Circulatory system

Heart

Heart is a four-chambered muscular central pumping organ that receives and pumps out blood to whole body. It is basically conical or heart shaped organ with 12 cm (5 in) in length, 8 cm (3.5 in) wide, and 6 cm (2.5 in) in thickness.

Location:

It is situated in the middle mediastinum in between the two lungs and obliquely placed behind the body of sternum. About one third of it is on the right side and two third of it is on the left side of the middle.

Layer of the heart:

Three layers of tissue form the heart wall.

1. Epicardium: The outer layer of the heart wall
2. Myocardium: The middle layer of the heart
3. Endocardium: The inner layer of the heart.

Chamber of heart:

The internal cavity of the heart is divided into four chambers:

1. Right atrium
2. Right ventricle
3. Left atrium
4. Left ventricle

The two atria are thin wall chambered that receive blood from veins. The ventricles are thick walled chambers that forcefully pump blood out of the heart. This differences in thickness is due to the presence of myocardium in chambers. The right atrium receives deoxygenated blood form systemic veins and left atrium receives oxygenated blood from pulmonary veins.

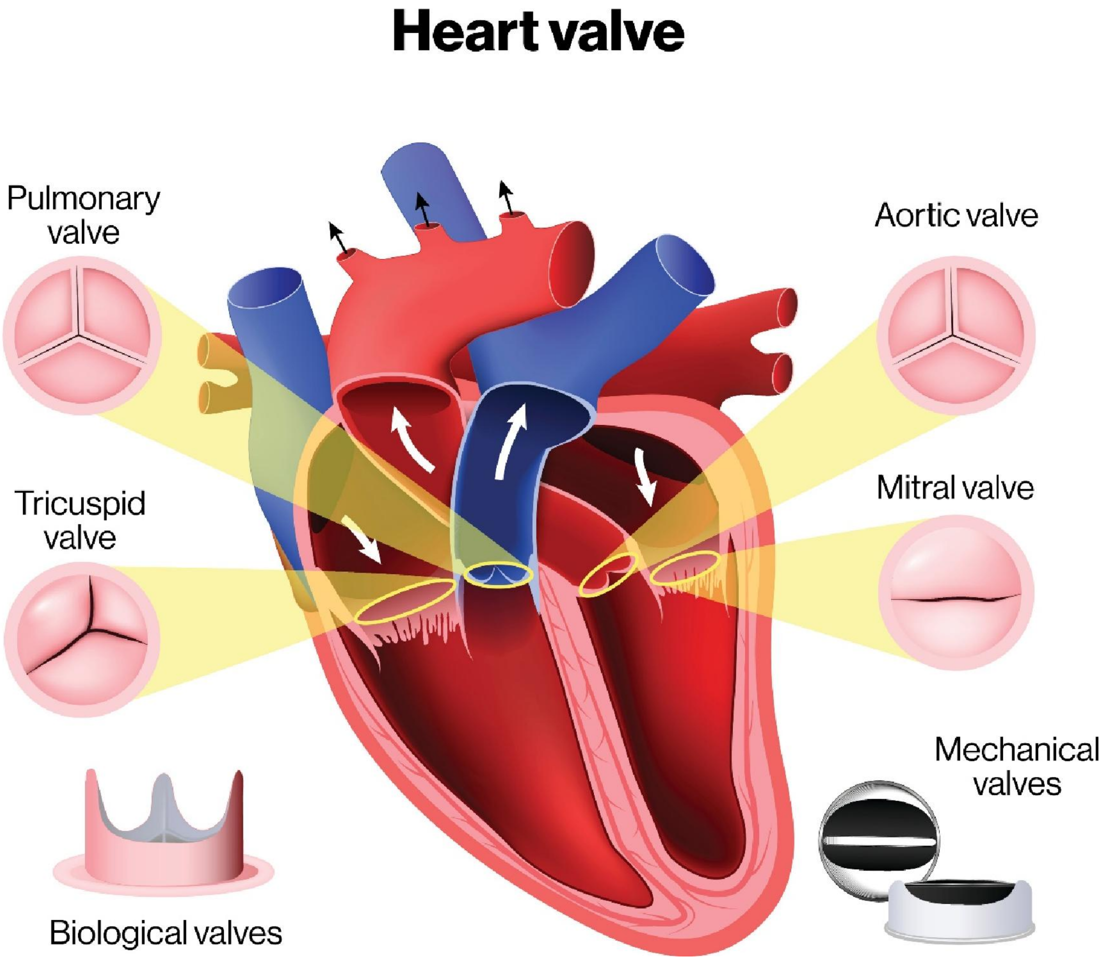
Valves of the heart:

There are four valves in heart.

1. Right atrioventricular valve
   a. It is situated between right atrium and right ventricles
   b. It is also called **tricuspid** valves.
   c. Is has three cusps
      i. Anterior or infundibular
      ii. Posterior or marginal
      iii. Medial or septal

2. Left atrioventricular valve
   a. It is situated between left atrium and left ventricles
   b. It is also called **bicuspid** valves or **mitral** valves
   c. It has two cusps
      i. Anterior or aortic
      ii. Posterior

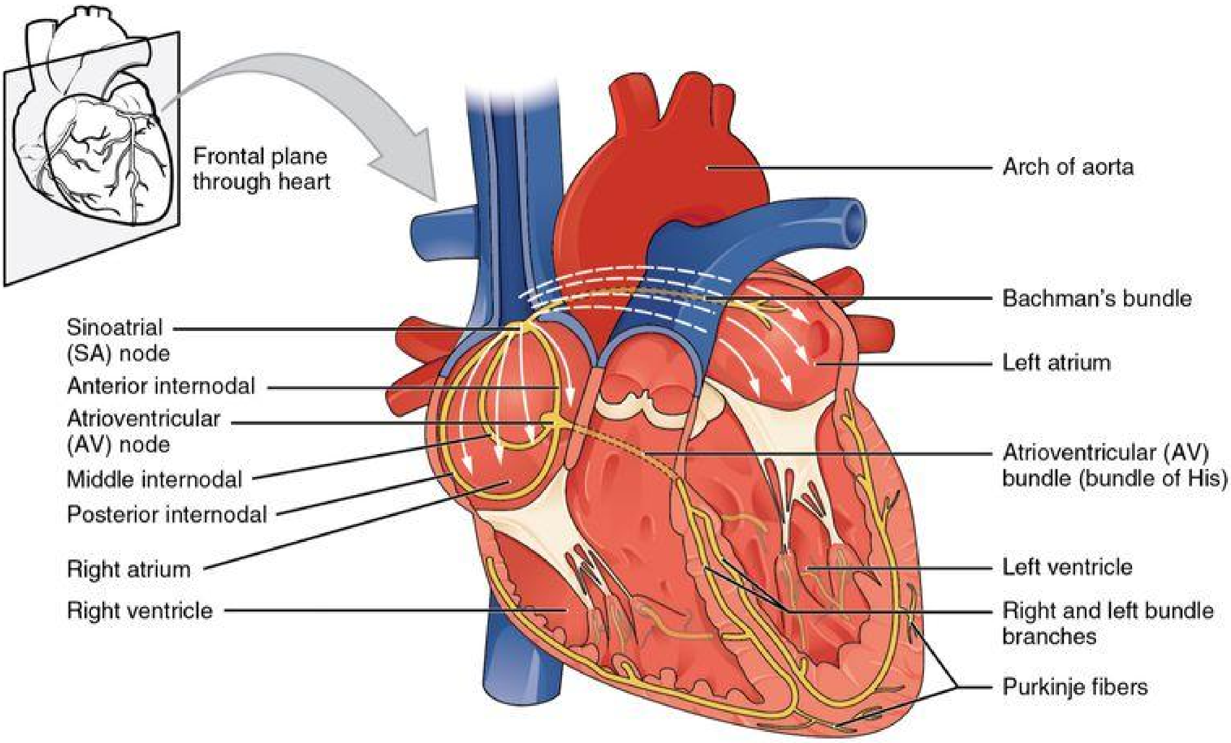
3. Semilunar valves
    a. They are situated at the base of large vessels leaving the ventricles
    b. They are two types: **pulmonary and aortic.**
    c. Pulmonary semilunar valve is situated between the right ventricle and pulmonary trunk.
    d. Aortic semilunar valve is situated between the left ventricle and the aorta.



Heart muscles

It is also called cardiac muscles, made up of involuntary striated muscles, called myocardium. The heart muscles are composed of three major types of cardiac muscles.

1. Atrial muscles
2. Ventricular muscles
3. Specialized excitatory and conductive muscles fibers-
    a. The sinus node (SA node)
    b. The intranodal pathway
    c. The Atrio-ventricular node (AV node)
    d. The AV bundles
    e. Purkinje fibers



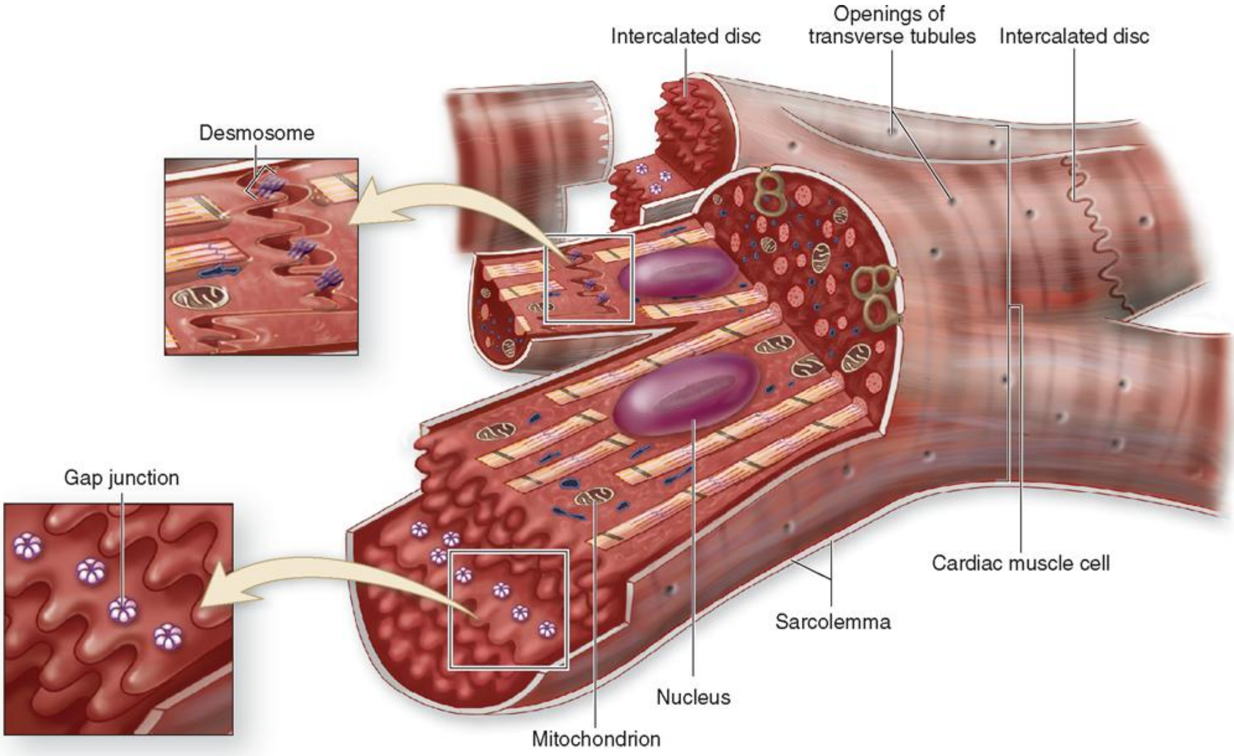
Functional anatomy of heart muscles:

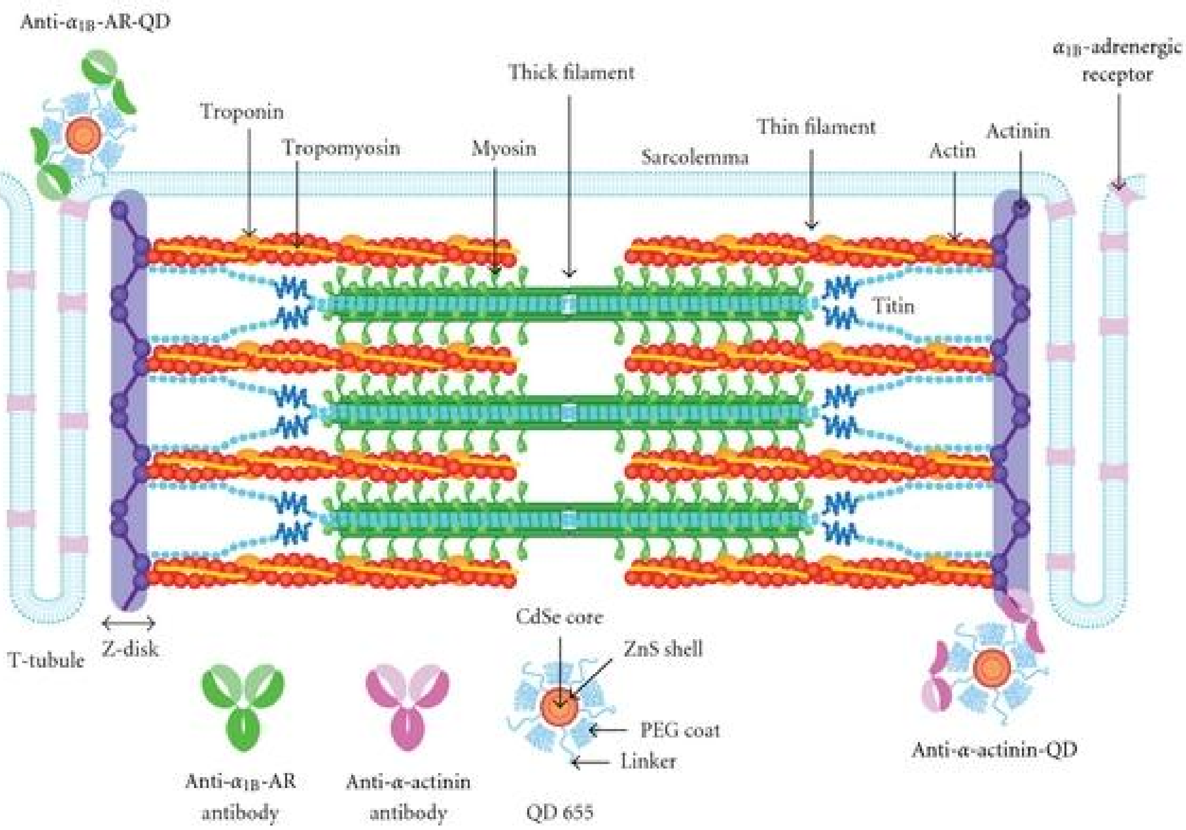
a. **Myocardial cells** or **Myocytes** are the functional unit of myocardium.
b. They are about 100μm long with branched manner.
c. They contain bundle of parallel **myofibrils**.
d. Each myofibril is made up of a series of **sarcomeres.**
e. A sarcomere is bound by two transverse Z lines.
f. The **actin** filaments attached with Z lines and overlap with thicker parallel protein filaments known as **myosin**.
g. Actin and myosin are attached by to each other by cross bridges that contain **ATPase.**
h. **Sarcomere is the contractile unit of myocardium.**
i. The muscle fibers cells are extensively branched and are connected to one another at their ends by **intercalated discs.**
j. Intercalated discs are part of the sarcolemma (cell membrane of a striated muscle fiber cell) and contain two structures: **gap junctions** and **desmosomes.**
k. A **gap junction** forms channels between adjacent cardiac muscle fibers that allow the current to flow from one cardiac muscle cell to the next.
l. A **desmosome** is a cell structure that anchors the ends of cardiac muscle fibers together so the cells do not pull apart during the stress of individual fibers contracting.
m. **Myocardium** are grouped into two population:
   1. Pace maker and conducting cells

i) SA node ii). AV junctionaltissue iii) Bundle of His iv)Purkinje fiber

   2. Working myocardial cells

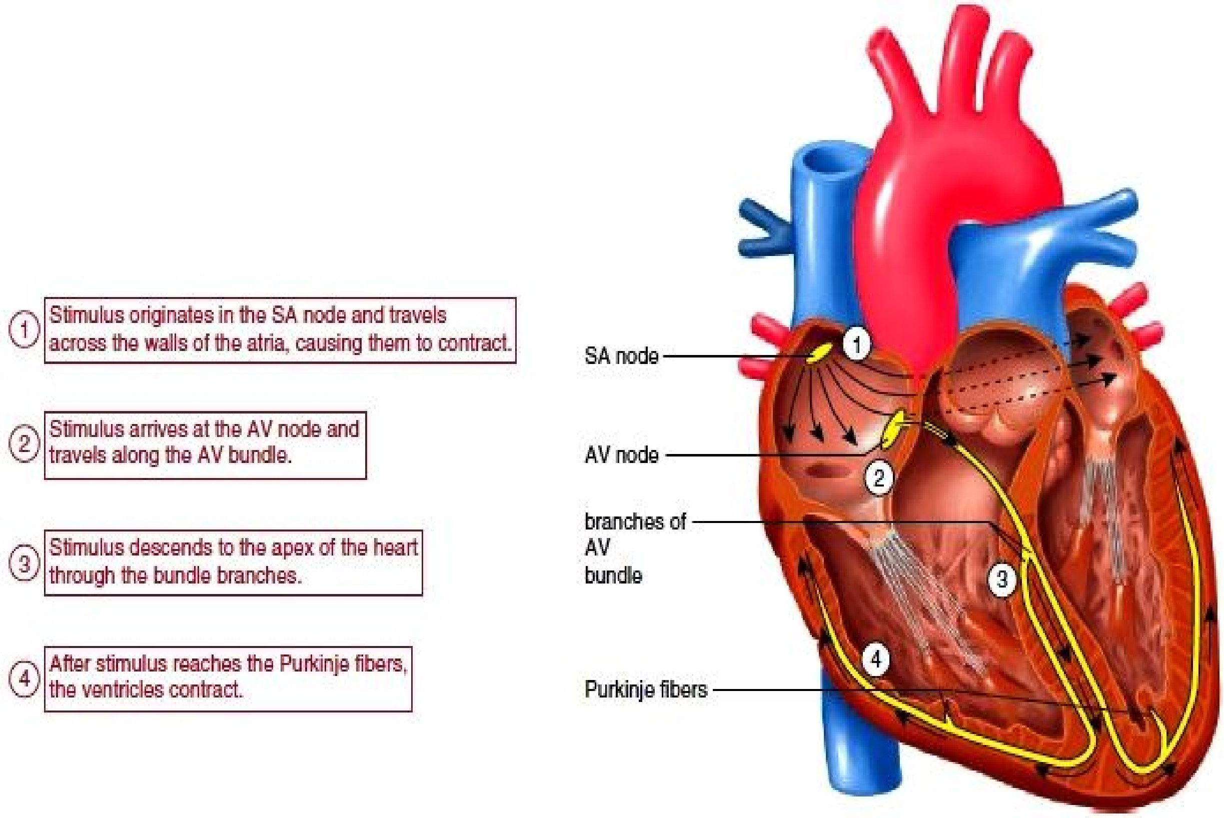
i) Actin ii) Myosin iii) Troponin iv) Tropomyosin


Intercalated disc
Openings of transverse tubules
Intercalated disc
Desmosome
Gap junction
Cardiac muscle cell
Sarcolemma
Nucleus
Mitochondrion


Anti-α_{1B}-AR-QD
Thick filament
α_{1B}-adrenergic receptor
Troponin
Tropomyosin
Myosin
Sarcolemma
Thin filament
Actinin
Actin
Titin
T-tubule
Z-disk
CdSe core
ZnS shell
PEG coat
Linker
Anti-α_{1B}-AR antibody
Anti-α-actinin antibody
QD 655
Anti-α-actinin-QD

Junctional Tissues of Heart

Cardiac muscle consists especially of certain specialized structures which are responsible for initiation and transmission of cardiac impulses at a regular and faster rate than rest of the muscles. These are called junctional tissue of heart.



1. The sinus node (Sino-atrial node or SA node)
2. The internodal atrial pathway
3. The Atrio-ventricular node (AV node)
4. The bundle of His and branches
5. Purkinje Fiber

1. SA node

- It is one of the major elements in the cardiac conduction system that controls the heart rate.
- It is a banana-shaped structure that varies in size, usually between 10-30 mm long, 5–7 mm wide, and 1–2 mm deep.
- In a healthy heart, the SA node continuously produces action potential, setting the rhythm of the heart and so is known as the**heart's natural pacemaker.**
- It consists of a cluster of cells that are situated in the upper part of the wall of the right atrium at the **junction of superior venacava.**These grooves run between the entrance of the superior vena cava and the inferior vena cava.
- It generates electrical impulses and conducts them throughout the muscle of the heart, stimulating the heart to contract and pump blood.
- These cells discharge impulse at a rate of about 70-80impulse per minute, which make up the natural heartbeat.

2. Internodal atrial pathway

- It is the pathway that conduct the impulse from the SA node to AV node and left atrium.
- These internodal tracts contain Purkinje fibers.
- There are three pathways
    1. Anterior internodal tract of Bachman [George Bachmann]
    2. Middle internodal tract of Wenckebach [Karel Frederik Wenckebach]
    3. Posterior internodal tract of Thorel
- Anterior internodal tract, after coming out from SA node, curved around the superior venacava and divided into two parts. Bachman bundle, providing impulse to left atrium, and another merged into AV node.
- Middle internodal tract, arises from the SA node merged into the AV node.
- Posterior internodal tract passes to reach the AV node.
- Combinedly, they serve as peripheral pathway for impulse conduction from SA node to AV node and left atrium.

3. AV node

- It is situated at the posterior and right border of the interatrial septum (the wall of tissue that separates the right and left atria of the heart.)
- The **atrioventricular node**, or **AV node** is a part of the electrical conduction system of the heart that coordinates the top of the heart.
- It is normally conducting impulse between atria and ventricle.
- The cells are basically cardiac muscle fiber with less myofibril.
- They transmit impulse to the ventricle from SA node through bundle of His and its branches at a rate of 0.1 m/sec.
- The rate of AV nodal impulse 40-60 impulse/min.
- In case of failure of SA node, AV node can produce impulse and that is why it is also called **reserve pacemaker.**

4. Bundle of His or AV bundle: [Wilhelm His Jr.]

- It extends from AV nodes and going across the inter ventricular septum.
- At the top of the inter ventricular septum, it is divided into left and right branches.
- The left bundle is further divided into **anterior and posterior fascicle.**
- All the fascicle and branches are merged into Purkinje fibers.
- It is the system that conduct impulse from atrium to ventricles.
- In case of failure of SA or AV nodes, these bundles of His may generate impulse at rate of 30-36 impulse/min.

5. Purkinje fiber

- The Purkinje fibers are specialized conducting fibers with **fewer myofibrils** and a large number of mitochondria.
- They are able to conduct cardiac action potentials more quickly and efficiently than any other cells in the heart.
- It arises from the branches of the Bundle of His, spread from the intraventricular septum to the papillary muscles of the heart.
- The fibers are spread over the all parts of the ventricular myocardium.
- It can initiate impulse at a rate of 15-40 impulse/min.

Properties of heart muscles
The properties of Heart muscles are:

1. Autorhythmicity
2. Excitability & contractility
    a. All or none law
    b. Frank Starling law
3. Conductivity
4. Refractory period
5. Tonicity

A. Autorhythmicity

1. Heart muscles does not require any external stimulation to produce impulse (automaticity) at regular interval (rhythmicity).
2. Heart muscles produce impulse at regular interval without any external stimuli by its junctional tissues.
3. The SA node and junctional tissues produce the impulse rather than myocardial cells.
4. SA node generates the impulse and other junctional tissues propagate them to the whole myocardial cells.

B. Excitability and contractility

1. Heart muscles response to a stimulus of adequate strength and duration.
2. The minimum potential for excitation is -90mV.
3. The stimulus and response both are may be electrical, mechanical or thermal.
4. Heart muscles shows excitability, when subjected to a stimulus and it develops an action potential.
5. This propagated action potential is responsible for initiating contraction.
6. This contraction is due to the chemical and mechanical change in actin and myosin.
7. All contractions generate force and produce squeeze on the blood in ventricle to eject from these cavities.
    a. All or none law

        If an adequate stimulus is applied to heart muscle, the muscles responds to its maximum, but if the stimuli is not adequate, it does not responds at all.

    b. Frank starling law

        Within the physiological limit, the greater the length of cardiac muscle fiber, the greater will be the force of contraction.

C. Conductivity

1. It is the ability to transmit the generated impulse from SA node to the rest of the heart muscles.
2. Impulse generated from the SA node at a rate of 70-80 impulse/min, passes to the junctional fibers of AV node through the internodal pathway at a speed of 0.04 sec.
3. From the junctional fibers, the impulse reaches to AV nodal fibers at a speed of 0.06 sec.
4. The impulse than travels to transitional fibers with a 0.1 sec delay before excitability.

D. Refractory period

1. It is the period during which heart muscle is nonresponsive to external stimuli.
2. The refractory period of heart is 0.30 sec.
3. It is two types: Absolute and relative.
4. In absolute RFP, heart muscle is refractory to any stimuli and it about 0.25 sec.
5. In relative RFP, heart muscle is responsive slightly to any strong stimuli and it is about 0.05 sec.

E. Tonicity

It is the partial contraction of heart muscle over the contained blood.

*** Pace maker (SA node)**

In general sense, Pace maker is that rider that sets the pace of any race. SA node is called the pacemaker of heart because it produces 70-80 impulse/min. Impulses are first generates at SA node and it maintain the whole cardiac rhythm. As the rate and rhythm is higher than any other junctional tissues of heart, SA node is called pace maker of heart.

\# **Cardiac cycle**

The cardiac events that occur from the beginning of one heart beat to the beginning of the next are called the cardiac cycle. The cardiac cycle is inversely proportional to the heart rate. If the normal heart rate is 75, then cardiac cycle would be 60/75 seconds or 0.8 sec.

 # <u>Events of cardiac cycle</u>

In atria

1. Atrial systole

Systole is the period of contraction of heart muscles. Atrial systole initiates the cardiac cycle as the pace maker (SA node) is in the atria. The duration is about 0.1 sec. It propels some blood (30%) into the ventricles.

2. Atrial diastole

Diastole is the period of relaxation of heart muscles. At the end of atrial systole, atrial diastole occurs. During this period, blood enters into atria from great veins. The duration is about 0.7 sec. About 70% of ventricular filling occurs during this time.

In ventricle

3. Ventricular systole

It starts at the end of atrial systole and last for 0.3 sec. At the beginning of this phase, AV and semilunar valves are closed and produced the 1st heart sound. The pressure arises to 120 mm-Hg, and semilunar valves open. This results the ejection of blood from ventricles.

4. Ventricular diastole

It starts at the end of ventricular systole and lasts for 0.5 sec. It starts with the closure of semilunar valves. As the diastole starts, pressure of ventricles falls to 80 mm-Hg and produce the second sound of the heart.

 # <u>Circulation of heart:</u>

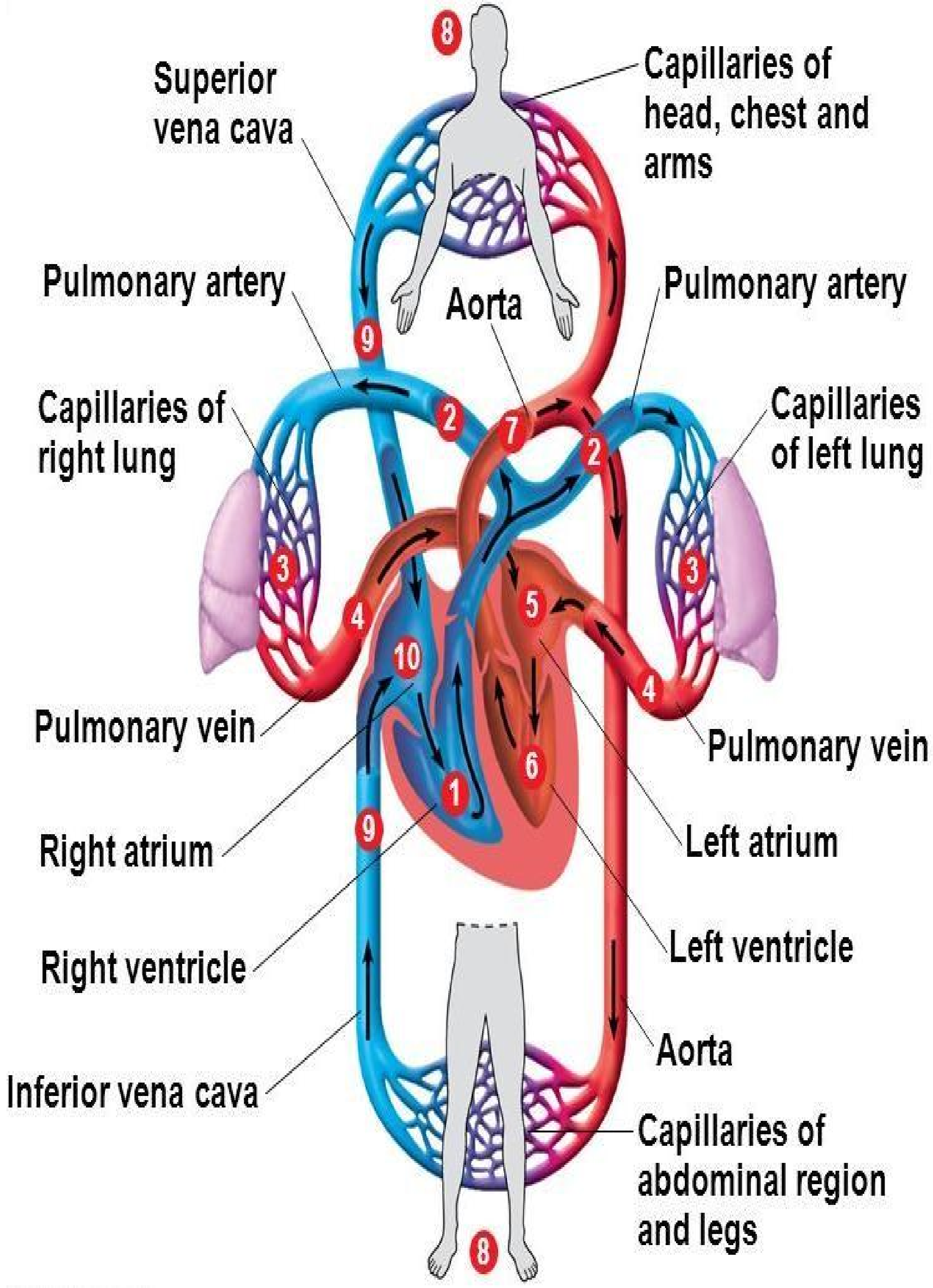
The human circulatory system has two-part systems (**systemic** and **pulmonary**) whose purpose is to bring oxygen-bearing blood to all the tissues of the body. In the **systemic loop**, the blood circulates into the body's systems, bringing oxygen and collecting carbon dioxide waste. In the **pulmonary loop**, the blood circulates to and from the lungs, to release the carbon dioxide and pick up new oxygen.

The Pulmonary loop (Controlled by right side of heart)

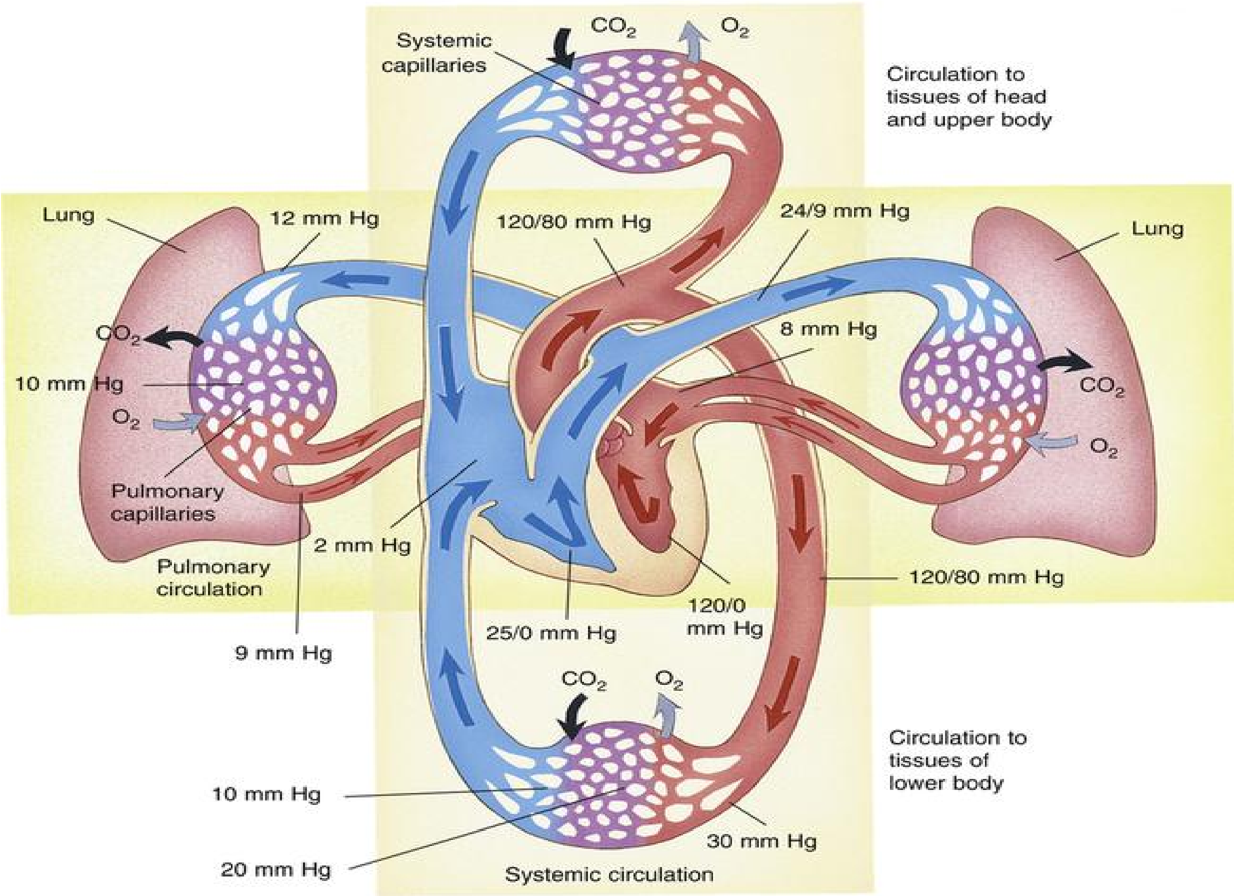
1. From the **right atrium (10)** the oxygen poor blood reaches into the **right ventricle (1)** through the **tricuspid valve**.
2. During ventricle contraction, the blood is pushed into the **pulmonary artery** (2) that divided into two main parts: one to the **left lung (3)** and one to the **right lung (3)**.
3. Here, in lungs carbon dioxide rich blood is converted into oxygen rich blood.
4. The fresh, oxygen-rich blood returns to the **left atrium (5)** of the heart through the **pulmonary veins (4)**.

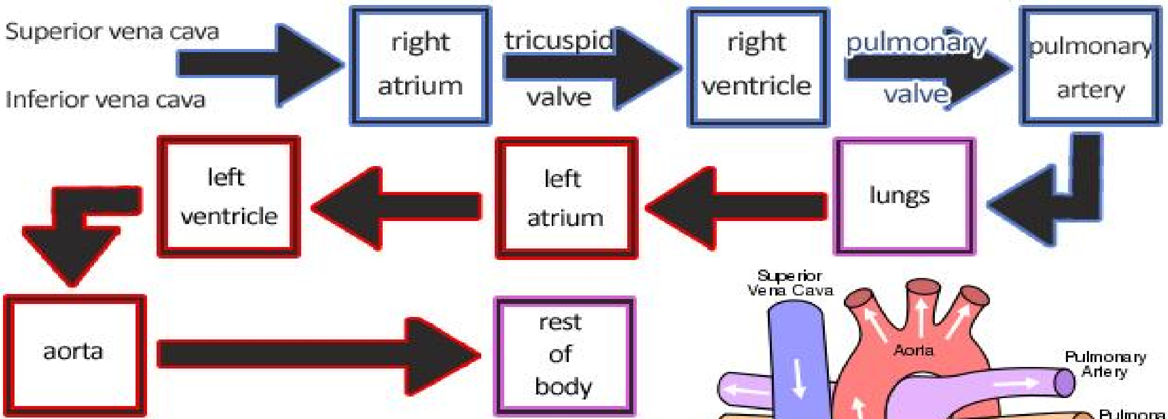
The **systemic loop** (Controlled by left side of heart)

1. The **oxygen-rich** blood coming from the **lungs** (3) enters the **left atrium** (5) of heart through **pulmonary vein (4)**.
2. As the chamber fills, it presses open the **mitral valve** and the blood flows down into the **left ventricle (6)**.
3. During the ventricle **contraction**, the blood on the left side is forced into the **aorta (7)**.
4. The blood leaving the aorta brings oxygen to all the body's cells through the network of **arteries** and **capillaries (8)**.
5. The used blood from the body returns to the heart through **veins**.
6. All of the blood from the body is eventually collected into the two largest veins: the **superior vena cava (9)**, which receives blood from the **upper body**, and the **inferior vena cava**, which receives blood from the **lower body** region.
7. Both veins, reach the blood into the **right atrium (10)** of the heart.

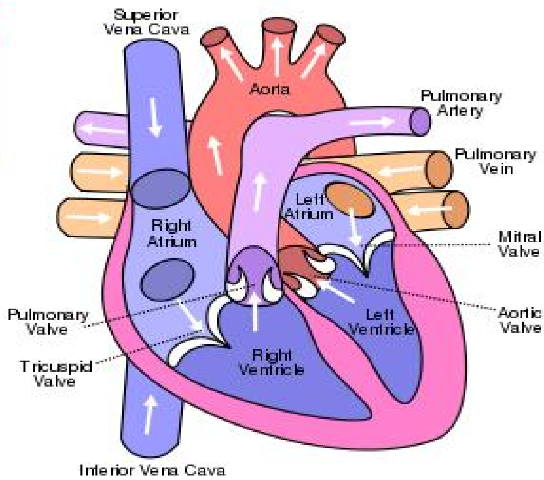


8
Superior vena cava
Capillaries of head, chest and arms
Pulmonary artery
Aorta
Pulmonary artery
9
Capillaries of right lung
2
7
2
Capillaries of left lung
3
4
5
3
10
4
Pulmonary vein
Pulmonary vein
6
1
9
Right atrium
Left atrium
Right ventricle
Left ventricle
Aorta
Inferior vena cava
Capillaries of abdominal region and legs
8





Circulation of Blood Through the Heart:



PULMONARY CIRCULATION
VERSUS
SYSTEMIC CIRCULATION

Pulmonary circulation	Systemic circulation
Pulmonary circulation carries deoxygenated blood from the right ventricle of the heart to the lungs through the pulmonary artery	Systemic circulation carries oxygenated blood from the left ventricle of the heart to the rest of the body by the aorta
Carries oxygenated blood from the lungs to the left atrium of the heart by the pulmonary vein	Carries deoxygenated blood from the body to the right atrium of the heart by the superior and inferior vena cava
Composed of pulmonary artery and pulmonary vein	Composed of inferior and superior vena cava, aorta, and other small blood vessels
Carries blood to the lungs	Carries blood throughout the body
Helps to release carbon dioxide from the blood while dissolving oxygen in the blood	Helps to provide nutrients and oxygen to the metabolizing cells in the body

PATHWAYS OF CIRCULATION

- PULMONARY CIRCULATION
  - It begins at the right ventricle, continues through the lungs, and terminates at the left atrium.
- SYSTEMIC CIRCULATION
  - It begins at the left ventricle, continues through all other body systems in parallel pathways, and terminates at the right atrium.
- HEPATIC PORTAL (SPALANCHNIC) CIRCULATION
  - This is a subdivision of systemic circulation in which blood from the abdominal digestive organs and spleen circulates through the liver before returning to the heart.

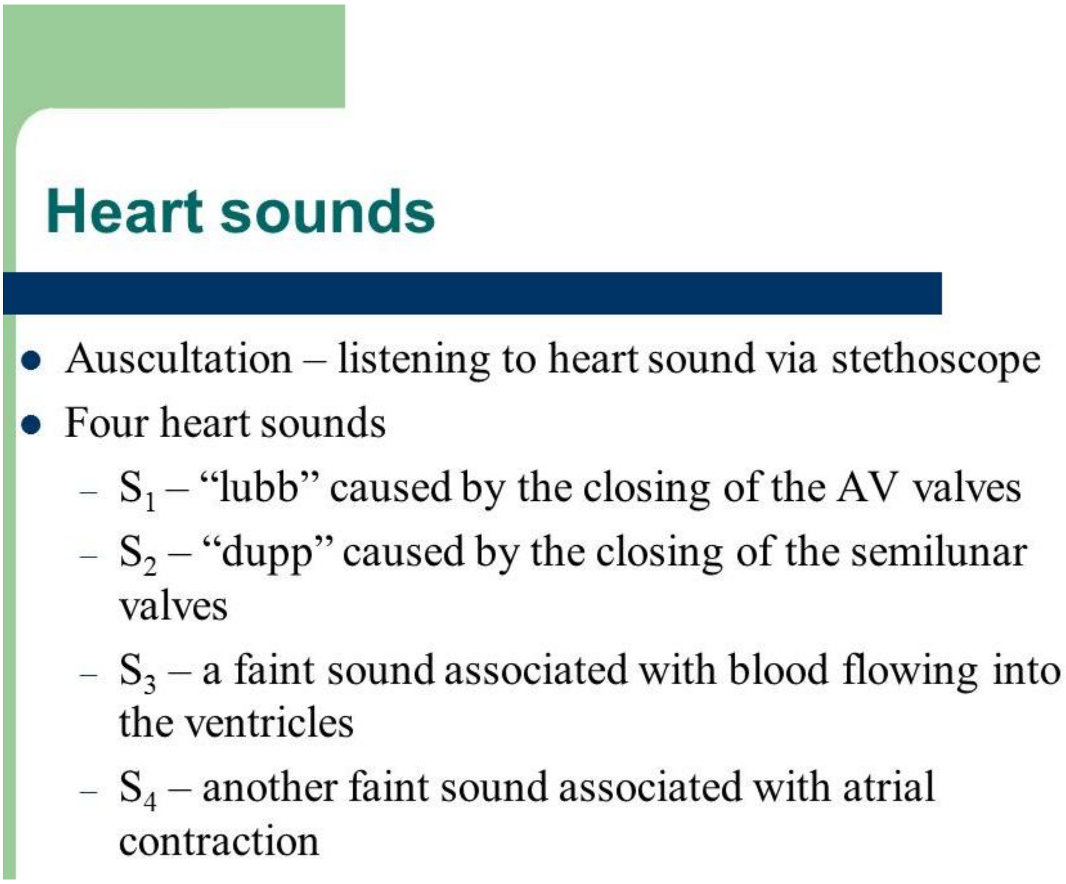
Renal Circulation:

The renal circulation supplies the blood to the kidneys via the renal arteries, left and right, which branch directly from the abdominal aorta. Despite their relatively small size, the kidneys receive approximately 20% of the cardiac output.

Cerebral circulation: Cerebral circulation is the movement of blood through the network of cerebral arteries and veins supplying the brain.

\# **Heart sound**

The vibratory motion of heart produced during the different events of cardiac cycle through the heart structure and produced special audible sound called heart sound. Heart sound is four in number. 1st and 2nd heart sound is audible through stethoscope but 3rd and 4th is detected by phonocardiograph.



Clinical significance:

1. Diagnosis of valvular heart diseases
2. Diagnosis of cardio-dynamic status
3. Diagnosis of congenital heart disease
4. Differentiating the murmur whether it is systolic or diastolic in origin.

Pulse

Pulse is the rhythmic dilation and elongation of atrial wall as a result of pressure changes created by the ejection of blood from heart to the periphery. The normal range of pulse is 6090/min.

Cardiac output

The amount of blood that ejected by each ventricle or pumped into the aorta per minute by heart is called cardiac output.

Cardiac output CO= stroke volume* heart rate = 70*72 ml = 5042 ml/minute = 5.04 liter/min.

As, stroke volume is 70 ml/beat and heart rate is 72 beats/min (average).

Stroke volume

The amount of blood pumped out by each ventricle in each beat is called stroke volume. It is about 70 ml. Stroke volume= end diastolic volume – end systolic volume.

Factors affecting cardiac output

1. Physiological
    a. Age: CO increase with ages
    b. Sex: Due to less body weight and surface area, female has 10-20% less CO than male.
    c. Surface area: More the surface area, more the CO.
    d. Posture: CO is greater in sitting and lying than erect posture.
    e. Exercise: CO markedly increase in severe exercise.
    f. Emotion, Temperature.
2. Pathological
    a. Hyperthyroidism: CO increase due to high body metabolism.
    b. Fever: CO increase as temperature and metabolism increases.
    c. Anemia, Fibrillation, Flutter

Factors regulating cardiac output:

1. Venous return 2. Force of contraction of heart 3. Frequency of heartbeat 4. Ejection fraction

5. Peripheral resistance

Cardiac index

The cardiac output per minute per square meter of body surface area is called cardiac index. The average value is 3.5 liter/min/Sq.m

End systolic volume

The volume of blood which remains in each ventricle at the end of the ventricular systole. It is about 40-50 ml.

 # End diastolic volume

The volume of blood which remains in each ventricle at the end of the ventricular diastole. It is about 110-120 ml.

 # Venous return

It is the amount of blood that come from periphery to right atria of heart in each minute. It is equal to cardiac output. It is about 5 liter/min.

 # Total Peripheral resistance

It is the resistance in which blood has to overcome while passing though the periphery. It is expressed as TPR= P/Q, where p is the pressure and Q is flow of blood.

Blood pressure: It is the force that **blood** exerts upon the walls of the **blood** vessels or chambers of the heart.

Comparison chart

Diastolic versus Systolic comparison chart		
	Diastolic	**Systolic**
Definition	It is the pressure that is exerted on the walls of the various arteries around the body in between heart beats when the heart is relaxed.	It measures the amount of pressure that blood exerts on arteries and vessels while the heart is beating.
Normal range	60 – 80 mmHg (adults); 65 mmHg (infants); 65 mmHg (6 to 9 years)	90 – 120 mmHg (adults); 95 mmHg (infants); 100 mmHg (6 to 9 years)
Importance with age	Diastolic readings are particularly important in monitoring blood pressure in younger individuals.	As a person's age increases, so does the importance of their systolic blood pressure measurement.
Blood Pressure	Diastolic represents the minimum pressure in the arteries.	Systolic represents the maximum pressure exerted on the arteries.
Blood Vessels	Relaxed	Contracted
Blood Pressure reading	The lower number is diastolic pressure.	The higher number is systolic pressure.

Heart rate

The number of heart beat per minute is called heart rate. The normal range is, 60-90/min for adult with an average of 72 beat/min.

Factors affecting heart rate

1. Respiration: HR increases during inspiration and decrease while expiration.
2. Cardio-vascular reflexes: Stimulation of baro receptor decrease and stimulation of Brain Bridge increases the HR.
3. Temperature: Increasing temperature increase the HR by stimulating SA node.
4. Intra cranial pressure: Increase intra cranial pressure slows down the HR.
5. Muscular exercise: It increase HR by decreasing O2 and increasing Body temperature.
6. Age: From infancy to old age, it progressively decreases.
7. Gender: Female has slight faster HR than male.
8. Surface area: HR in inversely proportional to surface area.

Tachycardia

The term, tachycardia means fast heart rate. The increase of HR above 100 beats/min is usually referring to as tachycardia.

Bradycardia

The term, bradycardia means slower heart rate. The decrease of HR below 60 beats/min usually refer to as bradycardia.

****

- **Autonomic nervous system**: The part of the nervous system that regulates the involuntary activity of the heart, intestines, and glands.
- **Sympathetic nervous system**: Part of the autonomic nervous system that under stress raises blood pressure and heart rate, constricts blood vessels, and dilates the pupils.
- **Parasympathetic nervous system**: Part of the autonomic nervous system that inhibits or opposes the effects of the sympathetic nervous system.

Norepinephrine: A catecholamine with multiple roles including as a hormone and neurotransmitter. Areas of the body that produce or are affected by this substance are described as noradrenergic.

Cardiovascular Center: The cardiovascular center is a part of the autonomic nervous system and is responsible for regulation of cardiac output.

Located in the **medulla oblongata, the** cardiovascular center contains **three distinct** components: the cardioaccelerator center, the cardioinhibitor center, and the vasomotor center. They are cluster of neurons that function independently to regulate blood pressure and flow.

- The **cardioaccelerato**r center stimulates cardiac function by regulating heart rate and stroke volume via sympathetic stimulation from the cardiac accelerator nerve.
- The **cardioinhibitor** center slows cardiac function by decreasing heart rate and stroke volume via parasympathetic stimulation from the vagus nerve.
- The **vasomotor center** controls vessel tone or contraction of the smooth muscle in the tunica media. Changes in diameter affect peripheral resistance, pressure, and flow.
- **Baroreceptors**: A nerve ending that is sensitive to changes in blood pressure. Baroreceptors are specialized stretch receptors located within thin areas of blood vessels and heart chambers that respond to the degree of stretch caused by the presence of blood.

- They send impulses to the cardiovascular center to regulate blood pressure.
- The **aortic sinuses** are found in the walls of the ascending aorta just superior to the **aortic valve**, whereas the **carotid sinuses** are located in the base of the **internal carotid arteries.**
- When blood pressure increases, the baroreceptors are stretched more tightly and initiate action potentials at a higher rate.
- At lower blood pressures, the degree of stretch is lower and the rate of firing is slower. When the cardiovascular center in the medulla oblongata receives this input, it triggers a reflex that maintains homeostasis.

Baroreceptors are found in :

- **Carotid Sinuses (blood going to brain) by glossopharyngeal nerve**
- **Aortic Arch (systemic blood going to body) by vagus nerve**

Blood pressure: It is the force exerted by circulating blood against the walls of the body's arteries, the major blood vessels in the body.

Blood pressure= Cardiac output × Peripheral resistance

= (Stroke volume× heart rate) × Peripheral resistance

Hypertension may be defined as the sustained elevation of systemic arterial blood pressure above the normal level related to the age and sex of the individual.

Types of hypertension:

Based on etiology / causes, Hypertension is of two types, such as-

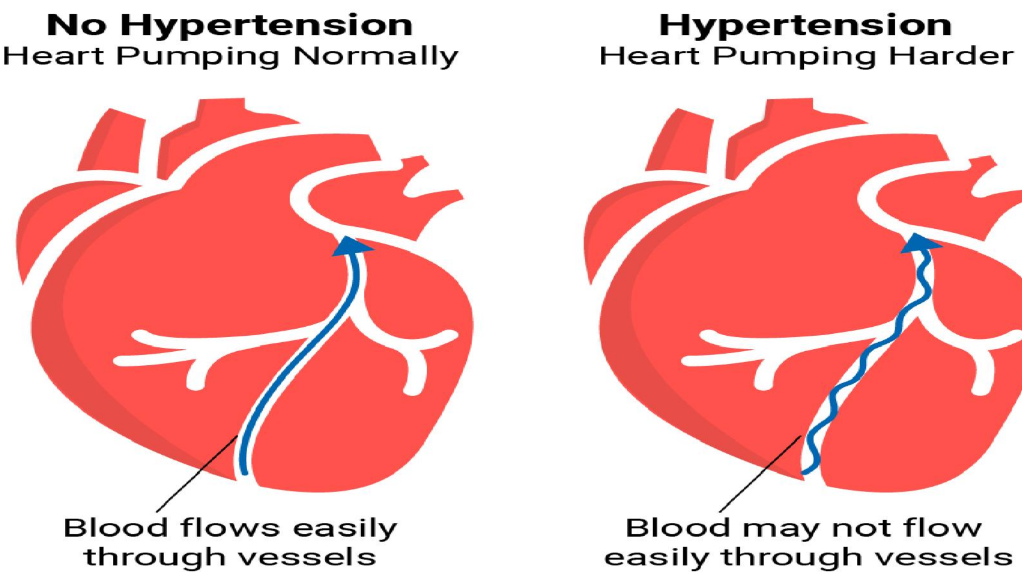
1. **Essential / primary/idiopathic hypertension:**

In this type of hypertension, no specific cause of it is not found. About 80-90% of hypertension is primary. Here, Peripheral resistance is increased but cardiac output is normal.

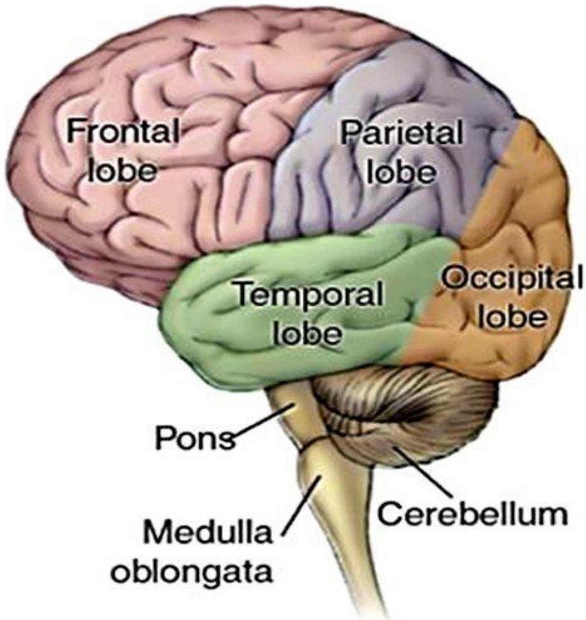
2. **Benign / Secondary hypertension:**

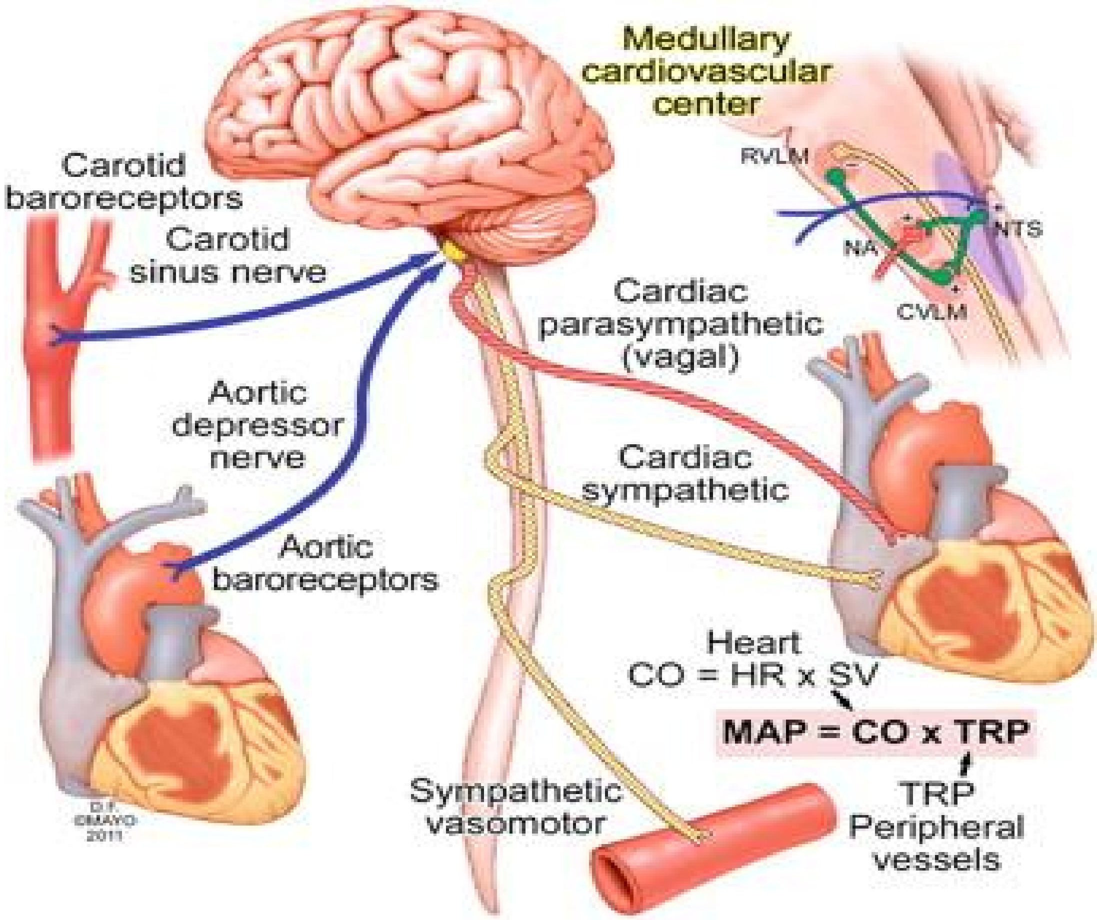
In this type of hypertension, specific cause of it is found. About 10-15% of hypertension is secondary. Here, cardiac output increases. It occurs due to other reasons.

Category	Systolic (mmHg)		Diastolic (mmHg)
Optimal	<120	and	<80
Prehypertension	120-139	or	80-89
Stage 1 hypertension	140-159	or	90-99
Stage 2 hypertension	≥160	or	≥100



Anatomy of the Brain





Regulation of Blood Pressure:

- There are two basic mechanisms for regulating blood pressure:
  (1) **short-term mechanisms.**
  regulate blood vessel diameter, heart rate and contractility
  (2) **long-term mechanisms.**
  regulate blood volume
- **Blood Pressure = cardiac output x peripheral resistance**
- Any change in cardiac output, blood volume or peripheral resistance will lead to a change in blood pressure.

1 Short-Term Regulation

- **Rapidly Acting Pressure Control Mechanisms, Acting Within Seconds or Minutes.**

A. Baroreceptor reflexes (60 – 100 mmHg)
   Change peripheral resistance, heart rate, and stroke volume in response to changes in blood pressure

B. Chemoreceptor reflexes (40 – 60 mmHg)
   Sensory receptors sensitive to oxygen lack, carbon dioxide excess, and low pH levels of blood

C. Central Nervous System ischemic response (< 40 mmHg)
   Results from severe decrease blood flow to the brain

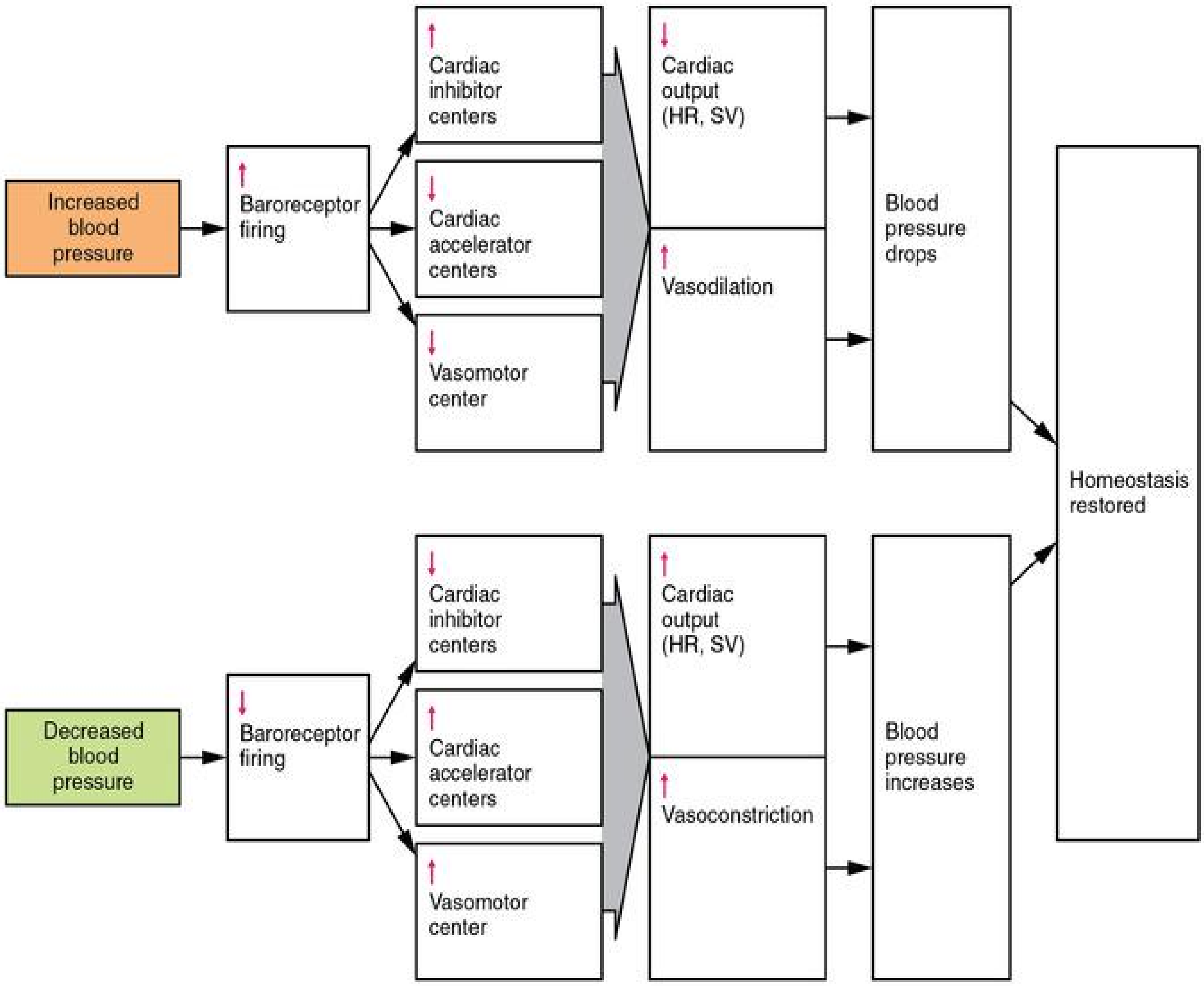
2. Long term control of blood pressure

- Involves control of blood volume/sodium balance by the kidneys
  - Hormonal control
    - Renin-angiotensin-aldosterone system
    - Antidiuretic hormone (vasopressin)
    - Atrial natiuretic peptide
  - Pressure natriuresis

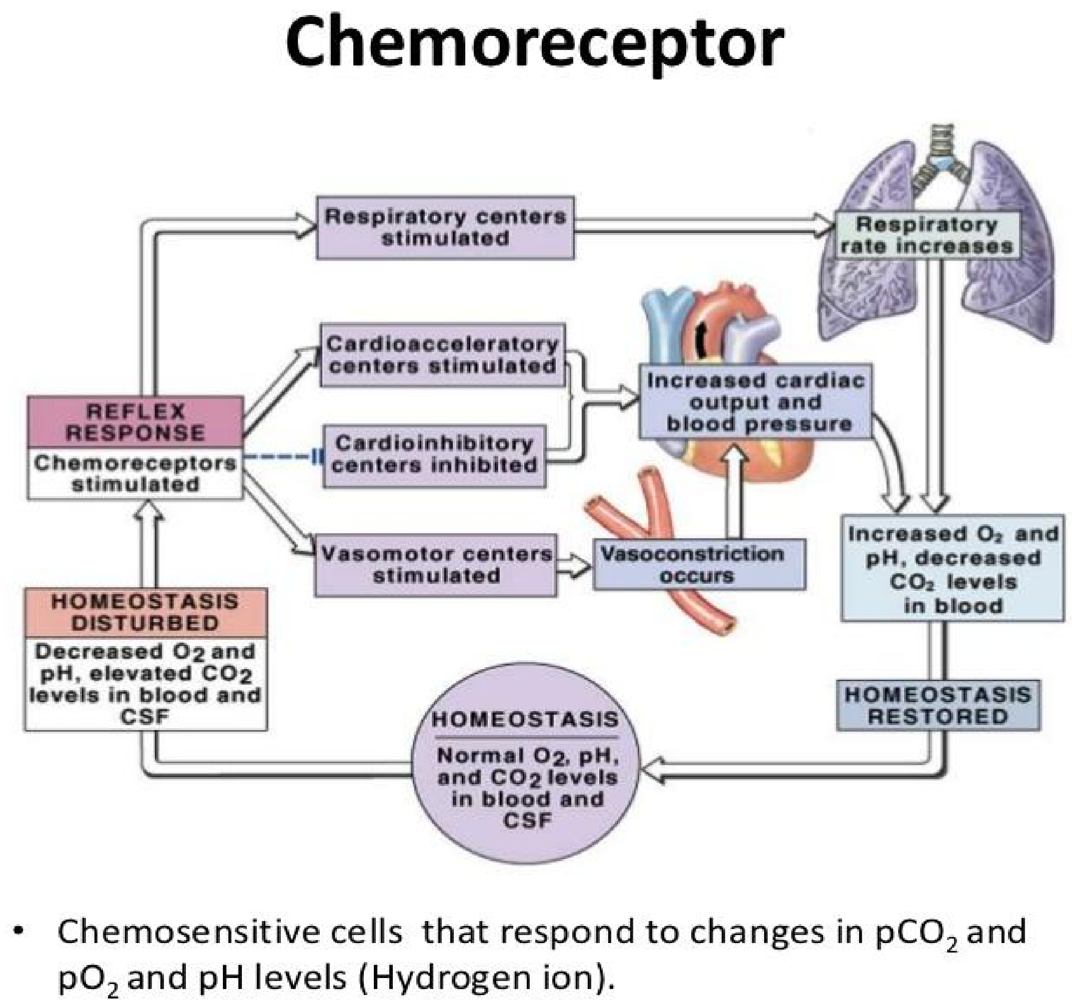
1A. Baroreceptor Reflexes:

When blood pressure **rises too high,** baroreceptors fire at a **higher rate** and trigger **parasympathetic stimulation** of the heart. As a result, cardiac output falls. Sympathetic stimulation of the peripheral arterioles will also decrease, resulting in vasodilation. Combined, these activities cause blood pressure to fall.

When blood pressure **drops too low,** the rate of baroreceptor firing decreases. This triggers an increase in **sympathetic stimulation** of the heart, causing cardiac output to increase. It also triggers sympathetic stimulation of the peripheral vessels, resulting in vasoconstriction. Combined, these activities cause blood pressure to rise.



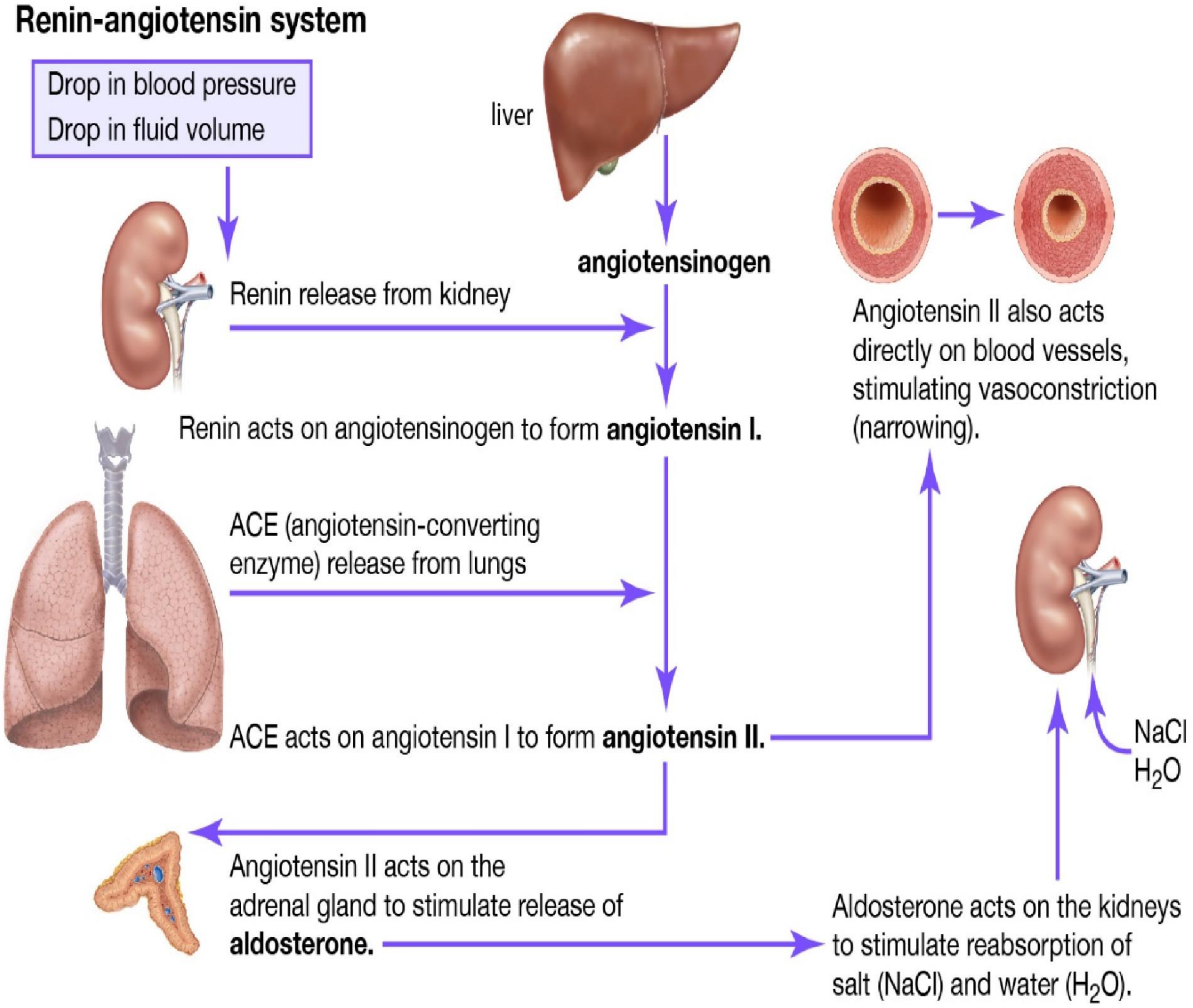
1B.Chemoreceptor mechanism:



2. Long-Term Regulation:

- **Juxtaglomerular cells**: The juxtaglomerular cells (JG cells, or granular cells) are cells in the kidney that synthesize, store, and secrete the enzyme renin.
- **Adrenal cortex**: The outer portion of the adrenal glands that produces hormones essential to homeostasis.
- **Aldosterone**: A mineralocorticoid hormone secreted by the adrenal cortex that regulates the balance of sodium and potassium in the body.

Renin-angiotensin-aldosterone system



 # Depolarization and repolarization of heart muscles

- Cardiac cells at **rest** are considered **polarized**, meaning no electrical activity takes place.
- Myocardial cell has a negative membrane potential when at rest.
- Electrical **impulses** are generated by automaticity of specialized cardiac cells.
- Once an electrical cell generates an electrical impulse, this electrical impulse causes the ions to cross the cell membrane, called **action potential.**
- Stimulation above a threshold value induces the opening of **voltage-gated ion channels** and a flood of cations into the cell.
- The **positively charged ions** entering the cell cause the **depolarization** characteristic of an action potential.
- The movement of ions across the cell membrane through **sodium, potassium and calcium** channels, cause **contraction** of the cardiac cells/muscle **(systole).**

- Depolarization with corresponding contraction of myocardial muscle moves as a **wave** through the heart.
- **Repolarization** is the return of the ions to their previous resting state, which corresponds with **relaxation** of the myocardial muscle (**diastole**).
- After a delay, **potassium channels** reopen, and the resulting flow of K+ out of the cell causes **repolarization** to the resting state.
- **Depolarization** and **repolarization** are electrical activities which cause muscular activity.
- The **action potential** curve shows the **electrical changes** in the myocardial cell during the depolarization – repolarization cycle.
- This **electrical activity** is what is detected on ECG, not the **muscular activity**.

 # Action potential

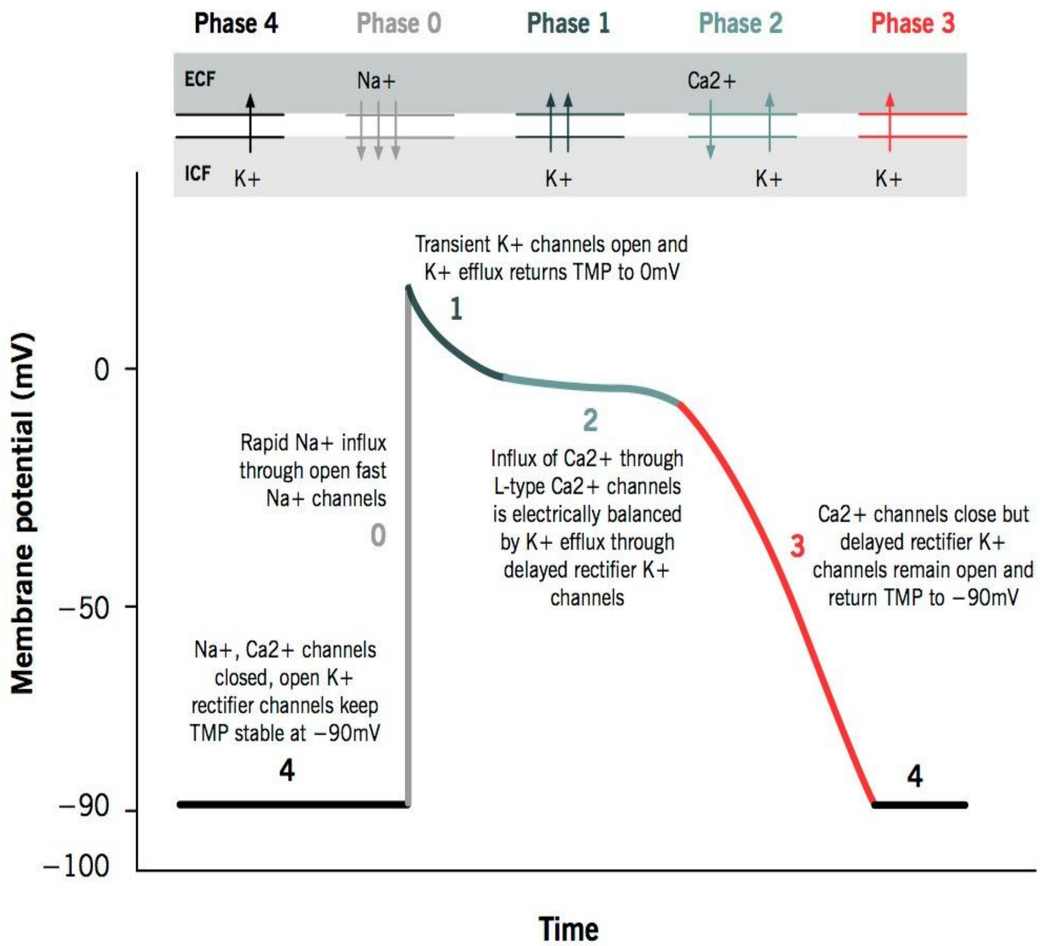
The cardiac action potential is a brief change in voltage (membrane potential) across the cell membrane of heart cells. This is caused by the movement of ions between the inside and outside of the cell, through ion channels.

NB: The leakage of these ions, across the membrane is maintained by the activity of pumps which serve to keep the intracellular concentration more or less constant.

1. The **sodium (Na+)** and **potassium (K+)** ions are maintained by the **sodium-potassium pump** which uses energy (in the form of adenosine triphosphate (ATP)) to move three Na+ out of the cell and two K+ into the cell.
2. The **sodium-calcium exchanger** which, removes one Ca2+ from the cell for three Na+ into the cell.

 # Phases of action potential

The resting membrane potential of myocardial cells, is around -90 millivolts. That is inside of the membrane is more negative than the outside. The main ions found outside the cell at rest are: sodium (Na+), and chloride (Cl−), whereas inside the cell it is mainly potassium (K+).



Phase 0: Depolarization

1. An action potential triggered in a neighboring cardio myocyte, causes the membrane potential to rise above −90 mV.
2. Na+ channels start to open one by one and Na+ leaks into the cell, further raising the membrane potential.
3. Membrane potential approaches to −70mV, at this point, enough fast Na+ channels have opened to generate a self-sustaining inward Na+ current.
4. The large Na+ current rapidly depolarizes the MP to 0 mV.
5. As Na+ channels are time-dependent, Na+ channels are closed.
6. L-type ("long-opening") Ca2+ channels open when the TMP is greater than −40 mV.

Phase 1: Early repolarization

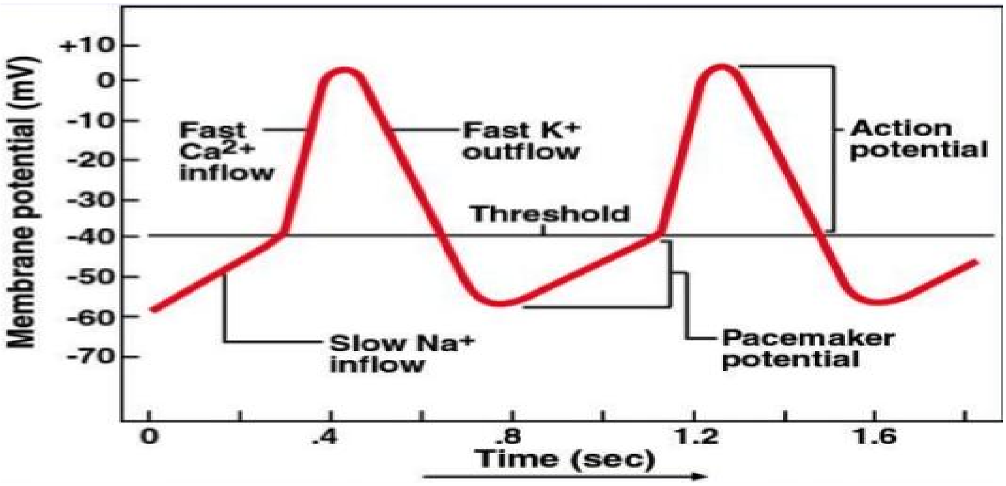
1. This phase begins with the rapid inactivation of the Na+ channels.
2. At the same time potassium channels open and close rapidly, allowing for a brief flow of potassium ions out of the cell, making the membrane potential slightly more negative.

Phase 2: The plateau phase

1. Ca^{2+} channels are still open and there is a small, constant inward current of Ca^{2+}.
2. K+ leaks out down its concentration gradient through K+ channels.
3. These two countercurrents are electrically balanced, and the membrane potential is maintained at a plateau just below 0 mV throughout phase

Phase 3: Repolarization

1. Ca^{2+} channels are gradually inactivated.
2. Persistent outflow of K+, brings membrane potential back towards resting potential of −90 mV to prepare the cell for a new cycle of depolarization.



 # ECG (electrocardiogram)

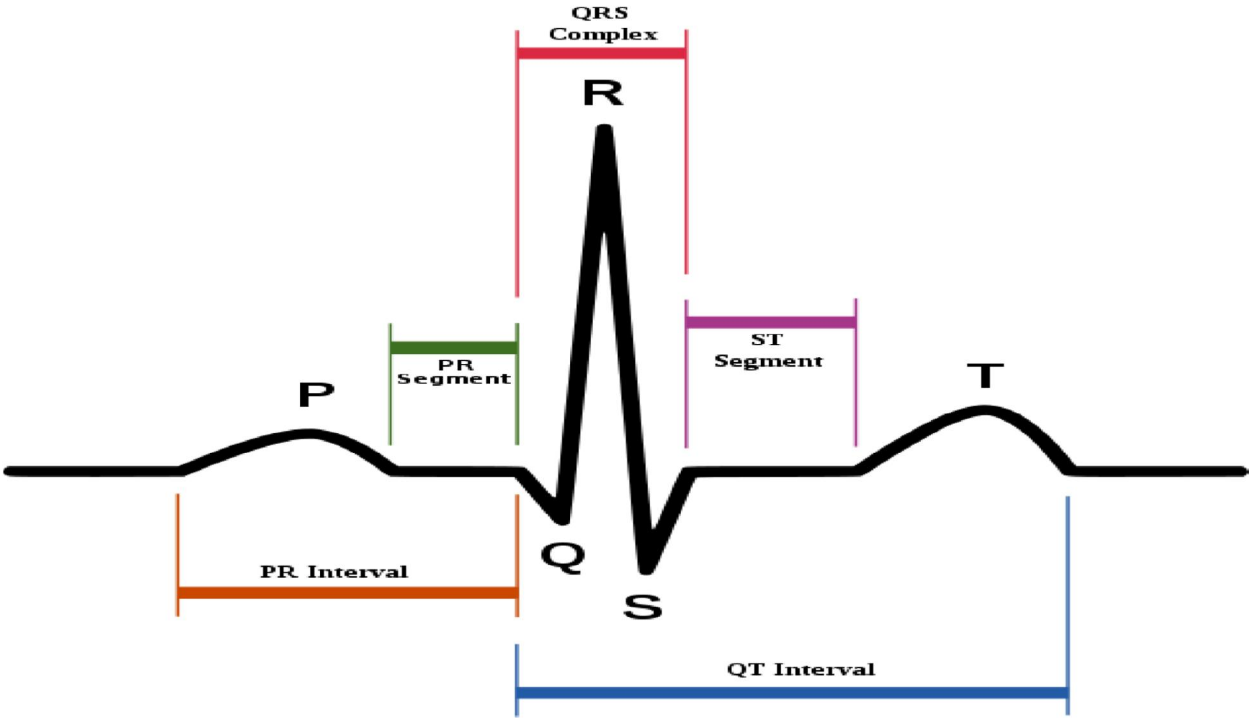
It records the electrical changes of heart from the surface of the body in each cardiac cycle.

 # A typical normal ECG

A normal ECG shows five consecutive waves PQRST. Of these there are three positive waves, P, R, T and two negative waves, Q, S and a complex QRS.

1. P wave:
   a. It is the first upward deflection with small constant wave.
   b. This represents the sequential activation of left and right atria (atrial depolarization).
   c. This impulse is originated in SA node with 0.10 sec duration and at 25 mv voltage.
   d. It indicates that SA node function properly.

2. Q wave:
    a. It is a downward, small deflection.
    b. It represents septal depolarization from left to right as it is caused by septal activity.
    c. It normally represents the left ventricular functions.
    d. Q wave greater than 1 small square in width and deeper than 2 mm, indicates the myocardial infraction.
3. R wave:
    a. It is an upward deflection with hith constant and conspicuous tallest peak.
    b. It follows immediately after Q wave.
    c. It indicates the apical left ventricular depolarization.
4. S wave:
    a. It is the downward deflection next to R wave.
    b. It represents the posterior basal left ventricular depolarization.



3. QRS complex:
    a. QRS complex represents the activation of right and left ventricles.
    b. It is produced by ventricular depolarization and atrial repolarization.
    c. The total duration is 0.08-0.10 sec.
    d. Due to large ventricular mass, the peak is larger than P wave.

4. T wave:

   a. It is a slow and low wave produced by ventricular repolarization.
   b. It has the duration of 0.13 sec with 0.2-0.4 mV voltage.
   c. Inversion of T wave seen in ischemia, heart block or digoxin toxicity.

5. ECG intervals:

a. P-R intervals

i. It is the length of the time from the start of P wave to the start of QRS complex.
ii. Duration is 0.12-0.20 sec.
iii. 0.4 sec interval indicates that heart block can occur at any time.

b. QT intervals

It extends from the start of the QRS complex to the end of the T wave.

i. Duration is < 0.44 sec.
ii. The lengthened of QT interval indicates the incident of sudden death.

c .R-R intervals

i. It is the interval of between two successive R waves.
ii. Same R-R intervals indicates the rhythmic ventricle depolarization.
iii. Duration is 0.80-0.83 sec.

d.P-P intervals

i. It is the interval between two successive P waves.
ii. Same P-P intervals indicates the rhythmic atrial depolarization.

e.S-T segments

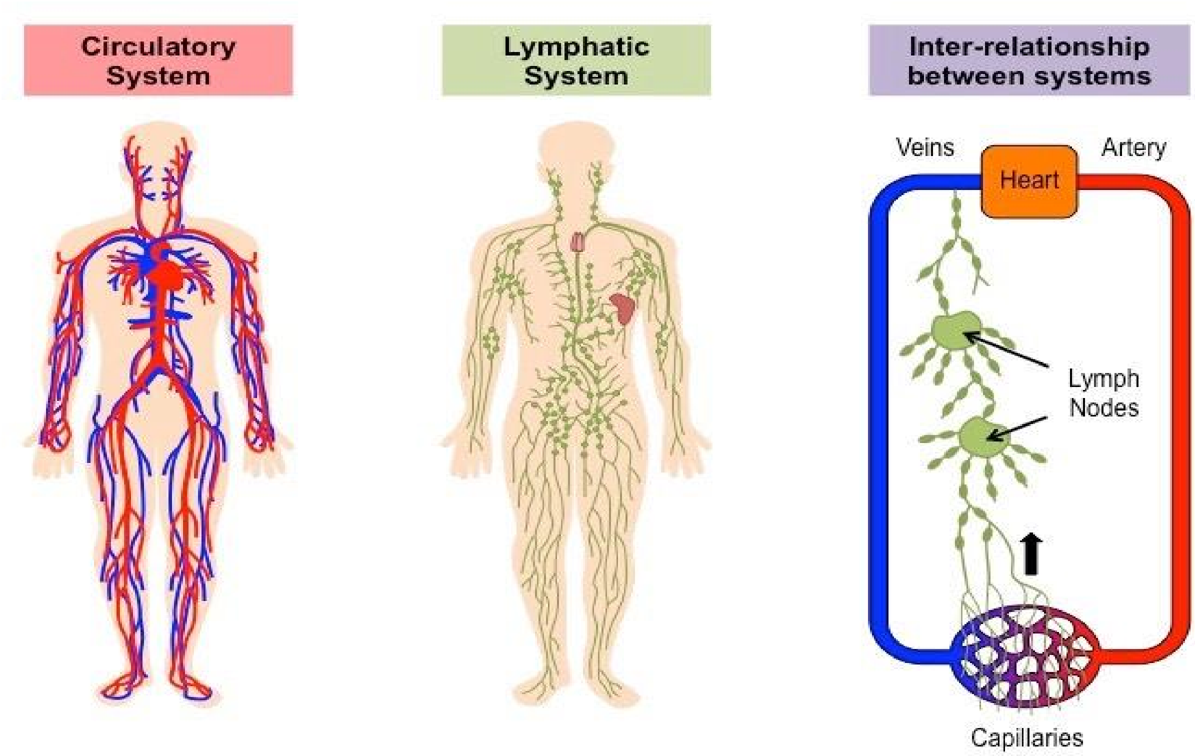
i. It is the duration between the end of the QRS and the start of T wave.
ii. This segment should be isoelectric and straight line.

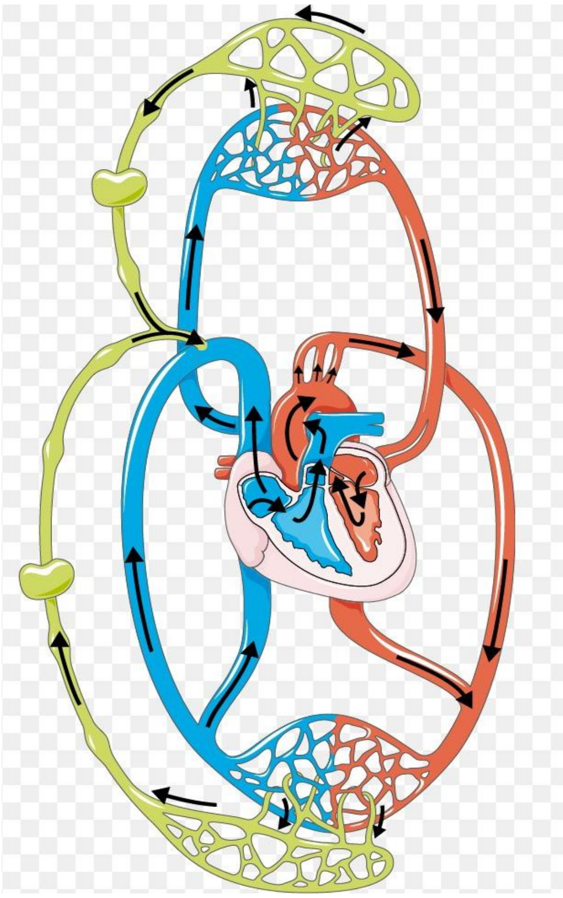
f. T-P intervals

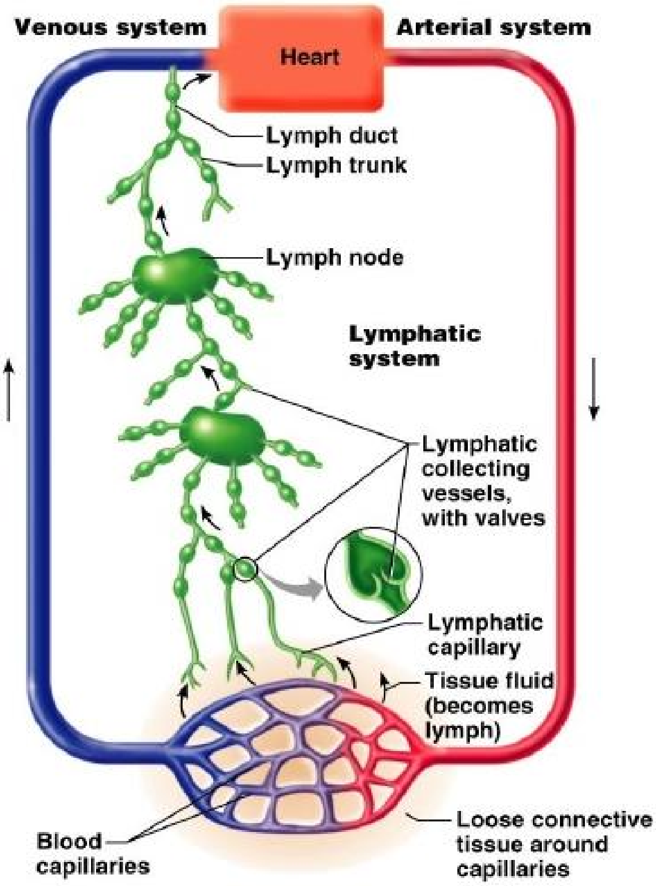
<u>Lymphetic System</u>

- The **lymphatic system** is part of circulatory system and an important part of the <u>immune system,</u> comprising a large network of lymphatic vessels that that **drains fluid from the blood vessels directionally towards the heart.** The lymphatic system was first described in the seventeenth century independently by Olaus Rudbeck and Thomas Bartholin.
- The lymphatic and blood circulation system are closely linked but they function quite differently. The blood system is a <u>closed</u> circulation system (blood is pumped through it but cannot pass out of it) which is **bi-direction** (blood flows two ways, away from and towards the heart). It is regulated by a central organ, the heart, which beats and causes blood to be pumped through the blood circulatory system.
- The **lymphatic system** is a **<u>one-way circulatory</u>** system (lymph always travels in one direction, towards the heart). It lacks a central pumping mechanism like the heart; instead, contractions of the lymph vessels push lymph through the system.

- The human circulatory system processes an average of **20 litres** blood/day through capillary filtration, which removes plasma while leaving the blood cells.
- Roughly **17 litres** of the filtered plasma is reabsorbed directly into the blood vessels, while the remaining 3 litres remain in the interstitial fluid.
- One of the main functions of the lymph system is to provide an accessory return route to the blood for the surplus three liters.







Components of **Lymphetic System:**

I. Lymph
II. Lymphatic vessels
III. lymph node:
IV. Lymphatic tissue & lymphatic organs

The Lymphatic System

- Lymphatic system functions:
  - Transport clean fluids back to the blood
  - Drains excess fluids from tissues
  - Removes "debris" from cells of body
  - Transports fats from digestive system

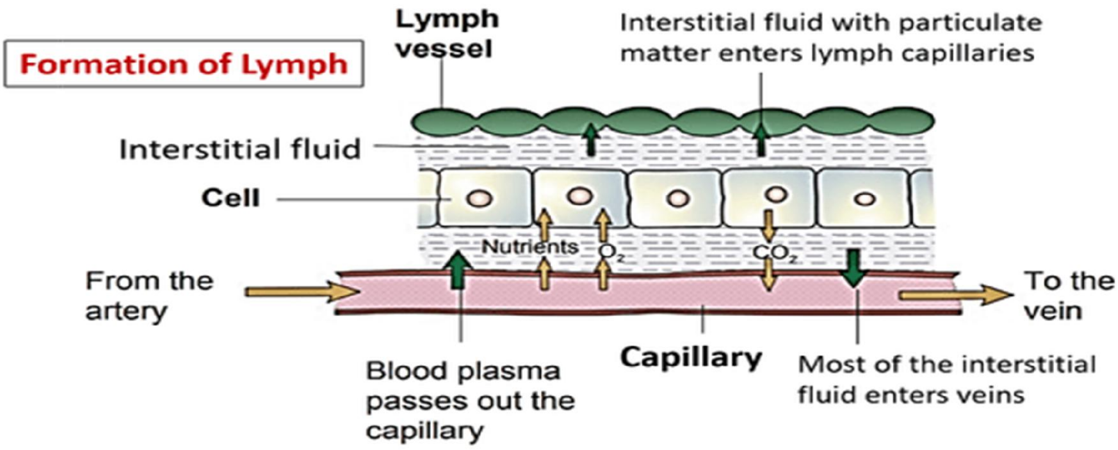
1. **Lymph:**A clear, sometimes faintly yellow, and slightly opalescent fluid collected from tissue throughout the body, flows in lymphatic vessels, and through the lymph nodes, and is eventually added to the **venous blood circulation.**

Lymph Composition:

- Lymph contains a variety of substances, including proteins, salts, glucose, fats, water, and white blood cells. Unlike your blood, lymph does not normally contain any red blood cells.

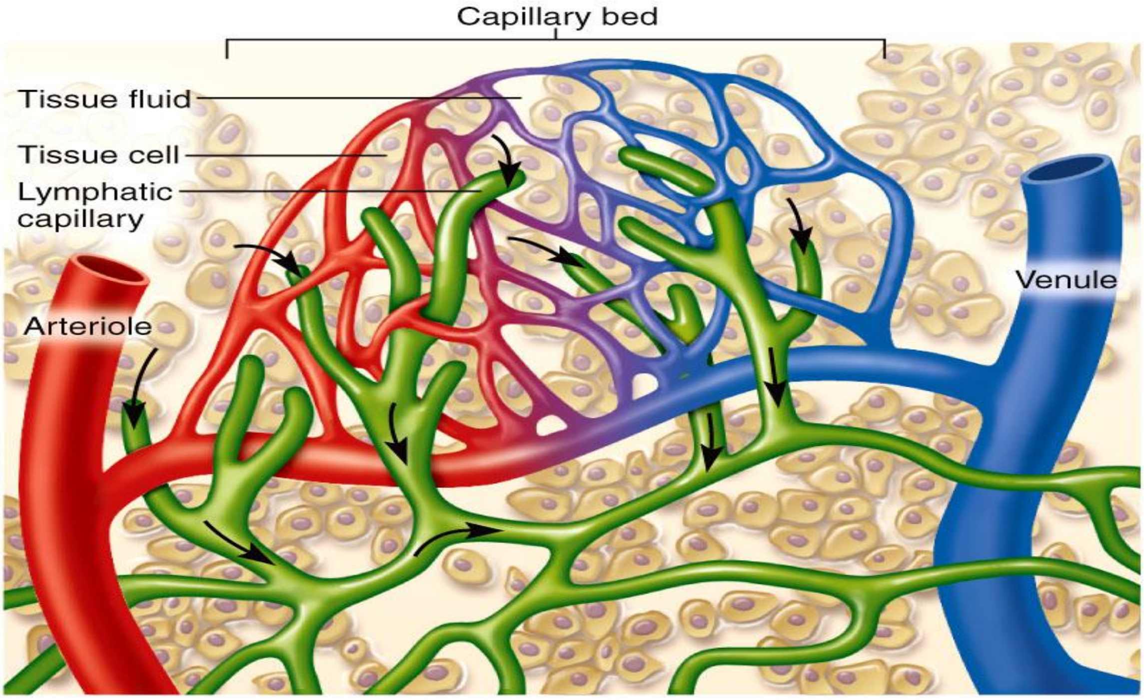
- The composition of lymph varies a great deal, depending on where in your body it originated. In the lymphatic vessels of your **arms and legs, lymph is clear and transparent**, and its chemical composition is similar to **blood plasma** (the liquid portion of blood). However, lymph contains less protein than plasma.

- The lymph returning from your **intestines is milky,** owing to the presence of fatty acids absorbed from your diet. This mixture of fats and lymph is called chyle, and the special lymphatic vessels surrounding your intestine that collect **chyle** are called **lacteals**.



2. **Lymph capillaries:** The lymphatic circulation begins with blind ending (closed at one end) highly permeable superficial lymph capillaries, formed by endothelial cells with button-like junctions between them that allow fluid to pass through them when the interstitial pressure is sufficiently high.

3. **Lymphatic vessels** which are similar to and connect to blood vessels. However, while the blood vessels transport blood which always stays in the blood circulation, the lymphatic vessels transport lymph which eventually enters the blood circulation.



i) Afferent vessels

The **afferent lymph vessels** enter at all parts of the periphery of the lymph node, and after branching and forming a dense plexus in the substance of the capsule, open into the *lymph sinuses* of the cortical part. It carries unfiltered lymph into the node.

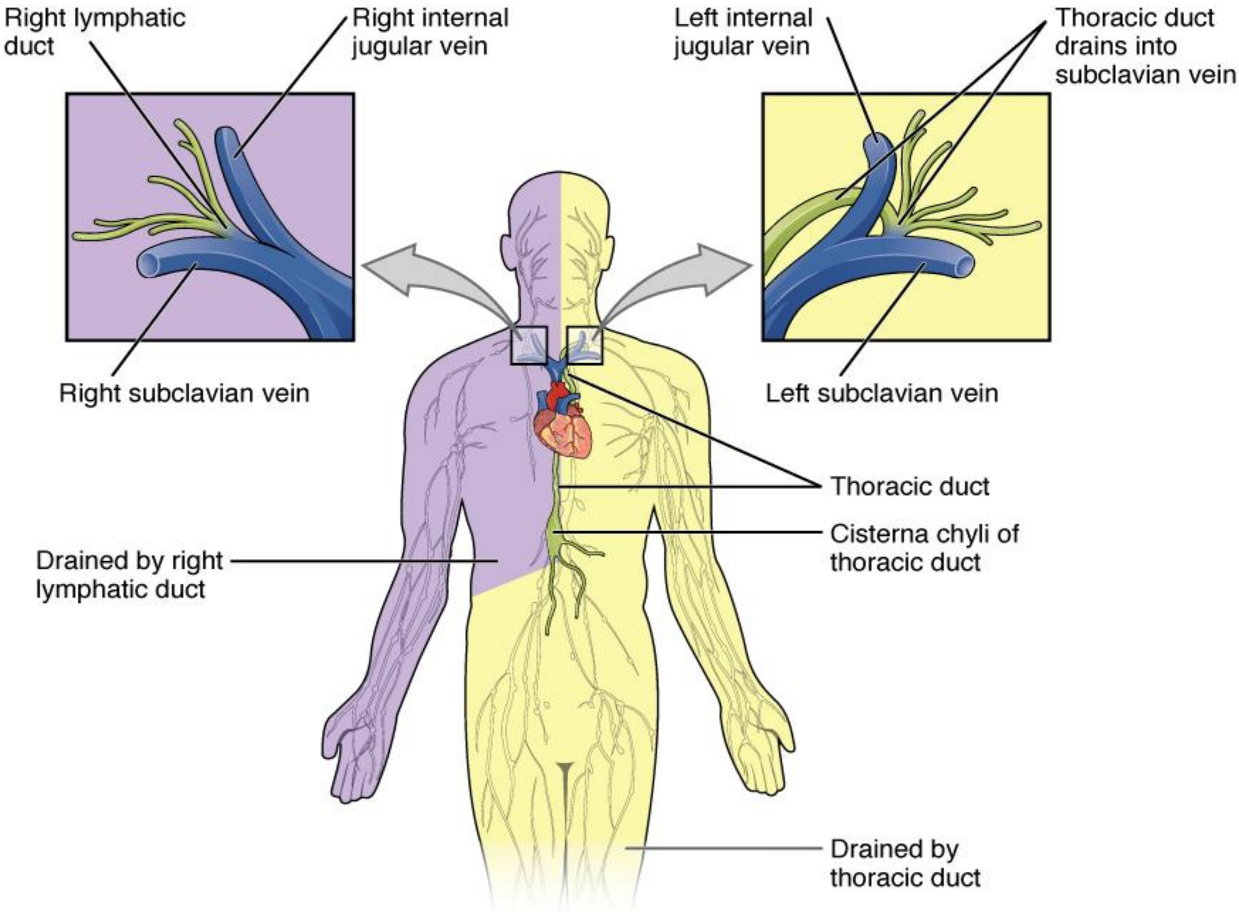
Afferent lymphatic vessels are only found in lymph nodes. This is in contrast to efferent lymphatic vessel which are also found in the thymus and spleen.

ii) Efferent vessels

The **efferent lymphatic vessel** commences from the lymph sinuses of the medullary portion of the lymph nodes and leave the lymph nodes at the hilum, either to veins or greater nodes. It carries filtered lymph out of the node.

4. **Lymphatic duct** is a great lymphatic vessel that empties lymph into one of the **subclavian veins**. There are two lymph ducts in the body— **the right lymphatic duct and the thoracic duct.**

The **right lymphatic duct** drains lymph from the right upper limb, right side of thorax and right halves of head and neck. The **thoracic duct** drains lymph into the circulatory system at the left brachiocephalic vein between the left subclavian and left internal jugular veins.



5. Lymph node: Small oval bodies of the lymphatic system, distributed along the lymphatic vessels clustered in the armpits, groin, neck, chest, and abdomen. Only organs that filter lymph; site for T and B cell activation.

Structure:

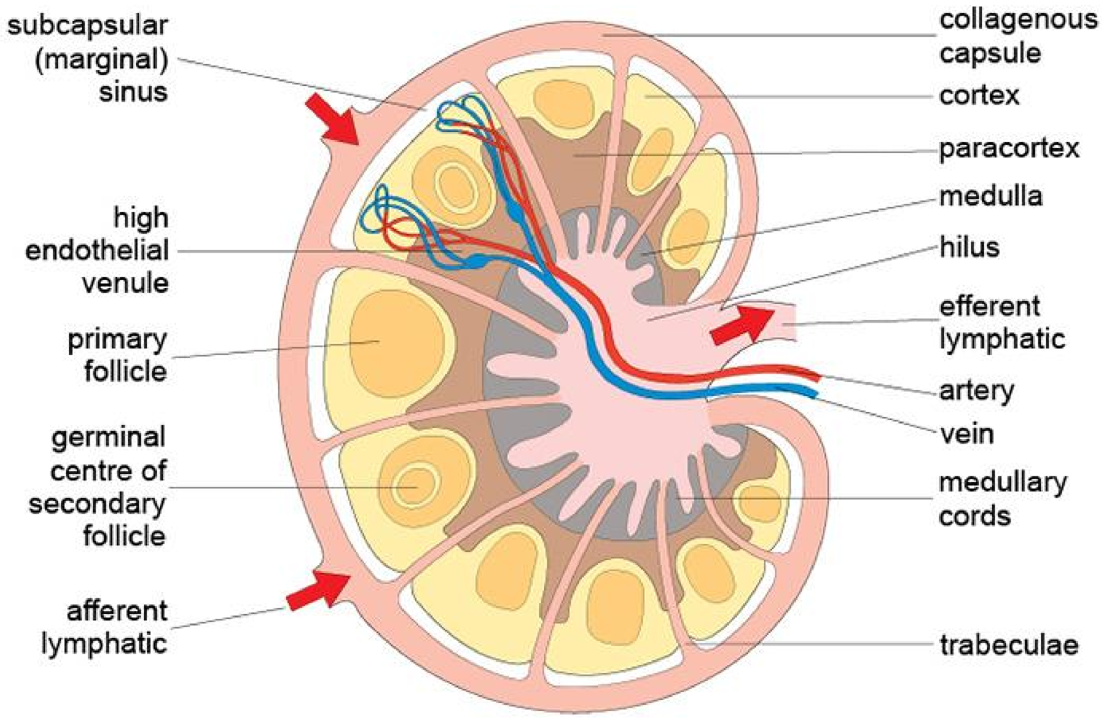
Cortex = outer portion

Germinal centers produce lymphocytes

Medulla = inner portion

Lymph enters nodes through afferent lymphatics, flows through sinuses, exits through efferent lymphatics.

6. Lymphoid tissues and organs which are found at various body sites and abundantly populated by lymphocytes (white blood cells which protect against infections and are part of the immune system).



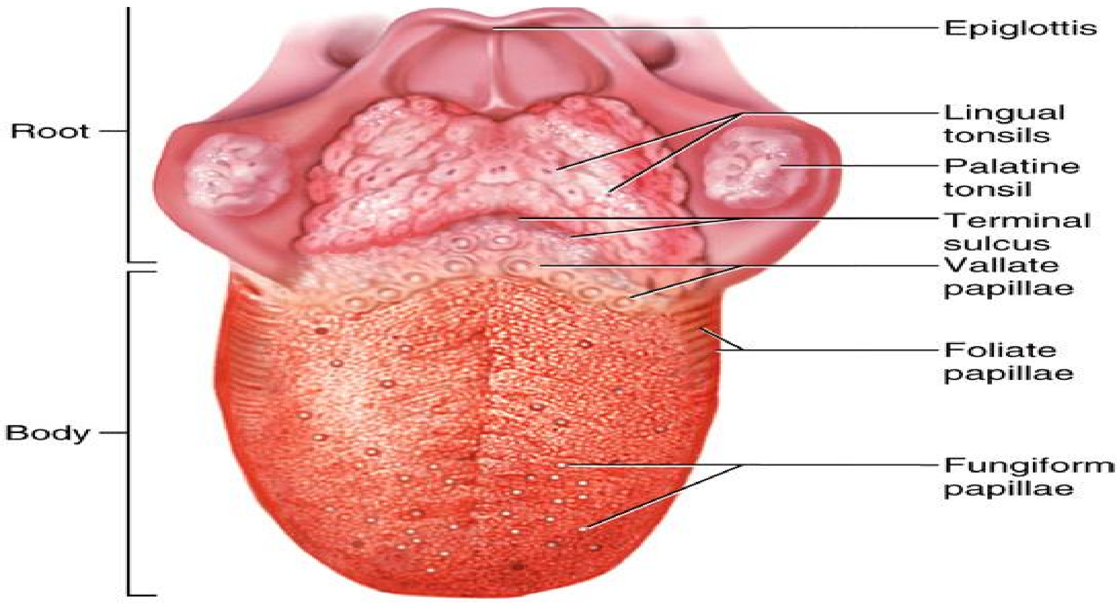
A. **Tonsils**

- **Pharyngeal tonsil (adenoid):** single tonsil on wall of pharynx
- **Palatine tonsils:** A pair; at posterior margin of oral cavity.
  Largest and most often infected called tonsillitis
- **Lingual tonsils:** at root of tongue

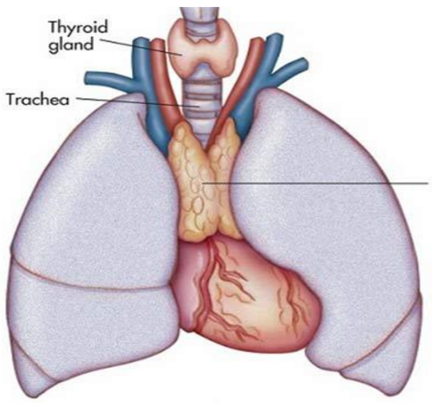
Function:

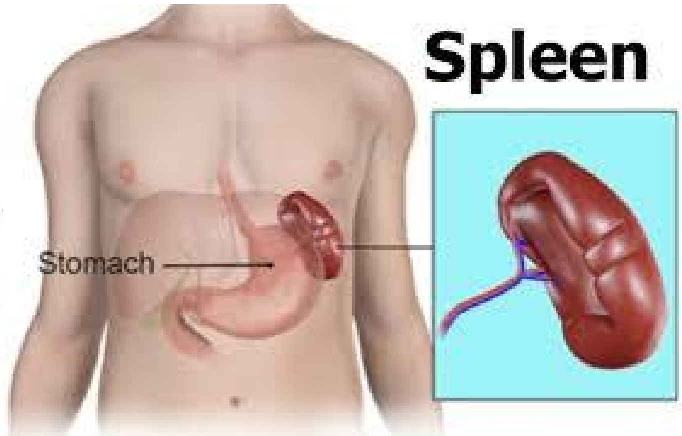
✓ The main function of tonsils is to trap germs (bacteria and viruses) which you may breathe in.

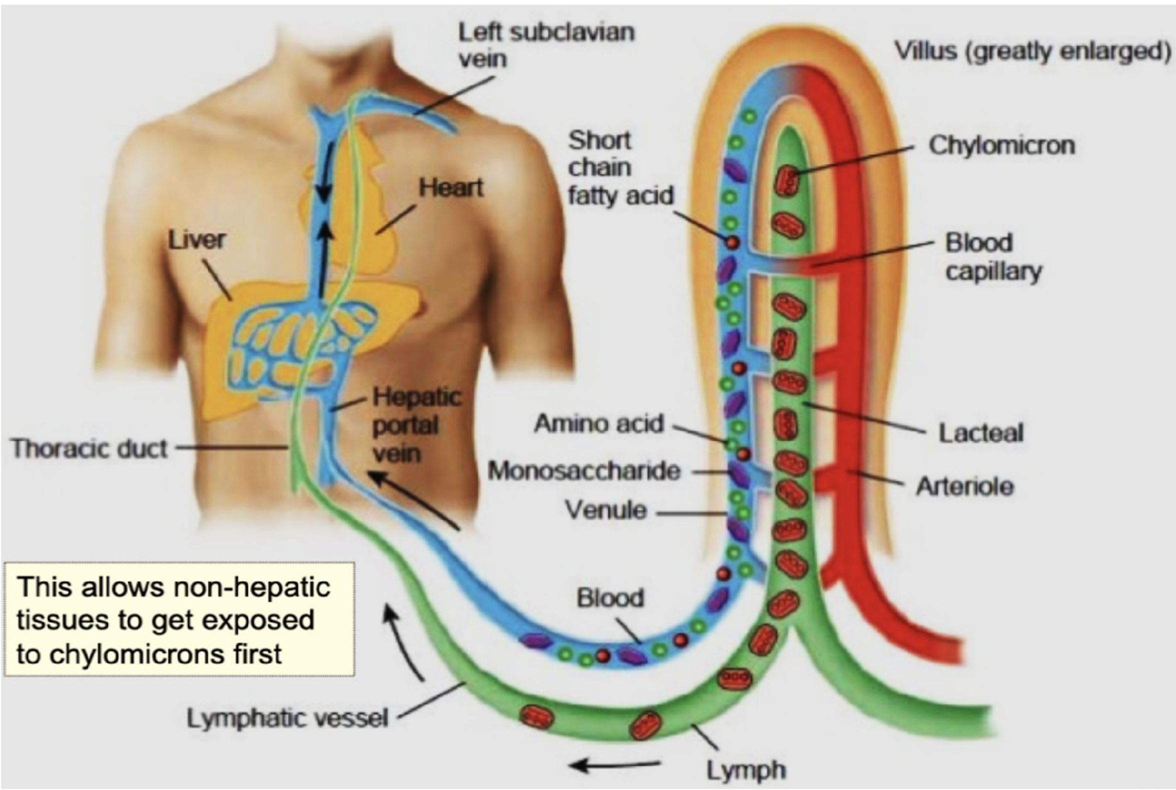
✓ **Antibodies** produced by the immune cells in the tonsils help to kill germs and help to prevent throat and lung infections.



B. Spleen Largest lymphatic organ Located between the stomach & diaphragm Structure is similar to a node **<u>Functions</u>** Filters blood ,Stores blood	**<u>C. Thymus Gland</u>** Location – behind the sternum in the mediastinum • Puberty – maximum size • Maturity – decreases in size **Function:** Differentiation and maturation of T cells







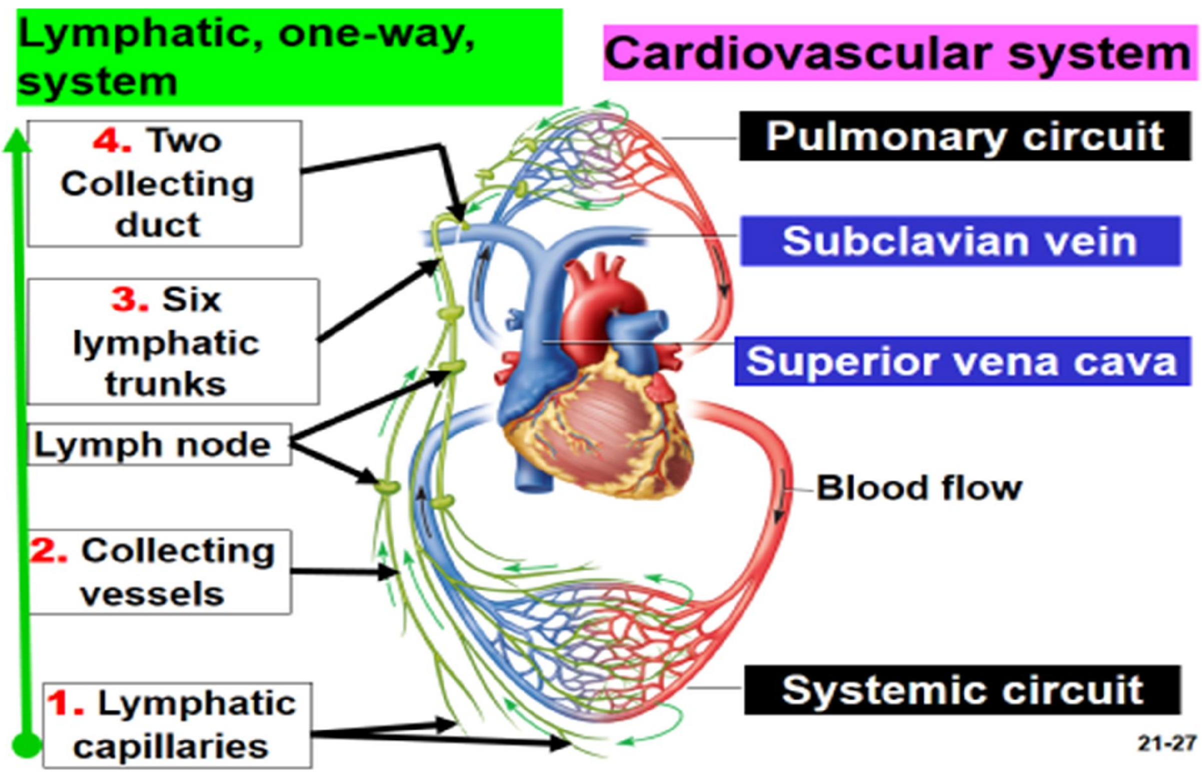
Functions of Lymphatic System

1. Fluid recovery:

   Absorbs ECF proteins and fluid (2 to 4 L/day) from tissues and returns it to the bloodstream.

- Interference with lymphatic drainage leads to severe edema eg. **Elephantiasis**
- **Cause-** mosquito-borne roundworms infect the lymph nodes and block the flow of **lymph**
- **Symptoms–** chronic edema, especially extremities; Thickening of the skin

2. **Immunity:**
   - fluids from all capillary beds are filtered
   - **immune cells** stand ready to respond to foreign cells or chemicals encountered
3. **Lipid absorption:**
   - **Lacteals** in small intestine absorb dietary lipids.



The Lymphatic System