Lecture (5 & 6)

Medical Physics

Fourth Stage

Department of Physics

College of Science

Al-Muthanna University

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Dr. Ahmed Almurshedi

Ph.D., M.Sc., B.Sc.

Medical Physics

Electricity within the Body

Resting and action Potentials

Resting Potential

- Surrounding the cells of the body are the body fluid which are ionic and which are provide a conductive medium for electric potential. The principle ions are sodium (Na^+), potassium (K^+) and chloride ions (Cl^-).
- The membrane of the cell is permits entry of K^+ and Cl^- ions but blocks the entry of Na^+ ions. So, the result is the concentration of sodium Na^+ ions more on the outside of the cell membrane than on the inside. Since the cell has negative charge along the inner surface of its membrane and positive charge along the outer surface. This membrane potential is called resting potential, and the membrane potential is generally made from inside the cell. So, the cell in resting potential have negative (-60 to -100) mv.
- The cell in the resting potential is said to be polarized.

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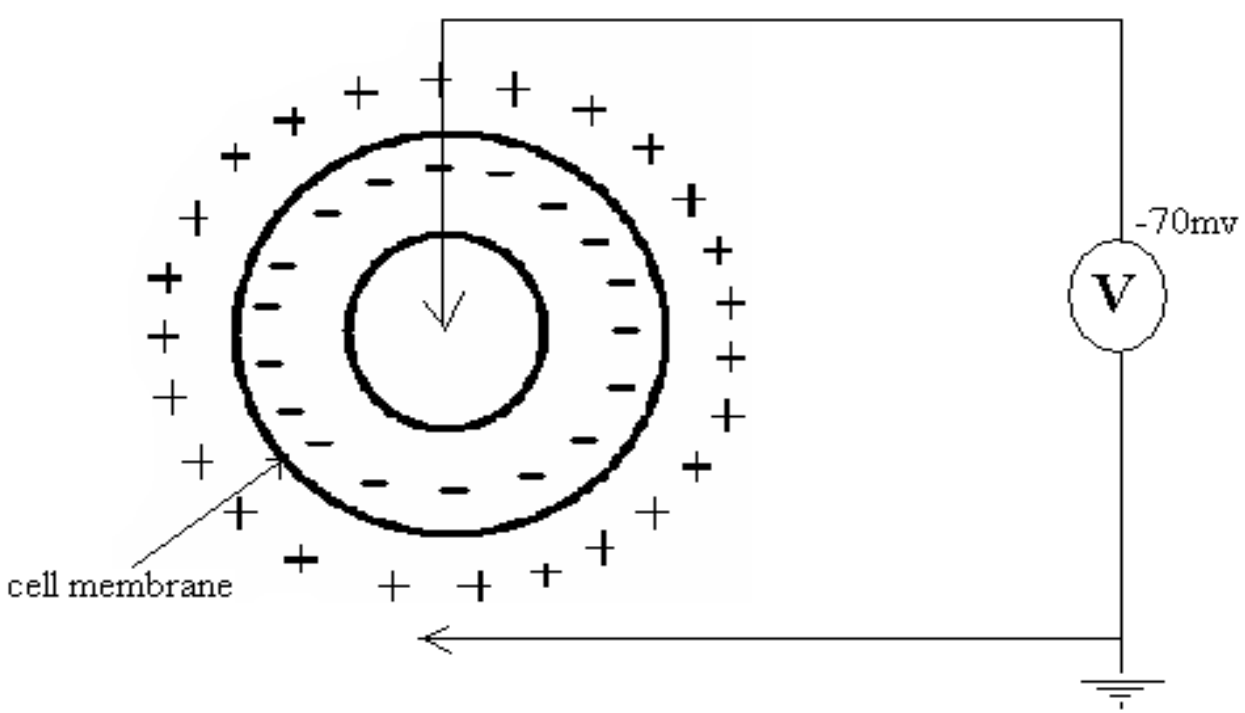
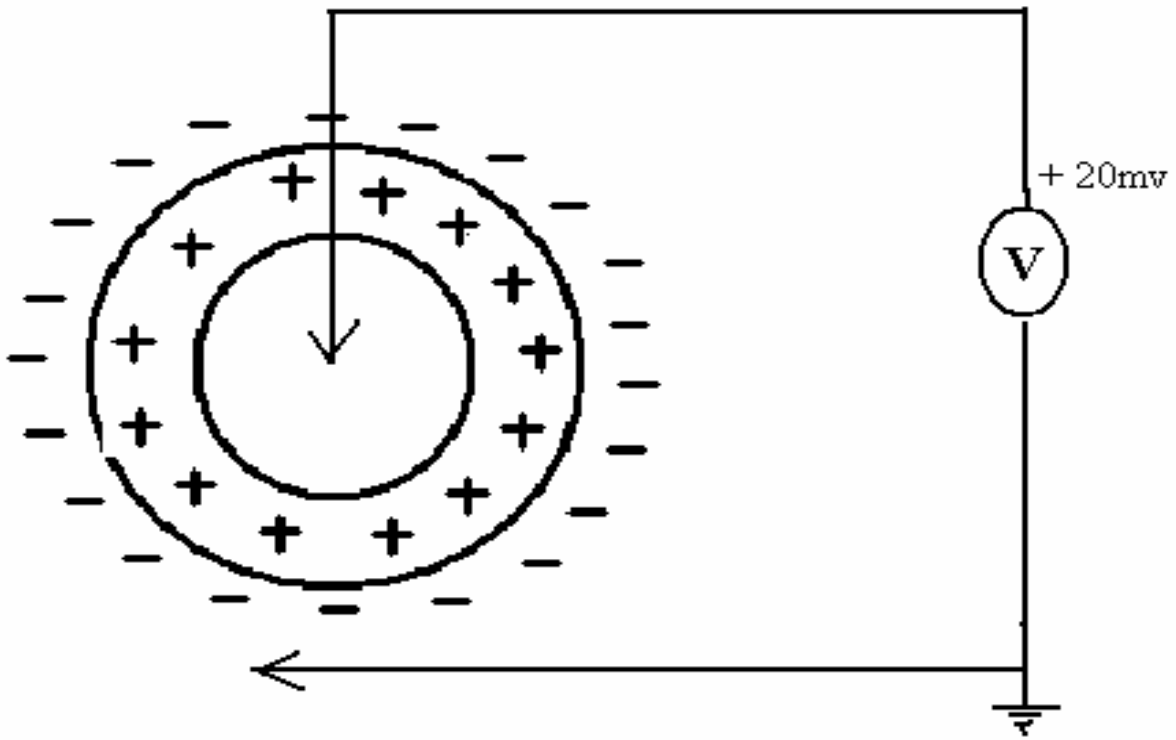
Resting Potential



Action Potential



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Action Potential

- When a section of the cell is excited by the flow of ionic current or by some form of externally applied energy to membrane charges its characteristics and being to allow some of Na^+ to enter. At the same time K^+ ions which were inside the cell during the resting potential try to leave the cell.
- As a result the cell has slightly positive potential in the inside. This potential is known as Action potential (+20 mv). The cell in this case is said to be Depolarization.
- By an active process called sodium pumps the Na^+ ionsquickly transported to the outside and the cell again becomes polarized and assumes its resting potential.
- This process is called as Repolarization.

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Wave of the resting and action Potentials

Note: The time scale of the action potential depends on the type of cell producing the potential as in the example (table) below.

Cell type	Potential (mv)
RBC	-30
Neuron	-70
Muscle	-90
Plant cell	-120

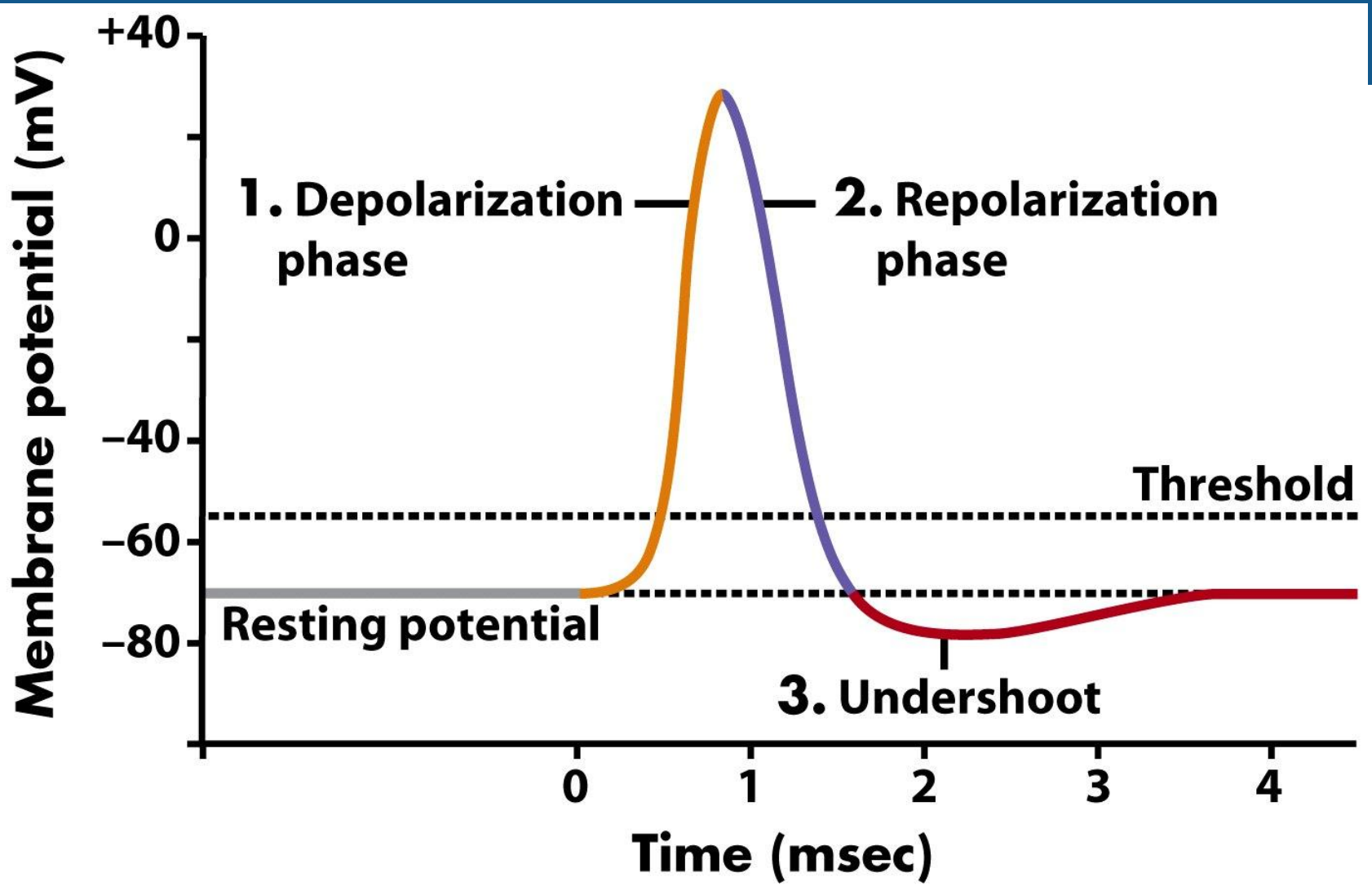

Figure 45-5 Biological Science, 2/e

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Nernst Equation

It gives potential across membrane and two concentration of ions:

$$E = \frac{RT}{zF} \log e^{\frac{c_o}{c_i}}$$

$$E = \frac{RT}{zF} \times 2.303 \ \log_{10} \frac{c_o}{c_i}$$

Where:

- E is potential inside the cell with respect to outside.
- R is gas constant $8.3 \times 10^7 \ erg \ mol \ /k$
- T is absolute temperature in K.
- Z is valance of electron.
- F is Faraday's constant (96500 C)

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- c_o, c_i is concentrations of ions outside and inside respectively.
- At Room Temperature = 27 C = 300 K

$$\frac{R\,T}{z\,F} = \frac{300 \times 8.3}{1 \times 96500}$$

$$\frac{R\,T}{z\,F} \times 2.303 = \frac{300 \times 8.3 \times 2.303}{96500} = 59\,mv$$

$$E = 59 \log_{10} \frac{c_o}{c_i}$$

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1- Electroencephalogram (EEG)

- It is the recording of electrical activity from the brain.
- The electrodes used for recording of EEG are small discs of chlorinated silver. They are attached to the scalp at a location that depend upon part of the brain to be studied.
- Signals due to electrical activity of neuron in the cortex of brain.
- Amplitude of EEG ≈ 50 μv.
- Movement of eye cause artifact in the recording.
- EEG composed of the following frequency range:

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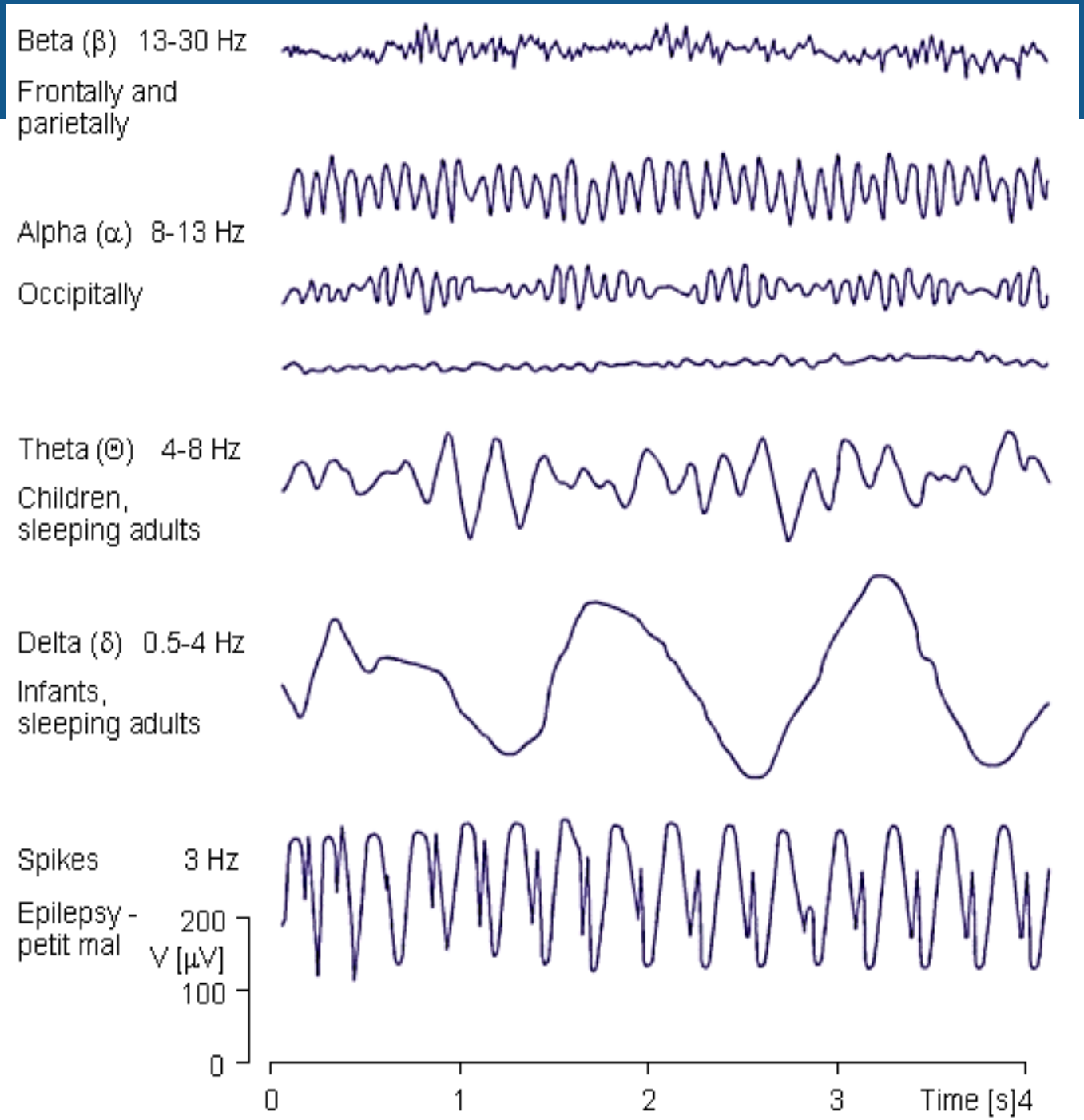

- **EEG is used:**

1. In the diagnosis of diseases involving brain.
2. In the diagnosis of epilepsy.
3. In confirming brain tumors.
4. In study of mental disorder.
5. As monitor in surgery when ECG cannot be used.
6. In surgery for indicating the anesthesia level of the patient.

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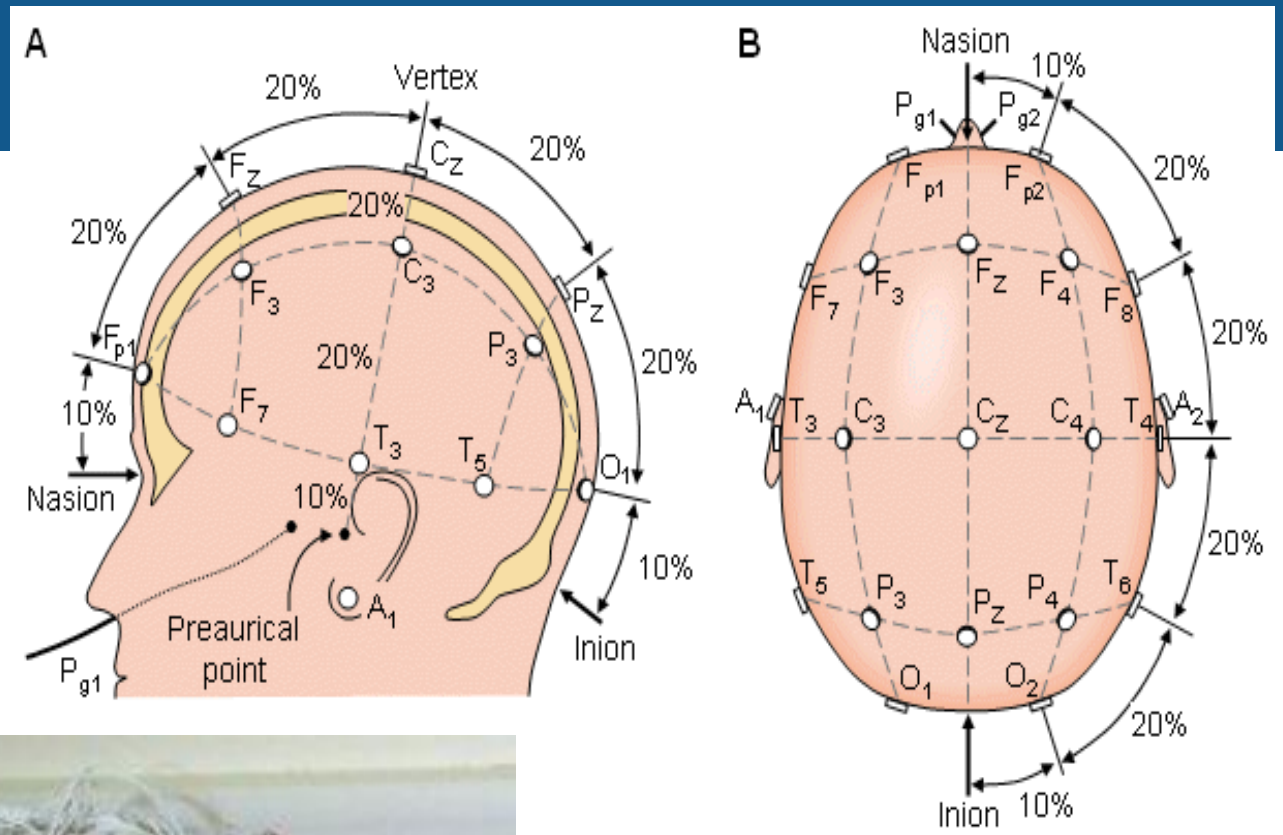

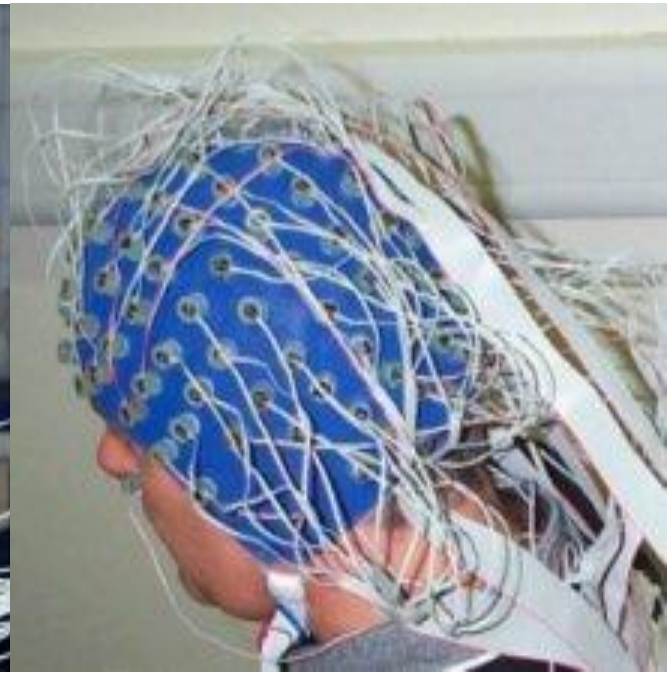

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2- Electrocardiogram (ECG)

- Recording of electro chemical activity associated with the functioning of the heart. ECG is a representation of electrical events of the cardiac cycle. It provides valuable information about heart disease.

- In ECG there are five electrodes attached to the body:

  1. Right arm (RA)
  2. Left arm (LA)
  3. Right leg (RL)
  4. Left leg (LL)
  5. Chest (v)

- From ECG we can calculate: $\boldsymbol{Heart\ rate = \frac{chart\ speed}{R-R\ interval} \times 60}$

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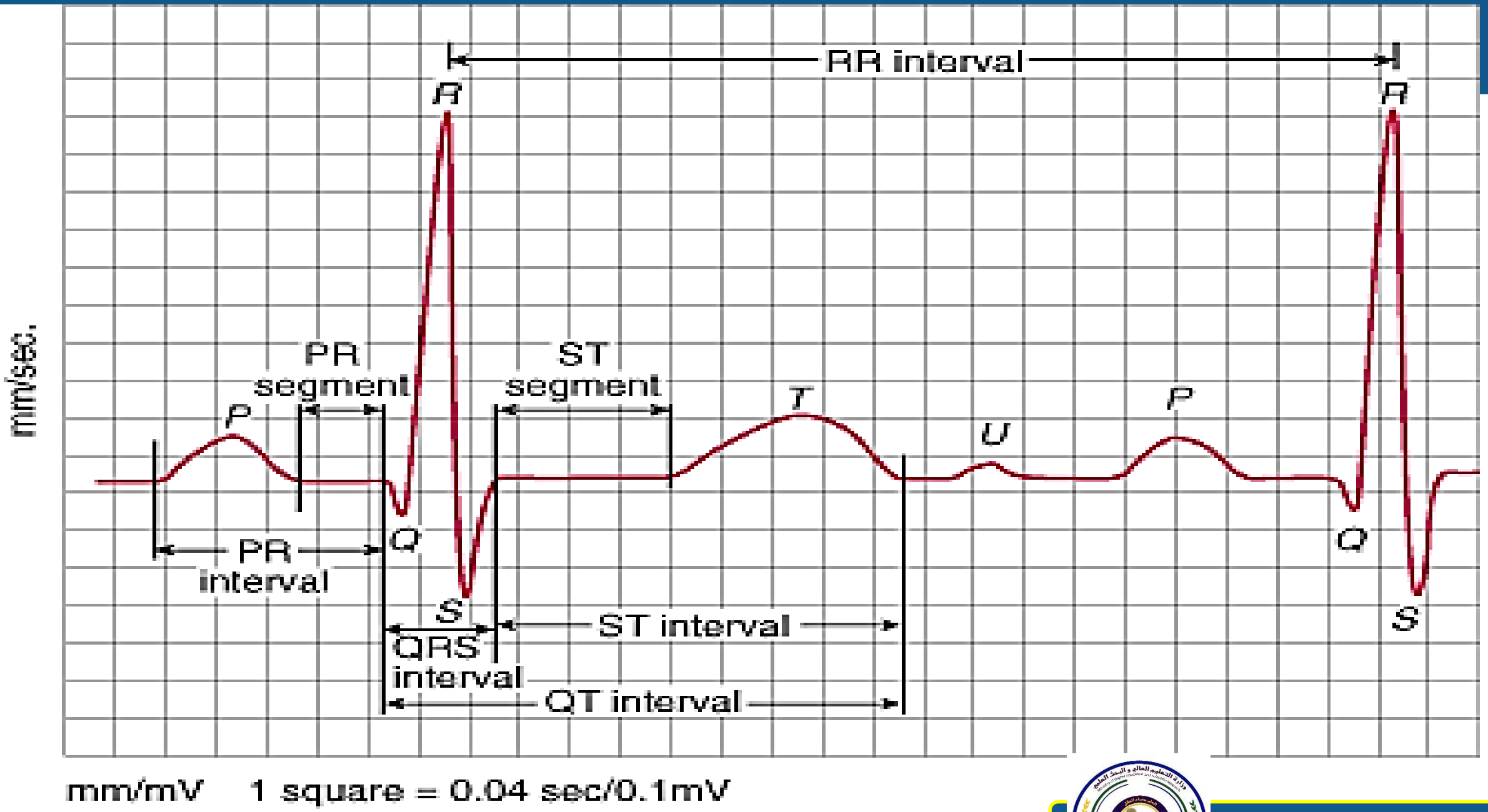

Figure ECG waveform

- Where Chart speed is the speed of the paper, It measure in beat per minute (bpm). The normal value of heart rate (60-100) bpm (72 bpm average value).

> 100 is called Tachycardia

< 60 is called Bradycardia

1- The horizontal segment of the wave form is known as base lin.

2- (P) wave represent depolarization of the atrial muscle.

3- (QRS) complex represent complain result of repolarization atria and depolarization of ventricles.

4- (T) wave represent ventricle repolarization.

5- (U) wave, if present, is the result of after potential in the ventricular muscle.

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3- Electromyogram (EMG)

- The recording of potential from muscles during movement is called electromyogram (EMG). EMG is a medical technique for evaluating and recording properties of muscle at rest and while contracting.

- Needle electrodes can be used to measure individual muscle fibers
- Amplitude: 1-10 mV and Bandwidth: 20-2000 Hz
- Latency Period: is the time between stimulation and beginning of response.
- The conduction velocity for sensory nerves can be measured by stimulating at one side and recording at several locations that are known distance from point of stimulations.
- Nerve damage decreases conduction velocity typical value (40-60) m/s
- If $c_d < 10\ m/s$ that indicate having problem.
- Normal nerve stimulated between 5 to 15 Hz and the rate of relaxation period 0.2s between pulses.

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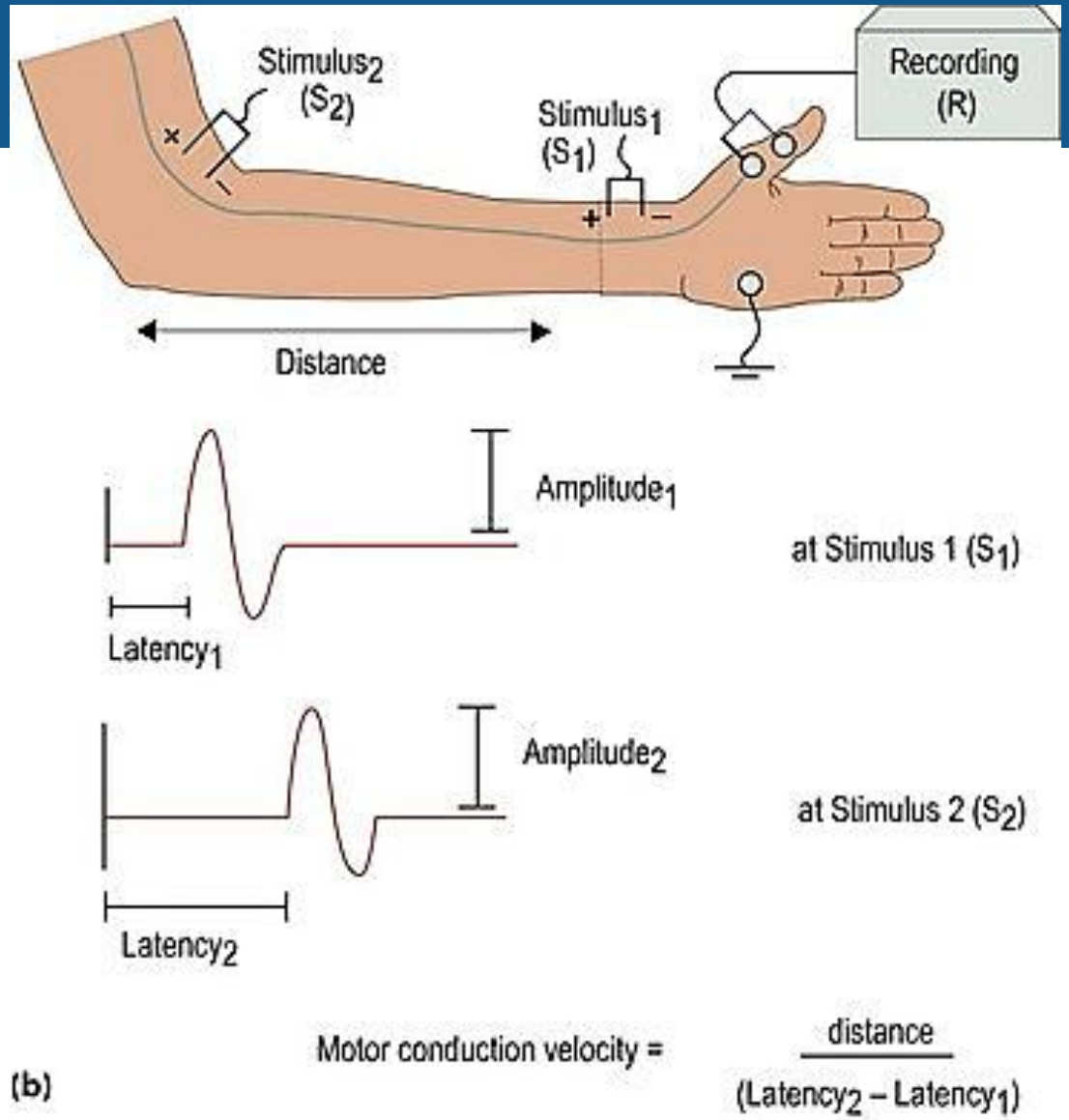


- **To determine conduction velocity,** Let the latency period for S1 is 4 ms larger than for response to S2

$$\Delta t = 4 \times 10^{-3}\ s$$

$$\Delta x = 0.25\ m$$

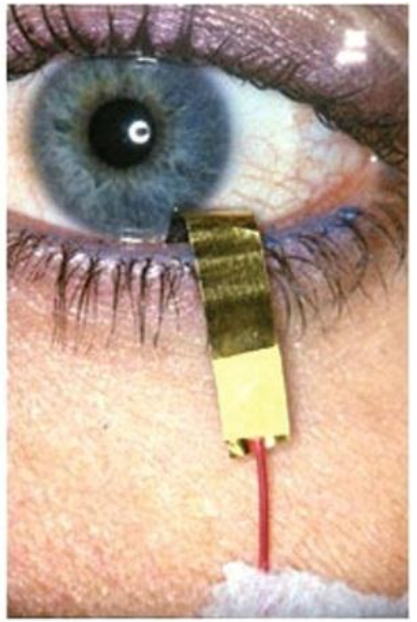
$$Nerve\ conduction\ velocity = \frac{\Delta x}{\Delta t}$$

$$= \frac{0.25}{4 \times 10^{-3}} = 62.5\ m/s$$

Figure experimental arrangement of obtaining an EMG

4- Eectroretinogram (ERG)

- The recording of potential changes produced by the eye when retina exposed to a flash of light is called Eectroretinogram (ERG).
- To record ERG one electrode is mounted on contact lens that fits the cornea and other electrode is attached above the ear or forehead.

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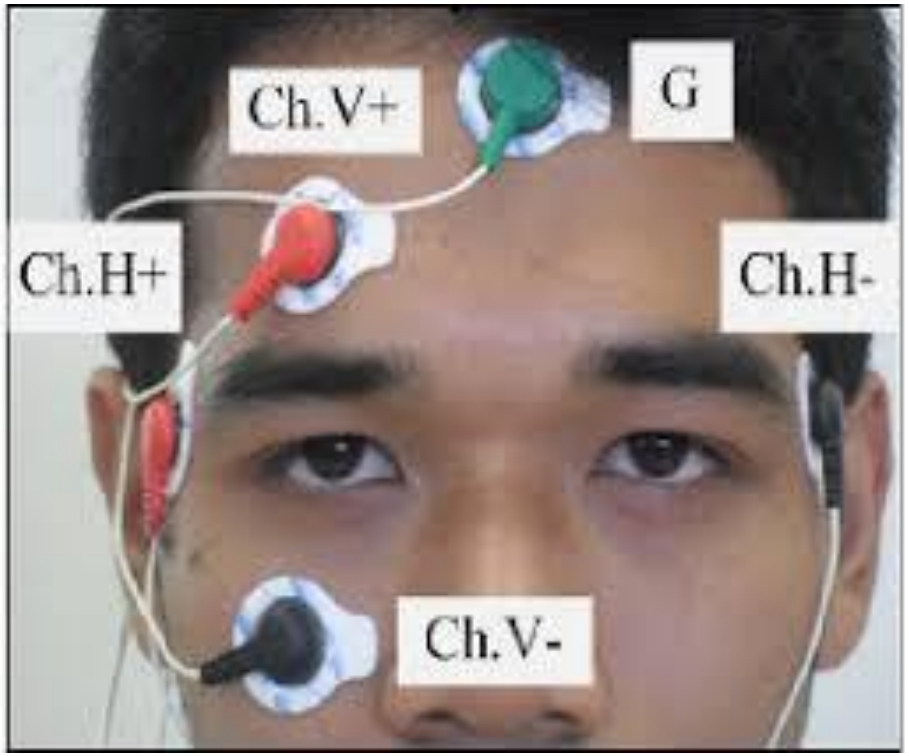
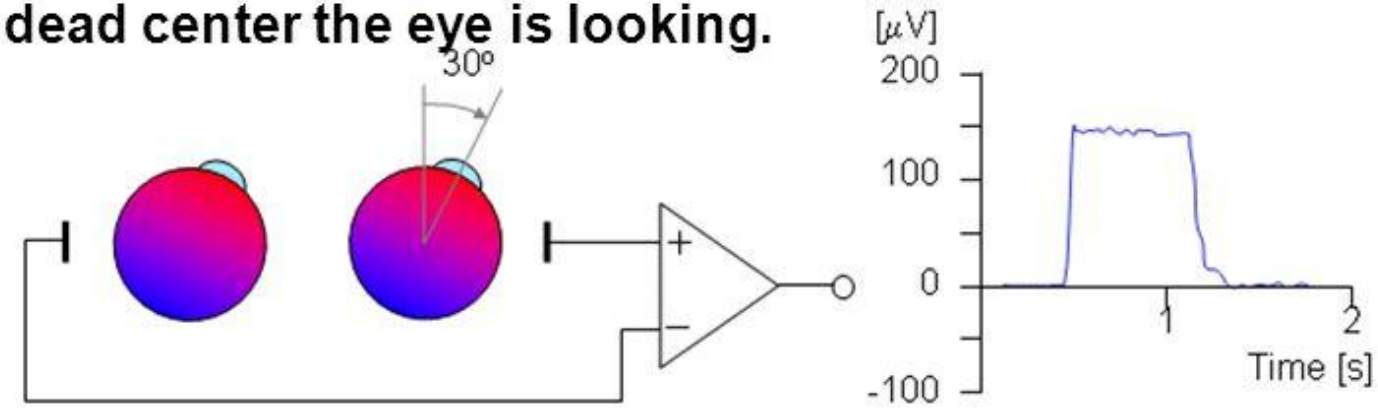
5- Electrooculogram (EOG)

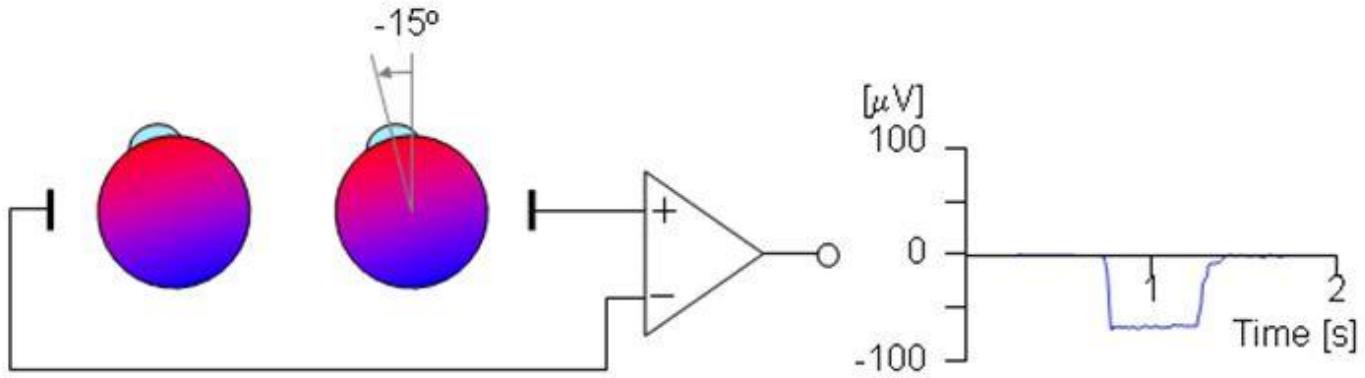
- It is record of variation in the corneal-retinal potential. For this measurement a pair of electrodes is attached near to the eye.
- EOG provides information on the orientation of eye. EOG is useful for recording reading ability and eye movement during sleep and dreaming.



Moving eyes to the right (keeping head STILL) causes a positive EOG voltage to be picked up by the electrodes, while moving eyes to the left (head fixed) produces a negative EOG voltage. The magnitude of the voltage indicates how much off of dead center the eye is looking.



Eyes moving 30º to the right



Eyes moving 15º to the left

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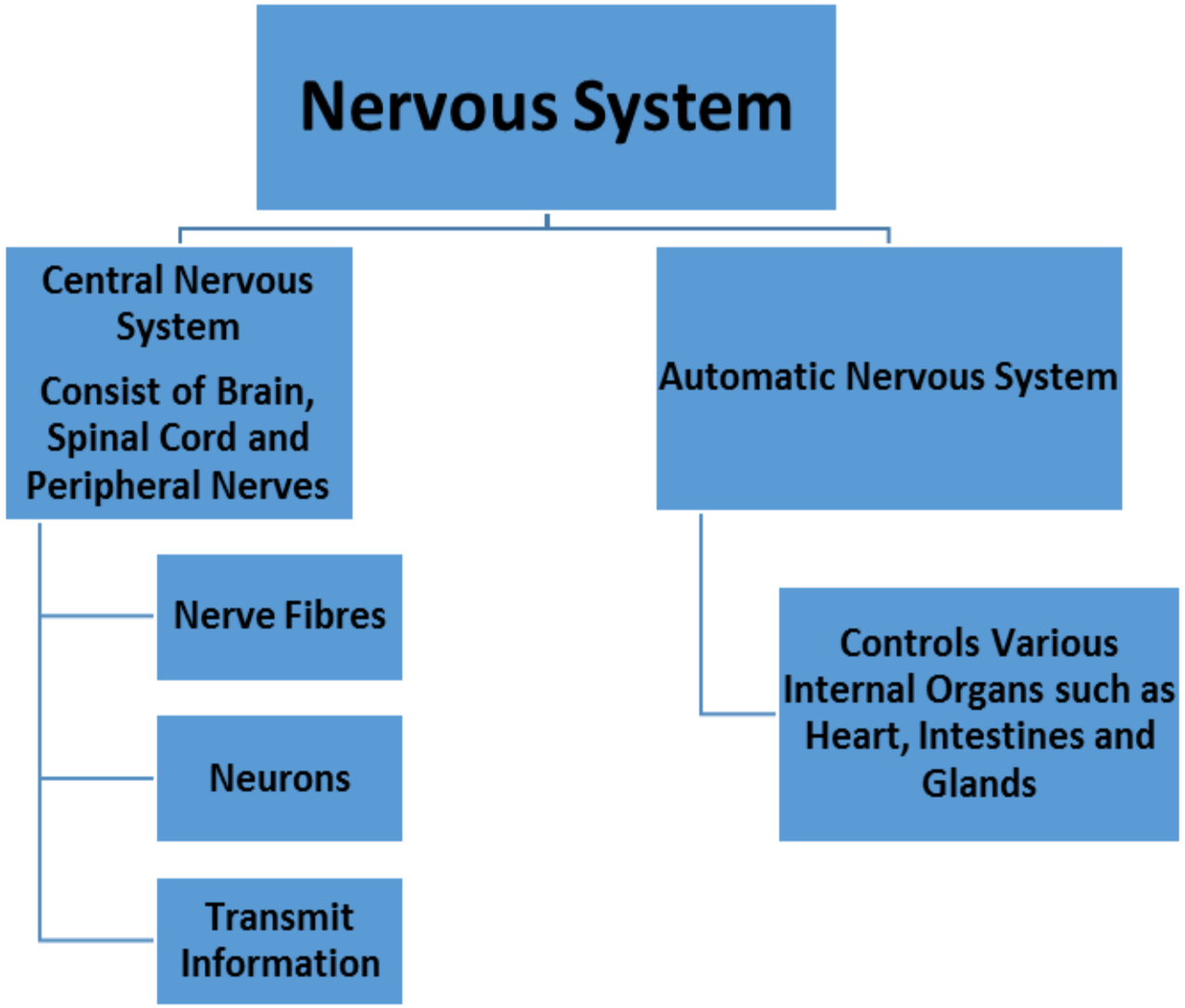
The nervous system and the neuron:



- Brain surrounded by three membrane within protective skull.
- Brain connected to spinal cord which is surrounded by CSF.
- **Neuron** is a basic structural unit of nervous system. Neuron is a nerve cell specialized for reception, interpretation and transmission of electrical message.
- Transmission of nerve impulse along an axon. The axon act as a cable.

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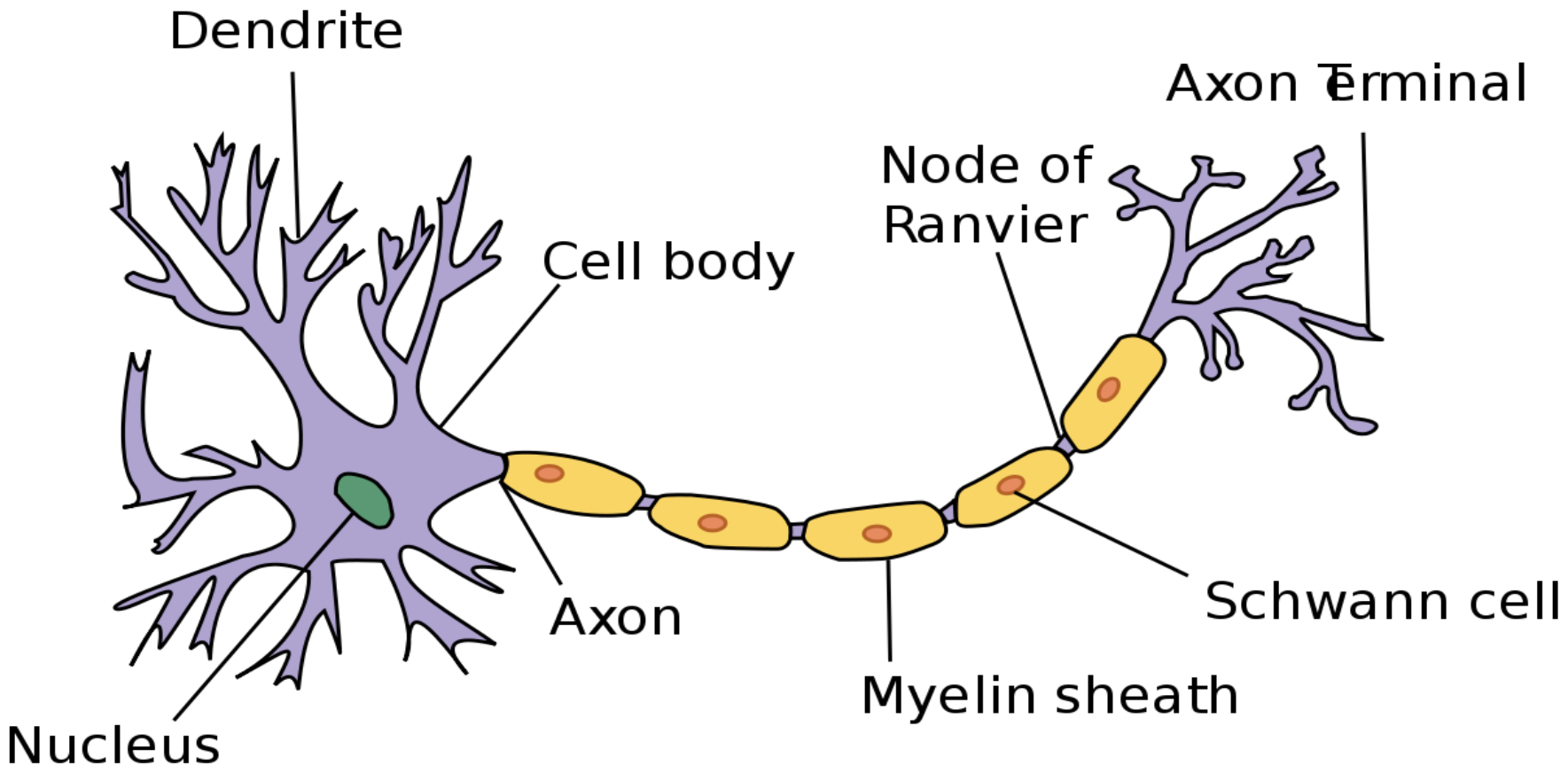

Schematic diagram of Motor Neuron

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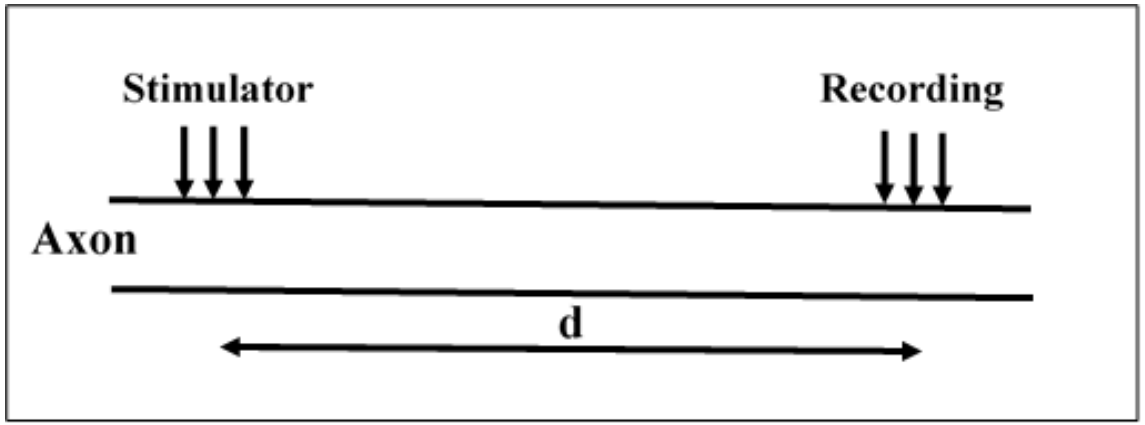
Conduction Velocity of Nerve



$$C_v = \frac{d}{t}$$

- Length of the axon
- 1-16 μm Man
- 1-12 μm Mouse
- Large 1 mm Squid

- Propagation rate is the rate at which action potential moves dawn a fiber.
- Conduction velocity due to ions:

$$c_v \propto \sqrt{D}$$

- Where: D is the diameter
- Range of c_v (1 to 140 m/s)
- For heart muscle, propagation through heart muscle is slower.

$$c_v \approx 0.2\ to\ 0.4\ m/s.$$

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