Bio-Medical Instrumentation
EC09 L25
Module 1

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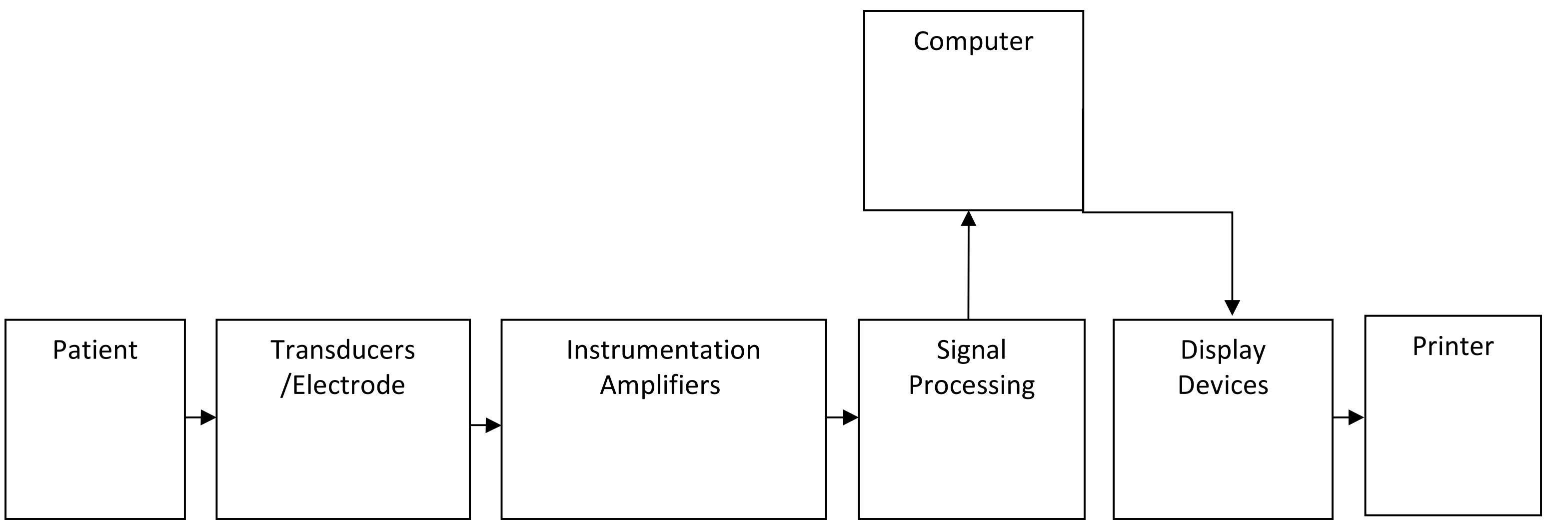
Topics

- Electrical activity of excitable cells –
- functional organization of the peripheral nervous system –
- electrocardiogram (in detail with all lead systems) - electroencephalogram –
- electromyogram –
- electroneurogram-
- electrode –electrolyte interface
- polarisation-
- polarisable and non polarisable electrodes-
- surface electrodes –needle electrodes-micro electrodes-
- practical hints for using electrodes-
- ‘skin- electrodes’ equivalent circuit-
- characteristics of ‘bio-amplifiers’

Basics of Biomedical Instrumentation System



μ

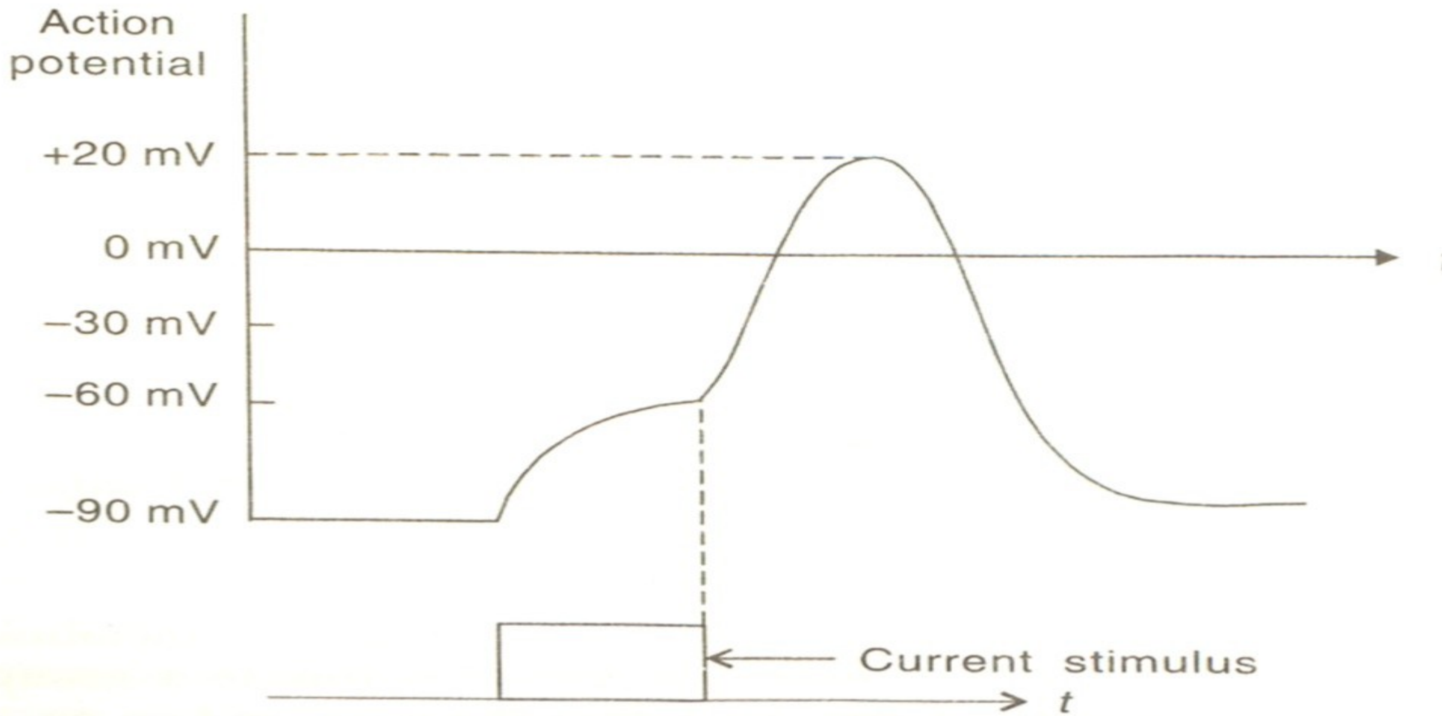
Sl.No	Parameter	Signal	Amplitude range		Frequency range
1	Electrical activity the heart	ECG (Electrocardiogram)	1mV -5 mV		0.05 Hz- 120 Hz
2	Electrical activity of brain	EEG (Electroencephalogram	2uV-200uV 50 V (typical)	0	0.5 Hz - 70 Hz
3	Nerve conduction and muscle activity	EMG (Electromyogram)	25uV-5000 uV		5Hz- 2000 Hz
4	Electrical activity of the eyes	EOG (Electro Occulogram -Potential due to movement of eye balls)	10uV-3500u V		Dc to 100 Hz

Electrical Activity of Excitable Cells

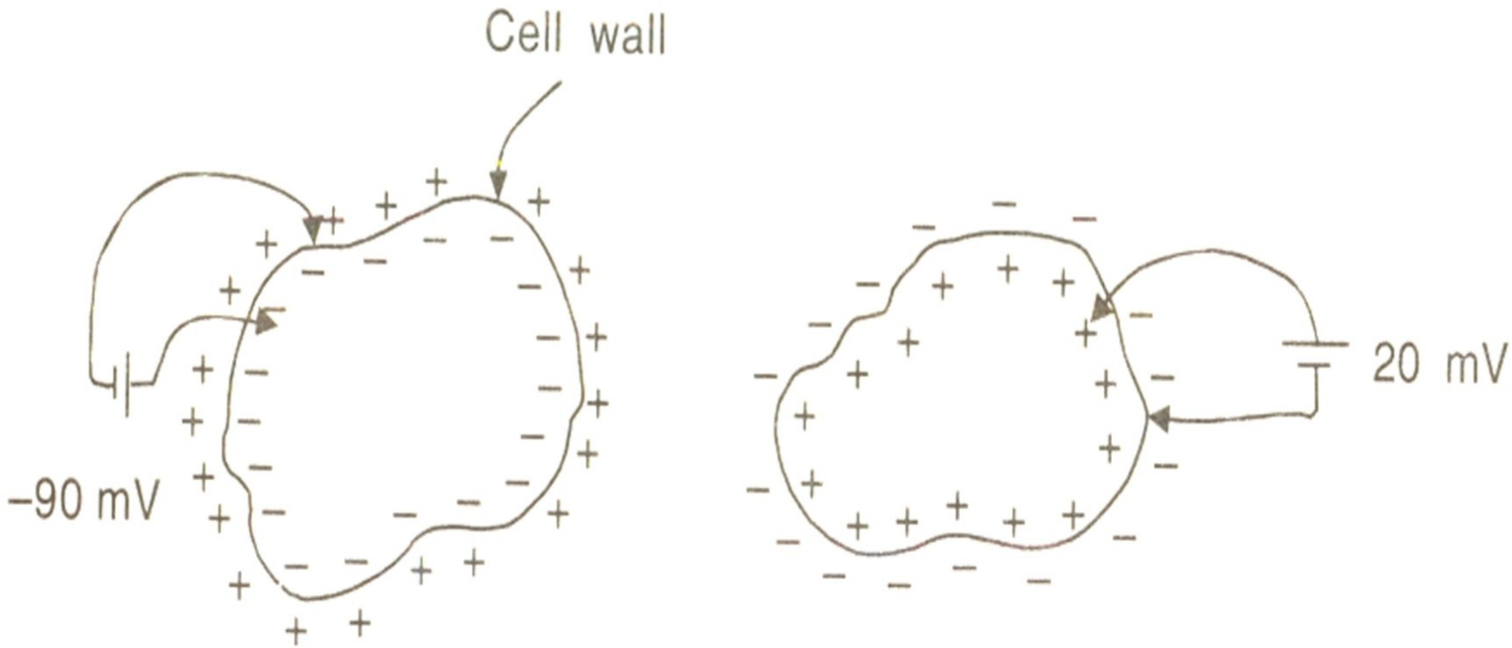
- Excitable cells
  - Exist in nervous, muscular and glandular tissue
  - Exhibit a resting potential and an action potential
  - Necessary for information transfer (e.g. sensory info in nervous system or coordination of blood pumping in the heart)

Resting vs. Active State

- Resting State
  - Steady electrical potential of difference between internal and external environments
  - Typically between -70 to -90mV, relative to the external medium
- Active State
  - Electrical response to adequate stimulation
  - Consists of “all-or-none” action potential after the cell threshold potential has been reached


Action potential
+20 mV
0 mV
−30 mV
−60 mV
−90 mV
t
Current stimulus
t

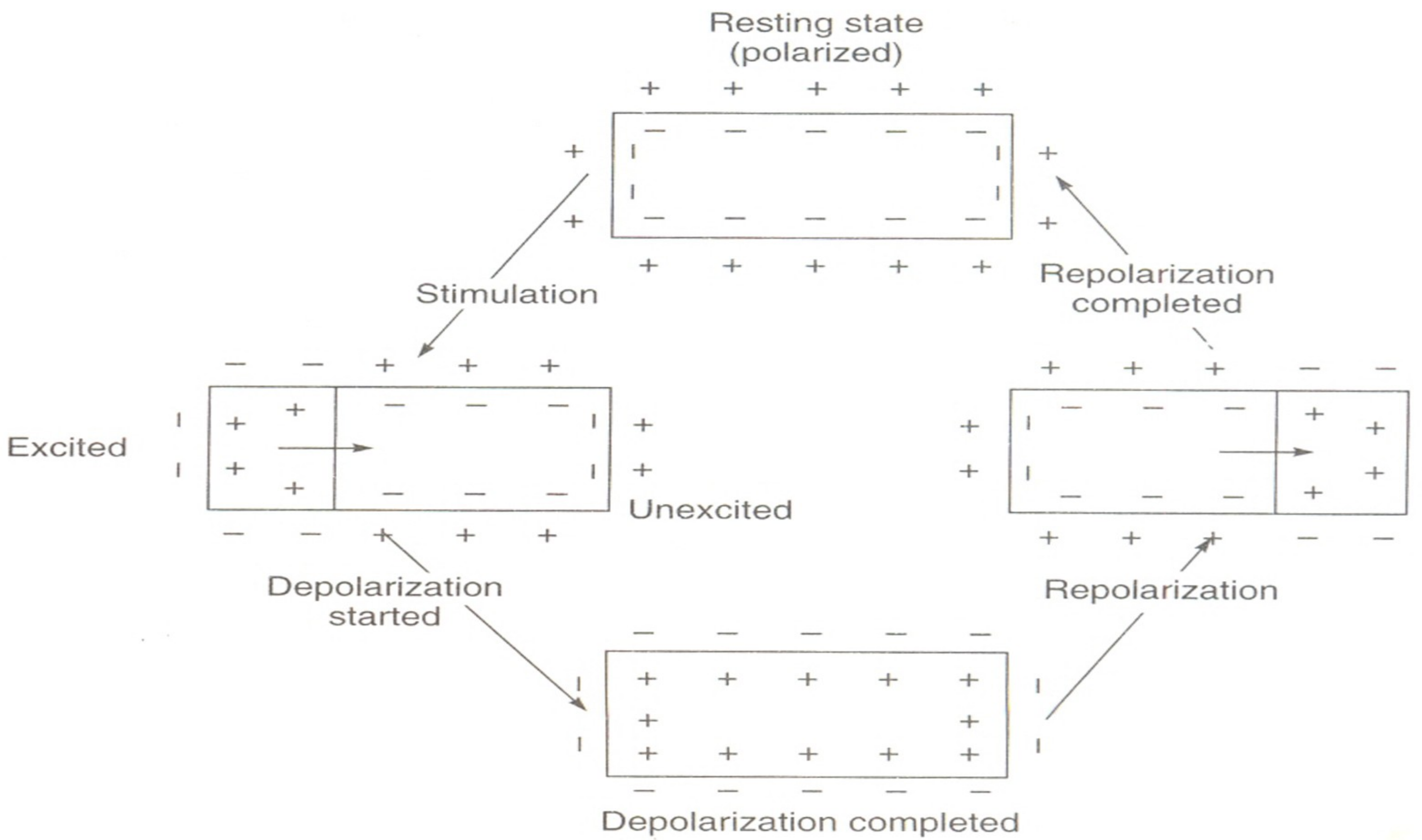
Electrical Activity of cell



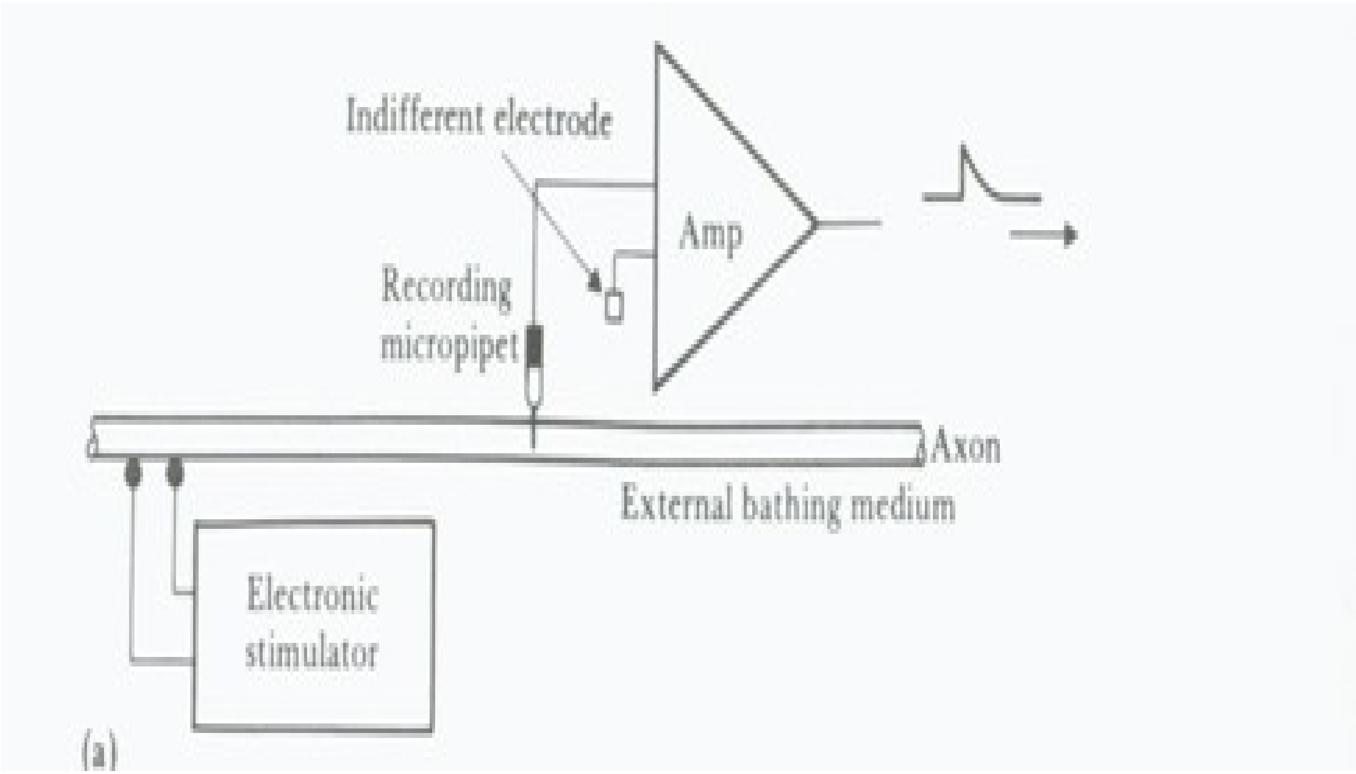
(a) Polarized cell

(b) Depolarized cell

Electrical Activity of muscles



Recording of Action Potential



Resting Membrane Potential

- Cell potential is a function of membrane permeability and concentration gradient to various molecules (i.e. K^+, Na^+, Cl^-, and Ca^{2+})
- Equilibrium potential is the membrane potential at which a given molecule has no net movement across the membrane
  - Nernst Equation (in Volts at 37 ^{0}C):

$$E_K = \frac{RT}{nF}\ln\frac{[K]_o}{[K]_i} = 0.0615\log_{10}\frac{[K]_o}{[K]_i}$$

  - *n* is the valence of K^+, $[K]_i$ and $[K]_0$ are the intra- and extracellular concentrations, *R* is the universal gas constant, *T* is the absolute temperature in Kelvin, *F* is the Faraday constant, and E_K is the equilibrium potential

Resting Membrane Potential

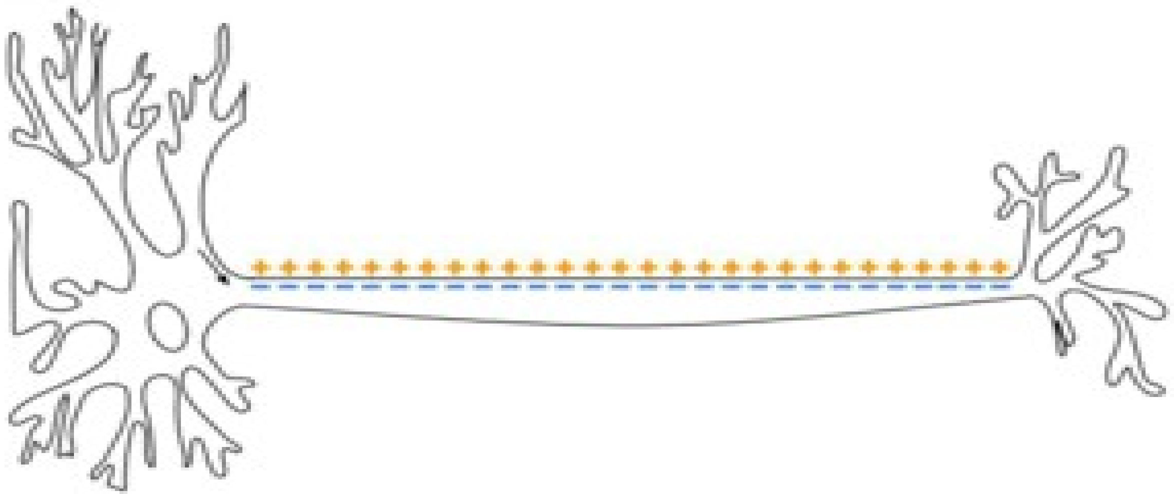
- Equilibrium membrane resting potential when net current through the membrane is zero

$$E = \frac{RT}{F}\ln\left[\frac{P_K[K]_o + P_{Na}[Na]_o + P_{Cl}[Cl]_i}{P_K[K]_i + P_{Na}[Na]_i + P_{Cl}[Cl]_o}\right]$$

  - *P* is the permeability coefficient of the given ion
- Factors influencing ion flow across the membrane
  - Diffusion gradients
  - Inwardly-directed electric field
  - Membrane structure
  - Active transport of ions against electrochemical gradient

all-or-none law

- The **all-or-none law** is the principle that the strength by which a nerve or muscle fiber responds to a stimulus is independent of the strength of the stimulus. If the stimulus exceeds the threshold potential, the nerve or muscle fiber will give a complete response; otherwise, there is no response.

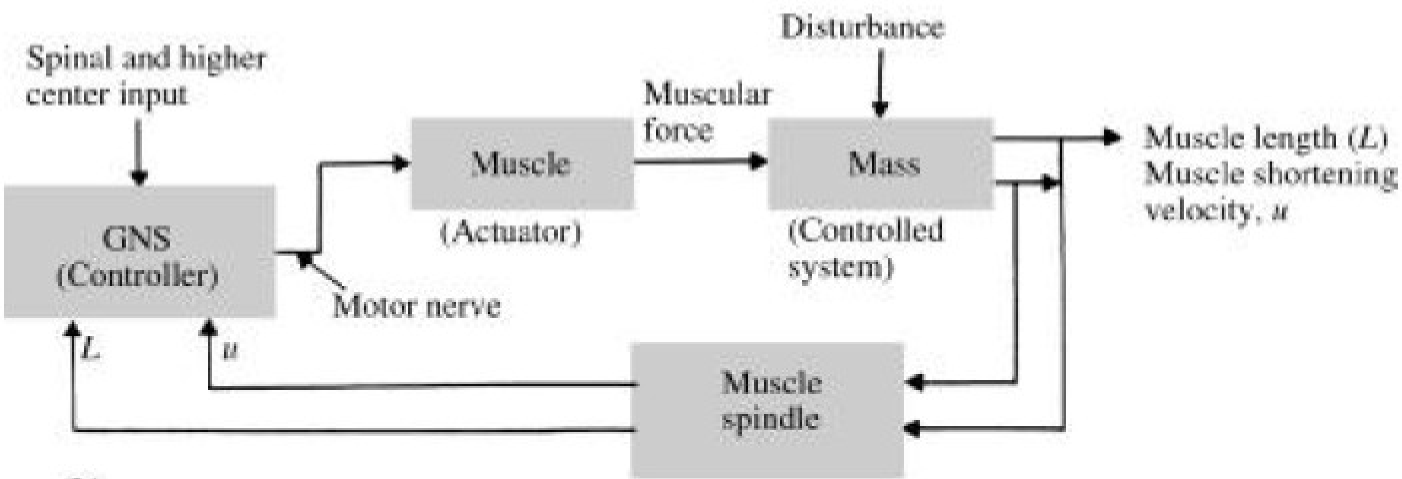


Action Potential

- Stimulation of excitable cells causes “all-or-none” response
- At threshold, the membrane potential rapidly depolarizes due to a change in membrane permeability
  - P_{Na} significantly increases causing the membrane potential to approach E_{Na} (+60mV)
- A delayed increase in P_K causes hyperpolarization and a return to resting potential

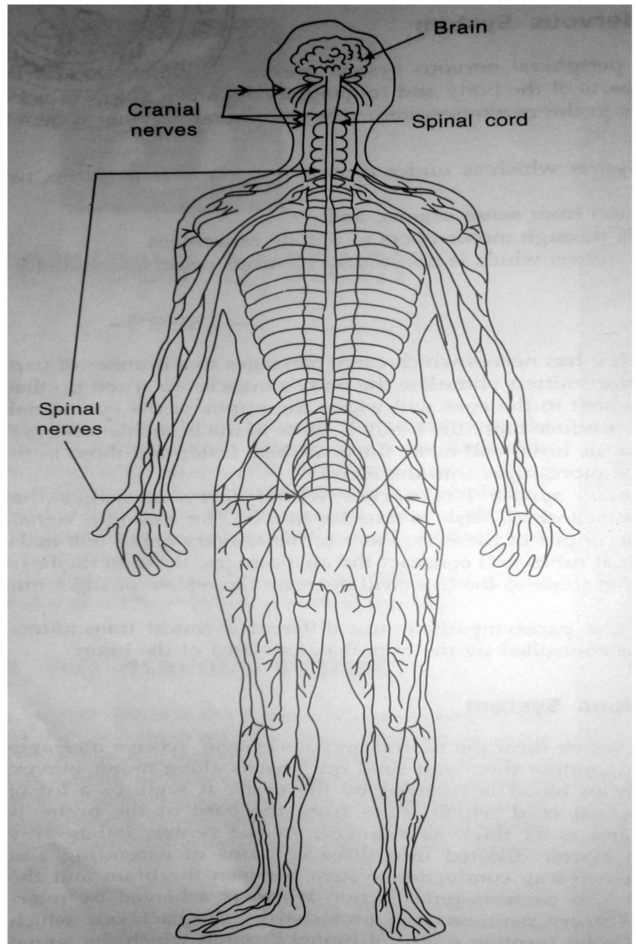
Organization of Peripheral Nervous System

- Reflex arc
  - Sense organ (e.g. receptors)
  - Sensory nerve (transfers information from receptor to CNS)
  - CNS (i.e. information processing station)
  - Motor nerve (transfers information from CNS to effector organ)
  - Effector Organ (i.e. muscles)
- Simplest example
  - Knee reflex

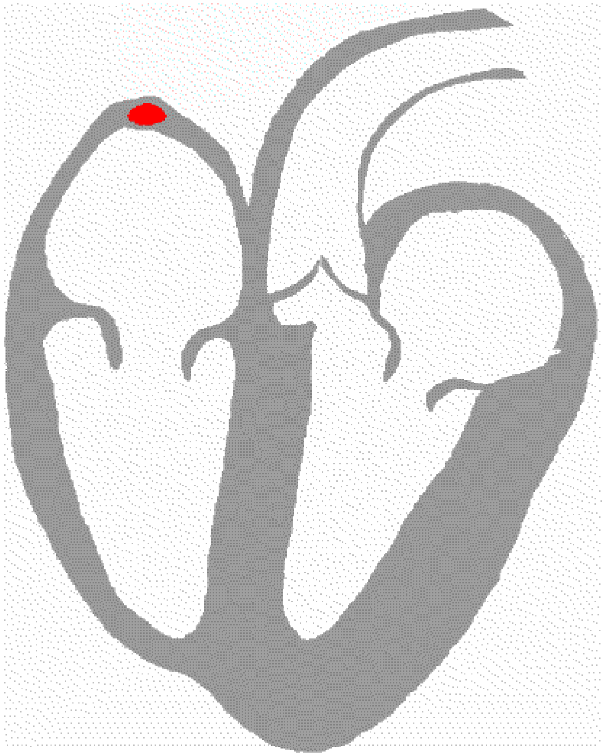


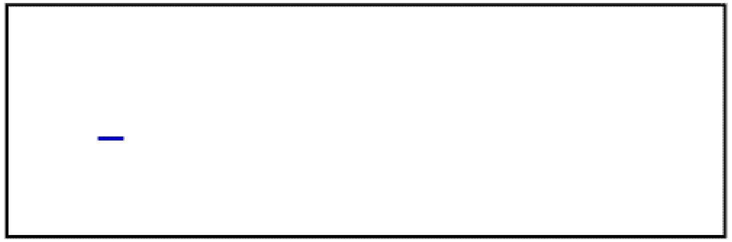
Disturbance
Spinal and higher center input
Muscular force
Muscle
Mass
Muscle length (L)
Muscle shortening velocity, u
GNS (Controller)
(Actuator)
(Controlled system)
Motor nerve
L
u
Muscle spindle

(b)

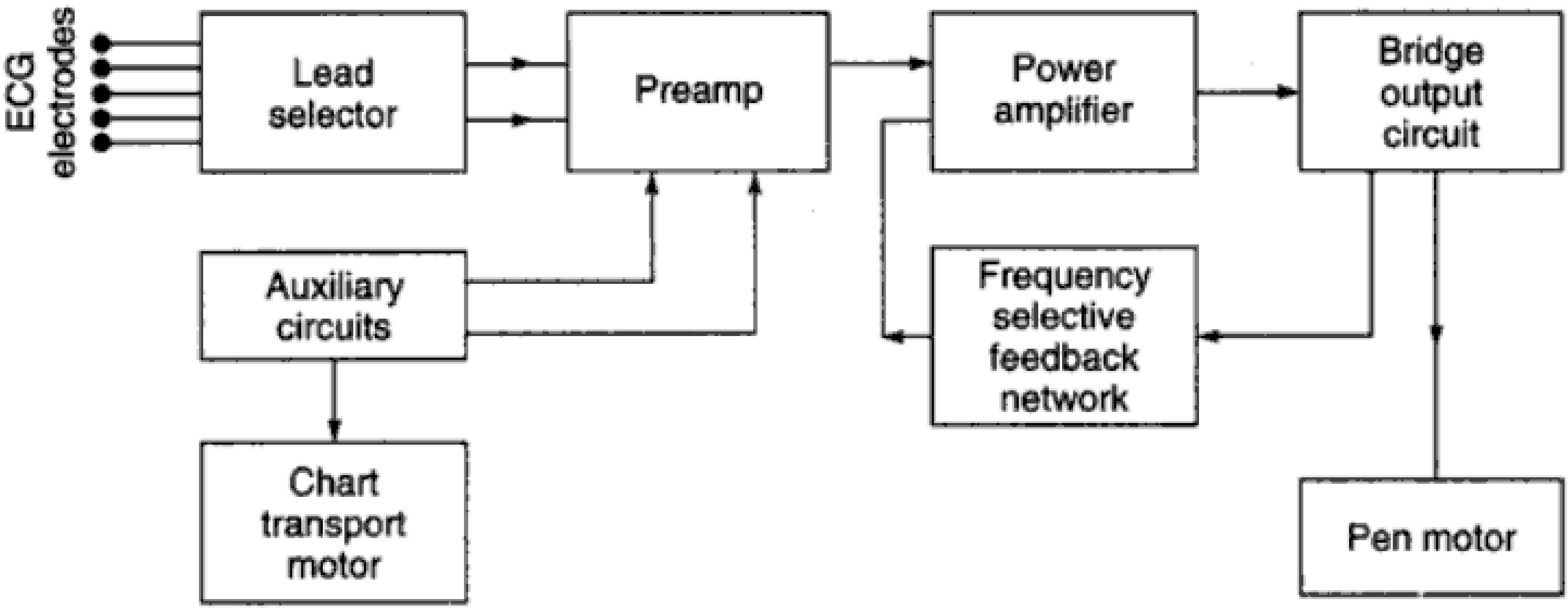

Brain
Cranial nerves
Spinal cord
Spinal nerves

Heart & ECG

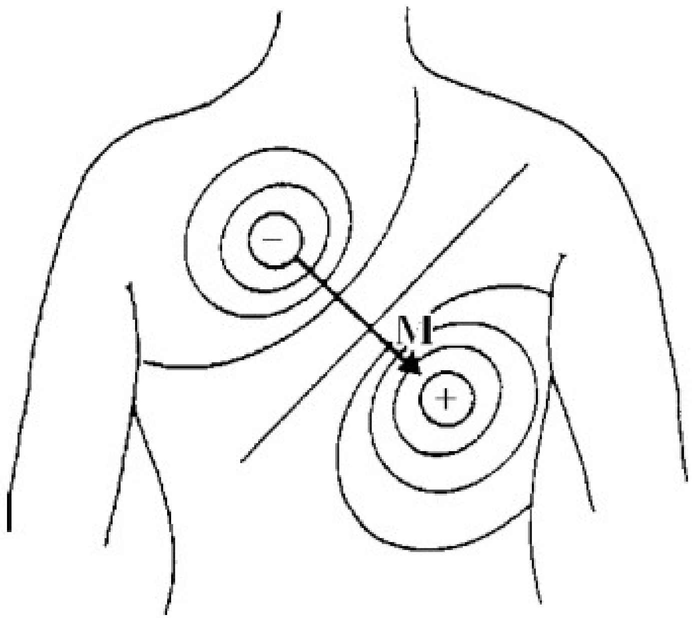


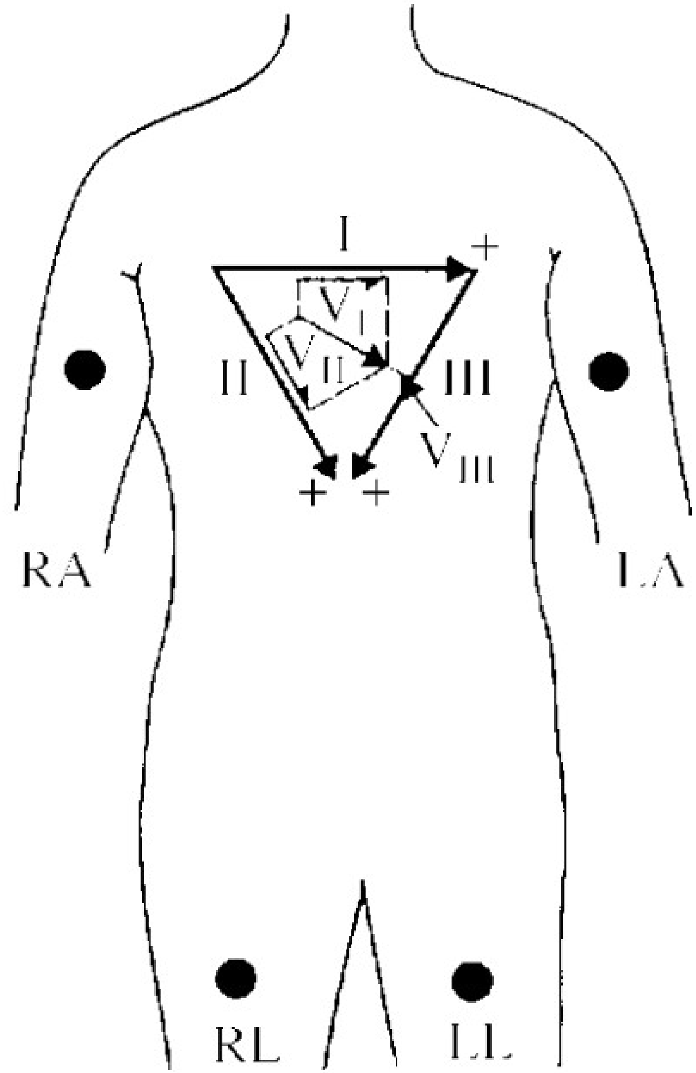


ECG Block Diagram

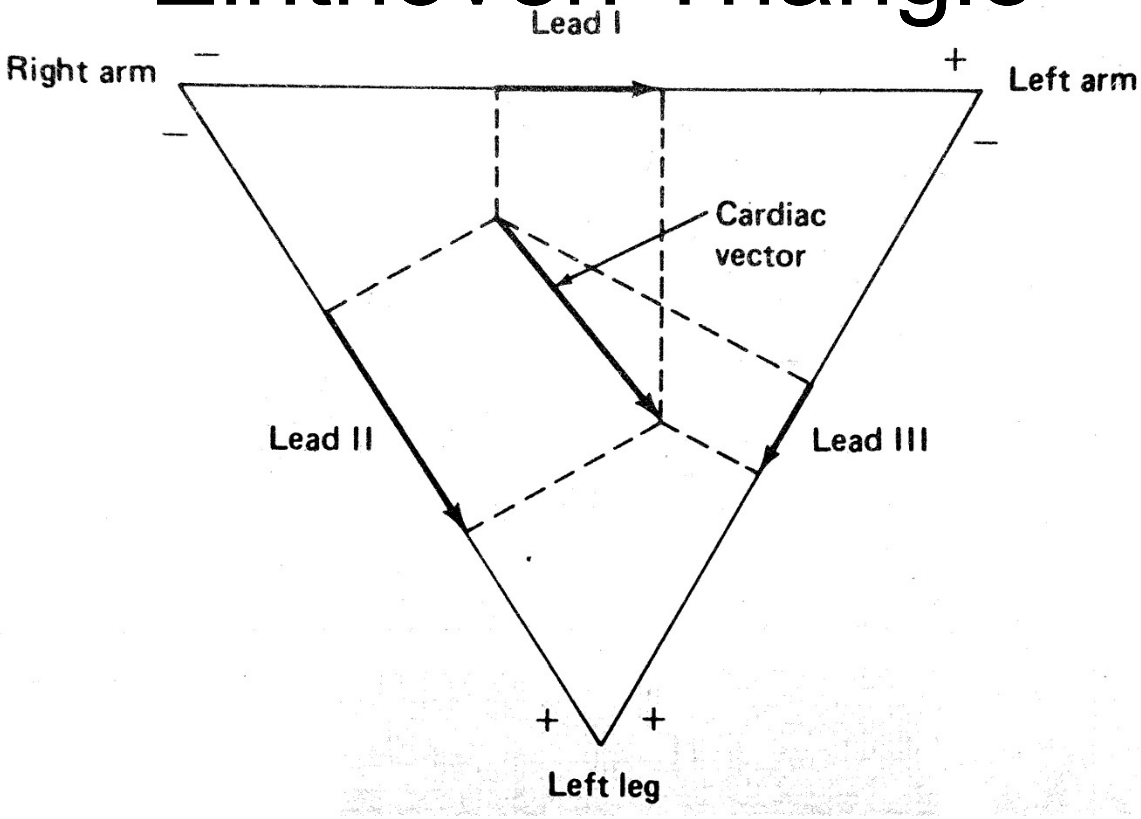


The Cardiac Vector





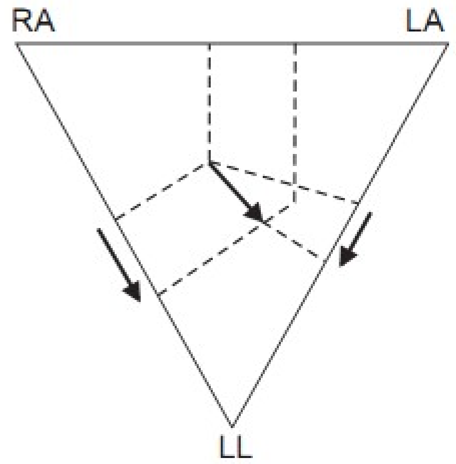
Einthoven Triangle



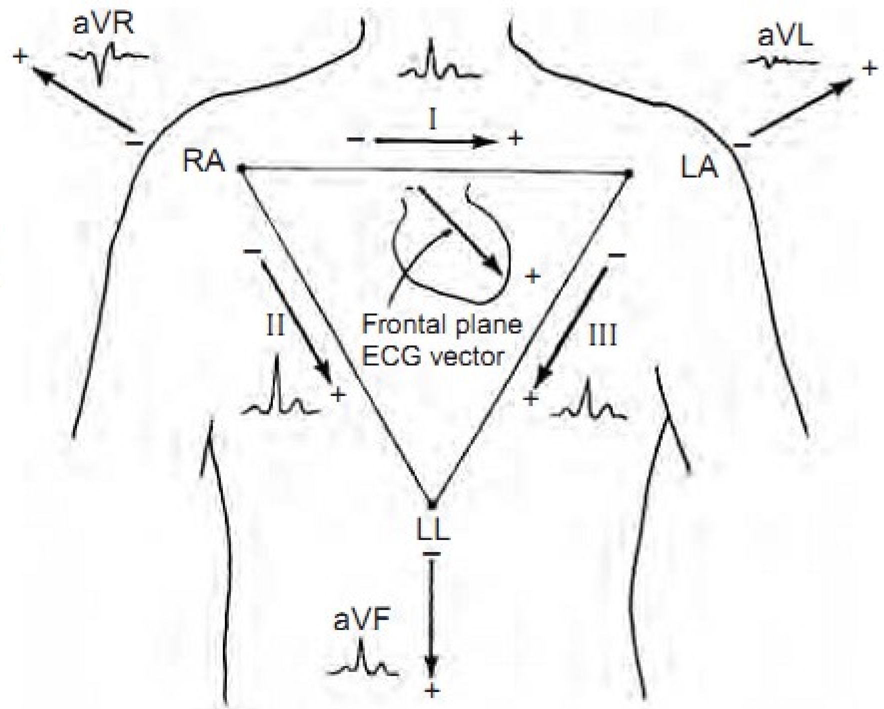
The vector sum of the frontal plane Cardiac Vector at any instant onto the three axes of the Einthoven Triangle will be zero.

- Lead 1: Potential between the Right Arm (RA) and the Left Arm (LA)
- Lead 2: Potential between the Right Arm and the Left Leg
- Lead 3: Potential between the Left Arm and the Left Leg

Einthoven Triangle



(a) Einthoven Triangle



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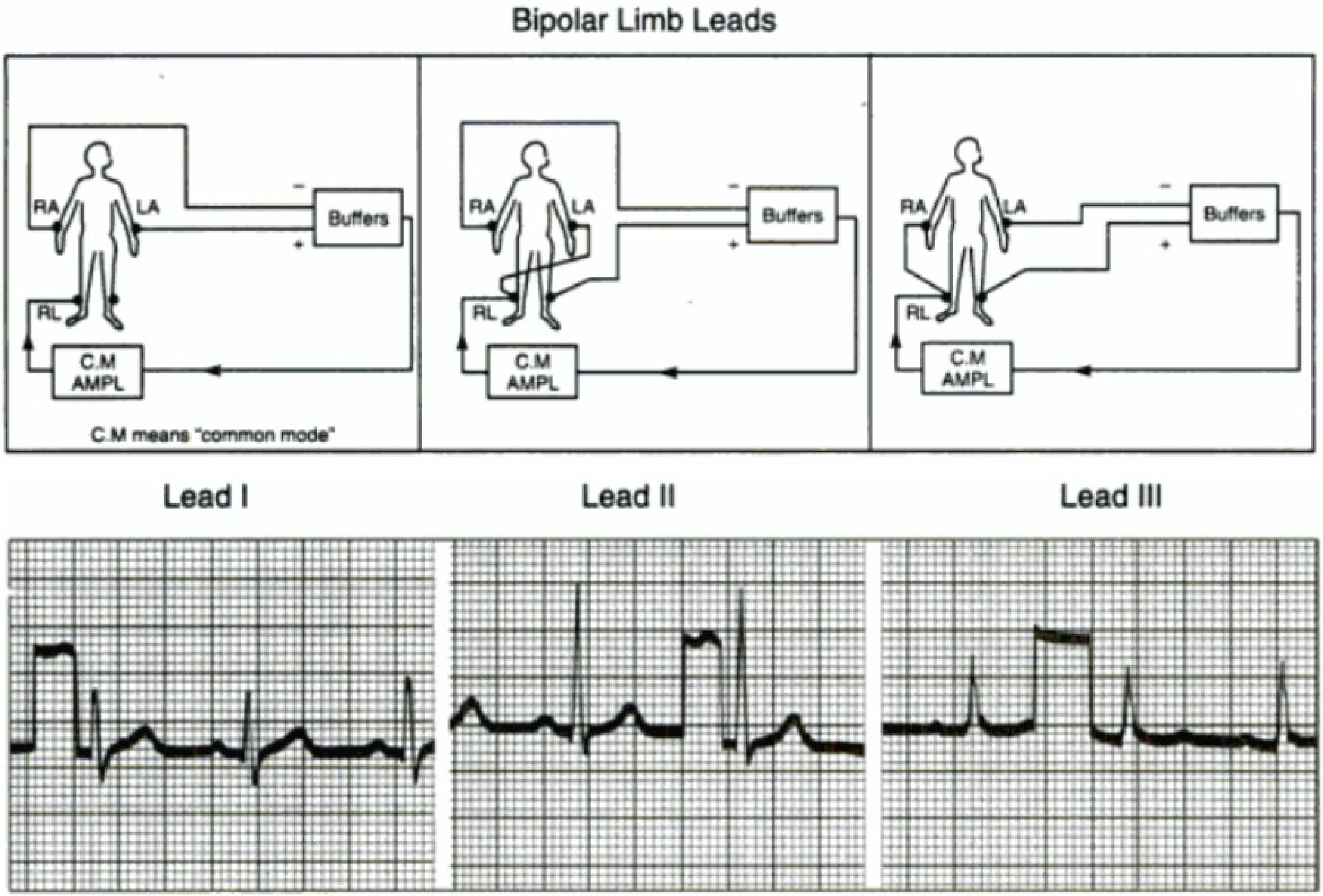
- Lead 3: Potential between the Left Arm and the Left Leg

ECE Leads

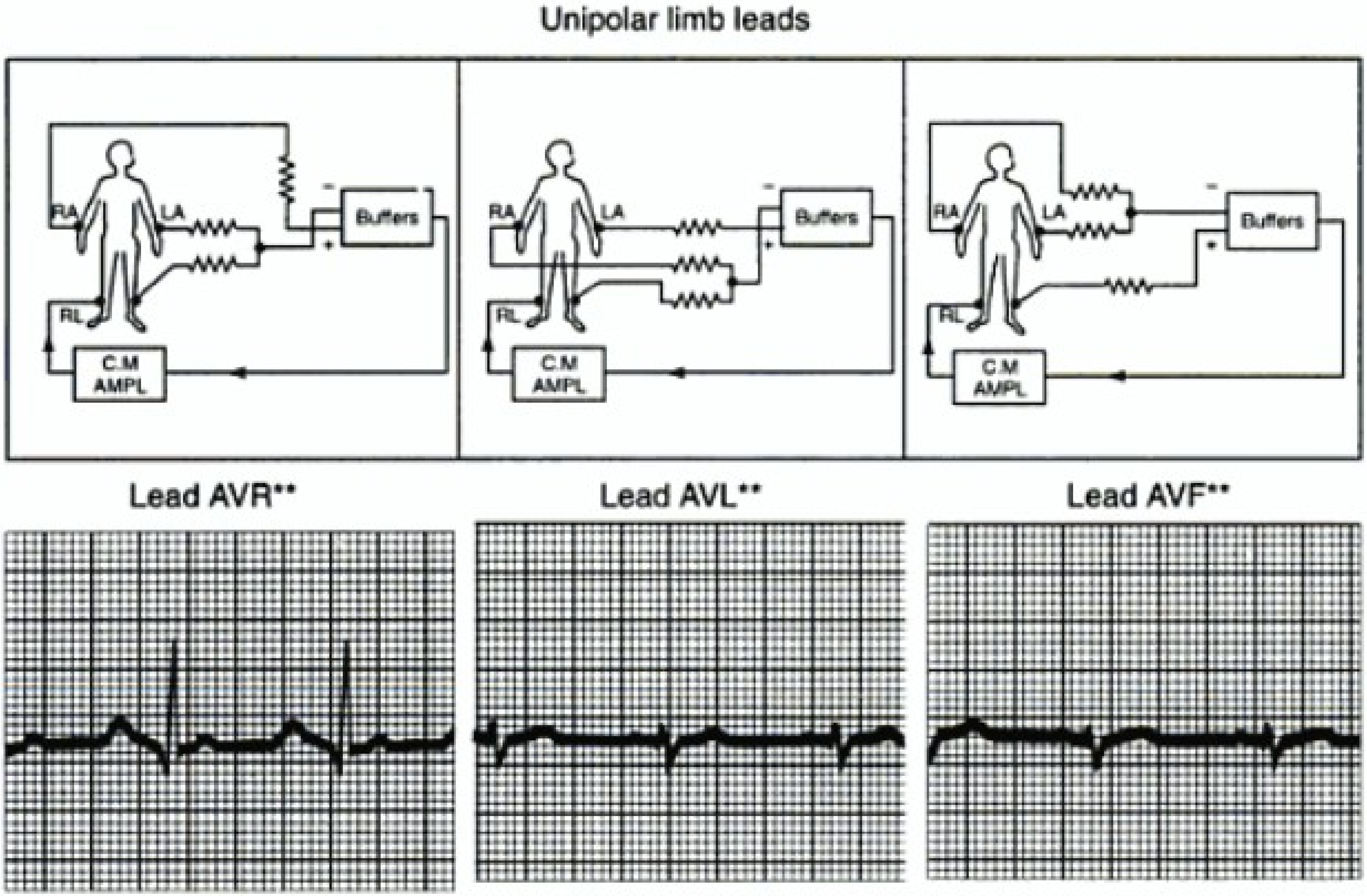
- Bipolar leads: ECG recorded by using 2 electrode. Eithovan lead
- Unipolar – Single electrode
  - Limb leads : two limb leads are tied together and recorded wrt to third limb AVR,AVL,AVF
  - Precordial leads : heart action on the chest at six different positions.

12 Lead ECG System



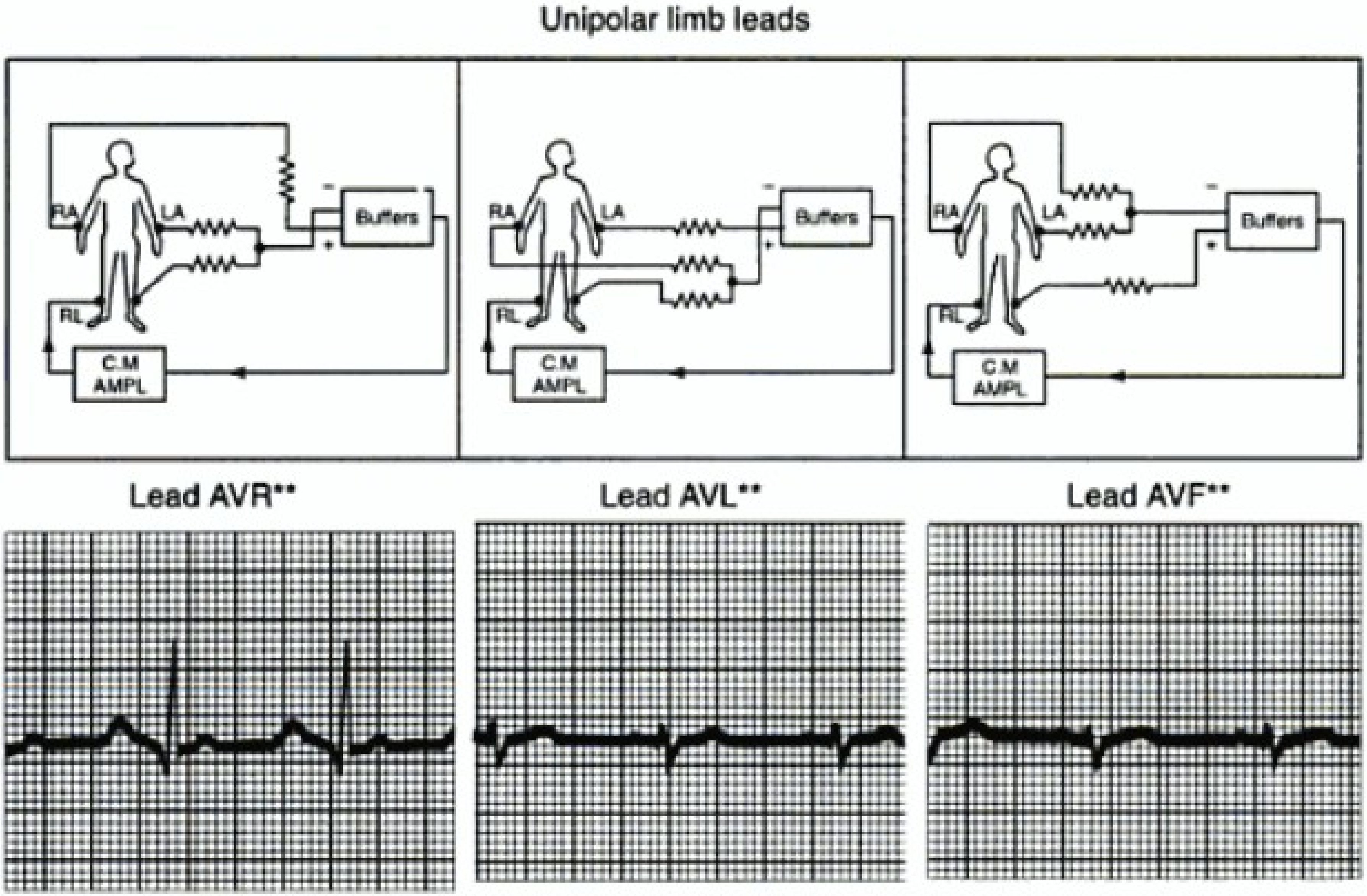
(a)

12 Lead ECG System

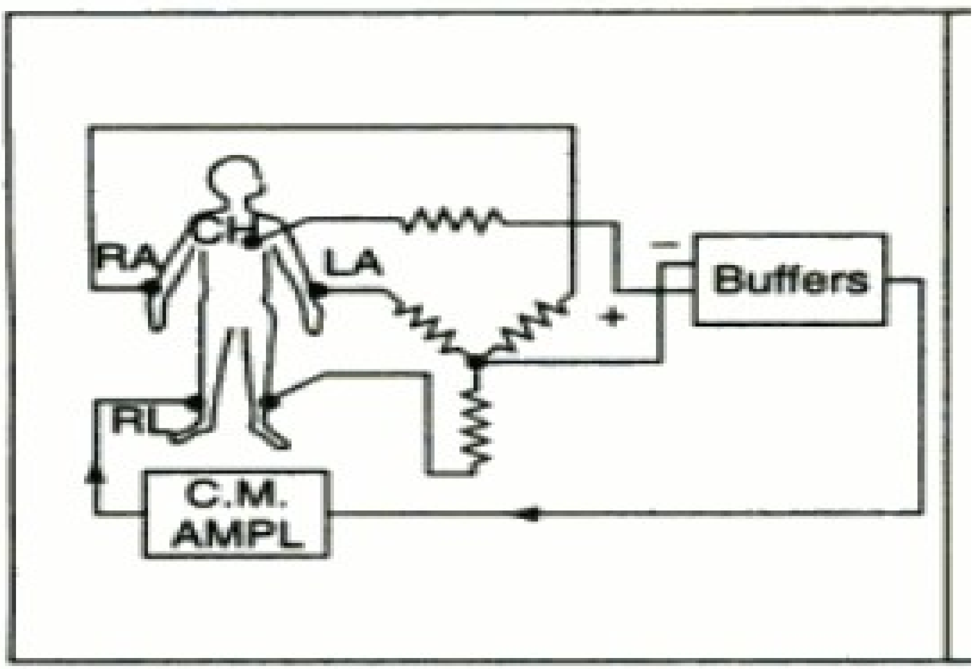


(b)

12 Lead ECG System

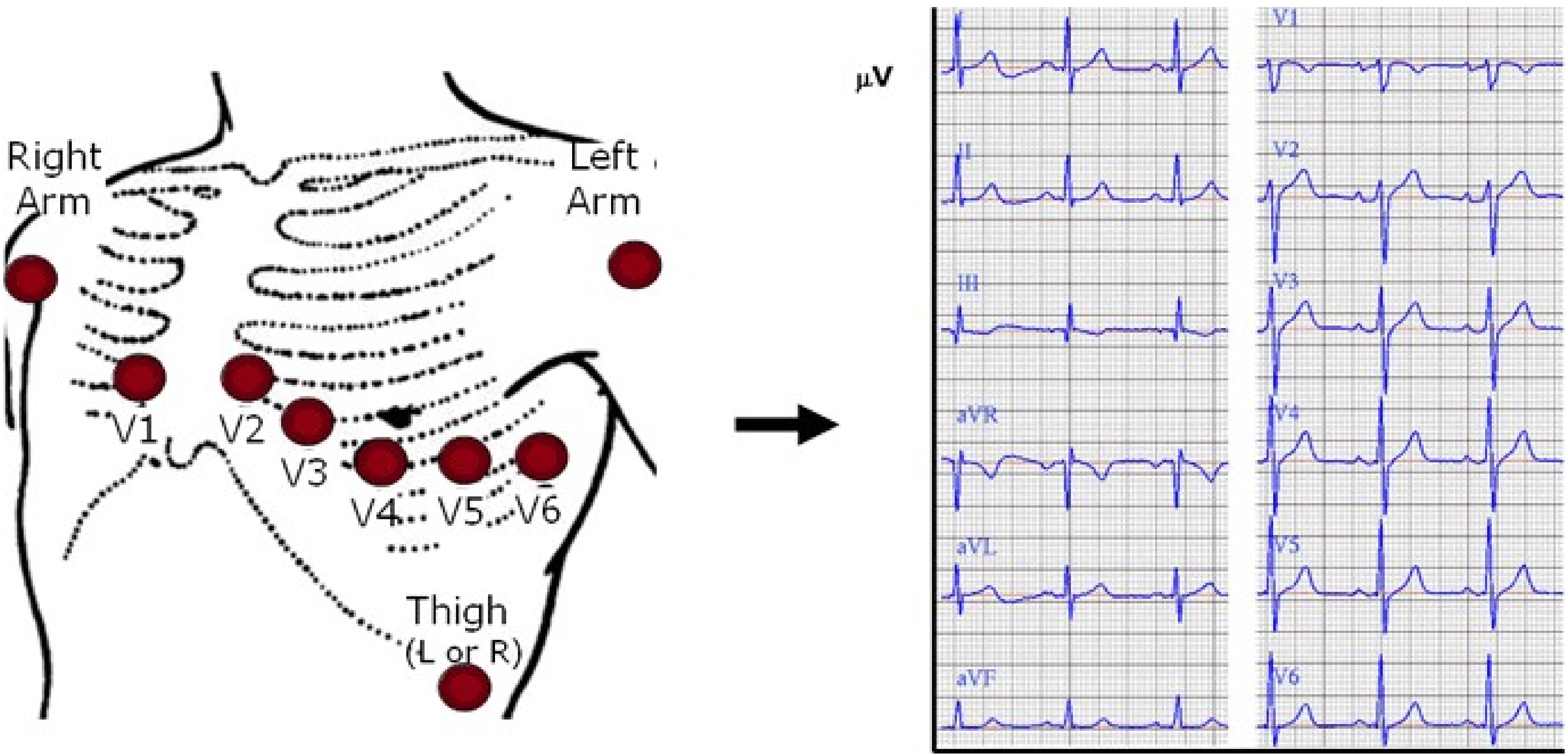


(b)



RA
CH
LA
RL
−
+
Buffers
C.M.
AMPL

12 Lead ECG System



ECG

- The electric potentials generated by the heart appear throughout the body and on its surface.
- The potential difference is determined by placing electrodes on the surface of the body and measuring the voltage between them.
- A ***lead vector*** is a unit vector that defines the direction a constant-magnitude cardiac vector must have to generate maximal voltage in the particular pair of electrodes.
- A pair of electrodes, or combination of several electrodes through a resistive network that gives an equivalent pair, is refered to as a ***lead***
- More than one lead must be recorded to describe the heart’s electric activity completely.
- In practice several leads are taken in the frontal plane and the transverse plane

ECG…

- The three ***bipolar limb lead*** selections was first introduced by Einthoven.
- Einthoven postulated that at any instant of the cardiac cycle, the frontal plane representation of the electrical axis of the heart is a 2-D vector.
- The ECG measured from any one of the three basic limb lead is a time-variant 1-D component of that vector.
- Einthoven also made the assumption that the heart is near the center of an equilateral triangle, the apexes of which are the right and left shoulders and the crotch.
- ECG potentials at the shoulders are essentially the same as the wrists and that the potentials at the crotch differ little from those at either ankle.
- The points of this triangle represents the electrode positions of the three limb leads.
- This triangle is called ***Einthoven Triangle***

ECG…

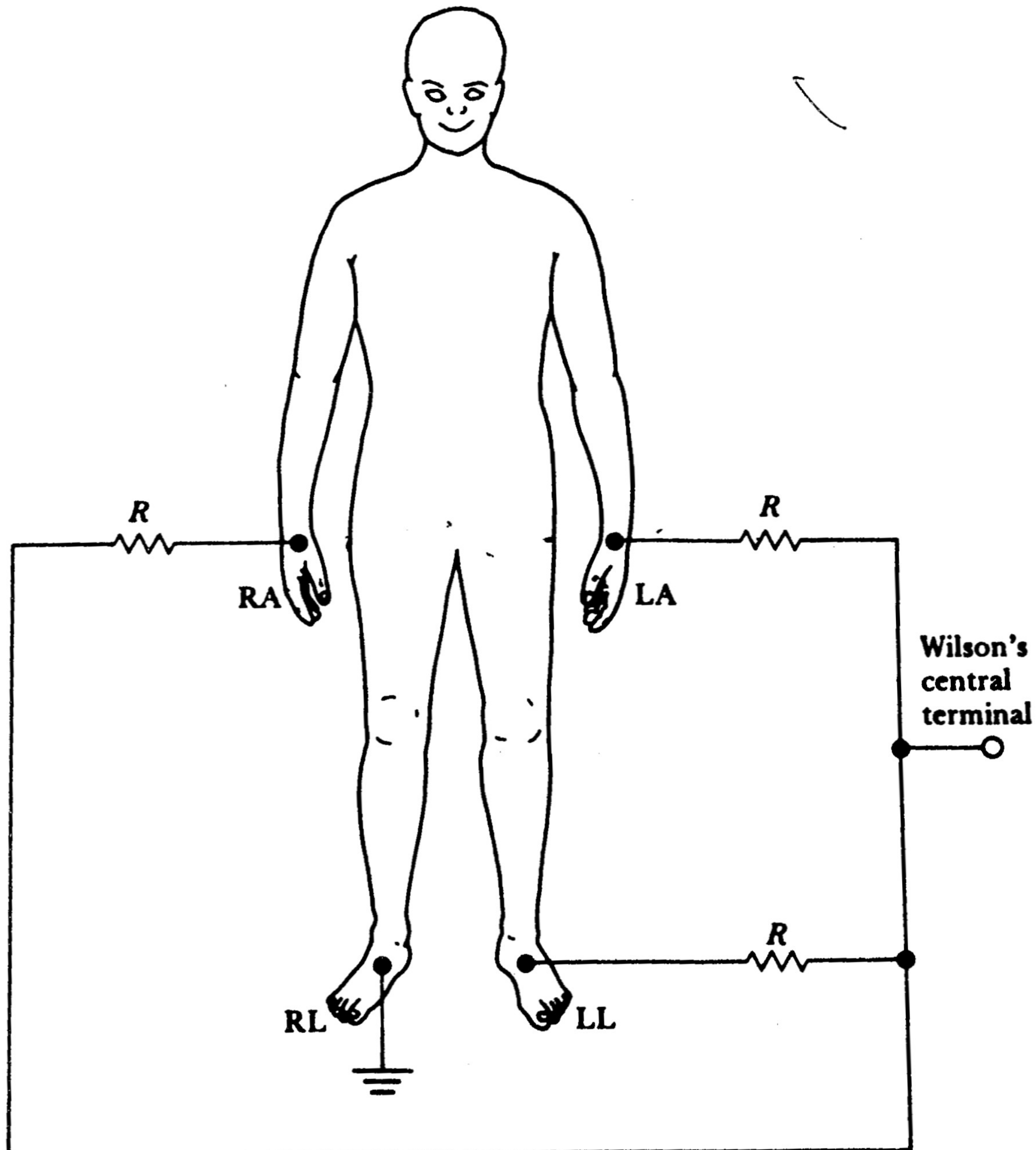
- The components of a particular cardiac vector can be determined easily by placing the vector within the triangle and determining its projection along each side.

- Three additional leads in the frontal plane as well as group of leads in the transverse plane are routinely used in taking clinical ECG.

- These leads are based on signals obtained from more than one pair of electrodes referred to as ***unipolar leads***

- ***Unipolar leads*** consists of potential appearing on one electrode taken with respect to an equivalent reference electrode, which is the average of the signals seen at two or more electrodes.

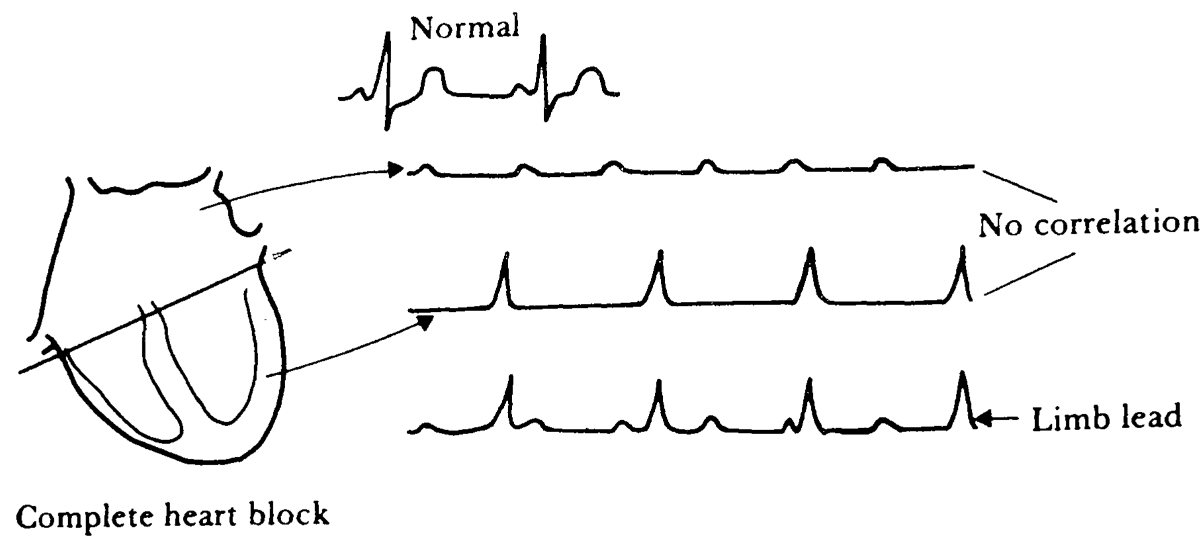
Wilson's central terminal



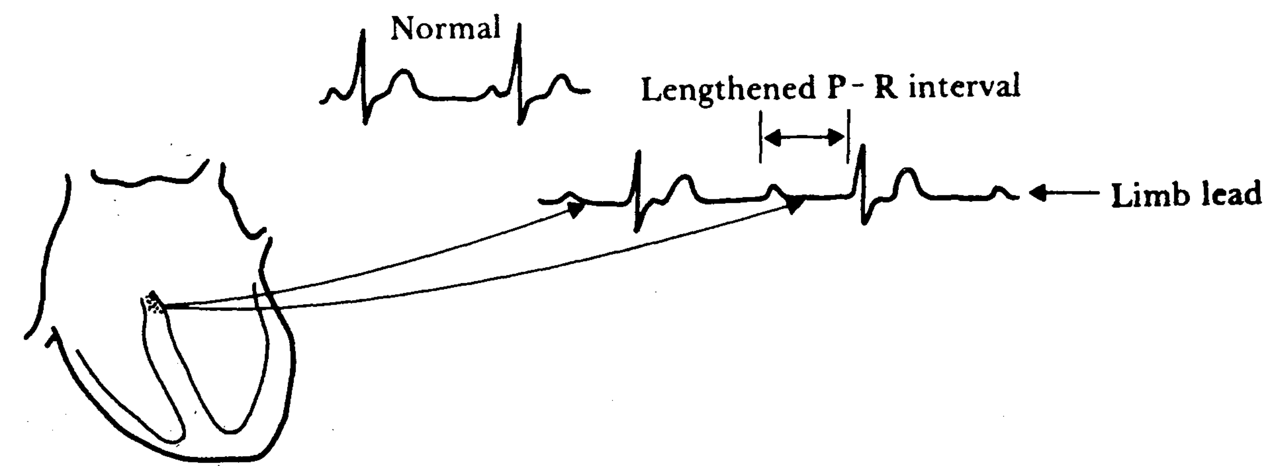
Effects of artefacts

- Interference from power line
- Shifting of base line :
  - Wandering base line
  - Due to movement of patient electrode
  - Eliminated by ensuring that patient lies relaxed and electrodes are properly attached.
- Muscle tremor

Abnormal ECGs



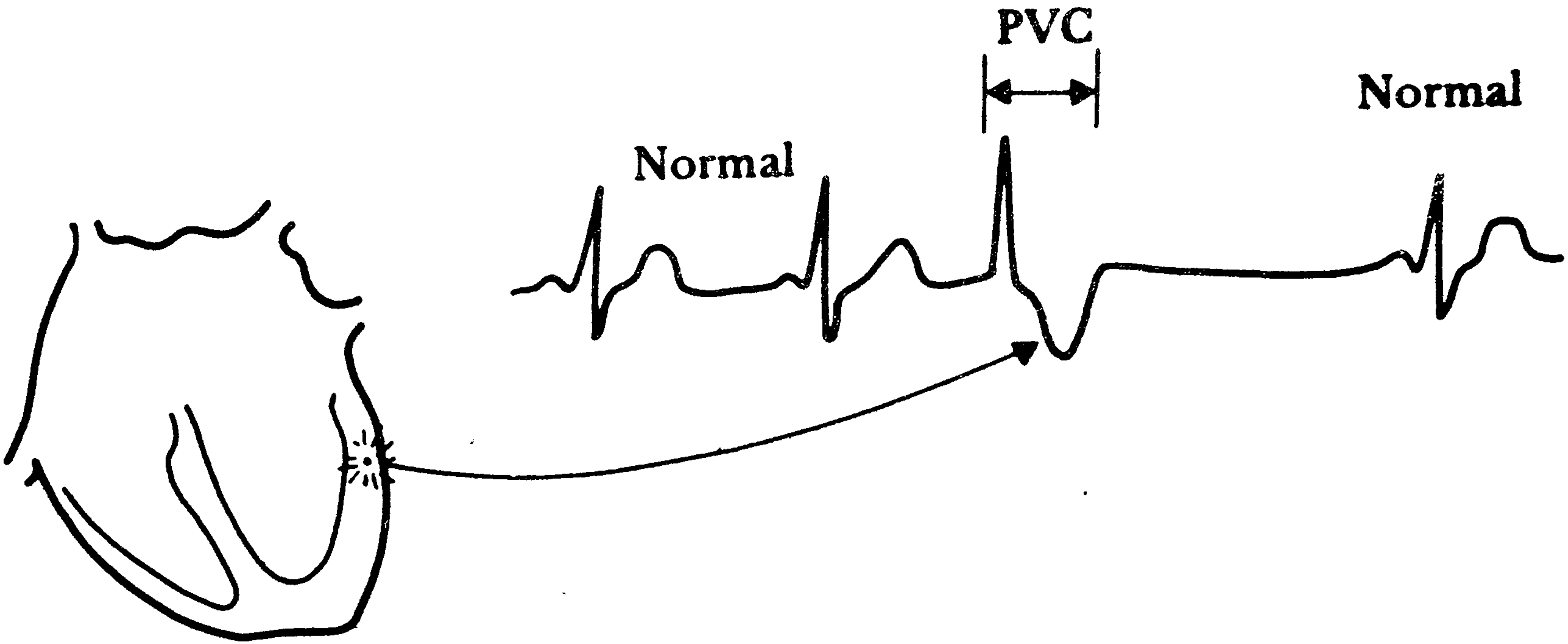
(a)



(b) AV Block, AV node delay is greatly increased

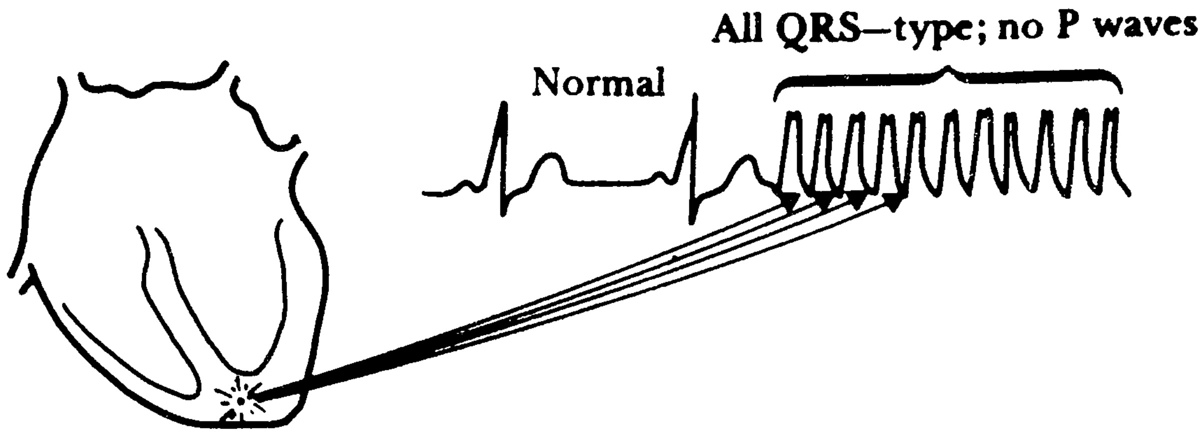
Abnormal ECGs

Premature Ventricular Contraction

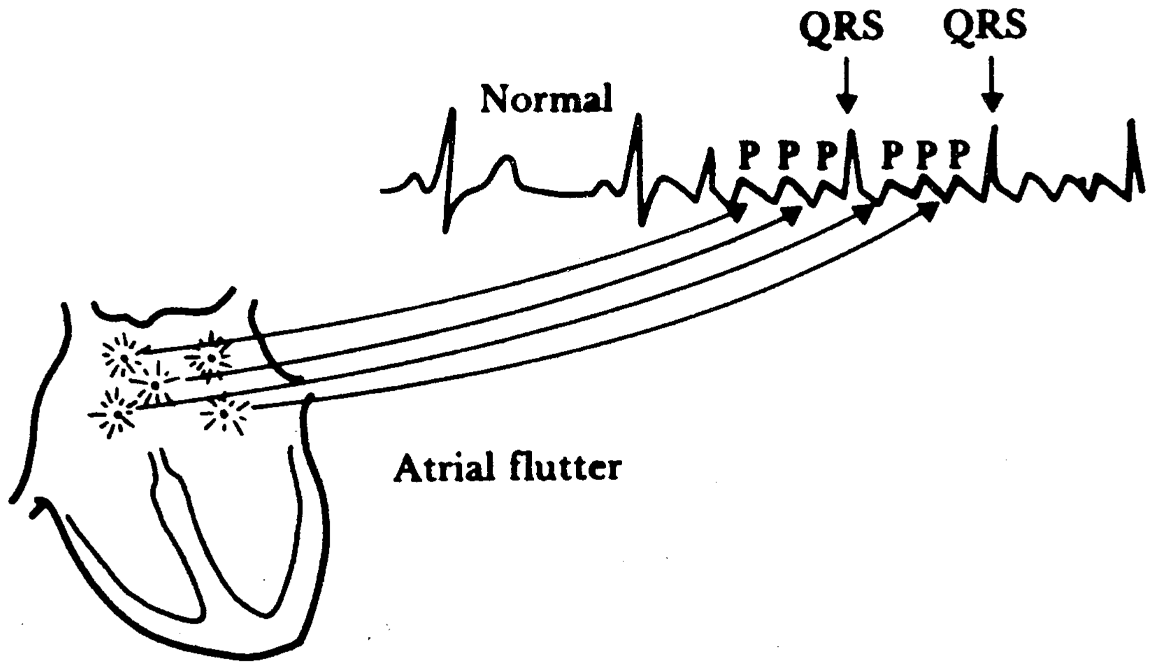


Ectopic (other-than-normal) beat

Abnormal ECGs



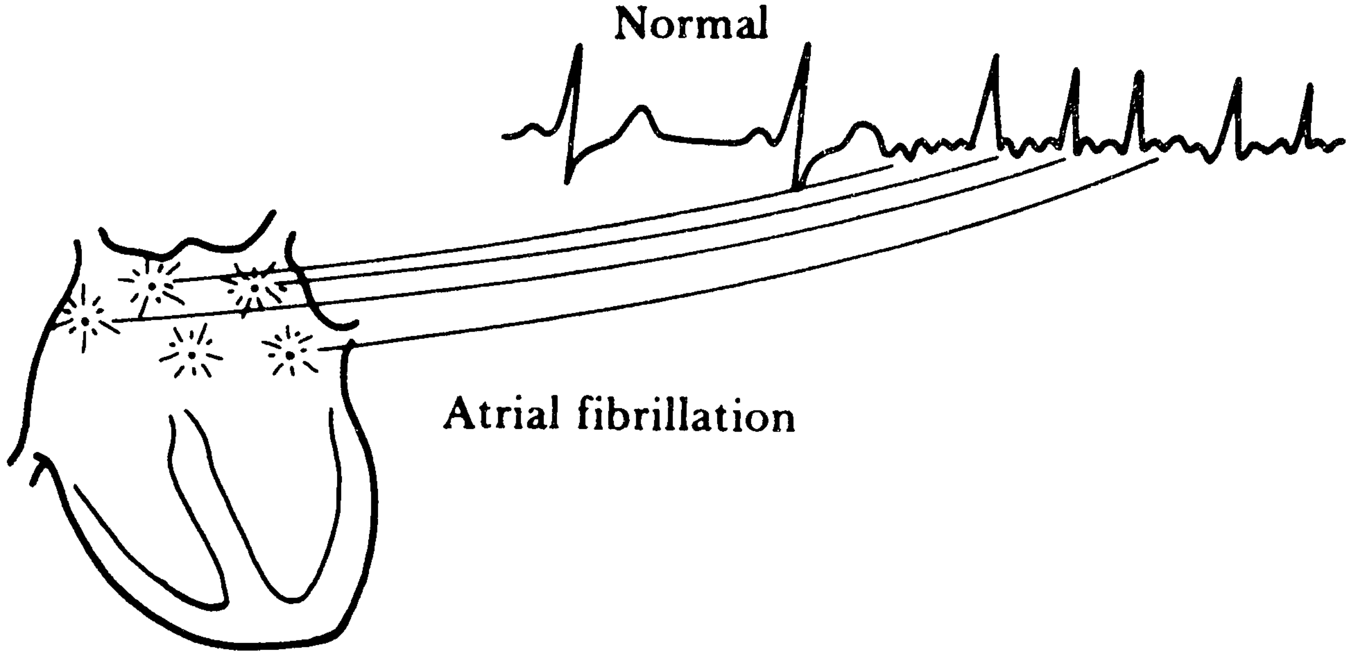
(a) Paroxysmal tachycardia



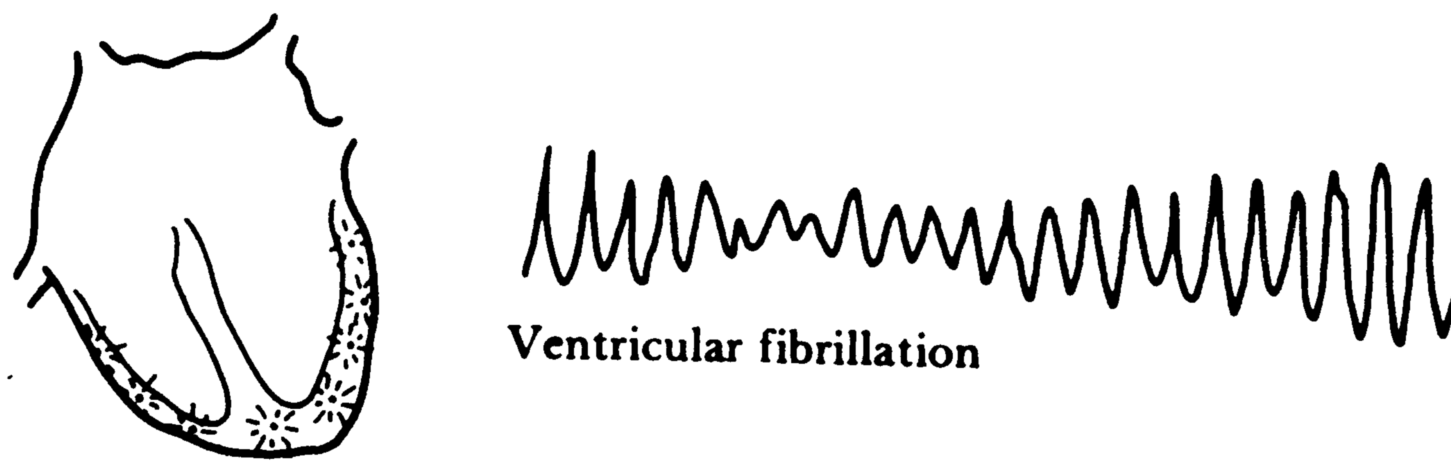
Atrial flutter

(b)

Abnormal ECGs



(a)



(b)

Electroencephalogram (EEG)

- The background electrical activity of the brain was first analyzed in a systematic manner by the German psychiatrist Hans Berger, who introduced the term ***electroencephalogram (EEG)*** to denote the potential fluctuations recorded from the brain.

- The recorded representation of bioelectric potentials generated by the neuronal activity of the brain is called the electroencephalogram (EEG).

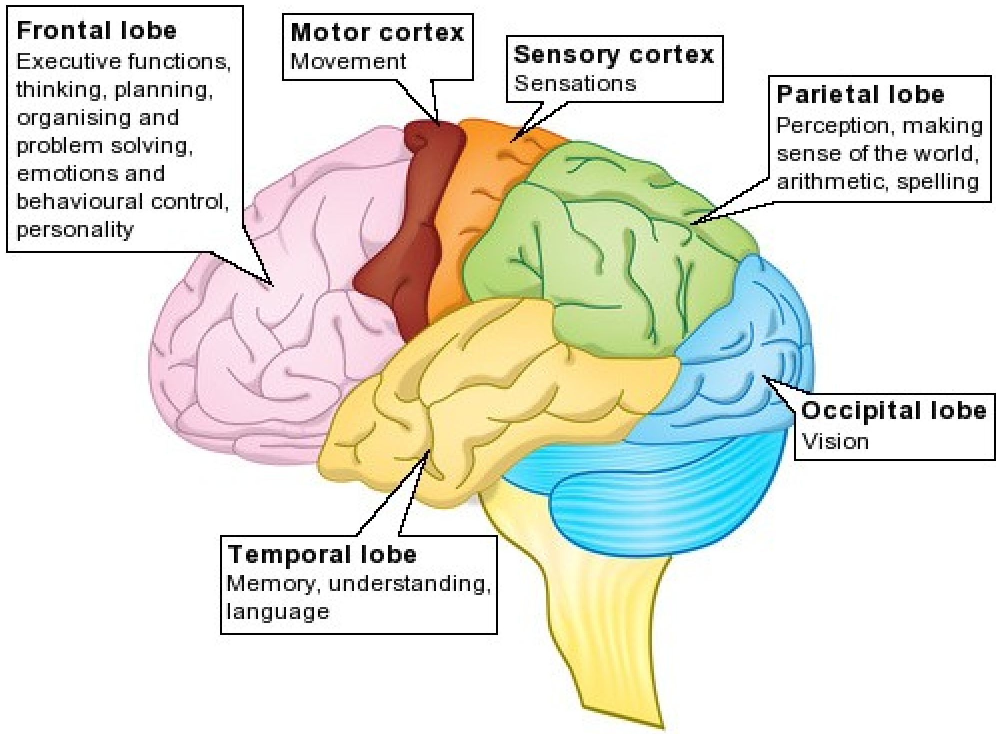
- EEG potentials measured at the surface of the scalp, actually represent the combined effect of potentials from a fairly wide region of the cerebral cortex and from various points beneath.

- Experiments have shown that the frequency of the EEG seems to be affected by the mental activity of a person.

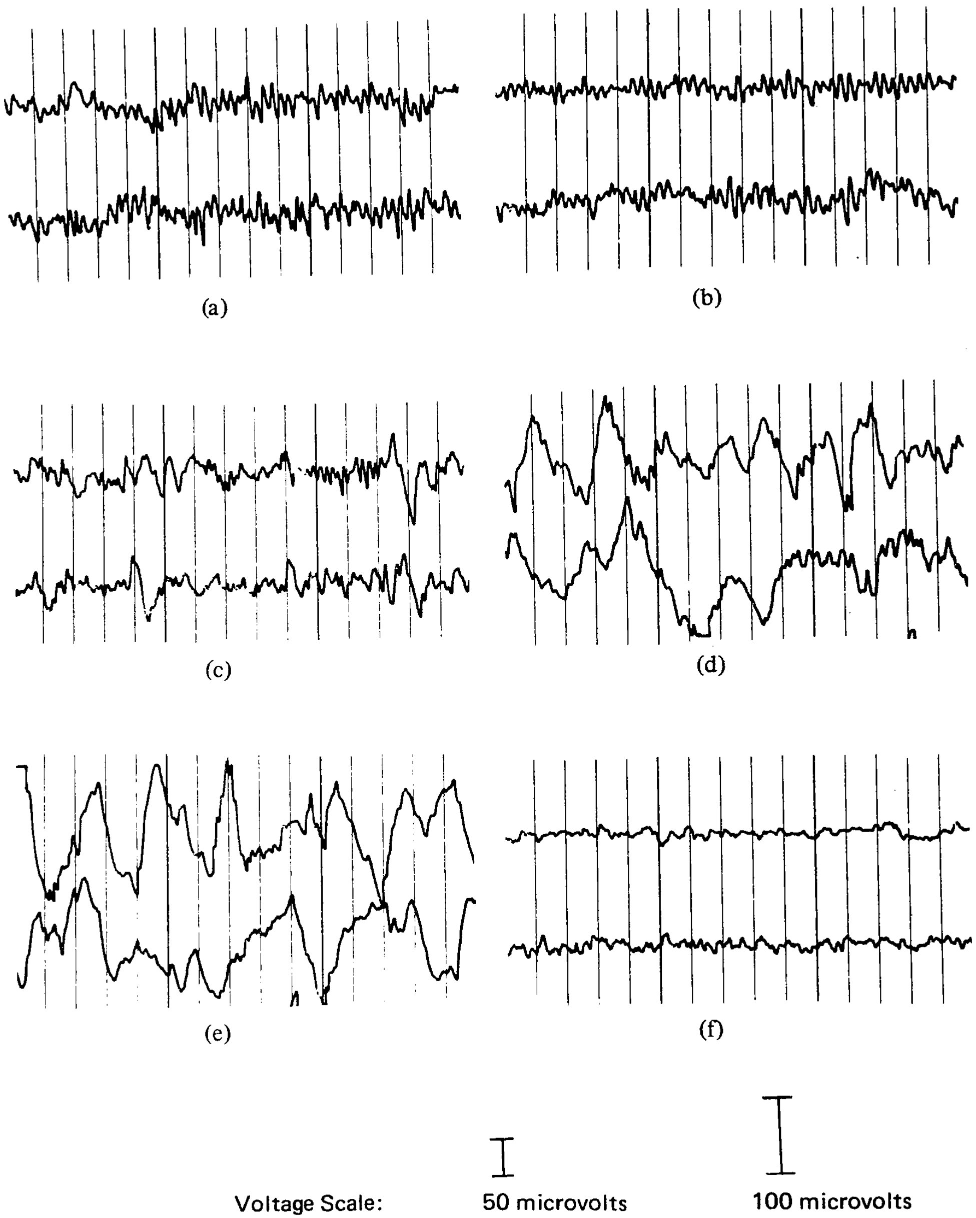
- The frequencies of these brain waves range from 0.5 to 100Hz, and their character is highly dependent on the degree of activity of the cerebral cortex.

- Some of these are characteristics of specific abnormalities of the brain, such as epilepsy.

The cerebral cortex



EEG Waveforms



Awake & Alert (Mixed frequencies)

Stage 1 Drowsy (Alpha waves)

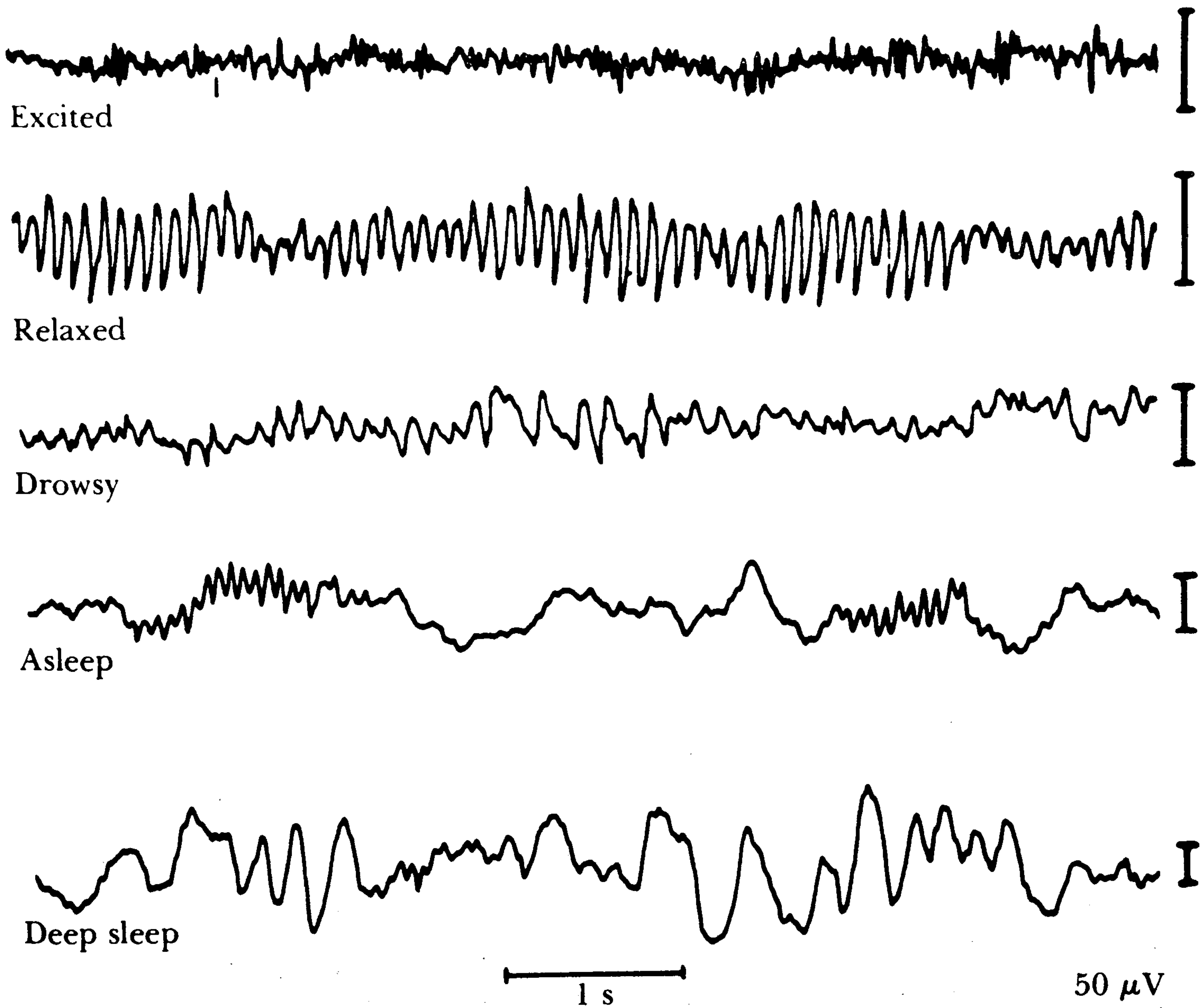
light sleep

Normal sleep

Deeper slow wave sleep

Paradoxical or rapid eye movement (REM) sleep

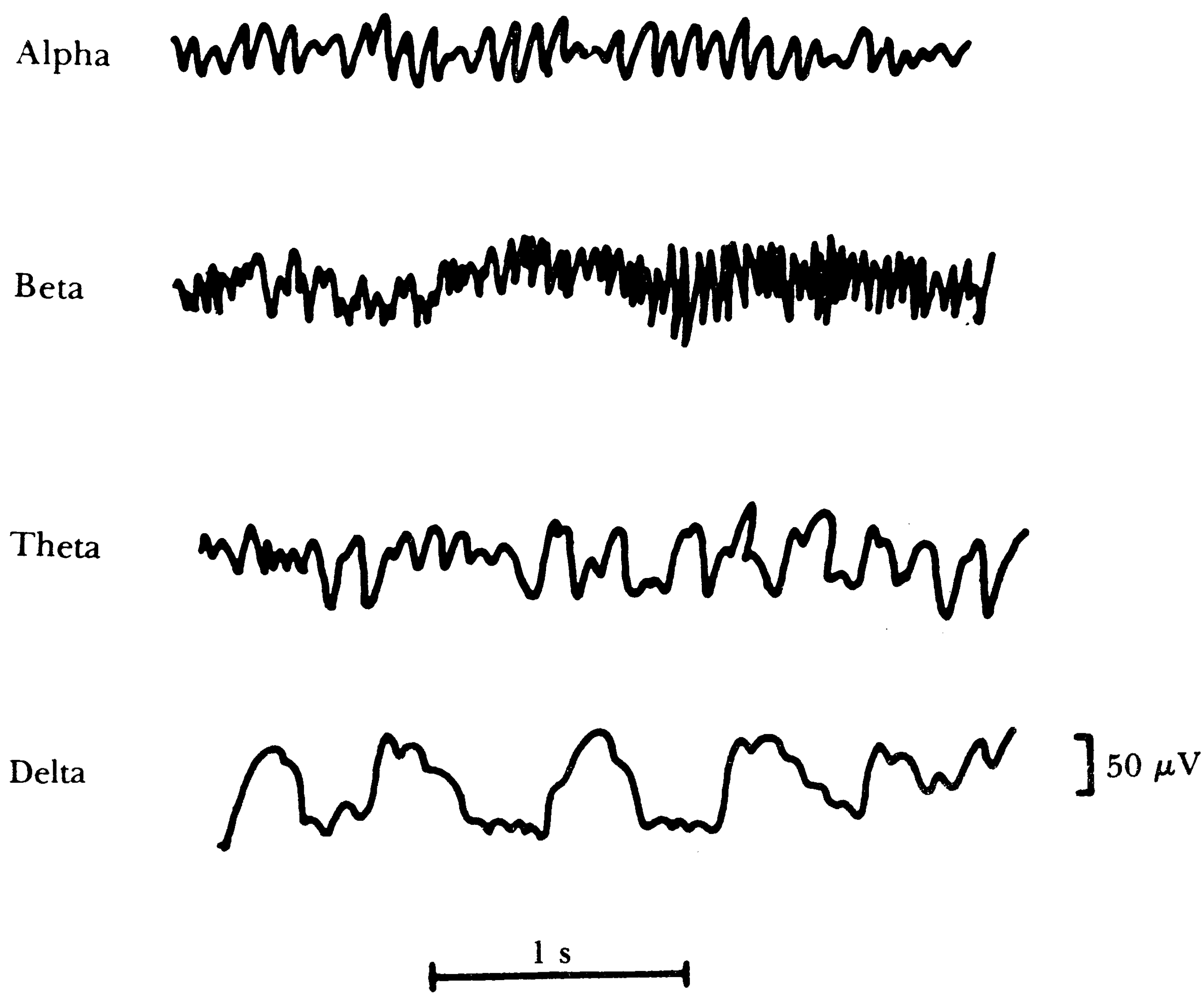
EEG Waveforms



EEG waveform types

Brain wave	Frequency range	Mental State	Voltage range	Region of activity
Alpha	8 to 13 Hz	Awake, quiet, resting state	20-200µV	Occipital Also from parietal and frontal regions of the scalp
Beta	14 to 30 Hz	High mental activity (tension)	“	Parietal & temporal regions
Theta	4 to 7	Emotional stress, Disappointment, Frustration		“
Delta	< 3.5 Hz	Deep sleep (infancy), serious organic brain disease,		Within the cortex

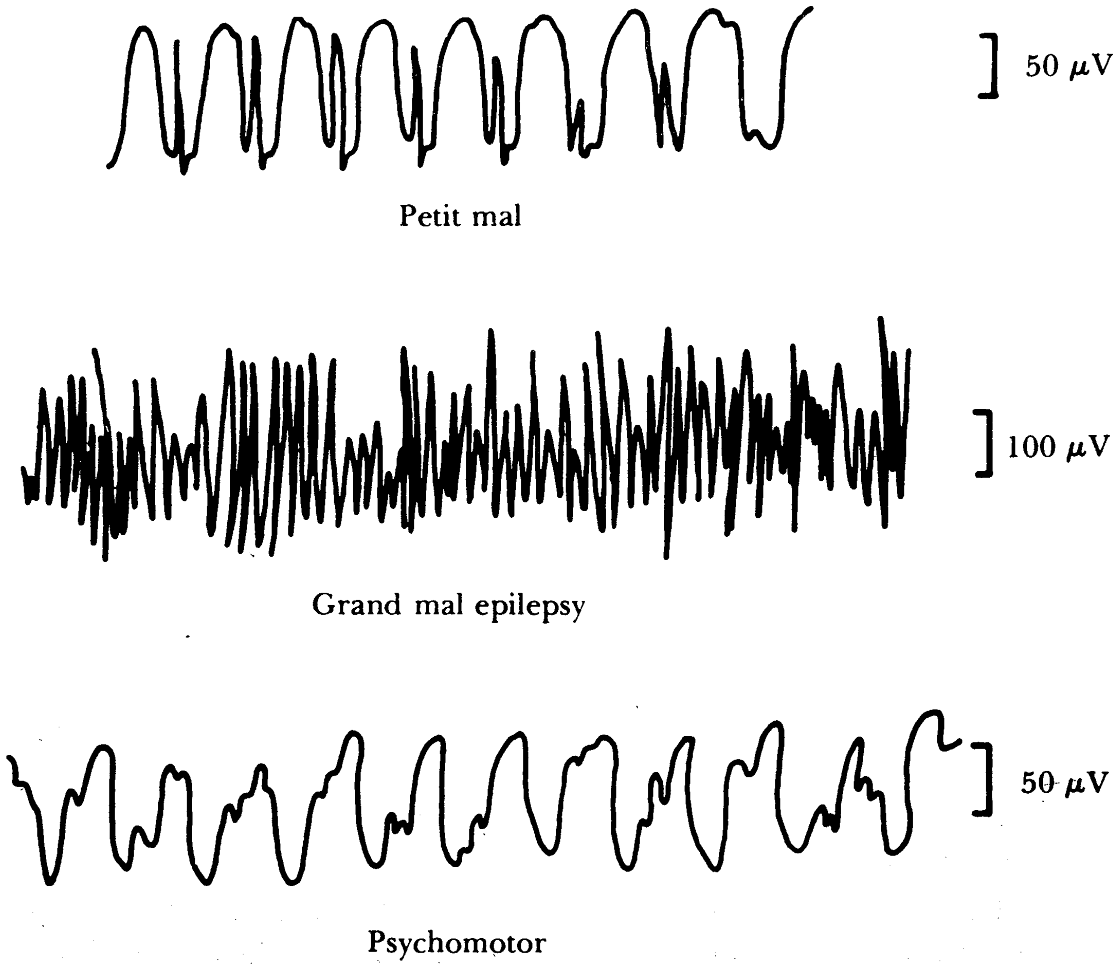
EEG Waveform types



EEG waveform types

- When the awake subject's attention is directed to some specific type of mental activity, the alpha waves are replaced by asynchronous waves of higher frequency but lower amplitudes.
- Above figure demonstrates the effect on the alpha waves of simple opening the eyes in bright light and then closing them again.
- The visual sensation causes immediate cessation of the alpha waves; these are replaced by low-voltage, asynchronous waves.

Abnormal EEG, during an epilepsy



Representative abnormal EEG Waveforms in different types of epilepsy

The 10-20 Electrode system

- The system most often used to place electrodes for monitoring the clinical EEG is the ***International Federation 10-20 System.***

- So named because electrode spacing is based on intervals of 10-20 percent of the distance between specified points on the scalp.

- This system uses certain anatomical landmarks to standardize placement of EEG electrodes.

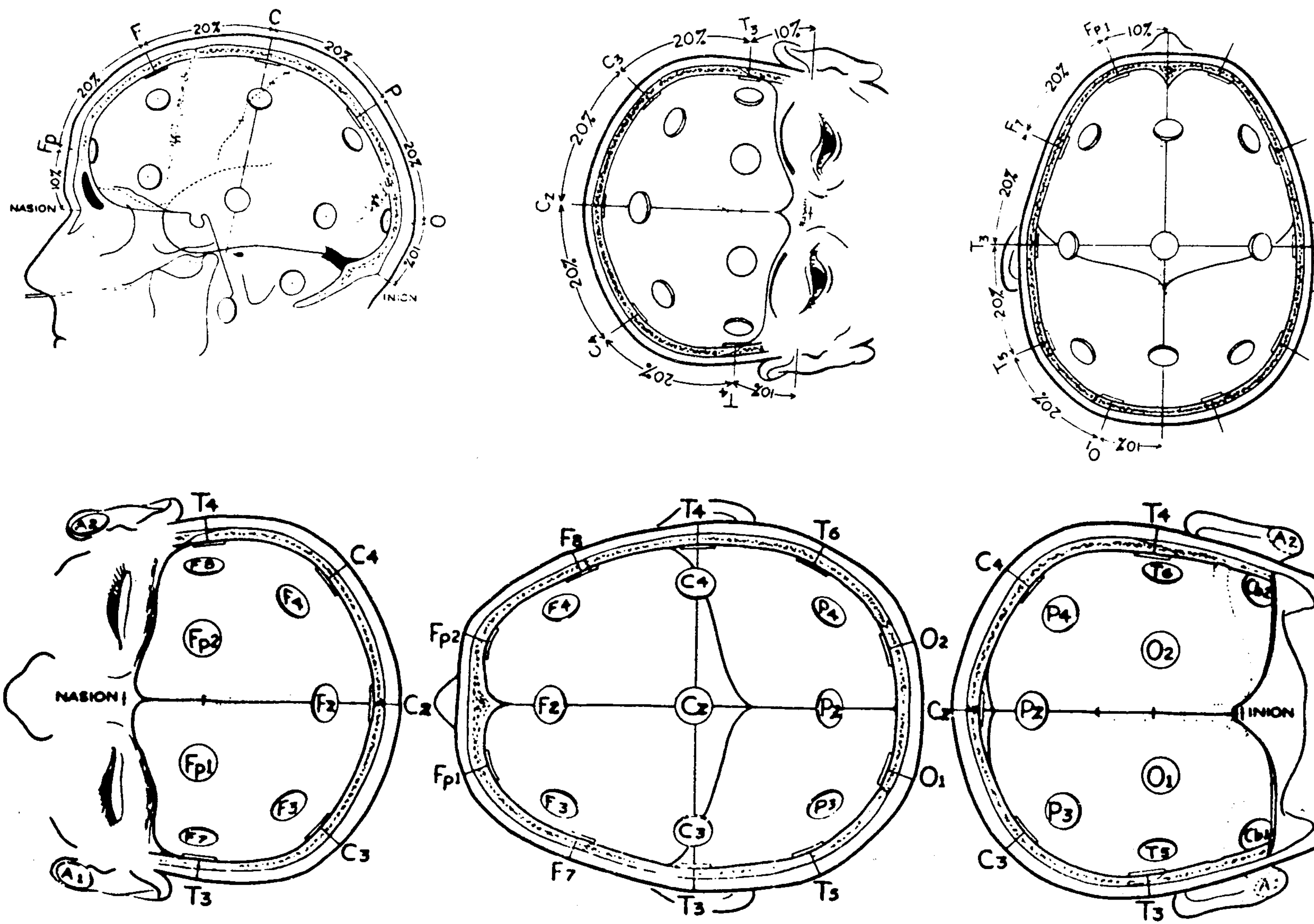
- The differential amplifier requires a separate ground electrode plus differential inputs to the following three types of electrode connections.

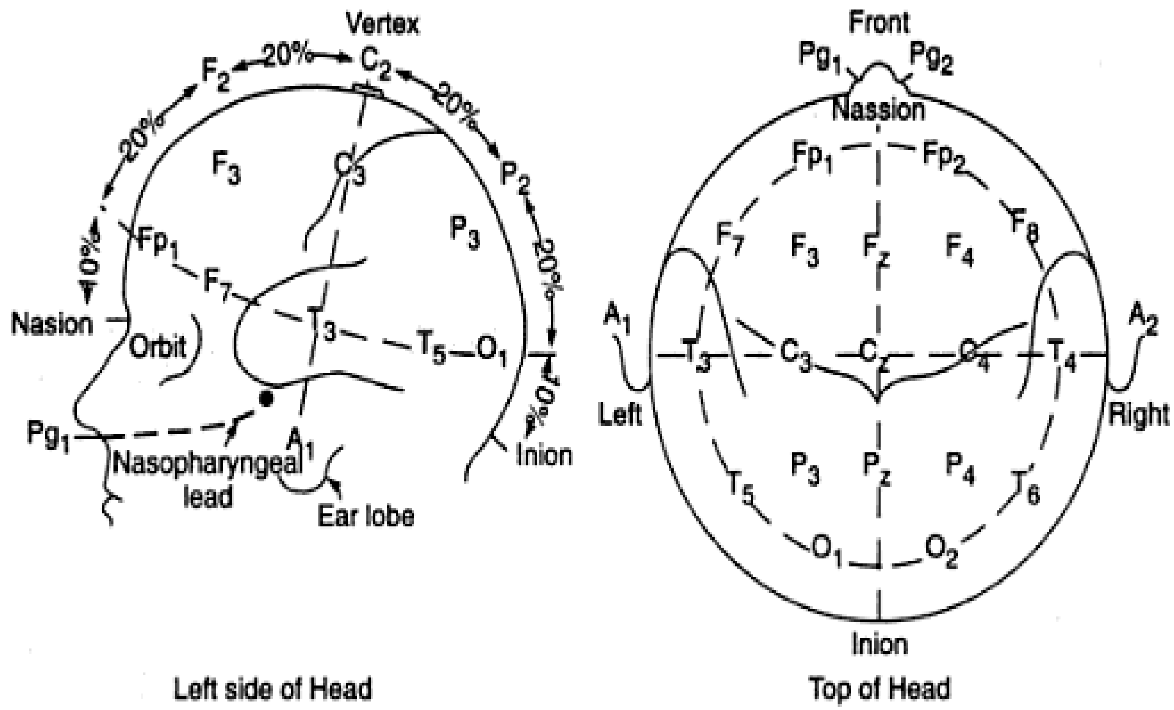
  1. Between each member of a pair (bipolar)
  2. Between one unipolar lead and a distant reference electrode (usually attached one or both ear lobes)
  3. Between one unipolar lead and the average of all.

- Differential recording cancels far-field activity common to both electrodes, thus responses are localized.

- The potential changes that occur are amplified by high gain, differential, capacitive coupled amplifiers.

The 10-20 Electrode system





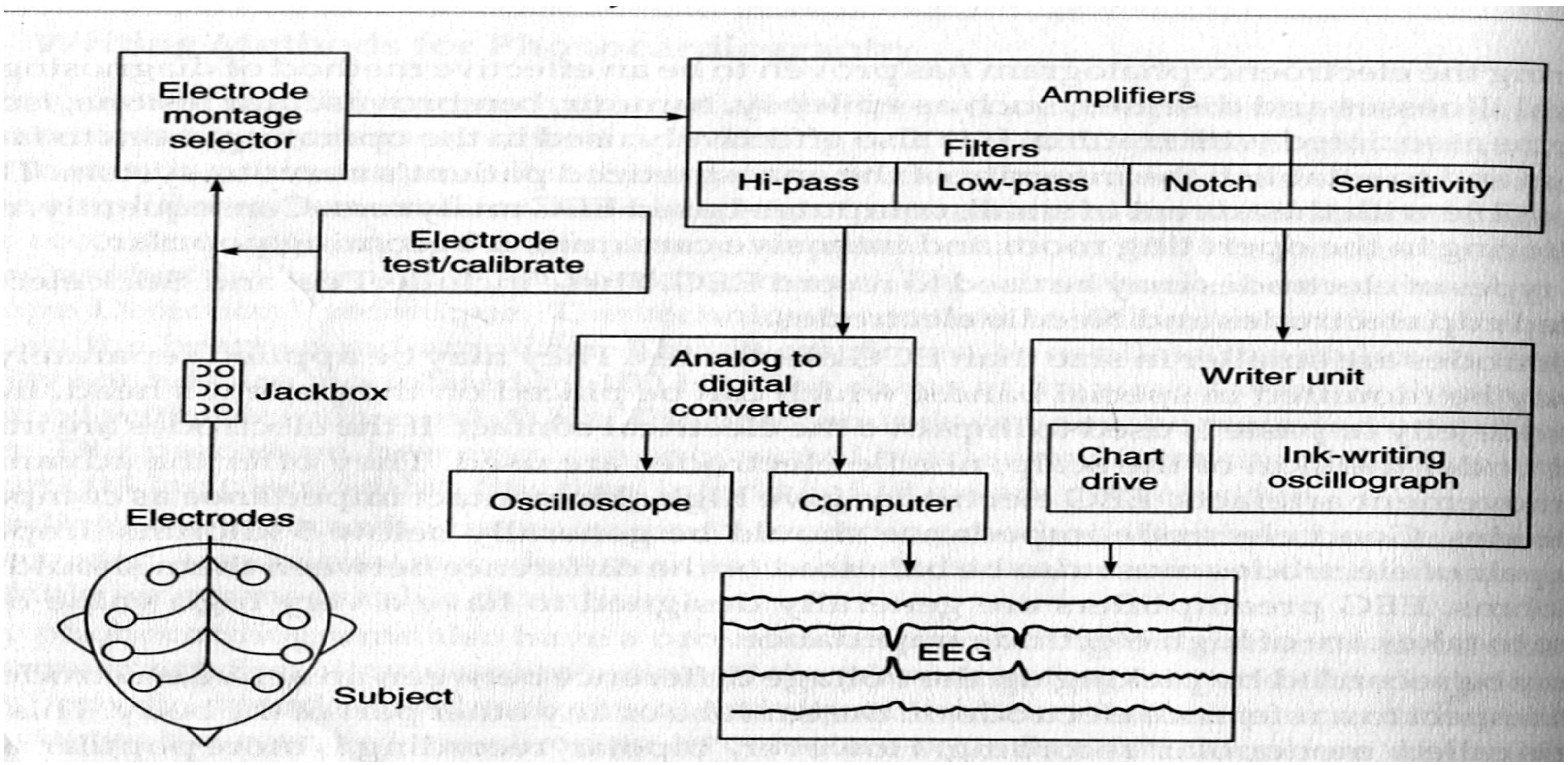
➤ **Fig. 5.12** *10-20 system of placement of electrodes*

Position of electrode

- Fp – frontal polar
- F – Frontal
- C- Central
- P- Parietal
- T – temporal
- O- occipital
- Z- Midline
- Pg- Naso Pharyngeal
- A- ear Lobe

The 10-20 Electrode system…

- Electrodes must be small
- Must be easily affixed to the scalp with minimal disturbance of the hair.
- Must not cause discomfort.
- Must remain in place for extended periods of time.
- The recording area on the surface of the scalp is degreased by cleaning it with alcohol.
- A conducting paste is applied, full electrical contact with the surface.
- Nonpolarizable Ag/AgCl electrodes are glued to the scalp with a glue, or held in place using rubber straps



Electrode montage selector
Amplifiers
Filters
Hi-pass
Low-pass
Notch
Sensitivity
Electrode test/calibrate
Analog to digital converter
Writer unit
Jackbox
Chart drive
Ink-writing oscillograph
Oscilloscope
Computer
Electrodes
EEG
Subject

- The advantage of selecting several montage is that each montage displays different spatial characteristics
- A calibrating signal is used to control sensitivity of amplifier channel.
- It supplies voltage step of 50uv/cm

Sensitivity control

- Sensitivity is the magnitude of the voltage required to produce a standard deflection in recorded plate
- Sensitivity of writer = gain of amplifier X over all gain of EEG

Evoked Potential

- When a patient suffering from some disorder shows a normal EEG record when at rest, then evoked potential are recorded.
- **Hyper Ventilation**. : The patient breaths deeply for 2-4 min at the rate of 20 breaths per min.The EEG record is then taken.
- **Photic Stimulation**: Repetitive Flashes of light are made incident on the patient at the rate of 1 -50 flashes per sec.
- **Induced Sleep**: EEG is obtained with drug induced sleep

Brain Computer Interface

Electroneurogram (ENG)

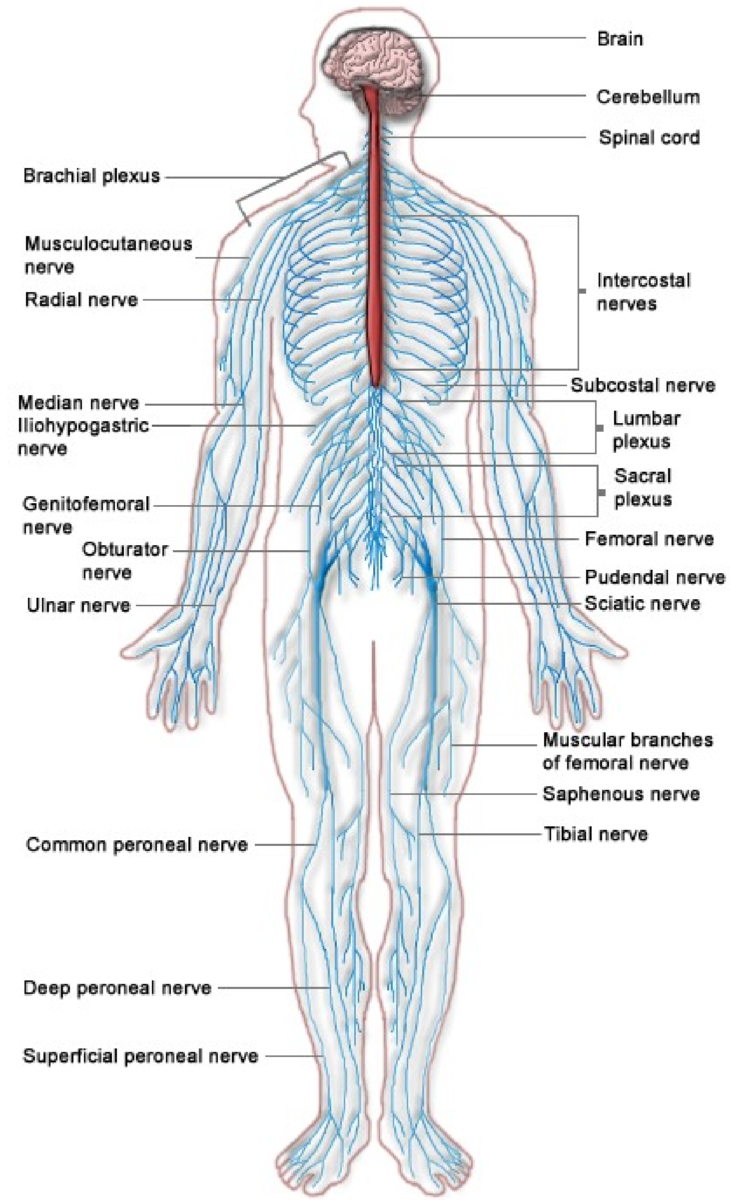
- An electroneurogram is a method used to visualize directly recorded electrical activity of neurons in the central nervous system (brain, spinal cord) or the peripheral nervous system (nerves, ganglions).

- An electroneurogram is usually obtained by placing an electrode in the neural tissue.

- The electrical activity generated by neurons is recorded by the electrode and transmitted to an acquisition system, which usually allows to visualize the activity of the neuron.

- Each vertical line in an electroneurogram represents one neuronal action potential.

- Depending on the precision of the electrode used to record neural activity, an electroneurogram can contain the activity of a single neuron to thousands of neurons.



Electroneurogram (ENG)

- Conduction velocity and latency in a peripheral nerve are the most generally useful parameters associated with peripheral nerve function.

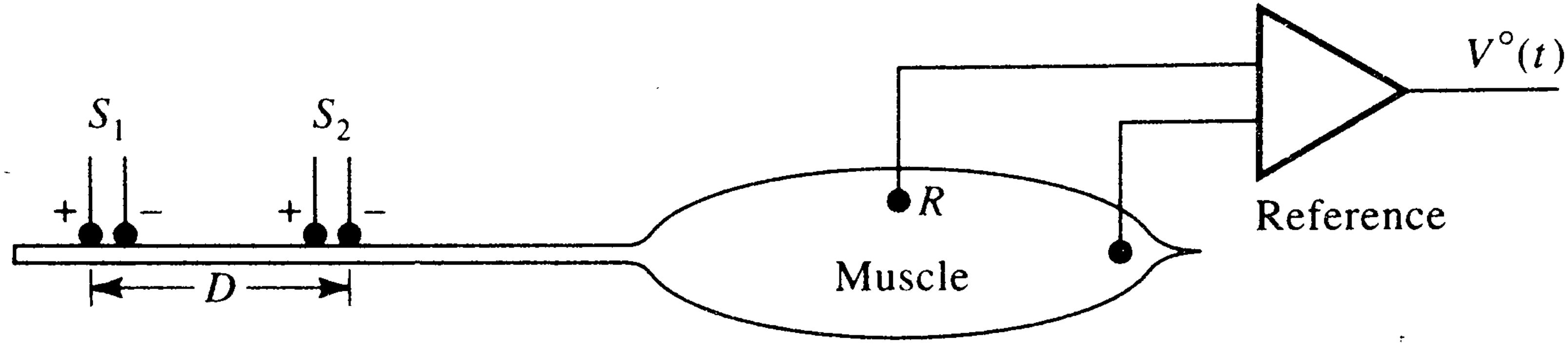
- It is measured by stimulating a motor nerve at two points a known distance apart along its course.

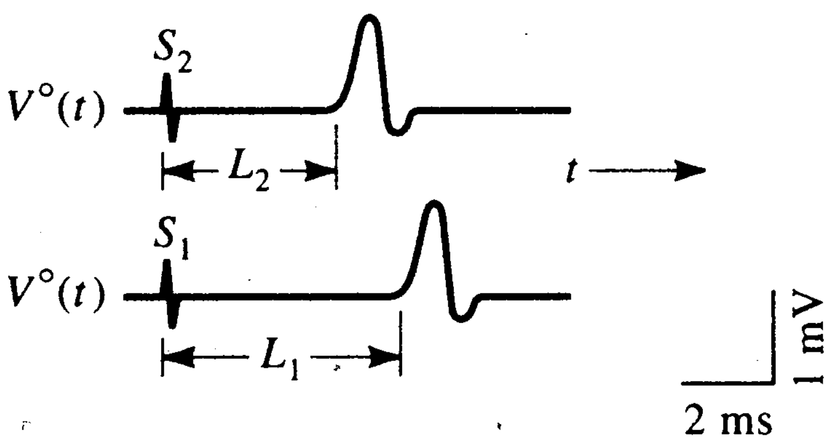
- Subtraction of shorter latency from longer latency gives the conduction time along the segment of nerve between the stimulating electrodes. Knowing the separating distance, the conduction velocity can be determined.

- Conduction velocity has potential clinical value.

- In a regenerating nerve fiber, conduction velocity is slowed following nerve injury.

Electroneurogram (ENG)



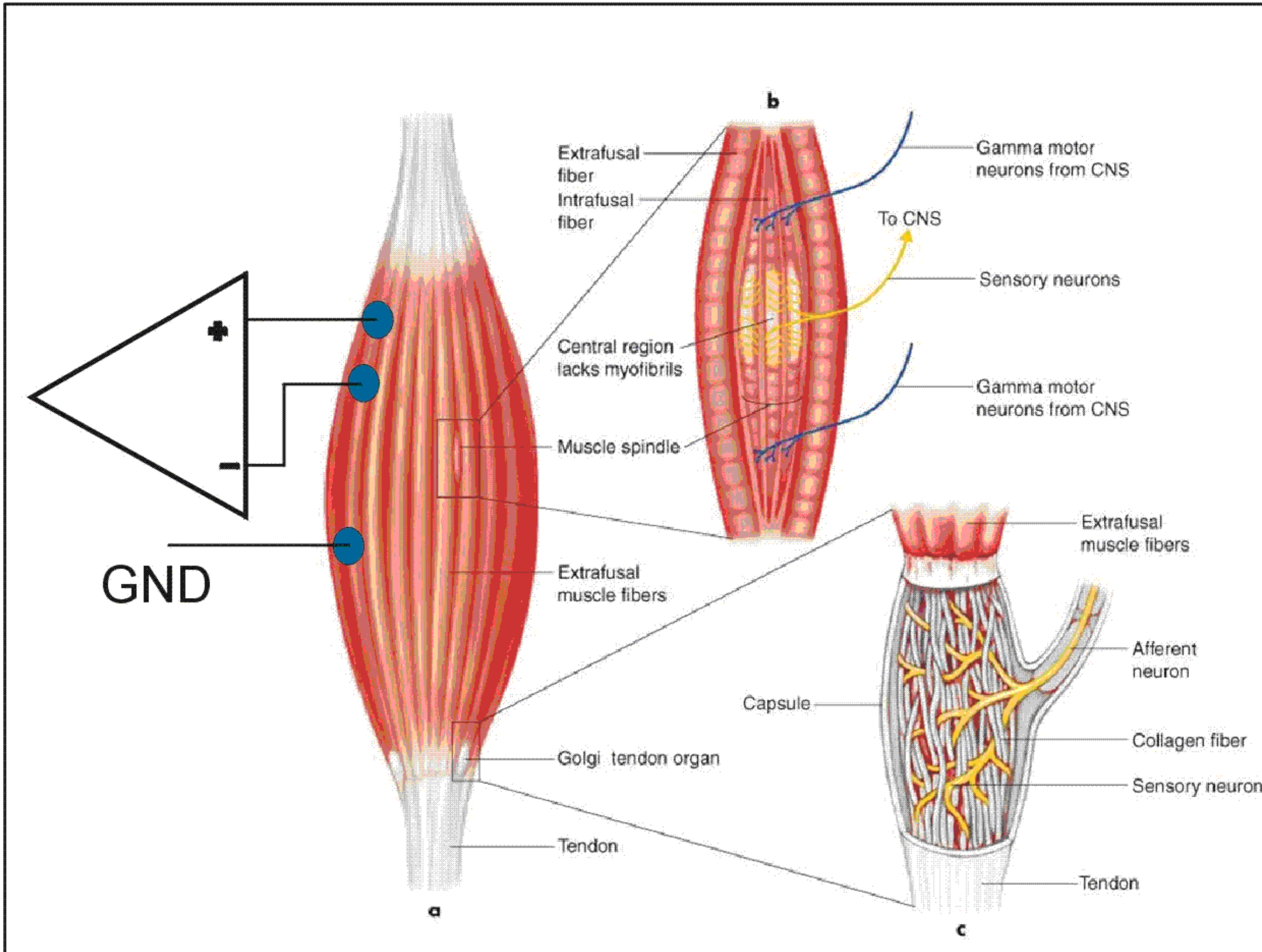


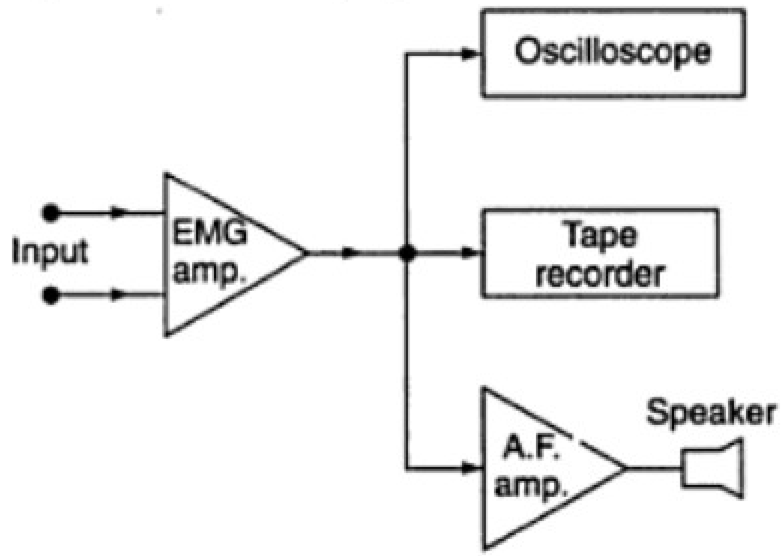
$$\text{Velocity} = u = \frac{D}{L_1 - L_2}$$

Electromyogram (EMG)

- The bioelectric potential associated with muscle activity constitute the electromyogram (EMG).
- Muscle is organized functionally on the basis of the motor unit.
- A motor unit is defined as one motor neuron and all of the muscle fibers it innervates.
- When a motor unit fires, the impulse (action potential) is carried down the motor neuron to the muscle. The area where the nerve contacts the muscle is called the ***neuromuscular junction***, or the ***motor end plate.***
- The potentials are measured at the surface of the body, near a muscle of interest or directly from the muscle by penetrating the skin with needle electrodes.
- EMG potentials range between less than 50 μV and up to 20 to 30 mV, depending on the muscle under observation.

Electromyogram (EMG)




Oscilloscope
Input
EMG
amp.
Tape
recorder
Speaker
A.F.
amp.

Electromyogram (EMG)

- The EMG pattern is usually a summation of the individual action potentials from the fibers consisting the muscle or muscles being measured.

- The signals can be analyzed to detect medical abnormalities, activation level, recruitment order or to analyze the biomechanics of human or animal movement.

- There are two kinds of EMG in widespread use:
  1. Surface EMG

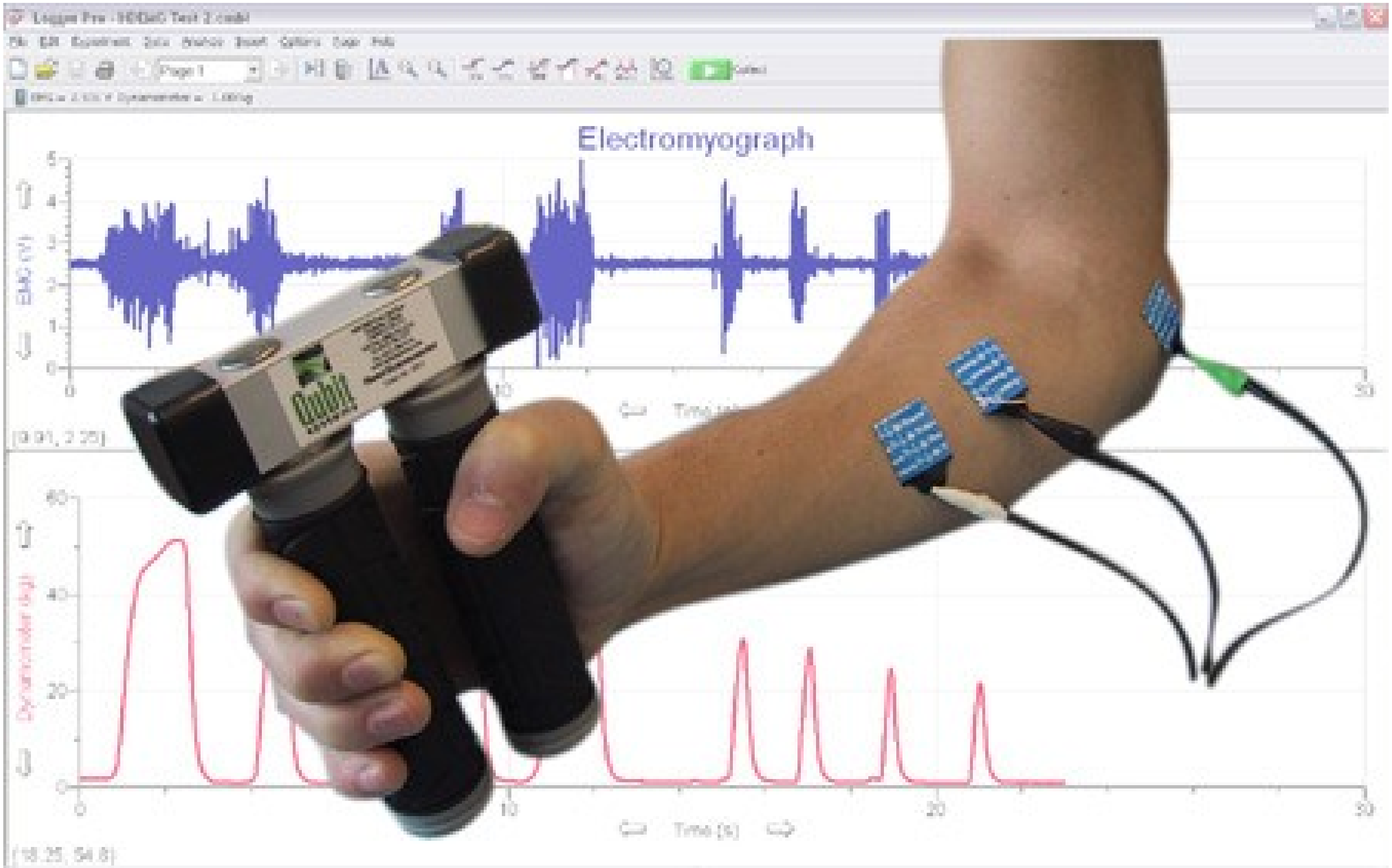
  2. Intramuscular (needle and fine-wire) EMG.
     A needle electrode or a needle containing two fine-wire electrodes is inserted through the skin into the muscle tissue.

     - Abnormal spontaneous activity might indicate some nerve and/or muscle damage

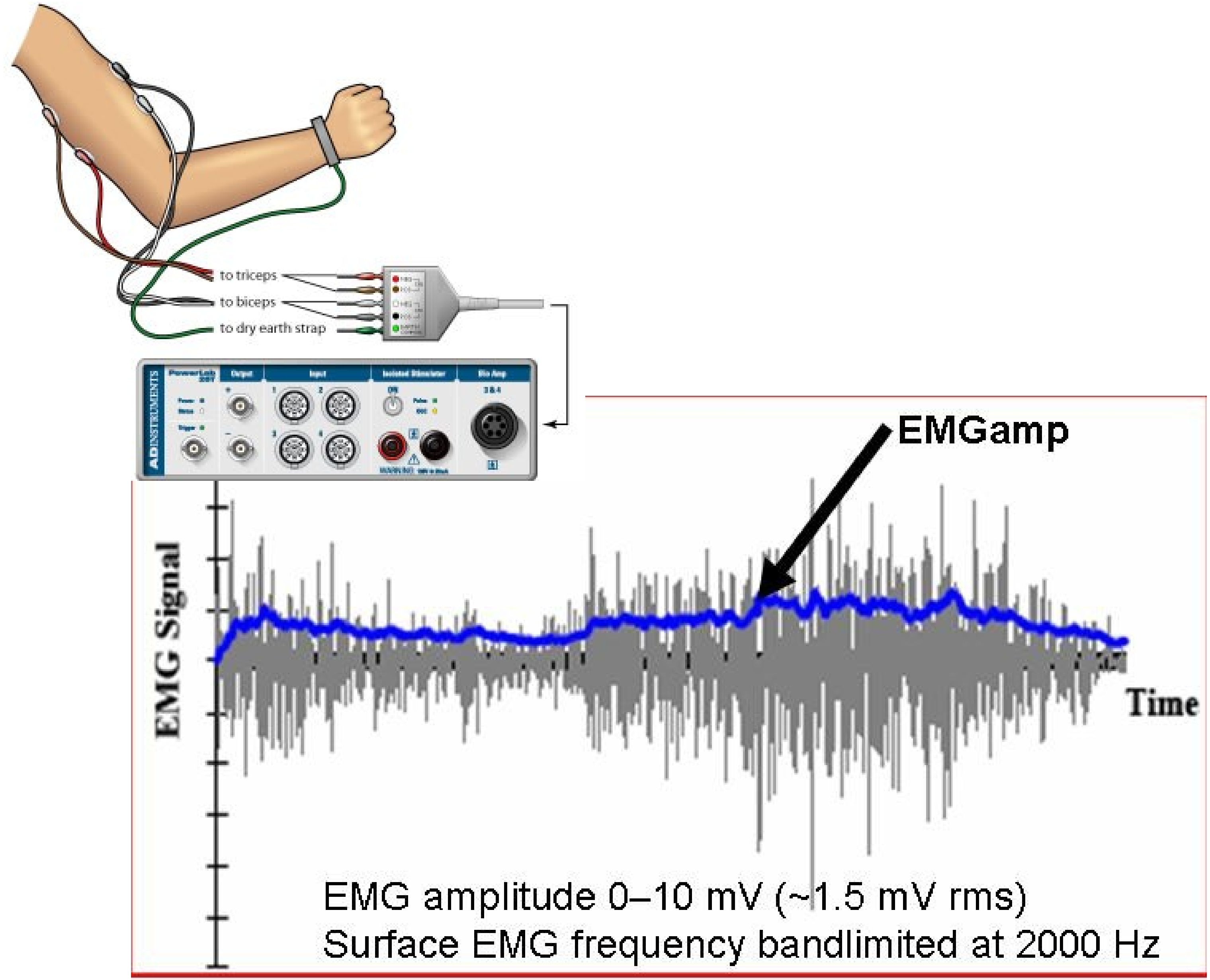
     - The shape, size, and frequency of the resulting motor unit potentials are analyzed.

     - The composition of the motor unit, the number of muscle fibres per motor unit, the metabolic type of muscle fibres and many other factors affect the shape of the motor unit potentials in the myogram.

Electromyogram (EMG)



Electromyogram (EMG)



EMG amplitude 0–10 mV (~1.5 mV rms)
Surface EMG frequency bandlimited at 2000 Hz

EMG Applications

- EMG is used as a diagnostics tool for identifying:
  - Neuromuscular diseases, assessing low-back pain
  - Disorders of motor control.

- EMG signals are also used as:
  - A control signal for prosthetic devices such as prosthetic hands, arms, and lower limbs.
  - To sense isometric muscular activity where no movement is produced. And can be used:
    - To control interfaces without being noticed and without disrupting the surrounding environment.
    - To control an electronic device such as a mobile phone or PDA.

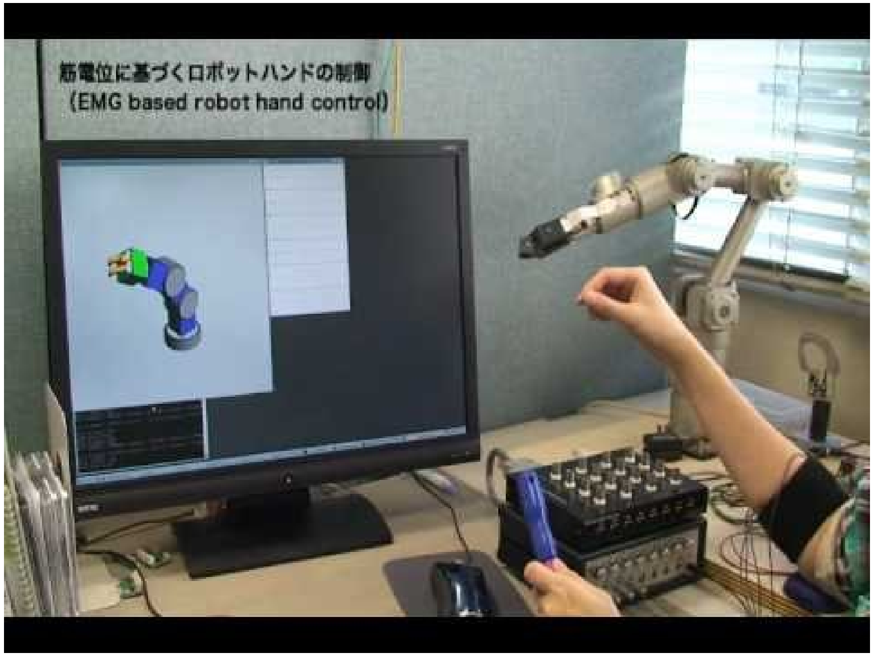
Electromyogram (EMG)

- EMG signals have been targeted as control for flight systems.

- The Human Senses Group at the NASA Research Center at Moffett Field, CA seeks to advance man-machine interfaces by directly connecting a person to a computer.

  - An EMG signal is used to substitute for mechanical joysticks and keyboards.

- EMG has also been used in research towards a "wearable cockpit," which employs EMG-based gestures to manipulate switches and control sticks necessary for flight in conjunction with a goggle-based display.



Biopotential Electrodes

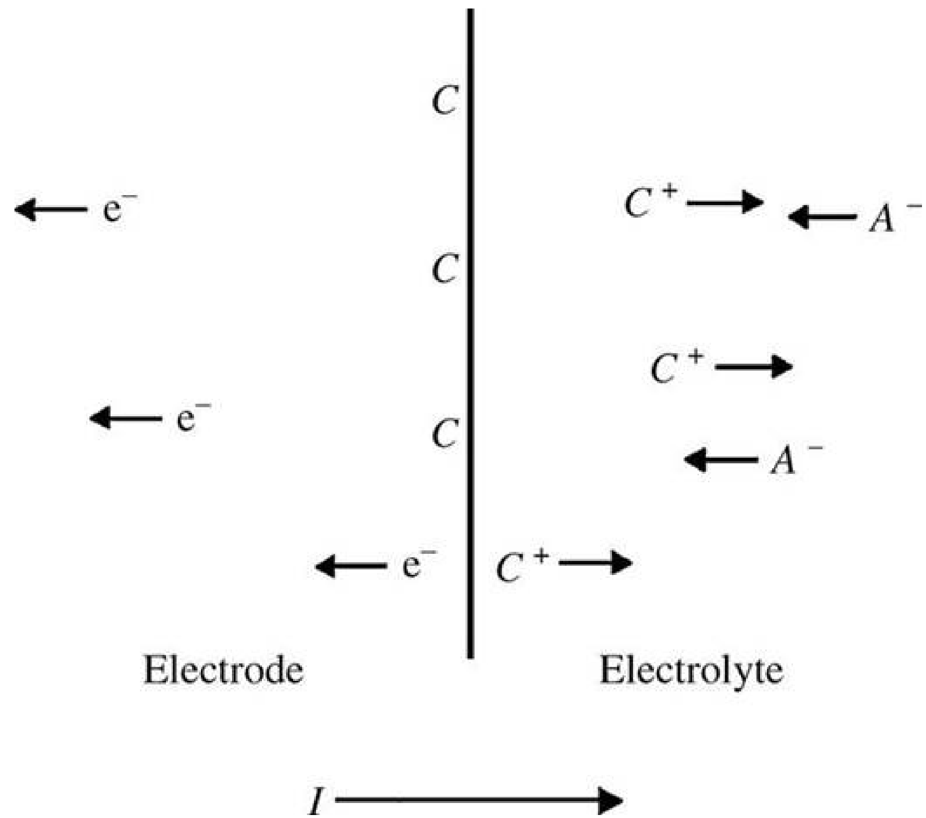
-Bioelectric potential generated in the body are ionic potential.
- A transducer that convert the body ionic current in the body into the traditional electronic current flowing in the electrode.
-Able to conduct small current across the interface between the body and the electronic measuring circuit.
-A net current that crosses the interface, passing from the electrode to electrolyte consist of
-1 electrons moving in a direction opposite to that of current in the electrode
-2 cations moving in the same direction
-3 Anios moving in direction opposite to that of current in electrolyte

Electrode–electrolyte interface

The current crosses it from left to right.

The electrode consists of metallic atoms C.

The electrolyte is an aqueous solution containing cations of the electrode metal C+ and anions A–.



$$C \rightleftarrows C^{n+} + ne^{-} \qquad A^{m-} \rightleftarrows A + me^{-}$$

where *n* is the valence of C and *m* is valence of A

Electrode-Electrolyte Interface

Oxidation reaction causes atom to lose electron
Reduction reaction causes atom to gain electron

Oxidation is dominant when the current flow is from electrode to electrolyte, and reduction dominate when the current flow is in the opposite.

- Electrode is made up of same atoms of the same material as the cations

Half-Cell Potential

- When the metal comes in contact with solution, The electrolyte surrounding the metal is at different electric potential from rest of the solution.
- A second electrode is required to find halfcell potential- hydrogen
- Half-Cell potential is determined by

- Metal involved
- Concentration of its ion in solution
- Temperature

Half-Cell Potential

Half-cell potential for common electrode materials at 25 °C

reduction reaction	E^o (V)
$Al^{3+} + 3e^- \rightarrow Al$	-1.662
$Zn^{2+} + 2e^- \rightarrow Zn$	-0.762
$Cr^{3+} + 3e^- \rightarrow Cr$	-0.744
$Fe^{2+} + 2e^- \rightarrow Fe$	-0.447
$Cd^{2+} + 2e^- \rightarrow Cd$	-0.403
$Ni^{2+} + 2e^- \rightarrow Ni$	-0.257
$Pb^{2+} + 2e^- \rightarrow Pb$	-0.126
$2H^+ + 2e^- \rightarrow H_2$	0.000
$AgCl + e^- \rightarrow Ag + Cl^-$	$+0.222$
$Hg_2Cl_2 + 2e^- \rightarrow 2Hg + 2Cl^-$	$+0.268$
$Cu^{2+} + 2e^- \rightarrow Cu$	$+0.342$
$Cu^+ + e^- \rightarrow Cu$	$+0.521$
$Ag^+ + e^- \rightarrow Ag$	$+0.780$
$Au^{3+} + 3e^- \rightarrow Au$	$+1.498$
$Au^+ + e^- \rightarrow Au$	$+1.692$

← Standard Hydrogen electrode

Electrochemists have adopted the Half-Cell potential for hydrogen electrode to be zero. Half-Cell potential for any metal electrode is measured with respect to the hydrogen electrode.

Polarization

Half cell potential is altered when there is current flowing in the electrode due to electrode polarization.

Overpotential is the difference between the observed half-cell potential with current flow and the equilibrium zero-current half-cell potential.

Mechanism Contributed to overpotential

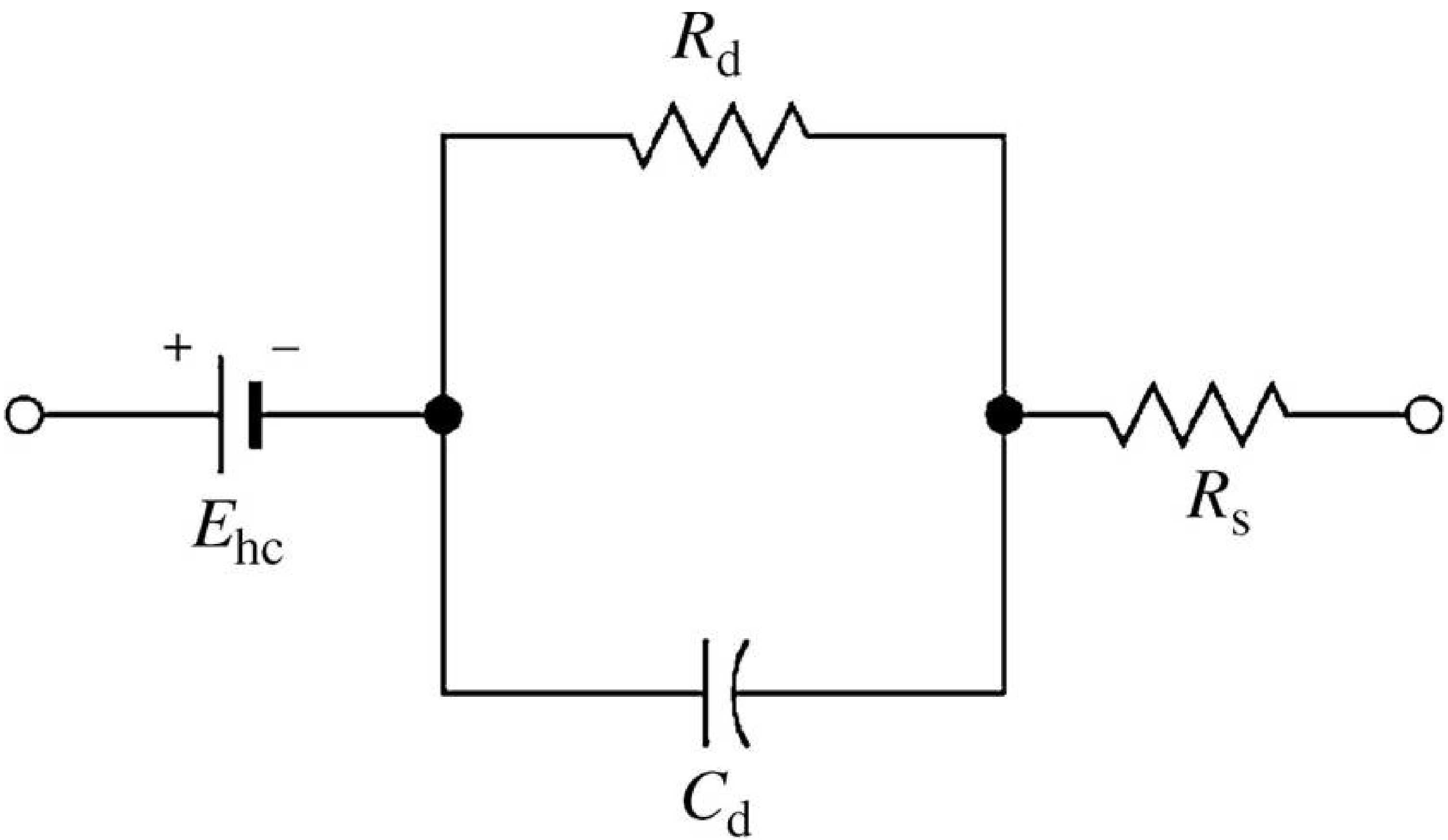
- **Ohmic overpotential**: voltage drop along the path of the current, and current changes resistance of electrolyte and thus, a voltage drop does not follow ohm's law.

- **Concentration overpotential:** Current changes the distribution of ions at the electrode-electrolyte interface

- **Activation overpotential:** current changes the rate of oxidation and reduction. Since the activation energy barriers for oxidation and reduction are different, the net activation energy depends on the direction of current and this difference appear as voltage.

$$V_p = V_R + V_C + V_A$$

Equivalent circuit for a biopotential electrode in contact with an electrolyte



E_{hc} is the half-cell potential,
R_d and C_d make up the impedance associated with the electrode-electrolyte interface and polarization effects,
Rs is the series resistance associated with interface effects and due to resistance in the electrolyte.

Half Cell Potential and Nernst Equation

When two ionic solutions of different concentration are separated by semipermeable membrane, an electric potential exists across the membrane.

$$E = -\frac{RT}{nF}\ln\left[\frac{a_1}{a_2}\right]$$

a_1 and a_2 are the activity of the ions on each side of the membrane.

Ionic activity is the availability of an ionic species in solution to enter into a reaction.

Note: ionic activity most of the time equal the concentration of the ion

If the activity is not unity (activity does not equal concentration) then the cell potential is

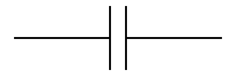
$$C \rightarrow C^{n+} + ne^{-} \qquad E = E_0 + \frac{RT}{nF}\ln\left[a_{C^{n+}}\right]$$

For the general oxidation-reduction reaction, the Nernst equation for half cell potential is

$$\alpha A + \beta B \leftrightarrow \gamma C + \delta D + ne^{-} \qquad E = E^0 + \frac{RT}{nF}\ln\left[\frac{a_C^{\gamma} a_D^{\delta}}{a_A^{\alpha} a_B^{\beta}}\right]$$

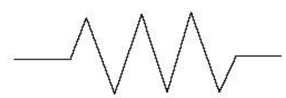
Polarizable and Nonpolarizable Electrodes

Perfectly Polarizable Electrodes



Electrodes in which no actual charge crosses the electrode-electrolyte interface when a current is applied. The current across the interface is a displacement current and the electrode behaves like a capacitor. Overpotential is due concentration. **Example** : Platinum electrode

Perfectly Non-Polarizable Electrode



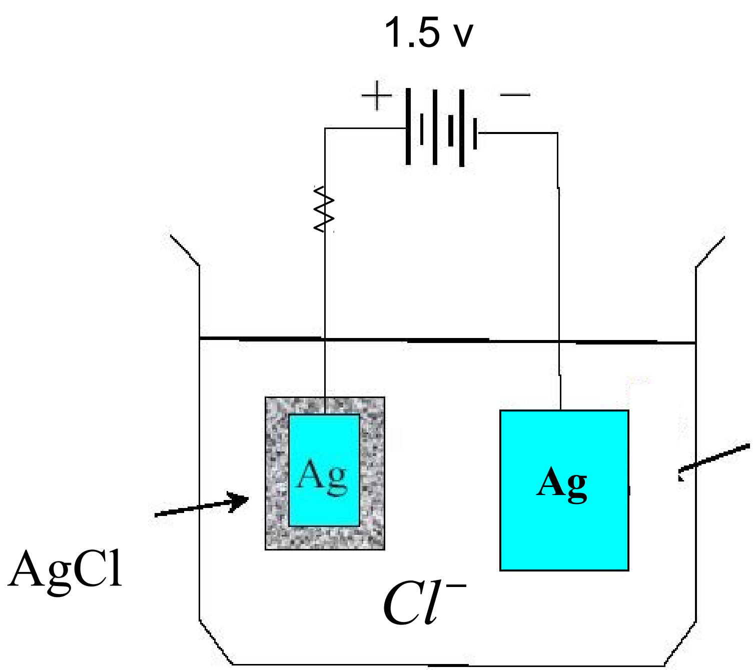
Electrodes in which current passes freely across the electrode-electrolyte interface, requiring no energy to make the transition. These electrodes see no overpotentials. **Example:** Ag/AgCl Electrode

Example: Ag-AgCl is used in recording while Pt is used in stimulation

The Silver/Silver Chloride Electrode

Approach the characteristic of a perfectly nonpolarizable electrode

Advantage of Ag/AgCl is that it is stable in liquid that has large quantity of Cl^- such as the biological fluid.

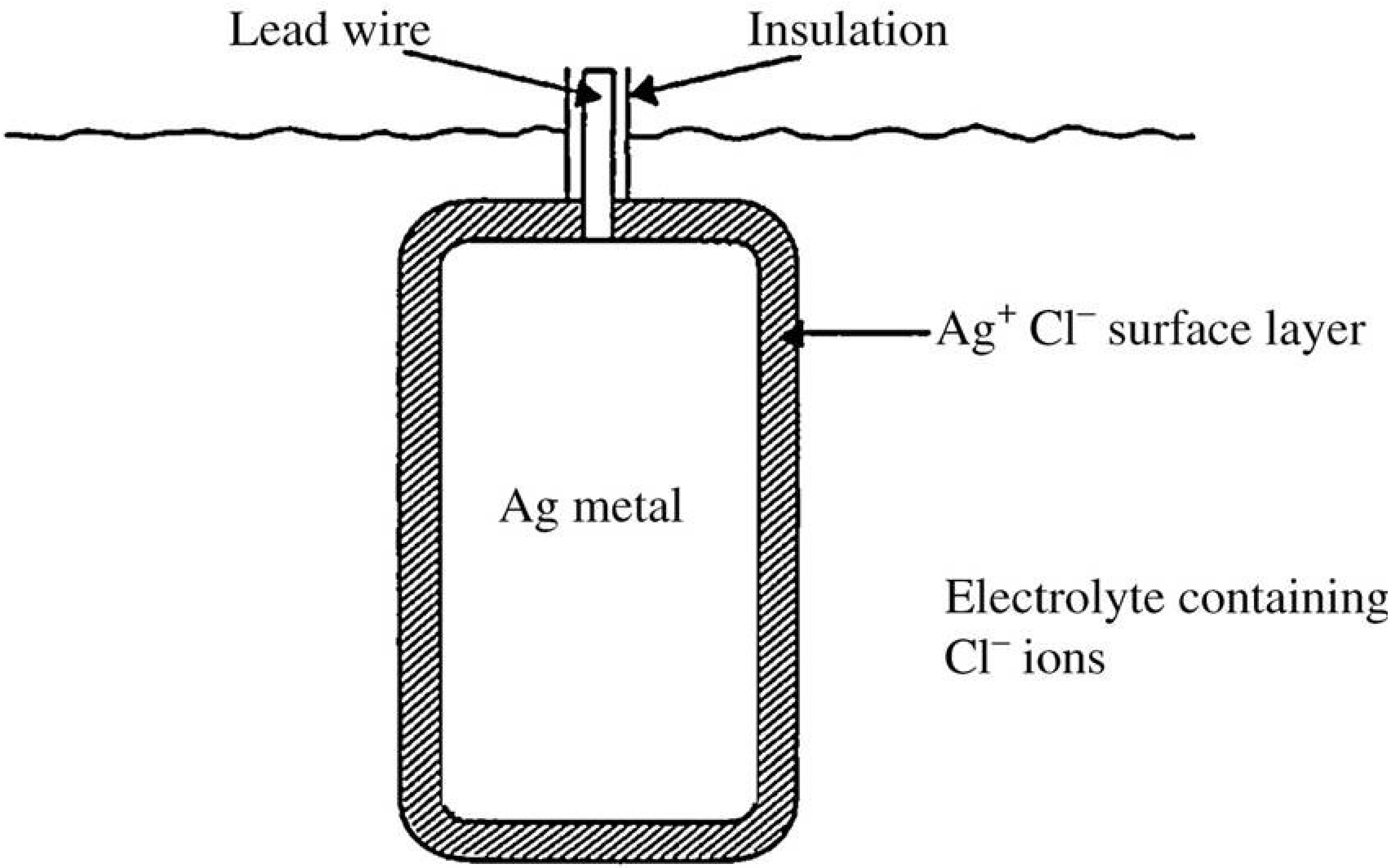


$$Ag \leftrightarrow Ag^+ + e^-$$

$$Ag^+ + Cl^- \leftrightarrow AgCl \downarrow$$

Ag/AgCl exhibits less electric noise than the equivalent metallic Ag electrode.

A silver/silver chloride electrode, shown in cross section

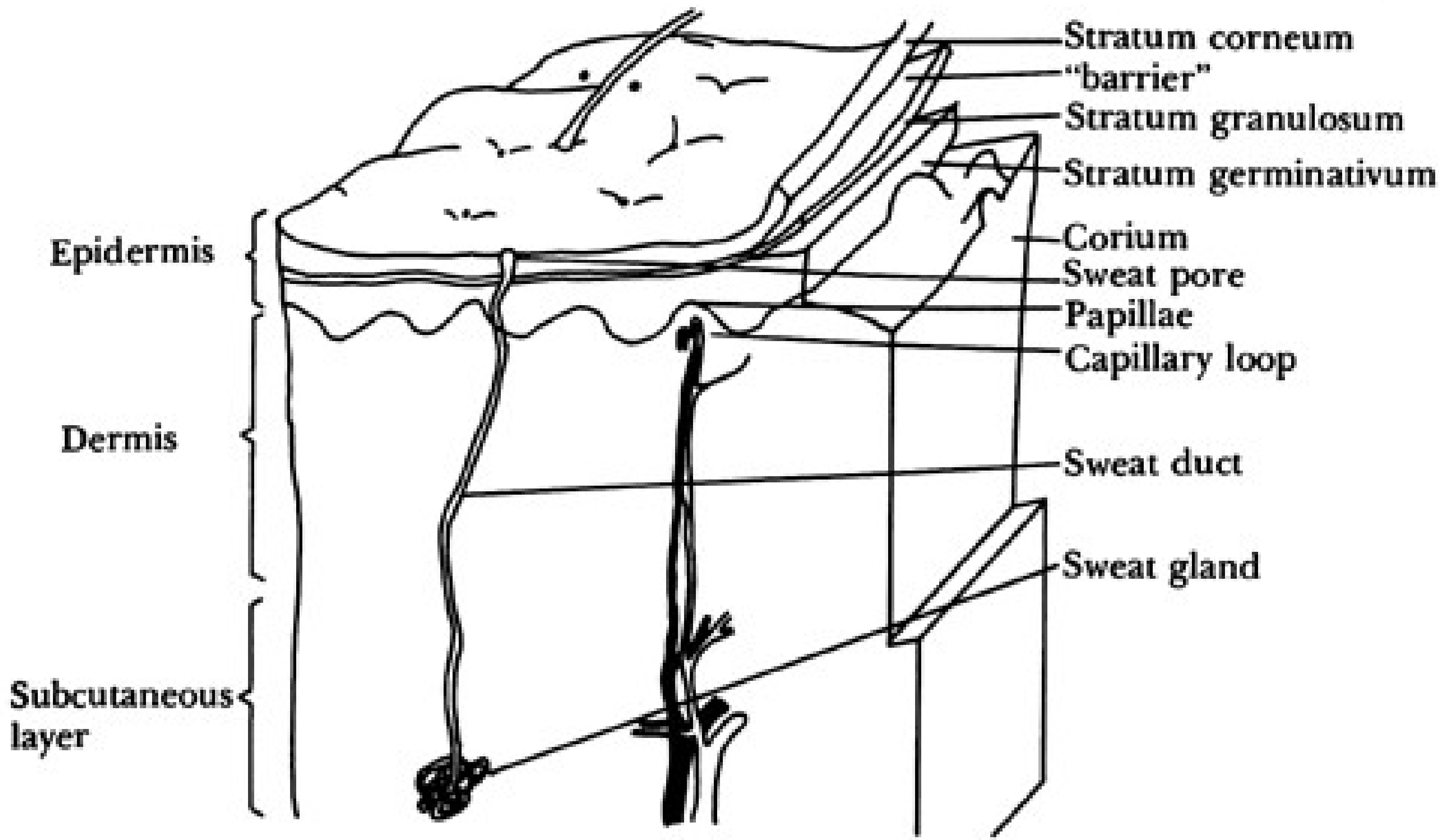


Properties of bioelectrodes

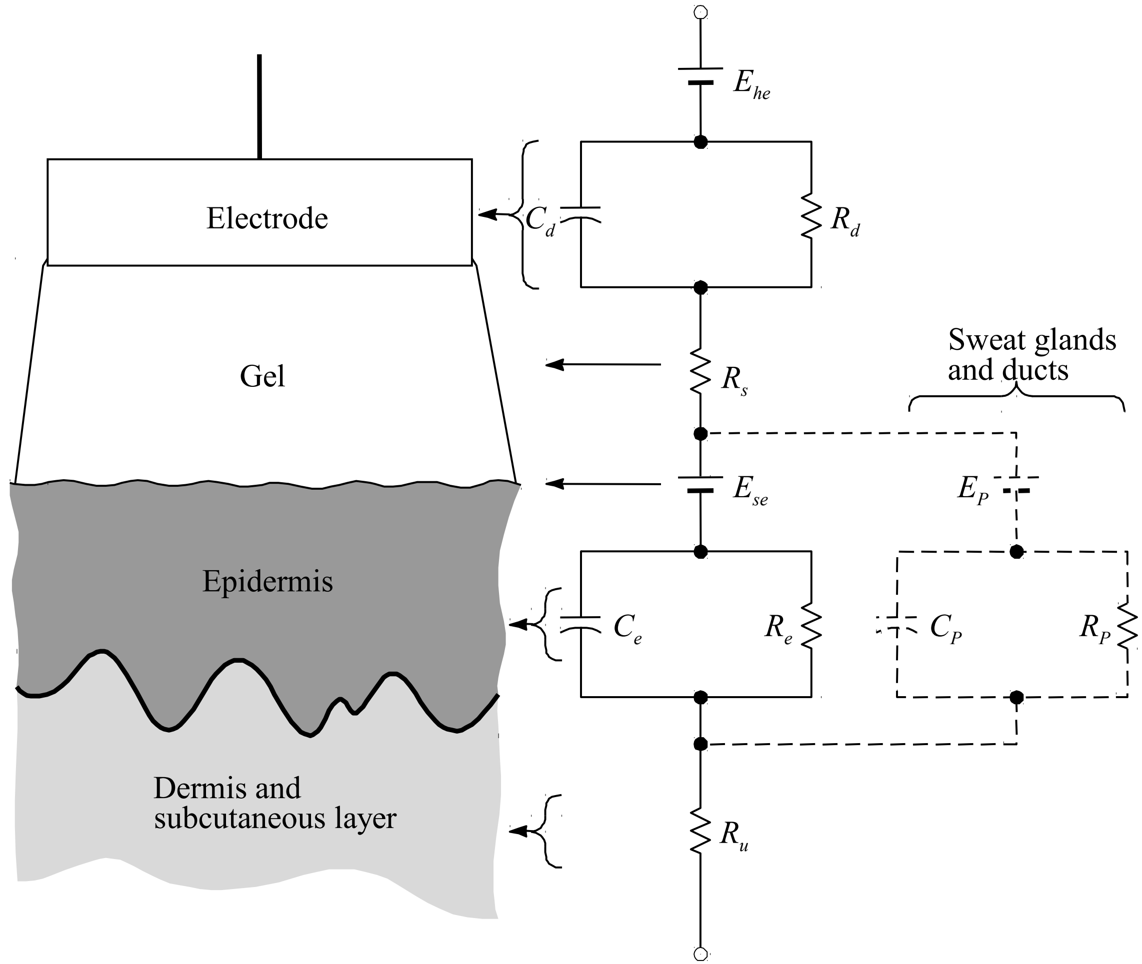
- Good conductors.
- low impedance.
- They should not polarize when a current flows through them.
- They should establish a good contact with the body and not cause motion.
- They should not cause itching swelling or discomfort to the patient.
- The metal should not be toxic.
- Mechanically rugged.
- Easy to clean.

The Electrode-Skin Interface and Motion Artifact

Transparent electrolyte gel containing Cl^- is used to maintain good contact between the electrode and the skin.



The Electrode-Skin Interface



For 1 cm^2, skin impedance reduces from approximately 200KΩ at 1Hz to 200Ω at 1MHz.

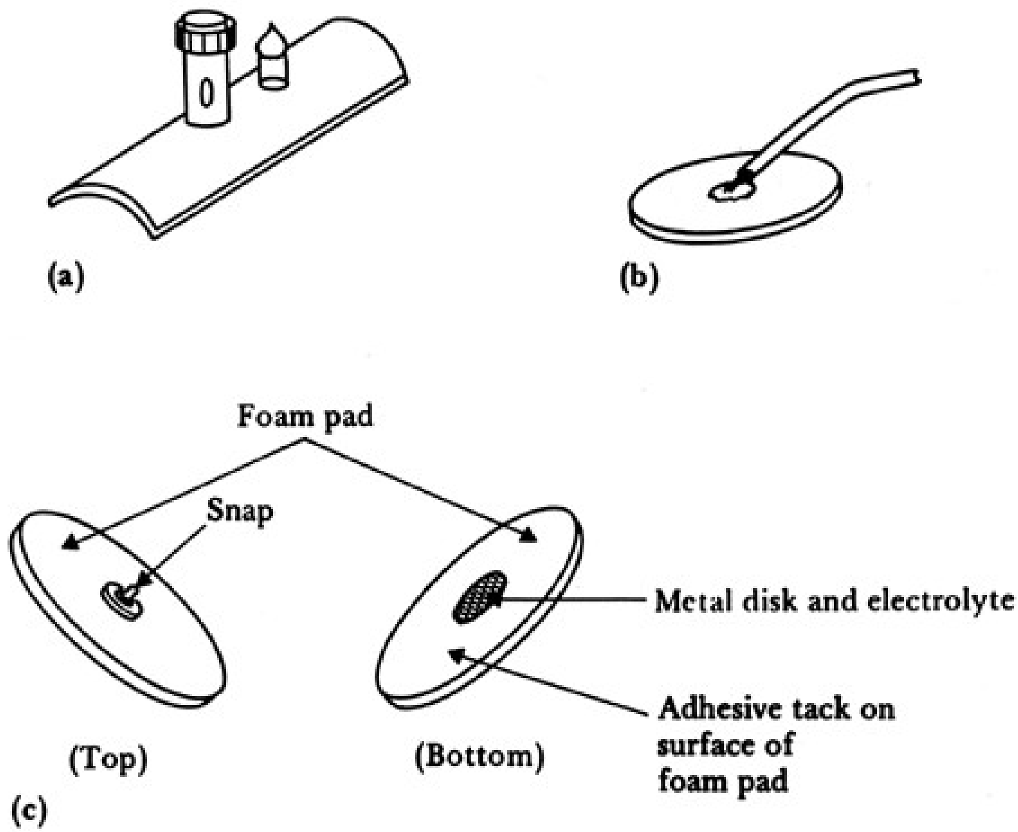
Motion Artifact

When polarizable electrode is in contact with an electrolyte, a double layer of charge forms at the interface. Movement of the electrode will disturb the distribution of the charge and results in a momentary change in the half cell potential until equilibrium is reached again. Motion artifact is less minimum for nonpolarizable electrodes.

Signal due to motion has low frequency so it can be filtered out when measuring a biological signal of high frequency component such as EMG or axon action potential. However, for ECG, EEG and EOG whose frequencies are low it is recommended to use nonpolarizable electrode to avoid signals due to motion artifact.

Body-Surface Recording Electrode

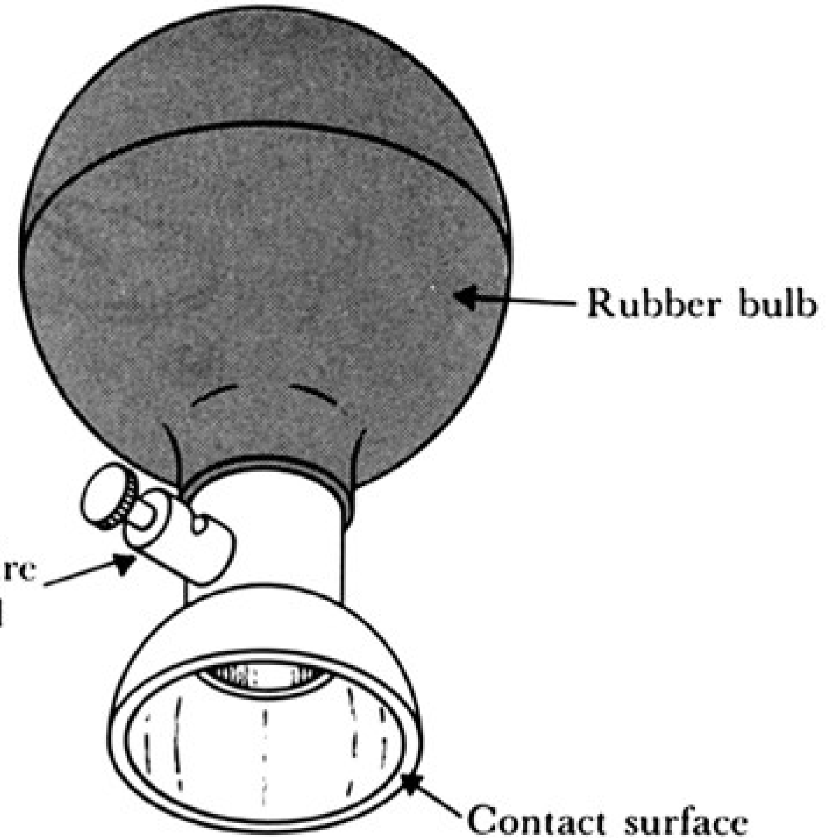
Metal-Plate Electrodes



Body-surface biopotential electrodes (a) Metal-plate electrode used for application to limbs. (b) Metal-disk electrode applied with surgical tape. (c) Disposable foam-pad electrodes, often used with electrocardiograph monitoring apparatus.

Body-Surface Recording Electrode

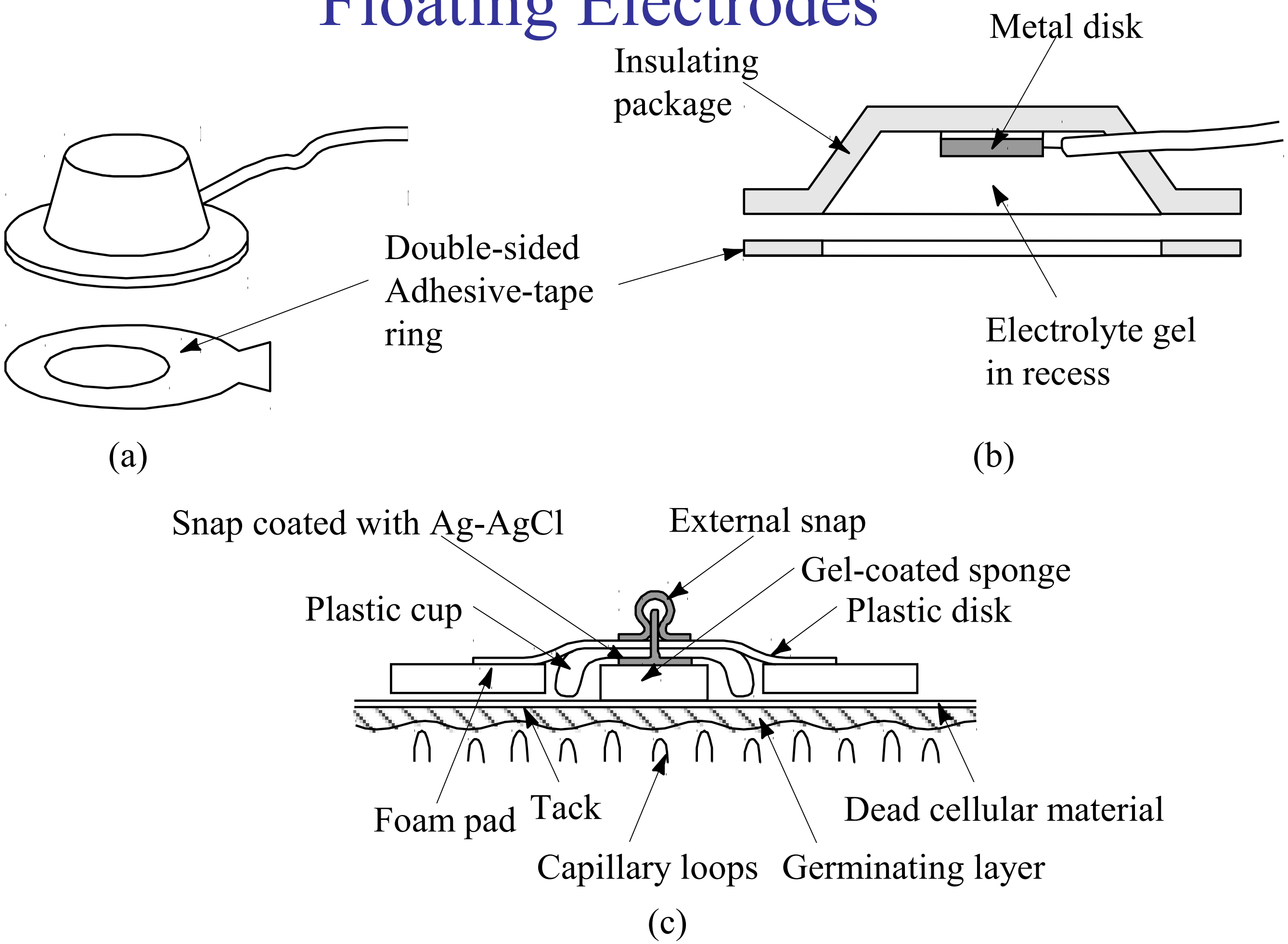
Suction Electrodes



A metallic suction electrode is often used as a precordial electrode on clinical electrocardiographs. **No need for strap or adhesive** and can be **used frequently**. **Higher source impedance** since the contact area is small

Body-Surface Recording Electrode

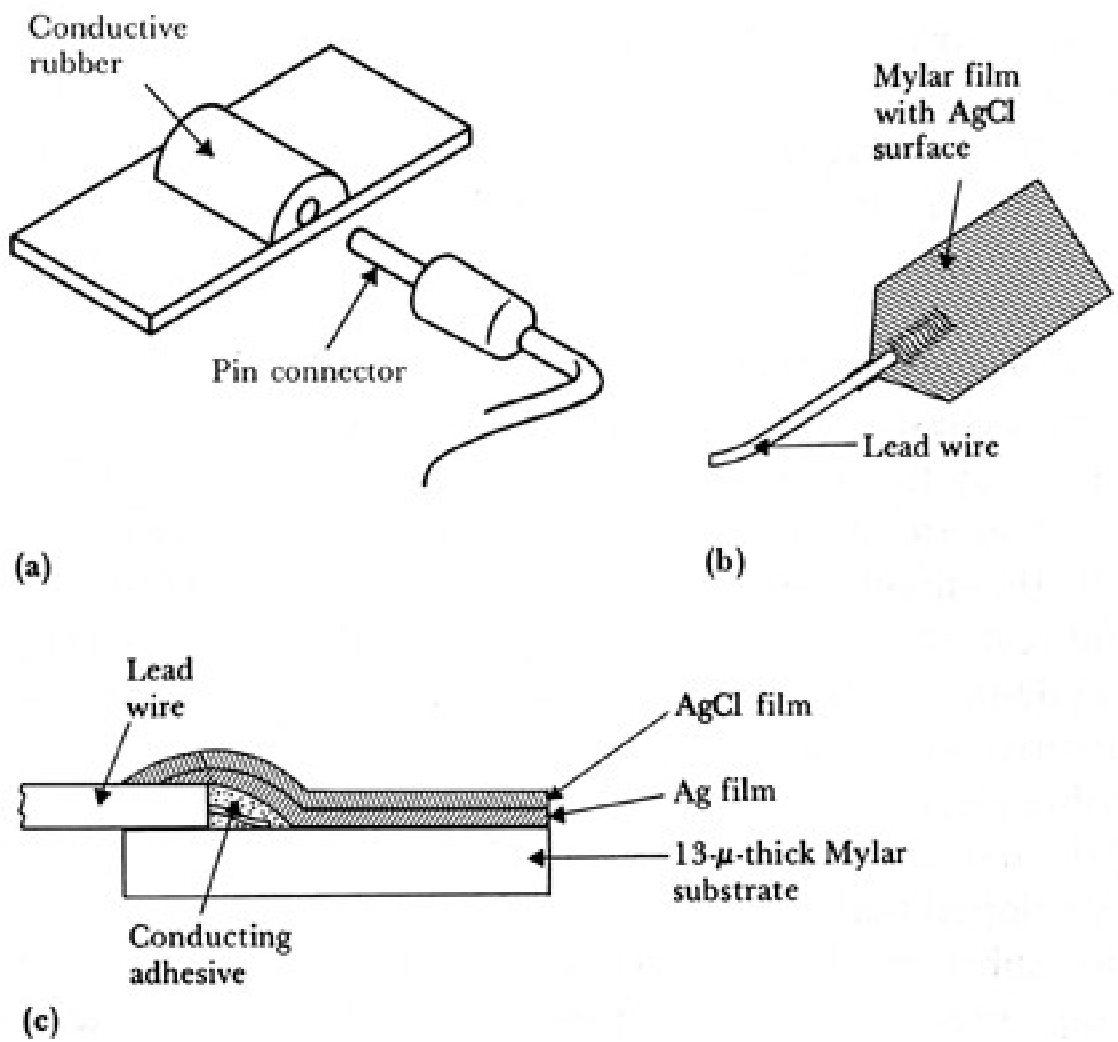
Floating Electrodes



The recess in this electrode is formed from an open foam disk, saturated with electrolyte gel and placed over the metal electrode. **Minimize motion artifact**

Body-Surface Recording Electrode

Flexible Electrodes



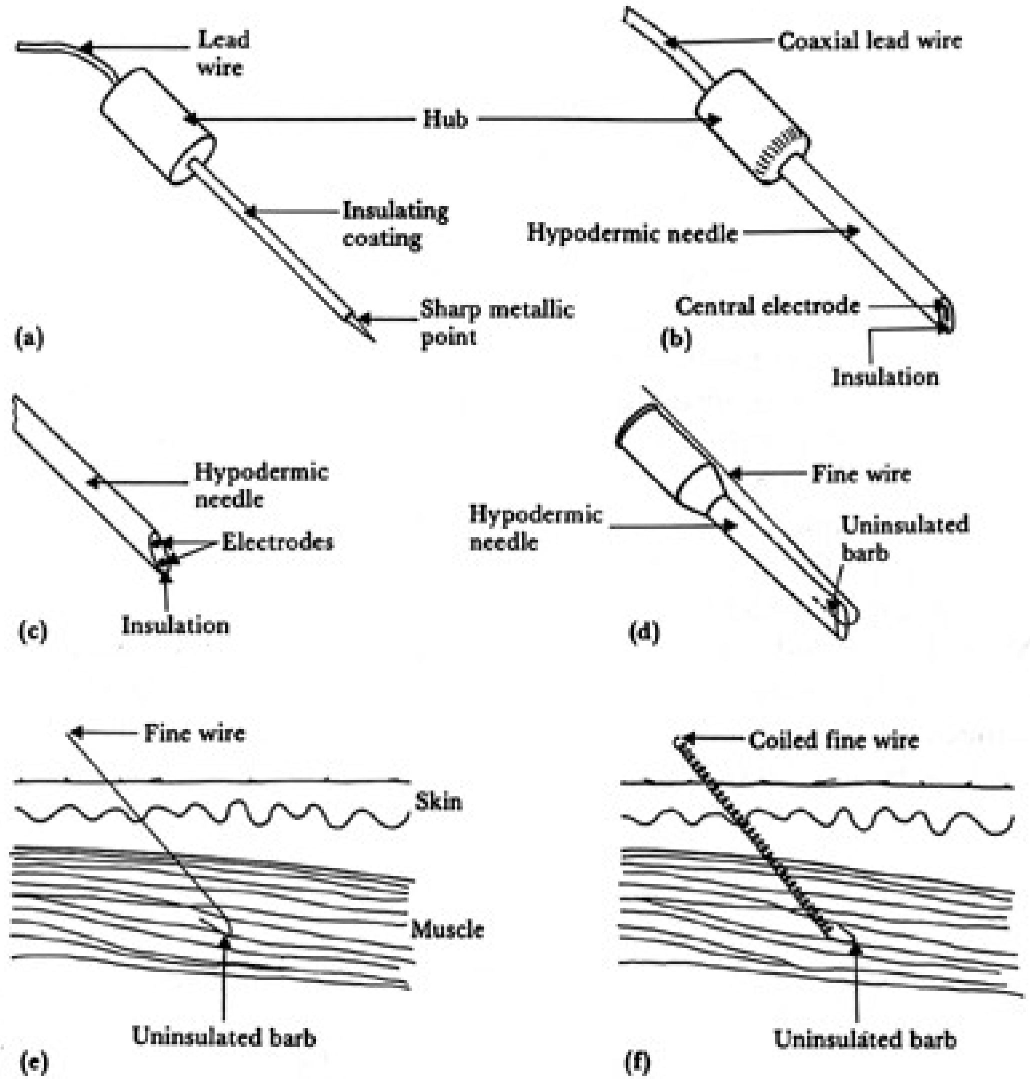
Flexible body-surface electrodes (a) Carbon-filled silicone rubber electrode. (b) Flexible thin-film neonatal electrode. (c) Cross-sectional view of the thin-film electrode in (b).

Used for **newborn infants**.
Compatible with X-ray
Electrolyte hydrogel material is used to hold electrodes to the skin.

Internal Electrodes

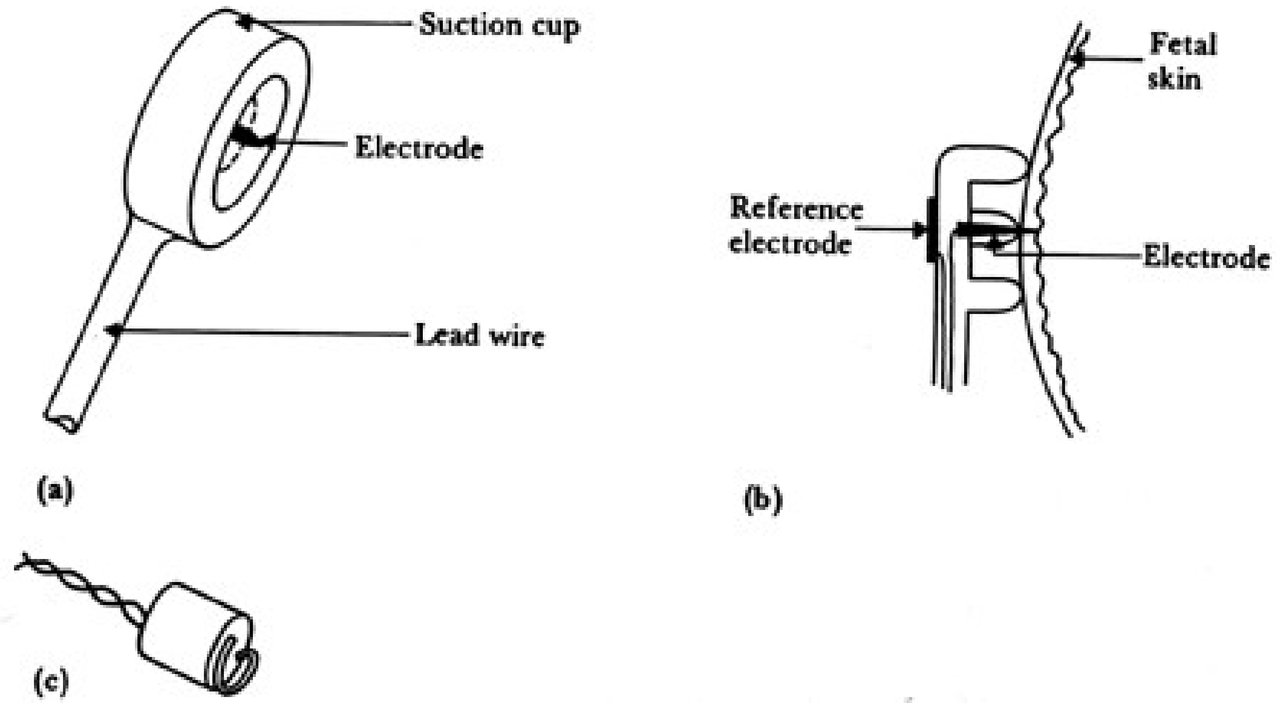
No electrolyte-skin interface
No electrolyte gel is required

Needle and wire electrodes for percutaneous measurement of biopotentials (a) Insulated needle electrode. (b) Coaxial needle electrode. (c) Bipolar coaxial electrode. (d) Fine-wire electrode connected to hypodermic needle, before being inserted. (e) Cross-sectional view of skin and muscle, showing coiled fine-wire electrode in place.



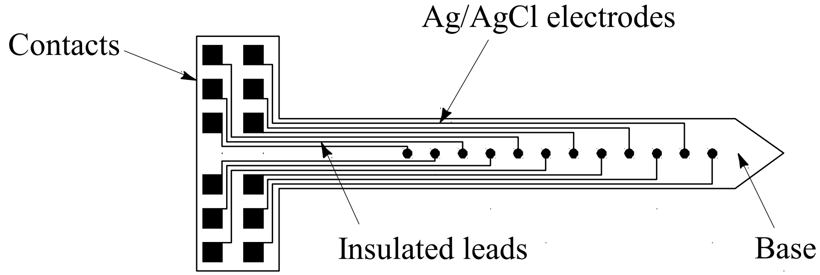
For EMG Recording

Internal Electrodes

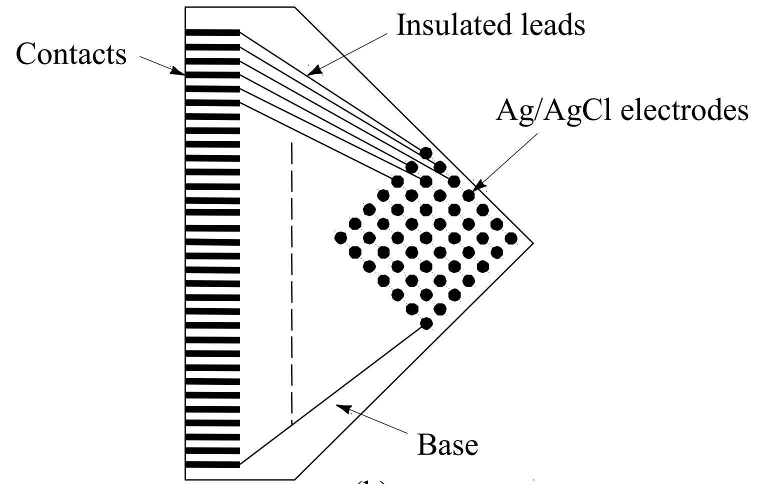


Electrodes for detecting fetal electrocardiogram during labor, by means of intracutaneous needles (a) Suction electrode. (b) Cross-sectional view of suction electrode in place, showing penetration of probe through epidermis. (c) Helical electrode, which is attached to fetal skin by corkscrew type action.

Electrode Arrays

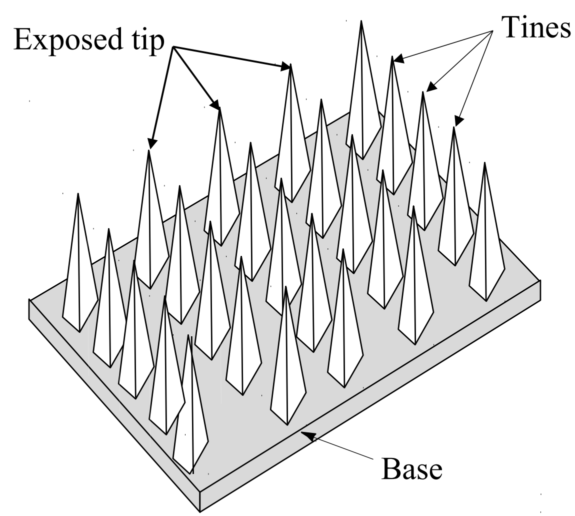


(a)



(b)

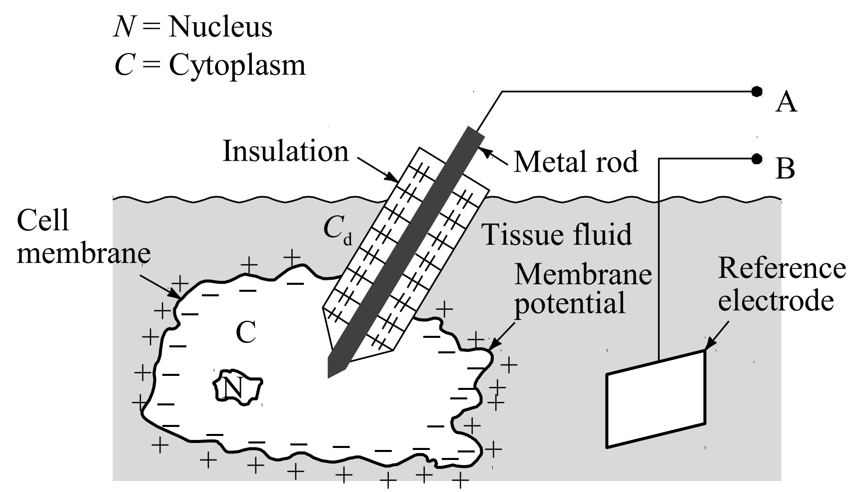
(a) One-dimensional plunge electrode array 10mm long, 0.5mm wide, and 125μm thick, used to measure potential distribution in the beating myocardium (b) Two-dimensional array, used to map epicardial potential and (c) Three-dimensional array, each tine is 1,5 mm



(c)

Microelectrodes

Used in studying the electrophysiology of excitable cells by measure potential differences across the cell membrane.

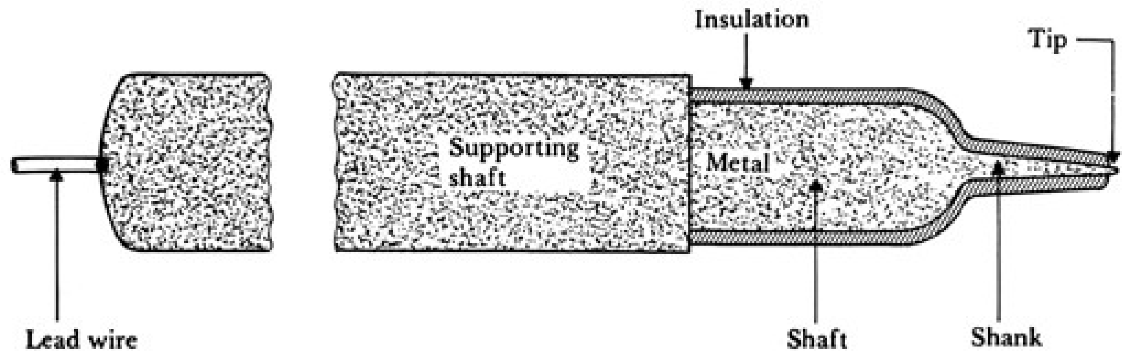


Electrode need to be small and strong to penetrate the cell membrane without damaging the cell.

Tip diameters = 0.05 to 10 μm

Microelectrodes

The structure of a metal microelectrode for intracellular recordings.



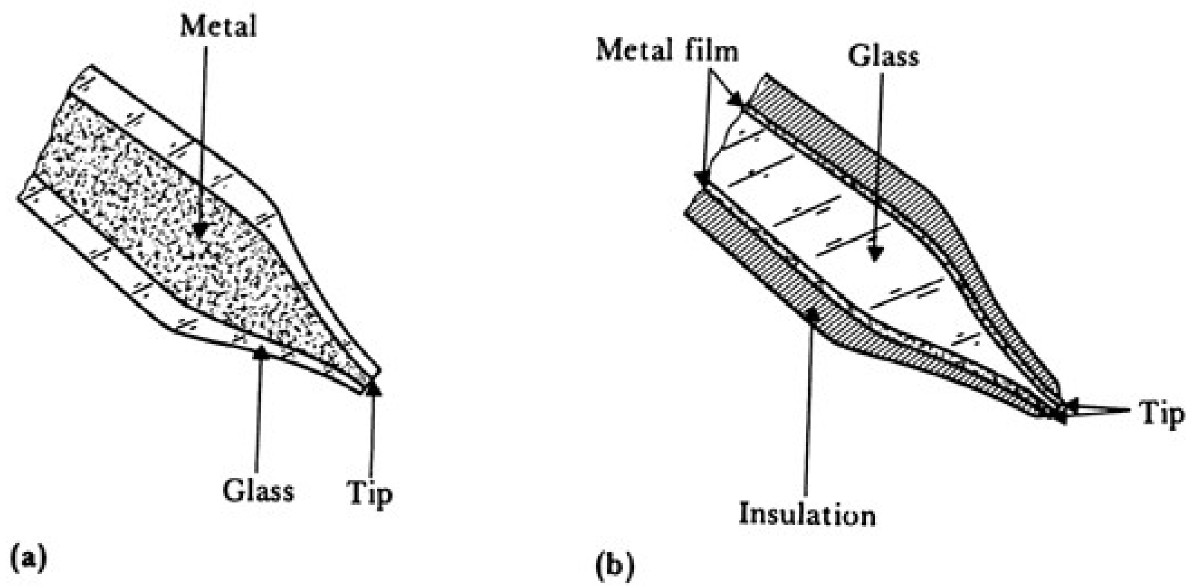
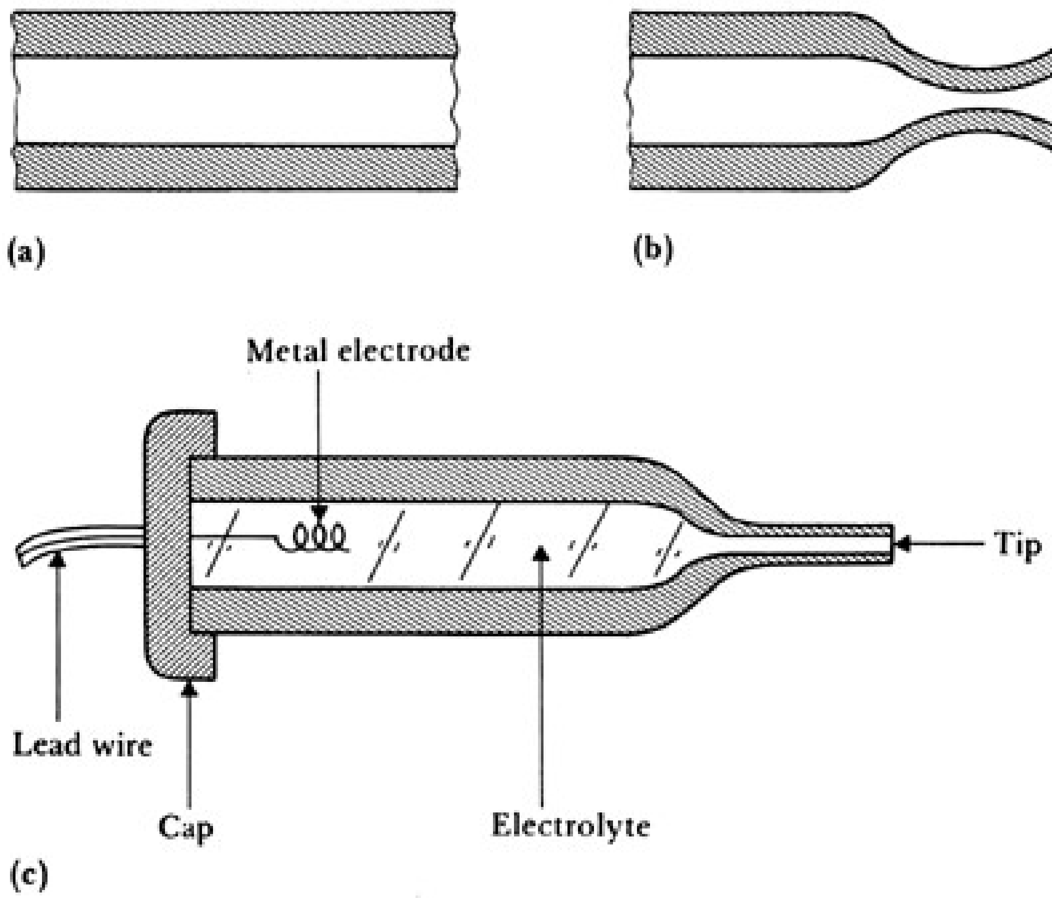


Figure 5.18 Structures of two supported metal microelectrodes (a) Metal-filled glass micropipet. (b) Glass micropipet or probe, coated with metal film.

Microelectrodes



A glass micropipet electrode filled with an electrolytic solution (a) Section of fine-bore glass capillary. (b) Capillary narrowed through heating and stretching. (c) Final structure of glass-pipet microelectrode.

Practical Hints in using Electrodes

- Electrode and any part of the lead wire that may be exposed to the electrolyte must be all of the same material.
- Third material such as solder should not be used to connect the electrode to its lead wire
- Provide mechanical bonding
- When pairs of electrodes are used for measuring differentials,its better to use the same material for each electrode.
- Electrodes placed on the skin's surface have a tendancy to come off.
- Lead wires to electrodes should be flexible.

Practical Hints in using Electrodes

- Insulation of these electrodes usually made of a polymeric material, so it can absorb water.
- The input impedance of amplifier to which the electrodes are connected must be higher than the source impedance.

Biopotential Amplifiers

- The essential function of a biopotential amplifier is to take a weak electric signal of biological origin.
- They Must have high input impedance. (10 M ohm)
- The input circuit of a biopotential amplifier must also provide protection to the organism being studied.
- The output circuit of a biopotential amplifier does not present so many critical problems as the input circuit.
- Biopotential amplifiers must operate in that portion of the frequency spectrum in which the biopotentials that they amplify exist.
- Quick calibration