

Module-3-HUMAN ORGAN SYSTEMS AND BIO-DESIGNS: (QUALITATIVE)

- **Brain as a CPU system** (architecture, CNS and Peripheral Nervous System, signal transmission, EEG, Robotic arms for prosthetics. Engineering solutions for Parkinson's disease).
- **Eye as a Camera system** (architecture of rod and cone cells, optical corrections, cataract, lens materials, bionic eye).
- **Heart as a pump system** (architecture, electrical signaling - ECG monitoring and heart-related issues, reasons for blockages of blood vessels, design of stents, pacemakers, defibrillators).
- **Lungs as purification system** (architecture, gas exchange mechanisms, spirometry, abnormal lung physiology - COPD, Ventilators, Heart-lung machine).
- **Kidney as a filtration system** (architecture, mechanism of filtration, CKD, dialysis systems).

THE BRAIN AS A CPU SYSTEM.

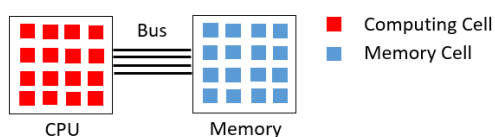
Introduction

- The brain is a complex CPU (Central Processing Unit) system with its own architecture and components.
- It consists of Central Nervous System (CNS) and the Peripheral Nervous System (PNS), which work together to process and transmit signals throughout the body.
- Both the brain and CPU: Receive and process inputs, Store information, and Perform calculations.
- Significant differences between the two are Human brain has the ability to learn and adapt and the human brain is capable of performing tasks such as perception, thought, and emotion.

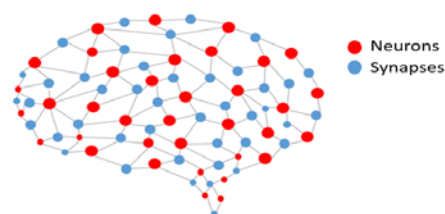
The Architecture of the Brain:

The architecture of the human brain as a CPU system can be compared to that of a **Parallel distributed processing system**, as proposed to the **Von Neumann architecture** of traditional computers.

- The human brain distributes information across multiple regions, each with specialized functions.
- Whereas computers are processed in a single centralized location.
- On the other hand, the human brain is an incredibly complex organ composed of billions of neurons and their connections. The precise understanding of its architecture is still being studied; some key features can be described below.

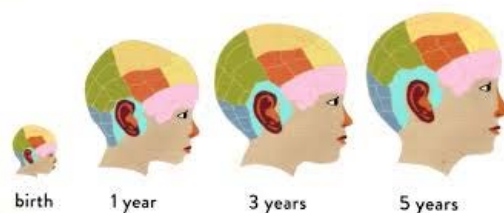
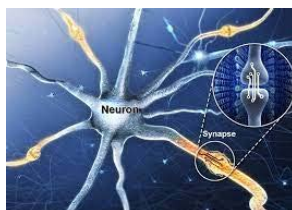
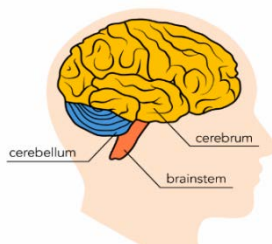


(a) Von Neumann Computing System



(b) Brain Computing System

1. **Neurons:** Neurons are specialized cells in the brain that transmit electrochemical signals. They are interconnected to form complex neural networks.
2. **Synapses:** Synapses are the connections between neurons where information is transmitted. Electrical signals called action potentials trigger the release of neurotransmitters, which carry signals across the synapse.
3. **Brain Regions:** The brain is divided into different regions, each responsible for specific functions. The main divisions include the cerebrum, cerebellum, and brainstem.
4. **Plasticity:** The brain exhibits plasticity, which means it can reorganize and adapt its structure and connections based on experience and learning. This allows the brain to develop and acquire new skills throughout a person's lifetime.



5. Computer's CPU also has memory units for storing information, and the human brain has **several regions** dedicated to **memory storage**.
6. It is important to note that the human brain is a **vastly more complex** and **capable system**, with many functions that are still not fully understood.

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

The Central Nervous System (CNS) and Peripheral Nervous System (PNS) are the two main components of the nervous system in the human body.

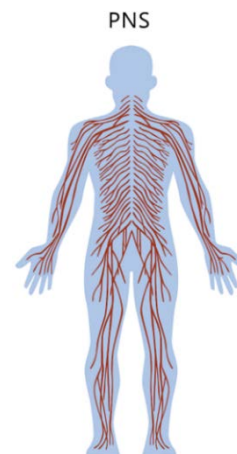
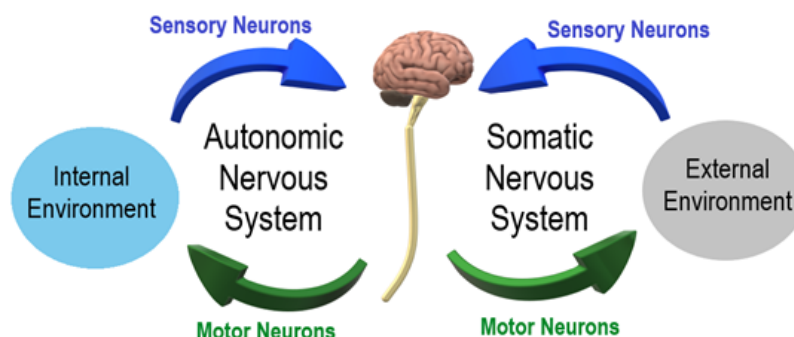
1. **CNS (Central Nervous System):** The CNS consists of the brain and the spinal cord. It serves as the main control center of the body, processing and coordinating information received from the peripheral nervous system.

- **Brain:** The brain is the most complex and critical organ in the CNS. It controls and regulates various bodily functions, including cognition, memory, emotions, sensory perception, and motor control.
- **Spinal Cord:** The spinal cord is a long, cylindrical bundle of nerves extending from the brain's base down the vertebral column. It acts as a relay between the brain and the rest of the body. The spinal cord is responsible for transmitting sensory information from the body to the brain and carrying motor commands from the brain to the muscles and organs.



2. **Peripheral Nervous System:** 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.

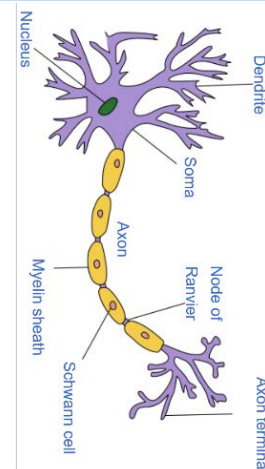
- The PNS can be further divided into the somatic and autonomic nervous systems.
- The **somatic nervous** system controls **voluntary movements**,
- The **autonomic nervous** system controls **involuntary functions** such as heart rate, digestion, and respiration.



Signal Transmission

Signal transmission in the brain occurs 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 its axon to the terminals.
- At the terminals, the neuron releases chemical neurotransmitters, leading to the initiation of another action potential.
- This process of transmitting information from one neuron to another is known as synaptic transmission and forms the basis of communication within the brain.



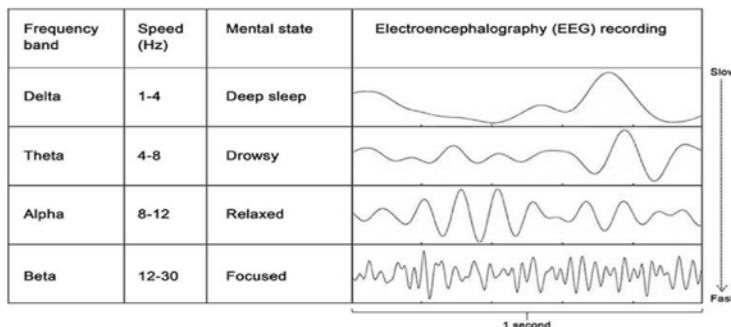
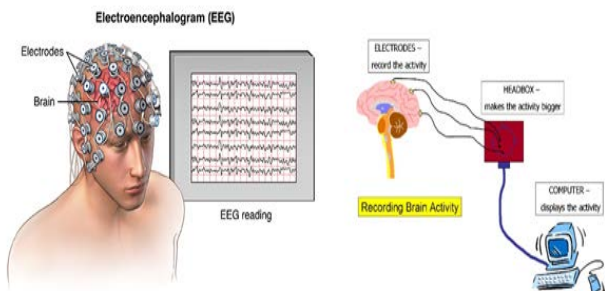
Electroencephalography (EEG)

- Electro-ence-phalo-graphy (EEG) is a technique used to record and analyze the brain's electrical activity.
- It measures the electrical potentials generated by neurons in the brain using electrodes placed on the scalp.

EEG Signals and Types of Brain Activity

- Electrodes:** EEG electrodes are typically placed on the scalp and are used to detect and measure the electrical signals produced by the brain. The electrodes are connected to an amplifier that amplifies and filters the signals for analysis.
- Brainwaves:** EEG recordings capture the brain's electrical activity in the form of brainwaves. Brainwaves are rhythmic patterns of electrical activity generated by groups of neurons firing together. Different types of brainwaves are associated with different states of consciousness and mental activity.
- Frequency Bands:** EEG signals are divided into different frequency bands associated with specific mental states and functions.

- **Delta (1-4 Hz):** Waves Associated with deep sleep and unconsciousness.
- **Theta (4-8 Hz):** Theta waves are present during light sleep, relaxation, and creative states.
- **Alpha (8-12 Hz):** Alpha waves are seen when the brain is in a relaxed and calm state, such as during meditation or when closing the eyes.
- **Beta (12-30 Hz):** Beta waves are associated with wakefulness, active thinking, and focused attention.



Applications

- **Diagnosis of Epilepsy:** EEG is a widely used tool to diagnose epilepsy and other seizure disorders
- **Sleep Studies:** EEG is used in sleep studies to evaluate sleep patterns and diagnose sleep disorders.
- **Research on Brain Function:** EEG is used in research to study brain function during various activities such as reading, problem-solving, and decision-making.
- **Diagnosis of Brain Disorders:** EEG can be used to diagnose a wide range of brain disorders including dementia, Parkinson's disease, and brain injury.
- **Anaesthesia Monitoring:** EEG can be used to monitor the depth of anesthesia during surgery to ensure that the patient remains safe and comfortable.
- **Monitoring Brain Activity during Coma:** EEG is also used to monitor brain activity in patients who are in a coma to determine the level of brain function and assess the likelihood of recovery.

Robotic Arms for Prosthetics

Robotic arms for prosthetics (Artificial body parts) are advanced prosthetic devices that use robotics technology to **restore functionality** to individuals with upper limb (**Complete removal of body parts**).

- These devices typically use **motors, actuators, and sensors** to mimic the movements of a **human arm and hand**, allowing the wearer to perform tasks such as reaching, grasping, and manipulating objects.
- Robotic arms for prosthetics can be controlled in a variety of ways,
 - **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.

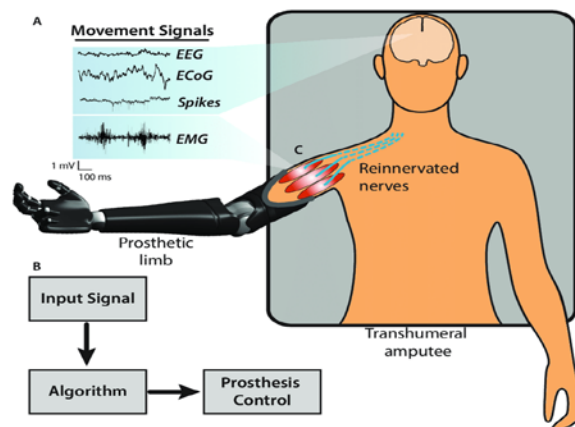


Advantages	Disadvantages
Myoelectric control has the advantage of being directly controlled by the user, allowing for more natural interaction with the prosthetic.	However, myoelectric control systems can be complex and may require extensive training to use effectively.
It can also provide a high level of control and precision, as the electrical signals generated by the muscles are unique to each individual.	Regular Maintenance to ensure proper function.

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

Sensors on the **skin detect electromyography (EMG)** (*An electromyograph detects the electric potential generated by muscle cells*).

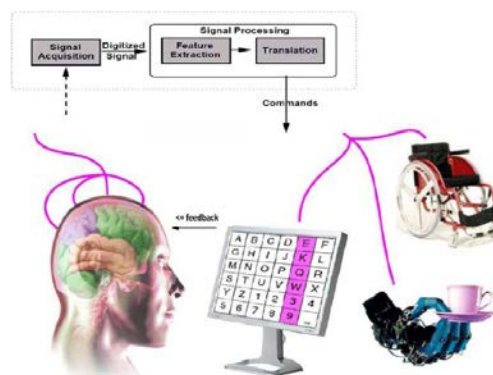
- The system involves electrodes placed on the skin or muscle.
- Then it **detects and interprets the electrical signals generated by the muscle contractions**.
- Each signal measured is then sent to a **controller**, which is either an onboard **microcontroller (mounted to the exoskeleton)** or to a nearby computer.
- 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.



2. Robotic Arm Prosthetic Direct Control through Brain Signals

Brain-machine interfaces (BMIs) are a type of technology that allows a user to control a **robotic arm prosthetic directly with their brain activity**.

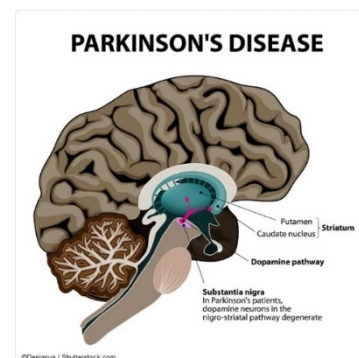
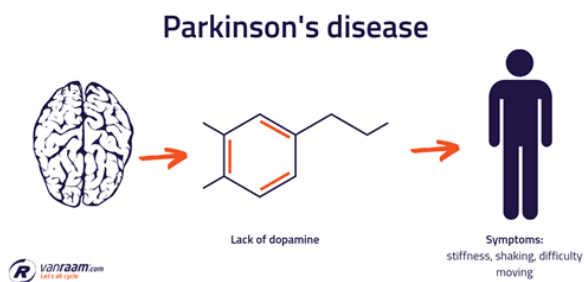
- The system typically involves electrodes placed on the **scalp or implanted directly into the brain** to detect and **interpret the user's brain signals**.
- When the user thinks **about moving the prosthetic arm**, the electrodes detect the corresponding brain activity and send the signals to a control 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**.



Advantages	Disadvantages
Brain-machine interfaces (BMIs) have the advantage of providing a direct connection between the user's brain and the prosthetic, allowing for a high level of control and precision.	BMIs can be complex and invasive systems, requiring surgical implantation and ongoing maintenance to ensure proper function
Additionally, BMIs can be used to provide sensory feedback to the user, allowing them to experience the sensation of touch through the prosthetic.	Regular Maintenance to ensure proper function.

Parkinson's Disease

- Parkinson's disease is a **brain disorder** that causes **involuntary** or **uncontrollable movements**, such as **shaking, stiffness, and difficulty with balance and coordination**.
- It is a degeneration of nerve cells in the part of the brain called the **substantia nigra**, which controls movement.
- These nerve cells **die or become impaired, losing the ability** to produce an important chemical called dopamine.



Engineering solutions for Parkinson's Disease

1. Deep Brain Stimulation (DBS):

- DBS is a surgical procedure that involves implanting electrodes into specific brain regions.
- These electrodes deliver electrical impulses to modulate abnormal brain activity, helping to alleviate symptoms like tremors, rigidity, and slowness of movement.

2. Wearable Devices:

- Various wearable devices have been developed to assist individuals with Parkinson's disease.
- These devices can monitor symptoms, provide real-time feedback, and improve mobility and balance.
- Examples** include smartwatches with motion sensors.

3. Assistive Technologies:

- Assistive technologies aim to enhance independence and improve the quality of life for individuals with Parkinson's disease. Examples: voice-activated home automation systems to control appliances and environments, assist with eating, perform tasks, and provide reminders.

4. Medication Delivery Systems:

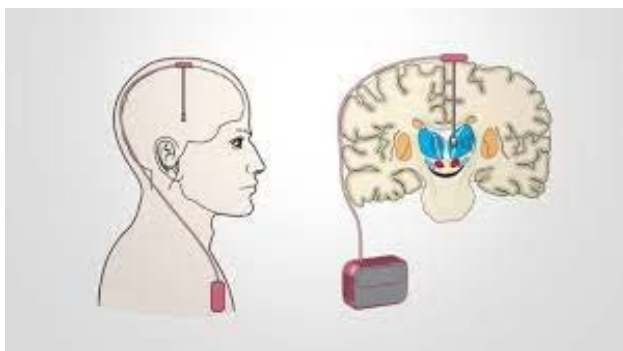
- People with Parkinson's disease often **require precise timing** and **dosage of medication** to manage their symptoms.
- Engineering solutions such as smart pill dispensers and these systems can provide reminders, **dispense medications** at specific times, and monitor medication intake.

5. Virtual Reality (VR) and Gamification:

- VR technology has shown promise in improving motor symptoms and balance in PD.
- Virtual reality games and exercises can be designed to **encourage movement, enhance coordination, and promote rehabilitation.**

6. Robotic Rehabilitation:

- Robotics has been employed in the rehabilitation of individuals with PD.
- Robotic devices can assist with repetitive exercises and movement training, providing precise and controlled assistance.
- These devices can help improve motor function, muscle strength, and coordination.



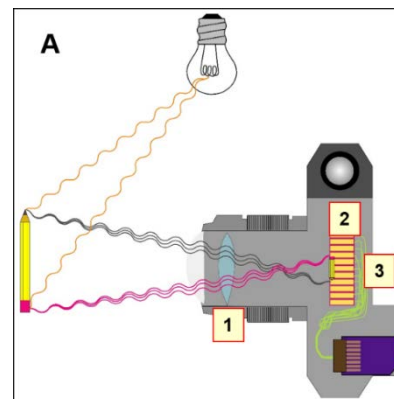
EYE AS A CAMERA SYSTEM

The eyeball is just like a camera, it can't function without the presence of light. As light hits the eyes, it's focused by the eye like a camera lens.

Camera System: Pinhole camera model: The pinhole camera is the simplest, and the ideal, model of camera function. It has an infinitesimally small hole through which light enters before forming an inverted image on the camera surface.

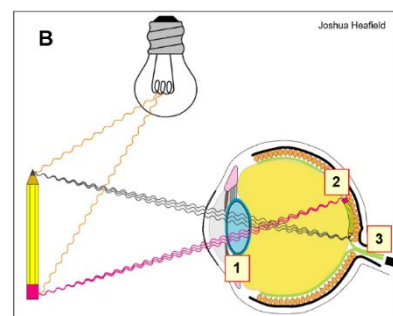
- Rays of light reflect from an object (a pencil) and enter the camera through **the lens (1)** which focuses it onto the **camera sensor chip (2)**.
- On the **sensor chip (2)**, light-sensitive cells convert the light energy into an electrical signal.
- The electrical signal is sent along with the **circuit (3)** to a processing unit.

Which processes the image and stores it.



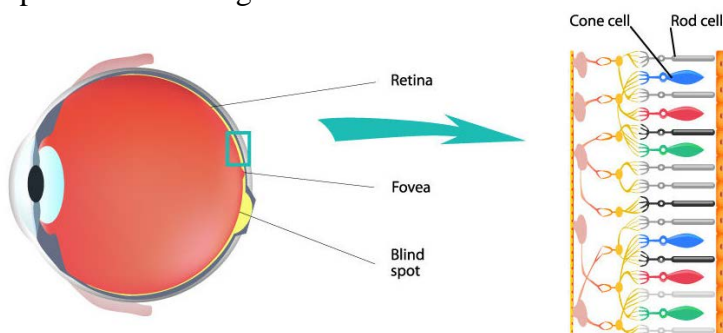
Human Eye: The eyeball is just like a camera; it can't function without the presence of light. As light hits the eyes, it's focused by the eye like a camera lens.

- The lens **cornea (1)** focuses light onto the **retina (2)**.
- Photoreceptor cells in the **retina (Rod and Cone Cells) (2)** convert the light energy into nerve impulses.
- The nerve impulses are sent through the **optic nerve (3)** toward the brain (black arrow).
- Neurons (Synaptic) send information via electrical impulses known as action potentials



The architecture of rod and cone cells

As the light reaches the center of the eye passes and reaches the final stop The Retina. Where the retina has Photoreceptors that further split into two designations – Rods and cones.



1. Cone Cells:

- **Function:** Cone cells are responsible for color vision in bright light conditions. They allow us to view a wide range of colors and provide sharper, high-resolution images.

- **Structure:** Cone cells have a tapered shape and contain different types of light-sensitive pigments that respond to specific wavelengths of light, corresponding to the colors blue, green, and red.
- **Density:** There are approximately 6 to 7 million cone cells in the human retina.
- **Visual Acuity:** Cones have high visual acuity, allowing them to resolve fine details.

2. Rod Cells:

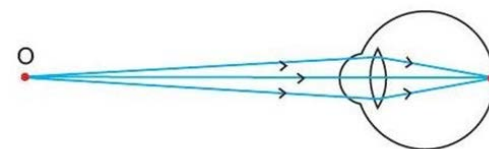
- **Function:** Rod cells are responsible for vision in low-light conditions, providing us with black-and-white, or grayscale, vision. They are highly sensitive to light and allow us to see in dim environments.
- **Structure:** Rod cells are cylindrical cells with a stacked arrangement of membranous disks containing light-sensitive pigments.
- **Density:** There are approximately 90 to 120 million rod cells in the human retina.
- **Visual Acuity:** Rods have lower visual acuity compared to cones, meaning they cannot distinguish fine details as effectively.
- The electrical signals generated by the rods and cones are further processed. After the processed signals are transmitted to the brain.

Optical Corrections

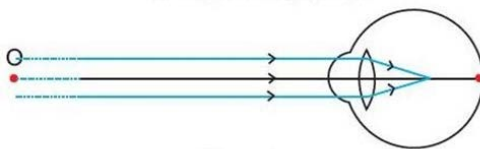
- Defects in the eye happen due to many reasons. Due to growing age, the vision also decreases, and when the focal length alters, the vision also alters.
- When the eye loses its ability its unable to view **nearby objects** or far away objects and the person cannot see the objects **comfortably and distinctly**.

Optical Corrections: Myopia or near-sightedness.

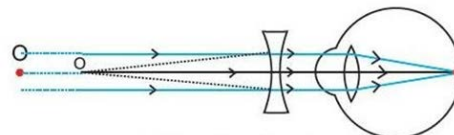
- **Myopia** is commonly known as **near-sightedness**. In this condition, the person can see the **objects nearby** but cannot see **distant objects clearly**. Faraway objects appear blurry.
- Myopia condition is due to the shape of the eyes leading the light rays to bend in the wrong way, **focusing images in front of the retina rather than focusing on the retina**.



(a) Far point of myopia eye



(b) myopia eye



(c) Correction of myopia

Symptoms:

- Difficulty in seeing while driving, particularly during night times.
- Blurry vision.
- Headaches due to eyestrain.

Correction:

- When a **concave lens** of suitable power is used, it assists in focusing the image onto the retina.

Optical Corrections: Hypermetropia or Far-Sightedness.

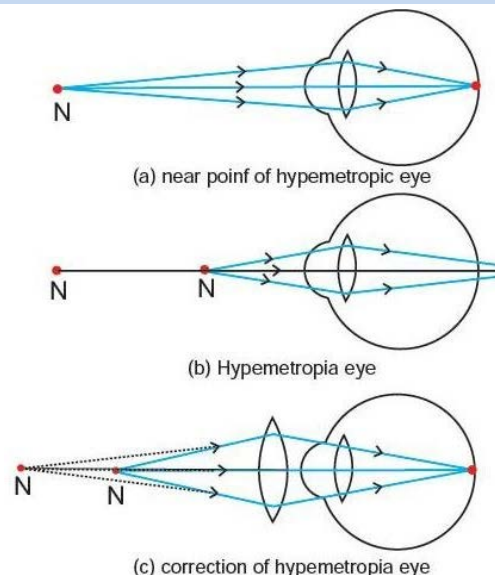
- Hypermetropia is commonly known as far-sightedness. In this condition, the person can see objects at a distance but cannot see nearby objects clearly.
- Hypermetropia is caused when the light rays from a close by object are focussed at a point behind the retina.

Symptoms:

- Blurry vision.
- Headaches due to eyestrain.
- Squinting.

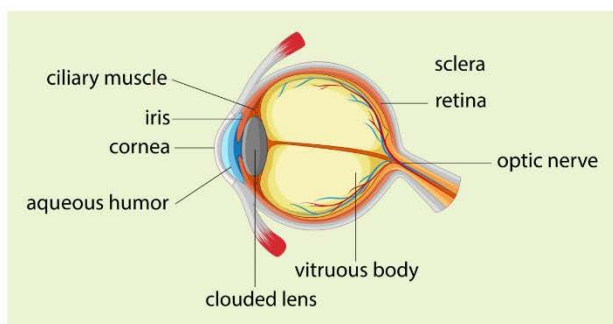
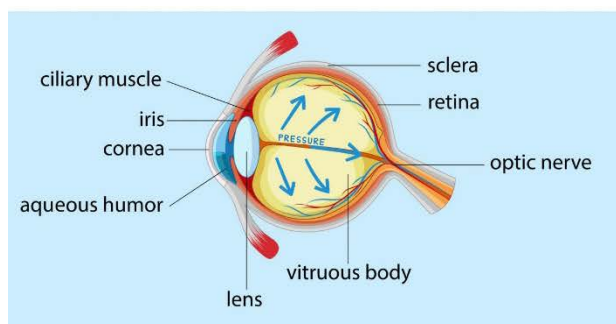
Correction:

- Using spectacles with a converging lens imparts additional focusing power and thus helps form the image on the retina.



Cataract

- Cataract** is the gradual loss of your eye's ability to focus on nearby objects.
- Cataract** usually becomes noticeable after **50 years**. Most cataracts develop **when aging or injury changes the tissue that makes up the eye's lens**. And also due to **genetic disorders**.
- Proteins and fibers in the lens begin to break down, causing vision to become hazy or cloudy.
- People have difficulties viewing **nearby objects clearly**.



Lens Material (Intra-ocular lens)

Intra-ocular lenses (IOLs) are artificial lenses implanted in the eye during cataract surgery or refractive lens exchange to replace the eye's natural lens that has become cloudy or is causing vision problems. These lenses help restore clear vision and can also correct certain refractive errors such as **myopia (near-sightedness), and hyperopia (far-sightedness) and for cataracts or other vision problems**.

1. Polymethylmethacrylate (PMMA):

- PMMA was one of the first materials used for IOLs and has a long history of successful use.

- It is a rigid material and does not fold, the incision needed for implantation is larger than with foldable lenses.
- It offers excellent optical clarity and stability once implanted.
- However, due to their rigid nature, PMMA lenses may cause more discomfort post-surgery compared to foldable lenses.

2. Hydrophobic Acrylic:

- Hydrophobic acrylic IOLs are the most commonly used lenses today. They are composed of crosslinked copolymers of acrylic esters.
- They have a foldable design, allowing for smaller incisions during surgery, leading to quicker recovery and less post-operative discomfort.
- The material is biocompatible and lightweight, providing good optical quality and long-term stability.
- Hydrophobic acrylic lenses have a low affinity for water, making them less susceptible to clouding.

3. Silicone:

- Silicone IOLs were among the first foldable lenses introduced.
- They offer excellent flexibility and are easy to fold, allowing for smaller incisions during surgery.
- Silicone lenses are biocompatible and have good long-term stability.
- However, compared to acrylic lenses, they may have a higher risk of some complications.

4. Hybrid Lenses:

- IOLs use a combination of materials, such as acrylic and silicone, to take advantage of the benefits of both materials.
- The hybrid design aims to minimize potential drawbacks while maximizing optical quality and biocompatibility.

Bionic eye

- **Bionic eyes**, also known as **artificial or electronic eyes**, are advanced medical devices designed to **restore vision or enhance visual perception** in individuals with severe vision impairment or blindness.
- These devices use sophisticated technology to stimulate the visual system and enable users to perceive visual information.

The Camera on the glasses streams images in real time. The signals are then sent to a wireless transmitter. The transmitter relays those signals to the sensor implanted on the retina. The sensors stimulate the retina with electric impulses. These impulses then send messages to the visual cortex portion of the brain.

Purpose and Function: Bionic eyes are developed for people with vision loss caused by conditions like Infections and age-related macular degeneration (AMD).

Components:

- Bionic eyes consist of several components, including an external camera, a processing unit, and an implanted electrode array.
- The external camera captures visual information from the surrounding environment and sends it to the processing unit.
- The processing unit converts the visual data into electrical signals and transmits them to the implanted electrode array.

Implantation: The electrode array is surgically implanted into the eye, typically on the retina or in the visual cortex of the brain.

Visual Perception: Bionic eyes do not restore normal vision but aim to provide users with visual perception and object recognition.

Training and Rehabilitation: After the implantation procedure, users need training and rehabilitation to adapt to and make the best use of the bionic.

Limitations:

- Bionic eyes have some limitations, including limited resolution and field of view.
- The visual perception provided by bionic eyes may not match natural vision, and experience some visual distortions.

HEART AS A PUMP SYSTEM

The architecture of the Heart

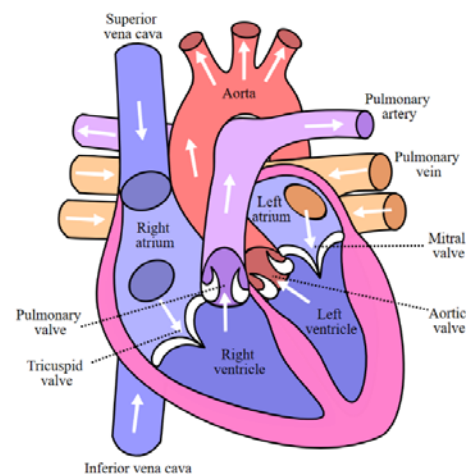
- The human heart can be considered a sophisticated pump system that is responsible for circulating blood throughout the body. **It consists of four chambers: Two Atrium and Two Ventricles.**
- The heart's pumping action is regulated by an electrical signaling system, ensuring that the chambers contract and relax in a coordinated manner to maintain blood flow.

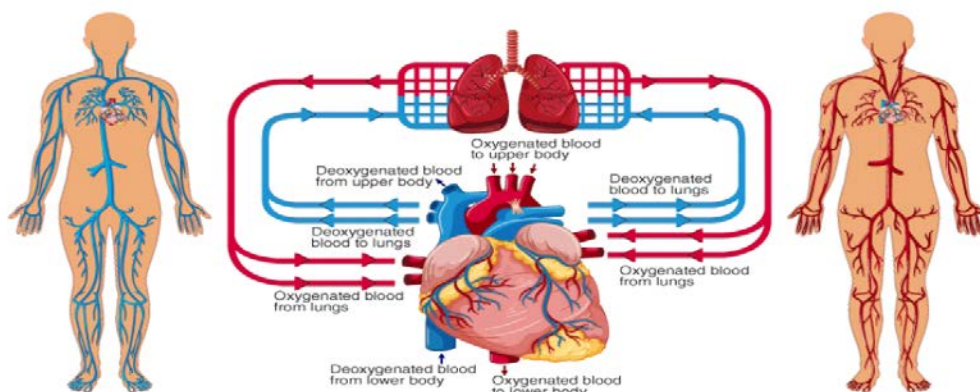
Atrium: The two upper chambers of the heart are the Right and Left Atrium.

- The right atrium receives deoxygenated blood from the body.
- The left atrium receives oxygenated blood from the lungs.
- The atria act as reservoirs that collect and store blood before it moves to the ventricles.

Ventricle: The two lower chambers of the heart are called the ventricles.

- The right ventricle pumps deoxygenated blood to the lungs for oxygenation.
- The left ventricle pumps oxygenated blood to the rest of the body.





Blood flow through the heart:

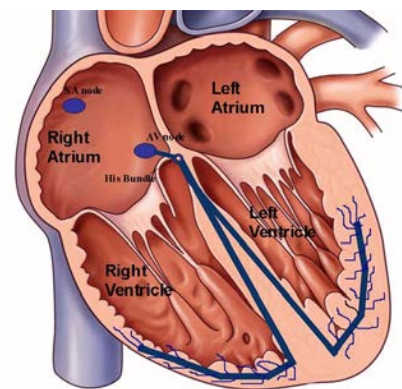
- Deoxygenated blood enters the right atrium from the body via the superior and inferior vena cava. And moves to the right ventricle.
- The right ventricle then pumps the blood to the lungs through the pulmonary artery to lungs.
- Oxygenated blood returns from the lungs to the left atrium via the pulmonary veins. From the left atrium, blood flows into the left ventricle, which then pumps it out to the rest of the body through the aorta.

The Heart Beat

The SA (sinoatrial) node generates an electrical signal that causes the upper heart chambers (atria) to contract. The signal then passes through the AV (atrioventricular) node to the lower heart chambers (ventricles), causing them to contract, or pump.

Sino-atrial node

- Known as the SA node, the sinoatrial node is nicknamed the pacemaker. The SA node is flat, up to 25 mm in length, and is located in the wall of the right atrium.
- It's made up of pacemaker cells: myocardial cells that are specialized to conduct electrical impulses.
- The SA node generates an electrical stimulus 60-100 times per minute, creating the sinus rhythm, which is the normal electrical pattern of the heart.



Atrio-ventricular node

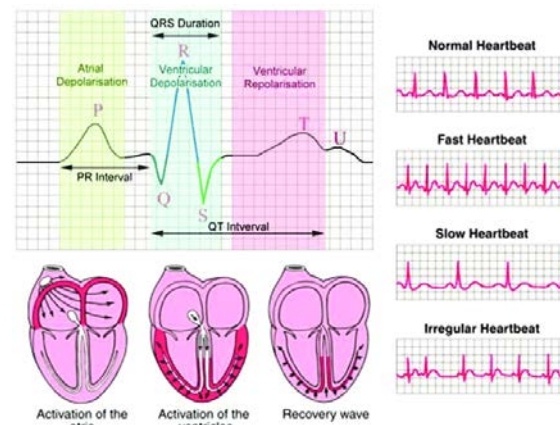
- The atrio-ventricular or AV node is the “secondary pacemaker” of the heart. It acts as a middleman, conducting electrical impulses received from the SA node.
- The AV node creates a slight pause before the electrical impulse is sent down the line.

- This pause allows the atrial to pump blood into the ventricles before the next impulse reaches the ventricles.
- The AV node conducts electricity slower the more it is stimulated. This protects against an excessive heart rate if the heart were to beat irregularly.

Electrocardiography (ECG)

Electrocardiography is the process of producing an electrocardiogram (ECG).

- A recording of the heart's electrical activity through repeated cardiac cycles.
- It is an electrogram of the heart which is a graph of voltage versus time of the electrical activity of the heart using electrodes placed on the skin.
- These electrodes detect the small electrical changes that are a consequence of cardiac muscle depolarization followed by repolarization during each cardiac cycle (heartbeat).



Types of ECG Monitoring: There are different types of ECG monitoring depending on the duration and context of monitoring:

- **Resting ECG:** A standard ECG is done while the patient is at rest.
- **Holter Monitor:** A portable device worn by the patient for 24 to 48 hours to monitor the heart's activity continuously.
- **Event Monitor:** A portable device worn by the patient for a more extended period (e.g., up to 30 days).
- **Stress Test (Exercise ECG):** An ECG is performed while the patient exercises to assess the heart's response to physical activity.

Purpose of ECG Monitoring:

- ECG monitoring is used to evaluate the heart's rhythm and detect any irregularities in electrical activity.
- It can help diagnose various heart conditions, such as arrhythmias (abnormal heart rhythms)
- Coronary artery disease, heart attacks.
- Disease treatments, Electrolyte abnormalities, such as hyperkalemia Pacemaker, working.

Reasons for Blockages of Blood Vessels

The blockages in blood vessels can have serious health consequences, such as heart attacks and stroke. Blockages in blood vessels, also known as arterial blockages or atherosclerosis, can occur for several reasons:

- **High cholesterol levels:** Excessive amounts of cholesterol in the blood lead to the formation of plaque in the blood vessels, which can narrow or block them.

- **High blood pressure:** Over time, high blood pressure can cause damage to the blood vessels, leading to the formation of plaque and blockages.
- **Smoking:** Smoking can damage the inner walls of blood vessels and promote the buildup of plaque, leading to blockages.
- **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.
- **Age:** As people age, the blood vessels can become stiff, increasing the risk of blockages.
- **Genetics:** Some people may be predisposed to developing blockages in their blood vessels due to genetic factors.
- **Poor diet:** A diet high in saturated fats, trans fats, and cholesterol can increase the risk of developing blockages in the blood vessels.



Design of Stents

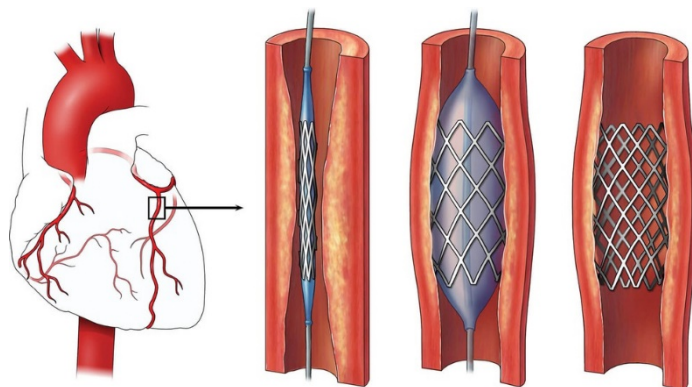
Stents are medical devices used to open and support narrowed or blocked blood vessels. They play a crucial role in the treatment of various cardiovascular conditions, such as coronary artery disease.

Stents Materials:

- **Bare Metal Stents (BMS):** These stents are made of metal (usually stainless steel) and provide structural support to keep the artery open.
- **Drug-Eluting Stents (DES):** These stents have a polymer coating that releases medication over time to prevent restenosis (re-narrowing) of the artery.
- **Bioresorbable Stents:** These stents gradually dissolve over time, leaving only the healed artery behind.

Stent Deployment:

- **Balloon-Expandable Stents:** Compressed stents mounted on a deflated balloon, which is expanded when the balloon is inflated at the target site.
- **Self-Expandable Stents:** Stents made of shape-memory alloys that can expand on their own once released from the delivery system.



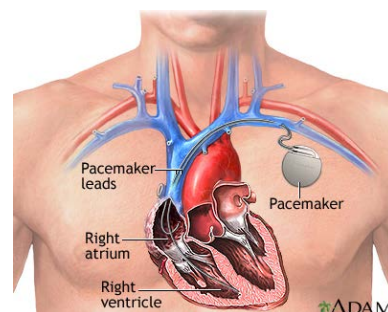
Considerations for Stent Design:

- **Biocompatibility:** Ensuring that the materials used do not provoke harmful reactions within the body.
- **Flexibility:** Stents should be flexible enough to adapt to the vessel's contours during deployment.

- **Drug Delivery (for DES):** Optimal drug release rate and dosage to prevent restenosis effectively.
- **Strut Thickness:** Balancing between minimizing obstruction and maintaining structural integrity.

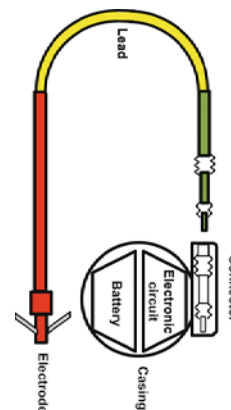
Pacemaker

- A Pacemaker is a medical device that helps regulate a person's heart rhythm.
- It is implanted, in the heart that generates electrical pulses by electrodes to one or more of the chambers of the heart, the upper atria or lower ventricles.
- Each pulse causes the targeted chamber(s) to contract and pump blood, thus regulating the function of the electrical conduction system of the heart.



Construction of a Pacemaker: The construction of a pacemaker involves the use of high-quality materials to ensure their safety and reliability.

- **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.
- **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.
- **Electronic components:** Electronic components, such as microprocessors, batteries, and capacitors, are used to control the delivery of electrical impulses and to provide power to the device.
- **Adhesives:** Adhesives, such as epoxy, are used to secure the components



Defibrillators

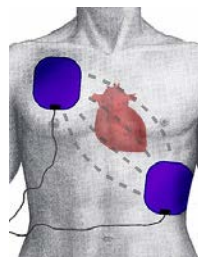
Defibrillators work by delivering a controlled electric shock to the heart. The shock interrupts the electrical activity of the heart during ventricular fibrillation, allowing the heart's natural pacemaker to reestablish a normal rhythm.

Types of Defibrillators:

- **Automated External Defibrillators (AEDs):** Portable devices designed by non-medical personnel, such as first responders. AEDs analyze the heart rhythm and provide voice prompts to guide the rescuer through defibrillation.
- **Implantable Cardioverter Defibrillators (ICDs):** Surgically implanted devices defibrillations for patients at high risk of sudden cardiac arrest due to underlying heart conditions. ICDs continuously monitor the heart rhythm and deliver an electrical shock when an abnormal rhythm is detected.

- **Transvenous Defibrillators:** Implanted in a patient's chest, connected to the heart through lead wires threaded into the blood vessels. These are used in patients who need long-term defibrillation support.

Defibrillators are safe to use, as they will not deliver a shock unless they detect a shockable rhythm (VF or pulseless VT). AEDs are designed to be user-friendly and can be used by individuals with minimal or no training. A quick application of defibrillation is crucial for the best chances of survival in cardiac arrest cases.



LUNGS AS A PURIFICATION SYSTEM

Introduction:

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 important to breathing.

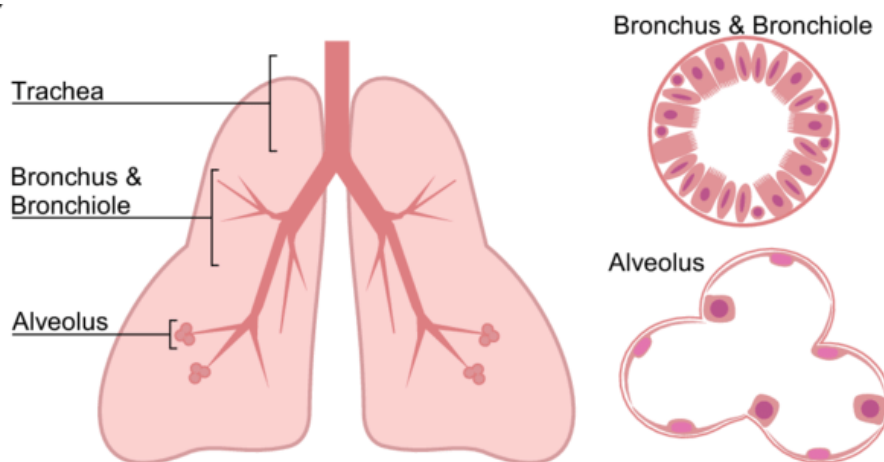
- Bringing air to the proper body temperature and moisturizing it to the right humidity level.
- Protecting your body from harmful substances. This is done by coughing, sneezing, and filtering.
- Supporting your sense of smell.

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

Lung's architecture

7. **Lobes:** The human lungs are divided into two main sections called the left and right lungs. The right lung has three lobes (superior, middle, and inferior lobes), The left lung is slightly smaller and has two lobes: (superior and inferior lobes)
8. **Bronchi:** The trachea, or windpipe, divides into two main bronchi—one leading to each lung. These bronchi then branch out into smaller bronchi, which further divide into bronchioles.
9. **Alveoli:** At the end of the terminal bronchioles, these grape-like structures are the primary sites of gas exchange. It allows oxygen diffusion from the alveoli into the bloodstream and carbon dioxide into the alveoli.

10. **Pulmonary Capillaries:** 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 of the lungs, attached to the walls of the alveoli, which exchange gases between the alveoli and the bloodstream.
11. **Pleura:** The lungs are covered by a double-layered pleura membrane.
12. **Diaphragm:** The diaphragm is a dome-shaped muscle located at the base of the lungs.

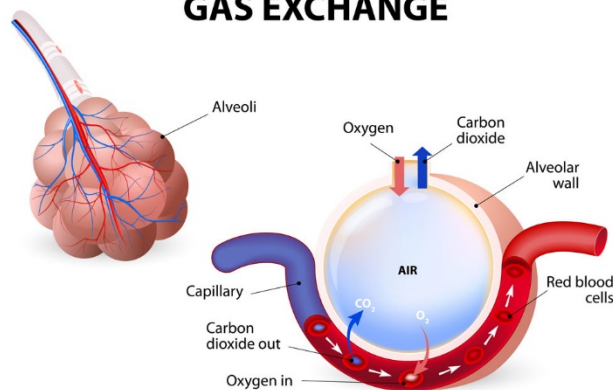


Gas exchange mechanisms



- 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 the 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.
- During gas exchange oxygen moves from the lungs to the bloodstream from alveoli. At the same time, the carbon dioxide molecules in the alveoli are blown out of the body the next time a person exhales. The gas exchange allows the body to replenish the oxygen and eliminate carbon dioxide. Doing both is necessary for survival.

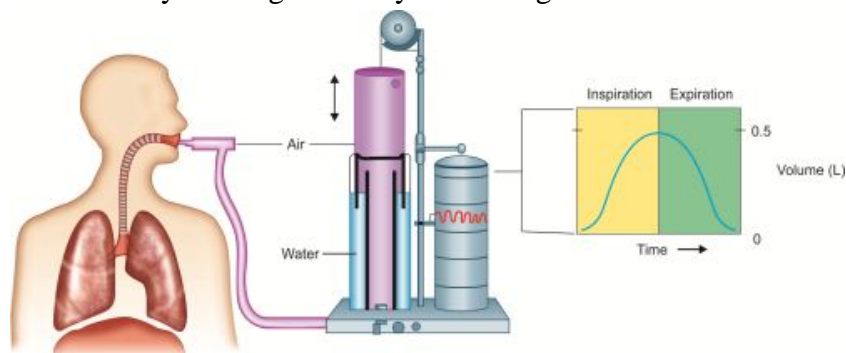
ALVEOLUS GAS EXCHANGE



Spirometry:

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

- How much air you inhale,
- how much do you exhale, and
- how quickly you exhale.
- Spirometry diagnoses asthma, chronic obstructive pulmonary disease (COPD), and other conditions that affect breathing.



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

How to calculate the normal rate of respiration in a spirometer:

Spirometry is performed using a spirometer, a device that consists of a mouthpiece, a flow sensor, and a volume sensor. The patient is asked to exhale as much air as possible into the spirometer, and the spirometer measures the volume and flow rate of the exhaled air. The volume of air exhaled is displayed on a flow-volume loop graph, which provides information about lung function.

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

Abnormal Lung Physiology – Chronic Obstructive Pulmonary Disease (COPD)

It is a chronic inflammatory lung disease that causes obstructed airflow from the lungs. In COPD, the airways and small air sacs (alveoli) in the lungs become damaged or blocked, leading to difficulty in exhaling air. This results in decreased lung function, leading to shortness of breath, wheezing, and coughing. Over time, these symptoms can worsen and limit a person's ability to perform everyday activities.

Causes due to

- long-term exposure to irritating gases.
- Cigarette smoke.
- Age-related issues.

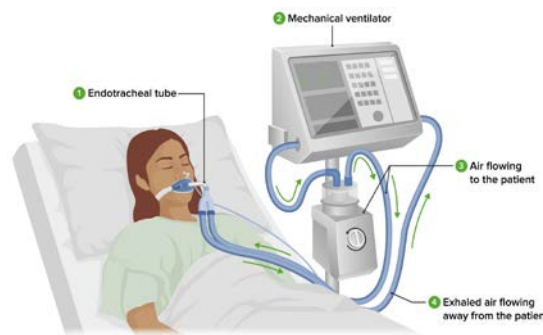
Symptoms:

- Breathing difficulty
- Cough
- Mucus (sputum) production, and Wheezing.

Ventilators

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 Ventilators

- Ventilators deliver oxygen directly to the lungs and 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, in a surgical procedure known as tracheostomy.
- The opposite end of the tube is connected to a machine (the ventilator) that pumps air and oxygen through the tube and into the lungs.
- 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, also called a cardiopulmonary bypass machine (CBM) or a heart-lung bypass machine, is equipment that temporarily takes over the work of the heart and/or lungs, providing blood and oxygen to the body. This machine is used during serious procedures that require the heart to be stopped and

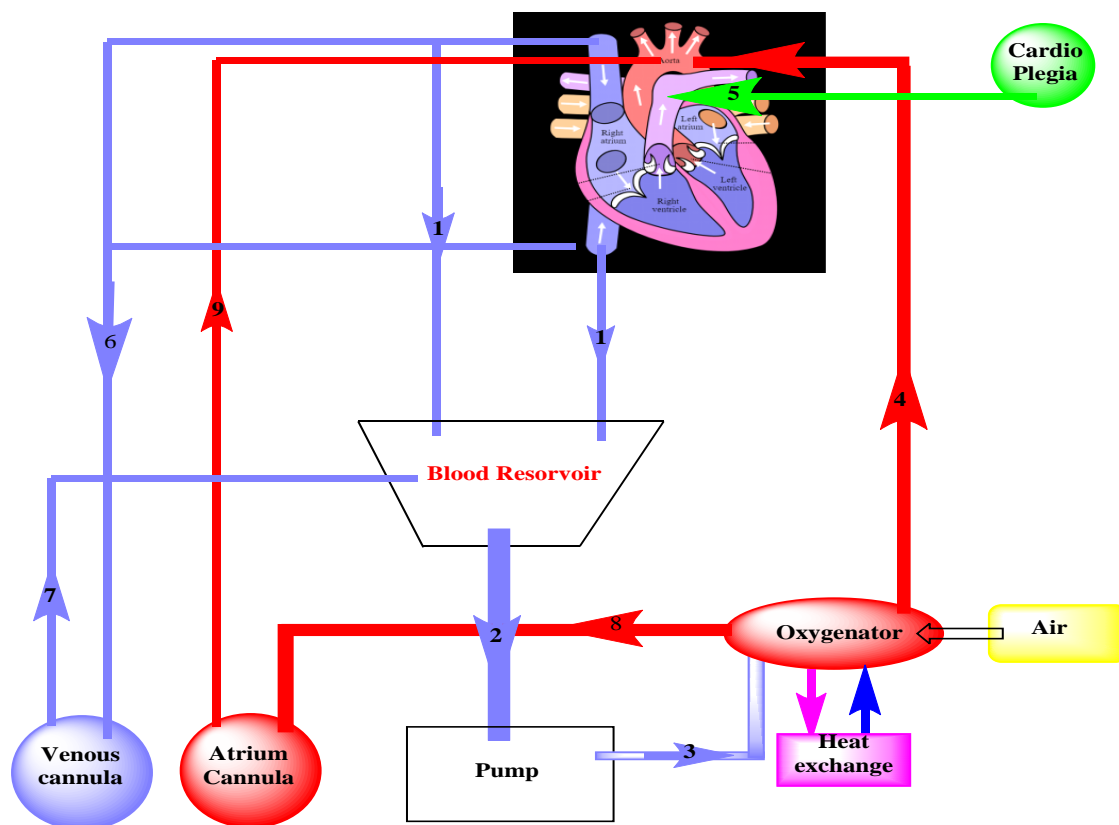
Components of heart-lung machine:

The heart-lung machine includes **Pump, Oxygenator, Filters, Temperature Control, And Monitoring Devices**. The pump is responsible for circulating the blood, while the oxygenator replaces the function of the lungs by adding oxygen and removing carbon dioxide.



Working:

- 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 to the body, thus maintaining blood circulation.
- To prevent blood from clotting within the machine, anticoagulants (blood-thinning medications) such as heparin are administered.
- A third tube is inserted near or directly into the heart but not connected to the CPM.
- 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.
- Cannulas (tubes) are inserted into large blood vessels. The arterial cannula is placed in the aorta to deliver oxygenated blood back into the systemic circulation. In contrast, the venous cannula is inserted into the right atrium or superior vena cava to draw blood from the body into the machine.

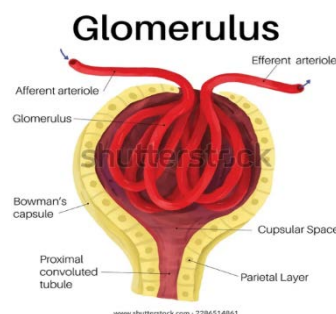
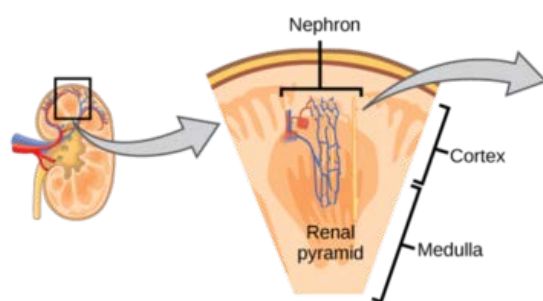
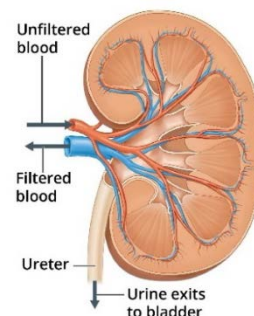


Kidney as a filtration system

Introduction Kidneys are two bean-shaped organs located just below the rib cage; they function as a filtration system by **removing toxic wastes** and extra fluid from the body. Healthy kidneys filter about half a cup of blood every minute, removing waste and extra water in the form of urine. The urine flows from the kidneys to the bladder through ureters connected to the bladder and stored in it.

Parts of kidney

- Each kidney comprises 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).



Mechanism of filtration:

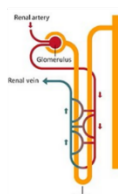
As blood flows across each nephron and enters to glomerulus through blood vessels, the thin walls of the glomerulus filter the smaller molecules and allow larger molecules, such as proteins and blood cells stay in the blood vessel. The tubule returns needed substances to your blood and removes wastes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



Kidney

Blood flows into the kidney

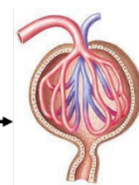
In the kidney, blood passes through millions of smaller blood vessels and reaches the nephrons



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 to filter wastes from the blood. People with CKD may not feel ill or notice any symptoms. But CKD can be diagnosed through specific blood and urine tests which include measuring both the creatinine level in the blood and the protein in the urine. Chronic kidney disease includes conditions that **damage kidneys** and decrease the ability of filtering **wastes from your blood**

Disorder	Symptoms
<ul style="list-style-type: none"> High blood pressure Anaemia (low blood count) weak bones Poor nutritional health Nerve damage 	<ul style="list-style-type: none"> 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

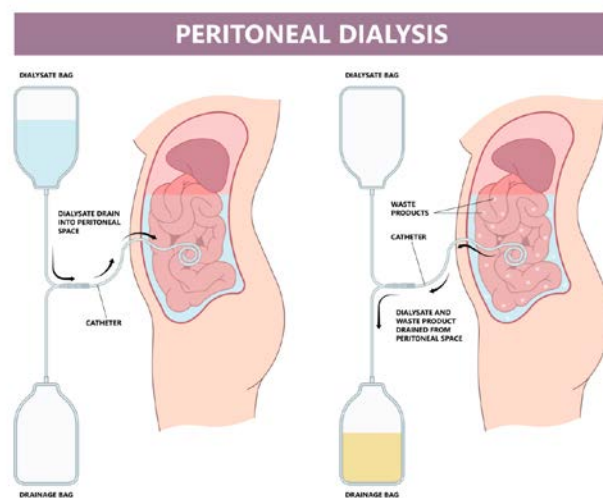
DIALYSIS:

it is a procedure to remove waste products and excess fluid from the blood when the kidneys stop working correctly. Dialysis can be done in two methods

1. **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.
2. **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.

Mechanism of Peritoneal Dialysis

- **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.
- **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.



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

Peritoneal dialysis is typically performed in cycles, with multiple daily and night exchanges. The frequency and duration of exchanges depend on the individual's needs and the type of peritoneal dialysis being performed.

Mechanism of Hemodialysis

- **Vascular Access:** a synthetic tube connection between an artery and a vein.
- **Blood Circulation:** The patient's blood is diverted from their body through the vascular access point into the dialysis machine.
- **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.
- **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.
- **Return of Purified Blood:** After filtration, the cleaned blood is returned to the patient's body through the vascular access point.

Hemodialysis sessions typically last around 3 to 5 hours and are usually performed thrice weekly. While hemodialysis effectively removes waste products and excess fluids from the blood, it may also cause fluctuations in blood pressure and other potential complications.

