VISWASS SCHOOL & COLLEGE OF NURSING

GNM 1ST YEAR

ANATOMY AND PHYSIOLOGY

UNIT-4

THE CIRCULATORY SYSTEM

SHORT QUESTION AND ANSWER

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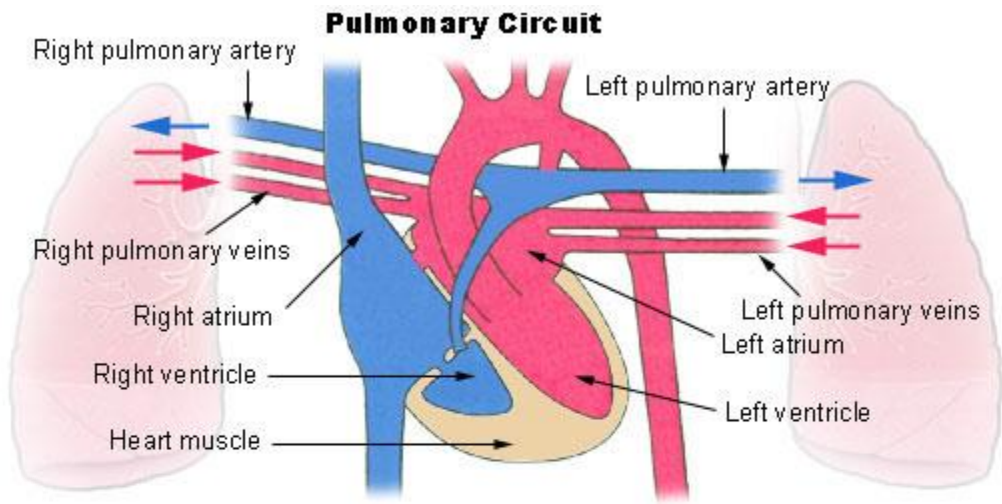
1.Explain about pulmonary circulation.(5)

Pulmonary circulation:

- The **pulmonary circulation** is the portion of the circulatory system which carries deoxygenated blood away from the right ventricle, to the lungs, and returns oxygenated blood to the left atrium and ventricle of the heart.
- The term pulmonary circulation is readily paired and contrasted with the systemic circulation.
- The vessels of the pulmonary circulation are the pulmonary arteries and the pulmonary veins.
- A separate system known as the bronchial circulation supplies oxygenated blood to the tissue of the larger airways of the lung.



- Deoxygenated blood leaves the heart, goes to the lungs, and then re-enters the heart; Deoxygenated blood leaves through the right ventricle through the pulmonary artery.
- From the right atrium, the blood is pumped through the tricuspid valve (or right atrioventricular valve), into the right ventricle.
- Blood is then pumped from the right ventricle through the pulmonary valve and into the main pulmonary artery.

Lungs

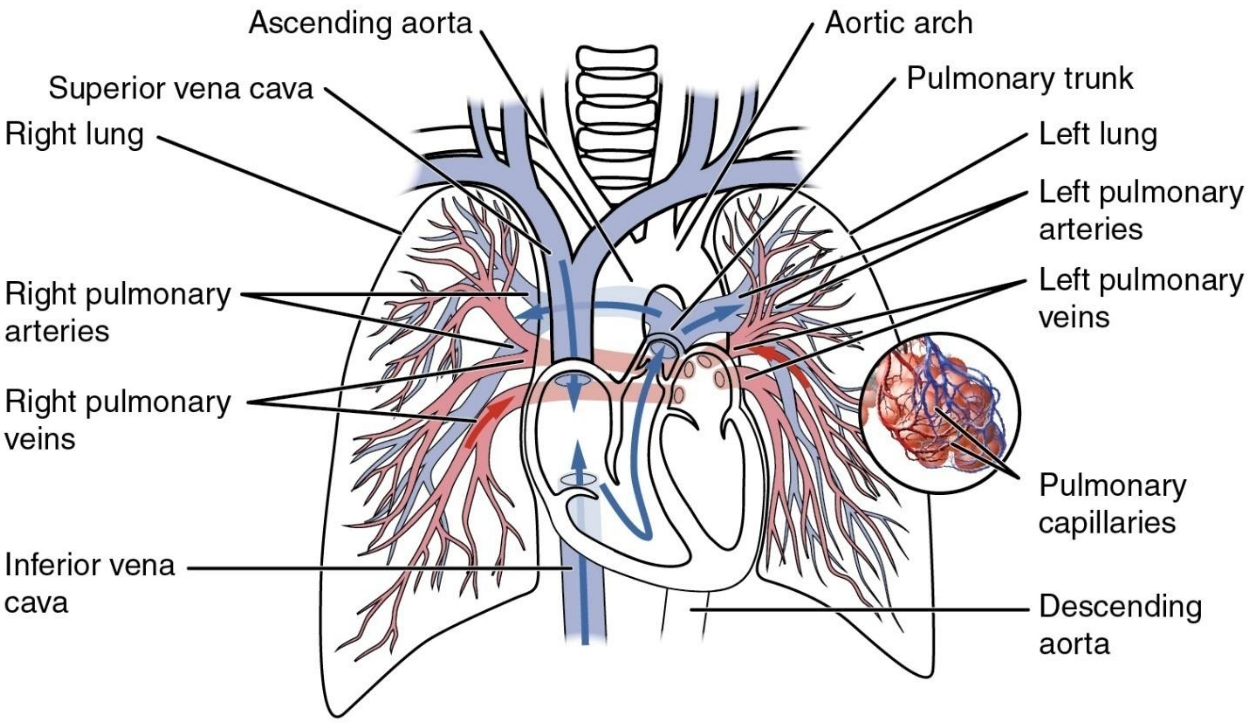
- The pulmonary arteries carry deoxygenated blood to the lungs, where carbon dioxide is released and oxygen is picked up during respiration.
- Arteries are further divided into very fine capillaries which are extremely thin-walled.
- The pulmonary vein returns oxygenated blood to the left atrium of the heart.

Veins

- The oxygenated blood then leaves the lungs through pulmonary veins, which return it to the left part of the heart, completing the pulmonary cycle.
- This blood then enters the left atrium, which pumps it through the mitral valve into the left ventricle.
- From the left ventricle, the blood passes through the aortic valve to the aorta.
- The blood is then distributed to the body through the systemic circulation before returning again to the pulmonary circulation.

Arteries

- From the right ventricle, blood is pumped through the semilunar pulmonary valve into the left and right main pulmonary arteries (one for each lung), which branch into smaller pulmonary arteries that spread throughout the lungs.



2.Systemic circulation.(5)

- The systemic circulation provides the functional blood supply to all body tissue.
- It carries oxygen and nutrients to the cells and picks up carbon dioxide and waste products.
- Systemic circulation carries oxygenated blood from the left ventricle, through the arteries, to the capillaries in the tissues of the body.
- From the tissue capillaries, the deoxygenated blood returns through a system of veins to the right atrium of the heart.

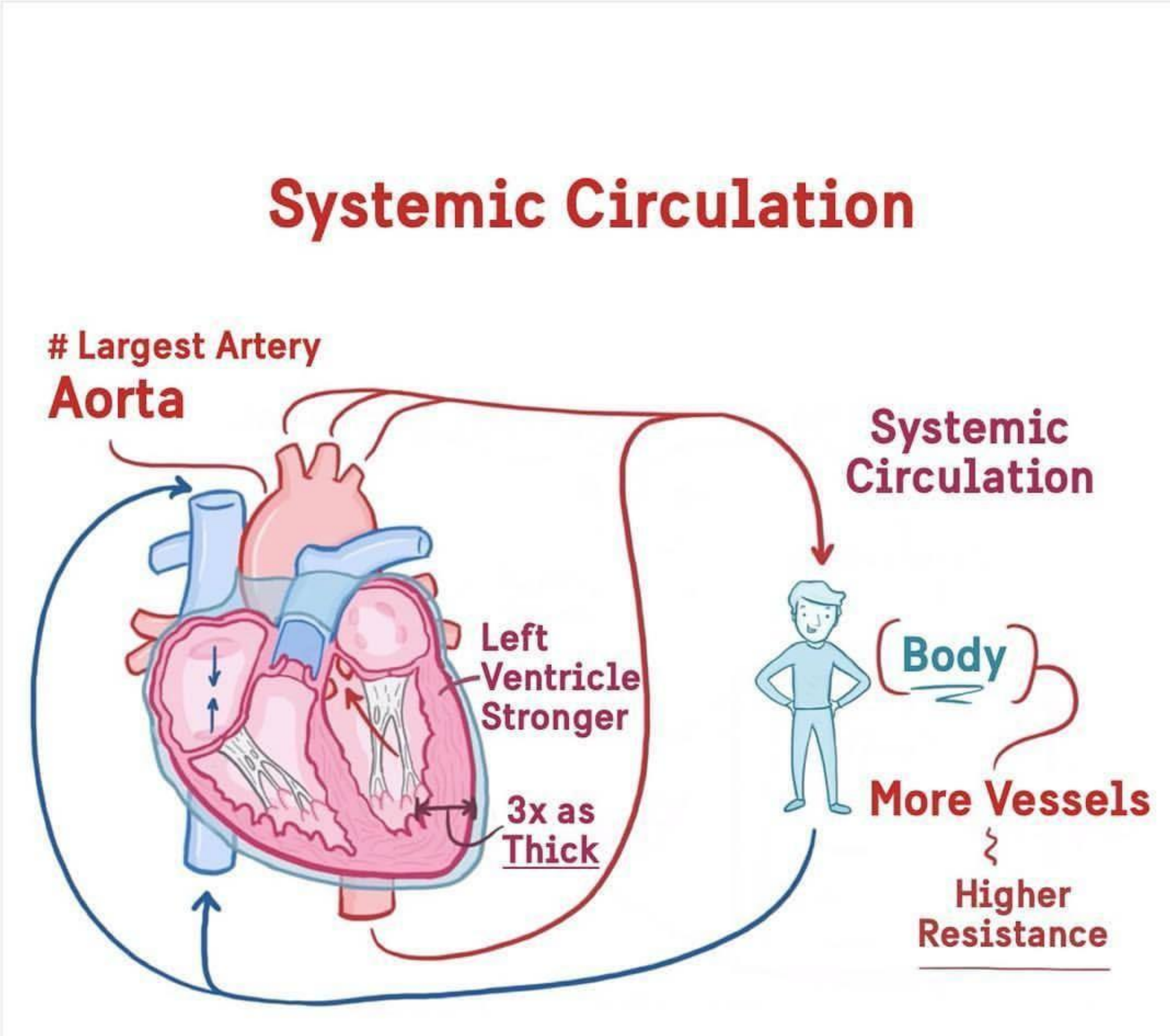
- The coronary arteries are the only vessels that branch from the ascending aorta.
- The brachiocephalic, left common carotid, and left subclavian arteries branch from the aortic arch.
- Blood supply for the brain is provided by the internal carotid and vertebral arteries.
- The subclavian arteries provide the blood supply for the upper extremity.
- The celiac, superior mesenteric, suprarenal, renal, gonadal, and inferior mesenteric arteries branch from the abdominal aorta to supply the abdominal viscera.
- Lumbar arteries provide blood for the muscles and spinal cord. Branches of the external iliac artery provide the blood supply for the lower extremity.
- The internal iliac artery supplies the pelvic viscera.

Major Systemic Arteries

- All systemic arteries are branches, either directly or indirectly, from the aorta. The aorta ascends from the left ventricle, curves posteriorly and to the left, then descends through the thorax and abdomen.
- This geography divides the aorta into three portions: ascending aorta, arotic arch, and descending aorta.
- The descending aorta is further subdivided into the thoracic arota and abdominal aorta.

Major Systemic Veins

- After blood delivers oxygen to the tissues and picks up carbon dioxide, it returns to the heart through a system of veins.
- The capillaries, where the gaseous exchange occurs, merge into venules and these converge to form larger and larger veins until the blood reaches either the superior vena cava or inferior vena cava, which drain into the right atrium.



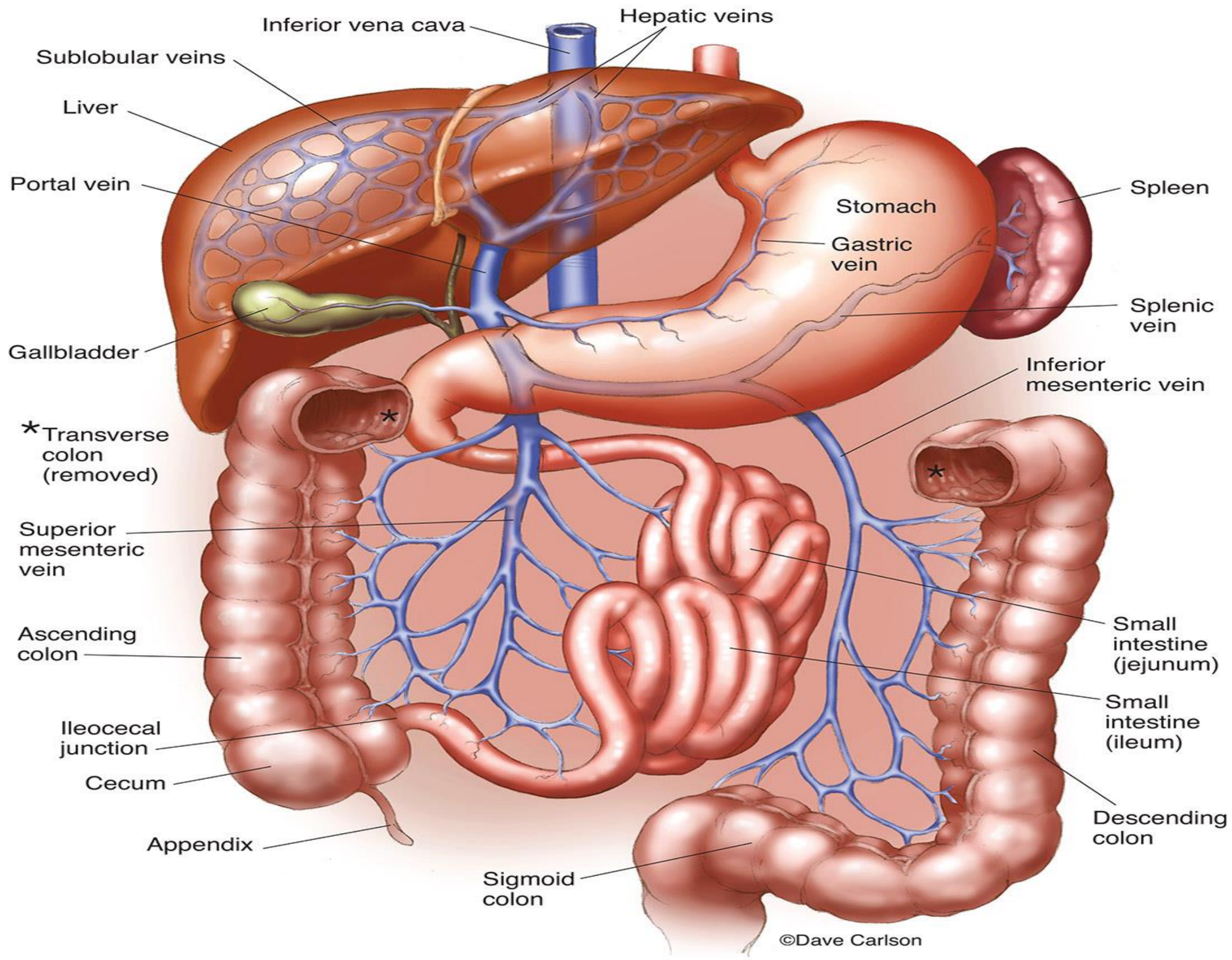
3.Portal circulation.(5)

- As a general rule, venous blood passes from the tissues to the heart by the most direct route through only one capillary bed.
- In the portal circulation, venous blood from the capillary beds of the abdominal part of the digestive system, the spleen and pancreas travels first to the liver.
- In the liver, it passes through a second capillary bed, the hepatic sinusoids, before entering the general circulation via the inferior vena cava.

- In this way, blood with a high concentration of nutrients, absorbed from the stomach and intestines, goes to the liver first.
- This supplies the liver with a rich source of nutrients for its extensive metabolic activities and ensures that the composition of blood leaving the alimentary tract can be appropriately regulated.
- It also ensures that unwanted and/or potentially toxic materials such as drugs are eliminated before the blood is returned into general circulation.
- This is called first-pass metabolism.
- Note that rectal veins draining blood from the lower two-thirds of the rectum empty into systemic veins, not the portal vein, and so this blood travels to the heart without first passing through the liver.
- Drugs absorbed from rectal formulations are therefore absorbed directly into the general circulation.
- This delays their elimination by the liver, which can be very useful clinically.

Portal vein:

- This is formed by the union of several veins, each of which drains blood from the area supplied by the corresponding artery:
  - The splenic vein drains blood from the spleen, the pancreas and part of the stomach.
  - The inferior mesenteric vein returns the venous blood from the rectum, pelvic structures and descending colon of the large intestine. It joints the splenic vein.
  - The superior mesenteric vein returns venous blood from the small intestine and the proximal parts of the large intestine, i.e. the caecum and ascending and transverse colon. It unites with the splenic vein to from the portal vein.
  - The gastric veins drain blood from the stomach and the distal end of the oesophagus, then join the portal vein.
  - The cystic vein drains venous blood from the gall bladder and joints the portal vein.
- Blood from the hepatic portal circulation is then returned directly to the inferior vena cava through the hepatic veins.



4.Fetal circulation.(5)

During pregnancy, the fetal circulatory system works differently than after birth:

- The fetus is connected by the umbilical cord to the placenta. This is the organ that develops and implants in the mother's uterus during pregnancy.
- Through the blood vessels in the umbilical cord, the fetus gets all needed nutrition and oxygen. The fetus gets life support from the mother through the placenta.
- Waste products and carbon dioxide from the fetus are sent back through the umbilical cord and placenta to the mother's circulation to be removed
    - The fetal circulatory system uses 3 shunts. These are small passages that direct blood that needs to be oxygenated. The purpose of these shunts is to bypass the lungs and liver. That's because these organs will not work fully until after birth. The shunt that bypasses

the lungs is called the foramen ovale. This shunt moves blood from the right atrium of the heart to the left atrium. The ductus arteriosus moves blood from the pulmonary artery to the aorta.

- Oxygen and nutrients from the mother's blood are sent across the placenta to the fetus. The enriched blood flows through the umbilical cord to the liver and splits into 3 branches. The blood then reaches the inferior vena cava. This is a major vein connected to the heart. Most of this blood is sent through the ductus venosus. This is also a shunt that lets highly oxygenated blood bypass the liver to the inferior vena cava and then to the right atrium of the heart. A small amount of this blood goes straight to the liver to give it the oxygen and nutrients it needs.
- Waste products from the fetal blood are transferred back across the placenta to the mother's blood.

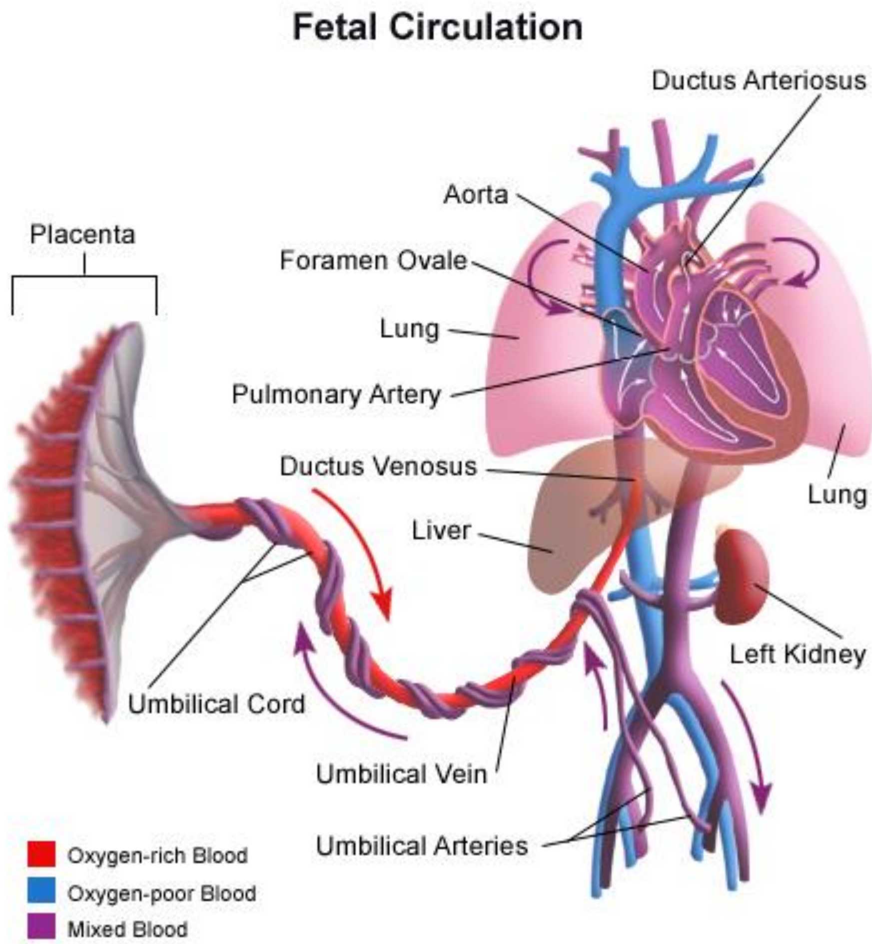
Inside the fetal heart

- Blood enters the right atrium. This is the chamber on the upper right side of the heart. When the blood enters the right atrium, most of it flows through the foramen ovale into the left atrium.
- Blood then passes into the left ventricle. This is the lower chamber of the heart. Blood then passes to the aorta. This is the large artery coming from the heart.
- From the aorta, blood is sent to the heart muscle itself and to the brain and arms. After circulating there, the blood returns to the right atrium of the heart through the superior vena cava.
- Very little of this less oxygenated blood mixes with the oxygenated blood. Instead of going back through the foramen ovale, it goes into the right ventricle.
- This less oxygenated blood is pumped from the right ventricle into the pulmonary artery. A small amount of the blood continues on to the lungs.
- Most of this blood is shunted through the ductus arteriosus to the descending aorta. This blood then enters the umbilical arteries and flows into the placenta.
- In the placenta, carbon dioxide and waste products are released into the mother's circulatory system. Oxygen and nutrients from the mother's blood are released into the fetus' blood.
- At birth, the umbilical cord is clamped and the baby no longer gets oxygen and nutrients from the mother. With the first breaths of life, the lungs start to expand.

- As the lungs expand, the alveoli in the lungs are cleared of fluid. An increase in the baby's blood pressure and a major reduction in the pulmonary pressures reduce the need for the ductus arteriosus to shunt blood.
- These changes help the shunt close. These changes raise the pressure in the left atrium of the heart.
- They also lower the pressure in the right atrium. The shift in pressure stimulates the foramen ovale to close.

Placenta

- The circulatory system of the mother is not directly connected to that of the fetus, so the placenta functions as the respiratory center for the fetus as well as a site of filtration for plasma nutrients and wastes.
- Water, glucose, amino acids, vitamins, and inorganic salts freely diffuse across the placenta along with oxygen.
- The uterine arteries carry blood to the placenta, and the blood permeates the sponge-like material there.
- Oxygen then diffuses from the placenta to the chorionic villus, an alveolus-like structure, where it is then carried to the umbilical vein.



5. Cardiac output.(5)

- The cardiac output is the amount of blood ejected from each ventricle every minute.
- The amount expelled by each contraction of each ventricle is the stroke volume.
- Cardiac output is expressed in litres per minute.(L/min) and is calculated by multiplying the stroke volume by the heart rate(measured in beats per minute)

  Cardiac output= Stroke volume x Heart rate
- Because cardiac output is related to the quantity of blood delivered to various parts of the body, it is an important component of how efficiently the heart can meet the body's demands for the maintenance of adequate tissue perfusion.
- Body tissues require continuous oxygen delivery which requires the sustained transport of oxygen to the tissues by the systemic circulation of oxygenated blood at an adequate pressure from the left ventricle of the heart via the aorta and arteries.

Stroke volume:

- **stroke volume** (**SV**) is the volume of blood pumped from the left ventricle per beat. Stroke volume is calculated using measurements of ventricle volumes from an echocardiogram and subtracting the volume of the blood in the ventricle at the end of a beat (called end-systolic volume) from the volume of blood just prior to the beat (called end-diastolic volume).
- The term *stroke volume* can apply to each of the two ventricles of the heart, although it usually refers to the left ventricle.
- The stroke volumes for each ventricle are generally equal, both being approximately 70 mL in a healthy 70-kg man.
- Stroke volume is an important determinant of cardiac output, which is the product of stroke volume and heart rate, and is also used to calculate ejection fraction, which is stroke volume divided by end-diastolic volume.
- Because stroke volume decreases in certain conditions and disease states, stroke volume itself correlates with cardiac function.

  SV(*stroke volume*) = EDV(end-diastolic volume) – ESV(end-systolic volume)

Venous return:

- Venous return (VR) is the flow of blood back to the heart. Under steady-state conditions, venous return must equal cardiac output (Q), when averaged over time because the cardiovascular system is essentially a closed loop.
- Otherwise, blood would accumulate in either the systemic or pulmonary circulations. Although cardiac output and venous return are interdependent, each can be independently regulated.
- The circulatory system is made up of two circulations (pulmonary and systemic) situated in series between the right ventricle (RV) and left ventricle (LV)
- venous return (VR) to the heart from the venous vascular beds is determined by a pressure gradient (venous pressure - right atrial pressure) and venous resistance (RV). T

- herefore, increases in venous pressure or decreases in right atrial pressure or venous resistance will lead to an increase in venous return, except when changes are brought about by altered body posture.
- Although the above relationship is true for the hemodynamic factors that determine the flow of blood from the veins back to the heart, it is important not to lose sight of the fact that blood flow through the entire systemic circulation represents both the cardiac output and the venous return, which are equal in the steady-state because the circulatory system is closed.
- Therefore, one could just as well say that venous return is determined by the mean aortic pressure minus the mean right atrial pressure, divided by the resistance of the entire systemic circulation (i.e., the systemic vascular resistance).

1. usculovenous pump: Rhythmical contraction of limb muscles as occurs during normal locomotory activity (walking, running, swimming) promotes venous return by the muscle pump mechanism.
2. Decreased venous capacitance: Sympathetic activation of veins decreases venous compliance, increases vesomotor tone, increases central venous pressure and promotes venous return indirectly by augmenting cardiac output through the Frank-Starling mechanism, which increases the total blood flow through the circulatory system.
3. Respiratory pump: During inspiration, the intrathoracic pressure is negative (suction of air into the lungs), and abdominal pressure is positive (compression of abdominal organs by diaphragm). This makes a pressure gradient between the infra- and supradiaphragmatic parts of v. cava inferior, "pulling" the blood towards the right atrium and increasing venous return.
4. Vena cava compression: An increase in the resistance of the vena cava, as occurs when the thoracic vena cava becomes compressed during a Valsalva maneuver or during late pregnancy, decreases return.
5. Gravity: The effects of gravity on venous return seem paradoxical because when a person stands up, hydrostatic forces cause the right atrial pressure to decrease and the venous pressure in the dependent limbs to increase. This increases the pressure gradient for venous return from the dependent limbs to the right atrium; however, venous return actually decreases. The reason for this is when a person initially stands, cardiac output

and arterial pressure decrease (because right atrial pressure falls). The flow through the entire systemic circulation falls because arterial pressure falls more than right atrial pressure; therefore the pressure gradient driving flow throughout the entire circulatory system is decreased.

6. Pumping action of the heart: During the cardiac cycle right atrial pressure changes alter central venous pressure (CVP), because there is no valve between the heart's atria and the large veins. CVP reflects right atrial pressure. Therefore, right atrial pressure also alters venous return.

Heart rate:

- The heart rate is a major determinant of cardiac output.
- If heart rate rises, cardiac output increases, and if it falls, cardiac output falls too.
- The main factors determining heart rate:
    - Autonomic nervous system: the intrinsic rate of at which the heart beats is a balance between sympathetic and parasympathetic activity and this is the most important factor in determining heart rate.
    - Circulating chemicals: the hormones adrenaline and noradrenaline, secreted by the adrenal medulla, have the same effect as sympathetic stimulation. i.e. they increase the heart rate.
    - Position: when a person is upright, the heart rate is usually faster than when lying down.
    - Gender: the heart rate is faster in women than man.
    - Age: the babies and small children the heart rate is more rapid than in older children and adults.
    - Temperature: the heart rate rises and falls with body temperature.

6. Pulse.(5)

- **pulse** represents the tactile arterial palpation of the heartbeat by trained fingertips.
- The pulse may be palpated in any place that allows an artery to be compressed near the surface of the body, such as at the neck (carotid artery), wrist (radial artery), at the groin (femoral artery), behind the knee (popliteal artery), near the ankle joint (posterior tibial artery), and on foot (dorsalis pedis artery).
- Pulse (or the count of arterial pulse per minute) is equivalent to measuring the heart rate.
- The heart rate can also be measured by listening to the heart beat by auscultation, traditionally using a stethoscope and counting it for a minute.
- The radial pulse is commonly measured using three fingers.
- This has a reason: the finger closest to the heart is used to occlude the pulse pressure, the middle finger is used get a crude estimate of the blood pressure, and the finger most distal to the heart (usually the ring finger) is used to nullify the effect of the ulnar pulse as the two arteries are connected via the palmar arches (superficial and deep).
- The pulse is an expedient tactile method of determination of systolic blood pressure to a trained observer.
- Diastolic blood pressure is non-palpable and unobservable by tactile methods, occurring between heartbeats.
- Pressure waves generated by the heart in systole move the arterial walls.
- Forward movement of blood occurs when the boundaries are pliable and compliant.
- These properties form enough to create a palpable pressure wave.
- The heart rate may be greater or lesser than the pulse rate depending upon physiologic demand.
- In this case, the heart rate is determined by auscultation or audible sounds at the heart apex, in which case it is not the pulse.
- The *pulse deficit* (difference between heart beats and pulsations at the periphery) is determined by simultaneous palpation at the radial artery and auscultation at the PMI, near the heart apex.
- It may be present in case of premature beats or atrial fibrillation.

- The pulse may be further indirectly observed under light absorbances of varying wavelengths with assigned and inexpensively reproduced mathematical ratios.

Characteristics of pulse

Rate

Normal pulse rates at rest, in beats per minute

The pulse rate can be used to check overall heart health and fitness level. Generally lower is better, but bradycardias can be dangerous. Symptoms of a dangerously slow heartbeat include weakness, loss of energy and fainting.

Rhythm:

A normal pulse is regular in rhythm and force. An irregular pulse may be due to sinus arrhythmia, ectopic beats, atrial fibrillation, paroxysmal atrial tachycardia, atrial flutter, partial heart block etc. Intermittent dropping out of beats at pulse is called "intermittent pulse". Examples of *regular* intermittent (regularly irregular) pulse include pulsus bigeminus, second-degree atrioventricular block. An example of *irregular* intermittent (irregularly irregular) pulse is atrial fibrillation..

Volume

The degree of expansion displayed by artery during diastolic and systolic state is called volume. It is also known as amplitude, expansion or size of pulse.

Hypokinetic pulse

A weak pulse signifies narrow pulse pressure. It may be due to low cardiac output (as seen in shock, congestive cardiac failure), hypovolemia, valvular heart disease (such as aortic outflow tract obstruction, mitral stenosis, aortic arch syndrome) etc.

Hyperkinetic pulse

A bounding pulse signifies high pulse pressure. It may be due to low peripheral resistance (as seen in fever, anemia, thyrotoxicosis, hyperkinetic heart syndrome, A-V fistula, Paget's disease, beriberi, liver cirrhosis), increased cardiac output, increased stroke volume (as seen in anxiety, exercise, complete heart block, aortic regurgitation), decreased distensibility of arterial system (as seen in atherosclerosis, hypertension and coarctation of aorta

Force

Also known as compressibility of pulse. It is a rough measure of systolic blood pressure.

Tension

It corresponds to diastolic blood pressure. A low tension pulse (pulsus mollis), the vessel is soft or impalpable between beats. In high tension pulse (pulsus durus), vessels feel rigid even between pulse beats.

Form

A form or contour of a pulse is palpatiory estimation of arteriogram. A quickly rising and quickly falling pulse (pulsus celer) is seen in aortic regurgitation. A slow rising and slowly falling pulse (pulsus tardus) is seen in aortic stenosis.

Equality

Comparing pulses and different places gives valuable clinical information.

A discrepant or unequal pulse between left and right radial artery is observed in anomalous or aberrant course of artery, coarctation of aorta, aortitis, dissecting aneurysm, peripheral embolism etc. An unequal pulse between upper and lower extremities is seen in coarctation to aorta, aortitis, block at bifurcation of aorta, dissection of aorta, iatrogenic trauma and arteriosclerotic obstruction.

Condition of arterial wall

A normal artery is not palpable after flattening by digital pressure. A thick radial artery which is palpable 7.5–10 cm up the forearm is suggestive of arteriosclerosis.

Radio-femoral delay

In coarctation of aorta, femoral pulse may be significantly delayed as compared to radial pulse (unless there is coexisting aortic regurgitation). The delay can also be observed in supravalvar aortic stenosis.

7.Describe blood pressure.(5)

Blood pressure:

- **Blood pressure** is the pressure exerted by the blood on the walls of the blood vessels. Unless indicated otherwise, *blood pressure* refers to **arterial blood pressure**,
- i.e., the pressure in the large arteries, such as the brachial artery (in the arm). The pressure of the blood in other vessels is lower than the arterial pressure.
- Blood pressure values are universally stated in millimetres of mercury (mm Hg), and are always given relative to atmospheric pressure—the absolute pressure of the blood in an artery with mean arterial pressure stated as 100 mm, on a day with atmospheric pressure of 760 mm, is 860 mm.
- The systolic pressure is defined as the peak pressure in the arteries during the cardiac cycle;
- the diastolic pressure is the lowest pressure (at the resting phase of the cardiac cycle).
- The mean arterial pressure and pulse pressure are other important quantities.
- Typical values for a resting, healthy adult are approximately 120 mmHg systolic and 80 mmHg diastolic (written as 120/80 mmHg), with large individual variations.
- These measures of blood pressure are not static, but undergo natural variations from one heartbeat to another or throughout the day (in a circadian rhythm); they also change in response to stress, nutritional factors, drugs, or disease.

Physiology

- The mean blood pressure in the arteries supplying the body is a result of the heart pumping blood from the veins back into the arteries.
- The mean blood pressure value is determined by the volume of blood the heart is pumping per minute, termed cardiac output, versus the resistance of the 20,000 to 30,000 arterioles, termed total peripheral resistance, through which the blood must flow to reach the capillaries and then veins.
- The up and down fluctuation of the arterial blood pressure results from the pulsatile nature of the cardiac output.
- The pulse pressure is determined by the interaction of the stroke volume versus the volume and elasticity of the major arteries.

- The larger arteries, including all large enough to see without magnification, are low resistance (assuming no advanced atherosclerotic changes) conduit vessels with high flow rates that produce very little pressure drop.
- For instance, about 5 mmHg mean pressure decrease is typical in the blood flow traveling from the heart all the way to the toes, assuming the individual is supine (horizontal with respect to gravity).

Regulation of blood pressure

- The endogenous regulation of blood pressure is not completely understood. Currently, three mechanisms of regulating blood pressure have been well-characterized:

- **B**aroreceptor reflex: Baroreceptors in various organs can detect changes in blood pressure, and adjust the mean arterial pressure by altering both the force and speed of the heart's contractions, as well as the total peripheral resistance.

- **Renin-angiotensin system (RAS)**: This system is generally known for its long-term adjustment of blood pressure. This system allows the kidney to compensate for loss in blood volume or drops in blood pressure by activating an endogenous vasoconstrictor known as angiotensin II.

- **Aldosterone release:** This steroid hormone is released from the adrenal gland in response to either high serum potassium levels or if angiotensin II is present. This hormone increases the excretion of potassium by the kidneys, while increasing sodium retention. Since sodium is the main ion which determines the amount of fluid in the blood vessels by osmosis, aldosterone will increase fluid retention, and indirectly, blood pressure.

- These different mechanisms are not necessarily independent of each other, as indicated by the link between the RAS and aldosterone release.

Factors influencing blood pressure

- The physics of the circulatory system, That said, there are many physical factors that influence blood pressure. Each of these may in turn be influenced by physiological factors, such as diet, exercise, disease, drugs, etc.

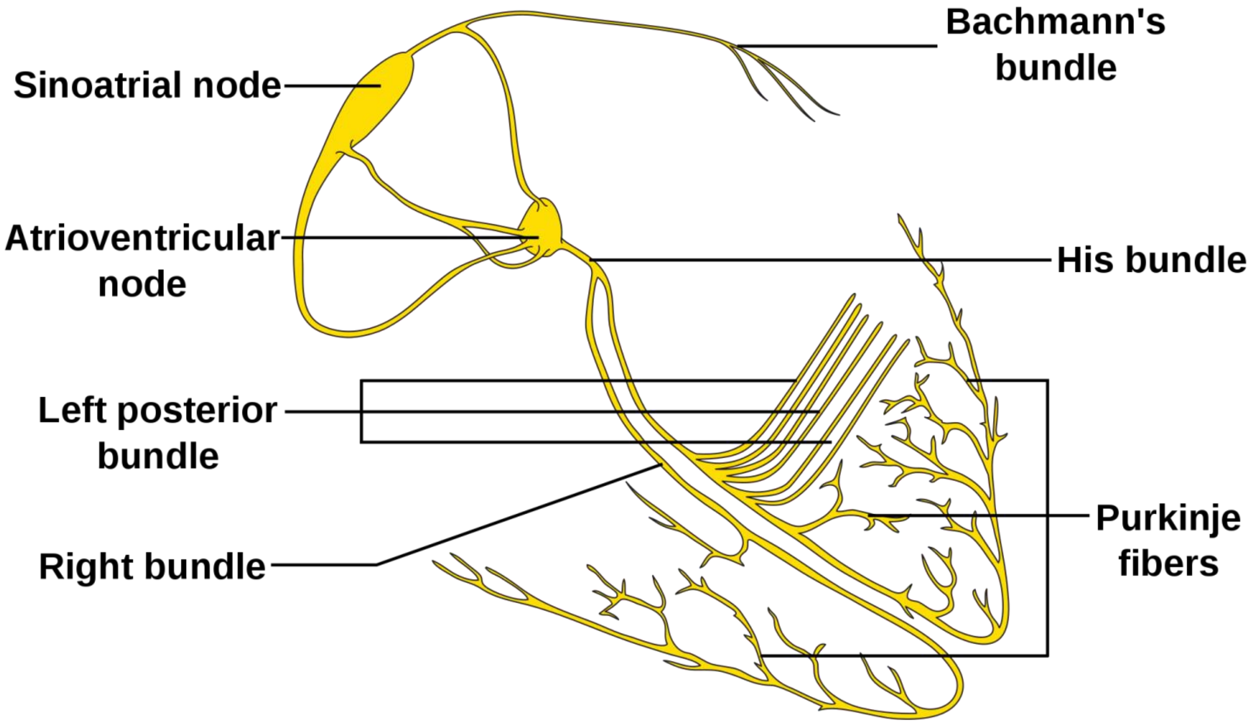
- Some physical factors are:

- Rate of pumping. In the circulatory system, this rate is called heart rate, the rate at which blood (the fluid) is pumped by the heart. The higher the heart rate, the higher (potentially, assuming no change in stroke volume) the blood pressure.
- Volume of fluid. In the case of the circulatory system, this is blood volume, the amount of blood present in the body.
- The more blood present in the body, the higher the rate of blood return to the heart and the resulting cardiac output.
- There is some relationship between dietary salt intake and increased blood volume, potentially resulting in higher blood pressure, though this varies with the individual and is highly dependent on autonomic nervous system response.
- In cardiac physiology, the rate and volume of flow are accounted for in a combined fashion by cardiac output.
- Cardiac output is the product of the heart rate, or the rate of contraction, multiplied by the stroke volume, the amount of blood pumped out from the heart with each contraction.
- Basically, it represents the efficiency with which the heart circulates the blood throughout the body.
- Resistance. In the circulatory system, this is the resistance of the blood vessels. The higher the resistance, the higher the blood pressure. Resistance is related to size (The larger the blood vessel, the lower the resistance), as well as the smoothness of the blood vessel walls.
- Smoothness is reduced by the buildup of fatty deposits on the arterial walls. Substances called vasoconstrictors can reduce the size of blood vessels, thereby increasing blood pressure.
- Vasodilators (such as nitroglycerin) increase the size of blood vessels, thereby decreasing blood pressure.
- Viscosity, or thickness of the fluid. If the blood gets thicker, the result is an increase in blood pressure.

- Certain medical conditions can change the viscosity of the blood. For instance, low red blood cell concentration, anemia, reduces viscosity, whereas increased red blood cell concentration increases viscosity.
- Viscosity also increases with blood sugar concentration—visualise pumping syrup. (It was thought that aspirin and other drugs decreased the viscosity of blood, but this has been found not to be so "blood thinners" reduce the tendency of the blood to clot, not viscosity.)

➢ In practice, each individual's autonomic nervous system responds to and regulates all these interacting factors so that, although the above issues are important, the actual blood pressure response of a given individual varies widely because of both split-second and slow-moving responses of the nervous system and end organs.

8. Explain about conducting system of heart.(5)



- The heart possesses the property of autorhythmicity, which means it generates its own electrical impulses and beats independently of nervous or hormonal control, i.e. it is not reliant on external mechanisms to initiate each heart beat.
- However it is supplied with both sympathetic and para sympathetic nerve fibres, which increase and decrease, respectively, the intrinsic heart rate.
- Small group of specialised neuromuscular cells in the myocardium initiate and conduct impulses, causing coordinated and synchronised contraction of the heart muscle.

Sinoatrial (SA) node

- Normal sinus rhythm is established by the sinoatrial (SA) node, the heart's pacemaker.
- The SA node is a specialized grouping of cardiomyocytes in the upper and back walls of the right atrium very close to the opening of the superior vena cava.
- The SA node has the highest rate of depolarization.

- This impulse spreads from its initiation in the SA node throughout the atria through specialized internodal pathways, to the atrial myocardial contractile cells and the atrioventricular node.
- The internodal pathways consist of three bands (anterior, middle, and posterior) that lead directly from the SA node to the next node in the conduction system, the atrioventricular node.
- The impulse takes approximately 50 ms (milliseconds) to travel between these two nodes.
- The relative importance of this pathway has been debated since the impulse would reach the atrioventricular node simply following the cell-by-cell pathway through the contractile cells of the myocardium in the atria.
- In addition, there is a specialized pathway called Bachmann's bundle or the interatrial band that conducts the impulse directly from the right atrium to the left atrium.
- Regardless of the pathway, as the impulse reaches the atrioventricular septum, the connective tissue of the cardiac skeleton prevents the impulse from spreading into the myocardial cells in the ventricles except at the atrioventricular node.
- The electrical event, the wave of depolarization, is the trigger for muscular contraction.
- The wave of depolarization begins in the right atrium, and the impulse spreads across the superior portions of both atria and then down through the contractile cells.
- The contractile cells then begin contraction from the superior to the inferior portions of the atria, efficiently pumping blood into the ventricles.

Atrioventricular (AV) node

- The atrioventricular (AV) node is a second cluster of specialized myocardial conductive cells, located in the inferior portion of the right atrium within the atrioventricular septum.
- The septum prevents the impulse from spreading directly to the ventricles without passing through the AV node.
- There is a critical pause before the AV node depolarizes and transmits the impulse to the atrioventricular bundle.

- This delay in transmission is partially attributable to the small diameter of the cells of the node, which slow the impulse.
- Also, conduction between nodal cells is less efficient than between conducting cells.
- These factors mean that it takes the impulse approximately 100 ms to pass through the node.
- This pause is critical to heart function, as it allows the atrial cardiomyocytes to complete their contraction that pumps blood into the ventricles before the impulse is transmitted to the cells of the ventricle itself.
- With extreme stimulation by the SA node, the AV node can transmit impulses maximally at 220 per minute.
- This establishes the typical maximum heart rate in a healthy young individual.
- Damaged hearts or those stimulated by drugs can contract at higher rates, but at these rates, the heart can no longer effectively pump blood.

Bundle of His, bundle branches, and Purkinje fibers

- Arising from the AV node, the bundle of His, proceeds through the interventricular septum before dividing into two <u>bundle branches</u>, commonly called the left and right bundle branches.
- The left bundle branch has two fascicles.
- The left bundle branch supplies the left ventricle, and the right bundle branch the right ventricle.
- Since the left ventricle is much larger than the right, the left bundle branch is also considerably larger than the right.
- Portions of the right bundle branch are found in the moderator band and supply the right papillary muscles.
- Because of this connection, each papillary muscle receives the impulse at approximately the same time, so they begin to contract simultaneously just prior to the remainder of the myocardial contractile cells of the ventricles.

- This is believed to allow tension to develop on the chordae tendineae prior to right ventricular contraction.
- There is no corresponding moderator band on the left.
- Both bundle branches descend and reach the apex of the heart where they connect with the Purkinje fibers. This passage takes approximately 25 ms.
- The Purkinje fibers are additional myocardial conductive fibers that spread the impulse to the myocardial contractile cells in the ventricles.
- They extend throughout the myocardium from the apex of the heart toward the atrioventricular septum and the base of the heart.
- The Purkinje fibers have a fast inherent conduction rate, and the electrical impulse reaches all of the ventricular muscle cells in about 75 ms.
- Since the electrical stimulus begins at the apex, the contraction also begins at the apex and travels toward the base of the heart, similar to squeezing a tube of toothpaste from the bottom.
- This allows the blood to be pumped out of the ventricles and into the aorta and pulmonary trunk.
- The total time elapsed from the initiation of the impulse in the SA node until depolarization of the ventricles is approximately 225 ms.