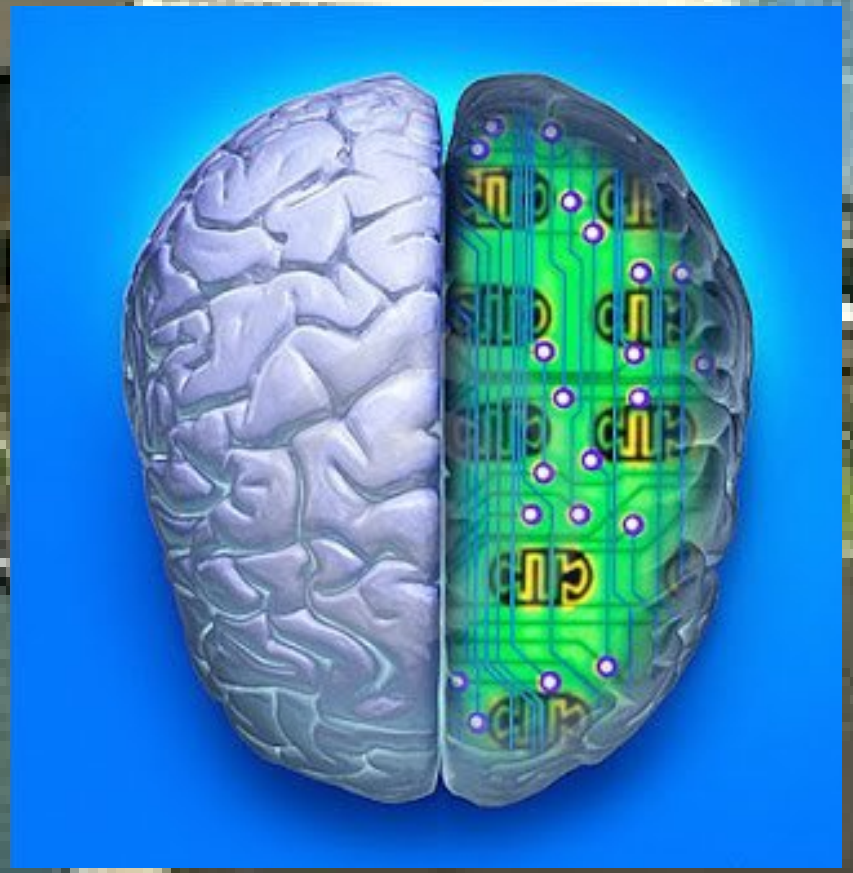
ATME College of Engineering

Biology for Engineers
BBOC407

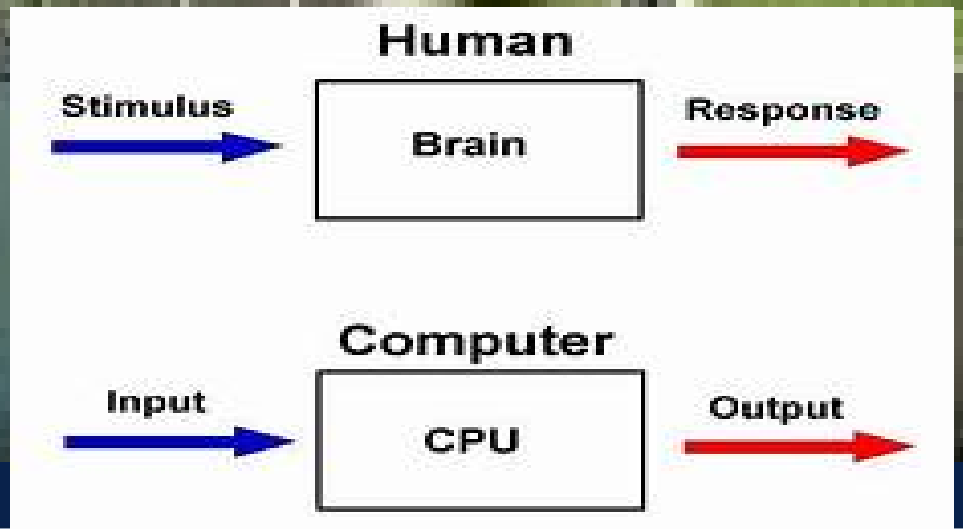
MODULE-3
HUMAN ORGAN SYSTEMS AND BIO DESIGNS

TEJASWINI B M
Assistant Professor,
Dept. of Chemistry,
ATMECE, Mysuru

Brain as a CPU System



- Both the brain and CPU receive and process inputs, store information, and perform calculations to produce outputs.
- Differences between the two - the human brain has the ability to learn and adapt, while a computer's CPU does not.
- Additionally, the human brain is capable of performing tasks such as perception, thought, and emotion, which are beyond the scope of a computer's CPU.



BRAIN VS COMPUTER

Term	Brain	Computer
Speed	Execution time is few milliseconds	Execution time is few nano seconds
Processing	Perform massive parallel operations simultaneously	Perform several parallel operations simultaneously. It is faster the biological neuron
Size and complexity	Number of Neuron is 10^{11} and number of interconnections is 10^{15}. So complexity of brain is higher than computer	It depends on the chosen application and network designer.
Storage capacity	i) Information is stored in interconnections or in synapse strength. ii) New information is stored without destroying old one. iii) Sometimes fails to recollect information	i) Stored in continuous memory location. ii) Overloading may destroy older locations. iii) Can be easily retrieved

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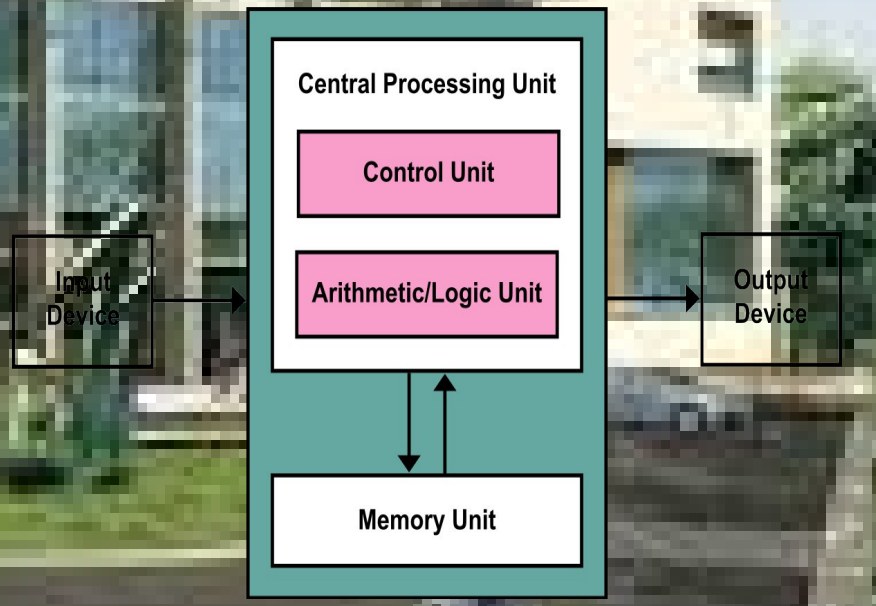
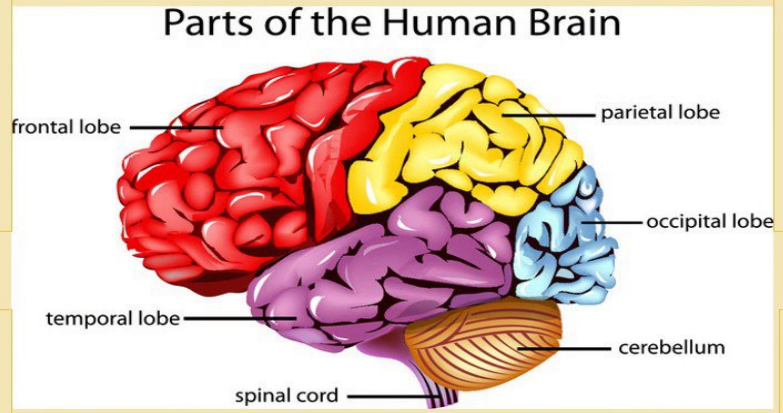
Architecture

- The human brain as a CPU system can be compared to that of a parallel distributed processing system, the Von Neumann architecture of traditional computers.
- In the human brain, information is processed in a distributed manner across **multiple regions**, each with **specialized functions**, rather than being processed sequentially in a single centralized location.
- Just like how a computer's CPU has an **arithmetic logic unit (ALU)** to perform mathematical calculations, the human brain has specialized regions for processing mathematical and logical operations.
- The prefrontal cortex, for example, is responsible for higher-level cognitive functions such as decision making and problem solving.



- Computer's CPU also has memory units for storing information, and the human brain has several regions dedicated to memory storage, including the hippocampus and amygdala.
- Human brain has so many functions that are still not fully understood.

Frontal Lobe function:
- Movement
- Problem-solving
- Concentrating
- Thinking
- Mood
- Personality



Parietal Lobe function:
- Sensations
- Language
- Perception
- Body awareness
- attention

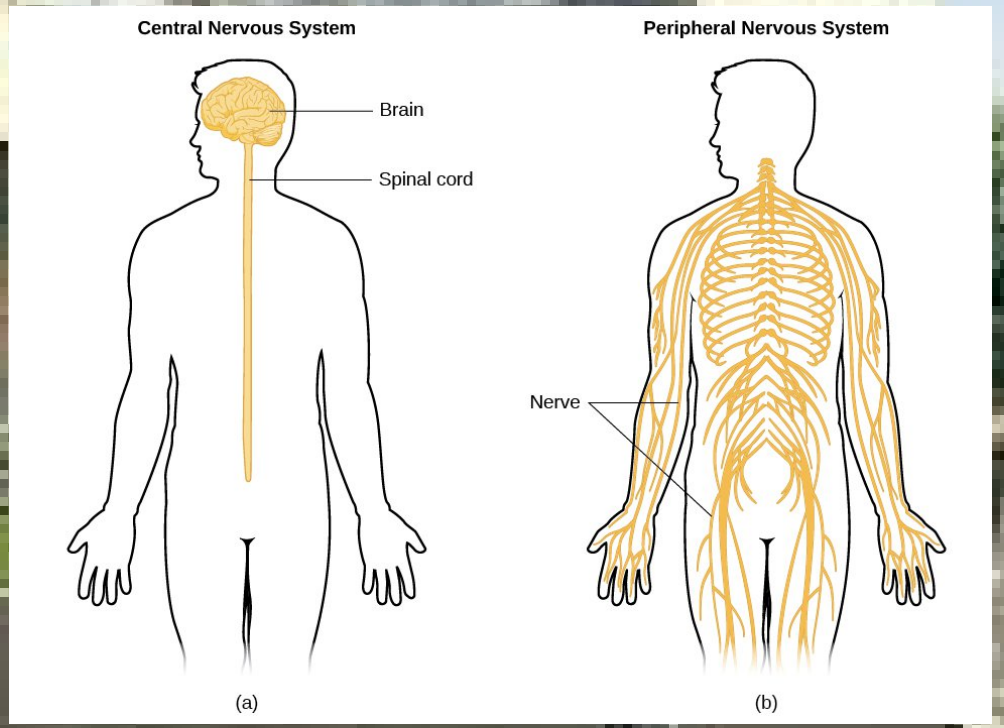
Temporal Lobe function:
- Hearing
- Language
- Memory

Occipital Lobe function:
- Vision
- Perception

Cerebellum function:
- Posture
- Balance
- Coordination of movement

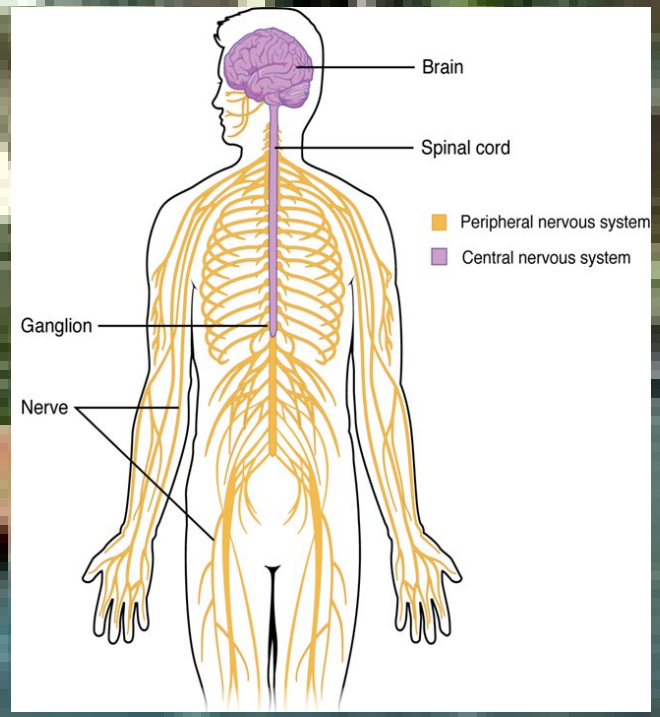
CNS and PNS (Central Nervous System and Peripheral Nervous System)

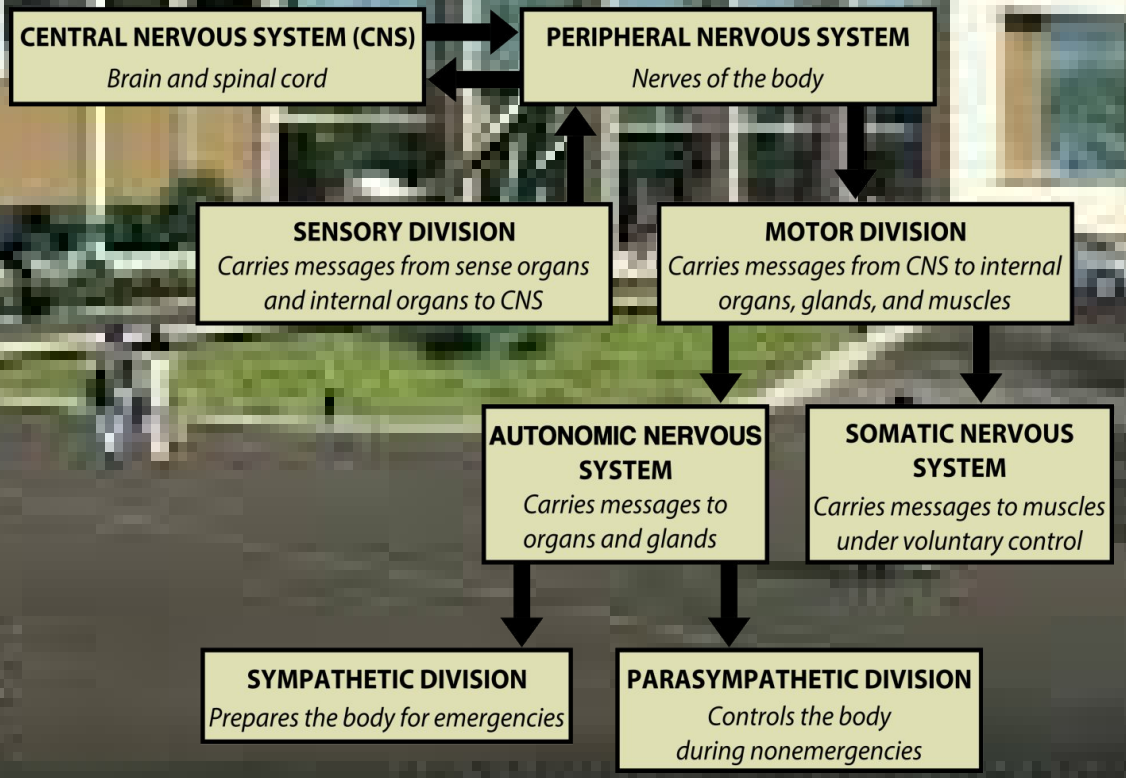
- The **CNS** consists of the **brain** and **spinal cord** and is responsible for receiving, processing, and integrating sensory information and transmitting commands to the rest of the body.
- **Brain- command center**, receiving and processing sensory inputs and generating motor outputs, while the **spinal cord - a relay center**, transmitting information between the brain and peripheral nerves.
- The **PNS** consists of **all the nerves** that lie outside the brain and spinal cord.
- It is responsible for transmitting sensory information from the periphery of the body (such as the skin, muscles, and organs) to the CNS, and transmitting commands from the CNS to the periphery.



- The PNS can be further divided into the **somatic nervous system** and the **autonomic nervous system**.

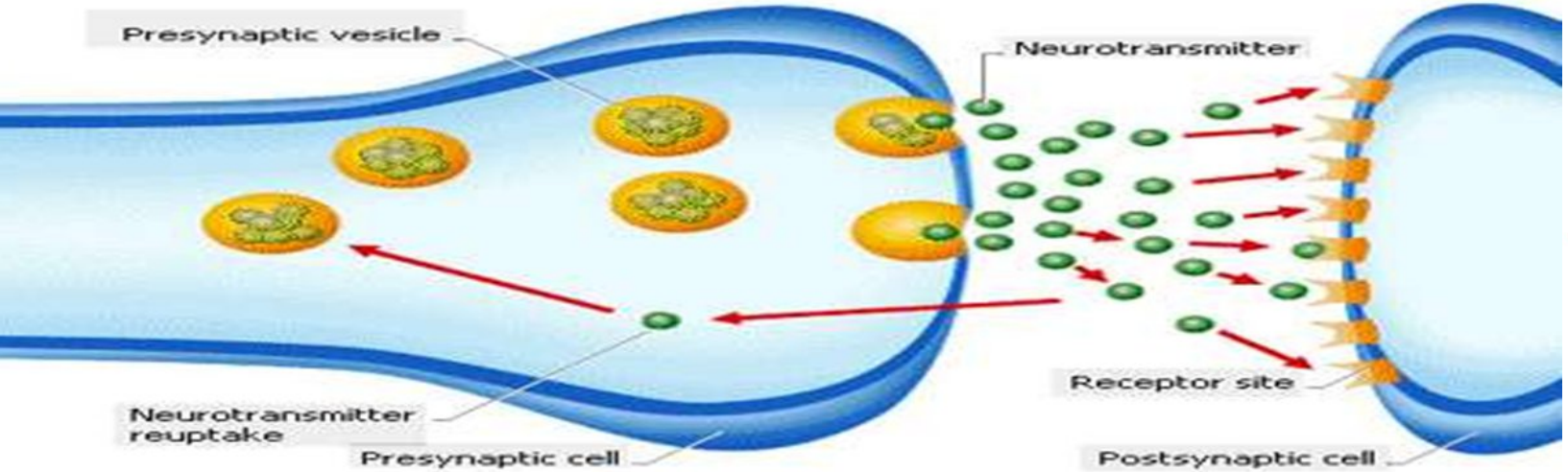
The **SNS** controls **voluntary movements**, while the **ANS** controls **involuntary** functions such as heart rate, digestion, and respiration



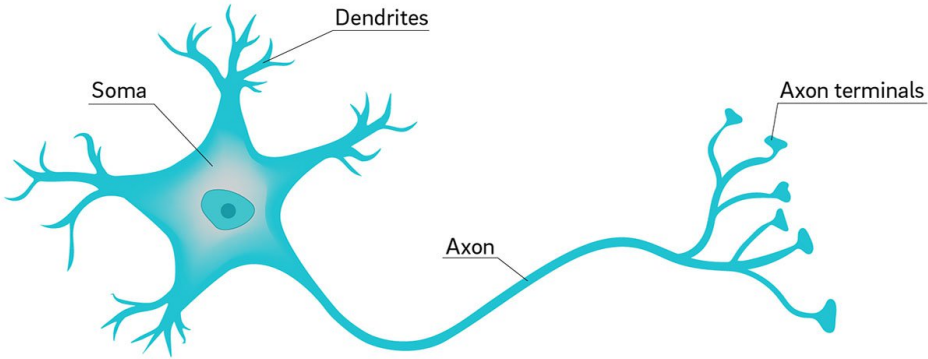


Signal Transmission - through the firing of nerve cells, or neurons.

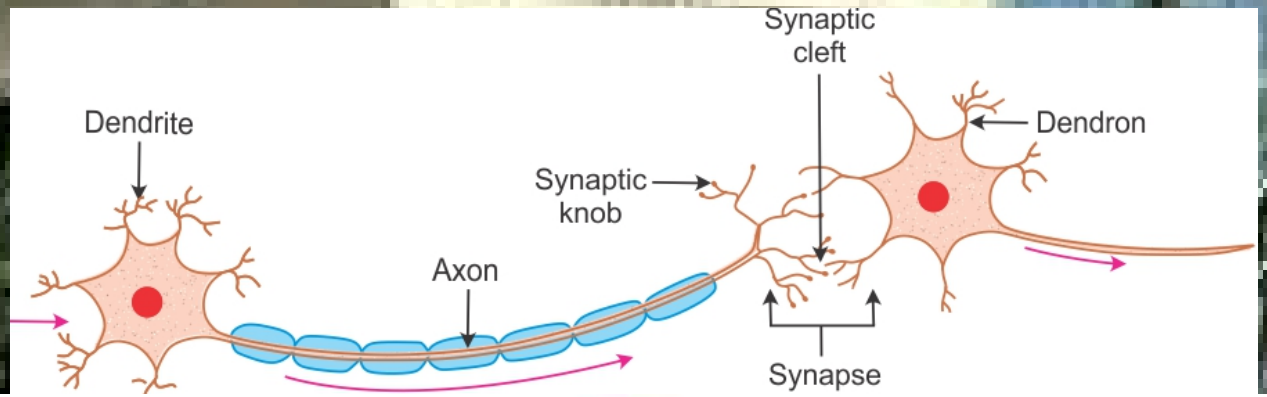
- A neuron **receives inputs** from other neurons at its **dendrites**, integrates the information, and then generates an electrical impulse, or action potential, that **travels down to axon** to the synaptic terminals.
- At the **synaptic terminals**, the neuron releases chemical **neurotransmitters**, which cross the synaptic gap and bind to receptors on the postsynaptic neuron, leading to the initiation of another action potential in the postsynaptic neuron.
- This process of transmitting information from one neuron to another is known as **synaptic transmission** and forms the basis of communication within the brain.

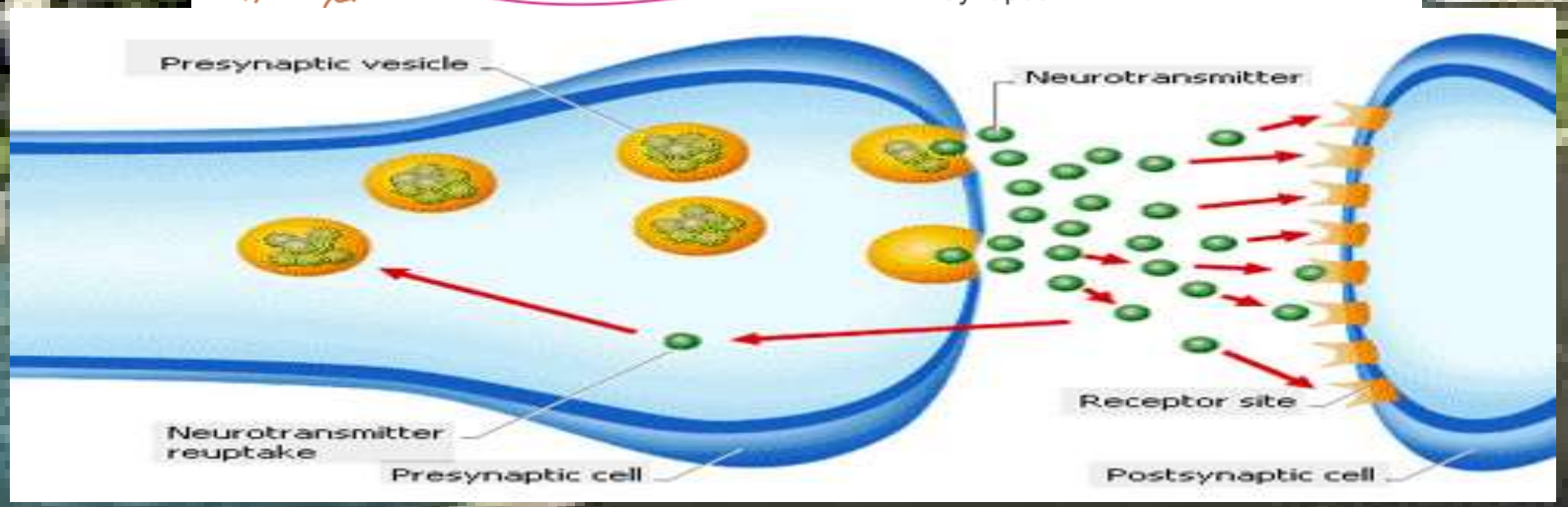


Neuron



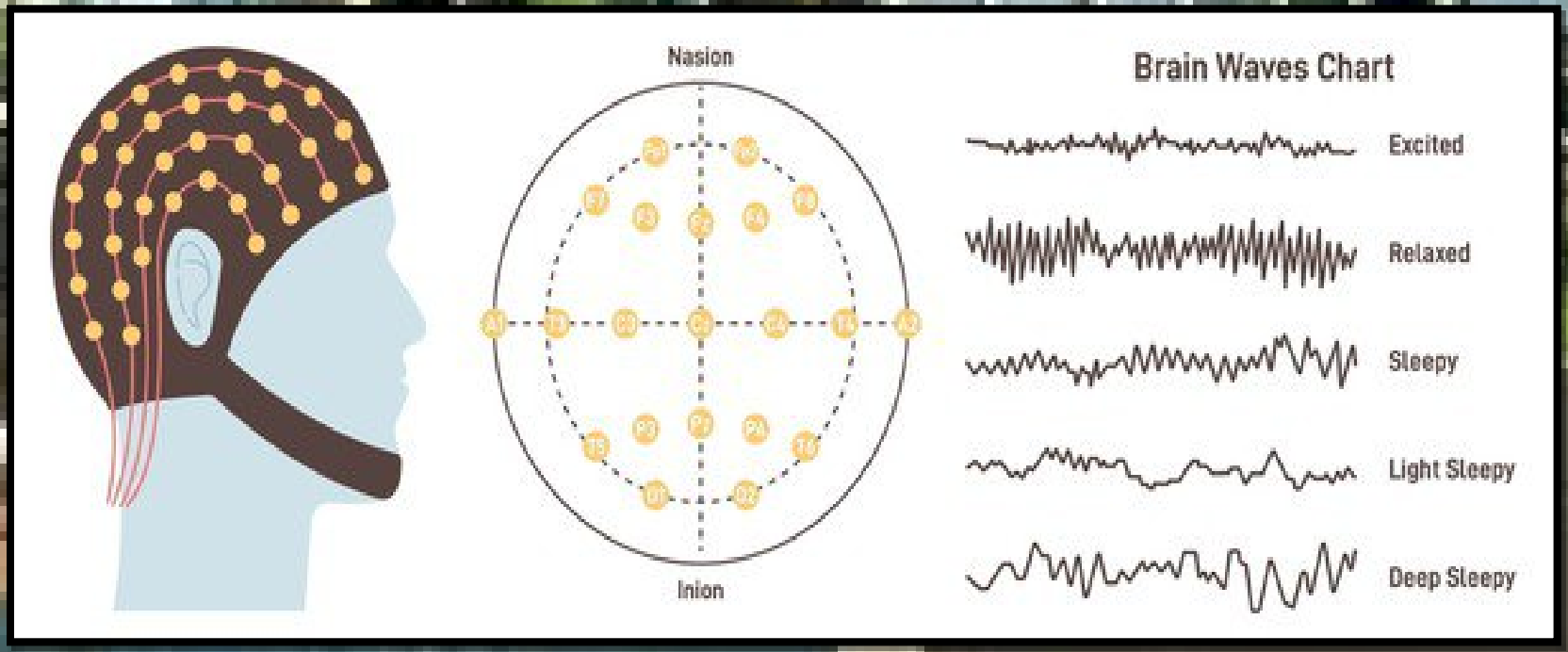
- Different types of neurotransmitters have different effects on post-synaptic neurons, and the balance of neurotransmitter levels can influence brain function, including mood, learning, and memory.





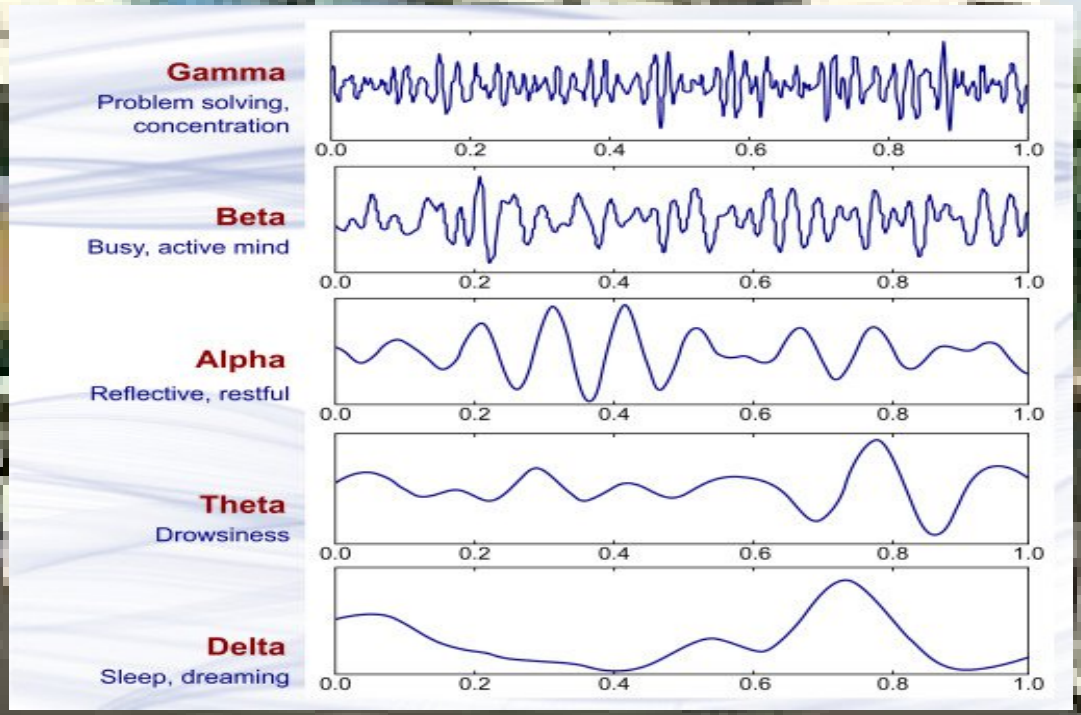
EEG (electroencephalography)

- Non-invasive method for measuring and recording of the electrical activity of the brain.
- The signals are recorded through electrodes placed on the scalp and the resulting EEG pattern provides information about the synchronized electrical activity of large populations of neurons.



- **EEG Signals and Types of Brain Activity**

1. **Delta waves (0.5-4 Hz)**: low-frequency waves associated with deep sleep, infancy, and brain disorders such as brain damage or dementia.
2. **Theta waves (4-8 Hz):** associated with sleep and relaxation, as well as meditation and hypnosis. They are present during memory encoding and retrieval processes.
3. **Alpha waves (8-12 Hz):** are present when the brain is relaxed and not focused on any particular task. They are associated with meditation and creativity.
4. **Beta waves (12-30 Hz):** are present when the brain is focused on a task, such as problem-solving or decision-making. They are associated with anxiety and stress.
5. **Gamma waves (30-100 Hz):** are associated with high-level cognitive processing, such as attention, perception, and memory. They are involved in sensory processing and motor control. The analysis of EEG signals can provide valuable information about brain function and activity, as well as offer insights into the workings of the human mind.

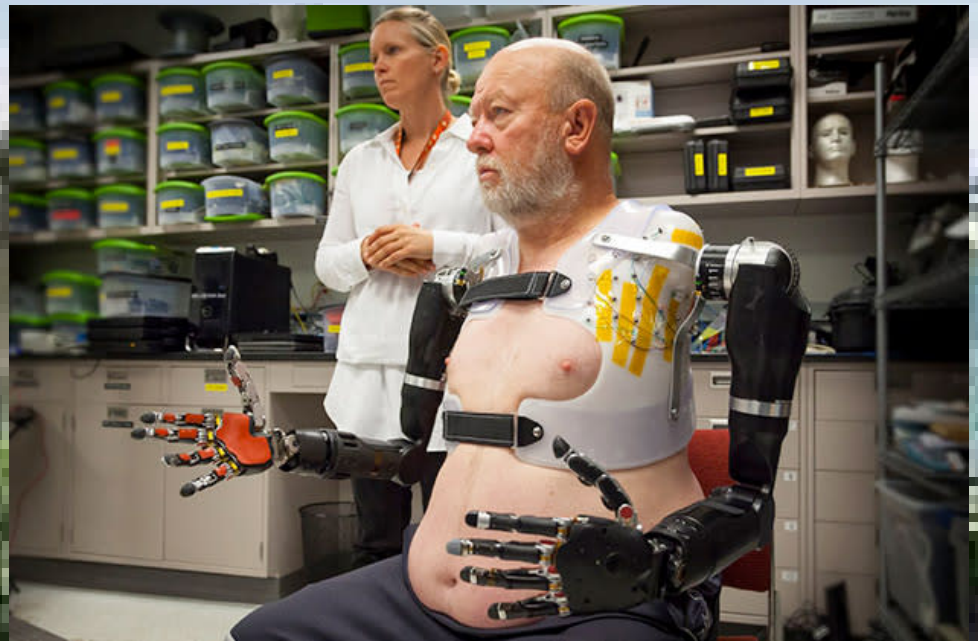


Applications of EEG

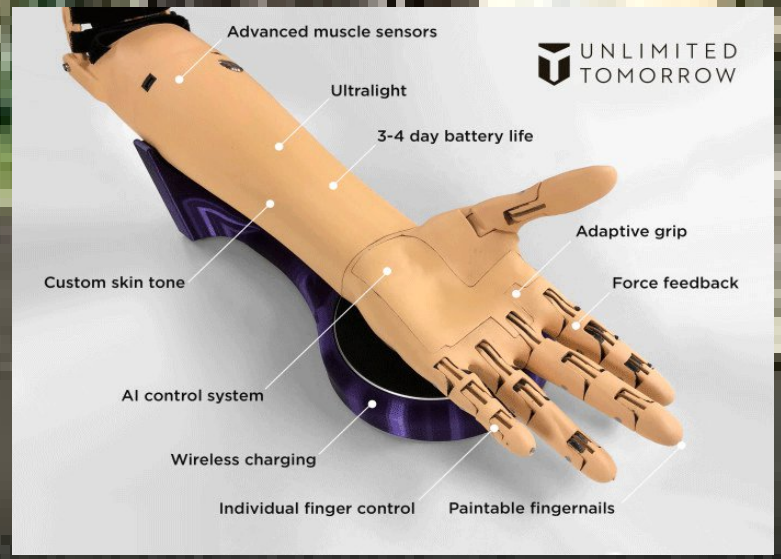
1. **Diagnosis of Epilepsy**: and **other seizure disorders**. It can detect abnormal electrical activity in the brain - diagnosis and determine the location of the seizure focus.
2. **Sleep Studies**: to evaluate sleep patterns and diagnose sleep disorders.
3. **Brain-Computer Interfaces (BCI):** EEG can be used to control external devices such as prosthetic limbs or computer software. This is done by detecting specific brain waves associated with a particular mental state, such as concentration or relaxation.
4. **Research on Brain Function**: during various activities such as reading, problem-solving, and decision-making. and also, be used to investigate how the brain responds to stimuli such as light, sound, and touch.
5. **Diagnosis of Brain Disorders:** including dementia, Parkinson's disease, and traumatic brain injury.
6. **Anesthesia Monitoring:** during surgery to ensure that the patient remains in a safe and comfortable state.
7. **Monitoring Brain Activity during Coma**: to determine the level of brain function and assess the likelihood of recovery.

Robotic Arms for Prosthetics

- The devices that use robotics technology to restore functionality to individuals with upper limb amputations.
- These devices typically use motors and sensors to mimic the movements of a human arm and hand, allowing the wearer to perform tasks such as reaching, grasping objects.
- It can be controlled in a variety of ways, including direct control through muscle signals (myoelectric control) or brain-machine interfaces, which use electrodes implanted in the brain or placed on the scalp to detect and interpret brain activity.
- Some prosthetic arms also incorporate machine learning algorithms to improve their performance and adapt to the user's needs over time.




USB-C charging port can recharge batteries in 1 hour
Water-Resistant
Bluetooth connectivity
The first commercially available hand with touch feedback
Patented brushless motor control enables fastest finger movements on the market
Patented compliant fingers are impact resistant
Carbon fiber palms make the hand light and strong
Multicolor power switch
Vibration unit inside for touch feedback


UNLIMITED TOMORROW
Advanced muscle sensors
Ultralight
3-4 day battery life
Adaptive grip
Force feedback
Custom skin tone
AI control system
Wireless charging
Individual finger control
Paintable fingernails

Robotic Arm Prosthetic Direct Control through Muscle Signals (myoelectric control)

- It involves using the electrical signals generated by the wearer's remaining muscles to control the movement of the prosthetic.
- The electrodes placed on the skin over the remaining muscle that are used to detect and interpret the electrical signals generated by the muscle contractions.
- When the wearer contracts their muscles, the electrodes detect the electrical signals and send them to a control unit, which interprets the signals and uses them to control the movement of the robotic arm.
- Depending on the specific design, the control unit may use pattern recognition algorithms (movement intending to perform) or a combination of muscle signals (specific degrees of freedom).

- Myoelectric control has the **advantage** of being **directly controlled by the user**, allowing for a more intuitive and natural interaction with the prosthetic.
- It can also provide a **high level of control and precision**, as the electrical signals generated by the muscles are unique to each individual and can be used to perform a wide range of movements.
- However, myoelectric control systems can be **complex and may require extensive rehabilitation and training** to use effectively, as well as **ongoing maintenance** to ensure proper function.
- Additionally, the system may not be suitable for individuals with muscle weakness or other conditions that affect the ability to generate strong electrical signals.

Robotic Arm Prosthetic by Brain-Machine Interfaces (BMIs)

- Brain-machine interfaces are a type of technology that allows a user to control a robotic arm prosthetic directly with their brain activity.
- The system typically involves electrodes placed on the scalp or implanted directly into the brain to detect and interpret the user's brain signals.
- When the user thinks about moving the prosthetic arm, the electrodes detect the corresponding brain activity and send the signals to a control unit, which uses algorithms to interpret the signals and control the movement of the prosthetic.
- The user can then control the movement of the prosthetic in real-time by thinking about the desired movement.

- BMIs have the **advantage** of providing a **direct and intuitive connection** between the user's brain and the prosthetic, allowing for a high level of control and precision.
- BMIs can be **used to provide sensory feedback to the user**, allowing them to experience the sensation of touch through the prosthetic.
- BMIs can be **complex** and **invasive systems**, requiring surgical implantation and ongoing maintenance to ensure proper function.
- They may not be suitable for individuals with conditions that affect brain activity or who are unable to generate strong enough brain signals to control the prosthetic effectively.
- Ongoing research and development is aimed to improving the performance and accessibility and increasing their ease of use and reliability.

Engineering Solutions for Parkinson's Disease

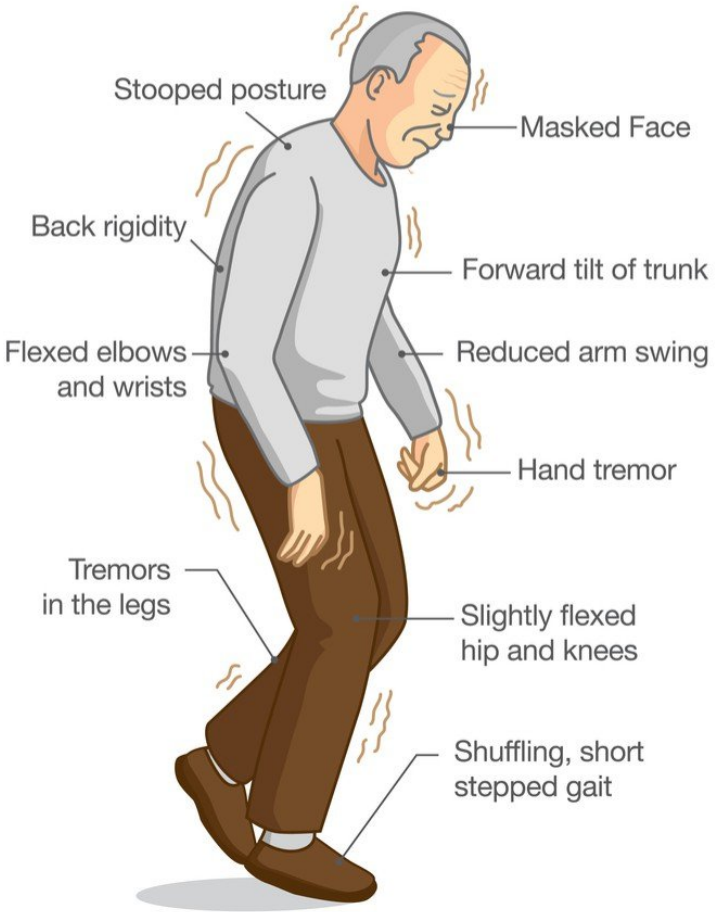
- Parkinson's disease is a neurodegenerative disorder that affects movement and motor function.

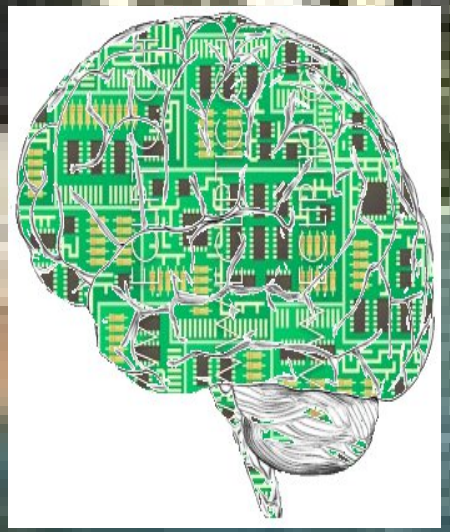
1. **Deep Brain Stimulation (DBS):** involves the implantation of electrodes into specific regions of the brain to deliver electrical stimulation - help to relieve symptoms like tremors, stiffness, and difficulty with movement.
2. **Exoskeletons**: are wearable devices that provide support and assistance for individuals with mobility issues and help to improve balance, reduce tremors, and increase overall mobility.
3. **Telerehabilitation**: involves the use of telecommunication technology to provide physical therapy and rehabilitation services without the need for in-person visits to a therapist.

4. **Smart watch Applications**: to monitor symptoms of Parkinson's disease, such as tremors, and provide reminders and prompts for medication and exercise.
5. **Virtual Reality**: is a system used for rehabilitation and therapy, providing interactive and engaging environments for patients to practice movements and improve coordination and balance.

- These engineering solutions have the potential to significantly improve the quality of life for individuals with Parkinson's disease.
- Ongoing research and development is aimed at improving their effectiveness and accessibility.
- However, these technologies are not a cure for Parkinson's disease and should be used in conjunction with other forms of treatment and care

Parkinson's Disease Symptoms





Artificial Brain or artificial general intelligence (AGI) or a synthetic brain

- It is a hypothetical machine that could possess cognitive abilities like those of a human brain.
- The idea behind artificial brains is to create a machine that can learn, reason, and solve problems in the same way that humans do.
- However, the development of artificial brains is still in the early stages and there are many technical, ethical, and philosophical challenges that need to be addressed.

- Currently, artificial intelligence (AI) systems are designed to perform specific tasks, such as image recognition, speech recognition, or decision making, but they are not capable of general intelligence
- This is because AI systems are designed to operate within a narrow domain and lack the ability to learn from new experiences, generalize from past experiences, or reason about the world in the same way that humans do.
- The development of artificial brains requires a deep understanding of the human brain and its functions, as well as advanced computer science and engineering skills.
- Researchers are working on creating artificial brain models that can simulate the complex processes of human cognition and adapt to new situations.

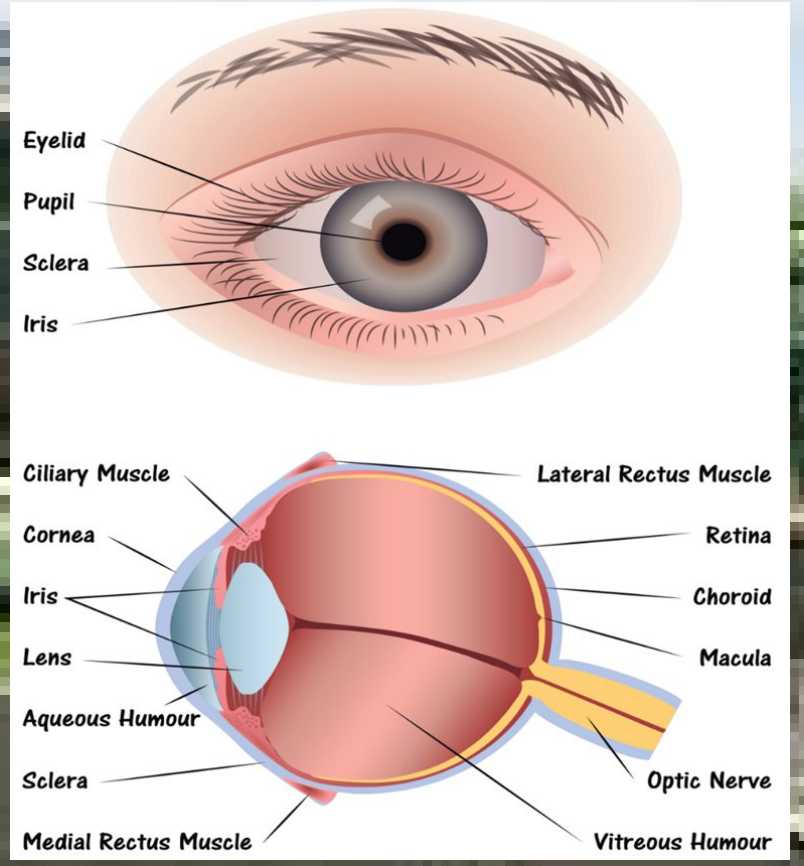
- Despite the significant challenges, some experts believe that artificial brains are a realistic possibility and that they have the potential to revolutionize the field of AI and bring about new technological advancements.
- However, others argue that it is unlikely that we will ever be able to recreate the human brain in a machine, due to the complexity and intricacy of the brain's structure and functions.

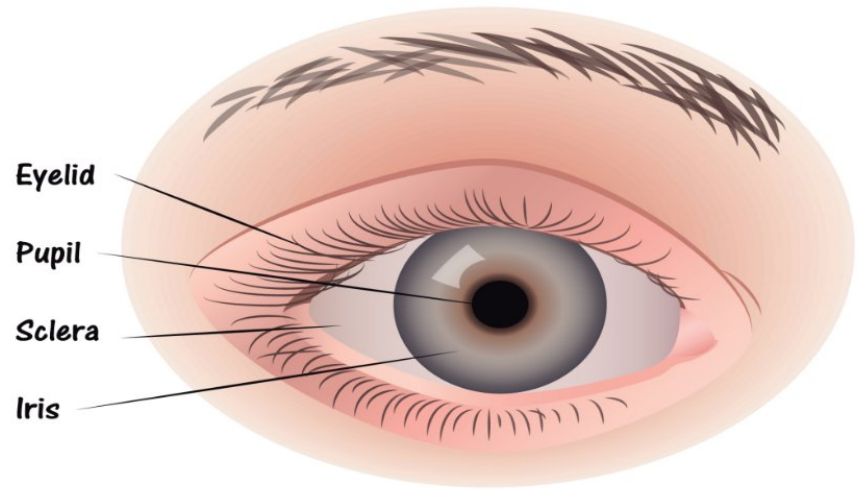
• In conclusion, the development of artificial brains is an exciting and rapidly advancing field of research that has the potential to change the world in many ways. However, it is important to approach this research with caution and to consider the ethical and philosophical implications of creating a machine that can think like a human.

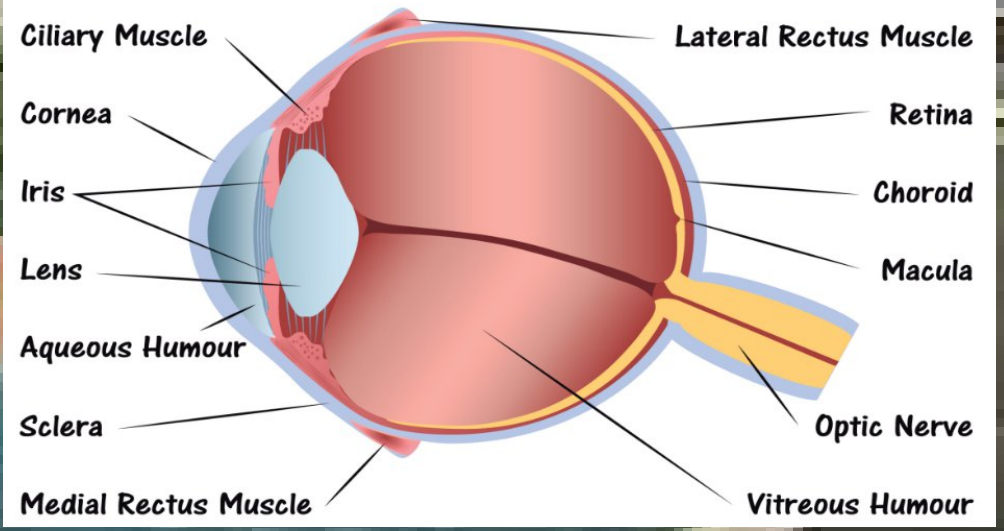
EYE AS CAMERA SYSTEM

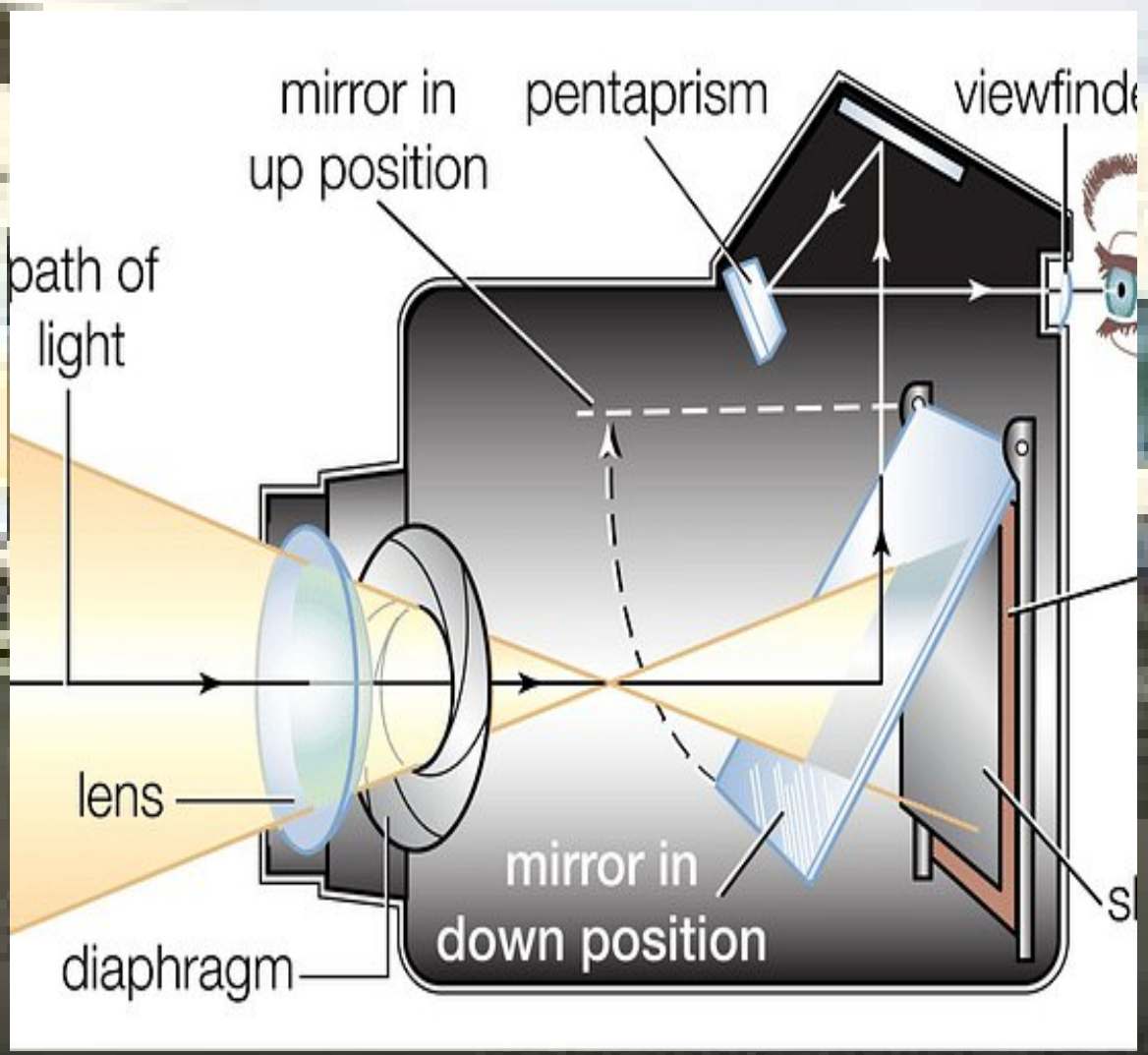
- The human eye can be analogized to a camera system, as both the eye and a camera capture light and convert it into an image.
- The main components of the eye that correspond to a camera system include:

1. The **Cornea**: This transparent outer layer of the eye functions like a **camera** lens, bending light to focus it onto the retina.
2. The **Iris**: The iris functions like the **diaphragm** in a camera, controlling the amount of light that enters the eye.
3. The **Pupil**: The pupil functions like the **aperture** in a camera, adjusting the size to control the amount of light entering the eye.
4. The **Retina**: The retina functions like the camera **film** or sensor, capturing the light and converting it into electrical signals that are sent to the brain.
5. The **Optic Nerve**: The optic nerve functions like the **cable connecting** the camera to a computer, transmitting the electrical signals from the retina to the brain.




Eyelid
Pupil
Sclera
Iris


Ciliary Muscle
Cornea
Iris
Lens
Aqueous Humour
Sclera
Medial Rectus Muscle
Lateral Rectus Muscle
Retina
Choroid
Macula
Optic Nerve
Vitreous Humour


mirror in
up position
pentaprism
path of
light
lens
mirror in
down position
diaphragm

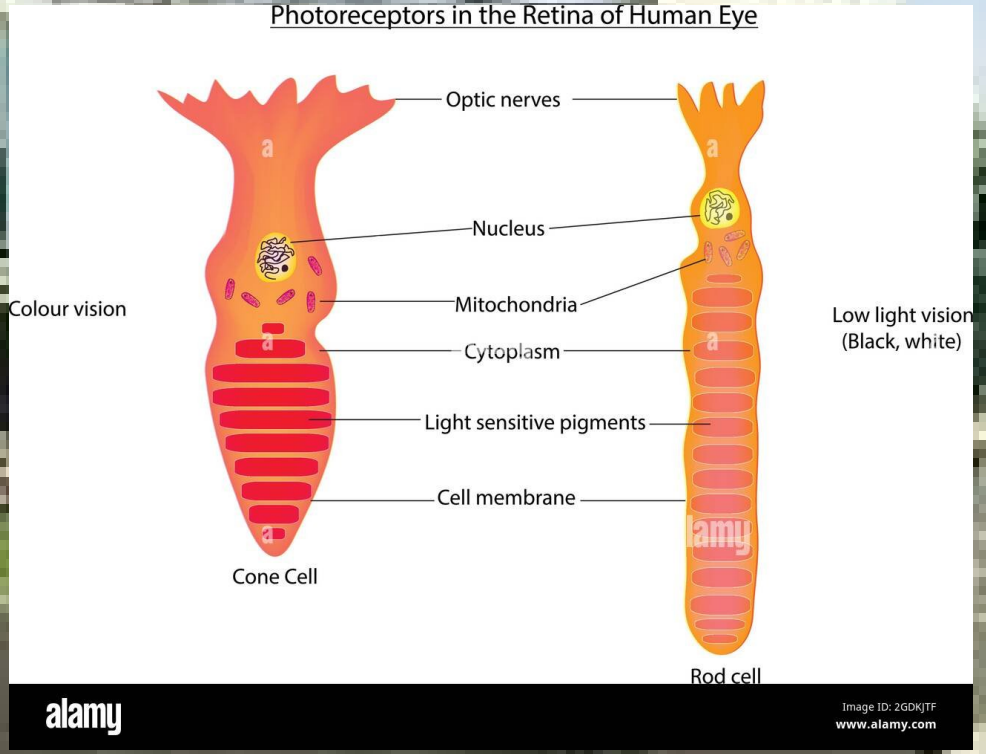
- In both, the eye and a camera, the captured light is transformed into an image by the lens and the light-sensitive component.
- The eye processes the image further, allowing for visual perception, while a camera stores the image for later use.
- The eye is much more complex than a camera and has several additional functions, such as adjusting for different levels of light and adjusting focus, that are not found in a camera.
- The eye also has the ability to perceive depth and color, as well as adjust to movements and provide a continuous, real-time image to the brain

Architecture of Rod and Cone Cells

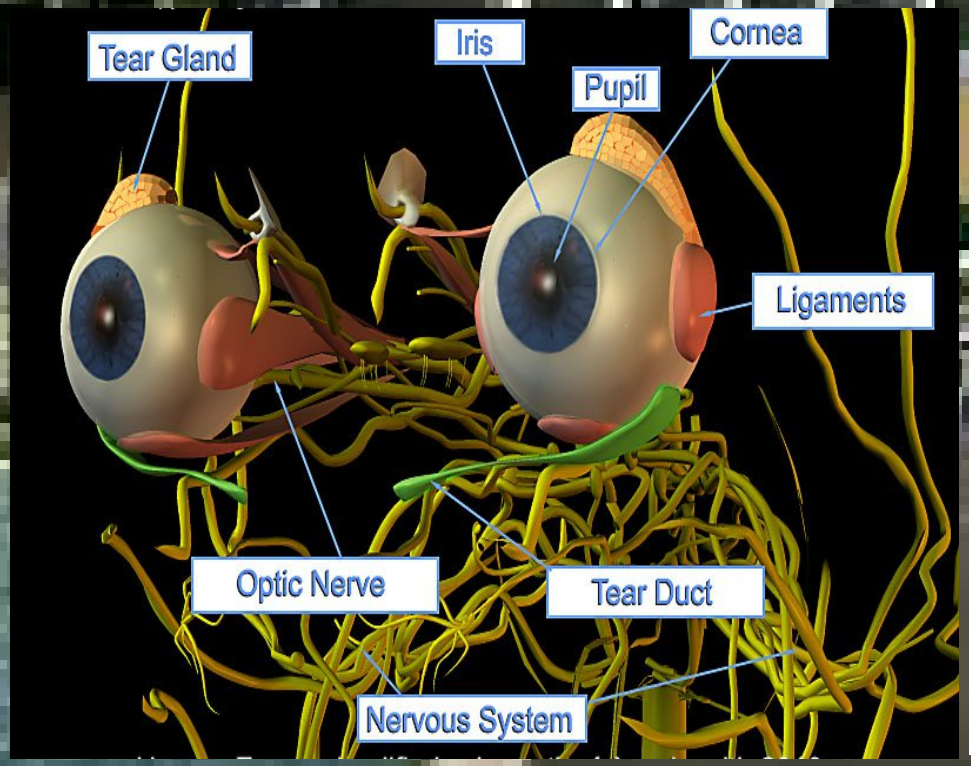
- **Rod Cells** are photoreceptor cells in the **retina** of the eye that are responsible for detecting light and transmitting signals to the brain for the perception of vision, especially in low light conditions.
- They contain a protein called **rhodopsin** that absorbs light and triggers a chain of events leading to the activation of neural signals.
- Rods are more sensitive to light than cone cells and do not distinguish color.

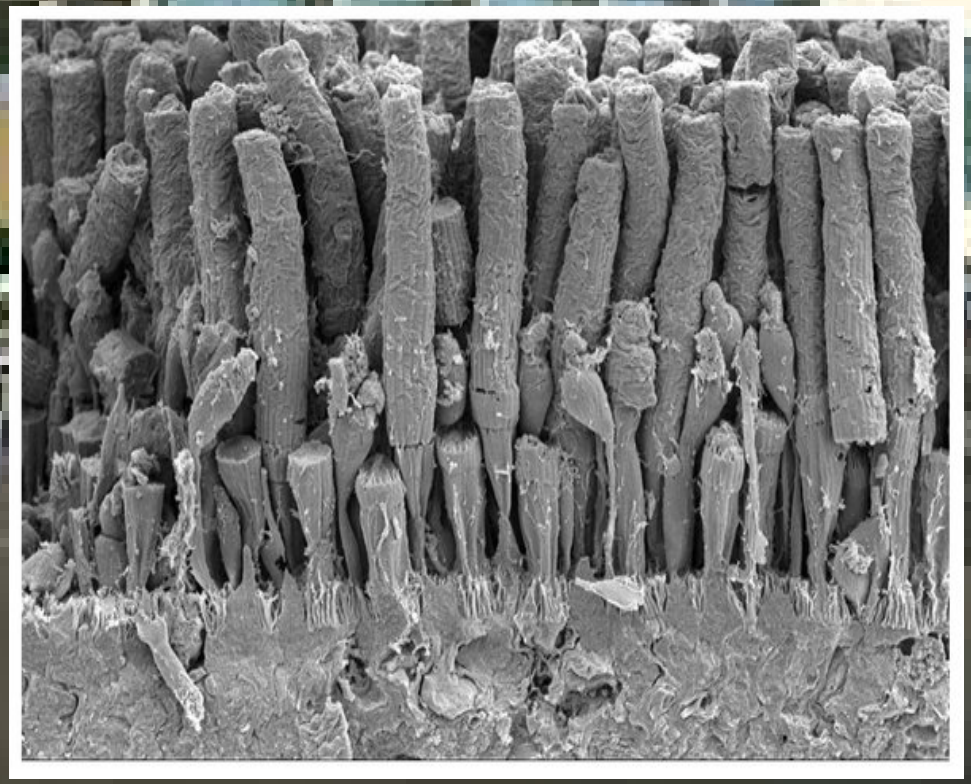
- **Cone Cells** are photoreceptor cells in the retina of the eye that are responsible for color vision and visual acuity (sharpness of vision).
- There are three types of cone cells, each containing a different photo pigment sensitive to different wavelengths of light (red, green, and blue), which allow for the perception of color.
- Cones are less sensitive to light than rod cells but provide better visual acuity and color discrimination.
- They are concentrated in the fovea, the central part of the retina responsible for detailed and sharp vision.
- Architecture Rod and cone cells have a similar basic structure, but there are some differences that are crucial for their different functions

- Outer segment contains photoreceptors and the inner segment contains the cell's organelles, including the nucleus and mitochondria.
- The major difference between rod and cone cells is their shape.
- Rod cells are elongated and cylindrical, while cone cells are shorter and more conical in shape.
- This difference in shape affects the distribution of photo pigments and the number of synaptic contacts with bipolar and ganglion cells, which transmit the signals to the brain.
- Rod cells have a single long outer segment, while cone cells have several shorter segments.
- Another difference between the two types of cells is the distribution of their synaptic contacts with bipolar cells.



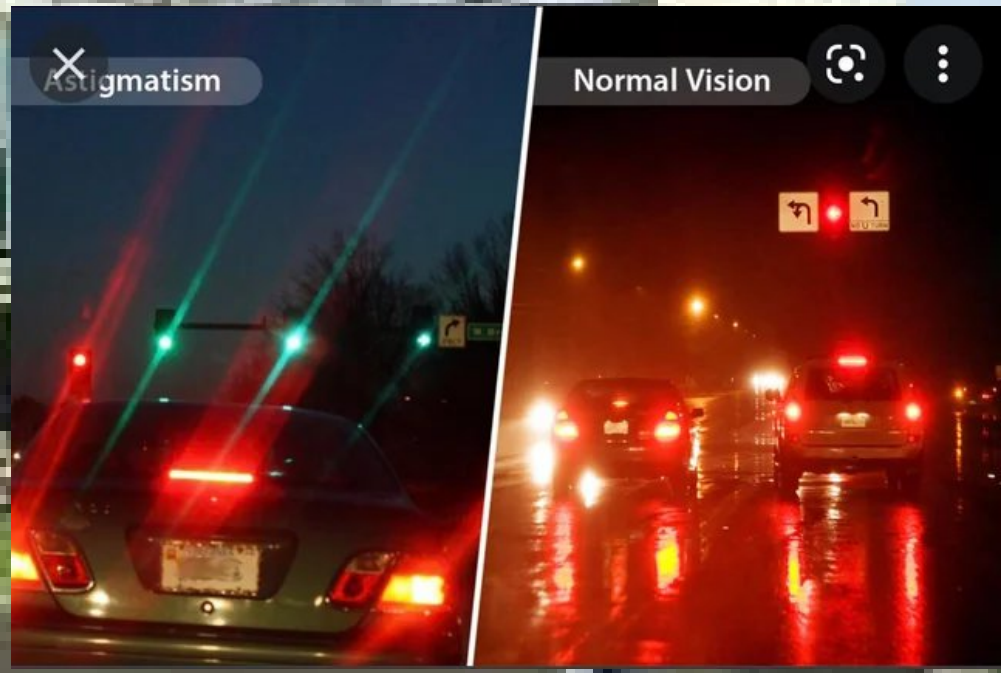
- Rod cells make synapses with one bipolar cell, while cone cells synapse with one of several bipolar cells.
- This difference in synapse distribution is critical for the different functions of rod and cone cells in vision.





- **Optical Corrections**
- Optical corrections refer to devices or techniques used to improve or correct vision problems caused by a refractive error in the eye.
- Refractive errors occur when light entering the eye is not properly focused on the retina, leading to blurred vision.
- There are several types of refractive errors, including:

1. **Myopia (nearsightedness):** Light is focused in front of the retina, making distant objects appear blurry.
2. **Hyperopia (farsightedness)**: Light is focused behind the retina, making near objects appear blurry.
3. **Astigmatism:** Light is not focused evenly on the retina, leading to blurred or distorted vision.

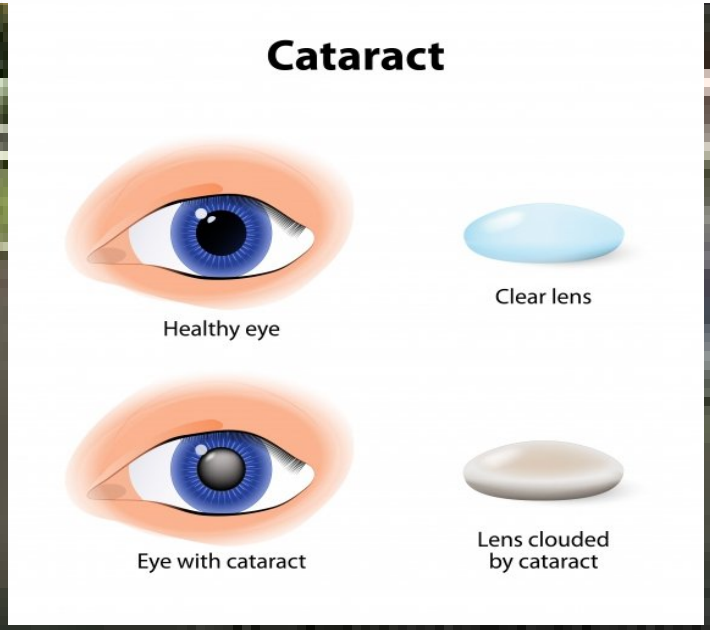


- The most common optical corrections include:

1. **Eyeglasses**: Glasses with corrective lenses can be used to refocus light onto the retina, improving vision.
2. **Contact lenses**: Corrective lenses in the form of contacts sit directly on the cornea and work similarly to eyeglasses.
3. **Refractive surgery**: Surgical procedures, such as LASIK and PRK, can reshape the cornea to correct refractive errors.

- Optical corrections can greatly improve visual acuity and quality of life for people with refractive errors.
- However, it is important to have regular eye exams to determine the appropriate correction and monitor eye health.

- **Cataract :**
- A cataract is a clouding of the lens of the eye that affects vision.
- The lens, located behind the iris and pupil, normally allows light to pass through to the retina and produces clear, sharp images.
- However, as we age or due to other factors, the proteins in the lens can clump together and cause the lens to become opaque, leading to vision problems.
- **Symptoms of a cataract** include blurred or hazy vision, increased sensitivity to glare and bright lights, faded or yellowed colors, and double vision in one eye.

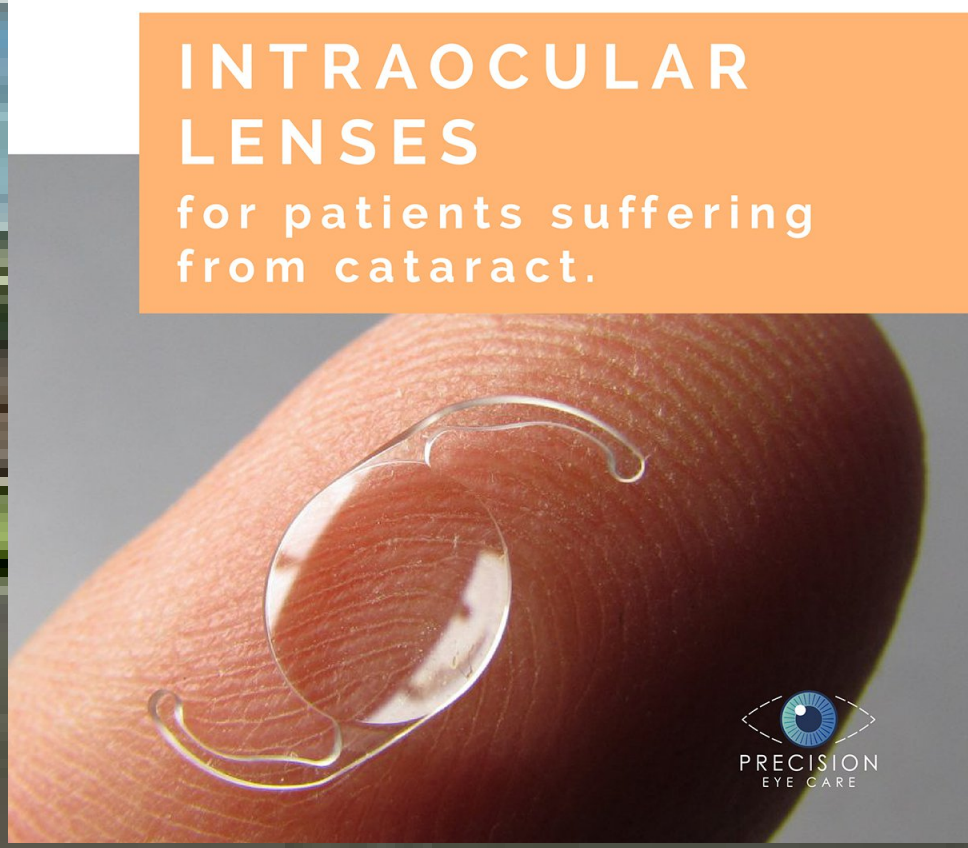


- Cataracts can also cause frequent changes in prescription for eyeglasses or contact lens.
- Cataract surgery is a common and safe procedure to remove the cloudy lens and replace it with an artificial lens.
- The surgery is typically performed on an outpatient basis and most people experience improved vision within a few days after the procedure.
- In conclusion, cataracts can significantly affect vision, but surgical removal and replacement with an artificial lens can restore clear vision and improve quality of life.
- Regular eye exams can help detect cataracts early and prevent vision loss

- **Lens Materials**
- The artificial lenses used in cataract surgery or for vision correction can be made of a variety of materials, each with its own unique properties and benefits.
- The most common lens materials include:

1. Polymethyl methacrylate (PMMA): PMMA is a type of plastic that has been used for many years in artificial lenses. It is a durable and affordable material but does not have the ability to flex and adjust focus like the natural lens.

2. Silicone: Silicone is a soft, flexible material that is resistant to cracking and breaking. It is often used in intraocular lenses (IOLs), which are implanted in front of the natural lens.



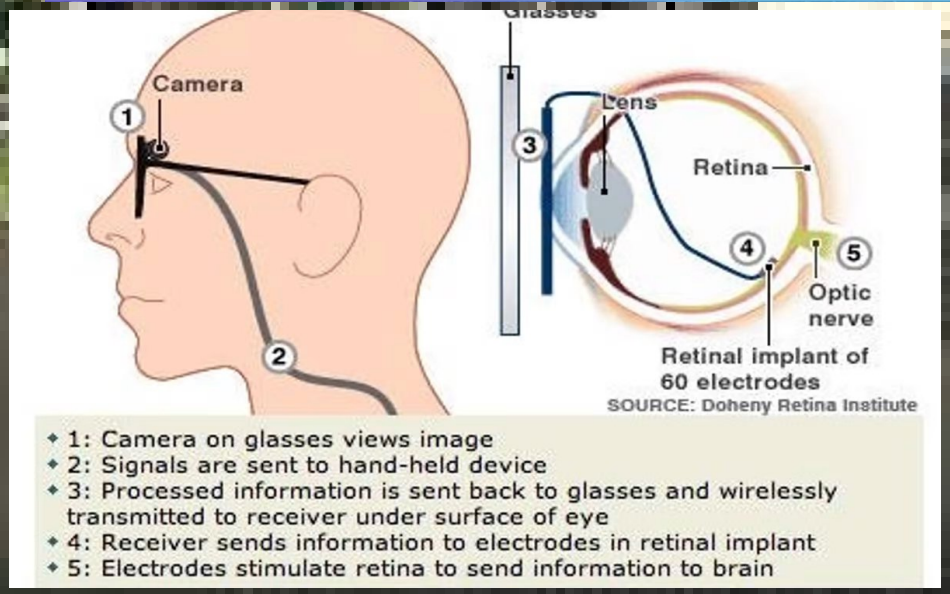
3. **Acrylic**: Acrylic is a lightweight, clear material that is similar in properties to PMMA. It is often used in foldable IOLs, which can be inserted through a smaller incision.

4. **Hydrophobic acrylic**: Hydrophobic acrylic is a type of acrylic material that has a special surface treatment that helps to reduce glare and halos around lights.

5. **Hydrophilic acrylic:** Hydrophilic acrylic is a type of acrylic material that is designed to be more compatible with the natural fluid in the eye, reducing the risk of vision-threatening complications.

• The choice of lens material will depend on several factors, including the patient's individual needs, the surgeon's preference, and the potential risks and benefits of each material is suggested by eye doctor.

- **Bionic Eye or Artificial Eye / retinal implant**
- It is a type of prosthetic device that is surgically implanted into the eye to help restore vision to people who have lost their sight due to certain conditions such as retinitis pigmentosa or age-related macular degeneration.
- The device typically consists of a camera, a processor, and an electrode array that is attached to the retina.
- The camera captures images and sends signals to the processor, which then transmits electrical stimulation to the electrodes in the retina to stimulate the remaining healthy cells and restore vision.
- The restored vision is not perfect, but it can help people with vision loss to perform daily tasks more easily and safely.



- **Materials Used in Bionic Eye**
- The materials used in a bionic eye can vary depending on the specific device and manufacturer.

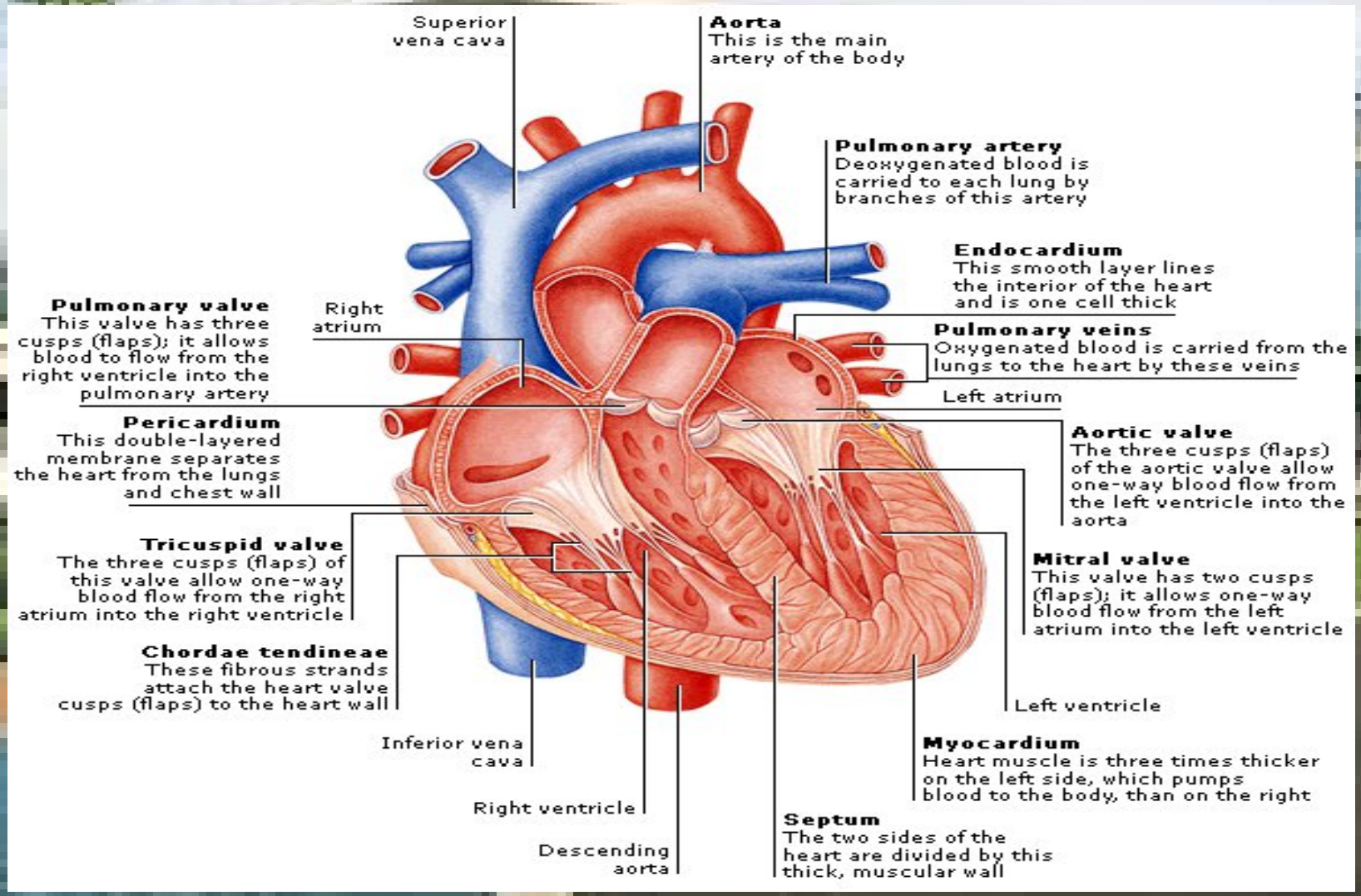
1. **Silicon** or other **semiconducting materials** for the camera and the electrode array.
2. **Biocompatible materials** for the casing of the device and the electrode array, such as titanium or titanium alloys, to minimize the risk of infection and rejection by the body.
3. **Conductive materials**, such as platinum, iridium, or gold, for the electrodes in the array to provide efficient electrical stimulation to the retina.
4. **Polymers**, such as silicone or polyimide, for insulation and protection of the electrodes and other components.
5. **Optical materials**, such as glass or acrylic, for the lens of the camera.
6. **Biocompatible and flexible materials** for the electrical connections between the camera and the processing unit and between the processing unit and the electrode array.
7. In addition to these materials, advanced computer algorithms and machine learning techniques are also used to improve the accuracy and reliability of the bionic eye technology.

- **Working of Bionic Eye**
- It works by capturing images with a small camera and transmitting the information to a processing unit that is attached to the eye.
- The processing unit then converts the visual information into electrical signals and sends them to an electrode array that is surgically implanted onto the retina.
- The electrodes stimulate the remaining healthy cells in the retina, which then sends signals to the brain to create the perception of vision.
- The restored vision is not perfect, but it can help people with vision loss to perform daily tasks more easily and safely.
- The amount and quality of vision that can be restored varies depending on the individual and the type of bionic eye being used.

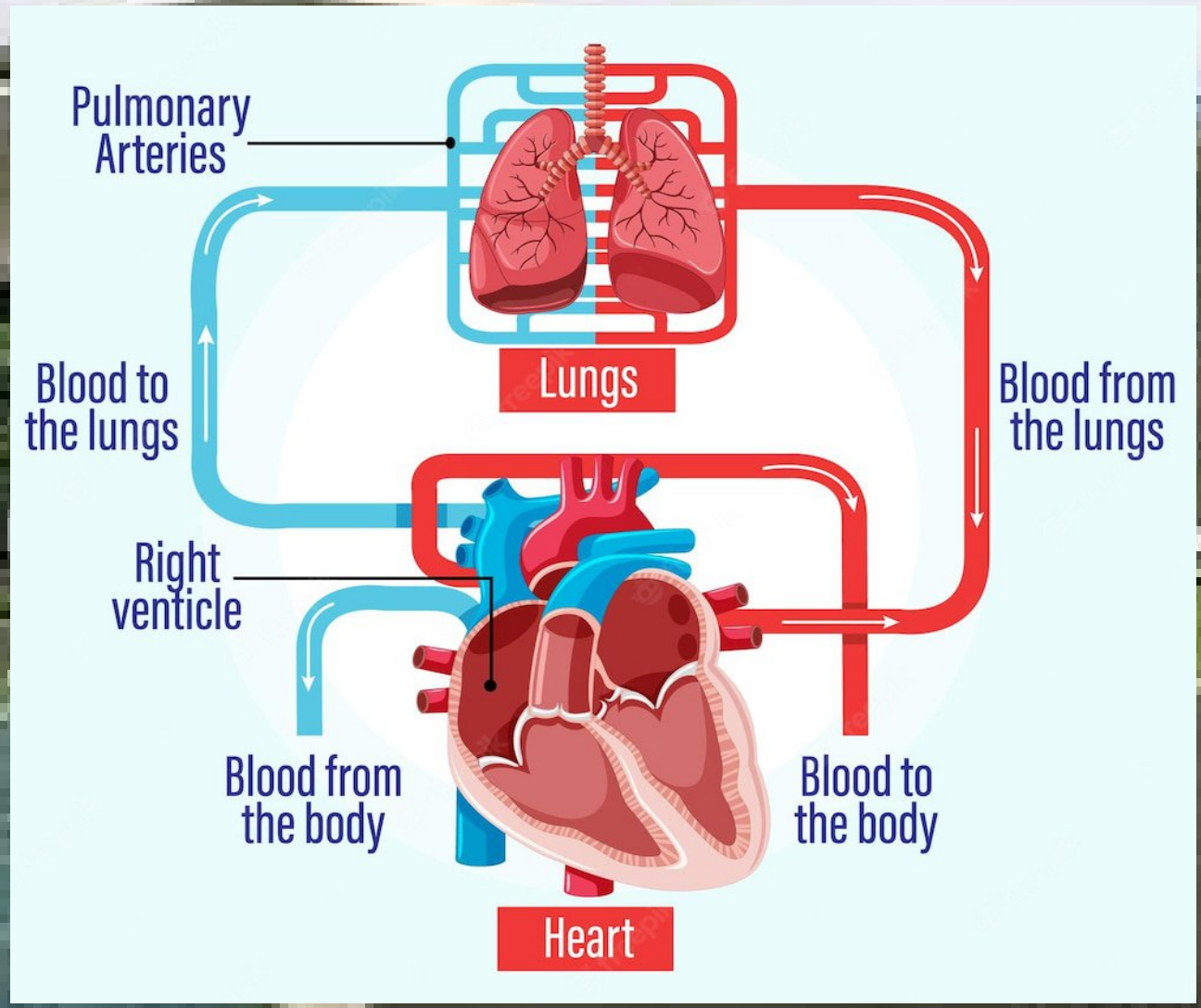
- Some bionic eyes only restore basic visual shapes and patterns, while others can provide more detailed vision.
- The bionic eye is powered by a battery that is typically implanted behind the ear.
- The battery is recharged through a device that is held near the eye, which transmits power wirelessly to the battery.
- The device is typically rechargeable and can be used for several years before it needs to be replaced.

HEART AS A PUMP SYSTEM

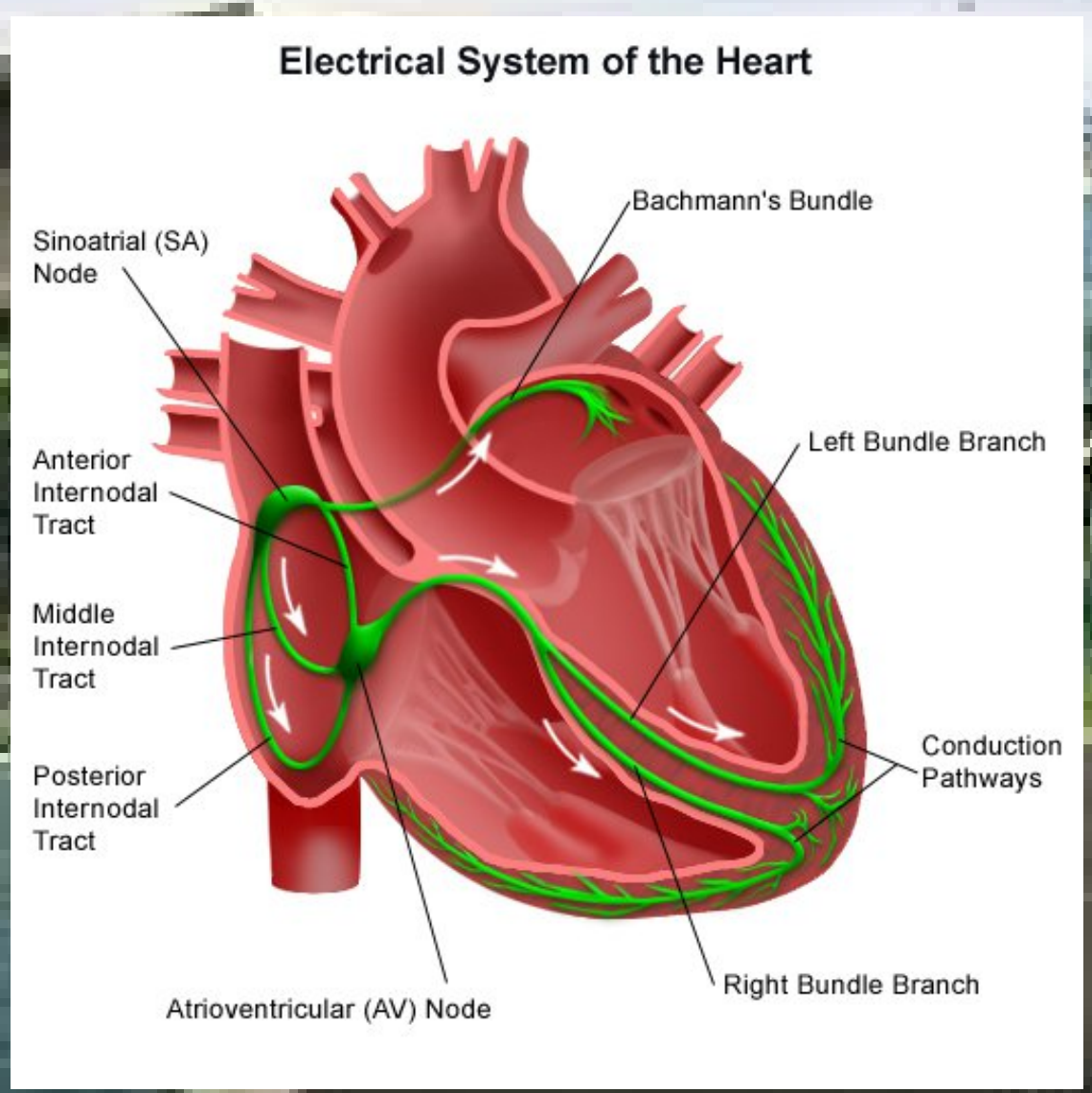
- **Architecture**
- The heart is a complex pump system that circulates blood throughout the body.
- It consists of four chambers: the right atrium, the left atrium, the right ventricle, and the left ventricle.
- Blood enters the right atrium from the body and is pumped into the right ventricle, which then pumps the blood to the lungs for oxygenation.
- Oxygenated blood returns to the heart and enters the left atrium, which pumps the blood into the left ventricle.
- The left ventricle then pumps the oxygenated blood out to the rest of the body. Between each chamber, there are one-way valves that ensure the blood flows in the correct direction and prevent backflow.
- The heart is also surrounded by the pericardium, a sac that contains a small amount of fluid and helps to protect and lubricate the heart as it beats


Superior vena cava
Aorta
This is the main artery of the body
Pulmonary artery
Deoxygenated blood is carried to each lung by branches of this artery
Endocardium
This smooth layer lines the interior of the heart and is one cell thick
Pulmonary valve
This valve has three cusps (flaps); it allows blood to flow from the right ventricle into the pulmonary artery
Right atrium
Pulmonary veins
Oxygenated blood is carried from the lungs to the heart by these veins
Left atrium
Pericardium
This double-layered membrane separates the heart from the lungs and chest wall
Aortic valve
The three cusps (flaps) of the aortic valve allow one-way blood flow from the left ventricle into the aorta
Tricuspid valve
The three cusps (flaps) of this valve allow one-way blood flow from the right atrium into the right ventricle
Mitral valve
This valve has two cusps (flaps); it allows one-way blood flow from the left atrium into the left ventricle
Chordae tendineae
These fibrous strands attach the heart valve cusps (flaps) to the heart wall
Left ventricle
Inferior vena cava
Myocardium
Heart muscle is three times thicker on the left side, which pumps blood to the body, than on the right
Right ventricle
Septum
The two sides of the heart are divided by this thick, muscular wall
Descending aorta

- **The HeartBeat**
- The heart's pumping action is controlled by a complex network of electrical and chemical signals, which generate the rhythm of the heartbeat.
- An electrical stimulus is generated in a special part of the heart muscle called the sinus node. It's also called the sinoatrial node (SA node).
- The sinus node is a small mass of special tissue in the right upper chamber of the heart (right atrium).
- In an adult, the sinus node sends out a regular electrical pulse 60 to 100 times per minute.
- This electrical pulse travels down through the conduction pathways and causes the heart's lower chambers (ventricles) to contract and pump out blood.
- The right and left atria are stimulated first and contract to push blood from the atria into the ventricles. The ventricles then contract to push blood out into the blood vessels of the body.


Pulmonary Arteries
Lungs
Blood to the lungs
Blood from the lungs
Right venticle
Blood from the body
Blood to the body
Heart

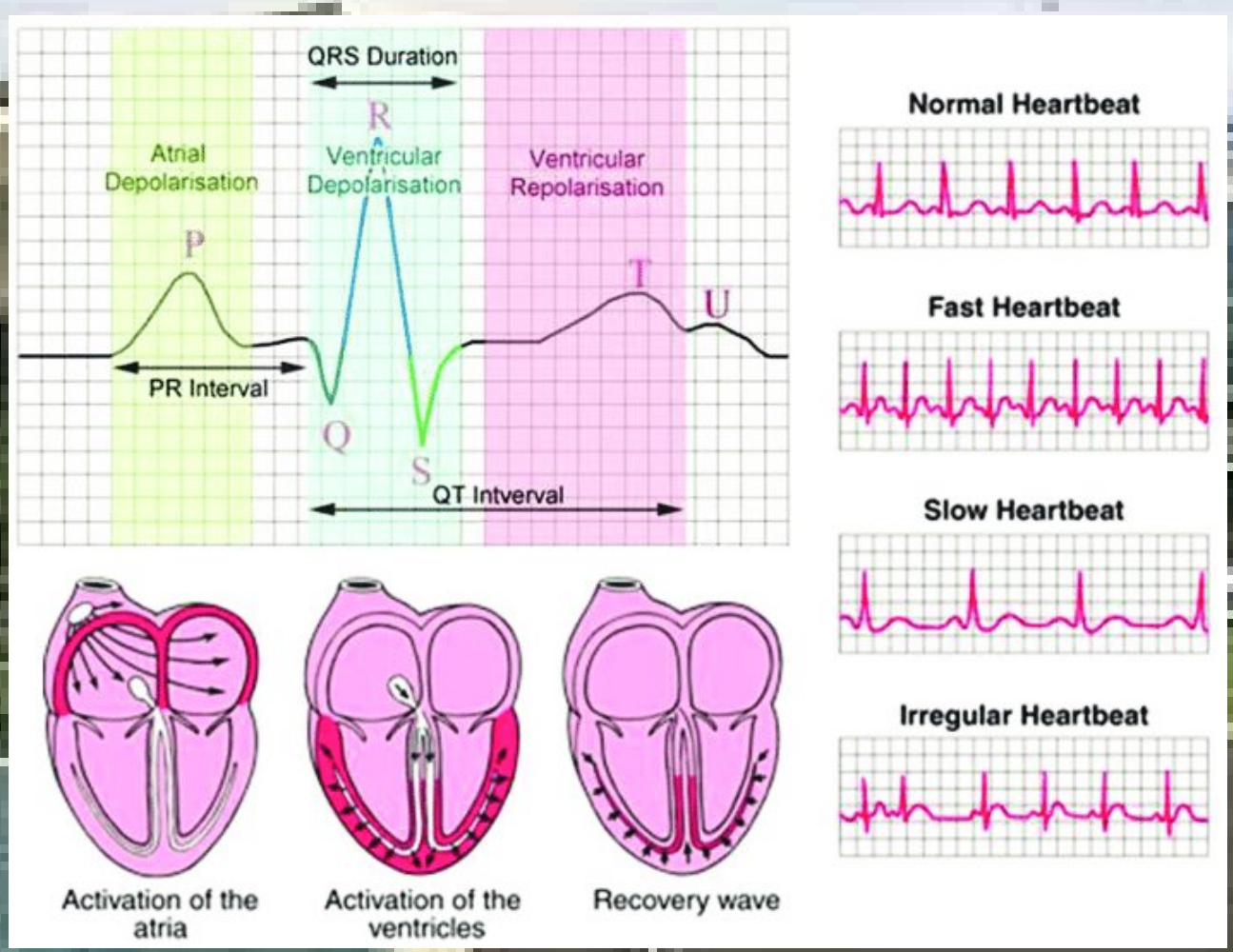
- **Electrical Signalling – ECG Monitoring and Heart Related Issues**
- The heart's pumping action is controlled by electrical signaling, which generates the rhythm of the heartbeat.
- This electrical signaling can be monitored using an electrocardiogram (ECG), which records the electrical activity of the heart and provides important information about the heart's function.
- An ECG measures the electrical signals produced by the heart as it beats and generates a trace or waveform that reflects the electrical activity of the heart.
- This trace can be used to diagnose heart conditions and monitor the heart's function.


Electrical System of the Heart
Bachmann's Bundle
Sinoatrial (SA) Node
Left Bundle Branch
Anterior Internodal Tract
Middle Internodal Tract
Conduction Pathways
Posterior Internodal Tract
Right Bundle Branch
Atrioventricular (AV) Node

- Some common heart-related issues that can be diagnosed or monitored using an ECG include:

1. **Arrhythmias**: Abnormalities in the heart's rhythm or rate can be detected using an ECG.
2. **Heart disease**: Changes in the heart's electrical activity can indicate the presence of heart disease, such as coronary artery disease or heart attacks.
3. **Heart attack**: An ECG can help diagnose a heart attack by detecting changes in the heart's electrical activity that indicate a lack of blood flow to the heart.

- Overall, the ECG is a useful tool for diagnosing and monitoring heart-related issues and helps to provide important information about the heart's function and health.



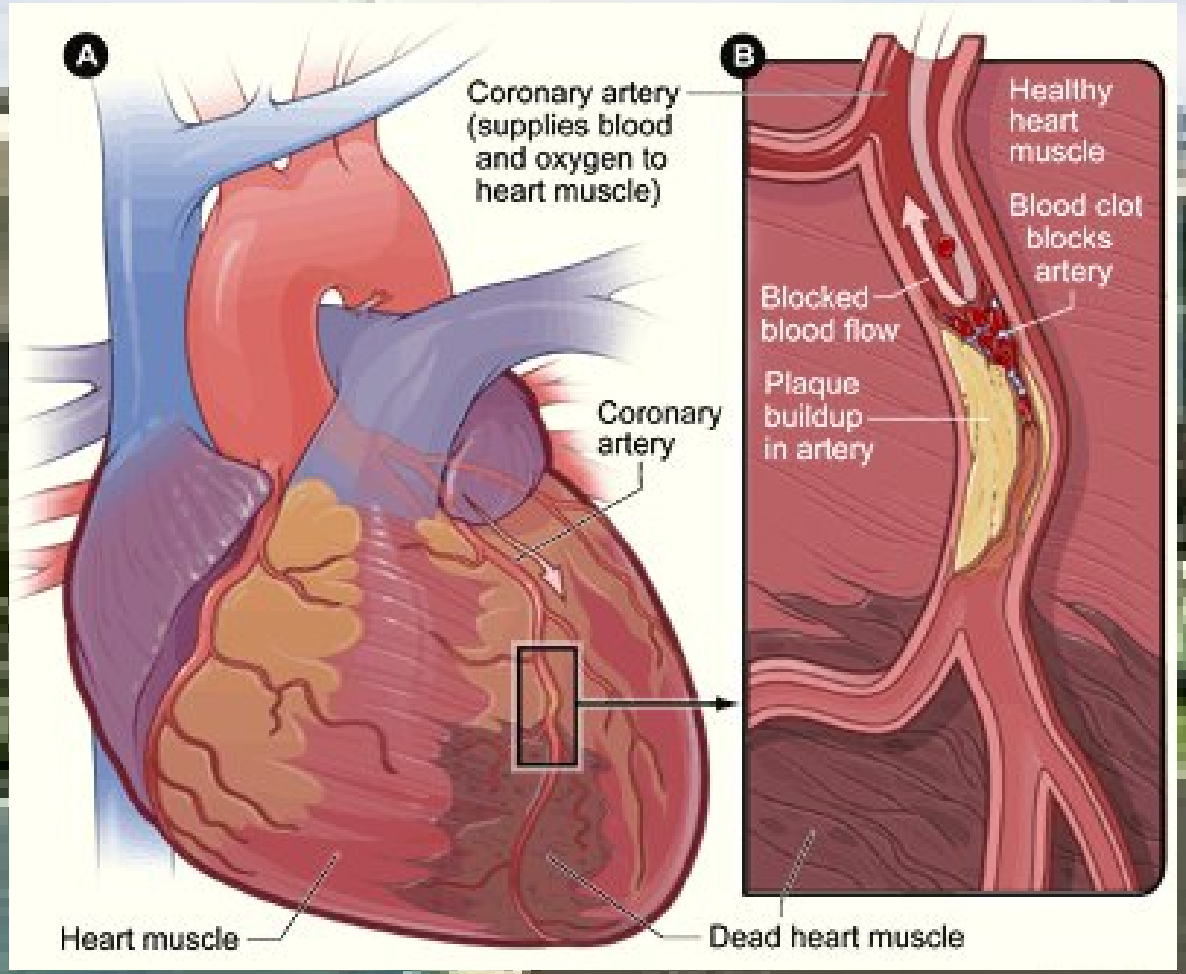
ECG waves and their relation to heart nodes

Reasons for Blockages of Blood Vessels / arterial blockages or atherosclerosis

1. **High cholesterol levels**: Excessive amounts of low-density lipoprotein (LDL) cholesterol in the blood can lead to the formation of plaque in the blood vessels, which can narrow or block them.
2. **High blood pressure:** Over time, high blood pressure can cause damage to the blood vessels, leading to the formation of plaque and blockages.
3. **Smoking**: Smoking can damage the inner walls of blood vessels and promote the buildup of plaque, leading to blockages.
4. **Diabetes**: People with uncontrolled diabetes are at a higher risk of developing blockages in their blood vessels, due to damage to the blood vessels from high levels of glucose.

5. **Age**: As people age, the blood vessels can become stiff and less flexible, increasing the risk of blockages
6. **Genetics**: Some people may be predisposed to developing blockages in their blood vessels due to genetic factors.
7. **Poor diet**: A diet high in saturated fats, trans fats, and cholesterol can increase the risk of developing blockages in the blood vessels.

- The blockages in blood vessels can have serious health consequences, such as heart attacks and stroke.
- Maintaining a healthy lifestyle, including eating a healthy diet, exercising regularly, and avoiding smoking, can help reduce the risk of developing blockages in blood vessels.



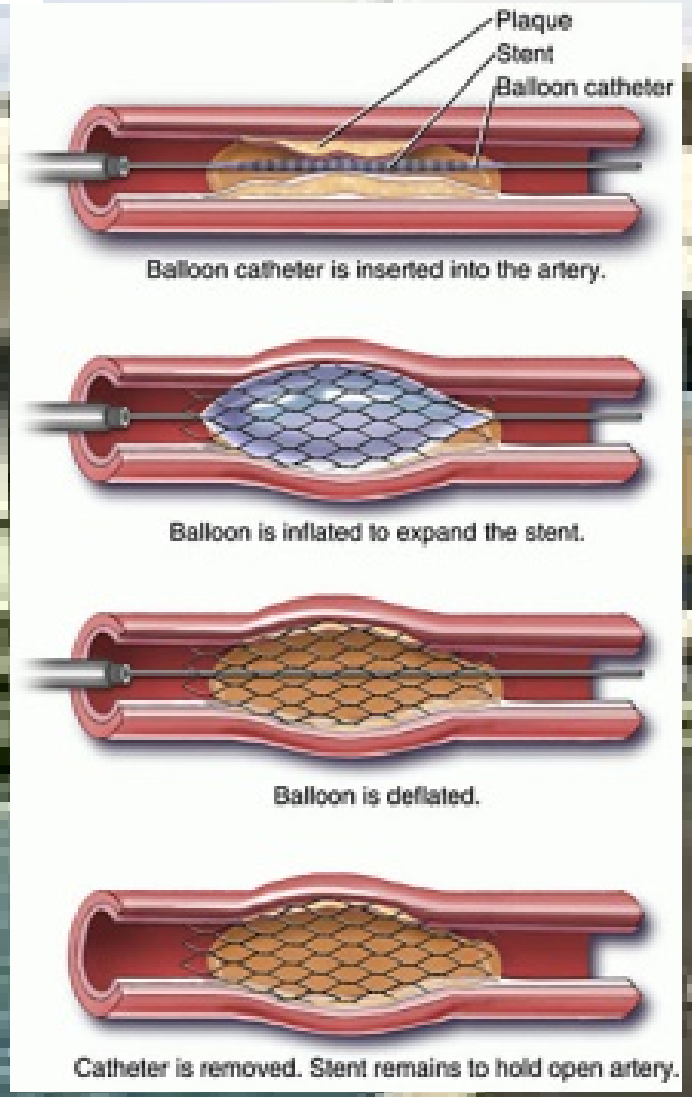
(A) shows damage (dead heart muscle) caused by a heart attack, (B) shows the coronary artery with plaque buildup and a blood clot.

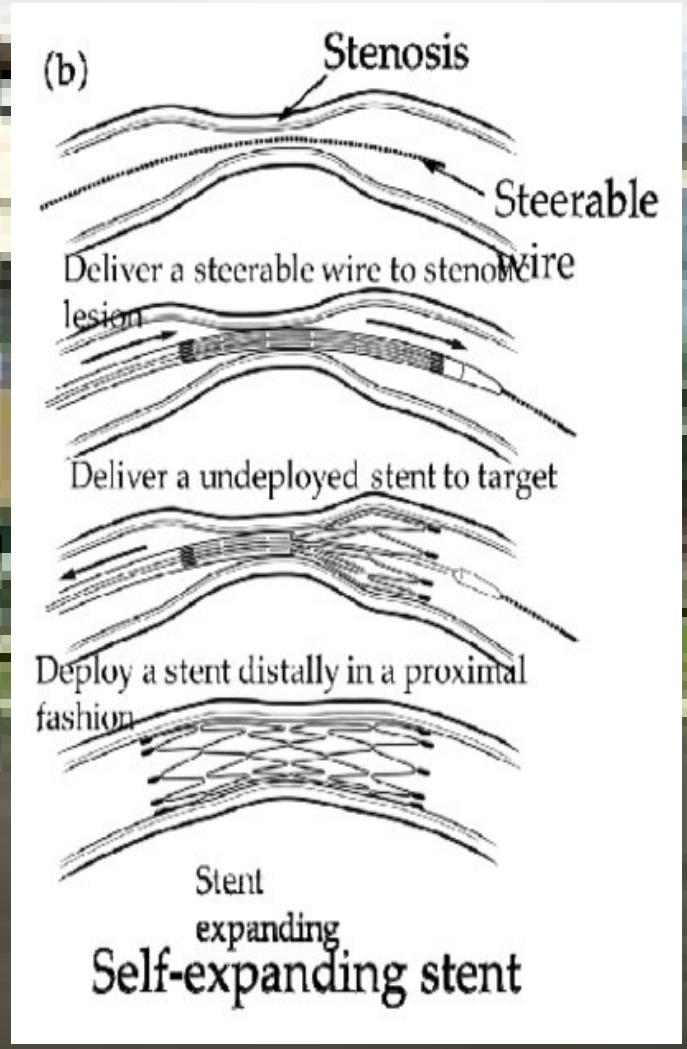
- **Design of Stents**
- Stents are small, metal mesh devices that are used to treat blockages in blood vessels.
- They are typically used in procedures such as angioplasty, where a balloon catheter is used to open up a blocked blood vessel and a stent is placed to keep it open.
- The design of stents can vary depending on the type of stent and the specific medical condition it is used to treat.
- Some common design features of stents include:

1. **Shape**: Stents can be designed in a variety of shapes, including cylindrical, helical, and spiraled, to match the shape of the blood vessel and provide adequate support.

2. **Material**: Stents can be made of different materials, including stainless steel, cobaltchromium, and nitinol (a type of metal that is flexible and can return to its original shape after being expanded).
3. **Coating**: Stents can be coated with different materials to prevent blood clots from forming and reduce the risk of restenosis (recurrent blockage of the blood vessel).
4. **Expansion mechanism**: Stents can be designed to expand in different ways, such as by balloon inflation or self-expansion, depending on the type of stent and the specific medical condition it is used to treat.

- Overall, the design of stents plays an important role in their effectiveness and safety. Stents must be designed to provide adequate support to the blood vessel, prevent restenosis, and minimize the risk of complications such as blood clots.


Plaque
Stent
Balloon catheter
Balloon catheter is inserted into the artery.
Balloon is inflated to expand the stent.
Balloon is deflated.
Catheter is removed. Stent remains to hold open artery.


(b)
Stenosis
Steerable wire
Deliver a steerable wire to stenotic lesion
Deliver a undeployed stent to target
Deploy a stent distally in a proximal fashion
Stent expanding
Self-expanding stent

- **PaceMakers**
- A pacemaker is a small device that is surgically implanted in the chest to regulate the heartbeat.
- It is used to treat heart rhythm disorders, such as bradycardia (a slow heartbeat) or arrhythmias (abnormal heart rhythms), by delivering electrical impulses to the heart to regulate its rhythm.
- The basic design of a pacemaker consists of:

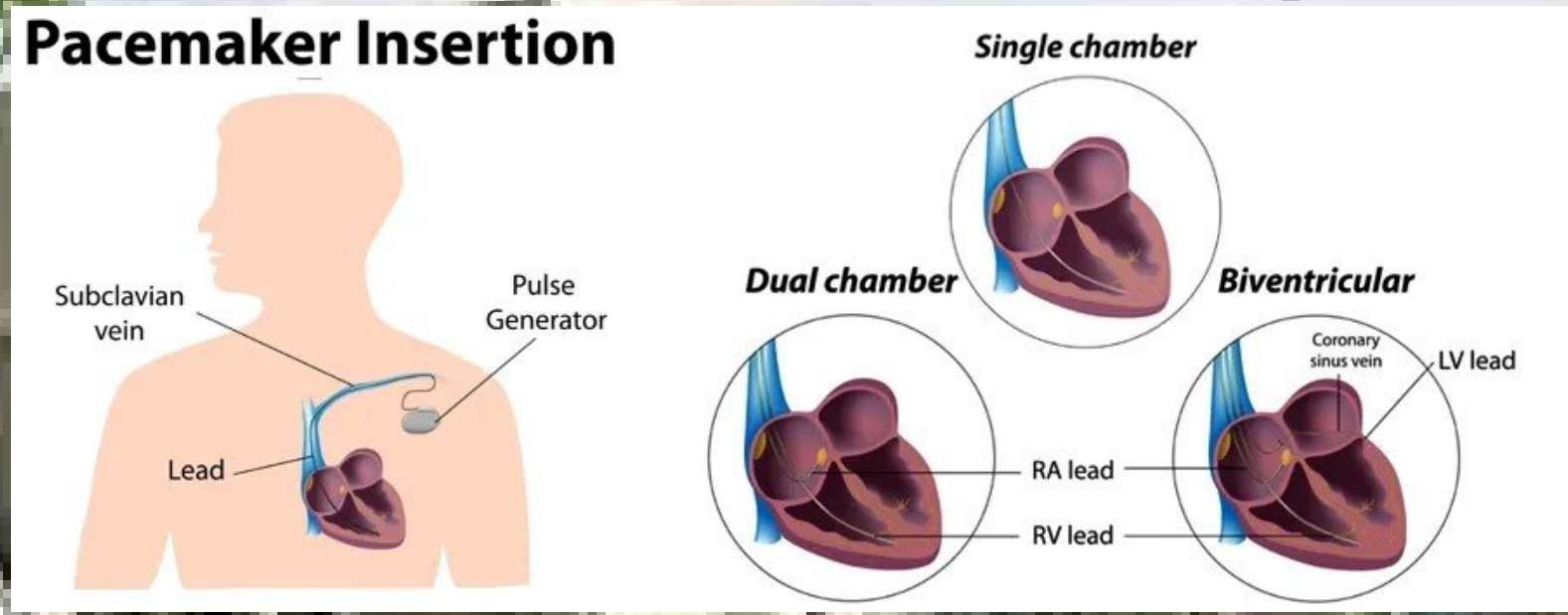
1. **Generator**: The generator is the main component of the pacemaker and contains a battery and electronic circuitry to generate and control the electrical impulses.
2. **Leads**: Leads are thin wires that connect the generator to the heart and carry the electrical impulses from the generator to the heart.

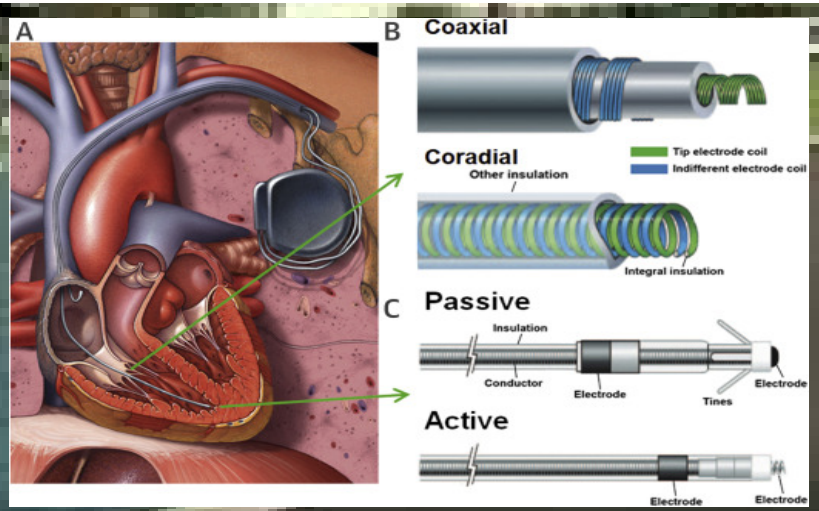
3. **Electrodes**: The electrodes are located at the end of the leads and are used to deliver the electrical impulses to the heart.

• Pacemakers can be designed to work in different ways, including:

1. **Single-chamber pacemaker**: A single-chamber pacemaker delivers electrical impulses to either the right atrium or the right ventricle of the heart to regulate its rhythm.
2. **Dual-chamber pacemaker**: A dual-chamber pacemaker delivers electrical impulses to both the right atrium and the right ventricle of the heart to regulate its rhythm.
3. **Biventricular pacemaker**: A biventricular pacemaker delivers electrical impulses to both ventricles of the heart to coordinate their contractions and improve heart function in people with heart failure.

Pacemaker Insertion



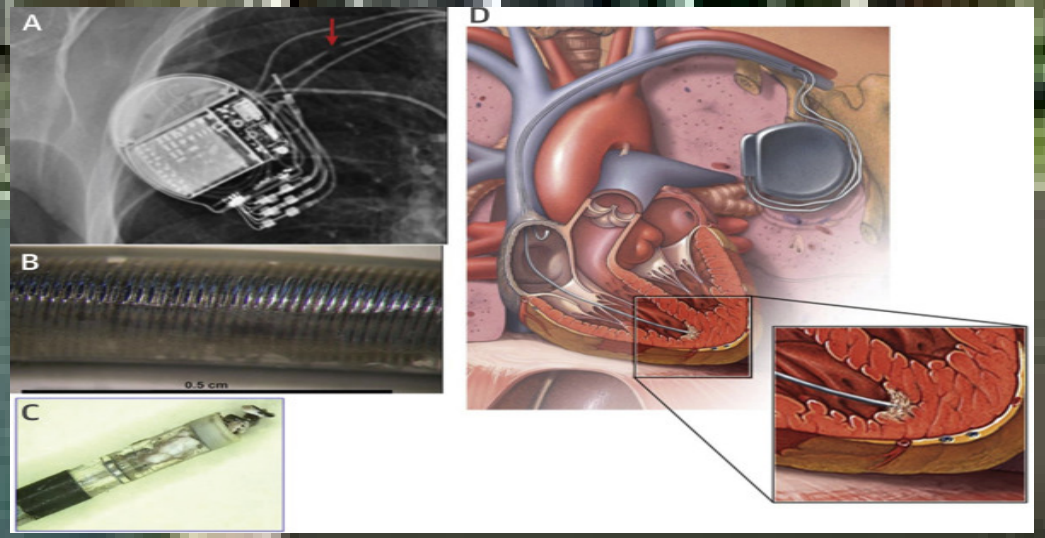


- **Construction of a Pacemaker**
- It involves the use of high-quality materials and specialized manufacturing processes to ensure their safety and reliability.
- Materials used in the construction of pacemakers include:

1. **Medical-grade plastics**: Medical-grade plastics, such as polycarbonate, are used to construct the exterior of the device and to provide insulation and protection for the internal components.
2. **Metals**: Metals, such as stainless steel and titanium, are used in the construction of the leads and electrodes to ensure their durability and long-lasting performance.
3. **Electronic components**: Electronic components, such as microprocessors, batteries, and capacitors, are used to control the delivery of the electrical impulses and to provide power to the device.

4. **Adhesives**: Adhesives, such as cyanoacrylate and epoxy, are used to secure the components of the device and to provide insulation and protection for the internal components.

- The manufacturing process for pacemakers includes multiple quality control measures to ensure their safety and reliability.
- This includes testing of individual components and final assembly testing to verify the proper operation of the device before it is released for use.

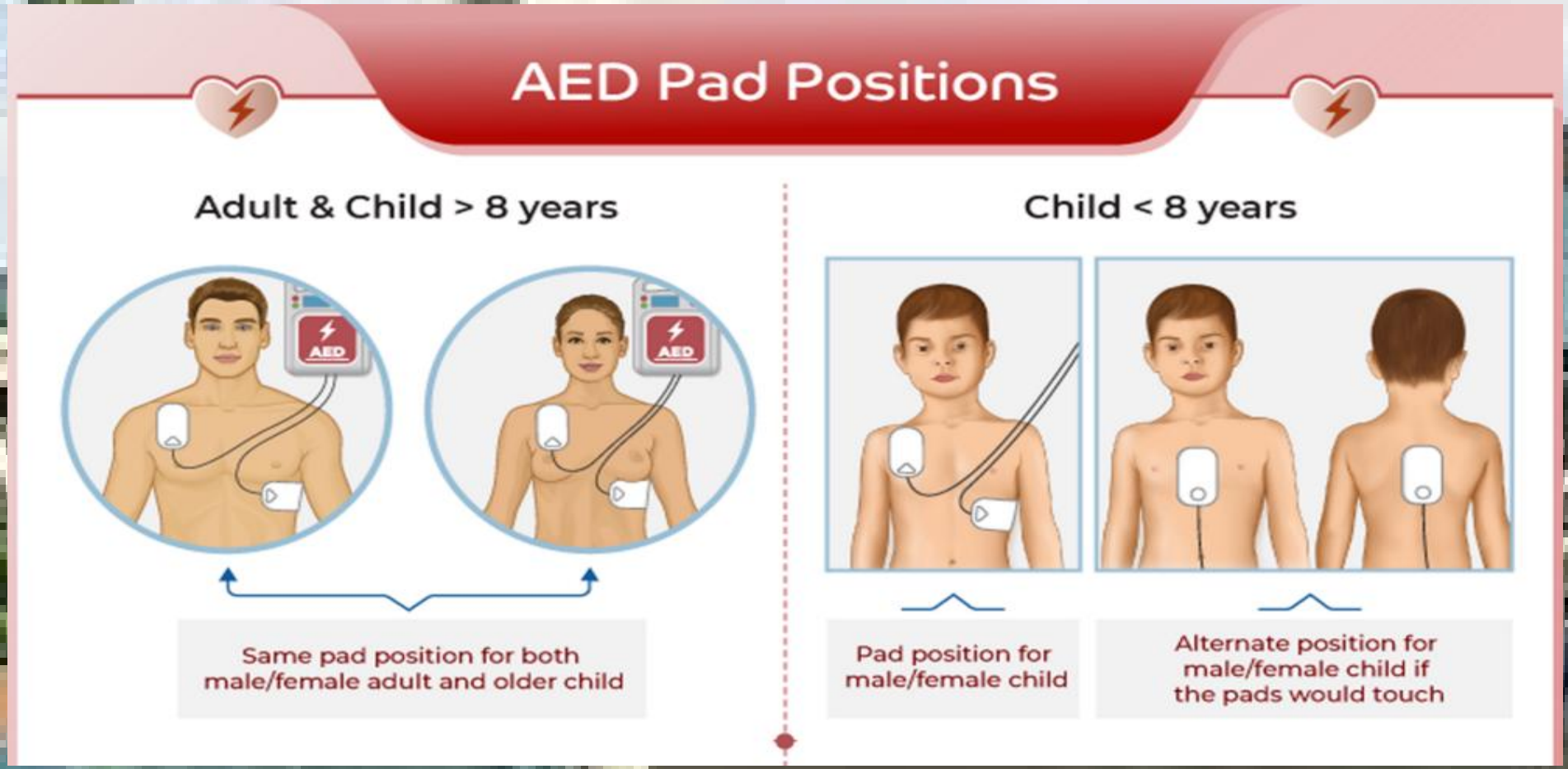


- **Defibrillators**
- A defibrillator is a medical device that delivers an electric shock to the heart to restore its normal rhythm in cases of cardiac arrest or other life-threatening heart rhythm disorders.
- Defibrillators can be external (placed on the chest) or internal (implanted within the body)

- The basic design of a defibrillator consists of:

1. **Power source**: The power source, typically a battery, provides energy to deliver the electric shock to the heart.
2. **Electrodes**: The electrodes are placed on the chest and deliver the electric shock to the heart.
3. **Circuitry**: The circuitry in the defibrillator controls the delivery of the electric shock, including the timing, strength, and duration of the shock.
4. **Display**: A display on the defibrillator provides information about the heart rhythm, battery life, and other relevant information.

- **Automated External Defibrillators (AEDs)/external defibrillators**
- These are designed for use by laypeople and are commonly found in public places such as airports, shopping centers, and schools.
- They are relatively simple in design and typically have voice prompts and visual cues to guide the user through the process of delivering the electric shock.
- **Implantable Cardioverter Defibrillators/Internal defibrillators** (ICDs)
- These are surgically implanted within the body and are used to treat people with a high risk of sudden cardiac arrest.
- They are typically more complex in design, including features such as continuous monitoring of the heart rhythm, and automatic delivery of shocks when necessary



An implantable cardioverter defibrillator (ICD) looks similar to a pacemaker, though slightly larger. It works very much like a pacemaker. But the ICD can send an energy shock that resets an abnormal heartbeat back to normal.

- **Construction of defibrillators**
- The construction of defibrillators involves the use of high-quality materials and specialized manufacturing processes to ensure their safety and reliability.
- Materials Used Materials used in the construction of defibrillators include:

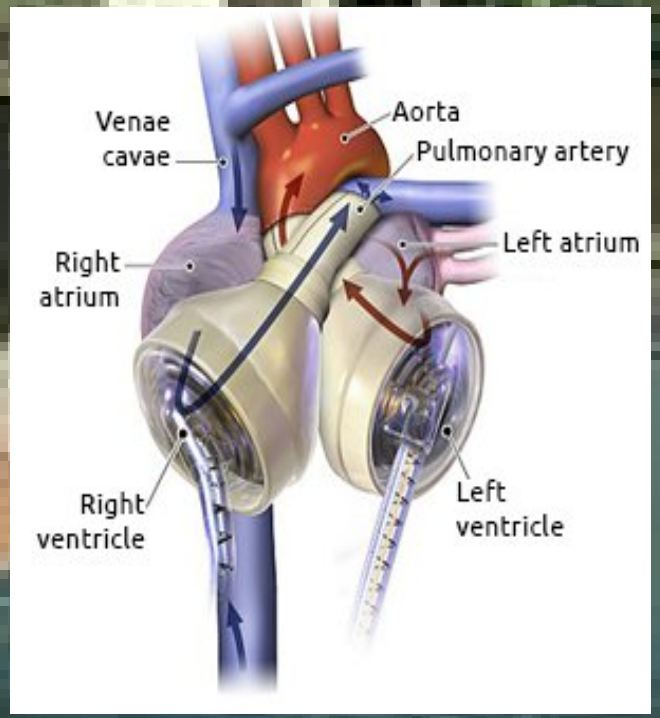
1. **Medical-grade plastics**: such as polycarbonate, are used to construct the exterior of the device and to provide insulation and protection for the internal components.
2. **Metals**: such as stainless steel and titanium, are used in the construction of the leads and electrodes to ensure their durability and long-lasting performance.
3. **Electronic components**: such as microprocessors, batteries, capacitors, and high-voltage transformers, are used to control the delivery of the electrical impulses and to provide power to the device.


atme

- **Basic Design**

1. **Power source**: The power source, typically a battery, provides energy to deliver the electrical impulses to the heart.
2. **Electrodes**: The electrodes are placed on the chest and deliver the electrical impulses to the heart to restore normal rhythm.
3. **Circuitry**: The circuitry in the defibrillator controls the delivery of the electrical impulses, including the timing, strength, and duration of the impulses.
4. **Display**: A display on the defibrillator provides information about the heart rhythm, battery life, and other relevant information

- **Heart assist devices**, are devices that are surgically implanted into the heart and work alongside the natural heart to support its functions.
- While these devices are still in the early stages of development, they have the potential to greatly improve the survival and well-being of people with heart disease.

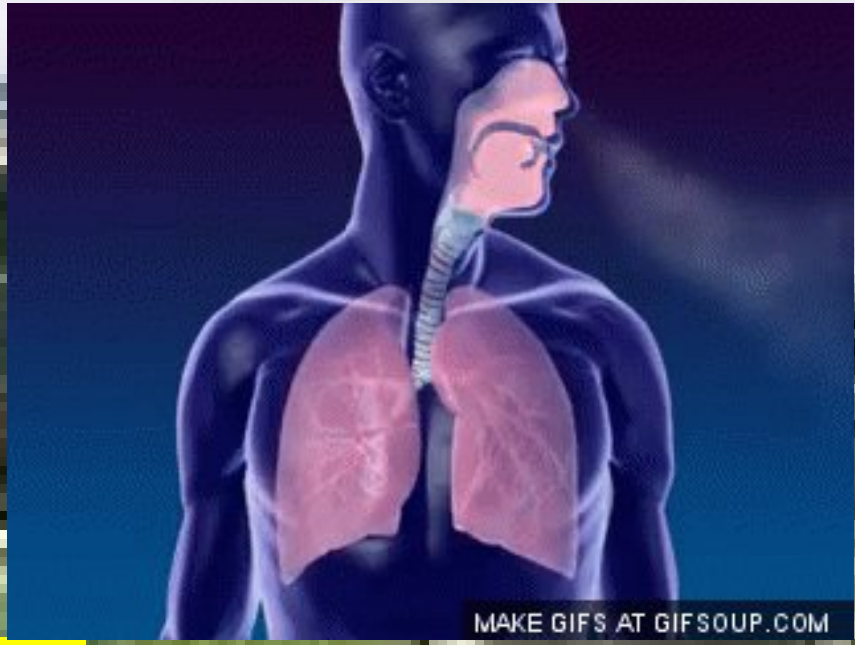


Lungs as purification system

Every cell in your body needs oxygen to live.

The air we breathe contains oxygen and other gases.

The respiratory system's main job is to move fresh air into your body while removing waste gases.

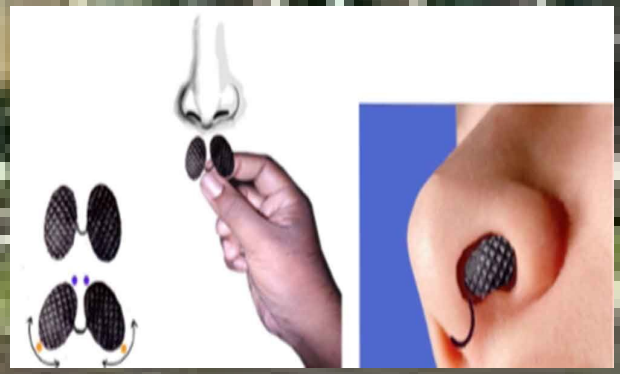


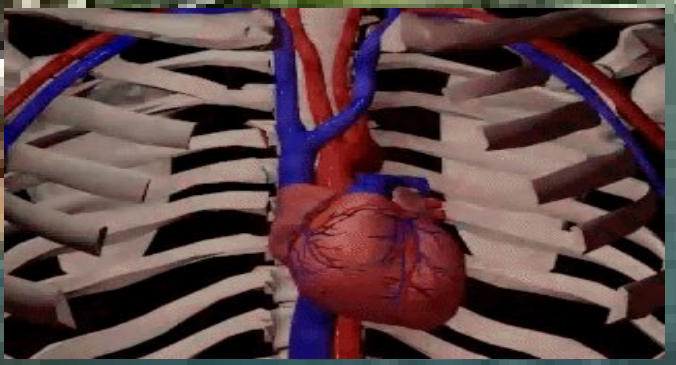
- Once in the lungs, oxygen is moved into the bloodstream and carried through your body, oxygen is exchanged for a waste gas called carbon dioxide.
- Your bloodstream then carries this waste gas back to the lungs where it is removed from the bloodstream and then exhaled.

In addition to **gas exchange**, our respiratory system performs other roles like.

- Bringing air to the proper **body temperature** and **moisturizing** it to the right **humidity level**.
- Protecting your body from harmful substances. This is done by **coughing, sneezing, and filtering**.
- Supporting your **sense of smell**.

In the nostrils, the air gets **warmed and moistened**. Tiny hairs in the nose called **cilia** filter out dust and other particles.





Lungs help in the purification of blood

When the **breath is inhaled**, oxygen from the air meets the **impure blood** and **the blood takes up oxygen**, releases CO2, and is purified in the lungs. The purified blood is carried to the heart by the veins.

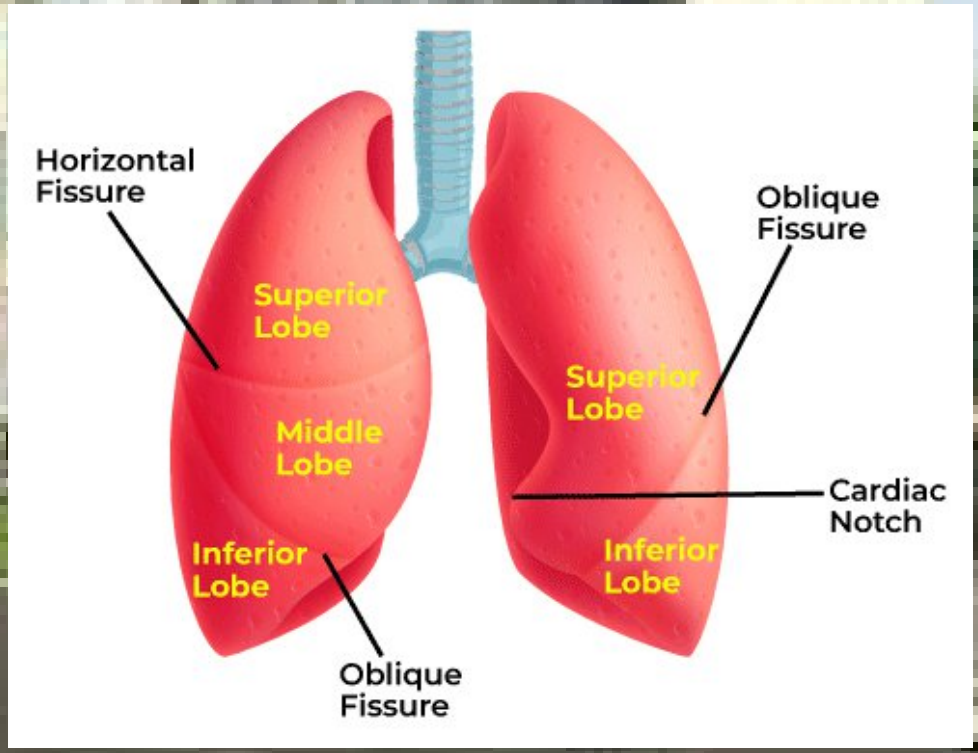
Lung's architecture

Lobes **Bronchi** **Alveoli** **Pulmonary Capillaries** **Pleura** **Diaphragm**

The human lungs are divided into two main sections called the left and right lungs.

The right lung has three lobes: the superior, middle, and inferior lobes.

The left lung is slightly smaller and has two lobes: the superior and inferior lobes.



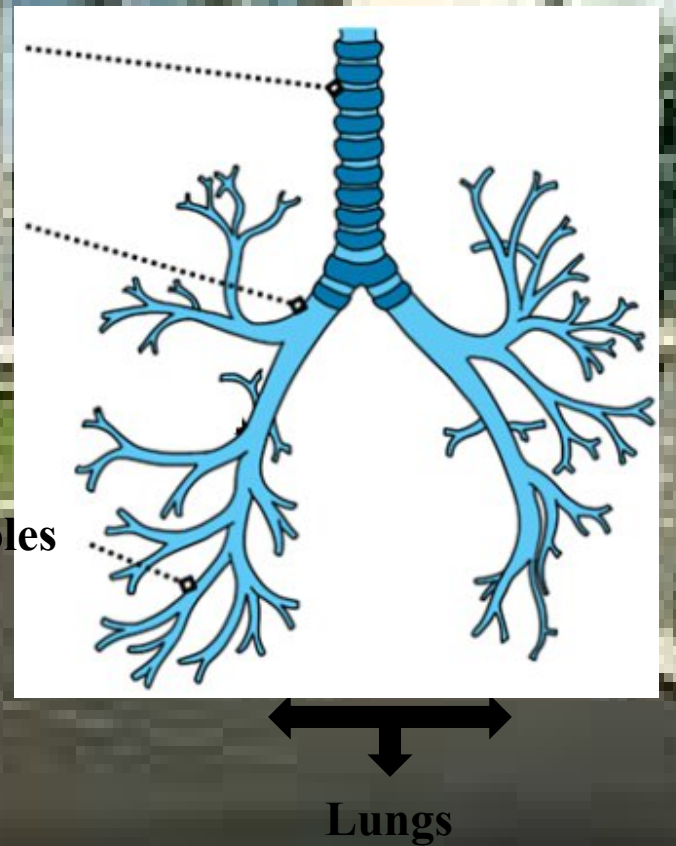
Lung's architecture

Lobes **Bronchi** **Alveoli** **Pulmonary Capillaries** **Pleura** **Diaphragm**

- The trachea, or windpipe, divides into two main bronchi—one leading to each lung.
- These bronchi is further divided into bronchioles.

Uses

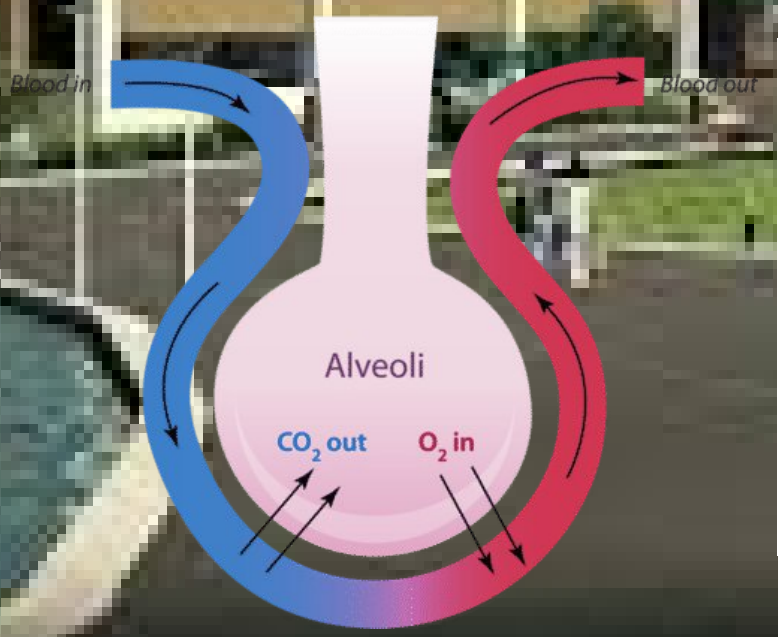
- Carry air to and from your lungs.
- The bronchi also help moisturize the air you breathe and screen out foreign particles

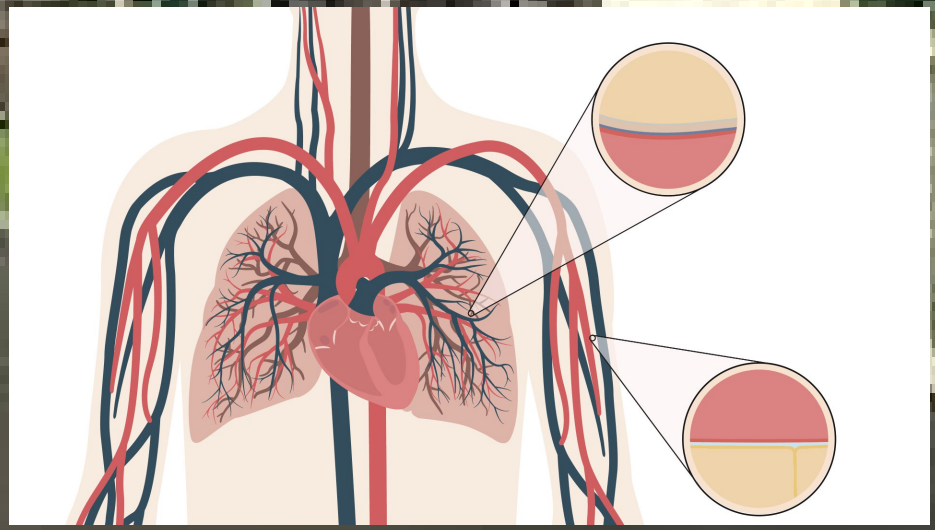


Lung's architecture

Lobes **Bronchi** **Alveoli** **Pulmonary Capillaries** **Pleura** **Diaphragm**

- At the end of the terminal bronchioles,
- These grape-like structures are the primary sites of gas exchange.
- It allows for the diffusion of oxygen from the alveoli into the bloodstream and the release of carbon dioxide into the alveoli.

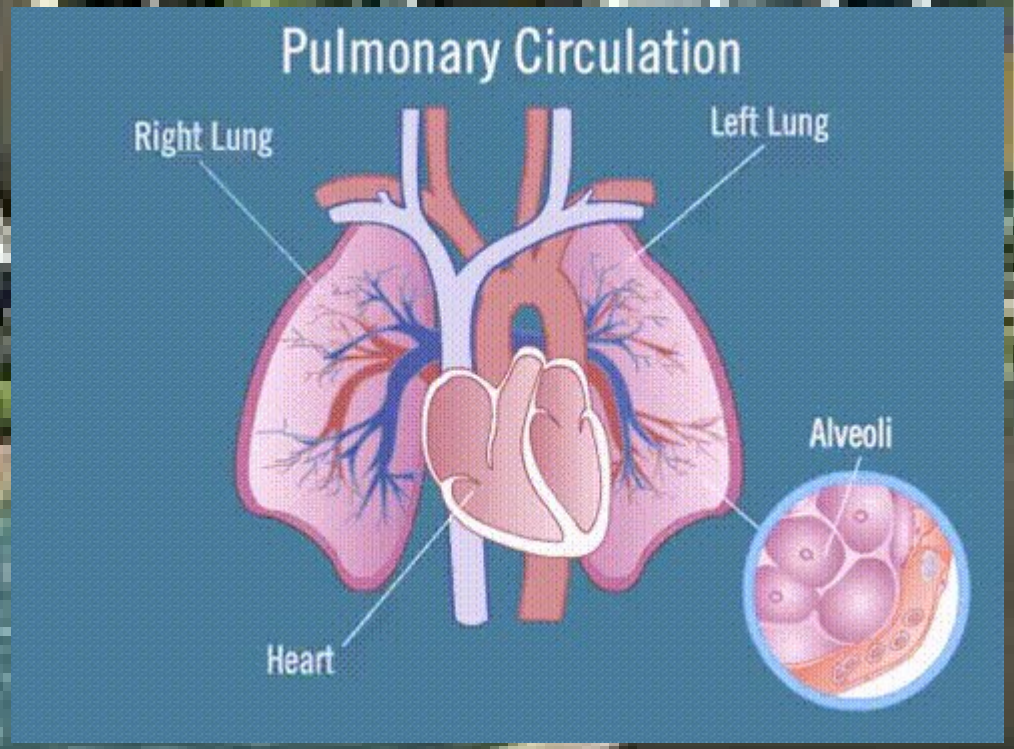


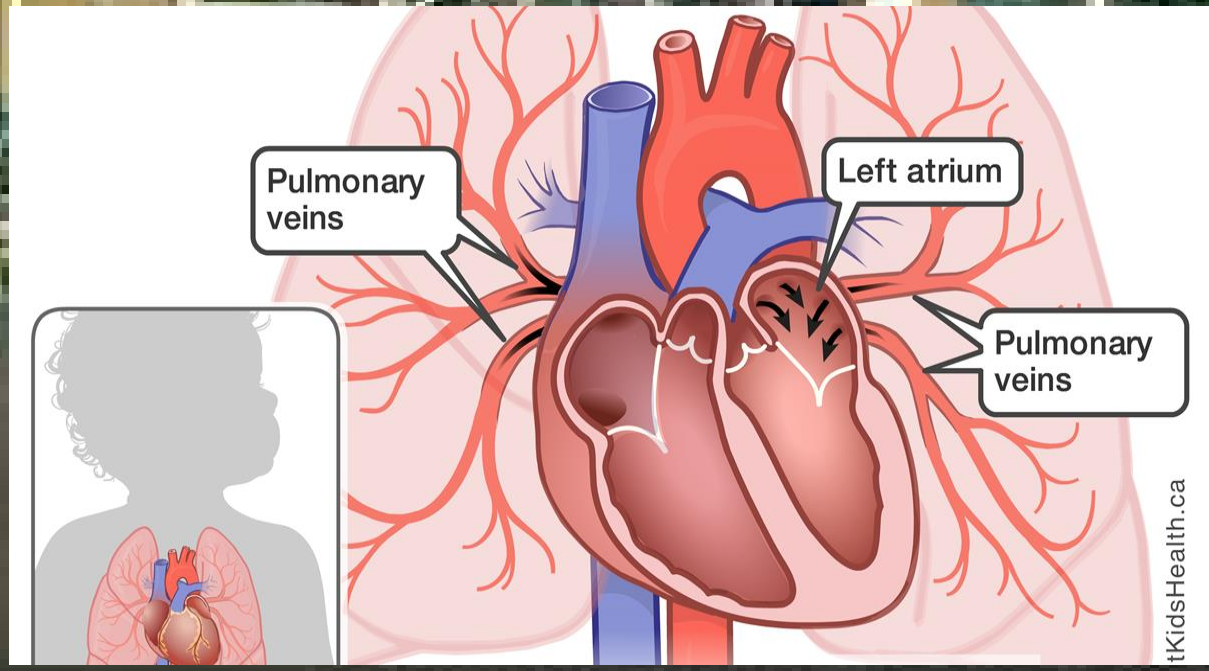


Lung's architecture

Lobes **Bronchi** **Alveoli** **Pulmonary Capillaries** **Pleura** **Diaphragm**

Deoxygenated blood enters the pulmonary arteries from the **right side** of the heart and is delivered to the **pulmonary capillaries**. It is the smallest blood vessel inside the lungs, attached to the walls of the alveoli which exchange gases between the alveoli and the bloodstream.

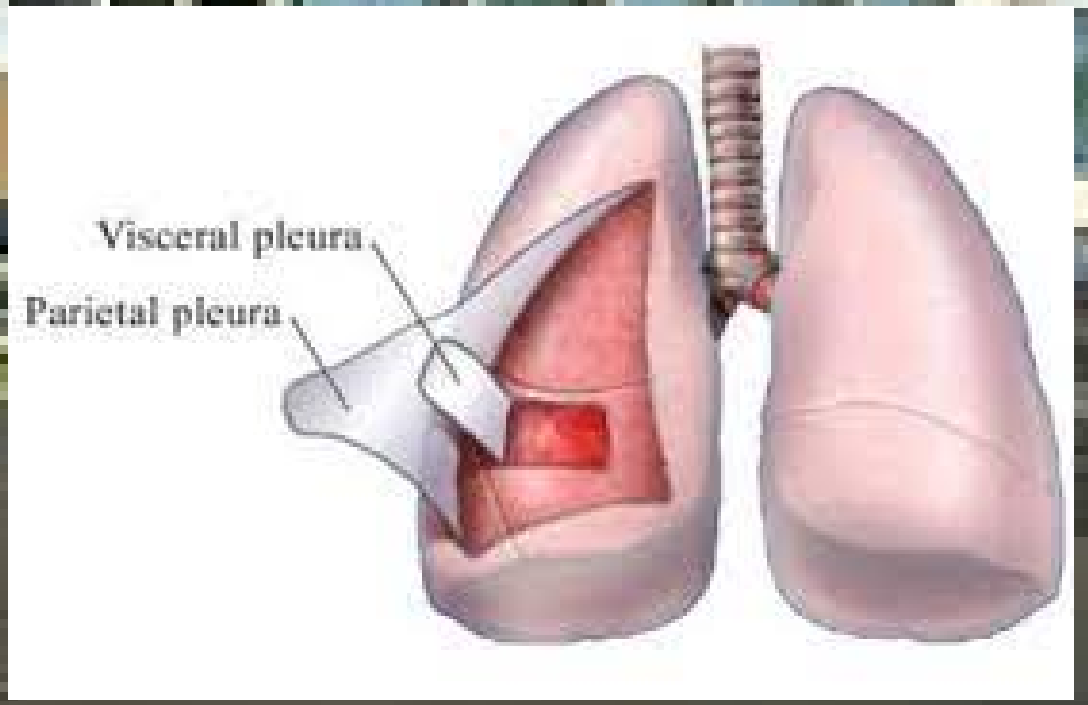




Lung's architecture

Lobes **Bronchi** **Alveoli** **Pulmonary Capillaries** **Pleura** **Diaphragm**

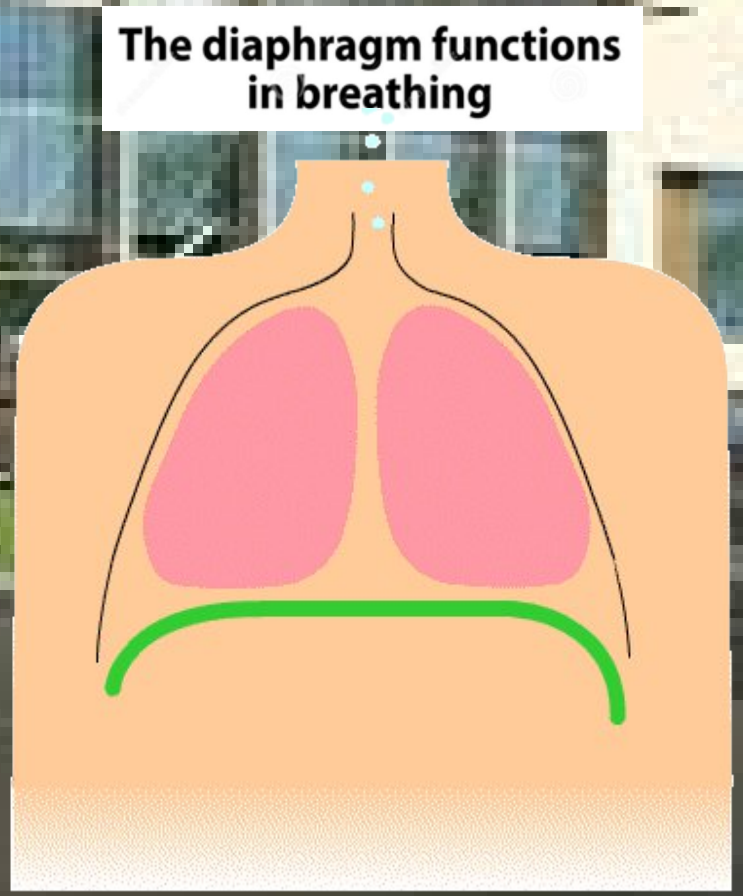
The lungs are covered by a double-layered membrane called the pleura.



Lung's architecture

Lobes **Bronchi** **Alveoli** **Pulmonary Capillaries** **Pleura** **Diaphragm**

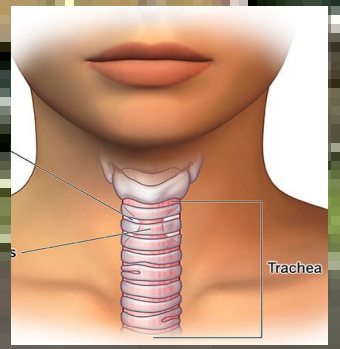
- The diaphragm is a dome-shaped muscle located at the base of the lungs.
- It plays a crucial role in respiration by contracting and flattening during inhalation, allowing the lungs to expand and fill with air.
- When the diaphragm relaxes, it returns to its dome shape, helping to expel air from the lungs during exhalation.

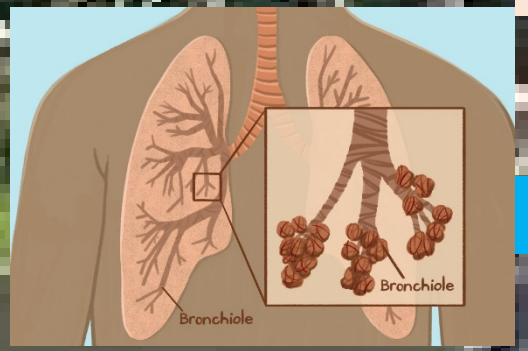


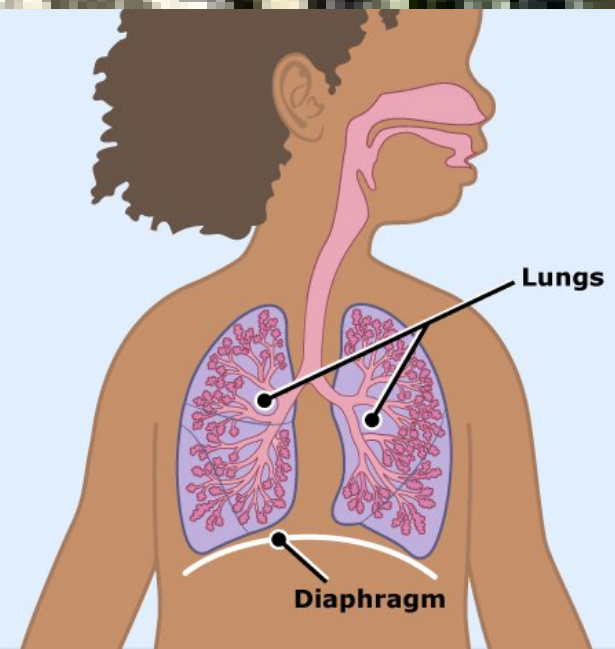
GAS EXCHANGE MECHANISMS:

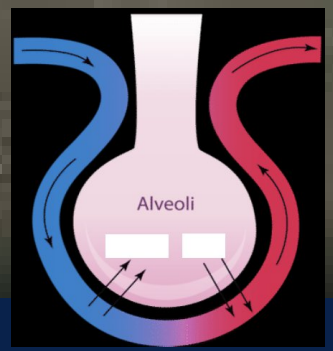
- Air enters the body through the mouth or nose and quickly moves to the throat.
- it passes through the voice box and enters the trachea.
- Within the lungs, the trachea branches into a left and right bronchus. These further divide into smaller and smaller branches called bronchioles. The smallest bronchioles end in tiny air sacs. These are called alveoli.

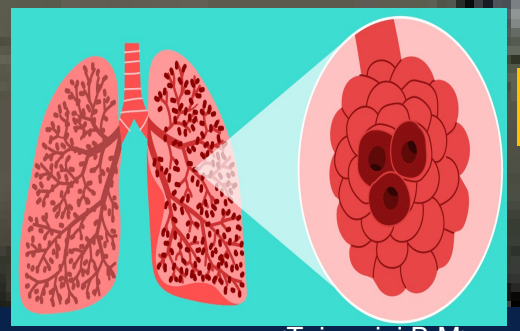
Air → Mouth or nose → Throat → Voice box → Trachea → Left/Right branches → Bronchioles → Alveoli











SAMPLE USE ONLY

nucleus
MEDICAL MEDIA

SPIROMETRY

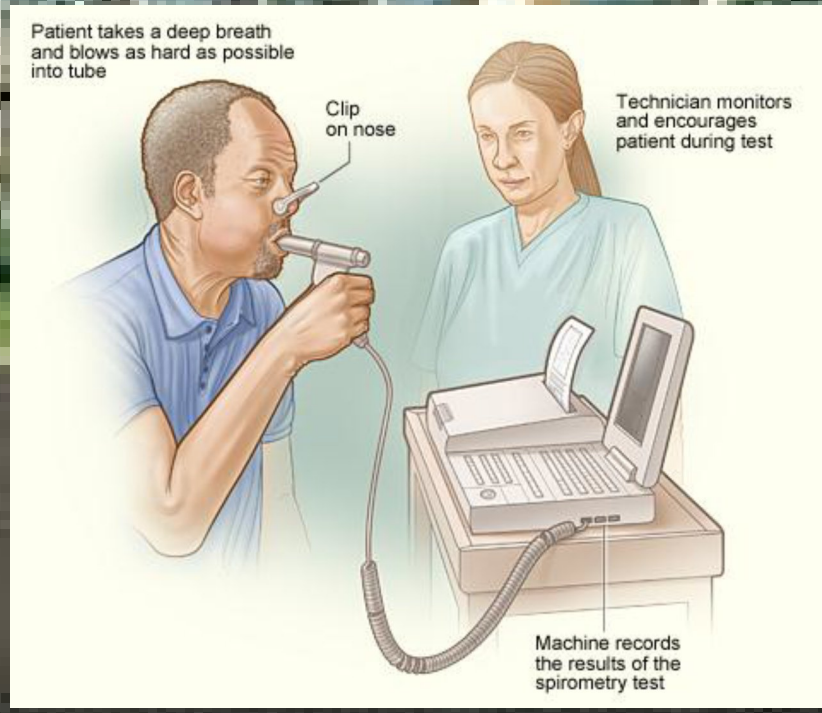
Spirometry is a standard office test used to assess **how well your lungs work** by measuring

How much air you **inhale**, how much you **exhale**, and how **quickly** you exhale.

Spirometry diagnoses **asthma, chronic obstructive pulmonary disease (COPD)**, and other conditions that affect breathing.

- During a spirometry test, you will be asked to breathe into a specialized spirometer device.
- The spirometer measures lung volumes and capacities as you breathe in and out.
- The test is typically performed while you are sitting or standing.

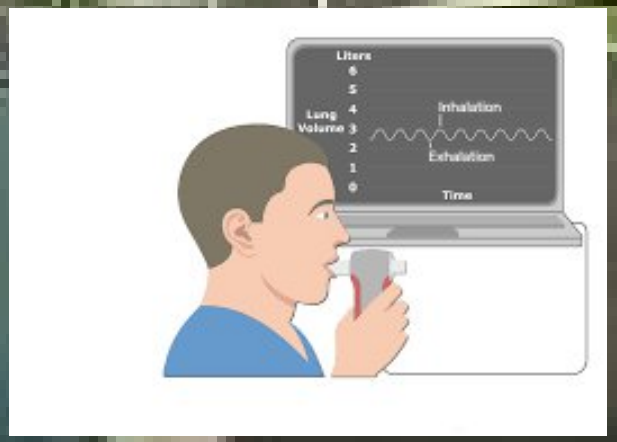
Spirometry results are compared to predicted values based on age, height, and gender.

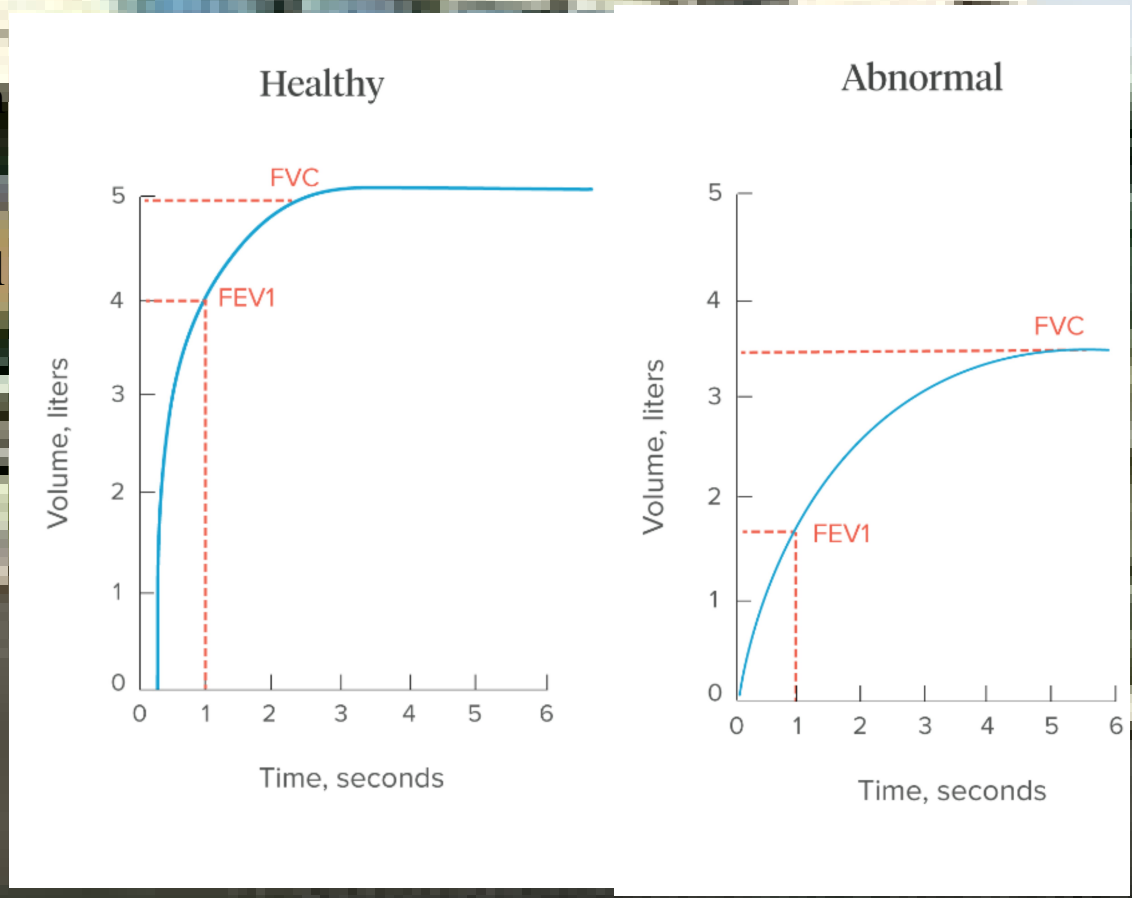


HOW TO CALCULATE THE NORMAL RATE OF RESPIRATION IN A SPIROMETER:

RATE OF RESPIRATION = $\frac{\textit{forced expiratory volume}}{\textit{forced vital capacity of the lungs}}$

- FVC - The maximum amount of air you can forcibly exhale from your lungs after fully inhaling.
- In healthy adults of the same gender, height, and age, the normal Predicted percentage should be between **70% and 85%.**
- Percentages **lower than 70%** are considered abnormal





Age	Rate
Newborn	30-40 breaths/minute
Infants	30-60 breaths/minute
Toddler	26-32 breaths/minute
Child	20-30 breaths/minute
Adolescent	16-20 breaths/minute
Adults	16-22 breaths/minute

Normal Respiration rate

Chronic obstructive pulmonary disease (COPD)

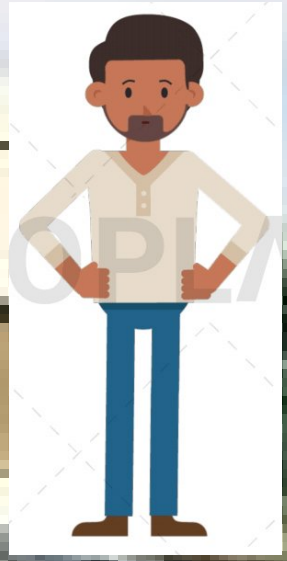
It is a chronic inflammatory lung disease that causes obstructed airflow from the lungs.

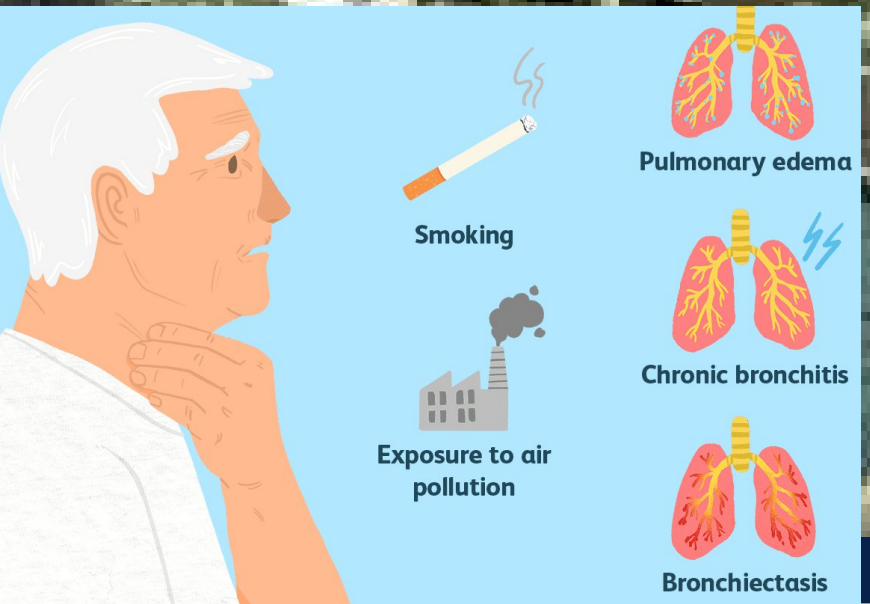
Symptoms:

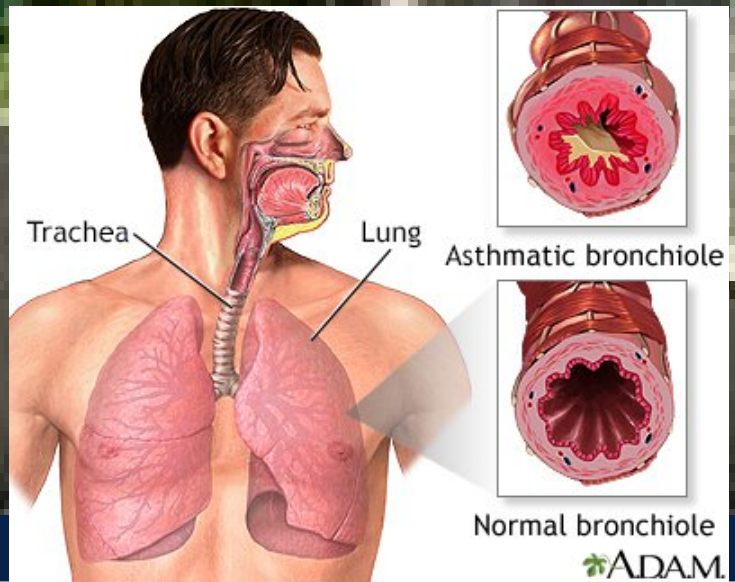
1. **Breathing difficulty**
2. **Cough**
3. **Mucus (sputum) production, and**
4. **Wheezing.**

Causes due to

1. **long-term exposure to irritating gases.**
2. **Cigarette smoke.**
3. **Age-related issues.**







Chronic obstructive pulmonary disease (COPD)

Signs and symptoms of COPD may include:

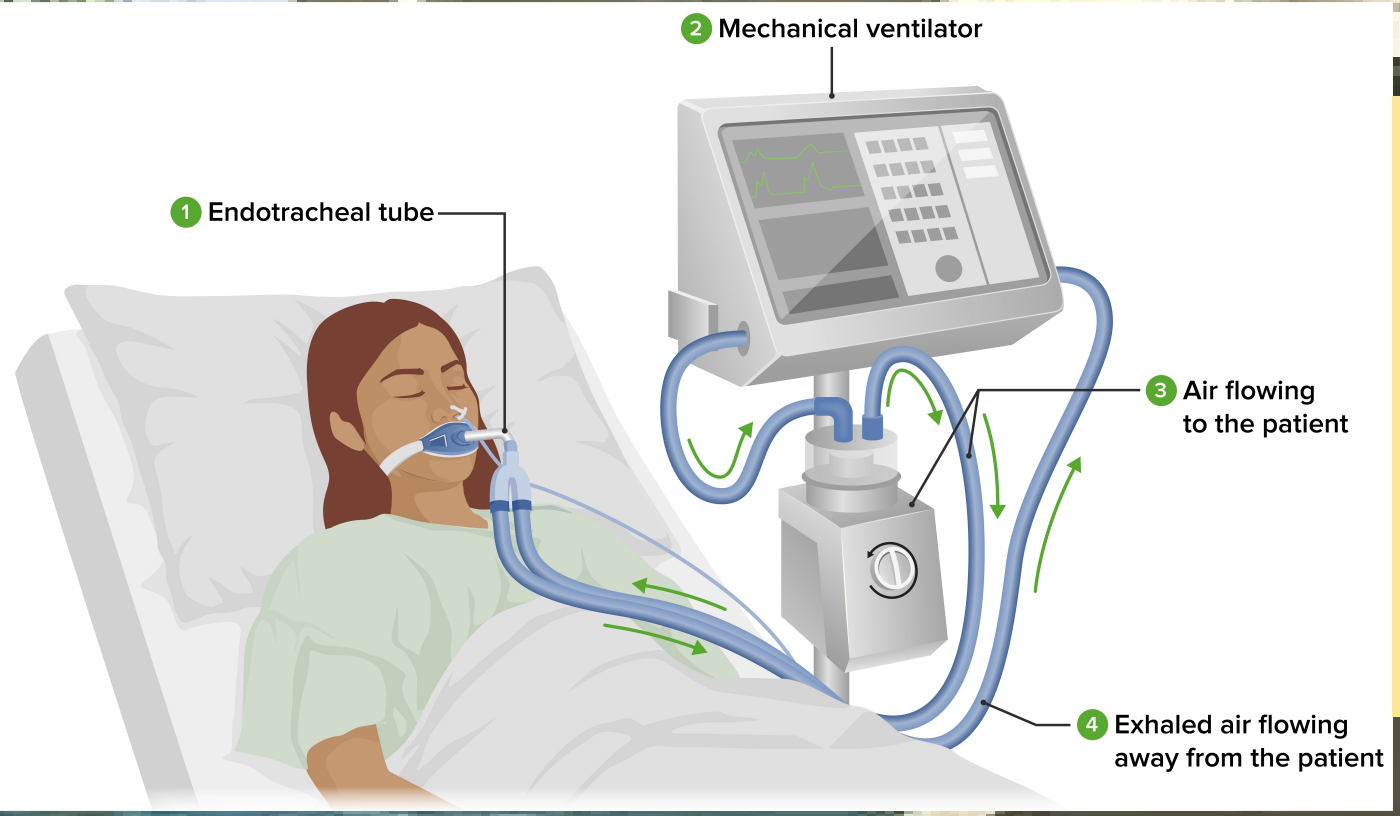
1. Shortness of breath, especially during physical activities
2. Wheezing
3. Chest tightness
4. A cough produces mucus that may be clear, white, yellow, or greenish
5. Frequent respiratory infections
6. Lack of energy
7. Unintended weight loss (in later stages)
8. Swelling in ankles, feet, or legs

Tests may include:

1. Lung (pulmonary) function test.
2. Chest X-ray.
3. CT scan.
4. Arterial blood gas analysis.
5. Laboratory tests.

VENTILATOR

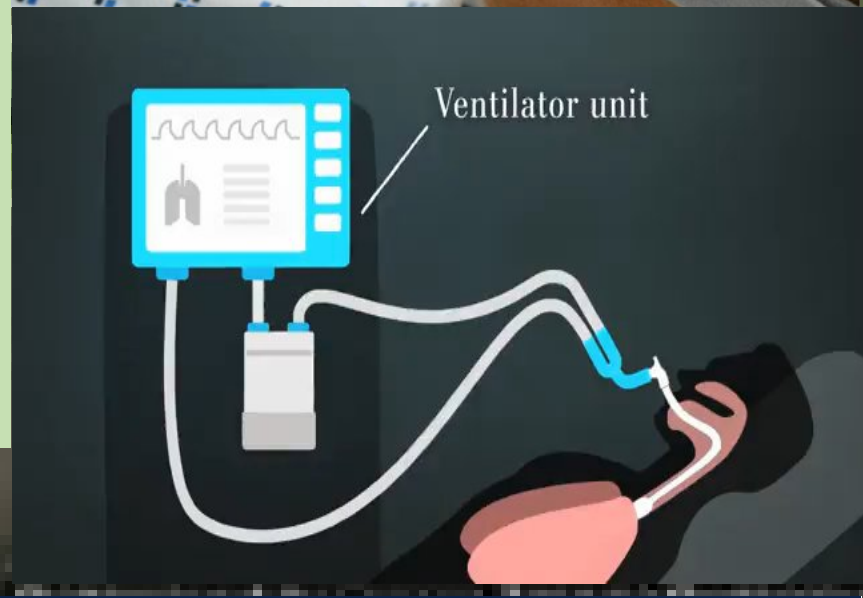
Mechanical ventilators are automated machines that breathe for patients who cannot use their lungs.



- Ventilators are commonly used when patients are experiencing severe shortness of breath, such as that caused by a respiratory infection or by conditions such as chronic obstructive pulmonary disease (COPD).
- They may also be used in persons with traumatic brain injury or stroke when the nervous system can no longer control breathing.

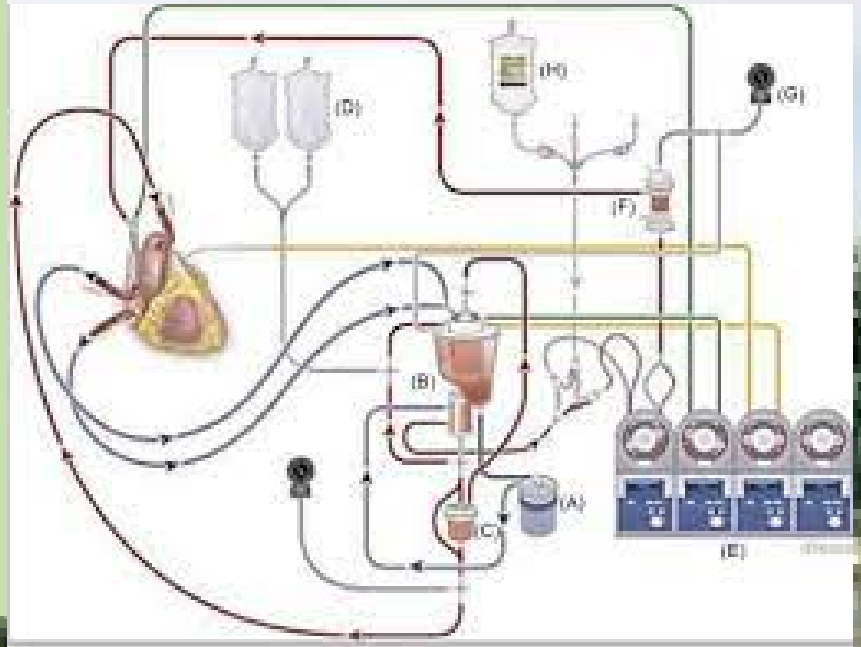
Working of Ventilator

- Ventilators deliver oxygen directly to the lungs, and they can also be programmed to pump out carbon dioxide for patients who cannot exhale on their own.
- The ventilator delivers oxygen via a tube inserted through the patient's nose or mouth in a procedure known as **intubation**, or that is placed directly into the **trachea** or windpipe.
- The opposite end of the tube is connected to a machine (the ventilator).
- The air is warmed and humidified before it goes into the body.
- The ventilator further plays a vital role in maintaining positive air pressure to help prevent small air sacs (alveoli) in the lungs from collapsing.
- Ventilators are set to pump air into the lungs several times per minute. The patient's heart, respiratory, and blood pressure are monitored constantly.



HEART LUNG MACHINE

- A heart-lung machine is a piece of equipment that **temporarily takes over the work of the heart and/or lungs**, providing blood and oxygen to the body.
- Also called a cardiopulmonary bypass machine (CBM) or a heart-lung bypass machine, it is most often used during serious procedures that require the heart to be stopped.
- A heart-lung machine may also be used on a person who needs heart or respiratory support for non-surgical reasons.

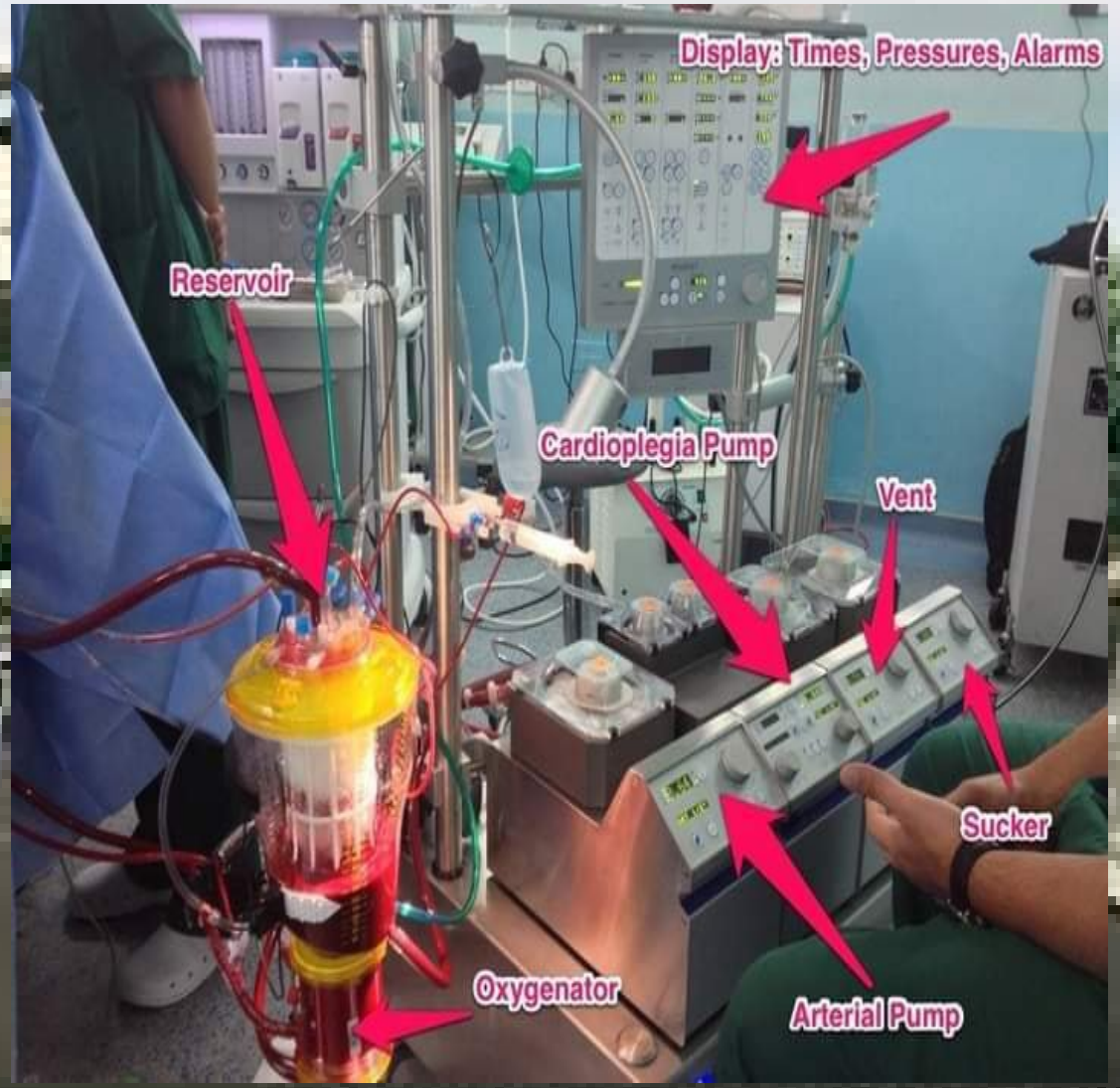


Components:

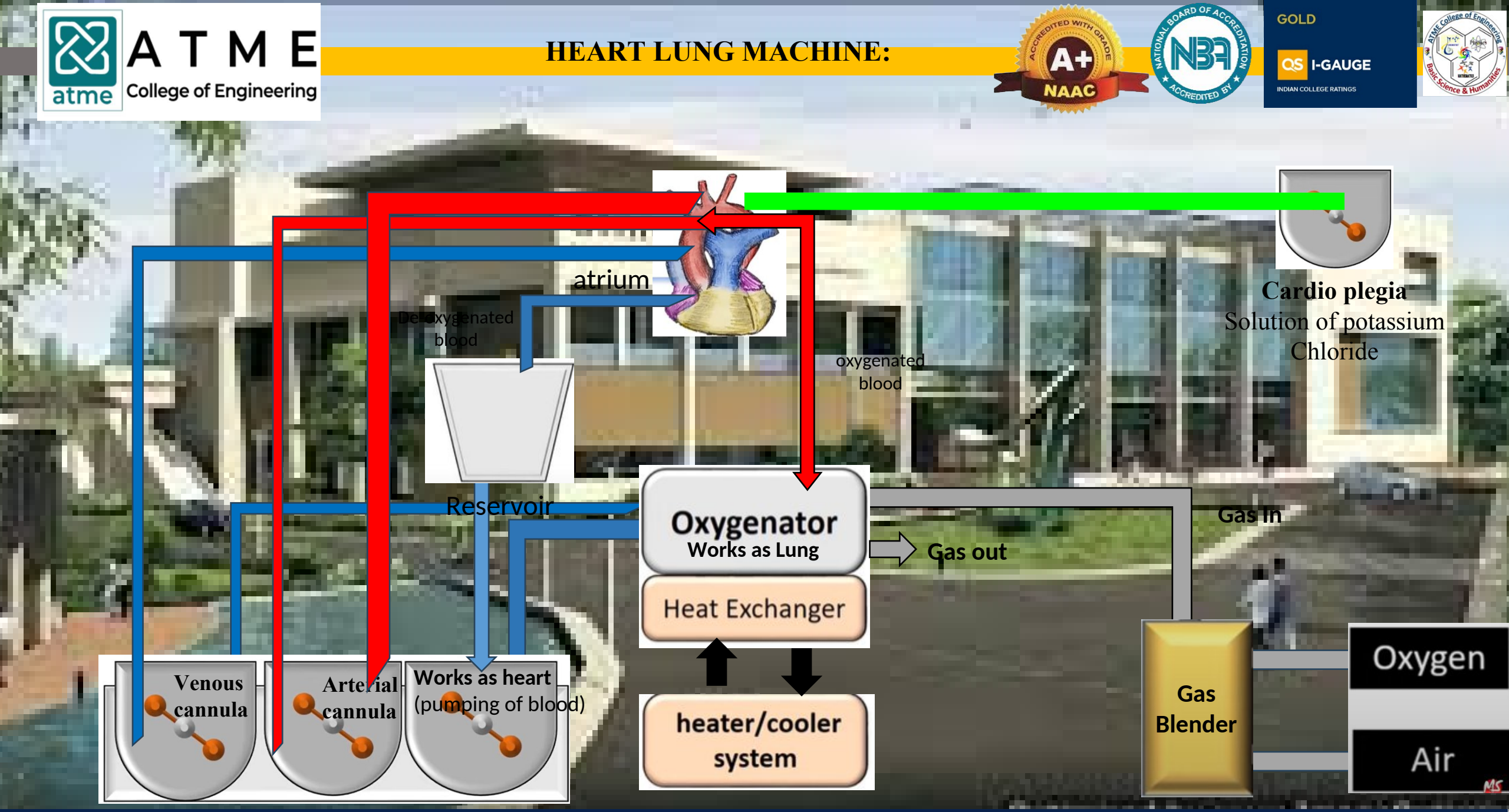
1. **Pump**,
2. Oxygenator
3. Filters
4. Temperature control, and
5. Monitoring devices.

- The pump is responsible for circulating the blood
- The oxygenator replaces the function of the lungs by adding oxygen and removing carbon dioxide.

- During surgery, The surgeon attaches special tubing to a large blood vessel. The machine draws deoxygenated blood from the body, pumps it through the oxygenator to add oxygen and remove carbon dioxide, and then returns the oxygenated blood back to the body, thus maintaining blood circulation.
- To prevent blood from clotting within the machine, anticoagulants (blood-thinning medications) such as heparin are administered. Continuous monitoring of the patient's blood clotting parameters is crucial to prevent excessive bleeding or clotting.
- A third tube is also inserted near or directly into the heart, but not connected to the CBM. It is used to flush the heart with **cardioplegia**, a **potassium solution that stops the heart**. Once the cardioplegia takes effect, the CBM is initiated and takes over the heart and lung function.

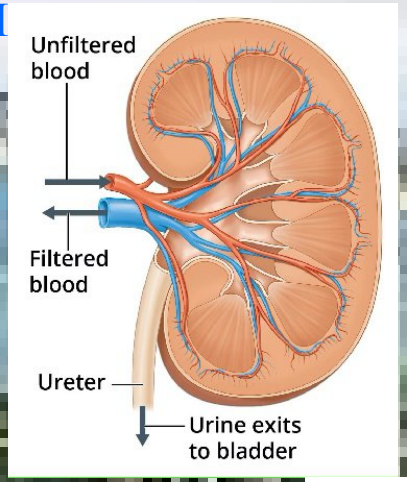


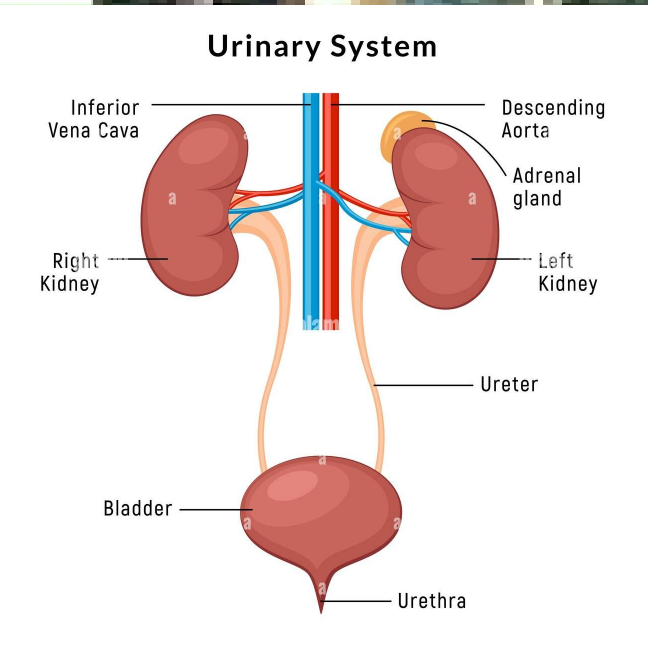
HEART LUNG MACHINE:



KIDNEY AS FILTRATION SYSTEM

- The kidneys are two **bean-shaped** organs located just below the **rib cage.**
- Kidneys **remove wastes** and extra fluid from the body
- Without this balance, **nerves, muscles, and other tissues** in the body may not work normally.
- Kidneys also **remove acid** that is produced by the cells of the body and maintain a healthy **balance of water, salts, and minerals in the blood**
- Healthy kidneys filter about **half a cup of blood every minute**, removing wastes and extra water in the form of urine.
- The urine flows from the **kidneys** to the bladder through **ureters** which are connected to the **bladder** and stored in it.

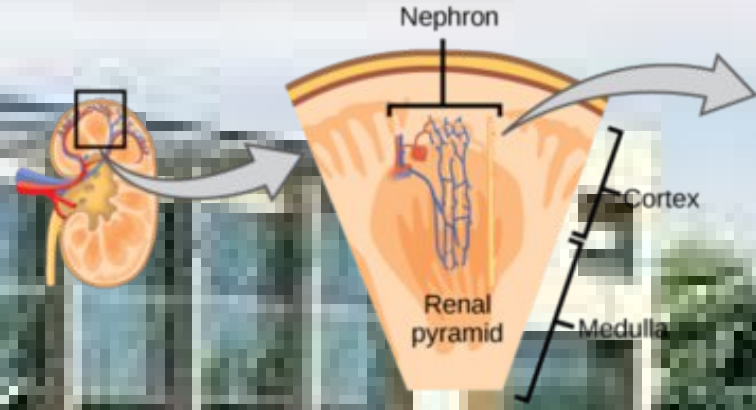




MECHANISM OF FILTRATION:

Parts in kidney

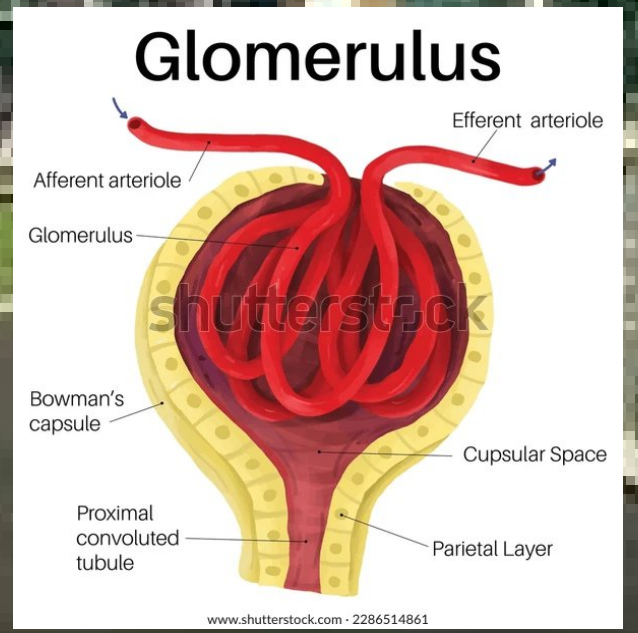
- Each kidney is made up of about a million **filtering units called nephrons**
- Each nephron includes a filter, called the **glomerulus**, and a **tubule**
- **Glomerulus** filters blood, and the Tubule **removes wastes (Urine)**.



Blood flows into Nephron

Glomerulus
(Which allows only smaller molecules and larger molecules like protein & blood cells to stay in blood)

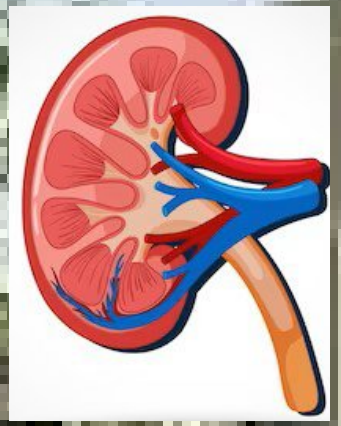
Tubule
(returns needed substance to blood and removes waste)



Mechanism

- As blood flows into each nephron and then enters to **glomerulus** through blood vessels.
- The thin walls of the glomerulus allow **smaller molecules**, Larger molecules, such as **proteins and blood cells** stay in the blood vessel.
- The tubule **returns needed substances** to your blood and **removes wastes** in urine.
- The tubule helps remove **excess acid from the blood**.

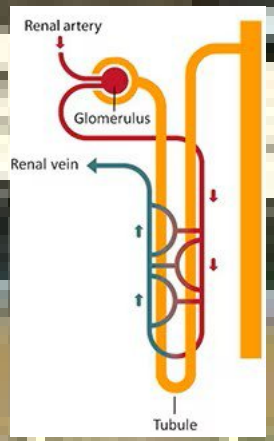
How does blood flow through kidneys?



Kidney

Blood flows into the kidney

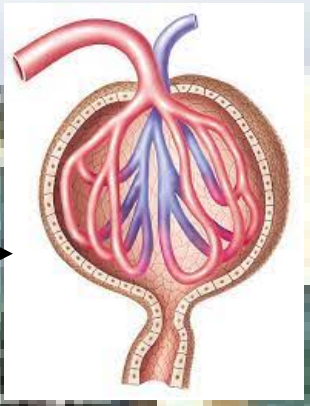
In the kidney, blood passes through millions of smaller blood vessels and reaches the nephrons



Nephron

Improper working of kidney leads to Chronic kidney disorder

Blood is filtered by the tiny blood vessels of the glomeruli



Glomeruli

Then flows out of the kidney through the **renal vein**

Wastes are removed out of the body through urine (1-2 liters per day)

Healthy kidney filters approx. 200 liters of blood in single day

This process continuous many times a day

Chronic kidney disease

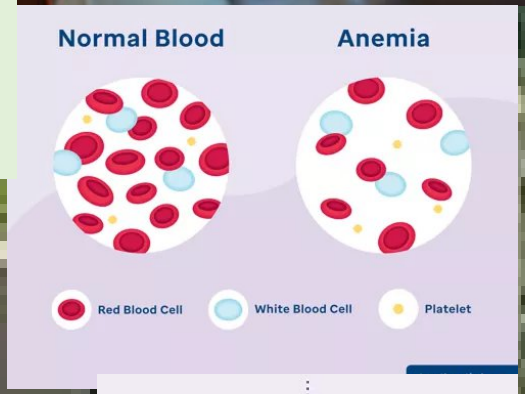
Chronic kidney disease includes conditions that **damage kidneys** and decrease the ability of filtering **wastes from your blood**

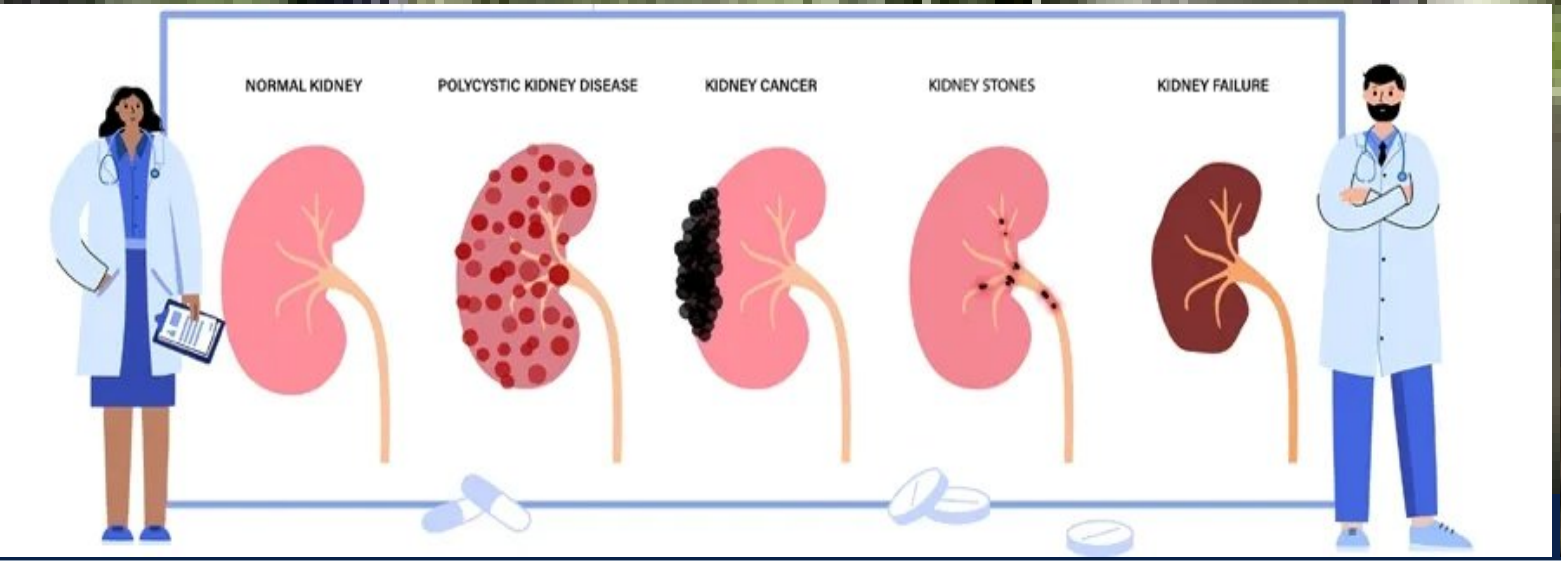
- High blood pressure
- Anaemia (low blood count)
- weak bones
- Poor nutritional health
- Nerve damage

Symptoms:

People with CKD may not feel ill or notice any symptoms.

- CKD diagnosed through specific **blood** and **urine** tests.
- These tests include the measurement of both **the creatinine level in the blood** and the **protein in the urine**.



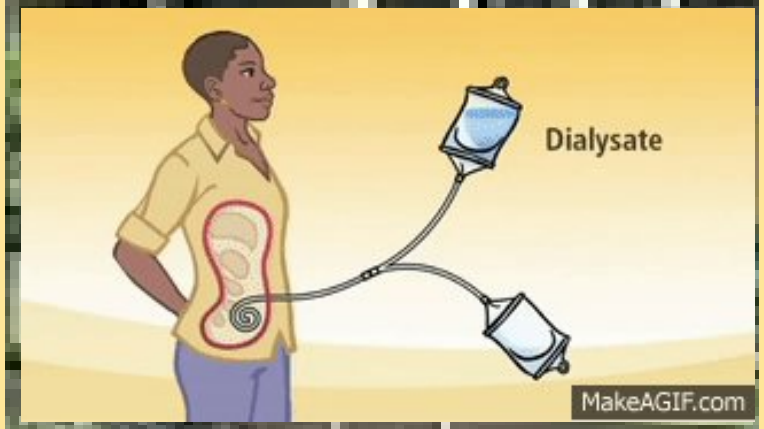


DIALYSIS:

Dialysis is a procedure to **remove waste products and excess fluid** from the blood when the **kidneys stop working correctly**.

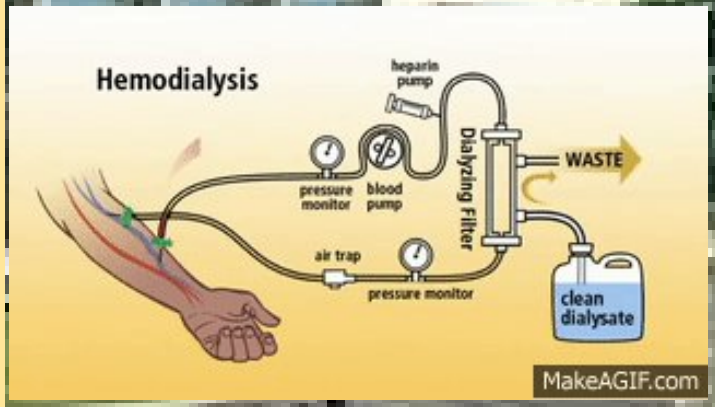
There are 2 main types of dialysis:

Peritoneal dialysis involves **pumping dialysis fluid** into the space inside your abdomen (tummy) to draw out waste products from the blood



It involves using the peritoneal membrane, a thin, natural lining surrounding the abdominal organs, as a filter to remove waste products and excess fluids from the blood.

Hemodialysis involves **diverting blood into an external machine**, where it's filtered before being returned to the body.



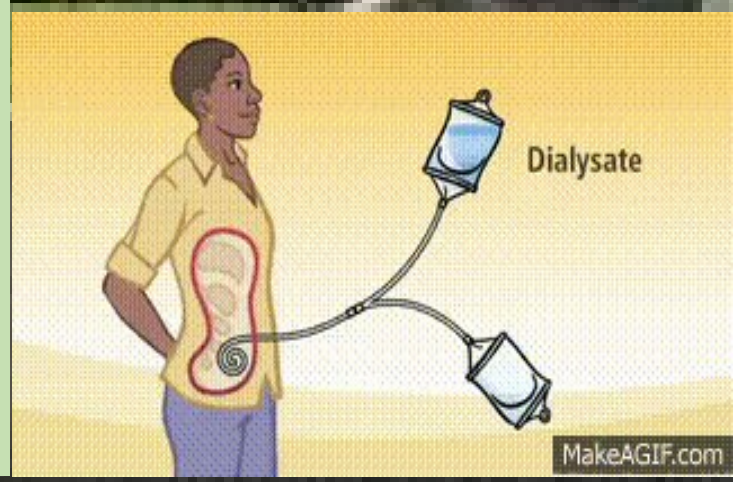
Hemodialysis is typically performed by artificially filtering and purifying blood under the supervision of trained healthcare professionals.

Peritoneal dialysis

1.Catheter Placement: A soft, flexible catheter is surgically placed into the abdominal cavity. This catheter serves as the access point for the dialysis solution to enter and exit the peritoneal cavity.

2.Dialysis Solution (Dialysate): A sterile dialysis solution consisting of electrolytes, glucose, and other substances, is infused into the peritoneal cavity through the catheter. The solution is left in the cavity for a specific period, absorbing waste products and excess fluids from the bloodstream.

3.Diffusion and Osmosis: The peritoneal membrane acts as a semipermeable barrier. Waste products, excess fluids, and electrolytes move across the membrane from the blood vessels into the dialysis solution through diffusion and osmosis. Diffusion refers to the movement of molecules from an area of high concentration to an area of lower concentration. Osmosis is a type of diffusion specifically for water molecules moving across a semi-permeable membrane.



4.Drainage: After a prescribed **dwell** time, the dialysate, now containing waste products and excess fluids, is drained out of the abdominal cavity and discarded.

Hemodialysis

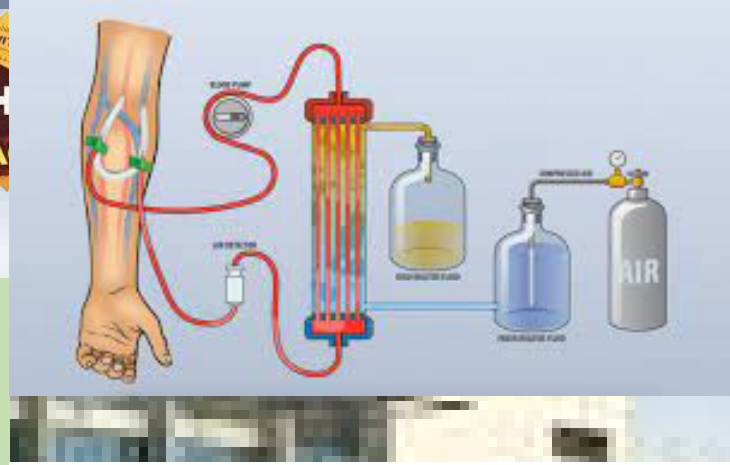
1.Vascular Access: a synthetic tube connection between an artery and a vein.

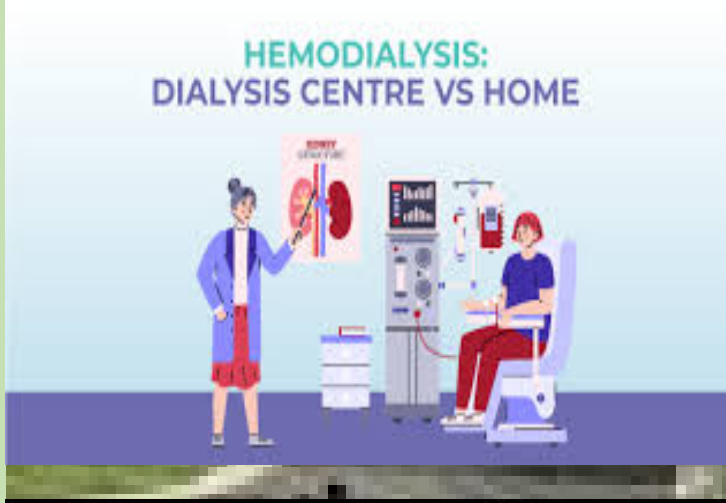
2.Blood Circulation: The patient's blood is diverted from their body through the vascular access point into the dialysis machine.

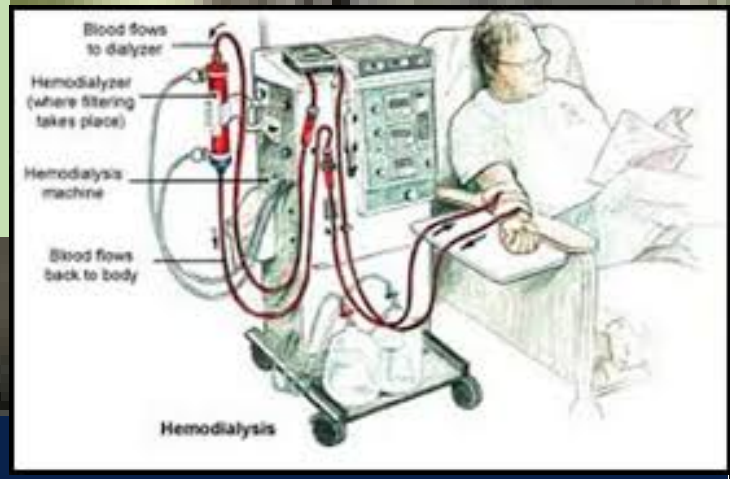
3.Dialysis Machine: The dialysis machine has a special filter called a dialyzer or artificial kidney. The dialyzer contains two compartments separated by a semipermeable membrane. Blood flows through one compartment, and a dialysis solution (dialysate) flows through the other.

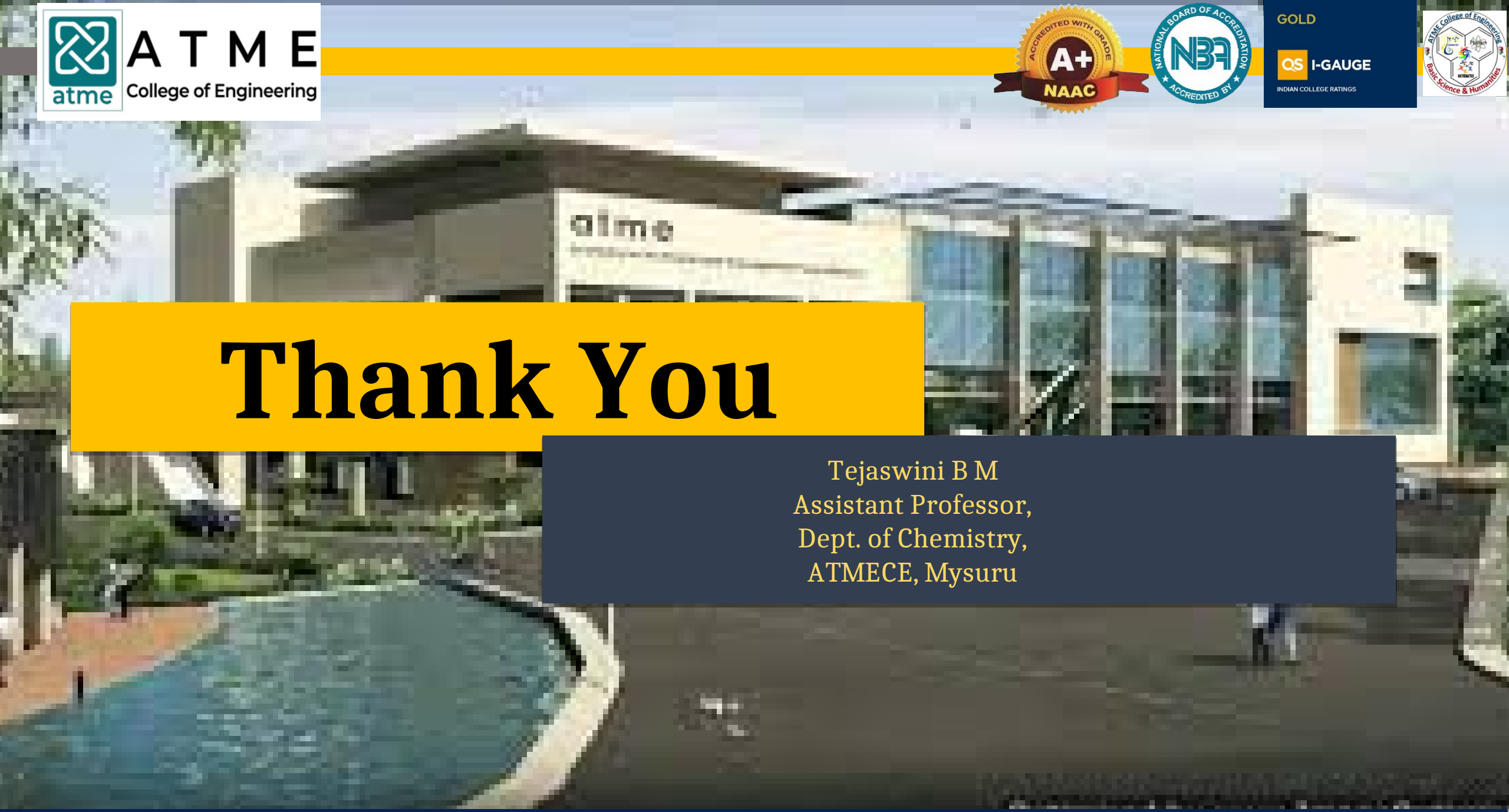
4.Filtration and Purification: As blood passes through the dialyzer, waste products, excess fluids, and electrolytes diffuse across the semipermeable membrane and into the dialysate. This process helps mimic the kidneys' natural function by filtering waste and excess substances from the blood.

5.Return of Purified Blood: After filtration, the cleaned blood is returned to the patient's body through the vascular access point.









Thank You

Tejaswini B M
Assistant Professor,
Dept. of Chemistry,
ATMECE, Mysuru