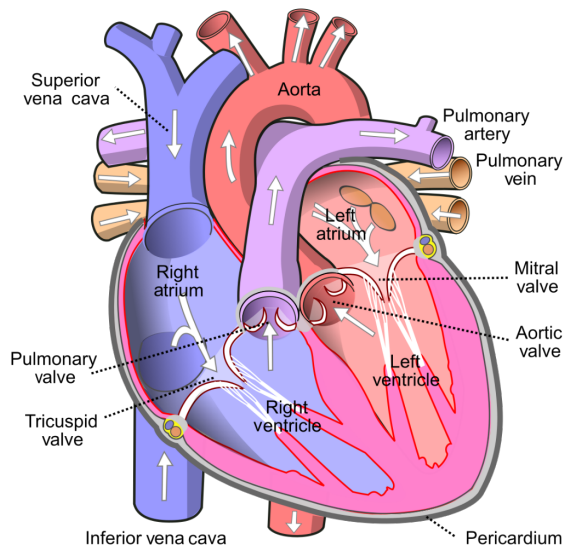


CARDIOVASCULAR SYSTEM



- Delivers nutrients, oxygen, hormones, and other related substances
- Removes metabolic end products for disposal
- Participates in the immune system
- RBC carries the oxygen, plasma carries the proteins, cholesterol and other substances which will be transported to the designated tissues

2 Systems:

- **Blood vascular system**- combination of the heart and the blood vessel that works together to distribute blood into the whole body
 - Main system
- **Lymph vascular system**- is the sewage system of the body.
 - Much of the substances, waste products and fluid produced by our tissues are collected here and these will eventually be returned to the blood vascular system.

Composed of:

1. **Heart**- enveloped by connective tissue known as the pericardium
 - Responsible for the circulation of blood
 - Divided into 4 components:
 - Right and Left Atrium
 - Right and Left Ventricles

2. Blood Vessels

- **Arteries**- carries blood away from the heart
 - Carries oxygenated blood, only the pulmonary arteries carries deoxygenated blood
- **Veins**- carries deoxygenated blood towards the heart except for the pulmonary vein
- **Capillaries**

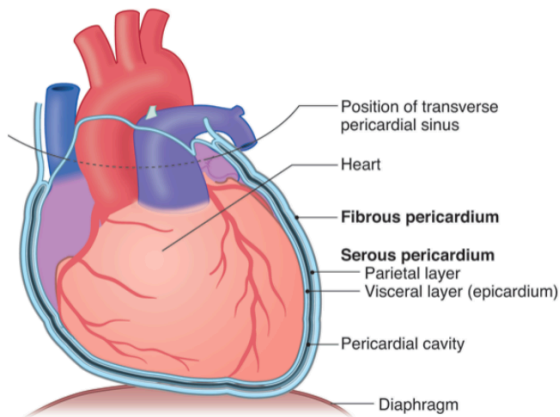
- The organ that oxygenates the blood is the lungs
- Right atrium is the compartment of the heart that receives blood from the superior and inferior vena cava which are the large veins that transport blood from the body towards the heart.
- The deoxygenated blood will be received by the right atrium. From here it will be pumped to the right ventricle, and it will be pumped from there and the blood will be carried to the lungs.
- After oxygenation, it will come back to the heart through the pulmonary vein. From here it will be received by the left atrium where it will be pumped to the left ventricle, from the left ventricle it will be pumped to the aorta and when the heart pumps the oxygenated blood will be transported to the different tissues of the body.
- Walls of the left ventricle are thicker compared to the walls of the other compartments, this is because this is the compartment that will be transported to the rest of our body so it requires thicker cardiac muscle so when it pumps it will have enough force to pump and circulate the blood throughout the body.

The Heart

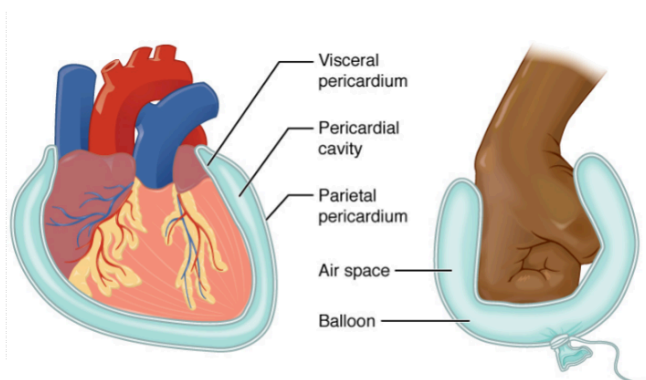
- Enveloped by connective tissue known as the pericardium
- **Pericardium** (outermost)
 - Comprised of two sacs/pouches
 - **Fibrous pericardium** (DICT)- major function is to anchor the heart and maintain

the position of the heart in the thoracic cavity by attaching the heart to surrounding tissues.

- It also protects the heart from damage and from being invaded by surrounding fluid outside the heart.



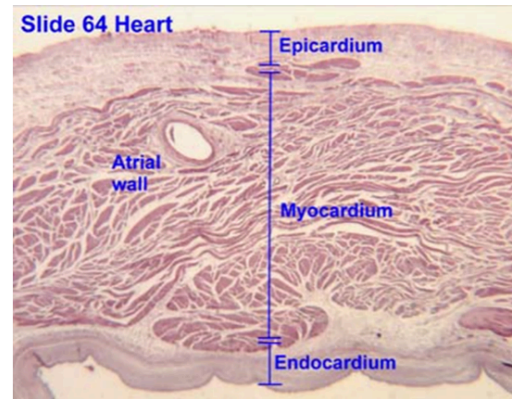
- **Serous pericardium** (Loose CT)- contains pericardial fluid.
 - Luminal surface is lined by SSE (mesothelium)
- not considered as part of the wall of the heart)
 - Parietal pericardium- the wall further from the heart, the outer wall
 - Visceral pericardium/Epicardium- indirect contact with the visceral organ or the heart
 - epicardium is part of the wall of the heart that is synonymous to the visceral pericardium
- **Pericardial Fluid**- acts as a lubricant when the hearts expands when it contracts in order to pull the blood into the arteries
 - 15-50 mL
 - Accumulation or increased volume is an indication that there is a problem in the heart like myocardial infarction



- **Serous Pericardium**- lined by mesothelium (SSE)
 - responsible for the production of serous fluid

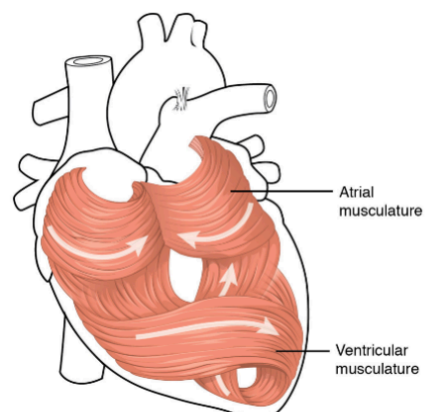
Histologic Layers of the Heart:

- **Endocardium**- innermost
- **Myocardium**- muscle and thickest
- **Epicardium**- outermost (Loose CT)



Endocardium

- Thinnest layer
- Lines the internal surface
- Continuous with the inner layer of the great blood vessels, aorta, pulmonary cavity and vena cava
- The innermost layer is lined with endothelium mad with SSE
- The outer layer attached to the cardiac muscle is made of loose CT filled with blood vessels, nerves, smooth muscles and Parkinje fibers (relaying of electrical impulses that coordinates heart contraction
- Blood vessels, Nerves, smooth muscles, and Purkinje fibers are found in the connective tissue layer
- **4 layers: endothelium** (innermost; SSE), **sub-endothelium** (Loose CT), not named (**DICT**), **sub-endocardium** (Loose CT; not a separate entity, still part of the endocardium)



Myocardium

- Thickest layer and mainly consists of cardiac muscles. Thickness depends on the location
- It is the thinnest walls of the atria and thickest in the walls of the left ventricle
- Thickest in the left ventricle and thinnest in the atria
- Arrangement-spiraling course
- Originate and insert in the cardiac skeleton (dense connective tissue)
- Cardiac muscles in atria and interventricular septum secrete atrial natriuretic peptide and brain natriuretic peptide which participate in cardio-renal homeostasis (target organs are kidneys, adrenals, pituitary gland and the brain)
- Cardiac skeleton acts a supporting framework that holds the muscle together as it contracts

Epicardium

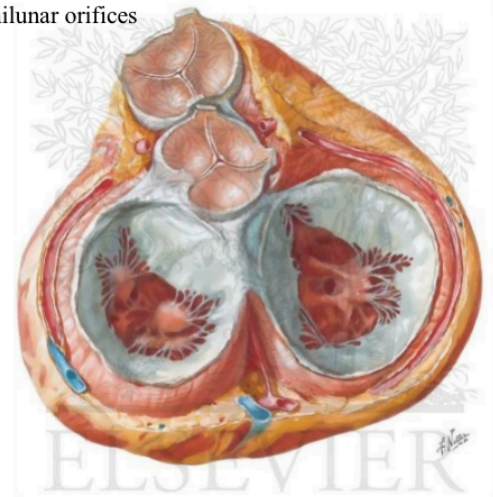
- Synonymous with the visceral layer of the serous pericardium
- Loose connective tissue lined with mesothelium (SSE) that lines the inner surface of the serous cavity
- Mesothelium is not only found in the epicardium but also the walls of serous cavities in visceral organs
- In the areas of the heart where bigger branches of the coronary arteries are lodged, the epicardium contains a lot of adipose cells, that increases in amount due to fatty foods that can accumulate and increase the chances of weakening of the heart.

Cardiac Skeleton

- Dense connective tissue that forms the stroma of the heart and provides attachment for cardiac muscles
- Not made of bone because bone is not flexible, flexibility is necessary for the heart
- Three components:
 1. **Septum membranaceum** (interventricular septum)
 2. **Annuli fibrosis** (surrounds the AV and semilunar orifices)

- **AV orifice** pertains to the opening between the atria and the ventricles
 - **semilunar orifice** is the opening between the ventricle and the arteries
3. **Trigona fibrosa** (between the semilunar and AV orifices)

semilunar orifices



Cardiac Valve

- found in the semilunar orifice
- Prevents backflow of blood from one compartment to another.
- Larger valves prevent backflow of blood from ventricles to atria and the smaller valves prevent backflow of blood from larger arteries towards the ventricle.
- Consist of reduplicated endocardia and a core of dense connective tissue that is continuous with the annuli fibrosi
- Surrounded by endocardia
- **Atrioventricular valve**
 - Tricuspid valve**- separates right atrium and the right ventricle
 - Bicuspid (mitral) valve**- left atrium and left ventricle
- **Semilunar valve**
 - Pulmonic valve**- right ventricle and pulmonary artery
 - Aortic valve**- left ventricle and aorta
 - increase heart rate makes the heart pumps stronger

Impulse-Conducting System

- Contraction of cardiac muscle fibers is triggered by electrical impulse generated and propagated by Purkinje fibers
- Cardiac muscles do not contract, they generate the impulse that initiates the contraction and conducts the impulse throughout the entire heart.
- Rhythm of the heartbeat is influenced by the NS as its rhythm can be influenced by tiredness, fatigue, nervousness, blood pressure and etc.
- Purkinje fibers are different from the Purkinje cells in the brain
- Not controlled by neural system

Has several components:

- **SA node**- responsible for generating electricity and also determines the frequency or the rate of contraction
- **3 internodal tracts** (distribution of signal)- small bundles of Purkinje fibers. Propagates the signal generated by SA node.
- **Atrioventricular node**
- **AV bundle of His**- Located in the dense connective tissue of the trigonum fibrosum.
- **2 bundle branches**
- **Purkinje fibers**

SA node

- Consists of Purkinje fibers
- Located at the boundary of the right atrium and the superior vena cava
- Cardiac pacemaker
- **Internodal tracts**
 - Small bundles of Purkinje fibers
 - Propagates the signal generated by SA node
- **AV node**
 - Located in the myocardium of the posterior lower part of the interatrial septum

AV bundle of His

- Located in the dense connective tissue of the trigonum fibrosum

Bundle branches

- Right branch: subendocardium of the right ventricle
- Left branch: subendocardium of the left ventricle

Purkinje fibers

- larger, paler, and has more glycogen than the typical cardiac muscle fibers
- Interconnected via intercellular junctions like desmosomes, fascia adherens and gap junctions
 - These junctions are necessary for the distribution/ fast distribution of the impulse from 1 Purkinje fiber to others.

Blood and lymphatic vessels, and nerves of the heart

- The heart is supplied by coronary arteries that arise from the ascending aorta and cardiac veins drain it.
- Coronary arteries are end arteries
- Cardiac veins empty either into the coronary sinus or directly into the right atrium
- Lymph channels are abundant in myocardium, subendocardium, and subepicardium
- Heart receives efferent nerve from vagus nerve and sympathetic division of ANS

- **Apoptosis**- natural death
- **Infarction**-pathological death due to lack of blood supply
- Inside in the body air bubble is harmful due to they can block pathways.

The Blood Vessels

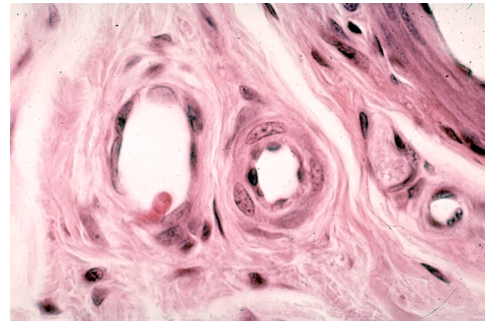
- Arteries- away from the heart (oxygenated)
- Capillaries- where exchange of substances happens
- Veins- delivering substances towards the heart (deoxygenated)

Endothelium

- **Simple squamous** inner lining of all blood vessels (determines which substances can pass through)

- In capillaries, endothelium is the only layer that forms the capillaries tubing. It is responsible for the selective permeability of the blood vessel, it only allows certain substances to leave/enter the blood vessel
- Serves as barrier containing the content of blood vessel
- Facilitate the flow of blood through the blood vessels
- Also regulates the diffusion of substances and cells to and from blood.
- Involved in regulatory functions through the secretion of substances that participate in blood clotting (Von Willebrand factor, prostacyclins and nitric oxide) and the inflammatory response. During infection/injury, there are substances secreted that induces blood coagulation/inflammation/relieving inflammation.

- Bending and folding of RBC is possible because they don't have nuclei



3 types of capillaries:

- Continuous
- Fenestrated
- Sinusoidal

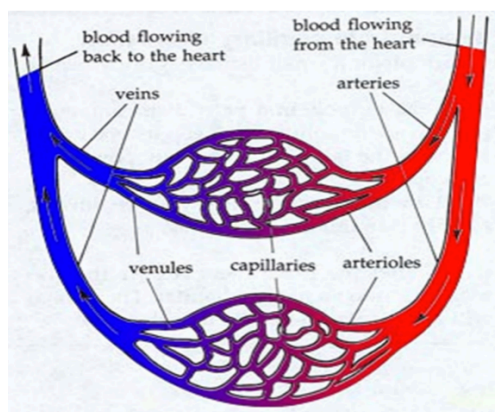
1. Continuous capillaries

- Found in muscles, lungs, CNS, and skin
- Endothelial cells are tightly packed together
- Cells are often interdigitating (no gaps between cells)
- Main function is to only allow small molecular weight substances to pass through the blood vessel, it only allows gas molecules like oxygen and carbon dioxide

2. Fenestrated capillaries

- Found in GI tract, endocrine glands, pancreas, and renal glomerulus
- Continuous exchange of substances and movement across endothelial cells
- It has holes or pores that is covered by fibrils called diaphragm
- Has pores in the cytoplasm that are bridged by diaphragms of fibrils
- Major function is to only allow smaller molecular weight substances in the tissue, there should be faster distribution or flow from the blood vessel to tissue.
- The fenestration allow faster transport of fluid/nutrients from the capillaries to the tissue, but the presence of the diaphragm still monitors the type or size of the molecule that can leave/enter the blood vessel
- In the GI tract, there should be faster absorption of nutrients, so the food won't be excreted as stool

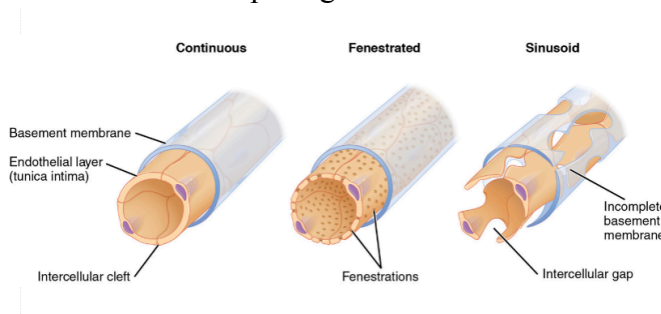
Capillaries



- Smallest of the blood vessels (7-9 micrometers)
- Walls are made of one layer of SSE
- No connective tissue and muscle tissue
- Simplest blood vessels that consists of endothelium only of the blood vessels
- Surrounded by pericyte
- **Pericyte** – envelop the wall of and influence the size of capillaries, helps in the movement of capillaries
- Only 1 RBC can pass or move inside at a time
- Movement is very slow that helps in the exchange of gases, that is a very significant mechanism to prevent obstruction.

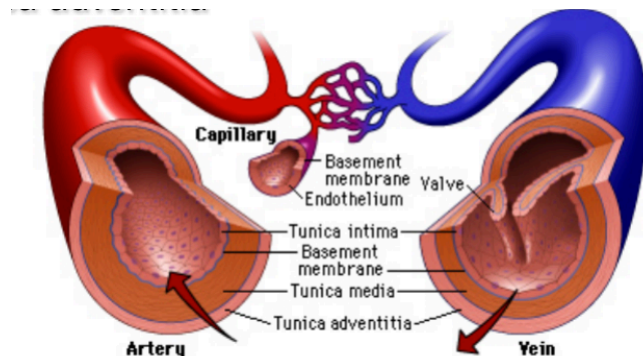
3. Sinusoidal capillaries

- Found in liver, spleen, bone marrow, and some endocrine glands
- In spleen, dead cells are being removed so if there are no gaps then the spleen won't be able to remove the blood cells from the blood vessel.
- In bone marrow, to put blood in the blood vessels then there should be gaps that allows the entry of those blood vessels. That is the major function of sinusoidal capillaries.
- Main difference is the presence/ absence of gap or possible entry points for molecules on the walls of the capillaries.
- Have discontinuities in their endothelium that allow free passage of blood



Histologic Layers of Veins & Arteries

- Tunica intima
- Tunica media
- Tunica adventitia



1. Tunica intima

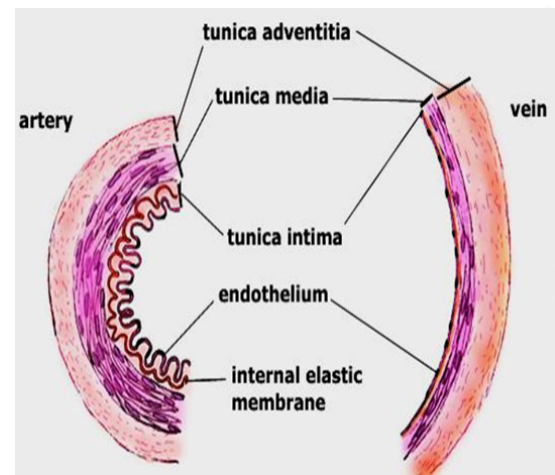
- endothelium + loose connective tissue (subendothelium)
- internal elastic lamina (arteries only)- allows the elasticity of the arteries
- Endothelium of arteries have Weibel-Palade bodies(storage site) which are granules that contain coagulation factor that is for arteries only

2. Tunica media

- smooth muscle fibers/ tissue
- External elastic lamina (arteries only)

3. Tunica adventitia

- loose connective tissue that is arranged longitudinally
- Main function is to attach/binds the blood vessels to the surrounding tissue.



Arteries

- Deliver blood away from the heart
- Most carries oxygenated blood to the tissues
- **Three types:**

1. Arterioles (small arteries)

- Tunica Intima- endothelium and internal elastic membrane (large vessels); no subendothelium
- Tunica Media- 1-5 layers of smooth muscle; no elastic membrane

2. Muscular arteries (medium arteries)

- Most of the named arteries in the body
- Tunica Intima- endothelium, subendothelium (Loose CT: elastic and collagen), and internal elastic membrane
- Tunica Media- well- developed; 40 layers of smooth muscle fibers

3. Elastic arteries (large arteries)

- Tunica media is a mixture of elastic fiber
- e.g. Aorta
- Tunica Intima- endothelium, subendothelium (Loose CT with smooth muscle fibers), and elastic membrane that is continuous with elastic lamella of tunica

- Tunica Media- has elastic lamella with smooth muscle and connective tissue in between the layers; external elastic membrane is continuous with elastic lamella
- Pump of the cardiovascular system during diastole (when the heart is resting after a contraction)
- During systole (contraction of the heart), the elastic arteries store part of the mechanical energy generated by the contraction of the heart by stretching their wall.

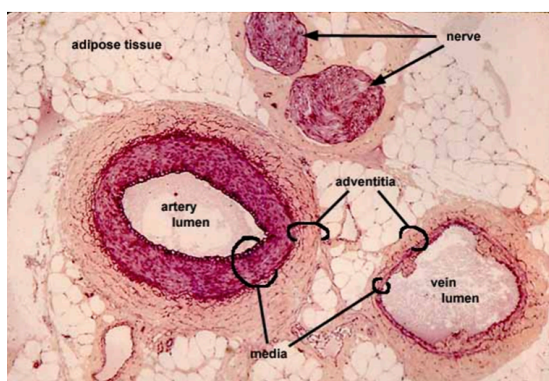
Vasa vasorum – small blood vessels within the wall of large blood vessels and that supply the blood vessel wall with nutrients, not limited to arteries only.

- This is necessary because the thickness of the wall impedes the passage of blood.

Sensory organs associated with arteries

- Major function is to detect changes in the levels of these substances.

- **Carotid and aortic bodies**
 - Sensitive to changes in the Oxygen and Carbon dioxide
 - Embedded in the tunica adventitia (carotid bodies in carotid artery; aortic Bodies in subclavian arteries)
- **Carotid sinuses**
 - Sensitive to changes in arterial blood pressure.



Veins

- Deliver blood from tissues towards the heart (carries deoxygenated blood and waste)
- Compared to arteries, veins have bigger calibers, more irregular lumens, and thinner and elastic walls
- Arteries- more muscular and elastic elements
- Veins- more connective tissue elements
- Thickened walls of veins shows accumulation of lipids or blockage that can lead to an embolus.

• Three types:

1. Venules

2. Medium veins

- Almost all named veins and their principal tributaries
- Diameter—1.9mm

3. Large veins

- **Tunica adventitia of large veins has 3 layers: internal zone** (dense fibroelastic CT), **middle zone** (smooth muscle), **outer zone** (collagen and elastic fibers)
- Larger venules have tunica media, but the muscle fibers are separated by connective tissue
- Tunica adventitia is thick

Venous valves

- One-way valves that ensure unidirectional flow of blood to the heart
- Inward projections of tunica intima
- Prevents back flow in our veins and is abundant in the lower extremities, because the upward flow of our legs is affected by gravity

Modification in the organization of blood vessels

- Arteriovenous anastomoses, arteries are directly connected to veins.
- Main function is to serve the backup in case capillaries/arteries/venules are blocked by embolus or thrombus. When this happens, blood is directly transported to the vein.
 - Found in the skin of the palm, sole lip, ear, nose and mucous membrane of the nose and the digestive tract, erectile tissue and tongue
 -
 - Major function is for the regulation of the temperature, for faster cool down.
 - Portal systems (capillary-vein-capillary)
 - Portal veins: found in the digestive system and pituitary gland
 - Portal arteries: found in kidneys (middle of two sets of capillaries)

• ***Right lymphatic duct***

- Collects all lymph from structures on the right side of the body above the diaphragm
- Drains its lymph into the right ***brachiocephalic*** vein at the junction of the internal jugular and subclavian veins

• ***Thoracic duct***

- Collects lymph from the rest of the body
- Drains its lymph into the venous system
- at the junction of the left jugular and subclavian veins

- Lymph is processed either by liver or kidney once the fluid is released into the blood vessels.
- Lymph passes through lymph nodes first to prevent infection.

Lymphatic Vessels

Lymph Vascular System

- Collect the substances that leaked from the capillaries and return them to the venous side of the circulation
- Contains lymph, a milky substance that is consist of water, proteins, lymphocytes and fat droplets
- Major function is to act as sewage system

Lymphatic Capillaries

- Composed of endothelium and underlying thin layer of connective tissue (collagen and elastic fibers)
- In large lymphatic vessels, three layers (tunica intima, tunica media, and tunica adventitia) are found.

Lymphatic ducts

- Contents are being collected here. It connects the system to the blood vessels/
Circulatory system