Module 2
HUMAN ORGAN SYSTEMS AND BIO DESIGNS

BIOLOGY FOR ENGINEERS

Dr. Pavan K J

DEPARTMENT OF BIOTECHNOLOGY

G M Institute of Technology

Davanagere

BIOLOGY FOR ENGINEERS
MODULE 2

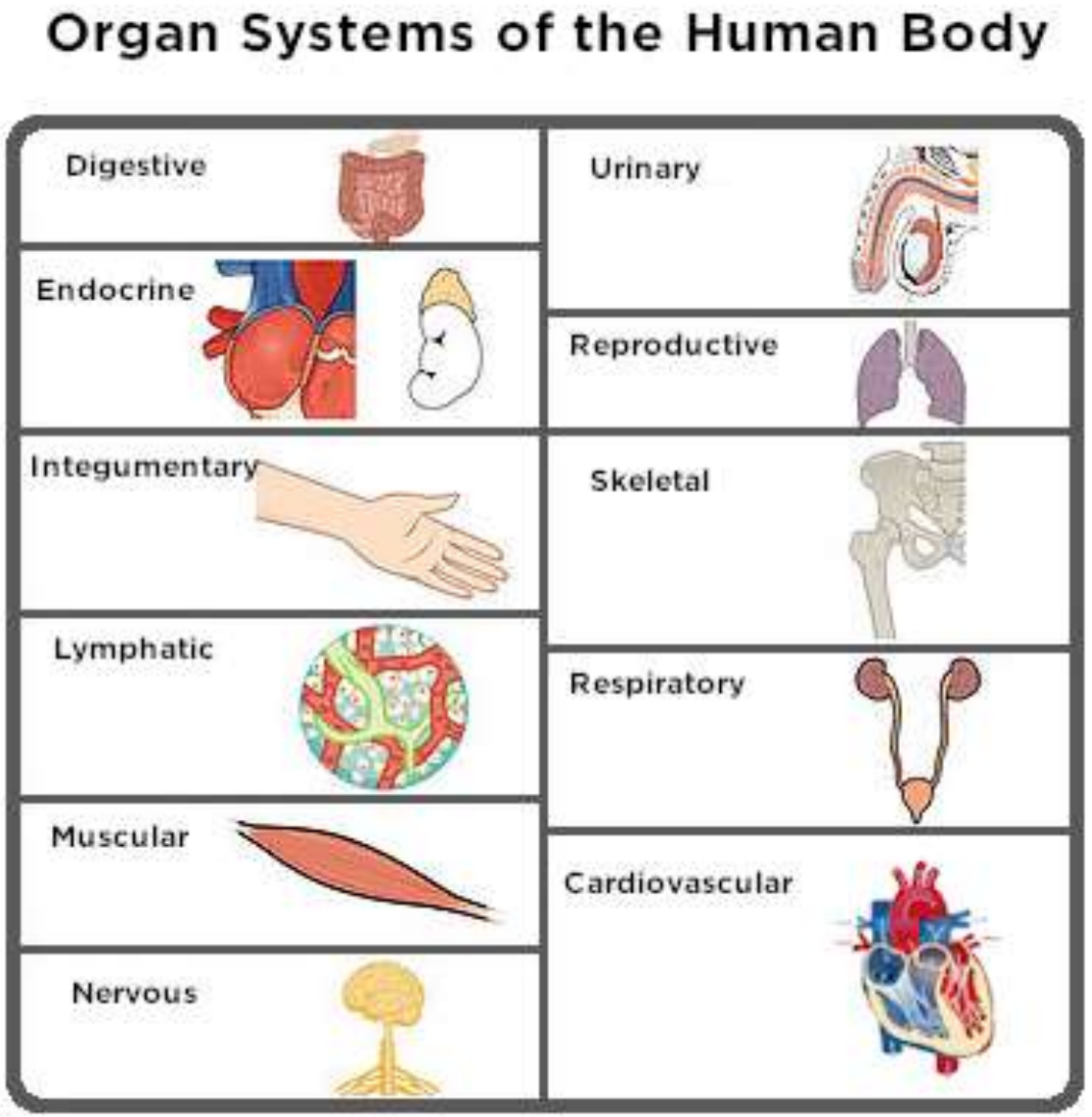
HUMAN ORGAN SYSTEMS AND BIO DESIGNS - 1 (QUALITATIVE):

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, pace makers, defibrillators).

HUMAN ORGAN SYSTEMS

The human body is a biological machine made up of various organ systems. Organ systems are made up of various organs working together to perform a vital body function. There are primarily 11 organ systems namely:

1. Skeletal system,
2. Muscular system,
3. Cardiovascular system,
4. Respiratory system,
5. Nervous system,
6. Digestive system,
7. Urinary system,
8. Endocrine system,
9. Lymphatic system,
10. Reproductive system,
11. Integumentary (Exocrine) system.



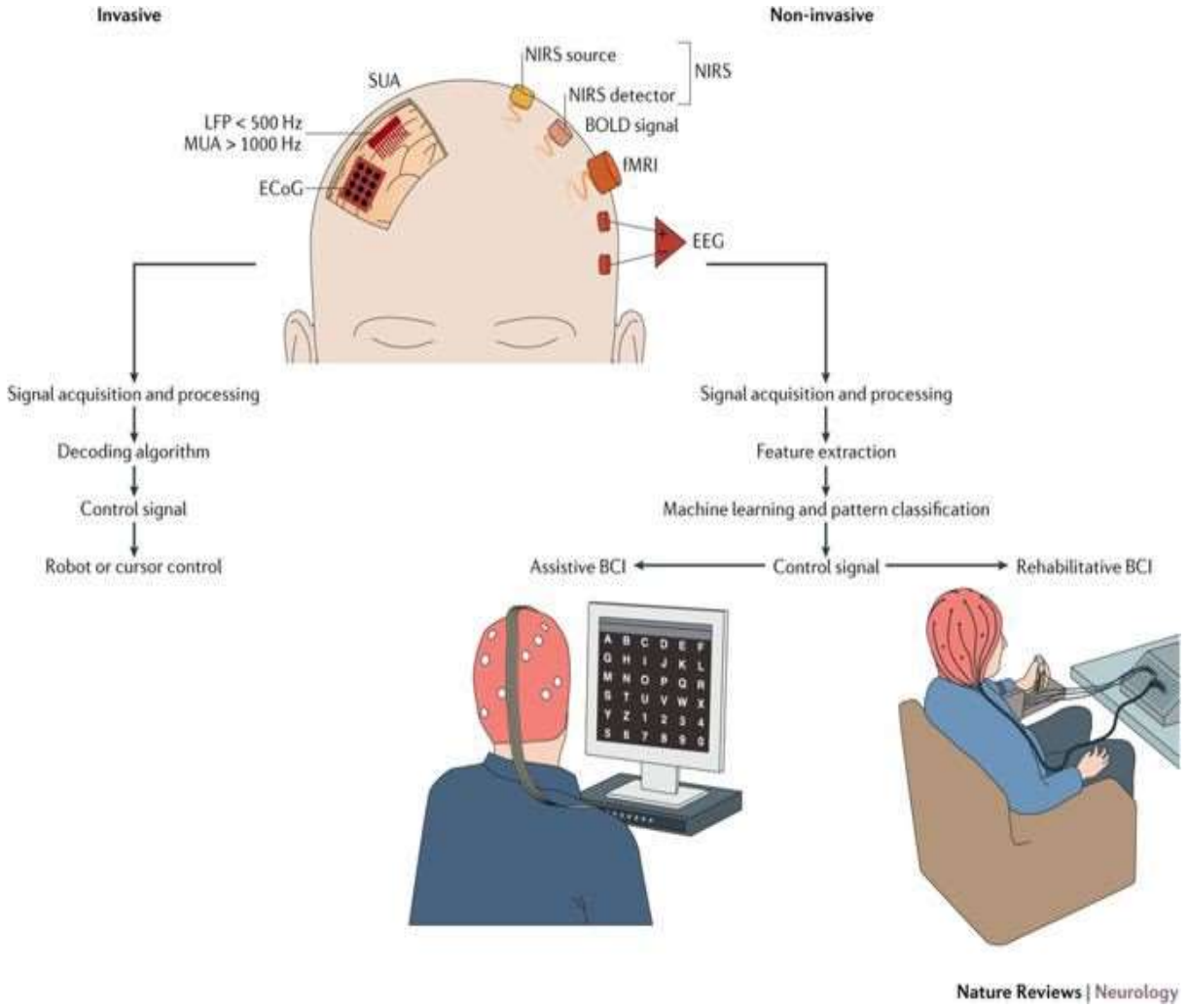
➢ Role and function of the organ Systems.

- **Biodesign** is the use of living organisms in design.
- Its processes can be used in the creation of fashion, textiles, furniture and architecture.
- Nonprofit design companies and universities around the world, increasingly implement biodesign practices into research and product development.
- This presents a new frontier in terms of design with nature as opposed to design by nature in the case of bio-inspired design.
- Bio-design was coined by William Myers in 2012 as “an emerging and often radical approach to design that draws on biological tenets and even incorporates the use of living materials into structures, objects and tools” (Myers, 2012).

- **<u>BRAIN AS A CPU SYSTEM</u>**
- Both CPU and brain use electrical signals to send messages.

- The brain uses chemicals to transmit information; the computer uses electricity.

- Even though electrical signals travel at high speeds in the nervous system, they travel even faster through the wires in a computer. Both transmit information.



DIFFERENCE BETWEEN HUMAN BRAIN AND COMPUTER

Biological neurons or nerve cells		Silicon transistors
200 billion neurons, 32 trillion interconnections		Few billion bytes RAM, trillion of bytes on disk
Neuron size: 10-6m		Single transistor size: 10-9m
Energy consumpion: 6-10 joules per operation per sec		Energy consumption: 10-16 joules per operation per second
Learning capability		Programming capability

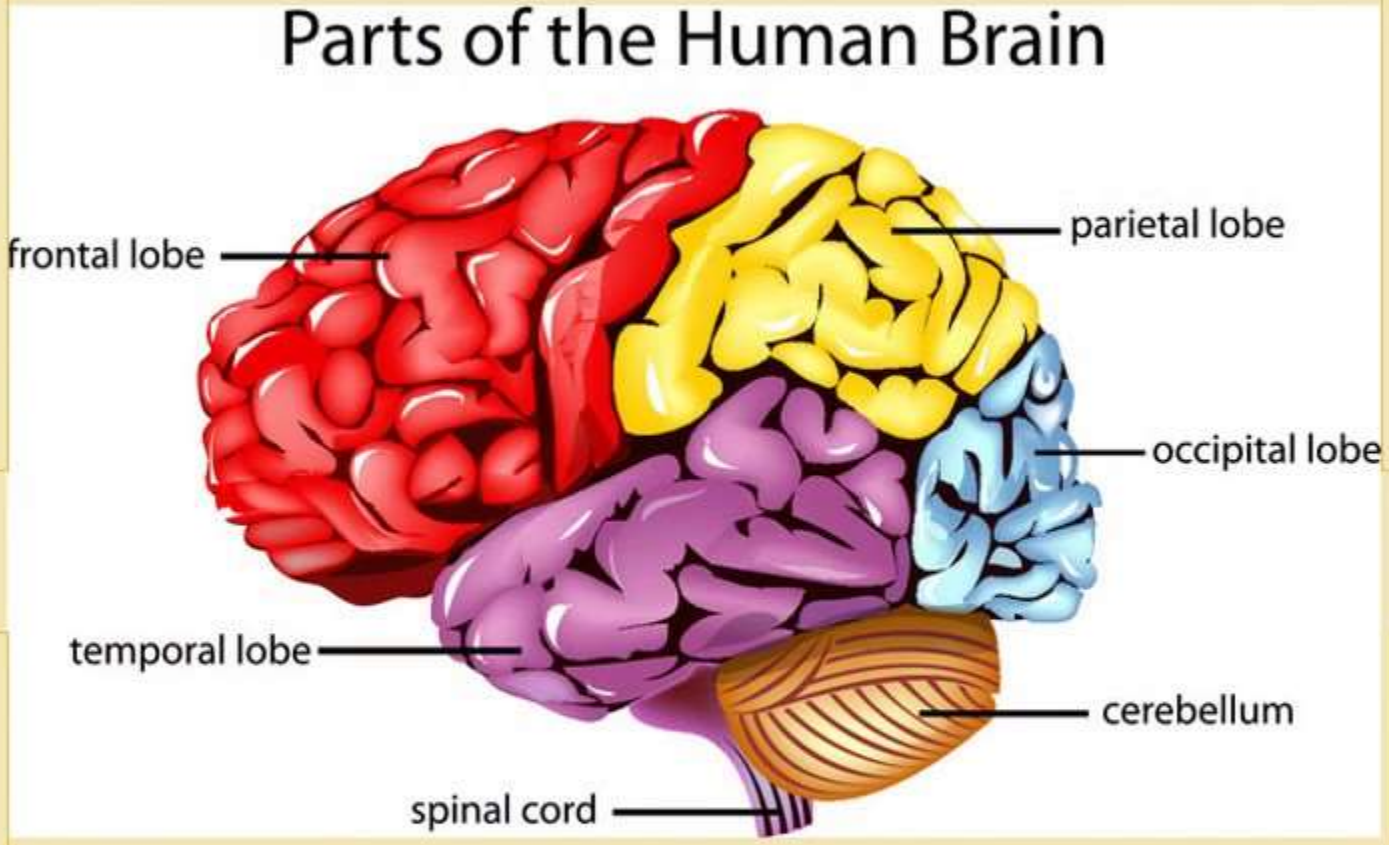
Source XenonStack - Infographic by Antonio Grasso

@antgrasso

Digital Business Innovation

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

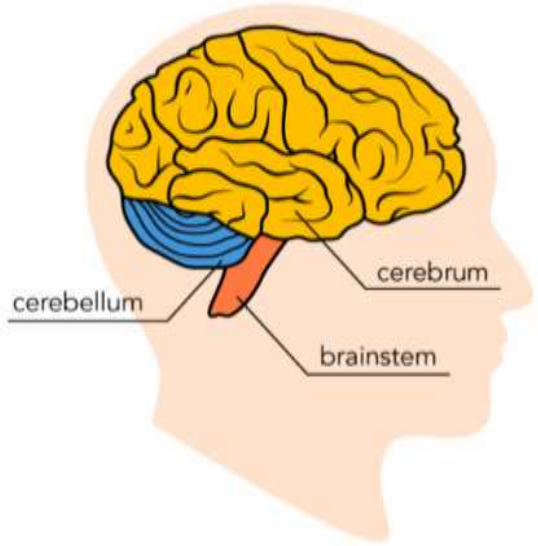
Cerebellum function:

- Posture
- Balance
- Coordination of movement

- The CPU is the brain of a computer, containing all the circuitry needed to process input, store data, and output the results.
- The CPU is constantly following instructions of computer programs that inform as to which data needs to be processed and how.
- The memory capacity of a human brain was testified to be equal to 2.5 petabytes, which is equivalent to 2.5 million gigabytes of memory.
- Comparing computer and brain frequencies, Bostrom noted that “biological neurons operate at a peak speed of about 200 Hz, a full seven orders of magnitude slower than a modern microprocessor (~2 GHz)”.

Architecture of human Brain

The human brain is one part of the **nervous system**. That's the control system that sends instructions to all the other parts of your body. The human Brain has many different parts. Each one plays a different function. But they all work together to manage complex thoughts, feelings and behaviours.



The three main parts of the brain

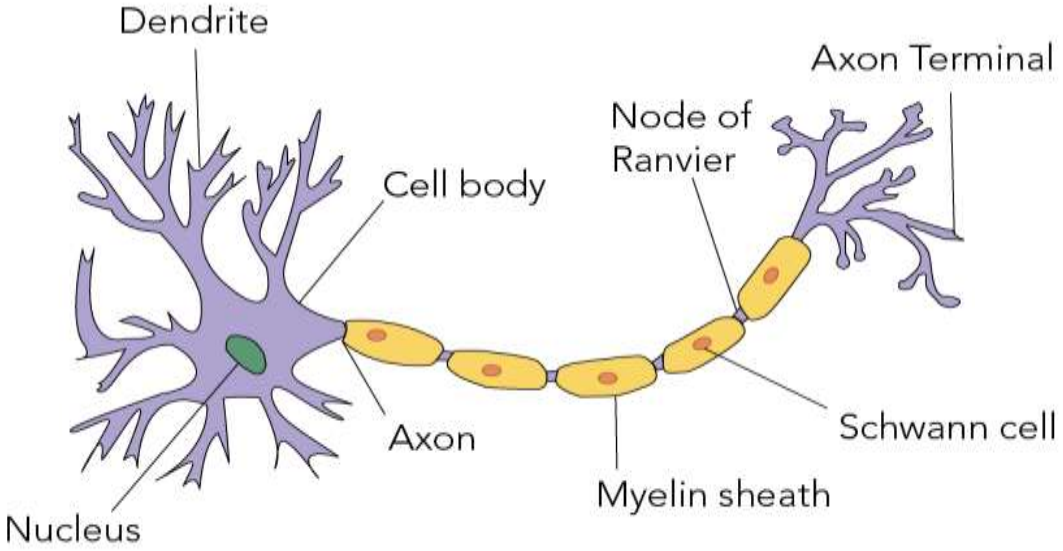


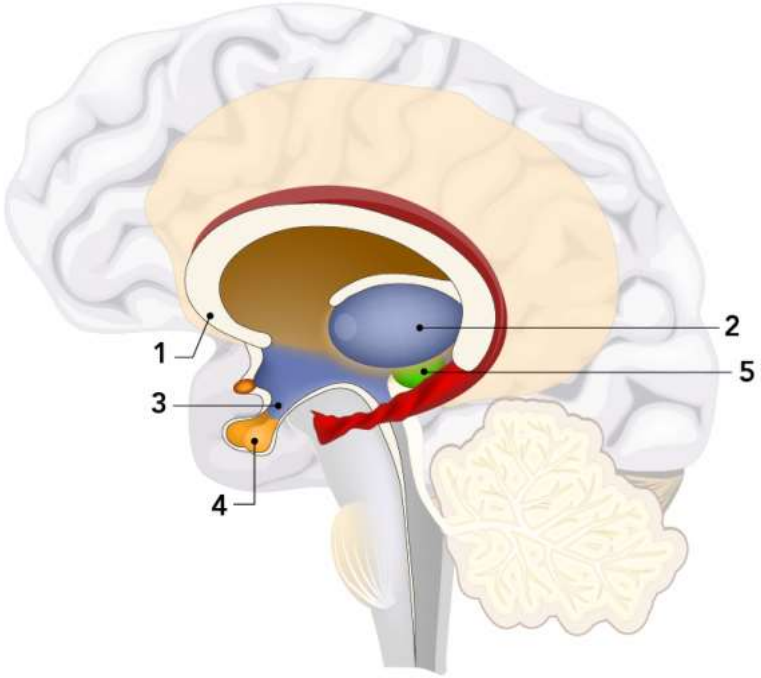
Fig: Parts of a neuron

- On average, an adult human brain weighs about 1300 grams. It uses about 20% of the body’s energy.

- The brain helps coordinate all of the body’s internal and external actions. Without your brain, you wouldn’t be able to sneeze, kick a ball or send a text.

The brain has three main parts. They are the cerebrum, the cerebellum and the brainstem.

1. The **cerebellum** helps fine-tune your muscle movement. For example, it helps control balance, posture and motor learning.
2. The **cerebrum** is the largest part of the brain, spanning both the left and right **hemispheres**. It sits on top of the cerebellum and the brainstem. Many of your body's higher functions rely on the cerebrum. For instance, it controls touch, vision, hearing, speech and fine motor skills. You also need your cerebrum to interpret emotions, solve problems and learn.
3. The **brainstem** connects the base of the brain to the spinal cord. It helps coordinate the brain's communication with the rest of the body. The brainstem also helps coordinate involuntary actions like breathing and heart rate.



Interior parts of the brain including the
(1) corpus callosum, (2) thalamus, (3) hypothalamus, (4) pituitary gland, and (5) pineal gland.

Nervous System

The nervous system helps all the parts of the body to communicate with each other. It also reacts to changes both outside and inside the body. The nervous system uses both electrical and chemical means to send and receive messages.

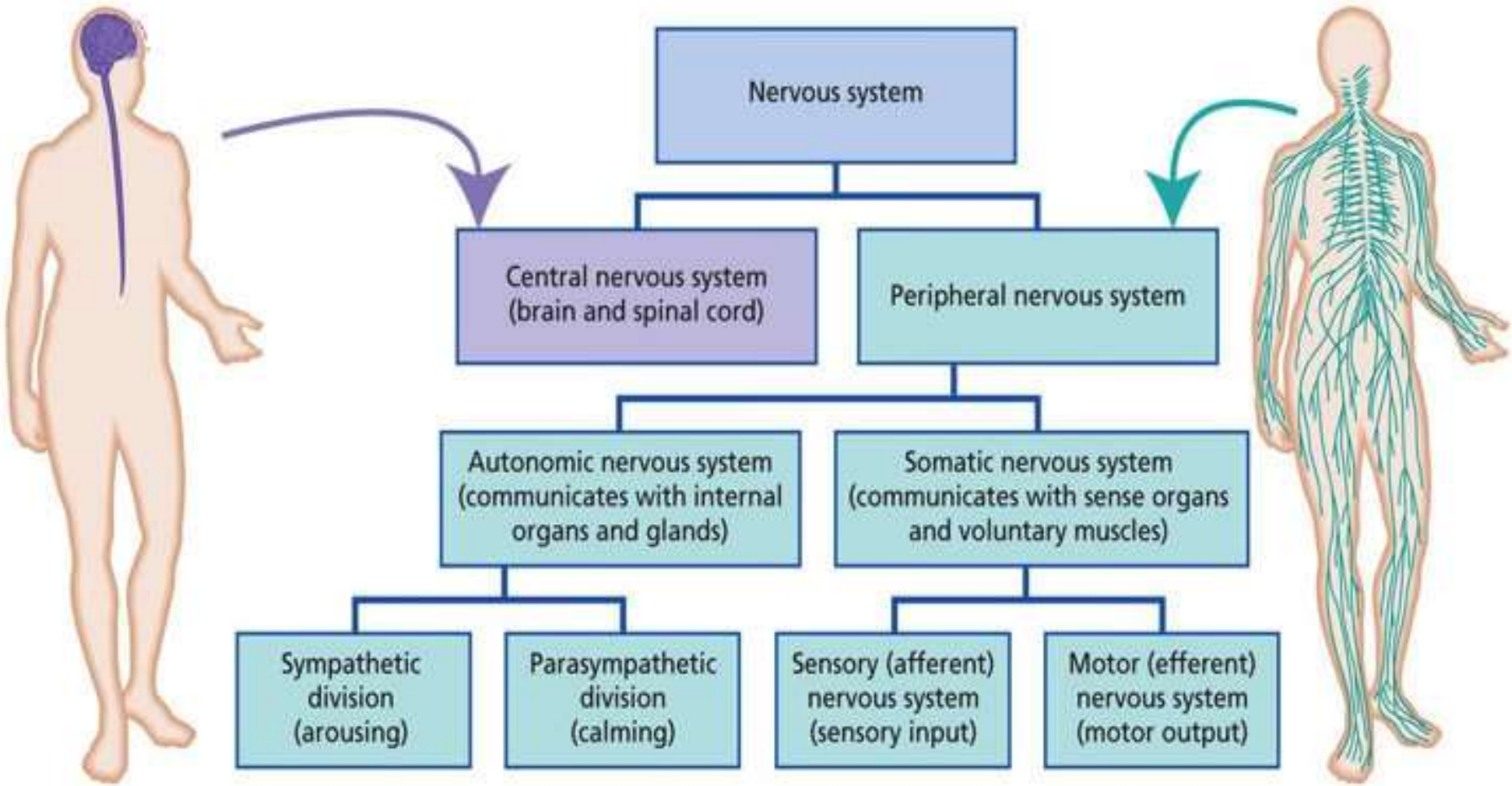
The nervous system has two main parts:

The central nervous system (CNS) and the **peripheral nervous system (PNS**).

CNS is made up of the brain and spinal cord. The brain is the body's "control center." The CNS has various centers located within it that carry out the sensory, motor and integration of data. These centers can be subdivided to Lower Centers (including the spinal cord and brain stem) and higher centers communicating with the brain via effectors.

CNS is usually considered to have seven basic parts: the spinal cord, the medulla, the pons, the cerebellum, the midbrain, the diencephalon, and the cerebral hemispheres.

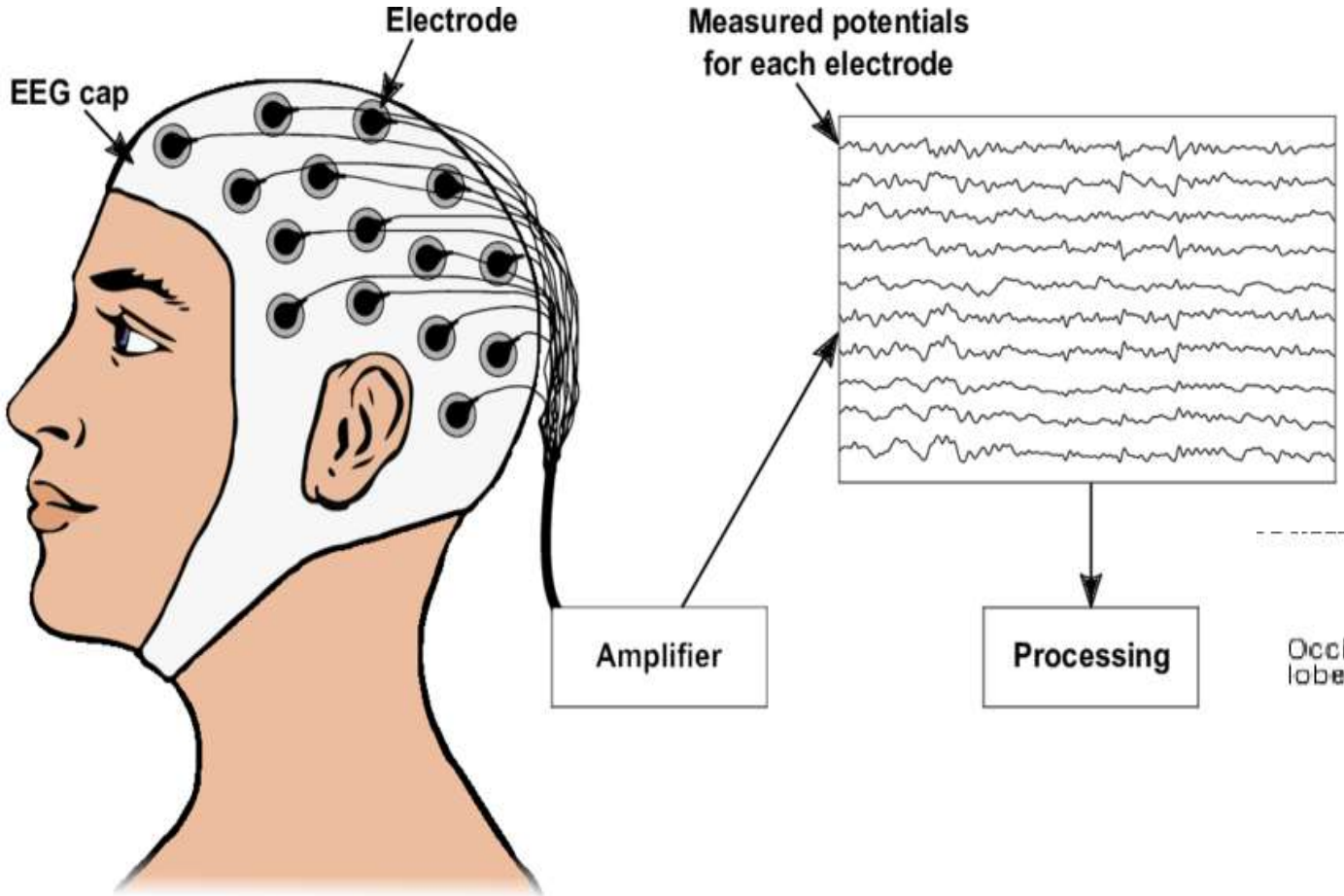
The peripheral nervous system is made up of nerves that branch off from the spinal cord and extend to all parts of the body.

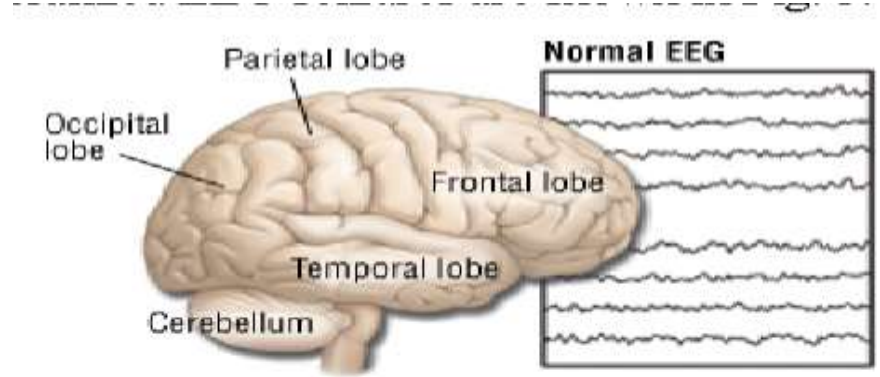

Nervous system
Central nervous system (brain and spinal cord)
Peripheral nervous system
Autonomic nervous system (communicates with internal organs and glands)
Somatic nervous system (communicates with sense organs and voluntary muscles)
Sympathetic division (arousing)
Parasympathetic division (calming)
Sensory (afferent) nervous system (sensory input)
Motor (efferent) nervous system (motor output)

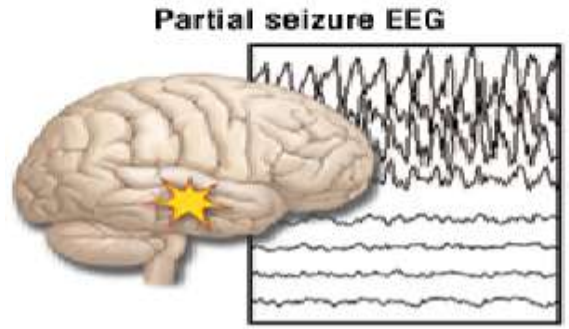
SIGNAL TRANSMISSION

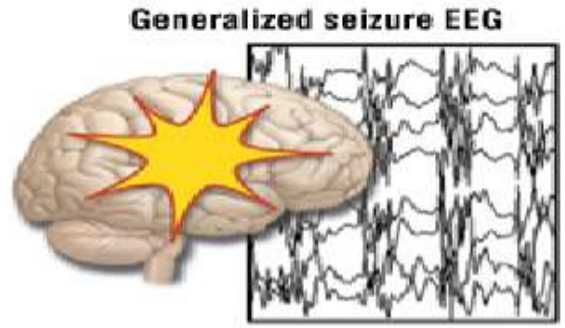
A neuron sending a signal (i.e., a presynaptic neuron) releases a chemical called a neurotransmitter, which binds to a receptor on the surface of the receiving (i.e., postsynaptic) neuron.

- **ELECTRO ENCEPHALO GRAM [EEG]**
- An electroencephalogram (EEG) is a test that measures electrical activity in the brain using small, metal discs (electrodes) attached to the scalp. Brain cells communicate via electrical impulses and are active all the time, even during asleep.
- This activity shows up as wavy lines on an EEG recording. An EEG is one of the main diagnostic tests for epilepsy.
- An EEG can also play a role in diagnosing other brain disorders. An EEG can find changes in brain activity that might be useful in diagnosing brain disorders, especially epilepsy or another seizure disorder.
- An EEG might also be helpful for diagnosing or treating Brain tumors, Brain damage due to head injury, Brain dysfunction that can have a variety of causes (encephalopathy), Sleep disorders, Inflammation of the brain (herpes encephalitis), Stroke, Creutzfeldt-Jakob disease etc.


Electrode
EEG cap
Measured potentials
for each electrode
Amplifier
Processing


Parietal lobe
Normal EEG
Occipital
lobe
Frontal lobe
Temporal lobe
Cerebellum


Partial seizure EEG

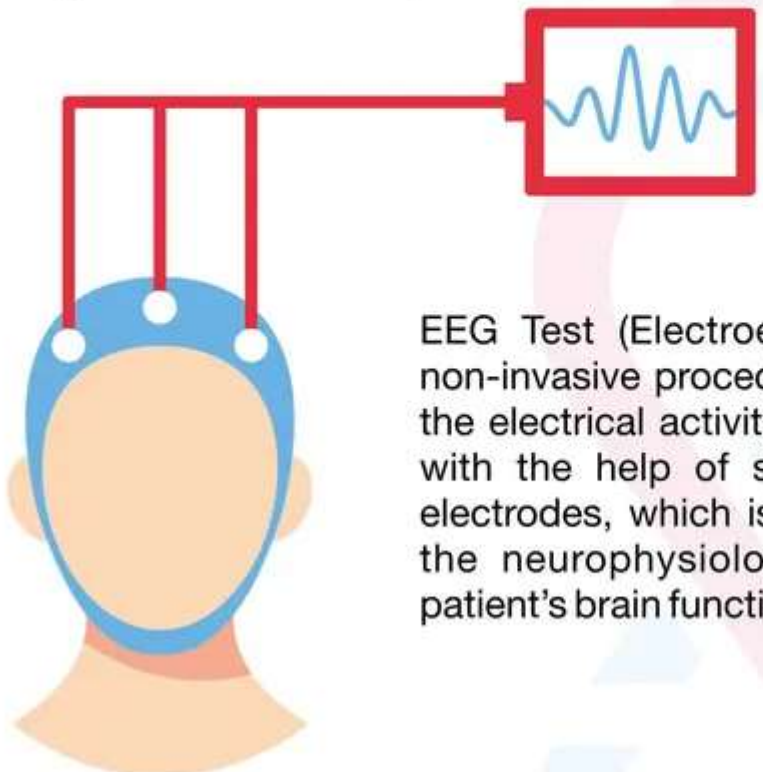

Generalized seizure EEG

EEG TEST

- Brain disorders
- Epilepsy
- Internal injuries
- Dementia
- Strokes
- Sleep disorders

What is EEG Test (Electroencephalogram)?

PACE HOSPITALS



EEG Test (Electroencephalogram) is a non-invasive procedure used to estimate the electrical activity of a patient's brain, with the help of small metal discs or electrodes, which is further observed by the neurophysiologist to analyse the patient's brain functions.

What is EEG?

Watch

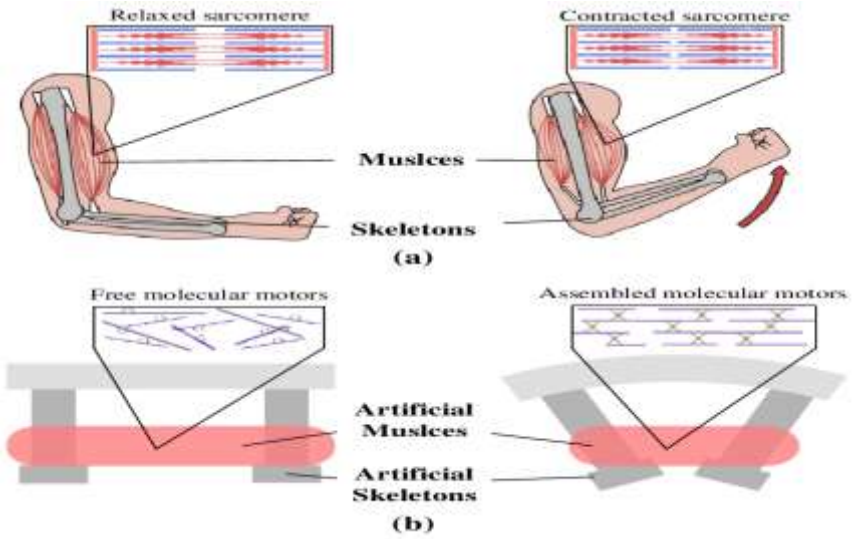
Uploaded: Aug 22, 2017

75.5K Views · 255 Likes

Dr Alissa Ferry explains what an electroencephalogram (EEG) is and how we use it in child languageh development researc to study what babies know long before...

ROBOTIC ARMS FOR PROSTHETICS

Robotic prosthetic limb is a well-established research area that integrates advanced mechatronics, intelligent sensing, and control for achieving higher order lost sensorimotor functions while maintaining the physical appearance of amputated limb. Robotic prosthetic limbs are expected to replace the missing limbs of an amputee restoring the lost functions and providing aesthetic appearance. The main aspects are enhanced social interaction, comfortable amputee's life, and productive amputee to the society. With the advancement of sensor technology, in the last few decades significant contributions have been made in this area.



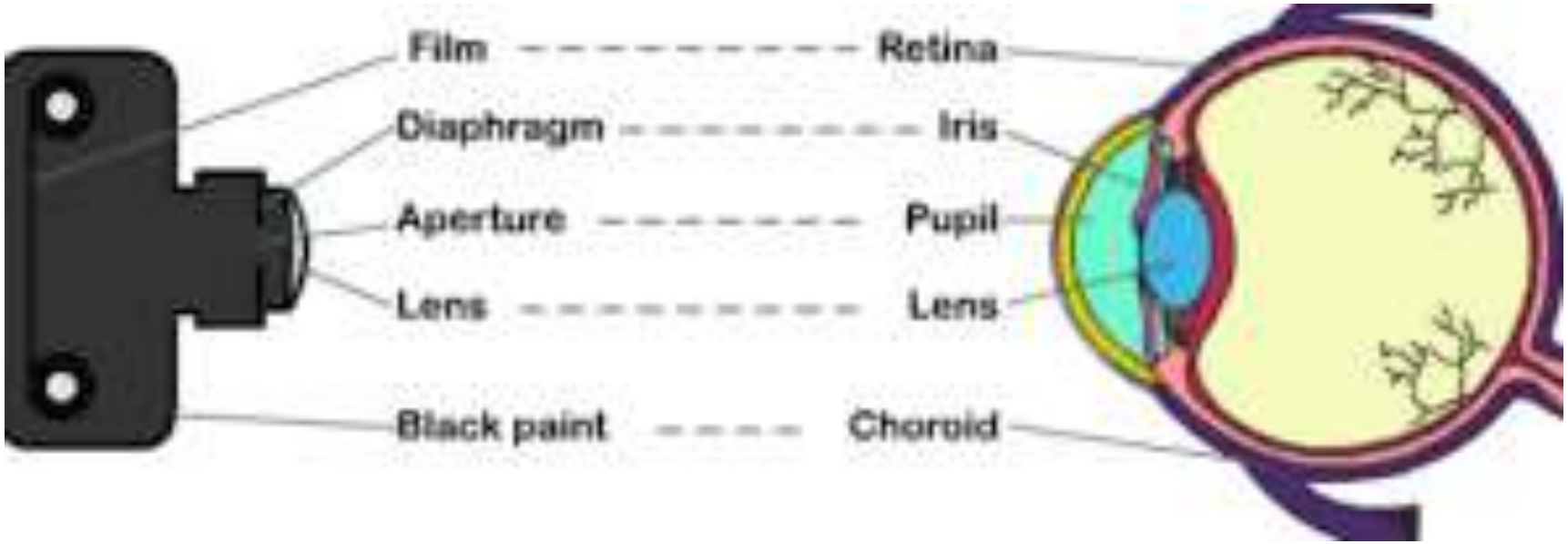
Deep Brain Stimulation

Deep Brain Stimulation (DBS) involves surgically implanting a neurotransmitter that sends electrical impulses to specific areas of your brain. This procedure has helped many people with Parkinson's reduce symptoms such as tremor, rigidity, and bradykinesia.

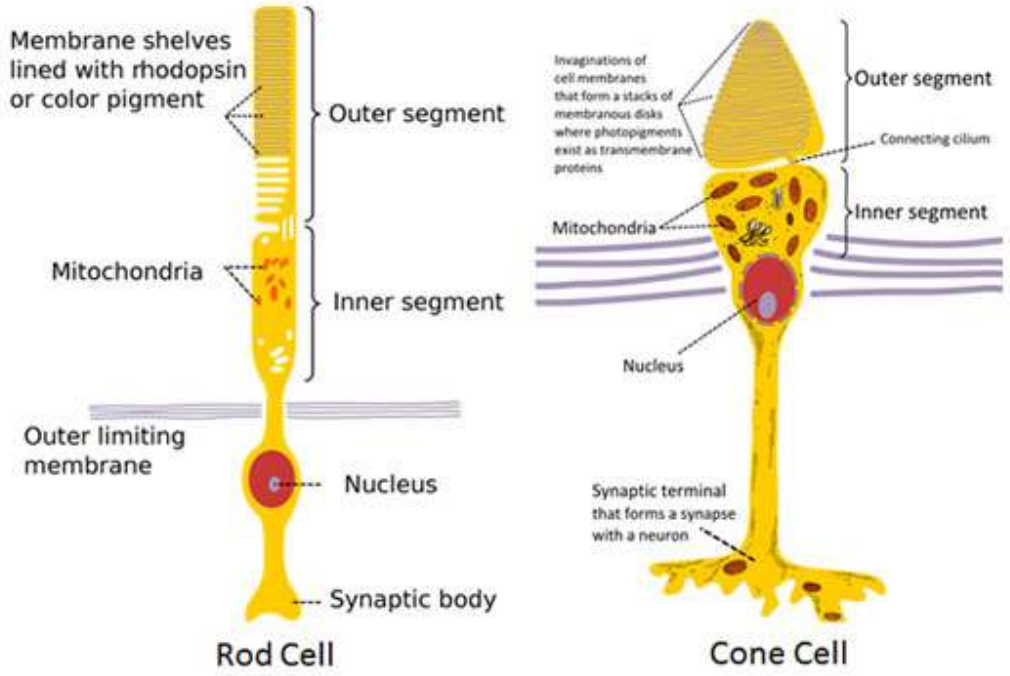
EYE AS A CAMERA SYSTEM

The human eye is a wonderful instrument, relying on refraction and lenses to form images. There are many similarities between the human eye and a camera, including:

A diaphragm to control the amount of light that gets through to the lens. This is the shutter in a camera, and the pupil, at the center of the iris, in the human eye. A lens to focus the light and create an image. The image is real and inverted. A method of sensing the image. In a camera, film is used to record the image; in the eye, the image is focused on the retina, and a system of rods and cones is the front end of an image-processing system that converts the image to electrical impulses and sends the information along the optic nerve to the brain.



Photoreceptors in the retina are classified into two groups, named after their physical morphologies, into **rods** and **cones**. These photoreceptors are localized around an area near the centre of the retina called the macula, which is the functional center of the retina

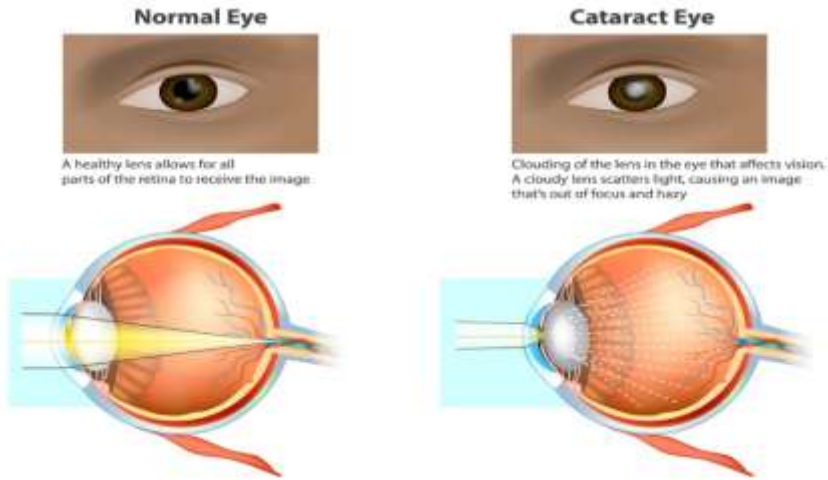


OPTICAL CORRECTIONS

A slight modification of geometrically correct lines (as of a building) for the purpose of making them appear correct to the eye. The ability to see images or objects with clear, sharp vision results from light entering the eye. Light rays bend or refract when they hit the retina, sending nerve signals to the optic nerve, which then sends these signals to the brain. The brain processes them into images, allowing you to understand what you see

CATARACT

A cataract is a clouding of the normally clear lens of the eye. At first, the cloudiness in your vision caused by a cataract may affect only a small part of the eye's lens and you may be unaware of any vision loss. As the cataract grows larger, it clouds more of your lens and distorts the light passing through the lens. This may lead to more-noticeable symptoms. A cataract is a cloudy lens. The lens is positioned behind the colored part of your eye (iris). The lens focuses light that passes into your eye, producing clear, sharp images on the retina — the light-sensitive membrane in the eye that functions like the film in a camera.



As you age, the lenses in your eyes become less flexible, less transparent and thicker. Age-related and other medical conditions cause proteins and fibers within the lenses to break down and clump together, clouding the lenses

- **EYE LENS MATERIALS**
- Corrective spherocylindrical lenses are commonly used to treat refractive errors such as myopia, hyperopia, presbyopia, and astigmatism.

- Both lenses and prisms are also frequently used to improve eye alignment and treat diplopia in strabismus.

- Eyeglasses also serve an important role in protecting the eyes from physical trauma and harmful radiation.

- Lenses can be produced using a variety of materials and designed with several optical profiles to optimize use in specific applications.

- There are 4 main types of lens materials for eyeglasses and sunglasses. Each type of lens material can help correct refractive errors such as nearsightedness, farsightedness, astigmatism, or presbyopia

Types of lens materials:

1. **CR-39 -**The most commonly used plastic lens material
2. **Crown Glass** is the most commonly used clear glass for ophthalmic lenses. In general, glass is the most durable material used for lenses. Crown glass is used mainly for single vision lenses and the distance carrier for most glass bifocals and trifocals.
3. **Flint Glass** uses lead oxides in its chemical make up to increase its index of refraction to approximately 1.58 to 1.69. Its Abbe value ranges from 30 to 40. This material is relatively soft, displays a brilliant luster and has chromatic aberration.
4. **Polycarbonate Lenses**

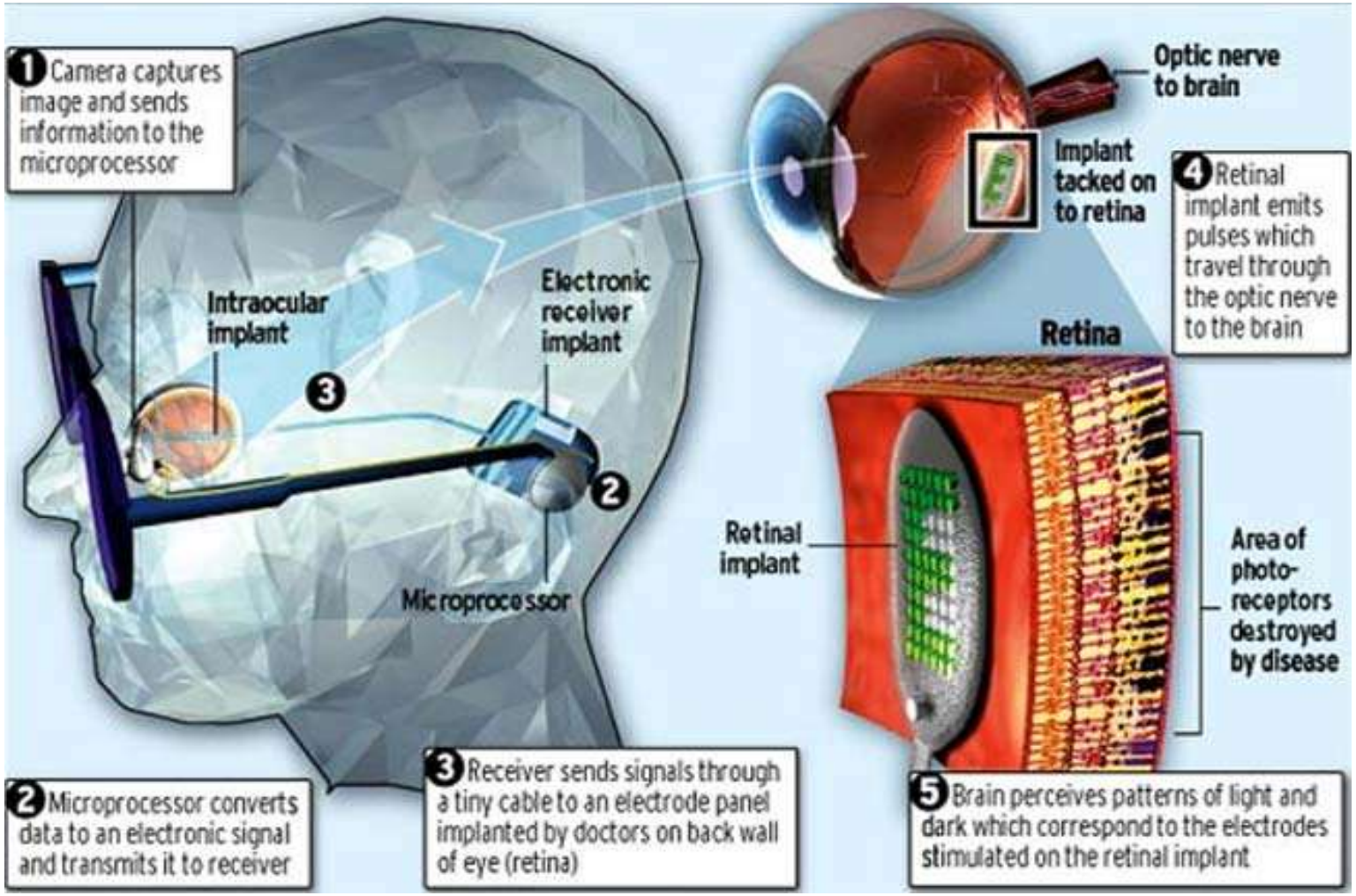
Polycarbonate lenses were first developed by a company named Gentex.

Polycarbonate is a thermoplastic which means it is moldable under sufficient heat.

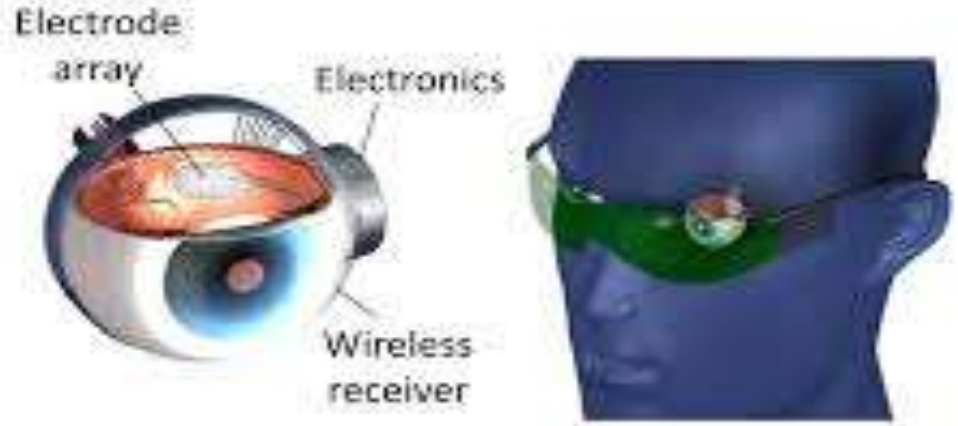
- **BIONIC EYES**
- Bionic eye, is an electrical prosthesis which is surgically implanted into a human eye in order to allow for the transduction of light (the change of light from the environment into impulses the brain can process) in people who have sustained severe damage to the retina.
- The bionic eye comprises an external camera and transmitter and an internal microchip.
- The camera is mounted on a pair of eyeglasses, where it serves to organize the visual stimuli of the environment before emitting high-frequency radio waveshttps

https://www.youtube.com/watch?v=05ee61Bu-Ok&t=1s

www.youtube.com/watch?v=WhYe6REdljw

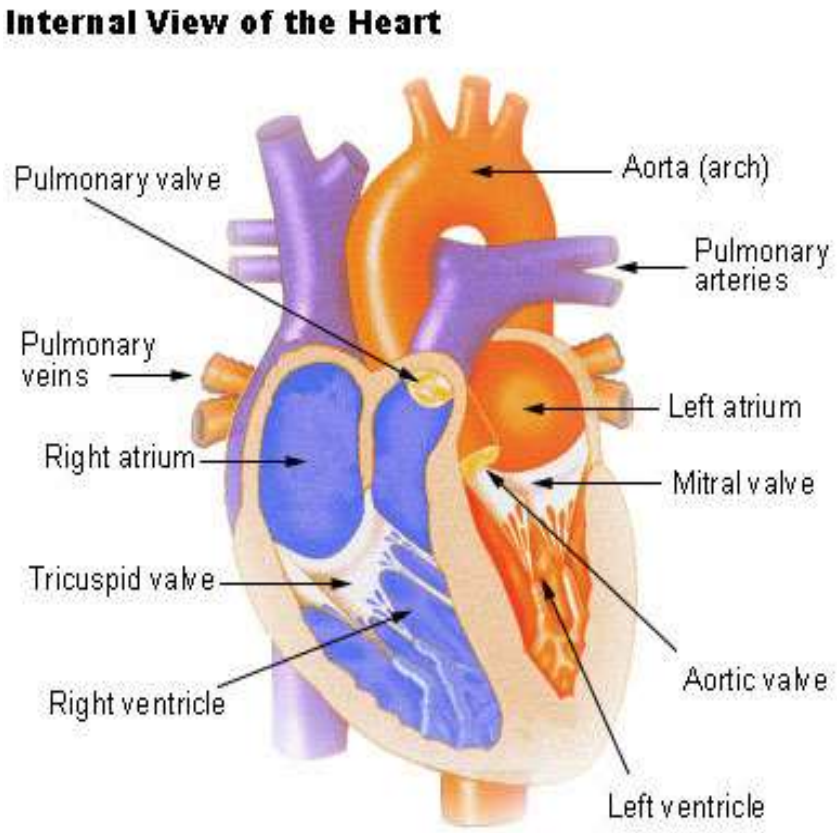

1 Camera captures image and sends information to the microprocessor
Intraocular implant
Electronic receiver implant
3
2
Microprocessor
Optic nerve to brain
Implant tacked on to retina
4 Retinal implant emits pulses which travel through the optic nerve to the brain
Retina
Retinal implant
Area of photo-receptors destroyed by disease
2 Microprocessor converts data to an electronic signal and transmits it to receiver
3 Receiver sends signals through a tiny cable to an electrode panel implanted by doctors on back wall of eye (retina)
5 Brain perceives patterns of light and dark which correspond to the electrodes stimulated on the retinal implant


Eyeglasses with camera
Video processing unit


Electrode array
Electronics
Wireless receiver

HEART AS A PUMP SYSTEM

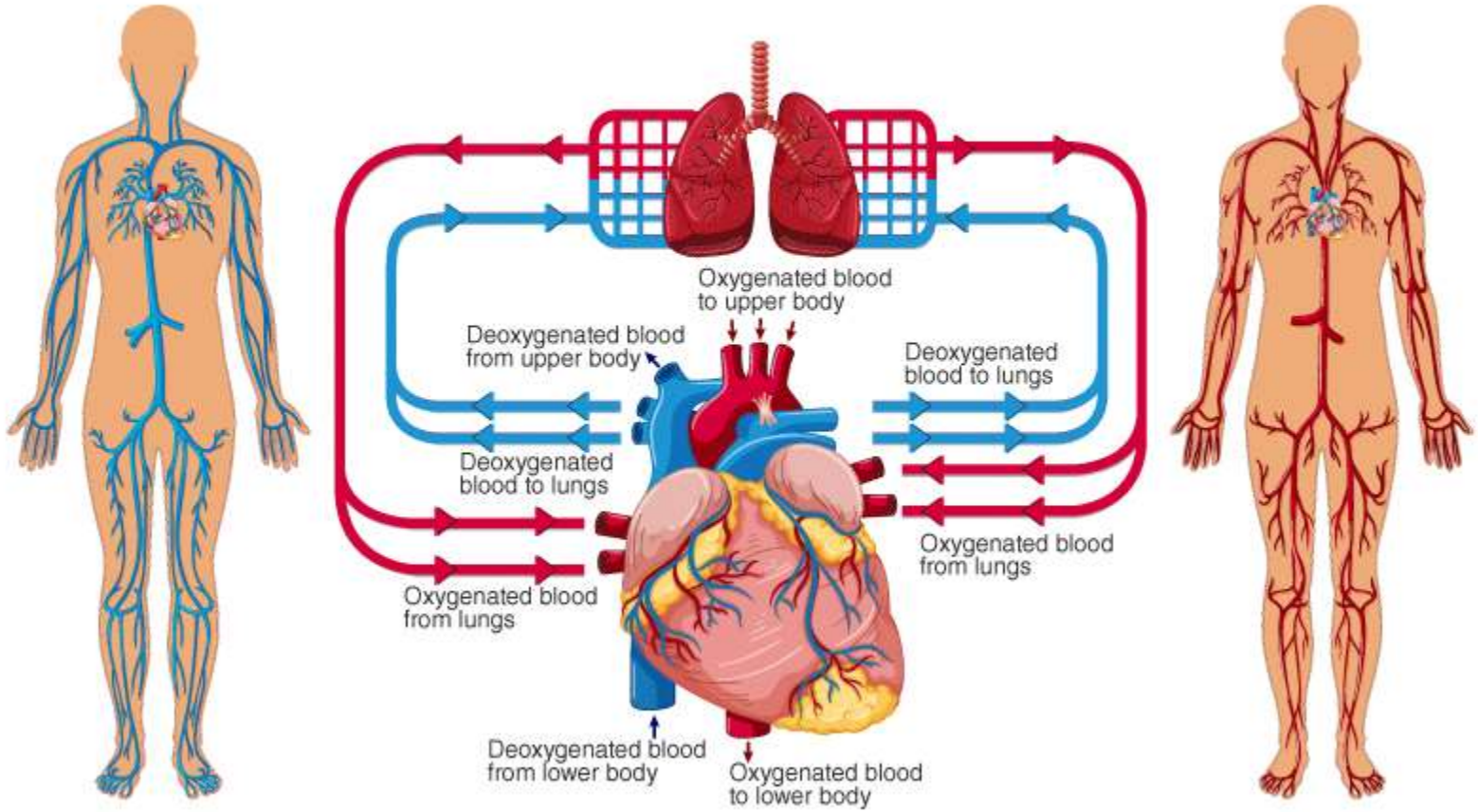
- Heart is sort of like a pump, or two pumps in one. The right side of your heart receives blood from the body and pumps it to the lungs.
- The left side of the heart does the exact opposite: It receives blood from the lungs and pumps it out to the body.
- The human heart is very strong and is capable of pumping blood up to 30 feet distance.
- An average heart beats maximum of 70-80 beats per minute and is considered healthy.
- The efficiency of the heart can be maintained and improved by performing physical activity.



Do you know that in a year your heart beats over 30 million times?

This means in a lifespan of 80 years, it would be around 2.5 billion times.
How does the heart make up its pace?
What are the different parts of a heart?

HEART – PUMP OF THE CIRCULATORY SYSTEM

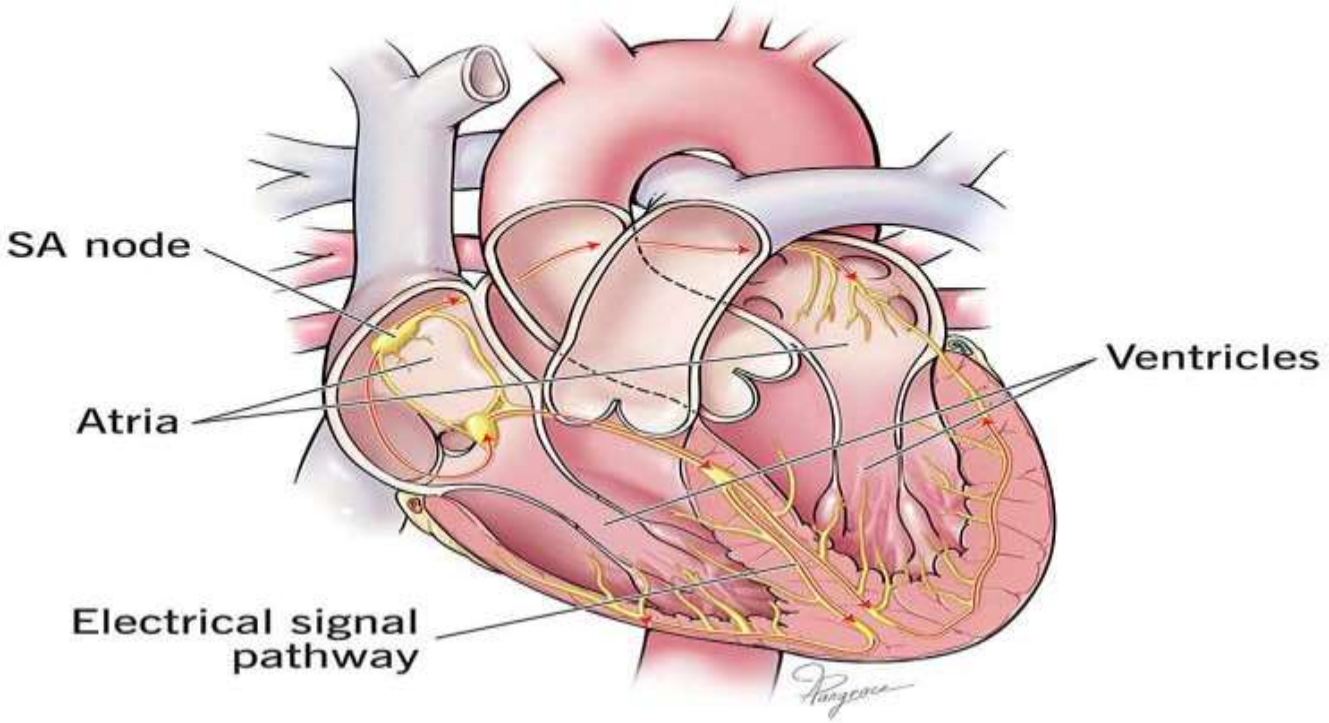


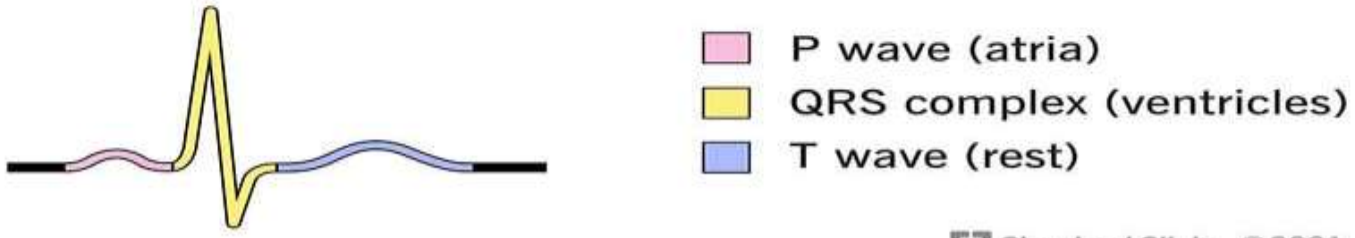
- **ELECTRICAL SIGNALING**
- The sinus node generates an electrical stimulus regularly, 60 to 100 times per minute under normal conditions. The atria are then activated. The electrical stimulus travels down through the conduction pathways and causes the heart's ventricles to contract and pump out blood.

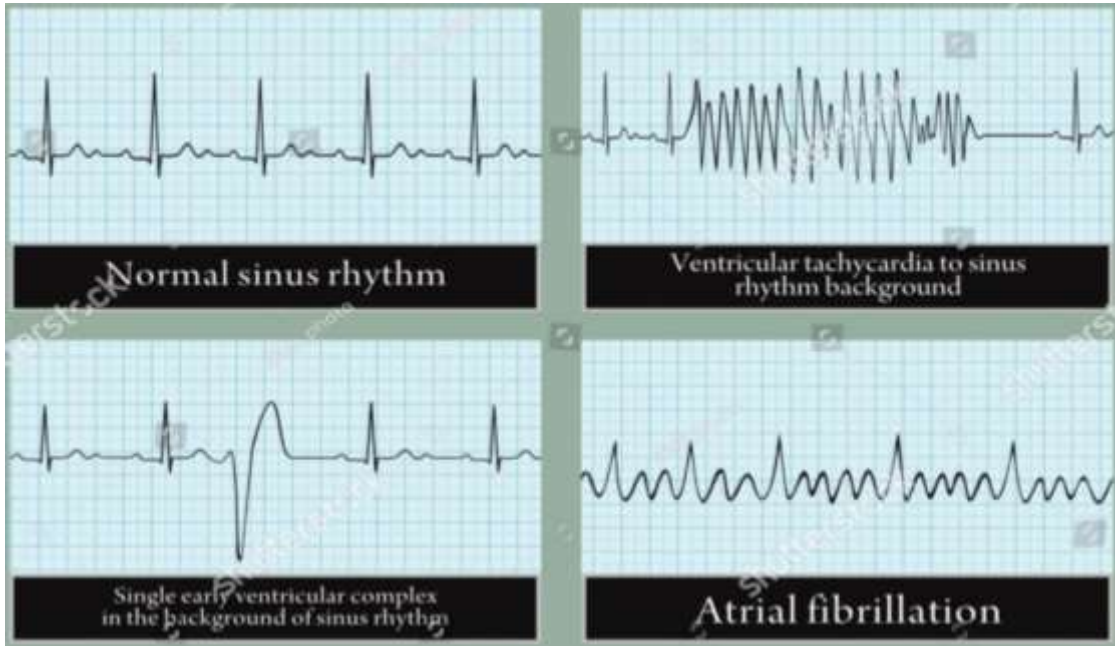
- **ECG MONITORING**
- ECG monitoring systems have been developed and widely used in the healthcare sector for the past few decades and have significantly evolved over time due to the emergence of smart enabling technologies.
- Nowadays, ECG monitoring systems are used in hospitals, homes, outpatient ambulatory settings, and in remote contexts.
- They also employ a wide range of technologies such as IoT , edge computing, and mobile computing.
- In addition, they implement various computational settings in terms of processing frequencies, as well as monitoring schemes.
- They have also evolved to serve purposes and targets other than disease diagnosis and control, including daily activities, sports, and even mode-related purposes.

https://www.youtube.com/watch?v=kwLbSx9BNbU

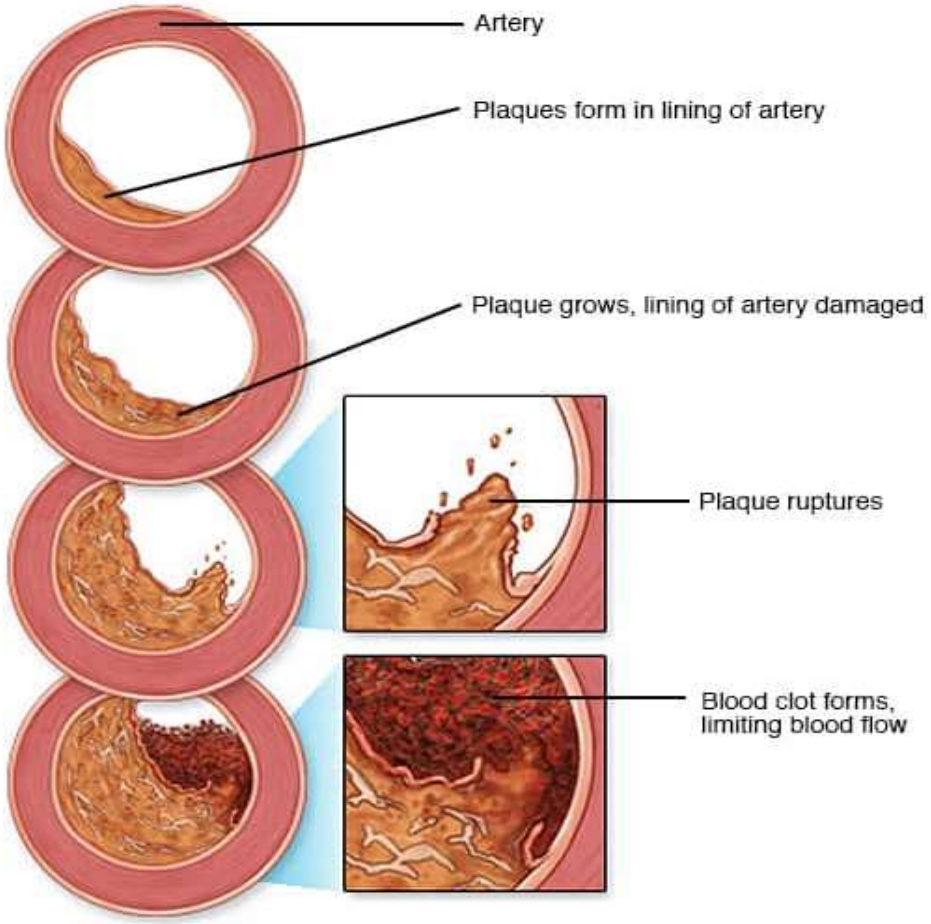
Electrocardiogram (EKG)

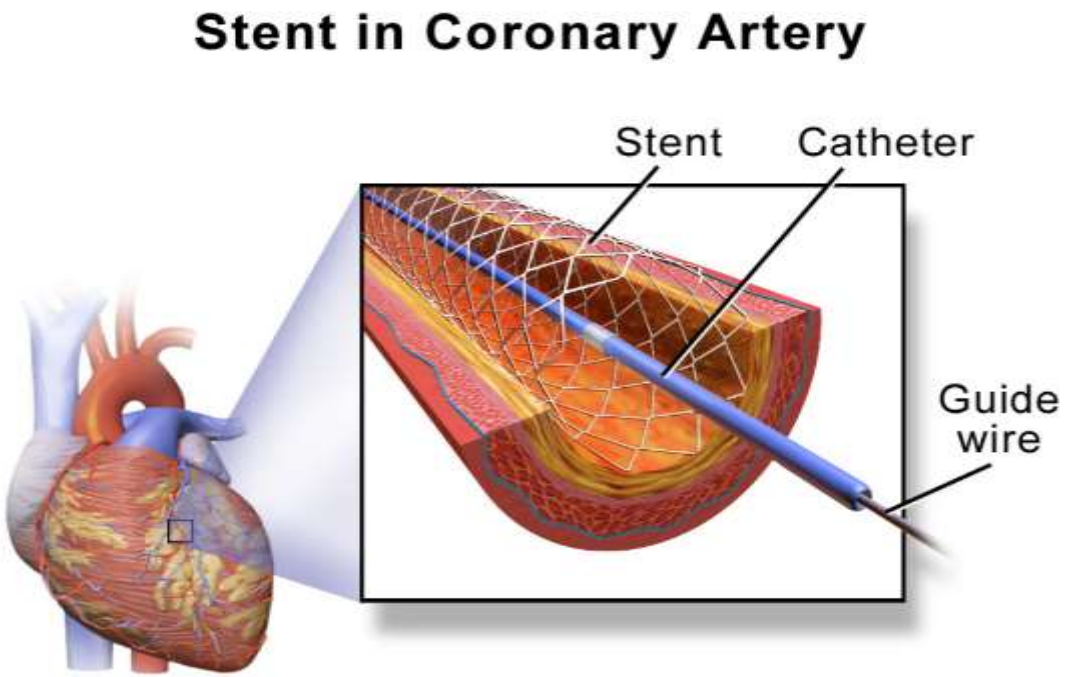


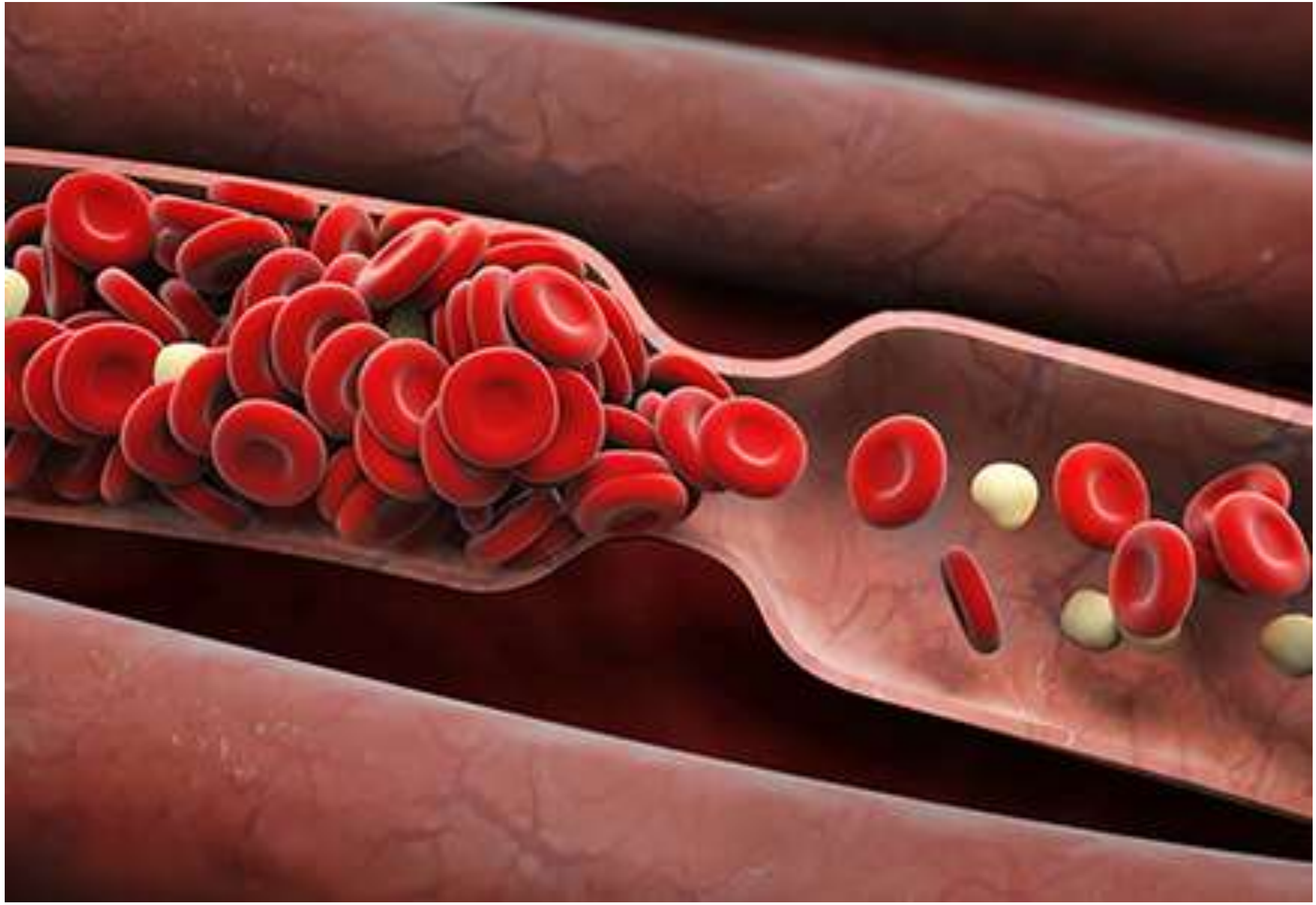




1. **Cardiovascular diseases** including **heart failure (HF)**.
2. **REASONS FOR BLOCKAGES OF BLOOD VESSELS:** Coronary artery disease is a common heart condition. The major blood vessels that supply the heart (coronary arteries) struggle to send enough blood, oxygen and nutrients to the heart muscle. Cholesterol deposits (plaques) in the heart arteries and inflammation are usually the cause of coronary artery disease. Signs and symptoms of coronary artery disease occur when the heart doesn't get enough oxygen-rich blood.

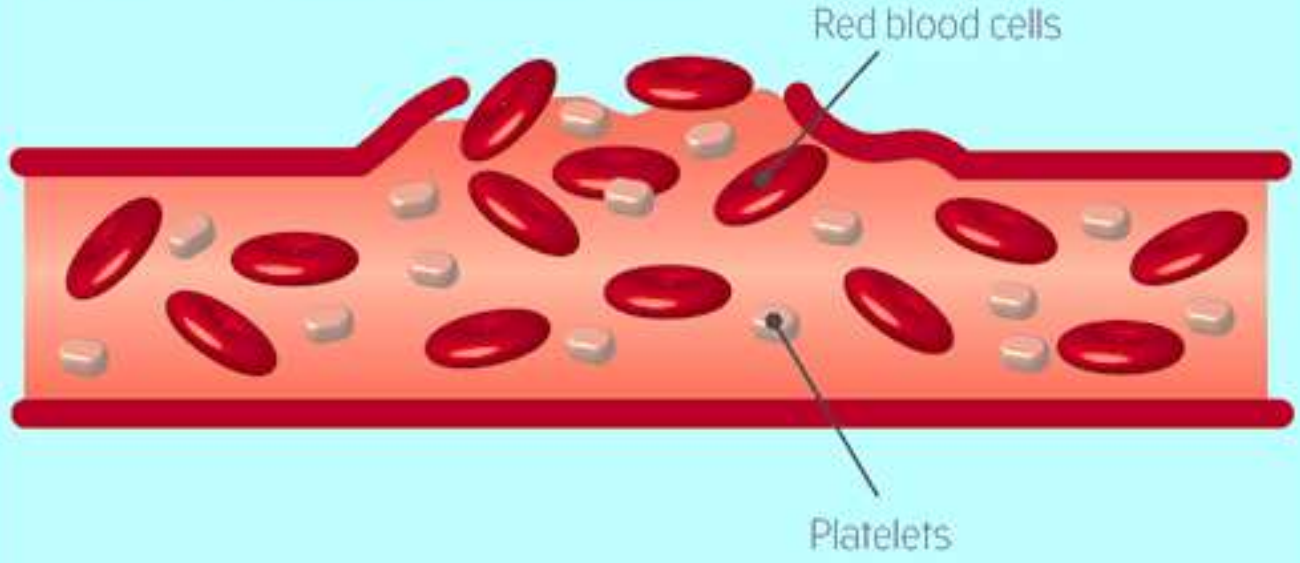




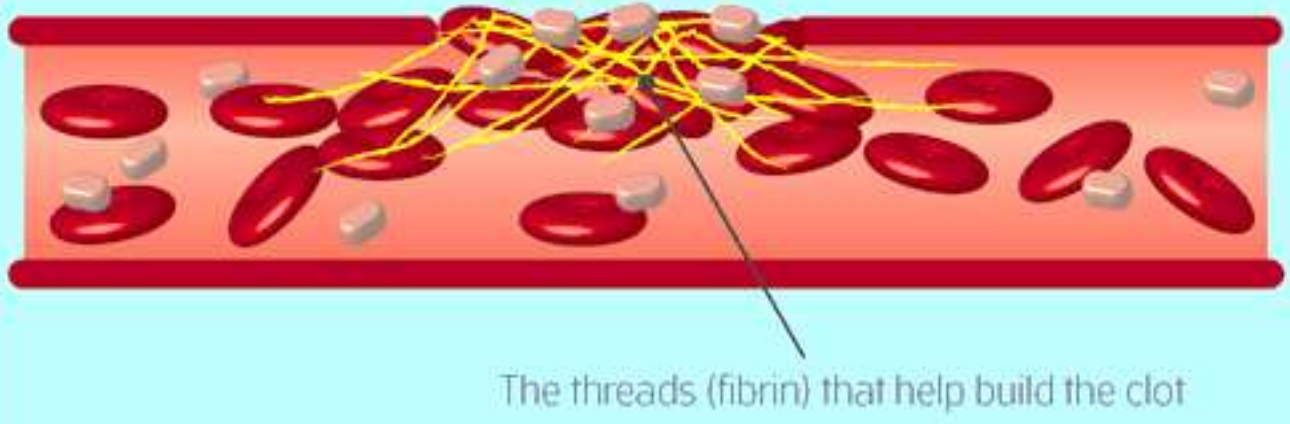


Formation of blood clots

1. Damaged blood vessel wall

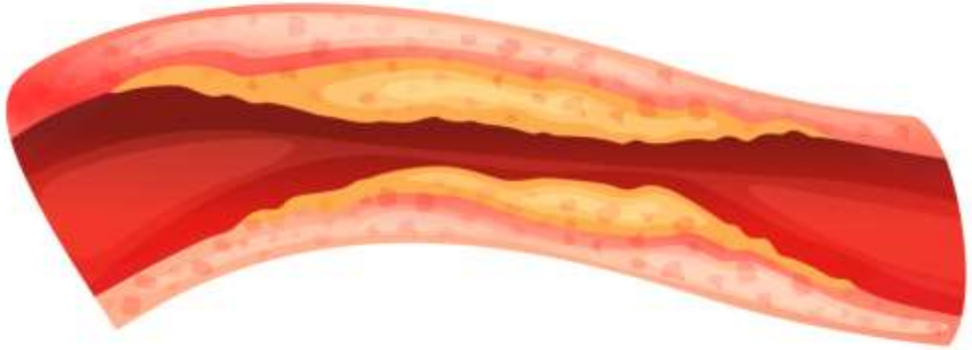


2. Repaired vessel wall



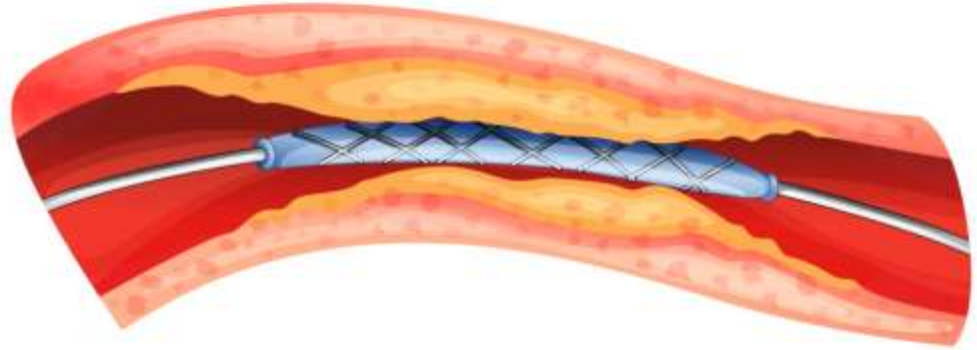
Stent with Balloon Angioplasty

1



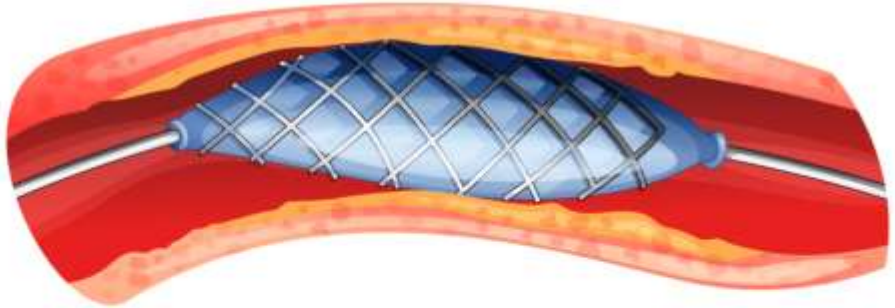
Build up of cholesterol partially blocking blood flow through the artery.

2



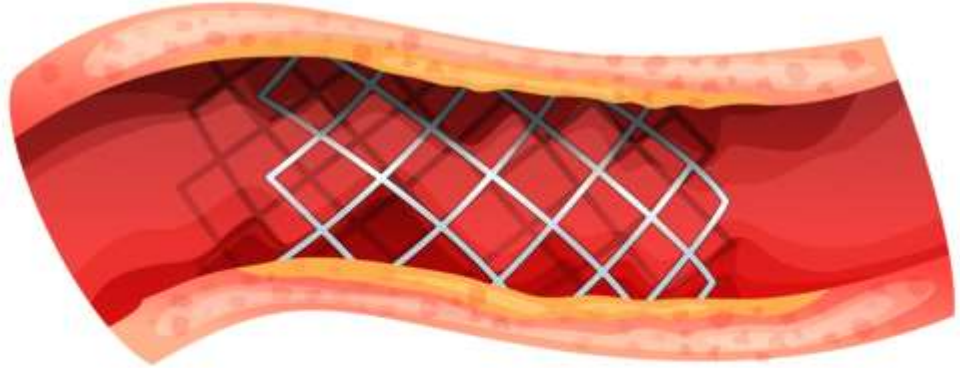
Stent with balloon inserted into partially blocked artery.

3



Balloon inflated to expand stent.

4



Balloon removed from expanded stent.

DESIGN OF STENTS

A stent is a tiny tube that can play a big role in treating your heart disease. It helps keep your arteries -- the blood vessels that carry blood from your heart to other parts of your body, including the heart muscle itself -- open.

Why Would You Need a Stent?

If a fatty substance called plaque builds up inside an artery, it can reduce blood flow to your heart. This is called coronary heart disease and it can cause chest pain.

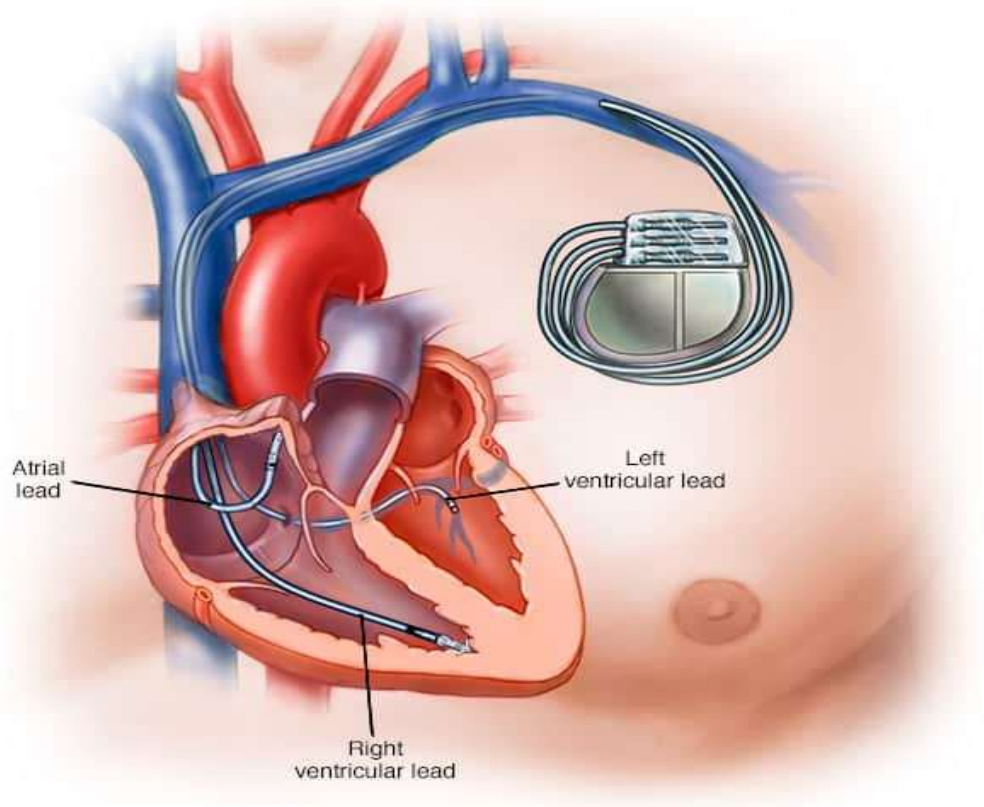
DESIGN

The majority of these stents are constructed from a nickel titanium alloy. Balloon expandable stents are susceptible to permanent deformation when they are compressed extrinsically, which is not an issue in the coronary tree.

- **PACE MAKERS**
- A pacemaker is a small device that's placed (implanted) in the chest to help control the heartbeat.
- It's used to prevent the heart from beating too slowly. Implanting a pacemaker in the chest requires a surgical procedure. A pacemaker is also called a cardiac pacing device.

Types

- Single chamber pacemaker. This type usually carries electrical impulses to the right ventricle of your heart.
- Dual chamber pacemaker. This type carries electrical impulses to the right ventricle and the right atrium of your heart to help control



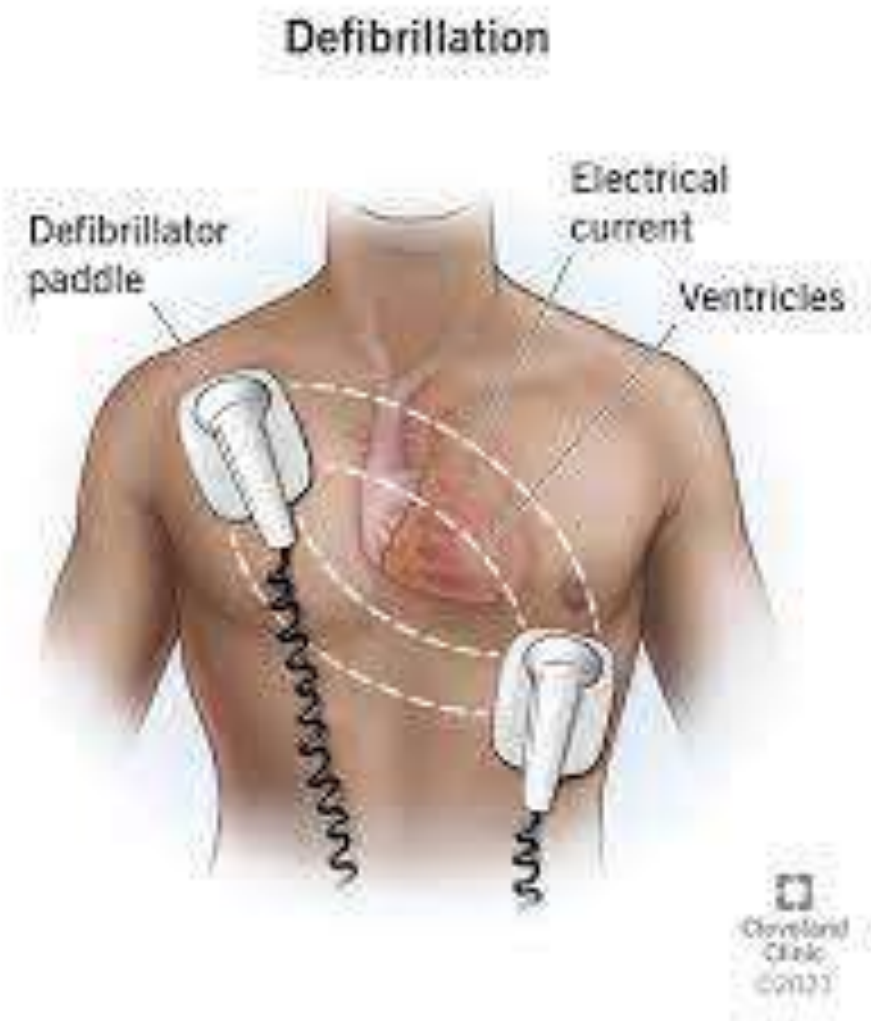
https://www.youtube.com/watch?v=WgKCUjPcDY0

A pacemaker has two parts:

Pulse generator. This small metal container houses a battery and the electrical circuitry that controls the rate of electrical pulses sent to the heart.

Leads (electrodes). One to three flexible, insulated wires are each placed in one or more chambers of the heart and deliver electrical pulses to adjust the heart rate. However, some newer pacemakers don't require leads. These devices, called leadless pacemakers, are implanted directly into the heart muscle.

- **DEFIBRILLATORS**
- **Defibrillators** are devices that send an electric pulse or shock to the heart to restore a normal heartbeat.
- they are used to prevent or correct an arrhythmia, an uneven heartbeat that is too slow or too fast.
- If the heart suddenly stops, defibrillators can also help it beat again. Different types of defibrillators work in different ways.
- Automated external defibrillators (AEDs), which are now found in many public spaces, are used to save the lives of people experiencing cardiac arrest.
- Even untrained bystanders can use these devices in an emergency.



- There are three types of defibrillators: AEDs, ICDs, and WCDs.

- **An AED** is a lightweight, battery-operated, portable device that checks the heart's rhythm and sends a shock to the heart to restore normal rhythm. The device is used to help people having cardiac arrest.
- **ICDs** are placed through surgery in the chest or stomach area, where the device can check for arrhythmias. Arrhythmias can interrupt the flow of blood from your heart to the rest of your body or cause your heart to stop. The ICD sends a shock to restore a normal heart rhythm.
- **WCDs** have sensors that attach to the skin. They are connected by wires to a unit that checks your heart's rhythm and delivers shocks when needed. Like an ICD, the WCD can deliver low- and high-energy shocks. The device has a belt attached to a vest that is worn under your clothes.

THANK YOU