EC6001-Medical Electronics Lesson Notes

Bio-Potential

Electrode – Electrolyte Interface

General Ionic Equations

$$C \leftrightarrow C^{n+} + ne^-$$

$$A^{m-} \leftrightarrow A + me^-$$

If electrode has same material as cation, then this material gets oxidized and enters the electrolyte as a cation and electrons remain at the electrode and flow in the external circuit.

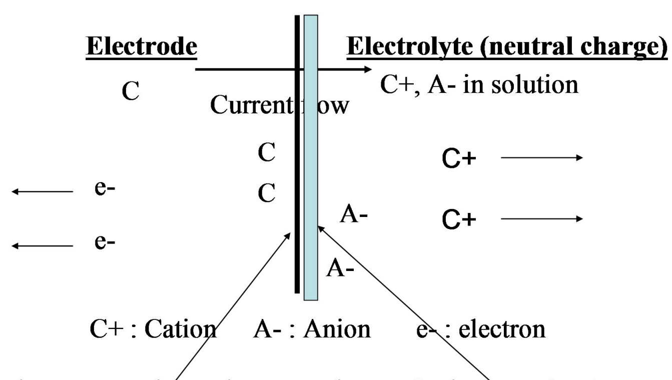
If anion can be oxidized at the electrode to form a neutral atom, one or two electrons are given to the electrode

The dominating reaction can be inferred from the following :

Current flow from electrode to electrolyte : Oxidation (Loss of e-)

Current flow from electrolyte to electrode : Reduction (Gain of e-)

Electrode – Electrolyte Interface



Fairly common electrode materials: Pt, Carbon, …, Au, Ag,…
Electrode metal is use in conjunction with salt, e.g. Ag-AgCl, Pt-Pt black, or polymer coats (e.g. Nafion, to improve selectivity)

Half Cell Potential

A characteristic potential difference established by the electrode and its surrounding electrolyte which depends on the metal, concentration of ions in solution and temperature (and some second order factors) .

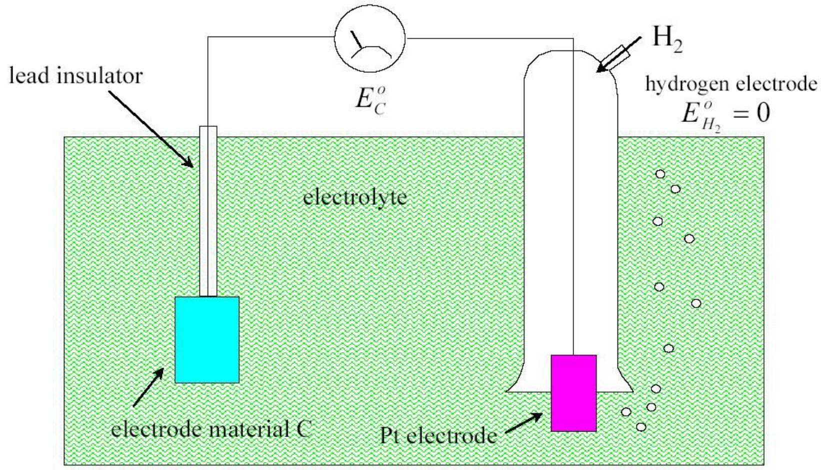
Half cell potential cannot be measured without a second electrode.

The half cell potential of the standard hydrogen electrode has been arbitrarily set to zero. Other half cell potentials are expressed as a potential difference with this electrode.

Reason for Half Cell Potential : Charge Separation at Interface

Oxidation or reduction reactions at the electrode-electrolyte interface lead to a double-charge layer, similar to that which exists along electrically active biological cell membranes.

Measuring Half Cell Potential



Polarization

If there is a current between the electrode and electrolyte, the observed half cell potential is often altered due to polarization.

Nernst Equation

When two aqueous ionic solutions of different concentration are separated by an ion-selective semi-permeable membrane, an electric potential exists across the membrane.

The Nernst equation for half cell potential is

$$E = E^0 + \frac{RT}{nF}\ln\left[\frac{a_C^{\gamma}a_D^{\delta}}{a_A^{\alpha}a_B^{\beta}}\right]$$

where E0 : Standard Half Cell Potential E : Half Cell Potential

a : Ionic Activity (generally same as concentration)

n : Number of valence electrons involved

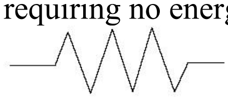
Polarizable and Non-Polarizable Electrodes

<u>Perfectly Polarizable Electrodes</u>

These are electrodes in which no actual charge crosses the electrode-electrolyte interface when a current is applied. The current across the interface is a displacement current and the electrode behaves like a capacitor. Example : Ag/AgCl Electrode

<u>Perfectly Non-Polarizable Electrode</u>

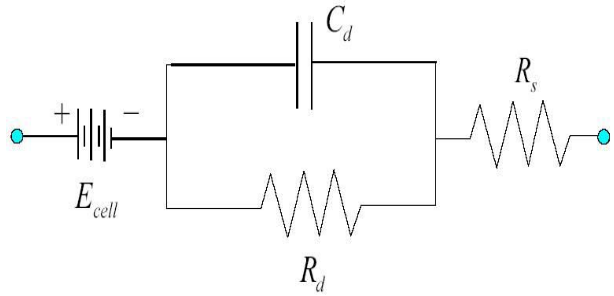
These are electrodes where current passes freely across the electrode-electrolyte interface, requiring no energy to make the transition. These electrodes see no



Over potentials. Example : Platinum electrode

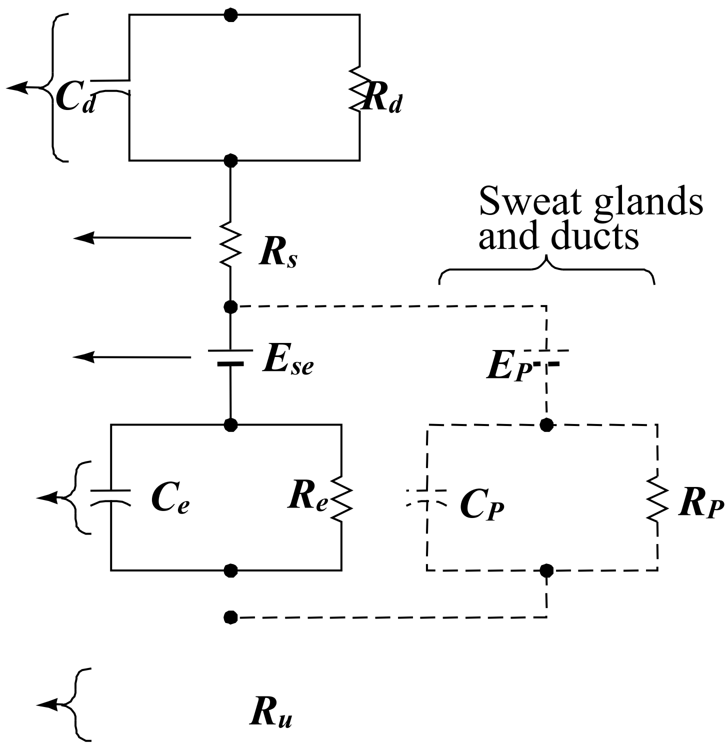
Example: Ag-AgCl is used in recording while Pt is use in stimulation

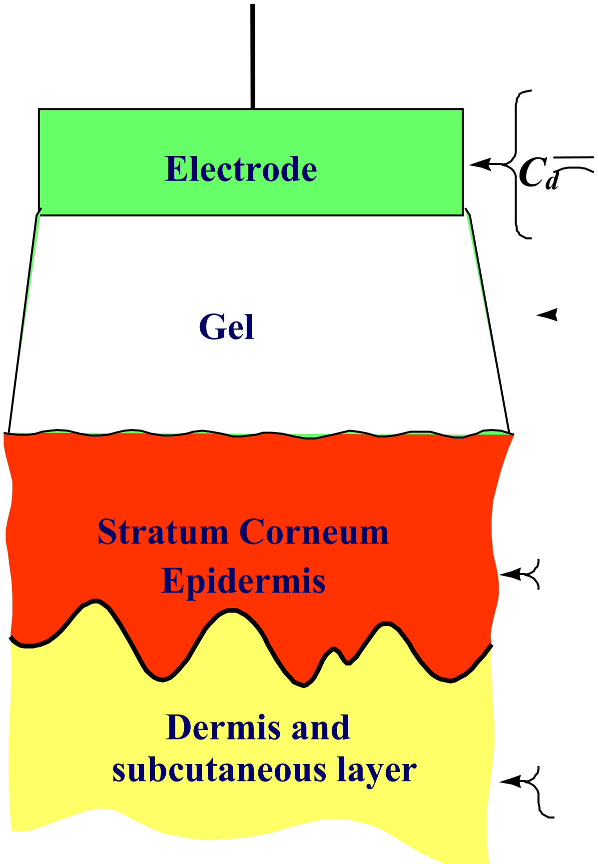
Equivalent Circuit



Cd : capacitance of electrode-eletrolyte interface
Rd : resistance of electrode-eletrolyte interface
Rs : resistance of electrode lead wire
Ecell : cell potential for electrode

Electrode Skin Interface





Capillary

Motion Artifact

<u>Why</u>

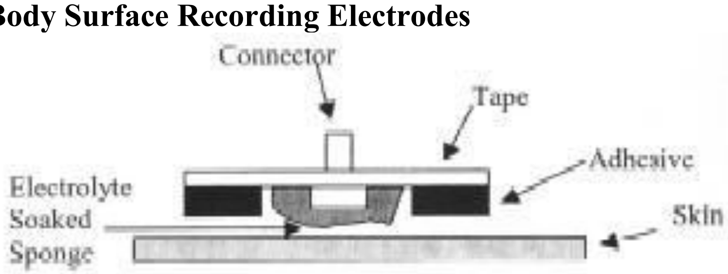
When the electrode moves with respect to the electrolyte, the distribution of the double layer of charge on polarizable electrode interface changes. This changes the half cell potential temporarily.

<u>What</u>

If a pair of electrodes is in an electrolyte and one moves with respect to the other, a potential difference appears across the electrodes known as the ***motion artifact.*** This is a source of noise and interference in biopotential measurements

Motion artifact is minimal for non-polarizable electrodes

Body Surface Recording Electrodes



1. Metal Plate Electrodes (historic)
2. Suction Electrodes

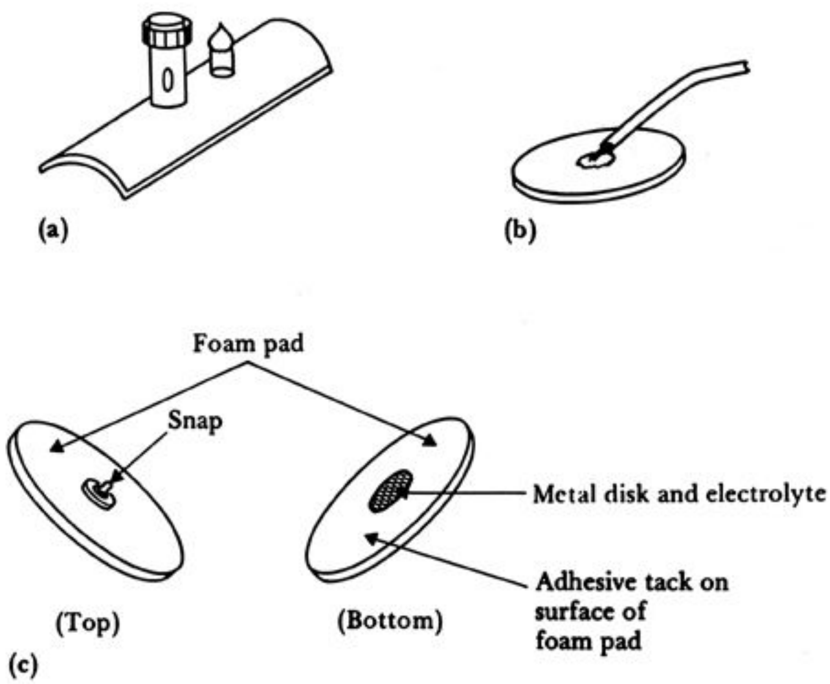
(historic interest)

1. Floating Electrodes
2. Flexible Electrodes

Commonly Used Biopotential Electrodes

Metal plate electrodes

- Large surface: Ancient, therefore still used, ECG
- Metal disk with stainless steel; platinum or gold coated
- EMG, EEG
- smaller diameters
- motion artifacts
- Disposable foam-pad: Cheap!



(a) Metal-plate electrode used for application to limbs.
(b) Metal-disk electrode applied with surgical tape.
(c)Disposable foam-pad electrodes, often used with ECG

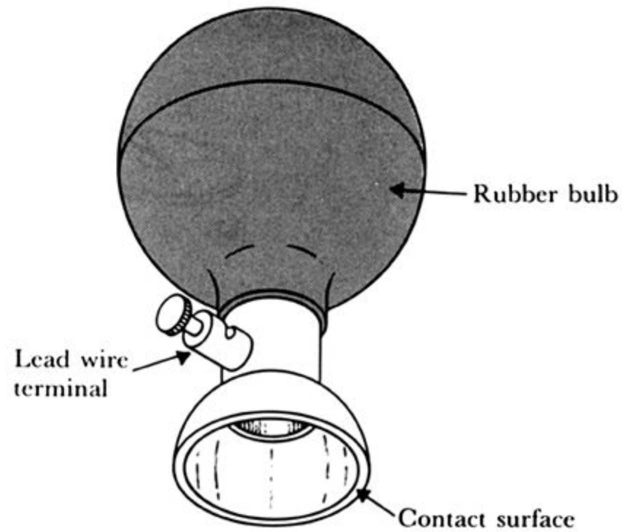
Commonly Used Biopotential Electrodes

Suction electrodes

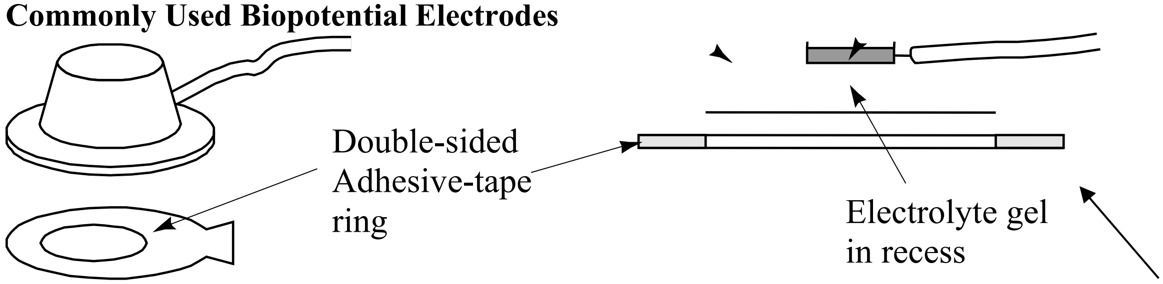
- No straps or adhesives required
- precordial (chest) ECG
- can only be used for short periods

Floating electrodes

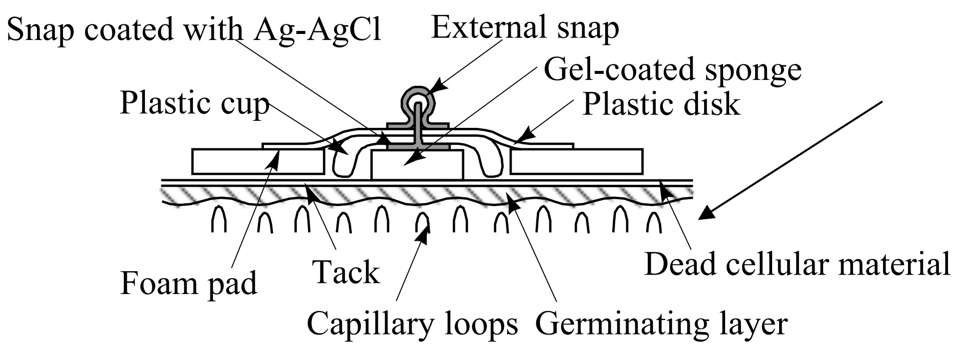
- metal disk is recessed
- swimming in the electrolyte gel
- not in contact with the skin
- reduces motion artifact



Commonly Used Biopotential Electrodes



(a) (b)

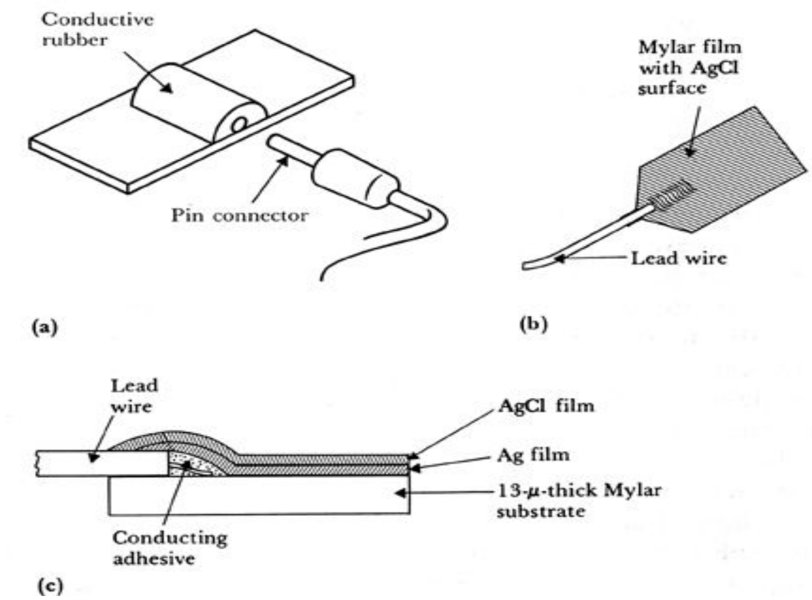


(c)

Floating Electrodes

Flexible electrodes

- Body contours are often irregular
- Regularly shaped rigid electrodes may not always work.
- Special case : infants
- Material :
  - Polymer or nylon with silver
  - Carbon filled silicon rubber (Mylar film)



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

Electrodes in Biopotential Measurements

3. Describe the construction of commercial ECG electrode (not the cheap polymer electrode used in the lab). What is the common electrode metal, and why is it preferred?
So, you are an inventor who has a better idea. Describe an improvement

- to make the electrode cheaper
- more suitable for lower noise measurement for EEG
- circumvent patents that are based on plastic/foam electrode body
- attractive to consumers for use with their ECG machines at home
- reduce artifact (minimize the motion of skin/electrode) in ambulatory recording

4. In a research laboratory, scientists want to record from single cells in a culture dish. They want to record action potentials from single, isolated heart cells. What kind of electrode would they need to use (describe material and design)? Give a simplified schematic (circuit model of the electrode) described in the notes given to you.

What is the challenge involved in designing an amplifier for use with a microelectrode for single cell recording? I.e. what are the critical amplifier design characteristics and specifications (hint: this is not the usual differential/instrumentation amplifier) ?

Electrodes and Microelectrodes (miscellaneous)

- How would you detect bacteria or other microorganisms in water supply? Make sure that your method distinguishes inert particulate matter from living cellular matter.

- Draw the equivalent circuit model of the skin and an ECG electrode. Identify the key sources of electrical interference and otherwise the elements that would likely contribute to the poor quality of recordings.

- Design an amplifier interface for the following two applications: Patch clamp ion channel current amplifier: Your goal is to amplify pA level current to produce 1 Volt output.

- Strain gauge sensor amplifier: Your goal is to convert 10 ohm change in resistance of a strain gauge to produce 1 volt output.

Neural electrodes/microelectrodes
You want to record from neurons in the brain. However, you want to record from dozens of neurons all at once from several closely spaced microelectrodes. What material and process would you use to make the microelectrode array?

- What metal would you prefer to use to make electrode arrays of about 10 micron square size to make electrical contacts with dozens of neurons?

- What metal would you prefer to use to stimulate dozens of neurons in a deep brain microelectrode based stimulator?

- (which metal provides good recording vs stimulating properties – and at the same time not be toxic to brain tissue)?

- You are asked to develop an experimental set up to record from rat brain cells using microelectrodes. What precautions would you take to minimize the electrical interference in your recording set up?

Biopotential Amplifiers

• These are very important part of modern medical instrumentation
• We need to amplify biopotentials which are generated in the body at low levels with a high source impedance
• Biopotentials amplifiers are required to increase signal strength while maintaining fidelity

Basic Requirements of Biopotential Amplifiers

Essential functions of a bioamplifier are:
• To take a weak biopotential and increase its amplitude so that it can be processed, recorded or displayed
• To amplify voltage, but it could be considered as a power amplifier as well
• To amplify current since in some cases a biopotential amplifier is used to isolate the load from the source current gain only

Input Impedance (Zin)

• All biopotential amplifiers must have **high input impedance** minimize loading (remember the characteristics of biopotential electrodes resulting into loading and distortion if input impedance of the amplifier is not high enough) – typical values of Zin over the frequency range of the measurand = 10 MΩ (remember the loading rule)

Protection & Isolation

• The input circuit of a biopotential amplifier must provide protection to the live measurand

Vbio

• Any potential or current at amplifier's input terminals can affect

Vbio

• Electric currents produced by the biopotential amplifier can result in microshock and macroshock

• The bioamplifier must have isolation and protection circuitry so that the current through the electrodes can be kept at safe levels and any artifact generated by such current can be minimized

Output Impedance (Zout)

• The output circuit does not present any critical problems, all it needs to do is to drive the load

• **Output impedance must be low** with respect to the load impedance and it must be capable of satisfying the power requirements of the load

Bandwidth (BW)

Frequency response requirements

• The biopotential amplifier must be sensitive to important frequency components of the biosignal

• Since biopotentials are low level signals, it is important to limit bandwidth optimize signal-to-noise ratio

Gain (G)

• Biopotential amplifiers have a gain of **1000** or greater

Mode of Operation

• Very frequently biosignals are obtained from bipolar electrodes

• Electrodes **symmetrically located with respect to ground** need differential amplification

• High **CMRR** required because:

1. Common mode signals much greater than the biosignal appear on bipolar electrodes
2. Symmetry with respect to ground is not perfect (mismatch between electrode impedances) – more on this later

Calibration Signal

• Medical and clinical equipment require quick calibration • The gain of the biopotential amplifier must be calibrated to provide us with an accurate indication of the signal's amplitude

• Push button to apply standard signal to the input of the biopotential amplifier

• Adjustable gain switch carefully selects calibrated fixed gains (in microprocessor–based systems, gain adjustment can be

Electrocardiography

♥ A very widely used medical instrument, which is utilized to diagnose and monitor cardiac beat abnormalities is the

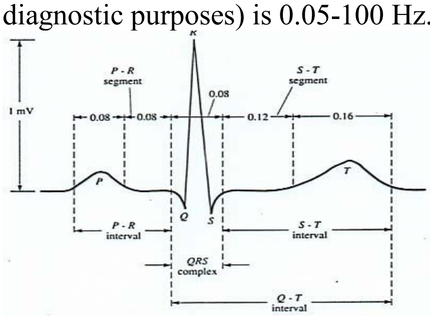
electrocardiograph

♥ It measures the electrical activity of the heart (more precisely biopotential differences arising from the electrical activity of myocardium). We've already talked about the genesis of the ECG signal.

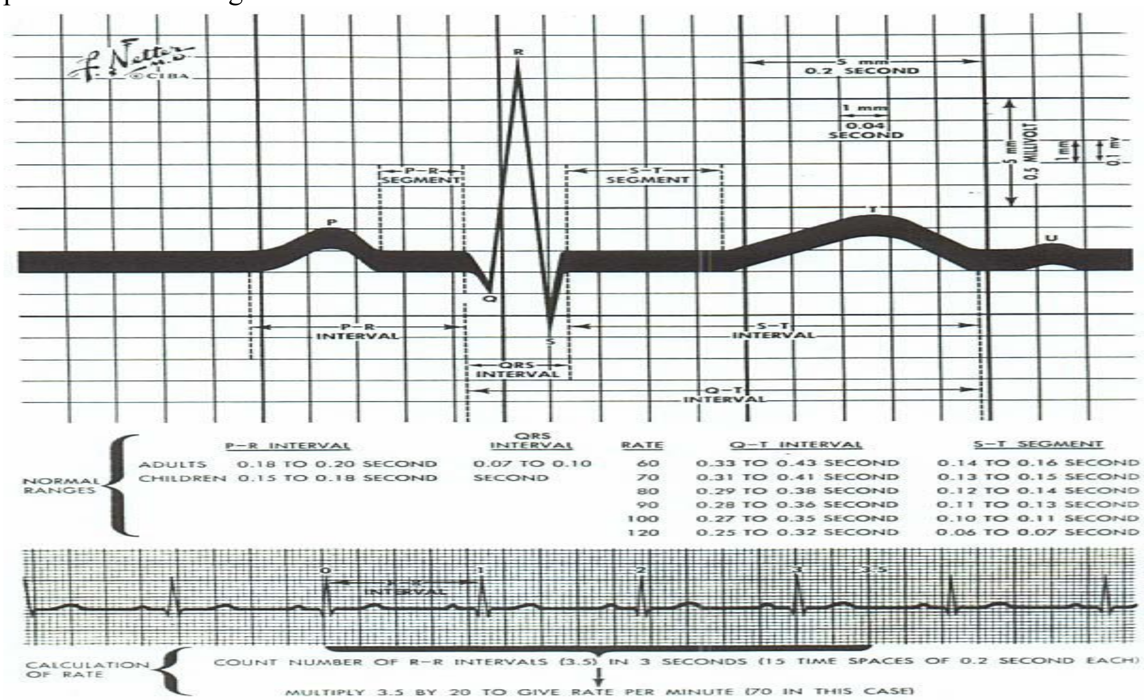
♥ The ECG machine uses surface electrodes and high input impedance

♥ Differential amplifiers with good common mode rejection ratio to record the electrocardiogram

♥ Normal ECG amplitude ranges between 0.5-4 mV. Normal frequency content of ECG (for diagnostic purposes) is 0.05-100 Hz. A typical ECG waveform is shown below:



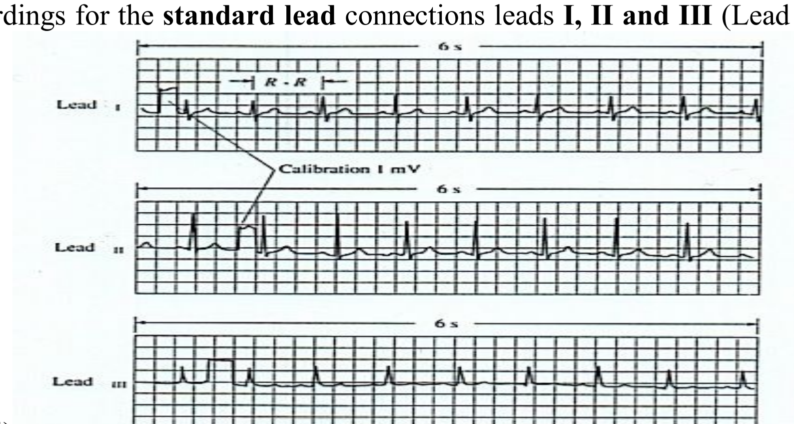
Obviously all human hearts are not the same and this leads into
variability in different parts of the ECG signal
Significant diagnostic features of the ECG signal are:
♥ Duration of component parts of the signal
♥ Polarities and magnitudes
♥ The details of the ECG signal and the degree of variability in different
parts of the ECG signal is shown below:



The QRS amplitude, polarity, time duration, the RR interval (indicator of heartbeat per min.) and the T-wave amplitude are some very important and distinctive features of the ECG signal.
The **heart rate** in **BPM** = Beats Per Minute) is simply = **60 (RR interval in seconds)**
Some ECG waveform abnormalities that may indicate illness are:
♥ An extended PR interval may be diagnosed as AV node block
♥ A widening of the QRS complex may indicate conduction problems in the bundle of His
♥ An elevated ST segment may indicate occurrence of myocardial Infarction (**MI**)
♥ A negative polarity in the T wave may be due to coronary insufficiency

ECG Leads

Normal ECG recordings for the **standard lead** connections leads **I, II and III** (Lead **II** provides



the strongest signal)
Obviously, all human hearts are not the same and this results into a high degree of **variability**

♥ Note the degree of variability of different parts of the ECG Signal

TABLE 6.1
Amplitudes of ECG Waves for Standard Lead Connections

Wave	Lead voltage magnitudes [nominal (range)] V_I (mV)	V_{II} (mV)	V_{III} (mV)
P	0.07 (0.01 to 0.12)	0.01 (0 to 0.19)	0.04 (0.0 to 0.13)
Q	0.03 (0 to 0.16)	0.03 (0 to 0.18)	0.04 (0 to 0.28)
R	0.53 (0.07 to 1.13)	0.71 (0.18 to 1.68)	0.38 (0.03 to 1.31)
S	0.10 (0 to 0.36)	0.12 (0 to 0.49)	0.12 (0 to 0.55)
T	0.22 (0.06 to 0.42)	0.26 (0.06 to 0.55)	0.05 (0.0 to 0.3)

Some abnormalities that may indicate illness:

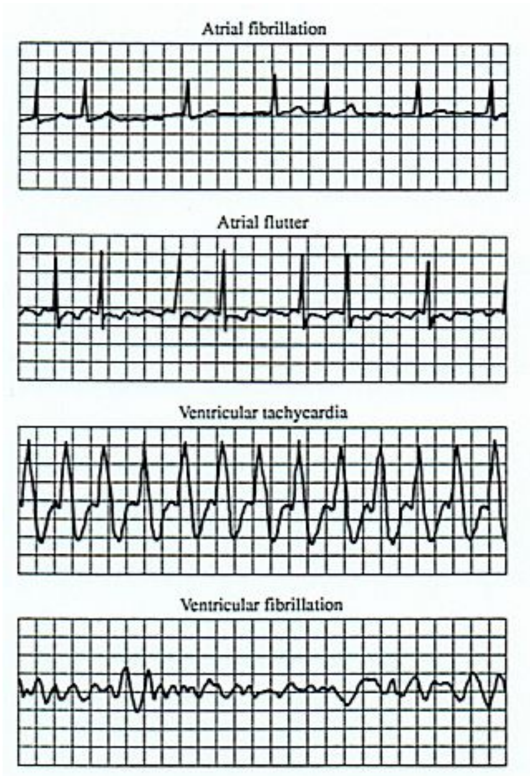
♥ An extended P-R interval may be diagnosed as AV node block

♥ Widening of the QRS complex conduction problems in the bundle of His

♥ Elevated ST segment may indicate occurrence of MI

♥ Negative polarity T wave may be due to coronary insufficiency QRS amplitude, polarity, time domain, PR interval (indicator of heat beat per min. & T-wave amplitude are some very important distinctive features.

1. Loss

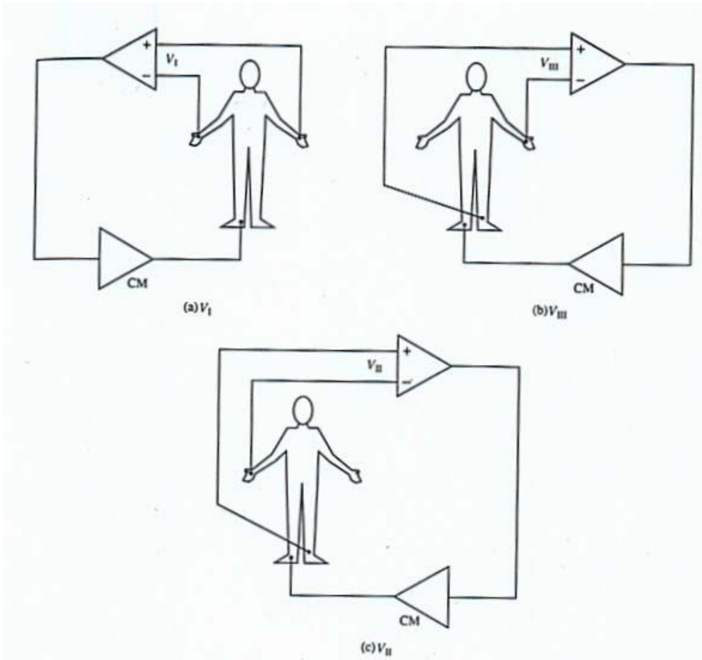


2.

Origin of the ECG signal

♥ We have already covered this concept extensively in the previous lectures (The **Dipole filed** of the heart, the **Eindhoven's Triangle**, the electrical **circuit model** for the electrocardiographic problem, etc.)

♥ **Standard Limb Leads (I, II, III)**



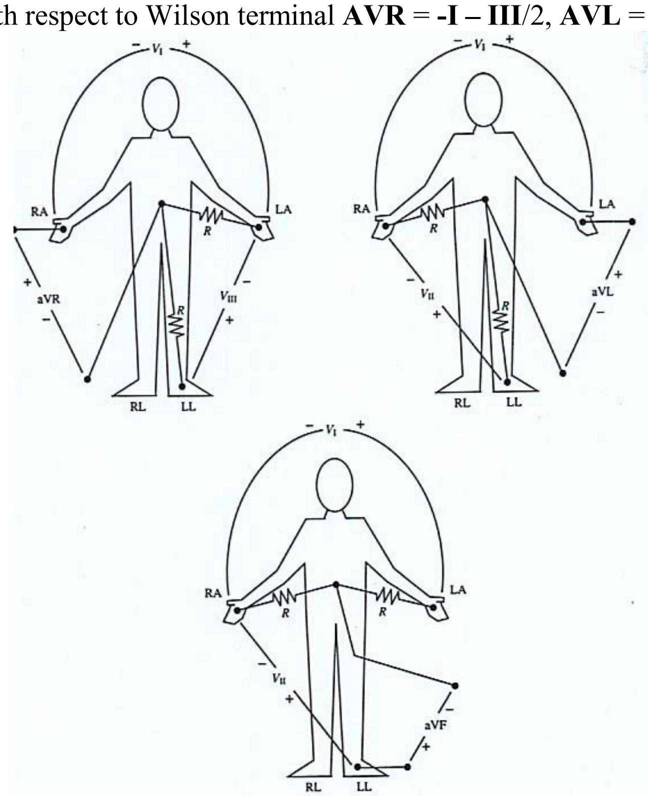
♥ The

The lead wires are color-coded according to some conventions. One example is: White –**RA** (Right Arm), Black – **LA (**Left Arm**)**, Green – **RL (**Right Leg**)**, Red – **LL (**Left Leg**)**, and Brown – **C** (Chest)

Note: There is a **CM** (common mode) amplifier connected to the right leg. We will discuss this in detail later.

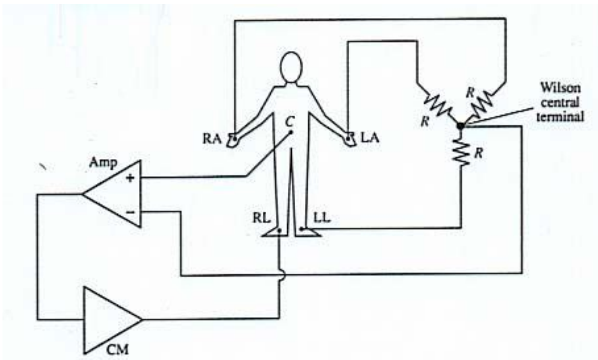
Augmented Limb Leads

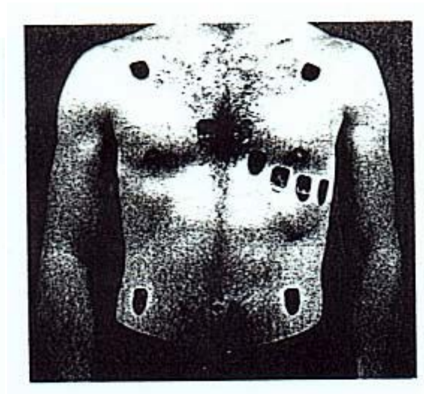
These leads offer a free 50% increase over leads **VR, VL**, and **VF** connections (unipolar leads) with respect to Wilson terminal **AVR** = **-I – III**/2, **AVL** = **I – II**/2, **aVF** = **II – I**/2



Each measurement is made from the reflected limb and the average of the other two limbs.

Chest Leads (Precordial)

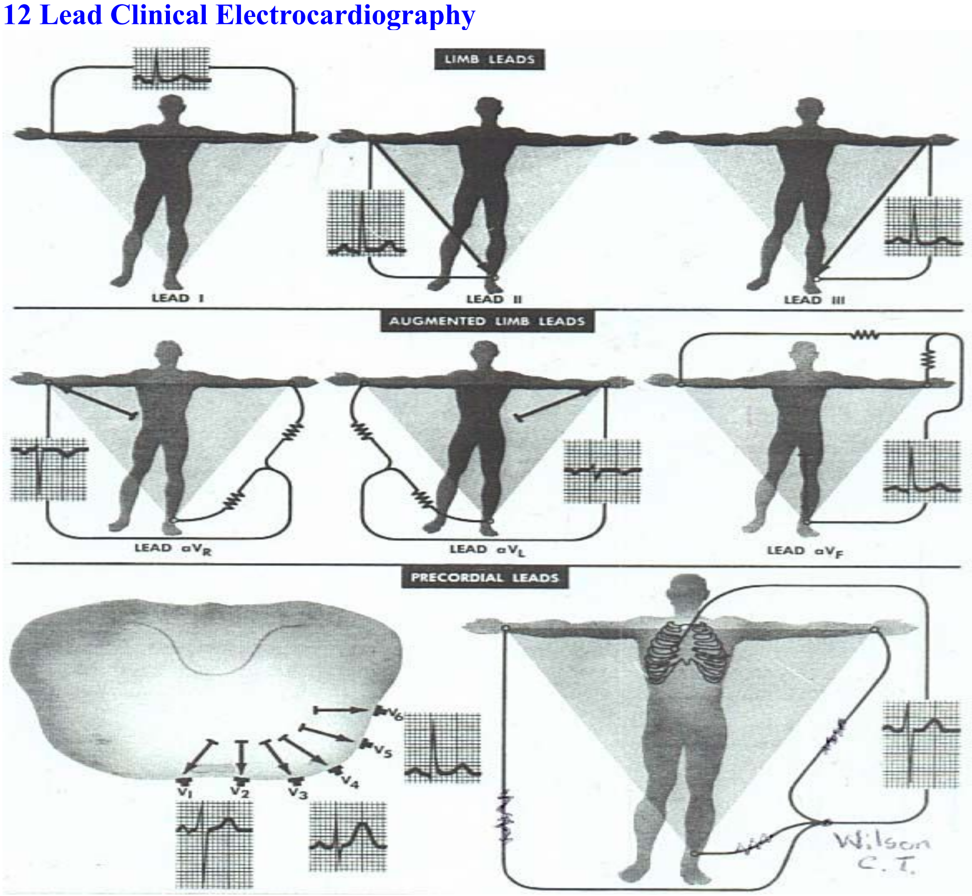




Chest Lead Anatomical Positions

V1 - 4th intercostal space – Right sternal margin
V2 - 4th intercostal space – Left sternal margin
V3 – Midway between V2 & V4
V4 – 5th intercostal space on mid-clavicular line
V5 – Same as V4, on the anterior axillary line
V6 – Same as V5, on the mid-axillary line

12 Lead Clinical Electrocardiography



The ECG Machine

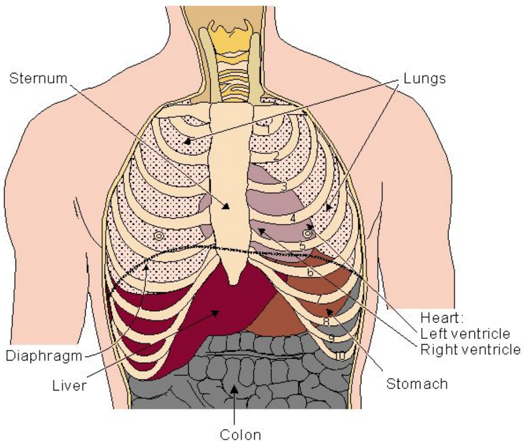
Most representative Specs:

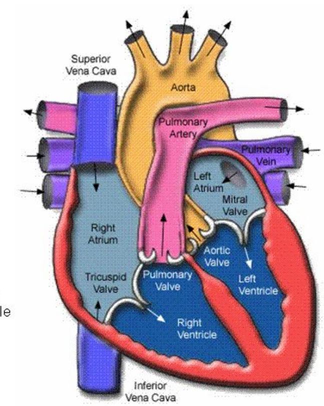
• Zin = 10 MΩ
• Frequency response = 0.05 –100 Hz
• Strip Chart Recorder Speed = 25 mm/sec.
• Fast Speed = 100 mm/sec.

For detailed Specs. Refer to the Table in your text "Summary of performance requirements for electrocardiographs"

Location of the Heart

- The heart is located between the lungs behind the sternum and above the diaphragm.
- It is surrounded by the pericardium.
- Its size is about that of a fist, and its weight is about 250-300 g.
- Its center is located about 1.5 cm to the left of the midsagittal plane.





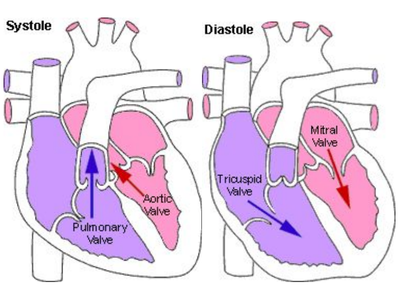
Anatomy of the heart

- The walls of the heart are composed of cardiac muscle, called *myocardium*.

- It consists of four compartments:
  - the right and left atria and ventricles

The Heart Valves

- The tricuspid valve regulates blood flow between the right atrium and right ventricle.
- The pulmonary valve controls blood flow from the right ventricle into the pulmonary arteries
- The mitral valve lets oxygen-rich blood from your lungs pass from the left atrium into the left ventricle.
- The aortic valve lets oxygen-rich blood pass from the left ventricle into the aorta, then to the body



Blood circulation via heart

- The blood returns from the systemic circulation to the right atrium and from there goes through the tricuspid valve to the right ventricle.

- It is ejected from the right ventricle through the pulmonary valve to the lungs.

- Oxygenated blood returns from the lungs to the left atrium, and from there through the mitral valve to the left ventricle.

- Finally blood is pumped through the aortic valve to the aorta and the systemic circulation..

Electrical activation of the heart

- In the heart muscle cell, or *myocyte*, electric activation takes place by means of the same mechanism as in the nerve cell, i.e., from the inflow of Na ions across the cell membrane.
- The amplitude of the action potential is also similar, being 100 mV for both nerve and muscle
- The duration of the cardiac impulse is, however, two orders of magnitude longer than in either nerve cell or sceletal muscle cell.
- As in the nerve cell, repolarization is a consequence of the outflow of K ions.
- The duration of the action impulse is about 300 ms

Mechanical contraction of Cardiac Muscle

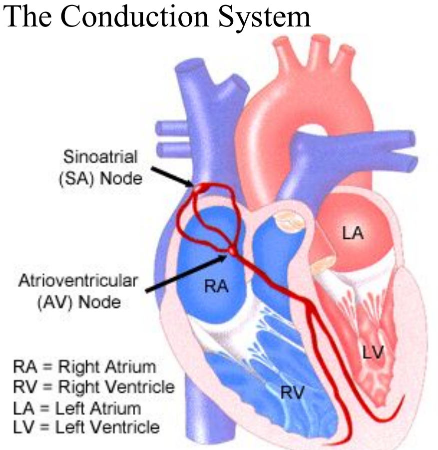
- Associated with the electric activation of cardiac muscle cell is its mechanical contraction, which occurs a little later.

- An important distinction between cardiac muscle tissue and skeletal muscle is that in cardiac muscle, activation can propagate from one cell to another

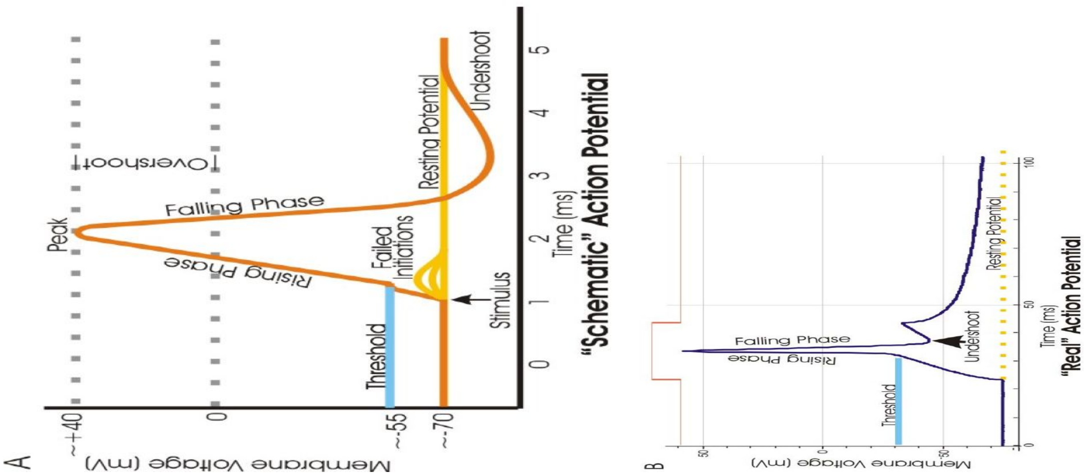
in any direction.

- Electrical signal begins in the sinoatrial (SA) node: "natural pacemaker." causes the atria to contract.
- The signal then passes through the atrioventricular (AV) node.
  - sends the signal to the ventricles via the “bundle of His”
  - causes the ventricles to contract.

The Conduction System



The Action Potential



Recording an AP requires the isolation of a single cell.

Microelectrodes (with tips a few µm across) are used to stimulate and record the response. A typical AP is 2-4ms long with an amplitude of about 100Mv

The Electroencephalogram EEG

EEG is the graphical representation of the electrical activity of the brain

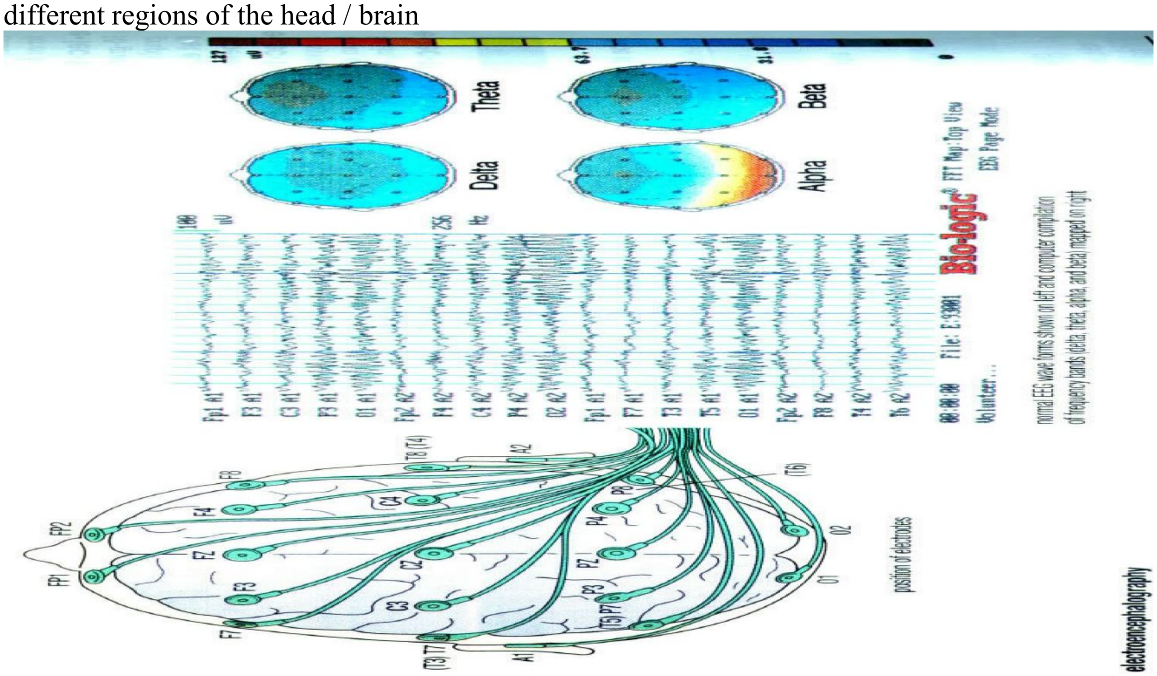
Very commonly used to diagnose certain neurological disorders, such as epilepsy

More recently, also investigated whether it can detect various forms of dementia or schizophrenia

EEG is the specific recording obtained using the scalp electrodes from the surface of the skull

During surgery, electrodes may also be placed directly on the cortex. The resulting signal is then **electrocorticogram** (ECoG).

Just like ECG, EEG is also obtained using several different electrodes places on different regions of the head / brain



The Event Related

Potentials – ERPs

ERPs are really EEGs obtained under a specific protocol that requires the patient to response to certain stimuli – hence event related potentials.

Also called **evoked potentials** these signals can be used to diagnose certain neurological disorders such as dementia, and they can also be used as a liedetector

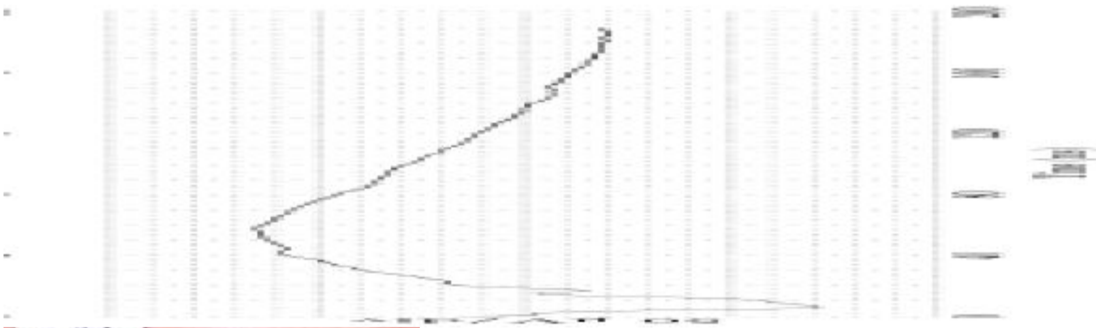
- ***The oddball paradigm***
- ***The guilty knowledge test***

Electroretinogram ERG

The ERG is the record of the retinal action currents produced by the retina in response to a light stimulus.

It measures the electrical responses of the light-sensitive cells (such as rods and cones). The stimuli are often a series of light flashes or rotating patterns

The ERG is recorded using contact lens electrode that the subject wears while watching the stimuli.



Phonocardiogram – PCG

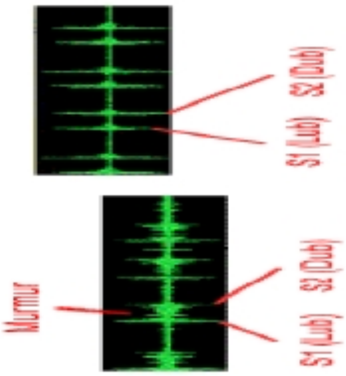
The PCG is the graphic record of the heart sounds and murmurs. It is thus a mechanical / audio signal, rather than an electrical signal

Can be easily heard using a stethoscope

Or can be converted into an electrical signal using a transducer

Typically used to determine the disorders related to the heart valve, since their routine opening and closing create the well-known sounds.

- S1 sounds: First heart sounds – ventricular contractions move blood into atria closing of the AV (mitral and tricuspid) valves, then semilunar valves open and blood ejected out of ventricles – immediately follows the QRS complex
- S2 sounds: Second heart sounds – Closure of semilunar (aortic and pulmonary) valves
- Any unexpected sound may indicate a malfunctioning valve that causes the blood flow into / out of a chamber when it should not. Also called heart murmurs.



Define ultrasound

- Mechanical waves in different modalities (longitudinal/lateral) → needs medium to be propagated (solid, liquid, gas)
- > 20 kHz
- Continuous/pulsed
- Spherical/planar/narrow beam/surface wave/Lamb-wave

Physical phenomena behind ultrasound measurements

Transmission
-
- reflection
- transit time
- differences in propagation velocities
  - returns to transit time
- doppler-shift in frequency
  - flow velocity
- change of acoustic impedance
  - comparing to reference
- interference of ultrasound waves (holography)
- interaction of ultrasound and light (photoacousticz)
- ultrasound needs medium for propagation → it doesn't propagate in vacuum
- because mechanical waves need moving massunits and spring forces between them
- in acoustic emission the medium creates ultrasound (for example, during pressure changes), which is received by sensors
- pulsed mode more common than continuous
- continuous reguires separate transducers for transmitting and receicving
- in pulsed mode an ultrasound burst is sent to the object and the same transducer is switched to listen echoes
- standing wave problem
- in us-therapy pulsed mode gives more effective care without too much heating

The Doppler Equation describes the relationship of the Doppler frequency shift to target velocity.

The frequency difference is equal to the reflected frequency (FR) minus the originating frequency (FT). If the resulting frequency is higher, then there is a positive Doppler shift and the object is moving toward the transducer, but if the resulting frequency is lower, there is a negative Doppler shift and it is moving away from the transducer. In its simplest form it would be calculated as if the ultrasound was parallel to the target's direction, as shown in diagram **A** below.

However, this would be a rare occurrence in clinical practice, because the transducer is rarely pointed head on to a blood vessel. In real life, the ultrasound waves would approach the target at an angle, called the Doppler angle ( ). On the following page, diagram **B** shows the Doppler equation used in general clinical situations, which includes the Doppler angle.

The Doppler Angle

The ultrasound beam usually approaches the moving target at an angle called the ***Doppler angle*** **( )**. This reduces the frequency shift in proportion to the cosine of this angle. If this angle is known then the flow velocity can be calculated. The equation used is:

The Doppler Equation

≡ Doppler shift frequency (the difference between the transmitted and received frequencies)

≡ transmitted frequency

≡ reflected frequency

V ≡ velocity of the blood flow towards the transducer

C ≡ velocity of sound in tissue

θ ≡ the angle between the sound beam and the direction of moving blood

Where:

The Doppler angle ( ) is also known as the angle of insonation. It is estimated by the sonographer by a process known as angle correction, which involves aligning an indicator on the duplex image along the longitudinal axis of the vessel.

There are a few considerations that affect the performance of a Doppler examination that are inherent in the Doppler equation, which are:

– The cosine of 90° is zero, so if the ultrasound beam is perpendicular to the direction of blood flow, there will be no Doppler shift and it will appear as if there is no flow in the vessel.

– Appropriate estimation of the angle of insonation, or angle correction, is essential for the accurate determination of Doppler shift and blood flow velocity. The angle of insonation should also be less than 60° at all times, since the cosine function has a steeper curve above this angle, and errors in angle correction will be magnified.

The simplest Doppler devices use continuous wave (CW Doppler), rather than the pulsed wave used in more complex devices. CW Doppler uses two transducers (or a dual element transducer) that transmit and receive ultrasound continuously. The transmit and receive beams overlap in a Doppler sample volume some distance from the transducer face, as shown in the diagram below.

volume) is the region of transmitting and receiving beam overlap (shaded region). Because there is continuous transducer transmission and reception, echoes from all depths within the area arrive at the transducer simultaneously.

So although CW Doppler can determine the direction of flow, it cannot discriminate the different depths where the motion originates. The usefulness of CW Doppler devices is limited, but they are used clinically to confirm blood flow in superficial vessels, as they are good at detecting low velocities. As they are easily portable, this can be done at the bedside or in the operating room. Most other clinical applications require pulsed wave Doppler.

Pulsed Wave Doppler (PW Doppler)

Pulsed wave Doppler (PW Doppler) uses a single-element transducer that emits brief pulses of ultrasound energy. The time interval between transmitting and then receiving the echoing sound can be used to calculate the depth from where the echo arises.
The Doppler sample volume can be chosen as to shape, depth, and position in sampling the flow data. For example, the depth is chosen by processing only the signals that return to the transducer in a stipulated time. For this technique, the ultrasound system transmits a short pulse. The eceiver is opened to detect the returning echoes only after a controlled delay, and only for a specific duration. This time-based gating of the receiving channel allows the definition of a fixed easuring distance which is often referred to as the Sample volume or Doppler gate.
Then the next ultrasound wave is transmitted. The number of pulses transmitted by the system within a second is referred to as the pulse repetition frequency (PRF). The upper PRF limit is given by the time interval required for the echoes to arrive from a sample volume located at a certain depth. The greater the sample-volume depth, the longer the time before the echoes are returned, and the longer the delay between pulse transmission. The greater the samplevolume depth, the lower will be the maximum PRF setting. Errors in the accuracy of the information arise if the velocities exceed a certain speed. The highest velocity accurately measured is called the Nyquist limit. Beyond this limit, the errors that occur are referred to as *aliasing*.

Volume and flow measurement

- Flow – volume of a liquid/gas passing some point over a given time
- Gases are compressible

Benedict Roth Spirometer

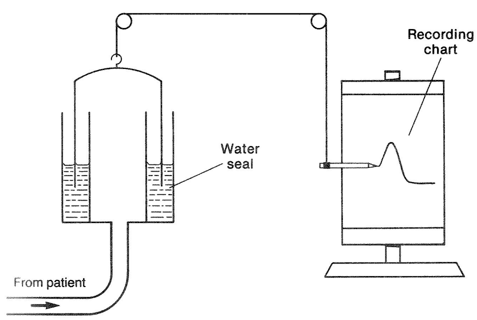
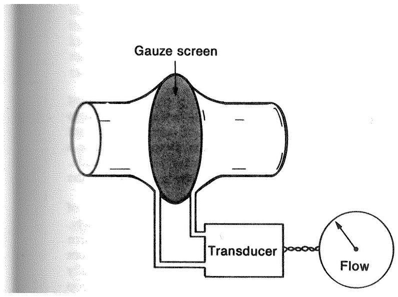


Figure 3.1 Benedict Roth spirometer.

- Widely used for physiological & clinical studies
- Light bell moves with the pt's breathing
- Movement recorded by a pen on a rotating drum
- Water seal prevents leakage of gas
- Small seal minimises volume of gas dissolved in water
- Suitable for measuring limited gas vols (few litres)

Pneumotachograph



Cardiac Output

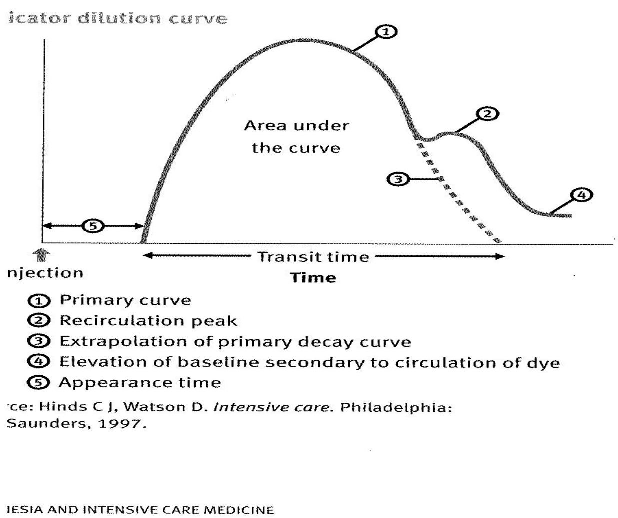
- Defn: vol of blood pumped by the heart per min
- CO = SV x HR
- Norm ~ 5 l/min
- Cardiac index – corrected for body surface area
- Affected by :
  - Met. Rate – pregnancy, hyperthyroid, septic
  - Preload / contractility / afterload
- Clinical indicators of CO imprecise
- Affected by anaesthetic agents used in everyday practice
- Provides estimate of:
  - whole body perfusion
  - oxygen delivery
  - left ventricular function
- Persistently low CO assoc. with poor outcome
- Methods:
  - Fick method
  - Dilution techniques – dye / thermal / lithium
  - Pulse contour analysis- LiDCO & PiCCO
  - Oesophageal doppler
  - TOE
  - Transthoracic impedance plethysmography
  - Inert gas through flow
  - Non-invasive cardiac output measurement
- Fick Principle: measure volume displacement

  - 1st proposed 1870
  - "the total uptake or release of a substance by an organ is the product of the blood flow through that organ and the arteriovenous concentration difference of the substance"
  - CO = O2 consumption (ml/min) art – mixed venous O2 conc. (ml/l)
  - Limited by cumbersome equipment, sampling errors, need for invasive monitoring and steady-state haemodynamic and metabolic conditions
- Indicator dilution techniques

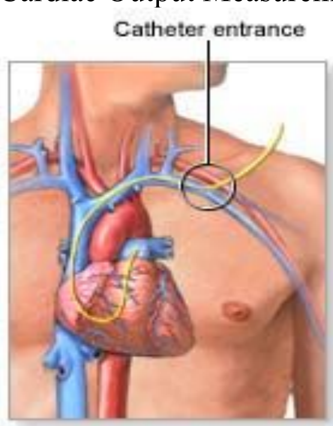
"An indicator mixed into a unit volume of constantly flowing blood can be used to identify that volume of blood in time, provided the indicator remains in the system between injection and measurement and mixes completely in the blood"

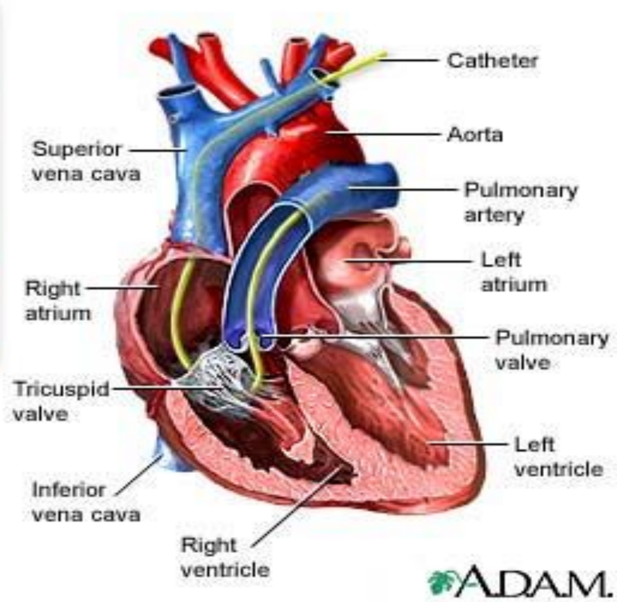
- Dye dilution
  - Inert dye – indocyanin green
  - Injected into pulmonary artery and arterial conc. measured using a calibrated cuvette densitometer
  - Plot indicator dilution curve (see diagram)
  - CO derived from area under curve

Indicator Dilution Curve



Cardiac Output Measurement





Blood Pressure

Why bother to check blood pressure?

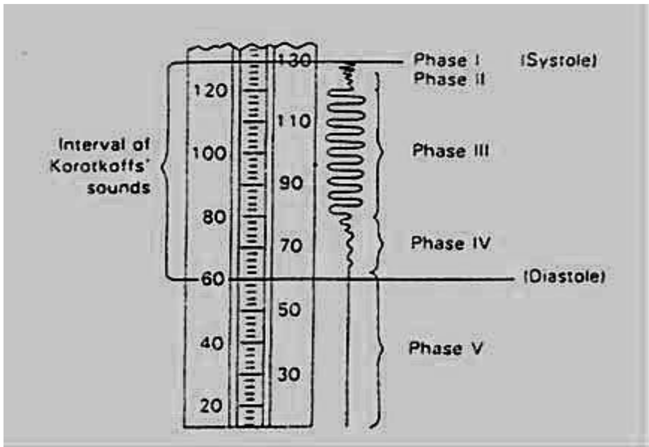
- For each 20 mm rise in systolic blood pressure or 10 mm rise in diastolic blood pressure over 115/75:
  - Risk of stroke increases
  - Risk of heart disease doubles
  - Risk of renal failure increases

Systolic and diastolic blood pressure :

- Systolic blood pressure is the highest pressure in the arteries, just after the heart beats
- Diastolic blood pressure is the lowest pressure in the arteries, just before the heart beats
- Blood pressure is measured indirectly by blood pressure cuff (sphygmomanometer)

HOW A CUFF MEASURES BLOOD PRESSURE

- Inflating cuff increases pressure until it cuts off arterial circulation to the arm
- Deflating cuff, decrease pressure by 2 to 3 mm of mercury per second until blood first enters the artery, creating turbulence; this causes a sound with each heartbeat
- Sounds continue with each heartbeat until pressure lowers to the lowest pressure in the artery; then turbulence stops, so the sound stops
- Systolic blood pressure is the cuff pressure at the first sounds; diastolic is the cuff pressure just before the sounds stop
- Phase 1: sharp thuds, start at systolic blood pressure
- Phase 2: blowing sound; may disappear entirely (the auscultatory gap)
- Phase 3: crisp thud, a bit quieter than phase 1
- Phase 4: sounds become muffled
- Phase 5: end of sounds -- ends at diastolic blood pressure



HOW TO MEASURE BLOOD PRESSURE

- Make sure the cuff is the right size - its width should be at least 40% of the arm's circumference. The cuff will overestimate blood pressure if too small and underestimate if too large.
- Place the cuff snugly on patient's proximal arm, on skin (not cloth), centered over the brachial artery (most cuffs have markings)
- Support the patient's arm at heart level, using your arm or a desk
- Your patient should sit in the chair for 5 minutes before BP is measured, and should have no caffeine or nicotine for 30 minutes before (JAMA 273, p.1211-1218, 1995)
- With fingers palpating radial or brachial artery, inflate cuff rapidly until you can't feel the pulse, then 20 mm higher
- Release cuff at 2 to 3 mm Hg per second until you again feel the pulse; this is the palpable systolic pressure
- Wait 30 seconds before measuring blood pressure
- Measuring palpable pressure first avoids risk of seriously underestimating blood pressure because of the auscultatory gap (mistaking Korotkoff phase 3 for phase 1). Many doctors skip this step for time reasons and instead pump cuff to 200 mm Hg at the next step)
- Phase 2 of the Korotkoff sounds can be inaudible - especially in older patients with systolic hypertension, who are at especially high risk of stroke. Inflating the cuff until you don't hear sounds can give you a reading of 140/86 when the patient's actual blood pressure is 220/86. Most physicians are pressed for time, so they instead inflate the cuff to 200 mm, which is beyond the auscultatory gap in most patients. But palpable systolic blood pressure is, according to research, more reliable.
- Place bell of stethoscope (diaphragm is acceptable) over brachial artery
- Rapidly pump the cuff to 20 to 30 mm Hg above palpable systolic pressure
- Release pressure in the cuff by 2 to 3 mm Hg per second and listen for Korotkoff sounds, including systolic (first) and diastolic (last)
- Record as systolic/diastolic. Check in both arms the first time you check a patient's blood pressure. It may differ by 10 mm Hg or more.

- If the sounds continues to zero, record diastolic blood pressure as the point when sounds become muffled (phase 4) over zero: e.g. 130/70/0, or just as 130/70.

Pulse

- Rate
  - Number of beats in 30 seconds x 2
- Strength
  - Bounding, strong, or weak (thready)
- Regularity
  - Regular or irregular
- You need three readings on two occasions to diagnose hypertension, unless blood pressure is very high
- Normal blood pressure in children is:
  - 102/55 at 1 year, 112/69 at 5 years, 119/78 at 10 years
- Blood pressures in adults (JNC VII: JAMA 289:2560-72, 2003):
  - Normal: <120/<80
  - Prehypertensive: 120-139/80-89
  - Stage 1 hypertension: 140-159/90-99
  - Stage 2 hypertension: >160/>100
- Adult: 60 to 100
- Newborn: 120-170
- 1 year: 80-160
- 3 years: 80-120
- 6 years: 75-115
- 10 years: 70-110

RESPIRATION

- **How to measure:** observe rise and fall of chest
- In infants, count for 60 seconds; in adults, 15 or 30 seconds
- **Normal respiration:**
- Adults: 12 to 20
- Children:
  - newborn 30-80
  - 1 year 20-40
  - 3 years 20-30
  - 6 years 16-22
- Rate
  - Number of breaths in 30 seconds x 2
- Quality
  - Character of breathing
- Rhythm
  - Regular or irregular
- Effort
  - Normal or labored

} Noisy respiration

} Normal, stridor, wheezing, snoring, gurgling

} Depth

} Shallow or deep

pH electrode

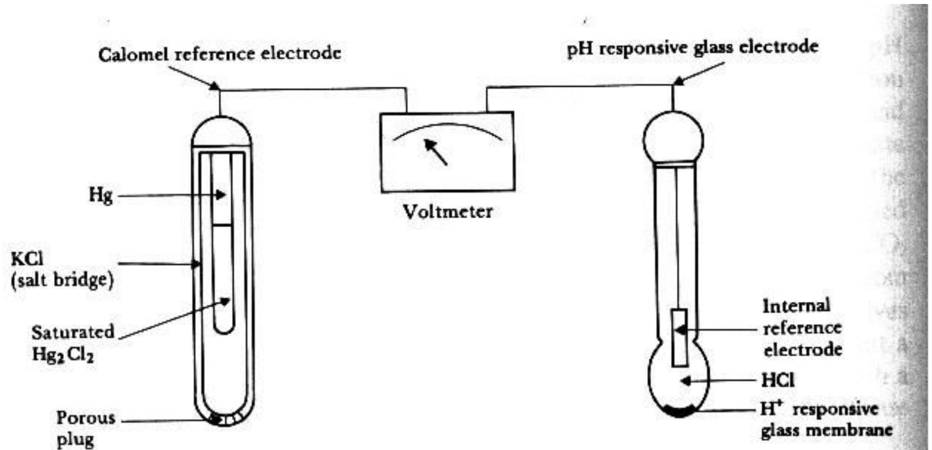


Figure 10.2 pH electrode (From R. Hicks, J. R. Schenken, and M. A. Steinrauf, *Laboratory Instrumentation.* Hagerstown, MD: Harper & Row, 1974. Used with permission of C. A. McWhorter.)

Governing equation is the Nernst Equation

$$E_H = \frac{RT}{nF} \ln\left(\frac{[H]_0}{[H]_i}\right)$$

pCO2 Electrode

The measurement of pCO2 is based on its linear relationship with pH over the range of 10 to 90 mm Hg.

$$H_2O + CO_2 \Leftrightarrow H_2CO_3 \Leftrightarrow H^+ + HCO_3^-$$

The dissociation constant is given by $$k = \frac{[H^+][HCO_3^-]}{a \cdot pCO_2}$$

Taking logarithms

pH = log[HCO3-] – log k – log a – log pCO2

Diathermy

In the [natural sciences](), the term** diathermy **means "electrically induced heat" and is commonly used for muscle relaxation. It is also a method of heating tissue electromagnetically or ultrasonically for therapeutic purposes in medicine.Contents

[hide]

Heating uses

Ultrasonic diathermy refers to heating of tissues by ultrasound for the purpose of therapeutic deep heating. No tissue is ordinarily damaged hence it is generally used in biomedical applications.

Electric diathermy uses high frequency alternating electric or magnetic fields, sometimes with no electrode or device contact to the skin, to induce gentle deep tissue heating by induction. Again, no tissue is ordinarily damaged.

Surgical uses

Surgical diathermy is usually better known as "electrosurgery." (It is also referred to occasionally as "electrocautery", but see disambiguation below). Electrosurgery and surgical diathermy involve the use of high frequency A.C. electrical current in surgery as either a cutting modality, or else to cauterize small blood vessels to stop bleeding. This technique induces localized tissue burning and damage, the zone of which is controlled by the frequency and power of the device. Some sources[1] insist that electrosurgery be applied to surgery accomplished by high frequency A.C. cutting, and that "electrocautery" be used only for the practice of cauterization with heated nichrome wires powered by D.C. current, as in the handheld battery-operated portable cautery tools.

Trivia

Medical Diathermy devices were used to cause interference to German radio beams used for targeting night time bombing raids in WWII during the Battle of the Beams.

I. Diathermy
   A. Therapeutic use
      1. Generation of local heating by high-frequency electromagnetic waves
      2. Capacitance technique—body is placed in an electric field
         a. Dipoles—structures with positive and negative poles
         b. Structures with large numbers of dipoles have a greater capacitance to store an electrical charge
         c. Greatest heating occurs in tissues with fewer dipoles, particularly fatty tissues
      3. Rapid rotation of dipoles causing mechanical friction and movement of electrons results in local heating
      4. Inductance technique—body is not placed in an electric field

a. Magnetic waves generated by driving current through a coiled wire

b. Magnetic field creates currents in tissues

c. Greatest heating occurs in tissues with low impedance, especially muscle

B. Precautions and contraindications

1. Diathermy should not be used:

a. Over metal implants and cardiac pacemakers—more research needed regarding its use over metallic fixations

b. Near the uterus of a pregnant woman or near the abdomen or back of a woman who might be pregnant

c. On individuals with infections

d. On individuals with acute inflammation

e. Over moist, open wounds

f. On patients with malignant tumors

g. Over large joint effusions

C. Pulsed electromagnetic fields and diathermy

1. Can be pulsed to decrease total energy transmitted to the tissues

2. Short-wave diathermy can be adjusted into a nonthermal range

a. Classified as pulsed electromagnetic field (PEMF) or

b. Pulsed radio frequency energy (PRFE)

3. Important reclassification as diathermy implies heating

D. Efficiency of diathermy and PEMF therapy for musculoskeletal conditions

1. Current research is limited, but results suggest that diathermy enhances treatments directed at soft tissue stretching

2. Some studies suggest that PEMF may speed wound healing and promote healing of nonunion fractures

Diathermy is a modality that uses electromagnetic energy to heat deeper tissues.

Diathermy is more effective than ultrasound at heating a larger area of deep tissues.

The athletic trainer must identify and respect contraindications to application of ultrasound and diathermy.

Pulsed ultrasound and diathermy are used to treat slow-to-heal lesions, including skin ulcers and nonunion fractures, and may be able to facilitate repair of other tissues, including ligaments and tendons.

Diathermy
Definition

In diathermy, high-frequency electrical currents are used to heat deep muscular tissues. The heat increases blood flow, speeding up recovery. Doctors also use diathermy in surgical procedures by sealing blood vessels with electrically heated probes.

The term diathermy is derived from the Greek words *therma,* meaning heat, and *dia,* meaning through. Diathermy literally means heating through.

Origins

The therapeutic effects of heat have long been recognized. More than 2,000 years ago, the Romans took advantage of heat therapies by building hot-spring bathhouses. Since then, various methods of using heat have evolved. In the early 1890s, French physiologist Arséne d'Arsonval began studying the medical application of high-frequency currents. The term diathermy was coined by German physician Carl Franz Nagelschmidt, who designed a prototype apparatus in 1906. Around 1925, United States doctor J. W. Schereschewsky began studying the physiological effects of high-frequency electrical currents on animals. It was several years, however, before the fundamentals of the therapy were understood and put into practice.

Benefits

Diathermy can be used to treat arthritis, **bursitis**, and other conditions involving stiff, painful joints. It is also used to treat pelvic **infections** and sinusitis. A benefit of diathermy is that it is a painless procedure that can be administered at a clinic. Also, if the treatment relieves **pain**, then patients can discontinue pain killers and escape their high cost and side effects.

Description

Diathermy involves heating deep muscular tissues. When heat is applied to the painful area, cellular metabolism speeds up and blood flow increases. The increased metabolism and circulation accelerates tissue repair. The heat helps the tissues relax and stretch, thus alleviating stiffness. Heat also reduces nerve fiber sensitivity, increasing the patient's pain threshold.

There are three methods of diathermy. In each, energy is delivered to the deep tissues, where it is converted to heat. The three methods are:

- Shortwave diathermy. The body part to be treated is placed between two capacitor plates. Heat is generated as the high-frequency waves travel through the body tissues between the plates. Shortwave diathermy is most often used to treat areas like the hip, which is covered with a dense tissue mass. It is also used to treat pelvic infections and sinusitis. The treatment reduces inflammation. The Federal Communications Commission regulates the frequency allowed for short-wave diathermy treatment. Most machines function at 27.33 megahertz.
- Ultrasound diathermy. In this method, high-frequency acoustic vibrations are used to generate heat in deep tissue.
- Microwave diathermy. This method uses radar waves to heat tissue. This form is the easiest to use, but the microwaves cannot penetrate deep muscles.

Diathermy is also used in surgical procedures. Many doctors use electrically heated probes to seal blood vessels to prevent excessive bleeding. This is particularly helpful in neurosurgery and eye surgery. Doctors can also use diathermy to kill abnormal growths, such as tumors, **warts**, and infected tissues.

Preparations

To keep patients from sweating, patients are usually asked to remove clothing from the body part being treated. If a patient sweats, the electrical currents may pool in the area, causing **burns**. Also, clothing containing metal must be removed, as must earrings, buttons, barrettes, or zippers that contain metal. Watches and hearing aids should be removed because the therapy may affect their function.

Practitioners of surgical diathermy should steer clear of alcohol-based solutions to prepare and cleanse the skin. These preparations can create a flammable vapor and cause burns and fires.

Precautions

Patients with metal implants should not undergo diathermy treatment because the metal can act as a conductor of heat and result in serious internal burns. Female patients with metallic uterine implants, such as an IUD, should avoid treatment in the pelvic area. Diathermy should not be used in joints that have been replaced with a prosthesis or in those with sensory impairment who may not be able to tell if they are burning. Furthermore, pulsed shortwave diathermy should be avoided during **pregnancy**, as it can lead to abnormal fetal development.

Patients with hemophilia should avoid the treatment because the increased blood flow could cause them to hemorrhage.

Side effects

Some patients may experience superficial burns. Since the therapy involves creating heat, care must be taken to avoid burns, particularly in patients whose injuries have caused decreased sensitivity to heat. Also, diathermy may affect pacemaker function.

Female patients who receive treatment in the lower back or pelvic area may experience an increased menstrual flow.

Research & general acceptance

For years, physiotherapists and physical therapists have used diathermy as a routine part of physical rehabilitation.

Electrical Safety

Electrical safety is very important in hospitals as patients may be undergoing a diagnostic or treatment procedure where the protective effect of dry skin is reduced. Also patients may be unattended, unconscious or anaesthetised and may not respond normally to an electric current. Further, electrically conductive solutions, such as blood and saline, are often present in patient treatment areas and may drip or spill on electrical equipment.

- Electric Current
- Leakage Current
- Extension Leads
- Double Adaptors
- Equipment Classification
  - Class I
  - Class II
  - Defibrillator-Proof
- Protective Devices

Electric Current

Injuries received from electric current are dependent on the magnitude of current, the pathway that it takes through the body and the time for which it flows.

The nature of electricity flowing through a circuit is analogous to blood flowing through the circulatory system within the human body. In this analogy the source of energy is represented by the heart, and the blood flowing through arteries and veins is analagous to current flowing through the conductors and other components of the electric circuit.

The application of an electric potential to an electric circuit generates a flow of current through conductive pathways. This is analogous to the changes in blood pressure caused by contraction of cardiac muscle that causes blood to flow into the circulatory system. For electric current to flow there must be a continuous pathway from the source of potential through electrical components and back to the source.

Leakage Current

Electrical components and systems are encased in non conducting insulation, to ensure that the electric current is contained and follows the intended pathways. If the insulation deteriorates or breaks down, current will leak through the insulation barrier and flow to earth. This may be through the protective earth conductor or through the operator.

Medical equipment and clinical areas are fitted with a number of protective devices to protect the patient and operator from harmful leakage currents.

Extension Leads

Extension leads are not permitted in clinical areas of RCH organisations. They may cause high earth resistance and excessive earth leakage current. An extension lead can allow equipment to be powered from areas other than the relevant protected treatment area. The power from the other area may not be protected to the same level as the power in the treatment area.

As the connection between the extension lead and the equipment mains cable is often on the floor there is a high danger from fluid spills, tripping and damage to the mains cable by trolleys when an extension lead is used.

Double Adaptors

Double adaptors must not be used in RCH organisations. They may not sit securely in a wall outlet, may not be able to provide adequate earth protection and may cause overloading, overheating, fire or loss of electrical supply.

EQUIPMENT CLASSIFICATIONS

There are several methods of providing protection for operators and patients from electrical faults and harmful leakage current.

Class I

Class I equipment is fitted with a three core mains cable containing a protective earth wire. Exposed metal parts on class I equipment are connected to this earth wire.

Should a fault develop inside the equipment and the exposed metal comes into contact with the mains, the earthing conductor will conduct the fault current to ground. Regular testing procedures ensure that earthing conductors are intact, as the integrity of the earth wire is of vital importance.

Class II

Class II equipment is enclosed within a double insulated case and does not require earthing conductors. Class II equipment is usually fitted with a 2-pin mains plug. An internal electrical fault is unlikely to be hazardous as the double insulation prevents any external parts from becoming alive. Class II or double insulated equipment can be identified by the class II symbol on the cabinet.

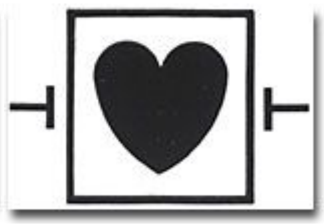
Class II Symbol:

Defibrillator-Proof

Some medical equipment within the hospital is classified as defibrillator proof. When a defibrillator is discharged through a patient connected to defibrillator proof equipment, the equipment will not be damaged by the defibrillator's energy. Defibrillator proof equipment can remain connected to the patient during defibrillation. It is identified by one of the following symbols.

Defibrillator proof symbols.

Body protected Cardiac protected

PROTECTIVE DEVICES

Most patient care areas in the hospital are fitted with protective devices. These devices are regularly tested, in accordance with the relevant guidelines published by Standards Australia. The level of protection provided is dependent upon the device and the area in which it is located.

Residual Current Devices (RCD)

RCD's (safety switches) are used in patient treatment areas to monitor and protect the mains supply. RCD's sense leakage currents flowing to earth from the equipment. If a significant leakage current flows, the RCD will detect it and shut off the power supplied to the equipment within 40 milliseconds. Hospital RCD's are more sensitive than those fitted in homes. A hospital RCD will trip at 10 milliamperes leakage current.

Power outlets supplied through an RCD have a 'Supply Available' lamp. The lamp will extinguish when the RCD trips due to excessive leakage current.

Resetting a RCD

- Lamp indicates supply is no longer available
- Disconnect all equipment from the supply
- Operate the reset button or lever on the supply panel and the 'Supply Available' lamp should illuminate. If not, contact Biomedical Engineering.
- Connect an item of equipment. If the RCD trips again, then this is the faulty item and should be labelled and sent to Biomedical Engineering.
- If the RCD does not trip, continue connecting equipment until the RCD trips. The last piece of equipment connected to the supply is most likely to be faulty as it will have caused the RCD to trip. Remove the faulty item from service, label it and send to Biomedical Engineering as mentioned above.

Line Isolation overload Monitors (LIMs)

In critical life support applications where loss of power supply cannot be tolerated, special power outlets powered by isolation transformers are installed.

Line Isolation Monitors are installed to continually monitor electrical leakage in the power supply system. If an electrical fault develops in a medical device connected to an isolated power outlet, the LIM will detect the leakage current. The LIM will alarm and indicate the level of leakage current, but will not shut off the electric supply.

The faulty equipment can be identified by un plugging one item of equipment at a time from the supply until the alarm stops sounding. Equipment that is not faulty may be reconnected. Faulty equipment should be appropriately labelled and sent to Biomedical Engineering for repair.

The LIM also monitors how much power is being used by the equpiment connected to it. If too much power is being used, the LIM will alarm and indicate that there is an overload. The power used must be reduced immediately by moving some equipment to another circuit as soon as possible until the alarm stops sounding. Failure to reduce the load on the LIM will result in the circuit breaker tripping and loss of power to the circuit.

Equipotential Earthing

Equipotential earthing is installed in rooms classified as 'Cardiac Protected' electrical areas. Equipotential earthing in treatment areas used for cardiac procedures is intended to minimise any voltage differences between earthed parts of equipment and any other exposed metal in the room.

This reduces the possibility of leakage currents that can cause microelectrocution when the patient comes into contact with multiple items of equipment, or if the patient happens to come into contact with metal items in the room whilr they are connected to a medical device.

All conductive metal in an equipotential area is connected to a common equipotential earth point with special heavy duty cable.

AREA CLASSIFICATIONS

Body Protected Area

These areas are designed for procedures in which patients are connected to equipment that lowers the natural resistance of the skin. Applied parts such as electrode gels, conductive fluids entering the patient, metal needles and catheters provide an easy pathway for current to flow.
The main occurrence of injury from Body-Type procedures is from high current levels causing electric shock. A direct connection to the patient's heart is not present so the risk of 'Microelectrocution' - fibrillation from minute current levels - is reduced.
Residual Current Devices (RCD) or Isolation Transformers and Line Isolation Monitors (LIMís), are used in Body Protected areas to provide protection against electrocution from high leakage currents. Body-Protected Areas are identified with this sign.

Cardiac Protected Area

Where the procedure involves placing an electrical conductor within or near the heart, protection against fibrillation induced from small leakage currents is required. Electrical conductors used in these procedures include cardiac pacing electrodes, intracardiac ECG electrodes and intracardiac catheters.

Equipotential earthing in conjunction with RCD's or LIM's provides protection against microelectrocution in Cardiac-Type procedures.
Fault currents are reduced to magnitudes that are unlikely to induce fibrillation. Used in conjunction with RCD's or LIM's, the magnitude and duration of any fault currents sourced from equipment are limited.
Cardiac-Protected Areas are identified with this sign.

Other electrical issues

This policy aims to provide guidance to those who find that they need more electrical outlets than those available, or that the existing electrical outlets are inconveniently located.

As extension leads and multiple outlet power boards can introduce additional hazards into an area the following procedures should be observed.

Extension leads

Approved extension leads (AS 3760, 1996) may be used in some areas within the hospital but MUST NOT BE USED IN PATIENT AREAS. All electrical extension leads must be tagged with an Engineering Department maintenance tag, and require a yearly safety inspection and test, via the Engineering Department.

Double adapters

Double adapters may cause overloading or equipment earthing problems and are not to be used in WCH

Mains extension device

The only mains extension device that is to be used in "Patient care areas" is the 4-way or 8-way portable Core Balance Unit.

The Biomedical Engineering Department must approve all units prior to use. These units contain a safety switch and can detect excessive leakage current and disconnect the power in the event of a hazardous situation.

Care must be exercised in the use of a portable Core Balance Unit. It should be located off the floor and in a position that will protect it from physical abuse and possible entry of fluids. These devices are expensive and easily damaged. The device must be sent to Biomedical Engineering every 6 months for safety testing.

Power boards

Approved multiple-outlet power boards can be used across RCH but must not be used in patient care areas, except areas approved by the Biomedical Engineering Department.

The power boards must have overload protection, be fitted with internal safety shutters that protect unused outlets and be fitted with an on/off switch for each outlet.

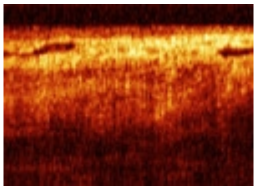
Medical Laser Applications

The main research subjects of the group of Medical Laser Application are in the field of online monitoring and diagnostics as well as the development of new therapheutic methods. The main focus in research is based upon the use of ultrashort (fs) laser pulses.

The main advantage of ultrashort laser pulses is the extrem short interaction time which suppress any unwanted side effects of the laser irradiation of the tissue. Secondly the broad spectra of the fs laser pulses give the advantage to use the same laser pulses for diagnostic applications like the optical coherence tomography (OCT).

Following research subjects have special attention at the moment:

Optical Coherence Tomographie (OCT)



A fs-laser light source can be used to obtain images from inside the tissue when the pulses are coherent superposed. This group uses this application to obtain an inside view of the vocal fold and to measure the outline of the crystalline lens.

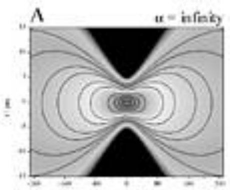
Refractive Surgery

The principle of getting rid of glasses with the help of a laser surgery (fs-LASIK), is underlying rapid improvements concerning precision and safety. New technologies were evaluated and transferred very fast in cooperation with an industrial partner.

Treatment of Presbyopia

The flexibility of the crystalline lens can be increase by pricise cuts which are induce by fs laser pulse inside the lens. The treatment of the presbyopia is thinkable.

Ultrafast Physics



Whereas the applications of ultrashort laser pulses increase rapidly is the physics of the interaction between the laser pulses and tissue in many case not fully understood. To obtain improved knowledge of the interaction for many fs-laser application this group preforms numerical simulations as well as fundamental experiments.

Thermography

Thermography, **thermal imaging**, or **thermal video**, is a type of infrared imaging. Thermographic cameras detect radiation in the infrared range of the electromagnetic spectrum (roughly 900–14,000 nanometers or 0.9–14 µm) and produce images of that radiation. Since infrared radiation is emitted by all objects based on their temperatures, according to the black body radiation law, thermography makes it possible to "see" one's environment with or without visible illumination. The amount of radiation emitted by an object increases with temperature, therefore thermography allows one to see variations in temperature (hence the name). When viewed by thermographic camera, warm objects stand out well against cooler backgrounds; humans and other warm-blooded animals become easily visible against the environment, day or night. As a result, thermography's extensive use can historically be ascribed to the military and security services.

Thermal imaging photography finds many other uses. For example, firefighters use it to see through smoke, find persons, and localize the base of a fire. With thermal imaging, power lines maintenance technicians locate overheating joints and parts, a telltale sign of their failure, to eliminate potential hazards. Where thermal insulation becomes faulty, building construction technicians can see heat leaks to improve the efficiencies of cooling or heating air-conditioning. Thermal imaging cameras are also installed in some luxury cars to aid the driver, the first being the 2000 Cadillac DeVille. Some physiological activities, particularly responses, in human beings and other warm-blooded animals can also be monitored with thermographic imaging. [1]

The appearance and operation of a modern thermographic camera is often similar to a camcorder. Enabling the user to see in the infrared spectrum is a function so useful that ability to record their output is often optional. A recording module is therefore not always built-in.

Instead of CCD sensors, most thermal imaging cameras use CMOS Focal Plane Array (FPA). The most common types are InSb, InGaAs, HgCdTe and QWIP FPA. The newest technologies are using low cost and uncooled microbolometers FPA sensors. Their resolution is considerably lower than of optical cameras, mostly 160x120 or 320x240 pixels, up to 640x512 for the most expensive models. Thermographic cameras are much more expensive than their visible-spectrum counterparts, and higher-end models are often export-restricted. Older bolometers or more sensitive models as InSb require cryogenic cooling, usually by a miniature Stirling cycle refrigerator or liquid nitrogen.

Contents

[hide]

[edit] Difference between IR film and thermography

Thermal imaging is going to be used on Mars to detect caves that could hold life.

[edit] Advantages of Thermography

- You get a visual picture so that you can compare temperatures over a large area
- It is real time capable of catching moving targets
- Able to find deteriorating components prior to failure
- Measurement in areas inaccessible or hazardous for other methods
- It is a non-destructive test method

[edit] Limitations & disadvantages of thermography

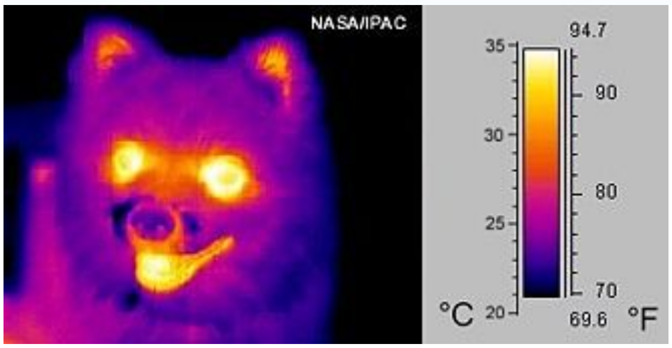
- Quality cameras are expensive and are easily damaged
- Images can be hard to interpret accurately even with experience
- Accurate temperature measurements are very hard to make because of emissivities
- Most cameras have ±2% or worse accuracy (not as accurate as contact)
- Training and staying proficient in IR scanning is time consuming
- Ability to only measure surface areas

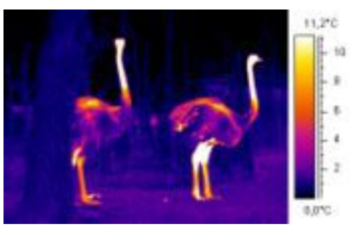
[edit] Applications

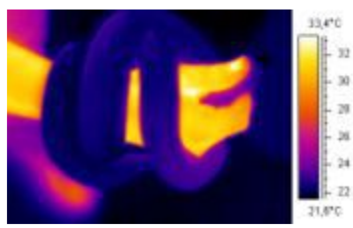
- Condition monitoring
- Medical imaging
- Night vision
- Research
- Process control
- Non destructive testing
- Surveillance in security, law enforcement and defense
- Chemical imaging

Thermal infrared imagers convert the energy in the infrared wavelength into a visible light video display. All objects above 0 kelvins emit thermal infrared energy so thermal imagers can passively see all objects regardless of ambient light. However, most thermal imagers only see objects warmer than -50 °C.

The spectrum and amount of thermal radiation depend strongly on an object's surface temperature. This makes it possible for a thermal camera to display an object's temperature. However, other factors also influence the radiation, which limits the accuracy of this technique. For example, the radiation depends not only on the temperature of the object, but is also a function of the emissivity of the object. Also, radiation also originates from the surroundings and is reflected in the object, and the radiation from the object and the reflected radiation will also be influenced by the absorption of the atmosphere







Endoscopy

This page is about having an endoscopy - a test that looks at the inside of your digestive system. There is information on

- What endoscopy is
- Why you may have an endoscopy
- Having an endoscopy
- Your results

What an endoscopy is

An endoscopy is a test that looks inside the body. The endoscope is a long flexible tube that can be swallowed. It has a camera and light inside it. Some doctors call it a telescope.

Why you may have an endoscopy

You are most likely to have an endoscopy to look at the inside of your

- Gullet (oesophagus)
- Stomach
- Duodenum - the first part of the small bowel that attaches to the stomach
- Large bowel (colon)

Your doctor may want to see inside because you have symptoms, such as abnormal bleeding or difficulty swallowing. The doctor can look down the endoscope and see if there are any growths or other abnormal looking areas. Also through the endoscope, the doctor can take samples (biopsies) of any abnormal looking tissues.

There is more detailed information about having a colonoscopy in the bowel cancer section of CancerHelp UK. Below is information about having other types of endoscopy.

Having an endoscopy

You can have this test as an out patient. Most people have a choice between having the test while they are awake, or after having a medicine to make them drowsy (a sedative). Your hospital may not be happy for you to have a sedative if you live alone and will have no one to look after you when you go home. If you live alone but really want sedation, your hospital may allow you to stay overnight. You should ask your doctor about this as early as possible, as extra arrangements will need to be made beforehand.

If you don't have a sedative, you will have a spray to numb the back of your throat and make it easier for you to swallow the endoscopy tube.

If you would prefer to be asleep during the test, you will have an injection to make you very drowsy just before the test. You will need to take someone with you to the hospital appointment. You won't be able to drive for the rest of the day and should have someone to go home with you.

You can't eat or drink for about 8 hours before the test so that your stomach and duodenum are empty. Your doctor will give you written instructions about this beforehand, or they may arrive with your appointment letter. When you get to the clinic, you may be asked to take your upper clothing off and put on a hospital gown. Some hospitals prefer to use gowns because your clothes won't get messy. Once you are ready, you get onto the bed or X-ray couch. When you are lying comfortably you have the sedative injection to make you very drowsy. Or your doctor will spray the back of your throat to numb it.

Once the sedative or throat spray has worked, the doctor will pass the endoscope tube down your throat to the area being investigated. Your doctor will ask you to swallow as the tube goes down, but if you've had a sedative, you won't remember that afterwards. If there are any abnormalities, the doctor will take pieces of tissue from the abnormal looking area to send to the laboratory for closer inspection under a microscope. These tissue samples are called biopsies.

When the test is over you will need to rest for a while. If you've had a sedative, you may not remember much (if anything) about the test once you have come round. You should be able to go home the same day.

The results

It can take time for test results to come through. How long will depend on why you are having the test. Usually, the doctor who carries out the endoscopy dictates a report straight way. The report is typed up by the department secretary and goes to your specialist, who gives the results to you. If your GP has sent you for the test, the results will go directly to the GP surgery.

Understandably, waiting for results can make you anxious. It usually takes a couple of weeks for the results to come through. If your doctor needed them urgently, it would have been noted on the test request form and the results will be ready sooner than that. Try to remember to ask your doctor how long you should expect to wait for the results when you are first asked to go for the test. If it is not an emergency, and you have not heard a couple of weeks after your test, ring your doctor's secretary to check if they are back.

Endoscopy

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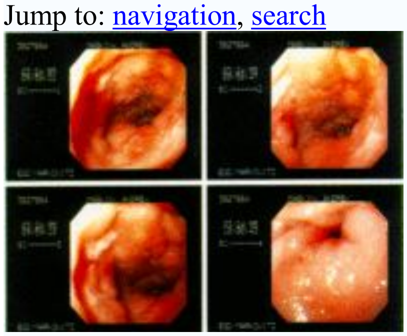

Endoscopic images of a duodenal ulcer

A flexible endoscope.

Endoscopy means *looking inside* and typically refers to looking inside the human body for medical reasons using an instrument called an **endoscope**. Endoscopy can also refer to using a borescope in technical situations where direct line-of-sight observation is not feasible.

Contents

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Overview

Endoscopy is a minimally invasive diagnostic medical procedure that is used to assess the interior surfaces of an organ by inserting a tube into the body. The instrument may have a rigid or flexible tube and not only provide an image for visual inspection and photography, but also enable taking biopsies and retrieval of foreign objects. Endoscopy is the vehicle for minimally invasive surgery.

Many endoscopic procedures are considered to be relatively painless and, at worst, associated with mild discomfort; for example, in esophagogastroduodenoscopy, most patients tolerate the procedure with only topical anaesthesia of the oropharynx using lignocaine spray.[1] Complications are not common (only 5% of all operations)[*citation needed*] but can include perforation of the organ under inspection with the endoscope or biopsy instrument. If that occurs open surgery may be required to repair the injury.

Components

An endoscope can consist of

- a rigid or flexible tube
- a light delivery system to illuminate the organ or object under inspection. The light source is normally outside the body and the light is typically directed via an optical fiber system
- a lens system transmitting the image to the viewer from the fiberscope
- an additional channel to allow entry of medical instruments or manipulators

Uses

Endoscopy can involve

- The gastrointestinal tract (GI tract):
  - esophagus, stomach and duodenum (esophagogastroduodenoscopy)
  - small intestine
  - colon (colonoscopy,proctosigmoidoscopy)
  - Bile duct
    - endoscopic retrograde cholangiopancreatography (ERCP), duodenoscope-assisted cholangiopancreatoscopy, intraoperative cholangioscopy
- The respiratory tract
  - The nose (rhinoscopy)
  - The lower respiratory tract (bronchoscopy)
- The urinary tract (cystoscopy)
- The female reproductive system
  - The cervix (colposcopy)
  - The uterus (hysteroscopy)
  - The Fallopian tubes (Falloscopy)
- Normally closed body cavities (through a small incision):
  - The abdominal or pelvic cavity (laparoscopy)
  - The interior of a joint (arthroscopy)
  - Organs of the chest (thoracoscopy and mediastinoscopy)
- During pregnancy
  - The amnion (amnioscopy)
  - The fetus (fetoscopy)
- Plastic Surgery
- Panendoscopy (or triple endoscopy)
  - Combines laryngoscopy, esophagoscopy, and bronchoscopy
- Non-medical uses for endoscopy
  - The planning and architectural community have found the endoscope useful for pre-visualization of scale models of proposed buildings and cities (architectural endoscopy)
  - Internal inspection of complex technical systems (borescope)
  - Endoscopes are also a tool helpful in the examination of improvised explosive devices by bomb disposal personnel.

- The FBI uses endoscopes for conducting surveillance via tight spaces.

History

The first endoscope, of a kind, was developed in 1806 by Philip Bozzini with his introduction of a "Lichtleiter" (light conductor) "for the examinations of the canals and cavities of the human body". However, the Vienna Medical Society disapproved of such curiosity. An endoscope was first introduced into a human in 1822 by William Beaumont, an army surgeon at Mackinac Island, Michigan[citation needed]. The use of electric light was a major step in the improvement of endoscopy. The first such lights were external. Later, smaller bulbs became available making internal light possible, for instance in a hysteroscope by Charles David in 1908[citation needed]. Hans Christian Jacobaeus has been given credit for early endoscopic explorations of the abdomen and the thorax with laparoscopy (1912) and thoracoscopy (1910)[citation needed]. Laparoscopy was used in the diagnosis of liver and gallbladder disease by Heinz Kalk in the 1930s[citation needed]. Hope reported in 1937 on the use of laparoscopy to diagnose ectopic pregnancy[citation needed]. In 1944, Raoul Palmer placed his patients in the Trendelenburg position after gaseous distention of the abdomen and thus was able to reliably perform gynecologic laparoscopy[citation needed].

The first gastrocamera was released in 1950 by Olympus Optical Co., Ltd. The device took pictures on monochromatic film using a small light bulb that was triggered manually. The device was of limited use, however, because it did not implement real-time optical capability. Olympus continued its development of endoscopes by incorporating fiber optics in the early 1960s, leading to the first useful endoscopes. In 1964, it released a gastrocamera guided by a fiberscope.[1] A few articles claim that Dr.Basil Hirschowitz of Univ.Of Michigan,Ann Arbor discussed the endoscope in early 50's.[2]

As endoscopic technology improved, so did the methods of gastrointestinal endoscopy. Owing primarily to the efforts of Dr. Hiromi Shinya in the late 1960s, GI endoscopy developed into what is more recognizable as today's colonoscopy. While many doctors experimented with techniques to take advantage of the new iterations of endoscopes, Dr. Shinya focused on techniques that would allow for successful operation of the endoscope by an individual, rejecting the common practice at the time of utilizing two people. Consequently, many of the fundamental methods and procedures of modern colonoscopy were developed by Dr. Shinya.

Dr. Shinya's other great contribution was to therapeutic endoscopy, in his invention of the electrosurgical polypectomy snare with the aid of Olympus employee Hiroshi Ichikawa. Shinya sketched his first plans for the device on January 8, 1969. He envisioned a loop of wire attached to the end of a colonoscope that would allow for easy removal of polyps during investigation by passing a current through the wire. By September of 1969, the first polypectomy using this device was performed. Polypectomy has since become the most common therapeutic procedure performed with an endoscope. (Sivak 2004)

By 1980, laparoscopy training was required by gynecologists to perform tubal ligation procedures and diagnostic evaluations of the pelvis. The first laparoscopic cholecystectomy was performed in 1984 and the first video-laparoscopic cholecystectomy in 1987[citation needed]. During the 1990s, laparoscopic surgery was extended to the appendix, spleen, colon, stomach, kidney, and liver[citation needed]. Wireless capsule endoscopy or Capsule Endoscopy is now approved in all the countries including Japan where government reimbusement will be available from Oct.2007.Capsule Endoscopy [3] increases detection of Small Bowel tumors where traditional Endoscopy is not very efficient.

Risks

- Infection
- Punctured organs
- Allergic reactions due to Contrast agents or dyes (such as those used in a CT scan)
- Over-sedation

After The Endoscopy

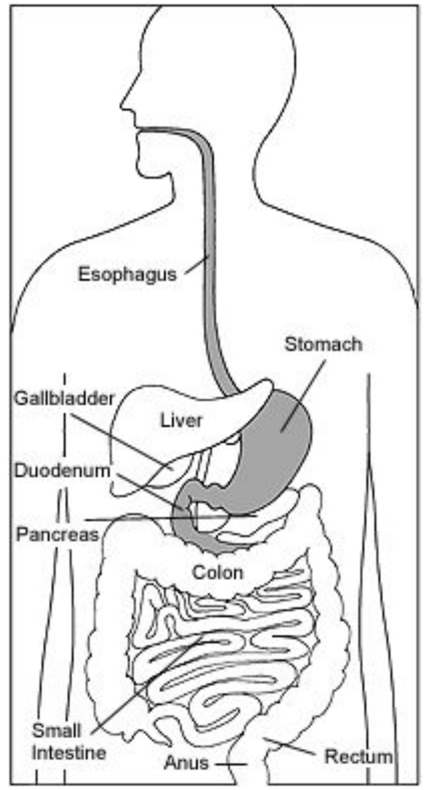
After the procedure the patient will be observed and monitored by a qualified individual in the endoscopy or a recovery area until a significant portion of the medication has worn off. Occasionally a patient is left with a mild sore throat, which promptly responds to saline gargles, or a feeling of distention from the insufflated air that was used during the procedure. Both problems are mild and fleeting. When fully recovered, the patient will be instructed when to resume his/her usual diet (probably within a few hours) and will be allowed to be taken home. Because of the use of sedation, most facilities mandate that the patient is taken home by another person and not to drive on his/her own or handle machinery for the remainder of the day.

Recent developments

With the application of robotic systems, telesurgery was introduced as the surgeon could operate from a site physically removed from the patient. The first transatlantic surgery has been called the Lindbergh Operation.

Upper Endoscopy

Upper endoscopy enables the physician to look inside the esophagus, stomach, and duodenum (first part of the small intestine). The procedure might be used to discover the reason for swallowing difficulties, nausea, vomiting, reflux, bleeding, indigestion, abdominal pain, or chest pain. Upper endoscopy is also called EGD, which stands for esophagogastroduodenoscopy (eh-SAH-fuh-goh-GAS-troh-doo-AH-duh-NAH-skuh-pee).



The digestive system

For the procedure you will swallow a thin, flexible, lighted tube called an endoscope (EN-doh-skope). Right before the procedure the physician will spray your throat with a numbing agent that may help prevent gagging. You may also receive pain medicine and a sedative to help you relax during the exam. The endoscope transmits an image of the inside of the esophagus, stomach, and duodenum, so the physician can carefully examine the lining of these organs. The scope also blows air into the stomach; this expands the folds of tissue and makes it easier for the physician to examine the stomach.

The physician can see abnormalities, like inflammation or bleeding, through the endoscope that don't show up well on x rays. The physician can also insert instruments into the scope to treat bleeding abnormalities or remove samples of tissue (biopsy) for further tests.

Possible complications of upper endoscopy include bleeding and puncture of the stomach lining. However, such complications are rare. Most people will probably have nothing more than a mild sore throat after the procedure.

The procedure takes 20 to 30 minutes. Because you will be sedated, you will need to rest at the endoscopy facility for 1 to 2 hours until the medication wears off.

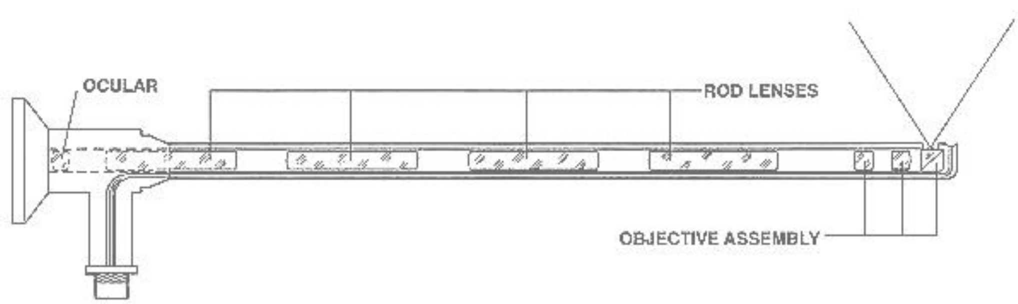
Preparation

Your stomach and duodenum must be empty for the procedure to be thorough and safe, so you will not be able to eat or drink anything for at least 6 hours beforehand. Also, you must arrange for someone to take you home—you will not be allowed to drive because of the sedatives. Your physician may give you other special instructions.

What is Endoscopy and Why is it Performed?

Endoscopy allows physicians to peer through the body's passageways. Endoscopy is the examination and inspection of the interior of body organs, joints or cavities through an endoscope. An endoscope is a device that uses fiber optics and powerful lens systems to provide lighting and visualization of the interior of a joint. The portion of the endoscope inserted into the body may be rigid or flexible, depending upon the medical procedure.

An endoscope uses two fiber optic lines. A "light fiber" carries light into the body cavity and an "image fiber" carries the image of the body cavity back to the physician's viewing lens. There is also a separate port to allow for administration of drugs, suction, and irrigation. This port may also be used to introduce small folding instruments such as forceps, scissors, brushes, snares and baskets for tissue excision (removal), sampling, or other diagnostic and therapeutic work. Endoscopes may be used in conjunction with a camera or video recorder to document images of the inside of the joint or chronicle an endoscopic procedure. New endoscopes have digital capabilities for manipulating and enhancing the video images.



This figure shows a rigid endoscope used for arthroscopy. The "image fiber" leads from the ocular (eye piece) to the inserted end of the scope. The "light fiber" is below and leads from the light source to the working end of the endoscope.

Why Is Endoscopy Performed?

Endoscopy can be used to diagnose various conditions by close examination of internal organ and body structures. Endoscopy can also guide therapy and repair, such as the removal of torn cartilage from the bearing surfaces of a joint. Biopsy (tissue sampling for pathologic testing) may also be performed under endoscopic guidance. Local or general anesthetic may be used during endoscopy, depending upon the type of procedure being performed

Internal abnormalities revealed through endoscopy include: abscesses, biliary (liver) cirrhosis, bleeding, bronchitis, cancer, cysts, degenerative disease, gallbladder stones, hernia, inflammation, metastatic cancer, polyps, tumors, ulcers, and other diseases and conditions.

Endoscopy is a minimally invasive procedure and carries with it certain minor risks depending upon the type of procedure being performed. However, these risks are typically far outweighed by the diagnostic and therapeutic potential of the procedure.

Prior to the widespread use of endoscopy and diagnostic imaging, most internal conditions could only be diagnosed or treated with open surgery. Until the last several decades, exploratory surgery was routinely performed only when a patient was critically ill and the source of illness was not known. For example, in certain dire cases, the patient's thorax or abdomen were surgically opened and examined to try to determine the source of illness.

Endoscopy can often be done on an outpatient basis. "Outpatient" means that the procedure does not require hospital admission and acute care and observation and may be performed outside the premises of a hospital. Outpatient procedures performed at hospitals or ambulatory centers allow the patient to go home or return to work within a short while after their procedure.

Types of Endoscopy

Fiber optic endoscopes now have widespread use in medicine and guide a myriad of diagnostic and therapeutic procedures including:

- **Arthroscopy:** examination of joints for diagnosis and treatment (arthroscopic surgery)
- **Bronchoscopy:** examination of the trachea and lung's bronchial trees to reveal abscesses, bronchitis, carcinoma, tumors, tuberculosis, alveolitis, infection, inflammation
- **Colonoscopy:** examination of the inside of the colon and large intestine to detect polyps, tumors, ulceration, inflammation, colitis diverticula, Chrohn's disease, and discovery and removal of foreign bodies.
- **Colposcopy:** direct visualization of the vagina and cervix to detect cancer, inflammation, and other conditions.
- **Cystoscopy:** examination of the bladder, urethra, urinary tract, uteral orifices, and prostate (men) with insertion of the endoscope through the urethra.

ERCP (endoscopic retrograde cholangio-pancreatography) uses endoscopic guidance to place a catheter for x-ray fluorosocopy with contrast enhancement. This technique is used to examine the liver's biliary tree, the gallbladder, the pancreatic duct and other anatomy to check for stones, other obstructions and disease. X-ray contrast is introduced into these ducts via catheter and fluoroscopic x-ray images are taken to show any abnormality or blockage. If disease is detected, it can sometimes be treated at the same time or biopsy can be performed to test for cancer or other pathology. ERCP can detect biliary cirrhosis,.

- cancer of the bile ducts, pancreatic cysts, pseudocysts, pancreatic tumors, chronic pancreatitis and other conditions such as gallbladder stones.
- **EGD (Esophogealgastroduodensoscopy):** visual examination of the upper gastro-intestinal (GI) tract. (also referred to as gastroscopy) to reveal hemorrhage, hiatal hernia, inflammation of the esophagus, gastric ulcers.
- **Endoscopic biopsy** is the removal of tissue specimens for pathologic examination and analysis.
- **Gastroscopy:** examination of the lining of the esophagus, stomach, and duodenum. Gastroscopy is often used to diagnose ulcers and other sources of bleeding and to guide biopsy of suspect GI cancers.
- **Laparoscopy:** visualization of the stomach, liver and other abdominal organs including the female reproductive organs, for example, the fallopian tubes.
- **Laryngoscopy:** examination of the larynx (voice box).
- **Proctoscopy,** sigmoidoscopy, proctosigmoidoscopy: examination of the rectum and sigmoid colon.
- **Thoracoscopy:** examination of the pleura (sac that covers the lungs), pleural spaces, mediastinum, and pericardium.

A Brief History of Endoscopy

In the early 1900s, the first attempts to view inside the body with lighted telescopes were made. These initial devices were often fully rigid. In the 1930s, semi-flexible endoscopes called gastroscopes were developed to view inside of the stomach. Fiber-optic endoscopy was pioneered by South African-born physician Basil Hirschowitz at the University of Michigan in 1957. Widespread use of fiber optic endoscopes began in the 1960s.

A fiber optic cable is simply a bundle of microscopic glass or plastic fibers that literally allows light and images to be transmitted through curved structures. Fiber optic cables are also replacing metal wires as the backbone of the world's telecommunications infrastructure. This Internet page may have traveled through a fiber optic cable as a stream of digital data (bursts of light) on its way to your computer

Endoscopy Equipment

Endoscopes have many practical needs. And H.M.B. Endoscopy Products (Hollywood, Florida) has been providing endoscopic equipment and educating people on the use of endoscopes for more than 17 years. Be sure to Browse our Catalog for all the details on how to purchase these medical instruments that can examine any part of the body.

Video Systems

Fiber Endoscopes

Video Endoscopes

In the simplest terms, Endoscopy equipment consists of instruments that can look at the inside of many different organs — these are small, flexible or rigid tubes with a light or lenses on the end that can look into the esophagus, stomach and colon — and in more general terms endoscopy equipment can help doctors look deep inside body structures and hollow organs.

An endoscope and related endoscope products and equipment are usually composed of three components:

- **An optic system** that allows the doctor to look through the scope into the organ or cavity, or to attach a video camera to the scope
- **A fiberoptic cable** to light up the bodily area
- **A lumen** (e.g. the bore of a tube, like a needle or catheter) to take tissue samples of the area being viewed

The beauty of endoscopic products is that they perform dual functions — with both diagnostic and therapeutic capabilities. For example, this means that these endoscopic products and instruments can perform biopsies (e.g. to evaluate tissue samples) as well as provide sclerotherapy (a medical procedure used to treat varicose veins and “spider veins”). In truth, these brief explanations only tell part of the story.

TYPES OF ENDOSCOPES

Take a look at the different types of endoscopic equipment you can get with H.M.B. Endoscopy Products. Again, in very general terms, there are two main types of endoscopes:


Rigid *Flexible*

1. **rigid endoscopes** – the majority of which use a convex (curving out, like one half of a circle) glass lens system, in which the small glass lenses are separated by large air spaces.
2. **flexible endoscopes** allow for just that — flexibility. In the animal kingdom, for example, a flexible endoscope would be perfect for examining the stomach area of a snake.

The popularity of endoscopy equipment continues to grow. Some of the industry's household names include Olympus, Pentax, Funjinon and Storz — with H.M.B. both selling and repairing pre-owned and completely refurbished endoscopic products from each of these major manufacturers. Browse our Catalog to get the ones you need!

THERMOGRAPH

APPLICATION: Thermographs are digital recording thermometers used to log temperature in the marine environment. The instruments are attached to a computer to set up recording parameters for deployment, downloading, and display of data in graphic or numeric format. These units are placed in underwater housings and attached to the bottom or suspended in the water column for deployment.

DESCRIPTION: Two types of thermograph are currently available. The Ryan Tempmentor is a reusable data logger that allows storage of a maximum of 6,361 temperature measurements in the range of -32°C to +70°C with 0.1° resolution and 0.3° accuracy. The instrument can be programmed to take measurements from once per second to once every other hour. Instrument dimensions are 3" x 6" x 1.3" and the unit weighs 11 ounces. The Hobo Temp is a miniature, reusable data logger that allows storage of 1,800 measurements in the range of -20°C to +70°C with 0.3° resolution and 0.7°

accuracy. Sampling intervals from 0.5 seconds to 4.8 hours are available. Instrument dimensions are 2.4” x 1.9” x 0.8” and the unit weighs 1 ounce. Both units are battery powered with the battery life of the Tempmentor being approximately two years and the battery life of the Hobo Temp being one year.

THERMOGRAPH

APPLICATION: Thermographs are digital recording thermometers used to log temperature in the marine environment. The instruments are attached to a computer to set up recording parameters for deployment, downloading, and display of data in graphic or numeric format. These units are placed in underwater housings and attached to the bottom or suspended in the water column for deployment.

DESCRIPTION: Two types of thermograph are currently available. The Ryan Tempmentor is a reusable data logger that allows storage of a maximum of 6,361 temperature measurements in the range of -32°C to +70°C with 0.1° resolution and 0.3° accuracy. The instrument can be programmed to take measurements from once per second to once every other hour. Instrument dimensions are 3” x 6” x 1.3” and the unit weighs 11 ounces. The Hobo Temp is a miniature, reusable data logger that allows storage of 1,800 measurements in the range of -20°C to +70°C with 0.3° resolution and 0.7°

accuracy. Sampling intervals from 0.5 seconds to 4.8 hours are available. Instrument dimensions are 2.4” x 1.9” x 0.8” and the unit weighs 1 ounce. Both units are battery powered with the battery life of the Tempmentor being approximately two years and the battery life of the Hobo Temp being one year.

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UNIT – III

ASSIST DEVICES

Cardiac Pacemakers, DC Defibrillator, Dialyzer, Ventilators, Magnetic Resonance Imaging Systems, Ultrasonic Imaging Systems.

1. Cardiac pacemakers

Explain the function and characteristics of the various types of cardiac pacemakers. [May/June 2014][May/June 2013][Nov/Dec 2012][May/June 2012][April/May 2011][Nov/Dec 2016]

Explain the different modes of cardiac pacemakers. [April/May 2019]

1.1 Definition:

- A device capable of generating artificial pacing impulses and delivering them to heart is known as pacemaker system or pacemaker.
- It consists of a pulse generator and electrodes.
- Sino Atrial (SA) node is responsible for the starting of heart beat.
- Hence it is called as Natural Pacemaker.

1.2 Types of pacemakers:

- Internal pacemaker
- External pacemaker

1.2.1 INTERNAL PACEMAKER

- It is placed inside the body.
- It may be permanently implanted on the patients whose SA nodes are failed to function or those who suffered from permanent heart block**.**

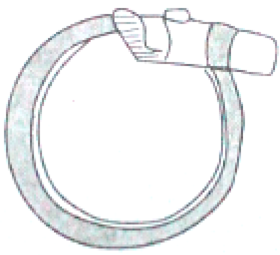

Fig. 1.1 Internal Pacemaker

- Internal pacemaker systems are implanted with the pulse generator placed in a surgically developed pocket below the right or left clavicle, in left sub costal region.
- In case of women it is placed beneath the left or right major pectoral's muscle.
- Internal leads are connected to the electrodes that directly contact the surface of the myocardium**.**
- The exact location of the pulse generator used in the internal pacemaker system depends on the following factors.
    - Type and nature of the electrode used.
    - Nature of the cardiac problems.

- Mode of operation of the pacemaker system.

- There is no external connection for applying power.
- So the pulse generator should be completely self-contained with a battery, which is capable of operating continuously for a specified period.

1.2.2 EXTERNAL PACEMAKER

- It consists of an externally placed pulse generator circuit connected to the electrodes placed on the myocardium.
- Temporary heart irregularities or disorders.
- Treating the patient from arrhythmias.
- Treatment of coronary patient and during the cardiac surgery.
- The external pacemaker consists of pulse generators.
- They are placed outside the body and connected normally to the electrode with the help of wires introduced into the right ventricle.
- The pulse generator may be strapped to the lower arm of the patient.

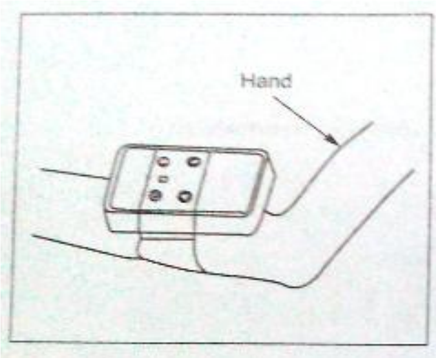

Fig.1.2 Portable external pacemaker strapped on arm

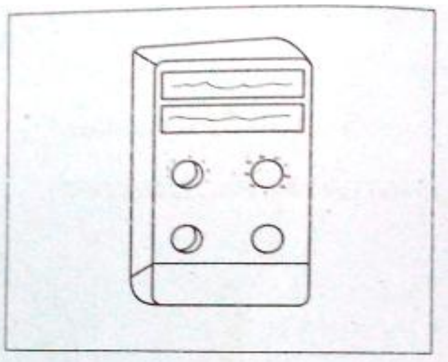

Fig 1.3 External demand pacemaker

1.3 TYPES OF PACING MODES

Based on the modes of operation of the pacemakers, they are classified into five types,

1. Ventricular asynchronous pacemaker (Fixed rate pacemaker)
2. Ventricular synchronous pacemaker (Standby pacemaker)
3. Ventricular inhibited pacemaker (Demand pacemaker)
4. Atrial synchronous pacemaker
5. Atrial sequential ventricular inhibited pacemaker

1.3.1 VENTRICULAR ASYNCHRONOUS PACEMAKER (FIXED RATE PACEMAKER)

- This type of pacemaker is intended for patients having permanent heart blocks.
- This pacemaker can be implemented in atrium or ventricle.
- It is suitable for the patients who are suffered by total AV block, atrial arrhythmia.
- The circuit shown below produces a stimulus at a fixed rate.
- There is a competition between the natural heart beats and the beats generated by this pacemaker.

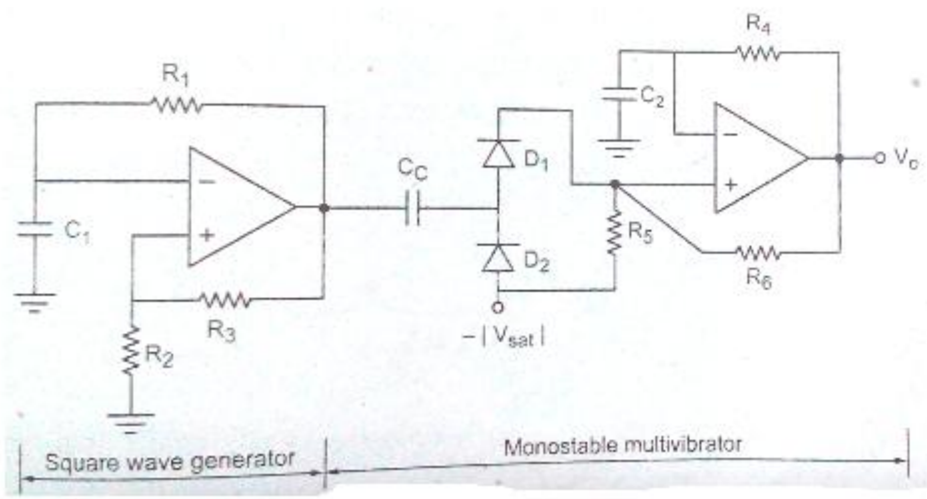

Fig. 1.4 Ventricular asynchronous pacemaker

- The figure consists of square wave generator and monostable multivibrator circuit.
- The period of the square wave generator is given as,

$$T = -2\ (RC)\ \ln\left(\frac{R_3}{2R_2 + R_3}\right)$$

T can be modified by changing the R, C, R_2 and R_3 values.

- The pulse duration is given by the following formula,

$$T_d = 5\ C_C\left(\frac{R_5 R_6}{R_5 + R_6}\right)$$

- The output of the square wave generator is connected with the monostable multivibrator circuit.

Disadvantages:

- Heart beat rate cannot be changed.
- If it is fixed in atrium, atrium beat at a fixed rate.
- If ventricle beat at a different rate, then it leads to a severe problem.
- Ventricular fibrillation may be occurred.

1.3.2 VENTRICULAR SYNCHRONOUS PACEMAKER (STANDBY PACEMAKER) [Nov/Dec 2016]

- Suitable for the patients who are suffered by short period of AV block.

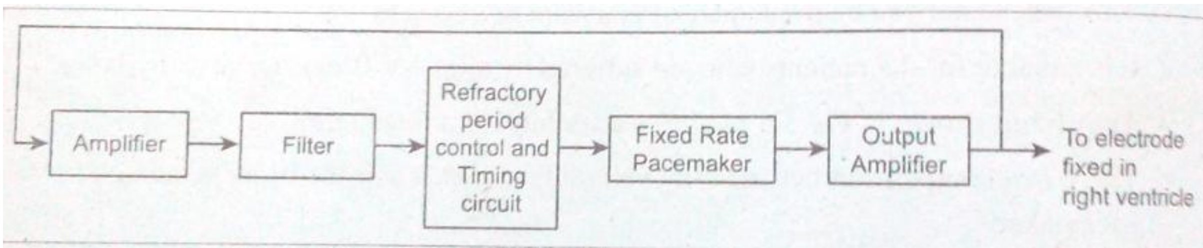

Fig.1.5 Ventricular synchronous pacemaker

- Electrode placed in the right ventricle of heart. This electrode is used to sense the R-wave.
- If ventricular contractions are absent, then the pacemaker provides the impulses.

- This type of pacemaker does not compete with the normal heart activity.

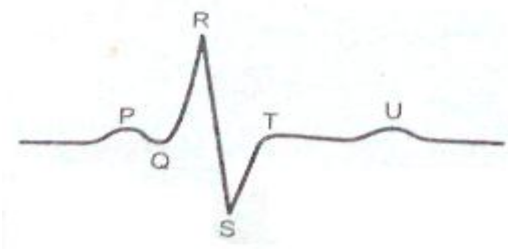

Fig.1.6 R-Wave

- Electrode is used to detect the heart rate and it is given to the amplifier and filter circuit.
- Because heart rate amplitude is very low.
- Amplifier is used to amplify the cardiac signal.
- Filter is used to remove unwanted noise signal.
- Signal is given to refractory period control and timing circuit.
- R-wave is below the certain level, at that time only; this pacemaker will deliver the pulses.

Advantages:

- Ventricular fibrillation is avoided.
- When R-wave is normal, then fixed rate pacemaker block is not in ON condition, so power consumption is reduced.

Disadvantages:

- Very sensitive to electromagnetic interferences.
- No synchronization between atrial and ventricular contraction.

1.3.3 VENTRICULAR INHIBITED PACEMAKER (DEMAND PACEMAKER)

Explain working principle of demand pacemaker with a diagram.	***[Nov/Dec 2017][Nov/Dec 2016]***

- The functional block diagram of demand pacemaker is shown in figure.

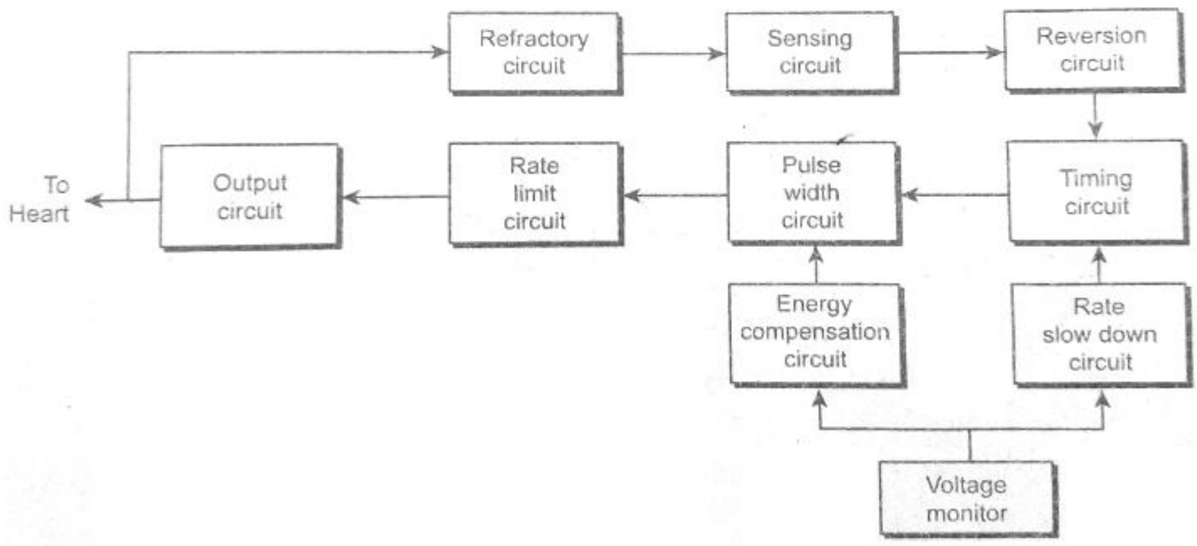

Fig.1.7 Ventricular Inhibited pacemaker

- Comparator determines the pacing rate of the pulse generator.

- Output is given to second RC network.
- The pulse width circuit determines the duration of the stimulating pulses.
- Rate limiting circuit disables the comparator for a short interval and limits the pacing rate.
- Output circuit provides a voltage pulse to stimulate the heart.
- Voltage monitor circuit senses the cell depletion and controls the rate slow down circuit and energy compensation circuit.
- Rate slow down circuit shuts off some current to the basic timing to slow down pulse rate during cell depletion.
- Energy compensation circuit causes the pulse duration unit to increase the battery voltage, when it decreases and it is used to supply the energy to heart.
- Sensing circuit detects a spontaneous R-wave and resets the oscillator timing capacitor.
- Reversion circuit helps the amplifier to detect spontaneous R wave in the presence of low level continuous wave interference.
- In the absence of R wave the circuit allows the oscillator to produce pacing pulses at its present rate.
- The inhibited pacemaker allows the heart to pace at its normal rhythm when it is able to do.
- If the R wave is missing for a preset period of time, then the pacemaker will turn ON and provide the heart a stimulus.
- Hence it is termed as Demand pacemaker.

1.3.4 ATRIAL SYNCHRONOUS PACEMAKER

Describe the working of atrial synchronous pacemaker.	***[Apr/May 2017]***

- It is used for temporary pacing for young patients with a mostly stable block.

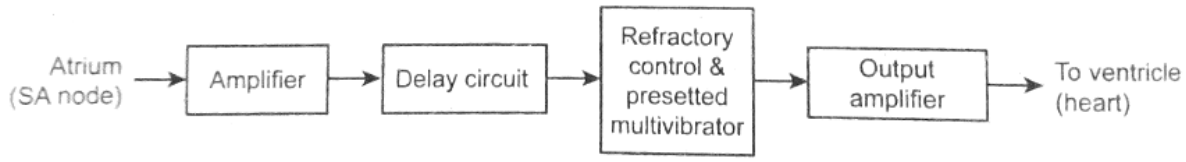

Fig.1.8 Atrial synchronous pacemaker

- P wave is sensed and picked by the electrode fixed on the atrium.
- It is given to the amplifier circuit.
- Amplifier circuit is used to amplify the P-waveform.
- Circuit is used to give the delay 0.12 second.
- The output of the delay circuit given to refractory control and preset multivibrator block.
- If the P wave amplitude is not in normal value, then fixed rate pacemaker will turn ON.
- When P-wave amplitude is normal, then fixed rate pacemaker is OFF.
- If fixed rate pacemaker is ON, then the output is given to amplifier.
- The amplified signal is given to ventricle through electrode.
- Refractory control circuit provides some time delay, because pacemaker pulse is too large.

1.3.5 ATRIAL SEQUENTIAL VENTRICULAR INHIBITED PACEMAKER

- It is used to stimulate both atrial and ventricles.
- It is a demand pacemaker, so based on the patients need, it provides the impulses.
- In the modern pacemakers, magnet is placed over the pacemaker on the skin of the patient.
- This magnet is used to activate the reed switch.
- This switch, switches the pacemaker into any one of the mode of operation, either to give the impulse for atrial or to ventricle.

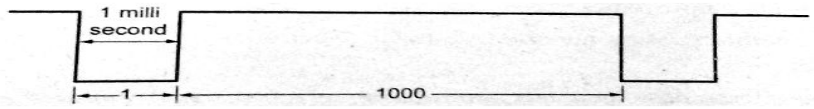

Fig. 1.9 Pacemaker pulses

1.4 COMPONENTS OF PACEMAKER

- Pulse generator
- Electrodes
- Battery

1.5 METHODS OF STIMULATION OF PACEMAKER

- **External stimulation -** Used to restart the normal rhythm of the heart in case of cardiac standstill.
- **Internal stimulation** - It prevents normal self triggering of the heart.

1.6 Pacemaker Batteries:

- ✓ **Mercury cell:** The lifetime is 2 – 3 years.
- ✓ **Lithium cells:** The lifetime is more than five years.
- ✓ **Rechargeable battery:** The lifetime is not reliable even for a year.
- ✓ **Nuclear cell:** The lifetime is more than ten years.

****

2. Difference between Internal and External pacemaker

Distinguish Internal and External pacemaker. ***[April/May 2015]***

Internal (Implanted) pacemaker	External pacemaker
The pacemaker is a surgically implanted in the skin near the chest or abdomen.	The pacemaker is placed outside the body.
Its output lead is connected directly to the heart muscle.	It may be in the form of wrist watch or in the pocket. From that one terminal will go in the heart through the vein.
Myocardiac electrodes are in contact with the outer wall of the myocardium (heart muscle).	Endocardiac electrodes are applied to the heart. They are in contact with the inner surface of the heart chamber.
It requires open chest minor surgery to place the	It does not require open chest surgery.

pacemaker.	
Battery can be replaced only by minor surgery and doctor's help is needed to rectify the defects.	Battery can be easily replaced and any defect can be easily attended without the help from doctor.
During placement, swelling and pain are due to maximum foreign body reaction.	During the placement of pacemaker swelling and pain do not arise due to minimum foreign body reaction.
There is 100% safety for circuit from the external disturbances.	There is no safety for the pacemaker, particularly in case of child carrying the pacemaker.
Implanted pacemakers are used for permanent heart regularity.	The external pacemakers are used for temporary heart regularity.

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3. DC Defibrillator

What is Defibrillator? With block diagram explain the operation of various defibrillators. [April/May 2015][Nov/Dec 2014][May/June 2013][Nov/Dec 2012][May/June 2012][April/May 2011][Nov/Dec 2017]

3.1 Fibrillation:

- ✓ During fibrillation the normal rhythmic contractions of either atria or the ventricles are replaced by rapid irregular switching of the muscular wall.
- ✓ ***Types of fibrillation:*** Fibrillation of atrial muscles is called ***atrial fibrillation*** and fibrillation of ventricles is known as ***ventricular fibrillation.***
- ✓ ***Electrodes used for fibrillation:***
  Two types of electrodes are used for defibrillation such as ***internal electrodes*** and ***External electrodes.***
- ✓ ***Internal electrodes*** are used during the ***open heart surgery. Spoon shaped electrodes*** are used here.

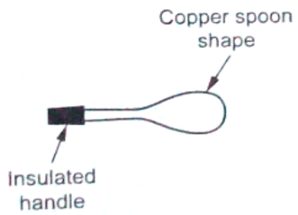

Fig.3.1 Internal Electrodes

- ✓ ***External electrodes*** use ***paddle shaped electrodes*** for external defibrillation**.**

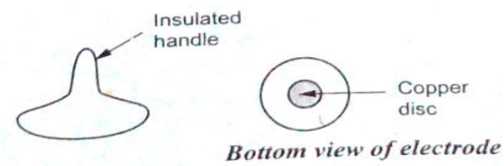

Fig.3.2 Paddle shaped electrode

3.2 Defibrillator

- ✓ Mechanical methods like heart massage have been tried over the years for fibrillating patients.
- ✓ The successful method of defibrillation is the application of an electric shock to the area of heart.
- ✓ If sufficient amount of current is applied for some period and then released.
- ✓ In this method, all the muscle fibers enter their refractory period together, and then the normal heart action takes place.
- ✓ The instrument for administering the electric shock is called as defibrillator.
- ✓ Defibrillator is an electronic device that creates a sustained myocardial depolarization of a patient's heart in order to stop ventricular fibrillation or atrial fibrillation.

3.3 Types of Defibrillators

- AC Defibrillators
- DC Defibrillators
- Dual peak DC Defibrillators
- Synchronized DC Defibrillators

3.3.1 AC Defibrillation

- ✓ This type of defibrillation method is widely used by applying a shock of 50 Hz a.c. to the chest of the patient through appropriate electrodes.
- ✓ The phenomenon of application of an electrical shock to resynchronize the heart is called as ***counter shock.***
- ✓ If the patient does not respond, the process is continued until defibrillation occurs. It is shown in figure below.

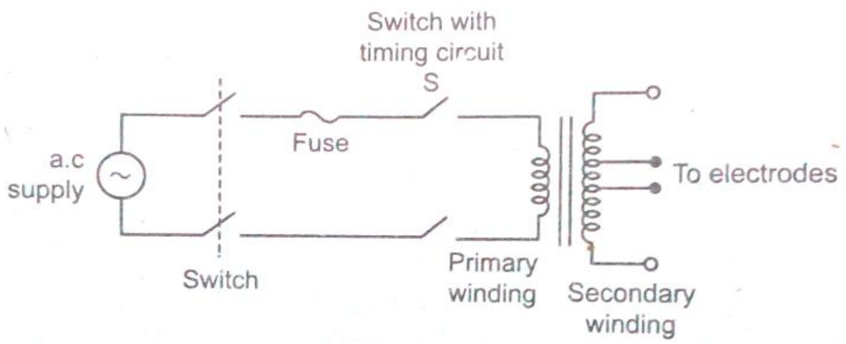

Fig. 3.3 A.C Defibrillator

Working

- ✓ A.C supply is applied to primary winding of the transformer through switches and fuse.
- ✓ The switch is connected with timing circuit.
- ✓ This timing circuit is used to set some particular time up to which the defibrillator delivers a shock to the patient.
- ✓ In secondary winding, various tapping's are available.
- ✓ These are connected to an electrode which is used to deliver the shock to the patient.

- ✓ 250V to 750V is applied by using this type of defibrillator.

Problems in A.C Defibrillation

- ✓ Since ventricular fibrillation is more dangerous than atrial fibrillation, successive methods are adopted to correct it.
- ✓ When atrial fibrillation is corrected by applying electric shock, then serious ventricular fibrillation occurs.

3.3.2 DC Defibrillator

With a neat diagram, illustrate the working of D.C. defibrillator. ***[Apr/May 2017][April/May 2019]***

INTRODUCTION

- ✓ To overcome the disadvantage of defibrillation method in 1962, Bernard lawn from Harward School of public health and peter bent of Brigham hospital developed a new method known as dc defibrillation.
- ✓ In this dc defibrillation method, capacitors charged to a high dc voltage and then rapidly discharged through electrodes across the chest of patient.
- ✓ DC defibrillation is capable of correcting both the atrial fibrillation and ventricular fibrillation.
- ✓ DC method produces some harm to the patient.

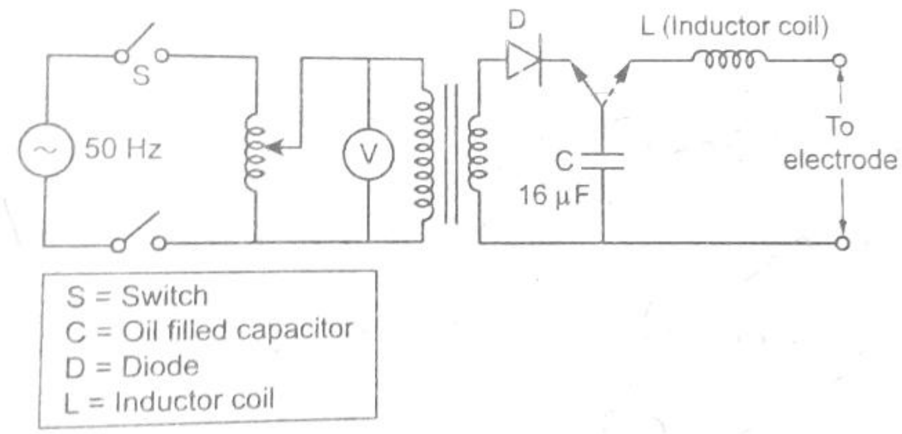

Fig.3.4 DC Defibrillator circuit

- ✓ Depending on the energy setting in the defibrillator, the amount of electrical energy discharged by the capacitor ranges between 100 to 400 joules.
- ✓ Discharge portion is approximately 5 ms.
- ✓ In discharge waveform, the peak value of current is nearly20 A and the wave is monophasic in nature.
- ✓ Monophasic means most of the excursion of curve is above the base line.
- ✓ Energy level of a defibrillator can be controlling the voltage amplitude V_P of the defibrillator by varying the setting on the varactor or Duration of the defibrillator pulse.
- ✓ The energy (W_A) stored in the capacitor *C* and available for the defibrillation is:

    Lown waveform: *Curve 1* shows a typical discharge pulse of defibrillator which called―Lown waveform.

- I rises rapidly to app. 20 A
- Then I decays to 0 with 5 ms
- A negative pulse is produced for 1 to 2 ms

✓ The pulse width is defined as the time that elapses between the start of the impulse and the moment that the current intensity passes the zero line for the first time and changes direction (5 ms or 2.5 ms).

3.3.3. DUAL PEAK DC DEFIBRILLATOR

✓ If peak voltage is as high as 6000V is used there is a possibility of damaging myocardium and the chest walls.

✓ Produce dual peak waveform of longer duration at lower voltage.

✓ Effective defibrillation is achieved in adults with lower level of delivered energy.

✓ Energy range is between 50 to 200 W-sec or joules.

✓ A typical dual peak waveform is shown below.

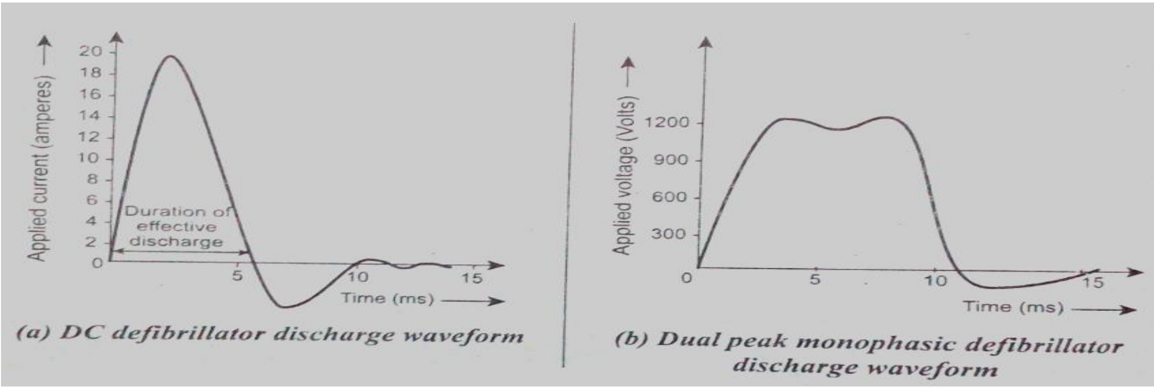

Fig.3 5 Dual peak waveform

✓ Effective defibrillation at the desirable lower voltage levels is also possible with the truncated waveform.

✓ The amplitude of the waveform is relatively constant, but is varied to get required energy.

✓ Large electrodes are used for the proper delivery of large current through the surface of the skin.

✓ These electrodes are called as paddles. A typical truncated waveform is shown in figure below.

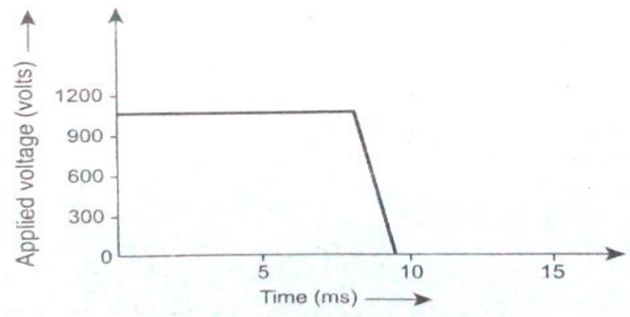

Fig.3.6 Truncated defibrillator discharge waveform

3.3.4 EXTERNAL DEFIBRILLATOR:

✓ A unit based on computer technology and designed to analyze the heart rhythm itself, and then advise whether a shock is required.

✓ It is designed to be used by lay persons, who require little training.

- ✓ It is usually limited in their interventions to delivering high joule shocks for VF and VT rhythms.
- ✓ The automatic units also take time (generally 10-20 seconds) to diagnose the rhythm, where a professional could diagnose and treat the condition far quicker with a manual unit.
- ✓ Automated external defibrillators are generally either held by trained personnel who will attend incidents, or are public access units which can be found in places including corporate and government offices, shopping centers, airports, restaurants,
- ✓ AEDS require self-adhesive electrodes instead of hand-held paddles for the two following reasons:
  - The ECG signal acquired from self-adhesive electrodes usually contains less noise and has higher quality.
  - It allows faster and more accurate analysis of the ECG and better shock decisions.
  - Hands off defibrillation are a safer procedure for the operator, especially if the operator has little or no training.

3.3.5 DC DEFIBRILLATOR WITH SYNCHRONIZER

Draw the block diagram of synchronized DC defibrillator and explain its working principle. [Nov/Dec 2018]

- ✓ Synchronization means, synchronized the working of the heart with the pacemaker.
- ✓ Synchronized DC defibrillator allows the electric shock at the right point on the ECG of the patient.

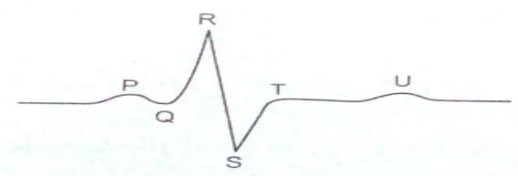

Fig.3.7

- ✓ During the T-wave, the electric shock should not be applied to the patient.
- ✓ Electric shock is delivered approximately 20 to 30 ms after the peak of R wave of patients ECG.

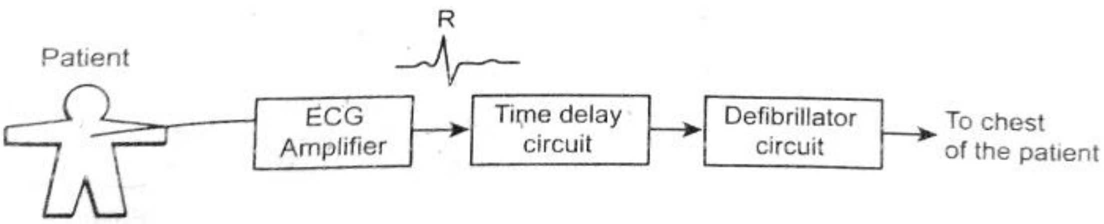

Fig.3.8 Block diagram of defibrillator with synchronizer

Working

- ✓ ECG waveform is traced from the patient.
- ✓ R-wave in the output of ECG amplifier triggers the time delay circuit.
- ✓ It gives the delay of 30 ms approximately.
- ✓ After that, defibrillator circuit is switched ON.
- ✓ So that, the capacitor discharges the electric shock to the patient's heart.

- ✓ The moment at which electric shock occurs is noted by producing the marker pulse on monitoring display.
- ✓ This type of circuit is preferred in cardiac emergencies
- ✓ The sudden cardiac arrest can be treated using a defibrillator and 80 percent of the patients will be cured from the cardiac arrest if it is given within one minute of the attack.

Electrodes used for defibrillation

- ✓ These paddles have metal disks of 8 to 10 cm in diameter for external use.
- ✓ For internal use smaller paddles are used on infants and children.
- ✓ For external use, pair of electrodes is firmly pressed against the patient's chest.

Need of Insulation Handle

- ✓ To prevent the person applying the electrodes from accidental electric shock specially insulated handles are provided in the paddles.
- ✓ When paddles are properly positioned, this prevents the patient from receiving a shock.
- ✓ In earlier equipment a foot switch is used instead of thumb switch.

Need of Thumb Switch

- ✓ There is a possibility of someone accidentally stepping on the foot switch in the excitement of an emergency before the paddles are placed.
- ✓ So thumb switches are mostly preferred.

Charging of Defibrillators

- ✓ In some defibrillators charging is done by means of a charge switch located in the front panel of the unit.
- ✓ The charge switch is located in the handle of one of its paddles.
- ✓ In few defibrillators the charging process begins automatically after discharge.

Types of Electrodes

- ✓ Two electrodes are
  - ➢ Anterior-anterior
  - ➢ Anterior-posterior
- ✓ Anterior-anterior paddles are applied to the chest.
- ✓ Anterior-posterior paddles are applied to both the patient's chest wall and back so that energy is delivered through the heart.
- ✓ Specially designed pediatric paddles are available with diameter ranging from 2 to 6 cm.
- ✓ Internal paddles can be either gas-sterilized or autoclaved.

Indication Meter

- ✓ Most of the defibrillators include a watt second meter to indicate the amount of energy stored in the capacitor before discharge.
- ✓ The energy indicated on the meter is lost or dissipated as heat in the components inside the unit.

4. Dialyzer

Explain the two types of dialyses.

With a neat block diagram explain the principle of operation of haemo dialyzer machine. [Nov/Dec 2018]

4.1 Dialysis:

- Kidney failures can be treated by dialysis.
- Dialysis is a process by which the waste products in the blood are removed and restoration of normal pH value of the blood is obtained by an artificial kidney machine.
- It consists of three important processes.
  - Diffusion
  - Osmosis
  - Ultra filtration
- Two methods are used to perform dialysis.
  1. Extra corporeal dialysis (Haemodialysis)
  2. Intra corporeal dialysis (Peritoneal cavity dialysis)

These methods are explained in the section given below.

4.2 Extra Corporeal Dialysis (Haemodialysis)

Haemodialysis machine is shown in figure below. We can see all the parts of machine one by one.

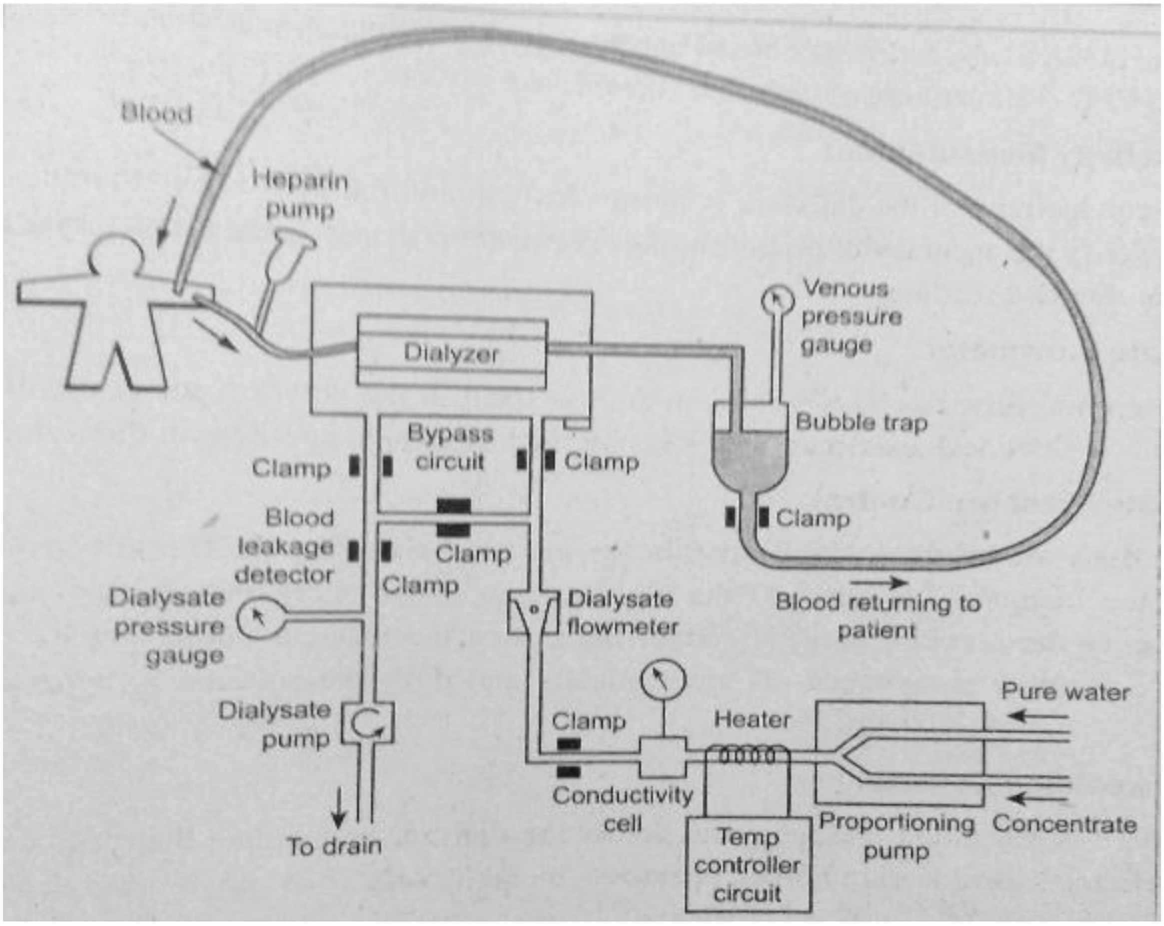

Fig 4.1 Haemodialysis machine

4.2.1 Proportioning pump

- It is used to mix the pure water with dialysate.
- Usually, 34:1 ratio of water and concentrate is maintained.
- There are two types of proportioning system available.

  1. Fixed ratio type: In this type, fixed ratio is maintained. Generally it is 34:1 (water: concentrate)

  2. Variable ratio type: In this type, variation of $\pm$5% on the standard ratio 34: 1 is possible.
- The output of the proportioning pump is given to heater circuit.

4.2.2 Dialysate temperature control

- The dialysis is normally done at specific temperature.
- The temperature of the dialysate should be monitored and controlled by using temperature control circuit before it is given to the dialyzer.
- If the temperature exceeds 40^oC, then the components of blood are damaged.
- So, safety valve is used to turn off the heater, if the temperature exceeds 43^oC.
- In the modern microprocessor based haemodialysis machine, temperature control circuit is given to CPU.
- Temperature of dialysate is displayed.

4.2.3 Conductivity Measurement

- The conductivity of the dialysate is continuously monitored by using conducting cell.
- It is used to verify the accuracy of proportioning.
- The result is displayed as a percentage deviation from the standard reading.

4.2.4 Dialysate Flow meter

- The normal flow rate is 500 ml/minute.
- It is fixed in the downstream of the dialyzer.
- If there is any blood leakage occurs, then it is observed by change of color in the fluid.

4.2.5 Dialysate Pressure control

- The dialysate pressure is indicated in the pressure gauge meter.
- The effective pressure across the membrane is equal to the algebraic sum of the dialysate pressure and venous pressure.
- If the pressure exceeds certain limit, then the effluent pump which creates the negative pressure is switched off automatically and dialysate solution is bypassed to the drain.

4.2.6 Blood Leakage Detector

- If there is any blood leakage occurs across the dialyzer membrane, then it is detected by photo electric transducer.
- In normal operation, blood leakage is 25 mg of haemoglobin/litre.
- If blood leakage is detected, then the dialysate is by-passed to the drain.

4.2.7 Bubble Trap

- Air embolism is serious hazard in dialysis.
- Now, ultra sound method is used for detecting the presence of air in the blood line.

4.2.8 Heparin Pump

- It is used to deliver heparin from the pump to the blood line.

4.2.9 Ultra Filtration Circuit

- It is used to monitor the amount of fluid removed from the patient.

$$\text{Ultra filtration rate} = \frac{\text{Total fluid removed in litres}}{\text{Treatment time in hours}}$$

4.2.10 Dialyzer

- Dialyzer is very important part in the artificial kidney.
- It consists of two circuits.
- In one circuit blood is circulated and in another circuit, dialysate solution is circulated.
- Three types of dialyzers can be used.
- These are ***parallel plate dialyzer, coil dialyzer, hollow fiber type of dialyzer.***
- The rate of clearance of waste products from the blood depends upon the rate of blood flow.
- The dialyzing surface area of parallel flow dialyzer is 1 square meter.
- The rate of blood flow is 200 ml/minute.
- The rate of dialysate flow is 500 ml/minute.
- The rate of clearance of waste product is 64 ml/minute.
- The membrane used in the dialyzer is used for ultra filtration.
- This dialyzer is not a disposable part.
- It should be cleaned before reuse.

*****Write short notes on peritoneal dialysis. [Nov/Dec 2016]**

4.3 Peritoneal Dialysis

The peritoneal dialysis is shown in figure below.

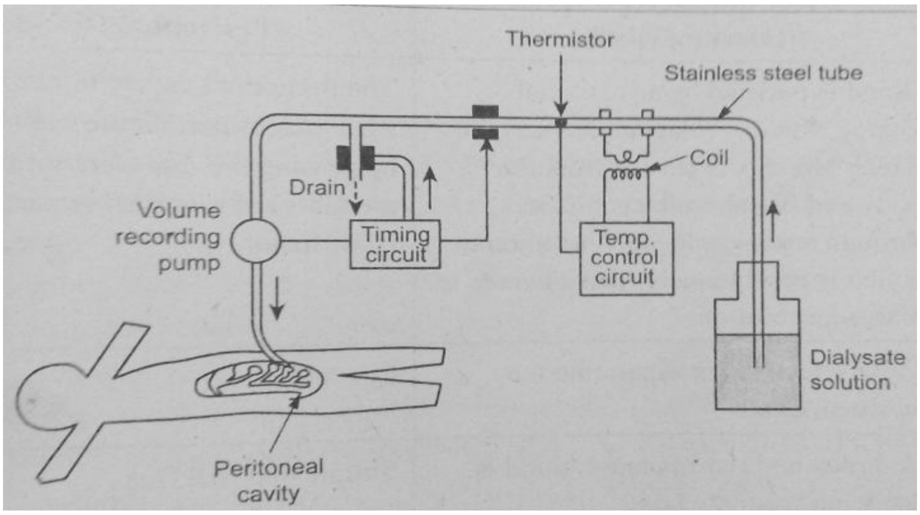

Fig.4.2 Peritonial dialysis

- ✓ In this technique, peritoneal cavity in the abdomen is used as semi permeable membrane.
- ✓ A catheter (sharp knife) is inserted in the abdomen.
- ✓ Dialysate solution of 1.5 – 2 litres is allowed to flow into the peritoneal cavity.
- ✓ Then diffusion takes place for 30 minutes.
- ✓ Then the dialysate solution is removed from the cavity.
- ✓ This same procedure is repeated for 20 to 30 times.
- ✓ Finally all waste substances are removed from the blood.
- ✓ Temperature control circuit is used to maintain the temperature of dialysate solution at 37^{o}C.
- ✓ In this control circuit, thermistor is used.
- ✓ Here timing circuit is used to monitor the volume of the dialysate solution.
- ✓ If 2 litres of solution is allowed, then the circuit delivers the signal to stop the dialysate flow into the peritoneal cavity.
- ✓ The same timing circuit is used to monitor the diffusion time also.
- ✓ After 30 minutes of diffusion time, the timing circuit delivers a signal to stop the diffusion process.
- ✓ Then the dialysate solution is removed from the abdomen using suction pump.
- ✓ After that, the fresh dialysate solution is allowed to enter into the peritoneal cavity.
- ✓ If the volume of the dialysate solution sucked from the peritoneal cavity is less than 2 litres, then the alarm circuit is operated.
- ✓ If alarm is operated, then sudden action should be taken to take care of the patient.

5. Differences between Extraporeal dialysis and Intracorporeal dialysis:

Write the differences between the Extraporeal dialysis and Intracorporeal dialysis.

S.No	Extra Corporeal Dialysis (Haemodialysis)	Intra Corporeal Dialysis (Peritoneal Dialysis)
1.	Blood is purified by an artificial kidney machine (Haemodialyzer), in which blood is taken out from the body and waste products diffuse through a semi permeable membrane which is continuously rinsed by a dialyzing solution.	The peritoneal cavity in our body is used as semi permeable membrane and by passing the dialysate into it; waste products are removed from the blood by diffusion.
2.	More effective for separating the waste products.	Less effective
3.	Complex and risk, because blood is taken out from the body.	Simple and risk free.
4.	Dialyzing time is about 3 to 6 hours.	Dialyzing time is about 9 to 12 hours.

****

6. Ventilators (Respirators)

Explain the principle and working of ventilators.

6.1 Introduction

- The terms ventilator and respirator are used ***interchangeably*** that may be employed ***continuously*** or ***intermittently*** to ***improve ventilation*** of the lungs and to supply humidity to the pulmonary tree.
- Ventilators may be defined as any machine designed to mechanically ***move breathable air into and out of the lungs*** to provide the mechanism of breathing for a patient who is ***physically unable to breathe.***
- Most ventilators in clinical settings use ***positive pressure*** during inhalation to inflate the lungs with various gases or mixture of gases (air, oxygen, CO_2, helium).
- ***Negative airway pressure*** is used under ***rare circumstances*** during expiration.
- Expiration is usually ***passive.***
- Under certain conditions, pressure may be applied during expiration.
- Also to improve ***"arterial oxygen tension".***

6.2 Modes of operation (Mechanical methods)

- Most respirators commonly used are classified as ***"Assistor-Controllers".***
- There are three different modes and modes differ by which type of inspiration is initiated (i.e. positive and negative).

6.2.1 Negative pressure:

1. Assist mode
2. Control mode
3. Assist - Control mode

In this three mode, ***a slight negative pressure*** is applied that respond by pressure sensor to begin inflating the lungs.

Assist mode

- Assist mode inspiration is triggered by the patient.
- Respirator helps the patient when they wants to breathe.
- A sensitivity adjustment is provided to select the amount of patient effort required to trigger the machine.
- It is used by the patients who are able to control their breathing but unable to inhale sufficient of air without assist.

Control mode

- Breathing is controlled by a timer set to provide the desired respiration rate.
- Controlled ventilation is required to patients who are unable to breathe their own.
- Respirator has complete control over the patient respiration.

Assist-Control mode

- The apparatus is normally triggered by the patient attempt to breathe like assist mode.
- If patient fails to breathe within the predetermined time, timer automatically triggers the device to inflate the lungs, like control mode.
- This mode is most frequently used in critical care settings.

6.2.2 Positive pressure:

- In this, many ***respirators can be triggered manually*** by means of a control on the panel.
- Once inspiration has been triggered inflation of the lungs is continuous until one of the following conditions occurs.
  1. Pressure - cycled
  2. Volume – cycled ventilators
  3. Time-cycled ventilators

Pressure-cycled

- The delivered gas reaches a predetermined pressure in the upper airways.
- A ventilator that ***operates primarily*** in this manner is said to be pressure cycled.

Volume-cycled

- A predetermined volume of gas has been delivered to the patient.
- This is the ***primary mode*** of operation of volume-cycled ventilators.

Time-cycled

- The air has been applied for a predetermined period of time.
- This is the ***characteristic mode*** of operation for time-cycled ventilators.

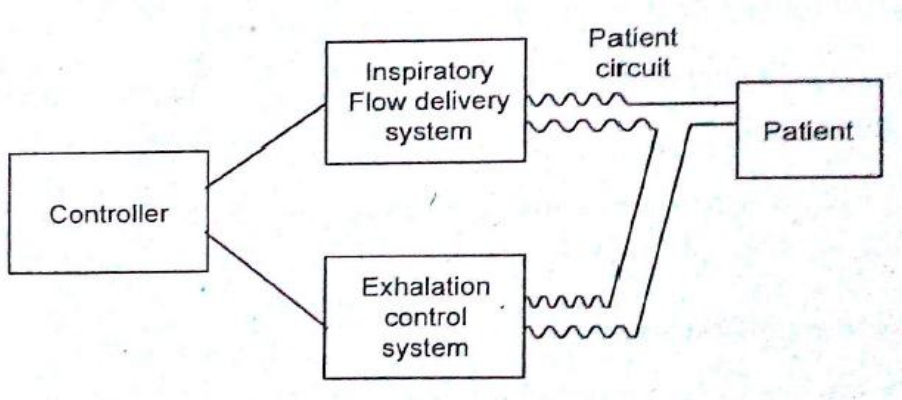

Fig 6.1 Functional diagram of a positive pressure ventilators

6.3 Types of ventilators

Based on the clinical usage, ventilators are categorized by two basic types.

1. Pressure-cycled (positive-pressure assistor) controller
2. Volume-cycled ventilator (volume respirator)

6.3.1 Pressure-cycled

- The first type ventilator is a “Positive-pressure assistor-controller”.

- In this, the device is powered pneumatically from a source of gas and requires no electrical power.
- Device with electrically powered compressor are used to permit ventilation with ambient air.
- It is quiet small and includes all necessary equipments to control the flow of gas.
  - ❖ Sense the patient's effort to inspire.
  - ❖ Terminate the inspiration when the desired pressure is reached.
  - ❖ Permit adjustment of the sensitivity of triggering mechanism and desired pressure level.
  - ❖ Generate a negative pressure to assist expiration.
- Special type of valve with magnet, sense the small negative pressure created by a patient to inhale.
- In the time of operation ***controlled mode*** is used to filling a chamber with gas.

6.3.2 Volume-cycled ventilators

- This is the second category of respirators often called "***volume respirator***".
- Device use a piston to dispense a precisely controlled volume for breathes.
- Where patients have pulmonary abnormalities and require predictable volumes and gas, this type of ventilators are preferred.
- It is ***much large than pneumatically*** operated units.
- Volume respirators are electrically operated and provide much greater degree than pressure cycled types.
- Most devices of this type have adjustable pressure limits and alarms for safety.
- Volume-cycled ventilators used in critical cases and supplied with a spirometer to the accurate monitoring of patient's ventilation.
- Other available features includes,
  - ❖ Heated humidifier
  - ❖ Nebulizers
  - ❖ Aspirators
  - ❖ Optional capabilities negative pressure
  - ❖ PEEP (positive and expiratory pressure)

Humidifier

- ❖ To prevent patient's lungs from damage, air (or) oxygen applied during respiratory, therapy must be humidified.
- ❖ All equipment humidifies the air by ***heat vaporization*** (stream).

Nebulizer

- When therapy requires water, it is ***suspended*** in the inspired air as an aerosol a device used for this process is called ***nebulizer.***
- Using high velocity oxygen it is nebulized and then applied to the patient via a respirator.
- More effective type of nebulizer is ***"ultrasonic nebulizer".***

Aspiration

- It is a part of a ventilators (or) inhalators to remove ***mucus and other fluids*** from airways.

6.4 Non-mechanical methods

- In emergency situation, it is very important to ensure that the air way is clear.
- First, clothing around the neck and chest should be loosened.
- Mouth and throat should be cleared of fluid.
- Tongue should be drawn forward.
- Two non-mechanical methods are,
    1. Holgen-Nielson method (Back pressure arm lift method)
    2. Mouth-to-mouth breathing (Expired air Resuscitation).

6.5 Modern ventilators

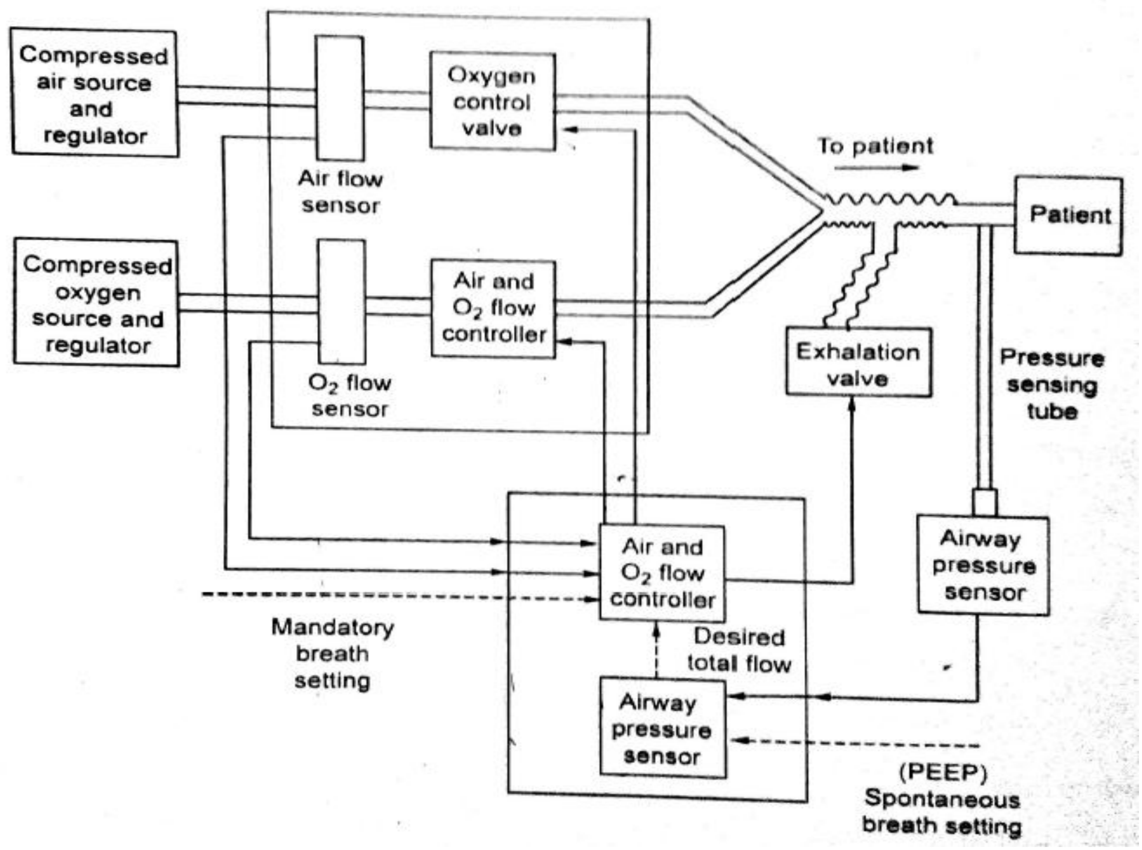

Fig 6.2 Microprocessor based controlled ventilators

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7. Magnetic Resonance Imaging (MRI) Systems

Explain MRI systems in detail.

7.1 Introduction

- Magnetic resonance imaging technique use RF region of the electromagnetic spectra to provide an image.
- First, a patient is placed in an external magnetic field which causes the magnetization of protons of hydrogen atoms in his body.

- Due to magnetization, these protons align and process about the external magnetic field.
- Now, a radio frequency pulse at resonance frequency is transmitted in to the patient under controlled and prescribed condition.
- Due to resonance condition the individual proton responds by emitting a radio frequency signal.
- This is called "**Nuclear Magnetic Resonance *(NMR)*** signal".
- These emitted signals by the protons, during their return from higher nucleus energy states to ground state.
- These are picked by RF coils and processed by computers using Fourier transforming techniques to produce an image.

7.2 Block diagram of MRI system

- The block diagram consists of super conducting magnetic coil, RF transmitter and receiver coil, (X, Y, Z gradient coil), computer and display unit.

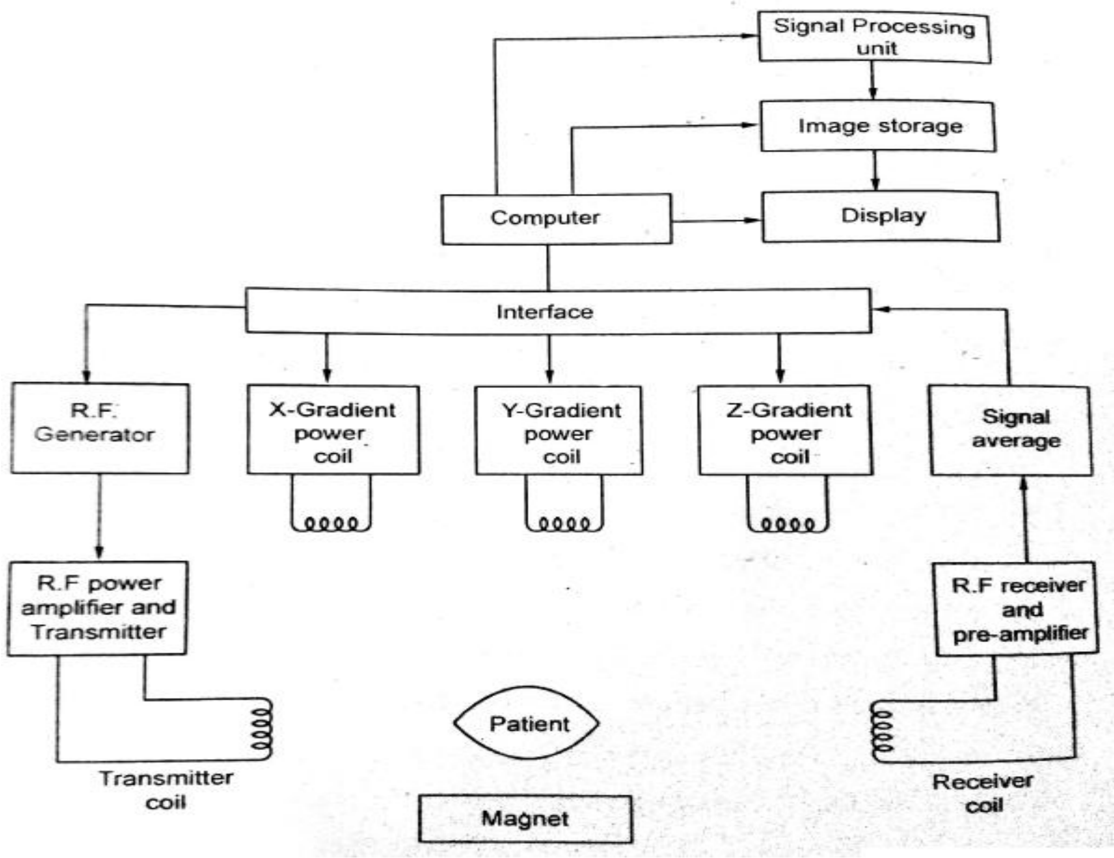

Fig 7.1 Block diagram of MRI system

- There is a super conducting magnetic coil which provides a strong, uniform steady magnetic field
- The coils are used to cool to liquid helium temperature and it can produce very high magnetic field.
- Therefore, the SNR (signal to noise ratio) of the received signals and image quality are better than the conventional magnets used in the MRI system.
- Different gradient coils (X, Y, Z) systems produce a time varying controlled spatial non uniform magnetic fields in different directions.

- By taking a series of these projections at different direction a two (or) three dimensional image can be obtained.
- Now the patient is kept in this gradient field space between the transmitter and receiver RF coils surrounding the site on which the image is to be constructed.
- A superposition of a linear magnetic field gradient on to the uniform magnetic field is applied to the patient.
- When this superposition takes place, the resonance frequencies of the processing nuclei will depend primarily and produces a one dimensional projection of the structure of the three dimensional object.
- The slice of the image depends upon the gradient.
- Magnetic field is controlled by computer and that field can be positioned in three time invariant planes i.e. (X, Y, Z).
- The transmitter provide the RF signal pulses and the received nuclear magnetic resonance signal is picked up by the receiver coil and is fed into the receiver for signal processing.
- By using two dimensional Fourier transformation, the image is constructed by the computer and displayed on the television screen.

7.3 Advantages

- Superior contrast resolution
- Direct multiplaner imaging
- Non invasive imaging technique

7.4 MRI parameter

There are three principal MRI parameters. They are,

- Spin density
- Spin-lattice (Longitudinal) relaxation time, T_1
- Spin-spin (or) transverse relaxation time, T_2

7.4.1 Spin density

- To measure the concentration of mobile hydrogen nuclei available to produce an NMR (Nuclear Magnetic Resonance) signal is called the spin density (SD).

7.4.2 Spin-lattice (Longitudinal) relaxation time, 'T_1'

- The time constant that describes the rate at which the Z-component of net magnetization will return to its equilibrium value.
- M_0 is the T_1 relaxation time and this happen due to the excited nuclei transforming their energy to the surrounding molecular environment, called the lattice and also called as spin-lattice (or) longitudinal relaxation.

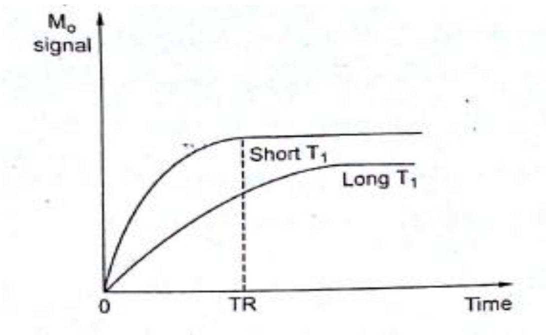

Fig 7.2 Spin-lattice relaxation time, 'T_1'

7.4.3 Spin-spin Relaxation time, 'T_2'

- T_2 represents the time constant associated with loss of magnetization M_{xy} in the XY plane.
- The spin-spin relaxation time is normally measured with a spin-echo pulse sequence involving multiple echoes.
- The relaxation of peak height of a spin echo at time te to the peak height of a FID is

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

A pulse sequence in MRI is basically a set of instructions to the magnet telling it how to make an image.

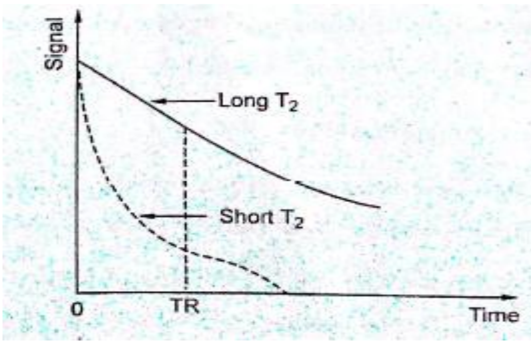

Fig 7.3 Spin-spin Relaxation time, 'T_2'

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8. Ultrasonic Imaging Systems

Explain briefly on ultrasonic imaging systems.

8.1 Introduction

- Ultrasound is a form of energy which consists of mechanical vibrations as the frequencies of high, above the range of human hearing.
- Most biomedical applications of ultrasound employ frequencies in the range of 1 to 15 MHz.
- The velocities of ultrasound in soft tissues and bones are 1570 m/sec and 3600 m/sec.
- Ultrasonic diagnostic aids are based on
    - ❖ Echo aspect
    - ❖ Doppler shift aspect
- Ultrasonic therapeutic aids are based on
    - ❖ The thermal effect
    - ❖ Cavitation effect (developed during the irradiation of ultrasound on the body).

8.2 Doppler ultrasonic blood flow meter

- It is used to determine the flow rate of blood in various blood vessels.
- It can cure cancer and also used to detect the ordinary begin tumors.
- The ultrasonic bondings are useful to fix the fractured bones at their proper place in the body.

8.3 Ultrasonography

- In this technique ultrasonic energy is used to detect the state of the internal body organs.
- When this energy strikes an interface between two issues of different acoustical impedance, reflections (echoes) are returned to the transducer.
- The transducer converts these reflections to an electrical signal.
- This echo signal is amplified and displayed on the oscilloscope at a distance proportional to the depth of the interface.

8.4 Block diagram of ultrasonic imaging instrumentation

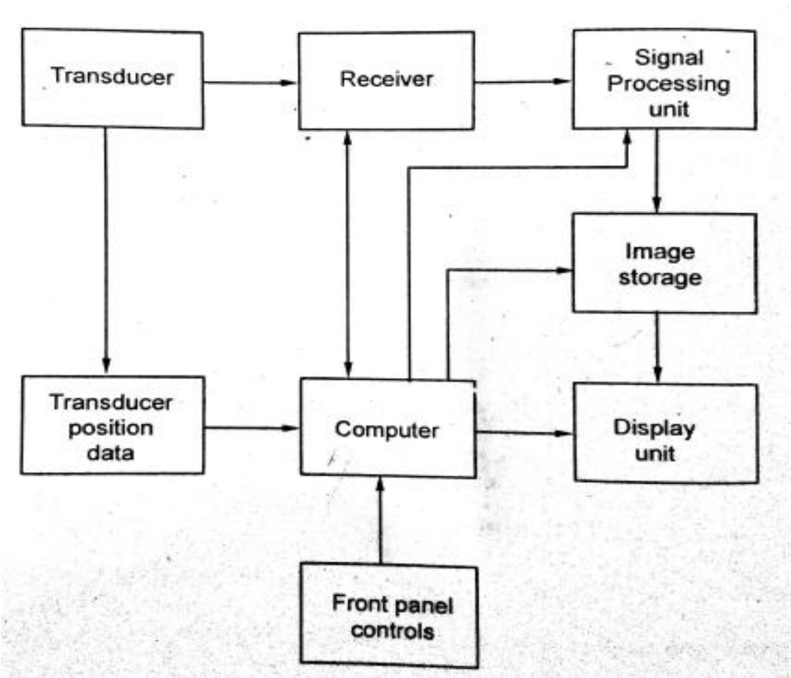

Fig 8.1 Block diagram of a computer controlled ultrasonic image forming system

- The ultrasonic image forming system consist of so many peripheral sub-units such as (transducer data, receiver panel controls, display unit, image storage and signal processing unit) which are controlled by a computer through control buses.
- Computer is the heart of the system.
- Signal processing unit receives information from transducer data through computer and also receiver transducer signal from receiver.
- Receiver sensitivity is controlled by control bus.
- Proper depth gain compensation is calculated by computer and given to signal processing unit.
- Like ultrasonic velocity is calculated and displayed using display unit.

- Past and current status of patient are stored and displayed for detailed examination using ultrasonic imaging technology and the functions are controlled by microcomputer.
- But it is difficult to carry out direct real time image processing.
- Therefore, an ultra high speed analog to digital converter have enabled for straight digitization of high frequency signals.
- Thus, the digital real time scanners are used for displaying ultrasound images.

8.5 Digital Real Time Scanner

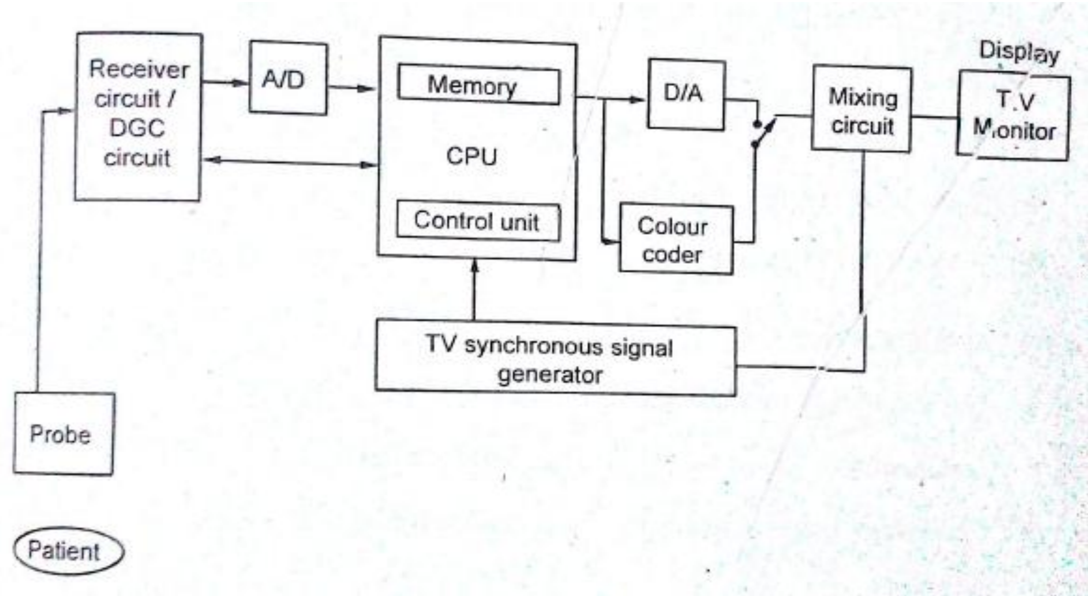

Fig 8.2 Block diagram of real time scanner

- The above block diagram of digital real time scanner consist of receiver / DGC circuit which is used to provide proper depth gain compensation signal and echoes from patient body surface are collected through probe by the receiver unit.
- The received signals are converted into digital signals by using A/D converter and stored in memory.
- Received signals of transducer position, TV synchronous pulses and generated X and Y information about patients which fed in memory are controlled by scan converter.
- The stored digital image signals are processed and colour coded and then given to digital to analog converter.
- Finally, the analog signal is displayed by the TV monitor with higher accuracy.

8.6 Display

The reflected echoes are displayed on the screen as a useful image by the following various modes of display.

- A-mode (Amplitude modulation)
- B-mode (Brightness modulation)
- T-M-mode (Time motion modulation)

8.7 Applications

- Used to find any brain tumor
- Ophthalmology is used to find foreign objects in eye.
- Cardiology is used to determine the cross-section of the heart and to determine heart rate.
- Gynecology is used to monitor the fetus growth and to indicate the presence of twins.

8.8 Limitations

- Bone injury, lung injury and intra-luminal injury of the GI tract cannot be evaluated.
- Ultrasound cannot penetrate gas and bones due to acoustic impedance mismatch at soft tissue (or) soft tissue gas interface.

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UNIT –III

ASSIST DEVICES

Two Marks Question & Answers

1. **What is pacemaker?** **[Apr/May 2011][May/June 2013]**

   A pacemaker is a device which is capable of generating artificial pacing impulses and delivering them to heart is known as pacemaker.

2. **What are the components of pacemaker?**

   Pacemaker components are pulse generator, electrodes and battery.

3. **What are the types of pacemaker?**

   Based on the placement of pacemaker, it is divided into two types namely,

   - Internal pacemaker
   - External pacemaker

4. **What are the types of pacing modes?**

   The pacing modes are classified as competitive mode and non-competitive mode.

5. **How are pulses generated in competitive pacemaker?**

   Competitive pacemaker is used to generate fixed rate pulses. It occurs along with the natural pulses generated by the heart.

6. **Write the classification of pacemaker based on the mode of operation.** **[May/June 2012]**

   Pacemaker is classified into five types based on the mode of operation.

   - Ventricular asynchronous pacemaker (Fixed rate pacemaker)
   - Ventricular synchronous pacemaker
   - Ventricular inhibited pacemaker
   - Atrial synchronous pacemaker
   - Atrial sequential ventricular inhibited pacemaker

7. **What is meant by demand pacemaker?** **[Nov/Dec 2013]**

   The pacemaker which provides the impulses based on the patient's need is known as demand pacemaker.

8. **What are the disadvantages of ventricular asynchronous pacemaker?**

   The disadvantages of ventricular asynchronous pacemaker are,

   - By using this type of pacemaker, the heart beat rate cannot be changed.
   - It may lead to the occurrence of ventricular fibrillation.

9. **Write the advantages and disadvantages of standby pacemaker.**

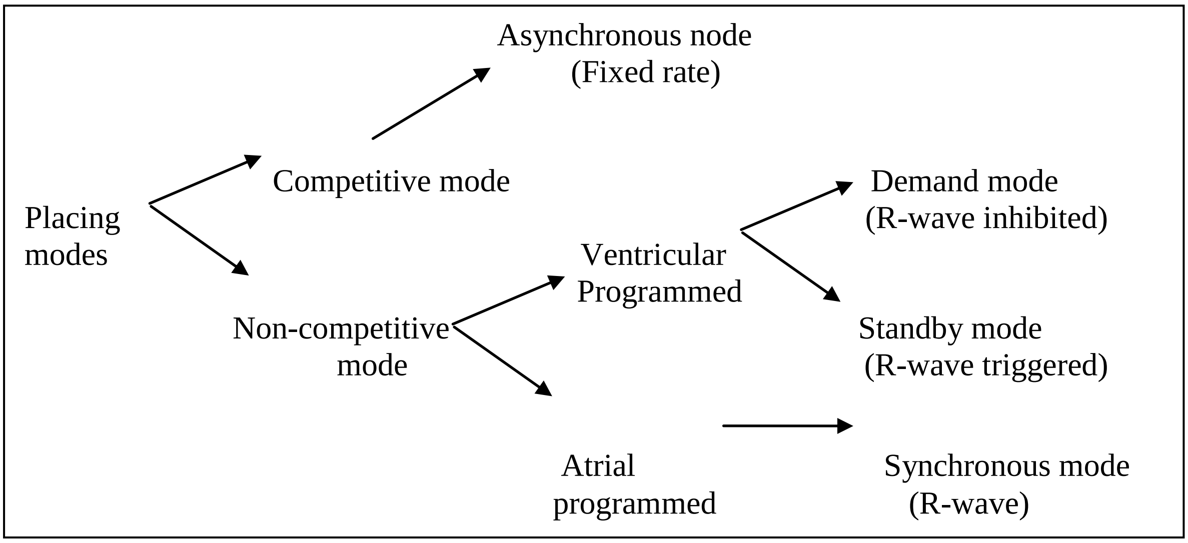
   The advantages of standby pacemaker are,

   - Ventricular fibrillation is avoided by using this pacemaker.
   - Power consumption is reduced.

   The disadvantages of standby pacemaker are,

- This pacemaker is sensitive to electromagnetic interferences.
- There is no synchronism between atrial and ventricular contraction.

10. Classify pacing modes. **[Nov/Dec 2007]**



11. What is fibrillation? What are the types of fibrillation? **[Nov/Dec 2017]**

The condition at which the necessary synchronizing action of the heart is lost is called fibrillation. The types of fibrillation are (i) Atrial fibrillation (ii) Ventricular fibrillation.

12. What are the various electrodes used for defibrillation? **[April/May 2018]**

Internal (spoon shaped) electrodes and External (paddle shaped) electrodes are used for defibrillation.

13. What is the function of synchronous pacemaker? **[Nov/Dec 2008][Nov/Dec 2011]**

Synchronous pacemaker is a device capable of generating artificial pacing impulses and delivering them to heart. It is suitable for patients, who are suffered by short period of AV block.

14. Distinguish between internal pacemakers and external pacemakers. **[April/May 2008]**

S.No	Internal pacemaker	External pacemaker
1.	In this method, entire unit is placed inside the body.	Pulse generator circuit is placed externally. It is connected to the electrodes placed on the myocardium.
2.	It is permanently implanted on the patients whose SA node is failed to function or who suffered from permanent heart block.	It is used for treating the patients suffered from arrhythmias.

15. What is a defibrillator? State its use. **[Nov/Dec 2007][Apr/May 2008]**

- The condition of heart at which the necessary synchronism is lost is known as fibrillation. Defibrillation is the application of an electric shock to the area of heart.
- That is, it is an electronic device that creates a sustained myocardial depolarization of a patient’s heart in order to step ventricular fibrillation and a trial fibrillation.

16. What is meant by defibrillation? [May/June 2007][May/June 2009][Nov/Dec 2010]

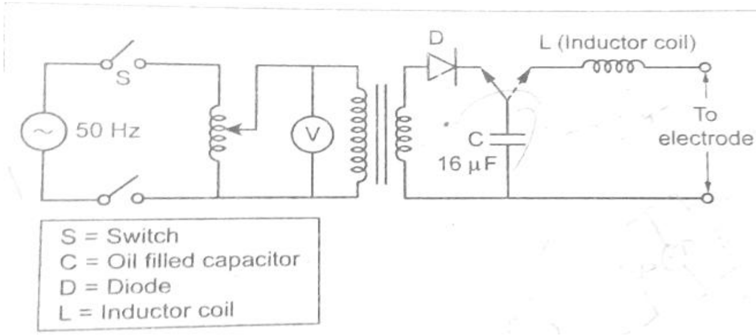
- Defibrillation is the method for producing the electric shock.
- Defibrillator is an electronic device that breath sustained myocardial depolarization of a patient's heart in order to stop ventricular fibrillation.

17. List out the different types of defibrillator electrodes. [Apr/May 2011][April/May 2018]

The different types of defibrillator electrodes are,

- Anterior-Anterior
- Anterior-Posterior

18. Draw the circuit of DC defibrillator and give its output specifications. [Apr/May 2011]



In discharge waveform, the peak value of current is nearly 20A and the wave is monophasic in nature. It means, most of the excursion of the curve is above the base line.

19. Mention the importance of defibrillator protection circuit in ECG recorder. [Nov/Dec 2011]

The defibrillation protection circuit in ECG recorder has buffer amplifiers for each lead electrode, and over voltage protection circuits to protect pre-amplifier and power amplifiers.

20. What is the use of biphasic D.C defibrillator? [Nov/Dec 2007]

The biphasis D.C defibrillator is used to correct the fibrillation effectively.

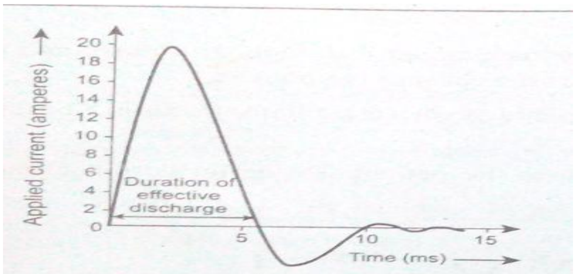
21. What do you understand by fibrillation? How do you correct it? [May/June 2009][May/June 2012]

- The condition at which the necessary synchronism is lost is known as fibrillation.
- Fibrillation of atrial muscles is called as atrial fibrillation and fibrillation of ventricles is known as ventricular fibrillation.
- Fibrillation can be corrected by heart massage or by applying electric shock by a device called Defibrillator.

22. Distinguish a Defibrillator from a pacemaker. [April/May 2008]

Sl.No	Defibrillator	Pacemaker
1.	It is an electronic device that creates a sustained myocardial depolarization of a patient's heart in order to stop the fibrillation.	Pacemaker is a device capable of generating pacing impulses and delivering them to the heart.

23. Draw the defibrillator output waveform and indicate the output energy level. [Nov/Dec 2012]



(a) DC defibrillator discharge waveform

The output energy level is 50 to 200 watts/sec (or) Joules.

24. What is counter shock?

The phenomenon of application of an electrical shock to resynchronize the heart is known as counter shock.

25. What is meant by monophasic waveform?

Monophasic means most of the excursion of curve is above the baseline.

26. What is dialysis? [May/June 2009]

Dialysis is a process by which the waste products in the blood are removed and restoration of normal pH value of the blood is obtained.

27. Mention the important process of diffusion. [May/June 2007]

The important processes of diffusion are

- Diffusion
- Osmosis
- Ultrafiltration.

28. Name the two types of dialysis. [Apr/May 2008]

The two types of dialysis are,

- Peritonial dialysis
- Haemodialysis

29. What is the use of proportioning pump?

The proportioning pump is used to mix the pure water with dialysate. Usual ratio of water and concentrate is 34: 1.

30. Write the principle of haemodialysis. (or) What is the function of haemodialysis system? [Apr / May 2008][April/May 2018]

Blood is purified by an artificial kidney machine (Haemodialyzer), in which blood is taken out from the body and waste products diffuse through a semi permeable membrane which is continuously rinsed by a dialyzing solution.

31. What is the pH value of arterial blood and venous blood? [Nov/Dec 2007]

- pH value of venous blood = 7.35
- pH value of arterial blood = 7.40

32. Define the parameter, Oxygen saturation and mention its use.

- Measurement of O2 saturation will give indication of effectiveness of cardio-pulmonary system.
- High oxygen saturation in right side of heart will indicate abnormalities in the heart and major vessels representing inability of the issue to metabolize oxygen.
- Low O_2 saturation in left side of heart will indicate reduced ability of the lungs to oxygenate the blood.

33. What is heart lung machine?

The machine which can provide extra corporeal circulation to the patient is known as heart lung machine.

34. Explain the principle of telestimulation. [April/May 2008][Nov/Dec 2011][Nov/Dec 2012]

Telestimulation is the measurement of biological signal over long distances.

35. What is the need for grounding in medical equipments? [April/May 2008]

Grounding is needed in medical equipments to avoid the macro shocks. The leakage current is also reduced by proper grounding.

36. What are the differences between extracorporeal dialysis & Extracorporeal Dialysis? [Nov/Dec 2017]

Sl.No	Extra Corporeal Dialysis (Haemodialysis)	Intra Corporeal Dialysis (Peritoneal dialysis)
1.	Blood is purified by an artificial kidney machine (Haemodialyser), in which blood is taken out from the body and waster products diffuse through a semi permeable membrane which is continuously rinsed by a dialyzing solution.	The peritoneal cavity in out body is used as semi permeable membrane and by passing the dialysate into it, waste produces are removed from the blood by diffusion.
2.	More effective for separating the waste products.	Less effective
3.	Complex and risk, because blood is taken out from the body.	Simple and risk free.
4.	Dialyzing time is about 3 to 6 hours.	Dialyzing time is bout 9 to 12 hours.

37. Why glass electrode is very much preferred as active electrode in a pH meter? [April/May 2008]

- The glass electrode provides a membrane interface for H’ ions. So that, it is preferred as an active electrode in pH measurement.
- The pH meter with hydroscopic glass observes the water readily and provides best pH value.

38. Why do we require heart lung machine?

At the time of open heart surgery, it is necessary to use the artificial heart lung machine, because the doctor has to do the surgery in heart. Hence the heart cannot maintain the circulation. Also, it is necessary to provide extra corporeal circulation with this machine.

39. What are the requirements met by oxygenators? [May/June 2012]

Oxygenator does the function of lungs. The oxygen is mixed with small percentage of CO_2 (2.5%). Oxygenator should oxygenate 5 liters of blood per minute. Blood is given to oxygenator for purification.

40. Give the different type of oxygenators used in heart lung machine. [Nov/Dec 2012]

Oxygenators used in heart lung machine are,

- Bubble oxygenator
- Film oxygenator
- Membrane type oxygenator
- Liquid liquid oxygenator

41. Calculate the energy stored in 16 μF capacitor of a DC defibrillator that is charged to a potential of 5000 Vdc. [April/May 2019]

Given: C = 16 μF; V = 5000 Vdc

Soln:

$$C = (1/2)\ CV^2$$

$$C = (1/2) \times 16 \times 10^{-6} \times 25 \times 10^{6}$$

$$C = 200 \text{ Joules}$$

42. What are the types of batteries used for implantable pacemaker? [April/May 2019]

The types of batteries used for implantable pacemaker are

- Mercury cell
- Lithium cell
- Nuclear cell

43. Write down the advantages of DC defibrillator over AC defibrillator? [Nov/Dec 2018]

- In AC defibrillator, when atrial fibrillation is corrected by applying electric shock, then serious ventricular fibrillation occurs.
- DC defibrillation is capable of correcting both the atrial fibrillation and ventricular fibrillation.

44. What is ventilator?

Ventilator is a device used in intensive care unit to provide oxygen enriched, medicated air to a patient at a controlled temperature. Ventilators can operate in different modes such as controlled mode and assist mode.

45. What are the types of ventilator?

Based on the clinical usage ventilators are categorized into two types.

1. Pressure-cycled (positive-pressure assistor) controller
2. Volume-cycled ventilator (volume respirator)

46. What is the need for ventilator?

- It is used to provide artificial respiration.

- Artificial respiration should be applied to the patient, whenever respiration is suspended due to reasons like gas poisoning, electric shock etc.

47. What are the important parameters of MRI?

There are three principal MRI parameters. They are,

- Spin density
- Spin-lattice (Longitudinal) relaxation time, T_1
- Spin-spin (or) transverse relaxation time, T_2

48. What is ultrasonography?

- A technique in which ultrasonic energy is used to detect the state of the internal body organs.

49. Differentiate internal and external defibrillator. [Apr/May 2017][Nov/Dec 2016]

- Internal defibrillator is used during open heart surgery. Here a large spoon shaped electrodes with insulated handle are used.
- External defibrillation is used on the heart using a paddle shaped electrodes.

50. Distinguish between endocardiac and myocardiac electrodes. [Nov/Dec 2016]

Myocardiac electrodes	Endocardiac electrodes
Myocardiac electrodes are used in internal pacemaker.	Endocardiac electrodes are used in external pacemaker.
Myocardiac electrodes are in contact with the outer wall of the myocardium (heart muscle).	Endocardiac electrodes are applied to the heart. They are in contact with the inner surface of the heart chamber.

51. What is dialysate? Mention its composition. [Nov/Dec 2018][Apr/May 2017]

- The main function of the dialysate is to remove waste material from the blood and to keep useful material from leaving the blood.
- Electrolytes and water are some materials included in the dialysate so that their level in the blood can be controlled.
- The general compositions of dialysate are sodium chloride, sodium bicarbonate, calcium chloride, potassium chloride and magnesium chloride.

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PHYSICAL MEDICINE AND BIOTELEMETRY

Diathermies – Shortwave, Ultrasonic and microwave type and their applications, Surgical Diathermy, Biotelemetry

1. DIATHERMY

Explain the working principle of a diathermy unit with a neat block diagram. [Nov/Dec 2016][April/May 2016][May/June 2006][April/May 2008][Nov/Dec 2016]

1.1 Introduction

- When heat is applied to the particular area of the body, the temperature of the tissue increases.
- Due to dilation of blood vessels, the flow of blood increases at that area.
- Various methods are used to raise the tissue temperature.
- One of them is called as external method or conductive heating.
- The main disadvantage of this method is, it increases the skin temperature but the heat does not penetrate very deeply into the body.
- The devices used for the purpose of external heating are hot compressors, infra-red lamp, etc.
- The externally used heat sources like hot towels, heat lamps, and heating pads often produce inconvenience and discomfort to the patient.
- This results in the burning of skin before the penetration of adequate heat to the deeper tissues.
- Hence to overcome such demerits, diathermy technique is adopted.
- In this method the patient's body becomes a part of electrical circuit, hence heat is produced within the body instead of transferring through the skin.
- Diathermy is the treatment process by which cutting, coagulation of tissues are obtained.

1.2 Advantages of Diathermy

The advantages of diathermy technique are as follows,

- The treatment can be controlled easily.
- Use of appropriate electrodes permits the heat to be localized only in the region to be treated.
- Amount of heat that is to be delivered can be adjusted accurately.
- Inter lying tissues, muscles, bones, internal organs, etc., can be provided with heat by using high frequency energy.

1.3 Types of Diathermy:

The types of diathermy techniques used are as follows:

- Short-wave diathermy
- Microwave diathermy
- Ultrasonic diathermy

- Surgical diathermy

The short-wave and microwave diathermy involves electromagnetic effects and the ultrasonic diathermy uses mechanical effect.

1.3.1 Short-wave Diathermy

Draw the block diagram of short wave and microwave diathermy and explain in detail. [April/May 2019][May/June 2016][April/May 2018][Nov/Dec 2017][April/May 2017][Nov/Dec 2016]

- Short-wave diathermy involves high frequency of 27.12 MHz and wavelength of 11m.
- Since high frequency currents are used, the motor and sensory nerves are not stimulated and there is no muscle contraction.
- This method has no discomfort to the patient.
- The basic operation of the short-wave diathermy unit can be explained with the help of block diagram as shown below.

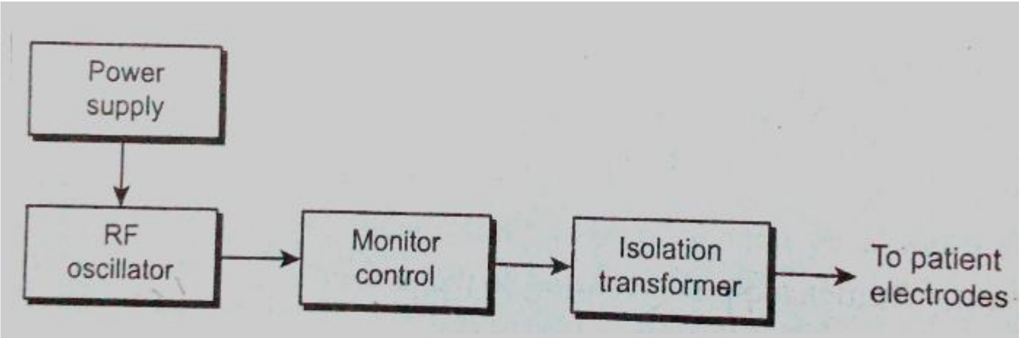

Fig 1.1 Short-wave diathermy unit – Block diagram

- The output of RF oscillator is given to the patient electrodes.
- The RF energy heats the tissues and helps in heating of injured tissues.
- The power delivered by the unit is about 500 W.
- The intensity of the current used can be regulated and adjusted.
- The electrodes are not directly in contact with the skin.
- Usually layers of towels are interposed between the metal and surface of the body.
- There are two methods of short-wave diathermy, they are:

  (i) Capacitive method

  (ii) Inductive method

Capacitive method

- Here, the patient electrode pads form a capacitor plates and the body tissues between the pads act as a dielectric.
- Thus the whole arrangement forms a capacitor.
- When the RF current is applied to the electrodes, the capacitor produces heat in the interlying tissues.
- This technique is called as capacitive method.

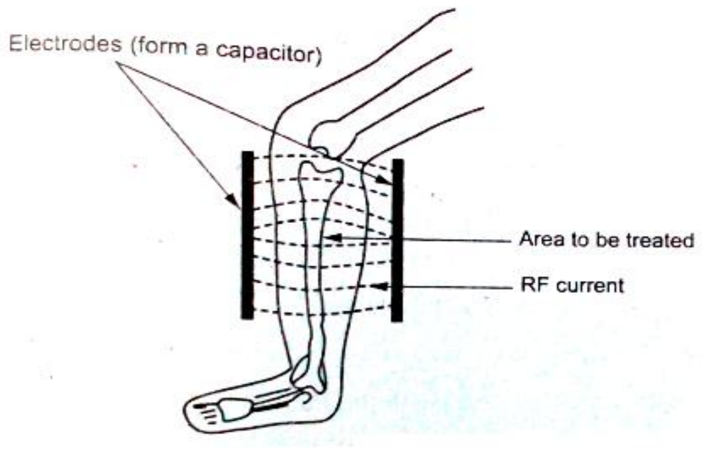

Fig 1.2 Capacitive method

Inductive method (Inductothermy)

- In the inductive method a flexible cable is coiled around the arm or knee or any other portion of the body which is to be treated.
- This is used where the plate electrodes are inconvenient to use.
- When the electrostatic field set up is given between the ends of the cable, deep heating of the tissue occurs.
- The superficial tissues are heated by the eddy currents that are produced due to the magnetic field around the cable. This technique is also called as ***Inductothermy.***

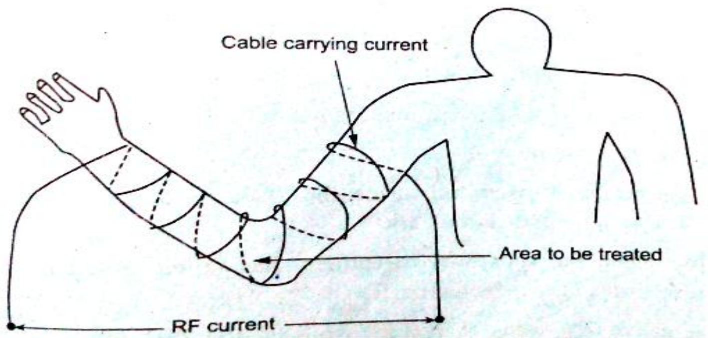

Fig 1.3 Inductive method

- Then instead of using continuous RF waves, RF pulses are used.
- This technique is called Diapulse short-wave diathermy.

Advantages:

- Heating rate of tissue is increased.
- Depth of penetration of RF waves can be easily adjusted.
- There is no danger of burns or irritation and the patient has no discomfort.

1.3.2 Microwave Diathermy

- In this method the tissues are heated by the absorption of microwave energy.
- The frequency used is about 2450MHz with a corresponding wavelength of 12.55 cm.

- Better results are obtained by the microwave method and it is more advantageous than the short wave method.
- Here, there is no usage of pad electrodes and flexible cable.
- Microwave is transmitted into body and treats directly from the direction of the unit.
- Usually microwaves are produced with the help of magnetron.
- A time period of 3 to 4 minutes is required for heating of magnetron.
- A lamp light arrangement is provided to indicate that the magnetron is ready to deliver its output.
- Proper cooling arrangements are made for the purpose of cooling the magnetron.

Precautions

- Necessary precautions should be taken during this method of treatment.
- Excessive dosage causes skin burns and the skin should be dry as the waves are rapidly absorbed by water.

Disadvantages

- Patients with implanted pacemaker should not undergo this treatment.
- There are possibilities of overheating.
- Care should be taken while the treatment is made near the eyes.

1.3.3 Ultrasonic Diathermy

- Ultrasonic diathermy is used for curing the diseases of peripheral nervous system, skeletal muscle system and skin ulcers.
- It is adopted when the short-wave treatment has failed and it helps to achieve the localization of heat to the affected part.
- The heating effect is produced in the tissues by the absorption of ultrasonic energy.
- The absorption effect is similar to that of a micro massage.
- Ultrasonic massage is better than the manual massage because the micro massage provides a greater depth of massage without causing any pain to the patient.

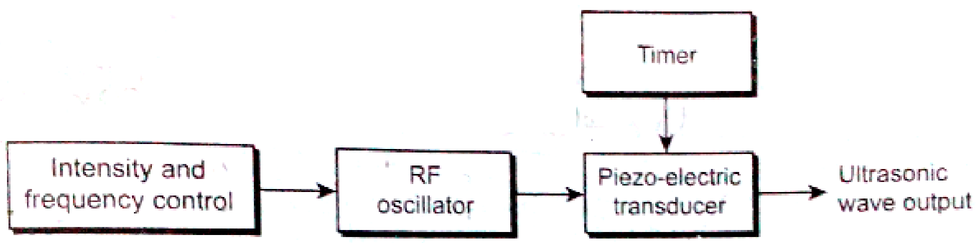

Fig 1.4 Block diagram of ultrasonic diathermy

- The piezo-electric transducer is excited by the high frequency alternating current produced by the RF oscillator.
- The ultrasonic output waveform from the piezo electric transducer is used for the purpose of treatment.

- ❖ The ultrasonic waves can be applied in continuous mode or pulse mode.
- ❖ Micro massage is obtained without any thermal heating in the pulsed mode.
- ❖ The metal face plate in the crystal is made to vibrate due to the oscillations of the crystal and ultrasonic waves are emitted from this plate.
- ❖ The frequency range of 800 KHz to 1 MHz is suitable for the ultrasonic method of treatment.
- ❖ The timer is an electrically operated contact which can be set upto 15 minutes and gets switched off after the preset time.
- ❖ The transducer probe is in direct contact with the patient and it can be moved up and down or circularly around the treatment area for uniform distribution of ultrasonic energy.

1.3.4 Surgical Diathermy

Write short notes on Surgical Diathermy. ***[May/June 2016]***

Explain the working principle of surgical diathermy unit with a neat block diagram. ***[Nov/Dec 2018]***

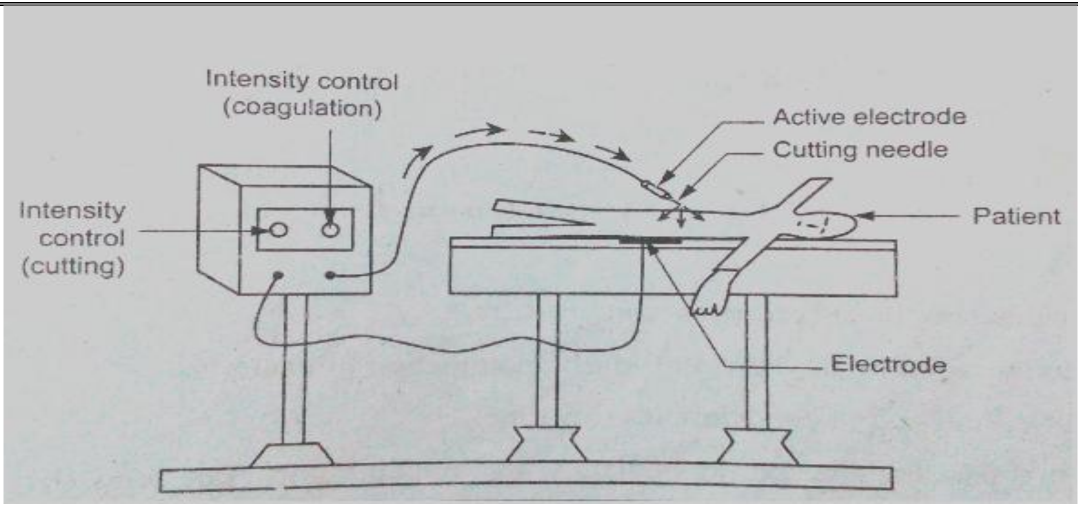

Fig 1.5 Surgical diathermy machine

- ❖ Apart from the thermal and therapeutical applications, the high-frequency currents are also used for surgical purposes like cutting and coagulation.
- ❖ The frequency of current used here is 1 to 3 MHz (low-frequency currents are not suitable for this method).

Cutting

- ❖ When a high frequency current flows through sharp edge of a wire or the point of a needle into the tissue, there is a high concentration of current at this point.
- ❖ The tissues get heated and as a result the cells immediately under the electrode are torn apart by the boiling of cell fluid.
- ❖ The other electrode called indifferent electrode has large area of contact with the patient and the RF current passed through it induces only a very little heat at the electrode.
- ❖ This type of tissue separation is called as electrosurgical cutting.

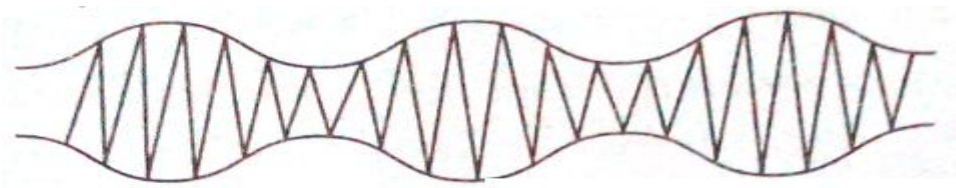

Fig 1.6 Cutting RF waveform

Coagulation

- The coagulation process is achieved by the high frequency current flowing through the tissue and results in heating and coagulation.
- The process of coagulation is accompanied by a grayish-white discoloration of the tissue at the edge of electrode.
- Better coagulation is achieved by high frequency currents as this does not cause burning.
- The continuous radio-frequency current is used for cutting and burst wave radio-frequency is used for coagulation.
- The electrode melts through the tissues and seals capillaries and other vessels. Even if the high-frequency surgery is not used, the method of electro-coagulation can be used.

Fig 1.7 Coagulation waveform

Advantages

- It provides simple and effortless surgery.
- This coagulation method prevents the contamination of bacteria.
- Simplified method of coagulation saves time.
- Bleeding can be arrested immediately by touching the spot with the coagulation electrode.

1.3.4.1 Electrosurgical diathermy

- Center logic board is used to produce the waveform for cutting, coagulation, etc.
- Astable multivibrator is used to generate the required pulses.
- 250 KHz frequency signal is used for cutting.
- The generated frequency is given to the power amplifier.
- Here, push pull amplifier is used.
- The transformer is used at the output of the push-pull amplifier.
- So, stepping up and stepping down is possible.
- Class B – push pull amplifier is shown in the figure.
- Audio tone generator is used to heat the 1 KHz signal which is used for coagulation.

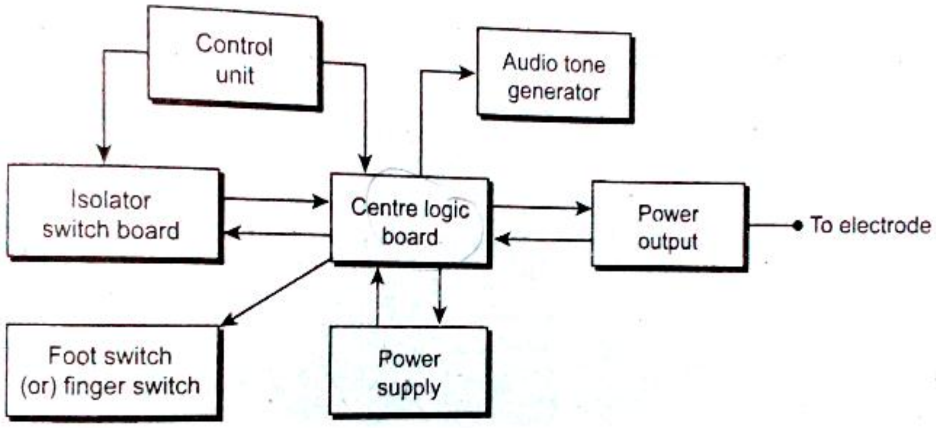

Fig 1.8 Block diagram of electrosurgical diathermy

- Isolation switch board is used to provide the isolation between main supply and the diathermy blocks.
- Foot switch is used to avoid the explosion formed by the existence of anesthesia gas used for the patient near the electrical contact.
- Now, finger switch is mostly used, because, in emergency, the persons in the operating room can press the foot switch without the proper preparation.
- So, the operator gets the supply by using Finger switch only.

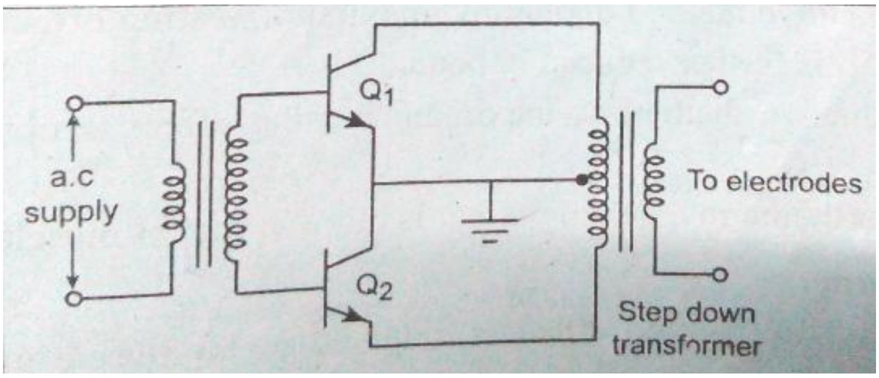

Fig 1.9 Class-B push-pull amplifier

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2. **Bio Telemetry**

What is bio telemetry? Explain the working of single channel and multi channel ECG telemetry system. [May/June 2016][Nov/Dec 2007][May/June 2006]

What are the components of biotelemetry system? Briefly discuss about biotelemetry. [April/May 2019]

Describe the working of biotelemetry system. [Nov/Dec 2018]

- Bio-telemetry is the measurement of biological parameters over long distances.
- For conveying biological information from a living organism and its environment to a different location where this can be recorded.
- This involves radio frequency signal as a carrier for modulation, referred to as radio-telemetry.

2.1 Elements of Biotelemetry

The essential blocks of a bio-telemetry system are shown below.

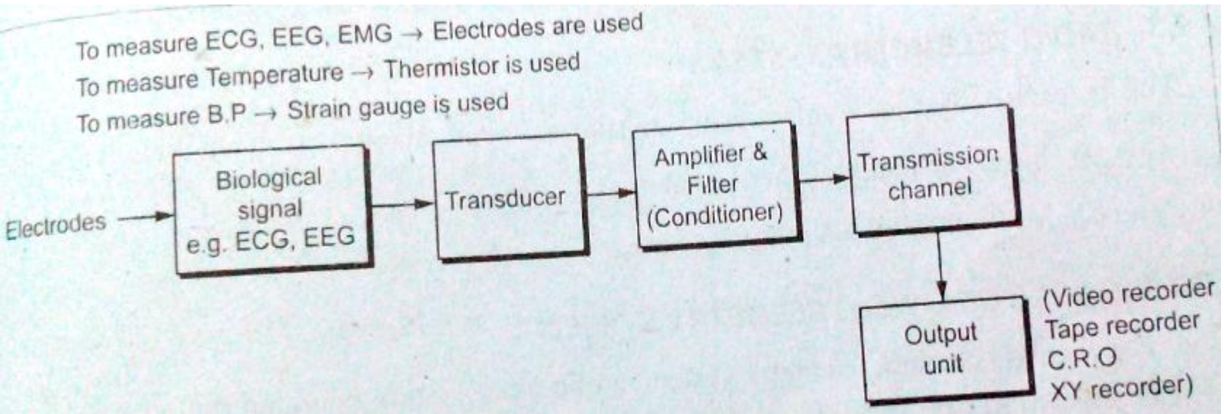

Fig 2.1 Block diagram of a bio-telemetry system

- ❖ The biological signal may be ECG, EEG, and EMG.
- ❖ The biological information is converted into corresponding electrical signal by using transducer.
- ❖ It converts one form of energy into another form.
    - For measuring ECG, EEG, EMG → Electrodes act as transducer
    - For measuring temperatures → Thermistor is used as transducer
    - For measuring blood pressure → Strain gauge is used as transducer
    - For measuring stomach pH → Glass electrode is used as transducer
- ❖ The signal (electrical) is not sufficient for transmission because they are weak in nature.
- ❖ So sufficient amplification and condition is needed.
- ❖ For that purpose conditioner element is provided.
- ❖ The transmission link provides a link between the transmitter and receiver. i.e, it changes the electrical signal sufficient for transmission.
- ❖ It modulates the signal as frequency modulated and allow for transmission.
- ❖ The read out devices are used to read the received signal.
- ❖ Some of the read out devices are video recorder, tape recorder, cathode ray oscilloscope, x-y recorder.

2.2 Design of Biotelemetry

- ❖ The telemetry system should be selected to transmit the bio-electric signal with maximum fidelity and simplicity.
- ❖ The system should not affect the living system by any interference.
- ❖ Smaller in size and light in weight.
- ❖ It should have more stability and reliability.
- ❖ The power consumption at the transmitter and the receiver should be small.
- ❖ The system should reject common mode interference rejection i.e., High CMRR can be provided to the system by using differential amplifier.

❖ The miniature radio telemetry system should be used to reduce noise.

2.3 Radio Telemetry Systems

With suitable diagram, explain how the ECG signal can be transmitted using single channel telemetry systems. ***[Nov/Dec 2016][April/May 2017][April/May 2018]***

The telemetry system involves radio transmission and reception of biosignals. They are:

(i) Single channel telemetry system

(ii) Multi channel telemetry system

2.3.1 Single channel telemetry system

❖ For a single channel telemetry system, a miniature battery operated radio transmitter is connected to the electrodes of the patients.

❖ The transmitter broadcasts the biopotential to a remote place in which the receiver detects the radio signal and recovers signal for further processing.

❖ The receiving system can even be located in a room separately from the patients.

❖ The only risk is shock to the patient.

❖ It is due to the battery powered transmitter itself.

❖ Since it is kept low, there is negligible risk to the patient.

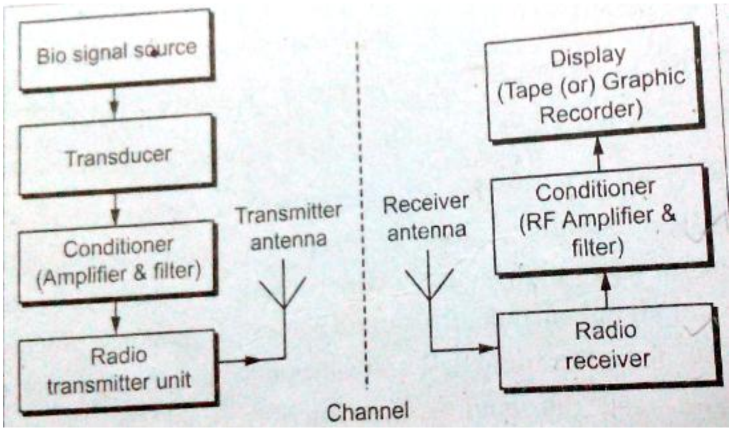

Fig 2.2 Block diagram of a typical single channel telemetry system

❖ Biosignal from the patient is converted into electrical signals by the transducer.

❖ Then they are amplified and filtered at the conditioner.

❖ Further they are frequency modulated or pulse modulated.

❖ Frequency modulation provides the high noise interference rejection and high stability.

❖ Amplitude modulation is not adopted because when relative motion occurs between transmitter and receiver, the signal amplitude will be varied and thus introduces serious error.

❖ The biosignals are amplified to radio frequency range of few hundred KHz to about 300 KHz and then they are transmitted by transmitter antenna.

❖ At radio receiver the corresponding frequency are received and then they are demodulated, amplified and displayed.

Transmission of Bioelectric variables – Various methods

(i) Active measurements: Bioelectric variables like ECG, EMG and EEG are measured directly without using any excitation voltage.

(ii) Passive measurements: The physiological variables like blood pressure, temperature, blood flow are measured indirectly by using this method. The bridge unbalance voltage obtained from the variations of these variables is measured.

1. Tunnel Diode FM Transmitter (For transmitting ECG, EEG, EMG, and Respiration Rate)

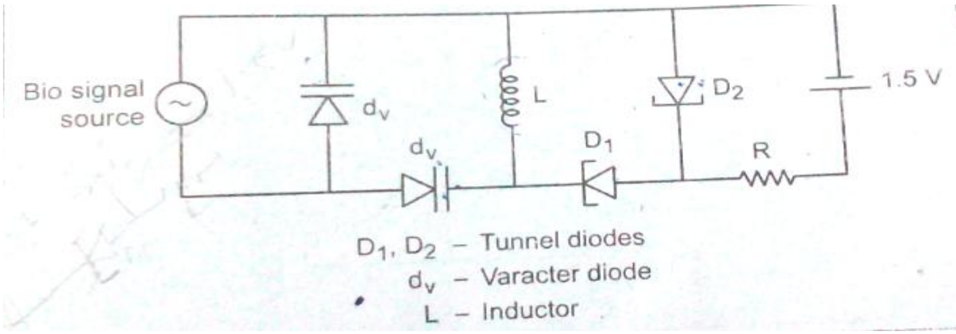

Fig 2.3 Single channel FM transmitter

- The tunnel diodes exhibit a specific characteristic known as negative resistance.
- They have extremely low values of inductance and capacitance.
- It is used for the transmission of EMG, ECG, respiration rate, etc.
- In this type, tunnel diodes are used as active devices and this circuit has higher fidelity and sensitivity.
- Total weight is 1.44 gm with battery and the size is small.
- These are the advantageous factors of this circuit. Some specifications are given below.
    - (a) Radio frequency used is 100 to 250 MHz
    - (b) Frequency range is 0.01 Hz to 20 KHz
    - (c) Input impedance is 300 KΩ to Mega Ωs
    - (d) Temperature stability of carrier frequency is 0.05% / ^{o}C
- Varactor diode is basically a reverse biased PN junction which utilizes the inherent capacitance of depletion layer.
- Varactor diodes (d_V) are voltage capacitors used for frequency modulation.
- The other names of varactor diode are varicap, voltcap, tuning diode.
- The signal is transmitted through the inductor 'L' of the tank circuit of RF oscillator.

Advantages

- All the signal can be transmitted by using this circuit
- No shielded room is needed.
- Interference is much reduced.

2. Hartley type FM transmitter

- It consists of two stages, first stage is known driver amplifier stage and second stage is known as oscillator circuit stage.
- R_4, R_5, R_1, R_2, R_3 are used as Biasing Resistors.
- The capacitor C and inductor L form the tank circuit component of Hartley oscillator.
- The capacitor C_1 is coupling capacitor.
- Q_1 is the driver amplifier transistor and it drives the next stage.

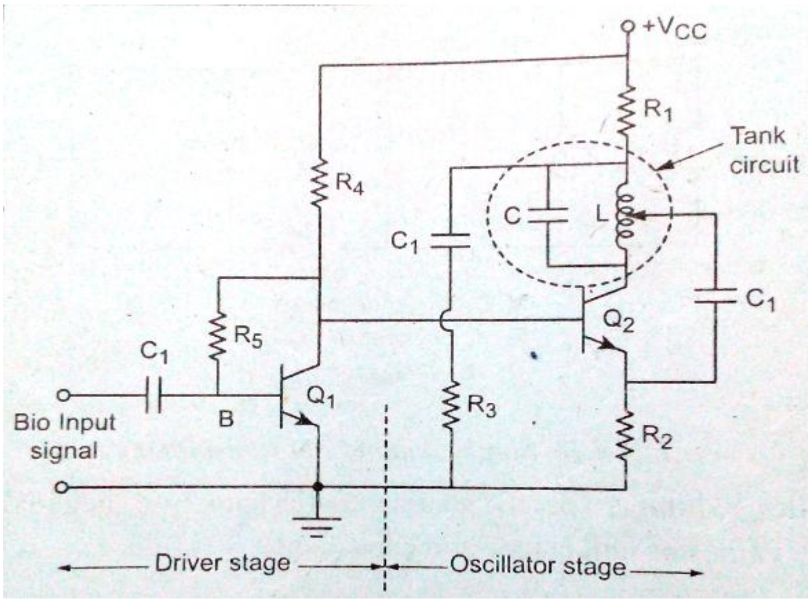

Fig 2.4 Hartley type transmitter

- Q_2 transistor is used in oscillator circuit.
- By using LC tank circuit, the specified frequency can be designed.
- The capacitance between the emitter and base of transistor (V_{BE}) is voltage sensitive and is used to modulate the carrier frequency.
- Amplitude of input signal may vary from 10 µV to several millivolts.
- The distance between T_X and R_X is varied from few meters to 30 meters.
- Bandwidth of the signal is varied from 100 Hz to 1 KHz.

3. Pulsed Hartley Oscillator (Transmission of Temperature Signals)

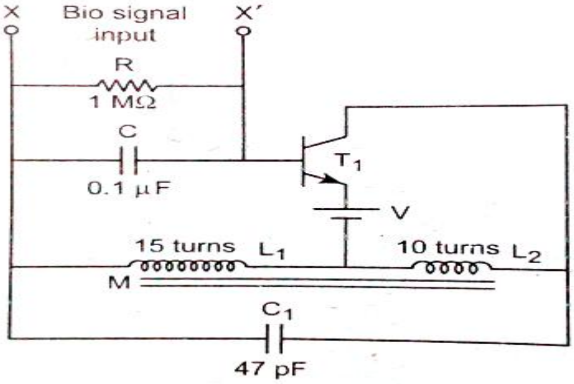

Fig 2.5 Pulsed Hartley oscillator

- It is used for transmission of temperature signals.
- L1, L2, C1 forms the tank circuit of Hartley oscillator.
- To measure temperature, a thermistor is placed in the place of R.
- To measure pressure, the pressure changes should be given to move the core 'M'.
- To measure pH or any voltage, suitable electrodes are connected in the input side.
- The transducer and conditioner are integrated into the components of the oscillator-transmitter.
- Continuous wave operation can be obtained by reducing the value of resistor R.

Advantages

- The circuit is simple.
- It consumes low power (from 5 μW to 10 μW)

Disadvantages

- Error can be produced by the power supply voltage variations.
- Interference can be generated over wide frequency band (due to self blocking pulsed carrier mode operation).

Radio Telemetry with Sub-carrier system

Explain the working of a biotelemetry system with sub-carrier.	***[Nov/Dec 2017]***

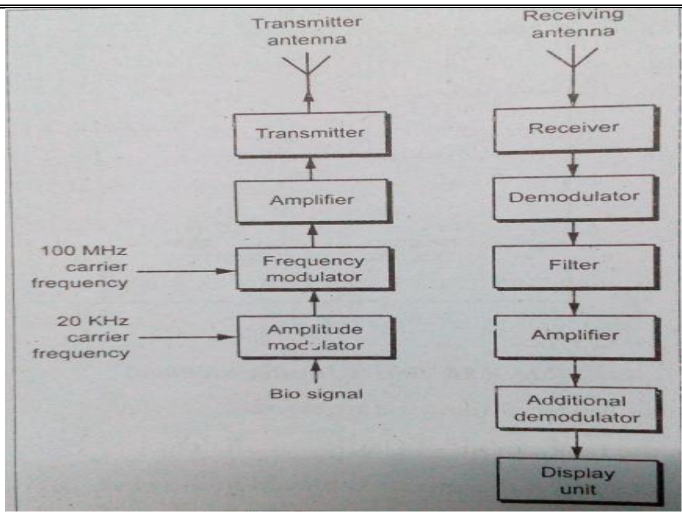

Fig 2.6 Bio-telemetry using sub-carrier system

This system is used for continuous measurement.

Need of Sub-carrier System

At the transmitter side:

- When the position of transmitter to the body or other conduction object change, the carrier frequency and amplitude will change, due to the loading change of the carrier frequency resonant circuit.
- If the signal has a frequency different from the loading effect, they can be separated by filters.
- Otherwise the real signal will be distorted by loading effect.
- To avoid this loading effect the sub-carrier system is needed.

- The signal is modulated on a sub-carrier to convert the signal frequency to the neighborhood of the sub-carrier frequency.
- Then the R.F carrier is modulated by this sub-carrier carrying the signal.
- The 20 KHz sub-carrier signal is given to amplitude modulator.
- It is then given to frequency modulator circuit to frequency modulate the 100 MHz R.F carrier.
- The signals are amplified and forwarded to the transmitter.

At the receiver side:

- At the receiver end, the receiver detects the R.F and recovers the sub-carrier carrying the signal.
- At the receiver side, the signals are passed to demodulator, demodulated signal is filtered, amplified by amplifier and then they are given to additional demodulator.
- It is used to convert the signal from the modulated subcarrier and to get the original signal.
- Finally this signal is displayed.

2.3.2 Multi Channel Telemetry system

******Write short notes on frequency selection for telemetry applications. [April/May 2016]***

Need

- For most biomedical applications, simultaneous recording of bio signals are required for correlation study.
- Each signal is in need of one channel.
- When the number of channels is more than the two or three, the simultaneous operation of the several single channels is difficult.
- At that time multiple channel (multiplex) telemetry system is adopted.
- Two types of multiplexing are used.

    (i) FDM

    (ii) TDM

(i) Frequency Division Multiplex system (FDM)

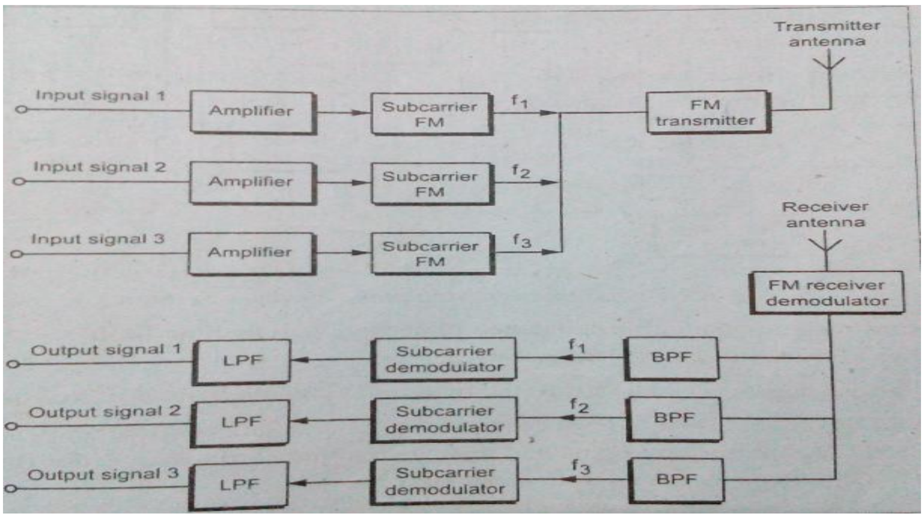

Fig 2.7 Frequency Division Multiplex System

- Each signal is frequency modulated on a sub-carrier frequency.
- Then these modulated sub-carrier frequencies are combined to modulate the R.F carrier.
- Then they are transmitted by using the FM transmitter and antenna.
- At the receiver side the modulated sub-carrier can be separated by the proper band pass filter.
- Then the each signal is demodulated by using specified frequency.
- The frequency of the sub-carrier has to be carefully selected to avoid interference.
- The low pass filter is used to extract the signals without any noise.
- Finally, the output unit displays the original signal.

2. Time Division Multiplex Telemetry System

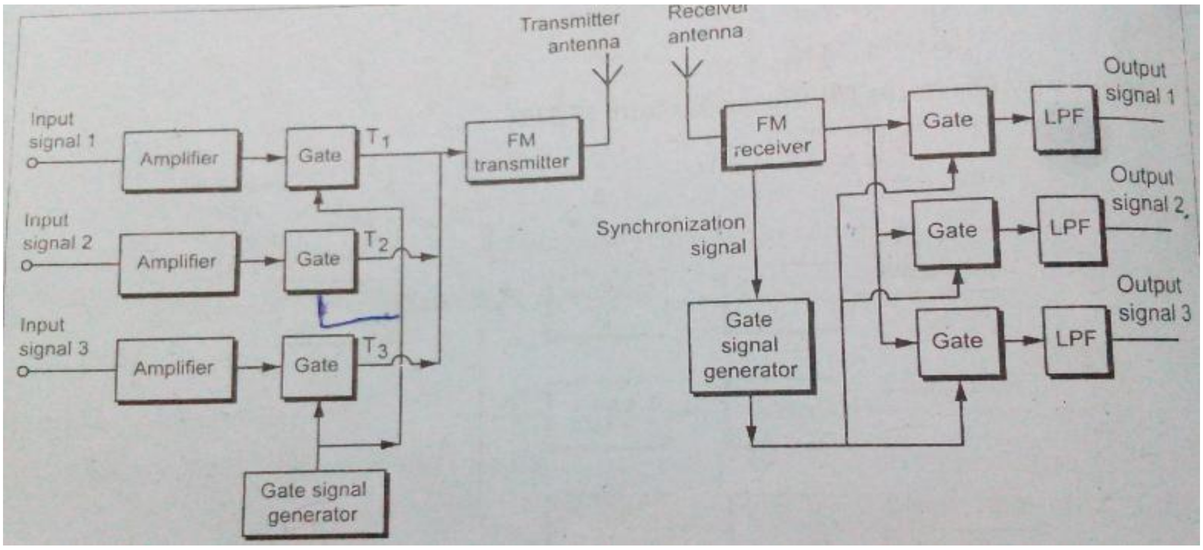

Fig 2.8 Time Division Multiplex Telemetry System

- Since most biomedical signals have low frequency bandwidth requirement, we can use time division multiplex system by time sharing scheme.
- The transmission channel is connected to each signal channel input for a short time to sample and transmit that signal.
- Then the transmitter is switched to the next input signal channel in a definite sequence.
- When all the channels have been scanned once, a cycle is completed and the next cycle will start.
- Scanning follows an order from signal 1 to signal 3.
- At the receiver, the process is reversed.
- The sequentially arranged, signal pulses are given to the individual channels by using Gate signal Generator.
- If the number of scanning cycles per second is large and if the transmitter and the receiver are synchronized, the signal in each channel at the receiver side can be recovered.
- But the scanning frequency has to satisfy the following condition.

$$f_{scan} > 2\ f_{max}$$

Scanning frequency > 2 x Maximum signal frequency

- The maximum number of channels, $n = \frac{T_n}{t_n} = \frac{\text{Scanning period}}{\text{Sampling time of each channel}}$
- The number of channels practically allowed is smaller than the calculated value of 'n' to avoid the interference between channels.

Problems in Implant Telemetry

- For long term telemetry, implant telemetry is very useful.
- The full electronic circuit is packed as a capsule and then implanted deep in the body to be closer to the signal source and to avoid the mechanical difficulties of surface mounted units for long-term observation.
- The size and weight limitations are much more serious and the reliability requirement is more critical.
- Reliability means the life time of a specified circuit. It should be good.
- **Body Reaction:** Size, weight, surface condition and shape of the implant system will be affected by the body reaction.
- The medical grade metals used as enclosures causes little foreign body reaction on tissues.
- The various coating materials used in electronic circuits is silicon, rubber, epoxy, plastics, paraffin, glass and metal.
- They are used to protect them from body fluid.
- At the time of scaling, the temperature should not be high because the electronic components may be affected by the temperature.
- **Power Supply:** Two special power supplies are used for long term implant telemetry units.
- They are:
    - ***Environmental power supply:*** Radio induction has been applied to transmit milliwatt of power to the implanted telemetry unit for months.
    - ***Microwatt power supply*** circuits using Piezo electric crystals placed on any blood vessel or aorta.

Advantages of Biotelemetry

- It is used to record the biosignals over long periods and while the patient is engaged in his normal activities.
- The medical attendant or computers can easily diagnose the nature of disease by seeing the telemetered biosignals without attending patient room.
- Patient is not disturbed during recording.
- For future reference or to study the treatment effect, the biotelemetry is the essential one.
- For recording on animals, particularly for research, the biotelemetry is greatly used.
- For monitoring the persons who are in action, the biotelemetry is an ideal one.
- Biotelemetry is extended for monitoring patients in a hospital from a remote location.

- Now, Tamilnadu government had taken great effort to implement this Bio Telemetry system.
- For monitoring astronauts in space, for monitoring patients who are on the job or at home and carrying implanted pacemakers or other stimulators.
- It is used to monitor the athletes running a race.

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3. Telemetry

What is telemetry? Mention the application of telemetry. [Apr/May 2007, Apr/May 2008, Nov/Dec 2006]

- **Telemetry** is a technology that allows remote measurement and reporting of information.
- The word is derived from Greek roots *tele* = remote, and *metron* = measure.
- Systems that need external instructions and data to operate require the counterpart of telemetry, telecommand.
- Although the term commonly refers to wireless data transfer mechanisms (e.g. using radio or infrared systems), it also encompasses data transferred over other media, such as a telephone or computer network, optical link or other wired communications.
- Many modern telemetry systems take advantage of the low cost and ubiquity of GSM networks by using SMS to receive and transmit telemetry data.

3.1 Applications

Motor racing

- Telemetry is a key factor in modern motor racing.
- It allows race engineers to interpret the vast amount of data collected during a test or race, and use that to properly tune the car for optimum performance.
- Systems used in some series, namely Formula One, have become advanced to the point where the potential lap time of the car can be calculated and this is what the driver is expected to meet.
- Some examples of useful measurements on a race car include accelerations (G forces) in 3 axis, temperature readings, wheel speed, and the displacement of the suspension.

Agriculture

- Most activities related to healthy crops and good yields depend on timely availability of weather and soil data.
- Therefore, wireless weather stations play a major role in disease prevention and precision irrigation.
- These stations transmit major parameters needed for good decisions to a base station: air temperature and relative humidity, precipitation and leaf wetness (for disease prediction models), solar radiation and wind speed (to calculate evapotranspiration), water deficit stress (WDS) leaf sensors and soil moisture, crucial to understand the progress of water into soil and roots for irrigation decisions.

Water management

- Telemetry has become indispensable for water management applications, including water quality and stream gauging functions.
- Major applications include AMR (automatic meter reading), groundwater monitoring, leak detection in distribution pipelines and equipment surveillance.

Defense, space and resource exploration systems

- Telemetry is an enabling technology for large complex systems such as missiles, RPVs, spacecraft, oil rigs and chemical plants because it allows automatic monitoring, alerting, and record-keeping necessary for safe, efficient operations.
- Space agencies such as NASA, ESA, and other agencies use telemetry/telecommand systems to collect data from operating spacecraft and satellites.
- Telemetry is vital in the development phase of missiles, satellites and aircraft
- Without telemetry, these data would often be unavailable.

Rocketry

- In rocketry, telemetry equipment forms an integral part of the rocket range assets used to monitor the progress of a rocket launch.
- Some special problems are the extreme environment (temperature, accelerations, vibration), the energy supply, the precise alignment of the antenna and (at long distances, e.g. in spaceflight) the signal travel time.

Flight test

- Flight test programs typically telemeter data collected from on-board flight test instrumentation over a PCM/RF link.
- This data is analyzed in real-time for safety reasons and to provide feedback to the test pilot.
- Particular challenges for telemetering this data includes fading, multipath propagation and the Doppler Effect.
- The bandwidth of the telemetry link is often insufficient to transfer all the data acquired and therefore only a limited set is sent to the ground for real-time processing

Enemy intelligence

- Telemetry was a vital source of intelligence for the US and UK when Soviet missiles were tested.
- For this purpose, the US operated a listening post in Iran.
- Eventually, the Russians discovered this kind of US intelligence gathering and encrypted their telemetry signals of missile tests.
- Telemetry was a vital source for the Soviets who would operate listening ships in Cardigan Bay to eavesdrop on the UK missile tests carried out there.

Energy monitoring

- In factories, buildings, and houses, energy consumption of systems such as HVAC are monitored at multiple locations, together with the related parameters (e.g. temperature) via wireless telemetry to one central location.
- The information is collected and processed enabling intelligent decisions regarding the most efficient use of energy to be implemented.
- Such systems also facilitate predictive maintenance.

Resource distribution

- Many resources need to be distributed over wide areas.
- Telemetry is essential in these cases, since it allows the system to channel resources to where they are needed.

Medicine

- Telemetry also is used for patients (biotelemetry) who are at risk of abnormal heart activity, generally in a coronary care unit.
- Such patients are outfitted with measuring, recording and transmitting devices.
- A data log can be useful in diagnosis of the patient's condition by doctors.
- An alerting function can alert nurses if the patient is suffering from an acute or dangerous condition.
- Also a system that is available in medical-surgical nursing to monitor a condition where heart condition may be ruled out.

Fisheries and wildlife research and management

- Telemetry is now being used to study wildlife, and has been particularly useful for monitoring threatened species at the individual level.
- Animals under study may be fitted with instrumentation ranging from simple tags to cameras, GPS packages and transceivers to provide position and other basic information to scientists and stewards.
- Telemetry is used in hydro acoustic assessments for fish which have traditionally employed mobile surveys from boats to evaluate fish biomass and spatial distributions.
- Conversely, fixed-location techniques use stationary transducers to monitor passing fish.

Electrical energy providers

- In some countries telemetry is used to assess the amount of electrical energy users have consumed.
- The electricity meter communicates with a concentrator and the latter sends that information through GPRS or GSM to the electrical energy provider's server.

Falconry

- In falconry, "telemetry" means a small radio transmitter carried by a falconry bird to let the bird's owner track it when it is out of sight.

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4. Electrical safety

Explain the physiological effects of current at 50 Hz. [Nov/Dec 2006][Nov/Dec 2010][May/June 2016]

State the influence of leakage current in cardiac patients and explain in detail about the preventive method. [Nov/Dec 2018]

What is the need of electrical safety in hospital? Discuss the various physiological effects of electricity. [April/May 2018]

4.1 Physiological Effects due to 50 Hz Current passage

- Patients and hospital equipment users are susceptible to shock, because they must make physical contact with the hardware.
- The physiological effects of shock range from discomfort to injury to death.
- An electrical shock is a physiological response to current i.e. electrical shock cause an unwanted cellular depolarization and its associated muscular contraction, or it may cause cell vaporization and tissue injury.

4.2 Physiological Effects of current at 50 Hz (Macro shocks, they are distributed over large areas)

Type of current	Current Range	Physiological Effect
Threshold	1 – 5	Tingling sensation
Pain	5 – 8	Intense or painful sensation
Let-go	8 – 20	Threshold of involuntary muscle contraction
Paralysis	> 20	Respiratory paralysis and pain
Fibrillation	80 – 1000	Ventricular and heart fibrillation
Defibrillation	1000 – 10,000	Sustained myocardial contraction, temporary respiratory paralysis and possible tissue burns

- Let-go current is the minimum current to produce muscular contraction.
  [For men → About 16 mA, for women → About 10.5 mA]
- Between 5 Hz to 200 Hz, value of let-go current is so low.
- Above 200 Hz, let-go current is directly proportional to the logarithm of frequency.

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5. Macro shock and Micro shock

Discuss briefly on macroshock and microshock. [Nov/Dec 2010][May/June 2006][April/May 2017]

Define leakage current. Explain the impact of leakage in cardiac patient and discuss about the prevention methods. [Nov/Dec 2017]

5.1 Macro Shock

- A physiological response to a current ***applied to the surface of the body*** that produces unnecessary stimulation like muscle contractions or tissue injury is called macro shock.

- The hospital patients and medical attendants are exposed to macro shocks from defective electrical devices and biomedical equipment.

5.2 Micro Shock

- A physiological response to a current ***applied to the surface of the heart*** that results in unwanted stimulation like muscle contractions or tissue injury is called micro shock.
- Micro shock occurs when currents in excess of 10 μA flow through an insulated catheter to the heart.

Macro shock to Micro shock

Current   Current lever

1000   :   1

- Macro shock can cause heart fibrillation, results in patient's death i.e. current applied directly to the heart.
- Shock is defined in terms of current, because the voltages that produce the currents are highly variable.
- The variance in voltage is caused by wide variation in skin resistance among individuals and among different clinical situation.

1. Dry skin
2. Electrode gel on skin
3. Penetrated skin

5.3 Micro Shock Hazards

- Many devices have a metal basis and cabinet that can be touched by the medical attendants and patients.
- If they are not grounded, then an insulation failure or short circuit results and lead to macroshock or microshock.
- Hence the patients must be isolated or insulated from the electrical circuit.

5.4 Factors

(a) Leakage current: The leakage current is due to:

(i) Ungrounded equipment

(ii) Broken ground wire

(iii) Unequal around potentials

- Leakage current is an extraneous current flowing along a path other than those intended.
- It could be due to resistive, inductive or capacitive couplings with the mains or some electric equipment.

(b) Static Electricity

- Static electricity may be dangerous to people and sensitive equipment having integrated circuits.

- Sparks from static electricity could ignite flammable gases causing an explosion.
- Shocks from static electricity could cause cardiac arrest, if applied to a pacing patient.
- Floor carpeting is common source for static electricity charge build up.

(c) Interruption of power

- Interruption of electrical power to life support equipment can also be dangerous.
- If a delay occurs before emergency power is brought into operation, the failure of a respirator monitor, defibrillator, pacemaker or other life support equipment can be fatal.
- The possibility of a power failure must be considered in the planning of a power distribution system.

Macro shock Hazards

- It occurs with two-wire systems than with three-wire systems. Hot H, Neutral N, Patient P leads. (Proper ground connection)

5.5 **Devices to protect against electrical hazards (Macro to micro shock)**

******Explain the working of a ground fault interrupter. [Nov/Dec 2016]***

The devices used to protect against electrical hazards are,

- Ground fault interrupter
- Isolation transformer

5.5.1 Ground Fault Interrupter (GFI)

- It protects against the shock that occurs if a person touches the hot lead with one hand and the ground with the other.
- It consists of a magnetic coil on which hot lead and neutral lead be wound with same number of turns, but in opposite directions.
- When system is normal, $I_N = I_H$, magnetic flux ϕ in the coil due to these current cancels.
- Hence in the sensing coil, no voltage is induced.
- When hot leads faults, the fault current I_F is shunted to ground.

$$I_N = I_H - I_F \; [I_N \neq I_H, \text{ hence flux are unequal, induces an voltage}]$$

- If I_F exceeds 2 mA for 0.2 second, relay opens the line and prevents a macro shock from injuring the person, as well as preventing further damage to the equipment.

Receptacle:

- The power delivery point in the hospital room consists of the outlets in the vicinity of the patient.
- The outlets should have 3-prong wall receptacles that meet the ground retention force requirements as per the relevant medical standards.
- These force requirements are very important to ensure that plugs on the medical devices do not fall out of the receptacle.
- Receptacle is to be tested for proper wiring, low ground resistance and mechanical tension.

- The tension in the receptacle should not be so high.
- Otherwise it will destroy the plug cable.

5.5.2 Isolation transformer

- It protects against a H-lead to G-lead macro shock.
- It also prevents sparks when H-lead touches ground.
- Important protection in an explosive or flammable environment, such as user flammable anesthetics or excessive oxygen is present.
- This reduces the isolation from either secondary lead to ground and then to the other secondary lead. (ECG isolation amplifier circuit)

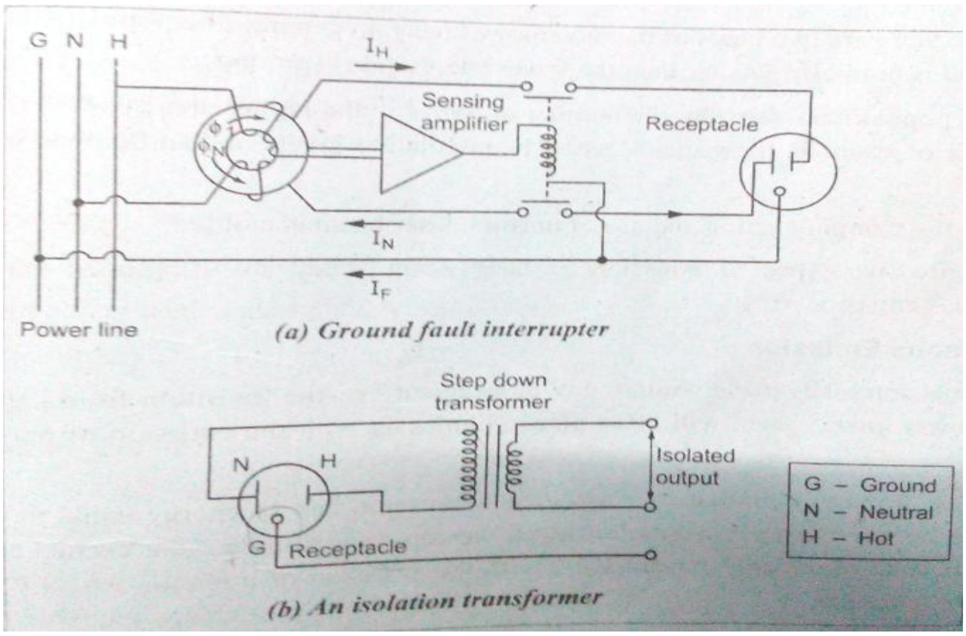

Fig 5.1

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UNIT –IV

PHYSICAL MEDICINE AND BIOTELEMETRY

Two Marks Question & Answers

1. What is diathermy? **[April/May 2011][Nov/Dec 2007][Nov/Dec 2012]**

- ❖ Diathermy is the treatment process by which cutting, coagulation of tissues are obtained.
- ❖ In this method, the patient's body becomes a part of electrical circuit.
- ❖ Hence, heat is produced within the body instead of transferring through the skin.

2. What are the advantages of diathermy?

The advantages of diathermy technique are as follows,

- The treatment can be controlled easily.
- Use of appropriate electrodes permits the heat to be localized only in the region to be treated.
- Amount of heat that is to be delivered can be adjusted accurately.
- Inter lying tissues, muscles, bones, internal organs, etc., can be provided with heat by using high frequency energy.

3. What are the types of diathermy? **[Nov/Dec 2007]**

The types of diathermy techniques used are as follows:

- ❖ Short-wave diathermy
- ❖ Microwave diathermy
- ❖ Ultrasonic diathermy
- ❖ Surgical diathermy

The short-wave and microwave diathermy involves electromagnetic effects and the ultrasonic diathermy uses mechanical effect.

4. What is meant by short wave diathermy?

- ❖ Short-wave diathermy involves high frequency of 27.12 MHz and wavelength of 11m.
- ❖ Since high frequency currents are used, the motor and sensory nerves are not stimulated and there is no muscle contraction.
- ❖ This method has no discomfort to the patient.

5. What are two methods of short wave diathermy?

There are two methods of short-wave diathermy, they are:

(i) Capacitive method

(ii) Inductive method

6. What is a capacitive method in diathermy?

- ❖ In the capacitive method, the patient electrode pads form a capacitor plates and the body tissues between the pads act as a dielectric.
- ❖ Thus the whole arrangement forms a capacitor.

- When the RF current is applied to the electrodes, the capacitor produces heat in the interlying tissues.
- This technique is called as capacitive method.

7. What is the inductive method (Inductothermy) in diathermy?

- In the inductive method a flexible cable is coiled around the arm or knee or any other portion of the body which is to be treated.
- This is used where the plate electrodes are inconvenient to use.
- When the electrostatic field set up is given between the ends of the cable, deep heating of the tissue occurs.
- The superficial tissues are heated by the eddy currents that are produced due to the magnetic field around the cable. This technique is also called as ***Inductothermy.***

8. Write the advantages of shortwave diathermy.

The advantages of shortwave diathermy are,

- Heating rate of tissue is increased.
- Depth of penetration of RF waves can be easily adjusted.
- There is no danger of burns or irritation and the patient has no discomfort.

9. What is meant by microwave diathermy?

- In this method the tissues are heated by the absorption of microwave energy. The frequency used is about 2450MHz with a corresponding wavelength of 12.55 cm.
- Better results are obtained by the microwave method and it is more advantageous than the short wave method.
- Here, there is no usage of pad electrodes and flexible cable.

10. What are the disadvantages of microwave diathermy?

The disadvantages of microwave diathermy are,

- Patients with implanted pacemaker should not undergo this treatment.
- There are possibilities of overheating.
- Care should be taken while the treatment is made near the eyes.

11. What is ultrasonic diathermy? [Nov/Dec 2011]

- Ultrasonic diathermy is used for curing the diseases of peripheral nervous system, skeletal muscle system and skin ulcers.
- It is adopted when the short-wave treatment has failed and it helps to achieve the localization of heat to the affected part.

12. Mention the features of ultrasonic type diathermy. [Nov/Dec 2018]

- It helps to achieve the localization of heat to the affected part.

- Ultrasonic diathermy is used for curing the diseases of peripheral nervous system, skeletal muscle system and skin ulcers.
- It is adopted when the short-wave treatment has failed.
- Ultrasonic massage is better than the manual massage because the micro massage provides a greater depth of massage without causing any pain to the patient

13. List the various techniques used in surgical diathermy.

The various techniques used in surgical diathermy are Cutting and coagulation.

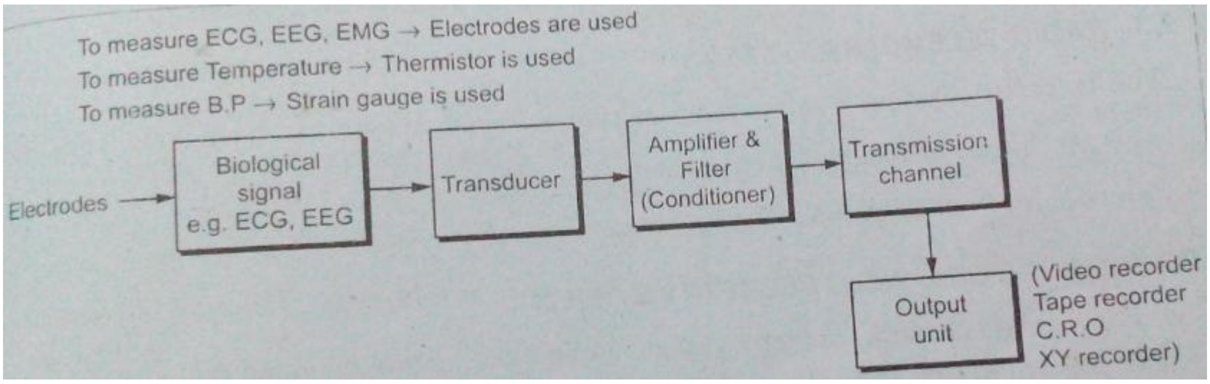
14. Bring out the need for patient plate in surgical diathermy. **[Nov/Dec 2013]**

Diathermy is a treatment process by which cutting, coagulations of tissues are obtained. It is found that when high frequency current in the range 1 -3 MHz is applied, heating of tissues take place.

15. What is meant by Biotelemetry? **[April/May 2011]**

- Bio-telemetry is the measurement of biological parameters over long distances.
- For conveying biological information from a living organism and its environment to a different location where this can be recorded.
- This involves radio frequency signal as a carrier for modulation, referred to as radio-telemetry.

16. Draw the block diagram of Biotelemetry system. **[April/May 2019]**



17. Mention the design of biotelemetry system. **[May/June 2007]**

The design of biotelemetry system is,

- The telemetry system should be selected to transmit the bio-electric signal with maximum fidelity and simplicity.
- The system should not affect the living system by any interference.
- Smaller in size and light in weight.
- It should have more stability and reliability.
- The power consumption at the transmitter and the receiver should be small.
- The system should reject common mode interference rejection i.e., High CMRR can be provided to the system by using differential amplifier.
- The miniature radio telemetry system should be used to reduce noise.

18. Mention the two radio telemetry system.

The two radio telemetry systems are

(i) Single channel telemetry system

(ii) Multi channel telemetry system

19. What is meant by single channel telemetry? [Nov/Dec 2011]

Single channel telemetry is used for the measurement of biological parameters over long distance. A miniature battery operated radio transmitter and receiver is used.

20. Name the various methods of single channel telemetry systems.

The various methods of single channel telemetry systems are,

- Tunnel Diode FM Transmitter (For transmitting ECG, EEG, EMG & Respiration Rate)
- Hartley type FM transmitter
- Pulsed Hartley Oscillator (Transmission of Temperature Signals)
- Radio Telemetry with Sub-carrier system

21. Write the two methods of multi channel telemetry system. (or) What are the choices of radio carrier frequency for medical telemetry purposes? (or) List the two types of multiplexing involved in multi channel wireless telemetry. [Nov/Dec 2013][Nov/Dec 2016]

The two methods of multi channel telemetry system are:

(i) Frequency Division Multiplexing (FDM)

(ii) Time Division Multiplexing (TDM)

22. Specify the problems in implant telemetry.

The problems in implant telemetry are,

❖ Mechanical difficulties

❖ Size and weight limitations

❖ Body reaction

❖ The temperature should not be high

23. Name the two power supply used for long term implant telemetry units.

The two power supply used for long term telemetry units are,

❖ Environmental power supply

❖ Microwatt power supply

24. Mention the advantages of biotelemetry. [May/June 2009]

The advantages of biotelemetry are,

❖ It is used to record the biosignals over long periods and while the patient is engaged in his normal activities.

❖ The medical attendant or computers can easily diagnose the nature of disease by seeing the telemetered biosignals without attending patient room.

- Patient is not disturbed during recording.
- For recording on animals, particularly for research, the biotelemetry is greatly used.
- For future reference or to study the treatment effect, the biotelemetry is the essential one.
- For monitoring the persons who are in action, the biotelemetry is an ideal one.

25. What is meant by telemetry?

Telemetry is a technology that allows remote measurement and reporting of information. The word is derived from Greek roots *tele* = remote, and *metron* = measure.

26. Mention the applications of telemetry. [April/May 2011][May/June 2013][April/May 2017]

The applications of telemetry are,

- Motor racing
- Agriculture
- Water management
- Enemy intelligence
- Energy monitoring
- Fisheries and wildlife research and management

27. What are the Physiological Effects due to 50 Hz Current passage?

- Patients and hospital equipment users are susceptible to shock, because they must make physical contact with the hardware.
- The physiological effects of shock range from discomfort to injury to death.
- An electrical shock is a physiological response to current i.e. electrical shock causes an unwanted cellular depolarization and its associated muscular contraction, or it may cause cell vaporization and tissue injury.

28. Name two different ways in which electricity can harm the body. [May/June 2012]

- An electrical shock is a physiological response to current. The two types of shock are macro shock and micro shock.
- A physiological response to a current applied to the surface of the body is called as macro shock.
- A physiological response to a current applied to the surface of the heart is called as micro shock.

29. What is microshock? [April/May 2011][April/May 2008][Nov/Dec 2007][Nov/Dec 2017]

A physiological response to a current ***applied to the surface of the heart*** that results in unwanted stimulation like muscle contractions or tissue injury is called micro shock.

30. What is macro shock? [April/May 2008][Nov/Dec 2007][May/June 2012][May/June 2013][Nov/Dec 2017]

A physiological response to a current ***applied to the surface of the body*** that produces unnecessary stimulation like muscle contractions or tissue injury is called macro shock.

31. State the difference between micro and macro shock. [Nov/Dec 2018]

Micro shock	Macro shock
1. A physiological response to a current ***applied to the surface of the heart.***	A physiological response to a current ***applied to the surface of the body.***
2. It results in unwanted stimulation like muscle contractions or tissue injury.	It produces unnecessary stimulation like muscle contractions or tissue injury.

32. Specify the factors that cause micro shock hazards.

The factors that cause micro shock hazards are,

(a) Leakage current

(b) Static Electricity

(c) Interruption of power

33. What is leakage current? How is leakage current caused? [May/June 2007][Nov/Dec 2007]

The leakage current is due to:

(i) Ungrounded equipment

(ii) Broken ground wire

(iii) Unequal around potentials

- ❖ Leakage current is an extraneous current flowing along a path other than those intended. It could be due to resistive, inductive or capacitive couplings with the mains or some electric equipment.

34. Mention the devices to protect against electrical hazards. (Macro to micro shock) [May/June 2016][April/May 2018]

The devices to protect against electrical hazards are

- ❖ Ground fault interrupter (GFI)
- ❖ Isolation transformer

35. What is ground fault interrupter (GFI)?

GFI protects against the shock that occurs if a person touches the hot lead with one hand and the ground with the other.

36. What is Isolation transformer?

- ❖ The isolation transformer protects against a H-lead to G-lead macro shock.
- ❖ It also prevents sparks when H-lead touches ground.
- ❖ Important protection in an explosive or flammable environment, such as user flammable anesthetics or excessive oxygen is present.
- ❖ This reduces the isolation from either secondary lead to ground and then to the other secondary lead. (ECG isolation amplifier circuit)

37. Define Let go current. [Nov/Dec 2016][Apr/May 2008][Nov/Dec 2011][May/June 2012]

- ❖ Let-go current is defined as the minimum current to produce muscular contraction.

- ❖ [For men → About 16 mA, for women → About 10.5 mA]
- ❖ Between 5 Hz to 200 Hz, value of let-go current is so low.
- ❖ Above 200 Hz, let-go current is directly proportional to the logarithm of frequency.

38. What are the different types of current?

The different types of currents are threshold current, pain current, let-go current, paralysis current, fibrillation and defibrillation current.

39. What is radiopill? [May/June 2016][April/May 2011][May/June 2012]

- Radio pill contains transducer sensitive to pH, temperature and pressure.
- It is used for telemetering continuous information about one or various variables from one place to another.

40. List out the devices used in micro sensors.

The devices present in micro sensors are,

1. A silicon diode
2. An ion-selective field effect transistor (ISFET)
3. A pair of direct- -contact gold electrodes and
4. A 3-electrode electrochemical cell.

41. What is the function of a silicon diode?

The silicon diode is used to measure the body core temperature and also identify local changes associated with tissue inflammation and ulcers.

42. What is ISFET?

- ❖ ISFET is Ion-selective field effect transistor
- ❖ It is used to measure pH.
- ❖ It is used to determine the presence of pathological conditions associated with abnormal pH levels, particularly associated with pancreatic disease, hypertension, inflammatory bowel disease, the activity of fermenting bacteria, the level of acid excretion, reflux to the oesophagus and the effect of GI-specific drugs on target organs.

43. What is the function of gold electrodes?

- ❖ A pair of direct contact gold electrode is used to measure conductivity.
- ❖ The conductivity sensor is used to monitor the contents of the GI tract by measuring water and salt absorption, bile secretion and the breakdown of organic components into charged colloids.

44. What is the 3-electrode electrochemical cell?

- ❖ The 3-electrode electrochemical cell is used to detect the level of dissolved oxygen in solution.
- ❖ The oxygen sensor measures the oxygen gradient from the proximal to the distal GI tract.
- ❖ This enables a variety of syndromes to be investigated including the growth of aerobic bacteria or bacterial infection.

45. What does the term fulguration refer to? [April/May 2018]

- The term 'fulguration' refers to superficial tissue destruction without affecting deep-seated tissues.
- This is undertaken by passing sparks from a needle or a ball electrode of small diameter to the tissue.

46. List the applications of diathermy. [Nov/Dec 2017]

The diathermy is used

- To treat muscle spams (or) tension
- Stiff joints
- Muscle joint pain

47. Define desiccation and haemostasis. [April/May 2017]

- In desiccation, needle-point electrodes are stuck into the tissue and then kept steady. Depending upon the intensity and duration of the current, a high local increase in heat will be obtained. The tissue changes due to drying and limited coagulation.
- The concurrent use of continuous radio-frequency current for cutting and a burst wave radio-frequency for coagulation is called Haemostasis mode.

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UNIT – V

RECENT TRENDS IN MEDICAL INSTRUMENTATION

Telemedicine, Insulin pumps, Radio pill, Endomicroscopy, Brain machine interface, Lab on a chip.

1. Telemedicine

Explain in detail on telemedicine.

1.1 Telemedicine

- Telemedicine is the application of telecommunications and computer technology to deliver health care from one location to another.
- Telemedicine technology includes hardware, software, medical equipment and communication links.

1.2 Applications of Telemedicine

Telemedicine are widely used in various applications such as teleradiology, telepathology, telecardiology, teleeducation, teleconsultation etc.

- ***Teleradiology:*** Radiological images such as X-ray, CT or MRI images can be transferred from one location to another location for expert consultation. The process involves image acquisition and digitization.
- ***Telepathology:*** To obtain an expert opinion on the microscopic images of pathology slides and biopsy reports.
- ***Telecardiology:*** Refers to the transmission of ECG, echo cardiography, colour Doppler, etc.
- ***Teleeducation:*** Delivery of medical education programmes to the physicians and the paramedics located at smaller towns that are isolated from major medical centres.
- ***Teleconsultation:*** Specialist doctor can be consulted either by a patient directly or by the local medical staff through telemedicine technology.

1.3 Telemedicine Concepts

- Store and forward concept
- Real time telemedicine

1.3.1 Store and forward concept:

- It involves compilation and storing of information relating to audio, video images and clips, ECG.
- The stored information in the digital form is sent to the expert for review.
- The expert's opinion can be transmitted back.

1.3.2 Real time Telemedicine:

- Real time exchange of information between the two centers simultaneously and communicating interactively.
- It may include video conferencing, interviewing and examining the patients, transmission of images of various anatomic sites, auscultation of the heart and lung sounds and a continuous review of various images.

1.4 Essential parameters for telemedicine

For telemedicine, a detailed electronic patient record can be created.

1. *Primary patient data:* Name, age, occupation, sex, address, telephone number, registration number, etc.

2. Patient history: Personal and family history and diagnostic reports

3. Clinical information: Signs and symptoms are interpretation of data obtained from direct and indirect patient observations.

- ***Direct observations:*** Data obtained from senses (sigh, touch, sound, smell, etc.) and through mental and physical interaction with patient.
- ***Indirect observations:*** Data obtained from diagnostic instruments such as temperature, pulse rate, blood pressure.

4. Investigations: Complete analysis reports of haemotology and biochemistry tests, urine examination.

5. Data and reports: Radiographs, MRI, CT, ultrasound and nuclear medicine images and reports, pathology slides, electrocardiogram, spirogram.

6. Video conferencing facility for online consultations.

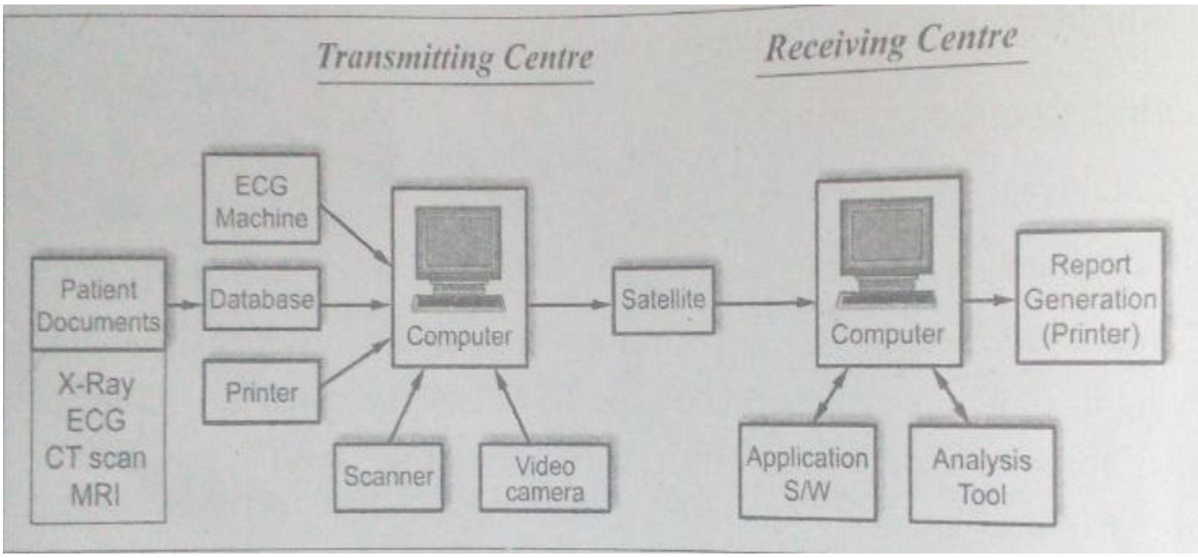

Fig 1.1 Block diagram of a typical telemedicine system

1.5 Telemedicine technology

(a) Transmission of medical images:

- One of the main aspects of telemedicine is the acquisition and transmission of medical images such as X-ray, CT, MRI, Histopathology slides, etc.
- These images are converted into digital form.

(b) Transmission of video images: Video clips, moving images, video conferencing, audio messages.

(c) Video conferencing: One of the essential components in a telemedicine system is the video conferencing facility, which permits transmission of both audio and video information.

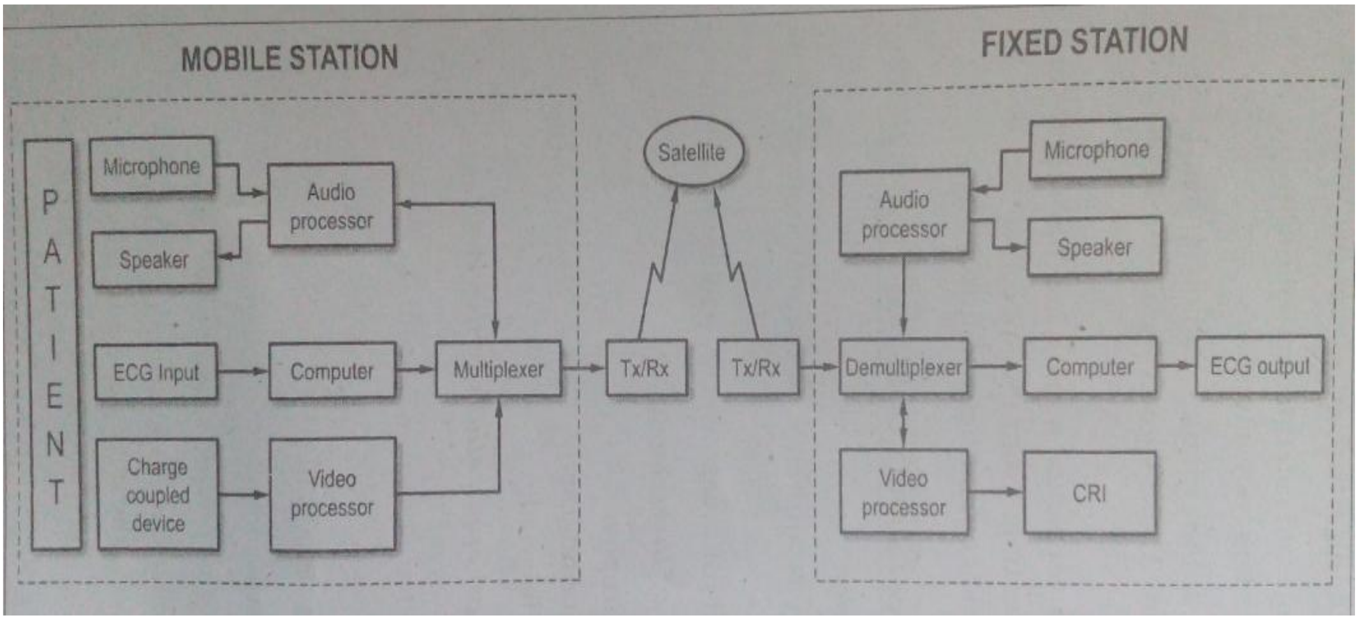

Fig 1.2 Principle of telemedicine using mobile satellite communication

Telemedicine using mobile communication

- Mobile communication and satellite communication made new possibilities for mobile telemedicine in emergency situation.
- In a moving vehicle, colour images, audio signals, ECG and blood pressure are obtained from the patient.
- These signals are multiplexed and transmitted to a fixed station.
- In fixed station, the received signals are demultiplexed and presented to a medical specialist.
- Instructions from the specialist are then transmitted back to the mobile station through the communication link.

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2. Insulin pumps

Briefly discuss the operation of insulin pumps.

2.1 What is Diabetes?

- Diabetes is a condition where the body is unable to regulate levels of glucose (a sugar) in the blood, resulting in excess glucose being present in the blood.
- Glucose is the main sugar digested from our foods.
- Blood glucose levels are regulated by insulin.

2.1 Insulin

- Insulin is a hormone produced in the pancreas that regulates blood glucose levels.
- Insulin enables the body to use Glucose.
- First discovered in 1921.
- Before the discovery children with diabetes were expected to live for under a year.
- Diabetics can’t produce insulin so it must be given to their body.

2.3 Types of Insulin Delivery

Insulin pens

- Needle that injects insulin units into blood stream
- Easy to use

Inhaled insulin

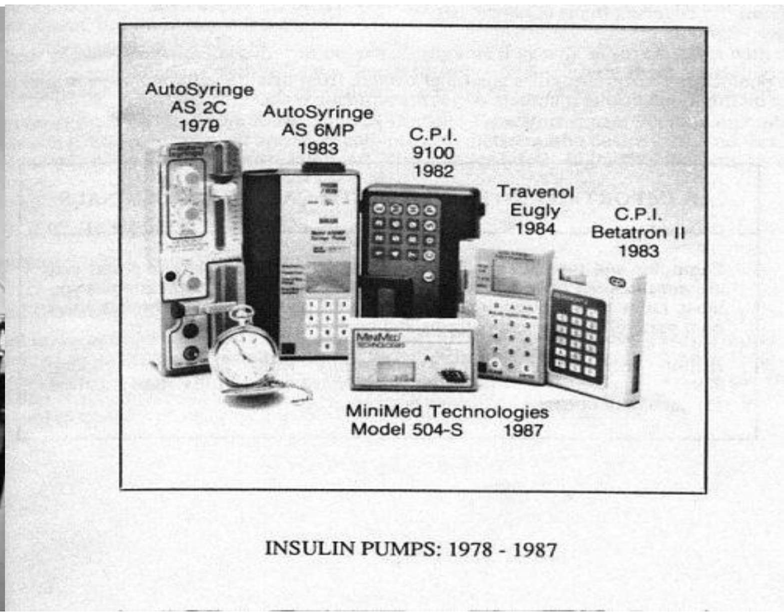
- Similar to an asthma inhaler where the insulin is inhaled and then absorbed into the bloodstream.

Insulin pumps

- Devices that deliver insulin through a flexible tube that ends in a needle attached at the abdomen.

2.4 History of the Insulin pump

- The first insulin pump was developed in 1963 by Dr. Arnold Kadish.
- 1976 Dean Kamen invented the first wearable insulin pump.
- 1980’s insulin pumps start to enter the market.
  - Minimed and Disetronic
- MiniMed 502 first popular insulin pump.
- 2003 MiniMed 512 first insulin pump to monitor glucose levels.



INSULIN PUMPS: 1978 - 1987

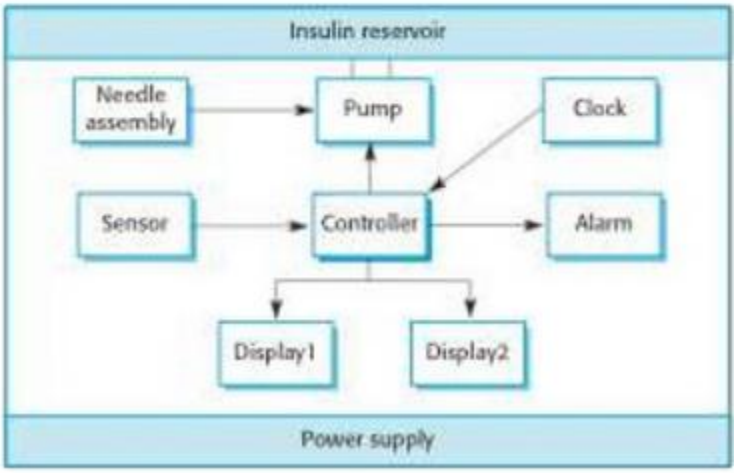
2.5 Using an Insulin Pump

- Insert needle anywhere into body typically the abdomen.
- Three programmable ways to deliver insulin
  - Basal rates
  - Bolus doses
  - Correctional doses
- Then press ok

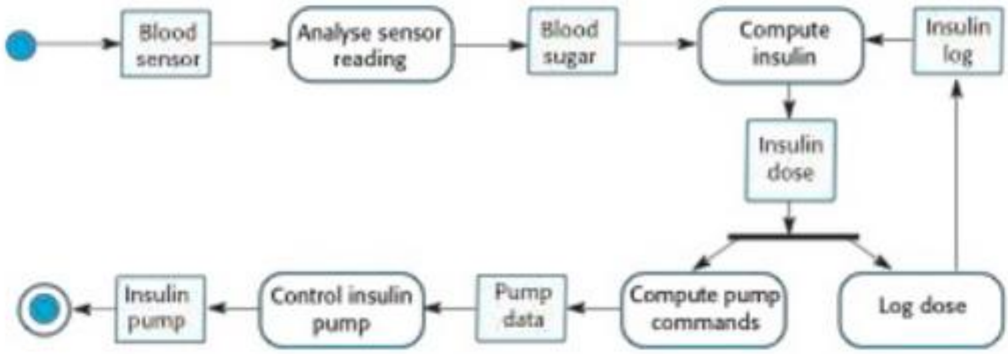
2.6 How Do Insulin Pumps Work?

- Insulin pumps are small, computerized devices.
- The human pancreas works by delivering small doses of short acting insulin continuously (basal rate).
- The device also is used to deliver variable amounts of insulin when a meal is eaten (bolus).
- The basal insulin rates are usually set up in your pump with doctor.
- Can have one or multiple basal settings programmed in the pump, based on their needs.
- They program the amount of insulin for the mealtime bolus directly on the pump.
- Most pumps come with built-in bolus calculators.
- It helps to figure out how much insulin is needed at mealtime based on the glucose levels and the amount of carbohydrates eating.
- The pump, which is about the size of a smart phone or deck of cards, is worn on the outside of body.
- It delivers insulin through a tube (catheter), connected to a thin cannula.
- It is placed into the layer of fat under your skin, typically around your stomach area.
- The pump can be worn around your waist in a pump case or attached to a belt, in a pocket, or on an armband.
- There are a variety of custom-made accessories available so they can carry your insulin pump with style.
- To use an insulin pump, hands-on training from the diabetes care team is needed.
- They will teach how to fill a pump reservoir, prime tubing, select an infusion site, change an infusion set, disconnect the device, calculate and program basal and bolus doses, troubleshoot potential problems, create backup plans in case of pump failure, and prevent diabetic ketoacidosis.

Insulin pump hardware schematic



Activity model of the personal insulin pump



2.7 Types of Pumps

A variety of insulin pumps are available, and diabetes care team can help to choose the best pump.

In general, there are two types of pump devices:

1. **Traditional Insulin pumps** have an insulin reservoir (or container) and pumping mechanism, and attach to the body with tubing and an infusion set. The pump body contains buttons that allow you to program insulin delivery for meals, specific types of basal rates, or suspend the insulin infusion, if necessary.
2. **Insulin patch pumps** are worn directly on the body and have a reservoir, pumping mechanism, and infusion set inside a small case. Patch pumps are controlled wirelessly by a separate device that allows programming of insulin delivery for meals from the patch.

2.8 What Are the Parts of an Insulin Pump?

Traditional insulin pumps contain three main parts:

2.8.1 Pump:

- Traditional insulin pumps are battery powered and contain an insulin reservoir (or container), pumping mechanism, and buttons or touch screen to program insulin delivery.
- Pumps send insulin through tubing into an infusion set that delivers the insulin to your body.

2.8.2 Tubing:

- A thin plastic tube (catheter) is connected to the insulin reservoir and insulin flows into the subcutaneous tissue through the infusion set.
- There are several length sizes of tubing length.
- They are chosen based on how you wear the insulin pump.
- For example, longer tubing may be good for people who wear their pump far from the infusion set.

2.8.3 Infusion set:

- Infusions sets are made of Teflon or steel and attach to your skin with an adhesive patch.
- On the underside of the infusion set is a short thin tube (cannula) that is inserted in your skin with a small needle that is housed within the cannula to deliver insulin into a layer of fatty tissue.
- The needle is necessary to puncture the skin and insert the set.
- After insertion, the needle is removed and the thin cannula stays under the skin.
- The set is usually implanted around your stomach area, but can be placed on the thigh, hips, upper arms.

Infusion sets fall into ***two*** categories:

Angled sets:

- These are inserted at a 30- to 45-degree angle to the surface of the skin.
- In general, these have longer cannulas.
- Athletes, thin or muscular people, pregnant women and active children may prefer these types of angled sets.
- Angled sets also allow for view of the cannula at the insertion site, monitor for signs of redness and for potential infections at the insertion site.

Straight sets:

- These are inserted at a 90-degree angle to the surface of the skin.
- They have shorter needles, and may be preferred by people when they insert the set on the arms, or in hard to reach areas.
- Also, people who are afraid of needles can use this type of set with an insertion device that hides the needle.

- People who are active or sweat a lot may need to use tape (such as Hy-Tape, IV3000, Micropore, Polyskin, Tegaderm, and Transpore) or stronger adhesive products (such as Mastisol) to keep the infusion set in place.
- Diabetes care team can provide sources for where to order different types of tape.

2.8.4 Patch pumps

Patch pumps contain three main parts:

- The three main parts of a patch pump include an insulin reservoir, pumping mechanism and cannula.
- But unlike traditional pumps, the parts are contained in one case without tubing, and the device is worn directly on the body, attaching with a self-adhesive.
- The cannula is inserted automatically after attaching the patch on the skin by programming the activation of the patch from a remote device.
- The patch pumps are usually replaced every three days.

2.9 Insulin Treatment for Diabetes

- People with ***type 1 diabetes*** cannot make insulin because the beta cells in their pancreas are damaged or destroyed.
- Therefore, these people will need insulin injections to allow their body to process glucose and avoid complications from hyperglycemia.
- People with ***type 2 diabetes*** do not respond well or are resistant to insulin.
- They may need insulin shots to help them better process sugar and to prevent long-term complications from this disease.
- Persons with type 2 diabetes may first be treated with oral medications, along with diet and exercise.
- Since type 2 diabetes is a progressive condition, the longer someone has it, the more likely they will require insulin to maintain blood sugar levels.

Various ***types of insulin*** are used to treat diabetes and include:

- **Rapid-acting insulin**: It starts working approximately 15 minutes after injection and peaks at approximately 1 hour but continues to work for two to four hours. This is usually taken before a meal and in addition to long-acting insulin.
- **Short-acting insulin:** It starts working approximately 30 minutes after injection and peaks at approximately 2 to 3 hours but will continue to work for three to six hours. It is usually given before a meal and in addition to a long-acting insulin.
- **Intermediate-acting insulin:** It starts working approximately 2 to 4 hours after injection and peaks approximately 4 to 12 hours later and continues to work for 12-18 hours. It is usually taken twice a day and in addition to a rapid- or short-acting insulin.

- **Long-acting insulin:** It starts working after several hours after injection and works for approximately 24 hours. If necessary, it is often used in combination with rapid- or short-acting insulin.

Insulin can be given by a syringe, injection pen, or an insulin pump that delivers a continuous flow of insulin.

Advantages

- Eliminates individual insulin injections.
- Deliver insulin more accurately and regularly.
- Allows for exercise without having to eat a lot of carbs.
- Makes diabetes management easier.
- Better control.

Disadvantages

- Can cause weight gain.
- Needle can fall out leading to no insulin.
- Expensive.
- Requires training.
- Constantly need to be attached to pump.

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3. Radio pill

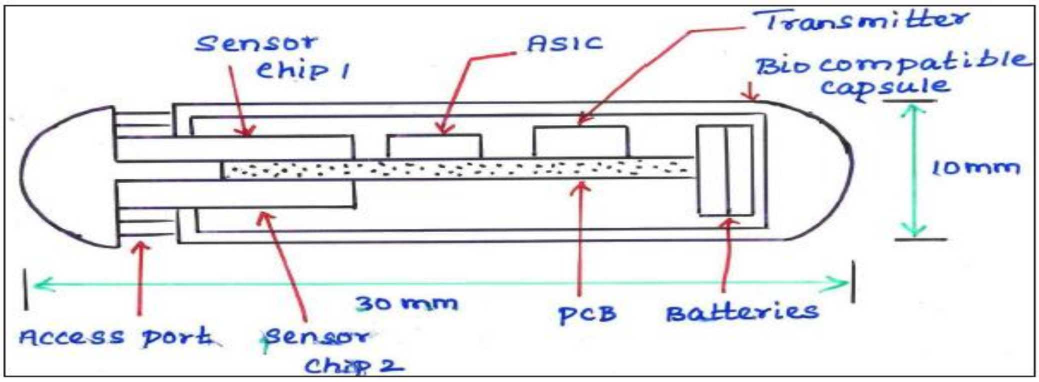
Explain briefly on radiopill.	***[April/May 2011]***

- Radio pill when swallowed, will travel the GI tract (Gastrointestinal tract) and simultaneously perform multi parameter in physiological analysis.
- After completing its mission it will come out of the human body by normal bowel movement.
- The pill is 10mm in diameter and 30mm long weighing around 5gm.
- It records parameters like temperature, pH, conductivity and dissolved oxygen in real time.
- The pill comprises an outer biocompatible capsule encasing micro sensors, a control chip, radio transmitter and two silver-oxide cells.

3.1 Inside the capsule:

- The schematic diagram of the microelectronic pill is as shown in figure below.
- The outer casing of the pill is made by machining chemically resistant polyetheterketone, which is biocompatible.
- It is made up of two halves, which are joined together by screwing.
- The pill houses a PCB chip carrier that acts as a common platform for attachment of,

    1. Sensors,
    2. Application- Specific Integrated Circuit (ASIC)
    3. Radio transmitter
    4. Batteries.



3.2 Task of the sensors:

❖ The device is provided with four micro sensors, namely

1. A silicon diode,
2. An ion-selective field effect transistor (ISFET),
3. A pair of direct- -contact gold electrodes and
4. A 3-electrode electrochemical cell.

3.2.1 Silicon diode:

❖ The silicon diode is used to measure the body core temperature.

❖ It also identifies local changes associated with tissue inflammation and ulcers.

3.2.2 ISFET:

❖ It is used to measure pH.

❖ It is used to determine the presence of pathological conditions associated with abnormal pH levels, particularly associated with pancreatic disease, hypertension, inflammatory bowel disease, the activity of fermenting bacteria, the level of acid excretion, reflux to the oesophagus and the effect of GI-specific drugs on target organs.

3.2.3 Gold electrodes:

❖ A pair of direct contact gold electrode is used to measure conductivity.

❖ The conductivity sensor is used to monitor the contents of the GI tract by measuring water and salt absorption, bile secretion and the breakdown of organic components into charged colloids.

3.2.4 3- Electrode electrochemical cell:

❖ The 3-electrode electrochemical cell is used to detect the level of dissolved oxygen in solution.

❖ The oxygen sensor measures the oxygen gradient from the proximal to the distal GI tract.

❖ This enables a variety of syndromes to be investigated including the growth of aerobic bacteria or bacterial infection.

❖ The implementation of a generic oxygen sensor will also enable the development of a first generation enzyme linked amperometric biosensors.

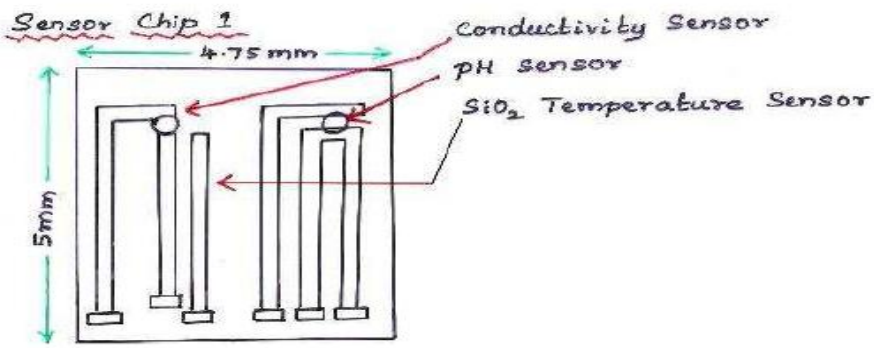
❖ It extends the range of future applications to include (eg.) glucose and lactate sensing, as well as immuno sensing protocols.

❖ The microelectronic sensors are attached to the PCB chip carrier by a 10 pin, 0.5mm pitch polyimide ribbon connector.

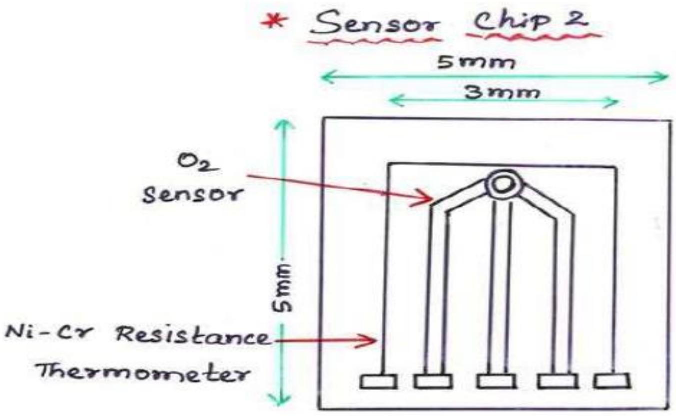
- The PCB carrier is made from 1.6mm thick fiberglass board.
- The transmitter and the ASIC are also integrated on the board.
- The integrated radio transmitter sends the signal to a local receiver prior to data acquisition on a computer.
- The unit is powered by two standard 1.55V silver-oxide cells with a capacity of 175mAh.
- The batteries are connected in series and provide an operating time of 40 hours at the rated power consumption of 12.1mW.
- The sensor chips are provided at the front end of the pill and are exposed to the ambient environment through access ports.
- They are scaled by two sets of stainless-steel clamps incorporating an 0.8mm thick sheet of fluoroelastomer seal.
- The 3mm diameter access channel in the center of each steel clamp exposes the sensing region of the chips to the ambient environment.

3.3 Sensors:

- The schematic diagram of sensor chips is as shown below.
- The sensors are fabricated on two silicon chips located at the front end of the capsule.
- Chip1, measuring 4.75 x 5mm2, comprises the silicon diode temperature sensor, the pH ISFET sensor and the two-electrode 5x $10^{-4}mm^2$ conductivity sensor.
- Predefined n-channels in the p-type bulk silicon form the basis for the diode and the ISFET.
- The 15x600mm floating gate of the ISFET is precovered with a 50nm thick proton sensitive layer of Si3N4 for pH detection.
- The pH sensor consists of the integrated 3x 10-2mm2 Ag/Agcl reference electrodes, a 500mm diameter and 10-nL electrolyte chamber and 15x600mm floating gate of the ISFET sensor.



- Chip2, measuring 5 x 5mm2, comprises the electrochemical oxygen sensor and a NiCr resistance thermometer.
- The oxygen sensor is embedded in the electrolyte chamber.
- The 3-electrode electrochemical cell of the oxygen sensor comprises the 1x10-1 mm2 counter electrode made of gold, a microelectrode array of 57x10mm diameter working gold electrodes and an integrated 1.5x 10-2mm2 Ag/Agcl reference electrodes.



❖ The microelectrode array has an inter-electrode spacing of 25mm and a combined area of 4.5x 10-3mm2.

❖ It promotes electrode polarization and reduces response time by enhancing transport to the electrode surface.

❖ The NiCr resistance thermometer is made from a 100nm thick layer of NiCr and is 5mm wide and 11mm long.

❖ The 500nm thick layer of thermally evaporated silver is used to fabricate the reference electrode. It is then oxidized to Ag/Agcl by chrono potentiometry.

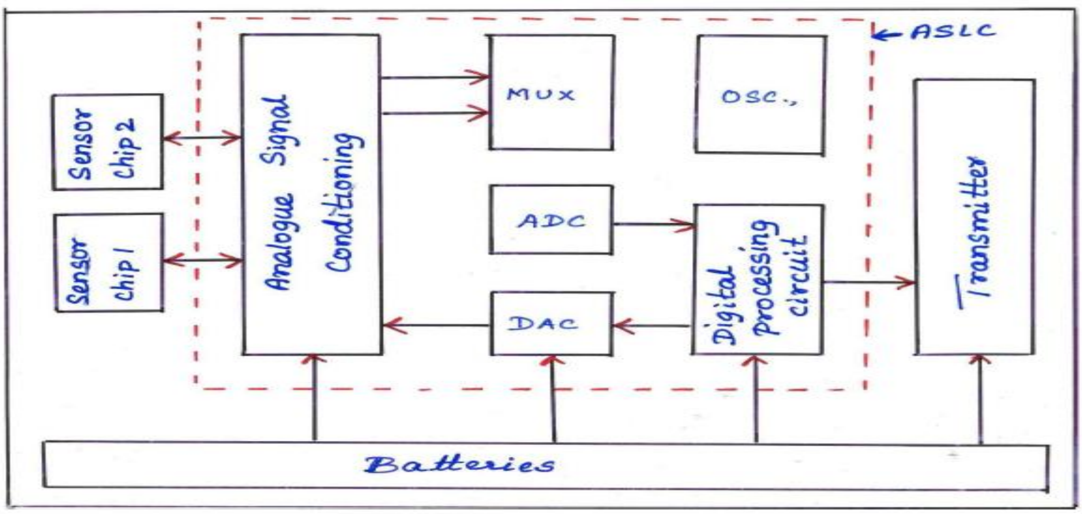
3.4 Control chip:

❖ The ASIC is the control unit that connects together other components of the microsystem as shown in the figure below.

❖ It contains an analogue signal conditioning module operating the sensors, 10-bit ADC and DAC converters and a digital data processing module. An oscillator provides the clock signal.

❖ The temperature circuitry biases the diode at constant current so a change in temperature reflects a corresponding change in diode voltage.

❖ The pH ISFET sensor is biased as a simple source and drain follower at constant current with the drain-source voltage changing with the threshold voltage and pH.



❖ The conductivity circuit operates at direct current, measuring the resistance across the electrode pair as an inverse function of solution conductivity.

- ❖ An incorporated potentiostat circuit operates the amperometric oxygen sensor with a 10-bit DAC controlling the working electrode potential with respect to the reference.
- ❖ The analogue signals have a full-scale dynamic range of 2.8V with the resolution determined by the ADC.
- ❖ These are sequenced through a multiplexer prior of being digitized by the ADC.
- ❖ The bandwidth for each channel is limited by the sampling interval of 0.2msec.
- ❖ The digital data processing module processes the digitized signals through the use of a serial bit stream data compression algorithm, which decides when transmission is required by comparing the most recent sample with the previous sampled data.
- ❖ The digital module is clocked at 32 KHz and employs a sleep mode to conserve power from the analogue module.

3.5 Radio transmitter:

- ❖ The size of the transmitter is 8x5x3mm. The transmission range is one meter and the modulation scheme frequency shift keying has a data rate of 1 kbps.
- ❖ The transmitter is designed to operate at a transmission frequency of 40.01 MHz at 20°C generating a signal of 10 KHz bandwidth.

3.6 Power consumption:

- ❖ Two SR44 Ag2O batteries are used, which provide an operating time of more than 40 hours of the microsystem.
- ❖ The power consumption of the system is around 12.1mW and current consumption is around 3.9mA at 3.1V supply.
- ❖ The ASIC and sensor consume 5.3mW corresponding to 1.7mA of current and the free running radio transmitter consumes 6.8mW at 2.2mA of current.

3.7 Range of measurement:

The microsystem can measure,

- ❖ Temperature from 0 to 70°C,
- ❖ pH from 1 to 13,
- ❖ Dissolved oxygen up to 8.2mg/litre
- ❖ Conductivity from 0.05 to 10 ms.cm-1(s=Siemens).

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4. Endomicroscopy

What is an endomicroscopy? Discuss the working of an endoscopic unit.

4.1 Introduction

- **Endomicroscopy** is a technique for obtaining histology-like images from inside the human body in real-time, a process known as 'optical biopsy'.
- It generally refers to fluorescence confocal microscopy.

- Multi-photon microscopy and optical coherence tomography have also been adapted for endoscopic use.
- Commercially available clinical and pre-clinical endomicroscopes can achieve a resolution on the order of a micrometer.
- They have a field-of-view of several hundred µm, and are compatible with fluorophores which are excitable using 488 nm laser light.
- The main clinical applications are currently in imaging of the tumour margins of the brain and gastro-intestinal tract, particularly for the diagnosis and characterization of Barrett's Esophagus, pancreatic cysts and colorectal lesions.
- A number of pre-clinical and transnational applications have been developed for endomicroscopy as it enables researchers to perform live animal imaging.
- Major pre-clinical applications are in gastro-intestinal tract, tumors margin detection, uterine complications, ischaemia, live imaging of cartilage and tendon, organoid imaging etc.

4.2 Principles

- Conventional, wide field microscopy is generally unsuitable for imaging thick tissue because the images are corrupted by a blurred, out-of-focus background signal.
- Endomicroscopes achieve optical sectioning (removal of the background intensity) using the confocal principle - each image frame is assembled in a point-by-point fashion by scanning a laser spot rapidly over the tissue.
- In table-top confocal microscopes the scanning is usually performed using bulky galvanometer or resonant scanning mirrors.
- Endomicroscopes either have a miniaturised scanning head at the distal tip of the imaging probe, or perform the scanning outside of the patient and use an imaging fibre bundle to transfer the scan pattern to the tissue.

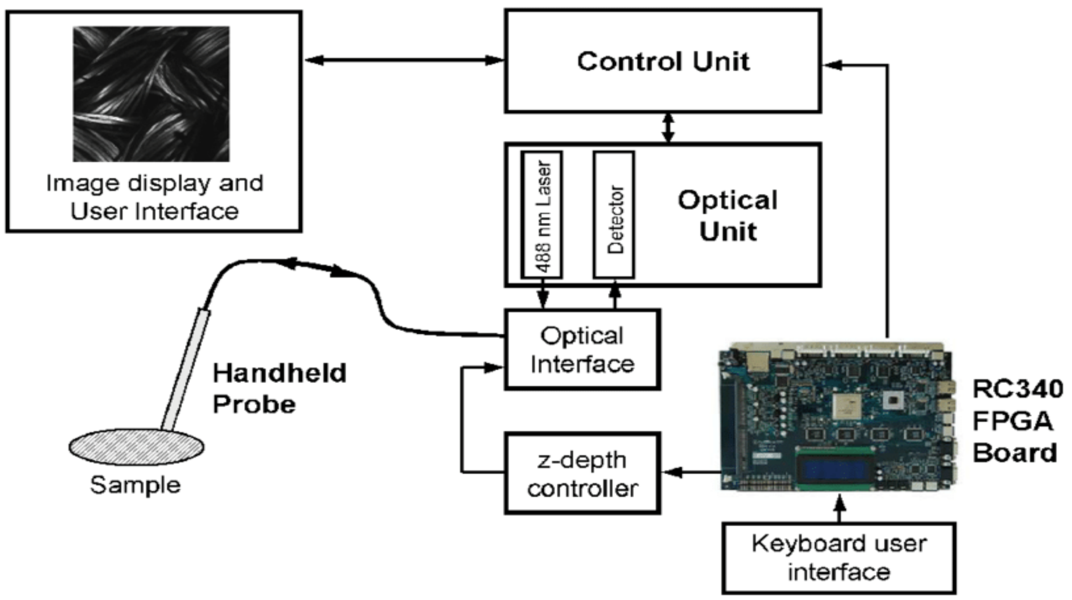

Fig 4.1 Block diagram of endomicroscope interfaced with a FPGA

4.3 Single Fibre Endomicroscopes

- Single fibre confocal endomicroscopes use the tip of an optical fibre as a spatial filter, enabling miniaturisation of the microscope.
- 488nm blue laser passes from the source through an optical fibre to a flexible hand-held probe.
- Optics in the probe focuses the laser to a spot in the tissue, exciting fluorescence.
- Emitted light is captured into the optical fibre and passed through an optical filter to a detector.
- An image is generated by scanning the focused spot throughout the image plane and compiling the point intensity measurements.
- The image plane can be translated up and down in the sample, allowing generation of 3D image stacks.
- Single fibre endomicroscopes have similar resolution of a conventional confocal microscope.

4.4 Fibre Bundle Endomicroscopes

- Fibre bundles were originally developed for use in flexible endoscopes.
- It has been adapted for use in endomicroscopy.
- They consist of a large number (up to tens of thousands) of fiber cores inside a single shared cladding.
- They are flexible, and have diameters on the order of a millimeter.
- In a coherent fiber bundle the relative positions of the cores are maintained along the fibre, meaning that an image projected onto one end of the bundle will be transferred to the other end without scrambling.
- Therefore, if one end of the bundle is placed at the focus of a table-top confocal microscope, the bundle will act as a flexible extension and allow endoscopic operation.
- Since only the cores, and not the cladding, transmit light, image processing must be applied to remove the resulting honeycomb-like appearance of the images.
- Each core essentially acts as an image pixel, and so the spacing between fibre cores limits the resolution.
- The addition of micro-optics at the distal tip of the bundle allows for magnification and hence higher resolution imaging, but at the cost of reducing the field-of-view.

4.5 Distal Scanning Endomicroscopes

- Distal scanning endomicroscopes incorporate a miniature 2D scanning apparatus into the imaging probe.
- The laser excitation and returning fluorescent emission are sent to and received from the scanning head using an optical fiber.
- Most experimental devices have either used MEMS scanning mirrors, or direct translation of the fiber using electromagnetic actuation.

4.6 Non-Confocal Endomicroscopes

- Wide field endomicroscopes (i.e. non-depth sectioning microscopes) have been developed for select applications, including the imaging of cells *ex vivo*.
- Optical coherence tomography and multi-photon microscopy have both been demonstrated endoscopically.
- Successful implementations have used distal scanning rather than fibre bundles due to problems with dispersion and light loss.

4.7 Commercial Products

- Four endomicroscope products have been developed:
  - ❖ The fluorescence in vivo endomicroscope - FIVE2 developed for pre-clinical research,
  - ❖ The neurosurgical device Convivo,
  - ❖ The Pentax ISC-1000/EC3870CIK endoscope, and
  - ❖ Cellvizio.
- The Pentax Medical device was packaged into an endoscope that used OptiScan's electromagnetic-controlled scanning of a single fibre to perform the confocal scanning at the distal tip of the device.
- This provides sub-micrometre resolution across a large field of view and up to a million pixels per frame.
- The original Pentax instrument had variable frame rate up to 1.6 fps and dynamic adjustment of working distance by the user over a depth range from surface to 250 µm.
- The second generation of OptiScan's scanner has an adjustable frame rate between 0.8fps to 3.5fps, field of view of 475µm and a depth range of surface to 400µm.
- Mauna Kea's Cellvizio device has an external laser scanning unit and offers a selection of fibre - bundle based probes with resolution, field of view and working distance optimised for different applications.
- These probes are compatible with standard endoscope instrument channels, and have a frame rate of 12 Hz.

4.8 Applications

- The majority of clinical trials have focused on applications in the gastro-intestinal (GI) tract, particularly the detection and characterization of pre-cancerous lesions.
- Research studies have suggested a large range of potential applications, including in the urinary tract, head and neck, ovaries, and lungs.

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5. Brain Machine interface

Write short notes on Brain machine interface.

5.1 Introduction

- A brain-machine interface (BMI) is a device that translates neuronal information into commands capable of controlling external software or hardware such as a computer or robotic arm.
- A brain computer interface (BCI), also referred to as a brain machine interface (BMI), is a hardware and software communications system.
- It enables humans to interact with their surroundings, without the involvement of peripheral nerves and muscles, by using control signals generated from ElectroEncephaloGraphic (EEG) activity.
- It is collaboration between a brain and a device.
- It enables signal from the brain to direct some external activity, such as control of a cursor or a prosthetic limb.
- The interface enables a direct communication pathway between the brain and the object to be controlled.
- In the case of cursor control, for example, the signal is transmitted directly from the brain to the mechanism directing the cursor, rather than taking the normal route through the body's neuromuscular system from the brain to the finger on a mouse.
- By reading signals from an array of neurons and using computer chips and programs to translate the signals into action.
- BCI can enable a person suffering from paralysis to write a book or control a motorized wheel chair or prosthetic limb through thought alone.
- To control a BCI, the user should produce various brain activity patterns which are captured in form of Electroencephalogram (EEG) and converted to commands by identifying the patterns by the system.

5.2 ElectroEncephalogram (EEG)

- EEG is an electrophysiological monitoring method to record electrical activity of the brain.
- It is typically non-invasive, with the electrodes placed along the scalp, although invasive electrodes are sometimes used such as in electrocorticography.
- EEG measures voltage fluctuations resulting from ionic current within the neurons of the brain.
- In clinical contexts, EEG refers to the recording of the brain's spontaneous electrical activity over a period of time as recorded from multiple electrodes placed on the scalp.

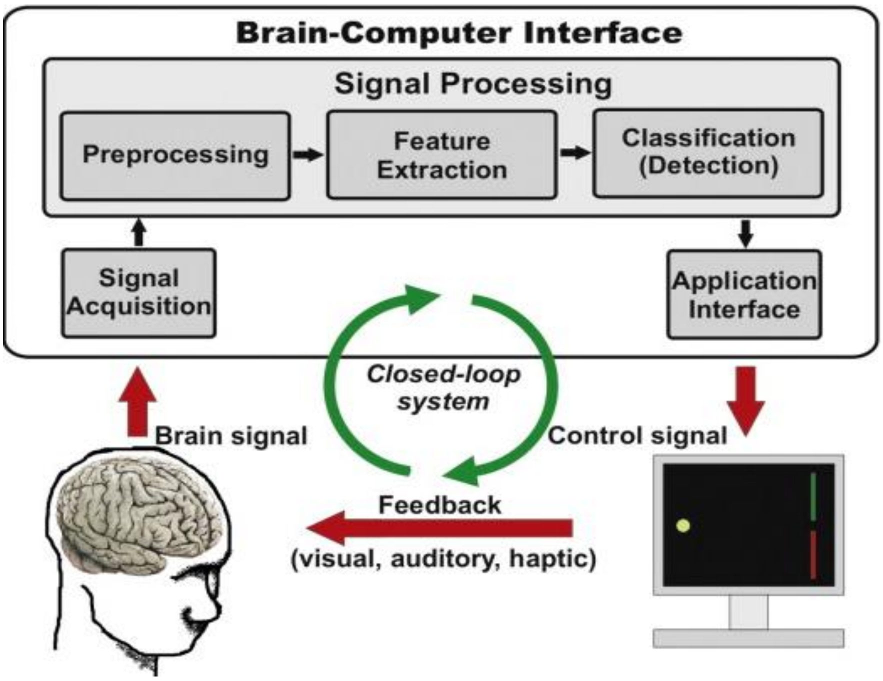

Fig 5.1 Schematic diagram of EEG based BCI

- The interface comprises EEG acquisition system, feature extraction through data processing software and pattern classification, and a system capable of transferring the command to external devices, providing feedback to operator.
- A BCI system whether it is invasive or non-invasive is composed of following phases i.e. Signal acquisition, signal pre-processing, feature extraction, signal classification and computer interaction.

5.3 Signal acquisition

- The ability of a signal acquisition system to measure different phenomena depends on the transducers to convert the physical phenomena into signals measureable by the signal acquisition hardware.
- It is the process of digitizing data from the world around us so it can be displayed, analyzed and stored in a computer.

5.4 Signal pre-processing

- Signal pre-processing is also called as signal enhancement.
- After data acquisition we first preprocess the data to extract the feature.
- It usually intensifies the signals and the upgrade signal to noise ratio (SNR).
- The general step in the preprocessing is band pass filtering which were designed to remove DC bias and high frequency noises.

5.5 Types of signal processing methods

- It may be used in the EEG signal generation according to the filtering types for preprocessing. Those are ***spatial filtering*** and ***frequency filtering***.

5.6 Feature extraction

- When the data is too large to be processed, the data will be transformed into a reduced representation set of features.

- The process of transforming the input data into the set of features is called feature extraction.
- The goal of feature extraction is selecting suitable data for the subsequent classification or detection of features needed to design.
- It is the process of collecting discriminative information from a set of samples.
- Transforming the input data into the set of features is called feature extraction.

5.7 Classification

- The central element in each BCI is the classification module which is also referred to as translation algorithm.
- It simply converts electrophysiological input from the user into output that controls external devices.
- The translation algorithm is an important stage in the signal processing module of the BCI system.
- It is responsible for translating the extracted signal features into device commands that performs the user's intent.
- Whatever the nature is, a translation algorithm changes signal features into device control commands.
- The first part of signal processing simply extracts specific signal features.
- The extracted signal features may be classified on both frequency and shape features based on linear methods or non-linear methods like the neural networks.

5.8 Application interface

- In computer programming, an application programming interface (API) is a set of subroutine definitions, communication protocols, and tools for building software.
- In general terms, it is a set of clearly defined methods of communication among various components.

5.9 Applications

- EEG based BCI systems
- ECoG based BCI systems
- Intracortical based BCI systems

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6. Lab On a Chip (LOC)

Explain briefly on Lab on a chip.

6.1 Introduction

- A **lab-on-a-chip** (**LOC**) is a device that integrates one or several laboratory functions on a single integrated circuit (commonly called a "chip") of only millimeters to a few square centimeters to achieve automation and high-throughput screening.
- LOCs can handle extremely small fluid volumes down to less than pico-liters.

- Lab-on-a-chip devices are a subset of microelectromechanical systems (MEMS) devices and sometimes called "micro total analysis systems" (µTAS).
- LOCs may use microfluidics, the physics, manipulation and study of minute amounts of fluids.
- However, strictly regarded "lab-on-a-chip" indicates generally the scaling of single or multiple lab processes down to chip-format.
- "µTAS" is dedicated to the integration of the total sequence of lab processes to perform chemical analysis.
- The term "lab-on-a-chip" was introduced when it turned out that µTAS technologies were applicable for more than only analysis purposes.

6.2 History

- After the invention of micro technology, these lithography-based technologies were soon applied in pressure sensor manufacturing (1966) as well.
- Due to further development of these usually CMOS-compatibility limited processes, a tool box became available to create micrometre or sub-micrometre sized mechanical structures in silicon wafers as well: the Micro Electro Mechanical Systems (MEMS) era had started.
- Next to pressure sensors, airbag sensors and other mechanically movable structures, fluid handling devices were developed.
- ***Examples*** are: channels (capillary connections), mixers, valves, pumps and dosing devices.
- The first LOC analysis system was a ***gas chromatograph***, developed in 1979 by S.C. Terry at Stanford University.
- However, only at the end of the 1980s and beginning of the 1990s did the LOC research start to seriously grow as a few research groups in Europe developed micropumps, flowsensors and the concepts for integrated fluid treatments for analysis systems.
- These µTAS concepts demonstrated that integration of pre-treatment steps, usually done at lab-scale, could extend the simple sensor functionality towards a complete laboratory analysis, including additional cleaning and separation steps.
- A big boost in research and commercial interest came in the mid 1990s, when µTAS technologies turned out to provide interesting tooling for genomics applications, like capillary electrophoresis and DNA microarrays.
- A big boost in research support also came from the military, especially from DARPA (Defense Advanced Research Projects Agency), for their interest in portable bio/chemical warfare agent detection systems.
- The added value was not only limited to integration of lab processes for analysis but also the characteristic possibilities of individual components and the application to other, non-analysis, lab processes.
- Hence the term "Lab-on-a-Chip" was introduced.

- Although the application of LOCs is still novel and modest, a growing interest of companies and applied research groups is observed in different fields such as analysis (e.g. chemical analysis, environmental monitoring, medical diagnostics and cellomics) but also in synthetic chemistry (e.g. rapid screening and microreactors for pharmaceutics).
- Besides further application developments, research in LOC systems is expected to extend towards downscaling of fluid handling structures as well, by using nanotechnology.
- Sub-micrometre and nano-sized channels, DNA labyrinths, single cell detection and analysis, and nano-sensors, might become feasible, allowing new ways of interaction with biological species and large molecules.

6.3 Chip materials and fabrication technologies

- The basis for most LOC fabrication processes is photolithography.
- Initially most processes were in silicon, as these well-developed technologies were directly derived from semiconductor fabrication.
- Because of demands for e.g. specific optical characteristics, bio- or chemical compatibility, lower production costs and faster prototyping, new processes have been developed such as glass, ceramics and metal etching, deposition and bonding, polydimethylsiloxane (PDMS) processing (e.g., soft lithography), Off-stoichiometry thiol-ene polymers (OSTEmer) processing, thick-film- and stereolithography as well as fast replication methods via electroplating, injection molding and embossing.
- The demand for cheap and easy LOC prototyping resulted in a simple methodology for the fabrication of PDMS microfluidic devices: ESCARGOT (Embedded SCAffold RemovinG Open Technology).
- This technique allows for the creation of microfluidic channels, in a single block of PDMS, via a dissolvable scaffold (made by e.g. 3D printing).
- Furthermore, the LOC field more and more exceeds the borders between lithography-based microsystem technology, nanotechnology and precision engineering.

6.4 Advantages

LOCs may provide advantages, which are specific to their application. Typical advantages are:

- Low fluid volumes consumption
- Faster analysis and response times due to short diffusion distances, fast heating, high surface to volume ratios, small heat capacities.
- Better process control because of a faster response of the system
- Compactness of the systems due to integration of much functionality and small volumes
- Massive parallelization due to compactness, which allows high-throughput analysis
- Lower fabrication costs, allowing cost-effective disposable chips, fabricated in mass production
- Part quality may be verified automatically

- Safer platform for chemical, radioactive or biological studies because of integration of functionality, smaller fluid volumes and stored energies

6.5 Disadvantages

The most prominent disadvantages of Labs-on-chip are:

- The micro-manufacturing process required to make them is complex and labor-intensive, requiring both expensive equipment and specialized personnel.
- It can be overcome by the recent technology advancement on low-cost 3D printing and laser engraving
- The complex fluidic actuation network requires multiple pumps and connectors, where fine control is difficult.
- It can be overcome by careful simulation, an intrinsic pump, such as air-bag embed chip, or by using a centrifugal force to replace the pumping, i.e. centrifugal micro-fluidic biochip
- Most LOCs are novel proof of concept application that is not yet fully developed for widespread use.
- More validations are needed before practical employment
- In the microliter scale that LOCs deal with, surface dependent effects like capillary forces, surface roughness or chemical interactions are more dominant.
- This can sometimes make replicating lab processes in LOCs quite challenging and more complex than in conventional lab equipment
- Detection principles may not always scale down in a positive way, leading to low signal-to-noise ratios

6.6 Applications

- Genomics and proteomics
- Environmental assays
- Medical diagnostics
- Drug discovery
- Chemical production
- Cellular analysis

6.7 Global health

- Lab-on-a-chip technology may soon become an important part of efforts to improve global health, particularly through the development of point-of-care testing devices.
- In countries with few healthcare resources, infectious diseases that would be treatable in a developed nation are often deadly.
- In some cases, poor healthcare clinics have the drugs to treat a certain illness but lack the diagnostic tools to identify patients who should receive the drugs.

- Many researchers believe that LOC technology may be the key to powerful new diagnostic instruments.
- The goal of these researchers is to create microfluidic chips that will allow healthcare providers in poorly equipped clinics to perform diagnostic tests such as immunoassays and nucleic acid assays with no laboratory support.

6.8 Global challenges

- For the chips to be used in areas with limited resources, many challenges must be overcome.
- In developed nations, the most highly valued traits for diagnostic tools include speed, sensitivity, and specificity; but in countries where the healthcare infrastructure is less well developed, attributes such as ease of use and shelf life must also be considered.
- The reagents that come with the chip, for example, must be designed so that they remain effective for months even if the chip is not kept in a climate controlled environment.
- Chip designers must also keep cost, scalability, and recyclability in mind as they choose what materials and fabrication techniques to use.

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UNIT-V

RECENT TRENDS IN MEDICAL INSTRUMENTATION

(TWO MARKS QUESTIONS & ANSWERS)

1. What is telemedicine?

- Telemedicine is the application of telecommunications and computer technology to deliver health care from one location to another.
- Telemedicine technology includes hardware, software, medical equipment and communication links.

2. Mention the applications of telemedicine. **[May/June 2016]**

Telemedicine are widely used in various applications such as teleradiology, telepathology, telecardiology, teleeducation, teleconsultation etc.

3. Under what concept does the telemedicine work?

Telemedicine works under the concept of

- Store and forward concept
- Real time telemedicine

4. What is store and forward concept?

- Store and forward concept involves compilation and storing of information relating to audio, video images and clips, ECG, etc.
- The stored information in the digital form is sent to the expert for review. The expert's opinion can be transmitted back.

5. What is the concept of real time telemedicine?

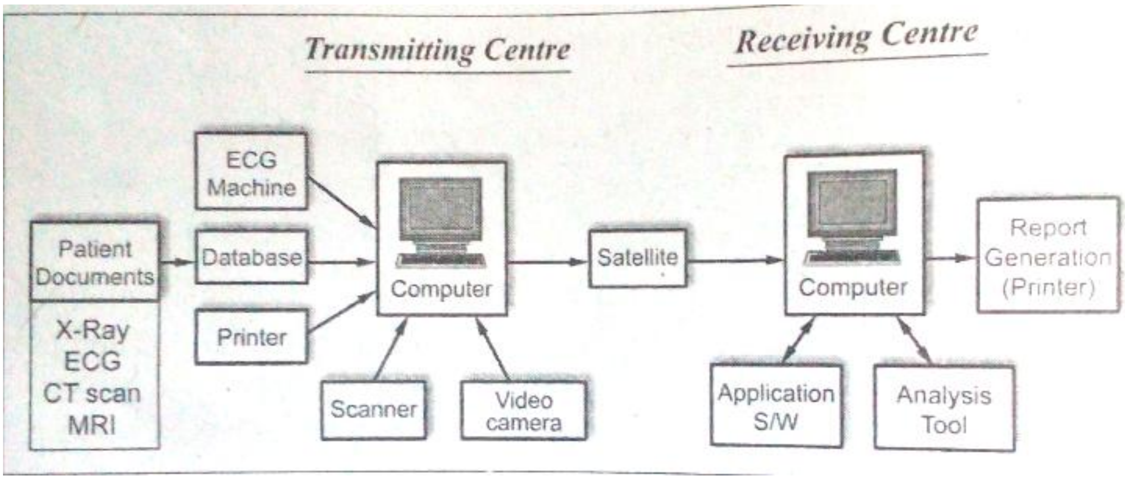
- Real time exchange of information between the two centers simultaneously and communicating interactively.
- It may include video conferencing, interviewing and examining the patients, transmission of images of various anatomic sites, asculation of the heart and lung sounds and a continuous review of various images.

6. Mention the essential parameters of telemedicine.

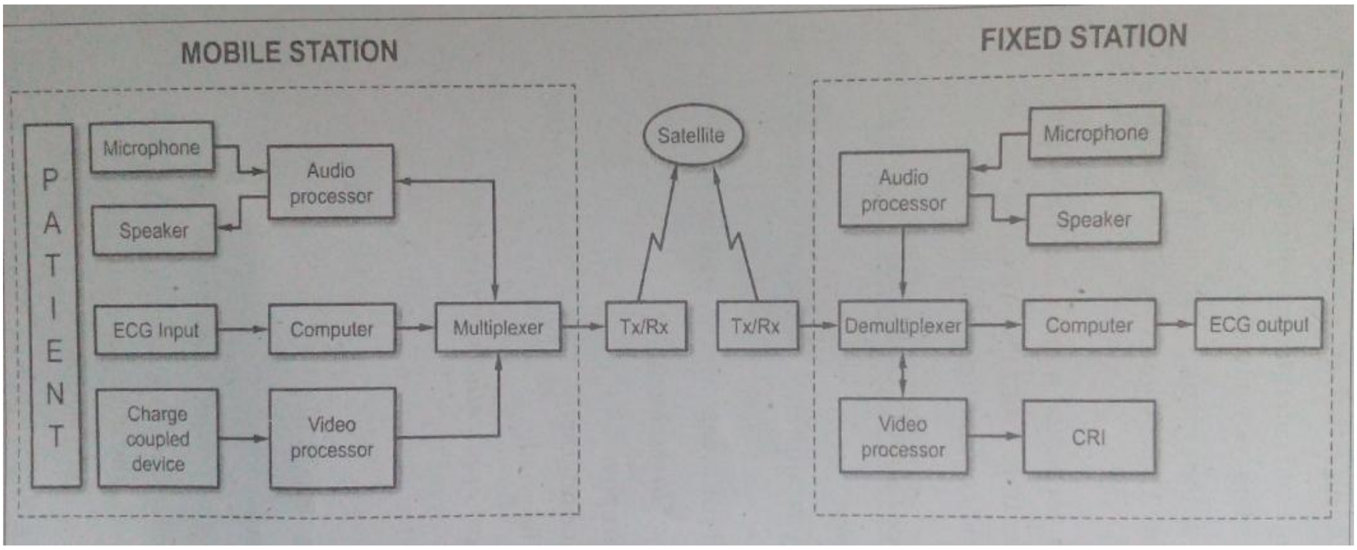
Some of the essential parameters of telemedicine are,

- Primary patient data
- Patient history
- Clinical information
  - ✓ Direct observations
  - ✓ Indirect observations
- Investigations
- Data and reports
- Video conferencing

7. **Draw the block diagram of a typical telemedicine system.**



8. **Draw the block diagram of a telemedicine system using mobile satellite communication.**



9. **What is radio pill?** **[May/June 2016][April/May 2011][May/June 2012]**

- Radio pill contains transducer sensitive to pH, temperature and pressure.
- It is used for telemetering continuous information about one or various variables from one place to another.

10. **List out the devices used in micro sensors.**

The devices present in micro sensors are,

1. A silicon diode
2. An ion-selective field effect transistor (ISFET)
3. A pair of direct- -contact gold electrodes and
4. A 3-electrode electrochemical cell.

11. **What is the function of a silicon diode?**

The silicon diode is used to measure the body core temperature and also identify local changes associated with tissue inflammation and ulcers.

12. **What is ISFET?**

❖ ISFET is Ion-selective field effect transistor

- It is used to measure pH.
- It is used to determine the presence of pathological conditions associated with abnormal pH levels, particularly associated with pancreatic disease, hypertension, inflammatory bowel disease, the activity of fermenting bacteria, the level of acid excretion, reflux to the oesophagus and the effect of GI-specific drugs on target organs.

13. What is the function of gold electrodes?

- A pair of direct contact gold electrode is used to measure conductivity.
- The conductivity sensor is used to monitor the contents of the GI tract by measuring water and salt absorption, bile secretion and the breakdown of organic components into charged colloids.

14. What is the 3-electrode electrochemical cell?

- The 3-electrode electrochemical cell is used to detect the level of dissolved oxygen in solution.
- The oxygen sensor measures the oxygen gradient from the proximal to the distal GI tract.
- This enables a variety of syndromes to be investigated including the growth of aerobic bacteria or bacterial infection.

15. What is diabetes?

- Diabetes is a condition where the body is unable to regulate levels of glucose (a sugar) in the blood, resulting in excess glucose being present in the blood.
- Glucose is the main sugar digested from our foods.
- Blood glucose levels are regulated by insulin.

16. What is Insulin?

- Insulin is a hormone produced in the pancreas that regulates blood glucose levels.
- Insulin enables the body to use Glucose.
- First discovered in 1921.
- Before the discovery children with diabetes were expected to live for under a year.
- Diabetics can’t produce insulin so it must be given to their body.

17. Mention the types of Insulin delivery.

Some of the types of insulin delivery are:

- Insulin pens
- Inhaled insulin
- Insulin pumps

18. List the three programmable ways to deliver insulin.

Three programmable ways to deliver insulin

- Basal rates
- Bolus doses
- Correctional doses

19. What are the types of insulin pump?

In general, there are two types of pump devices:

- ❖ Traditional Insulin pumps
- ❖ Insulin patch pumps

20. What Are the Parts of an Insulin Pump?

Traditional insulin pumps contain three main parts:

- ❖ Pump
- ❖ Tubing
- ❖ Infusion set

Infusion sets fall into ***two*** categories:

- Angled sets:
- Straight sets**:**

Patch pumps contain three main parts:

- ❖ The three main parts of a patch pump include an insulin reservoir, pumping mechanism and cannula.

21. Mention the various types of insulin used to treat diabetes.

Various types of insulin are used to treat diabetes and include:

- ❖ Rapid-acting insulin
- ❖ Short-acting insulin
- ❖ Intermediate-acting insulin
- ❖ Long-acting insulin

Insulin can be given by a syringe, injection pen, or an insulin pump that delivers a continuous flow of insulin.

22. What are the advantages of insulin pump?

Some of the advantages of insulin pump are:

- ❖ Eliminates individual insulin injections.
- ❖ Deliver insulin more accurately and regularly.
- ❖ Allows for exercise without having to eat a lot of carbs.
- ❖ Makes diabetes management easier.
- ❖ Better control.

23. Mention the disadvantages of insulin pump.

The disadvantages of insulin pump are:

- ❖ Can cause weight gain.
- ❖ Needle can fall out leading to no insulin.
- ❖ Expensive.
- ❖ Requires training.
- ❖ Constantly need to be attached to pump.

24. What is endomicroscopy?

- **Endomicroscopy** is a technique for obtaining histology-like images from inside the human body in real-time, a process known as 'optical biopsy'.
- It generally refers to fluorescence confocal microscopy.

25. Give the principle of endomicroscopy.

- Conventional, wide field microscopy is generally unsuitable for imaging thick tissue because the images are corrupted by a blurred, out-of-focus background signal.
- Endomicroscopes achieve optical sectioning (removal of the background intensity) using the confocal principle - each image frame is assembled in a point-by-point fashion by scanning a laser spot rapidly over the tissue.

26. Mention the types of endomicroscopy.

Some of the types of endomicroscopes are

- Single Fibre Endomicroscopes
- Fibre Bundle Endomicroscopes
- Distal Scanning Endomicroscopes
- Non-Confocal Endomicroscopes

27. List the applications of endomicroscopy.

- The majority of clinical trials have focused on applications in the gastro-intestinal (GI) tract, particularly the detection and characterisation of pre-cancerous lesions.
- Research studies have suggested a large range of potential applications, including in the urinary tract, head and neck, ovaries, and lungs.

28. What is brain machine interface?

- A brain-machine interface (BMI) is a device that translates neuronal information into commands capable of controlling external software or hardware such as a computer or robotic arm.
- A brain computer interface (BCI), also referred to as a brain machine interface (BMI), is a hardware and software communications system.

29. Mention the blocks in BMI.

- Signal acquisition
- Signal preprocessing
- Feature extraction
- Classification (Detection)
- Application interface

30. Mention the applications of BMI.

The applications of BMI are:

- EEG based BCI systems
- ECoG based BCI systems

- Intracortical based BCI systems

31. What is lab on chip?

A lab on chip is a miniaturized device that integrates onto a single chip one or several analyses, which are usually done in a laboratory, analyses such as DNA sequencing or biochemical detection.

32. Write the three examples of lab on a chip in medical applications.

Some examples of lab on a chip in medical applications are,

- Lithium chip
- Fertility chip
- Nanowire sensor for cancer diagnosis

33. Mention the classification of lab on chip.

The classification of lab on chip is,

- Bio-micro electromechanical systems (bio MEMS)
- Micro-total analysis system (μ TAS)

34. What are the types of LOC based on a moving fluid?

The types of LOC based on a moving fluid are,

- Single phase flow through micro channels.
- Multiphase flow of droplets through micro channels or on a surface.

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