CARDIOVASCULAR SYSTEM

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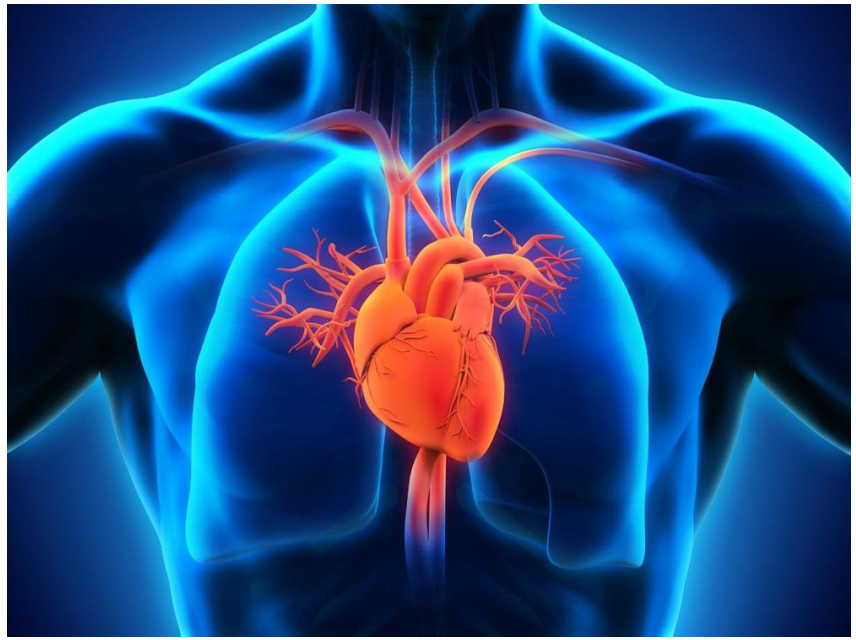
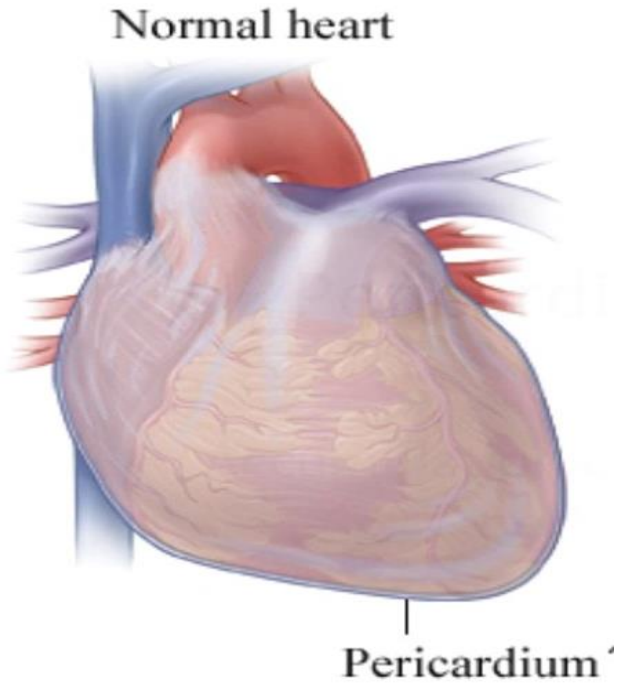
Heart

- Cone shape
- 300 gms in weight
- Situated near the middle of thoracic cavity, above the diaphragm, and between the lungs.
- Size: Length- about 12 cm, Breadth: about 9 cm.
- Thickness: About 6 cm
- Parts: Four chamber: Two atria and two ventricles
- Covering: Pericardium
- Made up of: Cardiac Muscle



Pericardium

- Heart is covered by triple layer sack are called pericardium.
- Outermost layer of epicardium is fibrous pericardium made up of dense irregular connective tissue.
- The fibrous nature of the tissue prevent over-distension of the heart and holds it at particular position.
- The inner two membranes of pericardium are made up of serous membrane and the space in between the two is filled with pericardial fluid which is secreted by serous membrane itself.
- This slippery pericardial fluid reduces down the friction and provide smooth moments between the layers when heart beats.



Heart Wall

- ***Epicardium (External layers)***

➢ The outermost, Thin, transparent outer layer of the heart wall.

➢ Coat the inner myocardium providing smooth and slippery texture to the heart.

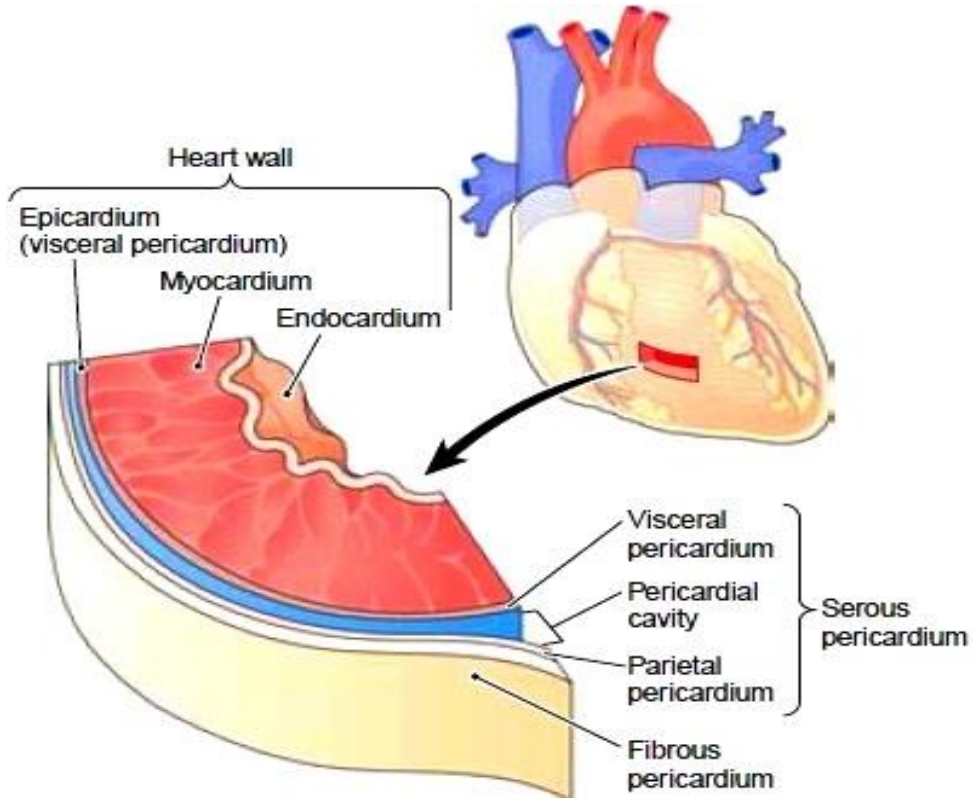
- ***Myocardium (Middle layer)***

➢ The middle layer is made up of cardiac muscle tissue.

➢ This middle layer makes up the bulk of the heart and is responsible for pumping action.

- ***Endocardium (inner layer)***

- It is the inner surface of myocardium
- It consists of thin layer of endothelial cells
- It provides smooth lining for the chambers of the heart and covers the valves of the heart
- The endocardium is continuous with the endothelial lining of the large blood vessels attached to the heart.



Chambers of Heart

- ***Two superior chambers***

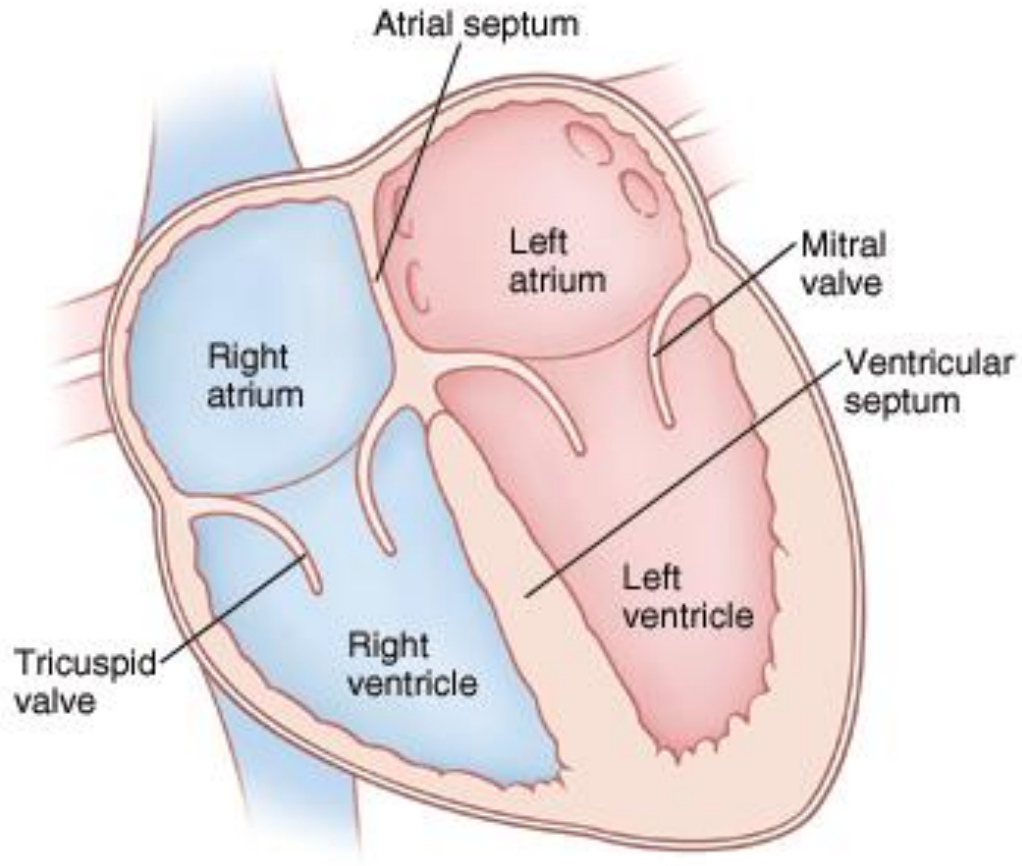
1.Right atrium

2.Left atrium

- ***Two inferior chambers***

1.Right ventricles

2.Left ventricles



Valves of Heart

- ***Atrioventricular***

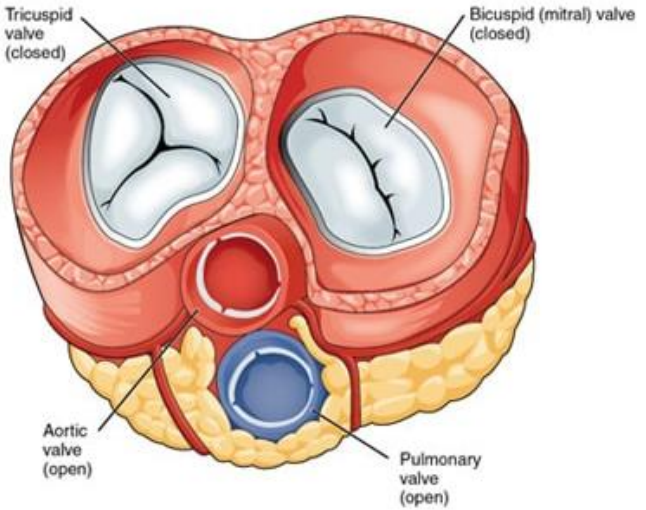
1.Tricuspid

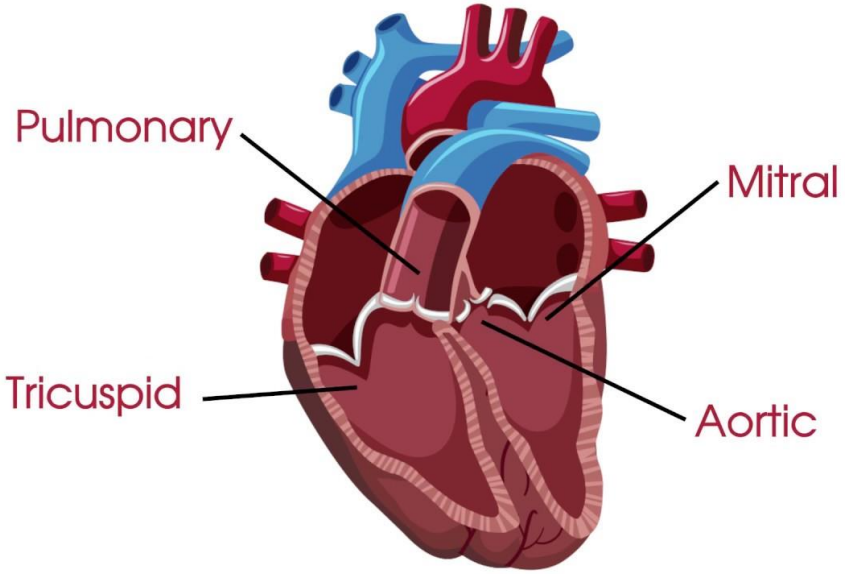
2.Bicuspid

- ***Semilunar***

1.Pulmonary

2.Aortic

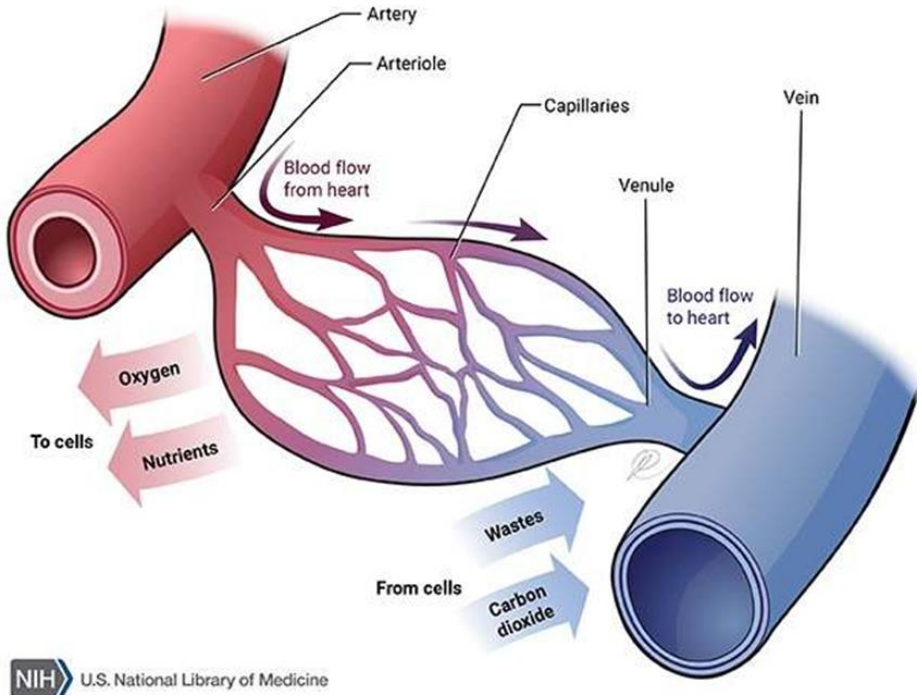




Blood vessels

- The heart pumps blood into vessels that vary in structure, size and function.
- Five main type of blood vessels are:

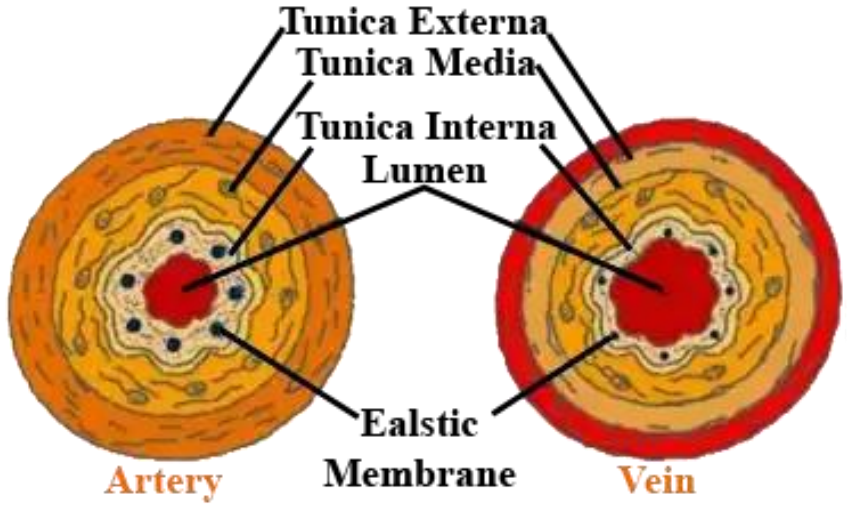
1. *Arteries:* carry blood away from the heart.
2. *Arterioles:* 10 to 100 μm in diameter, deliver blood and regulate blood flow to capillary.
3. *Capillaries:* arterioles break up into minute vessels. 4 to 10 μm, site for exchange of nutrients and waste.
4. *Venules:* capillaries reunite to form venules. Collect blood from capillaries and deliver it to vein.
5. *Vein:* convey blood from the tissues back to the heart.



Structure

- The wall of a blood vessel consists of three layers, or tunics, of different tissues:

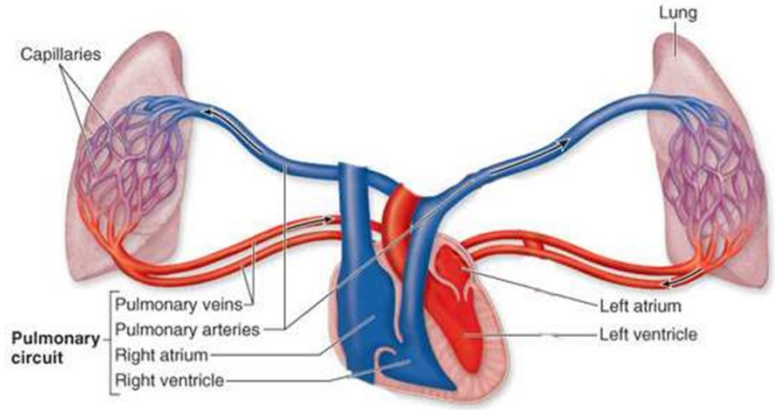
1. Tunica interna (intima): An epithelial inner lining,
2. Tunica media : A middle layer consisting of smooth muscle and elastic connective tissue,
3. Tunica externa (adventitia): A outer covering of connective tissue.



Blood flow through the heart (Circulation)

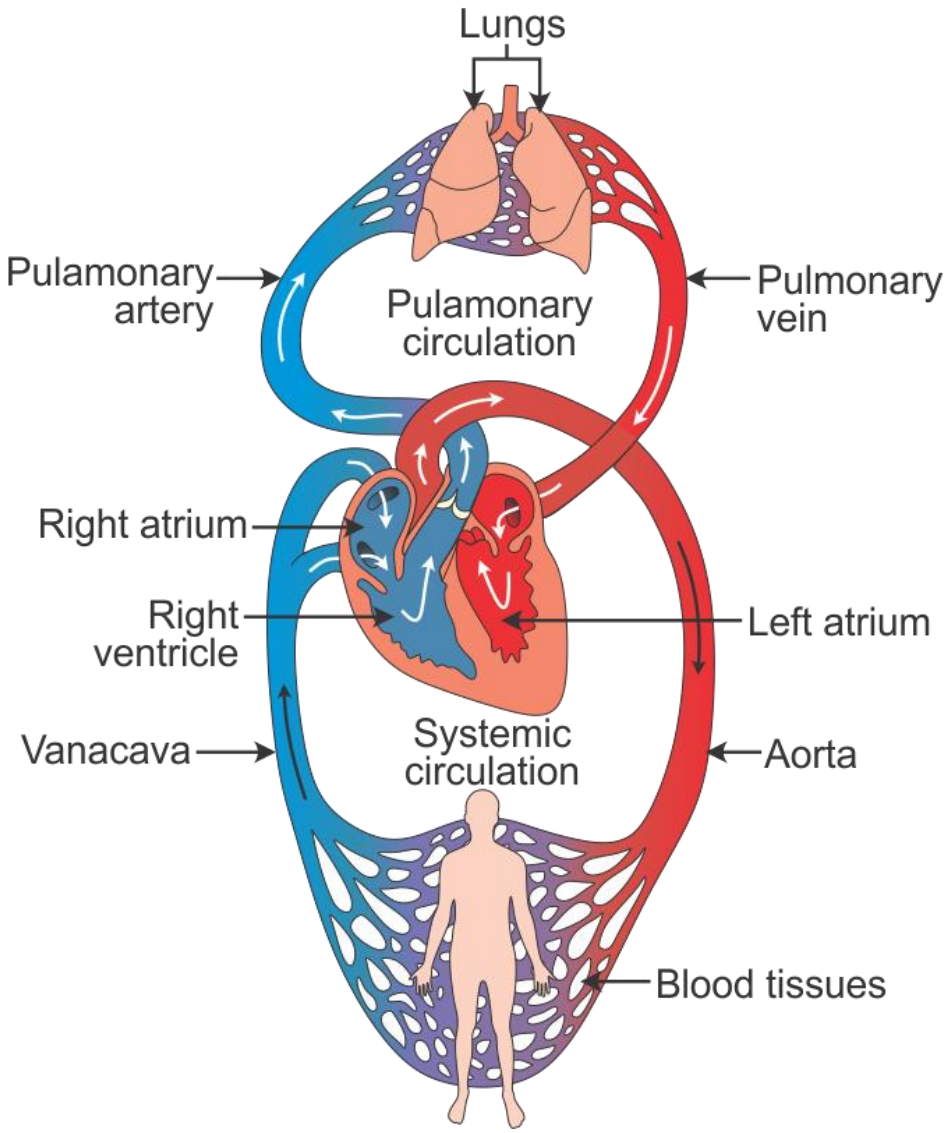
1. Pulmonary circulation

- Carries deoxygenated blood away from the heart, to the lungs and return oxygenated blood back to the heart.
- From the right atrium, deoxygenated blood pumped through the tricuspid valve into the right ventricle.
- Then is blood pumped from right ventricle through the pulmonary valve and into the pulmonary trunk of the pulmonary artery and travels to the lungs.
- Where carbon dioxide is released and oxygen is pickup by during respiration. Arteries are further divided into very fine capillaries which are extremely thin wall.
- Then the pulmonary vein returns oxygenated blood to the left atrium of the heart.



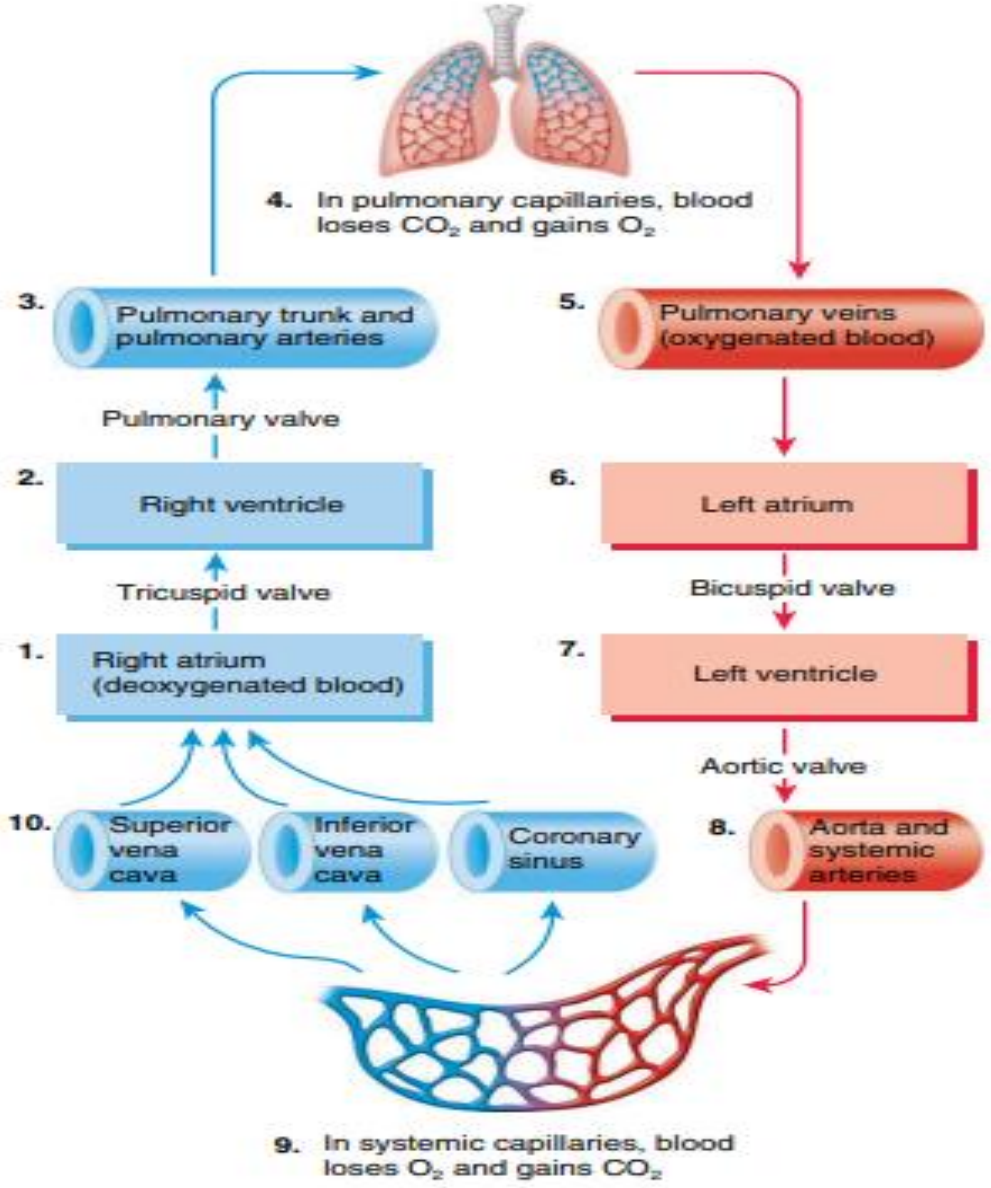
2. *Systemic circulation*

- carries oxygenated blood away from the heart to the body and returns the deoxygenated blood back to the heart.
- Oxygen rich blood from the lungs leave the pulmonary circulation when it enters the left atrium to the pulmonary veins.
- The blood is then pumped through the mitral valve into the left ventricle.
- From the left ventricle blood is pumped through the aortic valve and into the aorta.
- The aorta arch and branches into major arteries to the upper body.
- The arteries branched into smaller arteries, arterioles, and finally capillaries.
- Deoxygenated blood continue through the capillaries which merge into venules then veins and superior and inferior vena cava.
- which drains into the right atrium of the heart.
- from the right atrium the blood will travel through the pulmonary circulation.


Lungs
Pulamonary artery
Pulamonary circulation
Pulmonary vein
Right atrium
Right ventricle
Left atrium
Vanacava
Systemic circulation
Aorta
Blood tissues

Difference between pulmonary and systemic circulation

Pulmonary circulation	Systemic circulation
This involved circulation of blood between the heart and the lungs.	This involved circulation of blood between the heart and body organs (except lungs)
It is the function of the right side of the heart	It is the function of the left side of the heart
It carries deoxygenated blood to the lungs	It carries oxygenated blood to the body organ
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
It returns oxygenated blood back to the heart	It returns deoxygenated blood back to the heart

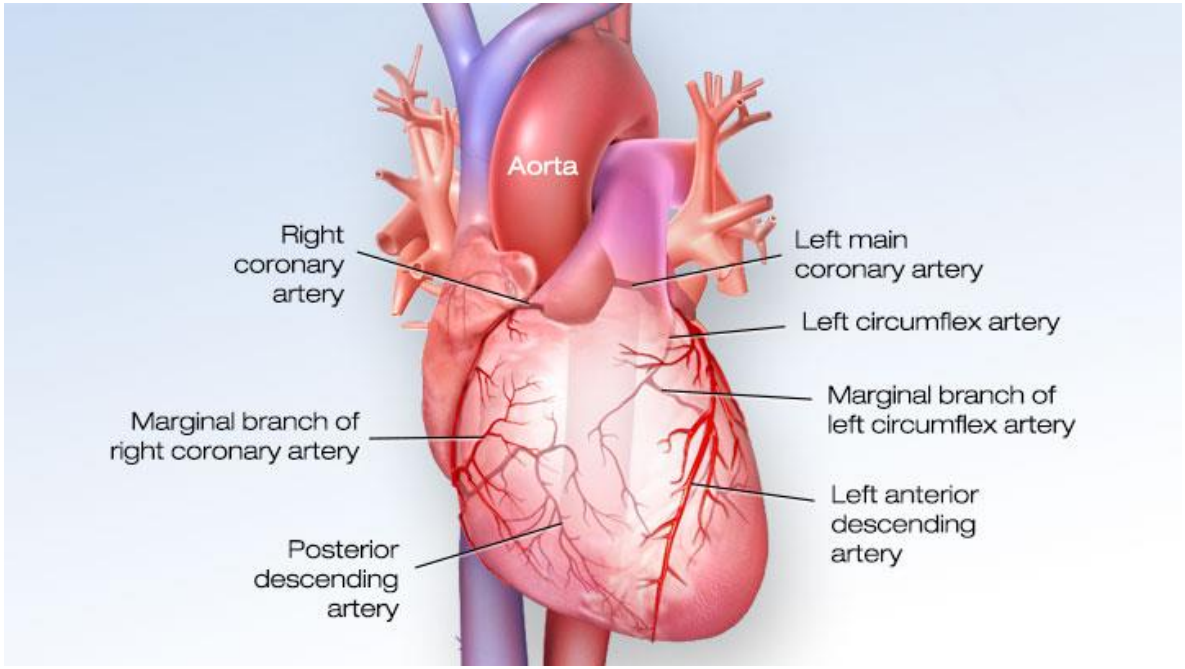


(b) Path of blood flow through systemic and pulmonary circulations

3. *Coronary circulation*

- Nutrients are not able to diffuse quickly enough from blood in the chambers of the heart to supply all layers of cells that make up the heart wall. For this reason, the myocardium has its own network of blood vessels, the coronary circulation or cardiac circulation.
- The coronary arteries branch from the ascending aorta and encircle the heart like a crown encircles the head.
- When the heart relaxes, however, the high pressure of blood in the aorta propels blood through the coronary arteries, into capillaries, and then into coronary veins.
- ***Coronary Arteries***
- Two coronary arteries, the left and right coronary arteries, branch from the ascending aorta and supply oxygenated blood to the myocardium.
- The left coronary artery passes inferior to the left auricle and divides into the anterior interventricular and circumflex branches.
- The right coronary artery supplies small branches (atrial branches) to the right atrium. It continues inferior to the right auricle and ultimately divides into the posterior interventricular and marginal branches.

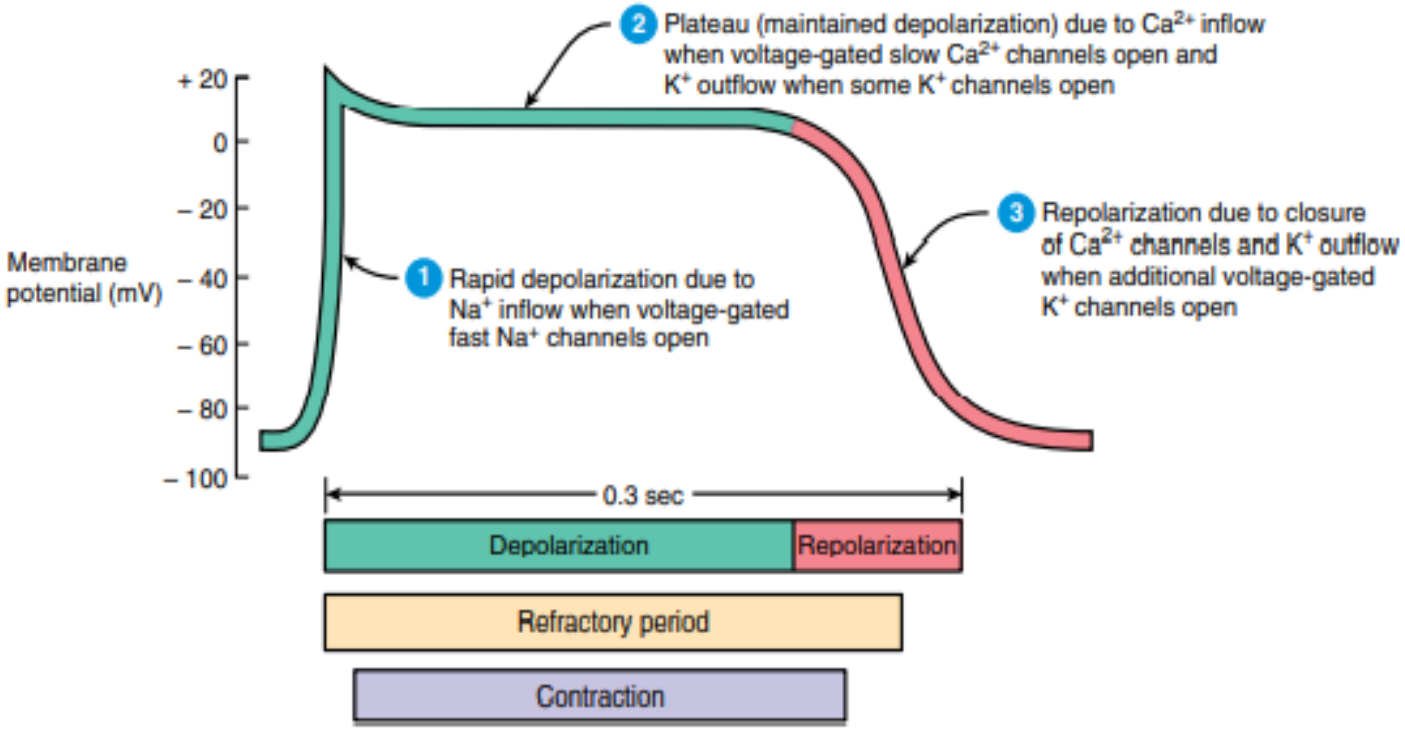
- ***Coronary Veins***
- After blood passes through the arteries of the coronary circulation, it flows into capillaries, where it delivers oxygen and nutrients to the heart muscle and collects carbon dioxide and waste, and then moves into coronary veins.
- Most of the deoxygenated blood from the myocardium drains into a large vascular sinus in the coronary sulcus on the posterior surface of the heart, called the coronary sinus.
- The deoxygenated blood in the coronary sinus empties into the right atrium.



Action potential

- The action potential initiated by the SA node travels along the conduction system and spreads out to excite the "working" atrial and ventricular muscle fibers, called contractile fibers.
- An action potential occurs in a contractile fiber as follows:

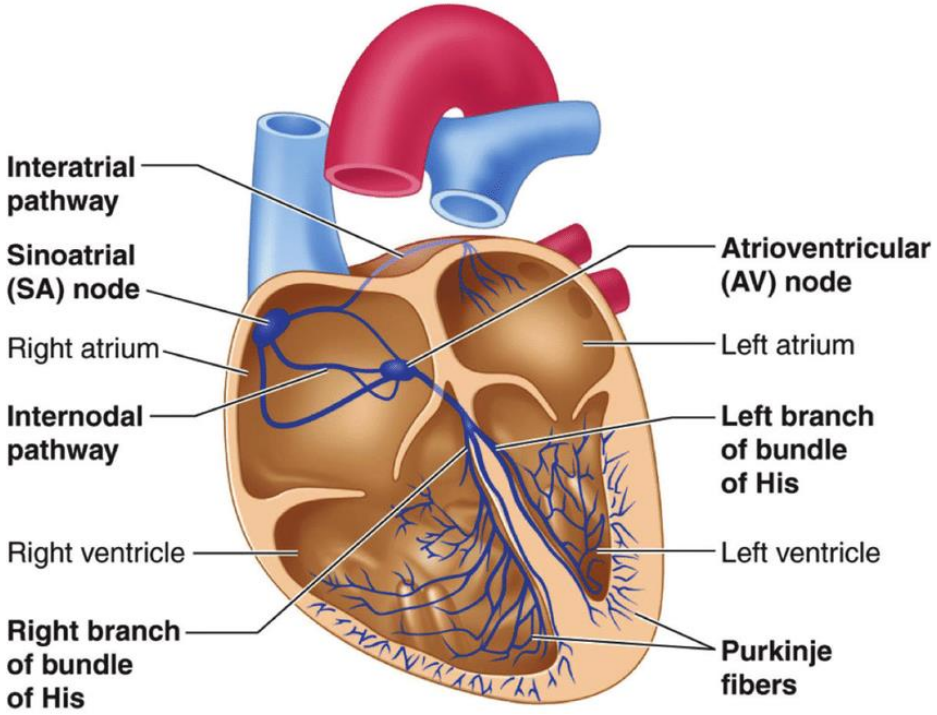
1. Depolarization
2. Plateau
3. Repolarization



Conducting System of Heart

- A special system in the heart is responsible for the rhythmic contraction and relaxation which leads to conduction of impulses in the heart.
- It consist of:

1. Sinoatrial node (SA node)
2. Atrioventricular node (AV node)
3. AV bundle or Bundle of His
4. Right and left bundle branches
5. Conduction myofibrils (Purkinje fibers)



SA node

- The heart beat originates in modified cardiac muscle called as SA node which lies in the **wall of right atrium near the opening of superior vena cava.**
- SA node is called as **Pace maker** because it has **power of generation of wave of contraction.**
- The wave of contraction or cardiac impulses generated by SA node is conducted by cardiac **muscle fibres** to both the atria causing their contraction.

AV node

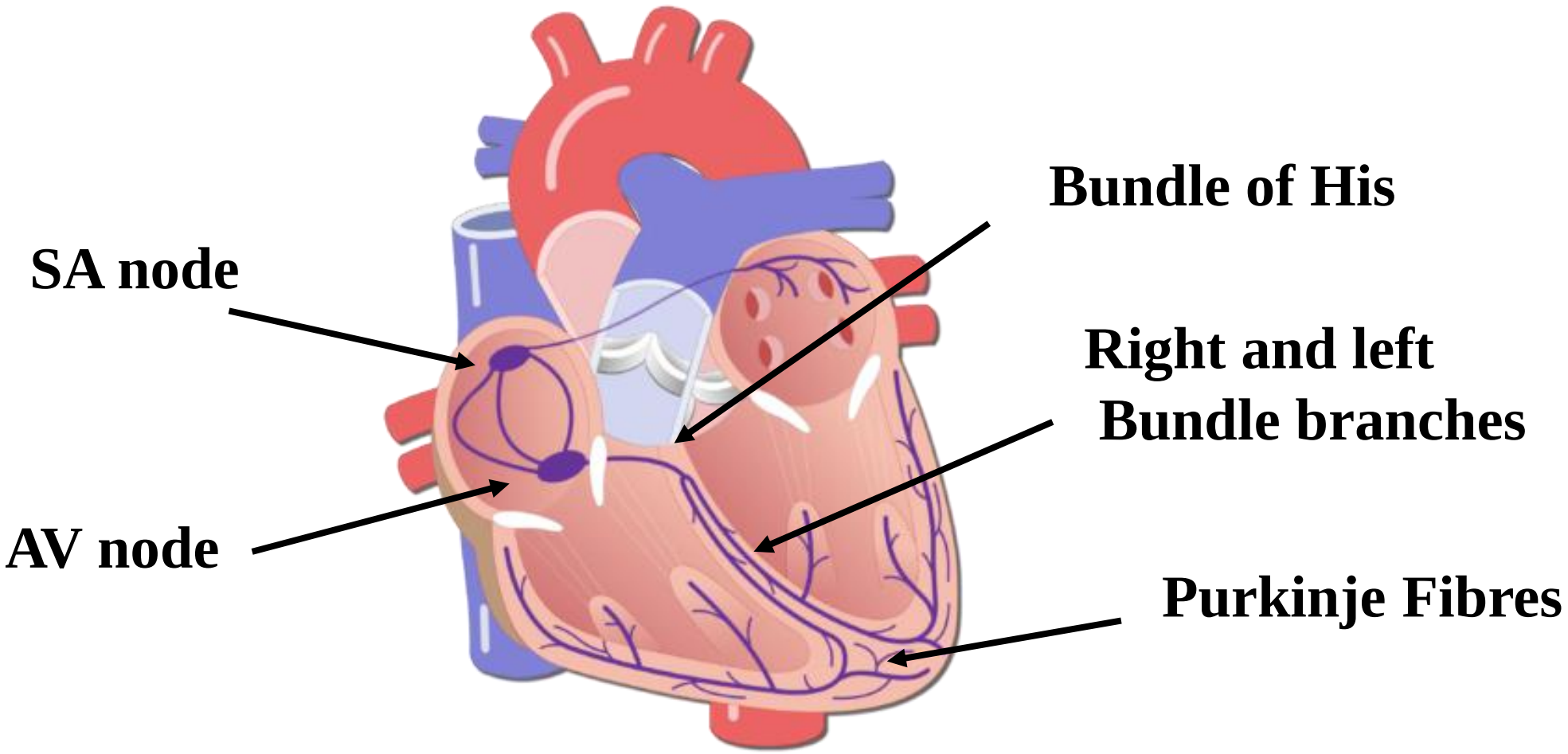
- Located in the **wall of right atrium near the opening of coronary sinus** receives the wave of contraction generated by SA node.
- During this period, the **atria contract and empty their content.**
- Once the atria are empty of blood, the valves between the atria and ventricle close.
- The **atria begin to refill and electrical stimulus passes through the AV node, bundle of his into the bundle branches and purkinje fibres.**

AV Bundle (Bundle of His)

- Connects with the distal part of the compact AV node and penetrate the membranous septum.
- From the **AV node the action potential enters the bundle of His**, ***the only electrical connection between atria and ventricle.***
- This **bundle of fibres branches off into two bundle** and impulses are carried down the centre of heart to the left and right ventricles.
- After travelling along the AV bundle, the action potential then enters both the right and left bundle branches that runs through the **interventricular septum towards the apex of heart.**

Purkinje Fibres

- The purkinje fibre **connects with the end of the bundle branches** to form interweaving networks on the endocardial surface of both ventricles.
- They transmit the cardiac impulses almost simultaneously to the entire right and left ventricular endocardium.


SA node
Bundle of His
Right and left
Bundle branches
AV node
Purkinje Fibres

The Cardiac Cycle

- During each heartbeat, or cardiac cycle, the heart contracts and then relaxes. The period of contraction is called systole and that of relaxation, diastole.
- A cardiac cycle consists of systole and diastole of the atria plus systole and diastole of the ventricle.
- Stages of the cardiac cycle
- Atrial systole — contraction of the atria
- Ventricular systole — contraction of the ventricles
- Complete cardiac diastole — relaxation of the atria and ventricles.

Atrial systole (0.1s)

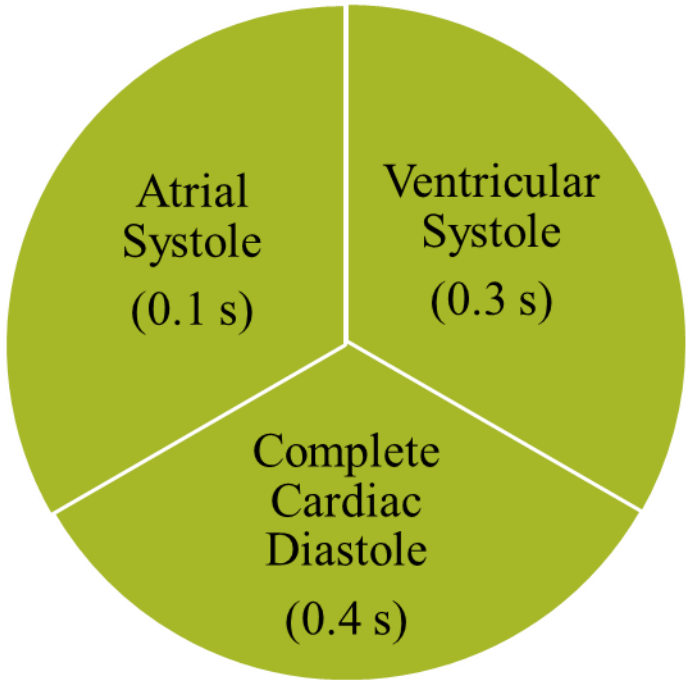
- The superior vena cava and the inferior vena cava transport deoxygenated blood into the right atrium at the same time as the four pulmonary veins convey oxygenated blood into the left atrium.
- The atrioventricular valves are open and blood flows through to the ventricles.
- The SA node triggers a wave of contraction that spreads over the myocardium of both atria, emptying the atria and completing ventricular filling.

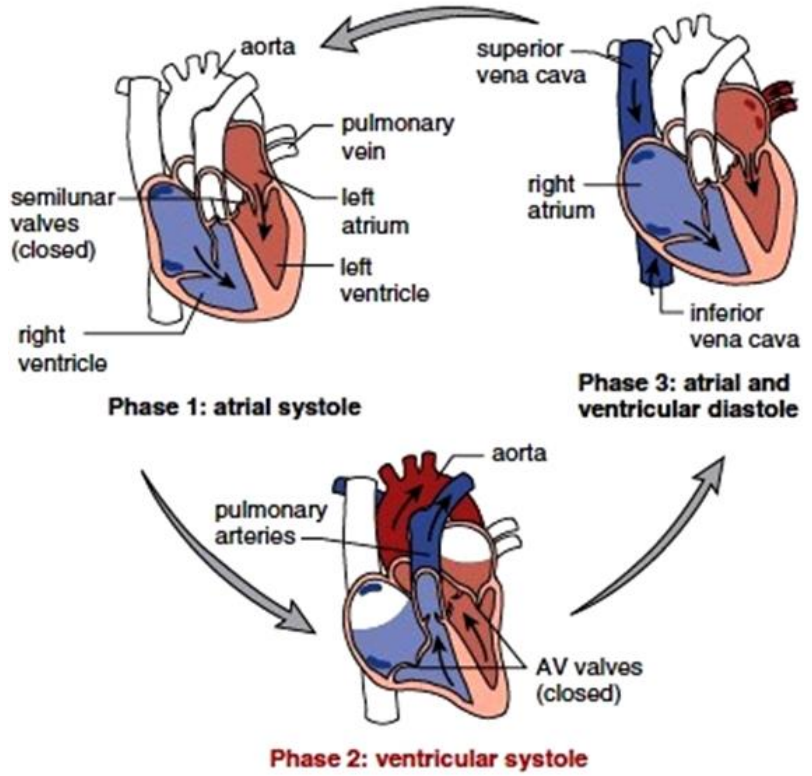
Ventricular systole (0.3s)

- When the wave of contraction reaches the AV node it is stimulated to emit an impulse which quickly spreads to the ventricular muscle via the AV bundle, the bundle branches and Purkinje fibres.
- This results in a wave of contraction which sweeps upwards from the apex of the heart and across the walls of both ventricles pumping the blood into the pulmonary artery and the aorta.

Complete cardiac diastole (0.4 s)

- After contraction of the ventricles there is complete cardiac diastole, a period of 0.4 seconds, when atria and ventricles are relaxed.
- During this time the myocardium recovers until it is able to contract again, and the atria refill in preparation for the next cycle.





Heart Sound

- During each cardiac cycle, there are four heart sounds, but in a normal heart only the first and second heart sounds (S1 and S2) are loud enough to be heard through a stethoscope.

- The first sound (S1), which can be described as a lubb sound, is louder and a bit longer than the second sound. S1 is caused by blood turbulence associated with closure of the AV valves soon after ventricular systole begins.

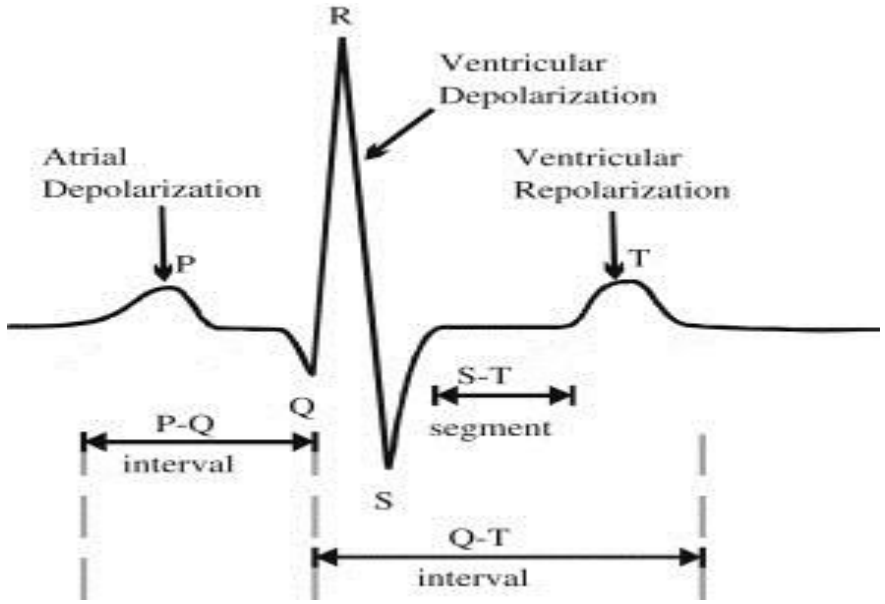
- The second sound (S2), which is shorter and not as loud as the first, can be described as a dupp sound. S2 is caused by blood turbulence associated with closure of the SL valves at the beginning of ventricular diastole.

- Normally not loud enough to be heard, S3 is due to blood turbulence during rapid ventricular filling, and S4 is due to blood turbulence during atrial systole

Electrocardiogram (ECG)

- As action potentials propagate through the heart, they generate electrical currents that can be detected at the surface of the body.
- The ECG is a composite record of action potentials produced by all of the heart muscle fibers during each heartbeat. The instrument used to record the changes is an electrocardiograph.
- In a typical record, three clearly recognizable waves appear with each heartbeat.

1. P wave
2. QRS wave
3. T wave



P wave: A small upward deflection on the ECG. The P wave represents atrial depolarization, which spreads from the SA node through contractile fibers in both atria.

QRS wave: The second wave, called the QRS complex, begins as a downward deflection, continues as a large, upright, triangular wave, and ends as a downward wave.

The QRS complex represents rapid ventricular depolarization, as the action potential spreads through ventricular contractile fibers.

T wave: The third wave is a dome-shaped upward deflection called the T wave.

It indicates ventricular repolarization and occurs just as the ventricles are starting to relax.

The T wave is smaller and wider than the QRS complex because repolarization occurs more slowly than depolarization.

Conclusion with altered ECG

- **Larger P wave:** It indicates enlargement of the atria.
- **Enlarged Q wave:** It indicates myocardial infraction.
- **Enlarged R wave:** It indicates enlargement of the ventricles.
- **Flatter T wave:** It indicates insufficient oxygen supply to myocardium.

Blood Pressure

- Blood pressure is lateral pressure exerted by blood on the vessels walls while flowing through it.
- The blood pressure is measured in terms of systolic and diastolic pressure.
- ***Systolic pressure:*** It refers to phase of ventricular contraction.
- ***Diastolic pressure:*** It refers to phase of ventricular relaxation.
- Normal Blood Pressure: 120/80 mmHg.
- The various methods for determination of blood pressure are as follows:

1. ***Oscillatory Method***
2. ***Palpatory Method***
3. ***Auscultory Method***

Factors affecting blood pressure

1. ***Age:*** Blood pressure tends to increase with age. Our blood vessels naturally thicken and stiffen over time. These changes increase the risk for high blood pressure.
2. ***Gender:*** Men are more likely than women to develop high blood pressure throughout middle age. But in older adults, women are more likely than men to develop high blood pressure.
3. ***Diet:*** Eat unhealthy foods often. This is especially true for foods with too much sodium and not enough potassium. saturated fats can increase blood pressure.
4. ***Exercise:*** Not exercising can cause weight gain. Increased weight raises the risk of high blood pressure. People who are inactive also tend to have higher heart rates.
5. ***Stress:*** High levels of stress can lead to a temporary increase in blood pressure. Stress-related habits such as eating more, using tobacco or drinking alcohol can lead to further increases in blood pressure.

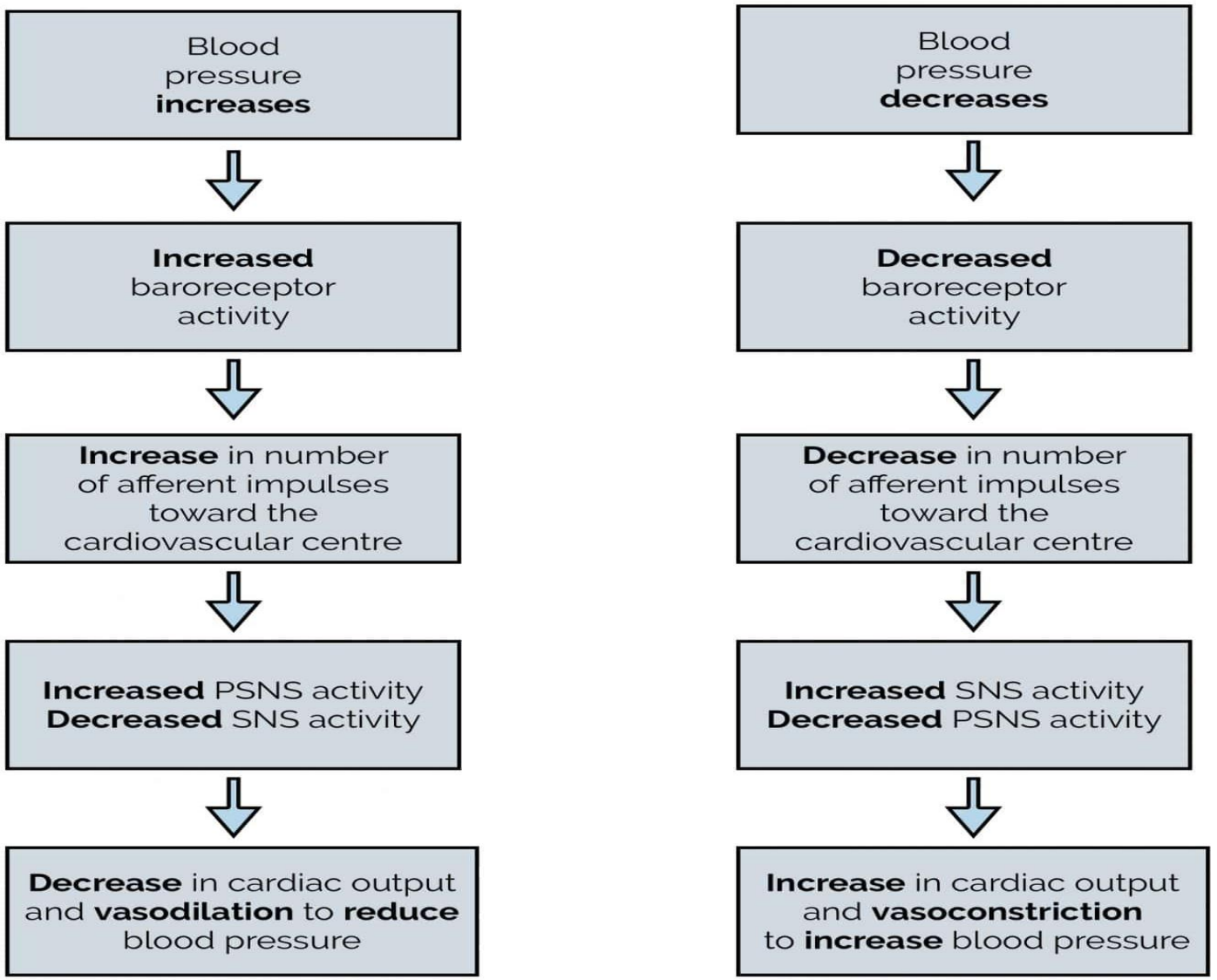
Regulation of Blood Pressure

- Blood pressure is controlled in two ways:
- Short term control: Baroreceptor reflex,
- Long term control: Renin Angiotensin Aldosterone System (RAAS), Antidiuretic hormones (ADH),

- ***Baroreceptor reflex:***
- Baroreceptors are special nerve cells or receptors that sense blood pressure, information related to the walls of the blood vessels stretch is sent from the baroreceptors to the brain to help keep blood pressure balanced.
- Baroreceptor control blood pressure is called as baroreceptor reflex.

- There are mechanoreceptors known as **baroreceptors** located in the **aortic arch** and **carotid sinus,** which constantly monitor the MABP (Mean Atrial Blood Pressure) and pulse pressure.
- Increases in arterial pressure result in increased baroreceptor activity, increasing the firing rate in the associated afferent neurons, carrying this information to the cardiovascular centre in the medulla.
- In response to this, the **parasympathetic nervous system** (PSNS) activity increases and the **sympathetic nervous system** (SNS) activity decreases. The net effect is reduced heart rate and systemic vasodilatation, collectively **reducing MABP**.
- Conversely, when blood pressure decreases, there is less baroreceptor activation meaning the impulse rate of the afferent fibres decreases, causing the cardiovascular centre to i**ncrease SNS outflow** and **decrease PSNS outflow**.
- The net effect of this is increased cardiac contractility, increased heart rate and increased systemic vasoconstriction, causing an overall **increase in blood pressure**.

Baroreceptor reflex



Renin-angiotensin-aldosterone system (RAAS):

- The **renin-angiotensin-aldosterone system** (RAAS) is an essential component of blood pressure regulation that acts to increase blood volume and increase systemic vascular resistance.
- This system is dependent on hormonal changes.
- The RAAS system starts with **renin**, a hormone released from **granular cells** in the **juxtaglomerular apparatus**, a specialised structure involving parts of the distal convoluted tubule (DCT) and the adjacent afferent arteriole of the glomerulus.
- Renin is released in response to increased concentration of salt in the blood, reduction in renal blood flow, or stimulation from the sympathetic nervous system acting on beta-1 receptors.
- Renin converts **angiotensinogen**, a protein synthesised by the liver, into **angiotensinogen I**, which is subsequently converted by **angiotensinogen-converting enzyme** (ACE) into **angiotensin II**. Angiotensin II causes **vasoconstriction** in the systemic circulation and the renal microvasculature, preferentially constricting the efferent arteriole.

- Importantly, angiotensin II **increases salt reabsorption** at the level of the kidney and does so indirectly through the activation of **aldosterone** released from the zona glomerulosa of the adrenal cortex. Increased salt retention subsequently increases plasma volume and blood pressure.

Antidiuretic hormone (ADH):

- **Antidiuretic hormone**, also known as **vasopressin**, is involved in the control of blood pressure. ADH is made by cell bodies located in the hypothalamus and released from the adjacent posterior pituitary.[1,6] The following physiological changes trigger ADH release:
- An increase in plasma osmolarity (detected by osmoreceptors in the hypothalamus)
- A reduction in blood volume
- An increase in the levels of angiotensin II

- ADH **increases water reabsorption** by binding to V2 receptors, subsequently anchoring water channels known as **aquaporins** to the apical membrane of its target, principal cells in the collecting duct and DCT of the kidney.
- These aquaporins, named AQP-2 channels, are accountable for the variable H_2O permeability at the distal part of the nephron, as water cannot pass through without them.
- When someone becomes dehydrated, the **osmolarity** of the extracellular fluid increases, leading to ADH release from the posterior pituitary.
- Water is then reabsorbed at an increased rate at the level of the kidney, ultimately acting to increase the intravascular fluid volume.
- This increases blood pressure through an increase in venous pressure, thereby boosting venous return to the heart, and increasing cardiac output.

Disorders of heart

- ***Coronary artery disease (coronary heart disease):*** is the most common type of heart disease. It happens slowly over time when a sticky substance called plaque builds up in the arteries that supply your heart muscle with blood. The plaque narrows or blocks blood flow to the heart muscle and can lead to other heart problems.
- ***Arrhythmia (dysrhythmia):*** abnormal rhythm as a result of a defect in the conduction system of heart.
- Classified as follows:
- ***Bradycardia:*** slow heart rate (below 50 beats/ min)
- ***Tachycardia:*** rapid heart rate (over 100 beats/ min)
- ***Fibrillation:*** rapid, uncoordinated heartbeat.

- ***Atherosclerosis:*** is the build-up of fats, cholesterol and other substances in and on the artery walls. This build-up is called plaque. The plaque can cause arteries to narrow, blocking blood flow. The plaque can also burst, leading to a blood clot.
- ***Angina pectoris:*** is the medical term for chest pain or discomfort due to coronary heart disease. It occurs when the heart muscle doesn't get as much blood as it needs. This usually happens because one or more of the heart's arteries is narrowed or blocked, also called ischemia.
- ***Congestive heart failure (heart failure):*** is a serious condition in which the heart doesn't pump blood as efficiently as it should. It means that the heart muscle has become less able to contract over time or has a mechanical problem that limits its ability to fill with blood.
- As a result, it can't keep up with the body's demand, and blood returns to the heart faster than it can be pumped out—it becomes congested, or backed up.
- This pumping problem means that not enough oxygen-rich blood can get to the body's other organs.