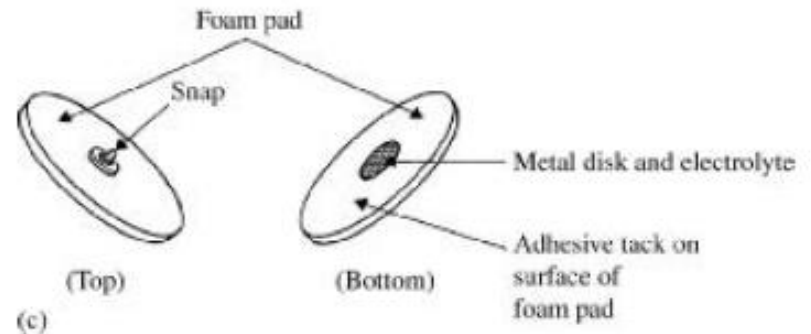
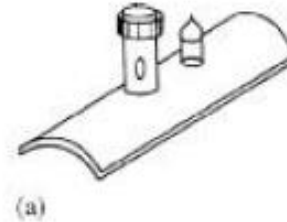
Biopotential electrodes are also transducers

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

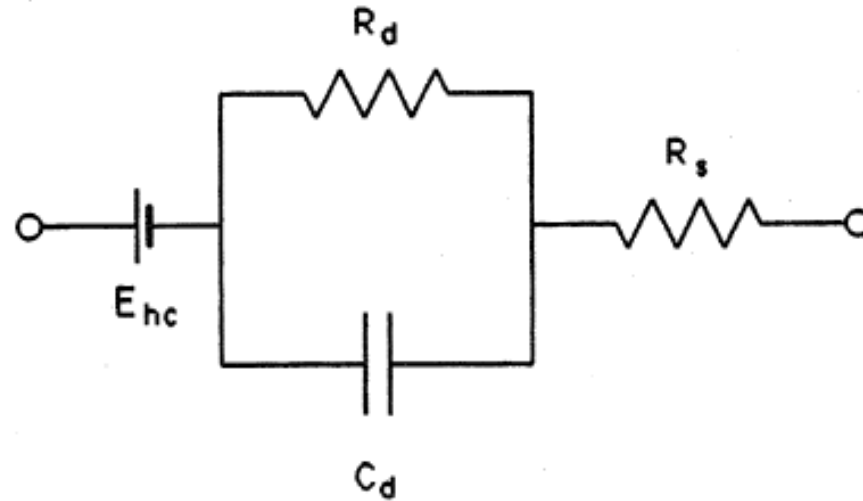
The electrochemistry of electrode materials governs their characteristics

Types of electrodes:

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



Equivalent circuit of electrode

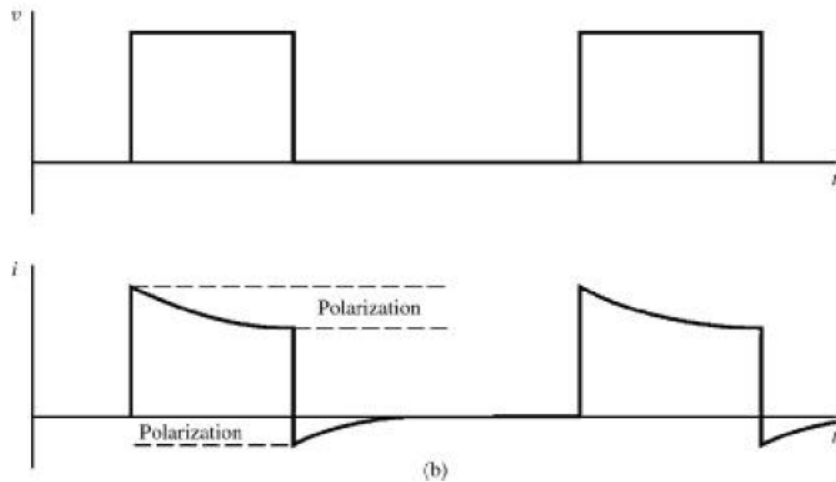


E_{hc} = Half cell potential

R_d , C_d = impedances associated with electrode-electrolyte systems

R_s = Series resistance

Effect of Polarization on Electrical Stimulation

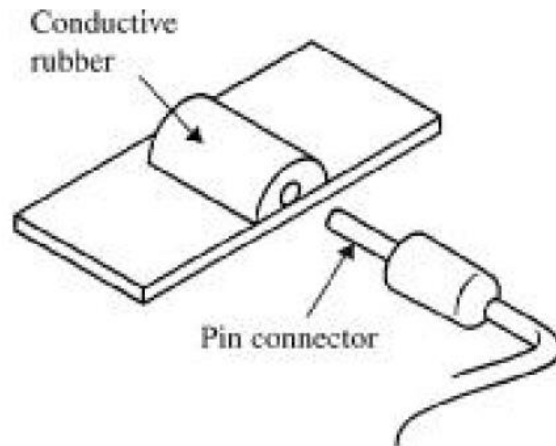


Constant Voltage Stimulation

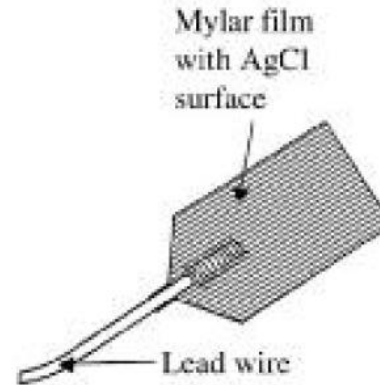


Constant Current Stimulation

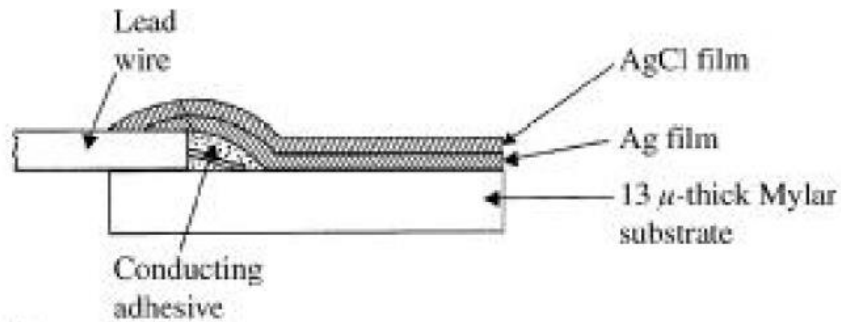
Flexible electrodes



(a)

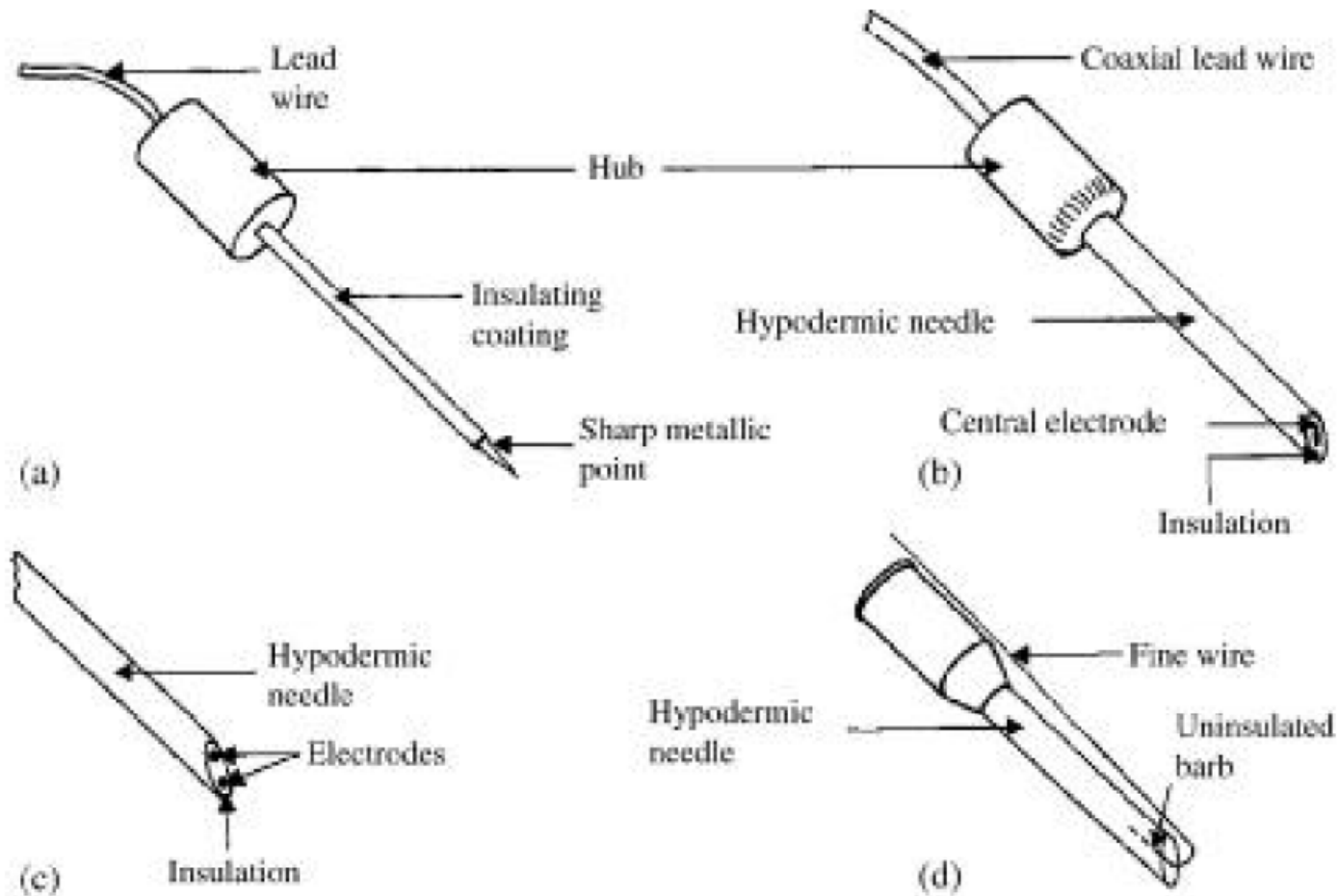


(b)

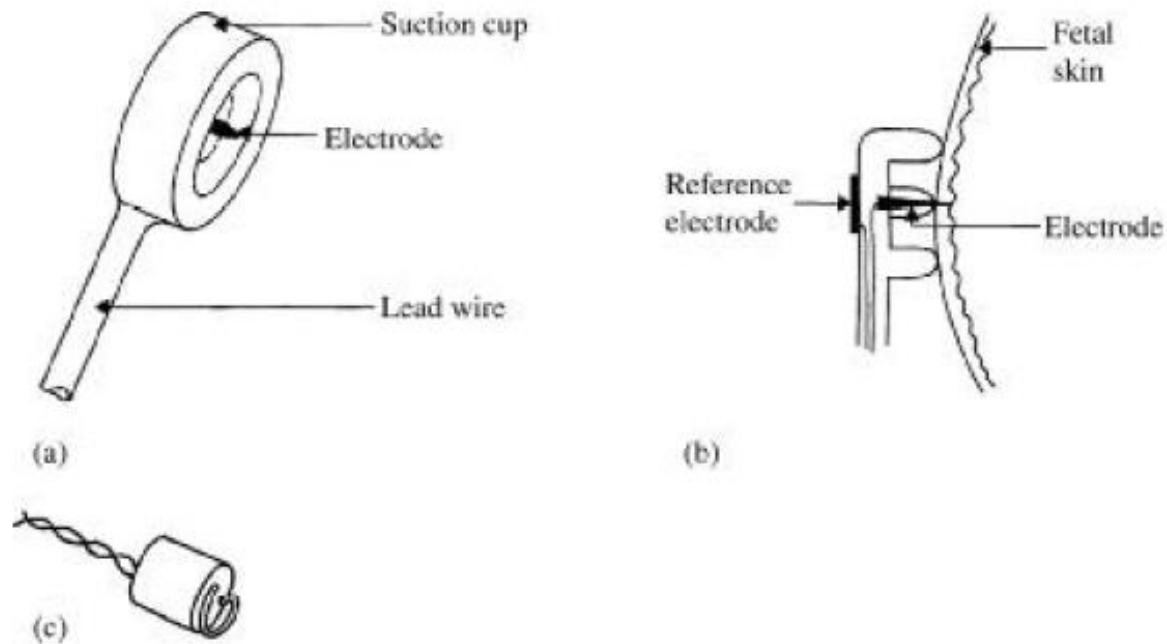


(c)

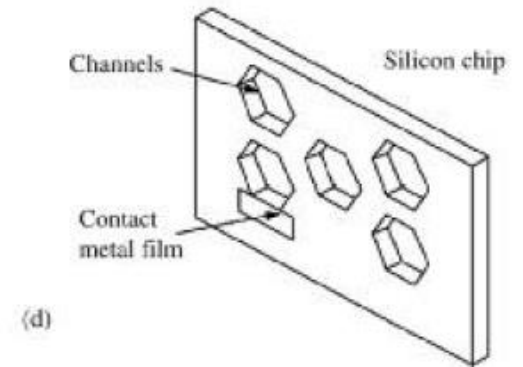
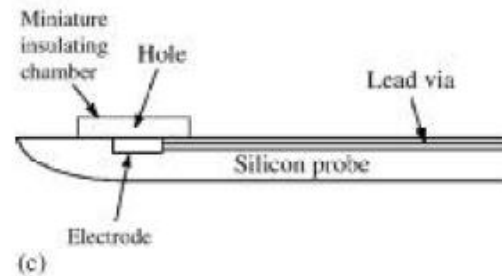
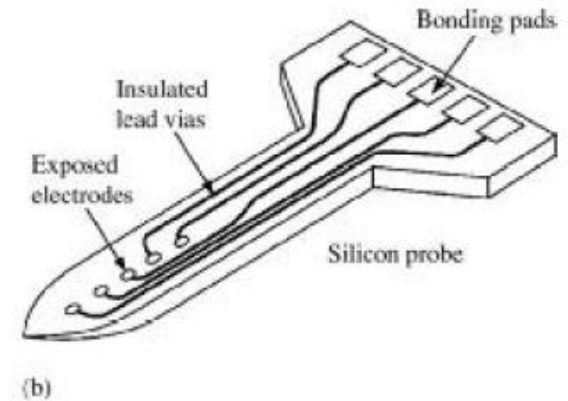
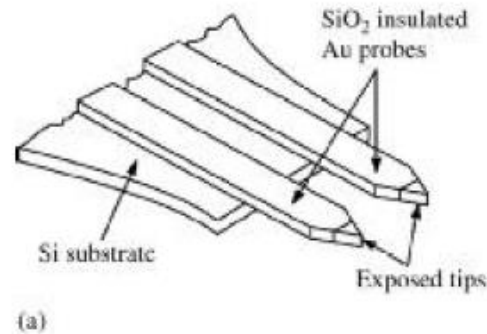
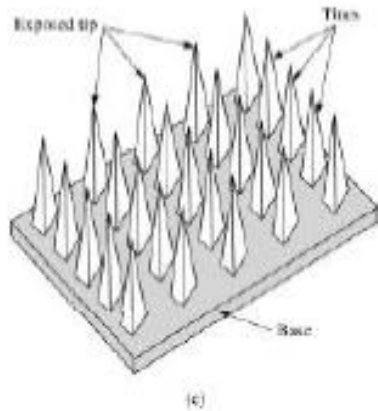
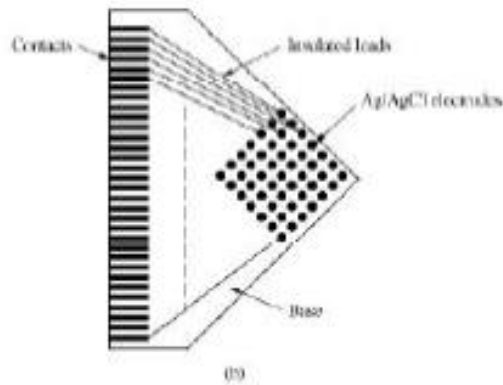
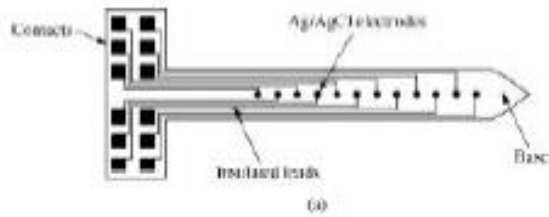
Needle electrodes



Foetal Electrode



Microelectrode Arrays

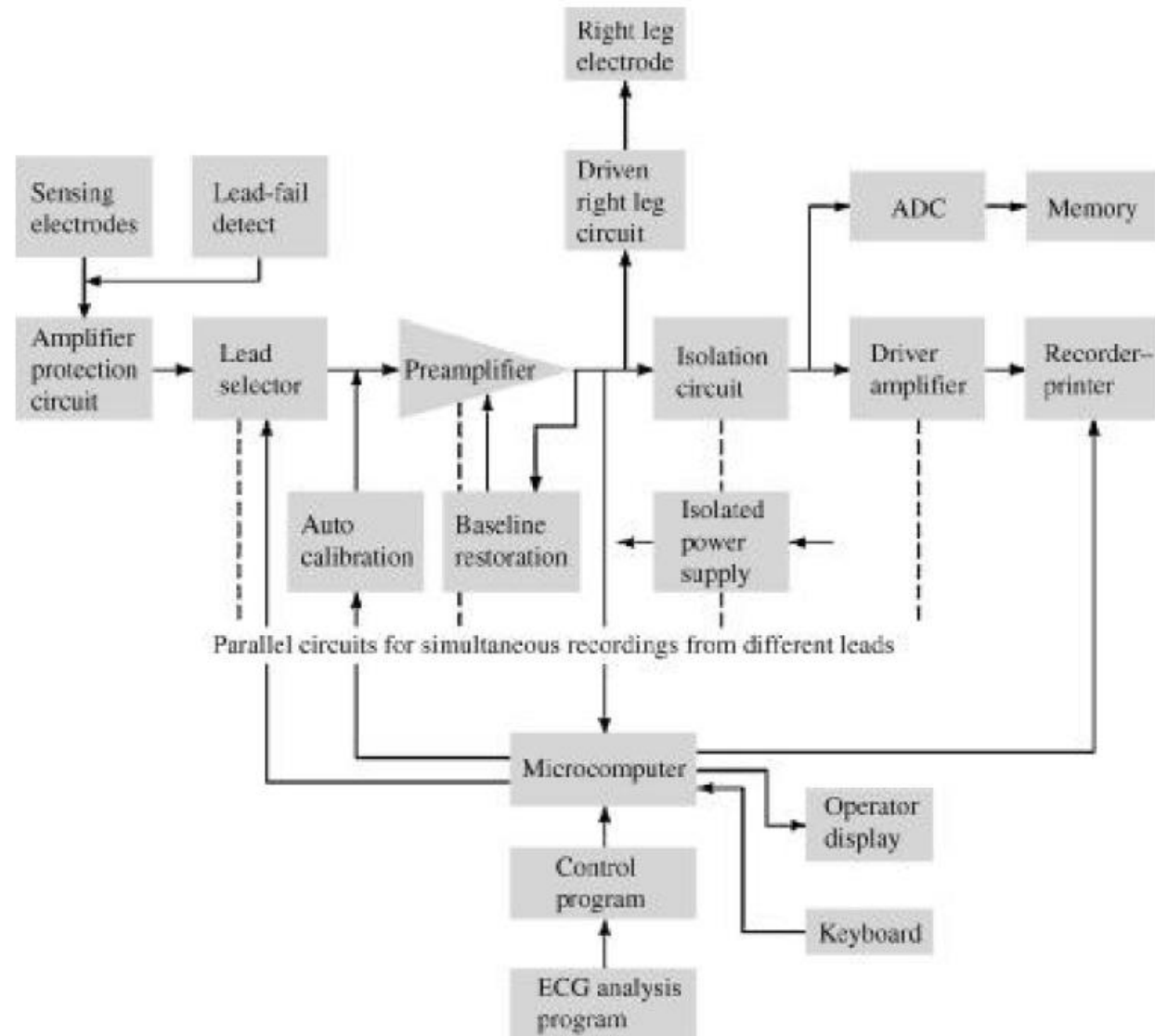


Microfabricated electrode array

Biopotential Amplifiers Requirements

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

Electrocardiogram (ECG)

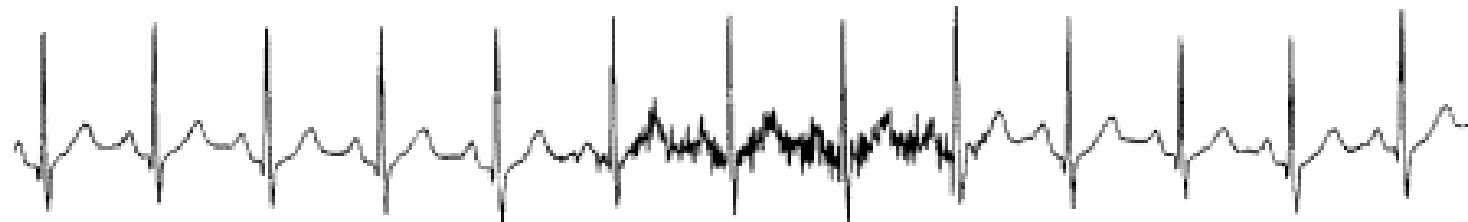


Electrical Interference



(a)

Power Line Pickup



(b)

Myogenic interference

Other Biopotential Amplifier

