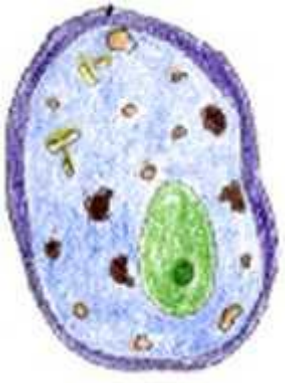
BIO–MEDICAL INSTRUMENTATION

BEE 007

Unit: I

ELECTROPHYSIOLOGY

Cell and its structure



CELL: The fundamental unit of every animal or plant is cells. Combination of cells is called TISSUES. Every ORGAN in the body is made up of combination of many tissues.

CELLS: All cells are same and they contain a gelatinous substance made up of or composed of water, protein, acids, fats, and various minerals.

CELL MEMBRANE: Cell membrane protects the cell and surrounds it that passes into and out of the cell.

NUCLEUS: The nucleus controls the structure of the cell. Cell reproduction process is directed by the nucleus only and which determines the function of the cell and the structure of the cell.

CHROMOSOMES: These are rod-like structures inside the cell. Human body cells (other than sex cells, the egg, and sperm cells) contain 23 pairs of chromosomes. Sex cells, such as sperm and egg cells have 23 single chromosomes only. When one egg cell unites with a sperm cell to for an embryo, then the embryonic cell has 46 chromosomes i.e. 23 pairs...understand the difference...

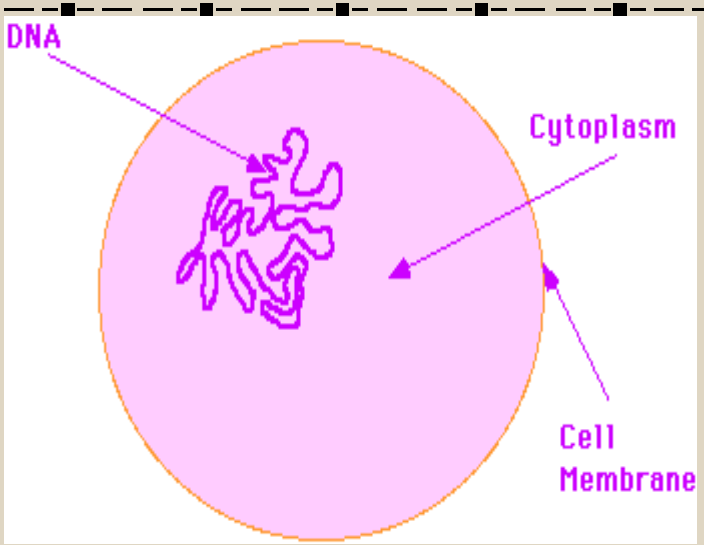
Chromosomes contains the regions called GENES. Thousands of genes are in an orderly sequence on each chromosome. Gene is made up of a chemical substance called DNA (deoxyribonucleic acid). DNA is an important compound that regulates the activities of the cell in a sequential order on each chromosome. The DNA is a series of codes. When DNA activity carries out of the nucleus to other parts of the cell, the activities of the cell i.e. cellular reproduction and the manufacture of proteins are controlled by DNA.

CYTOPLASM: It means cyto means cell, plasm means formation. Cytoplasm carries the work of a cell i.e. nerve cell conducts stimulation, muscle cell contracts. Cytoplasm contains MITOCHODRIA and ENDOPLASMIC RETICULUM.

MITOCHONDRIA: It is called power center of the cell. This is small and sausage-shaped bodies produce energy by burning food in the presence of oxygen. This process is called catabolism (cata-down, bol-to cast, -ism-process). This process makes complex food particles into simpler substances and energy is released after this action to do the work of the cell

ENDOPLASMIC RETICULUM: These like canal-like structures-this is a network within the cell. These canals contain a very small structures called RIBOSOMES like a tunnel system in this proteins are produced for the use of the cell. This process is called ANABOLISM (ana-up, bol-to cast, -ism-process). After this process, complex proteins are made up from the simpler parts of food.

Smaller proteins linked like a chain to become complex proteins in this process. Both these catabolism and anabolism in combination is called METABOLISM (meta-change, bol-to cast, -ism- process) i.e total chemical activities that occuring in a cell. In this process, the sugars and fat in the food are used up and burned quickly and so the ENERGY is released



Cell membrane. All cells have a phospholipid based cell membrane. The cell membrane is selectively permeable in that it allows some materials to pass into or out of the cell but not others.

Cytoplasm. Cells are filled with a complex collection of of substances in a water based solution. This substance is called cytoplasm. Across all cells there are a number of common features to all cell cytoplasm. For example all cells have ribosomes. Also, in all cells the first steps in cellular respiration take place in the cytoplasm.

DNA. All cells contain DNA. In the simplest cells, the DNA is in one loop more loop like structures free in the cytoplasm. In some cells such as those making up our body the DNA is isolated from the cytoplasm in a special structure called a nucleus. Remember not all cells have a nucleus!

The Nervous System

- A physical organ system like any other:

- 2 main kinds of cells
  - Neurons
  - Glia

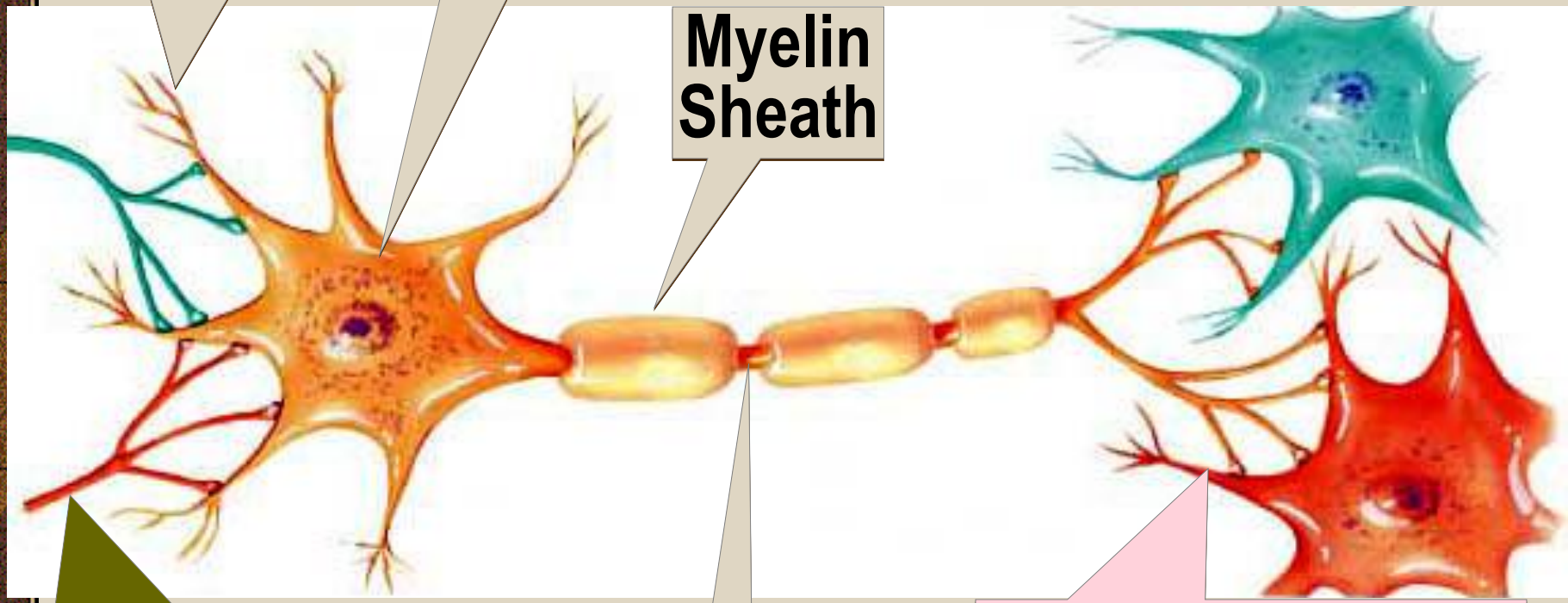
Neurons

- Basic units of the nervous system
- Receive, integrate, and transmit information
- Operate through electrical impulses
- Communicate with other neurons through chemical signals

Glial cells

- 100 billion neurons
- Glial cells
  - Support neurons (literally, provide physical support, as well as nutrients)
  - Cover neurons with myelin
  - Clean up debris

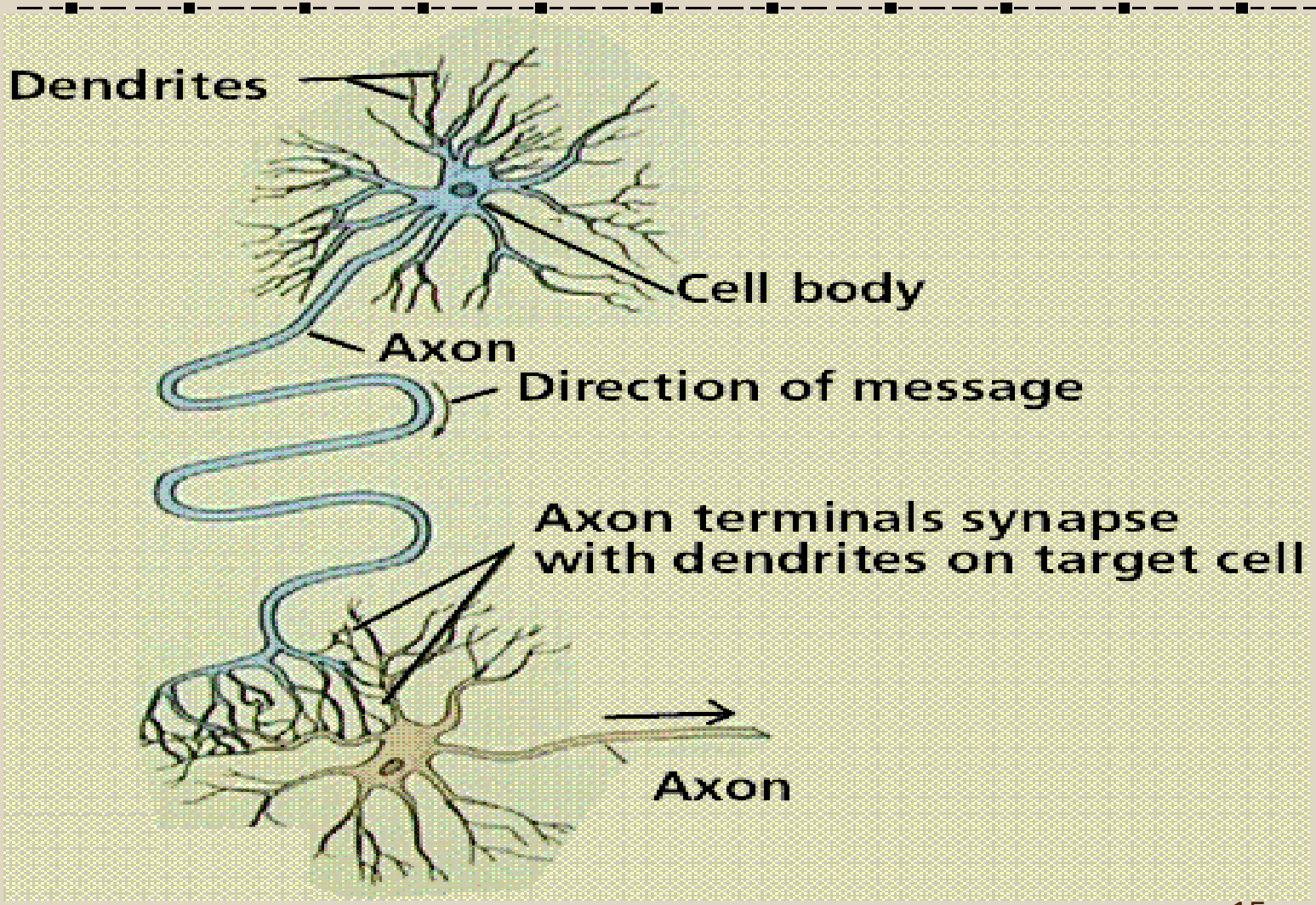
Neurons


Dendrites
Cell Body
Myelin Sheath
Axon of another neuron
Axon
Dendrites of another neuron

Synapse

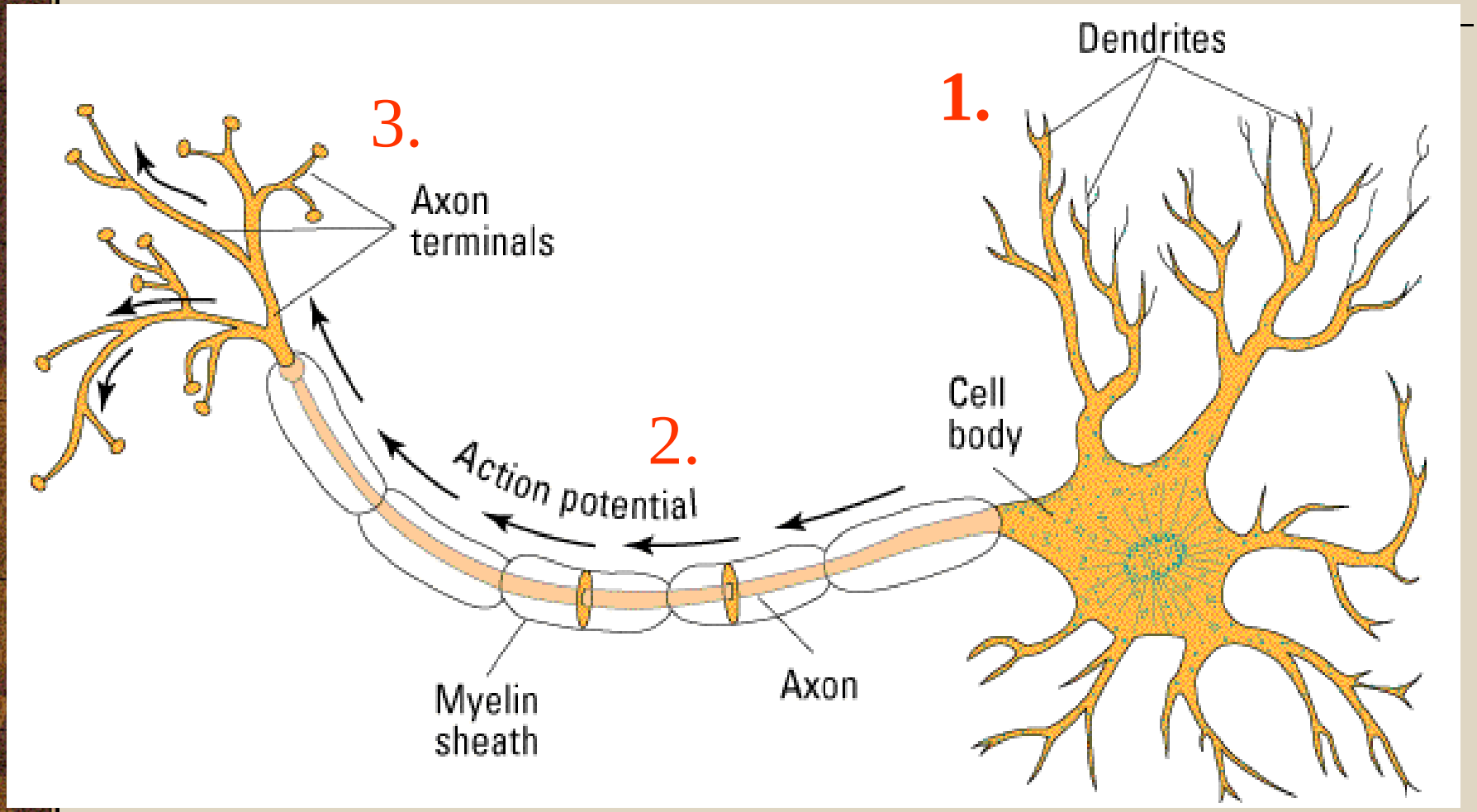
- junction between the axon tip of the sending neuron and the dendrite or cell body of the receiving neuron.
- tiny gap at this junction is called the *synaptic gap* or *cleft*

Nerve cell


Dendrites
Cell body
Axon
Direction of message
Axon terminals synapse
with dendrites on target cell
Axon

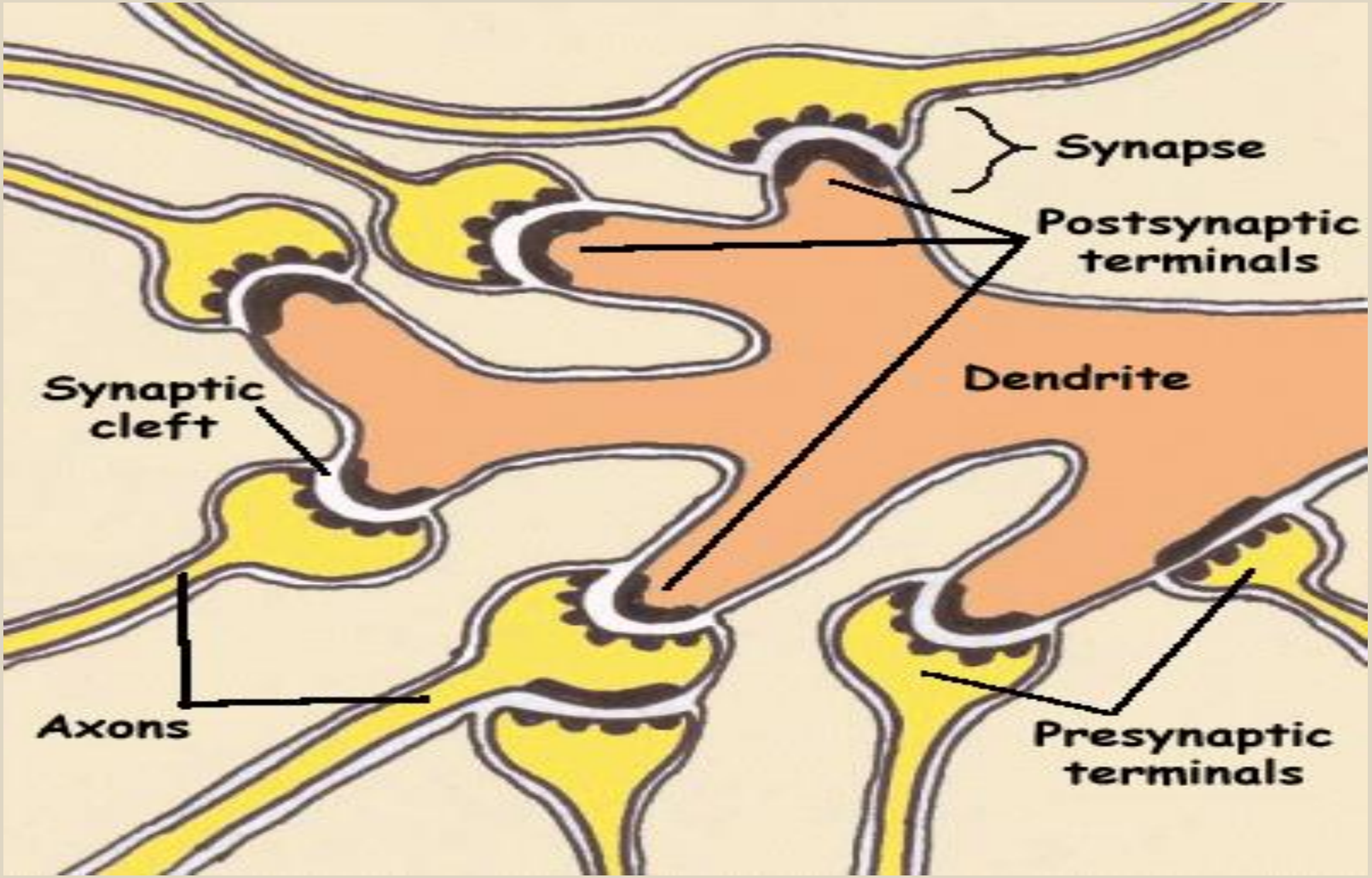
Specific Parts: The Neuron

Function



Neurons = 3 functions: Reception, Conduction, Transmission

Synapse


Synapse
Postsynaptic terminals
Dendrite
Synaptic cleft
Axons
Presynaptic terminals

The synapse is the connection between nerve cells (neurons) in animals including humans. The synapse joins the axons in one neuron to the dendrites in another. Here is a diagram showing how the synapse connects axons to dendrites:

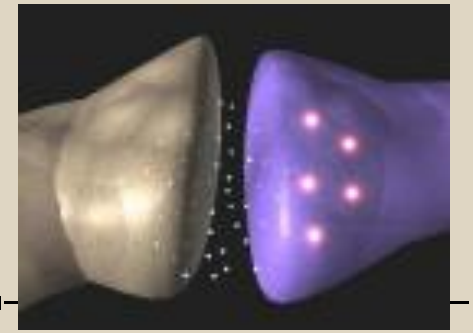
The synapse consists of:

- The presynaptic terminal at the end of an axon. This contains tiny vesicles which contain neurotransmitters - the small molecules which carry the nerve impulse from the sending neuron to the receiving neuron.
- The synaptic cleft - a gap between the two neurons across which the neurotransmitters migrate.
- The postsynaptic terminal usually in the dendrites of receiving neurons. This contains receiving sites for the neurotransmitters.

Nerve impulses are transmitted down to the presynaptic terminal in the axon of one neuron and across the synaptic cleft to the postsynaptic terminal in the dendrite of another neuron.

Synapses do not only join axons to dendrites (axodendritic synapses) - they can also joins axons to other axons (axoaxonic synapses) or to the soma - the neuronal cell body - (axosomatic synapses).

Relay Race



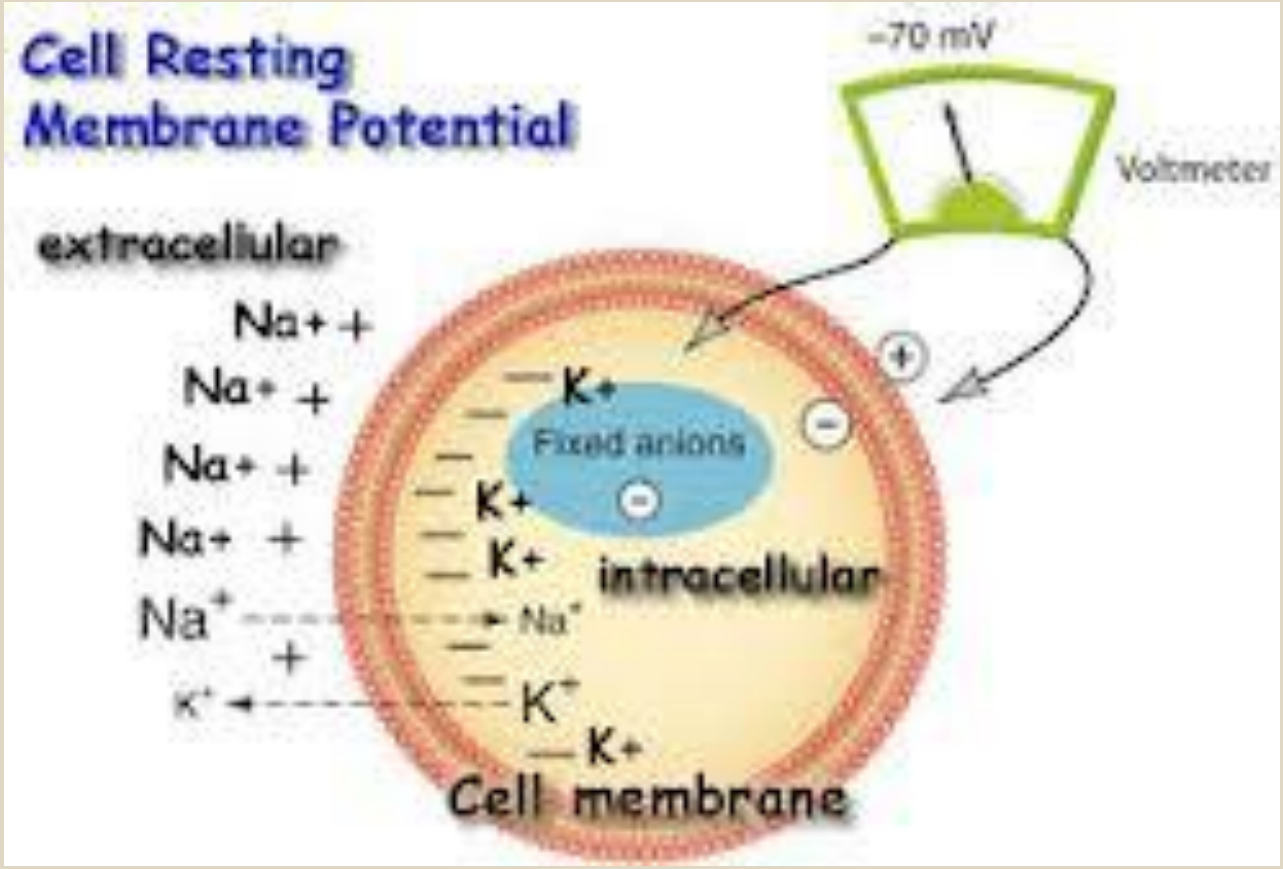
- Action Potential starts at dendrite
  - Through cell body
  - Down Axon
  - Axon Terminals
    - How does it get to the next cell's dendrites?

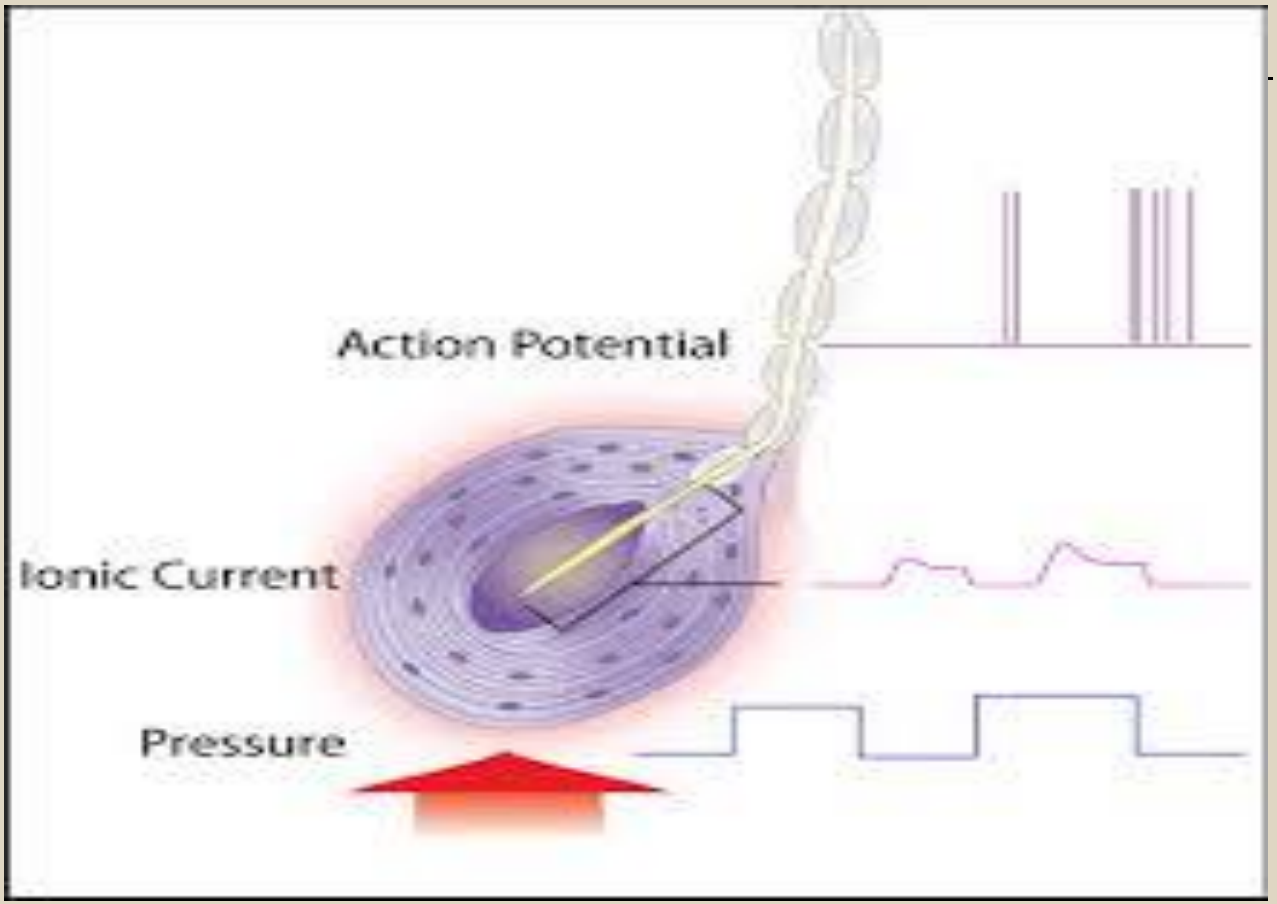
    - Neurons don't touch
      - Synapse = millionth inch gap
      - In synapse = vesicles w/ <u>neurotransmitters</u>
        - Chemical messengers that transmit info

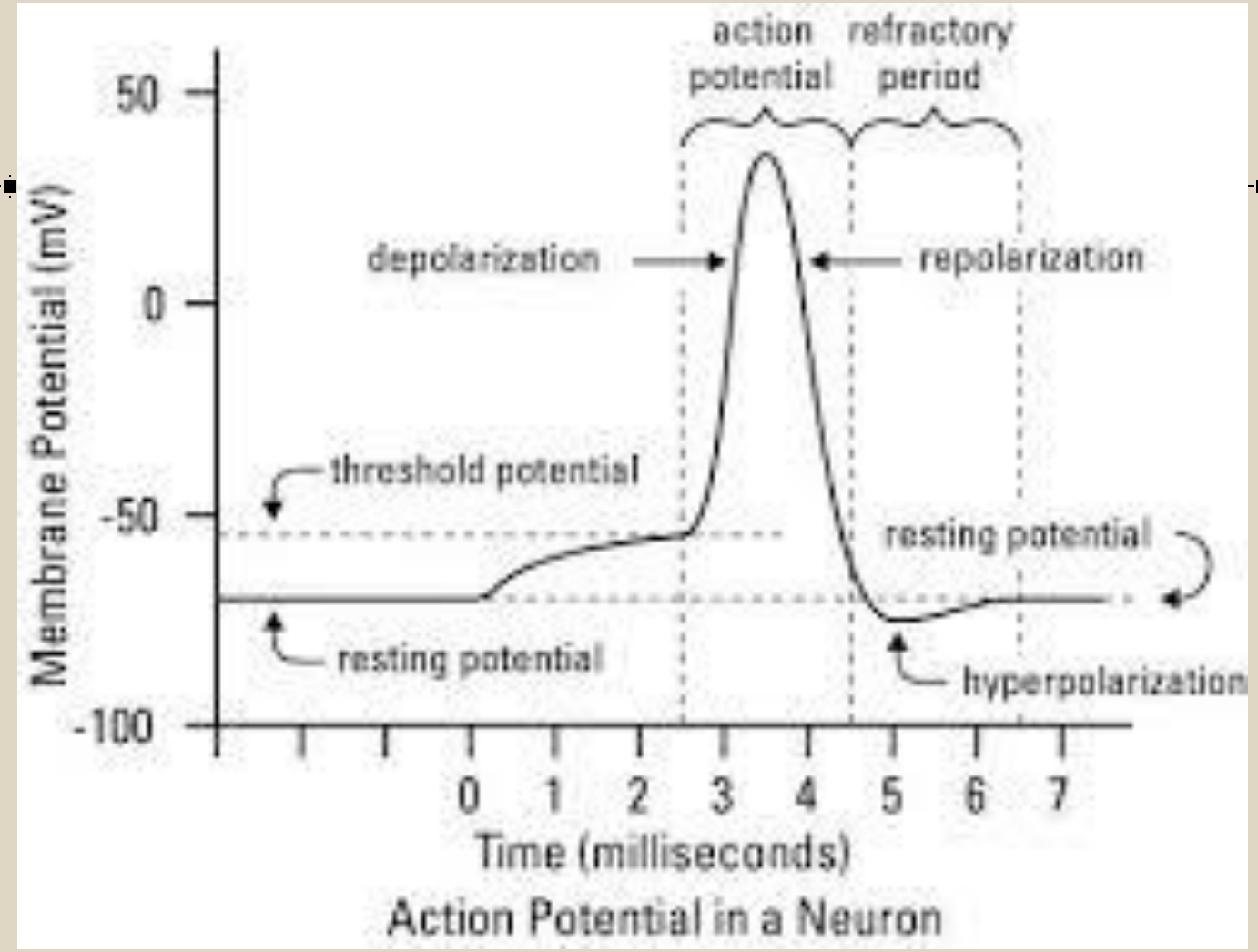
Action and resting – Potential propagation of action potential

An **action potential** (also known as a **nerve impulse** or a **spike**) is a self-regenerating wave of electrochemical activity that allows excitable cells (such as muscle and nerve cells) to carry a signal over a distance. It is the primary electrical signal generated by nerve cells, and arises from changes in the permeability of the nerve cell's axonal membranes to specific ions. Action potentials are pulse-like waves of voltage that travel along several types of cell membranes

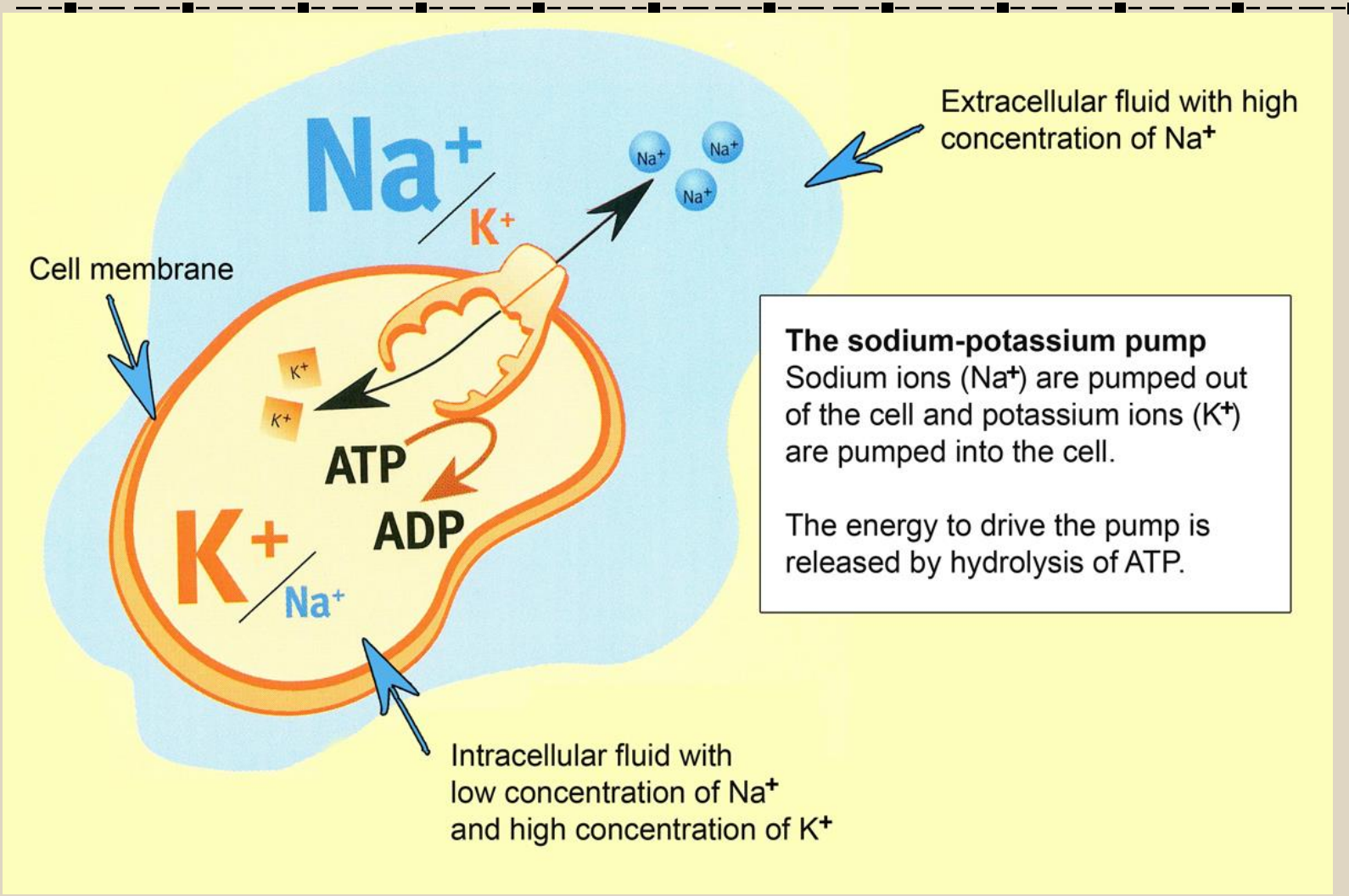
Relatively static membrane potential of quiescent cells is called **resting membrane potential** (or resting voltage), as opposed to the specific dynamic electrochemical phenomenona called action potential and graded membrane potential.


Cell Resting
Membrane Potential
-70 mV
Voltmeter
extracellular
Na+
Na+
Na+
Na+
Na+
K+
Fixed anions
K+
K+
intracellular
Na+
K+
K+
Cell membrane


Action Potential
Ionic Current
Pressure


action potential
refractory period
50
0
-50
-100
Membrane Potential (mV)
depolarization
repolarization
threshold potential
resting potential
resting potential
hyperpolarization
0 1 2 3 4 5 6 7
Time (milliseconds)
Action Potential in a Neuron

Sodium pump


Extracellular fluid with high concentration of Na+
Na+
K+
Cell membrane
K+
K+
ATP
ADP
K+
Na+
The sodium-potassium pump
Sodium ions (Na+) are pumped out of the cell and potassium ions (K+) are pumped into the cell.
The energy to drive the pump is released by hydrolysis of ATP.
Intracellular fluid with low concentration of Na+ and high concentration of K+

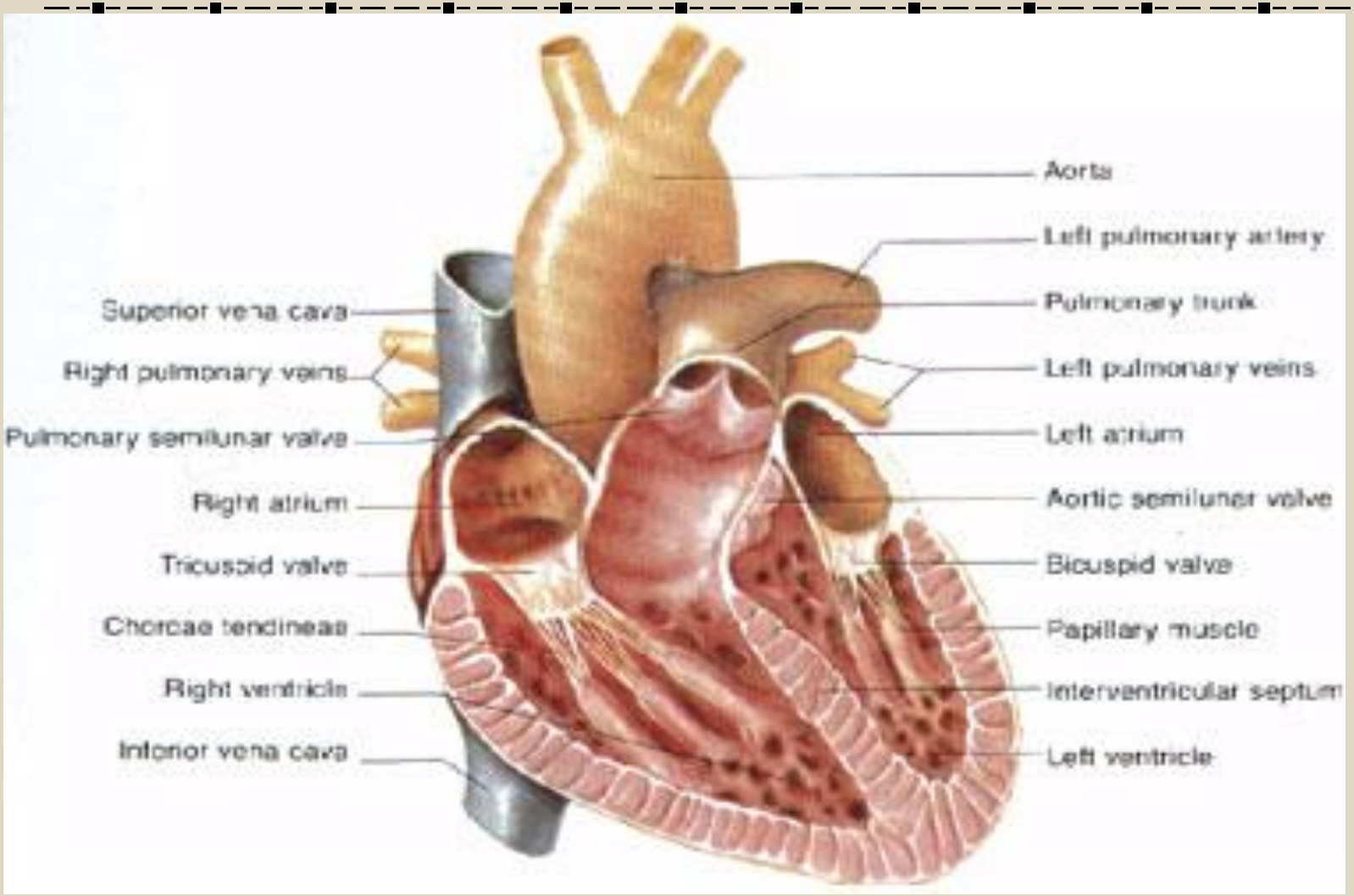
The process of active transport differs from diffusion in that molecules are transported away from thermodynamic equilibrium; hence, energy is required. This energy can come from the hydrolysis of ATP, from electron movement, or from light. The maintenance of electrochemical gradients in biologic systems is so important that it consumes perhaps 30–40% of the total energy expenditure in a cell. In general, cells maintain a low intracellular Na+ concentration and a high intracellular K+ concentration, along with a net negative electrical potential inside. The pump that maintains these gradients is an ATPase that is activated by Na+ and K+ (Na+-K+ATPase).

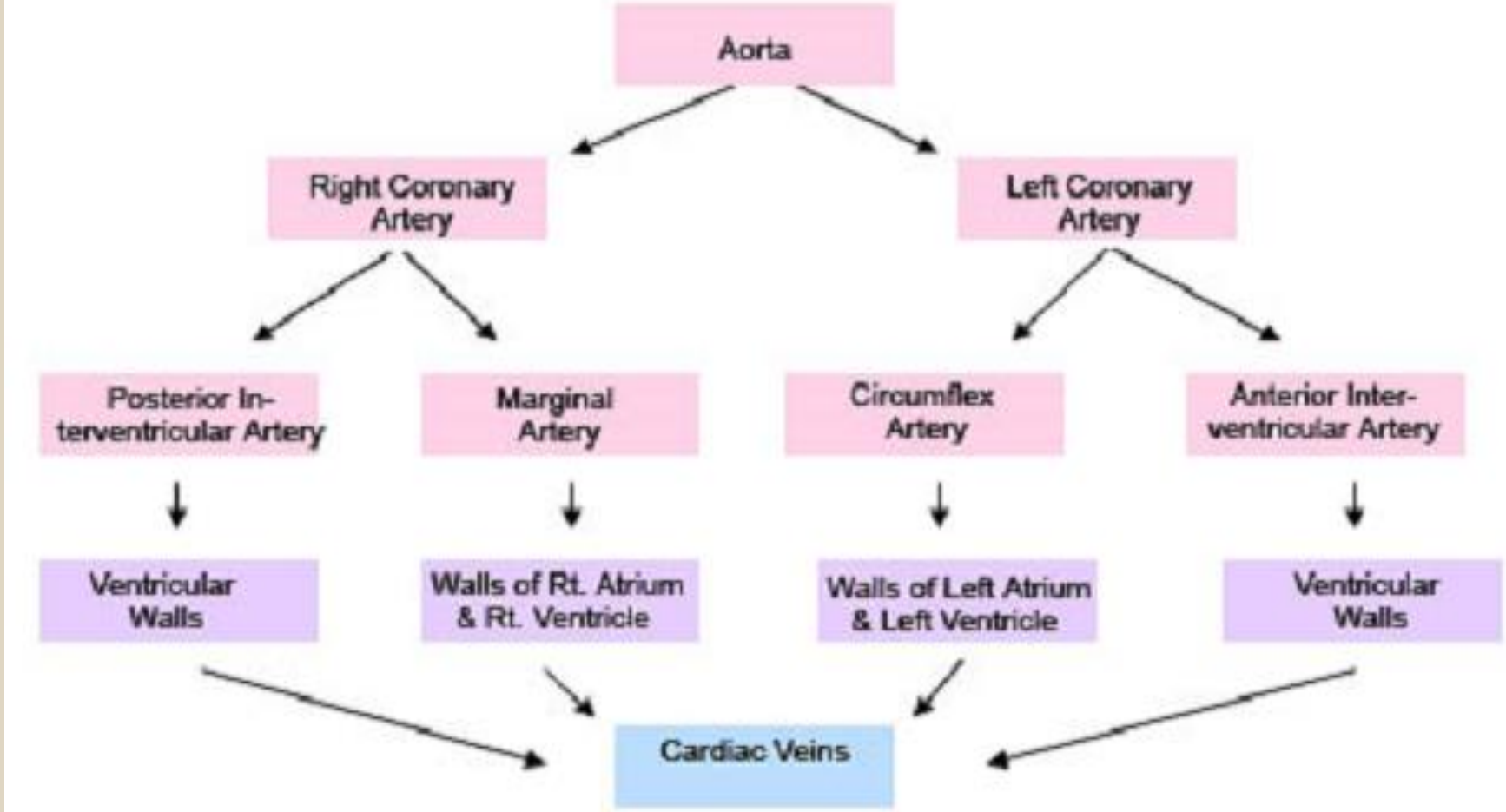
The ATPase is an integral membrane protein and requires phospholipids for activity. The ATPase has catalytic centers for both ATP and Na+ on the cytoplasmic side of the membrane, but the K+ binding site is located on the extracellular side of the membrane. Ouabain or digitalis inhibits this ATPase by binding to the extracellular domain. Inhibition of the ATPase by ouabain can be antagonized by extracellular K+.

The intracellular Na^+ concentration is lower than the extracellular.To equalise the difference, Na^+ automatically flows into the cell via channels in the cell membrane, but it is continuously pumped out again by means of the sodium-potassium pump.

It is very important that the pump continuously maintains the (unequal) intracellular and extracellular Na^+ balance because the flow of Na^+ into a nerve cell forms the basis for the nerve impulses that make it possible for us to move

Cardio pulmonary system

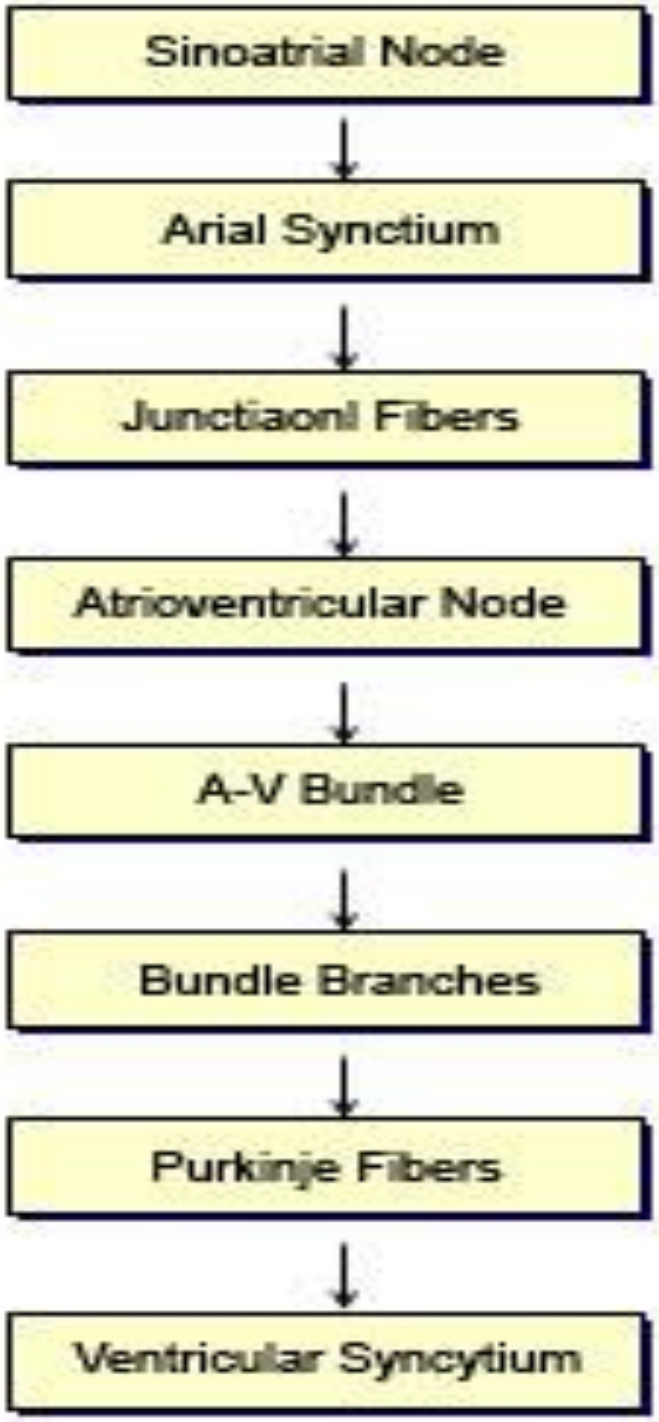




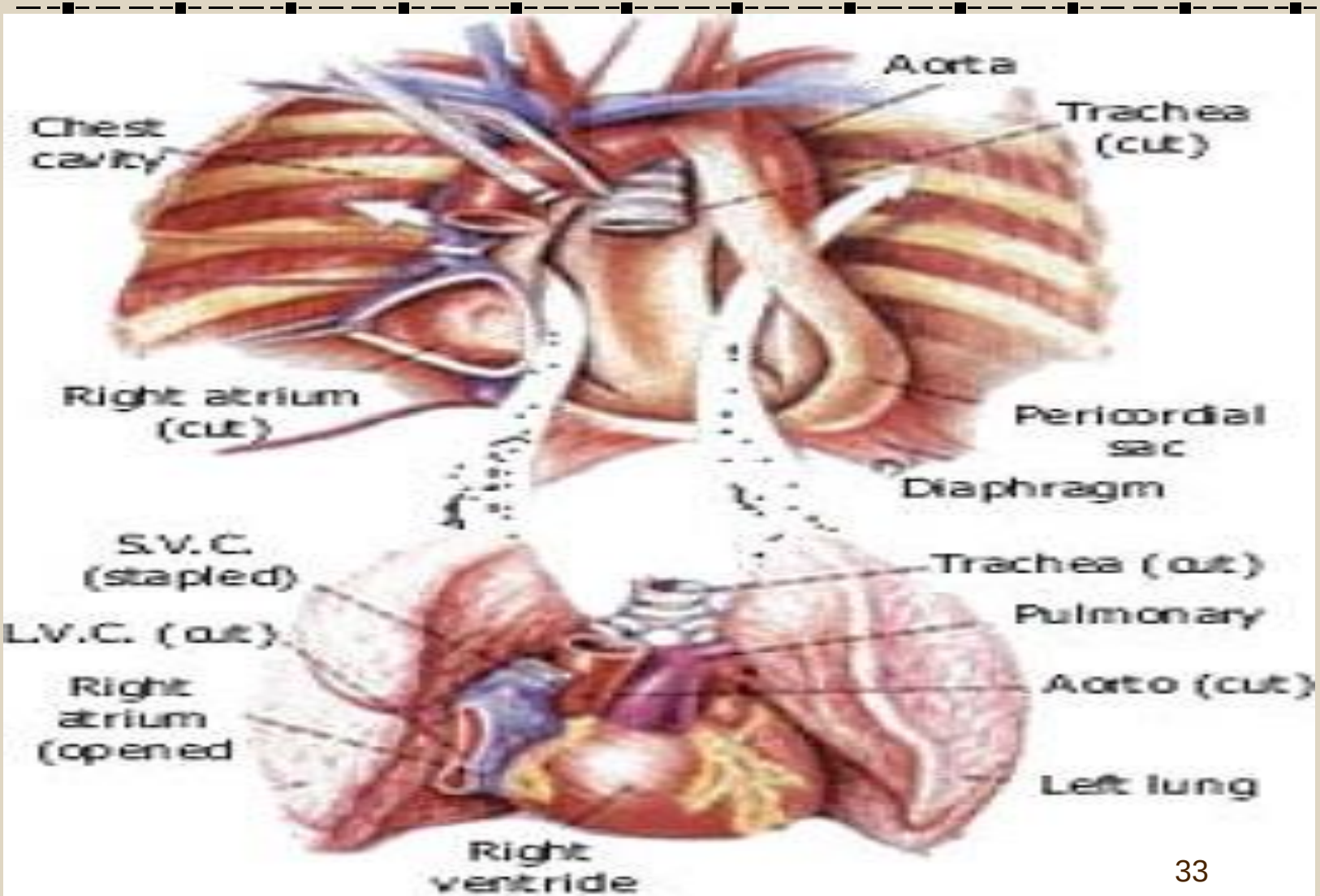
Pink boxes represent oxygented blood, feeding the myocardial cells

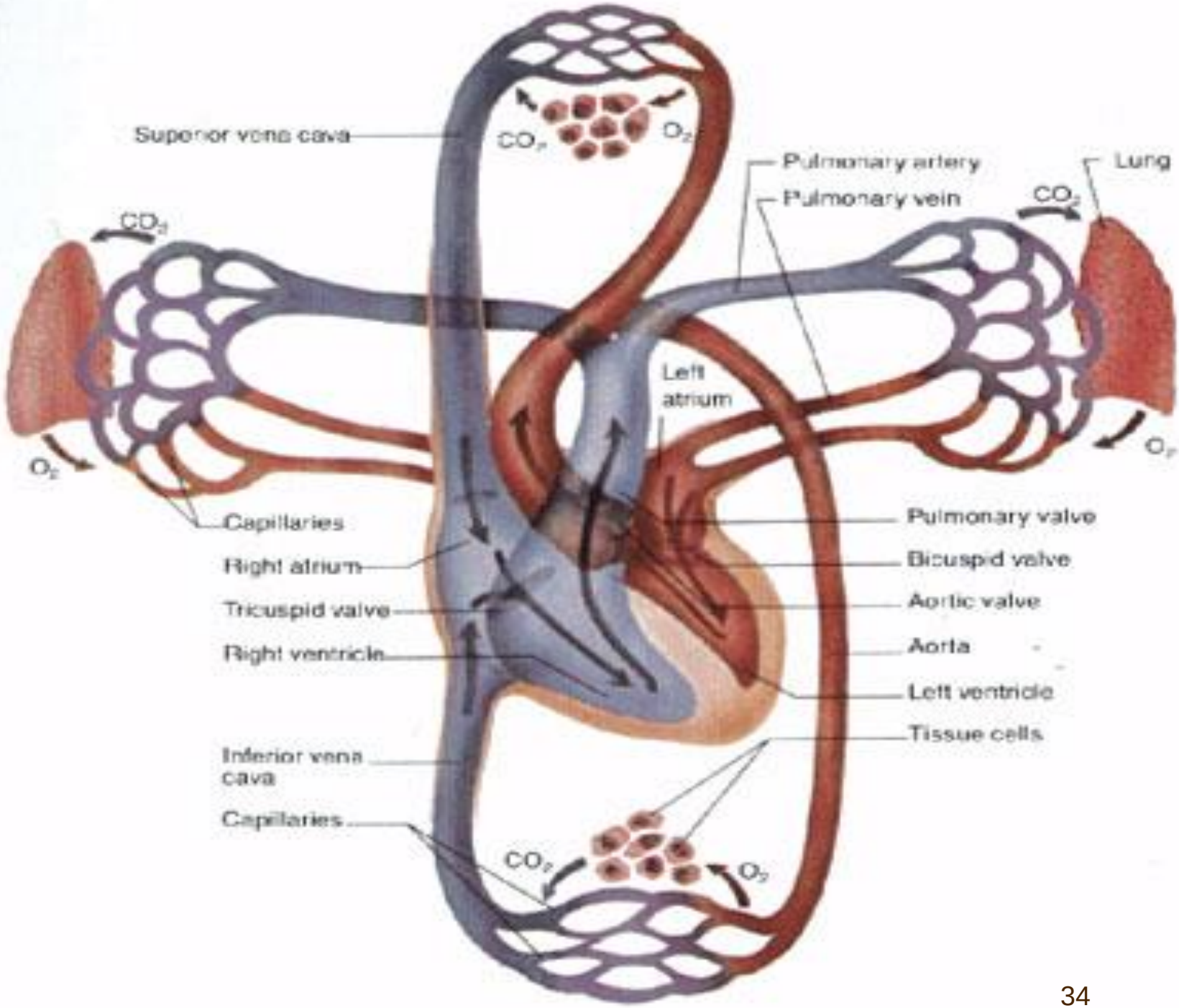
Purple - somewhat oxygenated

Blue - less oxygenated, as blood returns from myocardial cells, to be pumped back into the lungs.

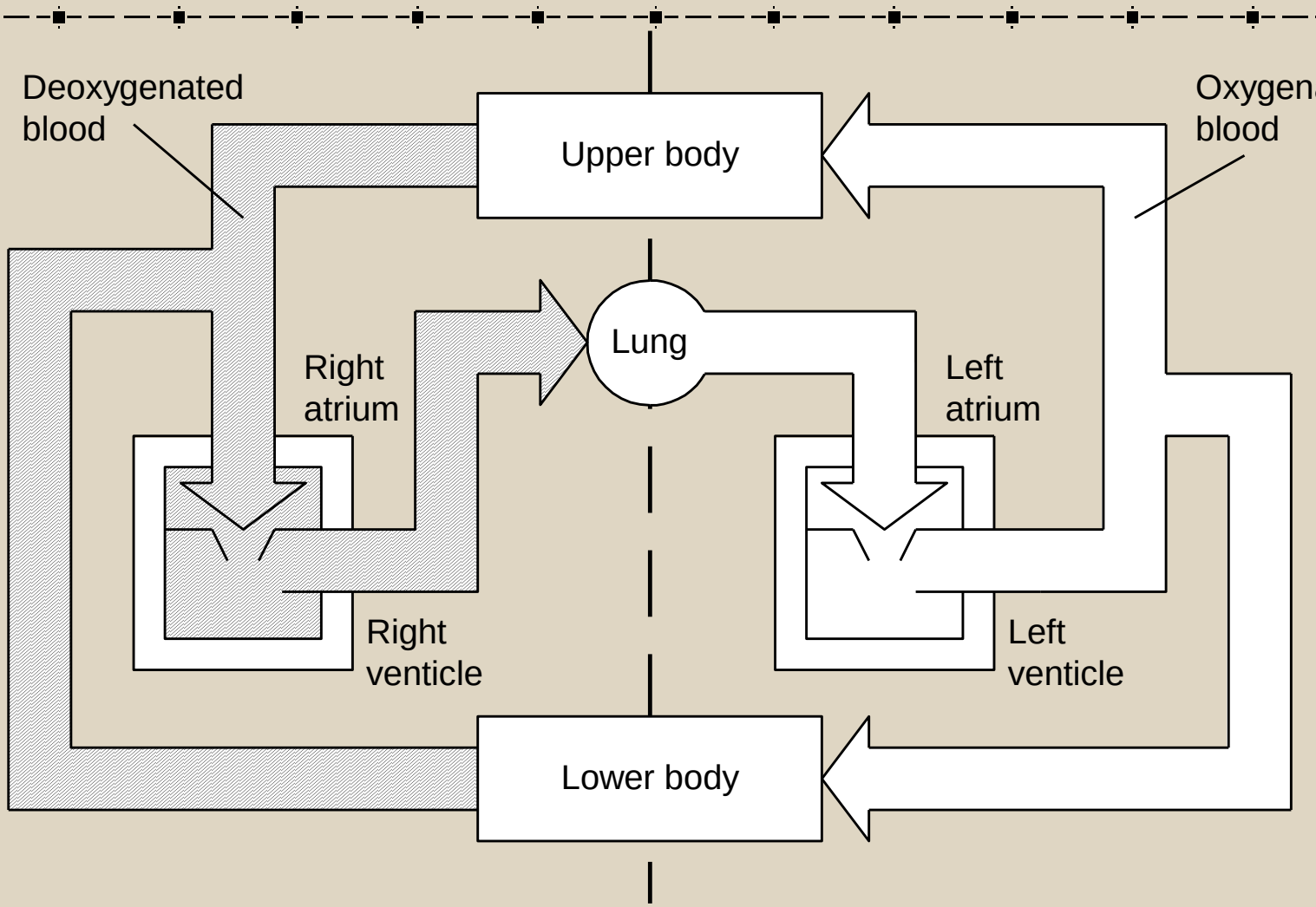

Sinoatrial Node
Arial Synctium
Junctiaonl Fibers
Atrioventricular Node
A-V Bundle
Bundle Branches
Purkinje Fibers
Ventricular Syncytium

Physiology of heart and lungs




Superior vena cava
CO_2
O_2
Pulmonary artery
Pulmonary vein
Lung
CO_2
CO_2
Left atrium
O_2
Capillaries
Right atrium
Tricuspid valve
Right ventricle
Pulmonary valve
Bicuspid valve
Aortic valve
Aorta
Left ventricle
Tissue cells
Inferior vena cava
Capillaries
CO_2
O_2

Circulation and respiration



ELECTROPHYSIOLOGY

•It is the study of the electrical properties of biological cells and tissues.

•It involves measurements of voltage change or electric current on a wide variety of scales from single ion channel proteins to whole organs like the heart.

• In neuroscience, it includes measurements of the electrical activity of neurons, and particularly action potential activity.

•Recordings of large-scale electric signals from the nervous system such as electroencephalography, may also be referred to as electrophysiological recordings.

Electrophysiology is the science and branch of physiology that pertains to the flow of ions in biological tissues and, in particular, to the electrical recording techniques that enable the measurement of this flow.

Classical electrophysiology techniques involve placing electrodes into various preparations of biological tissue. The principal types of electrodes are:

- simple solid conductors, such as discs and needles (singles or arrays, often insulated except for the tip).
- tracings on printed circuit boards, also insulated except for the tip.
- hollow tubes filled with an electrolyte, such as glass pipettes filled with potassium chloride solution or another electrolyte solution.

ELECTROPHYSIOLOGY

Many particular electrophysiological readings have specific names:

Electrocardiography - for the heart

Electroencephalography - for the brain

Electrocorticography - from the cerebral cortex

Electromyography - for the muscles

Electrooculography - for the eyes

Electroretinography - for the retina

Electroantennography - for the olfactory receptors in arthropods

Audiology - for the auditory system

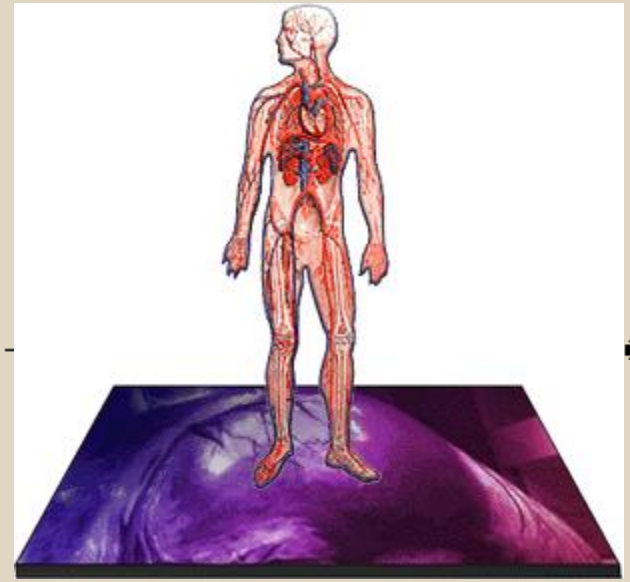
Cardiopulmonary Systems

Respiration rate

Primary functions of respiratory system are to supply oxygen and remove carbon dioxide from the tissues.

The action of breathing is controlled by a muscular action causing the volume of the lung to increase and decrease to effect a precise and sensitive control of the tension of carbon dioxide in the arterial blood.

Cardiopulmonary System

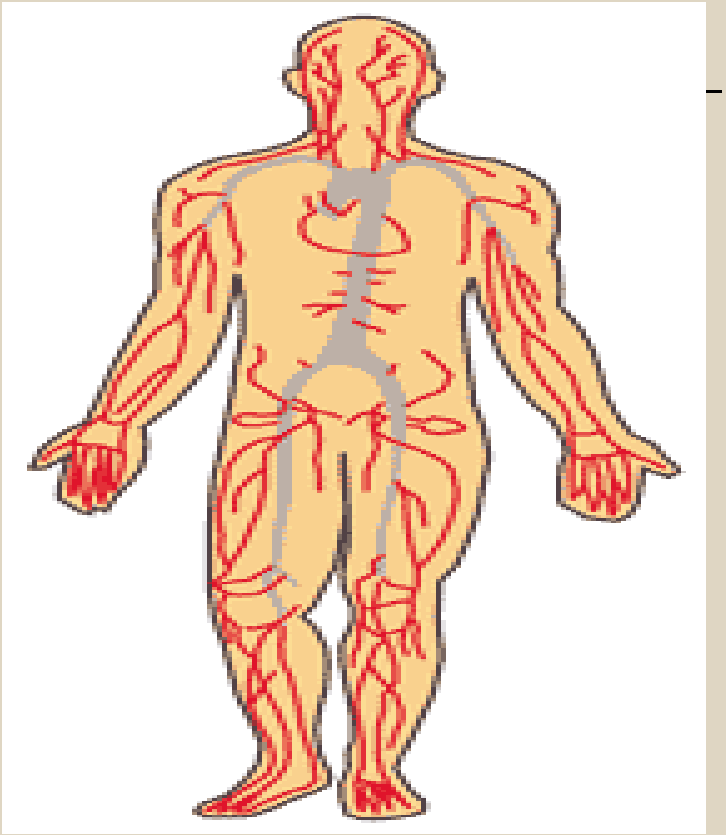


Goal of The Cardiovascular System

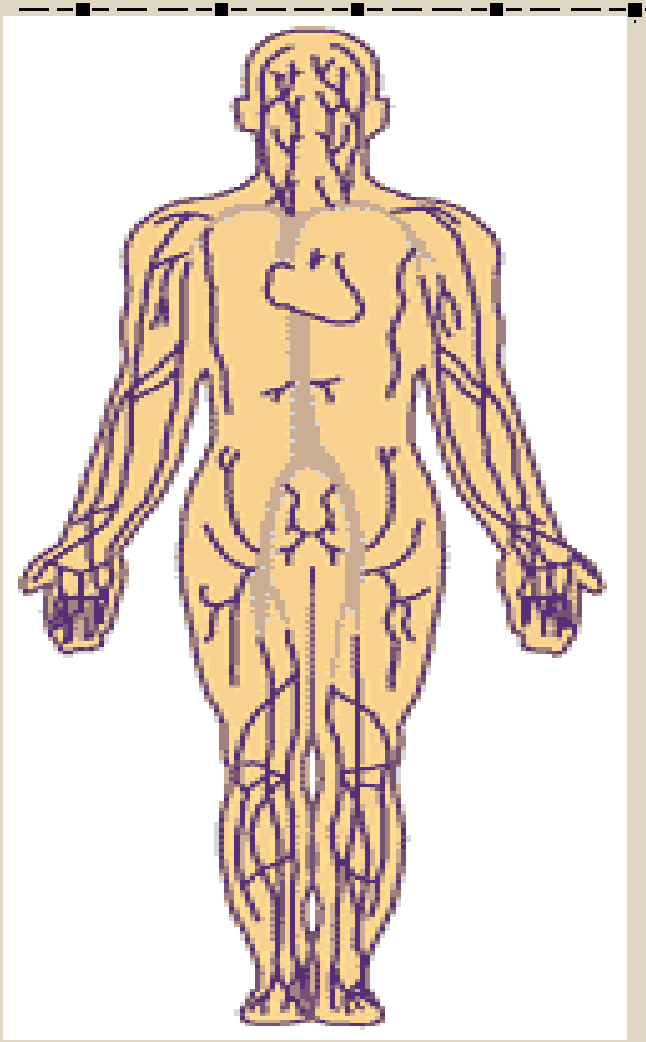
- To ensure delivery of oxygenated blood and nutrients to all the organs and tissues of the body.
- To carry cellular waste products from the area where they are produced to the kidneys and liver where they are processed for excretion by the body.

Blood Vessels

- Three types of blood vessels in body:
  - **Arteries: The large blood vessels that lead away from the heart. Their walls are elastic, and smaller branches of the arteries are called arterioles.**



Blood Vessels



- **Veins: They take de-oxygenated blood back to the heart and lungs to be re-oxygenated. They have thinner walls than arteries, and have valves within their inner walls, to keep blood moving in one direction.**

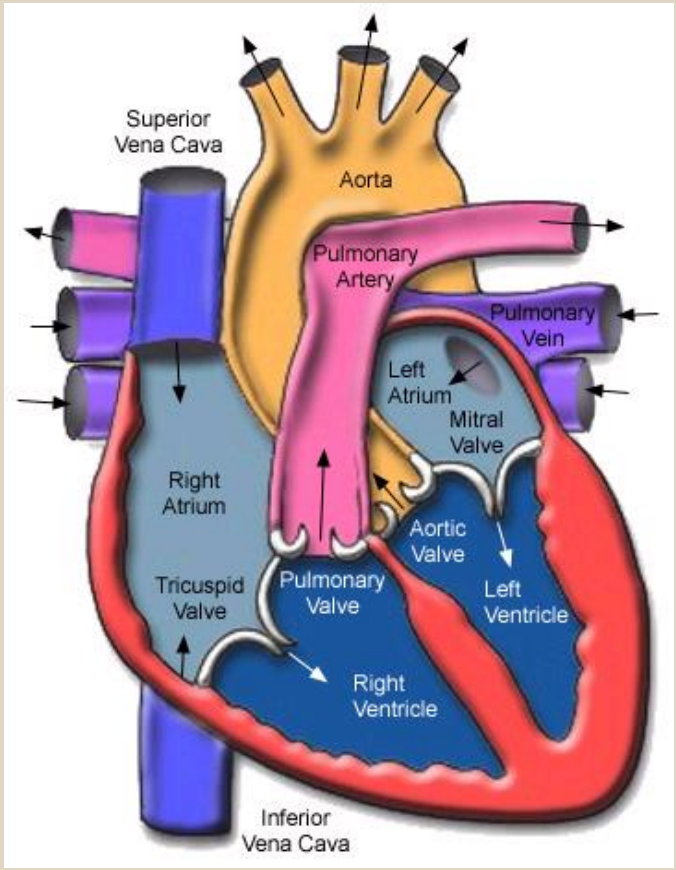
Blood Vessel

- **Capillaries:**
  Are delicate, microscopic vessels that are very thin.
- **Oxygen and nutrients can pass through them!**

Blood Circulation

- Three types:
  - Pulmonary
  - Cardiac
  - Systemic

Cardiac Circulation



- Inferior/Superior Vena Cava
- Right Atrium
- Right Ventricle
- Pulmonary Artery (to lungs)
  Pulmonary Vein
- Left Atrium
- Left Ventricle
- Aorta (to rest of body)

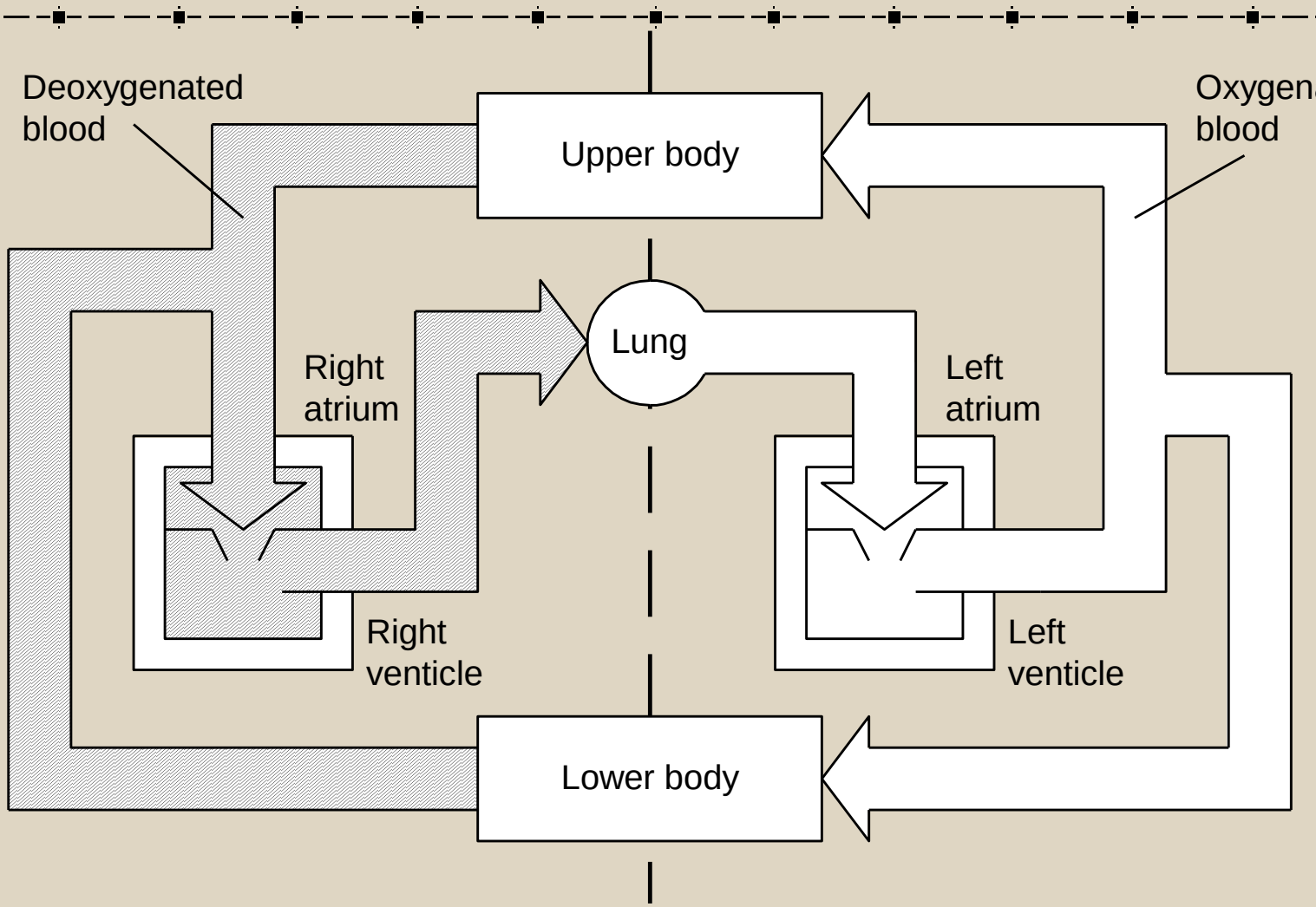
Circulation

- De-oxygenated blood flows through the venae cavae (plural) **Superior vena cava** and **Inferior vena cava** into the right side of the heart, through to **pulmonary artery** which divides the blood to each lung.
- And the branches keep getting smaller and smaller until it reaches the lung capillaries. While the blood is flowing through the lung capillaries, it picks up fresh oxygen, and heads back to the heart via the **pulmonary veins**.
- This fresh, oxygen-rich blood goes back to the left side of the heart where it is pumped out to the rest of the body through the **aorta**.

Circulation

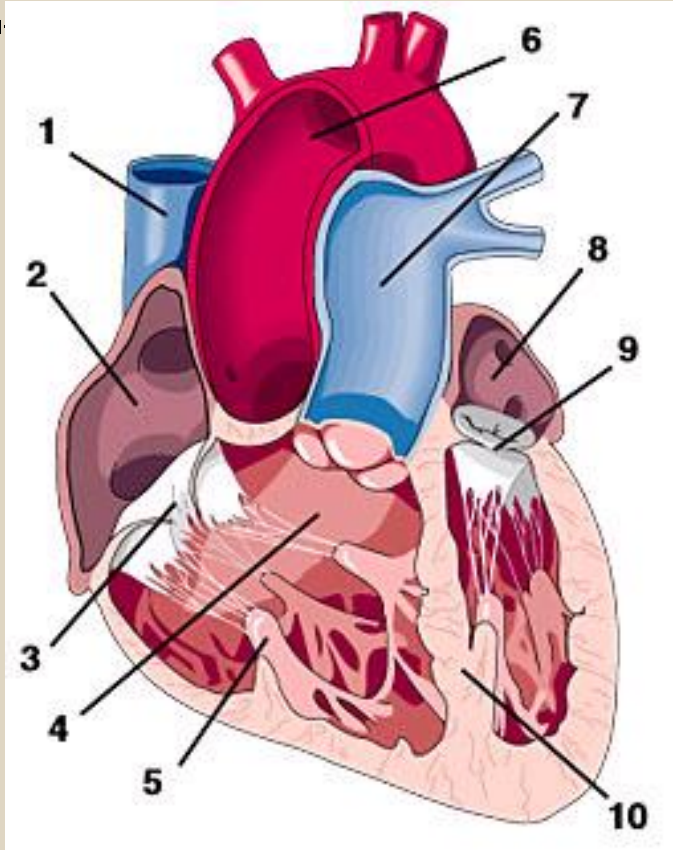
- When blood flows out the aorta, it flows through **arteries** to smaller vessels called **arterioles** and to smaller vessels called **capillaries**.
- At the capillary level, the fresh oxygen is exchanged for carbon dioxide along with other cellular waste products, and the blood begins to return to the heart via the veins.

Circulation and respiration



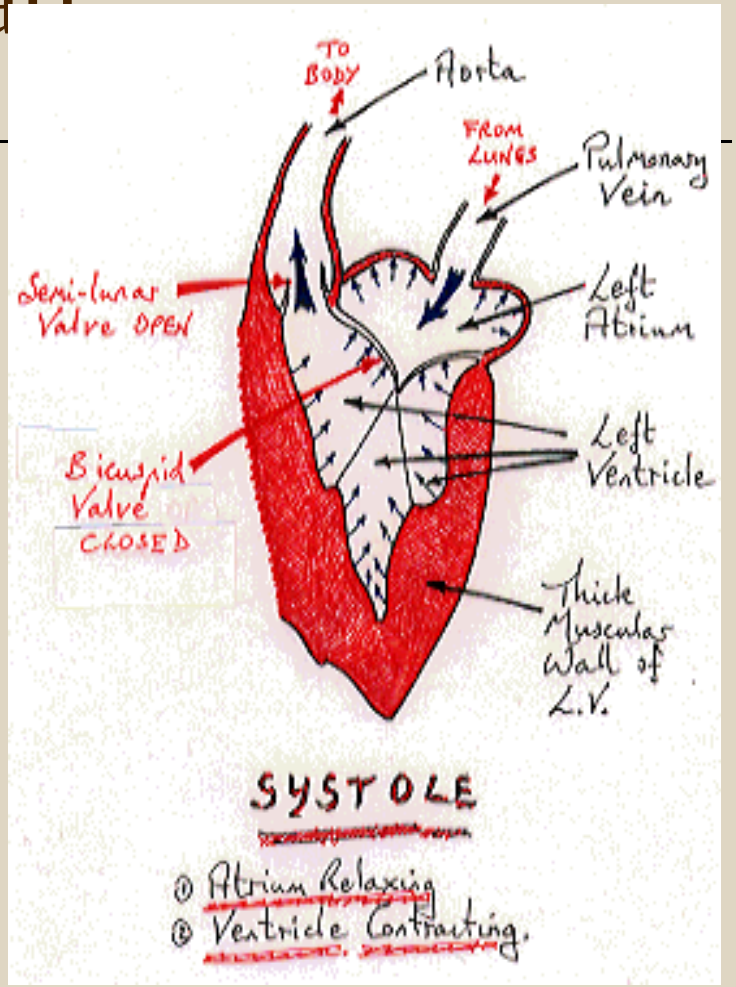
Cardiac Anatomy

- The heart is a muscular pump, made up of four chambers: two atria (right and left) and two ventricles (right and left)
- In between the atria (on top) and the ventricles (on the bottom) are valves.
- On the right side of the heart the valve is called the tricuspid valve.
- On the left side of the heart the valve is called the mitral valve.



Physiology of the Heart

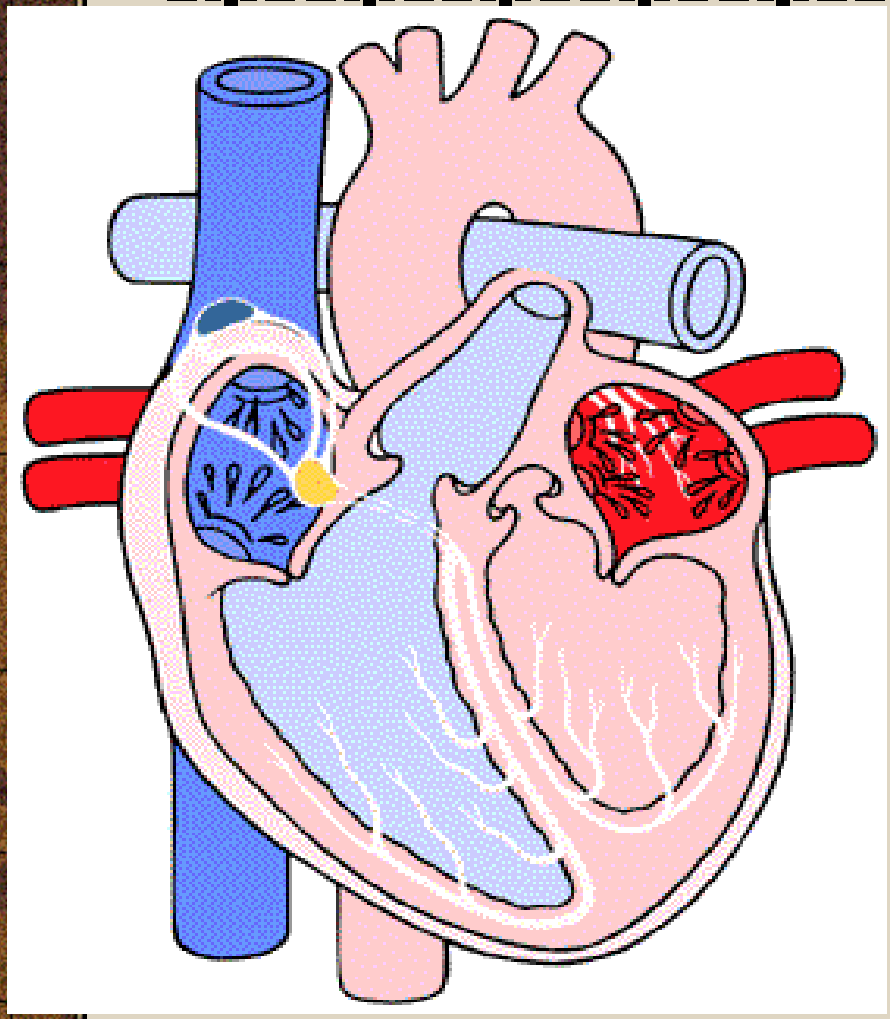
- Each heartbeat has two phases: systole (contraction) and diastole (relaxation).
- Diastole occurs when the walls of the ventricle relax, and blood flows into the heart from the venae cavae and the pulmonary veins.
- Systole occurs after that, as the walls of the right and left ventricles contract to pump blood into the pulmonary artery and the aorta.



Principles related to Cardiac Conduction

- Heart muscle has properties that no other muscle in body has: principle of automaticity, meaning that heart muscle actually initiates the impulse for the heart to beat.
- Specialized areas in the heart are responsible for this beat initiation.

Cardiac Conduction System



- Primary responsibility for initiating impulses comes from the sinoatrial node.
- Also called the SA node, and the pacemaker of the heart.
- The electricity produced in the SA Node travels through the atria down through the AV Node, and down through the Bundle of His, and the right & left bundle branches, which depolarizes the ventricles and produces the contraction.

Cardiac System

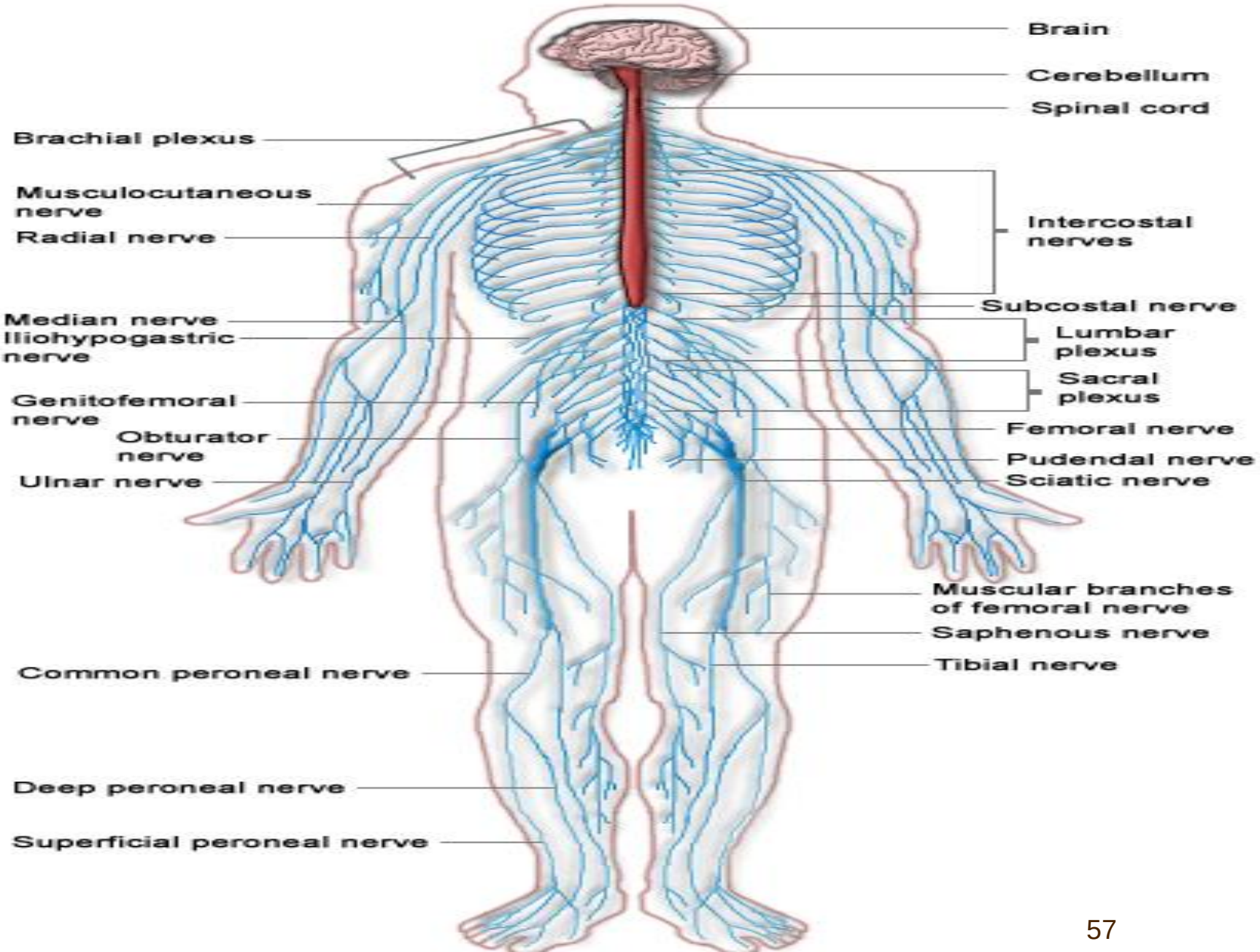
- The cardiac system is a complex and unique system. Nearly all changes that occur in the body affect the cardiac system in some way.
- It is a constantly adapting system!

Respiration

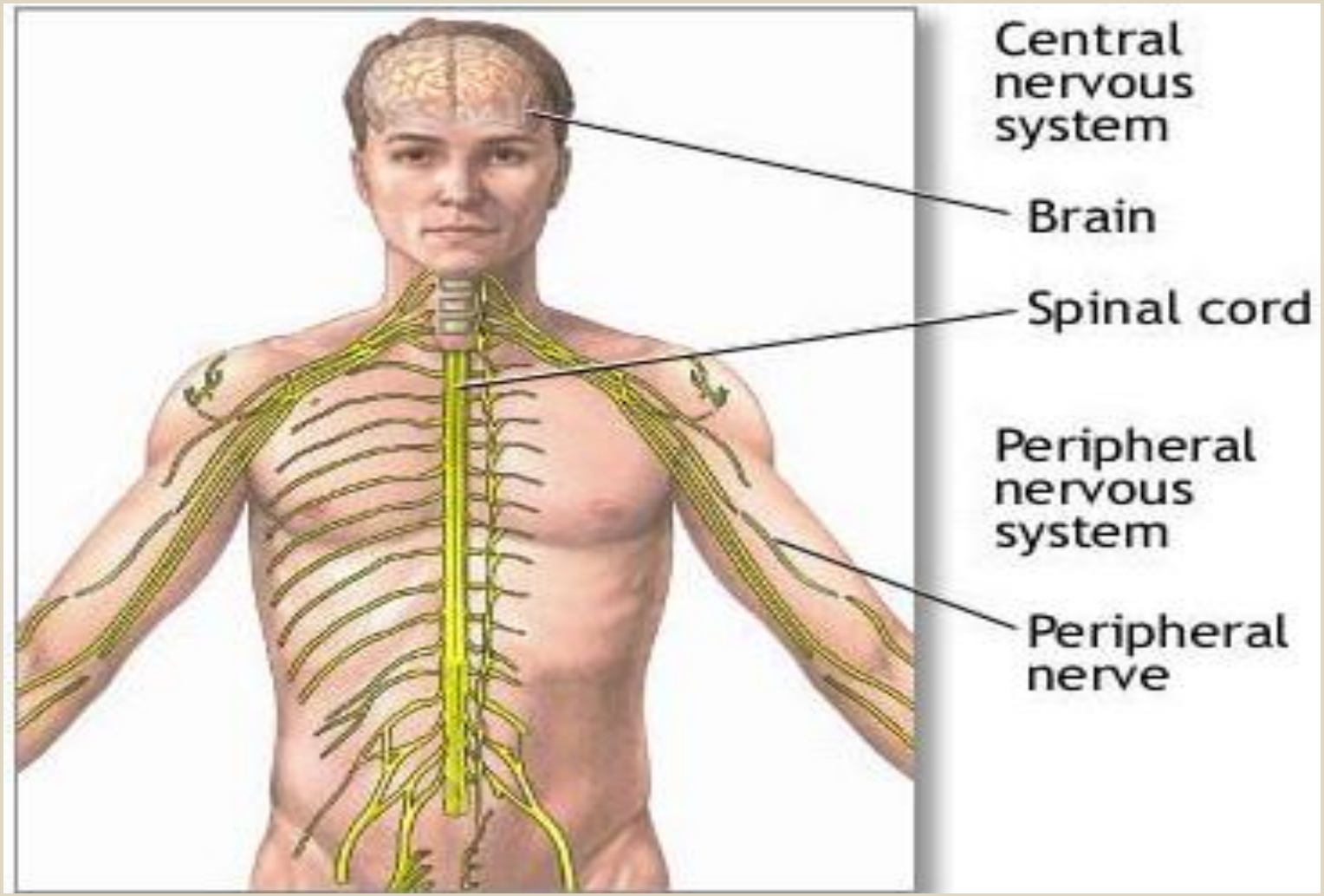
Primary functions of respiratory system are to supply oxygen and remove carbon dioxide from the tissues.

The action of breathing is controlled by a muscular action causing the volume of the lung to increase and decrease to effect a precise and sensitive control of the tension of carbon dioxide in the arterial blood.

Nervous system

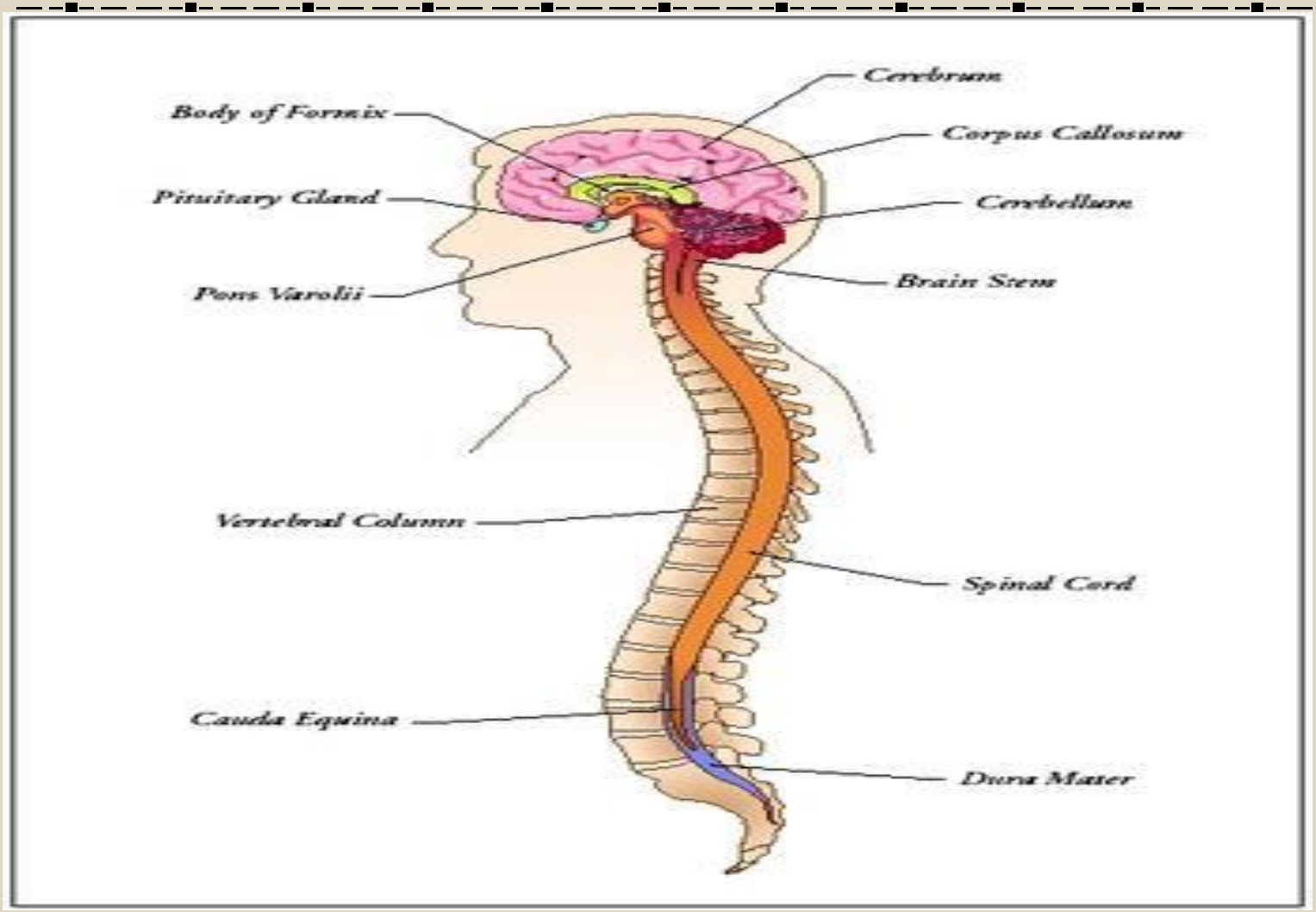


Central Nervous System (CNS)



The **central nervous system** (**CNS**) is the part of the nervous system that functions to coordinate the activity of all parts of the bodies of multicellular organisms. In vertebrates, the central nervous system is enclosed in the meninges. It contains the majority of the nervous system and consists of the brain and the spinal cord. Together with the peripheral nervous system it has a fundamental role in the control of behavior. The CNS is contained within the dorsal cavity, with the brain in the cranial cavity and the spinal cord in the spinal cavity. The brain is protected by the skull, while the spinal cord is protected by the vertebrae.

Peripheral Nervous System (PNS)



The **peripheral nervous system** (**PNS**) resides or extends outside the central nervous system (CNS), which consists of the brain and spinal cord. The main function of the PNS is to connect the CNS to the limbs and organs. Unlike the central nervous system, the PNS is not protected by bone or by the blood-brain barrier, leaving it exposed to toxins and mechanical injuries. The peripheral nervous system is divided into the somatic nervous system, autonomic nervous system and the sensory system

BIO–MEDICAL INSTRUMENTATION

BEE 007

Unit: II

SENSORS & RECORDERS

PHYSIOLOGICAL TRANSDUCERS

- Medical science has traditionally contributed to accumulated knowledge and guarded the health of men undertaking hazardous missions. Bioastronautic research and operations is a continuation of that responsibility and requires electronic techniques for crew selection, evaluation of the biological adequacy of space vehicles, and monitoring crew members during flight. Determining the optimum physiological parameters to measure, developing techniques for the transmission and intelligent analysis of multi-channel data, and providing reliable transducers have been and still are major tasks. Transducers for temperature, respiration, cardiac function and performance measurements have been used for successfully completed space programs. Thermistors, the electrical impedance pneumograph, pulse wave velocity, and performance measurement will be instrumentation techniques and devices of future bioastronautics research and operations.

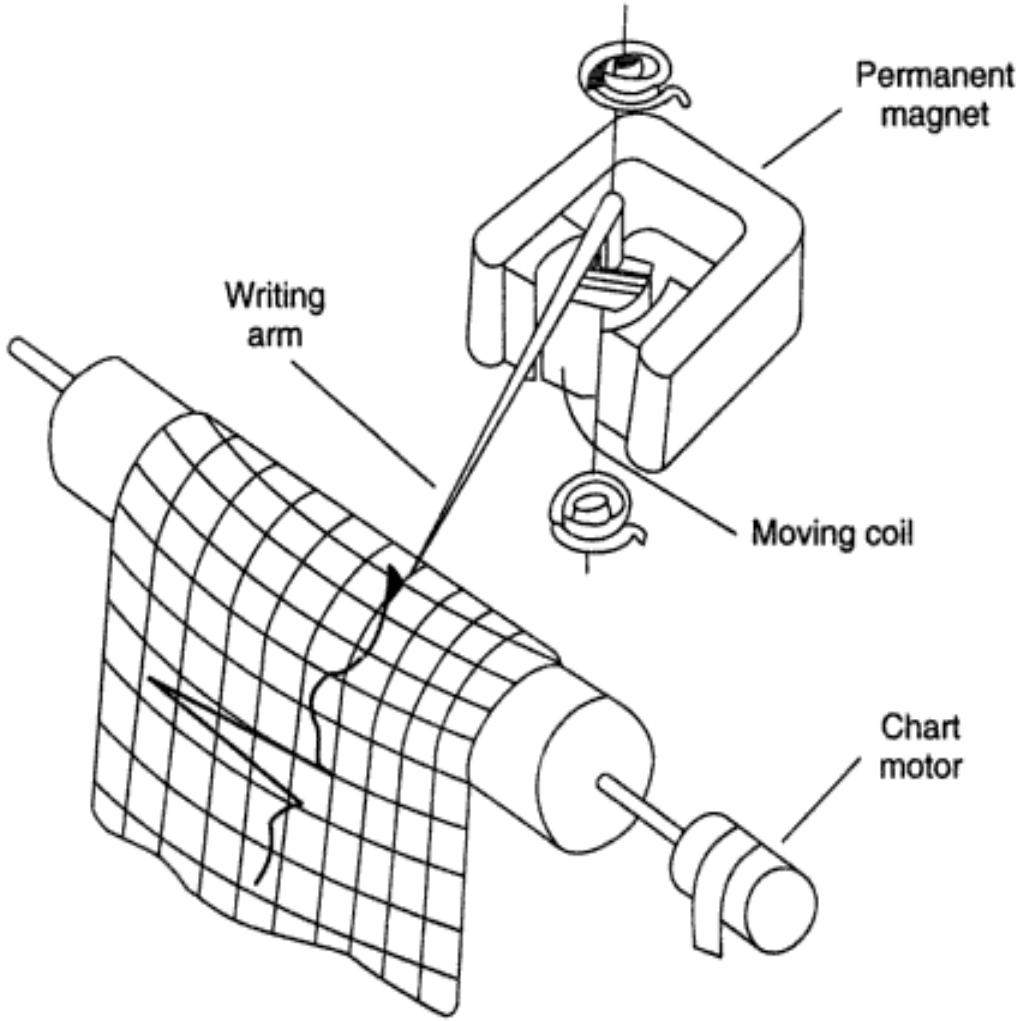
4.9 DIRECT WRITING RECORDERS

In the most commonly used direct writing recorders, a galvanometer activates the writing arm called the pen or the stylus. The mechanism is a modified form of the D'Arsonval meter movement. This arrangement owes its popularity to its versatality combined with reasonable ruggedness, accuracy and simplicity.

A coil of thin wire, wound on a rectangular aluminium frame is mounted in the air space between the poles of a permanent magnet (Fig. 4.18). Hardened-steel pivots attached to the coil frame fit into jewelled bearings so that the coil rotates with a minimum of friction. Most often, the pivot and jewel is being replaced by a taut band system. A light-weight pen is attached to the coil. Springs attached to the frame return the pen and coil always to a fixed reference point.

When current flows through the coil, a magnetic field is developed which interacts with the magnetic field of the permanent magnet. It causes the coil to change its angular position as in an electric motor. The direction of rotation depends upon the direction of flow of current in the coil. The magnitude of pen deflection is proportional to the current flowing through the coil. The writing stylus can have an ink tip or it can have a tip that is the contact for an electro-sensitive, pressure sensitive or heat sensitive paper. If a writing arm of fixed length is used, the ordinate will be curved. In order to convert the curvilinear motion of the writing tip into a rectilinear motion, various correcting mechanisms have been devised to change the effective length of the writing arm as it moves across the recording chart.

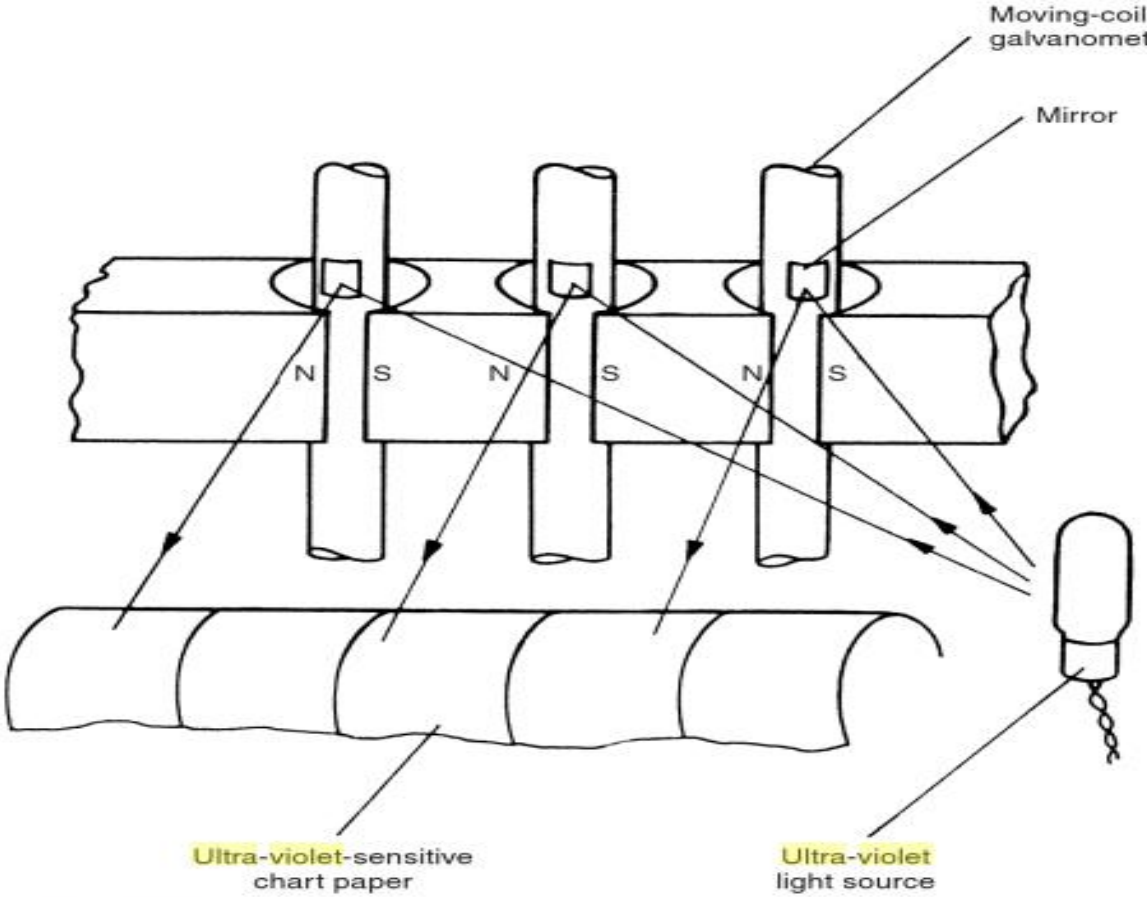
Taut band instruments are preferred over pivot and jewel type instruments because they have the advantages of increased electrical sensitivity, elimination of friction, better repeatability and increased service life.



➤ **Fig. 4.18** *Principle of a direct writing galvanometric recorder*

Ultra-violet recorders

The earlier discussion about galvanometric recorders concluded that restrictions on how far the system moment of inertia and spring constants can be reduced limited the maximum bandwidth to about 100 Hz. Ultra-violet recorders work on very similar principles to standard galvanometric chart recorders, but achieve a very significant reduction in system inertia and spring constants by mounting a narrow mirror rather than a pen system on the moving coil. This mirror reflects a beam of ultra-violet light onto ultra-violet sensitive paper. It is usual to find several of these mirror-galvanometer systems mounted in parallel within one instrument to provide a multi-channel recording capability, as illustrated in Figure 11.10. This arrangement enables signals at frequencies up to 13 kHz to be recorded with a typical inaccuracy of ±2% f.s. Whilst it is possible to obtain satisfactory permanent signal recordings by this method, special precautions are necessary to protect the ultra-violet-sensitive paper from light before use and to spray a fixing lacquer on it after recording. Such instruments must also be handled with extreme care, because the mirror galvanometers and their delicate

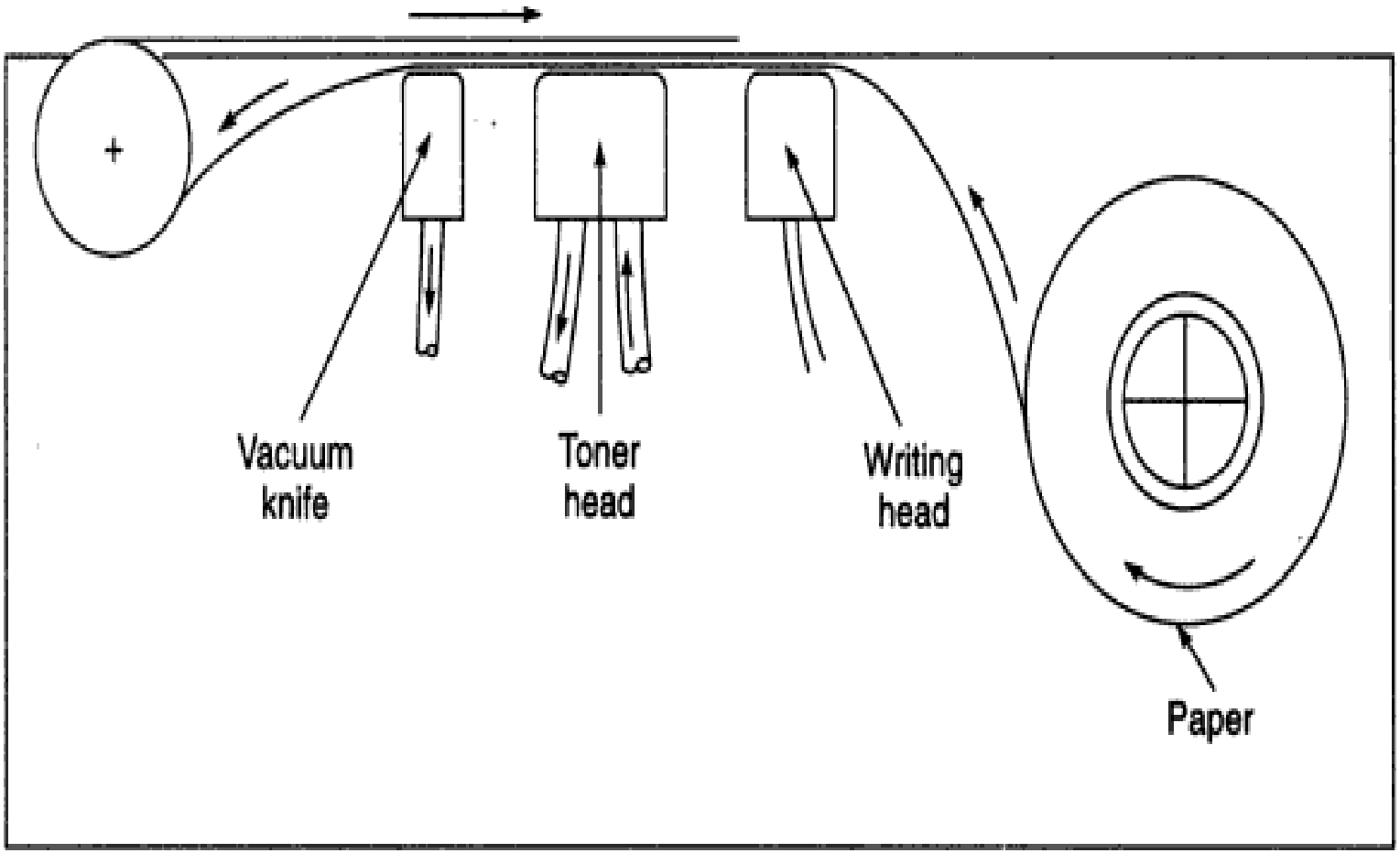


Ultra-violet recorder.

Electrostatic Recorder

Electrostatic recorders are high frequency analog recorders which employ a high resolution electrostatic device to produce records on a wide, low cost paper at chart speeds up to 250 mm per second. By eliminating moving writing parts, the electrostatic writing process disposes of the characteristic moving pen problems like: inertia effects such as overshoot or low-frequency response limits, linkage effects such as non-linearity, hysteresis, and the inability to overlap traces, and preprinted grids that move with paper movement and expand or shrink with changing humidity conditions.

The Gould ES 1000 (Fig. 4.30) electrostatic writing system is composed of three elements: the imaging head, the toning head, and the vacuum knife. The imaging head is composed of a linear array of 1000 wire elements, spaced 4 per mm, for a total length of 250 mm. On each side of the array are 32 copper bars called shoes. As the paper moves over the image head, a negative voltage is applied to selected wire elements and a positive voltage is applied to the closest shoes. This places a negative point charge on the paper at the point where the wire element was. The paper then passes the toner head and positively charged ink particles adhere to where the paper had negative charge. A vacuum knife finally removes all excess toner and particles, making the image with charged particles. Exposure to air causes the adhesive-coated particles to permanently bond to the paper and the record emerges from the machine completely dry.



Principle of electrostatic recorder (Courtesy: Gould Inc., USA)

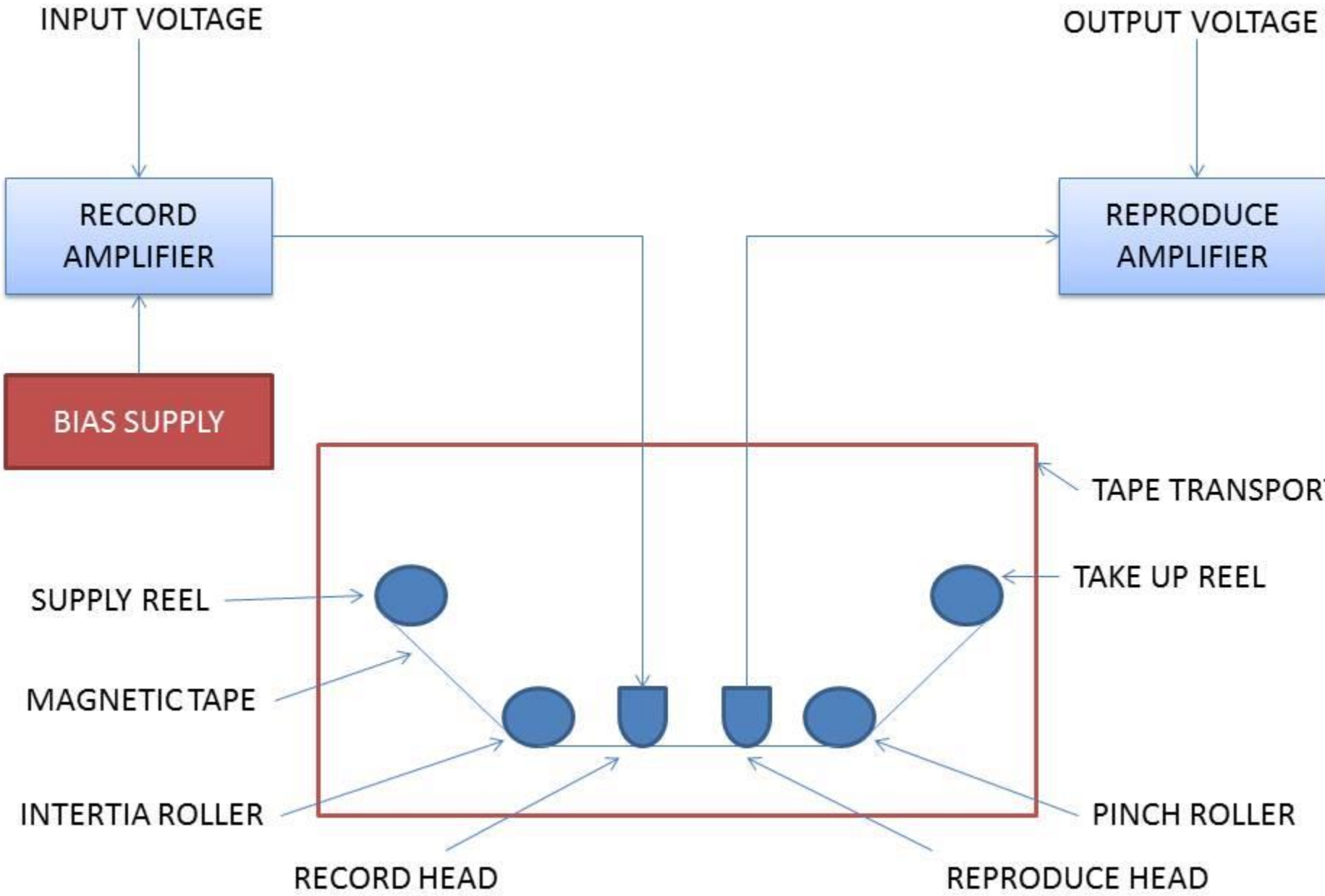
INSTRUMENTATION TAPE RECORDERS

Magnetic tape recording techniques and equipment have found extensive use in the hospital set-up. The fact that the signal is always available in electrical form, makes it possible to record the whole of an experimental procedure on a tape and then play it back for display on the CRT at a later time. The use of computers in the medical field has further broadened the field of magnetic tape recording. The information fed into the computers is coded and stored on magnetic tape, thus forming the memory banks for the digital computers.

Magnetic tape recording offers some useful features over other methods of recording. It permits the recording of signals, with suitable techniques, from dc up to several MHz. As the recordings of the tape can be erased any number of times, the tape becomes re-usable, thus offering economy in the recording process. The ability to alter the time base of the recorded events on the tape is something which no other recording medium provides. The events can be played back either faster or slower than they actually occurred. This permits the use of miniature tape recorders for ambulatory monitoring. Since the tape can be played back any number of times, it permits extracting every bit of useful information from the recording. It is also possible to have a very wide dynamic range of recording which may be in excess of 50 decibels. This permits an accurate and linear recording from full-scale signal level down to its 1/3%.

The most familiar method of recording signals on the magnetic tape, is the direct recording process. The electrical signal to be recorded is amplified by the recording amplifier and it is then fed into the recording head where corresponding magnetic fields are produced. The varying magnetic field is transferred to the tape in the form of magnetic patterns in accordance with the signal variations with the tape moving past the head. On replay, the recording process is repeated in the reverse order. The magnetized tape is pulled past and the magnetic field induces a current in the playback head coil. This is then amplified before being passed to a loud speaker, a recorder or any other display device.

Simple Magnetic Recording System



BIO–MEDICAL INSTRUMENTATION

BEE 007

Unit: III

MODERN IMAGING SYSTEMS

X-RAY MACHINE

- The basic components of a diagnostic X-ray machine are power supply arrangement,X-ray tube aluminium filters,collimator,budey diaphragm and lead shield.
- The various components in the machine are used to improve the quality of image,increase the contrast between different tissues,improve size resolution and minimize the dose of X-rays used on the patient.

7.9 X-RAY MACHINE

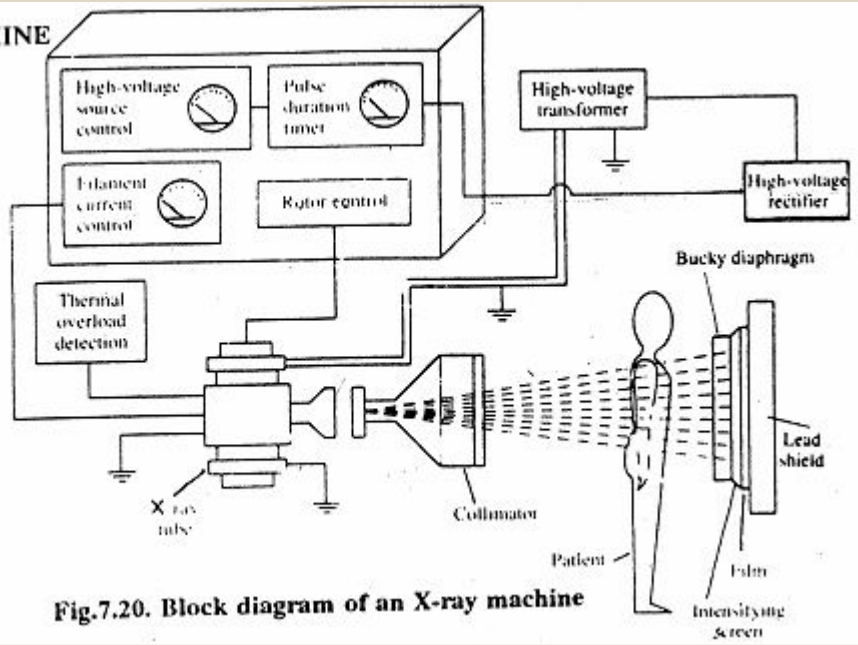


Fig.7.20. Block diagram of an X-ray machine

HIGH VOLTAGE SOURCE

- A high voltage source is an autotransformer which is used to get high voltages from 20 to 200kv in the X-ray machine.
- To avoid over heating of tube there is a temperature monitor.
- If it exceeds a specified value, the high voltage supply will be turned off automatically.

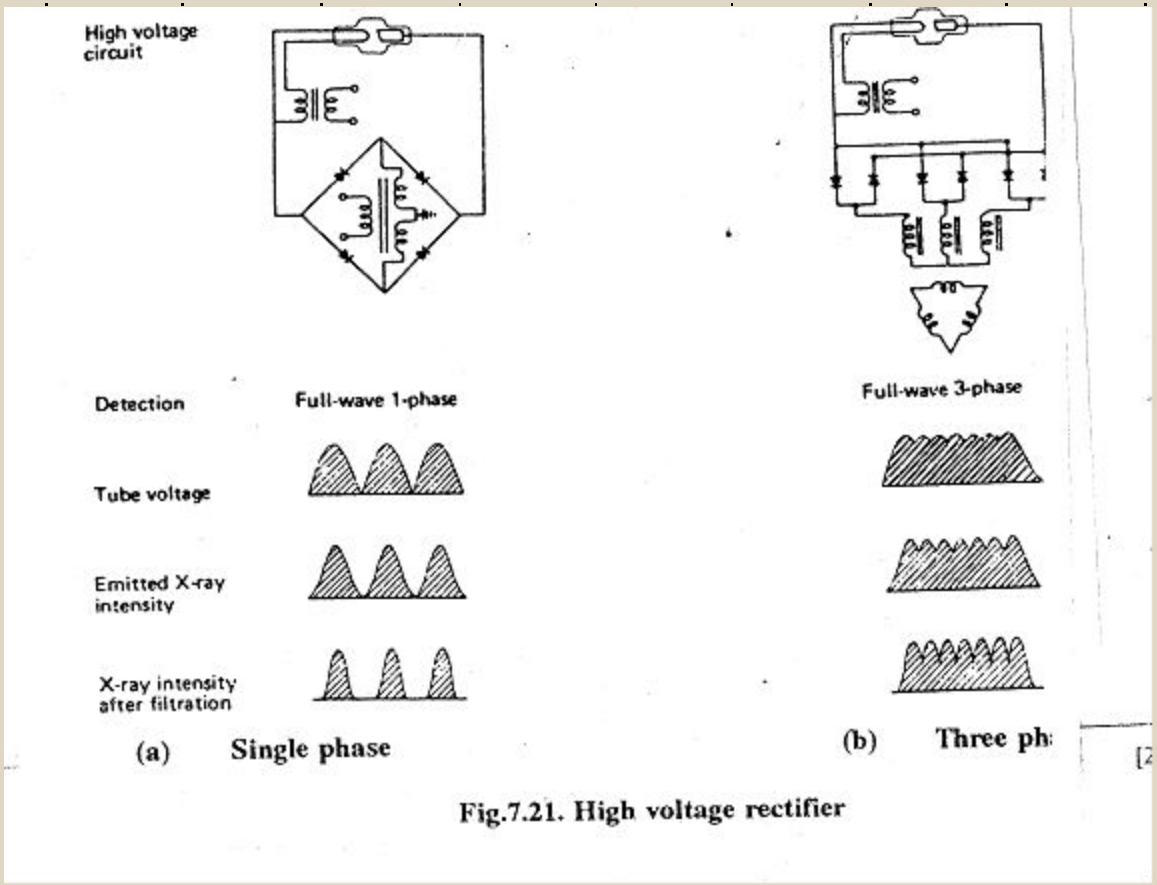


Fig.7.21. High voltage rectifier

High voltage rectifier

- Eventhough X-ray tube requires a high d.c. voltage, due to practical difficulties a high d.c. voltage with small a.c. ripples is used.

- A much better power output is provided by three phase rectifiers in

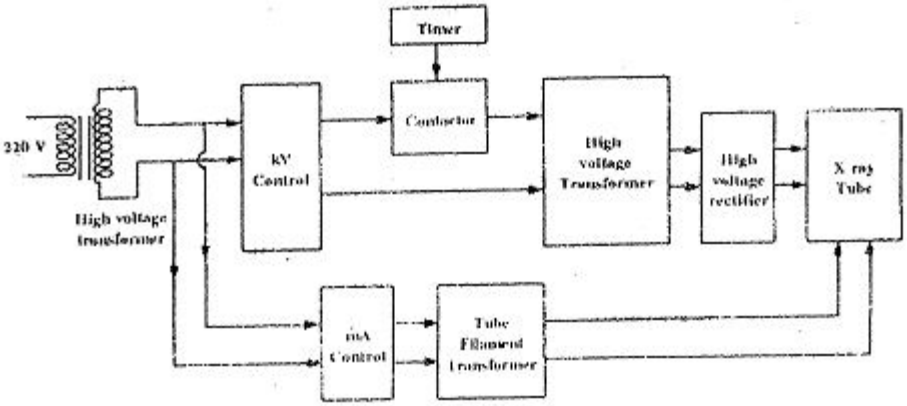
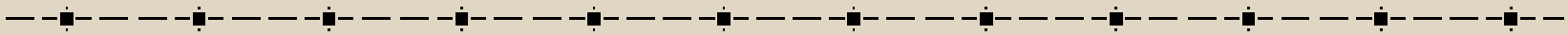


Fig.7.22. Power supply arrangement

APPLICATIONS

- Skeletal structures
- Respiratory organs
- Circulatory organ
- Digestive organ
- Excretory organ



MAGNETIC RESONANCE IMAGING(MRI)

MAGNETIC RESONANCE PHENOMENON

- MRI makes use of the RF region of the electromagnetic spectra to provide an image.
- Started by Felix Block in 1946,who won the Nobel prize for MRI.
- Our body consists of millions of atoms of which 80% are hydrogen atoms.
- Each H2 atom has a positively charged nucleus with only one proton. It spins and has a nuclear magnetic moment with it.
- Normally this spinning of nuclei is random. But in the presence of large magnetic field, its axis of rotation is parallel about the applied field.

MAGNETIC RESONANCE PHENOMENON

- Radio waves,10,000 to 30,000 times stronger than the earth's magnetic field are sent from the scanner into the patient's body.
- The radio waves knock the protons from their position.
- When the burst of radio waves stops, the protons go back into position.
- They realign back to being in parallel with the magnetic field.
- As the protons realign, they emit tiny radio signals. This is called Nuclear Magnetic Resonance Signal.
- These signals are detected by a receiving device in the scanner.
- The receiving device transmits the signals to a computer.

MAGNETIC RESONANCE IMAGING

During magnetic resonance (MRI) scan, a narrow table moves the patient through a tunnel-like structure which creates a magnetic field through which radio waves are sent, creating a 3-D image of the internal structures

A.D.A.M.

MAGNETIC RESONANCE IMAGING

ADVANTAGES:

- Superior contrast resolution
- Direct multiplanar imaging, slices in the sagittal, coronal and oblique directions can be obtained directly.
- There is a total absence of harmful radiations like X-rays,gamma rays, positrons etc. hence making it as a noninvasive imaging technique.

MAGNETIC RESONANCE IMAGING

- MRI is the representation of the spatial distribution of the NMR signal intensity and it is placed deliberately non-uniform magnetic field.
- The purpose is to place different parts of the specimen with different field strengths which represent different frequencies to be displayed.
- It also provides additional diagnostic insights through relaxation parameters, which are not possible from other imaging methods.

MAGNETIC RELAXATION AND MRI PARAMETERS

Three principal MRI parameters are

- SPIN DENSITY
- SPIN-LATTICE(LONGITUDINAL) RELAXATION TIME,T1
- SPIN-SPIN OR TRANSVERSE RELAXATION TIME,T2

1.SPIN DENSITY

One of the most important aspect of MRI is that the signal is proportional to the number of nuclei present.

In case of imaging,0 it is found that hydrogen is very tightly bound and creates no usable signal. Hence the signal should be arising from mobile hydrogen's, those nuclei which are loosely bound.

Example, is the bone which appears black because there are no protons and hence no detectable signal.

So, the measure of the concentration of mobile hydrogen nuclei available to produce an NMR signal is called Spin Density.

Higher the concentration of mobile hydrogen nuclei, stronger will be NMR signal and thus a better image.

T1 and T2 at a field strength of 1 tesla for various tissues with the relative values of mobile hydrogen

TISSUE	T1(ms)	T2(ms)	RELATIVE SPIN DENSITY (%)
FAT	180	90	98
LIVER	270	50	91
WHITE MATTER	390	90	100
GRAY MATTER	520	100	94
SPLEEN	480	80	92
MUSCLE	600	40	100
BLOOD	800	180	90
CSF	2000	300	96
WATER	2500	2500	100

2.SPIN-LATTICE(LONGITUDINAL) RELAXATION TIME

- The nuclei are disturbed from equilibrium by a process called Relaxation.
- The 90 degree RF pulse rotates the net magnetization Mz with the corresponding Mxy.
- MD is the relaxation time describes the rate at which Mz returns to the equilibrium and it happens due to the excited nuclei transferring their energy to the surrounding called spin-lattice.
- The recovery of magnetization is given by

$$Mz(t) = N(H)[1-\exp(-t/T1)$$

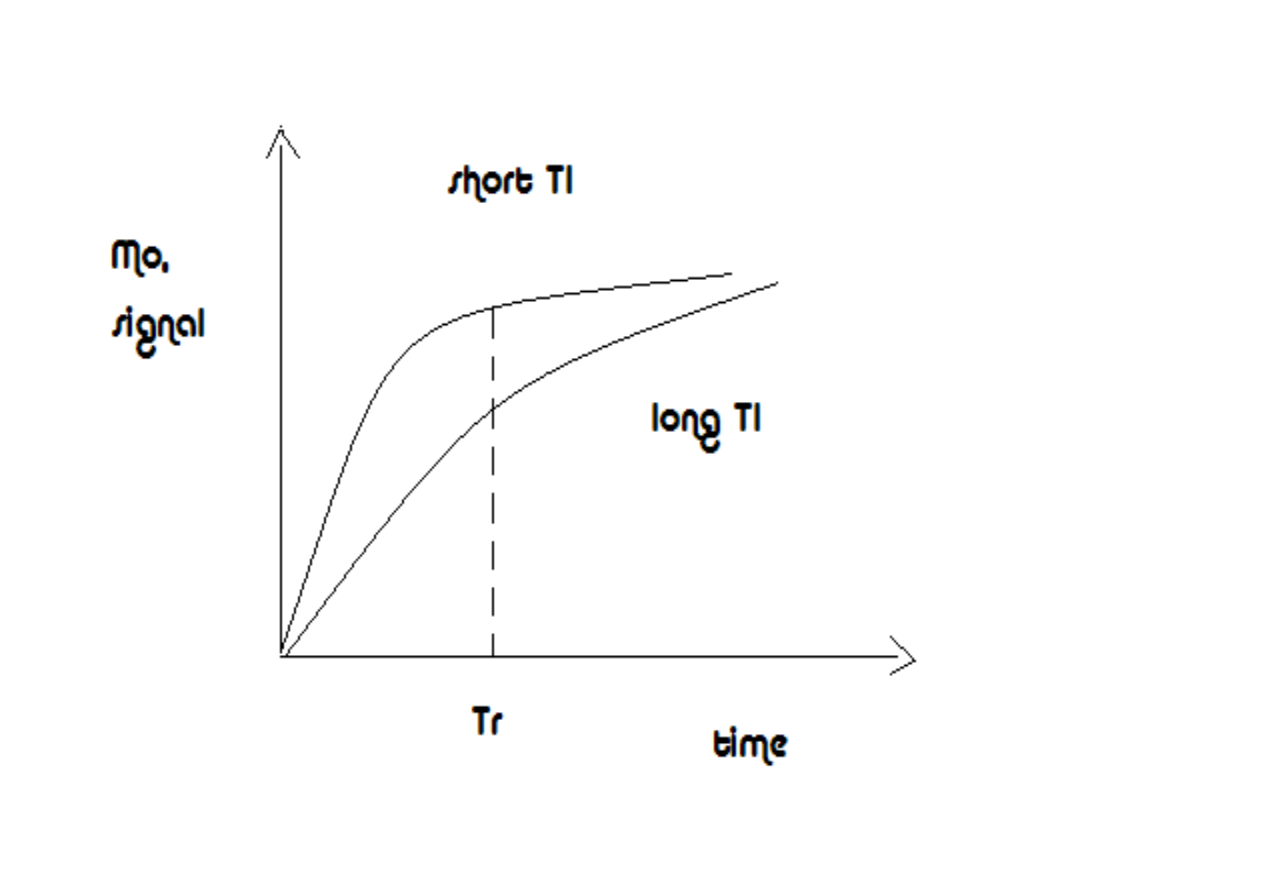
2.SPIN-LATTICE(LONGITUDINAL) RELAXATION TIME

- N(H) – Hydrogen density.
- t – Time elapsed from the start of free induction decay.

- The constant repetition time (t_r) establishes a steady state magnetization, and hence shown in the XY plane as

$$Mxy = N(H)[1-\exp(-t/T1)$$

2.SPIN-LATTICE(LONGITUDINAL) RELAXATION TIME



3.SPIN-SPIN OR TRANSVERSE RELAXATION TIME

- T_2 represents the time constant associated with the loss of magnetization M_{xy} in the XY plane.

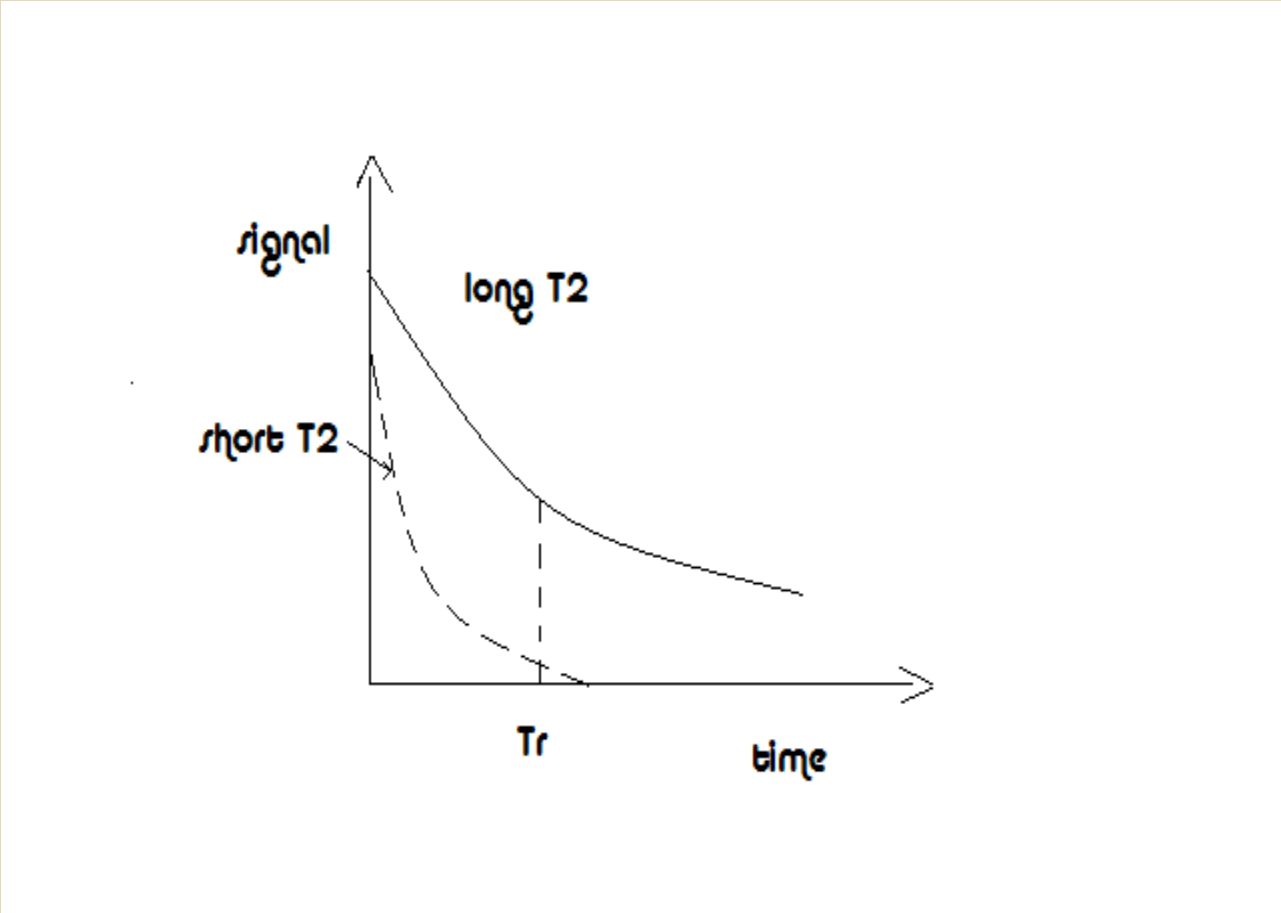
- There is loss of energy because of interaction of nuclei.T_2 is much shorter and occurs due to inhomogenities in the magnetic field.

- The relaxation of peak height of the spin echo at time t_e to the peak height is

$$M_{xy}(t_e) = M_{xy}(0)\exp[-t/T_2]$$

- The measurements of the relaxation times employs different pulse sequences. It is the set of instructions to the magnet telling how to make an image.

3.SPIN-SPIN OR TRANSVERSE RELAXATION TIME



IMAGING PROCESS

- The NMR signal produced through the use of pulse sequences cannot be directly translated into an image.
- It is necessary to convert from a frequency representation to a location representation.
- A digital computer performs these conversations. In the magnetic field gradient the NMR signal yields 1-D distribution.
- Of the two techniques, Projection Reconstruction Imaging and 2-D Fourier Transforms imaging, the latter is preferable because of the fast computational facility.

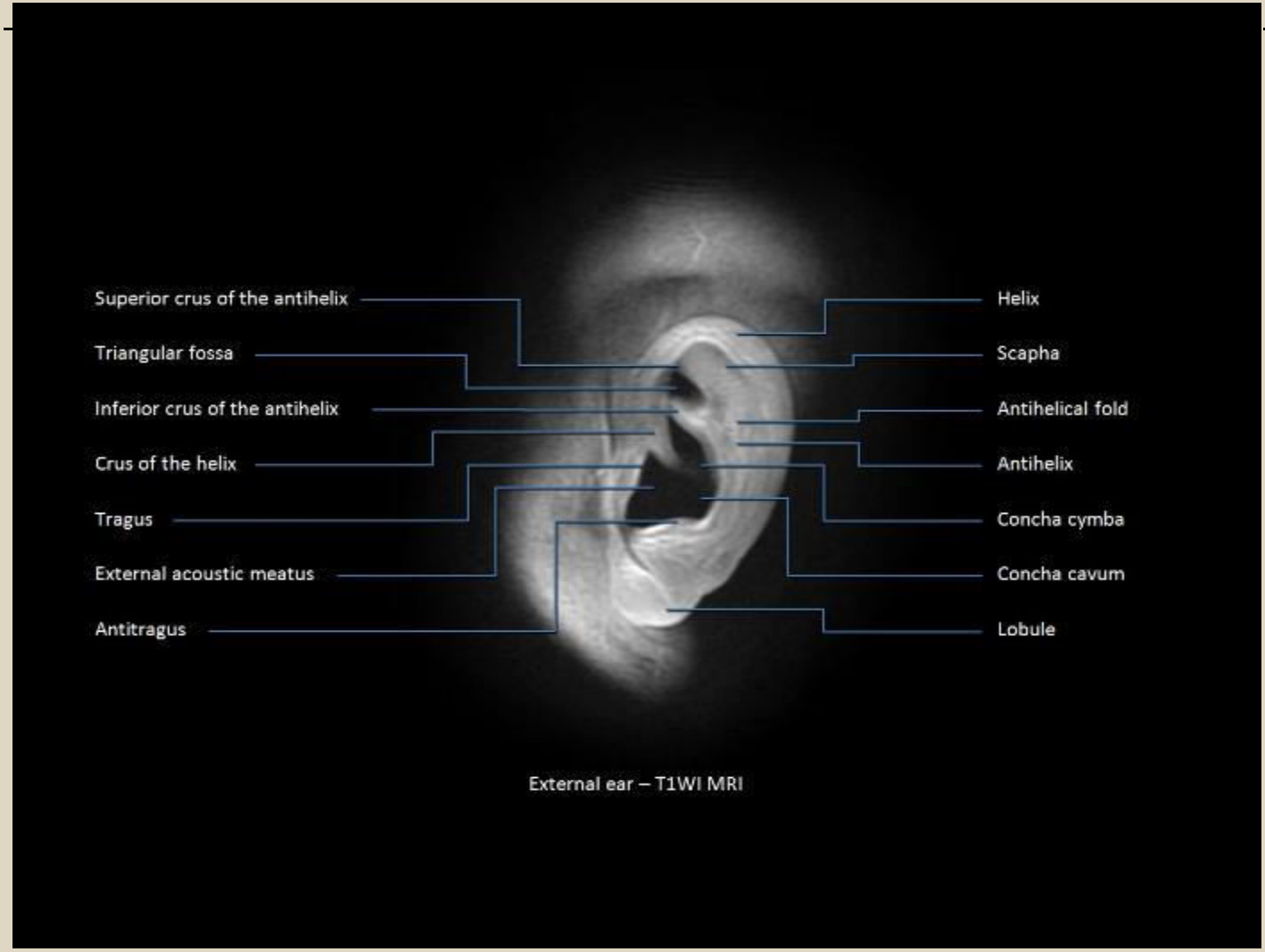
2D-FT METHOD

- It samples one line at a time in only one direction of the frequency representation.
- The direction of sampling is determined by the direction of the phase-encoding gradient while information along the line by the frequency encoding gradient.
- After the sampling of the entire frequency representation by repeated cycles of the 2D FT process, it is finally converted into an image in the computer by using the 2D Fourier transforms.

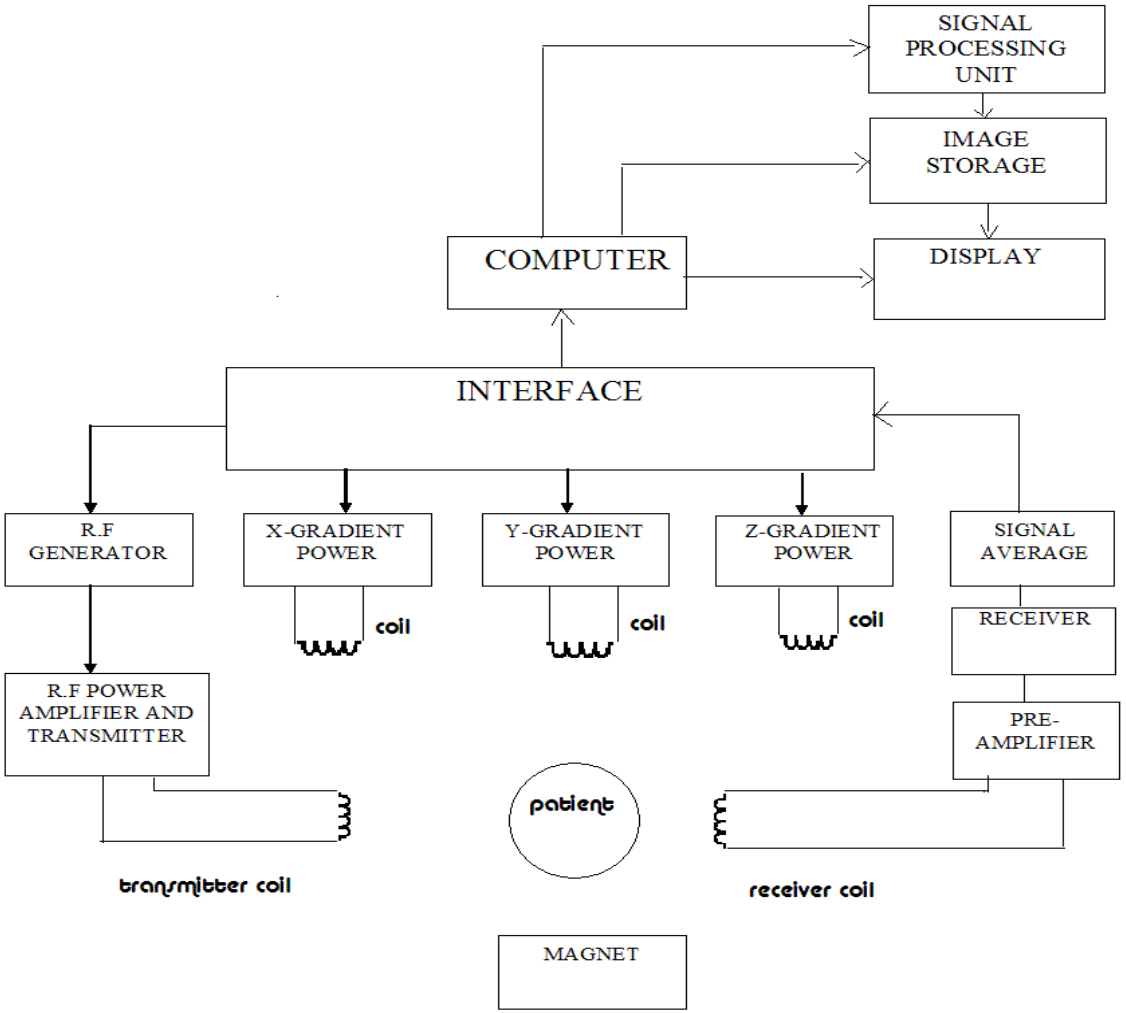
MRI SCAN OF THE BRAIN

MRI SCAN OF THE SPINAL CORD

MRI SCAN OF THE EXTERNAL EAR



MRI INSTRUMENTATION



MRI INSTRUMENTATION-CONSTRUCTION

- There is a super conducting magnet which provides a strong uniform, steady and very high magnetic fields.
- Hence the **Signal to Noise ratio** of the received signals and **image quality** are **better** than the conventional magnets.
- The patient is kept in the Gradient field systems which produce time varying, controlled spatial non-uniform magnetic fields.
- There is also the transmitter and receiver R.F coils, each of which placed on either side of the patient.

MRI INSTRUMENTATION - OPERATION

- There is a superposition of a linear magnetic field gradient on to the uniform magnetic field applied to the patient.
- When this superposition takes place, the resonance frequencies of the moving nuclei will depend primarily on the positions along the direction of the magnetic field gradient.
- It produces a 1D projection, by taking a series of projections at different orientations using the X,Y and Z gradient coils 2D or 3D dimensional images can be obtained.
- The transmitter produced RF pulses and the NMR signal is picked by receiver for signal processing. By 2D-FT this image is constructed and displayed.

RECENT TRENDS

- The future of MRI and MRS looks promising in the field of medicine.
- Multinuclear applications will be forthcoming with improvements in field strength & sensitivity,3D and 4D extensions.
- Combination of the above techniques opens entirely new approaches in wide variety of medical problems.

THERMOGRAPHY

INTRODUCTION

- Process of recording true thermal images of the surface of objects under study
- In medicine,thermography displays images representing in thermal radiation of skin area
- Important diagnostic aid in many diseases breast cancers and joint diseases

- Based on detection of thermal radiation from skin areas, we can classify the thermography into three methods
- Infrared thermography
- Liquid crystal thermography
- Microwave thermography

Infrared thermography

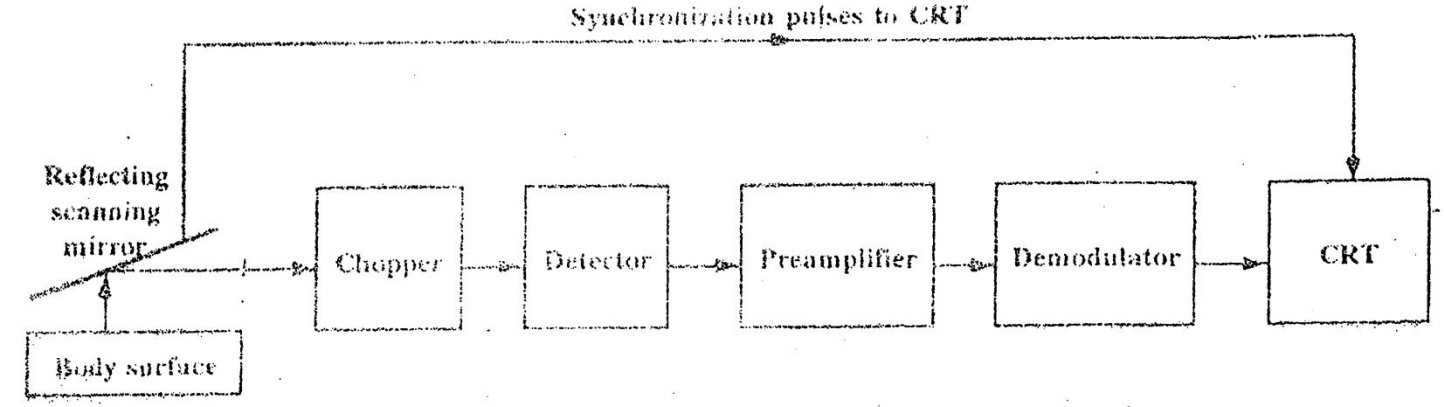


Fig.10.8. Simplified block diagram of a thermographic equipment

WORKING

- Thermographic equipment is provided with a special infrared camera that scans the object and display unit for displaying thermal picture.
- The camera contain system in the of an oscillating flat panel mirror which scans the field at very high speed focuses collected infrared radiation onto the chopper.

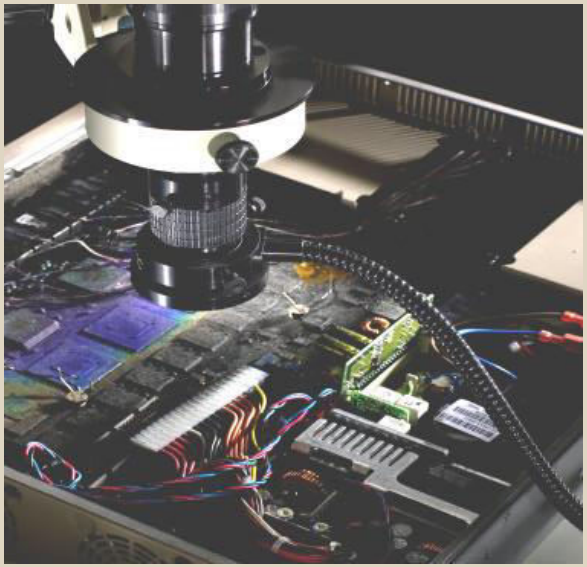
- The chopper disc interrupts the infrared beam so that ac signals are produced and amplified and demodulated further .

- The demodulated signals are given to the cathode ray tube in synchronisation with scanning mechanism.

- Signals are displayed on the screen by intensity modulation which controls brightness and contrast with the strength of signal.

Liquid crystal Thermography

- Liquid crystal are a class of compounds which exhibits colour temperature sensitivity in the cholesteric phase.
- Scattering effects with the material give rise to iridescent colours.
- High temperature sensitivity makes the cholesteric liquid crystals useful for thermal mapping.
- Thermal contact between the skin surface and plate produce a colour change in the encapsulted liquid colour.
- Red for relative low temperature & violet for high temperature.

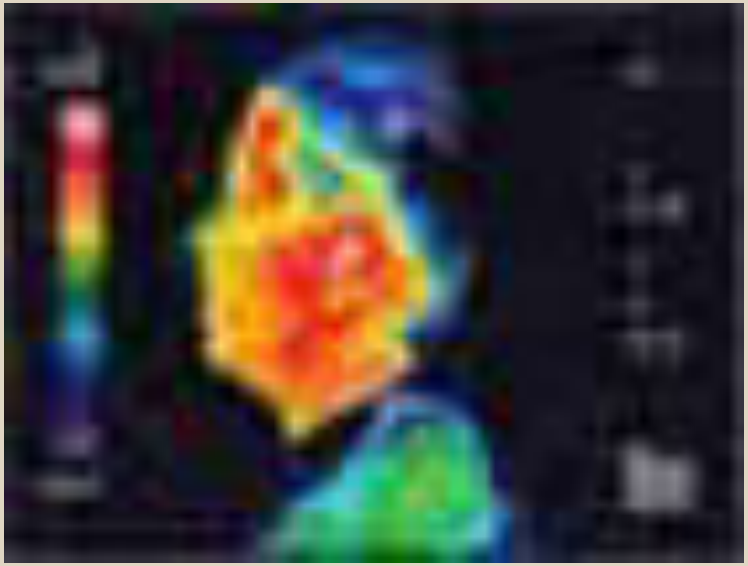


System Features

- *thermVIEW™ is designed to be an accurate and easy to use temperature* measurement system for scientific and engineering applications.
- Some of the system's features include:
- Transient and steady state temperature measurement capabilities
- Can be used for part (transistor) to board (PCB) level measurements
- Spatial resolution to 1 Micron
- Temperature accuracy to +/- 0.1oC
- A completely optical system based on visible light-- independent of surface emissivity
- Fast response liquid crystal for temperature measurement and data processing
- Uses *thermCAL™ for precision color-temperature calibration of TLC materials*
- Flexible and versatile 3D traversing camera support

Microwave thermography

- Microwave emission from the skin surface the intensity is very small
- Modern microwave radiometer one can detect temperature range of 0.1k
- Body tissues partially transparent to microwave radiation, temperature radiation originates from tissue volume extending from skin depth to several centimeters.
- Microwave radiometer consisting of matched antennae placed in contact with skin surface for use at 1.3 G hz and3.3 G hz used to sense subcutaneous temp.



Medical application

- Tumors
- Inflammation
- Diseases of peripheral vessels
- Burns
- Collagen diseases
- Orthopedic diseases
- Brain & nervous diseases
- Harmone diseases

ULTRASONIC DIAGNOSIS

Ultrasonography

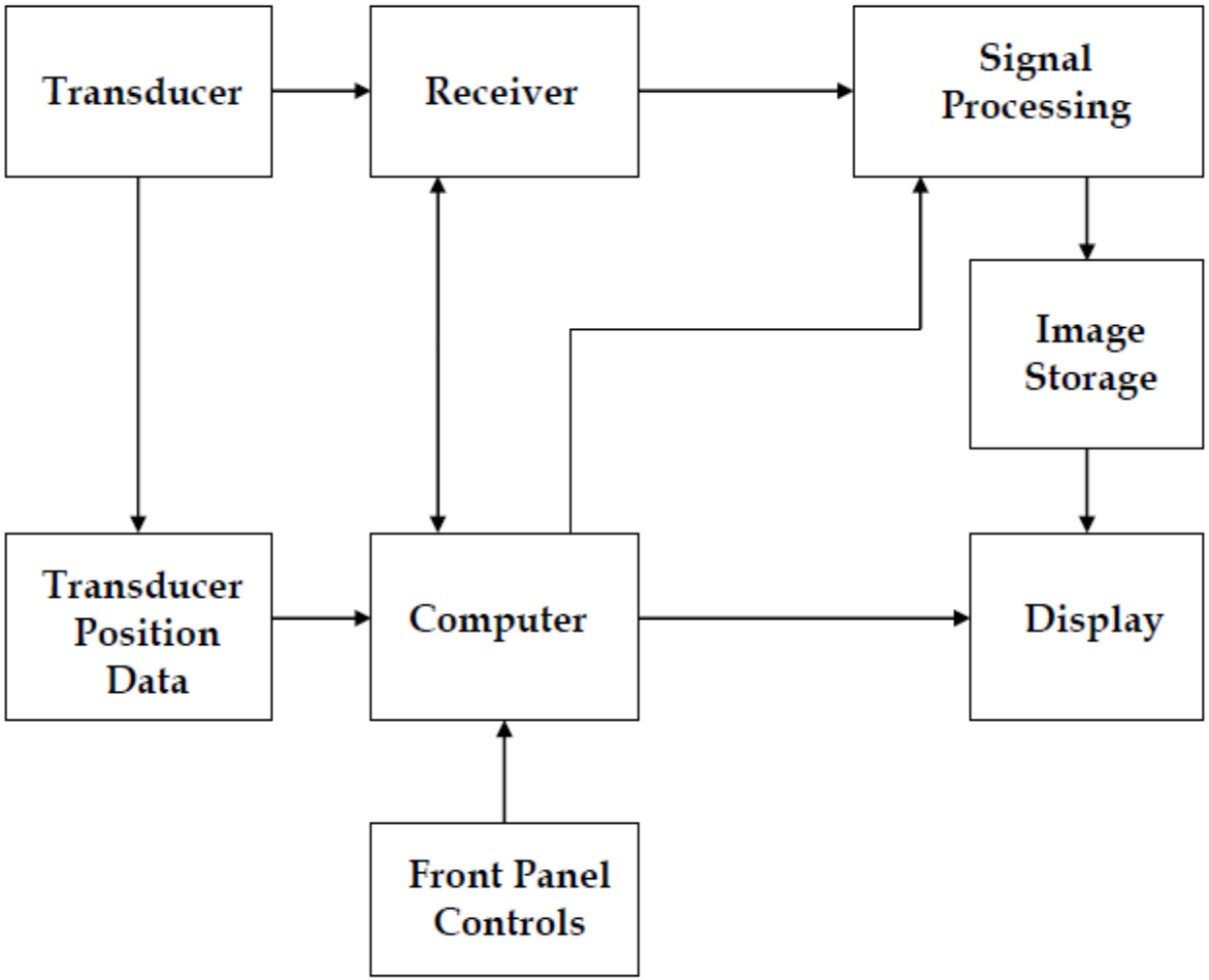
- Technique by which ultrasonic energy is used to detect the state of the internal body organs
- Bursts of ultrasonic energy are transmitted from a piezoelectric or magnetostrictive transducer through the skin and into the internal anatomy
- When this energy strikes an interface between two tissues of different acoustical impedance, reflections (echoes) are returned to the transducer
- The transducer converts these reflections to an electric signal
- This electric signal is amplified and displayed on an oscilloscope at a distance proportional to the depth of the interface
- Ultrasonic diagnosis differs from radiological (X – ray) diagnosis in that no shadow images are obtained
- The cross – sectional or linear images are obtained through parts of the body

- Ultrasonic imaging is safe
- Uses mechanical energy at a level which is not harmful
- Hence it is called a non – invasive technique

Potential applications

- Neurology – to find brain tumor
- Ophthalmology – to find any foreign objects in eye
- Cardiology – to determine the cross – section of the heart and the heart rate
- Gynecology – to monitor the fetus growth and to indicate the presence of twins
- To identify breast cancers

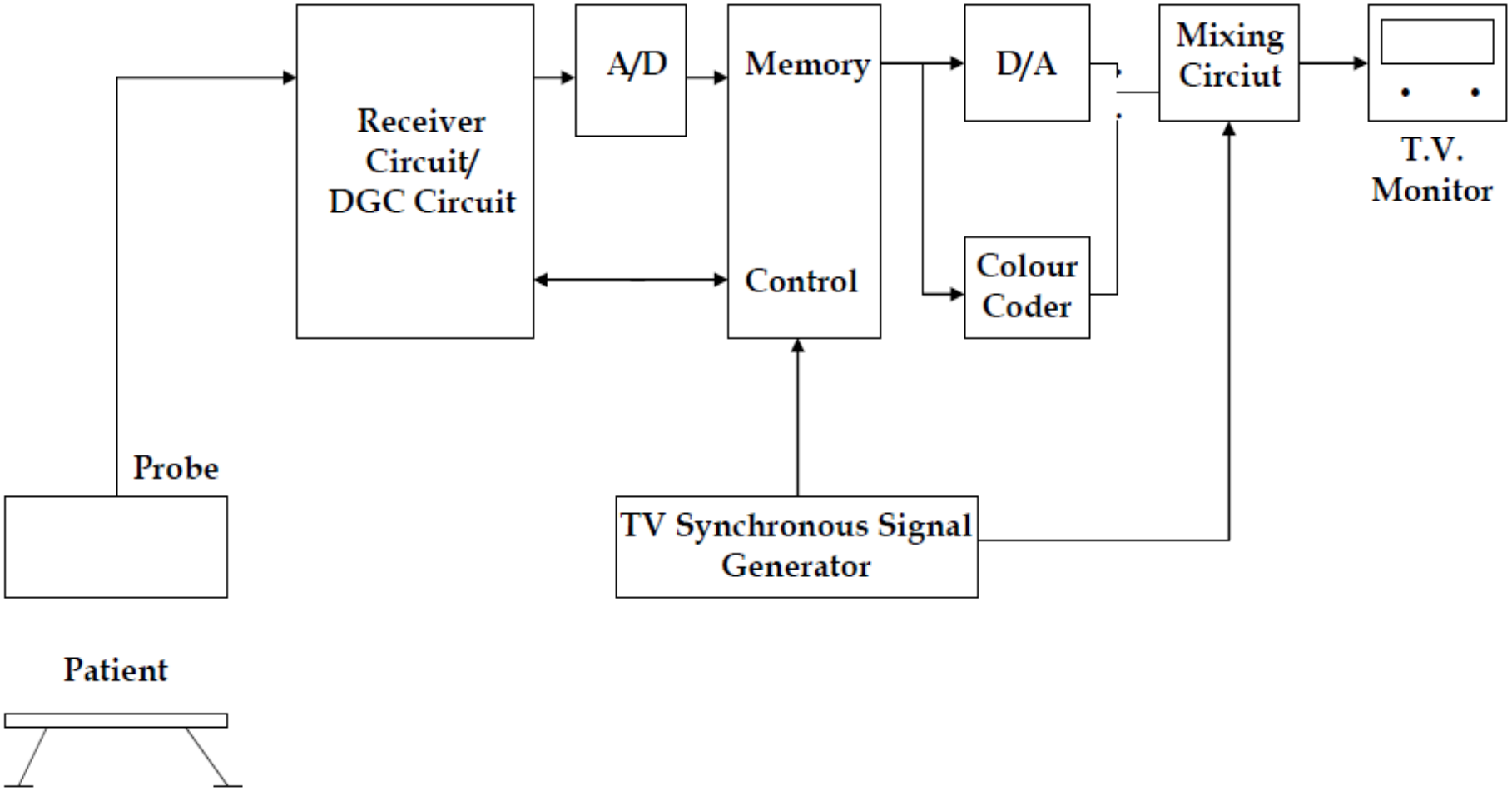
Block Diagram of a Computer Controlled Ultrasonic Image Forming System



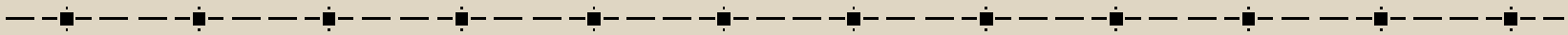
Ultrasonic Imaging Instrumentation

- The transducer position data are fed to the computer
- The computer sends this information to signal processing unit
- It also receives the signals from the receiver and controls the receiver sensitivity
- Proper depth gain compensation is calculated by the computer and given to the signal processing unit
- The ultrasonic velocity is calculated and given to display unit
- Using the image storage unit, the patient information is displayed
- Digital real time scanners are used for displaying ultrasound images

Digital Real Time Ultrasonic Scanner



- The echoes from the patient body surface are collected by the receiver circuit
- Proper depth gain compensation is given by DCG circuit
- The received signals are converted into digital signals and are stored in the memory
- Meanwhile, the scan converter control receives signals of transducer position and TV synchronous pulses and generates X and Y address information which is fed to the digital memory
- The stored digital image signals are processed and colour coded and are given to digital – to – analog converter
- Then they are fed into video section of the television monitor



BIO–MEDICAL INSTRUMENTATION

BEE 007

Unit: 4

DIAGNOSTIC EQUIPMENTS

MEASUREMENT OF HEART SOUNDS

- STETHOSCOPE (Chest – Examine) is simply a device that carries sound energy from the chest of the patient to the ear of the physician.
- Improved ideas made available of amplified heart sounds – electronic stethoscope has been developed.
- But they are trained with ordinary stethoscope so they will use ordinary type in general.

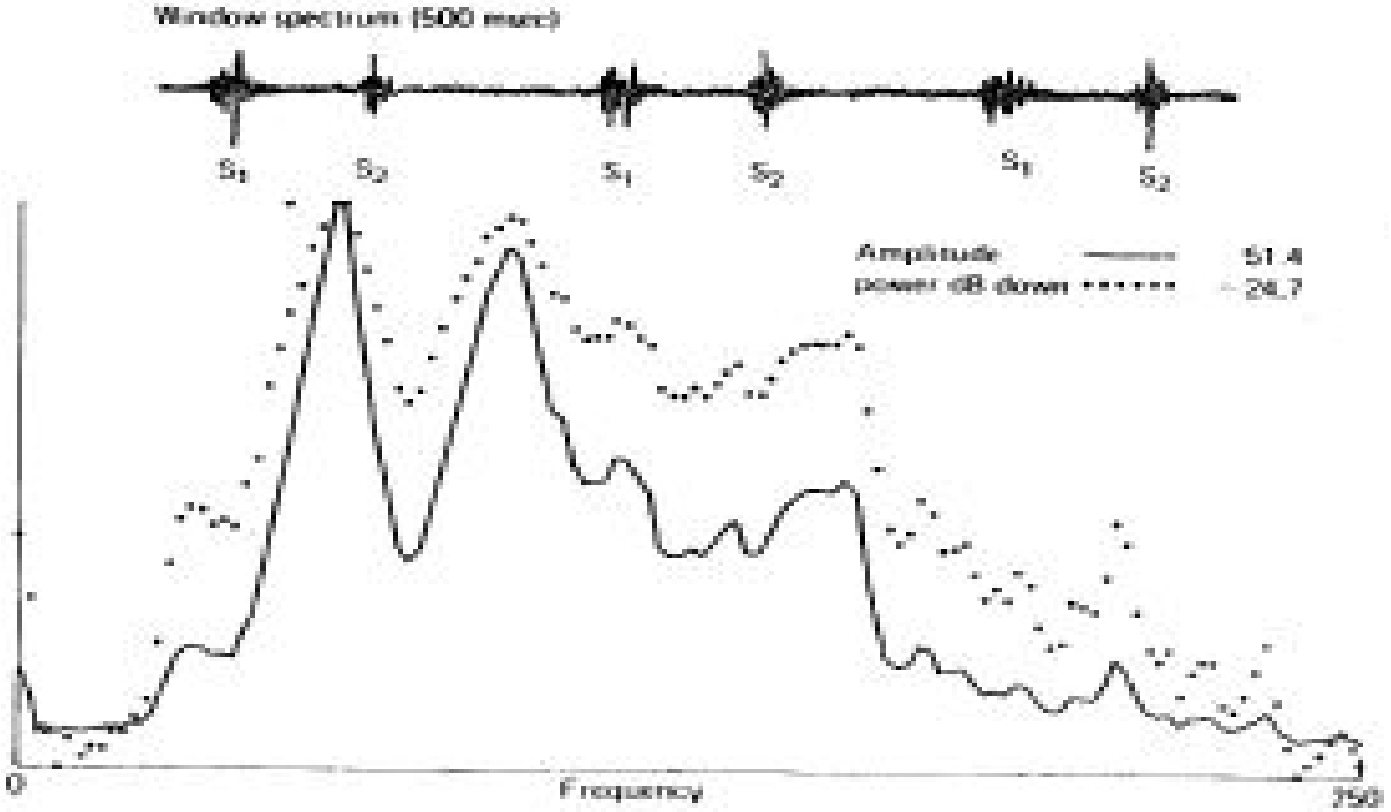
Recording Instrument - Phonocardiography

- Instruments graphically recording heart sounds are more successful, A graphic record of heart sound is called phonocardiogram.
- It uses microphone as transducer – frequency response ranging from below 5 Hz to above 1000 Hz.
- An amplifier in desired range – selective low pass filter – pen recorder and signals are recorded.

- The read out of a phonocardiography is high frequency chart recorder or oscilloscope.
- Pen recorder frequency falls – 100 to 200 Hz.
- Normal heart sounds fall within the range but murmurs have high freq – photographic device are used.
- Multi-channel physiological recording systems – microphone, amplifier and same as used in EMG.
- Even for special diagnosis a digital computer with high speed ADC is required.

Typical spectrum of Heart Sounds

Figure 6.47. Frequency spectrum of heart sounds. (Courtesy of Computer Medical Science Corporation, Tomball, TX.)



- Some other devices as Vibrocardiograph and the Apexcardiograph are also used to measure and uses different types of microphones.

Measurement of respiration rate

- Primary functions of respiratory system are to supply oxygen and remove carbon dioxide from the tissues.
- The action of breathing is controlled by a muscular action causing the volume of the lung to increase and decrease to effect a precise and sensitive control of the tension of carbon dioxide in the arterial blood.

Methods of measurement of respiration rate

Displacement Method

- Respiratory cycle is accompanied by changes in the thoracic volume.
- These changes can be sensed by means of a displacement transducer incorporating a strain gauge.
- Transducer held by elasticband – goes around the chest – respiratory movement causes changes in the resistance – wheatstone bridge detects the output.

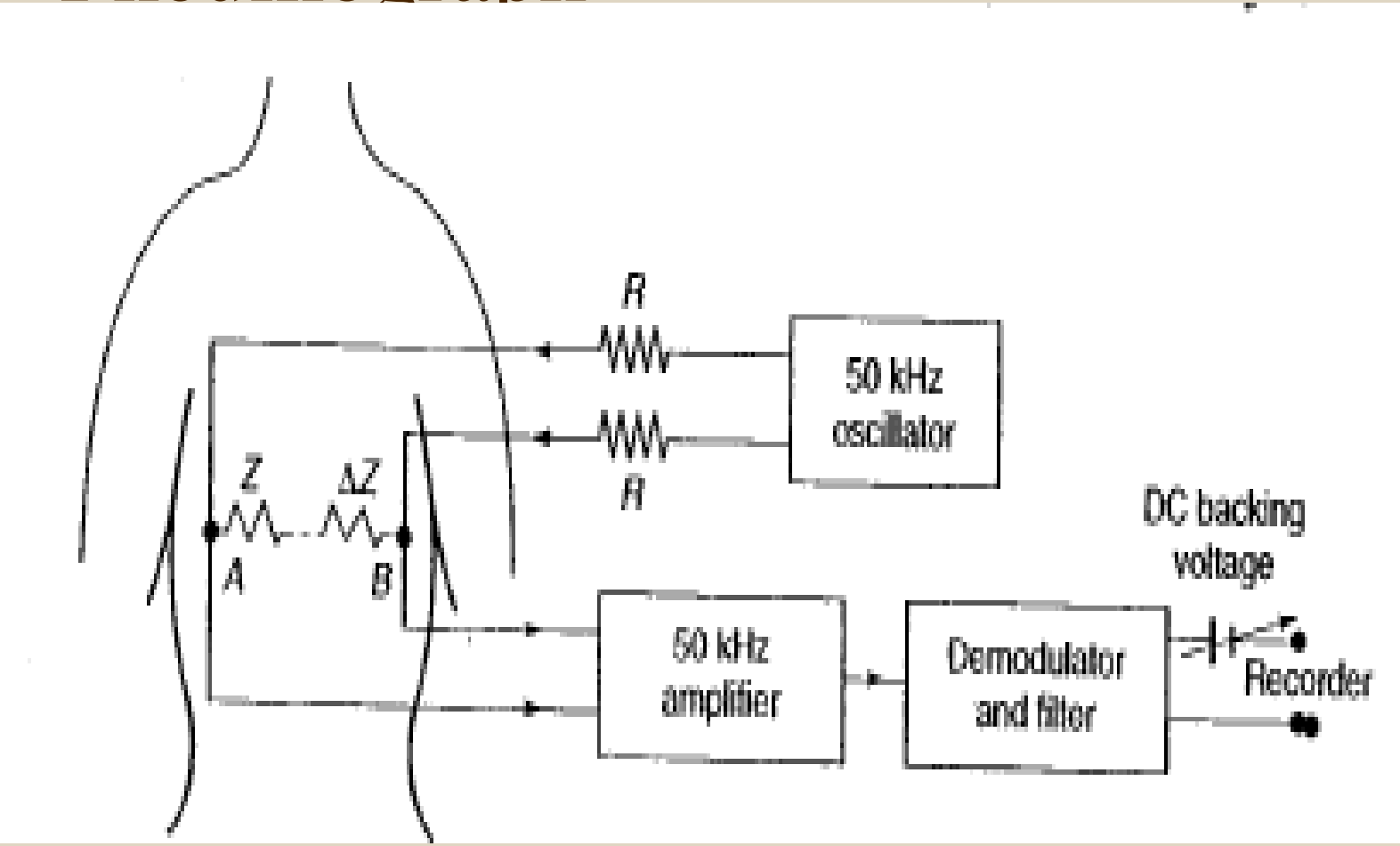
Thermistor Method

- **Air** is warmed during its **passage** through the **lungs** and the **respiratory tract**, there is a **detectable** difference of **temperature** between **inspired** and **expired** air.
- This is sensed by using thermistor -- even thermistor heated initially – match with respiration rate.
- Unconscious patients – tendency blocking breathing system – cannot measured.

Impedance Pneumography

- It is an indirect method for measurement of respiration rate.
- Externally applied electrodes on the thorax, the impedance pneumograph measures the relationship between respiratory depth and thoracic impedance change.
- This method – passing a high frequency current through the appropriately placed electrodes on the surface of the body and detecting modulated signal.

Principle of Impedance Pneumograph



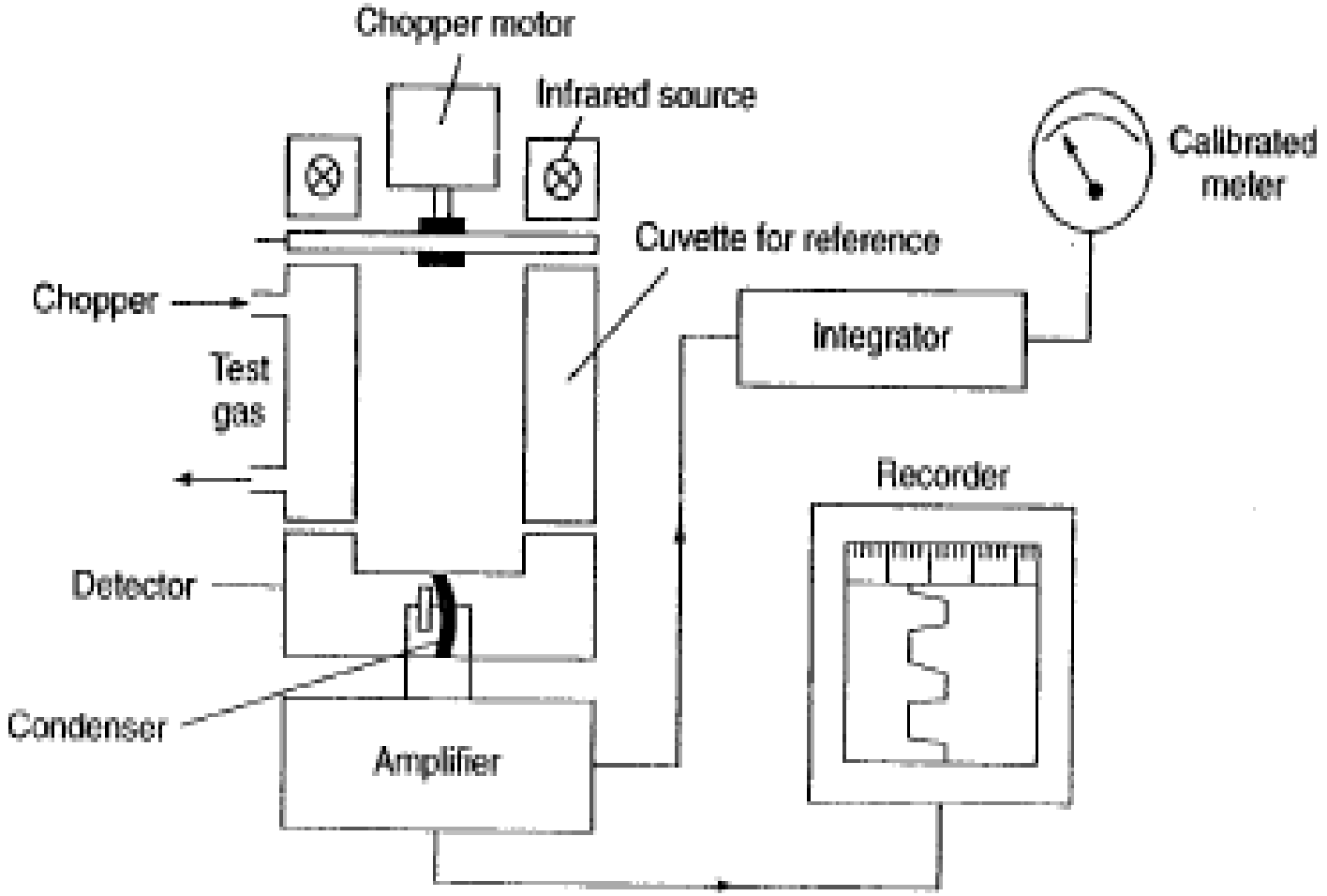
- The signal is modulated by changes in the body impedance and accompanying the respiratory cycle.
- Electrode used is adhesive type.
- To avoid the stimulation of sensory receptors, nerves and muscles, currents higher in frequency than 5 KHz must be used for the measurement of Physiological events by impedance, frequency less than 5 KHz are hazardous.

Co_2 Method of Respiration rate Measurement

- Respiration rate can also be derived by continuously monitoring the Co_2 contained in the alveolar air.(expired air)
- The measurement is based on the absorption property of infrared rays by certain gases.
- Suitable filters are required to determine the concentration of specific gases like Co_2 ,CO and NO_2 constituting the expired air.

How it Works

- When Infrared rays are passed through the expired air containing a certain amount of Co_2, some of the radiations are absorbed by it.
- There is a proportional loss of heat energy associated with the rays.
- The detector changes the loss in heating effect of the rays into an electrical signal.
- This signal is used to obtain the average respiration rate.



➤ **Fig. 6.37** *Schematic diagram for detection of CO_2 in the expired air for continuous monitoring of respiration rate*

Working Procedure

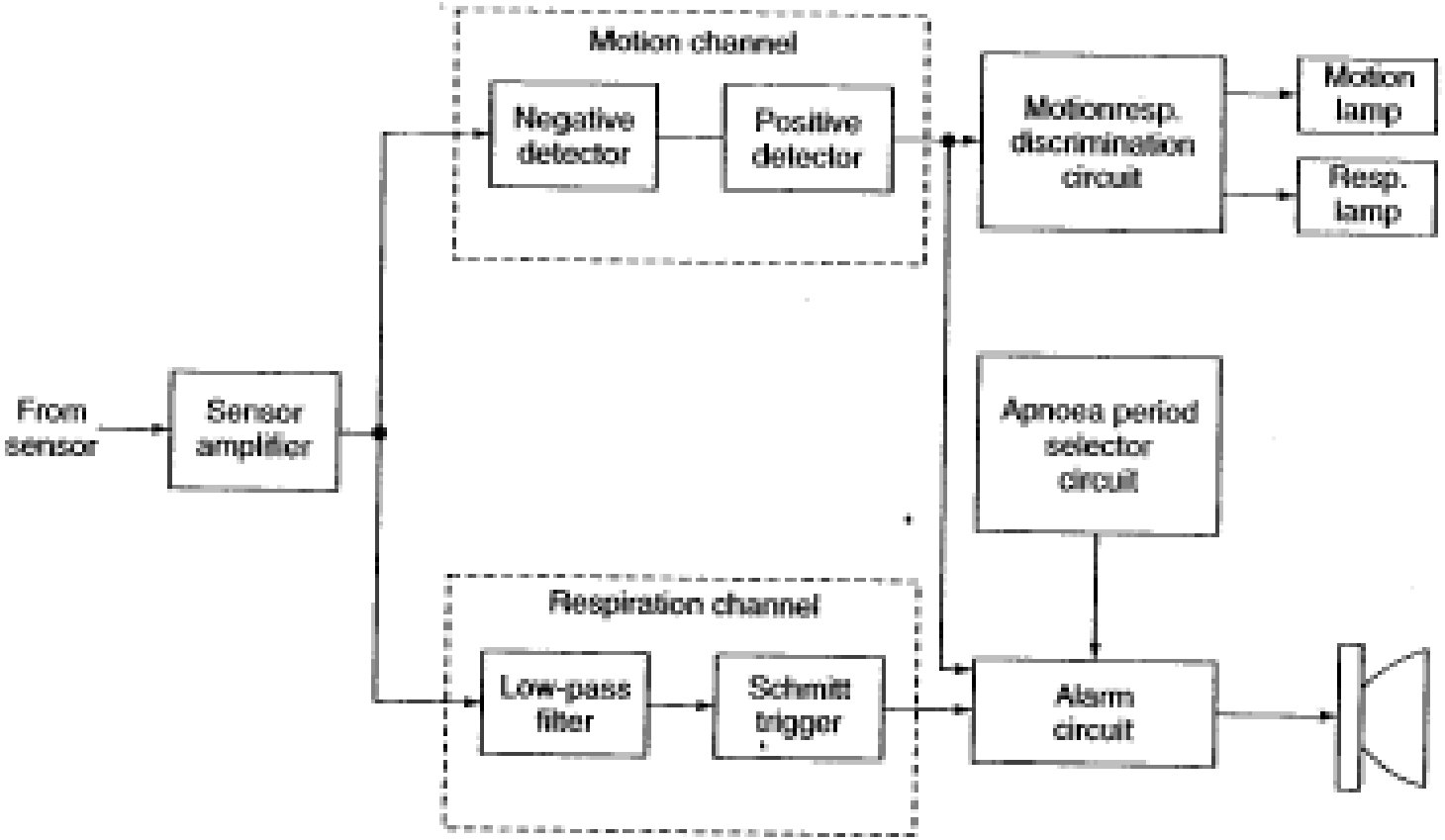
- Two beams of equal intensity of infrared radiations – falls on one half of condenser microphone.
- The detector has two identical portions separated by a thin, flexible metal diaphragm.
- Detector is filled with a sample of pure CO2, because absorption of CO2 in the analysis cell, the beam falling on the test side is weaker.
- Diaphragm is pushed towards analysis side and Diaphragm forms one plate of a capacitor, the alternating signal is amplified, shaped and suitably integrated to give the respiration rate.

Apnoea detectors

- Apnoea is the cessation of breathing which may precede the arrest of the heart and circulation in several clinical situations such as head injury, drug overdose, anaesthetic complications and respiratory diseases.
- It occurs in premature babies – brain damage occurs – apnoeic patients need monitoring of respiratory activity.

- Several contactless methods are available for monitoring the respiration of infants.
- Mattress monitors — breathing redistributes infants weight – pressure sensitive pad or mattress senses and can be measured.
- Capacitance type pressure sensor in the form of a thin square pad is usually placed under or slightly above the infants head.
- Respiratory movement – pressure changes – alters capacitance between the electrode plates and it is measured.

Apnoea monitors



➢ Fig. 6.38 *Block diagram of apnoea monitor (Courtesy: B-D Electrodyne, USA)*

- It consist of an input amplifier circuit, motion and respiration channels, a motion/respiration discrimination circuit, and an alarm circuit.
- Input – from sensor pad to logic circuit.
- The sensor may be a strain gauge transducer.
- output of the amplifier is adjusted to zero volts with offset adjustment provided in the amplifier.
- The amplified signal goes to motion and respiration channels connected in parallel.

- The output of the motion & respiration signals are combined in comparator circuit, and gives signals to indicate respiration.
- Presence of respiration is indicated by a flashing lamp.
- Alarm is also provided.
- Other alternating methods of detecting apnoea is – electromagnetic induction & by using Microwave energy.

ELECTROENCEPHALOGRAPHY (EEG)

- It deals with the recording and study of electrical activity of the brain.
- Electrodes attached to the skull of a patient, the brain waves can be picked up and recorded.
- The brain waves are summation of neural depolarizations in the brain due to stimuli from the five senses as well as from the thought process.

- Due to propagation through skull bone - 1 to 100micro volt which are picked up by EEG electrodes.
- They are in the frequency range from 0.5 to 3000Hz.
- The potentials vary with respect to position of electrode on the surface of skull.
- Electrodes are placed around the **frontal, parietal, temporal and occipital lobes** of the brain.

Origin of EEG

- **EEG potentials originate within the dendrite potentials of neurons in the brain.**
- **Electric charges are transferred between them (nerves & Dendrites) -** acetylcholine.
- **A great number of these potentials are then summed to produce EEG rhythms.**

Action Potentials of the brain

- Progressive transient disturbances of the resting potential along a nerve fiber is used to transmit information from one end to the other. – action potential – rapid change of membrane permeability.
- Propagated potential reaches the cell, the cell fires and thus a spike wave produced.

- If the transmitter substance is inhibitory, the membrane potential of the receptor neuron increases in a negative direction.
- It is likely to discharge, this induced potential change is called an **inhibitory post synaptic potential (IPSP)**
- If the transmitter substance is excitatory, the receptor membrane potential increases in a positive direction, so that the receptor neuron is more likely to discharge and produce a spike potential. This induced change is called an **excitatory post synaptic potential (EPSP).**

Evoked Potentials

- Evoked potentials are the potentials developed in the brain as the responses to external stimuli like light, sound etc.,
- The external stimuli are detected by the sense organs which cause changes in the electrical activity of the brain.
- Now – it is called as ‘Event related potential’ – because it relates to an event.

Anatomy of the Brain.

- Brain consists of three parts such as cerebrum, cerebellum and the brain stem.
- Cerebrum consists of two hemispheres separated by a deep fissure.
- The hemispheres divided into Frontal lobe, parietal lobe, occipital lobe and temporal lobe.
- The outer layer is called as cerebral cortex which is the center of intellectual functions.

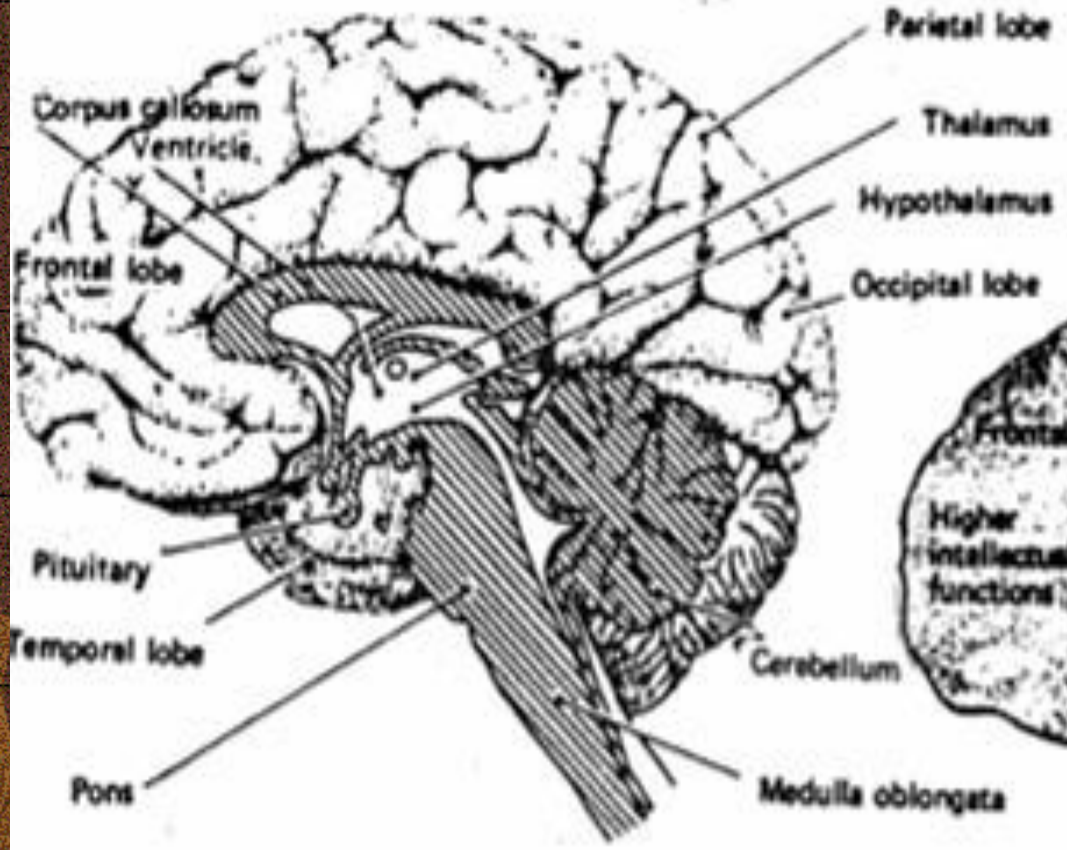


Fig.4.20. Median sagittal section of the brain

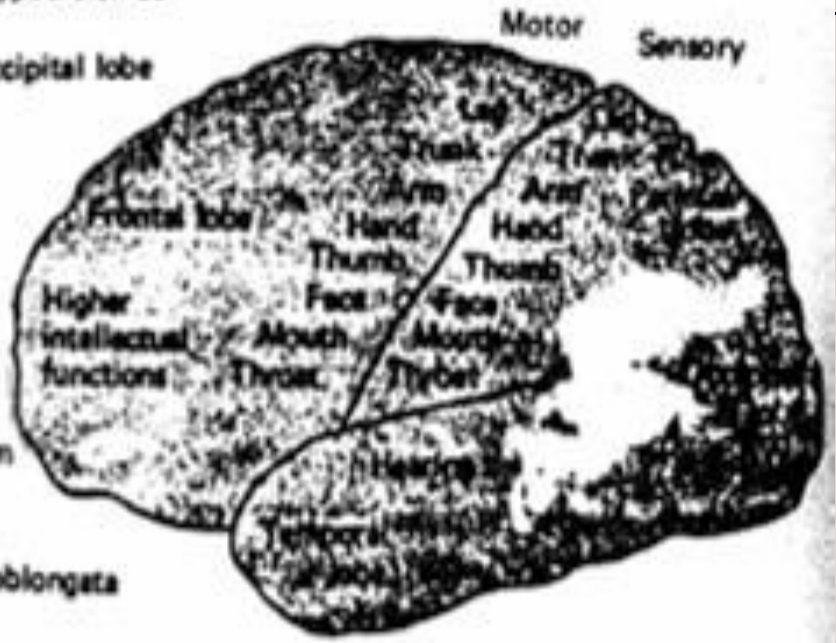
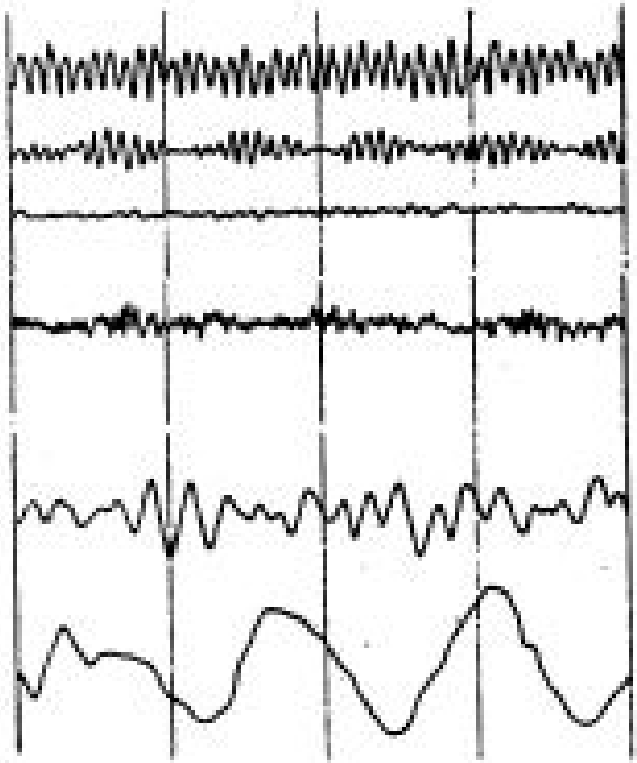


Fig.4.21. Cerebral cortex

- The frontal lobe is for intelligence.
- Upper side of the temporal lobe consists - **hearing center.**
- Posterior part of occipital lobe - **vision center** is situated.
- Anterior part of the parietal lobe - **sensory center & Motor center.**
- Temporal lobes are for the **storage process in the long term memory.**

BRAIN WAVES

- Electrical recordings from the surface of the brain demonstrates electrical activity of the brain.
- The intensities of the brain waves on the surface of the scalp range from 0-300micro volt.
- Mostly brain waves are irregular and no general pattern seen in ECG.
- If abnormalities occur then pattern changes.
- Alpha, Beta, Theta and Delta Waves - EEG



Alpha waves (α)	8–13	Normally occipitally
Beta waves (β)	13–30	Normally parietally and frontally
Theta waves (θ)	4–8	Children, sleeping adults
Delta waves (δ)	0.5–4	Premature babies, infants, sleeping adults

Fig.4.22. Brain Waves

PLACEMENT OF ELECTRODE

- EEG Electrodes Are Placed In Standard Positions On The Skull In An Arrangement Called 10-20 System.
- Position of electrodes are given by International Federation of Societies of EEG.

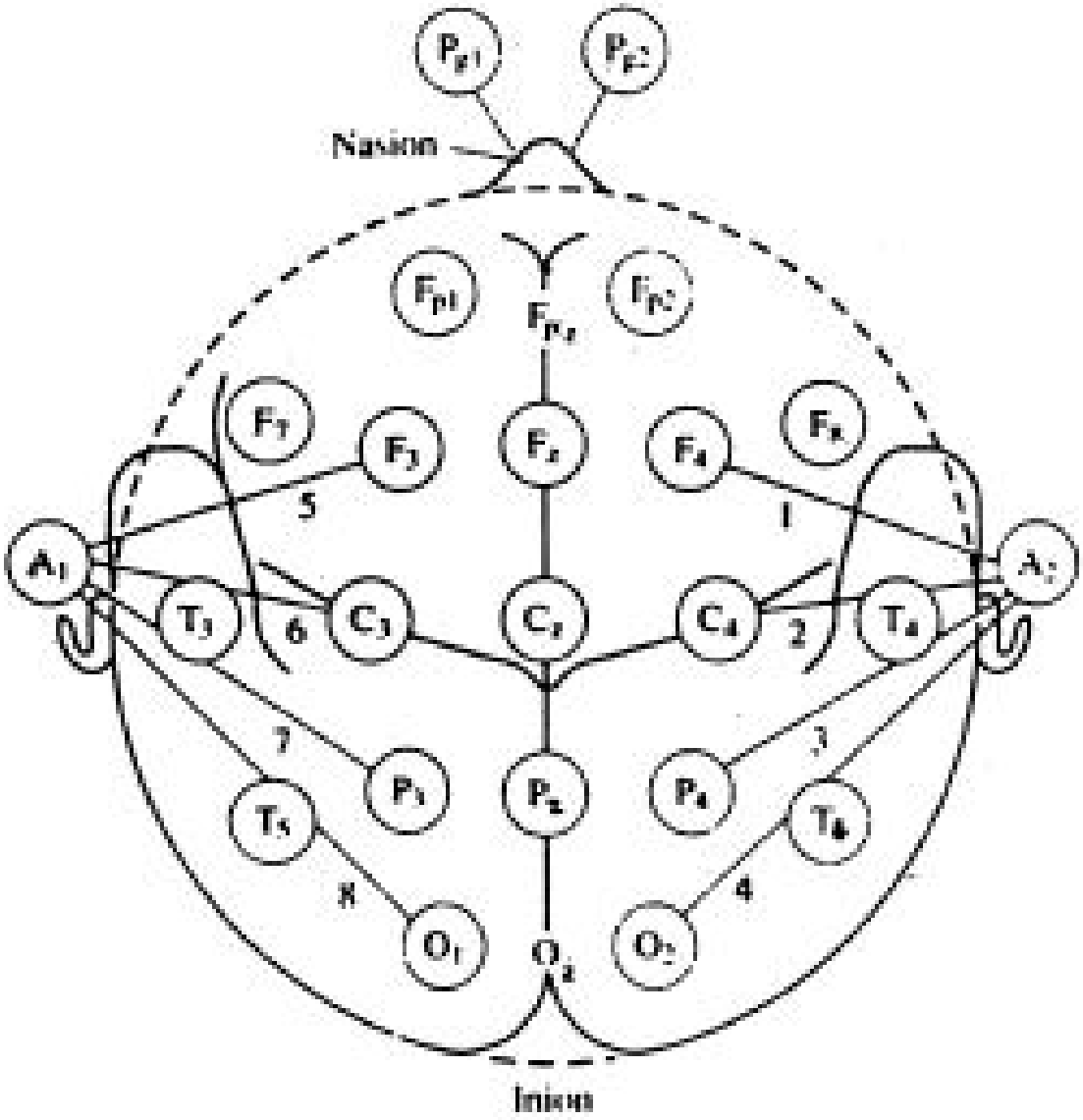


Fig.4.23. Placement of electrodes on the scalp for EEG recording

Position - Electrodes - Placing

- Placing electrodes scalp is cleaned and electrode paste is applied between the skin & Electrode.
- In **Bipolar technique** the difference in potential between two adjacent electrodes is measured.
- In **Monopolar technique** potential of each electrode is measured with respect to a reference electrode attached to earlobe or nostrils.

4.4.4 Recording Setup

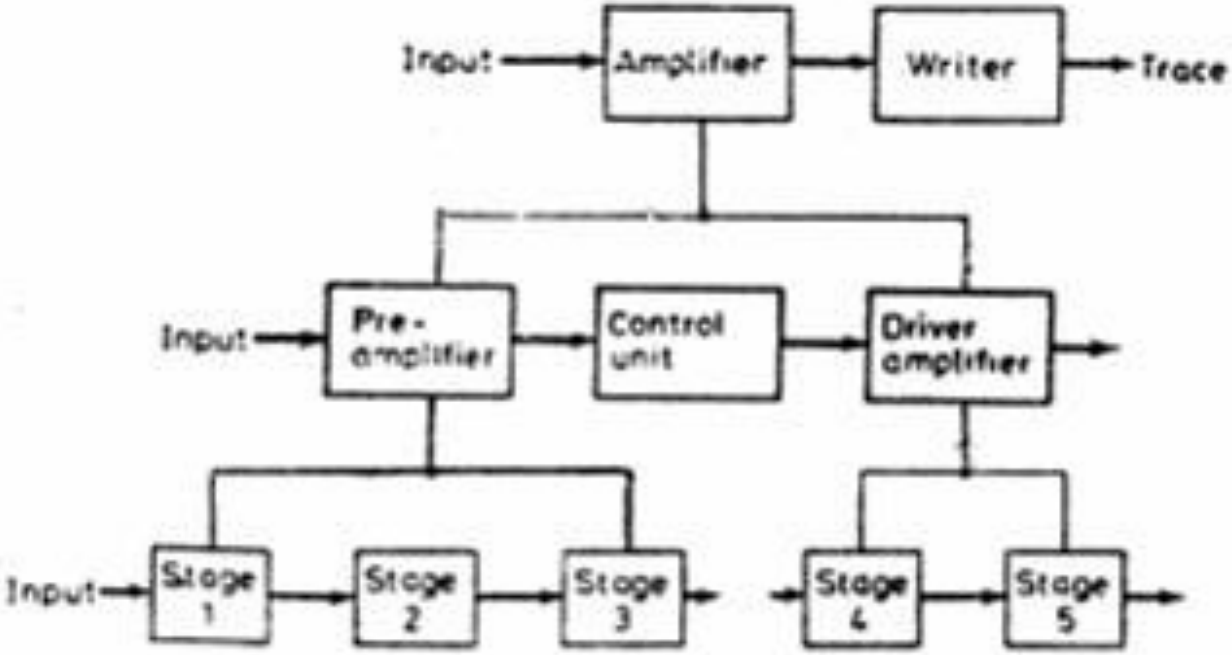


Fig.4.24 Simple block diagram of EEG recording set up

Modern EEG – Recording Setup

- 8 channel EEG recorder.
- Patient cable consists of 21 electrodes and connected to 8 channel selector.
- Ref fig 4.23 – distribution says right ear electrode act as reference electrode for the right brain electrodes & Vice Versa..
- EEG signals frequency less than 30Hz. So notch filters are used.

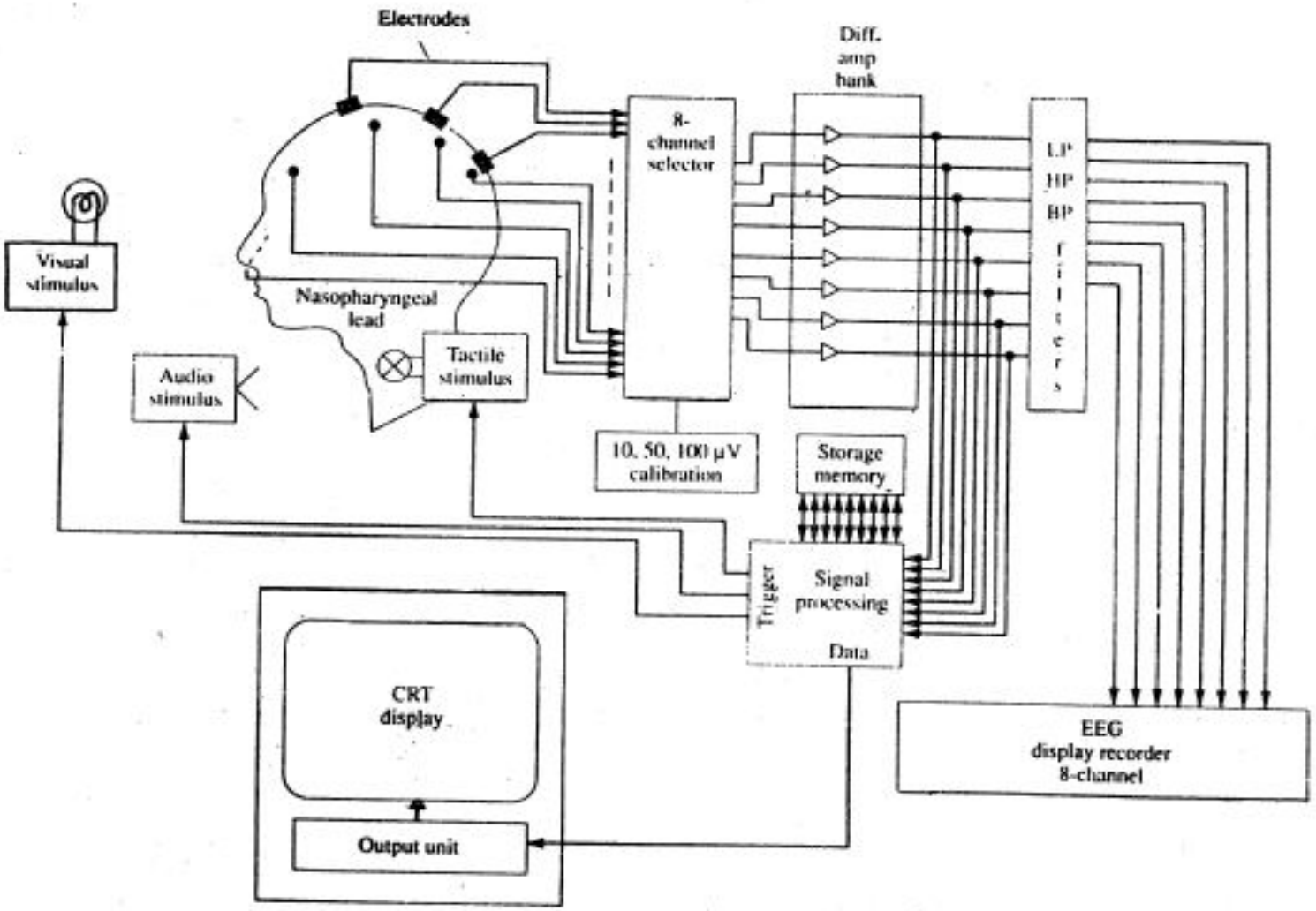


Fig.4.25. Modern EEG Unit

- Amplifier is used to increase gain in signals.
- Recorder or imaging crt is used to view output – computer memory to further processing.
- Normal paper chart speed is 30 mm/sec & 60mm/sec for higher frequency recording.

Analysis of EEG

- EEG – helps physicians to diagnose the level of consciousness, sleep disorders, brain death, brain tumors, epilepsy and multiple sclerosis.
- REM – Rapid Eye Movement.
- Epilepsy – symptom for brain damage. {defect in birth or due accident}.

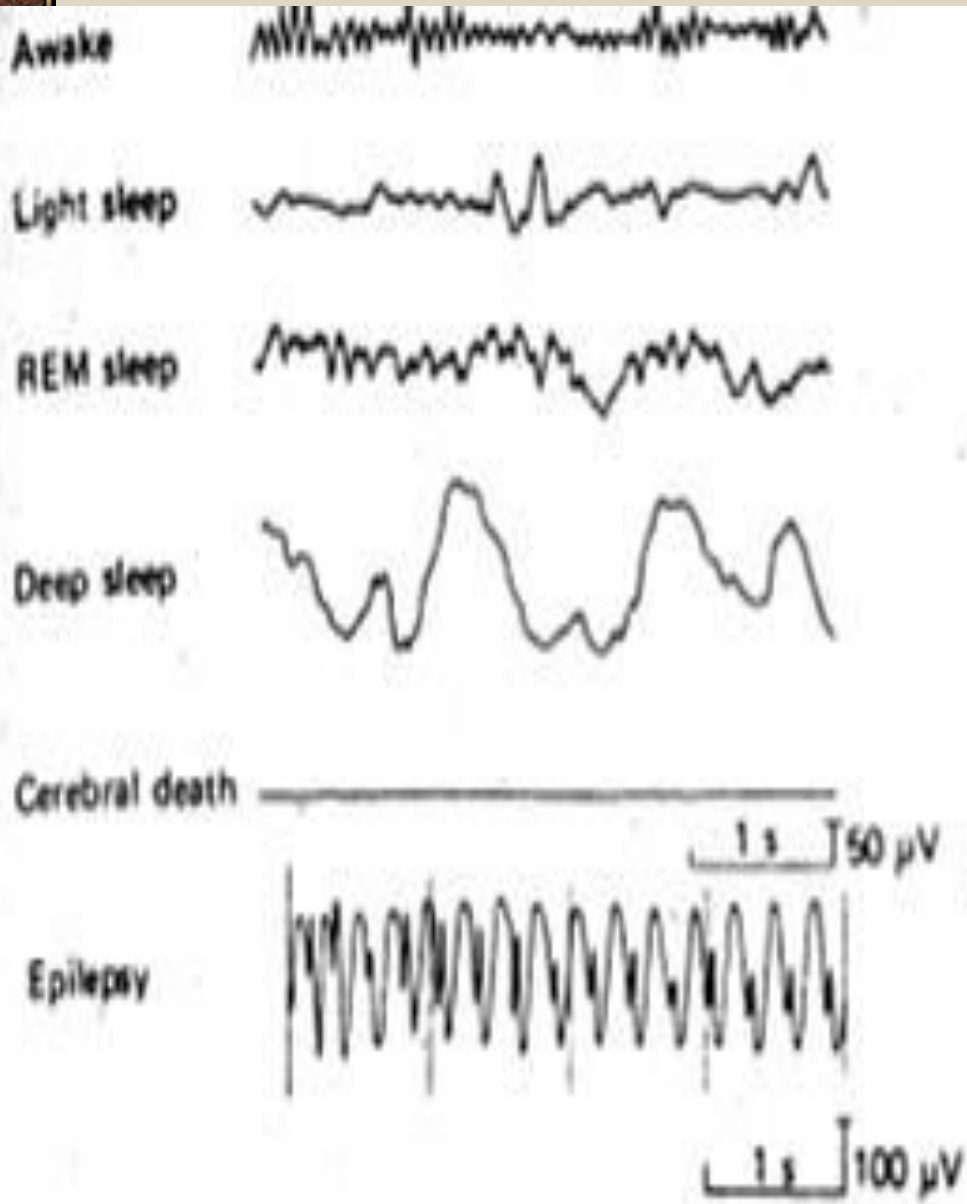


Fig.4.26 EEG waves for different level of consciousness

EMG

4.5.1 Recording setup

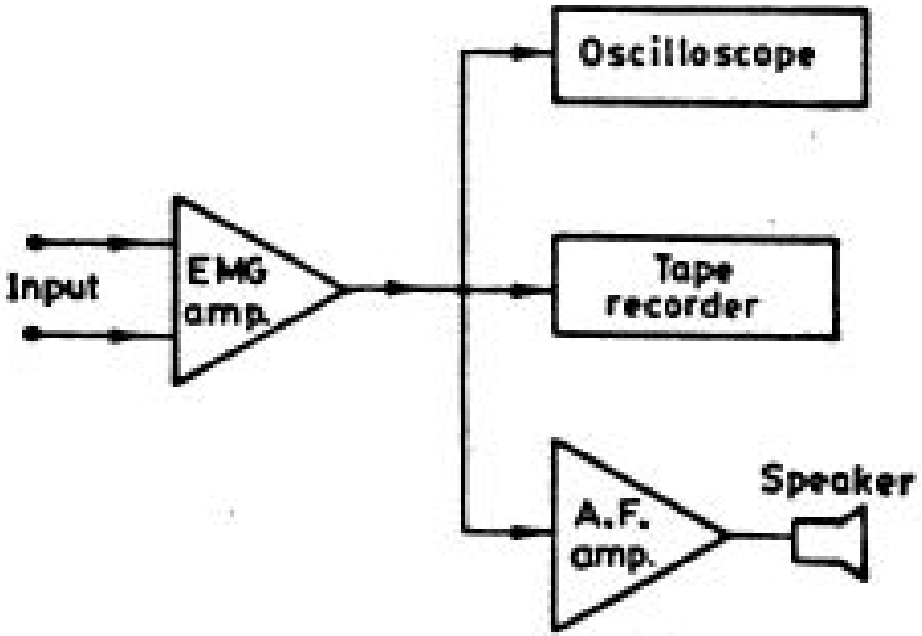


Fig.4.27 Block diagram for EMG recording set up

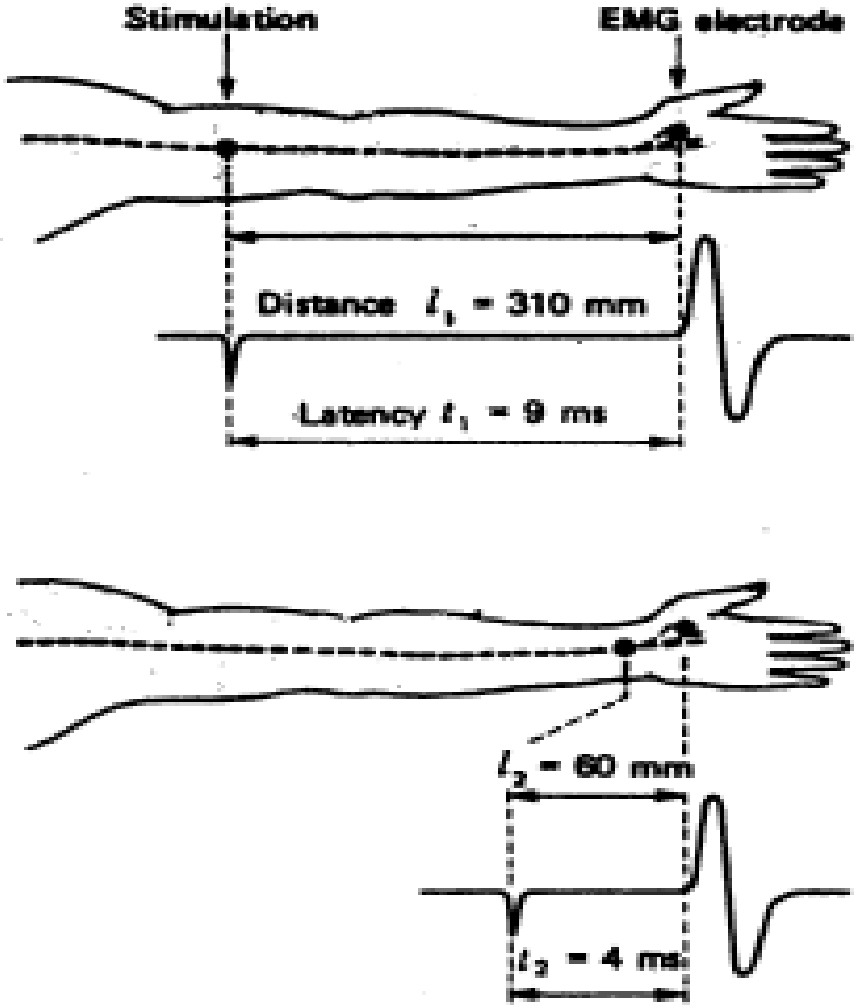


Fig.4.28. Determination of conduction velocity in a motor nerve

ERG

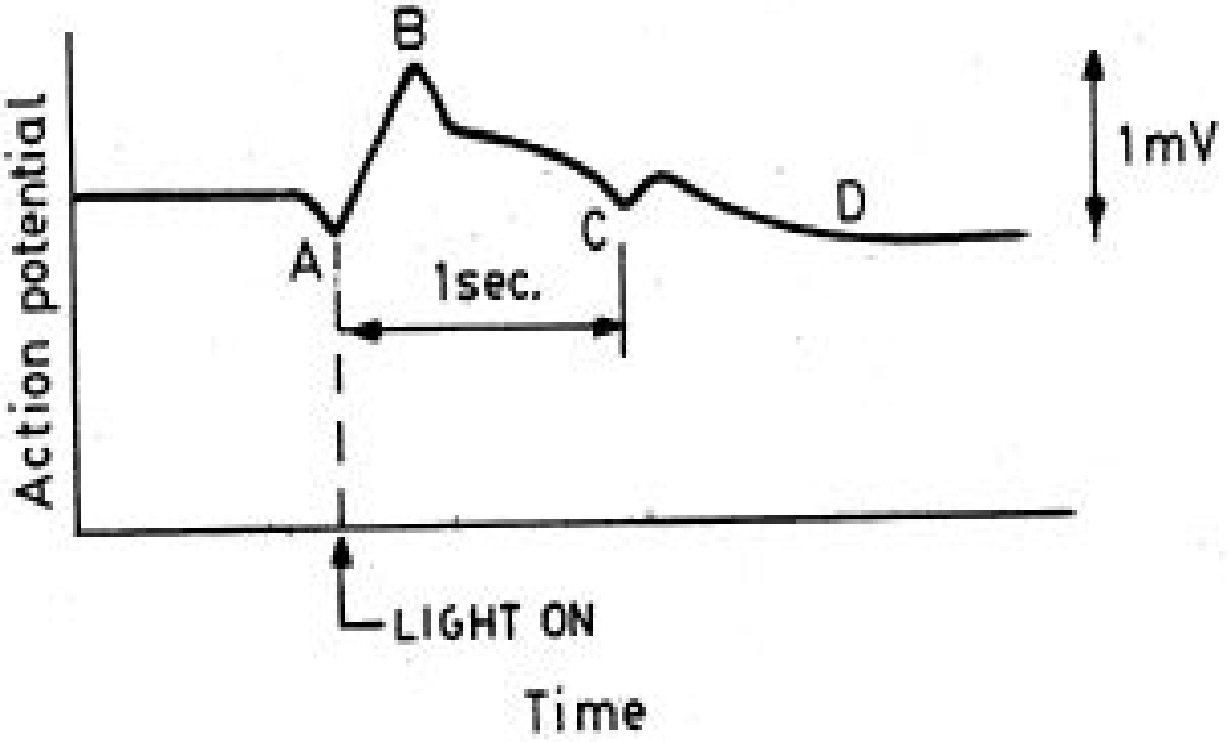


Fig.4.29 Electroretinogram

Measurement of Volume

- The volume of gas flowing into and out of the lungs is a factor of considerable importance in investigation of lung function.
- Volume of a single breath, or the total volume expired in a given time can be measured by continuously acting spirometers.
- One method is to integrate the flow rate electronically and record the resulting signals.

A simplified integrator set up is shown in fig for flow and volume measurement

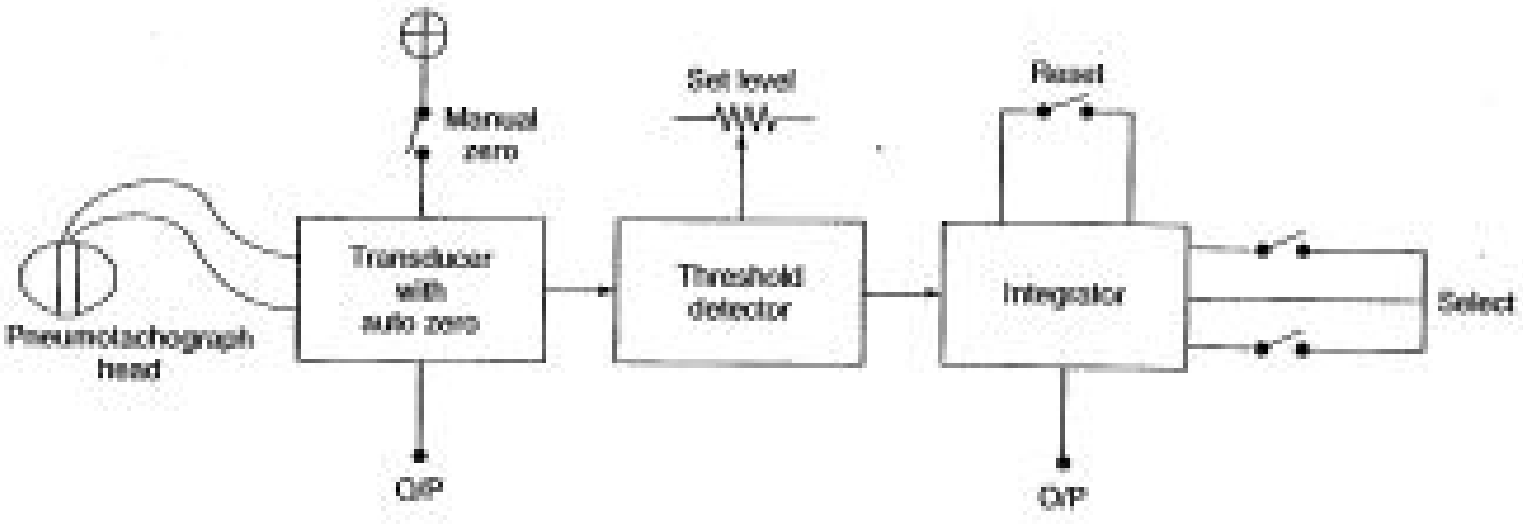


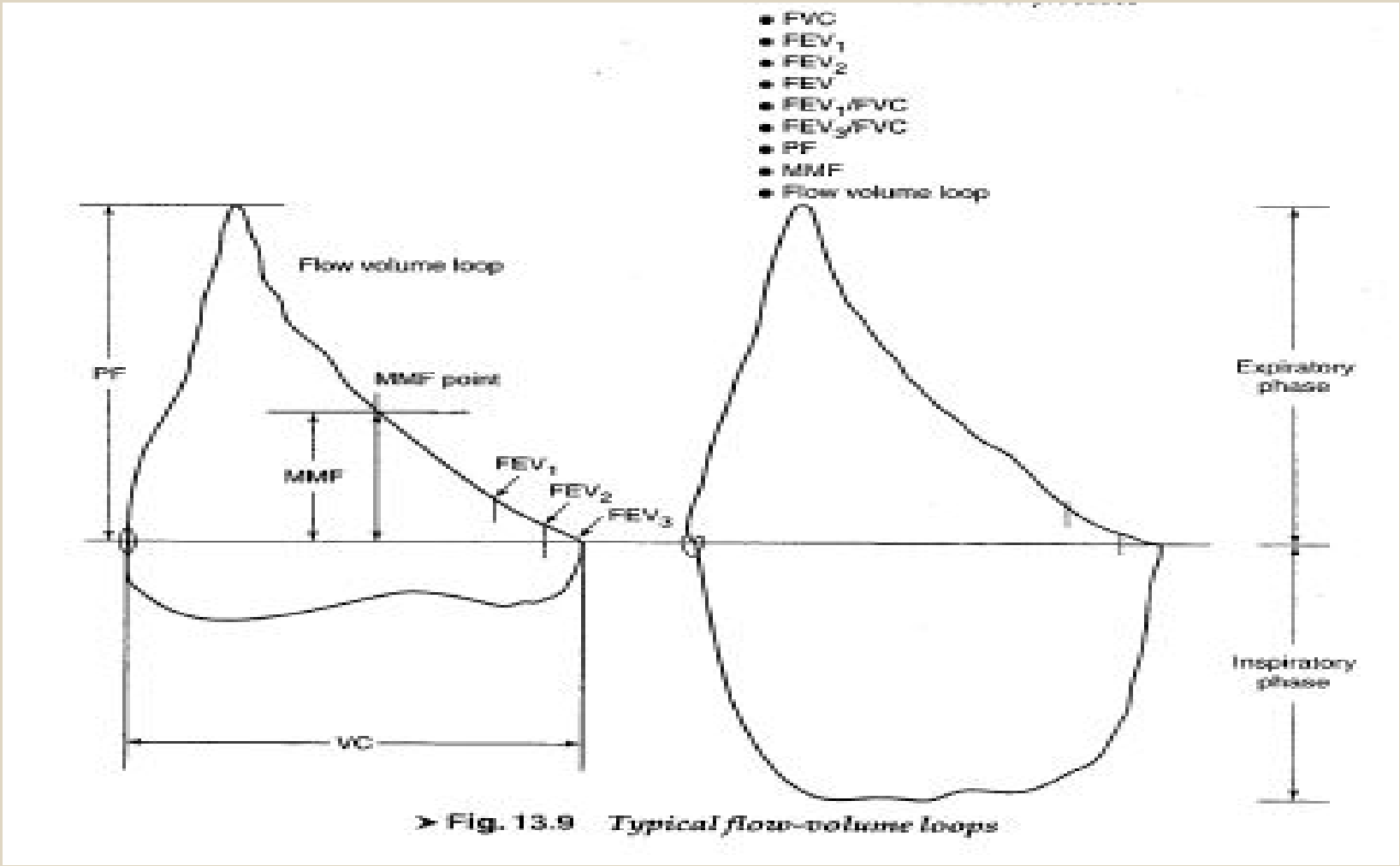
Fig. 13.8 *Schematic diagram of electrospirometer for measurement of flow and volume (Courtesy: Mercury Electronics, Scotland)*

- It consists of an ‘autozero’ flowmeter with a threshold detector and an integrator.
- The threshold detector selects portion of flow signal is to be integrated.
- Here both inspiration or expiration can be measured depending upon flow head is connected.
- Tidal volume size of each breath.
- Cumulative volume with staircase waveform.
- High quality amplifiers have to be used if not integrator circuit shows drift and system shows fault readings.

Flow Volume Curve

- It is a plot of instantaneous maximum expiratory flow rate versus volume.
- Patients with obstructive airway disease, the shape of this curve is drastically altered.
- Flow volume curve is a good early indication of abnormality.
- Typical MEFV curves are shown in fig.

Flow Volume Curve



➢ Fig. 13.9 *Typical flow–volume loops*

- Methods of producing the flow volume curve – common practice is to record it on storage oscilloscope & then permanent record by photographing – time consuming & costly.
- X-Y recorders are also not fast enough to follow rapid changes in signals.
- Special recorders are designed to meet the requirements.
- Lung abnormalities also detected by flow volume curve.

- A useful indicator of the relative degrees of inspiratory and expiratory obstruction is the $MEF_{50\%}$ / $MIF_{50\%}$ ratio.
- Microcomputer is connected with the instrument for further analysis.

Area of the Flow Volume Curve

- Area under the maximum expiratory flow volume curve is a sensitive indicator of lung function impairment.
- Area under the curve can be computed by using a square & integrating circuit. In the derivation of area the following equation is used $A = \int F \, dV$.

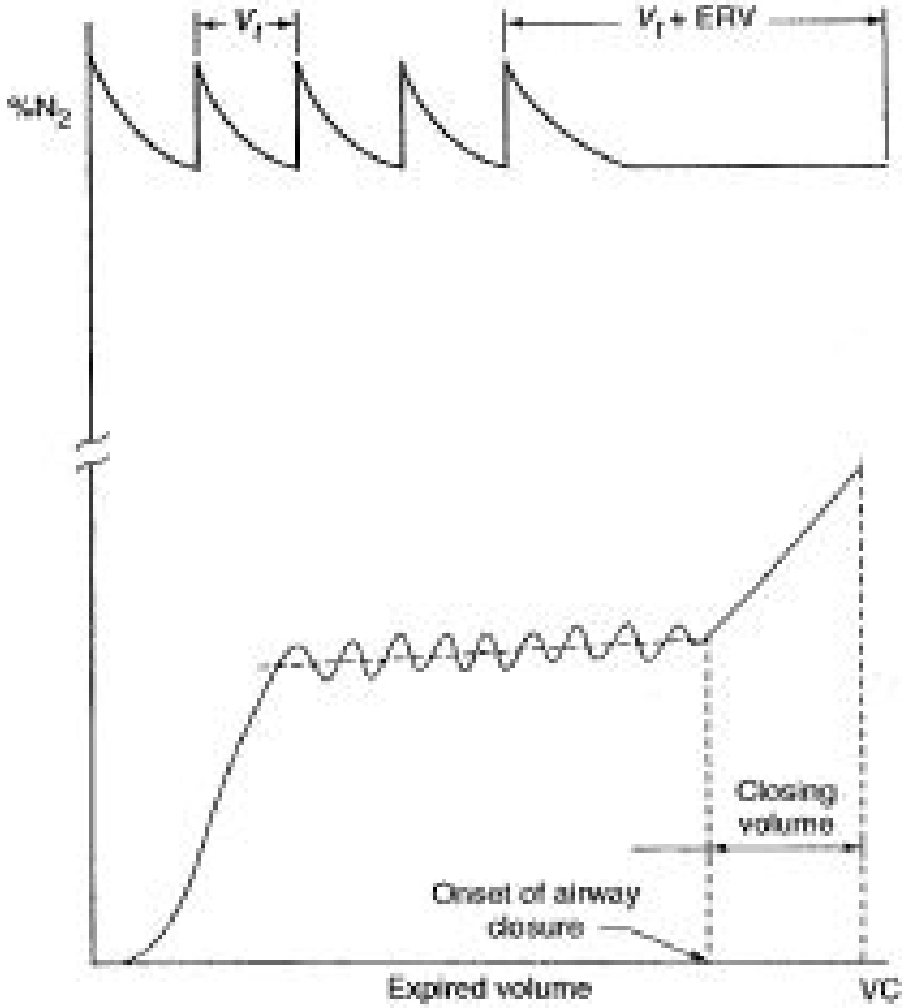
Nitrogen Washout Technique

- It is employed for the indirect determination of RV, FRC and TLC.
- Here the subject breathes 100% oxygen.
- A nitrogen analyzer is placed near the mouth piece to monitor the nitrogen content.
- The analyzer records nitrogen content which decreases with each successive expiration since it is progressively replaced with oxygen.

- The alveolar nitrogen concentration eventually decreases to 1% when steady state is reached.
- Nitrogen washout curves are plotted with time on the X-axis and $\%N_2$ in the expired air on the Y-axis.
- A typical complete multi breath nitrogen washout test would take about 10 minutes with modern instruments

- Single breath nitrogen washout test is another index of alveolar ventilation in addition to providing closing volume information.
- Test is performed with the subject exhaling to residual volume, making a maximal inspiration of 100% oxygen and exhaling his vital capacity slowly.
- $\%N_2$ vs Volume during expiration -- fig

Single – breath N2 washout curve



➤ Fig. 13.10 *Single-breath N_2 washout curve (Courtesy: Hewlett Packard, USA)*

- Analysis
- closing volume gives indication of small airway disease.
- Closing volume changes with age – lung expands.

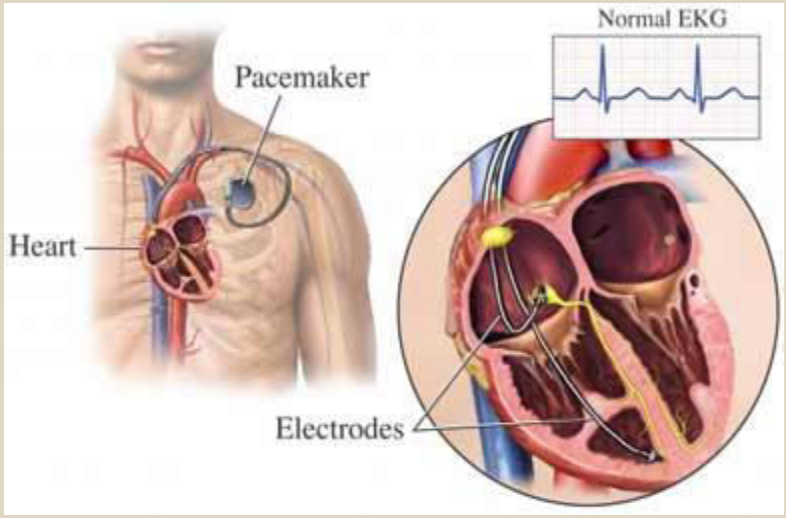
BIO–MEDICAL INSTRUMENTATION

BEE 007

Unit: 5

THERAPEUTIC INSTRUMENTS

PACEMAKER



Natural pacemaker:

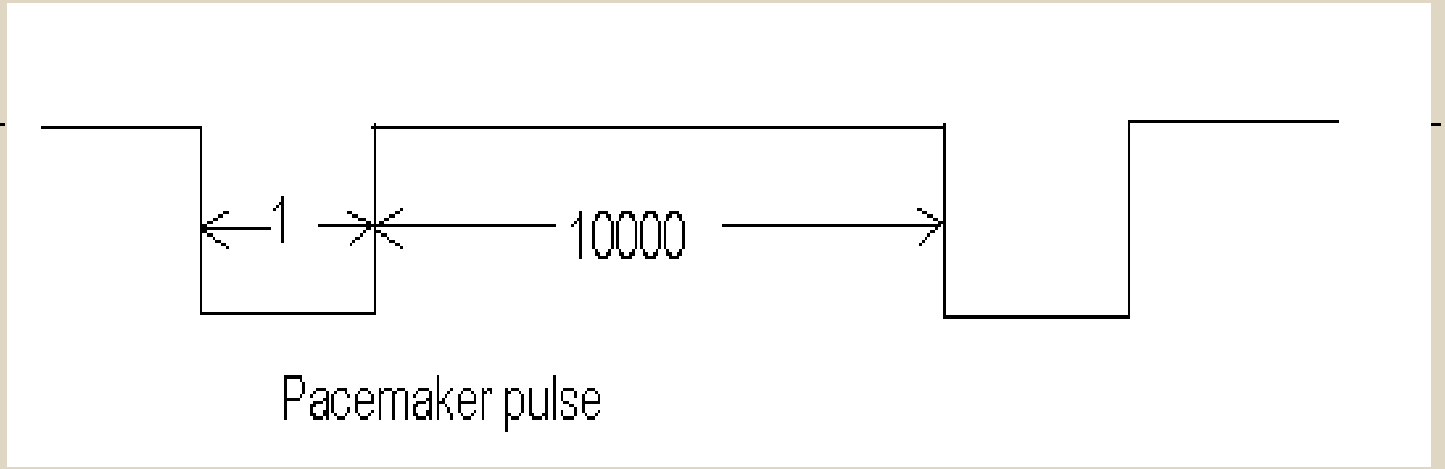
The heart's **"natural" pacemaker** is called the sinoatrial (SA) node or sinus node.

Artificial pacemaker:

It is a small, battery-operated device that helps the heart beat in a regular rhythm. They can replace a defective natural pacemaker or blocked pathway.

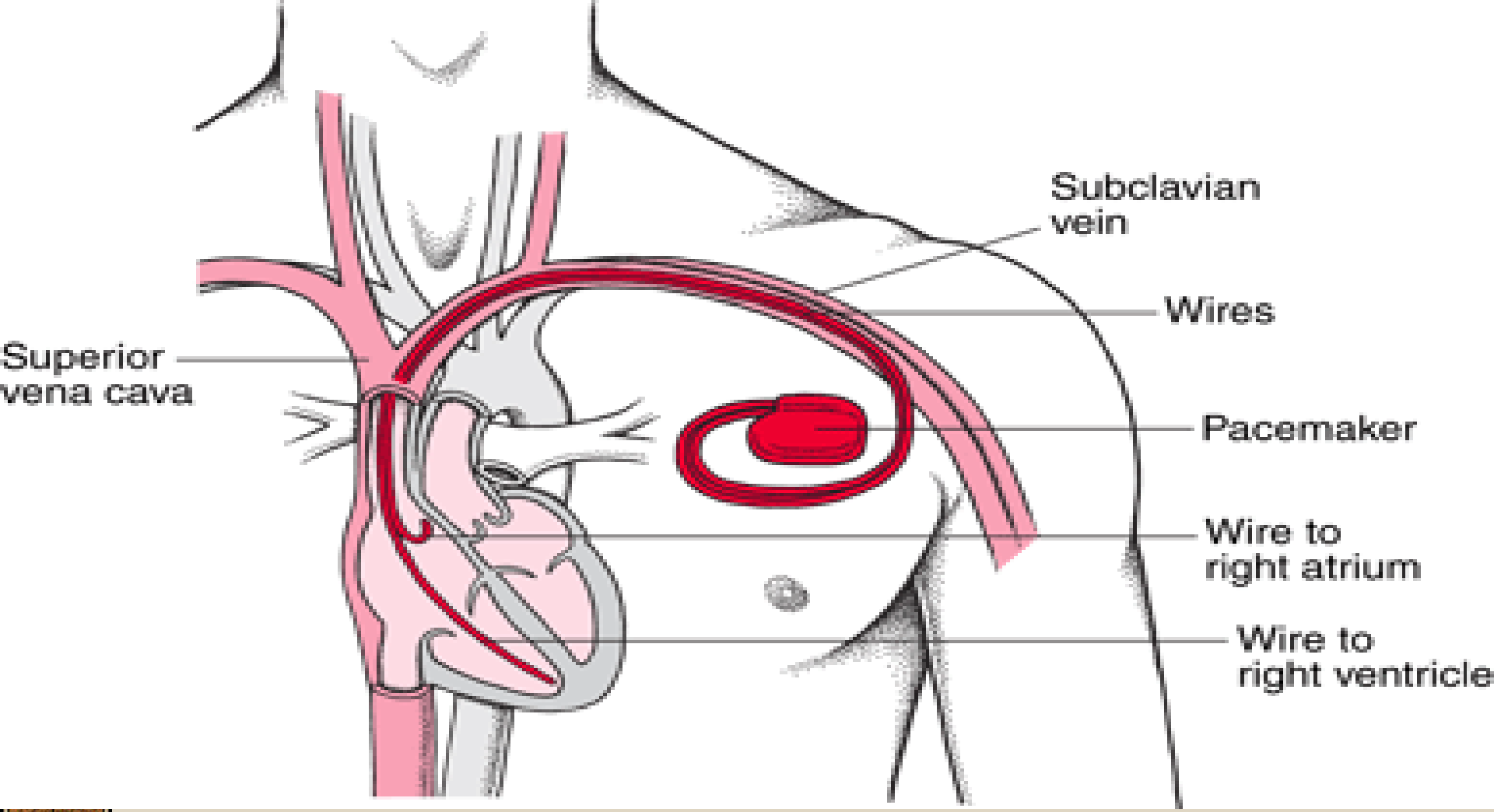
Energy required to excite heart muscle

- The heart muscles can be stimulated with an electric shock.
- The min energy required to excite the heart muscle is 10μJ .For better simulation a pulse of 100μJ is applied.
- Too high pulse may provoke ventricular fibrillation (ventricles fail to fill).
- The patient looses conscious and die in 10-15 seconds and brain cells die within few minutes from O_2 deficiency at 400μJ pulse.



- They have pulse to space ratio 1:10000 and that should be negatively going pulse to avoid ionisation.


Conduction
System



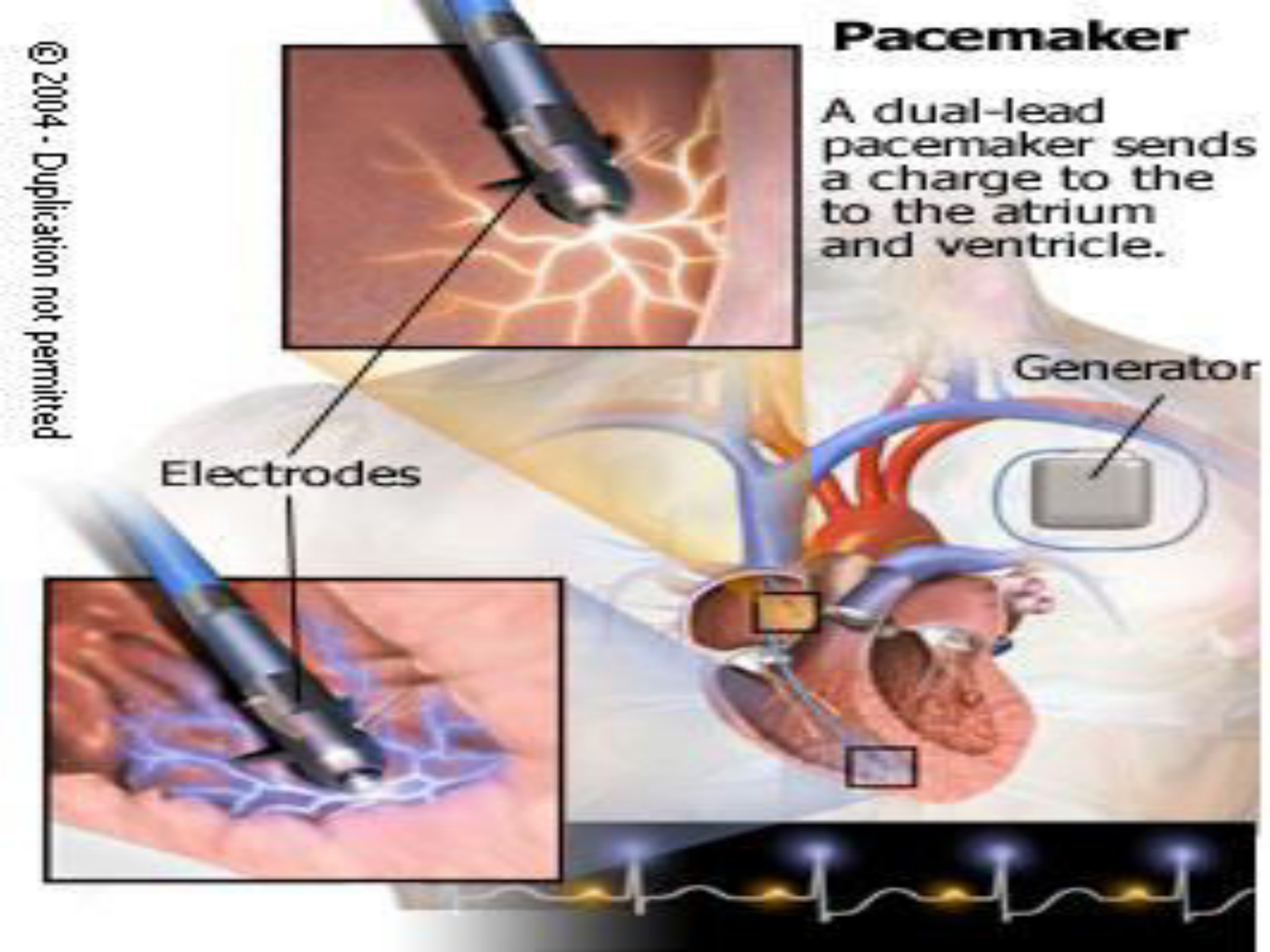
- Temporary or External pacemakers
- Internal or permanent pacemakers

Temporary or External pacemakers

- Temporary pacemakers are used in emergency settings or during overdose of medications to restart the normal rhythm of the heart.
- The pacemakers are placed outside the body.
- The electrodes used are called ENDOCARDIAC electrodes.
- The battery can be easily replaced and defects in the circuit can be easily made.

Internal or permanent pacemakers

- They are used when the slow heart rate becomes chronic or is believed to be irreversible.
- The electrodes used are called MYCORDIAC electrodes .ENDOCARDIAC electrodes are also used.
- It requires open heart minor surgery to place the circuit.
- The pacemaker is implanted into the chest or abdomen, usually on the left side of the chest.



- Attached to the generator are one or more *leads*, or wires, generally made of platinum with an insulating coating of either silicone or polyurethane. The leads carry the electrical impulses from the generator.

- At the tip of each lead is a tiny device called an *electrode* that delivers the necessary electrical impulses to the heart.

- Thus, the electric impulses are created by the generator, carried by the leads and delivered by the electrodes to the heart.

Different Modes of Operation

- Ventricular asynchronous pacemaker
- Ventricular synchronous pacemaker
- Ventricular inhibited pacemaker
- Atrial synchronous pacemaker
- Atrial sequential ventricular inhibited pacemaker

Ventricular asynchronous pacemaker

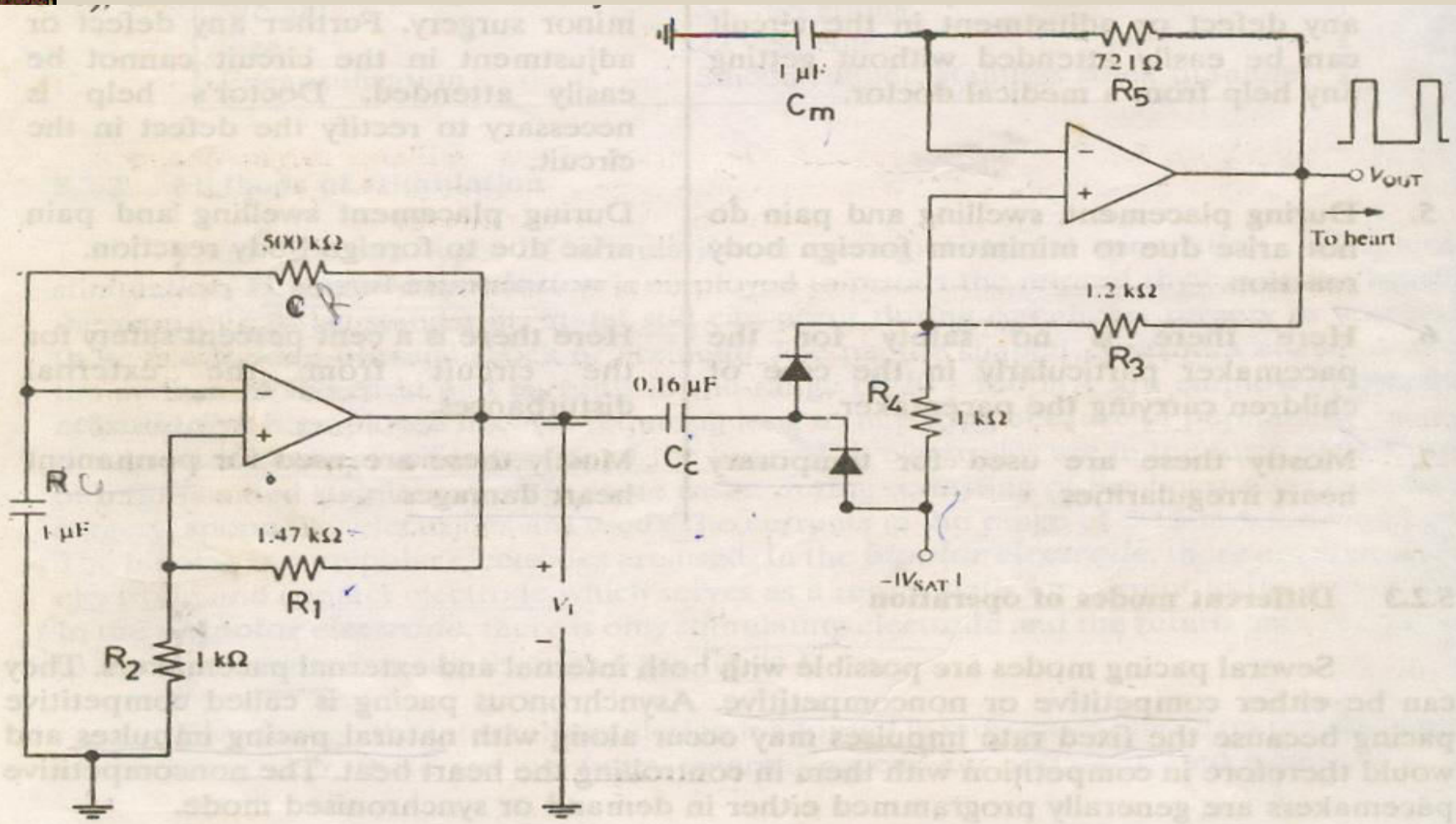


Fig.5.2. Ventricular asynchronous pacemaker

Ventricular asynchronous pacemaker

- The pacemaker can be used in atrium or ventricle.
- It uses a simple astable multivibirator.
- There may be competition between normal heart beat and pacemaker beats, this is dangerous.
- First blocking oscillator with transformer were used then transistorized blocking oscillator with a pulse amplifier were used.
- But now a days fixed rate pacemaker is fabricated on a single large scale integrated circuit.

- It consists of a square wave generator and a positive edge triggered monostable multivibrator.

- $T = -2RC\ln[(1-\alpha)/(1+\alpha)]$

- Where α is the feed back voltage such that

  $\alpha = [R2/(R1+R2)]$ according to the figure pulse with period T=.8589secs.

pulse duration $T_D = [(R_3R_4)/(R_3+R_4)]5C_C$

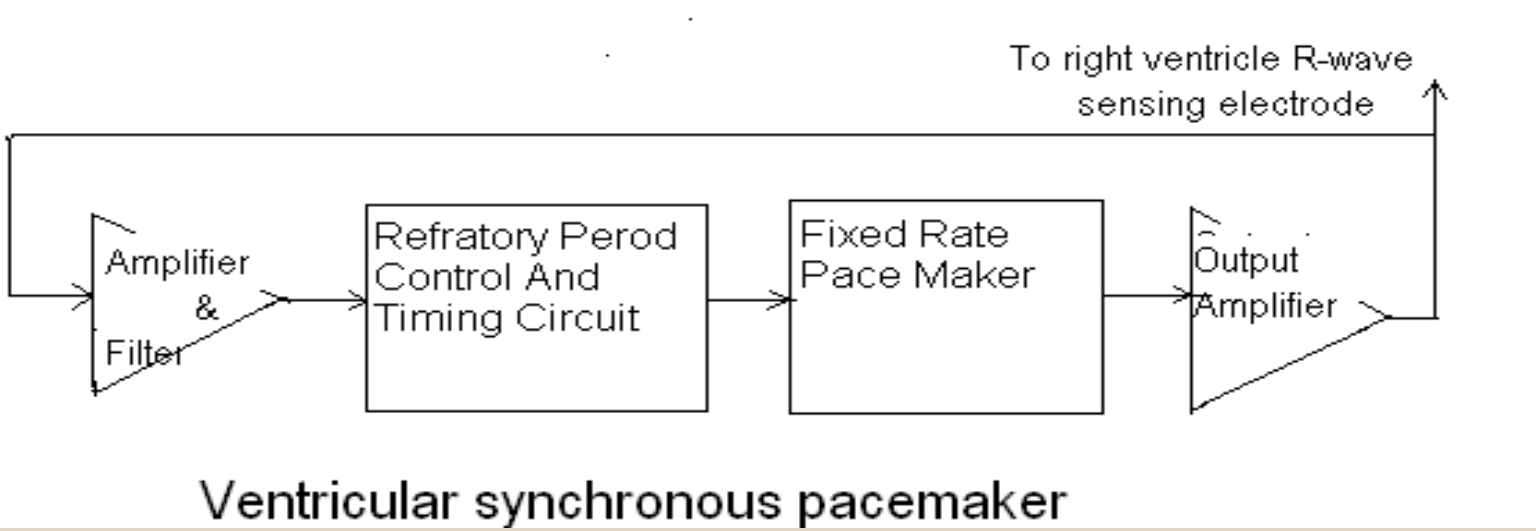
$T_D = .437$m secs

DISADVANTAGES:

- Here the heart rate cannot be increased to match greater physical effort.

- This varies stroke volume of the heart which cause some loss in cardiac output.

Ventricular synchronous pacemaker



Ventricular synchronous pacemaker

- They are preferred for short periods of AV block.
- Using sensing electrode heart rate is detected & is given to timing circuit of pacemaker.
- If the heart rate is below a min rate then pacemaker is turned on.

- The lead used to detect the R wave is now used to stimulate the heart.
- If natural contraction occurs then asynchronous pacer's timing circuit is reset so that it will tie its next pulse to detect the heart beat else produce pulse at its present rate.

ADVANTAGES:

- To arrest the ventricular fibrillation, this circuit an be used.
- Power consumption is reduced.

DISADVANTAGES:

- Atrial and ventricular contraction are not synchronized.
- The circuit is more sensitive to eternal electromagnetic interference .

Ventricular inhibited pacemaker

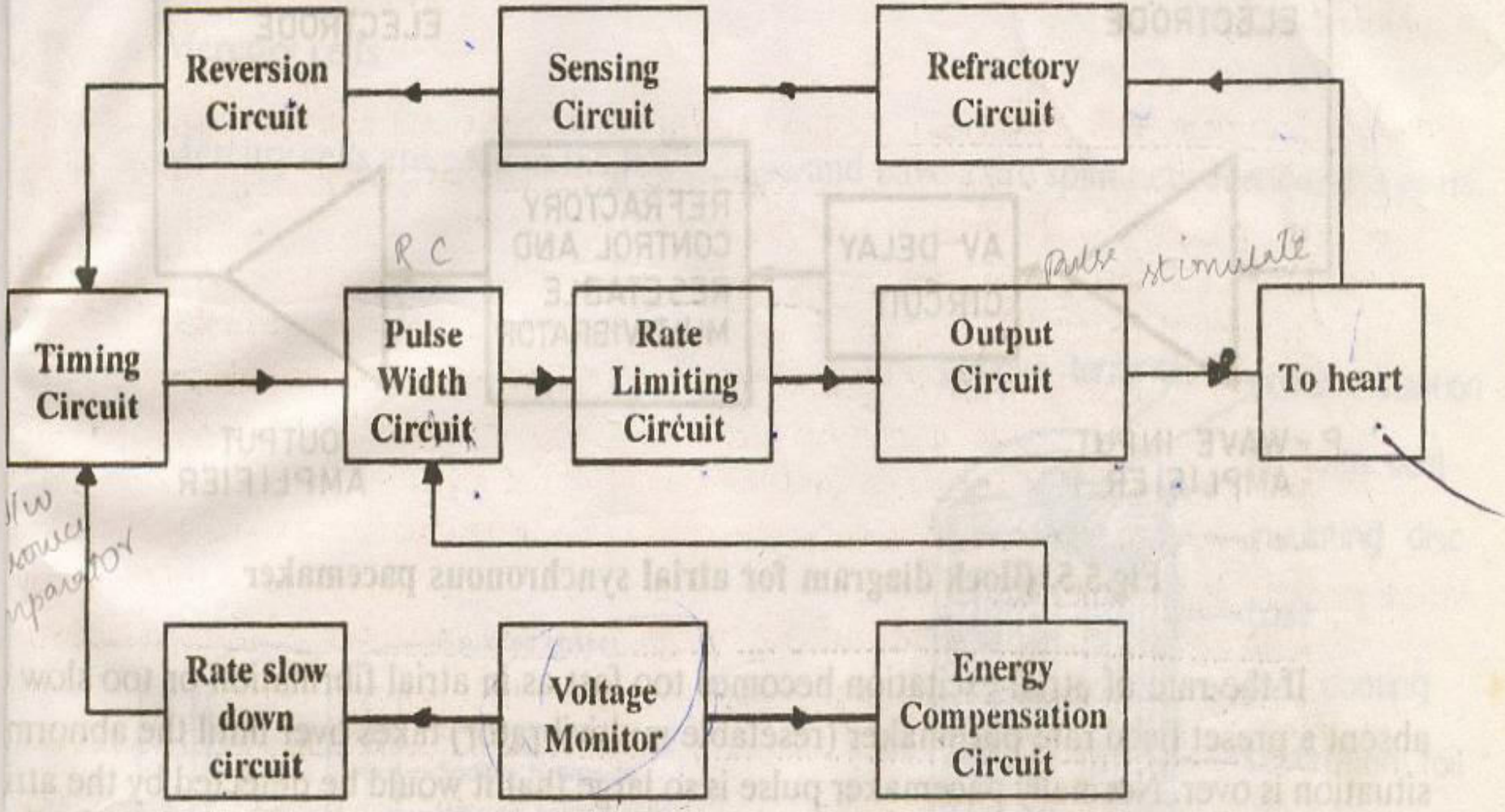


Fig.5.4. Ventricular inhibited pacemaker

Ventricular inhibited or demand pacemaker

- This pacemaker also allows the heart to pace at its normal rhythm when it is able to.
- Only if the heart beat falls to min rate the pacemaker turns on and hence called as DEMAND pacemaker.
- The timing circuit consists of an RC network a reference voltage source and a comparator which detects the basic rate of the pulse generator.
- The output of the timing circuit is fed into the RC network.
- The pulse width determines the duration of the pulse delivered to the heart. The output circuit provides proper pulse to stimulate the heart.

Atrial synchronous pacemaker

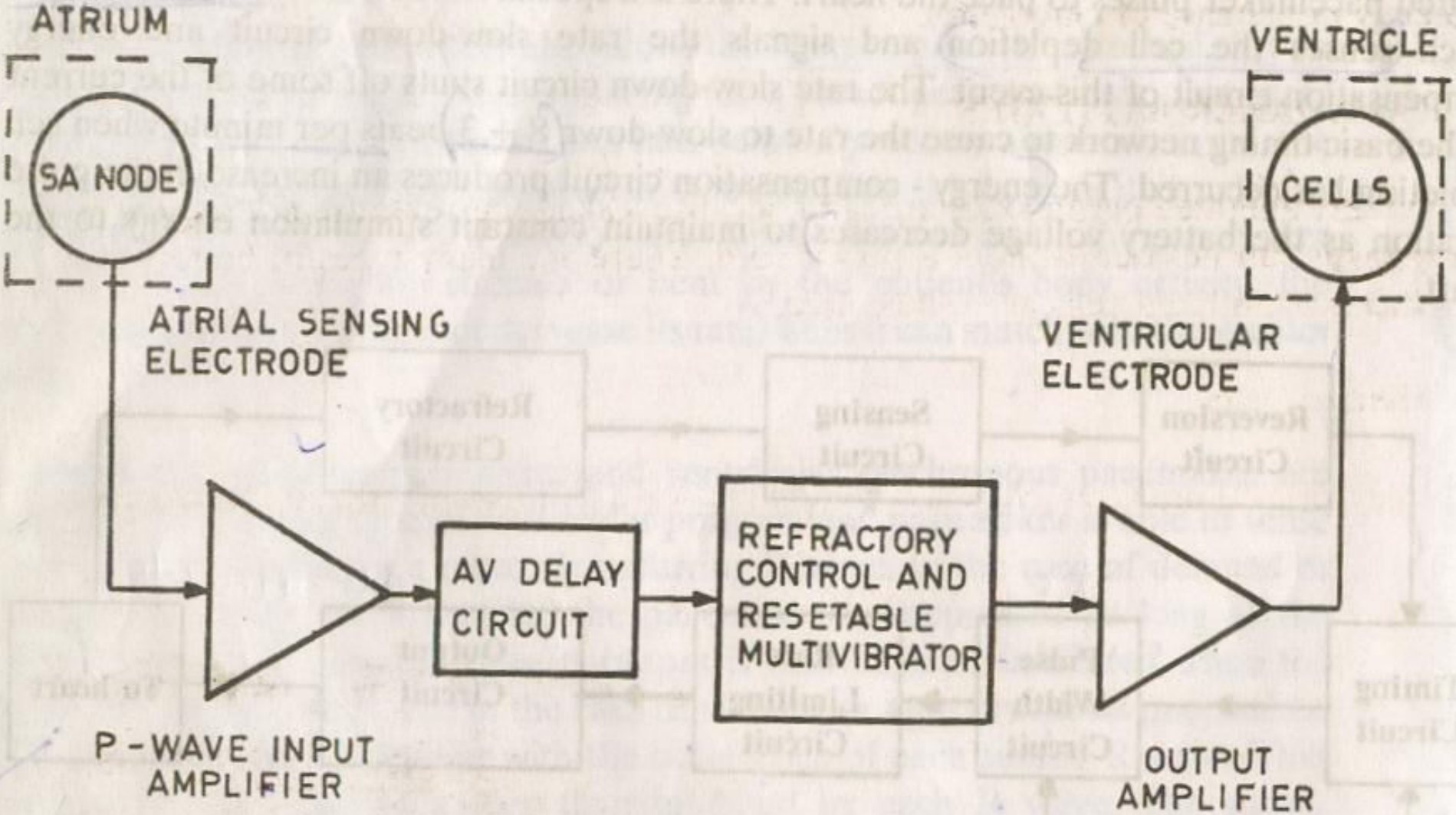


Fig.5.5. Block diagram for atrial synchronous pacemaker

Atrial synchronous pacemaker

- It is used for young patients with mostly a stable block.
- Used to terminate arterial flutter and paroxymal atrial tachycardia and act as temporary pacemaker for atrial fibrillation.
- The atria activity is picked up by a sensing electrode.
- The detected P wave is amplified and a delay of 0.12sec is provided by the AV delay circuit.
- This signal is used to trigger resetable multivbrator & the output is given to the amplifier which produces the stimulus to the heart.

Atrial sequential ventricular inhibited pacemaker

- It has the capability of stimulating both the atria and ventricle and adopts its method of stimulation to patient's needs.
- If atrial fails this pacemaker will stimulate the atrium and the sense the ventricular beat.
- A magnet is placed over the pacemaker on the skin of the patient order to activate a reed switch ,which switches the pacemaker to any modes.

Versatile electro diagnostic

- M1 is the variable rate multivibrator. The output from it trugger the mono stable multivibrater M2 which sets the pulse width .
- The output pulse from m2 provides interrupted galvanic pulse output .
- M3 is another astable multivibrator, which produces short duration Faradic currents.
- Faradic currents are modulated at the frequency set by multivibrator M1 in a mixer circuit M1.
- Since the modulation of Faradic pulses takes place with

A slow rate of increase and decrease, the output of M4 is surged Faradic current.

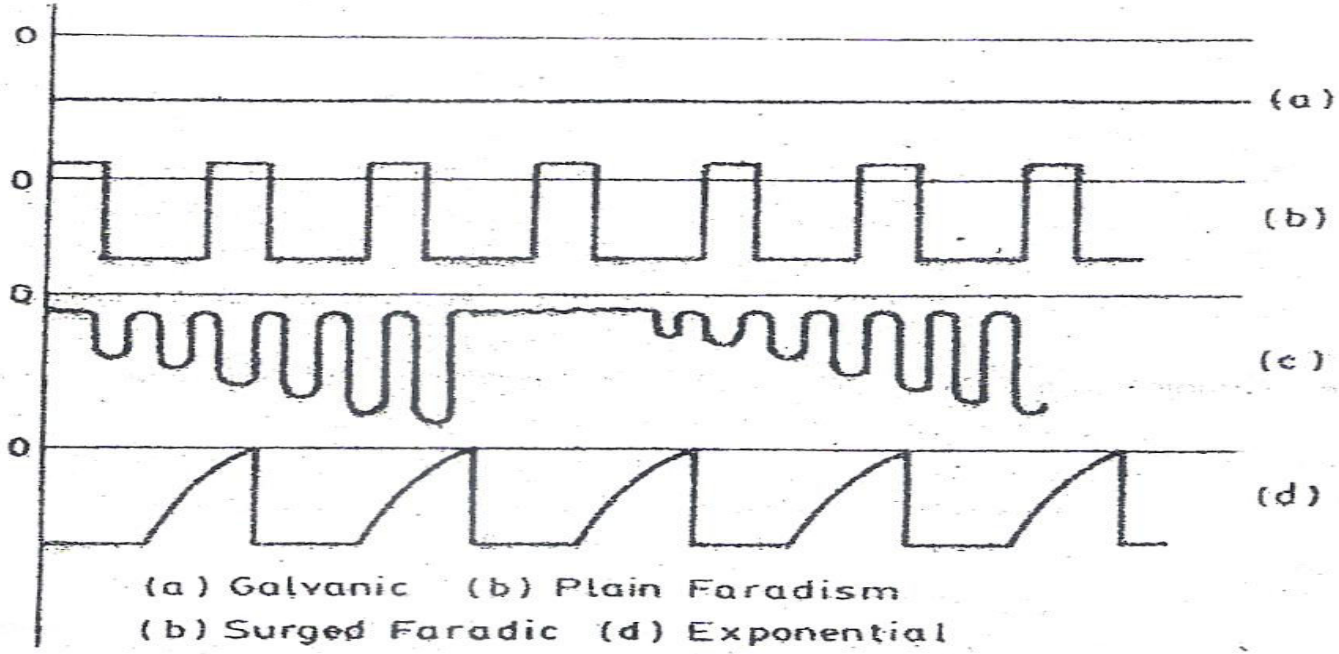


Fig.5.23. Different types of stimulator waveforms

ii) **Interrupted galvanic current**

Interrupted galvanic current pulses are a series of negative going rectangular pulses. The pulse duration is about 100 milliseconds with a repetition rate is in between 12 per minute and 70 per minute. A slighlty different form of interrupted galvanic pulses is the triangular wave pulses.

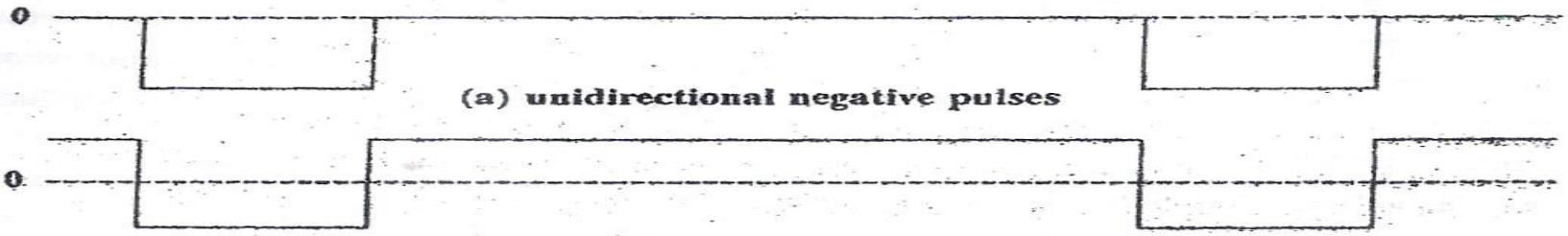


Fig.5.24. Interrupted galvanic pulses

Figure 5.24(a) shows the unidirectional interrupted galvanic pulses which create ionization of the skin of the patient and produce discomfort and inflammation. It is overcome by the application of a positive current in between the negative pulses proportional to the time interval.

- By integrating the output of M2 the triangular waveform is optained.
- Waveforms can be selected through a selector switch and fed either to an emitter follower input.
- The output of this unit is kept floating (or) Isolated from earth.

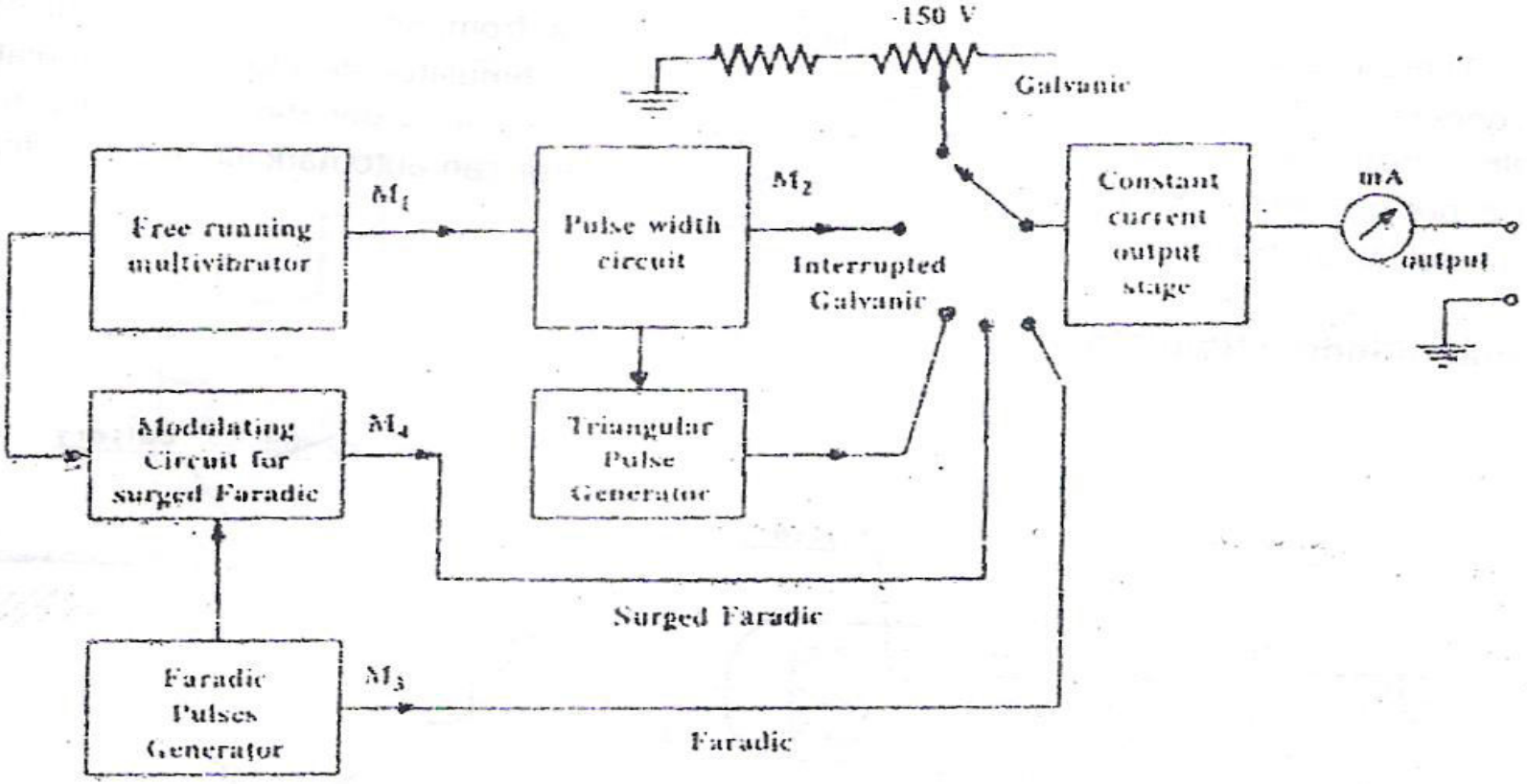


Fig.5.25. Block diagram of the versatile electrodiagnostic/therapeutic stimulator

5.6.4 Peripheral nerve stimulator

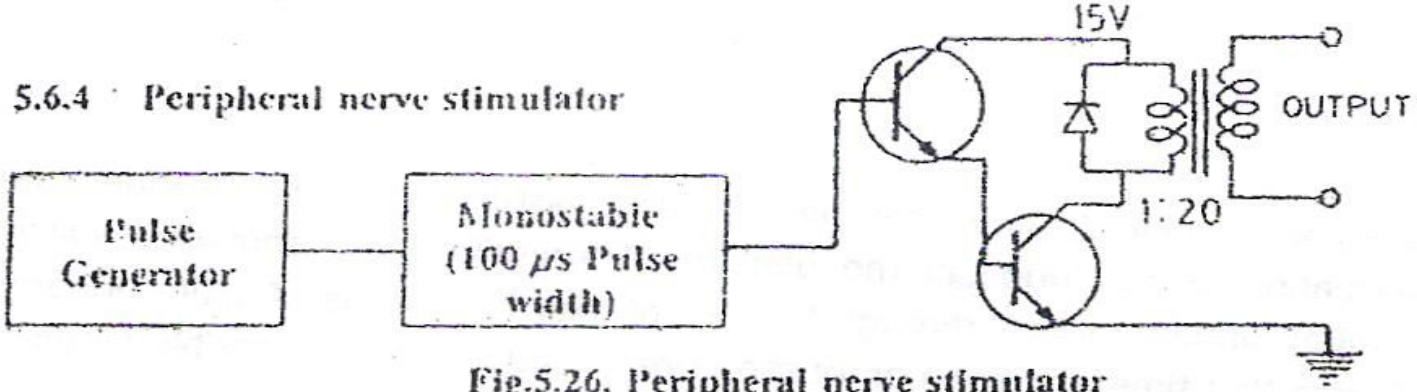


Fig.5.26. Peripheral nerve stimulator

Peripheral nerve stimulator

- The pulse generator which determines thepulse repetition rate – trigger the monotable multivibrator.
- The output of the monostable multivibrator drives an emitter follower and a Transconductance amplifier.
- The transformer is used to couple the stimulator with suitable energy to stimulate the nerve trunk.

Implanted prosthetc stimulator

- In the case of electronic pacemakers, the pulses are used to stimulate the ventricules or atria to maintain the normal heart beat in a defective heart.
- Similarly there are certain stimulators to stimulate the defective organs in our body to work in a normal manner.
- One of the implanted prosthetic stimulator is bladder stimulator which is used to stimulate the bladder muscles to discharge urine.
- Similarly there is alsclmplanted prosthetic stimulator, which is implanted in the hand or leg to get the functioning of the finger movements.
- These are adopted when the spinal cord's signal is not propagated to muscle fibers.

Implanted prosthetc stimulator

- There is a sensing electrode which picks up the signal from, spinal cord and it is used to trigger the pulse generator.
- The pulse generator and amplifier in the simulator develop the stimulating pulse with suitable energy and shape to stimulate the particular nerve so as to get the musucular action.

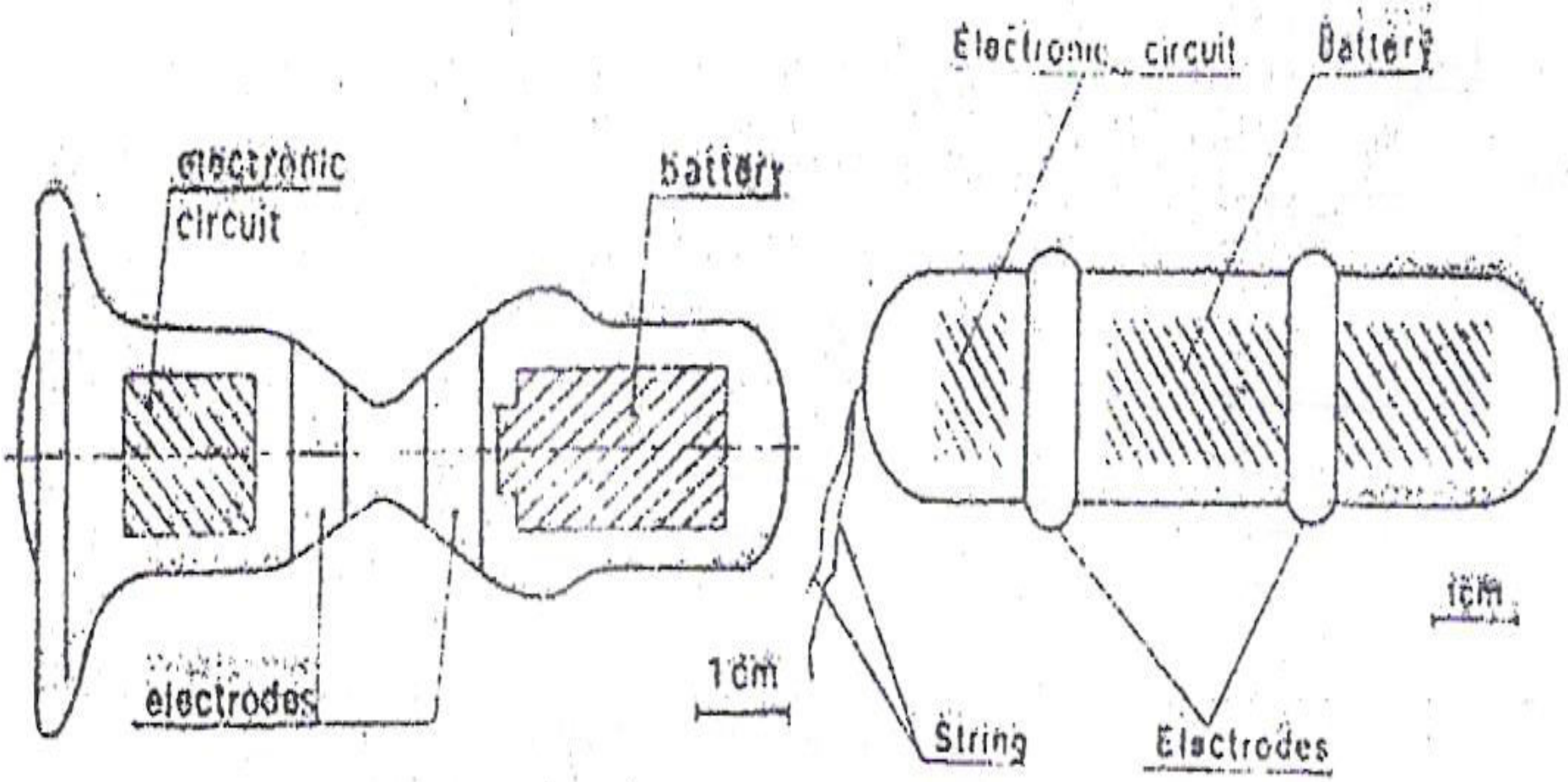
Implanted prosthetc stimulator

- Even if the signal is not obtained form the spinal cord the pulse generator can automatically work to initiate the nerve to do muscular contraction with the required amount.

External bladder stimulator

- When the spinal cord is injured, there may be immediate disturbance of the bladder function.
- So there is incomplete evacuation of the urine in the bladder.
- Progressive renal damage usually results and the patients often suffer ‘urinary misery’ through the rest of their lives or die of acute urinary sepsis or chronic renal failure

External Bladder stimulator



a. Anal Plug

b. Vaginal Plug

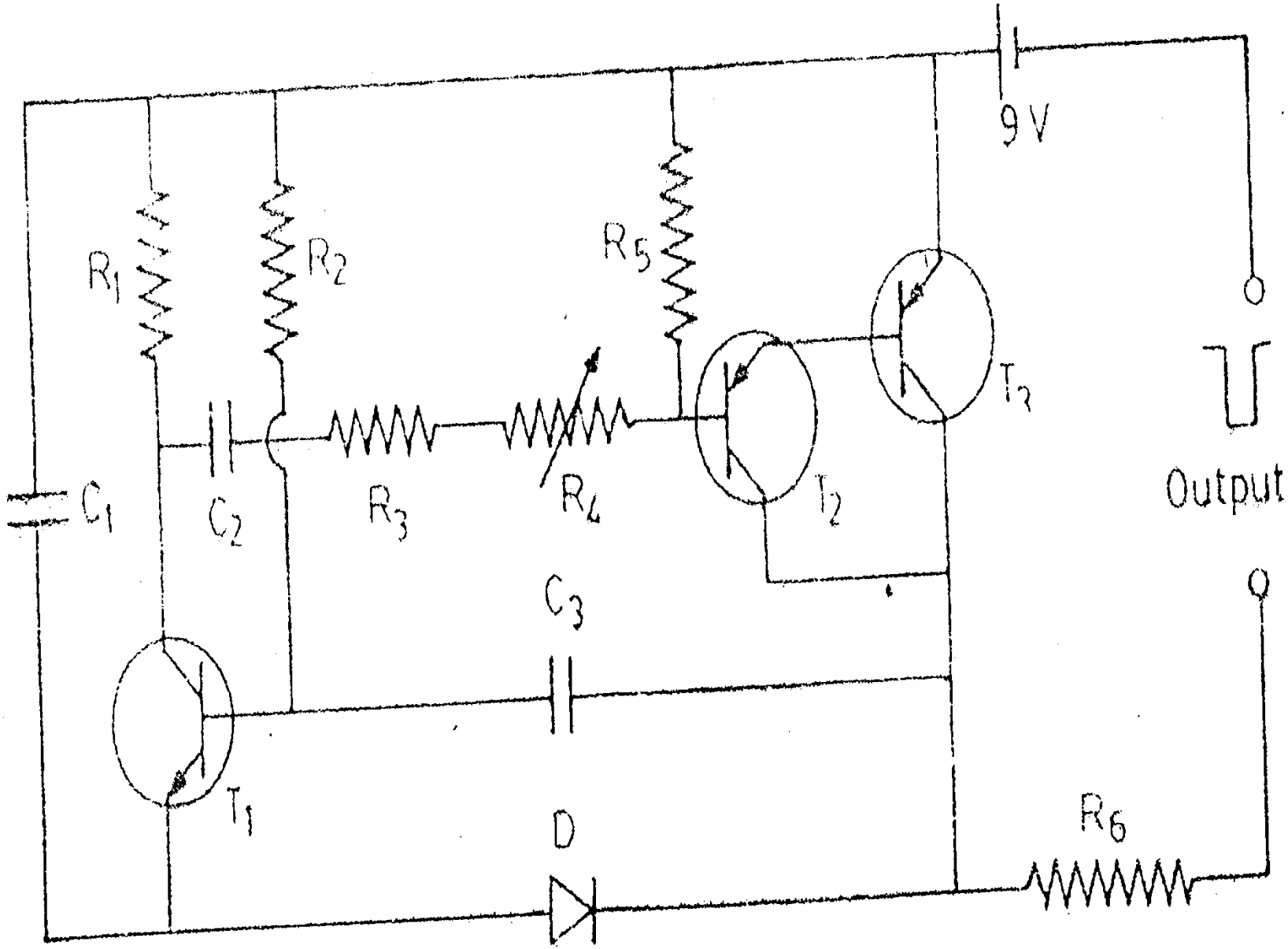


Fig.5.28. Circuit diagram of bladder stimulator

External bladder stimulator

- During that time, the function of the urinary bladder can be possible by electrical stimulation, unfortunaltely the bladder tissue.
- Unlike the heart tissue, is not self excitatory.
- A single excitation at one point does not propagate spontaneously through the whole structure.

External bladder stimulator

- Thus higher power and /or multiple electrodes must be used to achieve a reasonable contraction.
- Since most of the patients are not liking the implanted bladder stimulators, the non implantable vaginal plug and anal plug are newly developed as bladder stimulators.
- By means of these the complete evacuation of urine in the bladder can be achived in an efficient manner.

External bladder stimulator

External bladder stimulator

- Anal plug is used for correcting the urinary incontinence in men and vaginal plug is used for correcting the urinary incontinence in women.
- Once the plug is inserted, there is an automatic action of stimulation of the bladder muscles.
- If the urine is discharged completely, then the plug is removed and cleaned and can be kept in the pocket.

External bladder stimulator

- It consists of an astable multivibrator (T1 and T2) and a driver amplifier (T3)
- The circuit is closed when it is inserted in the area to be stimulated
- The astable multivibrator is formed by complementary transistor pair T1 and T2 where T1 and T2 are npn and pnp transistors respectively.

External bladder stimulator

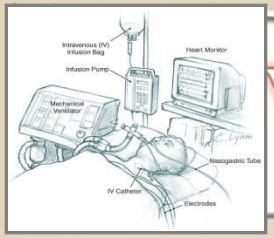
- With these transistors, pulses with extremely great pause duration ratio car obtained.
- The transistors should have the smallest possible current thus causing an additional direct current during pause.
- By changing the resistors R4 and R2 it is possible to adjust or pause durationn.

External bladder stimulator

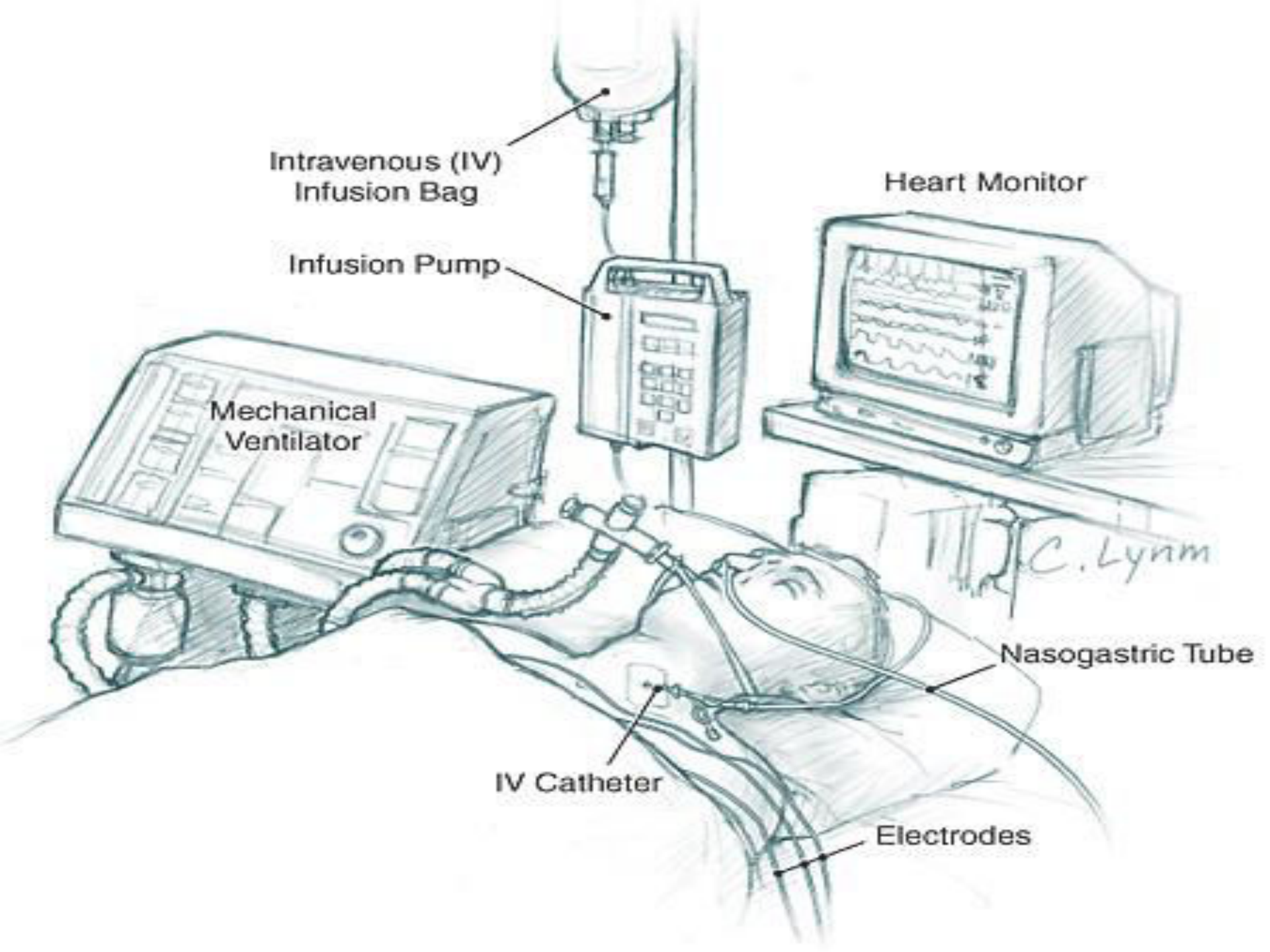
- The anal mucous tissue or vaginal pelvic floor muscle in contact with the output electrodes gives a load resistance of 100 ohms to several kilo ohms with a parrallel capacitance upto 20uF
- The circuit is available in the hybrid integrated circuit form.
- The driver amplifier is to get the pulse amplitude in the favourable manner to get proper stimulation of the bladder muscles.

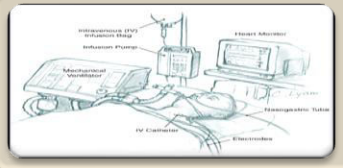
External bladder stimulator

- Some dysfunctions of urinary tract, such as incontinence, hyperreflexia of the detrusor, urine retention, etc. are successfully treated using this small size, reliable, nonimplantable bladder stimulators.
- More difficult cases fo the urges incontinence are treated by acute maximal functional electrical stimulation (AMFES)
- Here the frequency of the stimulation is around 20Hz and each pulse lasts 1 ms.
- The pulse height is of 6 to 25 v and the current is of 20 to 70 mA



VENTILATORS


Intravenous (IV)
Infusion Bag
Heart Monitor
Infusion Pump
Mechanical
Ventilator
C. Lynn
Nasogastric Tube
IV Catheter
Electrodes



introduction

- Ventilator is part of intensive care
- Require assistance of breath 4 the patient
- It is used to provide oxygen enriched medicated air to a patient at controlled temp

Origins of ventilation

The era of intensive care medicine began with positive-pressure ventilation

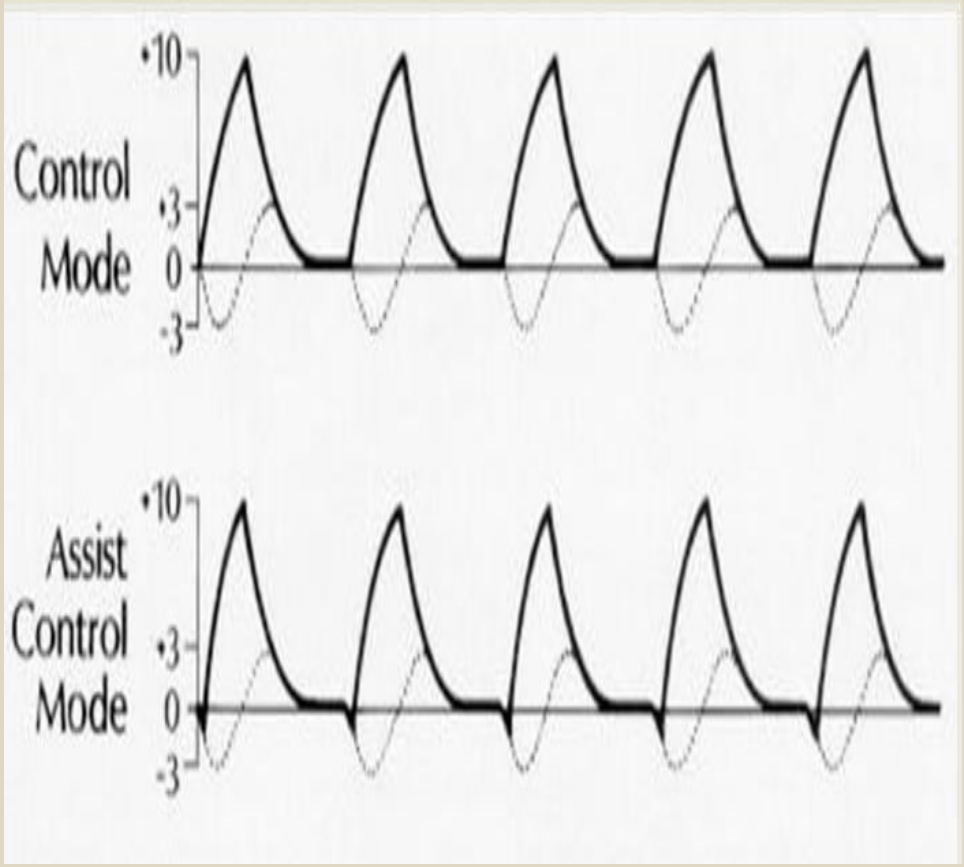
- **Negative-pressure ventilators ("iron lungs")**
  - **Non-invasive ventilation first used in Boston Children's Hospital in 1928**
  - **Used extensively during polio outbreaks in 1940s – 1950s**
- **Positive-pressure ventilators**
  - **Invasive ventilation first used at Massachusetts General Hospital in 1955**
  - **Now the modern**

The iron lung created negative pressure in abdomen as well as the chest, decreasing cardiac output.

Iron lung polio ward at Rancho Los Amigos Hospital in 1953.

Ventilator delivers a fixed volume

- **Control Mode**
  - it receives a set number of breaths and cannot breathe between ventilator breaths
  - Similar to Pressure Control
- **Assist Mode**
  - it initiates all breaths, but ventilator cycles in at initiation to give a preset tidal volume
  - it controls rate but



- Rapidly breathing pts can overventilate and induce severe respiratory alkalosis and

Purpose of ventilator

- Adequate ventilation:

  supply enough oxygen and right amount of co2 is eliminated
- Elimination of respiratory work
- Increased intrathoracic pressure :

  it prevents atlases is collapse portion of lung and counteracts edema of the lung

PRESSURE LIMITED VENTILATORS

- It is based on the principle of insufflation is terminated when the gaseous mixture pumped into the patients lungs reaches pre-set pressure.
- It is driven by compressed gaseous mixture used for ventilation.

VOLUME LIMITED VENTILATOR

- It is based on the principle that for each breath the constant volume of air is delivered.
- During insufflation a constant volume of air of air is sent to the lungs by appliying pressure to a chamber containing of constant volume.
- It don’t give desired ventilation in cases where the pre-set max. pressure cant completely empty the chamber.

Pressure ventilation vs. volume ventilation

Pressure-cycled modes deliver a fixed pressure at variable volume (neonates)

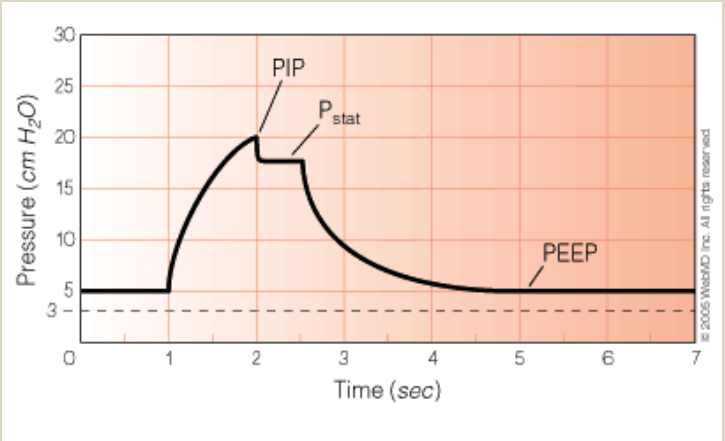
Volume-cycled modes deliver a fixed volume at variable pressure (adults)

Pressure-cycled modes

- **Pressure Support Ventilation (PSV)**
- **Pressure Control Ventilation (PCV)**

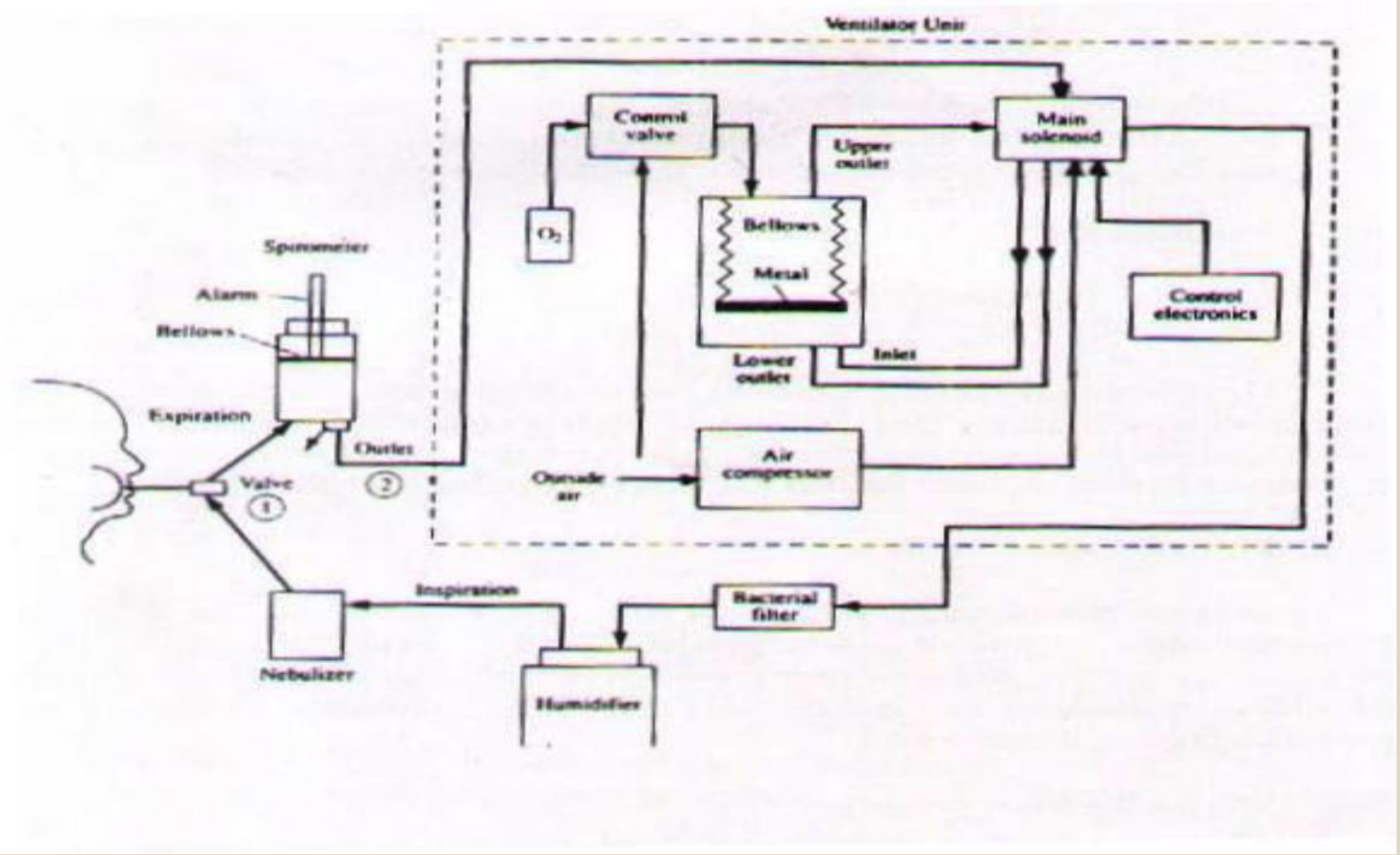
Volume-cycled modes

- **Control**
- **Assist**
- **Assist/Control**



Volume-cycled modes have the inherent risk of volutrauma.

SERVO CONTROLLED VENTILATORS



- This type of ventilators is controlled by feed back circuits .
- The electronic unit controls the amplifiers and logic circuits which control the ventilation.
- It monitors the pressures ,activate alarms and compute mechanical lung parameters.

Working

- During the inspiration the air compressor draws room air through an air filter and passes it to the main solenoid.
- Main solenoid forces the bottom inlet valve of the internal bellows chamber to open and the lower outlet valve to close.
- O2 passed into the bellows chamber in a controlled manner by the control valve.
- The high pressure in the below chamber compresses the bellows and forces the upper outlet valve open.

- Humidifier –to prevent damage to the patient lungs.
- Nebulizer –nebulizer compressor produces a fine spray of water or medication into the patient inspired air in the form of aerosols.
- Sensitivity controlled monitors
- Spiro meter-to measure the volume of exhaled air

MICROPROCESSOR BASED VENTILATOR

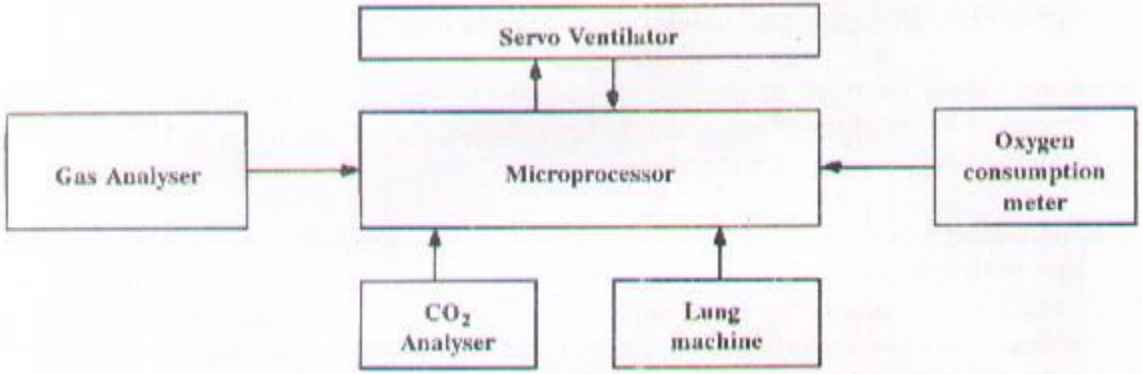


Fig.6.7. Microprocessor based ventilator

- It is used to control the mechanical ventilator
- It consist microprocessor with RAM,EPROM,A/D converter and CRT controller
- The i/p signals to the microprocessor are obtaind from co2 analyser,a lung machine,gas analyser
- The proper controlling signals are delivered to the servo ventilator so as to get correct ventilation with respect to patient metabolism