The Cardiovascular System

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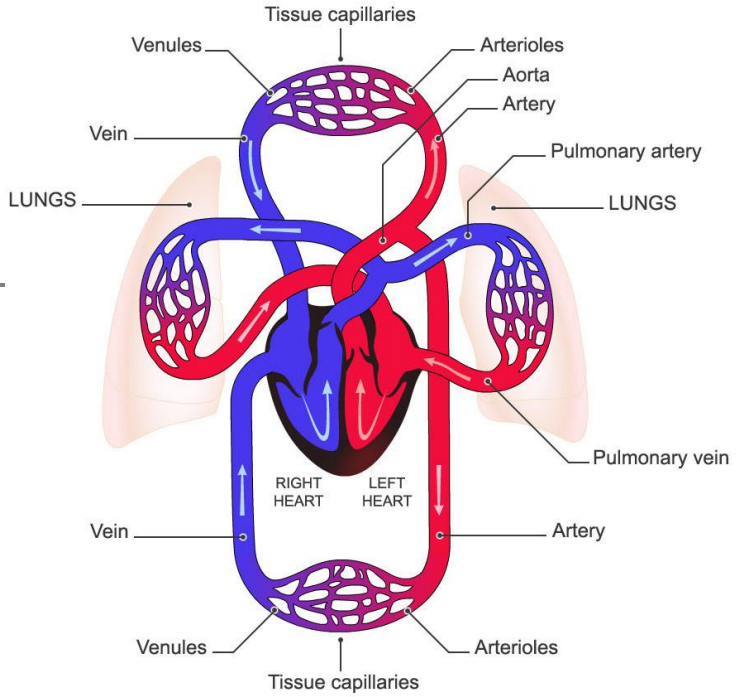
(2021)

The Blood

The Heart

and The Vessels



Blood

- Fluid connective tissue
  - Extracellular matrix = plasma
  - Cellular elements = Red blood cells, White blood cells and Platelets

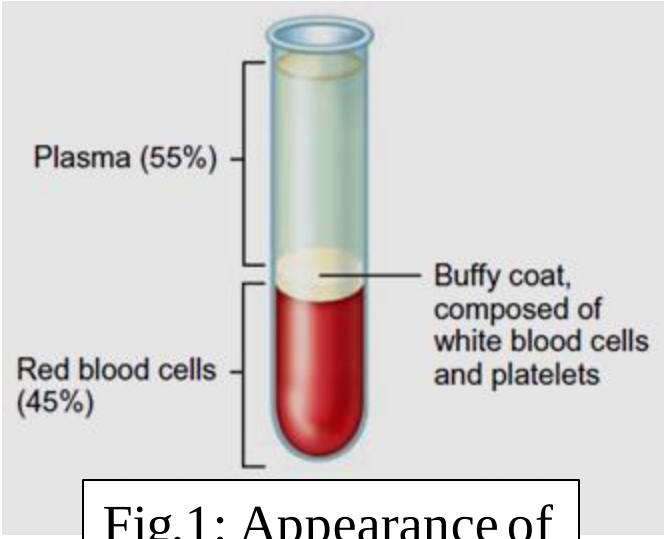


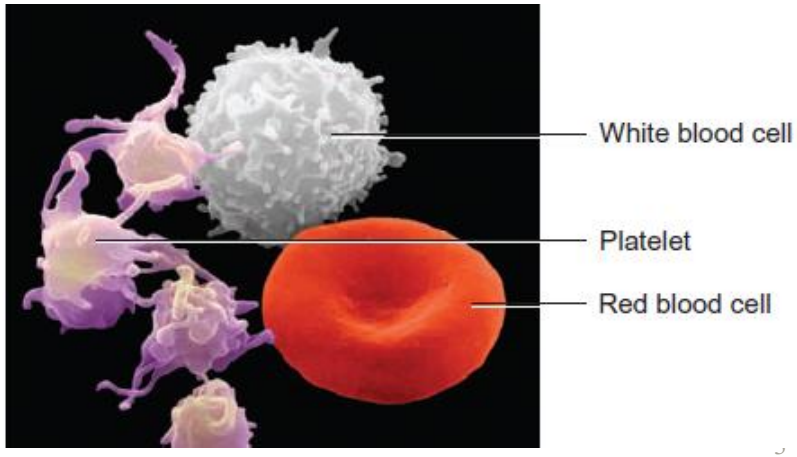
Fig.1: Appearance of centrifuged blood.

- Functions:
  1) Transportation
     - Gases, nutrients, hormones, waste products
  2) Regulation
     - pH, body temperature
  3) Protection
     - Clotting, white blood cells, proteins

Components of Blood

Blood

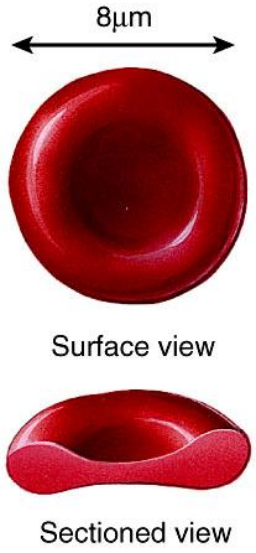
- **Plasma** — 55% of blood
  - Water — 91% of plasma
  - Solutes (mostly protein)
    - Proteins (Mostly Albumin)
    - Other Solutes
- **Formed Elements** — 45% of blood
  - Red Blood Cells
  - White Blood Cells
  - Platelets



Formed Elements of Blood

Red Blood Cells/ Erythrocytes

- Biconcave disc in shape. This increases surface area.
- Lack nucleus and other organelles:
  - No mitochondria – doesn't use oxygen
- Strong, flexible plasma membrane. This allows the cell to change its shape without rupturing as it passes through narrow capillaries.
- Life span about 120 days.
- Cytoplasm filled with the oxygen-carrying protein hemoglobin.



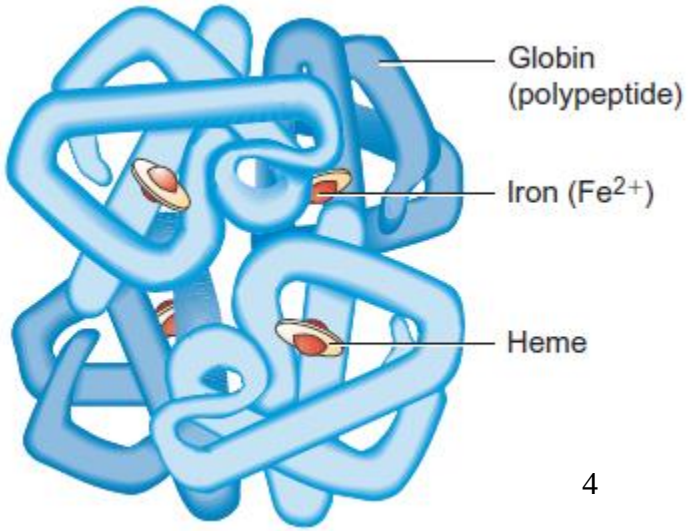


Fig.2: The shape of red blood cells and hemoglobin molecule.

Functions of the red blood cells

1) The hemoglobin in the RBCs functions in the transportation of:
   - Oxygen – this is the main function of RBCs.
   - CO_2
   - Nitric Oxide (NO) – this gas is a vasodilator that helps in increasing blood flow.
2) Glycolipids in plasma membrane are responsible for ABO and Rh blood groups.
3) When RBCs are destroyed by some microorganism, they release substances that can kill these microorganism.

White Blood Cells/ Leukocytes

- Wandering cells: formed in bone marrow, circulate in blood and enter tissues.
- Respond to local factors in inflammation.

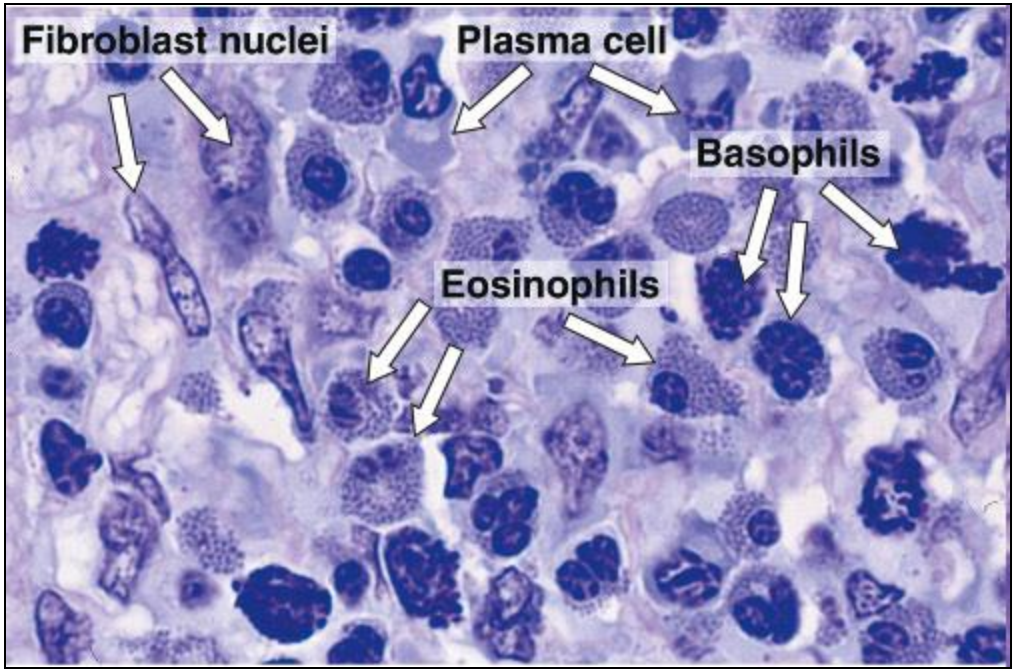
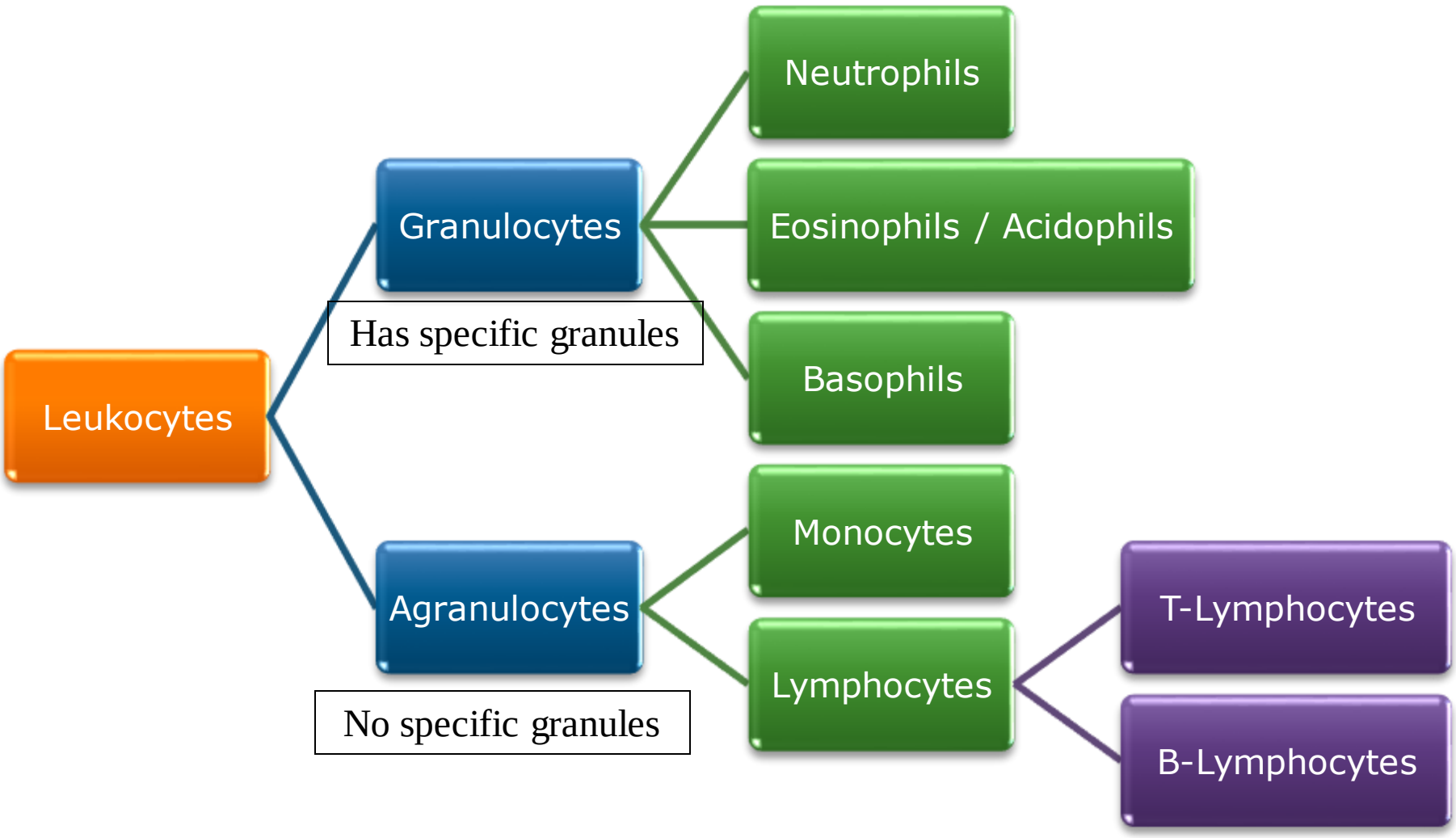


Fig.3: Leukocytes in inflamed tissue.

Classification of Leukocytes



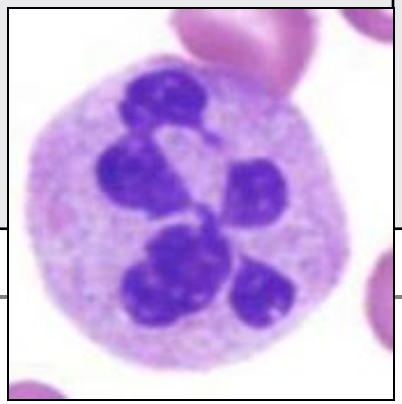
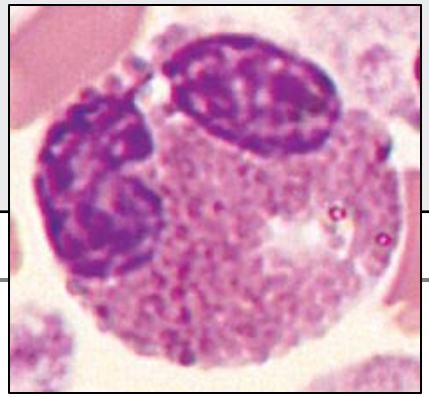
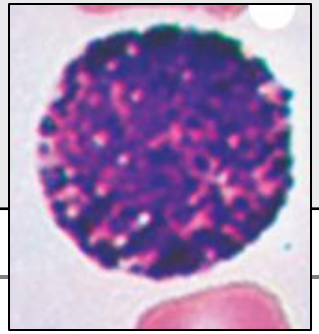
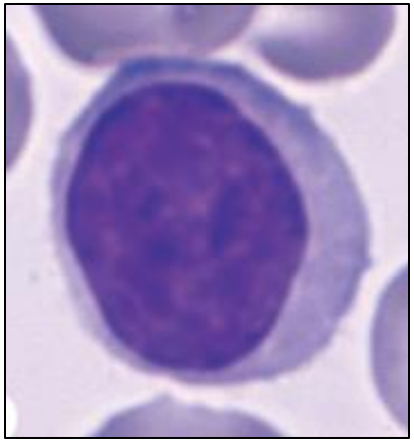
Granulocytes	Neutrophils	Eosinophils	Basophils
Abundance (% of leukocytes)	Most common		Least common
Nucleus	Multilobed	Bilobed	S shaped (obscured by granules)
Granules	Sparse and stain variably	Large eosinophilic	Large basophilic
Function	Phagocytosis	• Defense against parasitic infection • Allergic reactions	Release of inflammatory molecules
			

Fig.4: Granulocytes.

Fig.5:
Agranulocytes.



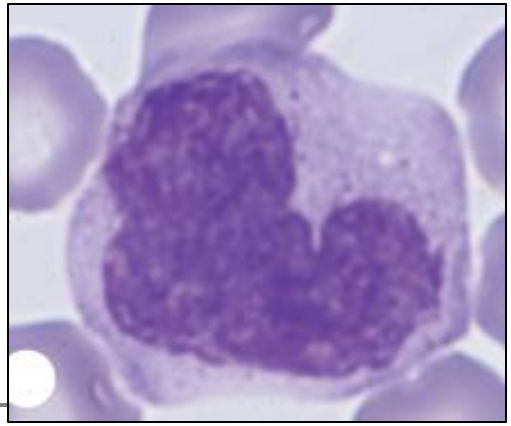
Agranulocytes:

Lymphocytes:

- Variable in size.
- Nucleus very dark and occupies most of the cell.
- Functions: T-cells → Cell mediated immunity.
  B-cells → Antibody-mediated immunity.

Monocytes:

- Kidney or U-shaped nucleus.
- Cytoplasm basophilic.
- Function: formation of macrophages.



Platelets/ Thrombocytes

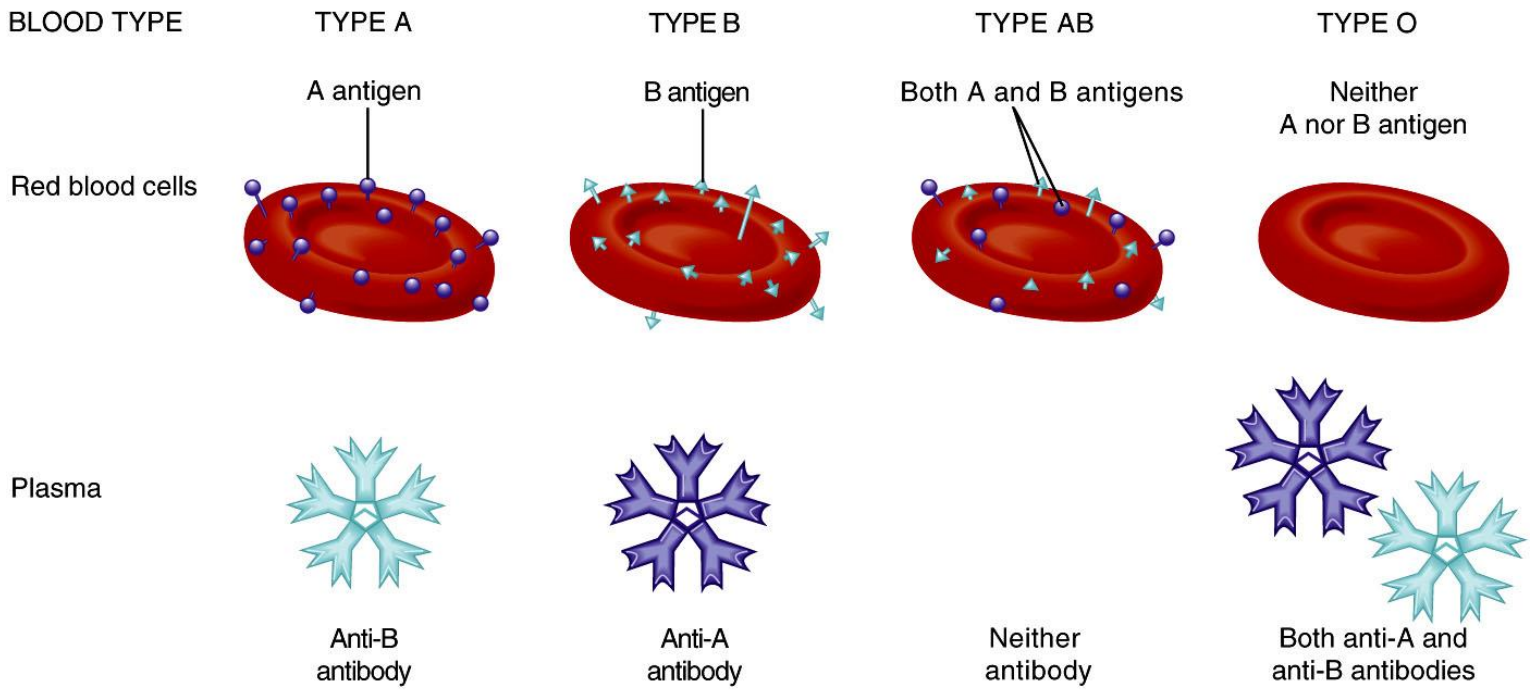
- Large cells in the bone marrow called ***Megakaryocytes*** send processes into blood vessels. These processes will splinter into small fragments called Platelets.
- This process continues until each megakaryocyte gives rise to about 2000 platelets.
- Each platelet is a disc-shaped structure surrounded by cell membrane and containing no nucleus but numerous vesicles containing blood-clotting promoting factors.
- Short life span: 5-9 days.
- Function: Stops bleeding by the formation of **(1)** platelet plug and **(2)** blood clot.

ABO Blood Group

- Blood group is type of blood designated to a person based on the presence/absence of an antigen on the surface of RBCs.
- The ABO blood groups are based on the A and B antigens.
- Reason for antibodies presence not clear.

Blood Type	Antigen on RBCs	Antibody in Plasma
A	A	Anti-B
B	B	Anti-A
AB	A & B	None
O	None	Anti-A & Anti-B

Fig.6: Antigens and antibodies in the different blood groups.



- Each blood group can give to itself
- ***AB*** is the ***Universal Recipient***
- ***O*** Is the ***Universal Donor***

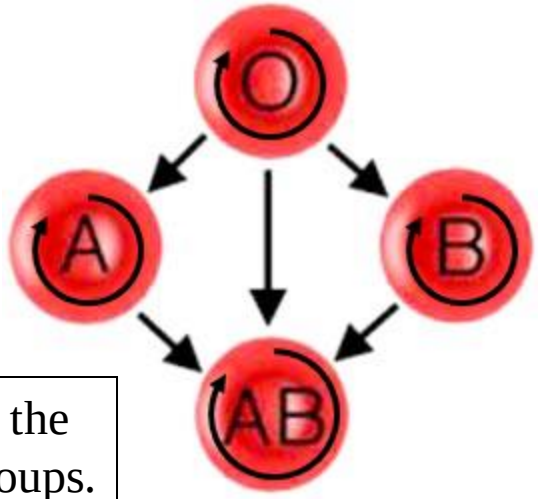


Fig.7: Relation of the different blood groups.

The Heart

A hollow pyramidal shaped muscular organ located within the pericardium in the middle mediastinum in the thoracic cavity.

The heart features:

- 3 surfaces (anterior, inferior and posterior).
- 4 borders (right, inferior, left and superior).
- Apex.
- 4 chambers (right and left atria and ventricles).

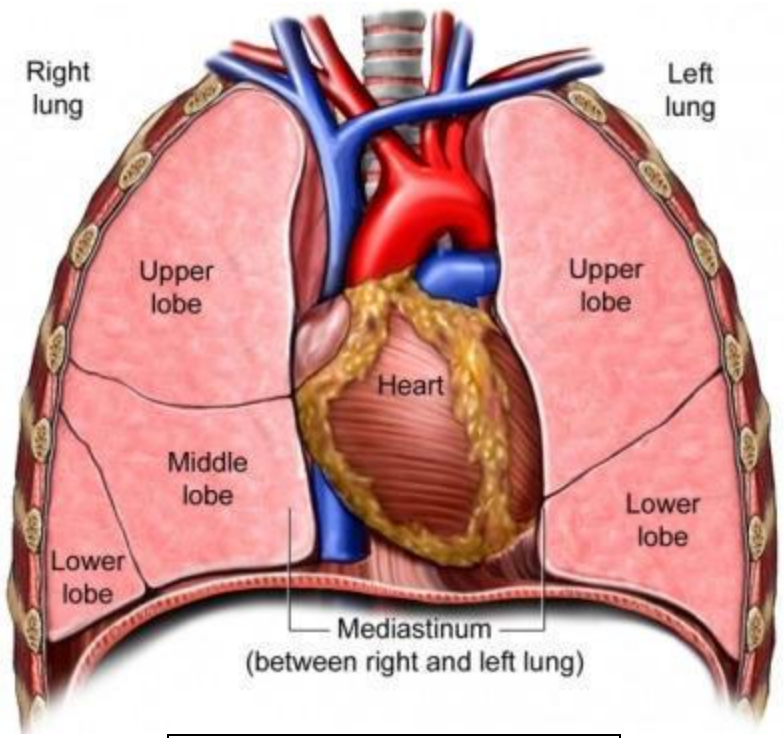


Fig.8: Position of the heart in the chest.

Thoracic (Chest) cavity:

A body cavity bounded by:

- **Anteriorly**: Sternum
- **Laterally**: Ribs, costal cartilages and contents of intercostal spaces
- **Posteriorly**: Thoracic vertebrae
- **Inferiorly**: Diaphragm
- **Superiorly**: The thoracic outlet, an oblique plane passing from the superior border of the sternum, between the two first ribs to the first thoracic vertebra

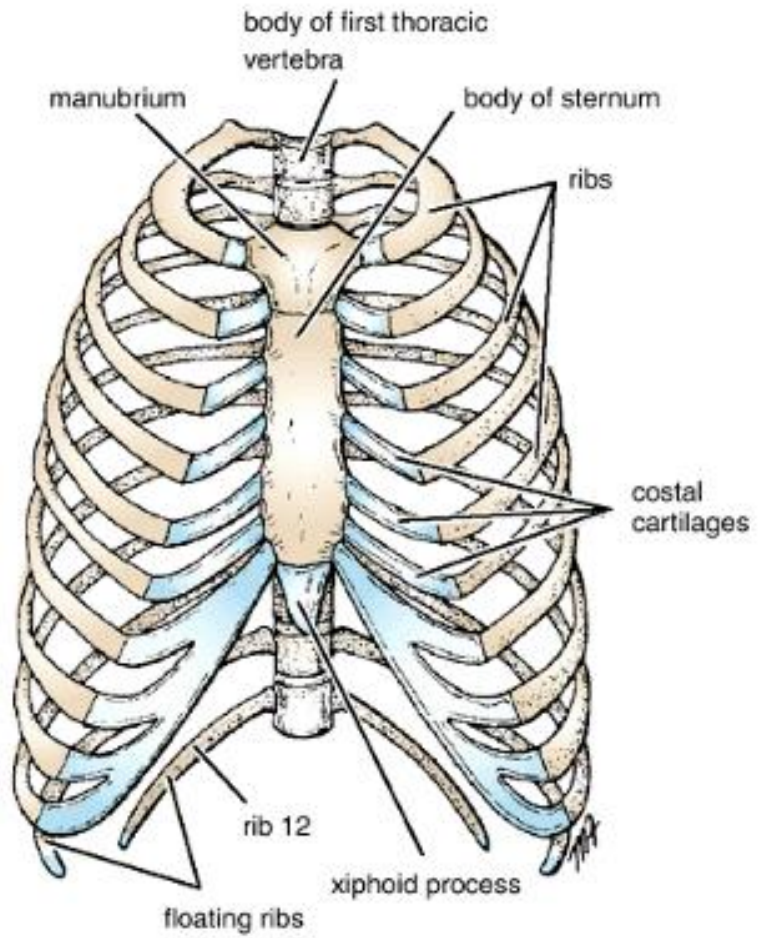
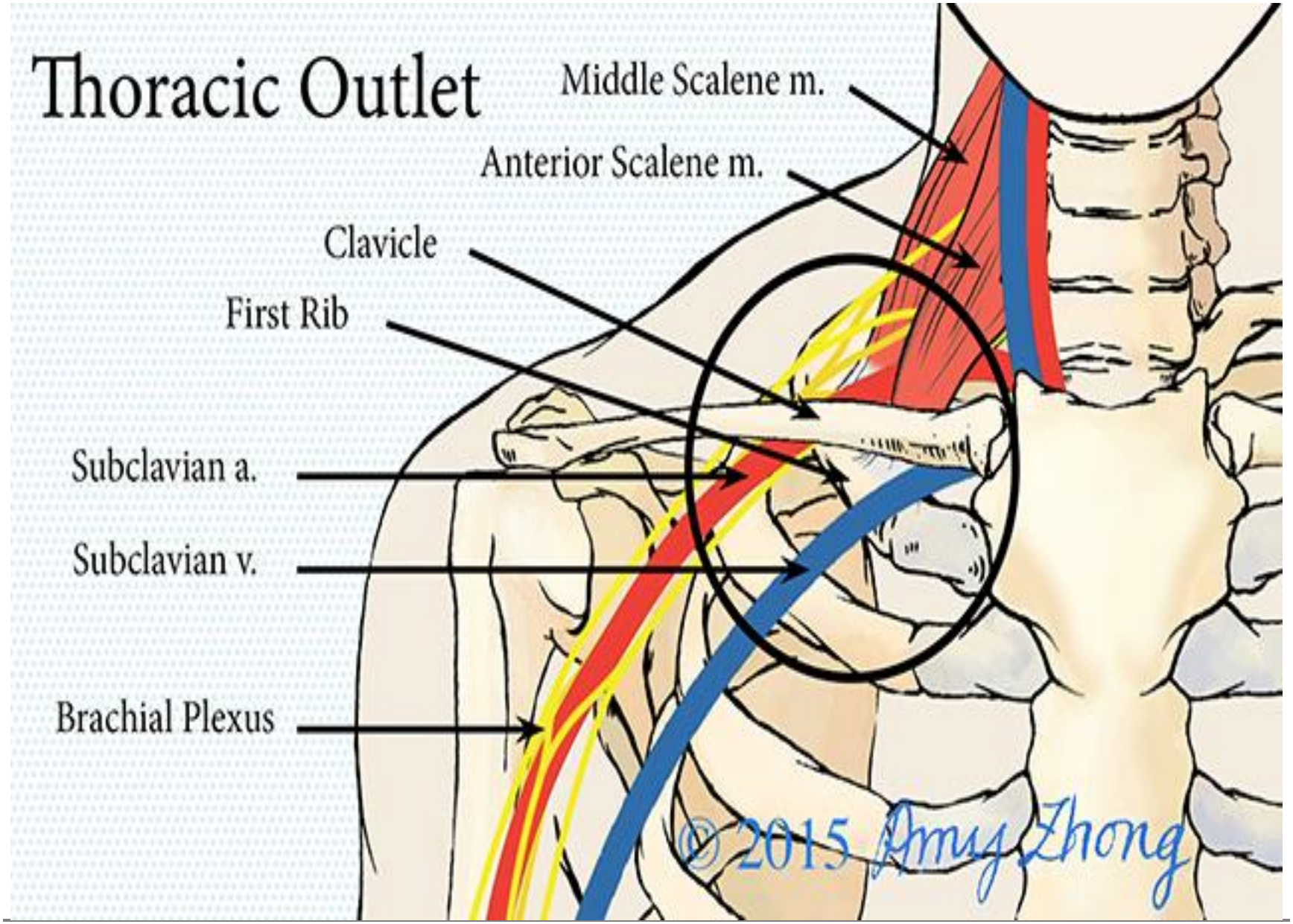


Fig.9: Boundaries of the thoracic cavity, anterior view.


Thoracic Outlet
Middle Scalene m.
Anterior Scalene m.
Clavicle
First Rib
Subclavian a.
Subclavian v.
Brachial Plexus
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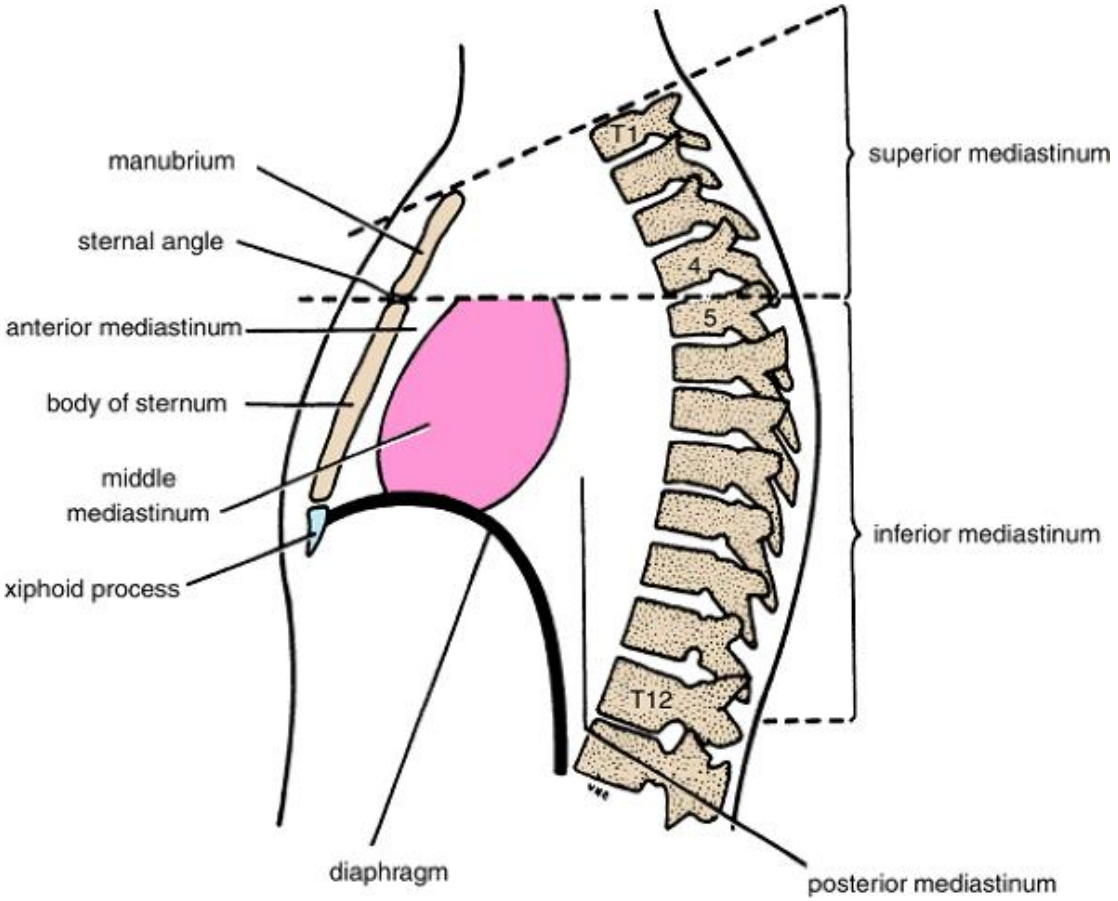
The Mediastinum:

- A midline region that extends from the thoracic outlet to the diaphragm. It's bounded by:
  - **Anteriorly**: Sternum
  - **Posteriorly**: Thoracic vertebrae
  - **Laterally**: Lungs and plurae
  - **Inferiorly**: Diaphragm

Fig.10: Lateral view of the mediastinum after removing the lung.



- The mediastinum is divided into superior and inferior parts by a plane passing from the sternal angle to the lower border of T4. The inferior mediastinum is divided into anterior, middle and posterior parts by the pericardium.

The Pericardium

- Membrane surrounding and protecting the heart. Formed of 2 main parts:

- Outer ***Fibrous pericardium***: tough layer that protects the heart and anchors it in place.
- Inner ***Serous pericardium*** (simple squamous epithelium): thin more delicate membrane. Formed of the parietal layer fused to fibrous pericardium and the visceral layer which is the epicardium.

- Between the two serous layers we have the pericardial cavity that's filled with the pericardial fluid to reduce friction.

Layers of the heart wall

1. ***Endocardium:*** Inner layer of the heart. Lined by endothelium (simple squamous epithelium) continuous with that of the blood vessels.

2. ***Myocardium:*** The thickest layer of the heart. Formed of cardiac muscle cells.

3. ***Epicardium:*** The outermost layer. The same as the visceral pericardium.

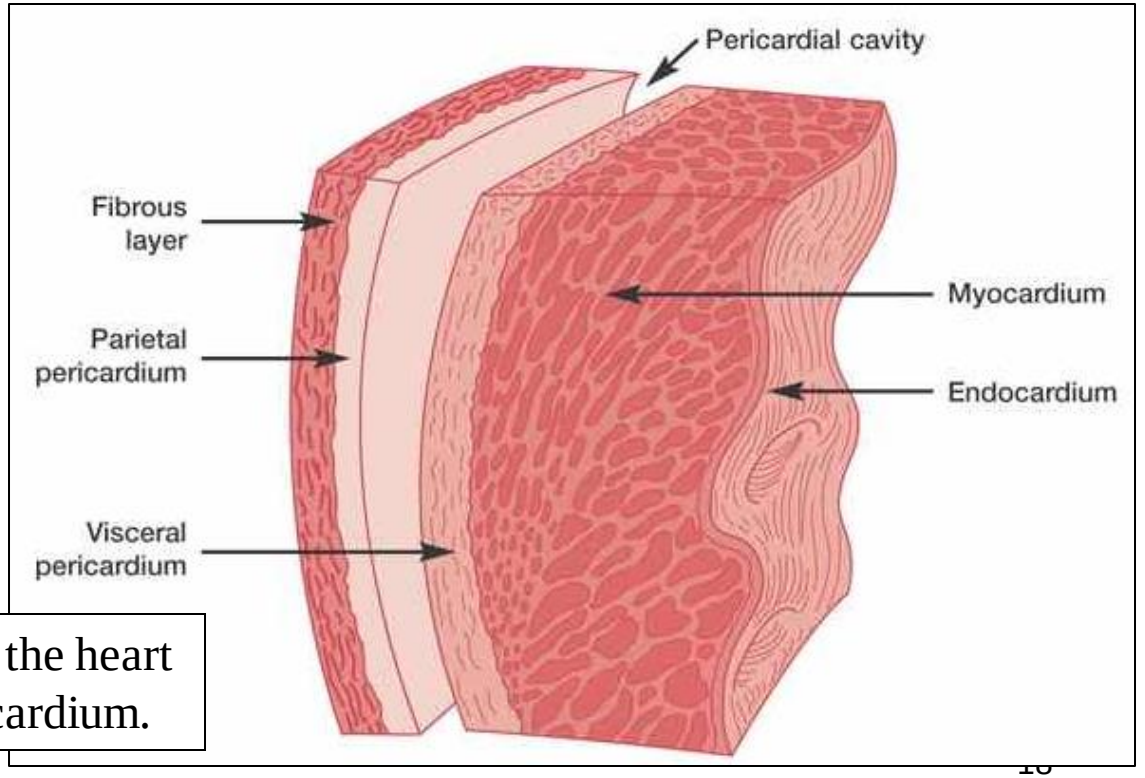


Fig.11: Layers of the heart wall and the pericardium.

Surfaces of the heart

Anterior Surface:

- ➢ Formed by the:
- Right atrium
- Right ventricle
- Left ventricle

- ➢ Related to the sternum.

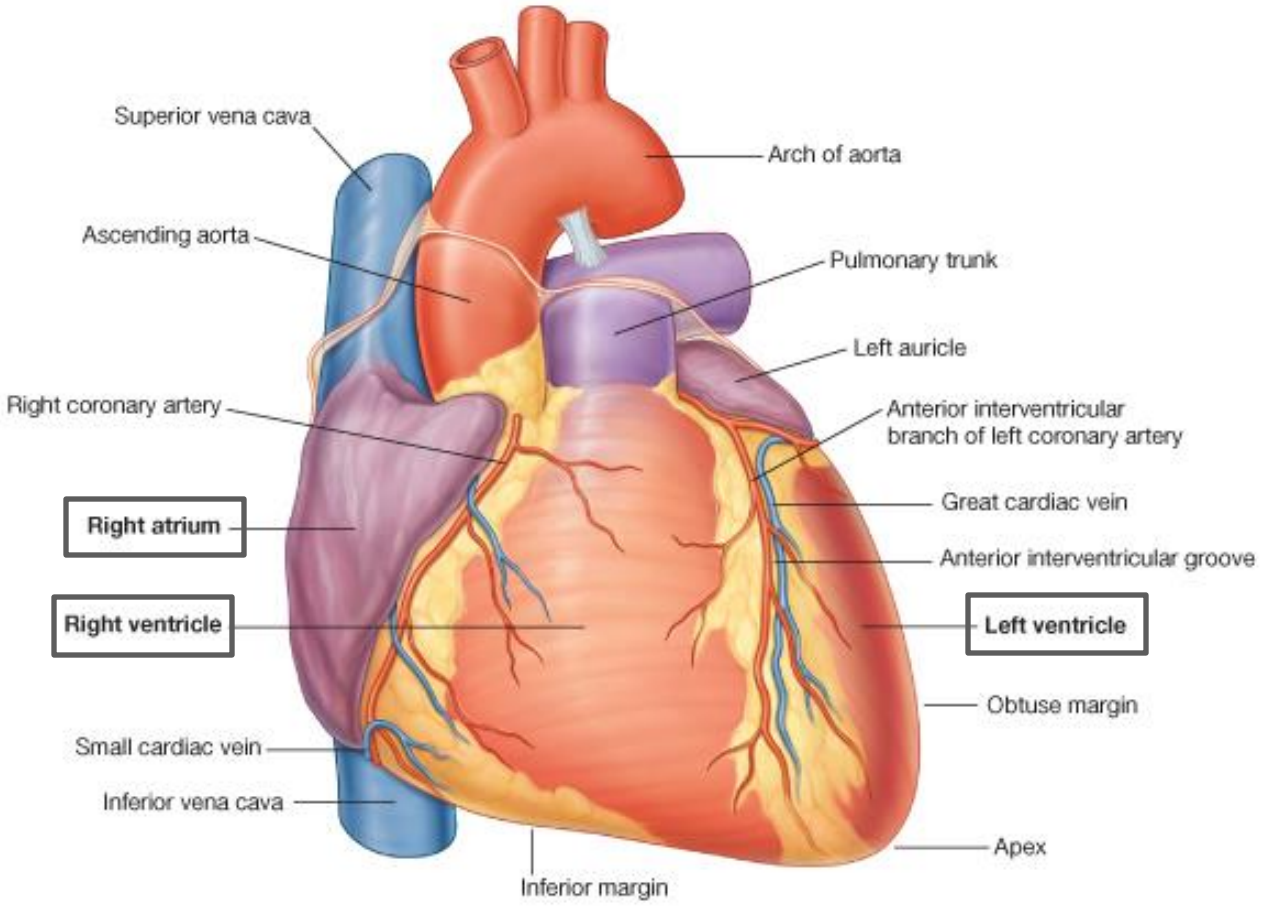


Fig.12: The anterior surface of the heart.

Posterior Surface (Base):

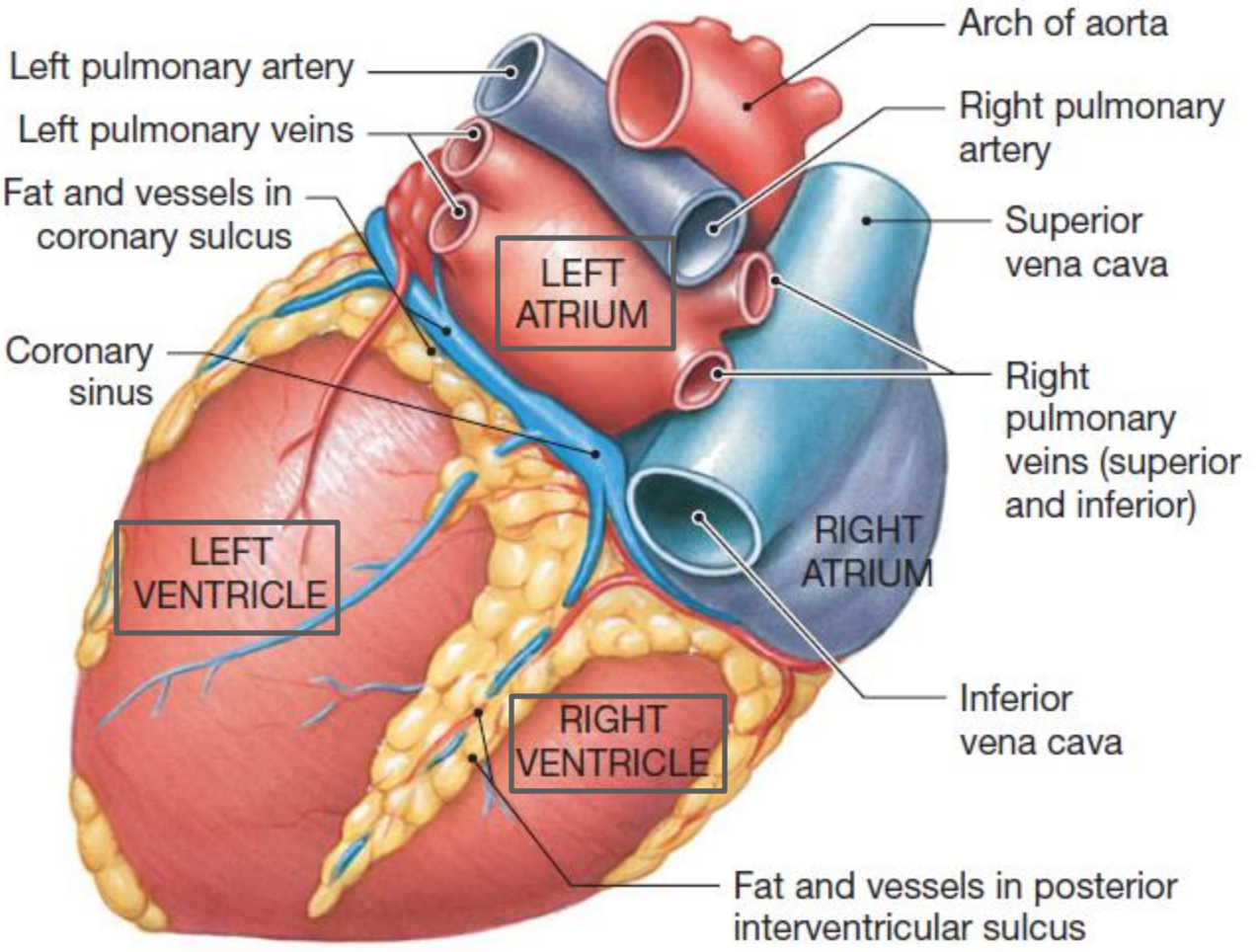
- ➢ Formed by the:
- Left atrium

- ➢ Related to the esophagus.

Inferior Surface:

- ➢ Formed by:
- Right ventricle
- Left ventricle

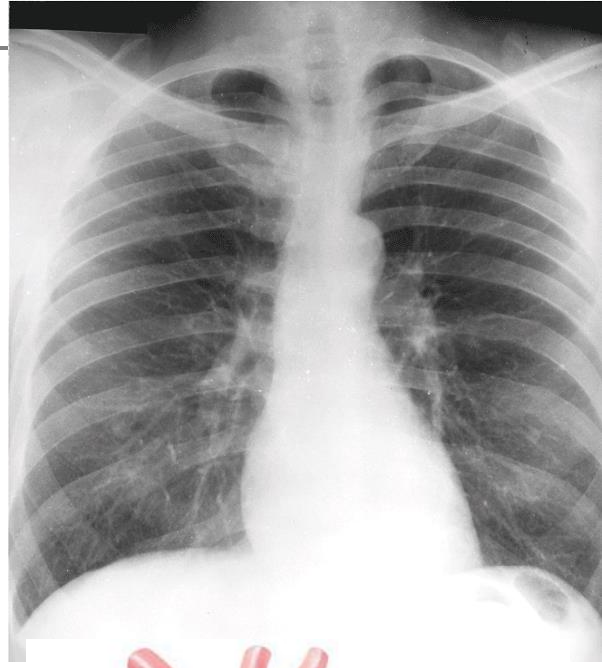
Fig.13: The posterior and inferior surfaces of the heart.



➢ It's the surface upon which the heart rests on the diaphragm.

Borders of the heart

They're very important to know to understand X-rays of the heart.



1. **Left border**: Left auricle and left ventricle.
2. **Inferior border**: Left ventricle, right ventricle, and right atrium.
3. **Right border**: Right atrium.
4. **Superior border**: is obscured by the great vessels.

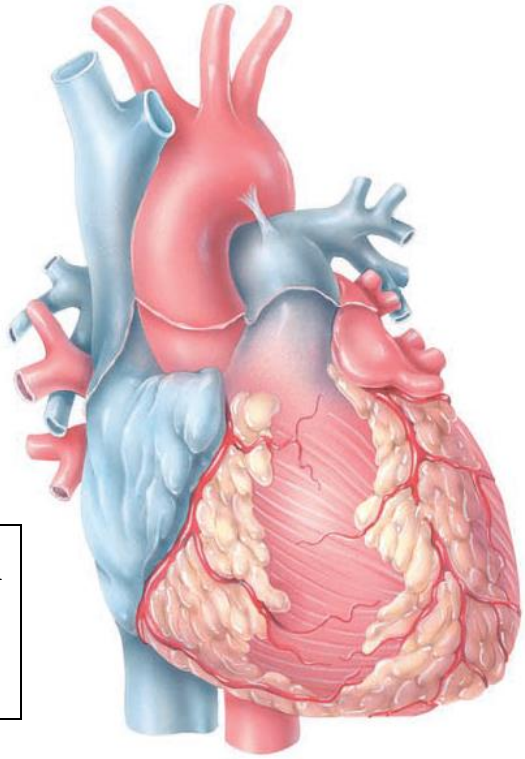


Fig.14: Boundaries of the heart as seen on an X-ray. Compare with the gross anatomy of the heart.

Apex of the heart

- Formed by the left ventricle.
- Directed downwards, forwards and to the left.
- Located at the left 5th intercostal space 9cm from the midline.
- Can be felt by palpation.

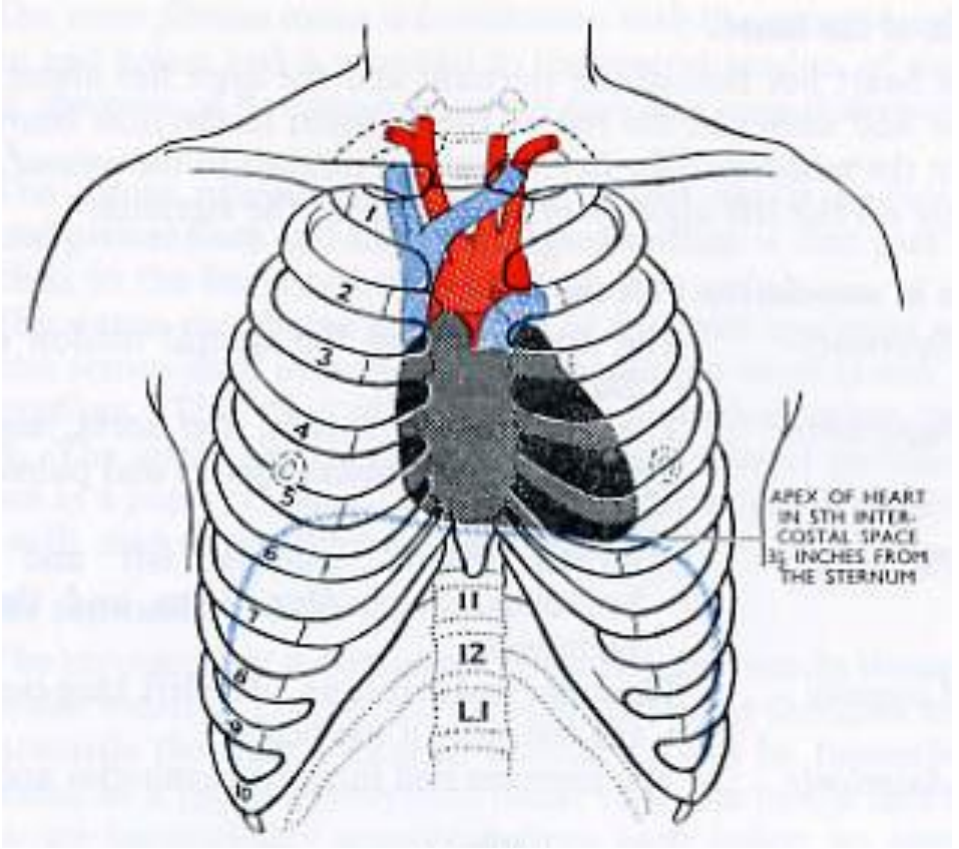
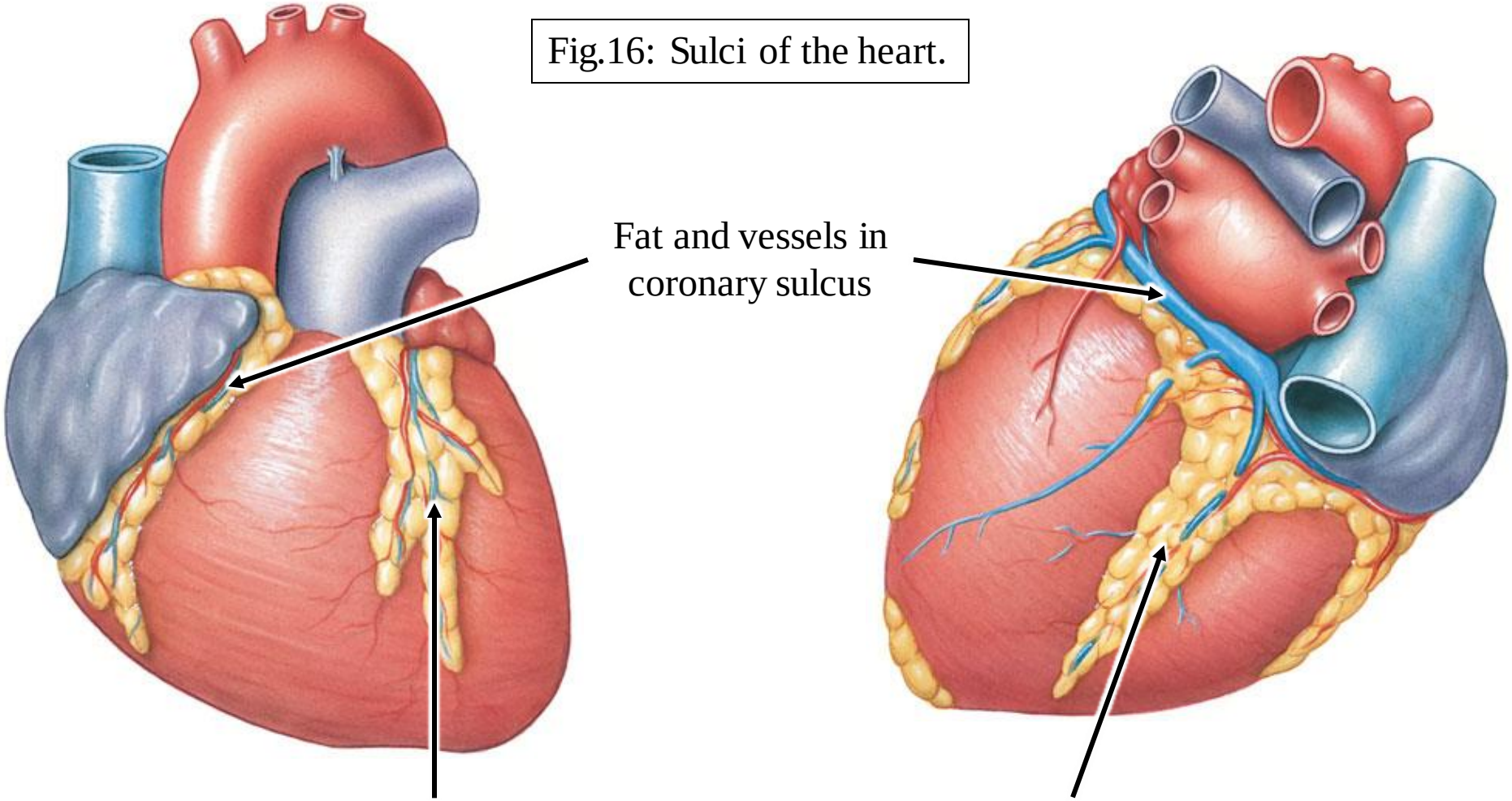


Fig.15: Location of the apex of the heart.

Chambers of the heart

- 2 atria – receiving chambers
  - Auricle: small pouch that increase capacity of atria
- 2 ventricles – pumping chambers
- Sulci – grooves on the surface of the heart that contain the coronary blood vessels.
  1. ***Coronary sulcus***: separating the atria from the ventricles.
  2. ***Anterior interventricular sulcus***: between the two ventricles anteriorly.
  3. ***Posterior interventricular sulcus***: between the two ventricles posteriorly.

Fig.16: Sulci of the heart.



Anterior view

Posterior view

The Right Atrium (RA)

- Receives blood from: (1)Superior vena cava, (2)Inferior vena cava, (3)Coronary sinus.
- Interatrial septum has fossa ovalis (remnant of foramen ovale)
- Blood passes through the right atrioventricular orifice (which's guarded by the tricuspid valve) into right ventricle

The Right Ventricle (RV)

- Possess trabeculae carneae – raised bundles of cardiac muscle fiber.
- Cusps of the tricuspid valve are connected to chordae tendinae which are connected to papillary muscles (3 in number).
- Interventricular septum.
- Blood leaves through pulmonary orifice which's guarded by the pulmonary semilunar valve into pulmonary trunk.

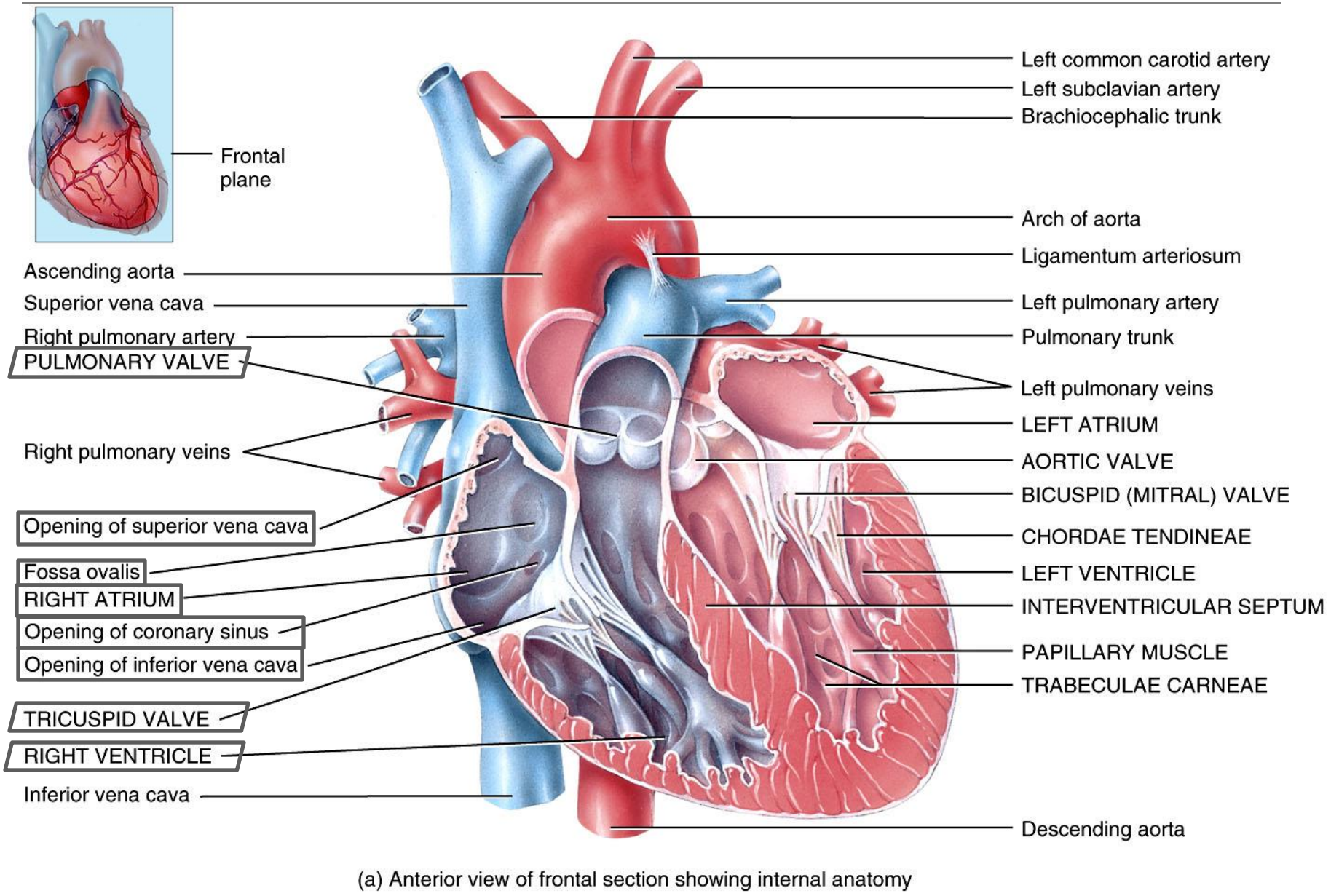


Fig.17: The left atrium and ventricle of the heart.

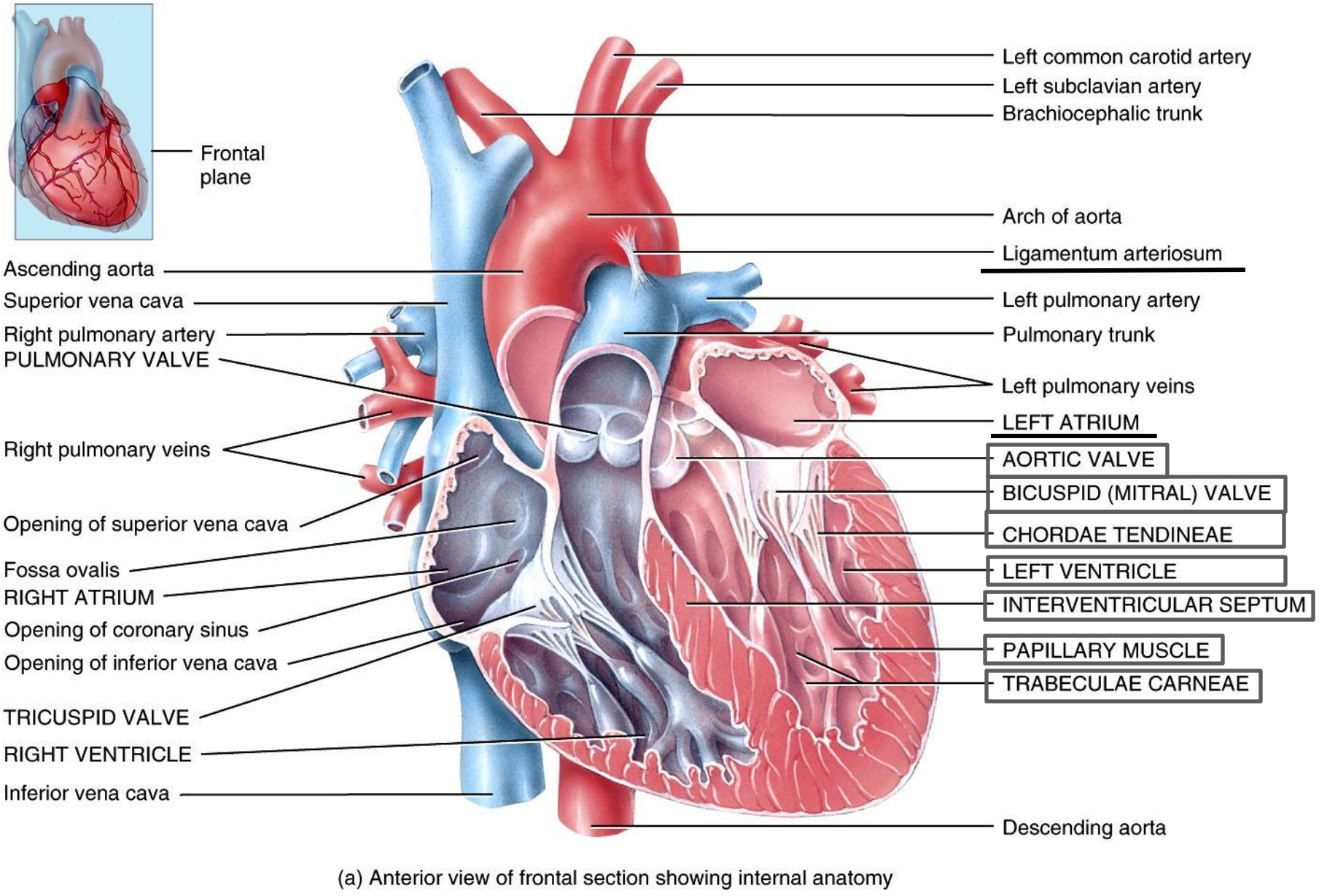
The Left Atrium (LA)

- About the same thickness as right atrium.
- Receives blood from the lungs through pulmonary veins.
- Blood Passes through the left atrioventricular orifice into the left ventricle. This orifice is guarded by the bicuspid/ mitral valve.

The Left Ventricle (LV)

- Thickest chamber of the heart.
- The cusps of the mitral valve are attached to chordae tendinae which are attached to papillary muscles (2 in number).
- Blood passes through aortic orifice into the aorta. This orifice is guarded by the aortic semilunar valve.
- The interventricular septum is convex on the side of the RV making the cavity of the LV larger.

Fig.18: R and L ventricles wall thickness and cavities.

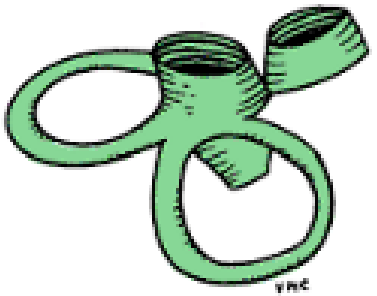


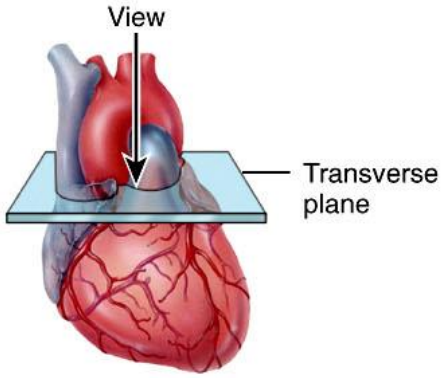
(a) Anterior view of frontal section showing internal anatomy

Fig.19: The right atrium and ventricle of the heart.

The Fibrous Skeleton of the heart

- Dense collagenous connective tissue that forms (1)base for the valves, (2)point of insertion for cardiac muscles and (3)electrical insulator between atria and ventricles.





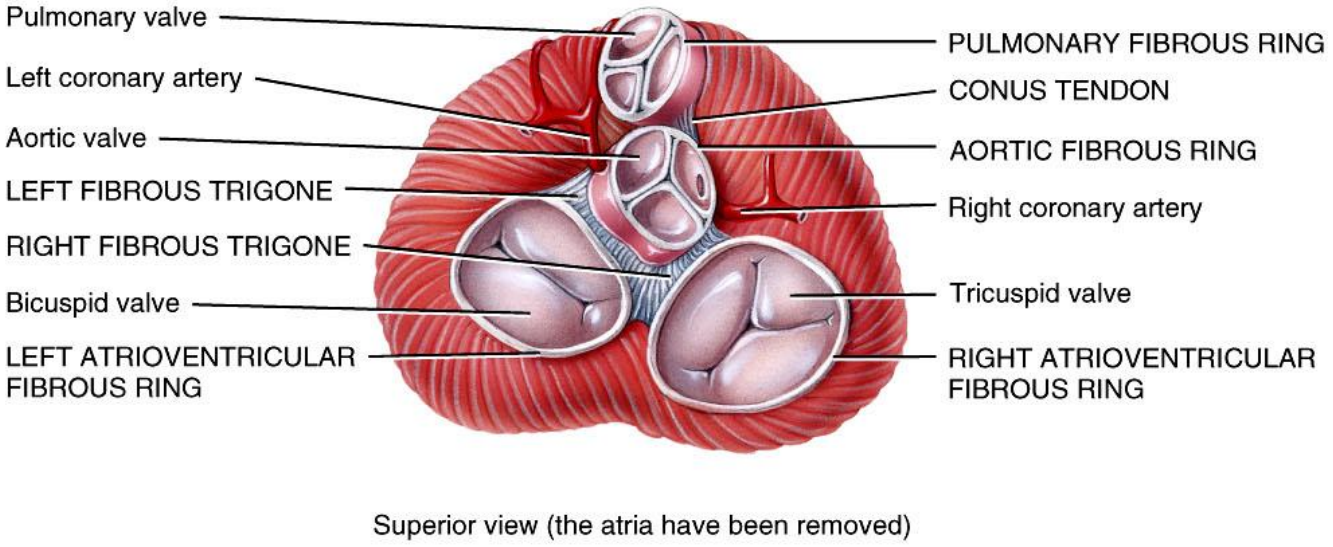


Fig.20: The shape and position of the fibrous skeleton of the heart.

Valves: Atrioventricular Valves

- Tricuspid (3 cusps) and bicuspid (2 cusps)

1. Atria contract/ ventricles relaxed
   - The higher pressure inside the atria pushes the cusps aside opening the valves and the cusps project into the ventricles
   - In the ventricles, papillary muscles are relaxed and chordae tendinae slack
2. Atria relax/ ventricles contract
   - Higher pressure in the ventricles drives the cusps towards the atria until edges of the cusps meet and close the valve
   - Papillary muscles contract tightening the chordae tendinae and preventing regurgitation

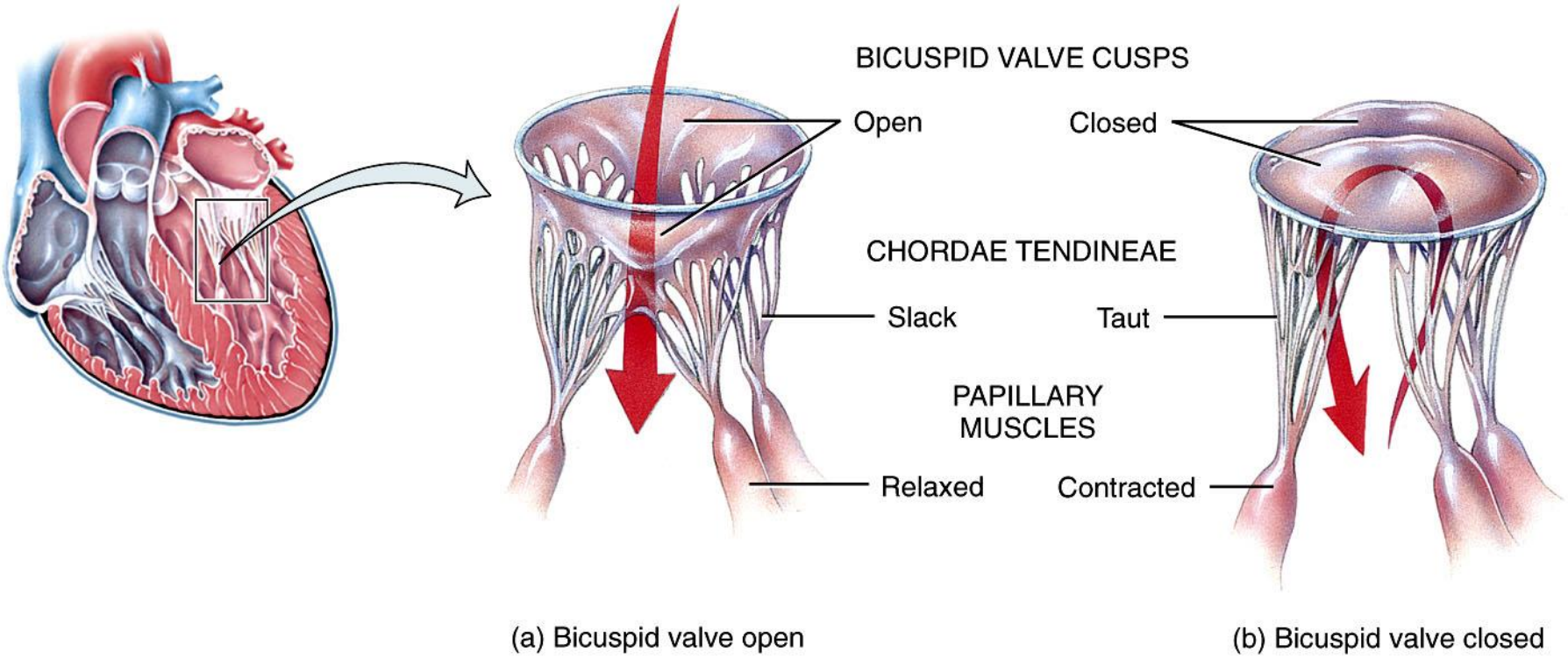
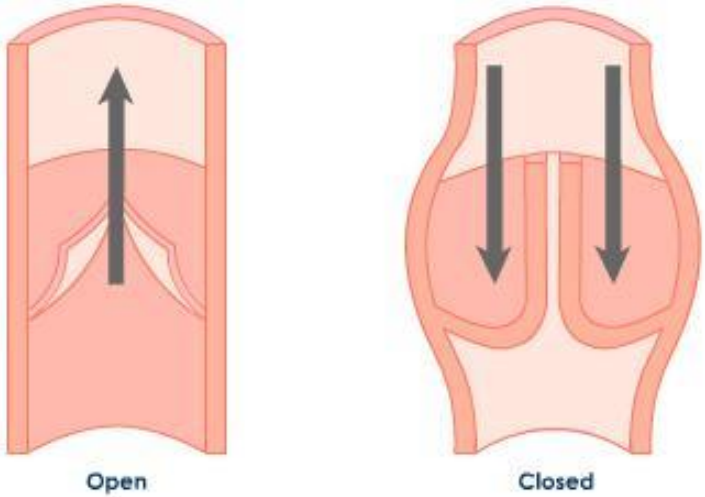


Fig.21: How the atrioventricular valves function.

Valves: Semilunar Valves

- Aortic and pulmonary valves (each has 3 cusps).
- When ventricles contract the pressure in ventricles exceeds pressure in arteries pushing the cusps aside and opening the valve.
- As ventricles relax, some blood flows back towards the ventricles, but blood fills the valve cusps closing them tightly.
- The aortic valve has openings for the coronary arteries into which blood flows when LV relaxes.



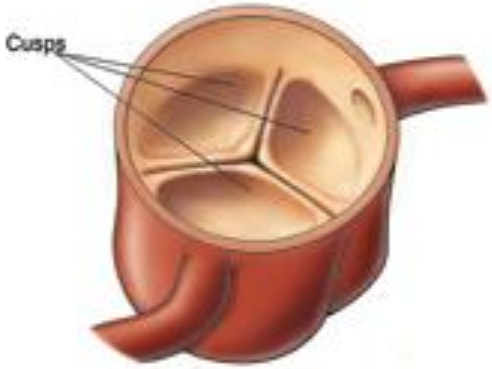


Fig.22: Above, how the semilunar valves function. Below, opening of the coronary arteries.

The Conduction System of the heart

- Formed of specialized cardiac muscle fibers.

- Nerve impulses from autonomic nervous system and hormones modify timing and strength of each heartbeat but do not establish fundamental rhythm.

- 2 important functions of these specialized cells:
  1. Act as pacemaker
  2. Form conduction system

Conduction Pathway

1. Begins in **sinoatrial (SA) node** in right atrial wall
   - Propagates through atria via gap junctions
   - Atria contract
2. Reaches **atrioventricular (AV) node** in interatrial septum where it's delayed
3. Enters **atrioventricular (AV) bundle** (Bundle of His)
   - Only site where action potentials can pass from atria to ventricles due to fibrous skeleton
4. Enters **right and left bundle branches** which extends through interventricular septum towards apex
5. Finally, large diameter **Purkinje fibers** conduct action potential to remainder of ventricular myocardium
   - Ventricles contract

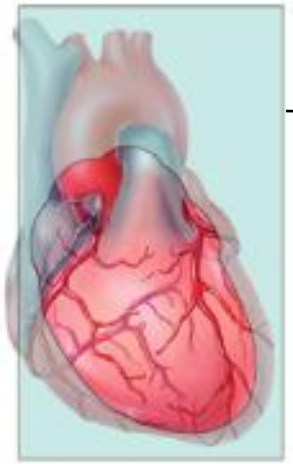
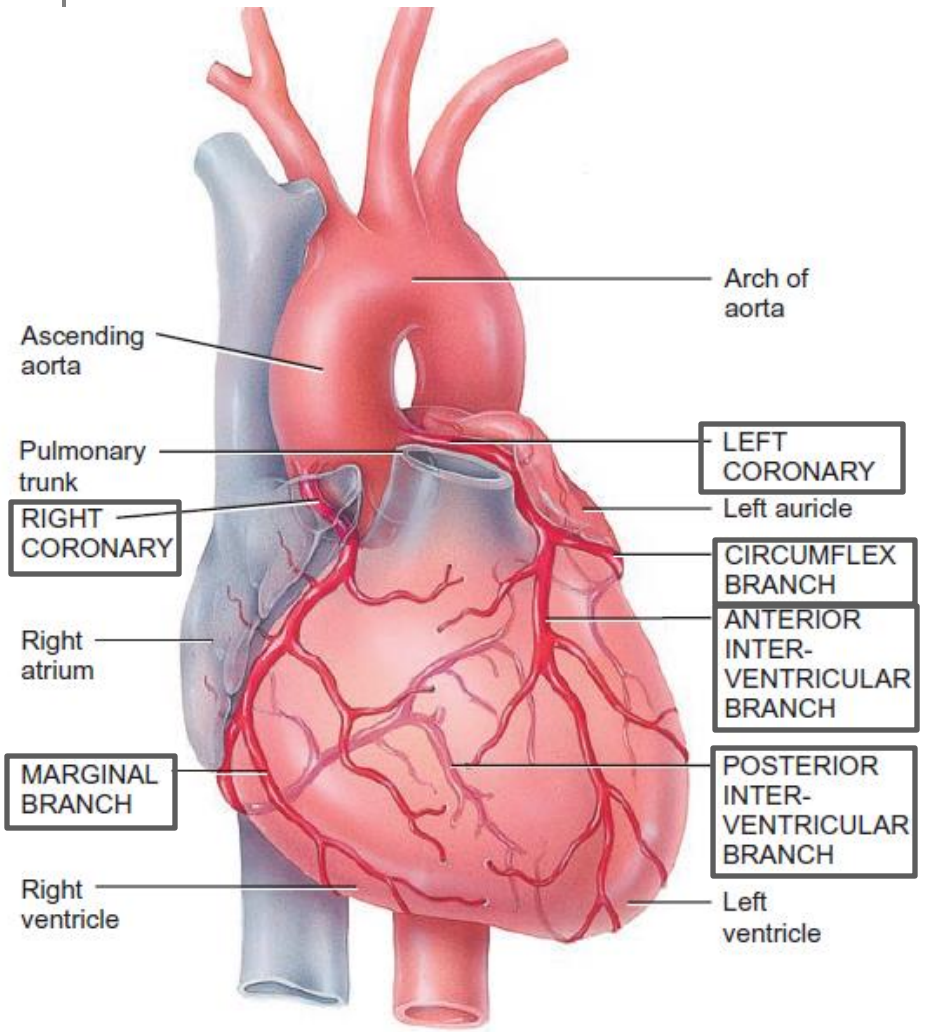


Fig.23: The conduction system of the heart.

The Coronary Circulation

- The heart has its own network of blood vessels.
- Coronary arteries branch from ascending aorta.
  - Anastomoses provide collateral circuits
  - Allows heart muscle to receive sufficient oxygen even if an artery is partially blocked
- **Left Coronary Artery** → Anterior Interventricular and Circumflex branches
- **Right Coronary Artery** → Marginal and Posterior Interventricular branches
- Coronary veins:
  - Include the **Great, Anterior, and Middle cardiac veins**
  - Drain into **Coronary Sinus** (in the coronary sulcus)



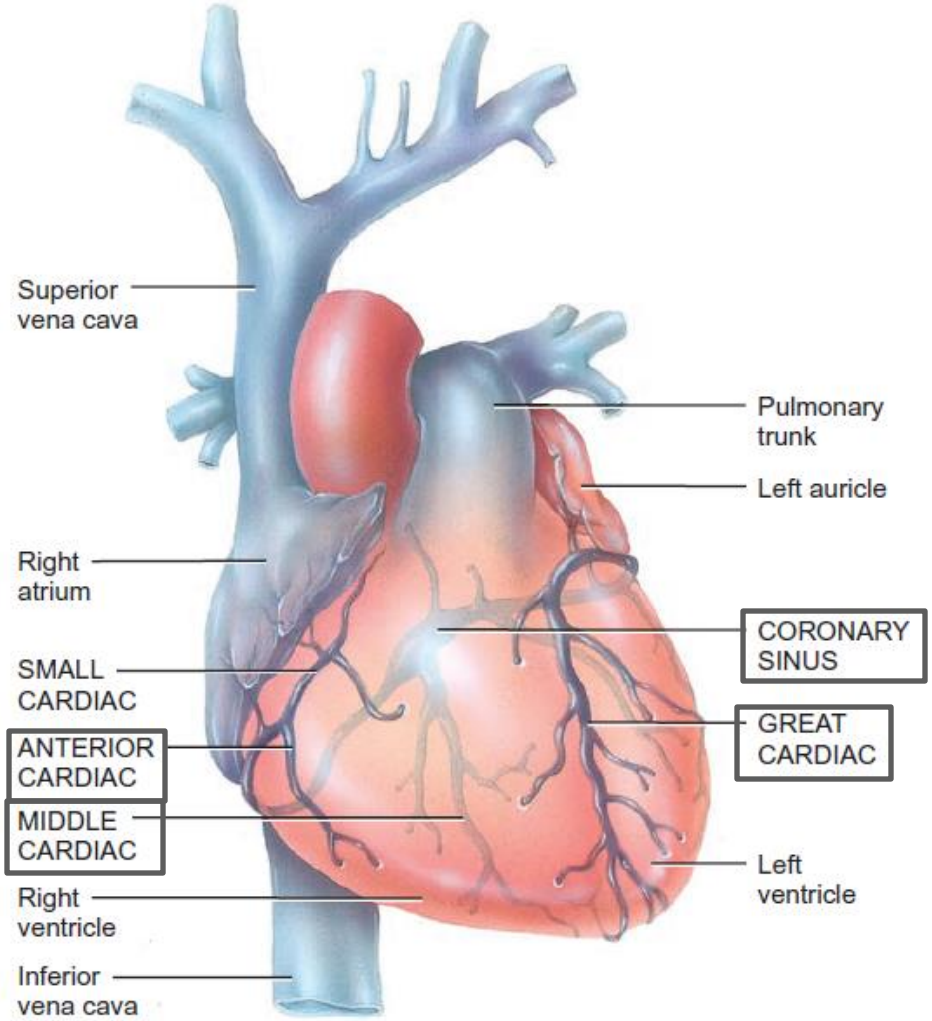


Fig.24: The coronary circulation.

The Blood Vessels

- Tube-like structures through which blood is carried

- 5 main types:
  - **Arteries** – carry blood AWAY from the heart
  - **Arterioles**
  - **Capillaries** – site of exchange
  - **Venules**
  - **Veins** – carry blood TOWARDS the heart and they possess valves

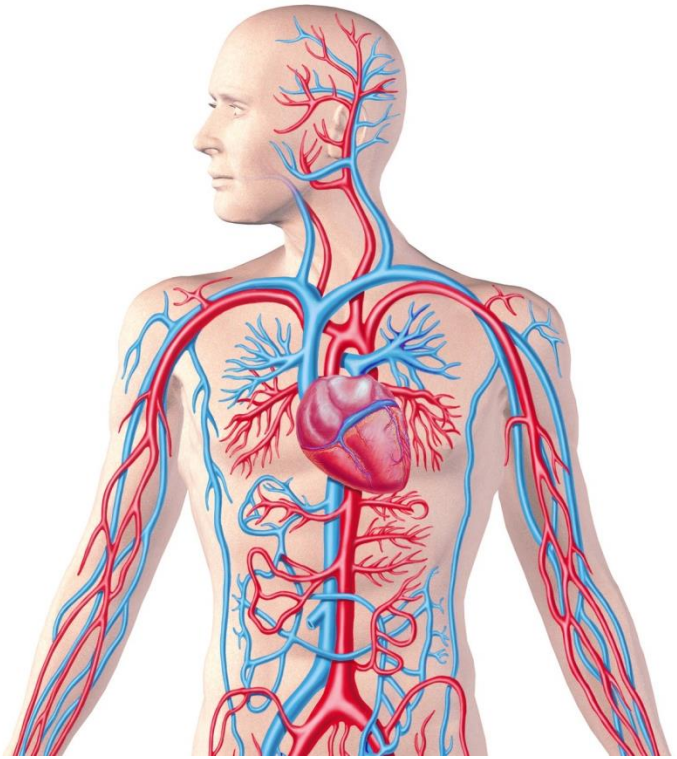


Fig.25: The blood vessels.

Basic structure of the wall of blood vessels

- **Tunica interna (intima)**
  - Inner lining in direct contact with blood
  - Endothelium continuous with endocardial lining of heart

- **Tunica media**
  - Muscular and connective tissue layer
  - Greatest variation among vessel types
  - Smooth muscle regulates diameter of lumen

- **Tunica externa**
  - Elastic and collagen fibers
  - Vasa vasorum (blood vessels that supply the blood vessel)
  - Helps anchor vessel to surrounding tissue

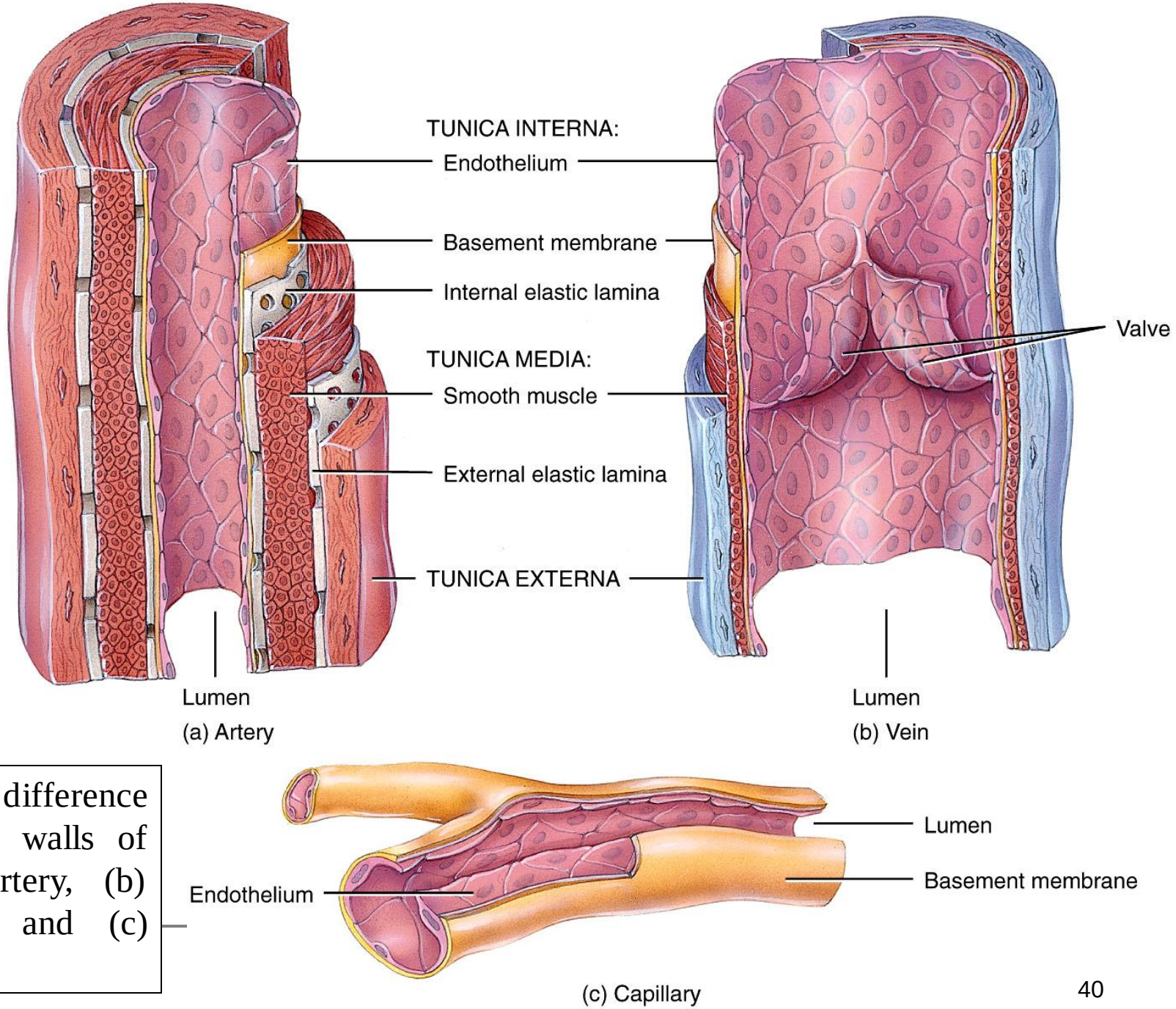


Fig.26: The difference between the walls of (a) large artery, (b) large vein, and (c) capillary.

Pulmonary and Systemic Circulations
Two circuits in series

- **Pulmonary circulation**
  - RA receives deoxygenated blood from systemic circulation
  - RA pumps blood into RV
  - RV ejects blood into pulmonary trunk then pulmonary arteries
  - Gas exchange in pulmonary capillaries in the lungs
  - Pulmonary veins take blood to LA
- **Systemic circulation**
  - LA receives oxygenated blood from lungs
  - LA pumps blood into LV
  - LV ejects blood into aorta
  - Systemic arteries, arterioles
  - Gas and nutrient exchange in systemic capillaries
  - Systemic venules and veins lead back to RA

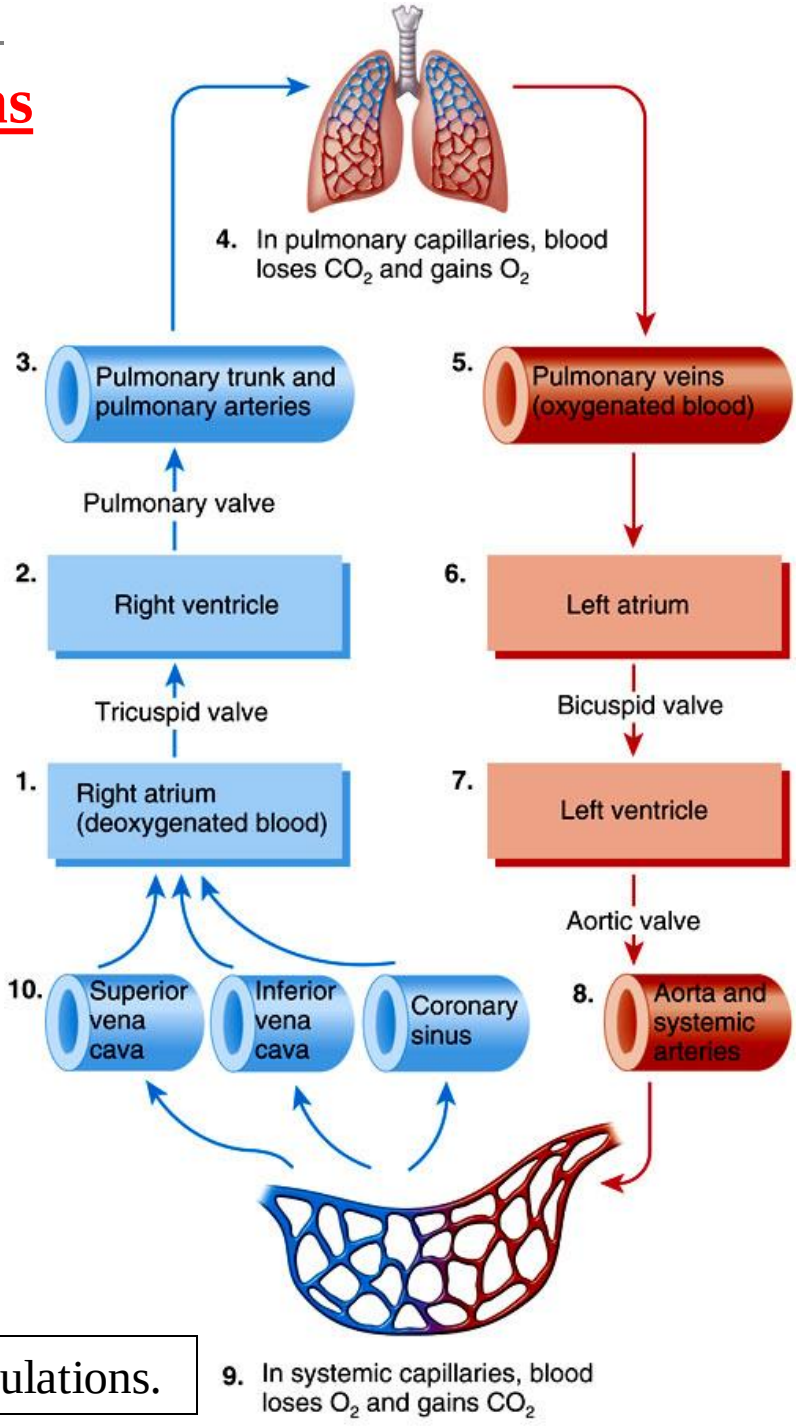


Fig.27: The two circulations.

Major Blood Vessels of the Thorax

The Major Arteries

The Aorta

- ❖ Is the largest artery in the body
- ❖ Arises from the LV

- ❖ Divided into 4 parts:

1. Ascending aorta
2. Arch of aorta
3. Descending Thoracic aorta
4. Abdominal aorta

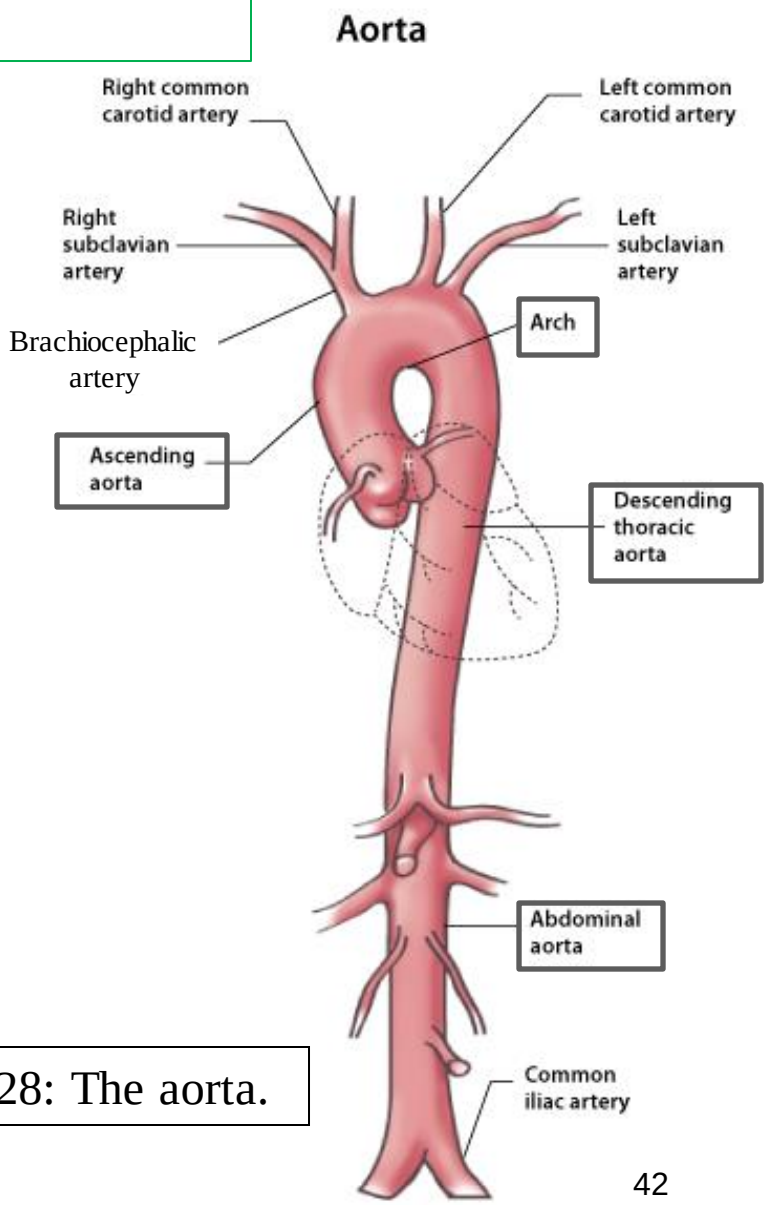


Fig.28: The aorta.

Important Branches (In the Thorax):

- Ascending Aorta:

1. Right Coronary artery
2. Left Coronary artery

- Arch of aorta:

1. Brachiocephalic trunk
   a. Right Subclavian artery
   b. Right Common Carotid artery
2. Left Common Carotid Artery
3. Left Subclavian Artery

- Descending Thoracic Aorta:

Gives various branches to nearby structures

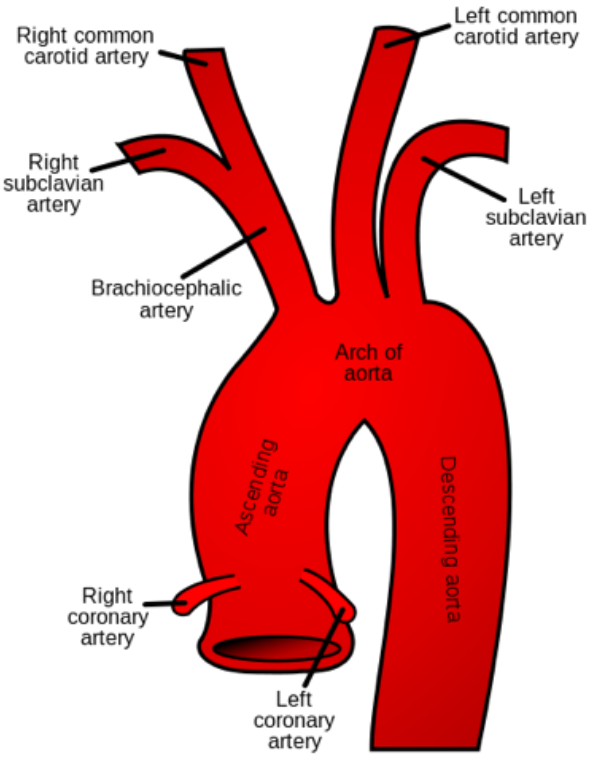


Fig.29: The ascending and the arch of aorta.

The Pulmonary Trunk

- Is the only artery in the body which carries ***deoxygenated blood.***
- Arises from the RV.
- Divides into the Right and Left Pulmonary arteries which pass into the corresponding lung.

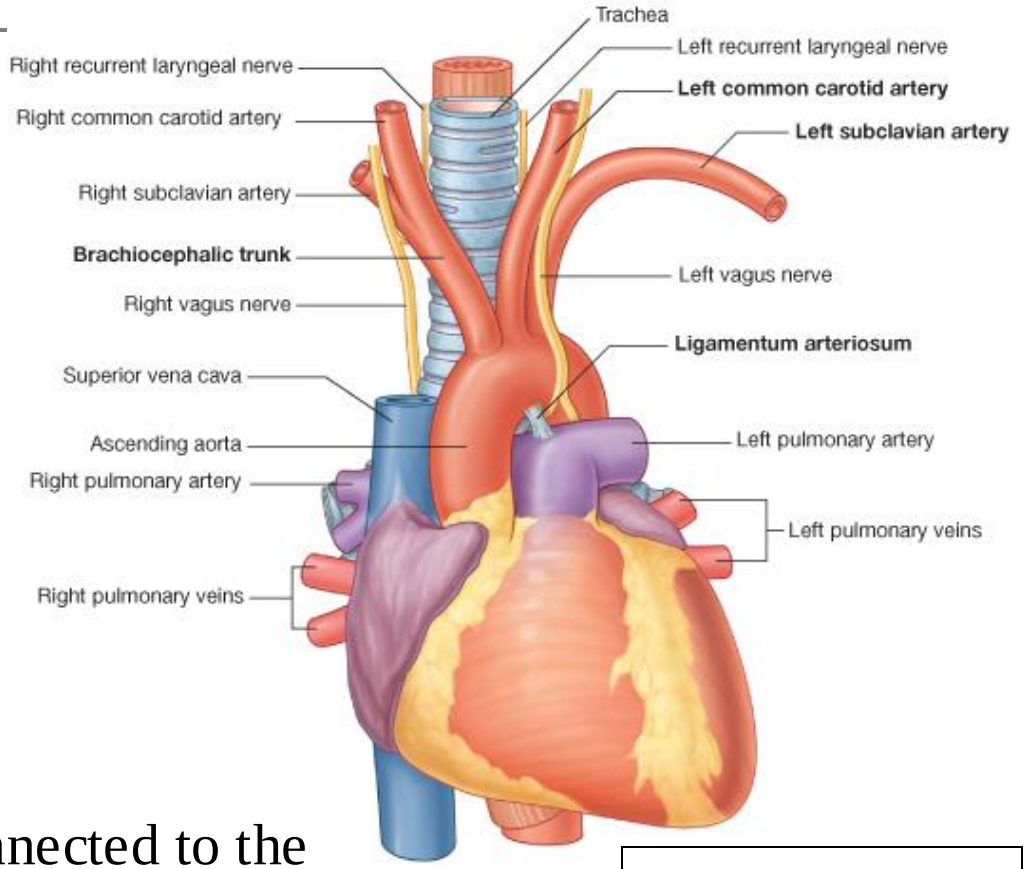


Fig.30: Anterior view of the heart.

- The pulmonary trunk is connected to the arch of aorta by the *ligamentum arteriosum*.
  - This is the remnant of the ductus arteriosus which shunted blood from the pulmonary trunk to the aorta during fetal life thus bypassing the lung. During fetal life, the fetus does not need his lungs because it already receives oxygenated blood from the mother.

The Major Veins

- Blood from the thoracic region is collected by several veins that ultimately drain into the **azygos system** which shows considerable variation among people.
- The azygos vein eventually arches forwards to enter the superior vena cava.

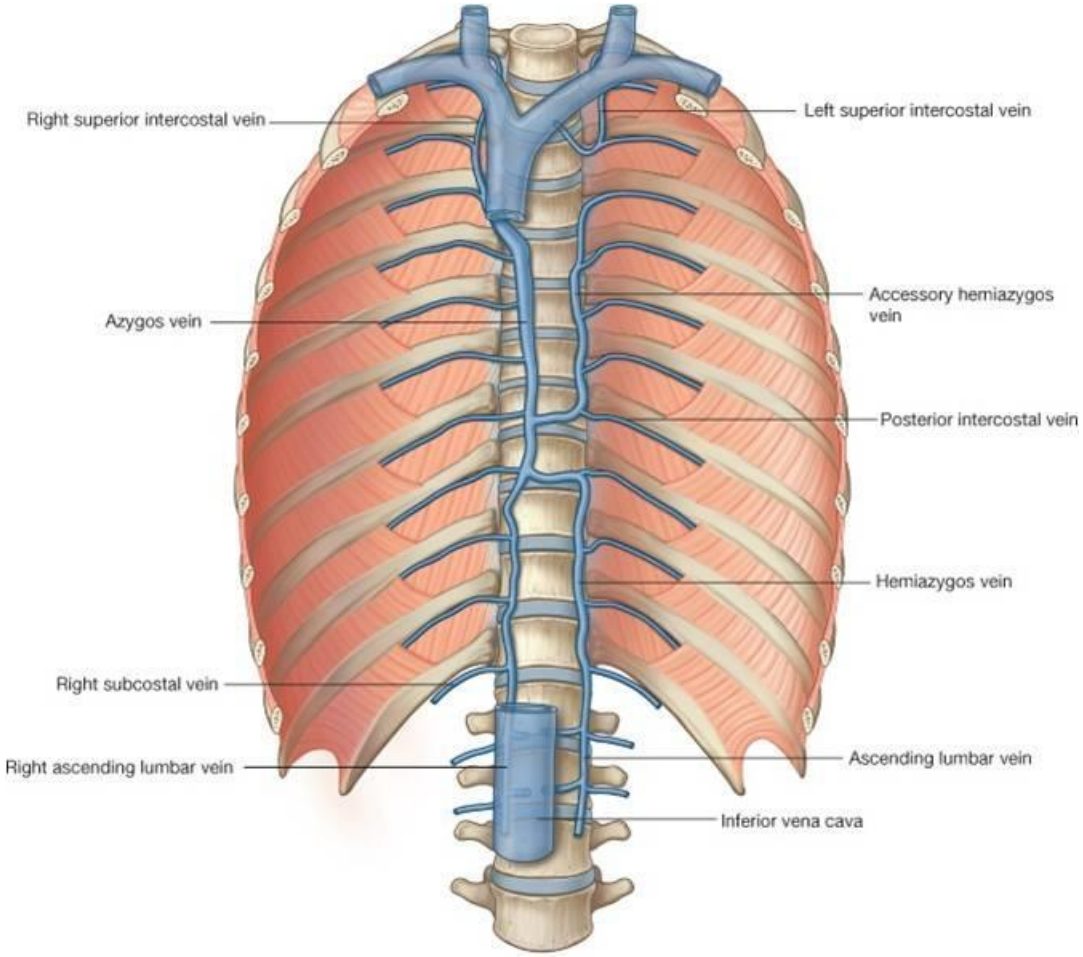


Fig.31: The azygos system of veins.

The Brachiocephalic veins:

The right brachiocephalic vein is vertical, whereas the left is more horizontal. They drain blood from the head, neck and upper limbs. They unite to form the Superior Vena Cava (SVC) which opens into the RA.

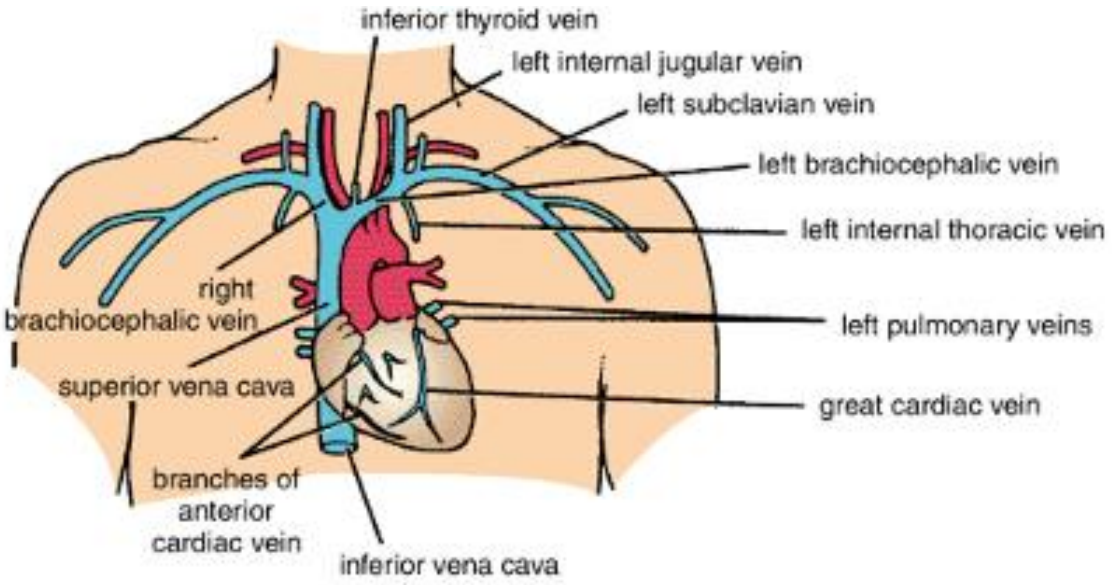


Fig.32: The major veins of the thorax..

The Pulmonary Veins:

These are 4 veins (2 from each lung) that carry ***oxygenated blood*** from the lung to the LA of the heart. Only veins that carry oxygenated blood.

The Inferior Vena Cava (IVC):

This is formed in the abdomen and its terminal part enters the thorax (through the diaphragm) to open into the RA.

Major Blood Vessels of the Head and Neck
The Major Arteries

The Carotid Arteries

- Responsible for supplying blood to structures in the head and neck.
- They ascend superiorly in the neck where they are closely related to the internal jugular vein and the vagus nerve.
- About the level of the upper border of the thyroid cartilage, each artery divides into the ***external and internal carotid arteries.*** (this is where the carotid pulse can be felt).

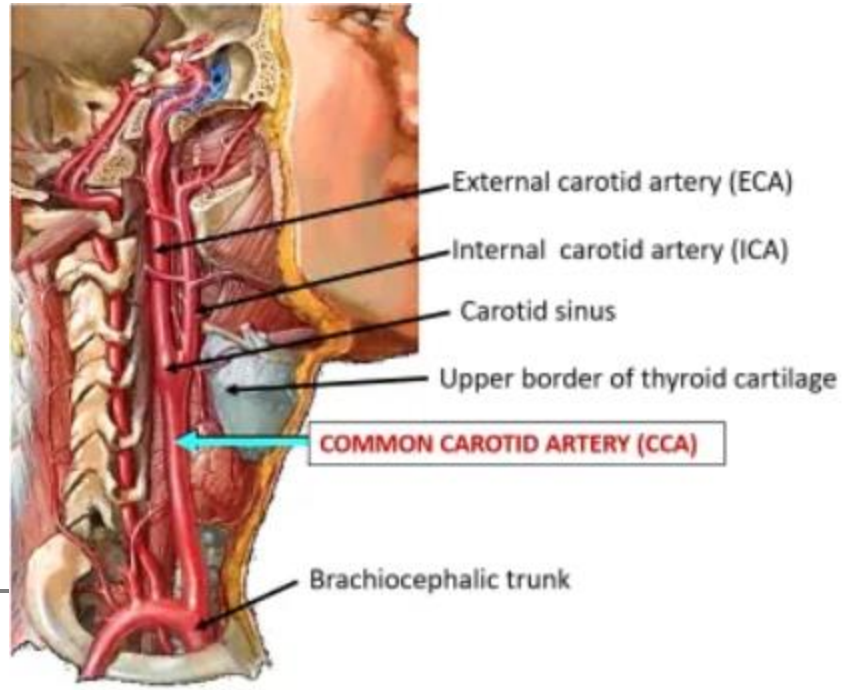


Fig.33: The carotid arteries.

- The branches of the external carotid supply almost all structures in the head and neck except the brain.
- The **internal carotid** supplies the brain and various other structures.
- Branches from the **internal carotid** and the **subclavian** arteries form an arterial circle under the brain called the ***Circle of Willis***. This provides blood to various parts of the brain.

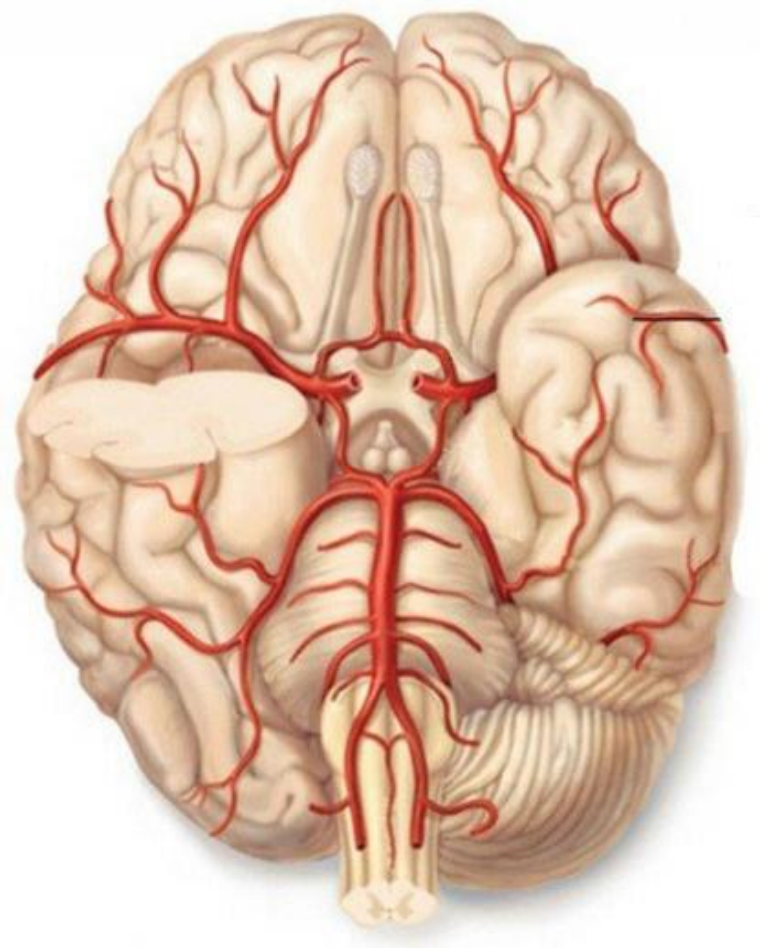


Fig.34: Inferior surface of the brain showing the circle of Willis.

The Subclavian Arteries

- The right and left subclavian arteries arch laterally from their origins.
- At the outer border of the first rib they become the axillary artery.
- The scalenus anterior muscle is related to this artery.
- They give off several branches that supply various structure in the head, the neck, and even the chest

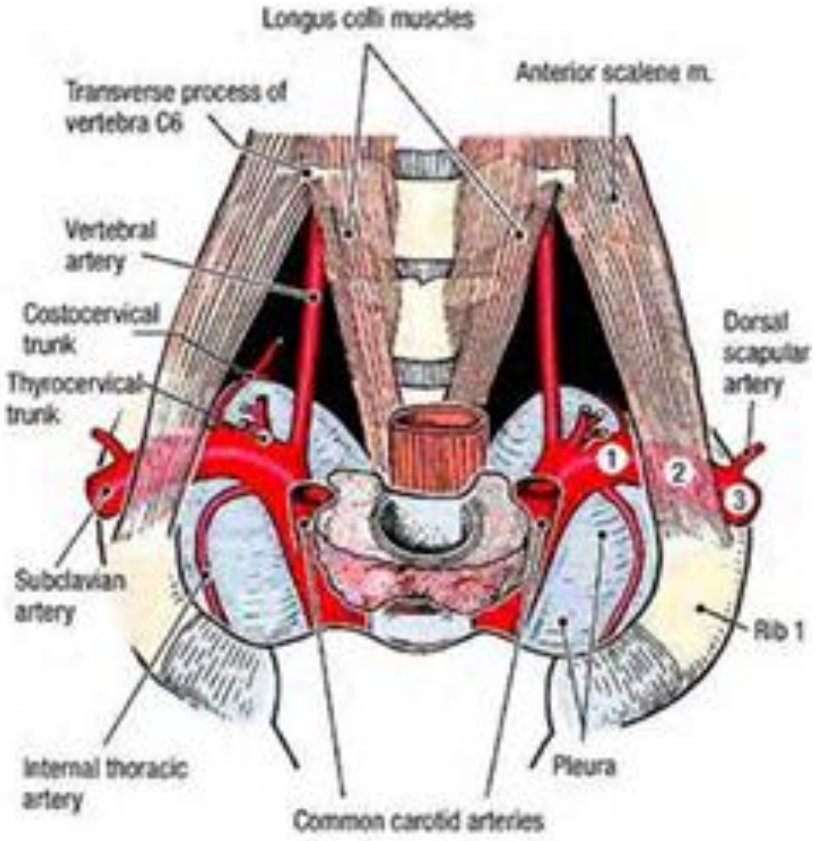
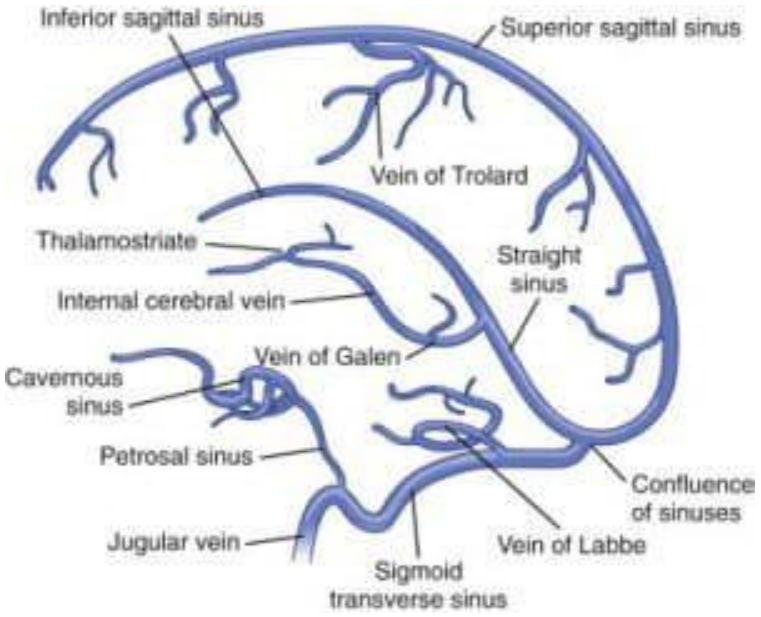


Fig.35: The subclavian arteries.

The Major Veins

Fig.36: Venous sinuses of the brain.



- All blood from the brain (and related structures) drains into ***sinuses*** (enlarged veins). These sinuses eventually drain into the **internal jugular vein** (IJV).
- The IJV is formed inside the skull, leaves the skull by passing through the jugular foramen and descends through the neck in close relation to the internal carotid and common carotid arteries.
- Blood from the neck drain into IJV and the **external jugular vein**.
- The external jugular will drain into the subclavian vein. This vein will unite with the IJV to form the brachiocephalic vein.

Major Blood Vessels of the Upper Limb
The Major Arteries

The Axillary Artery

- It's the direct continuation of the subclavian artery when it passes the lateral border of the first rib.
- The pectoralis minor muscle divides the artery into 3 part.
- Its several branches supply surrounding structures.
- At the lower border of the teres major muscle, it becomes the brachial artery.

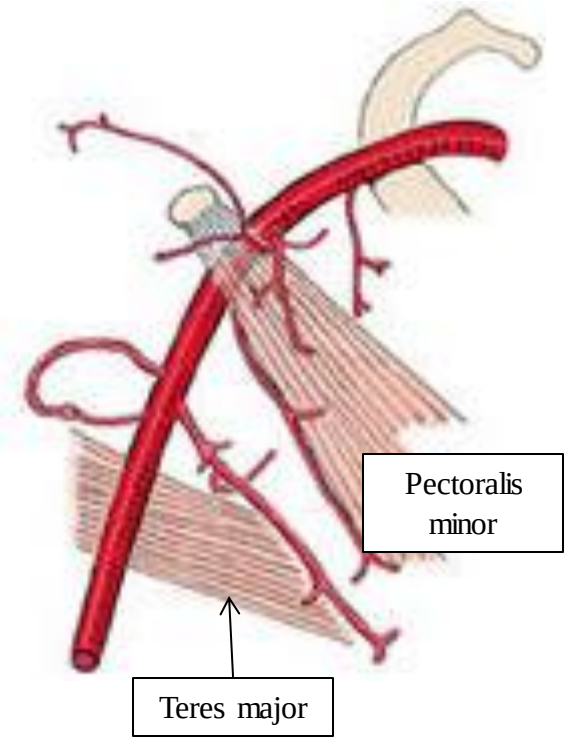


Fig.37: The axillary artery.

The Brachial Artery

- The direct continuation of the axillary artery when it passes the lower border of the teres major muscle. Its branches supply surrounding structures.
- It terminates at the neck of the radius by dividing into the radial and ulnar arteries.
- In the cubital fossa, the brachial artery passes medial to the tendon of the biceps muscle where it's superficial. This is the site for taking the brachial pulse and measuring the blood pressure.

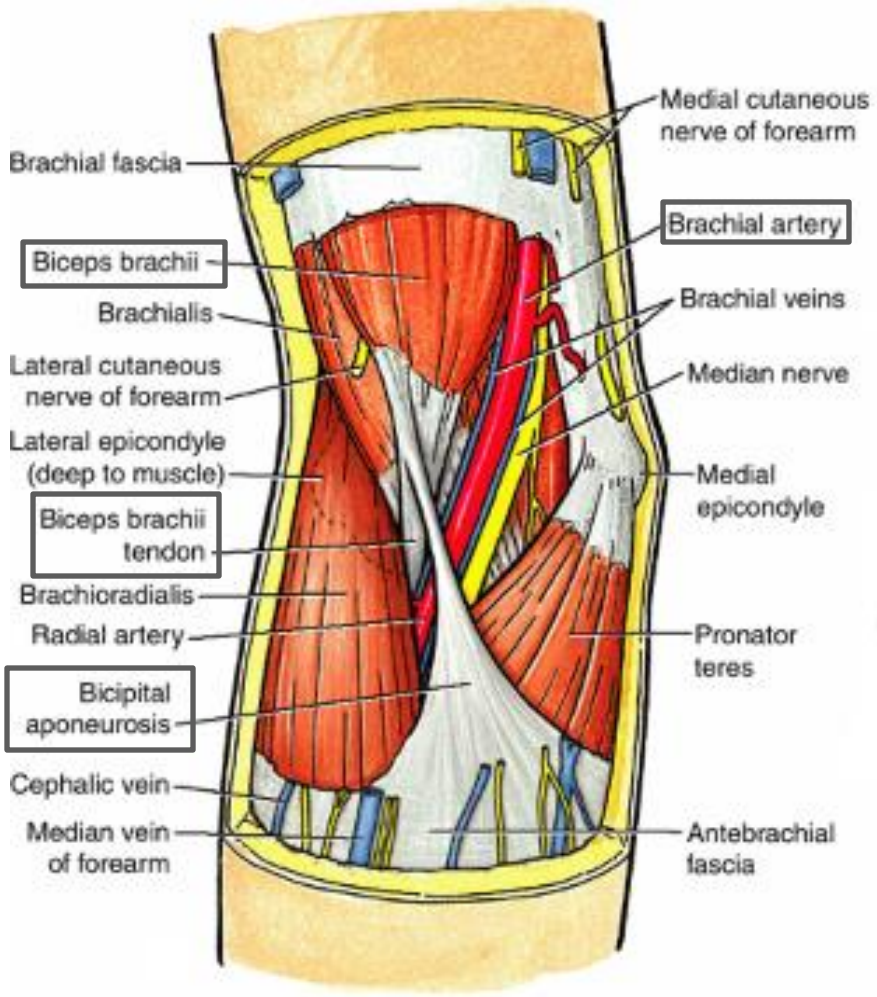


Fig.38: The brachial artery in the cubital fossa.

The Radial and Ulnar Arteries

- The radial artery passes down on the lateral aspect of the forearm. The ulnar passes on the medial side. They enter the palm where they form the superficial and deep palmar arches.
- The radial and ulnar arteries supply structures in the forearm. The two palmar arches supply structures in the hand and fingers.
- The radial artery is superficial as it passes over the wrist. It's here that the radial pulse can be felt.

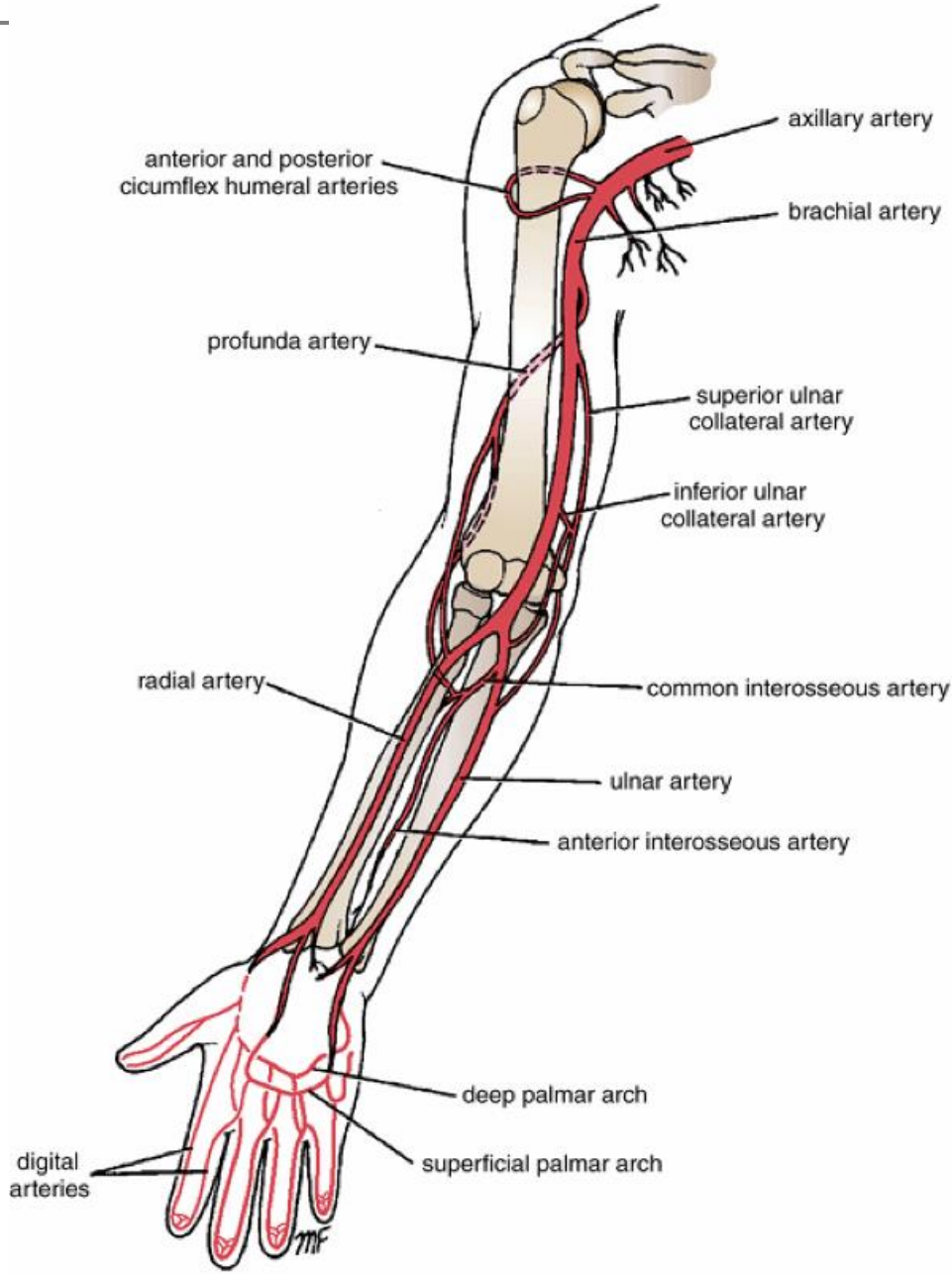


Fig.39: Arteries of the upper limb.

The Major Veins

- In the upper limb, we have superficial and deep veins. The **superficial veins** run just under the skin. They start as a network on the dorsum of the hand. From this network the **cephalic and basilic** veins arise. These two superficial veins are connected at the elbow by the **median cubital vein**. Superficial veins are used to take blood samples.
- Most of the **deep veins** are in the form of two small veins that accompany the arteries (**venae comitantes**).
- The basilic vein unites with the venae comitantes of the brachial artery to form the axillary vein (a large deep vein accompanying the axillary artery). This receives the cephalic vein. Upon passing the outer border of the first rib, the axillary vein becomes the subclavian vein.

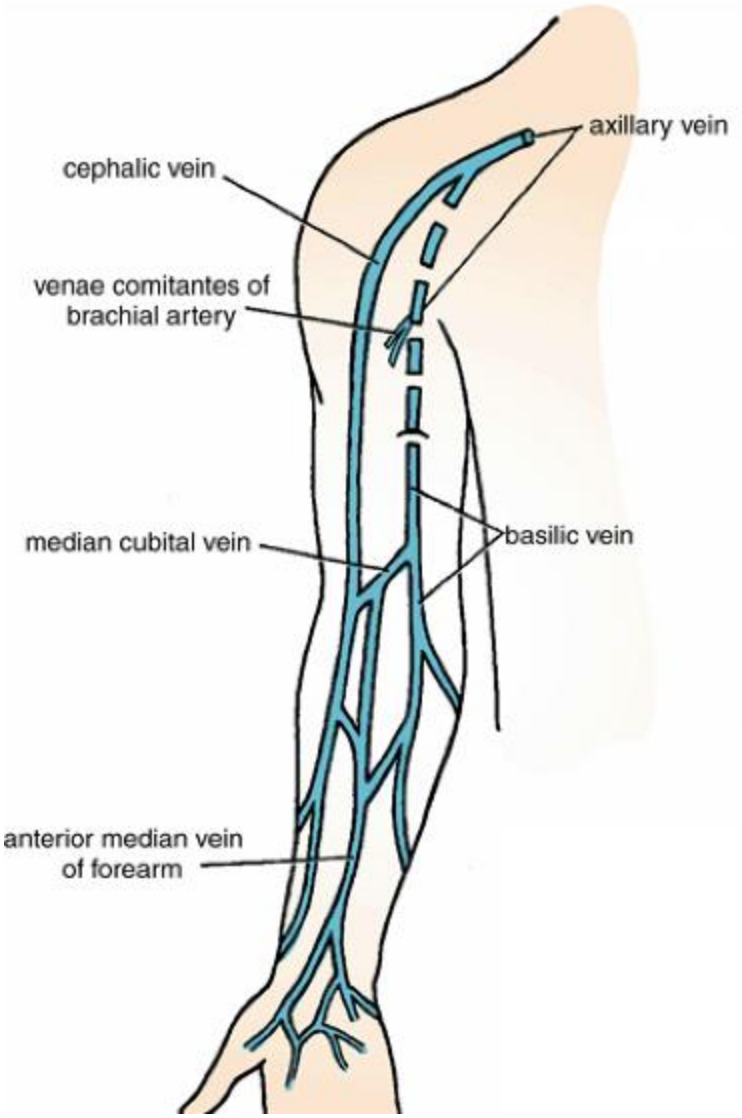


Fig.40: Veins of the upper limb.

Major Blood Vessels of the Abdomen

The Major Arteries

The Abdominal Aorta

- The abdominal aorta is the continuation of the descending thoracic aorta. It **begins** where the aorta passes through the diaphragm to enter the abdominal cavity opposite **T12** vertebra.
- The abdominal aorta is closely related to the vertebral column and the IVC.
- It **terminates** opposite **L4** by dividing into the two Common Iliac Arteries.

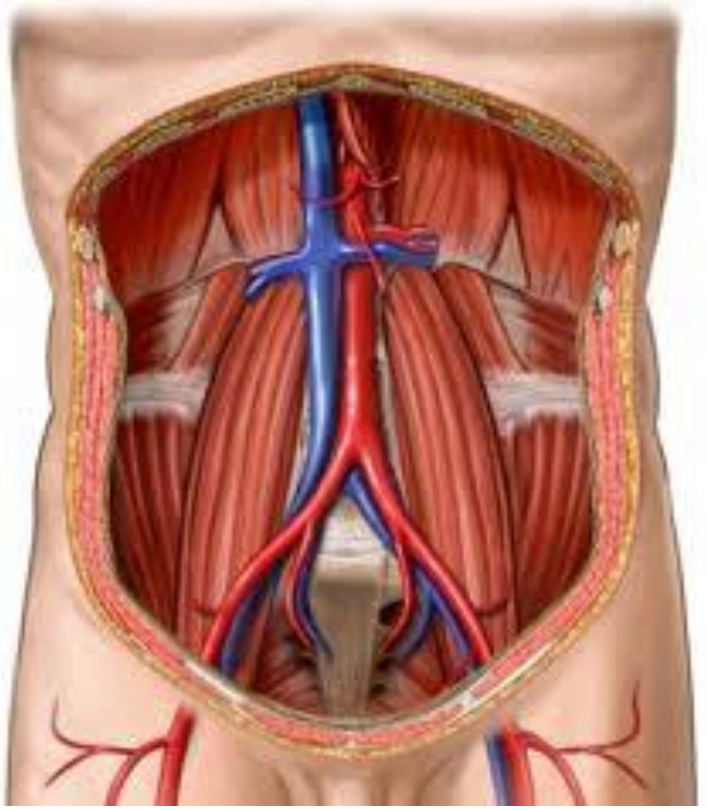


Fig.41: The abdominal aorta and the inferior vena cava.

Branches

- Celiac trunk, superior mesenteric artery, and inferior mesenteric artery which supply organs of the digestive system in the abdomen.
- Suprarenal arteries supply the adrenal gland.
- Renal arteries supply kidneys.
- Others.

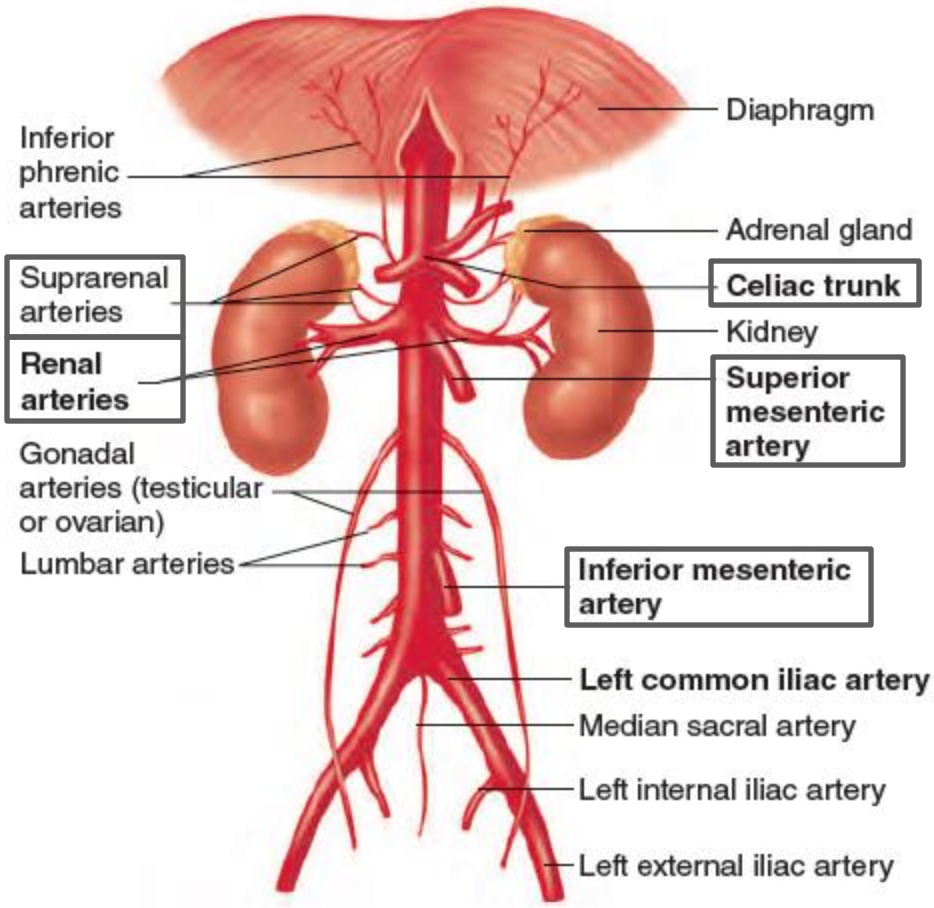


Fig.42: Branches of the abdominal aorta.

The Major Veins

- All Blood from the abdomen drains ultimately into the IVC.
- The IVC passes upwards close to the abdominal aorta, then passes through the diaphragm at level of **T8** to enter the thorax where it opens into the RA.
- The blood from the digestive organs (esophagus, stomach, small and large intestines, liver, pancreas and spleen) drains first into the **Portal vein** then into the IVC.

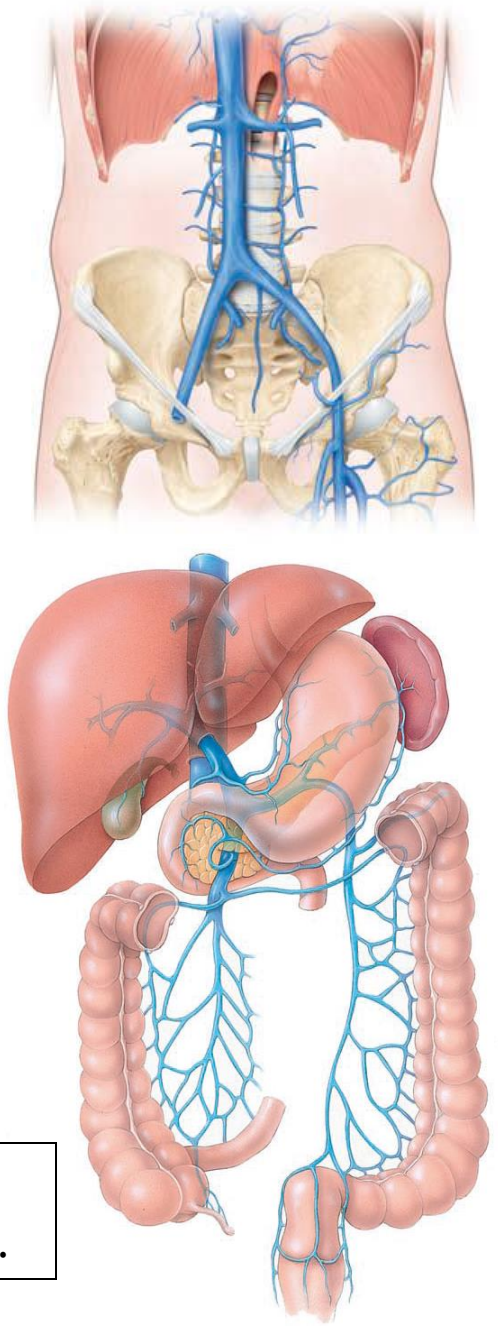
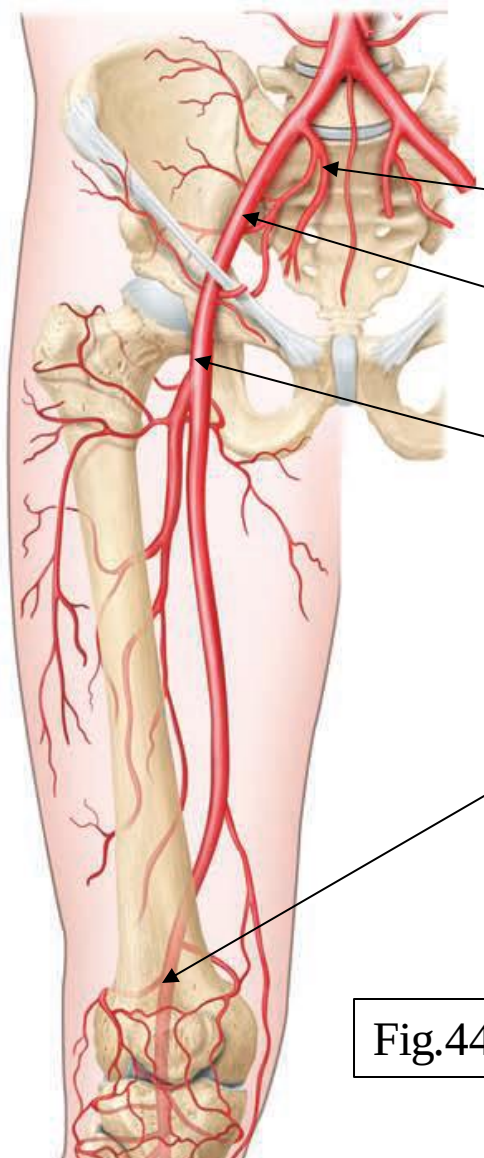


Fig.43: The inferior vena cava (above) and the portal vein (below).

Major Blood Vessels of the Lower Limb

The Major Arteries



- Each common iliac artery soon divides to give the internal and external iliac arteries.
- The **internal iliac artery** supplies structures in the pelvis.
- The **external iliac artery** passes into the thigh where it becomes the femoral artery.
- The **femoral artery** gives branches that supply structures in the thigh and the knee joint.
- When this artery reaches the knee joint it becomes known as the **popliteal artery**. The branches of this artery supply structures in the leg and foot.

Fig.44: Major arteries of the lower limb.

The Major Veins

- ✓ Here we have superficial and deep veins.
- ✓ The deep veins are venae comitantes. Some large deep veins correspond to the larger arteries.
- ✓ The superficial veins are:

a. The **Great Saphenous vein** which drains into the femoral vein.

b. The **Small Saphenous vein** which drains into the Popliteal vein.

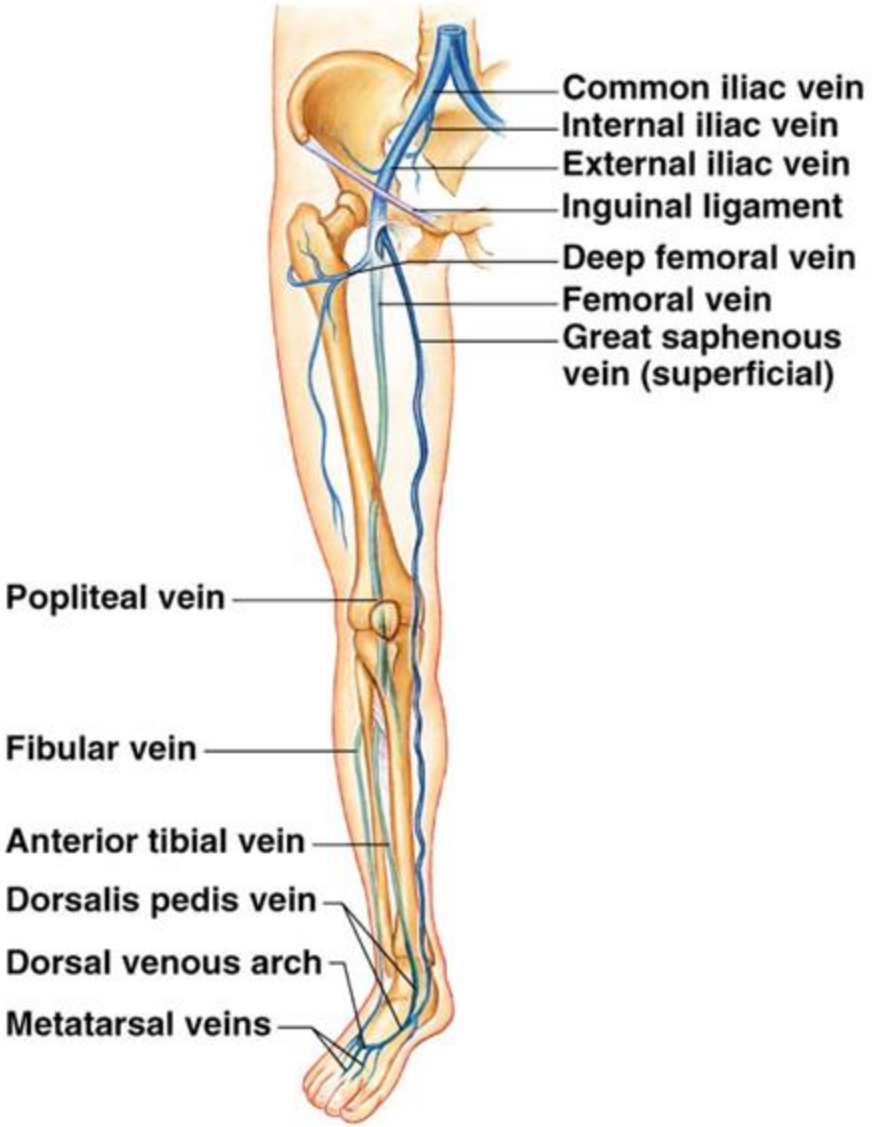


Fig.45: Major veins of the lower limb.