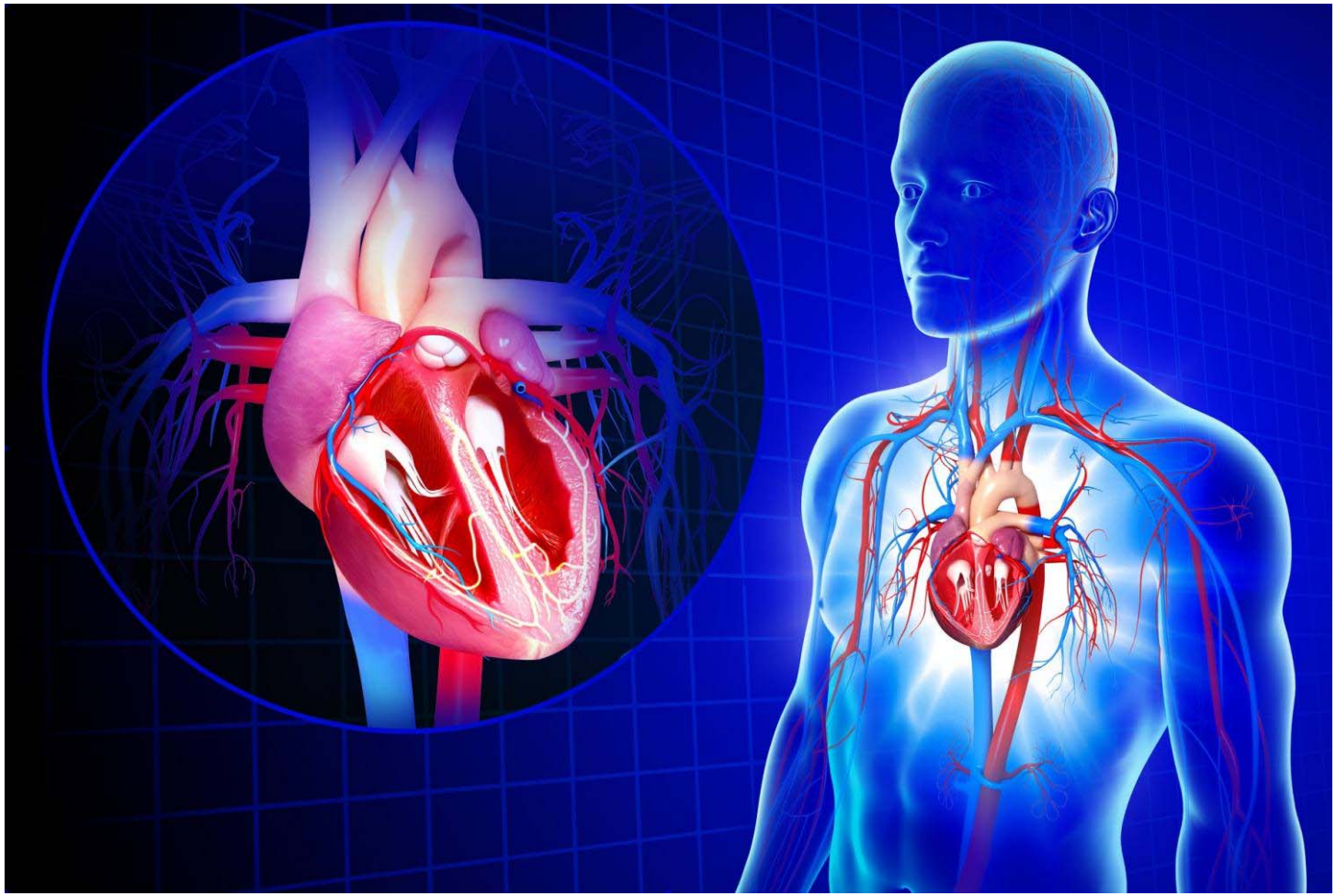


Asst. Lec. Safa Jalil Al-Yassiri

Cardiovascular system

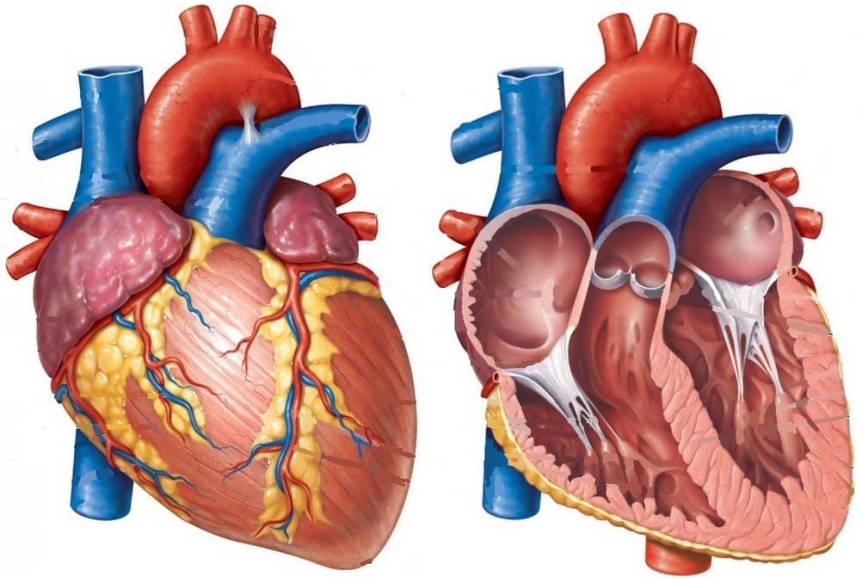
Department of occupational Therapy Techniques

Cardiovascular system: consists of the heart, blood vessels and blood. Its primary function is to transport nutrients and oxygen-rich blood to all parts of the body and to carry deoxygenated blood back to the lungs.

Anatomy and physiology of the cardiovascular system:

The heart:

- The heart lies in the mediastinum, an anatomical region that extends from the sternum to the vertebral column, from the first rib to the diaphragm, and between the lungs.
- About two-thirds of the mass of the heart lies to the left of the body's midline.
- for all its might, the heart is relatively small as closed fist.
- It is about 12 cm long, 9 cm wide at its broadest point, and 6 cm thick, with an average mass of 250 g in adult females and 300 g in adult males. The heart rests on the diaphragm, near the midline of the thoracic cavity.
- The heart as a cone lying on its side. The pointed apex is formed by the tip of the left ventricle (a lower chamber of the heart) and rests on the diaphragm. It is directed anteriorly, inferiorly, and to the left . The base of the heart is opposite the apex and is its posterior aspect. It is formed by the atria (upper chambers) of the heart, mostly the left atrium.

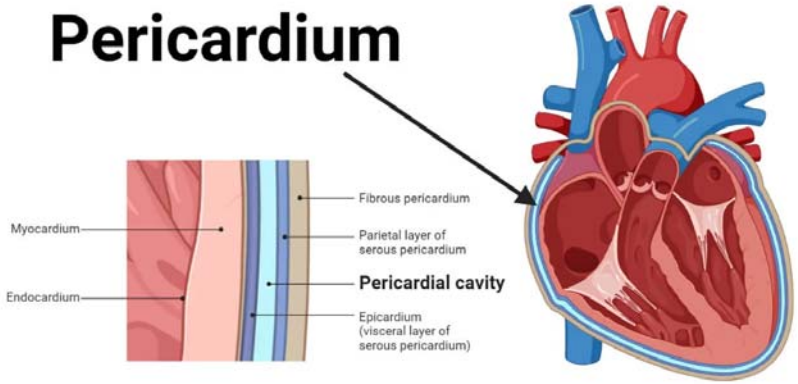


Pericardium:
The membrane that surrounds and protects the heart. It confines the heart to its position in the mediastinum, while allowing sufficient freedom of movement for vigorous and rapid contraction.

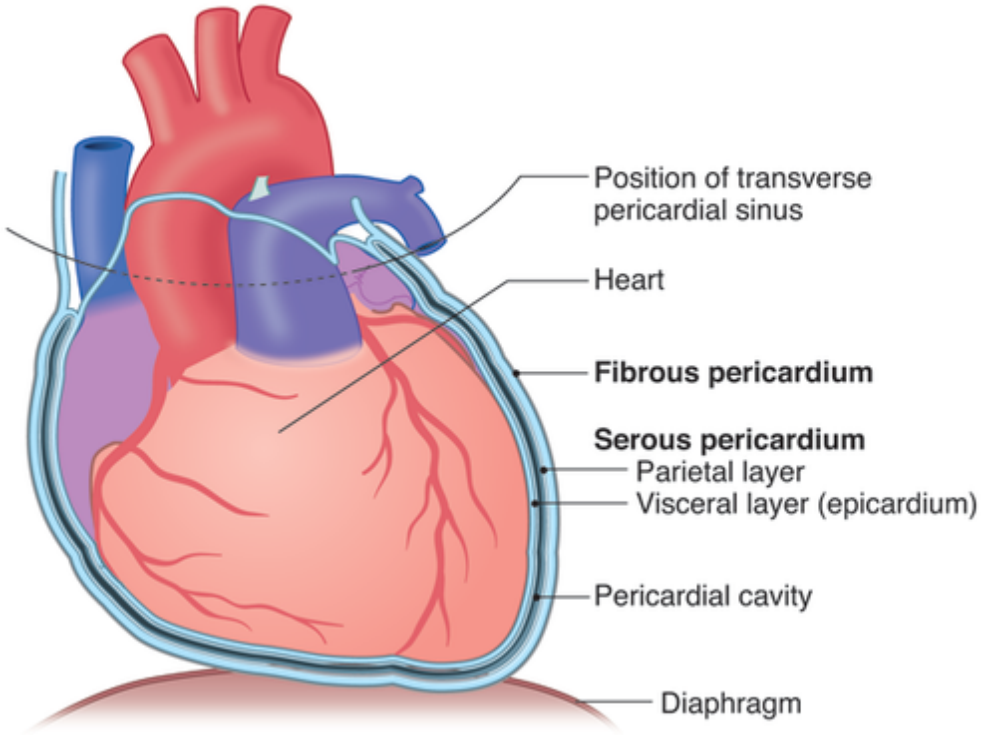
The pericardium consists of two main parts:
(1) the fibrous pericardium and (2) the serous pericardium.

- **The superficial fibrous pericardium:** is composed of tough, inelastic, dense irregular connective tissue. It resembles a bag that rests on and attaches to the diaphragm; its open end is fused to the connective tissues of the blood vessels entering and leaving the heart. The fibrous pericardium prevents overstretching of the heart, provides protection, and anchors the heart in the mediastinum.

- **The deeper serous pericardium:** is a thinner, more delicate membrane that forms a double layer around the heart.
  - **The outer parietal layer of the serous pericardium,** is fused to the fibrous pericardium.
  - **The inner visceral layer of the serous pericardium**, which is also called the **epicardium**, is one of the layers of the heart wall and adheres tightly to the surface of the heart.



Between the parietal and visceral layers of the serous pericardium is a thin film of lubricating serous fluid. This slippery secretion of the pericardial cells, known as pericardial fluid, reduces friction between the layers of the serous pericardium as the heart moves. The space that contains the pericardial fluid is called the pericardial cavity.


Position of transverse pericardial sinus
Heart
Fibrous pericardium
Serous pericardium
Parietal layer
Visceral layer (epicardium)
Pericardial cavity
Diaphragm

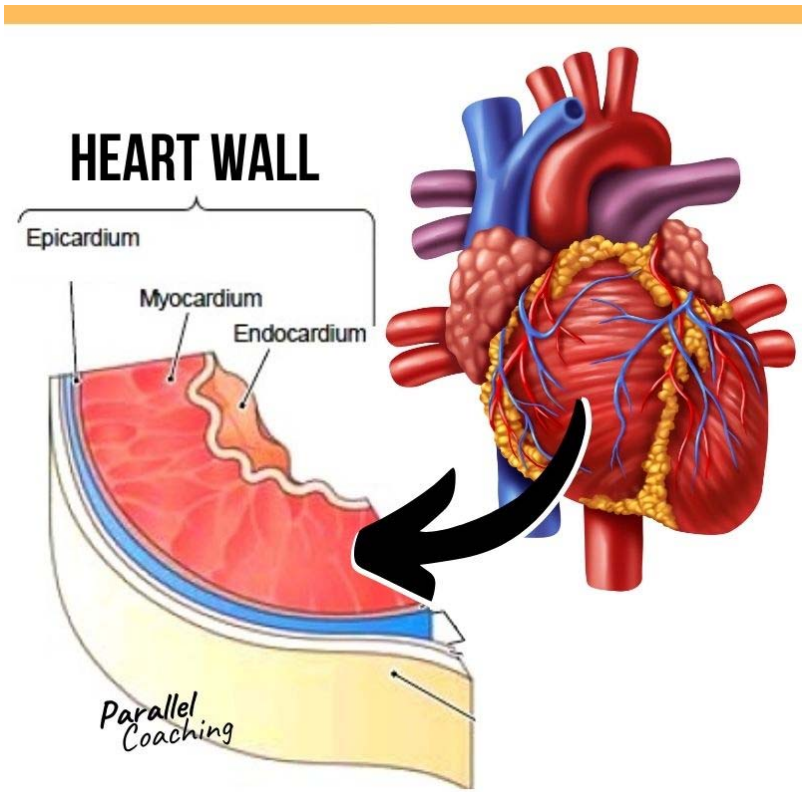
Layers of the heart wall:

The wall of the heart consists of three layers: the epicardium (external layer), the myocardium (middle layer), and the endocardium (inner layer).

1. **The epicardium:** The outermost, is called the visceral layer of the serous pericardium. This thin, transparent outer layer of the heart wall is composed of mesothelium. The epicardium contains blood vessels, lymphatics, and vessels that supply the myocardium.

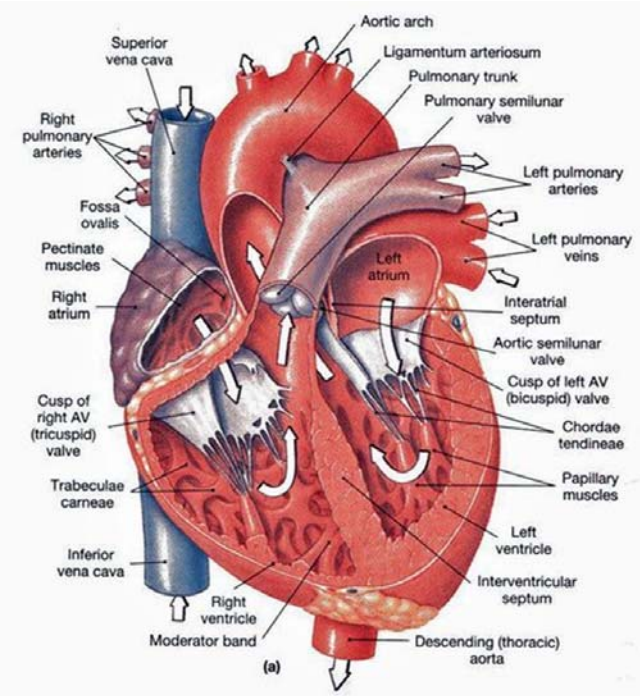
2. **The middle myocardium:** is responsible for the pumping action of the heart and is composed of cardiac muscle tissue. It makes up approximately 95% of the heart wall.

3. **The innermost endocardium:** is a thin layer of endothelium overlying a thin layer of connective tissue. It provides a smooth lining for the chambers and covers the valves of the heart. The smooth endothelial lining minimizes the surface friction as blood passes through the heart. The endocardium is continuous with the endothelial lining of the large blood vessels attached to the heart.



Chambers of the heart:

The heart has four chambers. The two superior receiving chambers are the atria, and the two inferior pumping chambers are the ventricles. The paired atria receive blood from blood vessels returning blood to the heart, called veins, while the ventricles eject the blood from the heart into blood vessels called arteries.



1. Right Atrium:

- The right atrium forms the right surface of the heart and receives blood from three veins: the superior vena cava (receives blood from the upper body), inferior vena cava (receives blood from the lower body). The coronary sinus (which drains most of the blood from the heart wall).
- Between the right atrium and left atrium is a thin partition called the interatrial septum.
- Blood passes from the right atrium into the right ventricle through a valve that is called the tricuspid valve because it consists of three cusps or leaflets. It is also called the right atrioventricular valve which prevents backflow of blood from the right ventricle to the right atrium when the right ventricle contracts.

2. Right Ventricle:

- The right ventricle is forms most of the anterior surface of the heart.
- Internally, the right ventricle is separated from the left ventricle by a partition called the interventricular septum.
- Blood passes from the right ventricle through the pulmonary valve (pulmonary semilunar valve prevents backflow of blood from the pulmonary artery to the right ventricle when the right ventricle relaxes.) into a large artery called the pulmonary trunk, which divides into right and left pulmonary arteries and carries blood to the lungs.

3. Left Atrium:

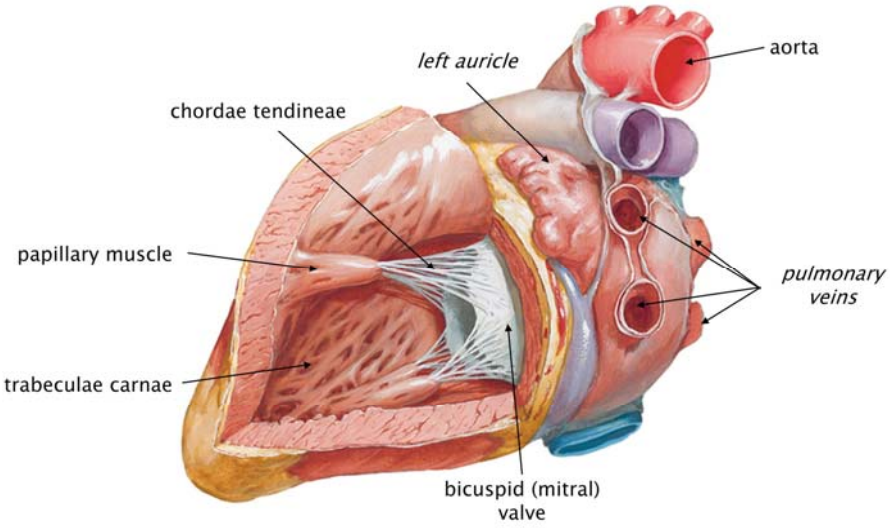
- The left atrium is about the same thickness as the right atrium and forms most of the base of the heart.
- It receives blood from the lungs through four pulmonary veins.
- Blood passes from the left atrium into the left ventricle through the bicuspid (mitral) valve which has two cusps also called the left atrioventricular valve.

4. Left Ventricle:

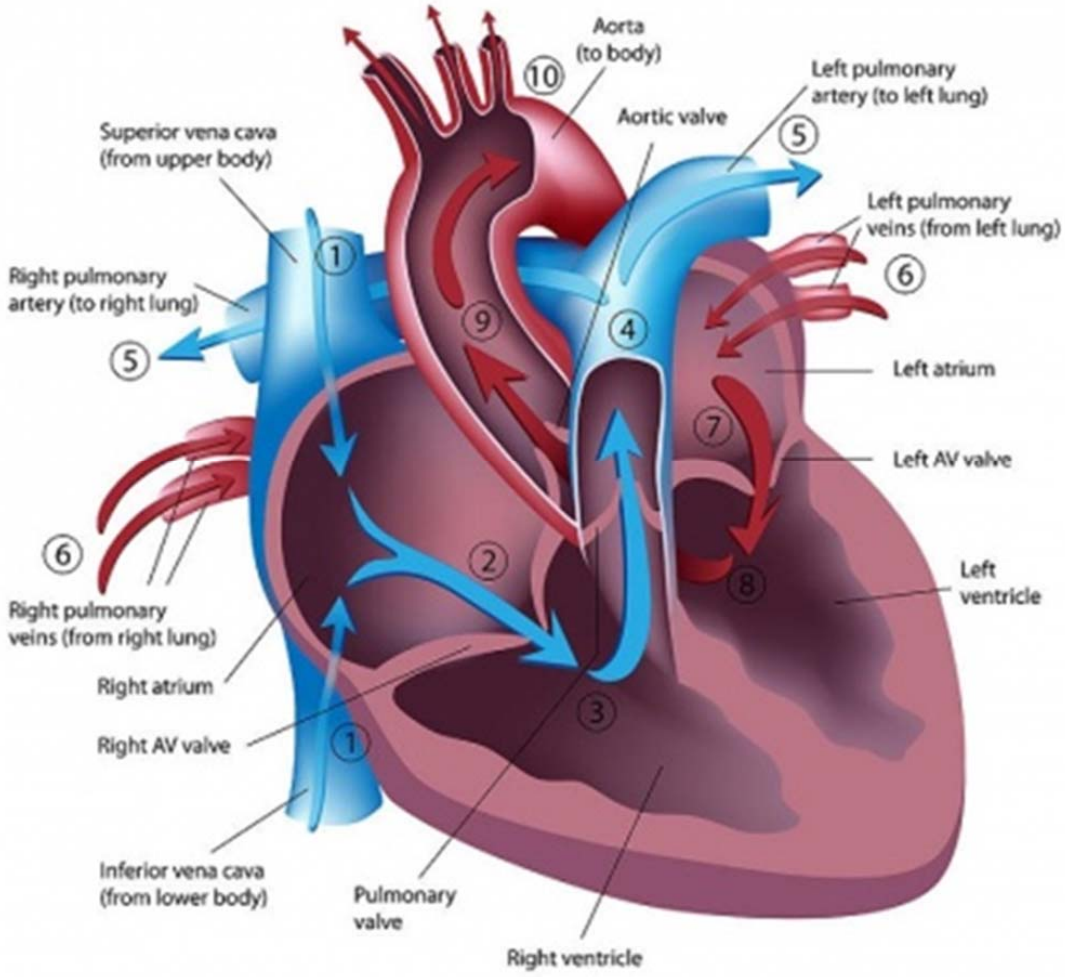
- The left ventricle is the thickest chamber of the heart, averaging 10–15 mm, and forms the apex of the heart.
- Blood passes from the left ventricle through the aortic valve (aortic semilunar valve which prevents backflow of blood from the aorta to the left ventricle when the left ventricle relaxes) into the ascending aorta.

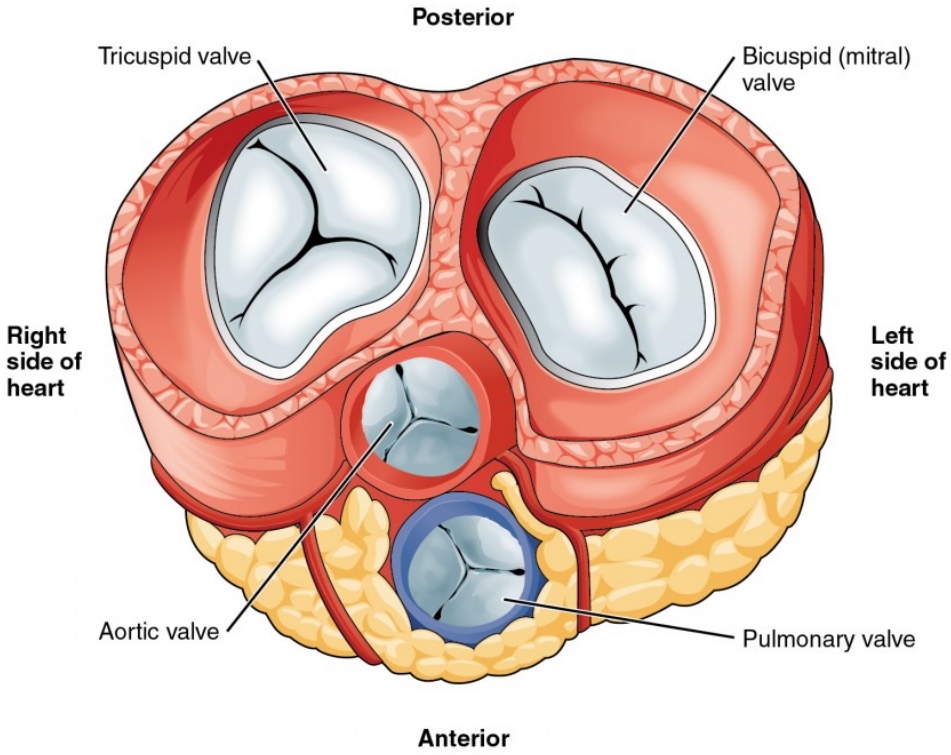
Each ventricle features large cone-shaped trabeculae carneae known as papillary muscles which are anchored at one end to the surface of the ventricle. The opposite end is connected to thin, tendon-like structures called chordae tendineae, which extend to attach to the free edges of the tricuspid and mitral valve cusps in the right and left ventricles, respectively.

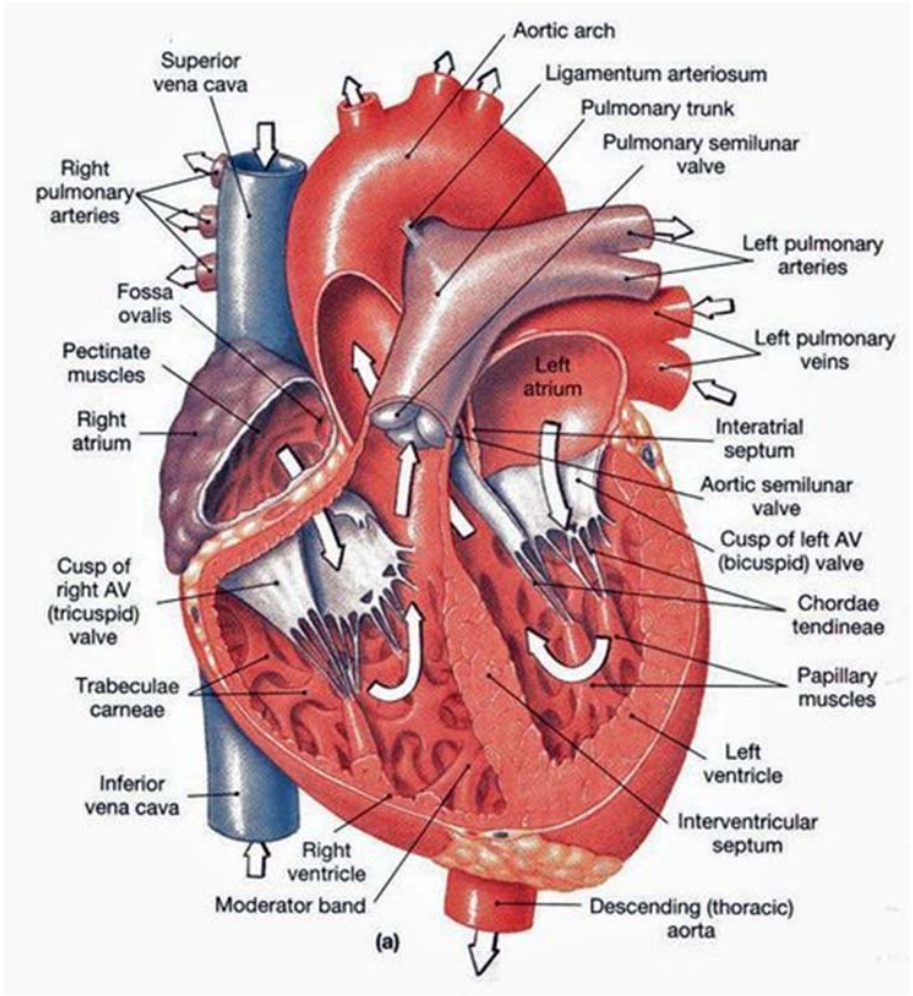
The chordae tendineae function to prevent the inversion of the valves into the atrium during ventricular contraction.



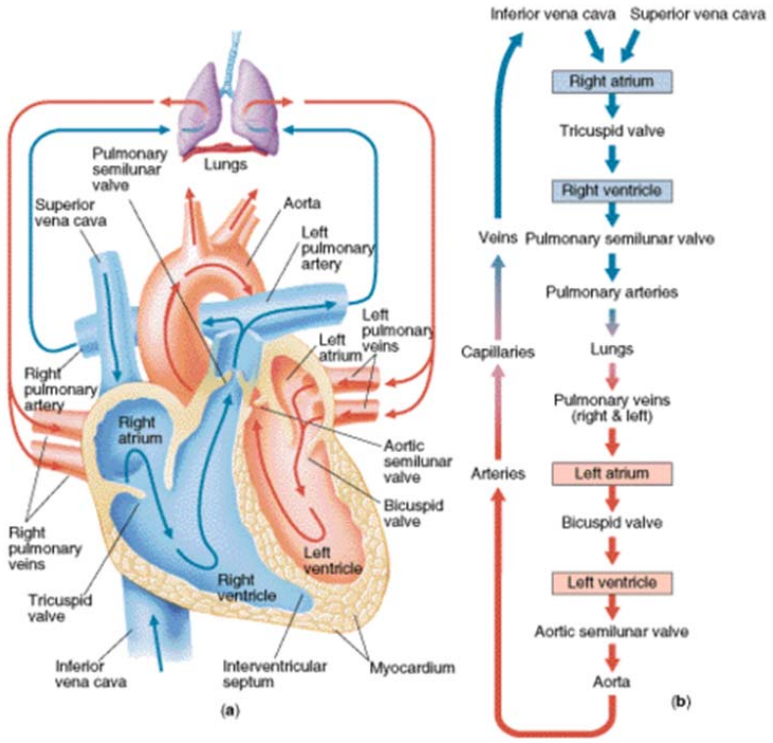
The pathway of blood flow through the heart




Posterior
Tricuspid valve
Bicuspid (mitral) valve
Right side of heart
Left side of heart
Aortic valve
Pulmonary valve
Anterior


Aortic arch
Superior vena cava
Ligamentum arteriosum
Pulmonary trunk
Pulmonary semilunar valve
Right pulmonary arteries
Left pulmonary arteries
Fossa ovalis
Left pulmonary veins
Pectinate muscles
Left atrium
Right atrium
Interatrial septum
Aortic semilunar valve
Cusp of left AV (bicuspid) valve
Cusp of right AV (tricuspid) valve
Chordae tendineae
Trabeculae carneae
Papillary muscles
Left ventricle
Inferior vena cava
Interventricular septum
Right ventricle
Moderator band
Descending (thoracic) aorta
(a)

Systemic and Pulmonary Circulations: In postnatal (after birth) circulation, the heart pumps blood into two closed circuits with each beat—systemic circulation and pulmonary circulation.

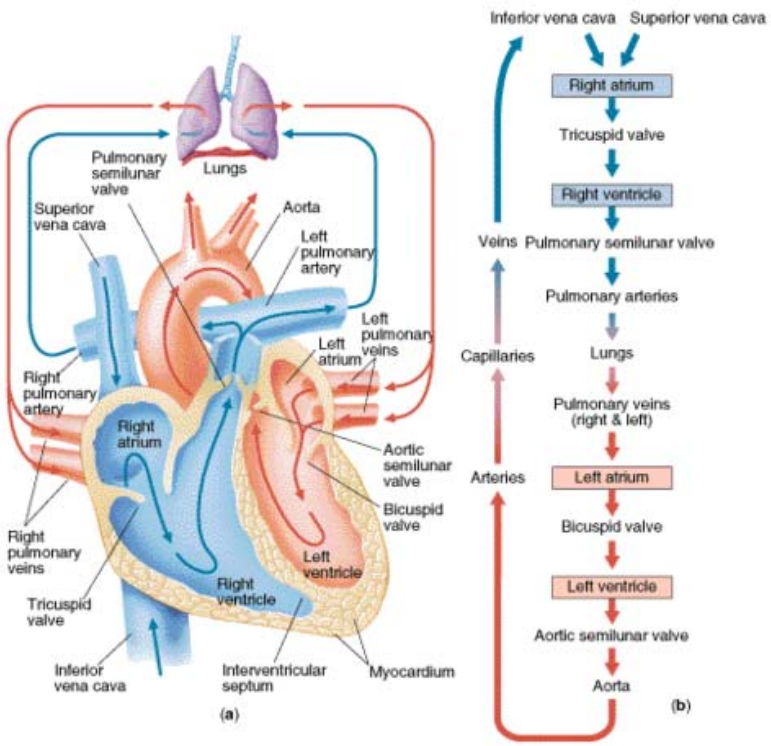


The right side of the heart is the pump for pulmonary circulation:

- It receives all of the dark-red deoxygenated blood returning from the systemic circulation.
- Blood ejected from the right ventricle flows into the pulmonary trunk, which branches into pulmonary arteries that carry blood to the right and left lungs.
- In pulmonary capillaries, blood unloads CO_2, which is exhaled, and picks up O_2 from inhaled air.
- The freshly oxygenated blood then flows into pulmonary veins and returns to the left atrium.

The left side of the heart is the pump for systemic circulation:

- it receives bright red oxygenated (oxygen-rich) blood from the lungs.
- The left ventricle ejects blood into the aorta. From the aorta, the blood divides into separate streams, entering progressively smaller systemic arteries that carry it to all organs throughout the body except for the air sacs (alveoli) of the lungs, which are supplied by the pulmonary circulation.
- In systemic tissues, arteries give rise to smaller-diameter arterioles, which finally lead into extensive beds of systemic capillaries. Exchange of nutrients and gases occurs across the thin capillary walls.
- Blood unloads O2 (oxygen) and picks up CO2 (carbon dioxide). In most cases, blood flows through only one capillary and then enters a systemic venule.
- Venules carry deoxygenated (oxygen-poor) blood away from tissues and merge to form larger systemic veins. Ultimately the blood flows back to the right atrium



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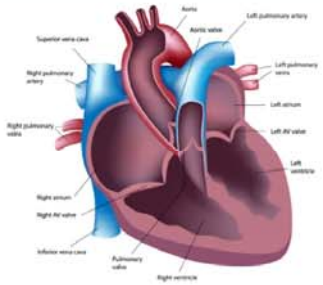
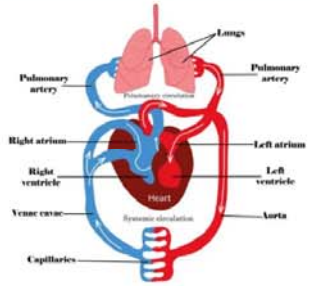
Difference Between Pulmonary & Systemic Circulation



Pulmonary Circulation

1. Heart to lungs and back
2. Oxygenates blood in the lungs
3. Carries deoxygenated blood to lungs
4. Uses pulmonary arteries and veins



Systemic Circulation

1. Heart to body and back
2. Delivers oxygen to tissues
3. Carries oxygenated blood to organs
4. Uses aorta, arteries, veins, capillaries

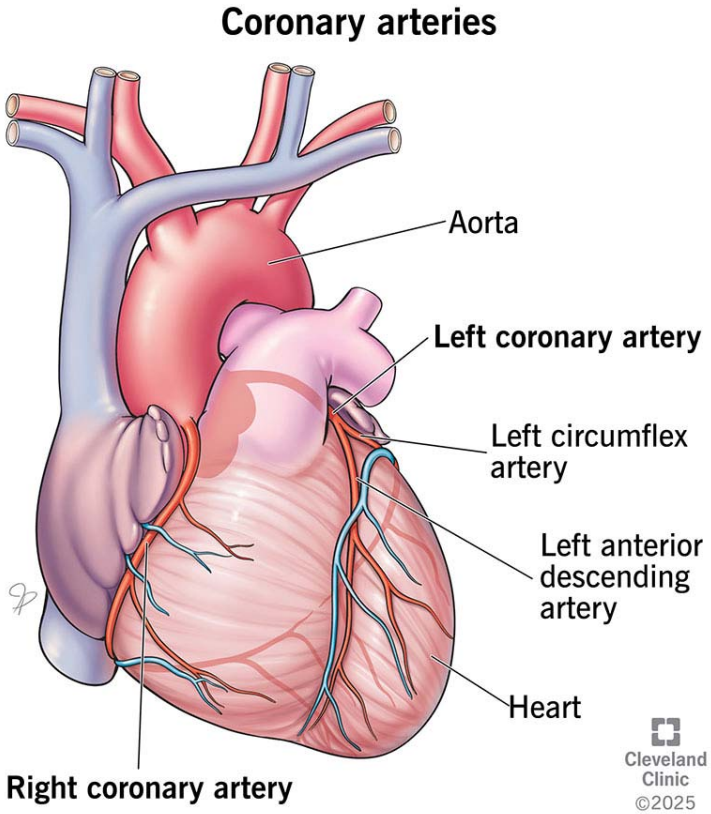
Coronary Circulation:

- 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 left and right coronary arteries deliver blood to the heart; the coronary veins drain blood from the heart into the coronary sinus

- The coronary arteries branch from the ascending aorta and encircle the heart like a crown encircles the head.

- While the heart is contracting, little blood flows in the coronary arteries because they are squeezed shut. 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.



The Vascular System:

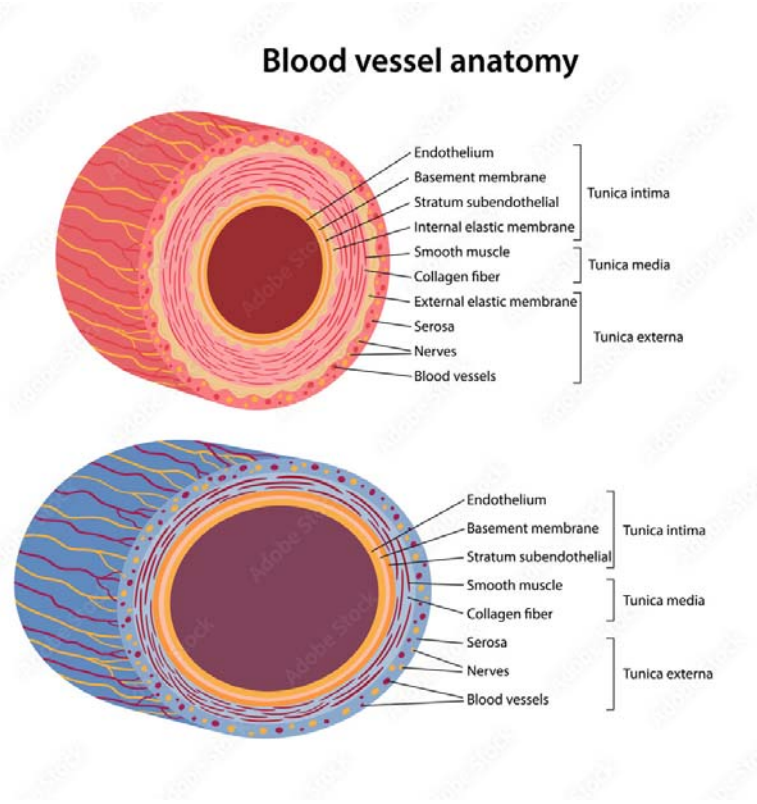
The vascular system consists of the arteries, veins and capillaries through which the heart pumps blood throughout the body.

❑ Arteries:

- Blood is pumped from the ventricles into large elastic arteries carries blood away from the heart. Its branch repeatedly into smaller arteries called arterioles. The arterioles play a key role in regulating blood flow into the tissue capillaries

- In cross-section, we find three layers or (tunics) of tissues, each with different functions.

- **Inner layer (tunica intima):** single layer of simple squamous epithelial tissue (endothelium), very smooth to prevent abnormal blood clotting; secretes nitric oxide (NO) as a vasodilator.
- **Middle layer (tunica media):** smooth muscle and elastic connective tissue; contributes to maintenance of diastolic blood pressure (BP).
- **Outer layer (tunica externa):** Composed mainly of fibrous connective tissue, including collagen Type I and elastic fibers, which provide tensile strength. Its prevent rupture under the high pressure.



Types of Blood Vessels

Heart

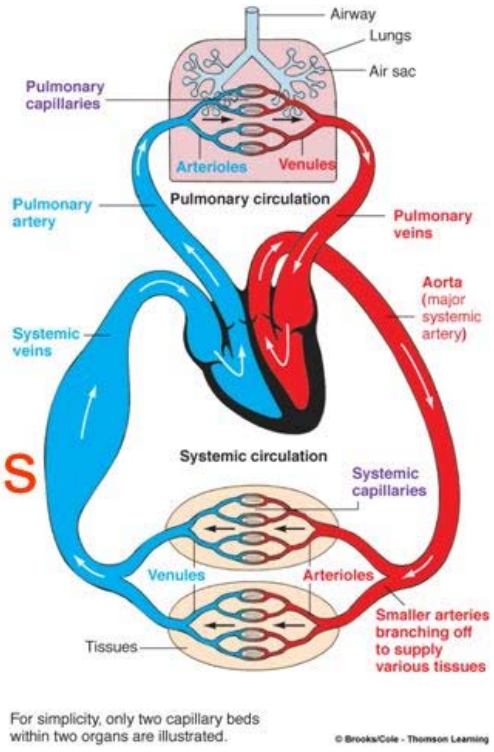
Arteries

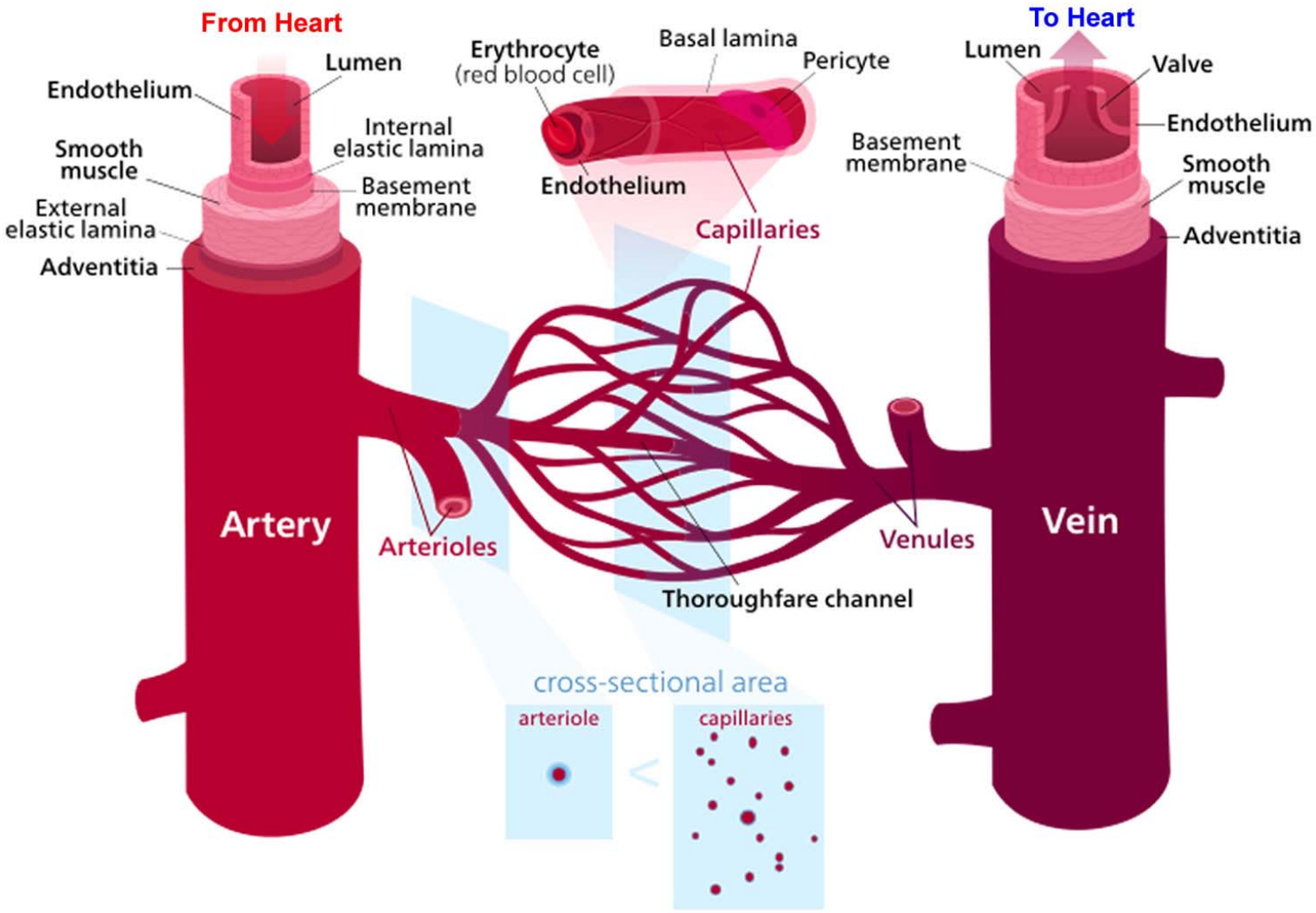
Arterioles

Capillary Beds

Venules

Veins




From Heart
To Heart
Lumen
Endothelium
Internal elastic lamina
Smooth muscle
Basement membrane
External elastic lamina
Adventitia
Erythrocyte (red blood cell)
Basal lamina
Pericyte
Endothelium
Capillaries
Lumen
Valve
Endothelium
Basement membrane
Smooth muscle
Adventitia
Artery
Arterioles
Venules
Vein
Thoroughfare channel
cross-sectional area
arteriole
<
capillaries

Veins:

- Veins carry blood toward the heart. After blood passes through the capillaries, it enters the smallest veins, called venules. From the venules, it flows into progressively larger and larger veins until it reaches the heart.

- In the pulmonary circuit, the pulmonary veins transport blood from the lungs to the left atrium of the heart. This blood has a high oxygen content because it has just been oxygenated in the lungs.

- Systemic veins transport blood from the body tissue to the right atrium of the heart. This blood has a reduced oxygen content because the oxygen has been used for metabolic activities in the tissue cells.

- The walls of veins have the same three layers as the arteries but, is less smooth muscle and connective tissue. This makes the walls of veins thinner than those of arteries, which is related to the fact that blood in the veins has less pressure than in the arteries.

- **Medium and large veins have venous valves**, similar to the semilunar valves associated with the heart, that help keep the blood flowing toward the heart. Venous valves are especially important in the arms and legs, where they prevent the backflow of blood in response to the pull of gravity.

Capillaries:

- capillaries are actually the extension of the endothelium, the simple squamous lining of arteries and veins. Carry blood from arterioles to venules.

- Some tissues do not have capillaries; these are the epidermis, cartilage and the lens/cornea of the eye.

- Walls are one cell thick (simple squamous epithelial tissue) to permit exchanges between blood and tissue fluid.

- Precapillary sphincters found at the beginning of each network. are constrict or dilate depending on the needs of the tissues. Because there is not enough blood in the body to fill all of the capillaries at once, precapillary sphincters are usually slightly constricted. In an active tissue that requires more oxygen, such as exercising muscle, the precapillary sphincters dilate to increase blood flow.

- Some organs have another type of capillary **called sinusoids** are very permeable capillaries found in the liver, spleen, pituitary gland, and red bone marrow to permit proteins and blood cells to enter or leave the blood.

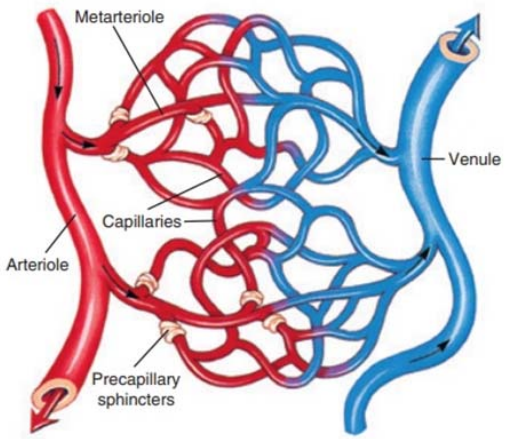
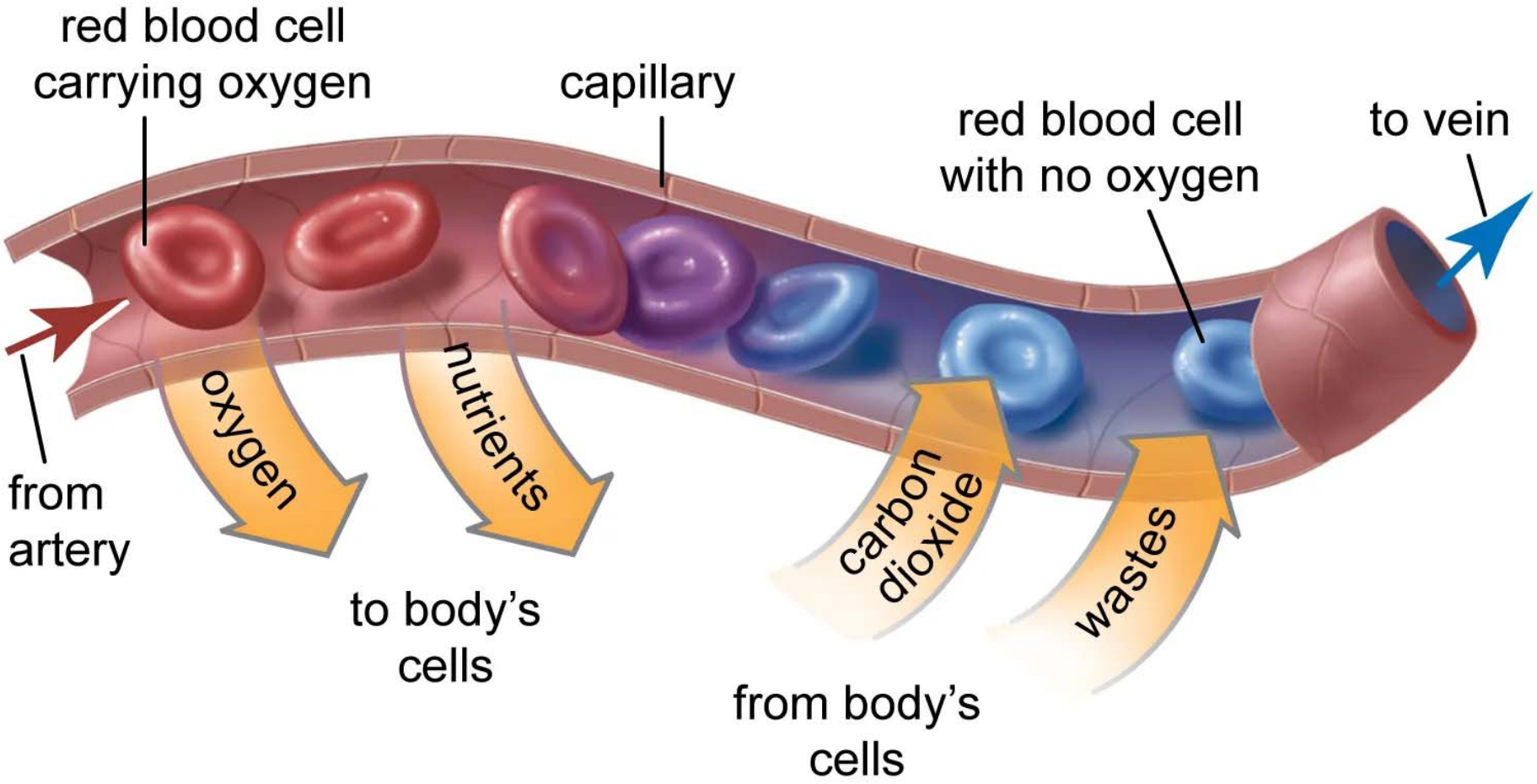


FIGURE 19-4 Just as we travel on different types of roads, our vasculature consists of several different types of vessels.

- Capillaries are the sites of exchanges of materials between the blood and the tissue fluid surrounding cells, some of these substances move from the blood to tissue fluid, and others move from tissue fluid to the blood.

- Blood pressure here is about 30 to 35 mmHg, and the pressure of the surrounding tissue fluid is much lower, about 2 mmHg. Because the capillary blood pressure is higher, the process of filtration occurs, which forces plasma and dissolved nutrients out of the capillaries and into tissue fluid. This is how nutrients such as glucose, amino acids, and vitamins are brought to cells.

- Gases move by diffusion, that is, from their area of greater concentration to their area of lesser concentration. Oxygen, therefore, diffuses from the blood in systemic capillaries to the tissue fluid, and carbon dioxide diffuses from tissue fluid to the blood to be brought to the lungs and exhaled.


red blood cell
carrying oxygen
capillary
red blood cell
with no oxygen
to vein
from
artery
oxygen
nutrients
carbon
dioxide
wastes
to body's
cells
from body's
cells

Heart sounds:

When listening to a normal heart with a stethoscope, one hears a sound usually described as “lub, dub, lub, dub.”

- ❑ The “lub” is associated with closure of the atrioventricular (A-V) valves at the beginning of systole.
- ❑ The “dub” is associated with closure of the semilunar (aortic and pulmonary) valves at the end of systole.
- ❑ The “lub” sound is called the first heart sound, and the “dub” is called the second heart sound, because the normal pumping cycle of the heart is considered to start when the A-V valves close at the onset of ventricular systole.
- ❑ If any of the valves do not close properly, an extra sound called a heart murmur may be heard.

- ❑ Valve and septal disorders will trigger abnormal heart sounds. If a valvular disorder is detected or suspected, a test called an echocardiogram, or simply an “echo,” may be ordered. Echocardiograms are sonograms of the heart and can help in the diagnosis of valve disorders as well as a wide variety of heart pathologies.

Heart rate:

- A healthy adult has a resting heart rate (pulse) of 60 to 80 beats per minute.
- A rate less than 60 (except for athletes) is called bradycardia; a prolonged or consistent rate greater than 100 beats per minute is called tachycardia.
- A child's normal heart rate may be as high as 100 beats per minute, that of an infant as high as 120, and that of a near-term fetus as high as 140 beats per minute.
- These higher rates are not related to age, but rather to size: the smaller the individual, the higher the metabolic rate and the faster the heart rate.

Cardiac output: is the amount of blood pumped by **a ventricle per minute**. A certain level of cardiac output is needed at all times to transport oxygen to tissues and to remove waste products. During exercise, cardiac output must increase to meet the body's need for more oxygen.

Venous return: is the quantity of blood flowing from the veins into the right atrium each minute.

Stroke volume: is the term for the amount of blood pumped by **a ventricle per beat**.

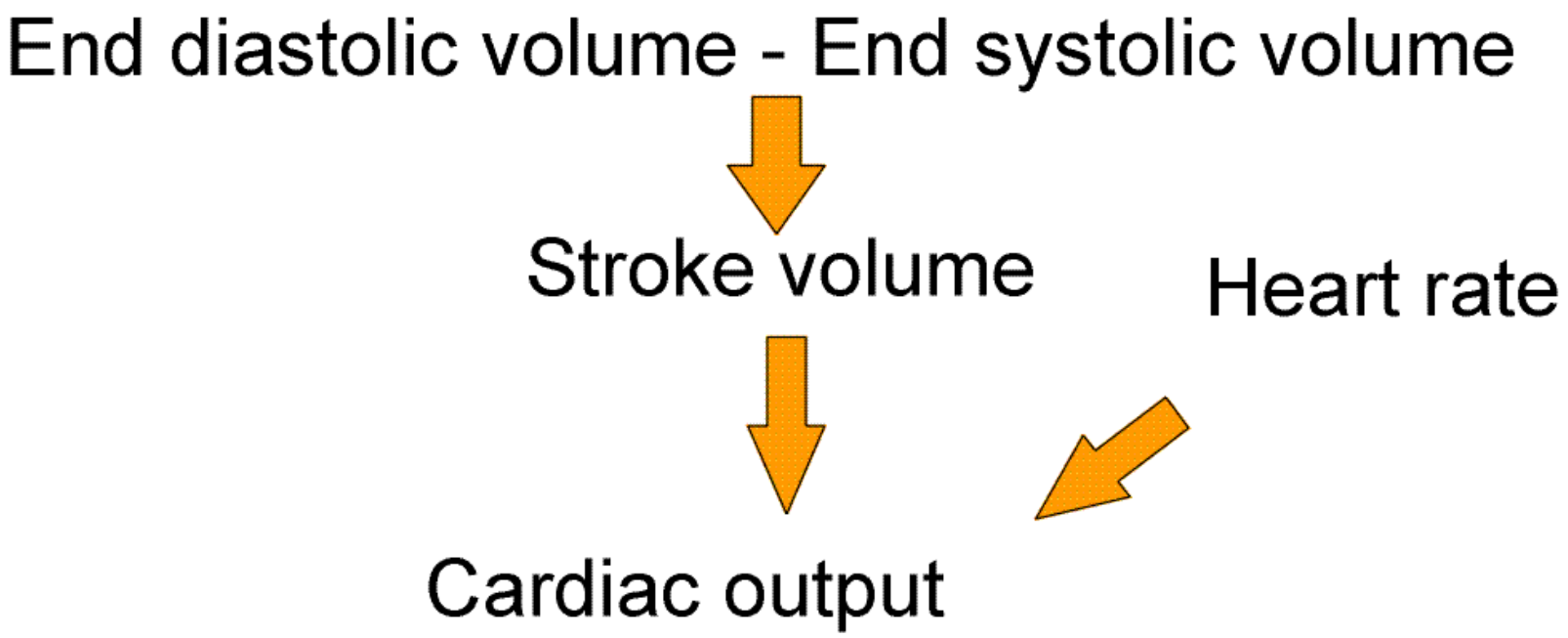
- During diastole (relaxed) , normal filling of the ventricles increases the volume of each ventricle to about 110 to 120 ml. This volume is called the end diastolic volume (EDV).

- Then, as the ventricles empty during systole (contracted), the volume decreases by about 70 ml, which is called the stroke volume .
- The remaining volume in each ventricle, about 40 to 50 ml, is called the end-systolic volume (ESV).

EDV-ESV=stroke volume

Cardiac output= stroke volume * pulse (heart rate)

Cardiac output = (70 ml/beat) * (70 beats/m)
Cardiac output 4900 ml/m (approximately 5 liters)


End diastolic volume - End systolic volume
Stroke volume
Heart rate
Cardiac output

- The fraction of the end-diastolic volume that is ejected is called **the ejection fraction**, usually equal to about (60%). The ejection fraction percentage is often used clinically to assess cardiac systolic (pumping) capability. A lower percentage would indicate that the ventricle is weakening.

Heart rate (pulse) increases during exercise, and so does stroke volume. The increase in stroke volume is the result of

Starling's law of the heart: which states that the more the cardiac muscle fibers are stretched, the more forcefully they contract. During exercise, more blood returns to the heart; this is called venous return. Increased venous return stretches the myocardium of the ventricles, which contract more forcefully and pump more blood, thereby increasing stroke volume.