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BATCH: EN2
Biomedical Instrumentation.

Assignment 1

1. Draw the generalized medical instrumentation system block diagram and explain in detail.

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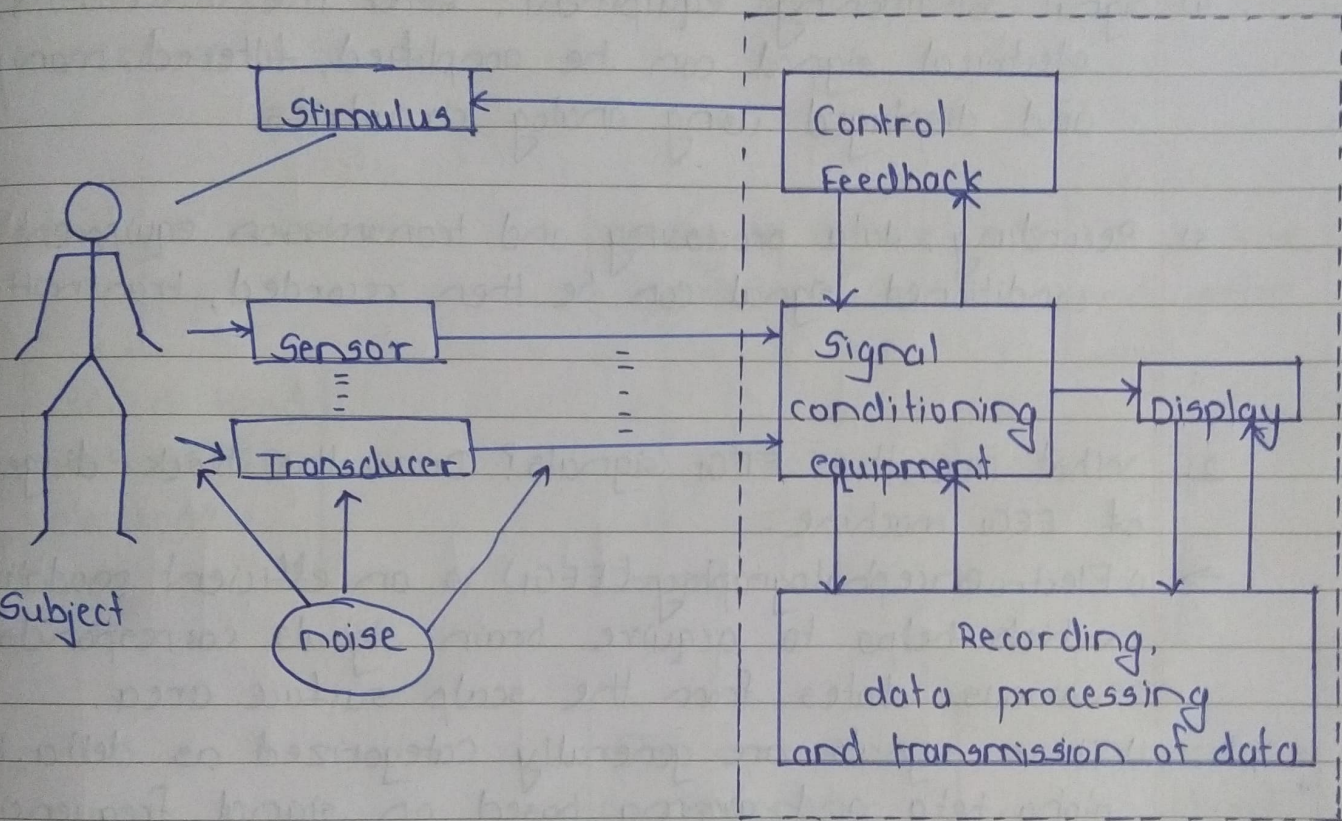


Components of man-instrument system:

1) Subject : Human body is the subject on which measurement is performed.

2) Stimulus : External stimulus is required. i.e. auditory tone, flash of light. Stimulus may be visual or direct electrical stimulation of some part of the nervous system.

3) The transducers: A transducer converts a physical measured quantity to an electric output. A transducer converts one form of energy to another.

4) Signal conditioning equipment: After the conversion, the electrical signal can be amplified, filtered, manipulated and displayed using analog circuitries.

5) Recording; data processing and transmission equipment: The conditioned signal can be then recorded, transmitted.

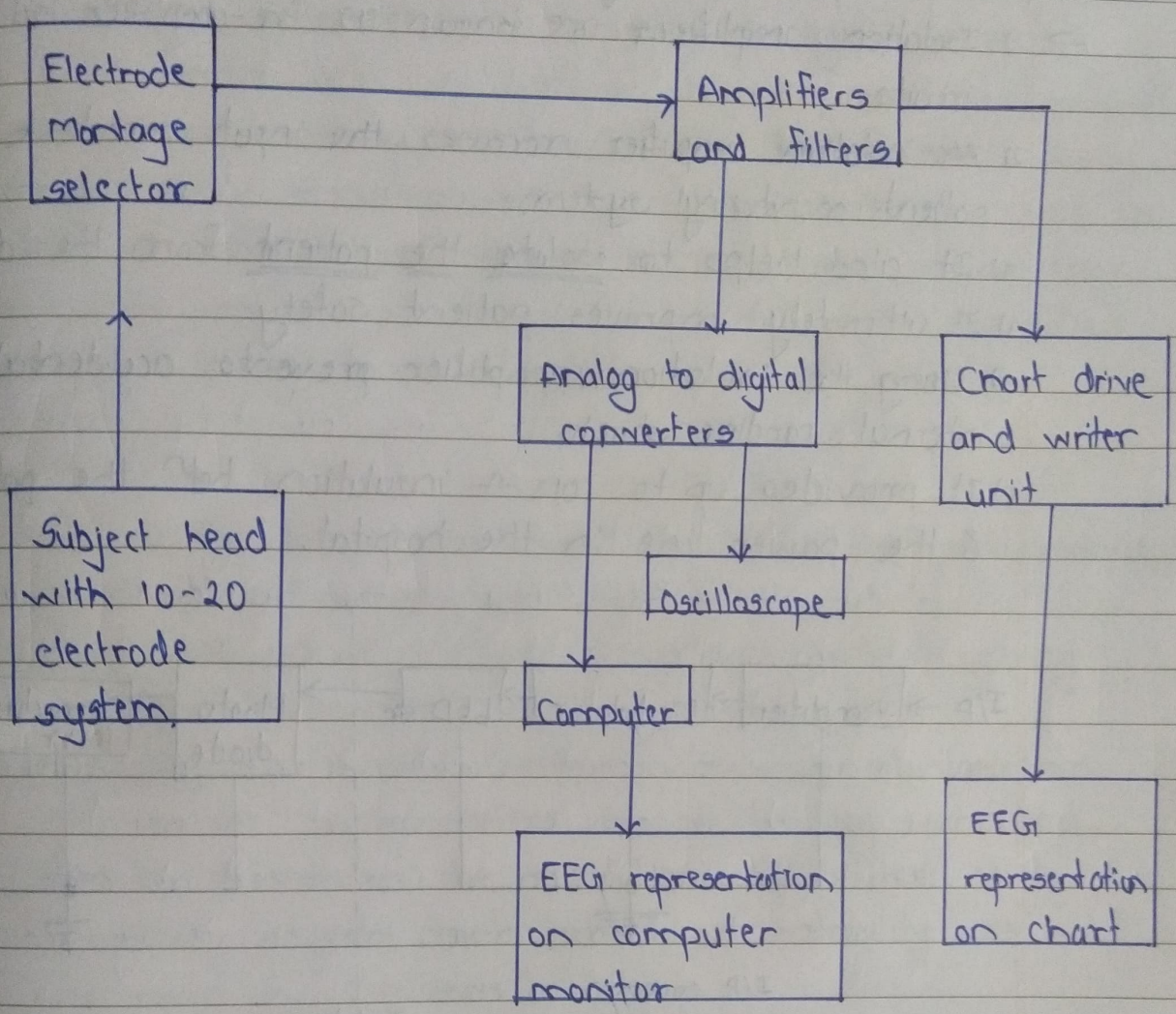
2. What are the EEG signals? Draw the block diagram of EEG machine.

→ 1) Electroencephalography (EEG) is an efficient modality which helps to acquire brain signals corresponds to various states from the scalp surface area.

2) These signals are generally categorized as delta, theta, alpha, beta and gamma based on signal frequencies ranges from 0.1 Hz to more

a) Delta (< 4 Hz)
b) Theta (4 - 7 Hz)
c) Alpha (7 - 12 Hz)
d) Beta (12 - 30 Hz)
e) Gamma (30 - 50 Hz)

- Block diagram of EEG Machine.



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3. What is need of isolation amplifiers in biomedical instrumentation set-up. Explain optically isolated Isolation amplifier.

→ 1) Isolation amplifiers are known as Pre-amplifier isolation circuits.

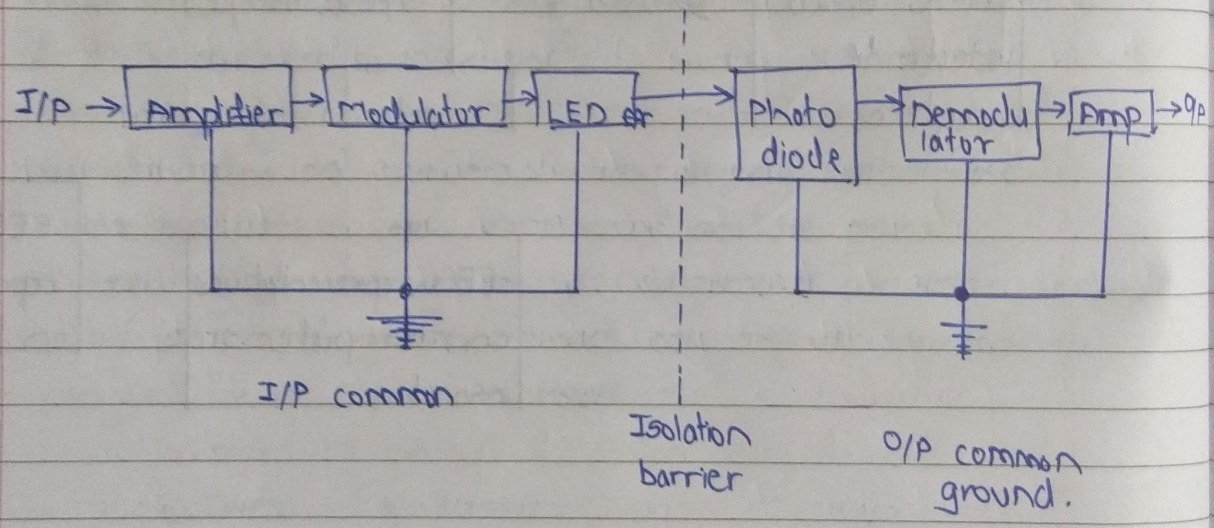
2) An isolation amplifier increases the input impedance of a patient monitoring system.

3) It also helps to isolate the patient from the device.

4) It ultimately improves patient safety.

5) Using the isolation amplifier prevents accidental internal cardiac shock.

6) It provides up to $10^{12}\,\Omega$ insulation betn. the patient & the power line in the hospital.



Block Diagram of Isolation Amplifier.

The electrical signals are obtained with electrodes. The signals received goes to the amplifier block, where signal amplification occurs. After amplication, the signal enters the modulation block. When either it goes to

the isolation barrier, optical cable or transformer. can be used. If in case of optical cable, modulator o/p travels to LED. The LED converts electrical signals into light energy. If the transformer acts an isolation barrier, modulator output connects the primary winding of the transformer. Energy from primary transfers to secondary winding based on mutual induction principle. At the next stage, secondary o/p enters the demodulation block. Finally, the amplified demodulated signal is obtained.

4. What are the factors considered to decide the performance of medical instrumentation system?

→ 1. Range: The range of input amplitude and frequency over which the device is expected to operate.

2. Sensitivity: Instrument determines how small variation of variable or parameters can be reliably measured, which determines the resolution of device. High sensitivity results nonlinearities or instability. It is measured in cm/mm of Hg.

3. Linearity: It is defined as ratio of change in output to change in input. variations in the output of n instrument follows input variables.

4. Hysteresis: It is a characteristics of some instruments where a given value of the measured variable results in a different reading when reached in an ascending and descending direction.

5. Frequency response: Freq. response of an instrument is its variation in sensitivity over which the freq. range of the measurement. System should be able to

respond rapidly enough to reproduce all frequency components of the waveform with equal sensitivity.

6. Accuracy: Accuracy is a measure of systemic error. Errors come due to tolerances of electric components, mechanical errors, component errors due to drift, errors due to poor freq. response, errors due to change in atmospheric pressure or temperature, reading errors due to parallax.

7. Signal to Noise ratio: It should be as high as possible. Noise come due to power line freq. noise, interference due to electromagnetic, electrostatic or diathermy equipment and due to poor grounding.

8. Stability: It is the ability of the system to resume a steady state condition following a disturbance at the input.

9. Isolation: Instrument should not produce a direct electrical connection betn. subject & ground.

10. Simplicity: The design of the biomedical instrumentation system should be simple, easy to debug for errors and for measurements.

5. Draw the bio potential waveform and define following terms.
a) Absolute and relative refractory period.
b) Resting and Action state of bio cell.

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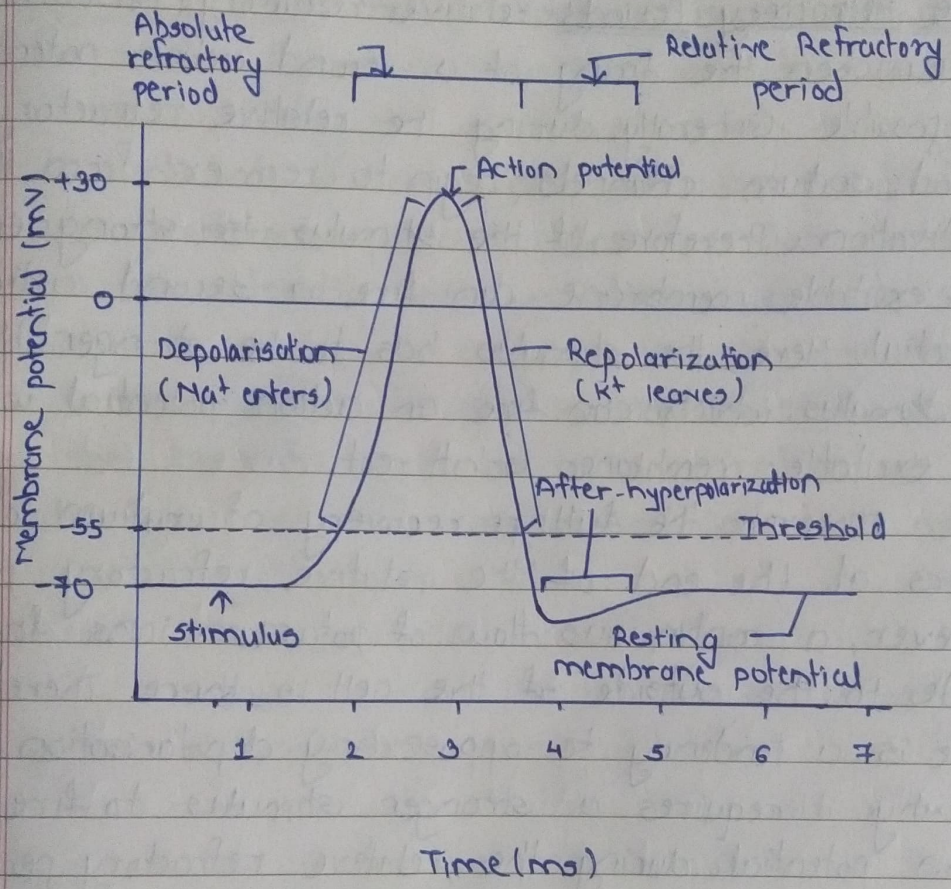


1. <u>Absolute Refractory Period</u>: Absolute refractory period is the time just after the firing of an action potential. Generally, just after the firing of an action potential, sodium channels undergo inactivation spontaneously and rapidly at the peak of the action potential. However, when the sodium channels are inactivated, they are unable to reactivate immediately. This recovery from inactivation is a time and voltage-dependent process. Moreover, the full ~~rave~~ recovery of the reactivation usually takes

about 4-5 msec. However, the initial time period after the peak of the action potential is the absolute refractory period.

2. Relative Refractory Period: Relative refractory period is the time when the firing of a second action potential is possible. Generally, during the relative refractory period, sodium channels begin to recover from their inactivation. Therefore, if the stimulus is strong enough, the excitable membrane can fire a second action potential. Here, the stimulus has to be stronger than the stimulus, which can fire an action potential when the excitable membrane is at rest.

Morever, the full ~~ro~~ recovery of sodium channels occurs at the end of the relative refractory period. However, a continuous flow of potassium ions from inside to the outside of the cell is there. Therefore, there is a tendency to oppose any depolarisation. That is why it requires a stronger stimulus to fire an action potential during the relative refractory period.

3. Resting State: The membrane potential caused by the different concentration of ions is called the resting potential of the cell. Resting potential is defined as the electrical potential of an excitable cell relative to its surroundings when not stimulated or involved in passage of an impulse. It ranges from -60mV to -100mV. The nerve and muscle cells permit the entry of potassium & chloride ions it blocks the entry of sodium ions. The permeability of sodium

ions is about 2×10^{-8} cm/s & for potassium & chloride ions is 4×10^{-6} cm/s. When the cell is in resting state, then it is said to be polarised.

4. Action state: Action potential is defined as the change in electrical potential associated with the passage of an impulse along the membrane of a cell. An action potential is a rapid rise and subsequent fall in voltage or membrane potential across a cellular membrane with a characteristic pattern. Sufficient current is required to initiate a voltage response in a cell membrane; if the current is insufficient to depolarize the membrane to the threshold level, an action potential will not fire. Examples of cells that signal via action potentials are neurons & muscle cells.

6. Define the following terms:

a) ECG: A line graph that shows changes in the electrical activity of the heart over time. It is made by instrument called an electrocardiograph. The graph can show that there are abnormal conditions, such as blocked arteries, changes in electrolytes (particles with electrical charges), and changes in the way electrical currents pass through the heart tissue. Also called EKG and electrocardiogram.

b) EEG: Electroencephalogram (EEG) is a record of the electric signal generated by the ~~coorp~~ cooperative action of brain cells or more precisely, the time coursera of

an extracellular field potentials generated by their synchronous action. During an EEG, a technician places small metal disks (electrodes) on your scalp. The electrodes attatch to a machine that gives your healthcare provider information about your brain's activity.

c) EMG: Electromyography is a technique for evaluating & recording the electrical activity produced by skeletal muscles. EMG is performed using an ~~istr~~ instrument called an electromyograph to produce a record called an electromyogram. An electromyograph detects the electric potential generated by muscle cells when these cells are electrically or neurologically activated.

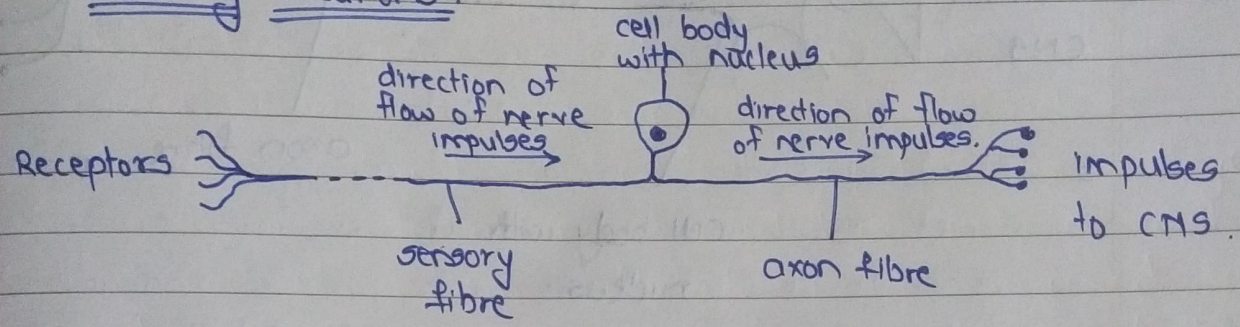
d) PCG: The phonocardiogram (PCG) detects and records heart sounds, the sounds made by the various cardiac structures pulsing & moving blood. The sound is caused by the acceleration and deceleration of blood and turbulence developed during rapid blood flow.

e) VCG: vectorcardiogram (VCG) signals monitor both spatial and temporal cardiac electrical activities along three orthogonal planes of the body.

7. What are the types of nerve cells and explain Nervous system?

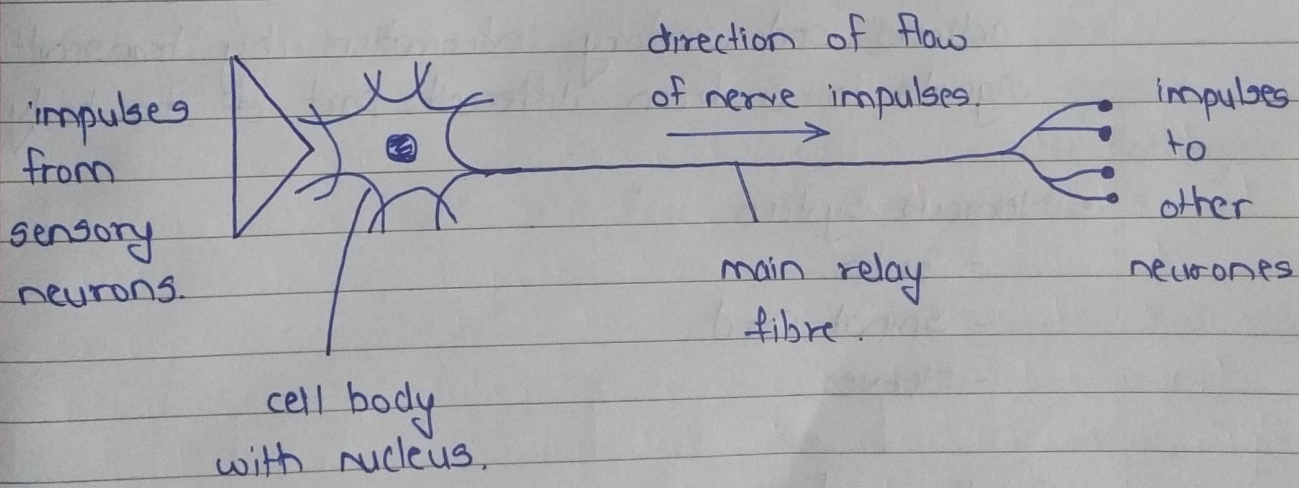
→ A] Types of Nerve Cells.

1. Sensory neurons:



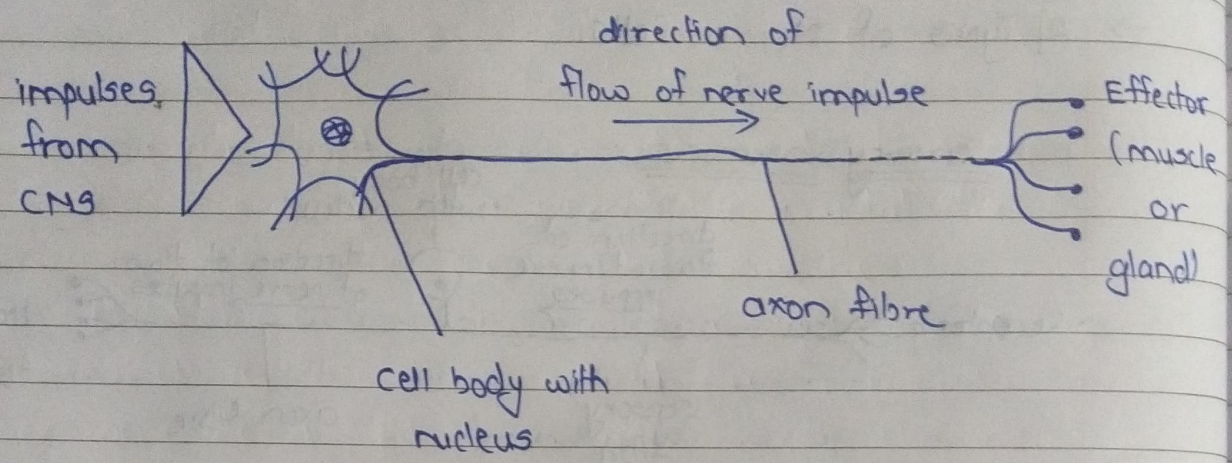
Carries impulses from receptors.
eg. pain receptors in skin to CNS (brain or spinal cord)

2. Relay neuron:



Carries impulses from sensory nerves to motor nerves.

3. Motor neuron:



Carries impulses from CNS to effector. eg.
eg. muscle to bring about movement or gland to bring about secretion of hormone eg. ADH.

B] Nervous System: The nervous system is a highly complex part of an animal that coordinates its actions and sensory information by transmitting signals to & from different part of its body.

- Nervous System
  - Brain
  - Spinal cord
  - Nerves.

- Functions of Nervous System
  - Regulates and coordinates all body activities.
  - Center of all mental activity, including thought, learning & memory.

Nervous System Divisions:

- Central Nervous System (CNS)
  - Brain
  - Spinal Cord
    - Processes & stores sensory & motor information.
    - Controls consciousness.

- Peripheral Nervous System (PNS)
  - 12 Pairs of Cranial Nerves.
  - 31 Pairs of Spinal Nerves
    - Transmits sensory and motor impulses back & fourth betn. CNS & rest of body.

8. What are types of bio sensors? which sensors are used for the measurement of heart rate. & explain any one method.

→ 1. Immunosensors were established on the fact that antibodies have high affinity towards their respective antigens, i.e. the antibodies specifically bind to pathogens or toxins or interact with components of the host's immune system.

2. The DNA biosensors: were devised on the property that single-strand nucleic acid molecule is able to recognize and bind to its complementary strand in a sample. The interaction is due to the formation of stable hydrogen bonds betn. the two nucleic acid strands.

3. Magnetic biosensors: miniaturized biosensors detecting magnetic micro and nano particles in microfludic channels using the magnetoresistance effect have

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great potential in terms of sensitivity and size.

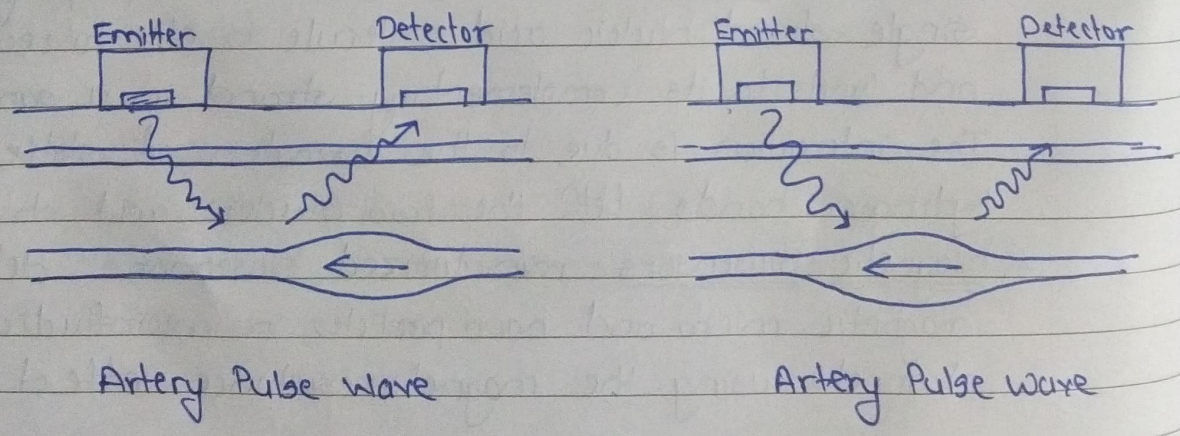
4. Piezoelectric biosensors:
   a. The quartz crystal microbalance.
   b. Surface accoustic wave device.

   They are based on the measurement of changes in resonance freq^n of a piezoelectric crystal due to mass changes on the crystal structure.

5. Optical biosensor: consists of a light source, as well as numerous optical ~~Au~~ components to generate a light beam with specific characteristics and to beeline this light to a modulating agent, a modified sensing head along with a photodetector.

6. The electrochemical biosensor: is one of the typical sensing devices based on transducing the biochemical events to electrical signals. In this type of sensor, an electrode is a key component that is employed as a solid support for immobilization of biomolecules & electron movement.

- Sensors that are used for the measurement of Heart rate.



An optical heart rate sensor measures pulse waves, which are changes in the volume of a blood vessel that occur when the heart pumps blood. Pulse waves are detected by measuring the change in volume using an optical sensor & green LED.

Method:

Photoplethysmography (PPG) is a simple optical technique used to detect volumetric changes in blood in peripheral circulation. It is a low cost and non-invasive method that makes measurements at the surface of the skin.

The technique provides valuable information related to our cardiovascular system. Recent advances in ~~techniques~~ technology has revived interests in this technique, which is widely used in clinical physiological measurement and monitoring.