Module 4

Therapeutic Equipments: Principle, block schematic diagram, working and applications of : pacemakers, cardiac defibrillators, heart–lung machine, dialyzers, surgical diathermy equipment, ventilators

Medical instruments

- Sense various physiological signals
- Carry out some processing of these signals
- Display or record those signals
- They are useful therapeutically and as prostheses
- Eg: Electric stimulators, incubators, ventilators, artificial kidneys

Therapeutic Equipments

- Equipments that replace certain critical physiological functionalities, or provide needed pain therapy.

ELECTRIC STIMULATORS

- Used in patient care and research.

  1.Low current low duty cycle stimulators

  eg: Cardiac Pacemaker

  2.High current single pulse stimulator

  eg: Defibrillators

Why Pacemaker?

- Rhythmic beating of the heart is due to the triggering pulses that originate in an area of specialized tissue in the right atrium of the heart which is called the natural cardiac pacemaker , located at the SA node.
- In abnormal situations if this natural pacemaker ceases to function or becomes unreliable or if the triggering pulses do not reach the heart muscle because of blocking by the damaged tissue, natural and normal synchronization of the heart action gets disturbed.
- It causes decrease in heart rate and changes in ECG waveform.
- By giving external electric stimulation to the heart muscle, it is possible to regulate heart rate.
- These impulses are given by pacemaker.

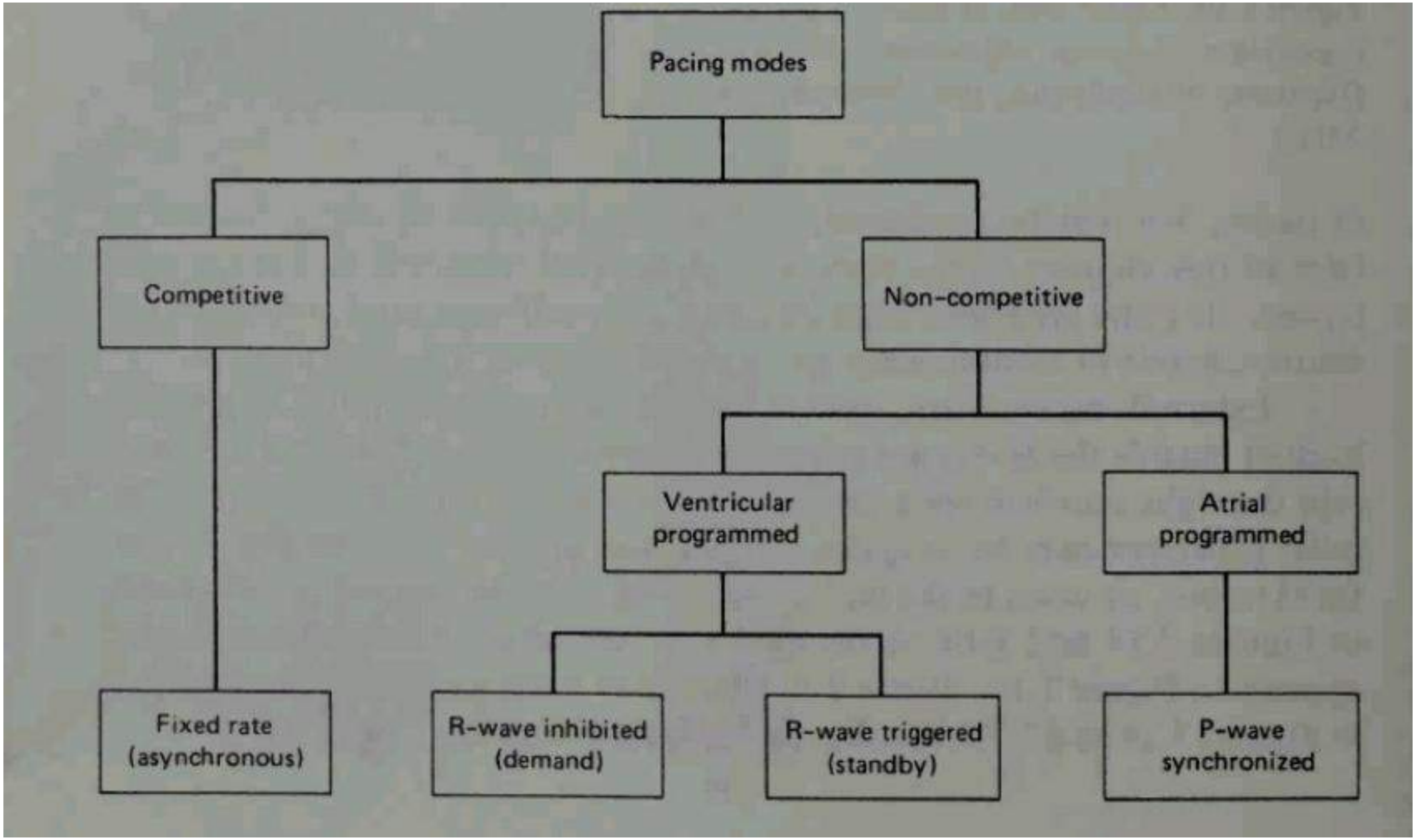
- Each pacing impulse is propagated throughout the myocardium, spreading over the surface of the atria to the atrioventricular node(AV).
- A normal sinus rhythm depends on the continuous , periodic performance of the pacemaker and the neuronal conducting pathways.
- Any change in the normal sinus rhythm is called arrhythmia.
- If the heart beat is slower between 30 to 50 beats per minute , the result is bradycardia , in which heart cannot provide sufficient blood circulation to meet the bodys physical demands.
- Dizziness and loss of consciousness may occur because of diminished cardiac output.
- Heart attack may occur when conduction system fails to transmit the pacing impulse from atria to ventricles.

- First degree block – excessive delay at AV node , causing PR interval to exceed 0.2 seconds for normal adults.
- Second degree block results in complete but intermittent inhibition of pacing impulse.
- Total and continuous impulse blockage is third degree block , this may occur at the AV node or anywhere in the conduction system.

CARDIAC PACEMAKERS

- Produces periodic electric pulses that are conducted to electrodes normally located on the surface of the heart, within the heart muscle or the lining of the heart
- The stimulus thus conducted to the heart causes it to contract.
- This effect can be used prosthetically in disease state in which the heart is not stimulated at a proper rate on its own.
- The principal pathologic conditions in which cardiac pacemakers are applied are known collectively as **heart block.**

Types of Pacing Modes



Two types of pacing modes

1. Asynchronous pacemaker / competitive

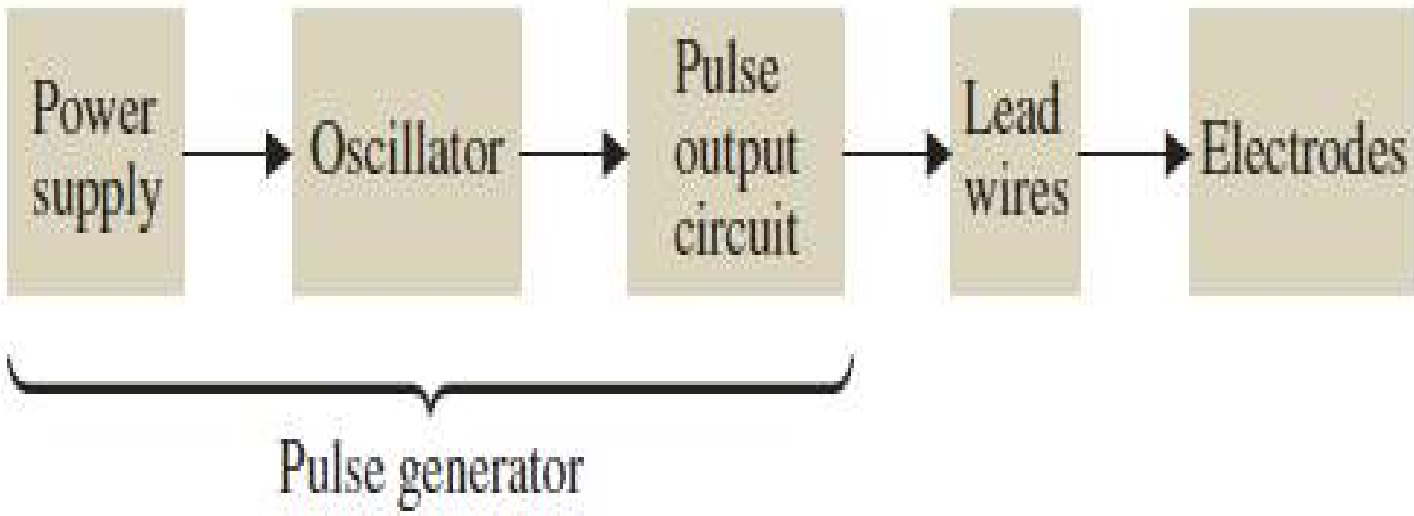
- It was the first type of pacemaker that was developed.
- Free running pacemaker
- Its electric stimulus appears at a uniform rate regardless of what is going on in the heart or the rest of the body.
- It therefore gives a fixed heart rate.the rate is pe-set at 70bpm
- Since the fixed rate pacemaker functions regardless of the patients natural heart rhythms, it poses a potential danger because of competition between the patients rhythm and that of pacemaker

2.Synchronous pacemakers/non competetive

- Often patients require cardiac pacing only intermittently, because they can establish a normal cardiac rhythm between periods of block.
- For these patients, it is not necessary to stimulate the ventricles continuously
- Continuous stimulation can even result in serious complications in some cases

Asynchronous Pacemaker

- Block diagram



- The power supply is necessary to supply energy to the pacemaker circuit.
- Primary or secondary battery sources are used.
- The oscillator establishes the pulse rate for the pacemaker; this, in turn, controls the pulse output circuit that provides the stimulating pulse to the heart.
- This pulse is conducted along lead wires to the cardiac electrodes.
- Each of these blocks is important in the construction of the pacemaker, and each must be made highly reliable, because faulty operation of this device can cost a patient's life.

- Another component of the overall construction of the pacemaker is the **package** itself.
- The package of an implanted pacemaker must be **compatible** and **well tolerated** by the body.
- It also provide the necessary protection to the circuit components in order to ensure their **reliable o**peration.
- The body is a corrosive environment, so the package must be designed to operate well in this environment, while occupying **minimal volume and mass.**
- Cardiac pacemakers are contained in **hermetically sealed metal packages**. **Titanium and stainless steel** are frequently used for the package.
- Special **electron beam or laser welding techniques** have been developed to seal these packages without damaging the electronic circuit or the power source.

Power Supply

- The usual power supply for implantable pacemakers is a battery made up of primary cells.
- **Lithium iodide** battery is commonly used.
- The fundamental lithium iodide cell involves the following reactions,
- At Cathode,

$$Li \rightarrow Li^{+} + e^{-}$$

- At Anode,

$$I_2 + 2e^{-} \rightarrow 2I^{-}$$

- Combined reaction, $2Li + I_2 \rightarrow 2LiI$
- This cell has an open-circuit voltage of **2.8 V** and is much more **reliable**
- Major limitation is its relatively **high source resistance**

Timing Circuit

- The asynchronous pacemaker represents the simplest kind of pacemaker because it provides a train of stimulus pulses at a constant rate regardless of the functioning of the heart.
- A free-running oscillator is all that is required for the timing pulse in such a system.
- More advanced pacemakers uses timing circuits to determine when a stimulus should be applied to the heart
- complex logic circuits, quartz crystal control, and microprocessors replace the simple, free-running oscillator

Output Circuit

- The pulse output circuit of the pacemaker generator produces the actual electric stimulus that is applied to the heart.

- Usual types of stimuli produced by the output circuit are

  1. **Constant-voltage amplitude pulses---** typically in the range of **5.0 to 5.5 V** with a duration of **500 to 600 ms**
  2. **Constant current amplitude pulses---** typically in the range of **8 to 10mA** with pulse durations ranging from **1.0 to1.2 ms**

- Rates for asynchronous pacemakers range from **70 to 90 beats/min**, whereas pacemakers that are not fixed rate typically achieve rates ranging from **60 to 150 beats/min.**

Lead wires and Electrodes

- The pulse generator is located at some position remote from the heart itself, there must be an appropriate conduit to carry the electric stimuli to the heart and to apply them in the appropriate place.

- The lead wires are used for this purpose.

- They are good electrical conductors and are mechanically strong.

- As the individual in whom the pacemaker is implanted moves about, these lead wires have to be able to withstand the stress of being flexed in various positions.

- A second requirement of the lead-wire system is that it must be **well insulated**. If not, wherever faults in the insulation occur, there is effectively another stimulating electrode that, in addition to possibly stimulating the tissue in its vicinity, shunts important stimulating current away from its intended point of application on the heart.
- To meet these requirements, the lead wires presently used consist of **interwound helical coils of spring-wire alloy molded in a silicone-rubber or polyurethane cylinder.**
- The helical coiling of the wire minimizes stresses applied to it, and the multiple strands serve as insurance against failure of the pacemaker following rupture of a single wire.
- The soft compliant silicone rubber or polyurethane encapsulation maintains **flexibility** of the lead-wire assembly and provides **electrical insulation and biological compatibility**.

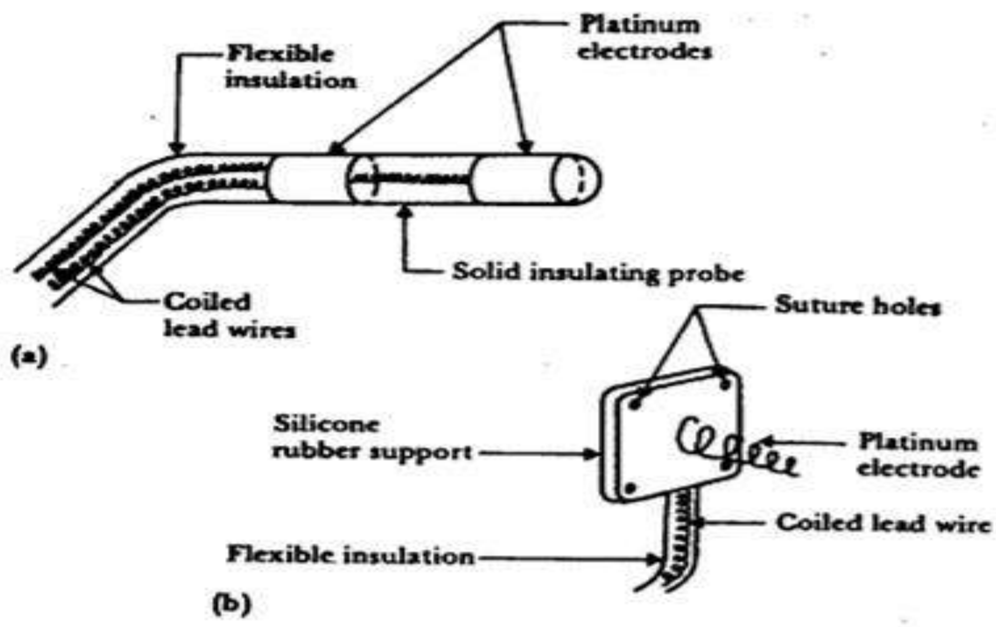
- Cardiac pacemakers are either of the **unipolar or the bipolar type.**
- **In a unipolar device,** a single electrode is in contact with the heart, other electrode can be placed anywhere in the body. and negative going pulses are connected to it from the generator
- **In the bipolar system**, two electrodes are placed within the heart, and the stimulus is applied across these electrodes.
- The electrodes themselves can be placed on the external surface of the heart,buried within the heart,or pressed against the inside surface of the heart (endocardial or intraluminal electrodes).
- It is possible to introduce the electrodes into the heart through a shoulder or neck vein so that it is not necessary to expose the heart surgically during the implantation process.

- The materials which electrodes are made are important.

- The electrodes must be able to stand up to the **repeated stress** they may encounter as a result of the mechanical activity of the heart, and they must remain in place to provide effective pacing.
- They must also be made of materials that do not dissolve during long-term implantation, cause undue irritation to the heart tissue adjacent to them, or undergo electrolytic reactions when the stimulus is applied.
- To avoid any electrolytic corrosion problems, these electrodes are often made of the same materials as the lead wires.

- Materials used include **platinum and alloys of platinum** with other materials:
- various formulations of stainless steel, carbon, and titanium; and specialized alloys such as
- **Elgiloy** (40% cobalt, 20% chromium, 15% iron, 15% nickel, 7% molybdenum,2% manganese, and traces of carbon and beryllium,
- **MP35N** (35% nickel, 35% cobalt, 20% chromium, 10% molybdenum, and a trace of iron).
- In early pacemakers, a common type of failure was associated with breakage of the lead wire. this problem has been greatly reduced, and lead wires and electrodes usually remain in place when the generator circuit and batteries are replaced

- Figure shows the basic structure of typical bipolar intraluminal electrodes and single intramyocardial electrode.



(a) Bipolar intraluminal electrode. (b) Intramyocardial electrode.

- **Intraluminal electrodes :**The conducting bands around the circumference of the solid intraluminal probe contact the endocardium (internal surface of the heart wall) and electrically stimulate it.
- **Intramyocardial electrode :** Placed on the exterior surface of the heart. A puncture wound is made in to the wall of the heart and the helical spiral shaped electrode is placed on this hole. To hold the electrode in place, the silicone rubber supporting piece is then sutured to the external surface of the heart.
- This flexible back support provides a good mechanical match between the electrode and the heart wall.
- For bipolar intramyocardial stimulation, a pair of these electrodes is attached to the myocardium**.**

SYNCHRONOUS PACEMAKERS

- Used for intermittent stimulation as opposed to continuous stimulation as in asynchronous pacemakers
- Prevents possible deleterious outcomes of continuous pacing (i.e. tachycardia, fibrillation)
- Thus it is important in these cases that the artificial pacemaker not compete with the heart’s normal pacing action.
- A better solution involves the use of synchronous pacemakers

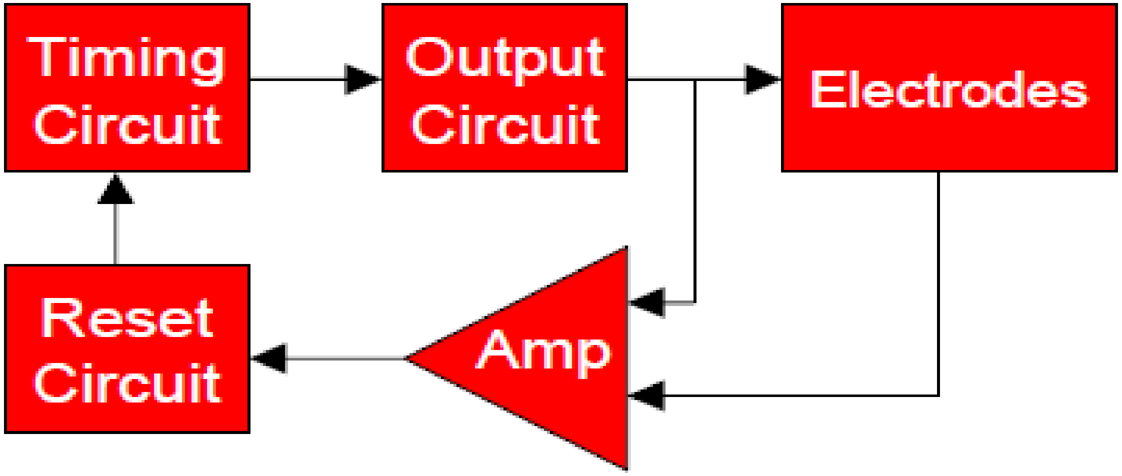
- **Two types** of synchronous pacemakers:

  1.Demand pacemaker

  2. Atrial-synchronous pacemaker.

Demand pacemaker

- Consists of asynchronous components and feedback loop
- Timing circuit runs at a fixed rate (60 to 80 beats per min)
- After each stimulus, the timing circuit resets itself, waits the appropriate interval to provide the next stimulus, and then generates the next pulse



- However, if during this interval a natural beat occurs in the ventricle
    - Feedback circuit detects the QRS complex of the ECG signal from the electrodes
    - Amplifies that signal
    - This signal is then used to reset the timing circuit.

- It awaits its assigned interval before producing the next stimulus. If the heart beats again before this stimulus is produced, the timing circuit is again reset and the process repeats itself.

- Normal cardiac rhythms prevent pacemaker stimulation, the pacemaker remains in a standby mode, and the heart operates under its own pacing control.

- In this way the heart can respond to changing demands of the organism by changing its rate in the usual manner.

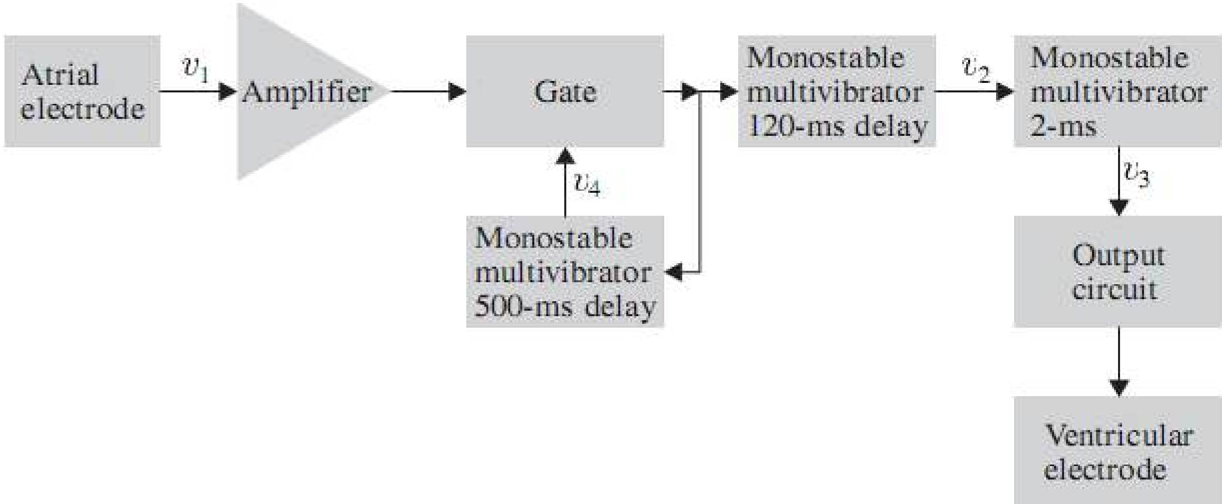
- If temporary heart block occurs, the pacemaker takes over and stimulates the heart at the fixed rate of the timing circuit.

Atrial-synchronous pacemaker

- It is the pacemaker designed to replace the blocked conduction system of the heart.

- The heart's physiological pacemaker, located at the SA node, initiates the cardiac cycle by stimulating the atria to contract and then providing a stimulus to the AV node, which, after appropriate delay, stimulates the ventricles.

- If the SA node is able to stimulate the atria, the electric signal corresponding to atrial contraction can be detected by an electrode implanted in the atrium and used to trigger the pacemaker in the same way that it triggers the AV node
- SA node firing triggers the pacemaker



- Voltage v1 is detected by the atrial electrodes is the pulse that corresponds to each beat.
- The atrial signal is then amplified and passed through a gate to a monostable multivibrator giving a pulse **v2** of **120 ms duration, the approximate delay from SA node to the AV node.**
- Another monostable multivibrator giving a pulse duration of **500 ms** is also triggered by the atrial pulse. It produces v4, which causes the gate to block any signals from the atrial electrodes for a period of 500 ms following contraction.

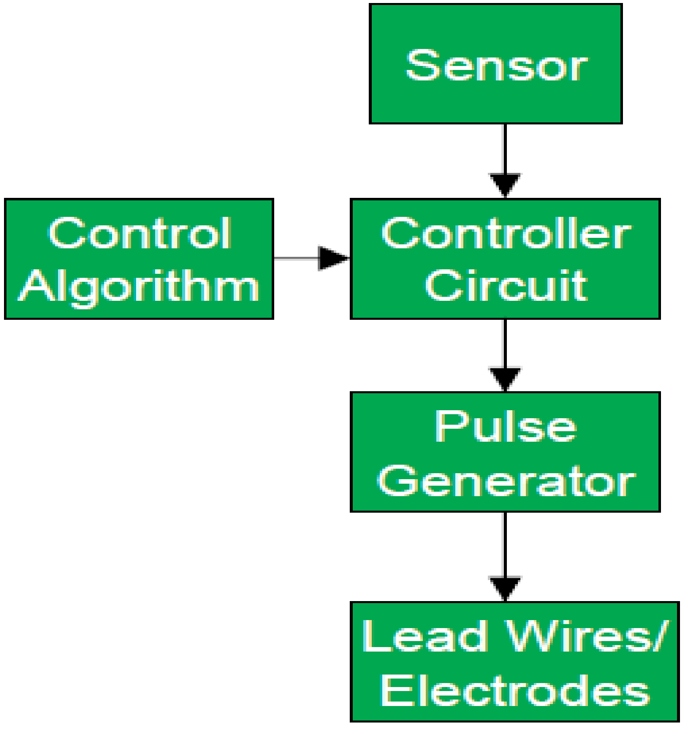
- Delays are used to simulate natural delay from **SA to AV node (120ms) and to create a refractory period (500ms)**
- The falling edge of the 120 ms-duration pulse, v2, is used to trigger a monostable multivibrator of 2 ms duration.
- Thus the pulse v2 acts as a delay, allowing the ventricular stimulus pulse v3 to be produced.

- Then v3 controls an output circuit that applies the stimulus to appropriate ventricular electrodes for ventricular contraction

- Combining the demand pacemaker with this design allows the device to let natural SA node firing to control the cardiac activity

Rate-Responsive Pacing

- Used for variable rates of pacing as needed based on changes in physiological demand
- Replicates cardiac function in a physiologically intact individual



- A sensor is used to convert a physiological variable in the patient to an electric signal that serves as an input to the controller circuit

- This block of the pacemaker is programmed to control the heart rate on the basis of the physiological variable that is sensed.

- As with the demand pacemaker, this controller can determine whether any artificial pacing is required and can keep the pacemaker in a dormant state when the patient’s natural pacing system is functional.

- The sensor can be located within the pacemaker itself, or it can be located at some other point within the body.

R wave triggered pacemaker:

- The ventricular synchronized demand type pacemaker is meant for patients who are general in heart block with occasional sinus rhythm.
- The pacemaker detects ventricular activity and stimulates the ventricles after a very short delay time of some milliseconds.
- If there is sinus rhythm, the stimulating impulse will occur in the ventricular de-polarization.
- If there is asystole, the unit will stimulate the heart after a preset time.

R wave blocked Pacemaker:

- The ventricular inhibited the pacemaker is meant for patients who generally have sinus rhythm with occasional heart block
- The circuit detects spontaneous R wave potentials at the electrodes and the pacemaker provides a stimulus to the heart after pre-set asystole.
- In case of ventricular activity, the R wave does not trigger the output circuit of the pacemaker but blocks the output circuit and no stimulation impulse is given to the heart

External Pacemakers

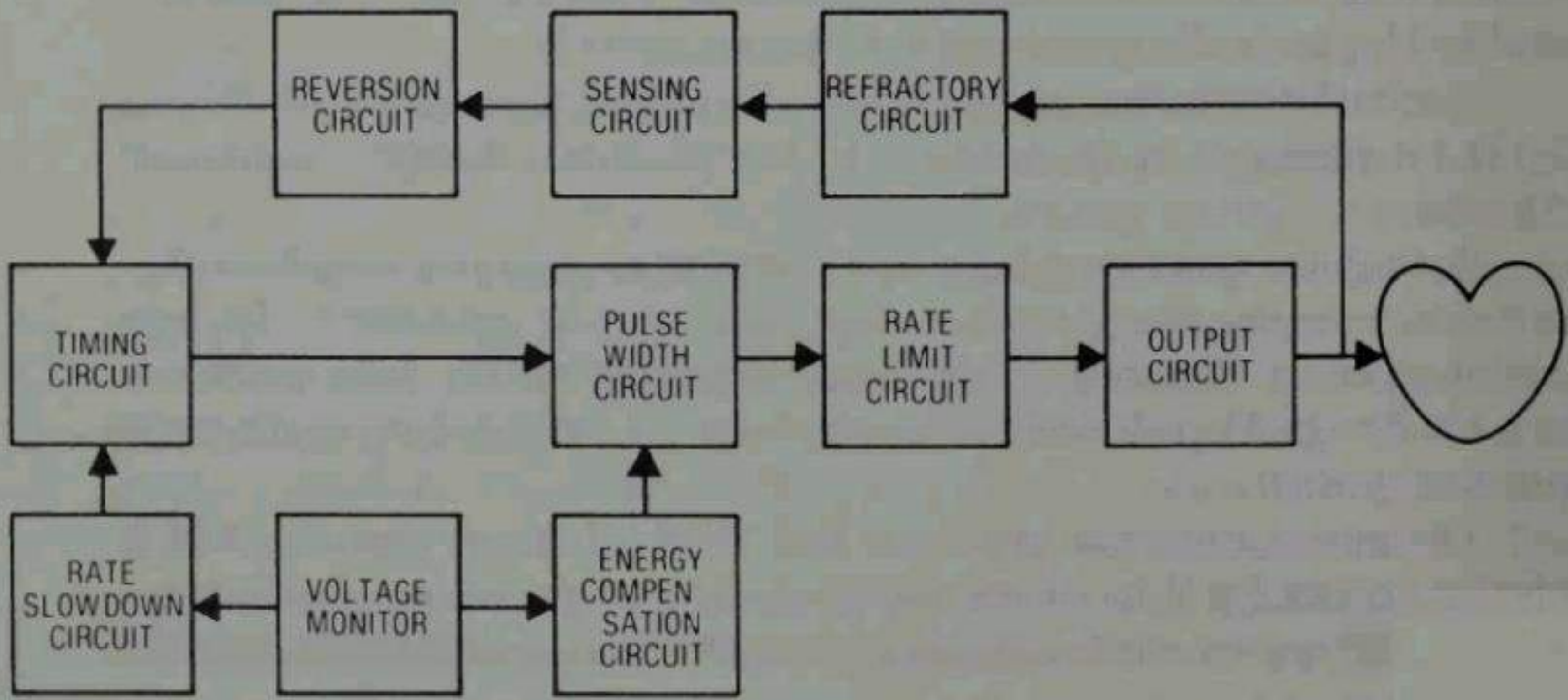
- Employed to restart the normal rhythm of the heart in cases of cardiac standstill, in cases where short term pacing is considered adequate, while the patient is in the ICU or waiting for implantation of a permanent pacemaker.

- Used for patients recovering from cardiac surgery to correct temporary conduction disturbances resulting from the surgery.

- As the patient recovers, normal conduction returns and the use of pacemaker is discontinued.
- In this the pulse generator located outside the body and connected to ventricle using a long thin tube called catheter.
- The pacing impulse(80 mA) is applied through metal electrodes placed on the surface of the body.

Implantable/Internal pacemaker

- Implanted beneath the skin along with its electrodes.
- Permanently implanted in the body whose SA node failed to function properly
- Output leads are connected directly to the heart muscle.
- The pacemaker is miniaturized pulse generator and is powered by small batteries.
- Batteries should provide power for a long period.
- Components must be highly reliable
- Circuit is covered with biologically inert material so that the implant is not rejected by the body.
- Unit should be covered in such a way that the body fluids do not enter the circuit causes the short circuit of batteries and results in malfunction.


REVERSION CIRCUIT
SENSING CIRCUIT
REFRACTORY CIRCUIT
TIMING CIRCUIT
PULSE WIDTH CIRCUIT
RATE LIMIT CIRCUIT
OUTPUT CIRCUIT
RATE SLOWDOWN CIRCUIT
VOLTAGE MONITOR
ENERGY COMPEN SATION CIRCUIT

- Above fig shows an RC, reference voltage source, and a comparator determines the basic pacing rate of the pulse generator.
- Its output signal feeds into a second RC network, the pulse width circuit, which determines the stimulating pulse duration.
- A third RC network, the rate-limiting circuit, disables the comparator for a preset interval and the limits the pacing rate to a maximum of 120 pulses per minute for most component failures.
- The output circuit provides a voltage pulse to stimulate the heart. The voltage monitor circuit senses cell depletion and the rate slowdown circuit and energy compensation circuit of this event.
- The rate slowdown circuit shuts off some of the current to the basic timing network to cause the rate to slow down 8 ± 3 beats per minute when ceil depletion has occurred.

- The energy-compensation circuit causes the pulse duration to increase as the battery voltage decreases, to maintain nearly constant stimulation energy to the heart.
- There is also a feedback loop from the output circuit to the refractory circuit, which provide a period of time following an output pulse or a sensed R-wave during which the amplifier will not respond to outside signals.
- The sensing circuit detects a spontaneous R wave and resets the oscillator timing capacitor.
- The reversion circuit allows the amplifier to detect a spontaneous R wave in the presence of low-level continuous wave interference. In the absence of an R wave, this circuit allows the oscillator to pace at its preset rate ± 1 beat per minute.

Defibrillators

- Heart is able to perform the pumping action through synchronized action of the heart muscle fibers.
- The rapid spread of action potential over the surface of the atria causes these 2 chambers of heart to contract together and pump blood through the 2 AV valves into the ventricles.
- After a critical time delay , a powerful ventricular muscles are synchronously activated to pump blood through the pulmonary and systemic circulatory systems.
- Ventricular fibrillation is a serious cardiac emergency resulting from the asynchronous contraction of the heart muscles.
- A condition in which this necessary synchronization is lost is known as **fibrillation**

- This uncoordinated movement of the ventricle walls of the heart is due to the abnormalities of body chemistry or electric shock.
- There is no synchronous occurrence of events as the heart muscles are continuously stimulated by the adjacent cells.
- Because of this irregular contraction of muscle fibers the ventricle stops pumping the blood effectively.
- Fibrillation leads to loss of cardiac output to near zero
- It must be corrected as soon as possible to avoid irreversible brain damage to the patient or death.
- Electric shock can be used to reestablish normal cardiac activity
- Ventricular fibrillation can be converted to a more efficient rhythm by applying a high energy shock to the heart.
- This causes all muscle fibers to contract simultaneously.

- Possibly the fibers may then respond to normal physiological pacemaking pulses.
- Instruments used for this purpose is called defibrillators.
- Electric machines that produce energy to carry out this function are known as **defibrillators**
- **Defibrillators is the application of electric shock to the area of the heart**
- Defibrillators are used to reverse fibrillation of the heart
- 2 types- Atrial fibrillation – Fibrillation of the atrial muscles
- **Atrial fibrillation** (**AF**) is an abnormal heart rhythm characterized by rapid and irregular beating of the atria. This abnormal rhythm stops your heart from pumping as well as it should. Your blood flow can slow enough to pool and form clots. AF raises your chances for a stroke and other heart complications.

- If that happens, and a clot travels through the bloodstream to your brain and gets stuck, you could have a stroke
- Ventricular Fibrillation- Fibrillation of the ventricles
- Even in case of atrial fibrillation, the circulation is still maintained though not efficiently and ventricles can function normally.
- Ventricular fibrillation is dangerous as the ventricles cannot pump blood , and if fibrillation is not corrected , death will surely occur.

- Four basic types of Defibrillators
    - –AC Defibrillator- give shock to patients to resynchronise the heart
    - –Capacitative-discharge Defibrillator- Capacitor is charged to high Dc voltage and then rapidly discharged through electrodes across chest of patient. This can be used also for correcting atrial fibrillation and other types of arrhythmias.
    - –Capacitative-discharge Delay-line Defibrillator
    - –Rectangular-wave Defibrillator
- Defibrillation by electric shock is carried out by passing current through electrodes placed:

  –External –Shock delivered to the heart by means of electrodes placed on the chest.

  –Internal –Electrodes placed directly against heart when the chest is opened.

Defibrillator: Electrodes

- Excellent contact with the body is essential
  - –Serious burns can occur if proper contact is not maintained during discharge
- Sufficient insulation is required
  - –Prevents discharge into the physician
- Conventional electrode systems are circular , a little concave with sharp rims and insulated back side.
- Three types are used:
  - –Internal –used for direct cardiac stimulation
  - –External –used for transthoracic stimulation
  - –Disposable –used externally
- For internal defibrillation when chest is open , large spoon shaped electrodes are used.

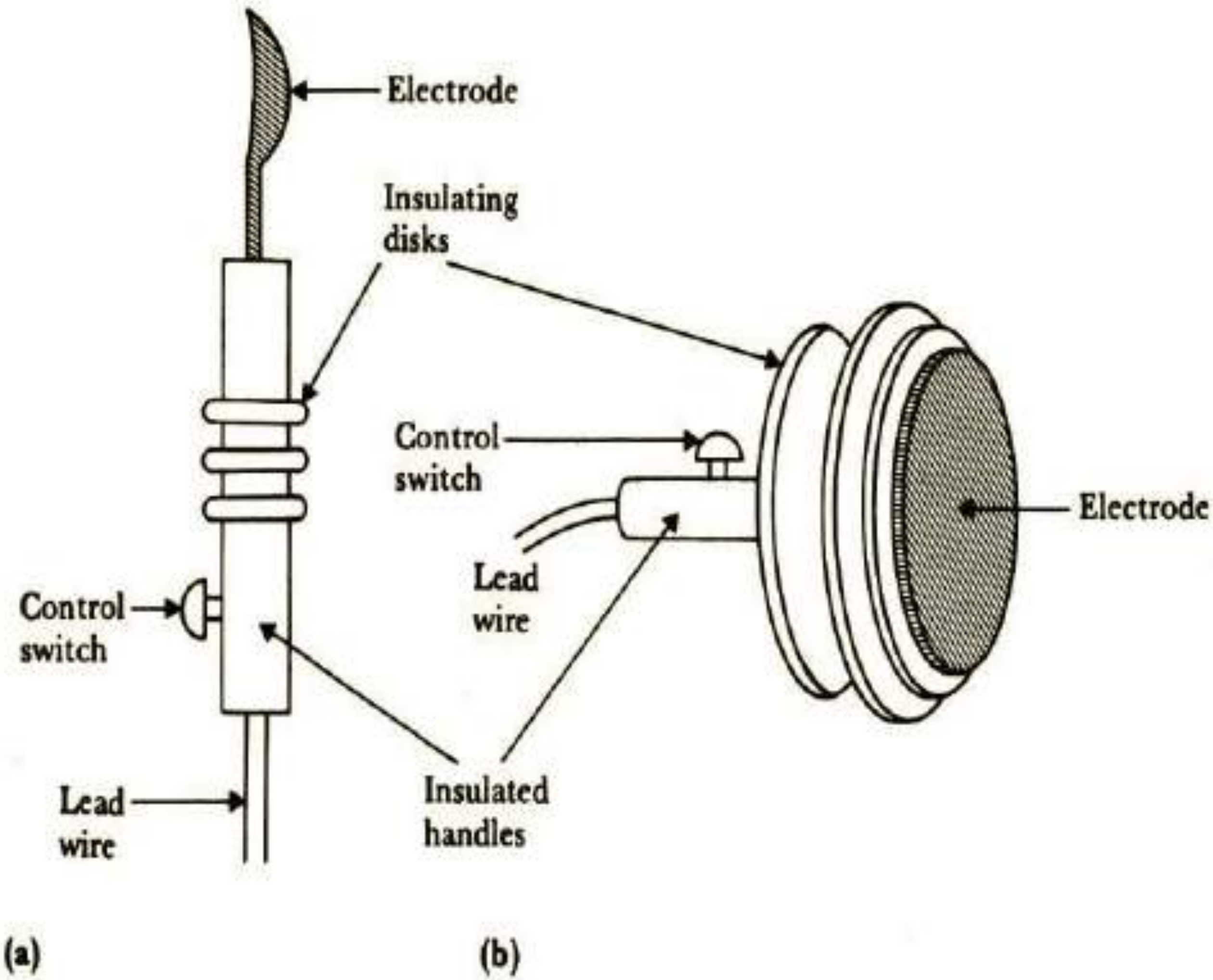
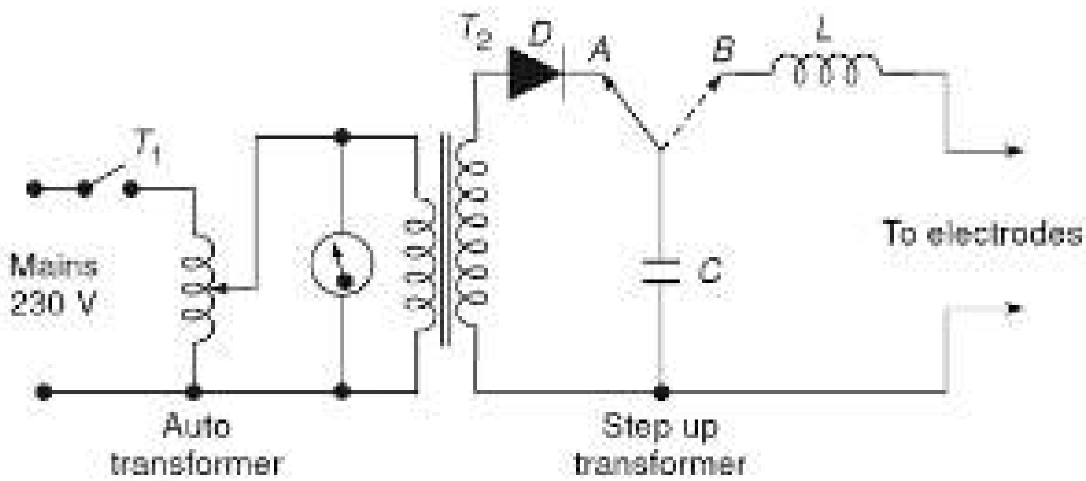


Figure 13.10 Electrodes used in cardiac defibrillation (a) A spoon-shaped internal electrode that is applied directly to the heart. (b) A paddle-type electrode that is applied against the anterior chest wall.

- The two defibrillator electrodes applied to the thoracic walls are called either anterior-anterior or anterior-posterior.
- Anterior –anterior paddles are applied to the chest
- Anterior –posterior paddles are applied to both the patients chest wall and back.

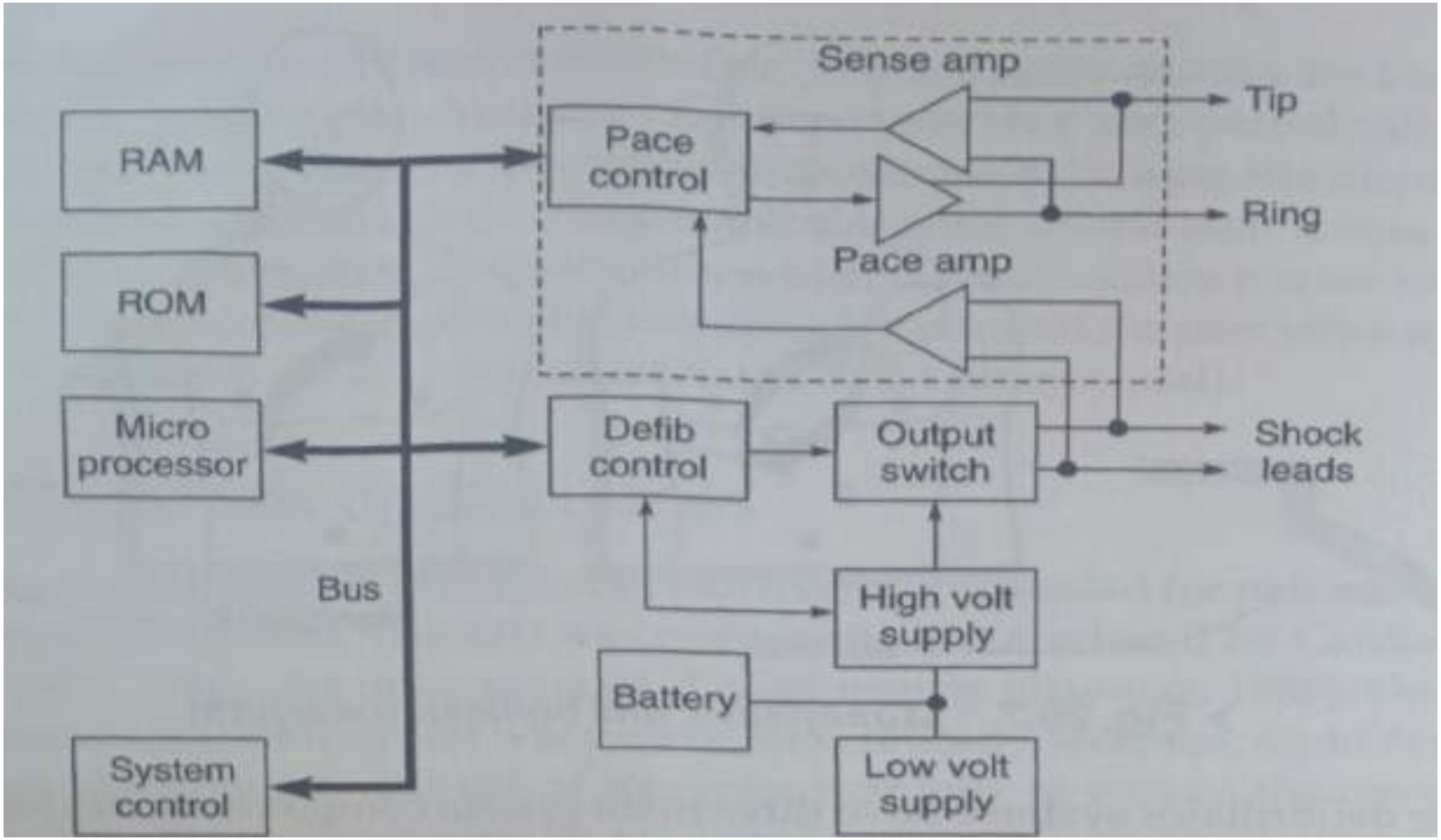
<u>A schematic diagram of DC defibrillator:</u>



Schematic diagram of a defibrillator

- A variable auto transformer T1 forms the primary of the high voltage transformer T2
- The output of the transformer is rectified by a diode and is connected to a vacuum type high voltage change over switch.
- In position A, switch is connected to one end of capacitor.In this position , the capacitor charges to a voltage set by the position of the transformer.
- When shock is to be delivered to the patient , the switch is changed to position B and capacitor is discharged across the heart through the electrodes.

IMPLANTABLE DEFIBRILLATORS



- An implantable defibrillator is continuously monitors a patient's heart rhythm.
- If the device detects fibrillation, the capacitors within the device are charged up to750 V. The capacitors then discharged into the heart which mostly represents a resistive load of 50 ohm and to bring heart into normal rhythm.
- This may require delivery of more than one high energy pulse.
- Implantable defibrillator systems have three main system components: the defibrillator itself (AID), the lead system, and the programmer recorder/monitor (PRM). The AID houses the power source, sensing, defibrillation, pacing, and telemetric communication system. The leads system provides physical and electrical connection between the defibrillator and the heart tissue. The PRM communicates with the implanted AID and allows the physician to view status information and modify the function of the device as needed.

- The PRM is an external device that provides a bidirectional communications link to an implanted AID. This telemetry link is established from a coil which is contained within the wand of the PRM, to a coil which is contained within the implanted device.
- The modern implantable defibrillators make use of a single transvenous lead with the multiple electrodes inserted into the right ventricle for ventricular pacing and defibrillation.
- ROM provides non-volatile memory for system start-up tasks and some program space,whereas RAM is required for storage of operating parameters, and storage of electro-cardiogram data.
- The system control part includes support circuitry for the microprocessor like a telemetry interface, typically implemented with a UART-like (universal asynchronous receiver/transmitter) interface and general purpose timers.

- The power supply to the circuit comes from lithium Silver Vanadium oxide (Li SVO)batteries.
- Digital circuits operate from 3 V or lower supplies whereas analog circuits typically require precision nanoampere current source inputs. Separate voltage supplies are generated for pacing (approximately 5 V) and control of the charging circuit (10-15 V)
- High power circuits convert the 3-6 V battery voltage to the 750 V necessary for a defibrillation pulse, store the energy in high voltage capacitors for timed delivery, and finally switch the high voltage to cardiac tissue or discharge the high voltage internally if the cardiac arrhythmia self- terminate.

VENTILATORS

- A ventilator is a machine that supports breathing.

- These machines mainly are used in hospitals.

Ventilators perform the following:

- Get oxygen into the lungs.
- Remove carbon dioxide from the body.
- Help people breathe easier.
- Breathe for people who have lost all ability to breathe on their own.

- A ventilator often is used for short periods, such as during surgery when you're under general anesthesia

- The term "anesthesia" refers to a loss of feeling and awareness. General anesthesia temporarily puts you to sleep.

- The medicines used to induce anesthesia can disrupt normal breathing.

- A ventilator helps make sure that you continue breathing during surgery.

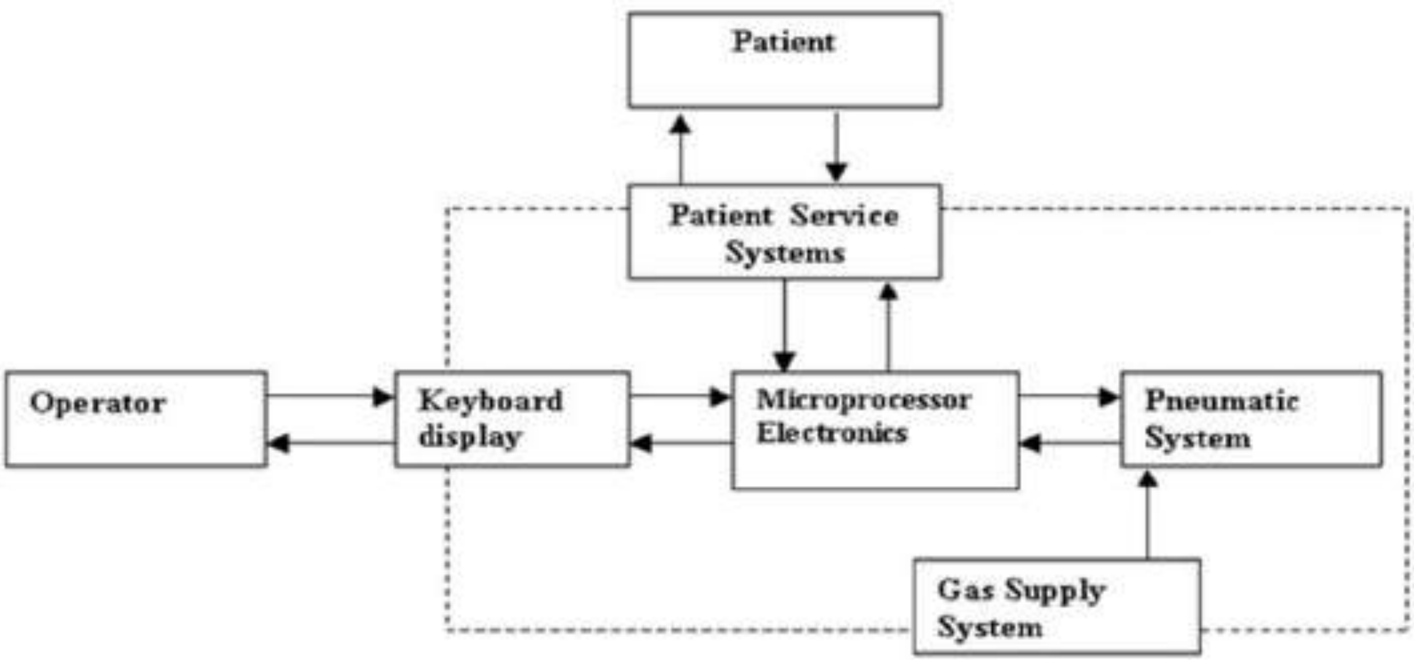
- A ventilator also may be used during treatment for a serious lung disease or other condition that affects normal breathing.

- Some people may need to use ventilators long term or for the rest of their lives.

- A ventilator **doesn't treat a disease or condition**. It's used only for life support

Other Names for a Ventilator

- Mechanical ventilator
- Respirator
- Breathing machine



- The pneumatic system is responsible for delivery of the gas mixture to the patient.
- The pneumatic system can be single circuited or double circuited
- In case of single circuit ventilators, the same gas that powers pneumatic system is the same gas that is delivered to the patient.
- But for double circuit ventilators the gas delivered to the patient is different from the gas that powers pneumatic system.
- The microprocessor controls the inspiratory and expiratory valves. The microprocessor also controls the information flow from the monitoring system of the ventilator , ie the pressure , flow and volume and display of that information.
- The ventilator alarms are also controlled by the microprocessor.

Who Needs a Ventilator?

Ventilators most often are used:

- During surgery if you're under anesthesia (that is, if you're given medicine that makes you sleep and/or causes a loss of feeling)

- If a disease or condition impairs your lung function

During Surgery

- If you have general anesthesia during surgery, you'll likely be connected to a ventilator. The medicines used to induce anesthesia can disrupt normal breathing. A ventilator helps make sure that you continue breathing during surgery.

- After surgery, you may not even know you were connected to a ventilator. The only sign may be a slight sore throat for a short time. The sore throat is caused by the tube that connects the ventilator to your airway.

- Once the anesthesia wears off and you begin breathing on your own, the ventilator is disconnected. The tube in your throat also is taken out. This usually happens before you completely wake up from surgery.
- However, depending on the type of surgery you have, you could stay on a ventilator for a few hours to several days after your surgery.

For Impaired Lung Function

- You may need a ventilator if a disease, condition, or other factor has impaired your breathing.
- Although you might be able to breathe on your own, it's very hard work.
- You may feel short of breath and uncomfortable.
- A ventilator can help ease the work of breathing.
- People who can't breathe on their own also use ventilators.

Many diseases, conditions, and factors can affect lung function.

Examples include:

- Pneumonia and other infections
- Chronic obstructive pulmonary disease (COPD): Damage to the lungs results in difficulty blowing air out, causing shortness of breath. Smoking is by far the most common cause of COPD.
- Upper spinal cord injuries, and other diseases or factors that affect the nerves and muscles involved in breathing
- Brain injury or stroke
- Drug overdose

- Can be separated into 3 general categories

  Controller type

  Assister type

  Assist-Control mode

- Another classification is

  Negative-pressure devices.

  Positive-pressure devices.

Controller type

- When a patient is connected to a controller type of ventilator, his or her respiratory ventilation is determined by the machine.

- Breathing is controlled by a timer set to provide the desired respiration rate.

- Controlled ventilation is required for patients who are unable to breathe on their own.

- Respirator has complete control over the patient's respiration and does not respond to any respiratory effort on the part of the patient.

Assister Type

- It is controlled by the patient and used to augment his or her own ventilation activities.
- The assister detects the patient's attempt at ventilation and augments it mechanically.
- Respirator helps the patient inspire when he wants to breathe.
- It is used for patients who are able to control their breathing but are unable to inhale a sufficient amount of air without assistance or for whom breathing requires too much effort.
- Thus it assists rather than controls the patient in ventilation

Assist/Control type

- It is normally triggered by the patient's attempts to breathe, as in assist mode.
- If a patient fails to breathe within a predetermined time, a timer automatically triggers the device to inflate the lungs.
- Thus the patient controls his own breathing as long as he can, but if he should fail to do so, the machine is able to take over for him.

Negative-pressure ventilators

- Are more physiological, in that the body of the patient is contained in a sealed chamber in which the pressure can be reduced.

- Producing a negative pressure around the chest and abdomen.

- Negative pressure moves across the chest and diaphragm and causes air to move into the lungs in the normal fashion

- When the negative pressure stops being applied, the chest returns to atmospheric pressure and the inspired air then is exhaled.

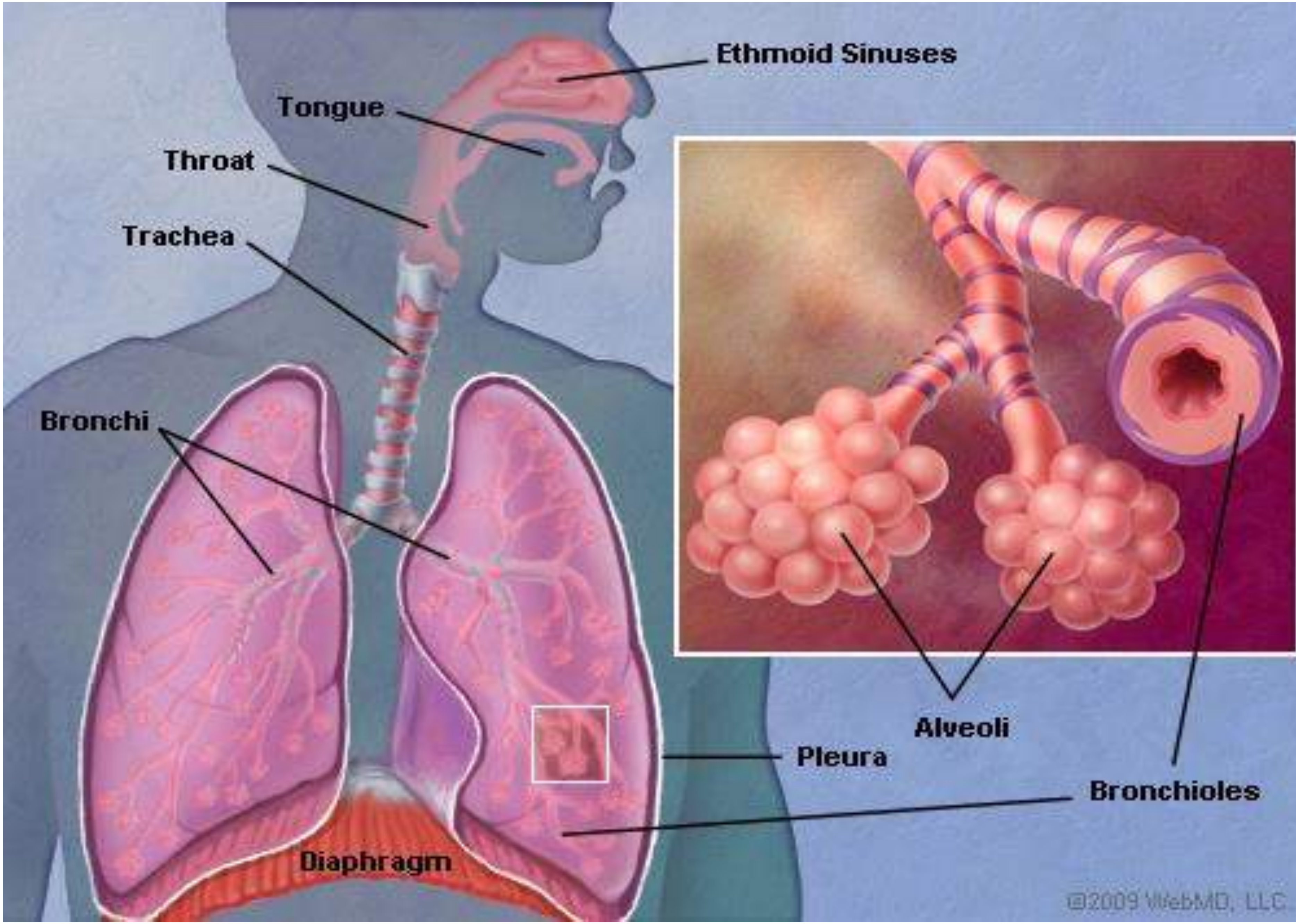
Positive-pressure ventilators

- Blow air into the lungs by increasing the pressure in the trachea.

- This causes the lungs to expand due to internal pressure and then to recoil naturally, expelling a portion of the air once the positive pressure is removed.

- Even though negative pressure ventilators are more physiological, they are by necessity large and limit access to the patient for therapy.

- For these reasons, they are seldom used clinically today.


Ethmoid Sinuses
Tongue
Throat
Trachea
Bronchi
Alveoli
Pleura
Bronchioles
Diaphragm
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- Ventilators can be time cycled, volume cycled, or pressure cycled.

Time Cycled Ventilator

- This means that the air/oxygen is applied to the body for a given period of time and then released for another given period of time before the process is repeated.

- Modern time cycled ventilators are electronically controlled. Microprocessors are used to establish the cycling or the rate of ventilation, as well as the ratio between inspiration and expiration times or volumes.

volume-cycled ventilator

- A predetermined volume of gas has been delivered to the patient.

- The progression of the cycles of the ventilator is controlled by the volume of air administered to the patient.

- Thus, if a machine is set to cycle on a given volume, it does not cycle until that volume of air has been administered to the patient.

pressure-cycled ventilator

- Air is administered to the patient until the pressure reaches a predetermined limit, at which time the ventilator switches to its expiratory portion of the cycle, and the process is repeated

What To Expect While on a Ventilator

- Ventilators normally don't cause pain. The breathing tube in your airway may cause some discomfort. It also affects your ability to talk and eat.

- If you're on a ventilator for a long time, you'll likely get food through a nasogastric or feeding tube. The tube goes through your nose or mouth or directly into your stomach or small intestine through a surgically made hole.

- A ventilator greatly restricts your activity and also limits your movement. You may be able to sit up in bed or in a chair, but you usually can't move around much.

What Are the Risks of Being on a Ventilator?

- Infections
- One of the most serious and common risks of being on a ventilator is **pneumonia.** The breathing tube that's put in your airway can allow bacteria to enter your lungs. As a result, you may develop ventilator-associated pneumonia (VAP).
- Another risk of being on a ventilator is a **sinus infection**
- **Lung damage.** Pushing air into the lungs with too much pressure can harm the lungs.

- **Oxygen toxicity**. High levels of oxygen can damage the lungs.

What To Expect When You're Taken Off of a Ventilator

- "Weaning" is the process of taking you off of a ventilator so that you can start to breathe on your own. People usually are weaned after they've recovered enough from the problem that caused them to need the ventilator
- Weaning usually begins with a short trial. You stay connected to the ventilator, but you're given a chance to breathe on your own. Most people are able to breathe on their own the first time weaning is tried. Once you can successfully breathe on your own, the ventilator is stopped
- A ventilator helps you breathe until you recover. If you can't recover enough to breathe on your own, you may need a ventilator for the rest of your life.

Haemodialysis

- The kidneys are responsible for filtering waste products from the blood.
- Dialysis is a procedure that is a substitute for many of the normal duties of the kidneys.
- The kidneys are two organs located on either side of the back of the abdominal cavity.
- Dialysis can allow individuals to live productive and useful lives, even though their kidneys no longer work adequately

When is dialysis needed?

- You need dialysis when you develop end stage kidney failure
- --usually by the time you lose about 85 to 90 percent of your kidney function

What does dialysis do?

Like healthy kidneys, dialysis keeps your body in balance.

Dialysis does the following:

- removes waste, salt and extra water to prevent them from building up in the body
- keeps a safe level of certain chemicals in your blood, such as potassium, sodium and bicarbonate
- helps to control blood pressure

What is hemodialysis?

- Hemodialysis is a procedure in which a machine filters harmful waste and excess salt and fluid from your blood.
- A needle is inserted into your arm through a special access point.
- Your blood is then directed through the needle to a machine called a dialyzer, which filters your blood a few ounces at a time.
- The filtered blood returns to your body through another needle


BPH

Complications of Kidney failure

- kidneys play a role in many of body's systems.
- When kidneys stop working, these other systems don't work as well as they did before.
- This can lead to various complications, including:
  - Lack of red blood cells (anemia)
  - Bone diseases
  - High blood pressure
  - Fluid overload
  - Inflammation of the membrane surrounding the heart
  - High potassium levels, which can affect your heart rhythm
  - Nerve damage
  - Infection
  - Heart disease

Who needs hemodialysis?

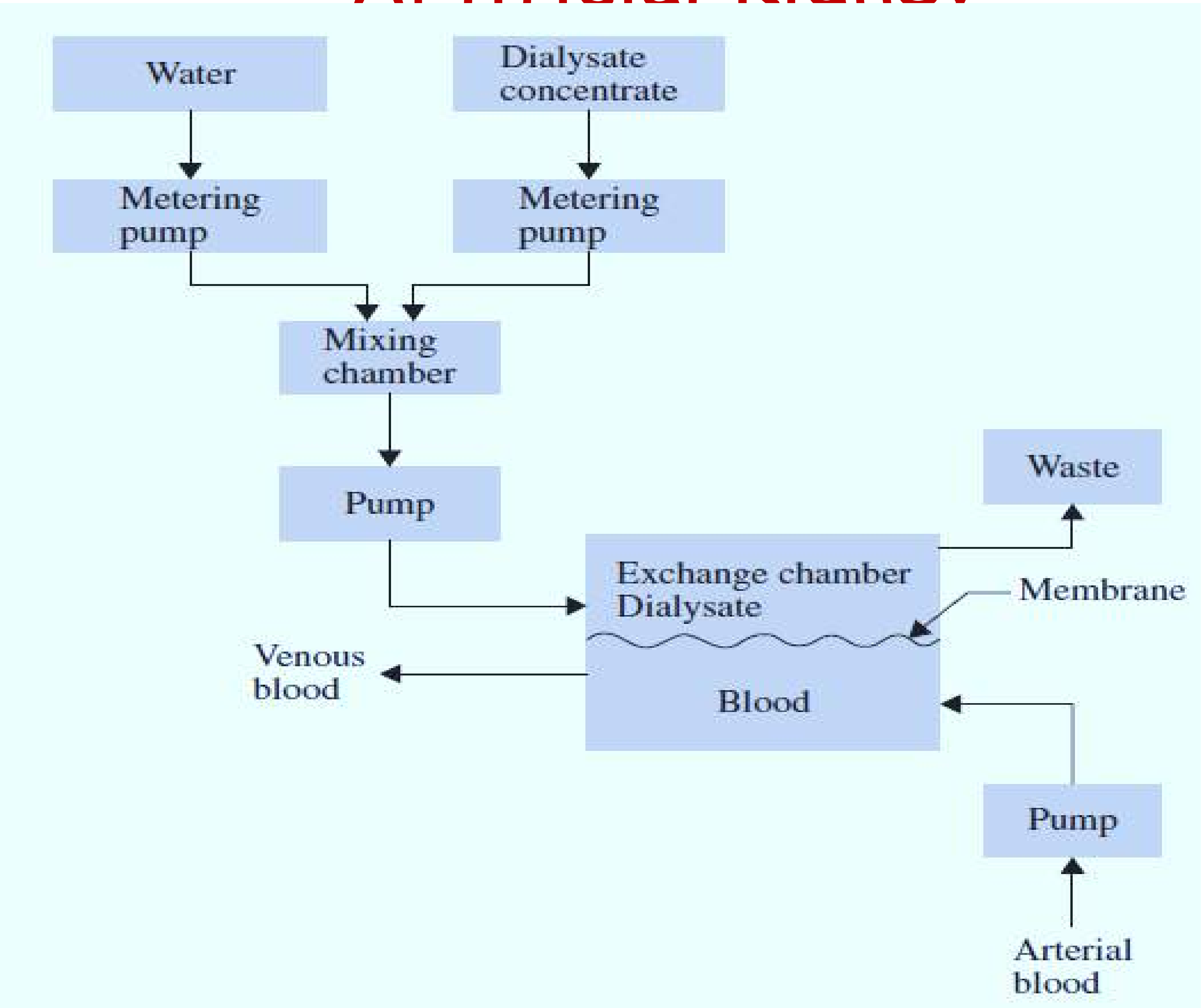
- If your kidneys are failing, you may need dialysis to help control your blood pressure and maintain the proper balance of fluid and various chemicals — such as potassium and sodium — in your body.

- Dialysis also helps your body maintain the proper acid-base balance

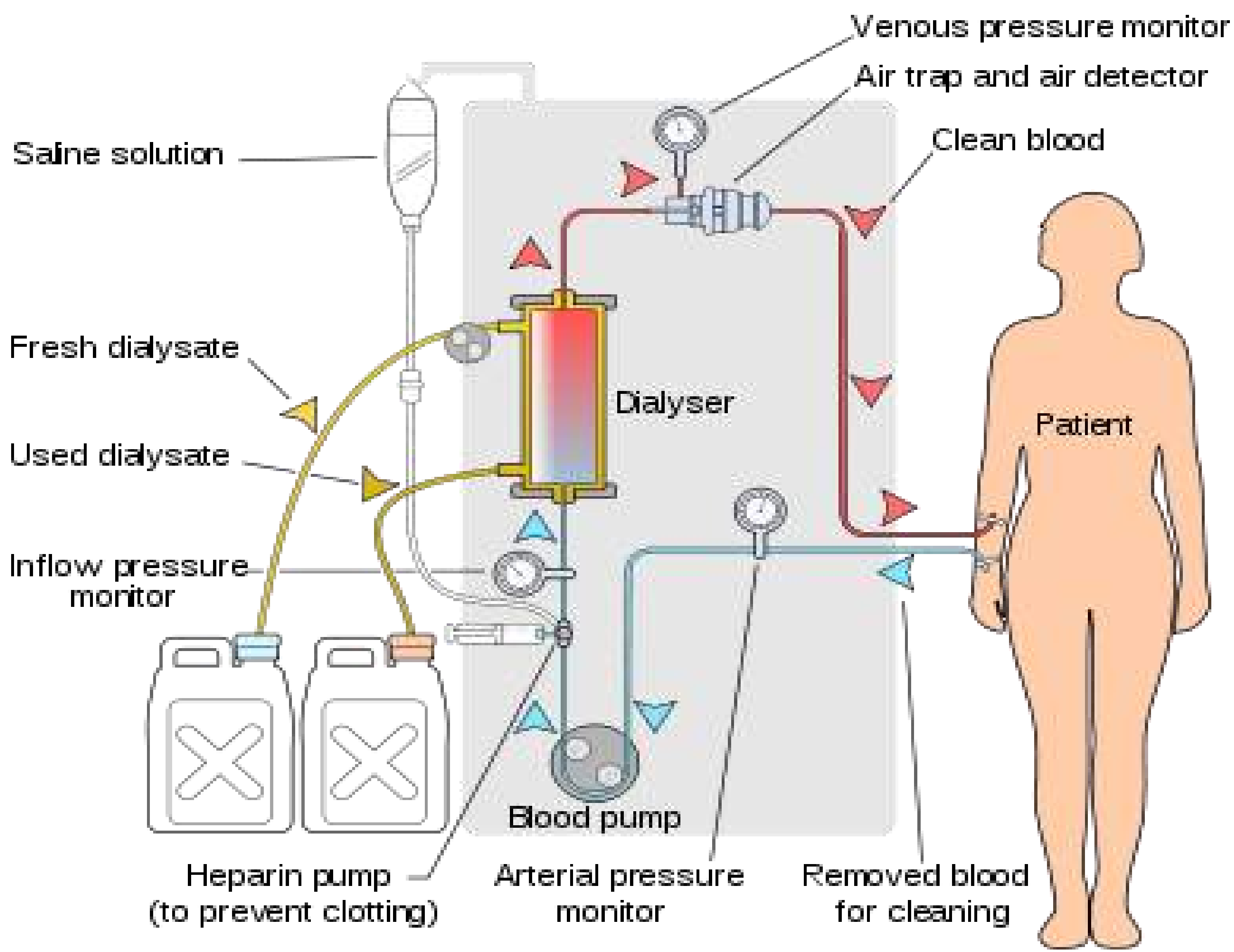
Sometimes kidney failure is caused by a specific kidney disease. In other cases, it's a complication of another condition, such as:

- Diabetes
- High blood pressure (hypertension)
- Kidney inflammation
- Inflammation of blood vessels
- Polycystic kidney disease

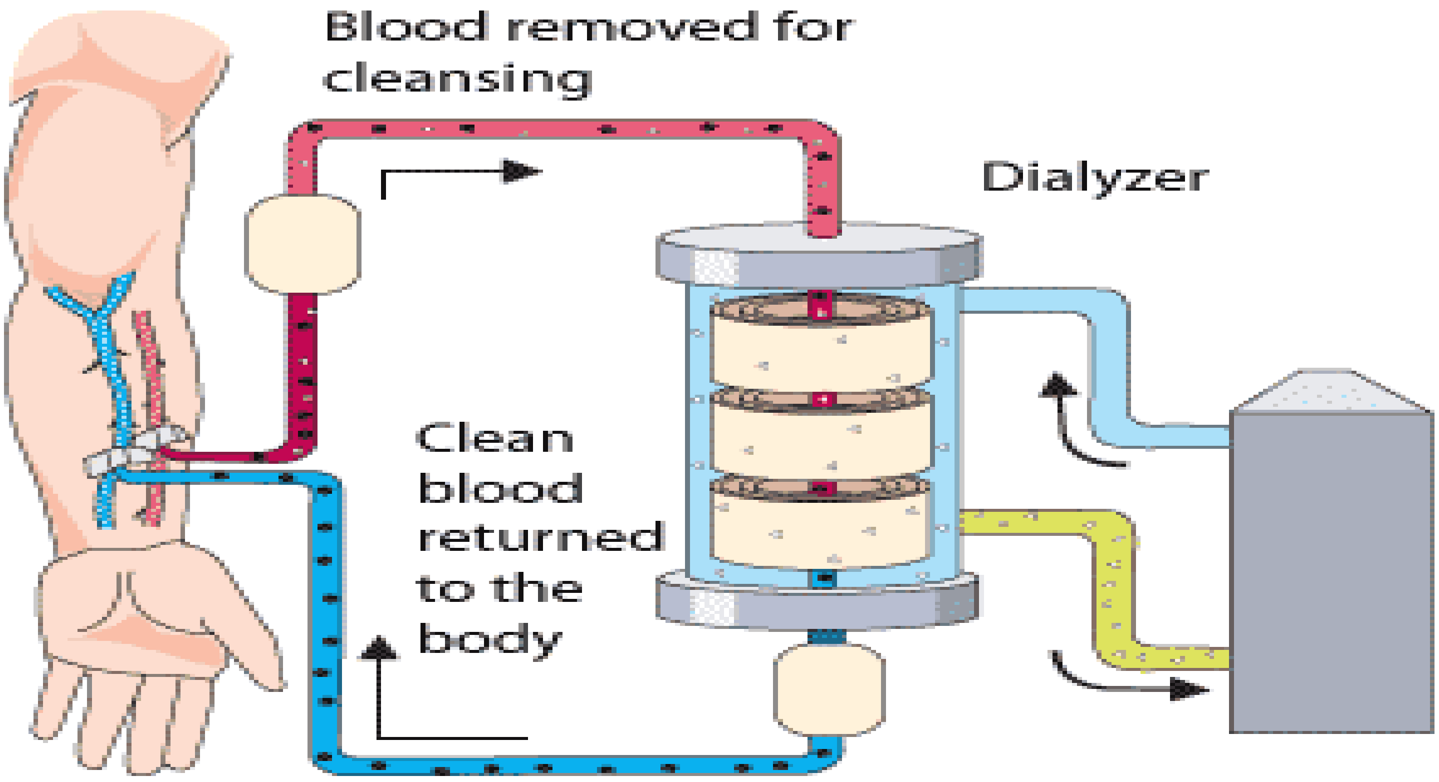
Artificial Kidney



- Two basic units---exchanger and dialysate delivery system
- Exchanger consist of dialysis chamber—which consist of a compartment containing patient’s blood and a compartment containing the dialysate
- These two compartments are separated by a semipermeable membrane that allows the waste components in the blood to diffuse through to the dialysate, which carries them away.
- Dialysate is made of water with some solutes added.

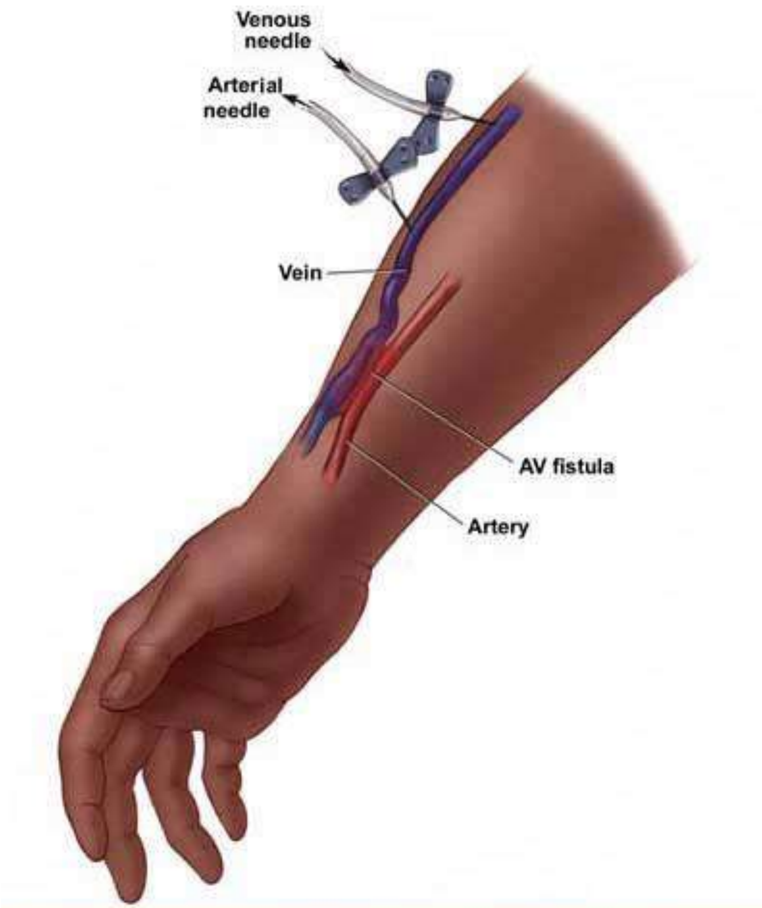

Venous pressure monitor
Air trap and air detector
Clean blood
Saline solution
Fresh dialysate
Dialyser
Patient
Used dialysate
Inflow pressure monitor
Blood pump
Heparin pump (to prevent clotting)
Arterial pressure monitor
Removed blood for cleaning

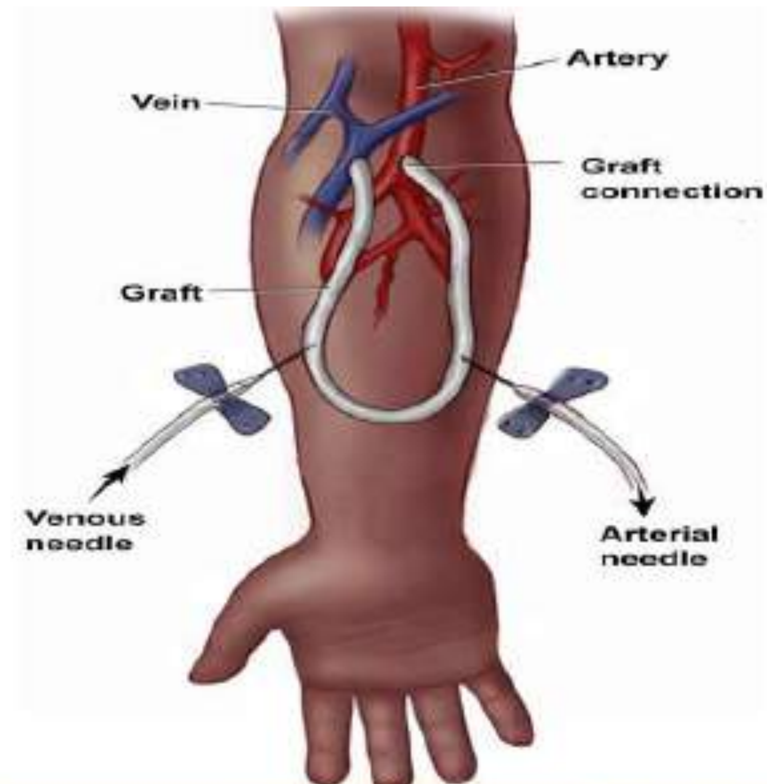
- Blood flows from the body into the hemodialysis machine through a filter called a dialyzer.
- The dialyzer removes waste from the blood. This blood then re-enters the body



- Before you start hemodialysis, a surgeon creates a vascular access point for blood to leave for cleansing and then re-enter your body during treatment.
- There are three types of access points :

- First, the hemodialysis machine is attached to your bloodstream by inserting a needle into three possible places: directly into a blood vessel using a plastic catheter (this is more common for emergency hemodialysis-temporary access), into a fistula, or into a graft.
- A **fistula** is created by surgically attaching a vein and an artery together to increase blood flow into the vein, making it larger and stronger. This larger and stronger vein is easier to connect to the dialysis machine and perform repeated hemodialysis treatments.
- A **graft** is used when the artery and vein can't be connected directly. A nylon tube is used instead with one end connected to the vein and the other to the artery. You may feel some pain when the needle is inserted.





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Artificial Kidney

- Dialyzing membrane has small holes.
- Average diameter of holes is 10^{-10} m.
- Waste products in blood are able to pass through these holes into dialysate fluid.

Diffusion

- Due to concentration gradient across membrane, waste product will pass through.
- Dialysate fluid free from waste product molecules.
- Thus, waste products in blood tend to distribute evenly throughout blood and dialysate.
- Movement of waste products from blood to dialysate results in cleaning of the blood.

Convection

- Volume of body fluid cannot be controlled by dialysis.
- Ultra-filtration across membrane is employed.
- Positive pressure applied to blood compartment.
- Or negative pressure established in dialysate compartment.
- Thus, fluid (water and electrolytes) will move from blood compartment to dialysate.
- Degree of ultra-filtration depends on pressure difference across membrane and ultra-filtration characteristic of membrane.

Comparison with Natural Kidney

- Artificial kidney is a membrane separation device that serves as mass exchanger during clinical use.
- It is unable to perform any metabolic functions of normal kidney.
- Therefore, it cannot correct abnormalities results from the loss of kidney function.
- Artificial kidney can only substitute kidney in the transfer of unneeded substances from blood to be eliminated from the body.

Dialyzers

- The part in artificial kidney system where blood is freed from waste products.

Components of Dialyzer

- Blood compartment.
- Dialysate compartment.
- Semipermeable membrane.
- Membrane support structure.

Design Consideration of Dialyzer

- Can be classified according to three basic design considerations : parallel plate, coil and hollow fiber.
- Clearance of substances from blood depends upon the rate of blood flow.

- Rate and pattern of dialysate flow could also influence overall performance.
- Since dialysis is based on concentration gradient, it is desirable to maintain zero concentration of waste substances in dialysate.
- This could be done by using dialysate only once.
- Resistance to blood flow in dialyzer should be as low as possible.
- The purpose having low resistance is to eliminate the need for blood pump.
- All the blood that flow through the blood compartment of dialyzer should be completely returned to patient.

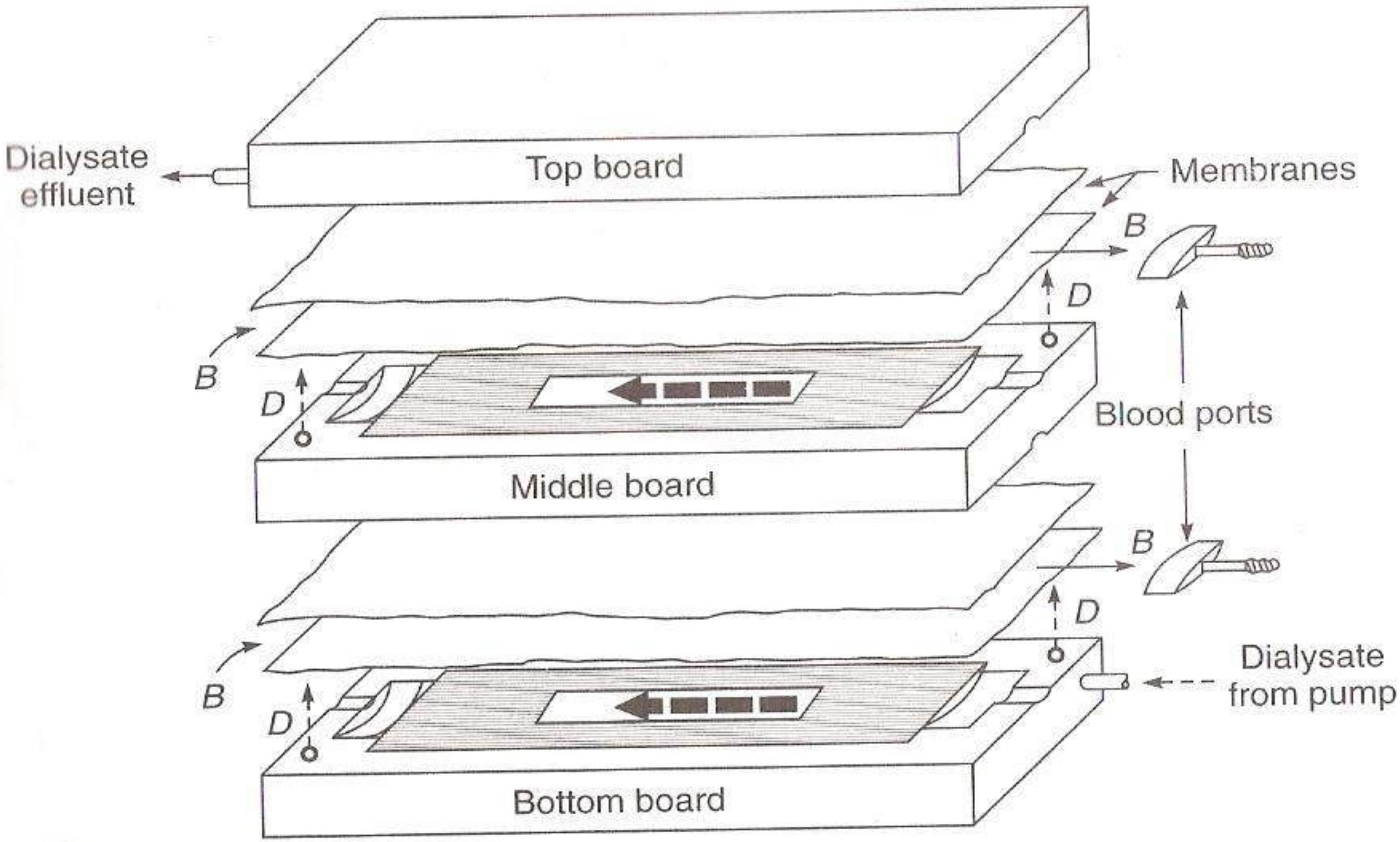
Parallel Flow Dialyzer

- Use parallel plates with ridges and grooves in them.
- Low internal resistance, allows adequate blood flow through dialyzer.
- Rigid supports permit negative pressure to be created on dialysate side for ultra-filtration.

KIIL Dialyzer

- An example of this kind of dialyzer is KIIL Dialyzer.
- Consists of three polypropylene boards with dialyzing membranes laid between them.
- Rubber gasket runs along the periphery of the boards inner surface to prevent blood and dialysate leakage.

Dialyzers



Dialysate effluent
Top board
Membranes
B
D
B
D
Blood ports
Middle board
B
D
B
D
Dialysate from pump
Bottom board

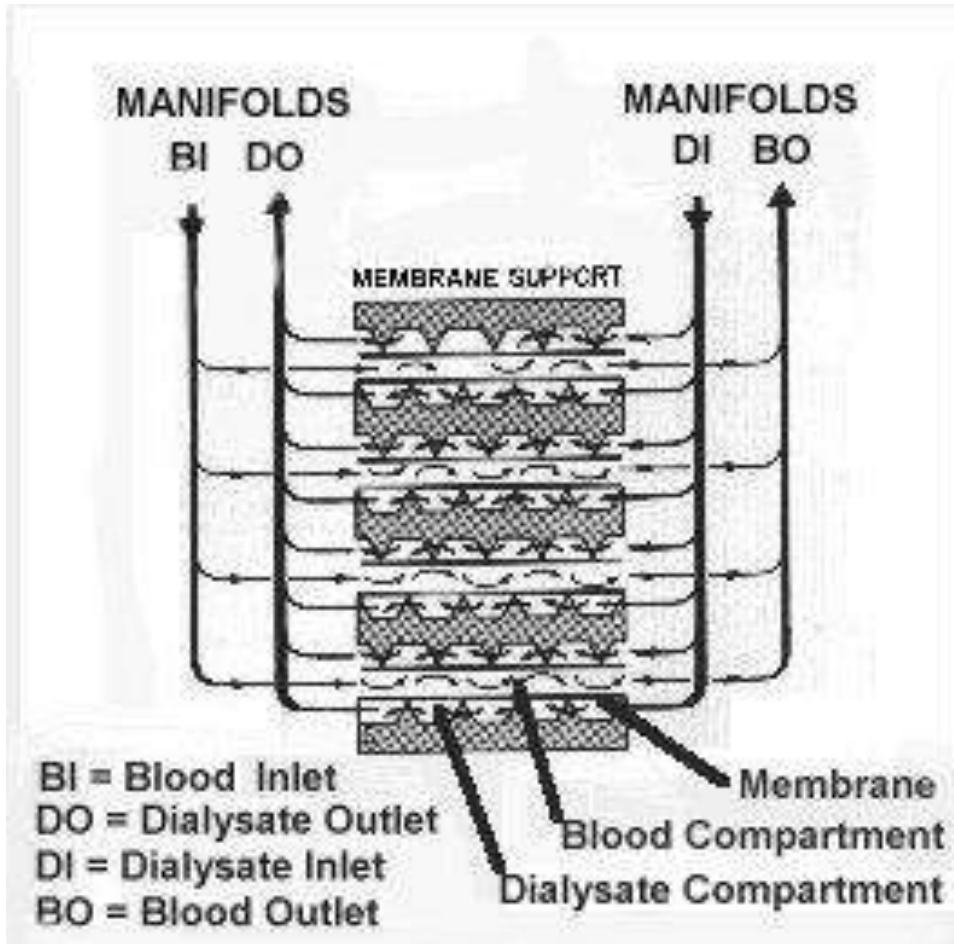
Dialyzers

- Dialysate enters through a stainless steel port.
- It is then distributed to grooves running across the end of the board above and below membrane of each layer.
- It flows down longitudinal grooves in the boards before collected and flow out at opposite end of the board.
- Dialyzer not disposable but need to be cleaned after each dialysis operation.

Coil Dialyzer

- Tubular membrane placed between flexible support wrapped around a rigid cylindrical core.
- The coil is immersed in a dialyzing bath.

Dialyzers

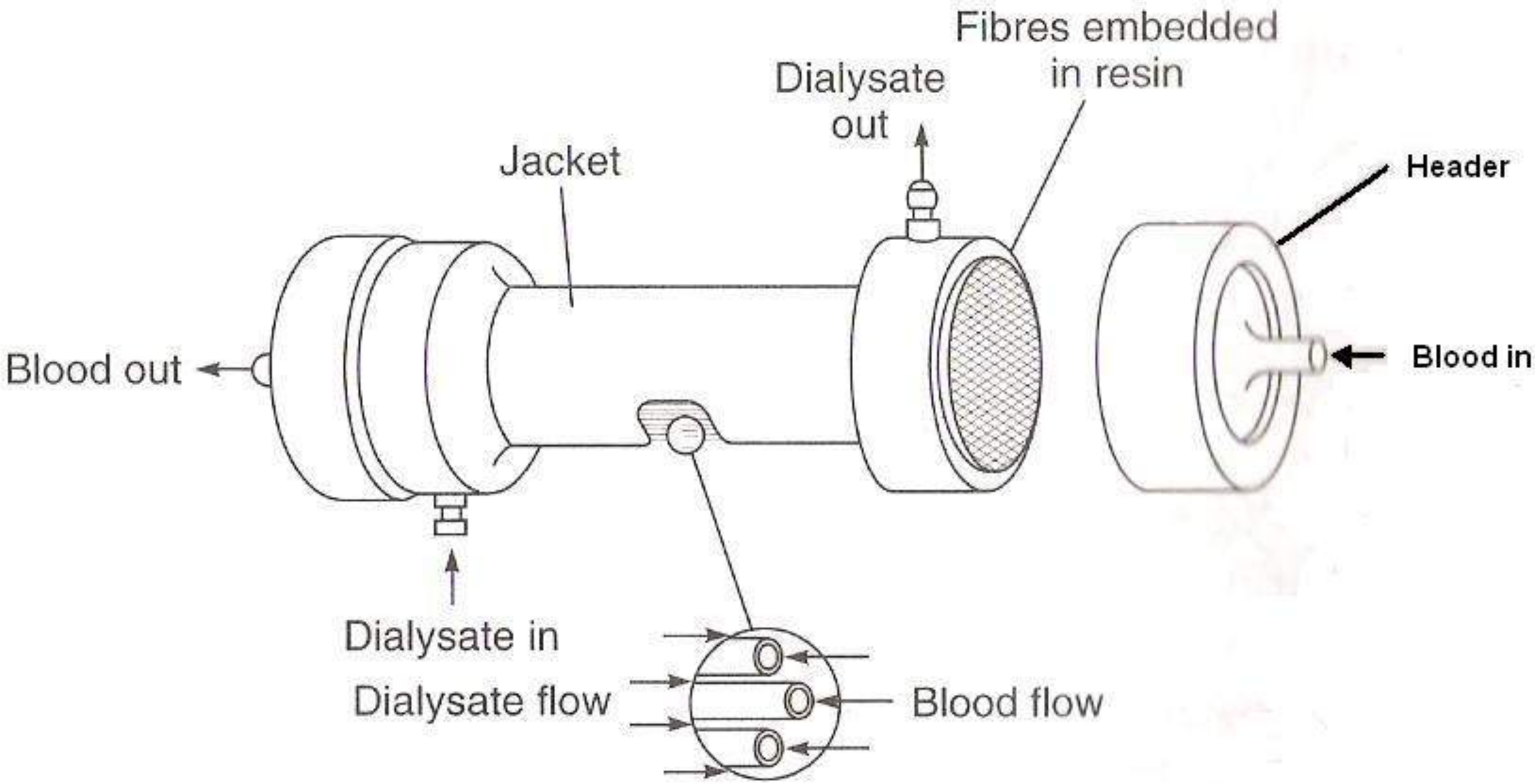

MANIFOLDS
BI DO
MANIFOLDS
DI BO
MEMBRANE SUPPORT
BI = Blood Inlet
DO = Dialysate Outlet
DI = Dialysate Inlet
BO = Blood Outlet
Membrane
Blood Compartment
Dialysate Compartment

- The design of coil dialyzer is simple.
- However it has performance limitations which restricted its use better design evolved.
- Coil design did not produce uniform dialysate flow distribution across membrane.
- High resistance to blood.

Hollow Fibre Dialyzer

- Most commonly used.
- Consists of thousands of hollow de-acetylated cellulose diacetate capillaries.
- The capillaries are jacketed in a plastic cylinder.

Dialyzers



Fibres embedded in resin
Dialysate out
Jacket
Header
Blood out
Blood in
Dialysate in
Dialysate flow
Blood flow

- The capillaries range from 200-300 mm internal diameter and wall thickness of 25-30 um.
- Dialyzing area approximately 9000 cm^2/unit.
- The blood introduced and removed through manifold headers.
- The dialysate is drawn through the jacket under negative pressure outside of the capillaries.
- Dialyzers are disposable.

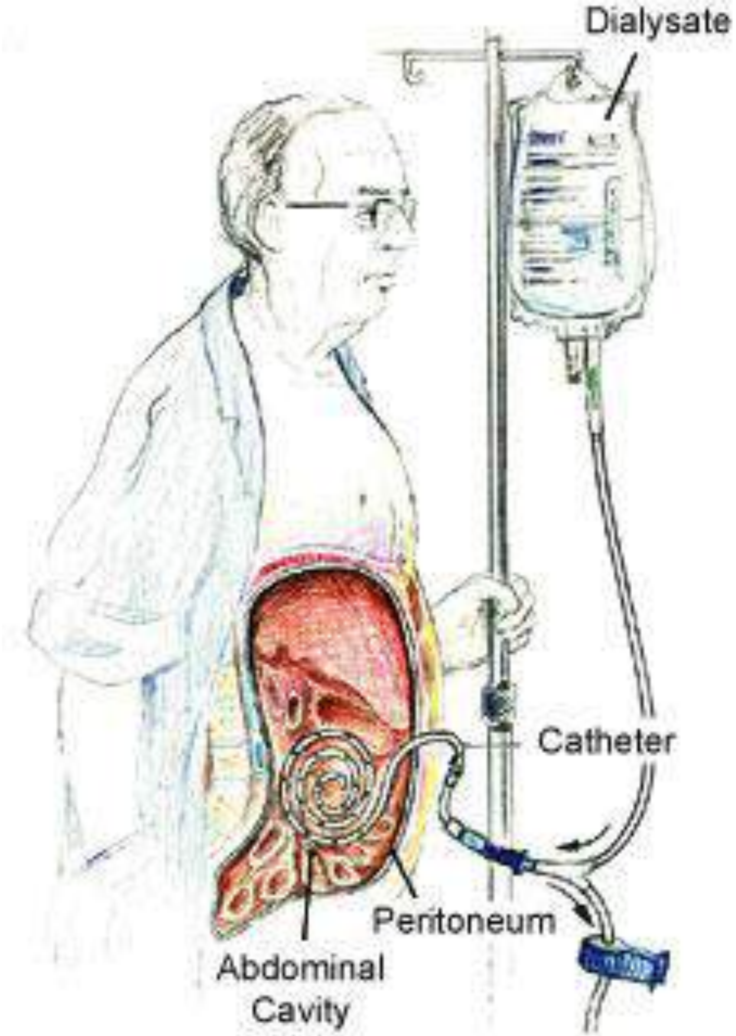
Advantages of disposable dialyzers :

- reduction in infection risk.
- reduce operator set-up time.
- eliminate dialyzer sterilization procedure.

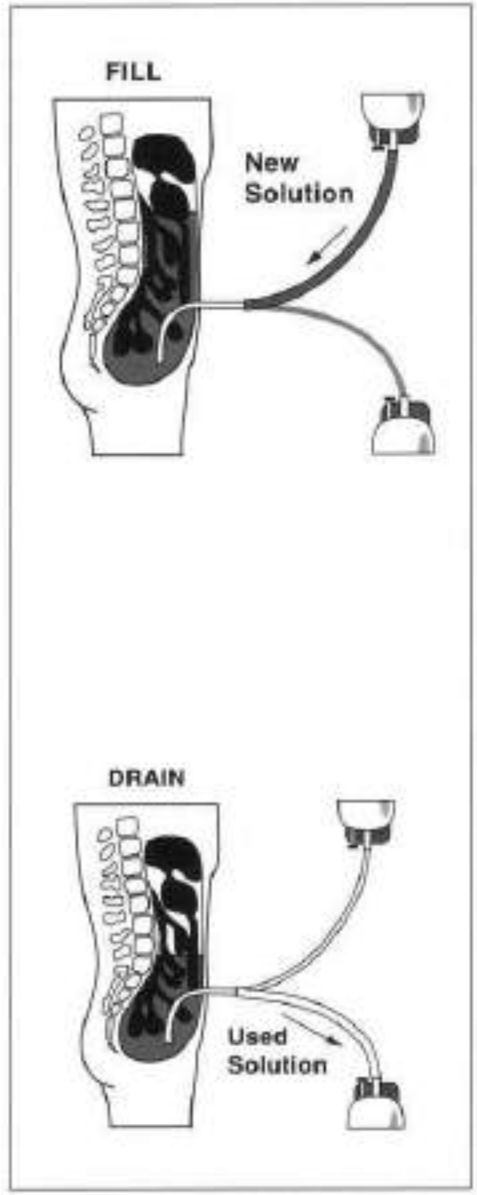
Peritoneal Dialysis

- Peritoneum acts as a filter/semipermeable membrane.
- *Peritoneum is a membrane that lines the abdomen and covers the abdominal organs*.
- A sterile solution containing minerals and glucose is run through a tube into the peritoneal cavity.
- Peritoneum membrane has a large surface area and a rich network of blood vessels. Substances from the blood can easily pass through the peritoneum into the abdominal cavity .
- The dialysate is left there for a period of time to absorb waste products, and then it is drained out through the tube and discarded.

Peritoneal Dialysis



Continuous Ambulatory Peritoneal Dialysis



Peritoneal Dialysis works inside the body. Dialysis solution flows through a tube into the abdominal cavity where it collects waste products from the blood.

Periodically, the used dialysis solution is drained from the abdominal cavity, carrying away waste products and excess water from the blood.

Heart Lung machine

- A medical equipment that provides Cardiopulmonary bypass, (temporary mechanical circulatory support) to the stationary heart and lungs)
- Cardiopulmonary bypass (CPB) is a technique that temporarily takes over the **function** of the **heart** and **lungs** during surgery, maintaining the circulation of blood and the oxygen content of the patient's body. The CPB pump itself is often referred to as a **heart–lung machine** or "the pump".
- Heart and Lungs are made “functionless temporarily” , in order to perform surgeries

  CABG (Coronary artery bypass grafting)

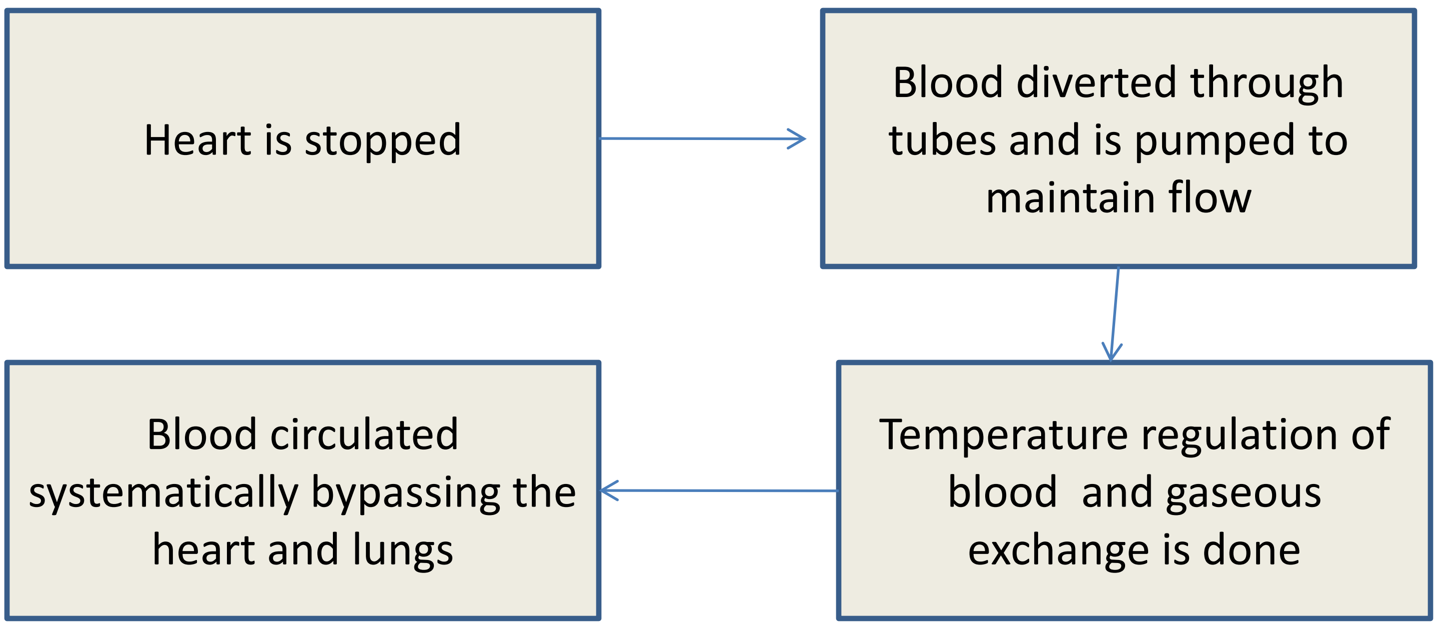
  Valve repair

  Aneurysm

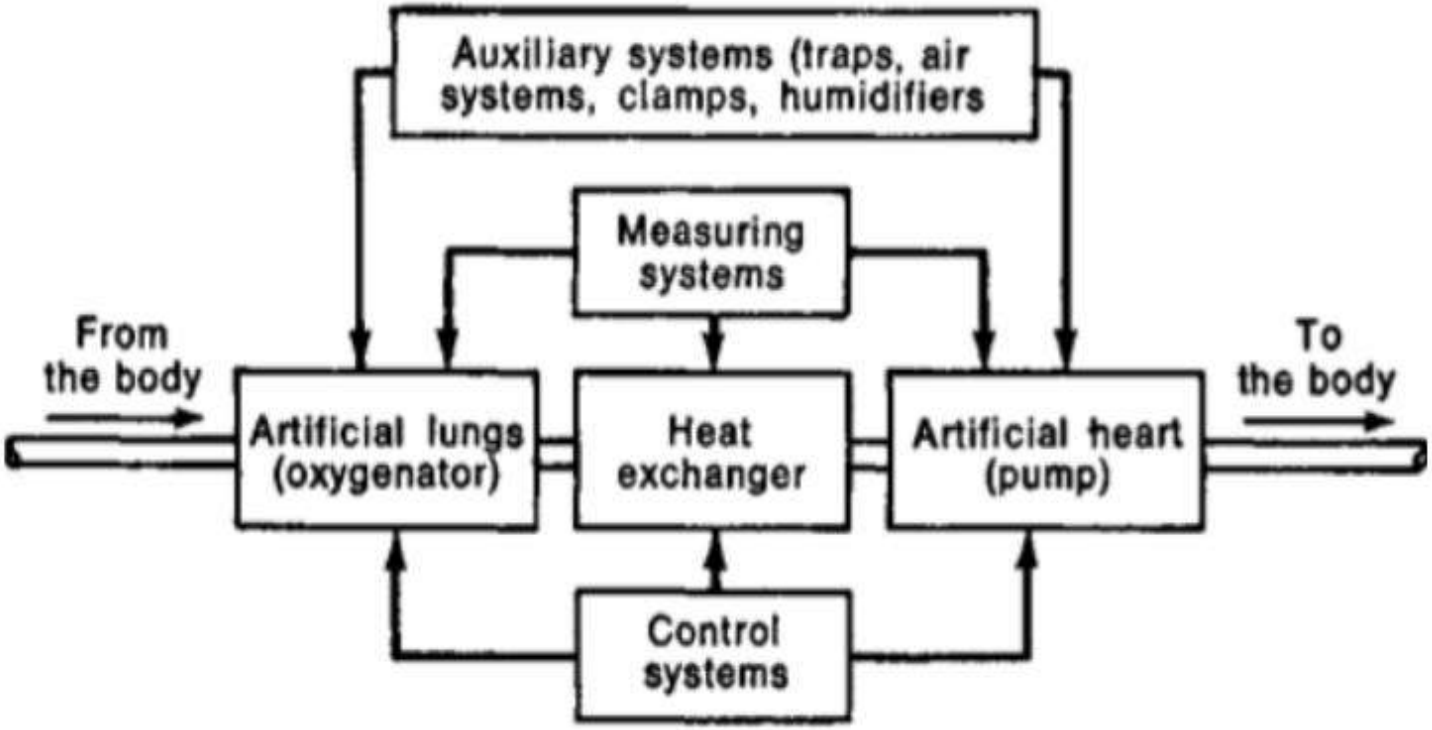
  Septal Defects

- On May 6, 1953, Dr. Gibbon used his heart–lung machine to successfully repair an atrial septal defect in an 18 year-old girl, Marking the first successful clinical use of a Heart– Lung Machine
- You'll be given medicine to stop your heartbeat once you're **connected** to the **heart-lung** bypass **machine**. A tube will be placed in your **heart** to drain blood to the **machine**. The **machine** will remove carbon dioxide (a waste product) from your blood, add oxygen to your blood, and then pump the blood back into your body.

➢ Principle and Necessity:



Block diagram of a Heart lung machine



Parts

- Five pump assemblies
- Venous Cannula
- Arterial Cannula - dual-stream aortic perfusion catheter / meshed cannula
- Venous Reservoir
- Oxygenators
- Heat Exchangers
- Cardiotomy Reservoir and Field Suction
- Filters and Bubble Traps
- Tubing and Connectors

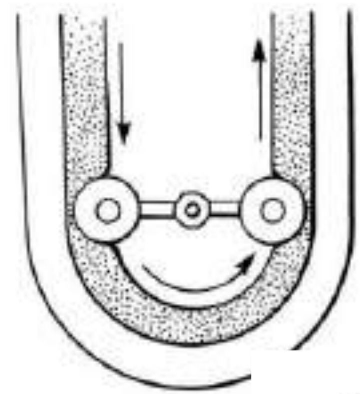
FIVE PUMP ASSEMBLIES

- A centrifugal or roller head pump can be used in the arterial position for extracorporeal circulation of the blood.
- Left ventricular blood return is accomplished by roller pump, drawing blood away from the heart.
- Surgical suction created by the roller pump removes accumulated fluid from the general surgical field.
- The cardioplegia delivery pump.
- Emergency Backup of the arterial pump in case of mechanical failure. Centrifugal pumps consist of plastic cones, which when rotated rapidly, propel blood by centrifugal force.

- Forward blood flow, varies with the speed of rotation and the after load of the arterial line.
- Centrifugal blood pumps generate up to 900 mm Hg of forward pressure, but only 400 to 500 mm Hg of negative pressure. Hence, less gaseous micro emboli.
- Centrifugal pumps produce pulse less blood flow
- Roller pumps consist tubing, which is compressed by two rollers 180° apart. Forward flow is generated by roller compression and flow rate depends upon the diameter of the tubing, rate of rotation.

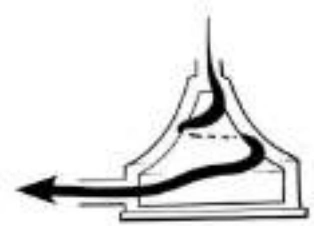
Pump Types

- Roller pump



- Impeller pump

- Centrifugal pump

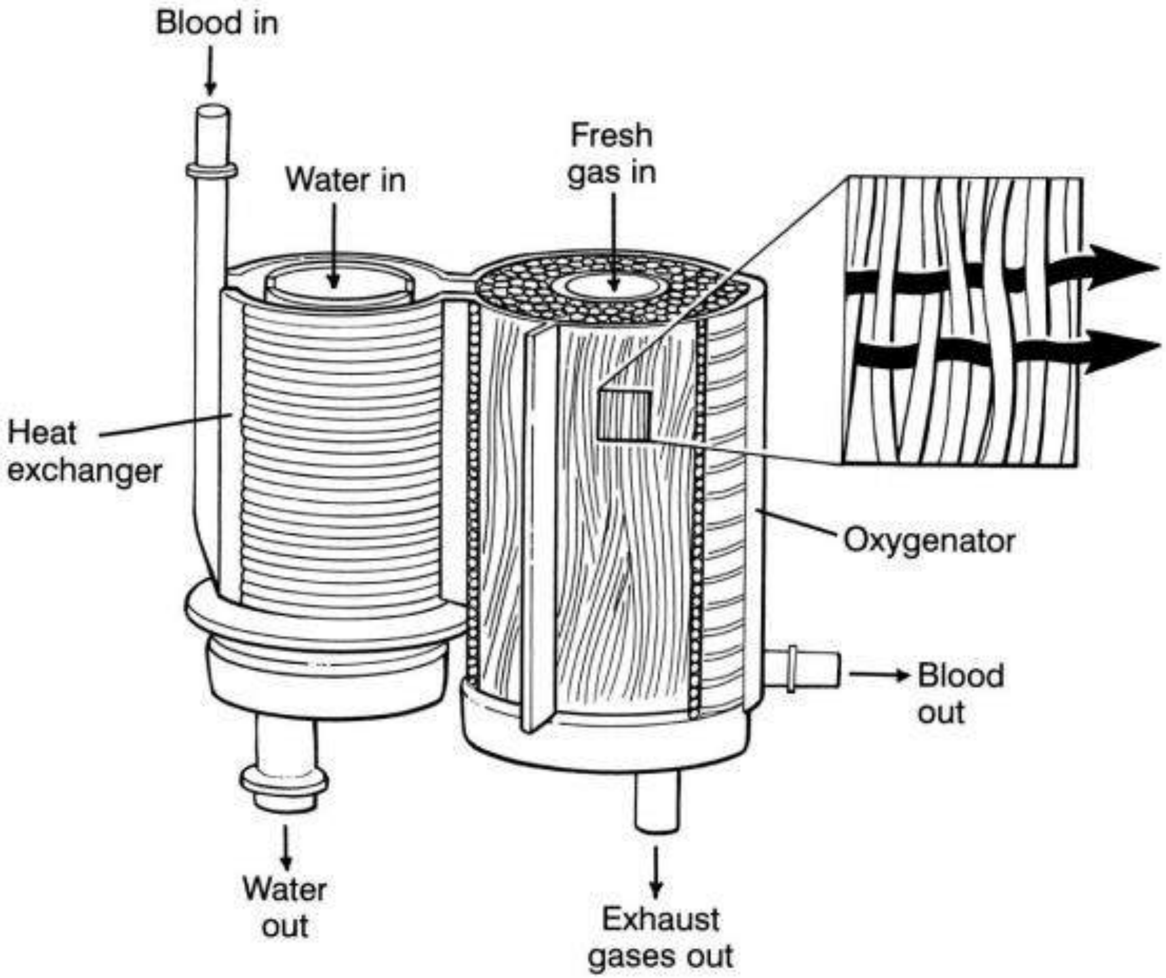


VENOUS RESERVOIRS

- Reservoirs may be rigid (hard) plastic canisters ("open" types) or soft, collapsible plastic bags ("closed" types).
- The venous reservoir serves as volume reservoir
- Facilitates gravity drainage,
- Venous bubble trap present,
- Provides a convenient place to add drugs, fluids, or blood, and adds storage capacity for the perfusion system.

Oxygenators

The artificial lung also called oxygenator takes lung function and is responsible for exchange of gases



Membranous Oxygenators

- Imitate the natural lung by interspersing a thin membrane of either micro porous polypropylene or silicone rubber between the gas and blood phases.
- With micro porous membranes, plasma-filled pores prevent gas entering blood but facilitate transfer of both oxygen and CO_2.
- The most popular design uses sheaves of hollow fibers connected to inlet and outlet manifolds within a hard-shell jacket.

Bubble Oxygenators

- Large bubbles improve removal of CO_2 greater in oxygenation
- Smaller bubbles are very efficient at oxygenation but poor in CO_2 removal
- Venous blood drains directly into a chamber into which oxygen is infused through a diffusion plate (sparger).
- The sparger produces thousands of small (approximately 36 µm) oxygen bubbles within blood.
- Gas exchange occurs across a thin film at the blood-gas interface around each bubble
- Produce more particulate and gaseous microemboli are more reactive to blood elements.

Heat Exchangers

- Control body temperature by heating or cooling blood passing through the perfusion circuit
- Temperature differences within the body and perfusion circuit are limited to 5°C to 10°C to prevent bubble emboli

Filters and Bubble Traps

- In the circuit, micro emboli are monitored by arterial line ultrasound or monitoring screen filtration pressure.
- Depth filters consist of porous foam, have a large, wetted surface and remove micro emboli by impaction and absorption
- Screen filters are usually made of woven polyester or nylon thread

Tubing

- Medical grade Polyvinyl Chloride (PVC) tubing
- It is flexible, compatible with blood, inert, nontoxic, smooth, nonwettable, tough, transparent, resistant to kinking and collapse,
- Can be heat sterilized
- The Duraflo II heparin coating ionically attaches heparin to a quaternary ammonium carrier (alkylbenzyl dimethyl - ammonium chloride), which binds to plastic surfaces.

Perfusion Monitors and Sensors

- A low-level sensor with alarms on the venous reservoir and a bubble detector on the arterial line are desirable safety devices.
- Flow-through devices are available to continuously measure blood gases, hemoglobin/hematocrit , and some electrolytes
- Temperatures of the water entering heat exchangers

STERILIZATION

- Ethylene dioxide is commonly used
- 4 hours of sterilization at 55°C or 18 hours at 22°C .
- Disadvantages of ethylene dioxide , are the toxicity and explosive nature
- Disposable tubing ,reservoirs and oxygenator
- Steam sterilization as PVC can withstand heat

ADVANTAGE

- Allow doctor to operate in a blood-free area, should contribute to less surgical error
- In the future, the heart-lung pump will hopefully become portable, allowing for paramedics to aid heart attack patients on the scene
- In future development to allow for less brain damage after the surgery

DIATHERMY

- High frequency currents, apart from their usefulness for therapeutic applications, can also be used in operating rooms for surgical purposes involving cutting and coagulation.
- The frequency of currents used in surgical diathermy units is in the range of 1-3 MHz in contrast with much higher frequencies employed in short wave therapeutic diathermy machines.
- This frequency is quite high in comparison with that of the 50Hz mains supply.
- This is necessary to avoid the intense muscle activity and the electrocution (death caused by electric current passing through the body) hazards which occur if lower frequencies are employed.
- For their action, surgical diathermy machines depend on the heating effect of electric current

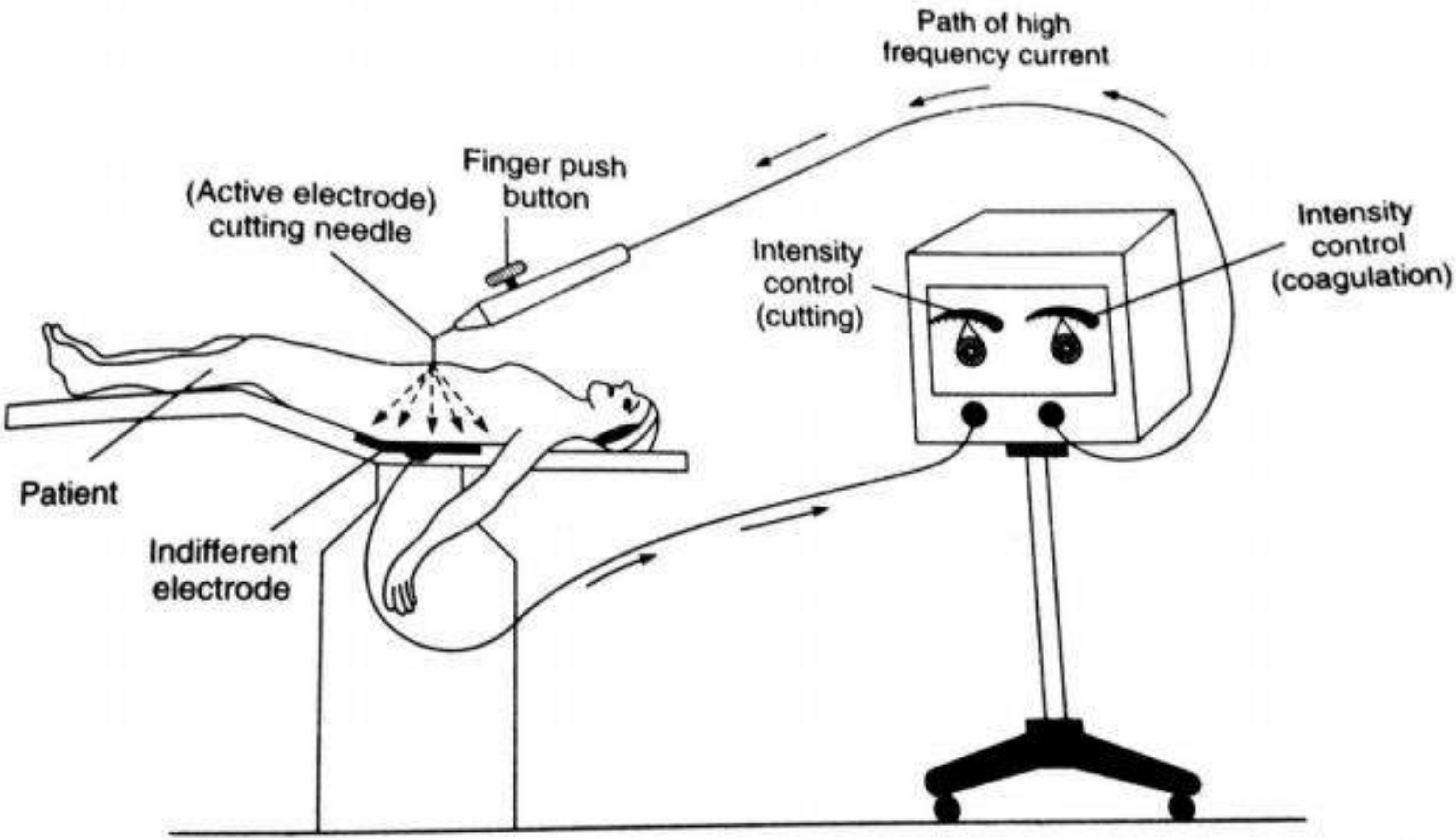


Figure 13: Principle of Surgical diathermy machine

- When high frequency current flows through the sharp edge of a wire loop or band loop or the point of a needle into the tissue , there is high concentration of current at this point.
- The tissue is heated to such an extent that the cells which are immediately under the electrode, are torn apart by the boiling of the cell fluid.
- The indifferent electrode establishes a large area contact with the patient and the RF current is therefore, dispersed so that very little heat is developed at this electrode.
- This type of tissue separation forms the basis of electro-surgical cutting.
- There are various electro-surgery techniques using diathermy unit.

ELECTROTOMY

- When the electrode is kept above the skin, an electrical arc is sent.
- The developed heat produces a wedge shaped narrow cutting of the tissue on the surface.
- By increasing the current level, deeper level cutting of the tissue takes place.
- Normally continuous RF current is used for cutting

COAGULATION

- When the electrode is kept near the skin, high frequency current is sent through the tissue in the form of bursts and heating it locally so that it coagulates from inside.
- The concurrent use of c continuous RF current for cutting and a RF wave burst for coagulation is called Haemostasis.

FULGURATION

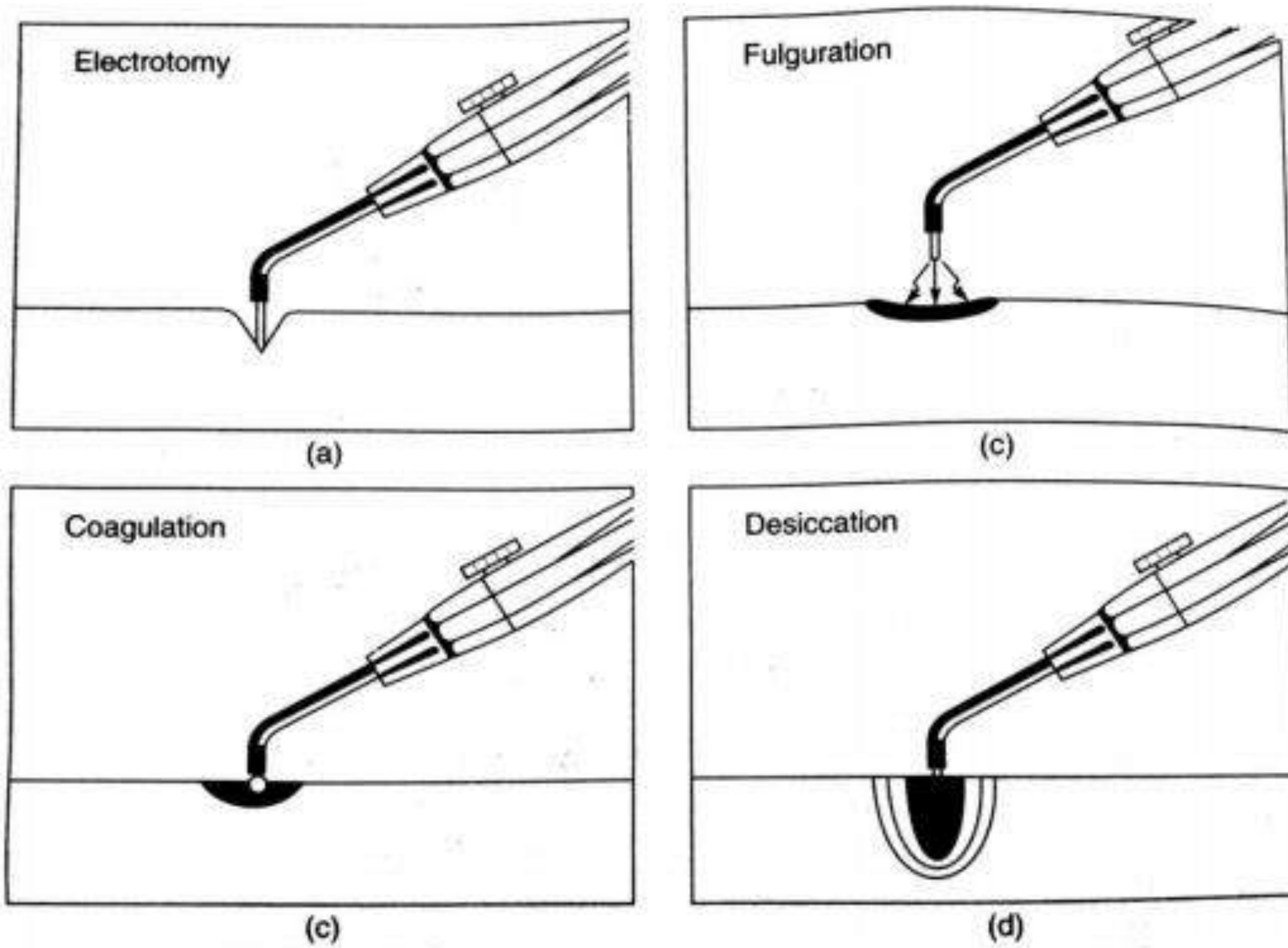
- By passing sparks from a needle or a ball electrode of small diameter to the tissue, the developed heat dries out the superficial tissue without affecting deep-seated tissues.
- This is called _Fulguration' in which the electrode is held near the tissue without touching it and due to the passage of the electric arc, the destruction of superficial tissue takes place.
- Thus it is related to the localised surface level destruction of the tissues.

DESICCATION

- The needle point electrodes are stuck into the tissue and kept steady while passing electric current.
- This is called desiccation' which produces dehydration in the tissues.

BLENDING

- When the electrode is kept above the skin, the separated tissues or nerves can be welded or combined together by an electric arc. This is called blending.
- Figure given below shows various types of electro surgery techniques that are commonly employed in practice.



Various types of electro-surgery techniques commonly employed in practice