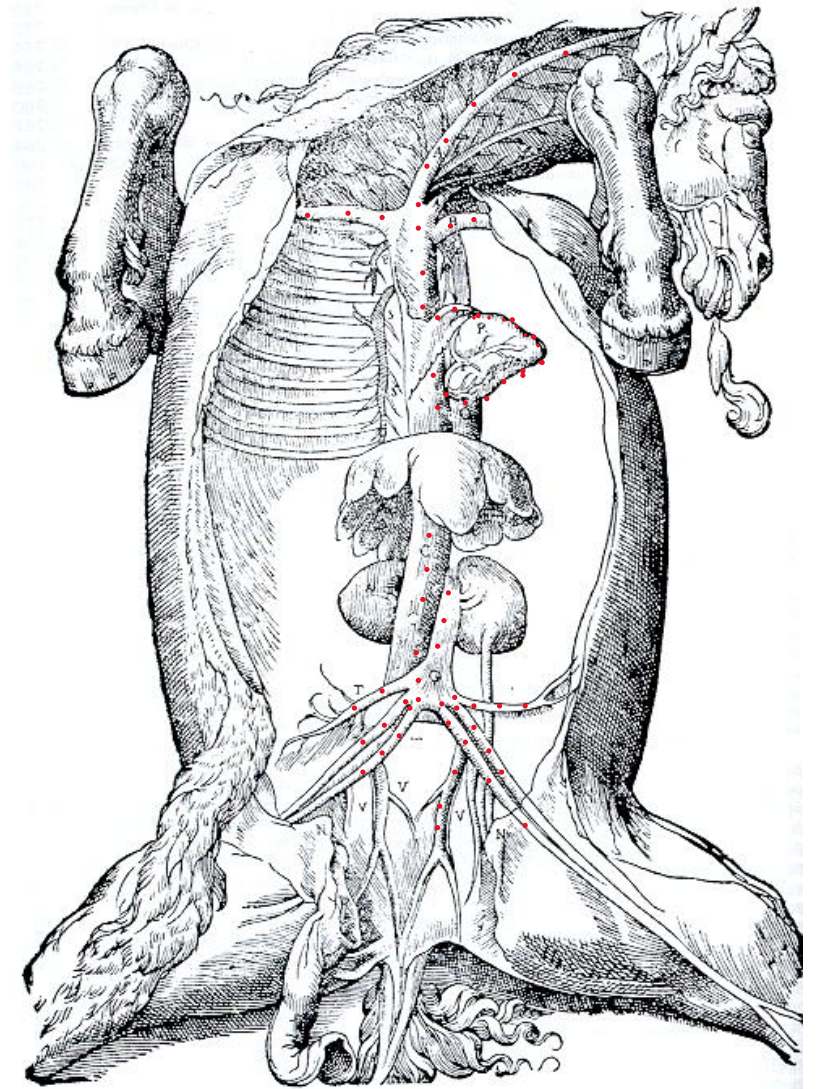


CARDIOVASCULAR SYSTEM

ANATOMY OF THE HEART AND BLOOD VESSELS



Carlo Ruini: "Anotomia et infirmita' del cavallo" 1598

CARDIOVASCULAR SYSTEM

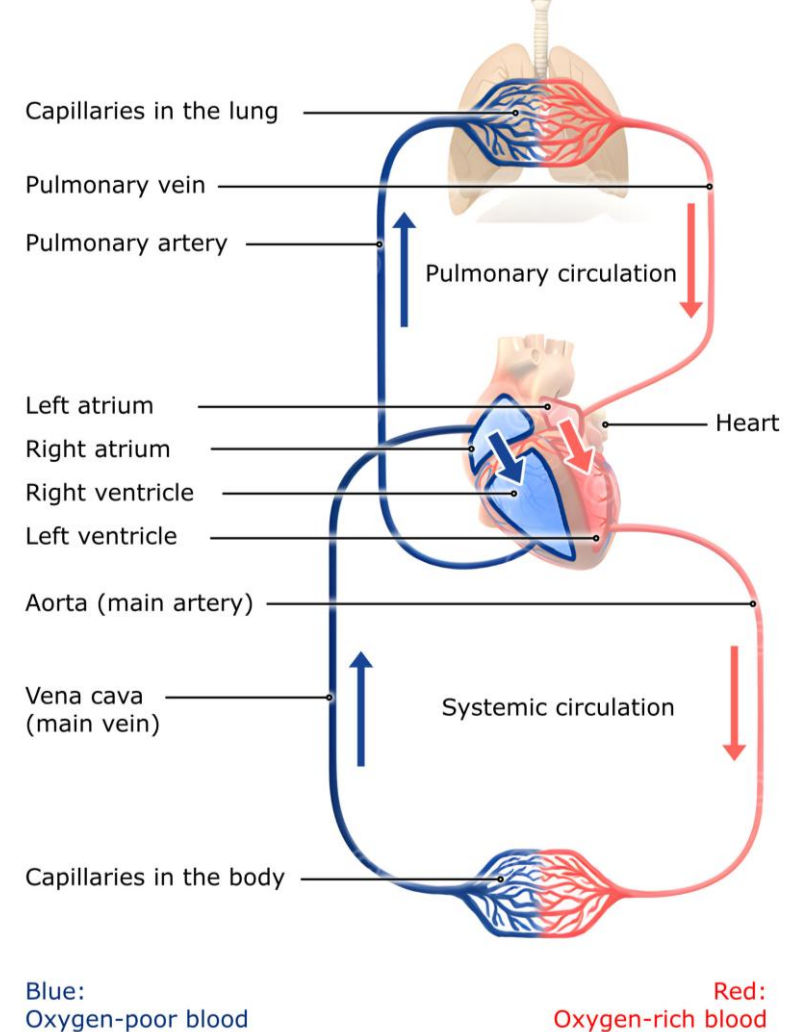
The **cardiovascular system** consists of a pump represented by **the heart and blood vessels**, which provide the route by which blood circulates to and from all parts of the body

The cardiovascular system is made up of:

1) The heart and

2) a closed system of channels called **Blood vessels (arteries, capillaries, and veins)**.

Lymphatic vessels are part of the **lymphatic system**, not the **blood circulatory system**. The lymphatic system works together with the circulatory system, but it is a **separate system**.



BLOOD CIRCULATORY SYSTEM

The **heart** is a hollow muscular organ that acts as a pressure pump

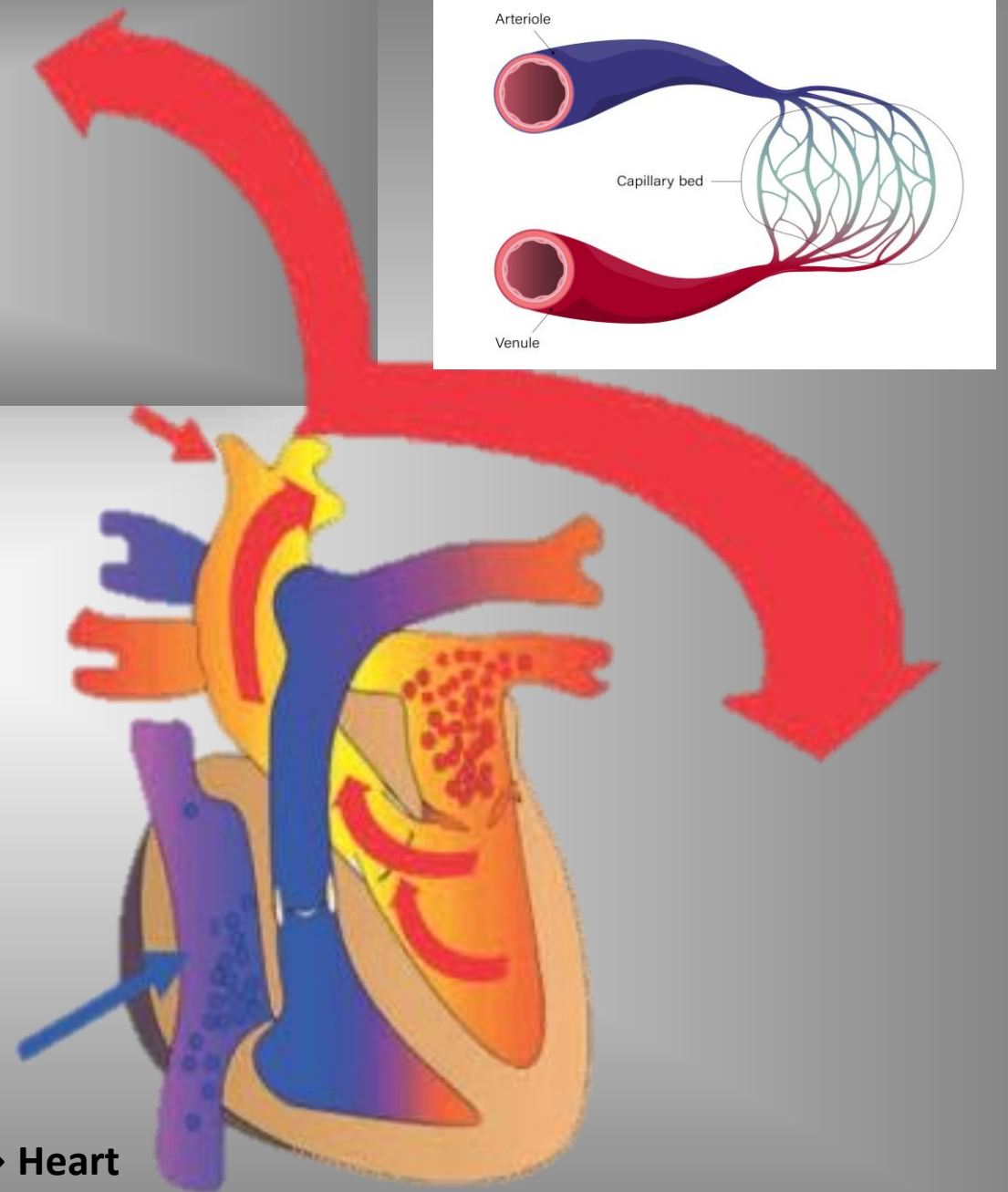
The **heart** pumps the blood through the arterial system under significant pressure;

blood is returned to the heart under low pressure with the assistance of negative pressure in the thoracic cavity during inspiration and compression of the veins by skeletal muscle.

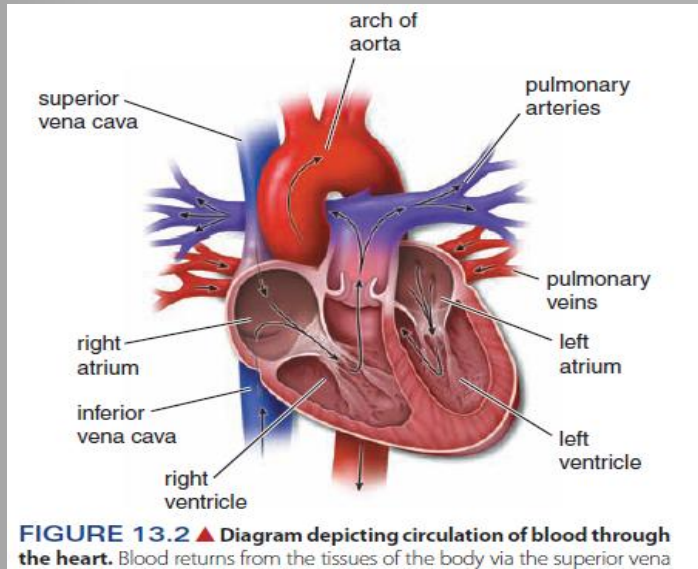
The movement of blood along the system of closed channels is ensured by the heart pump, which has rhythmic activity

The pathway of blood is:

Heart → Arteries → Arterioles → Capillaries → Venules → Veins → Heart



Two circuits distribute blood in the body: the systemic and the pulmonary circulations.



- **Pulmonary circulation** conveys blood from the heart to the lungs and from the lungs to the heart (Fig. 13.2).
- **Systemic circulation** conveys blood from the heart to other tissues of the body and from other tissues of the body to the heart.

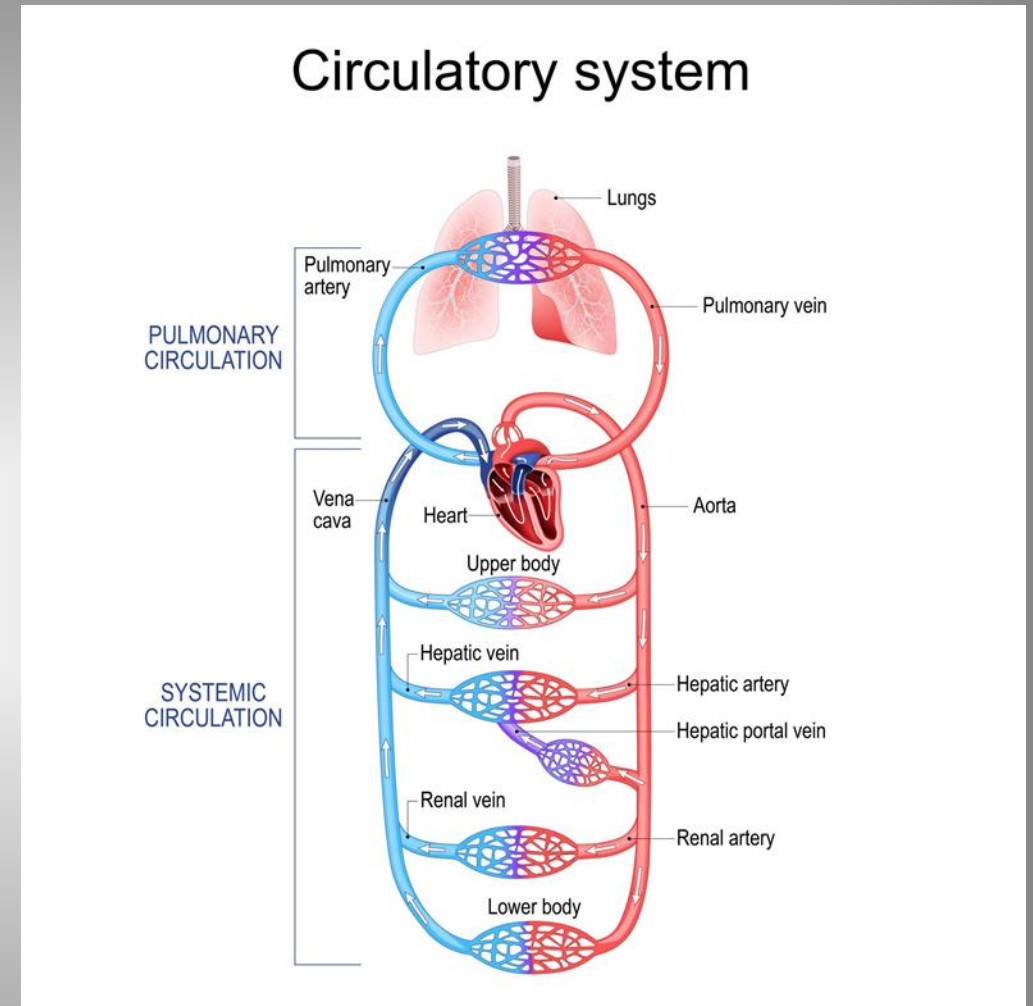
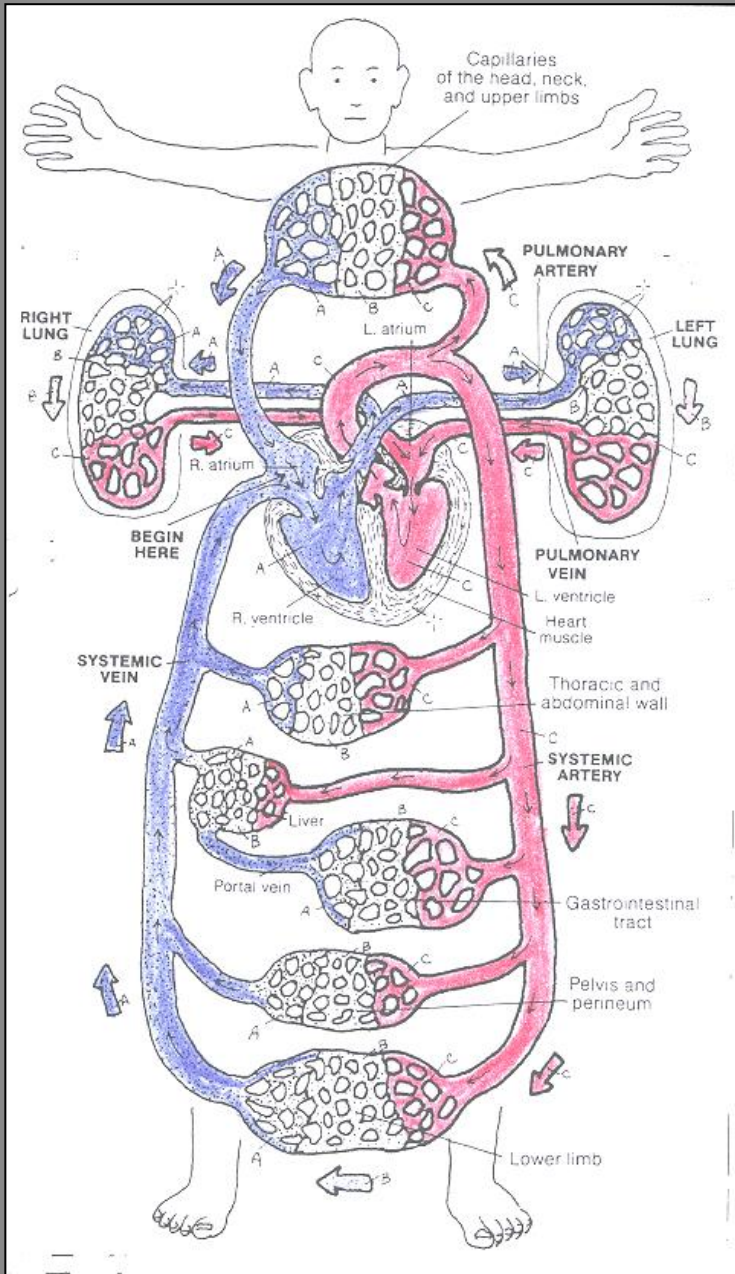
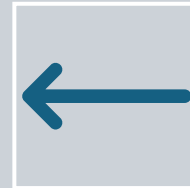


Diagram of Blood Circulation



The contraction of the heart pump the blood in a centrifugal direction.

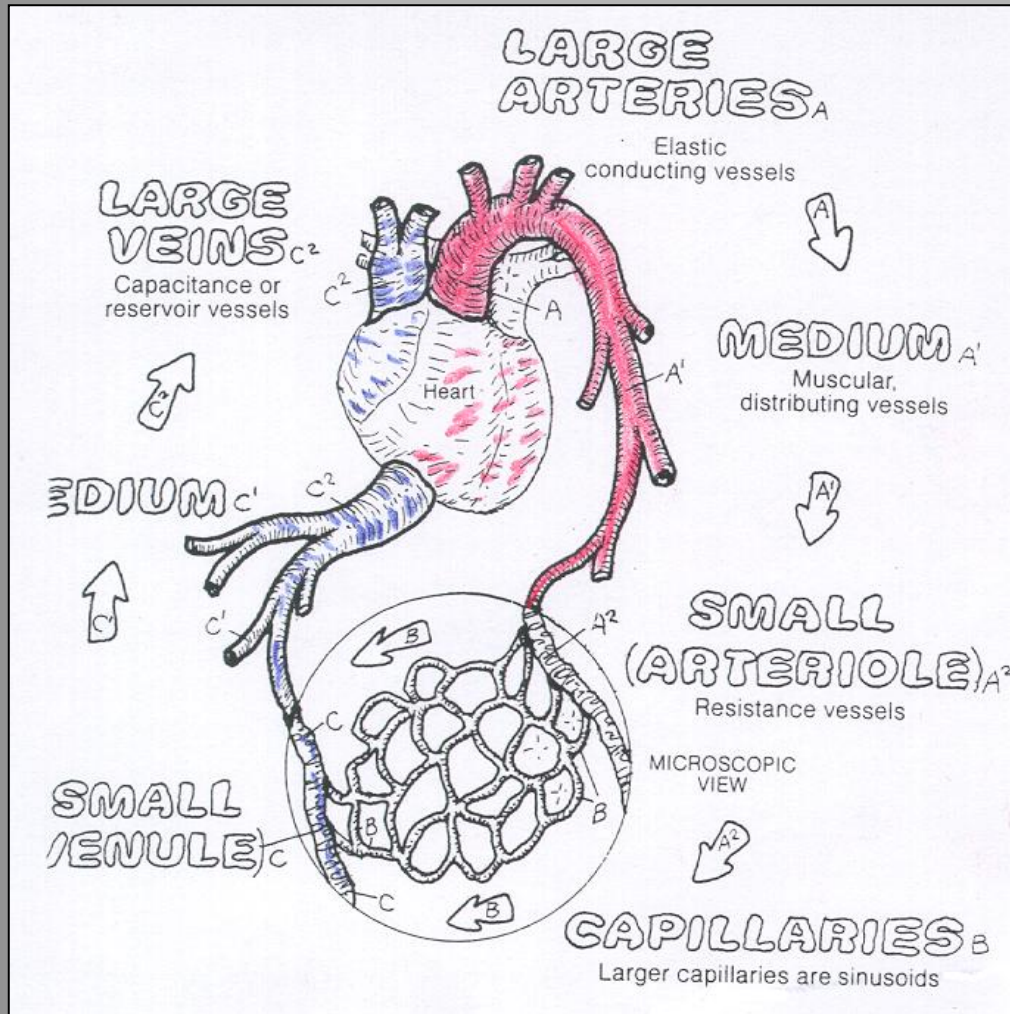


Toward the arteries, which branch out and end in capillaries, from which the veins originate



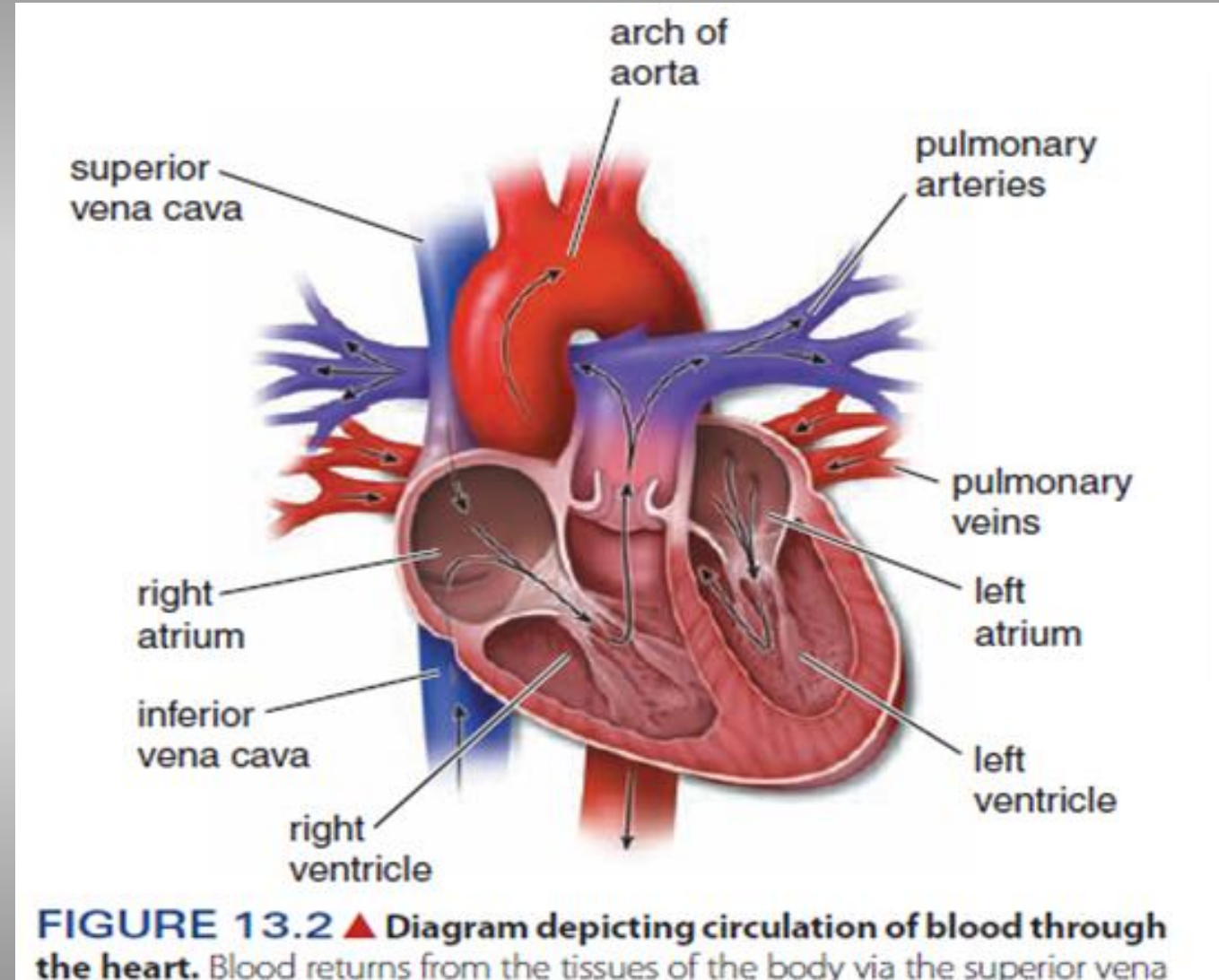
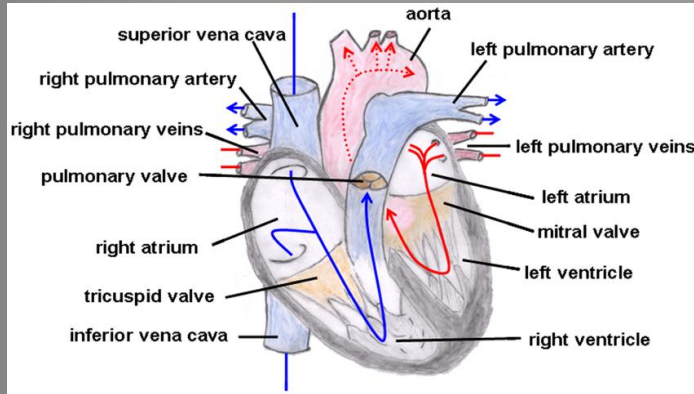
The veins then converge, carrying the blood back to the heart in a centripetal direction

BLOOD VESSELS and BLOOD CIRCULATION



- 1) The **Systemic (greater) circulation** begins at the heart with the **aorta** and ends with the **venae cavae**
- 2) The **Pulmonary (lesser) circulation** starts from the heart with **the pulmonary trunk**, which carries venous blood to the lungs; from the lungs originate the **pulmonary veins**, which carry arterial blood back to the heart

CIRCULATION OF BLOOD THROUGH THE HEART

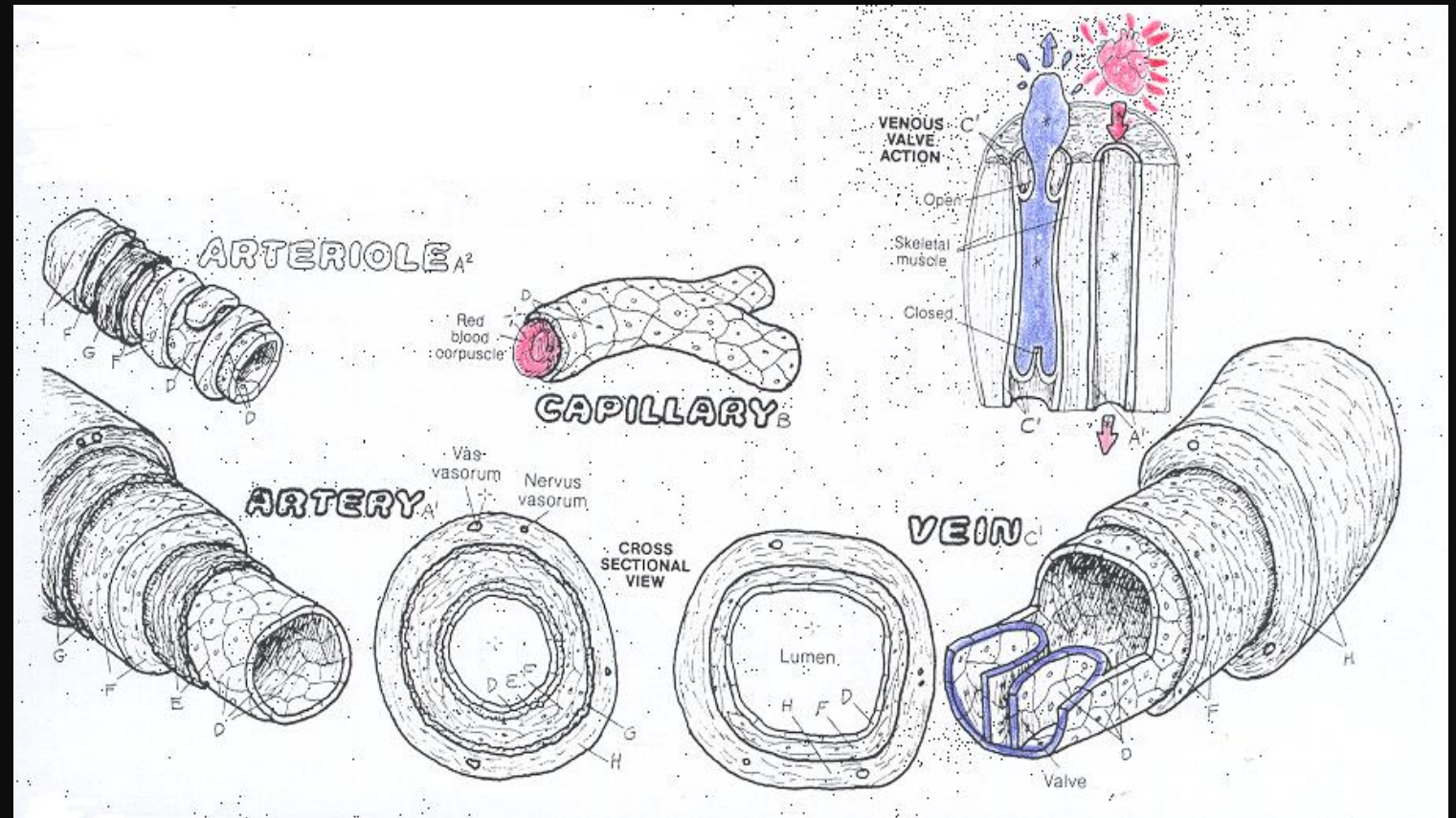


STRUCTURE OF BLOOD VESSELS

ARTERIES AND VEINS

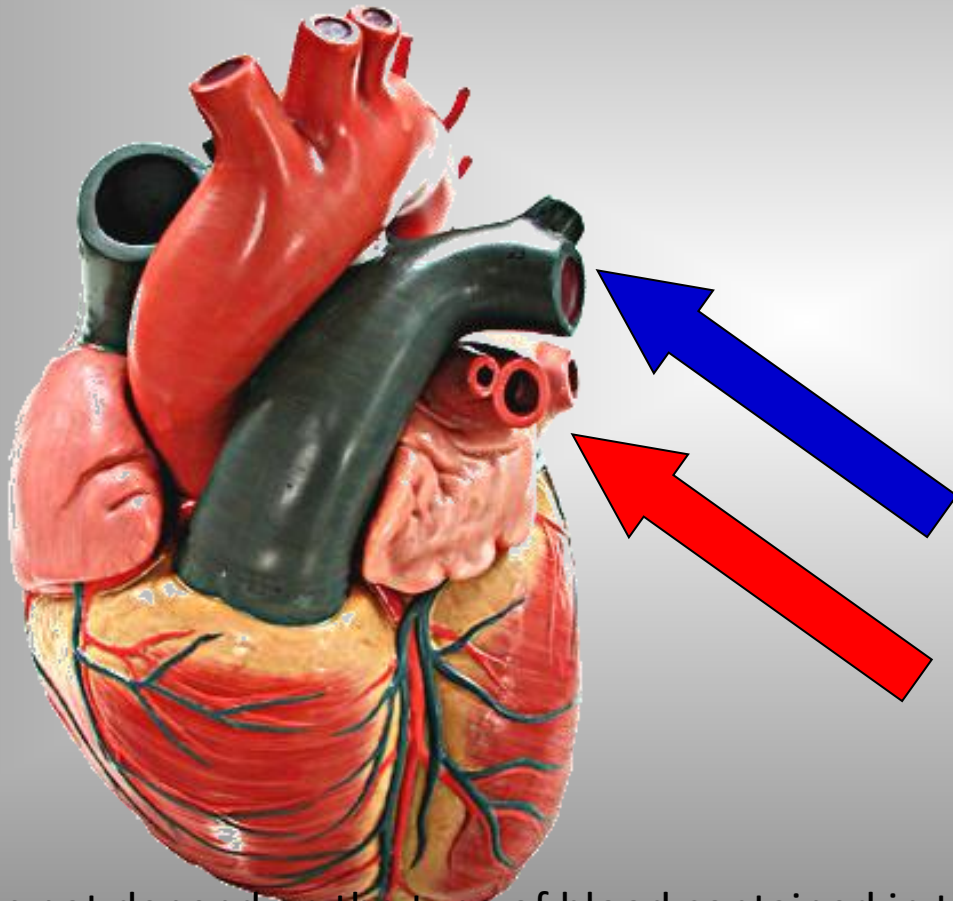
ARTERIOLES AND VENULES

ARTERIAL AND VENOUS CAPILLARIES



PULMONARY VEINS

PULMONARY ARTERIES



Example:

Pulmonary veins carry oxygenated blood from the lungs to the heart.

Example:

Pulmonary arteries originate from the pulmonary trunk and carry venous (deoxygenated) blood from the ventricle to the lungs..

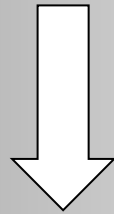
The terminology does not depend on the type of blood contained in the vessels but on the direction of blood flow: toward the center are the **veins**, toward the periphery are the **arteries**.

ARTERIES AND VEINS

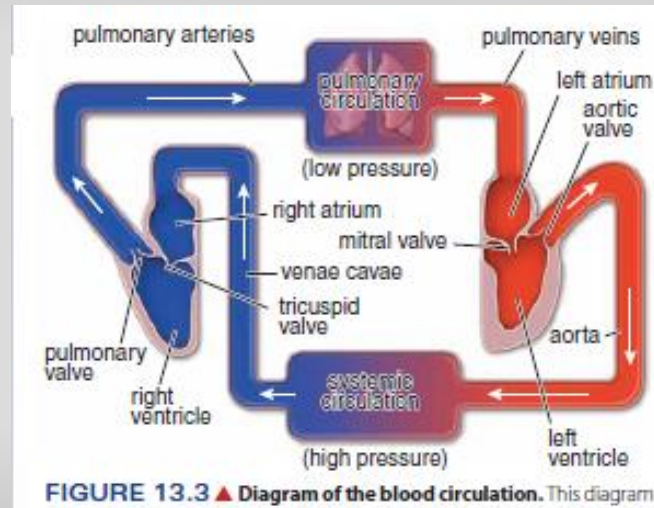
In summary

The terminology does not depend on the type of blood contained in the vessels but on the direction of blood flow: toward the center are the **veins**, toward the periphery are the **arteries**.

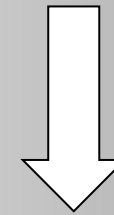
Vessels that arrive
at the heart from
the periphery:



VEINS



Vessels that depart
from the heart
toward the
periphery:



ARTERIES

Pulmonary veins → (arterial/oxygenated blood)
Pulmonary arteries → (venous/deoxygenated blood)

GENERAL FEATURES OF ARTERIES AND VEINS

TUNICA INTIMA

TUNICA MEDIA

TUNICA ADVENTITIA

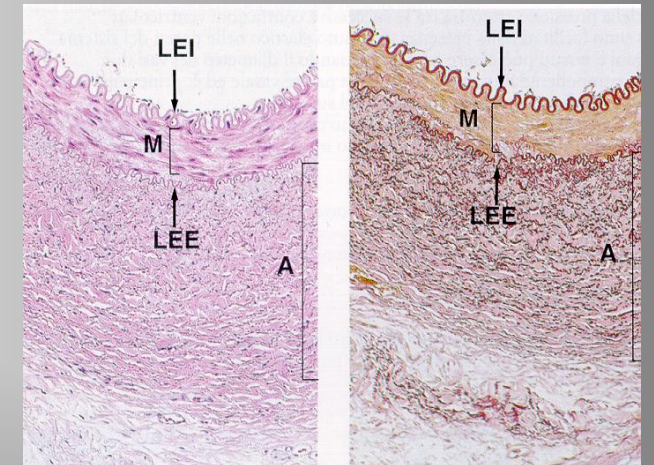
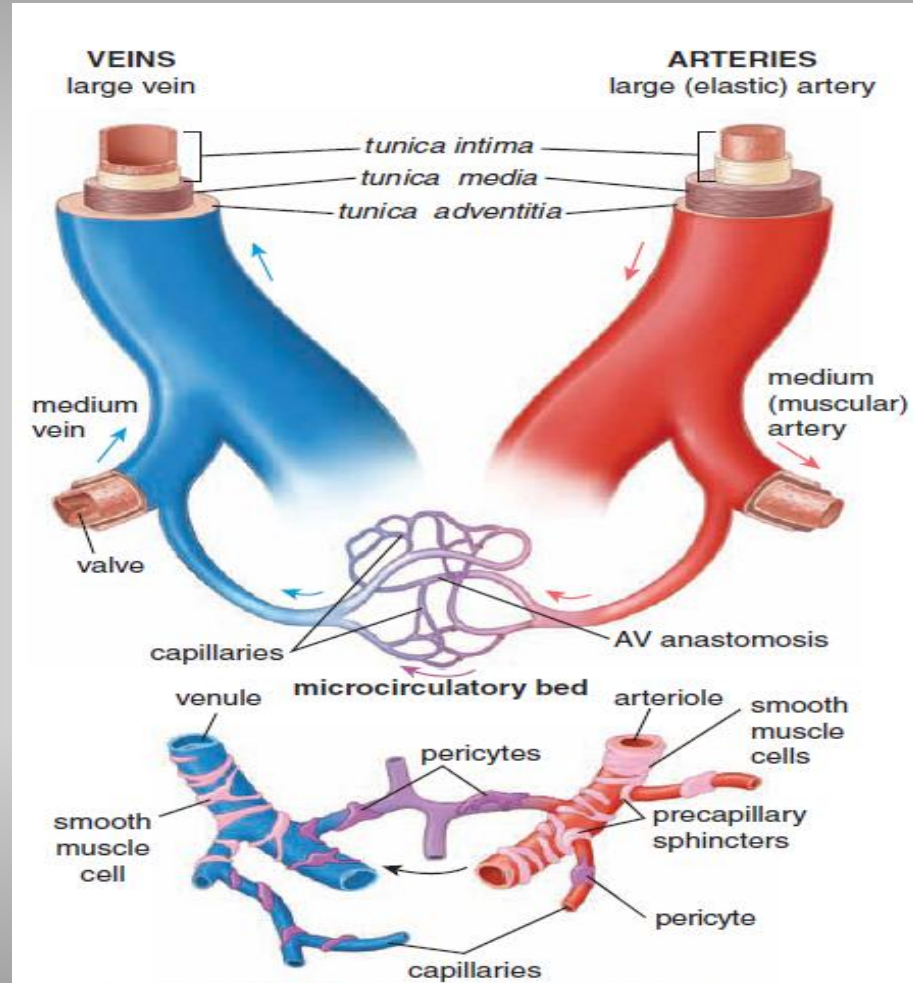


FIGURE 13.11 ▲ Schematic diagram of the major structural features of blood vessels. The layers or tunics of the blood vessel walls are labeled in the upper two panels. The arrangement of the microcirculatory bed in certain parts of the body is shown in the lowest panel. Note the location of pericytes and their relationship to the basal lamina. Also, an arteriovenous (AV) anastomosis is shown within the microcirculatory bed.

TABLE 13.1 Characteristics of Blood Vessels

Arteries				
Vessel	Diameter	Tunica Intima (Inner Layer)	Tunica Media (Middle Layer)	Tunica Adventitia (Outer Layer)
Large artery (elastic artery)	>10 mm	Endothelium Connective tissue Smooth muscle	Smooth muscle Elastic lamellae	Thinner than tunica media Connective tissue Elastic fibers
Medium artery (muscular artery)	2–10 mm	Endothelium Connective tissue Smooth muscle Prominent internal elastic membrane	Smooth muscle Collagen fibers Relatively little elastic tissue	Thinner than tunica media Connective tissue Some elastic fibers
Small artery	0.1–2 mm	Endothelium Connective tissue Smooth muscle Internal elastic membrane	Smooth muscle (8–10 cell layers) Collagen fibers	Thinner than tunica media Connective tissue Some elastic fibers
Arteriole	10–100 μm	Endothelium Connective tissue Smooth muscle	Smooth muscle (one or two cell layers)	Thin, ill-defined sheath of connective tissue
Capillary	4–10 μm	Endothelium	None	None
Veins				
Vessel	Diameter	Tunica Intima (Inner Layer)	Tunica Media (Middle Layer)	Tunica Adventitia (Outer Layer)
Postcapillary venule	10–50 μm	Endothelium Pericytes	None	None
Muscular venule	50–100 μm	Endothelium	Smooth muscle (one or two cell layers)	Thicker than tunica media Connective tissue Some elastic fibers
Small vein	0.1–1 mm	Endothelium Connective tissue Smooth muscle (two or three layers)	Smooth muscle (two or three layers continuous with tunica intima)	Thicker than tunica media Connective tissue Some elastic fibers
Medium vein	1–10 mm	Endothelium Connective tissue Smooth muscle Internal elastic membrane in some cases	Smooth muscle Collagen fibers	Thicker than tunica media Connective tissue Some elastic fibers
Large vein	>10 mm	Endothelium Connective tissue Smooth muscle	Smooth muscle (2–15 layers) Collagen fibers	Much thicker than tunica media Connective tissue Some elastic fibers, longitudinal smooth muscles Cardiac muscle extensions (myocardial sleeves) into great veins near the heart

ARTERIES

- ▶ **Arteries** are classified into three types based on size and thickness of their tunica media: large arteries (elastic arteries), medium arteries (muscular arteries), and small arteries (including arterioles).
- ▶ **Elastic arteries** have a tunica media that consists of multiple layers of vascular smooth muscle cells separated by elastic lamellae. Fibroblasts are not present in the tunica media.
- ▶ **Muscular arteries** have a tunica media with more smooth muscle and less elastic lamellae than the elastic arteries. They also have a prominent internal elastic membrane in the tunica intima.
- ▶ **Small arteries** and arterioles are distinguished from one another by the number of smooth muscle cell layers in the tunica media.
- ▶ **Arterioles** have one to two layers of smooth muscles and regulate **vascular resistance**, thus controlling blood flow to capillary networks.
- ▶ **Arteriovenous shunts** allow blood to bypass capillaries by providing direct routes between arteries and veins. This pathway is regulated by contraction of precapillary sphincters on the **metarterioles**.

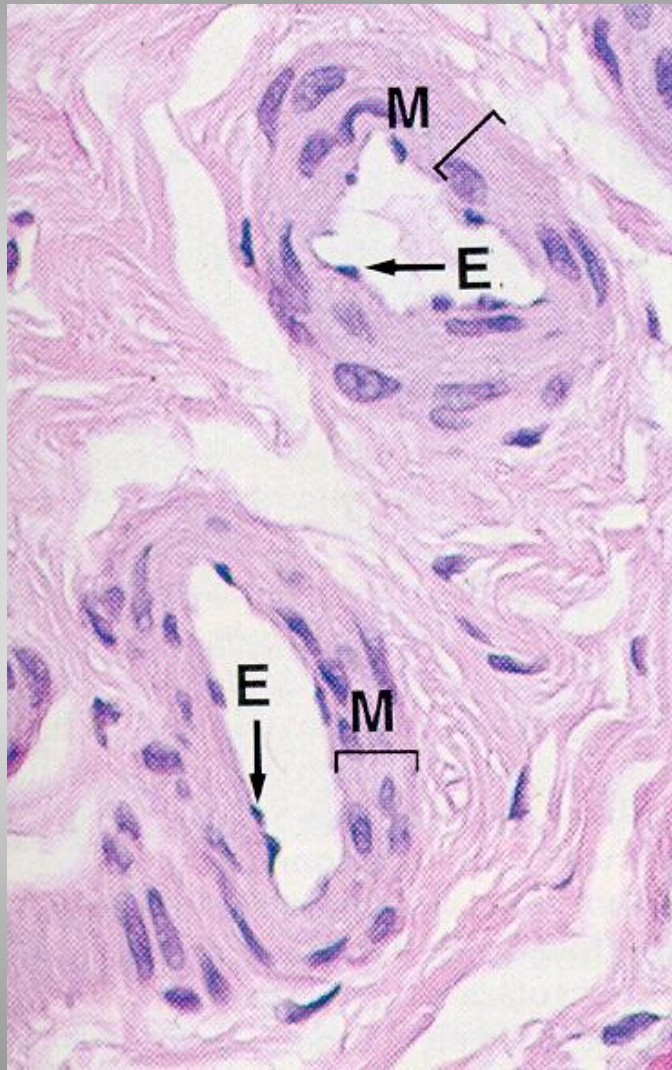
CAPILLARIES

- ▶ **Capillaries** are the smallest diameter blood vessels and are classified into three different types: **continuous** (characterized by uninterrupted vascular endothelium), **fenestrated** (characterized by numerous openings in the capillary wall and by the continuous basal lamina), and **discontinuous** or **sinusoidal** capillaries (larger in diameter with large openings, intercellular gaps, and a **discontinuous basal lamina**).
- ▶ **Pericytes** associated with capillaries represent a population of undifferentiated mesenchymal stem cells.

VEINS

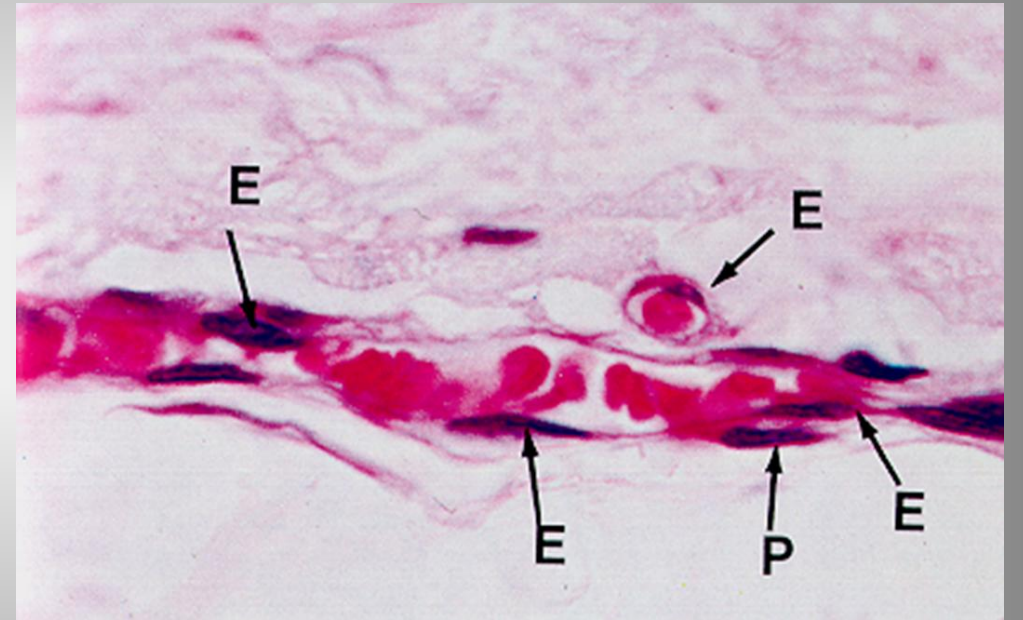
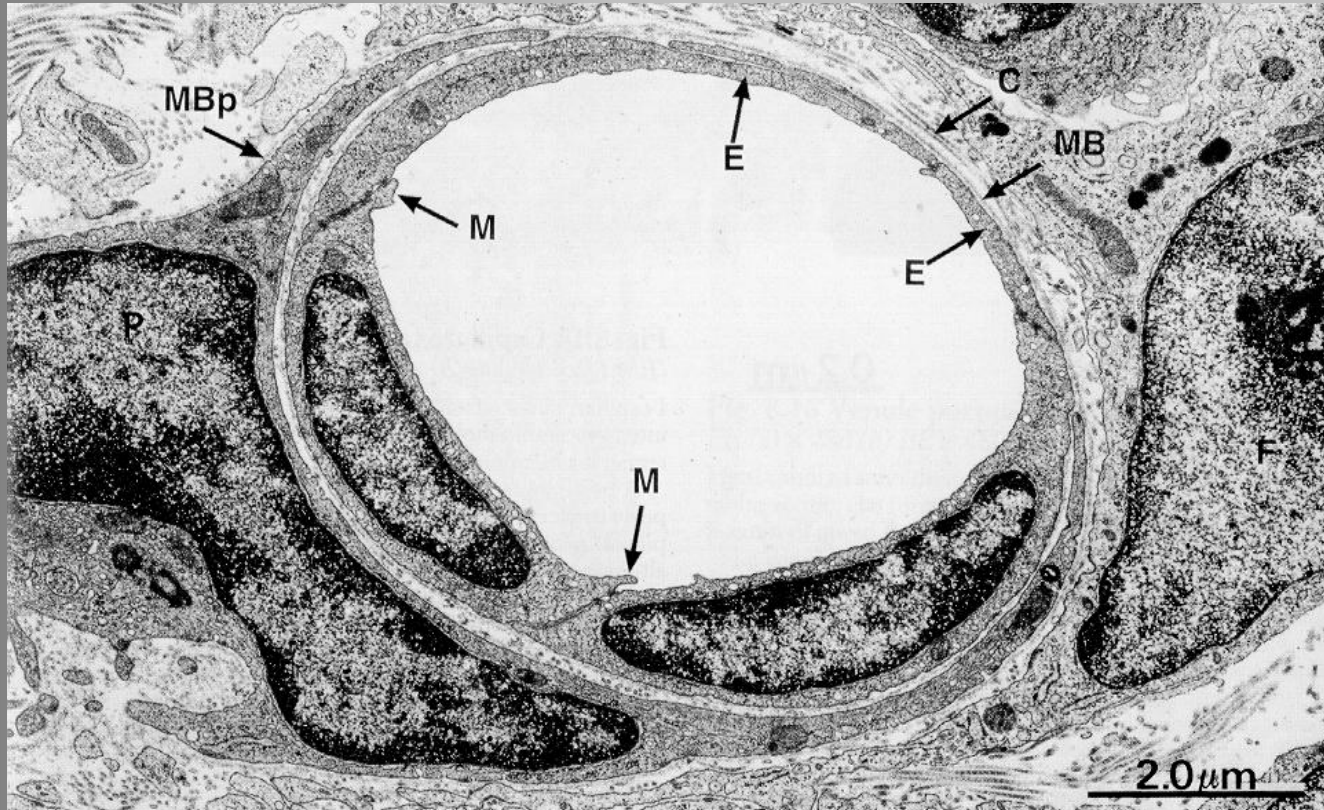
- ▶ **Veins** are divided into four types based on their size (diameter): **venules** (<0.1 mm), **small veins** (<1 mm), **medium veins** (<10 mm), and **large veins** (>10 mm).
- ▶ **Postcapillary venules** collect blood from the capillary network and are characterized by the presence of pericytes. In lymphoid tissues, they are lined by cuboidal endothelium (**high endothelial venules**), which facilitates extensive lymphocyte migration from the blood.
- ▶ **Small, medium, and large veins** have a relatively thin layer of tunica media and a more pronounced tunica adventitia.
- ▶ Veins, especially of limbs, may contain **valves** preventing backflow of blood.
- ▶ Large veins near the heart may contain **myocardial sleeves** in the tunica adventitia.

SMALL ARTERIOLES



Arterioles in dense connective tissue of the dermis.

CONTINUOUS CAPILLARIES



MACROSCOPIC ANATOMY
OF THE HEART

HEART

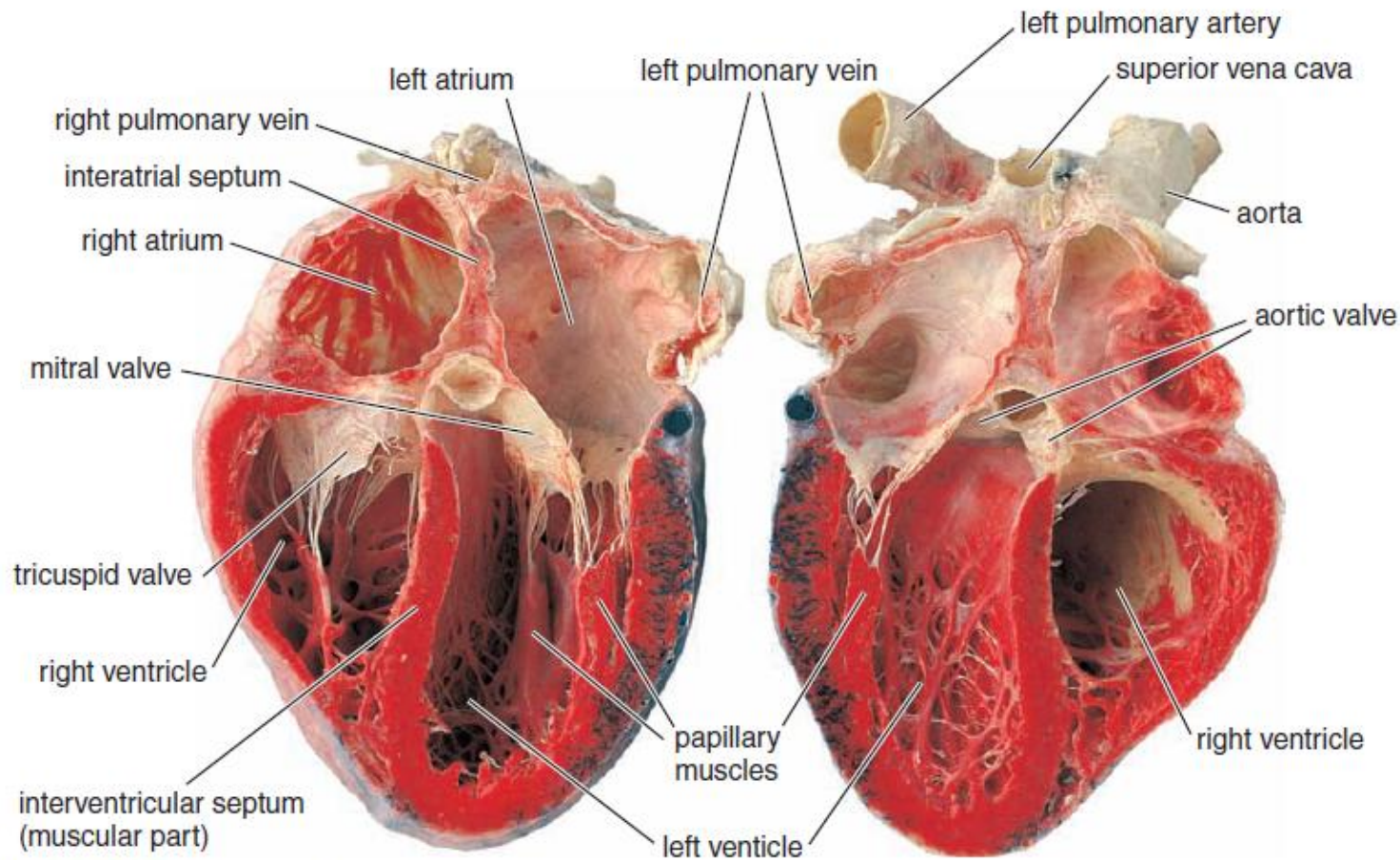


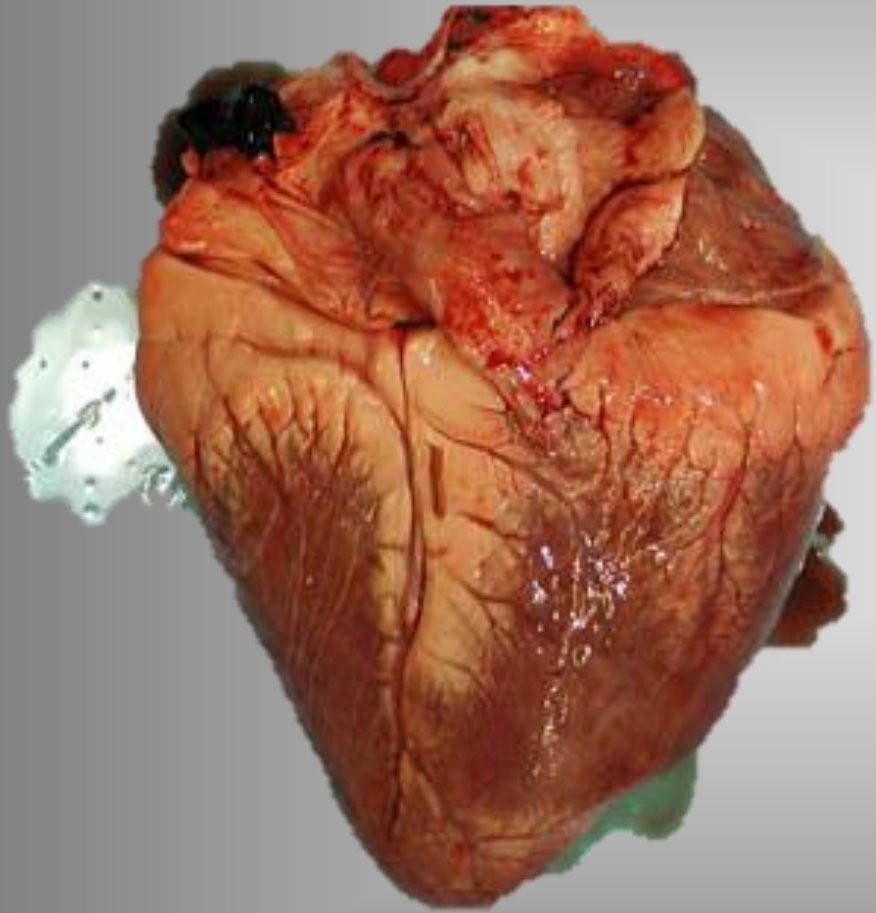
FIGURE 13.1 ▲ **Photograph of the human heart.** This specimen was sectioned in the oblique plane to visualize all of the chambers of the heart. The posterior part of the heart is on the *left*; the anterior part has been removed and is shown on the *right*. Note the thickness of the ventricular walls and the intermuscular septum. The interatrial septum, which separates the atria, is also visible.

The **heart** lies obliquely, about two-thirds into the left side of the thoracic cavity, in the **middle mediastinum**—the space enclosed between sternum, vertebral column, diaphragm, and lungs.

It is surrounded by a tough fibrous sac, the **pericardium**, which also contains the beginnings and ends of the great vessels entering and leaving the heart. Through the pericardium, the heart is strongly attached to the diaphragm and neighboring organs that lie in the thoracic cavity

The heart is a muscular pump that maintains unidirectional flow of blood.

HEART DIMENSIONS



Approximate weight:

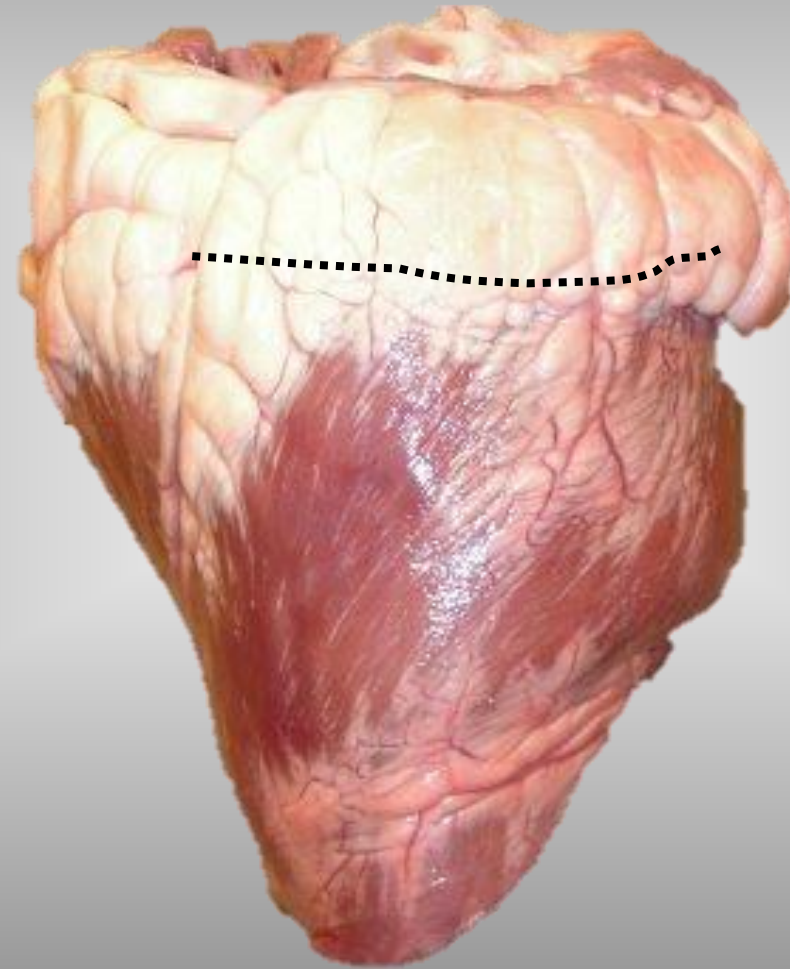
- **3.5 kg in the horse**
- **300 g in cattle**
- **200 g in sheep**
- **250–350 g in humans**



MACROSCOPIC ANATOMY OF THE HEART ATRIAL AND VENTRICULAR MASS

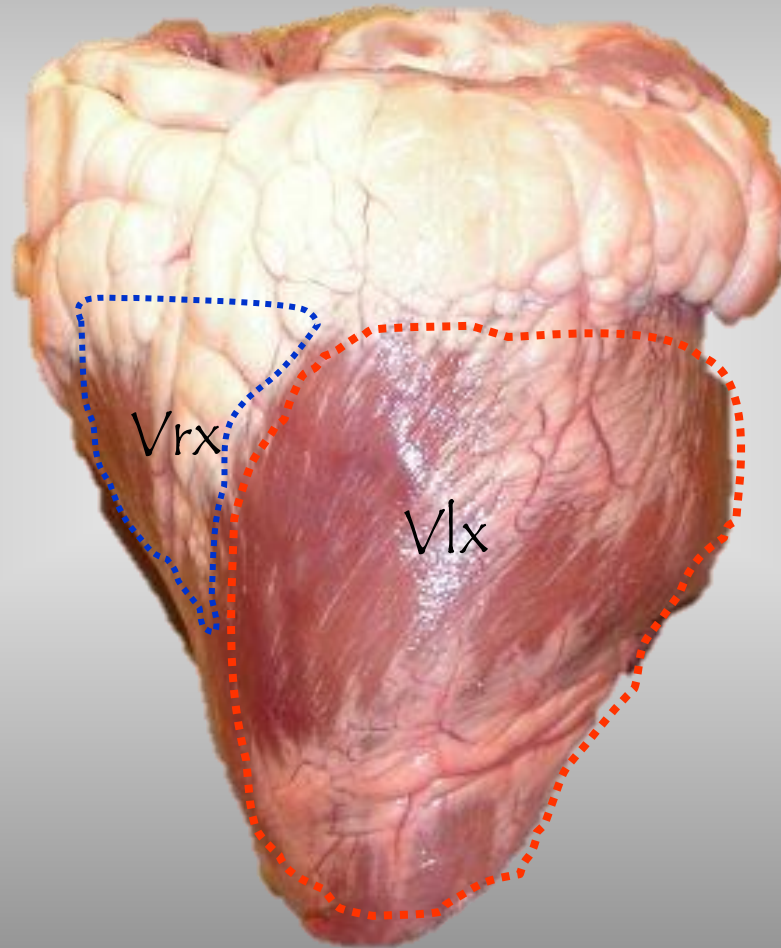
ATRIAL MASS

VENTRICULAR MASS



Coronary sulcus

MACROSCOPIC ANATOMY OF THE HEART: VENTRICLES



MACROSCOPIC ANATOMY

RIGHT AND LEFT HEART

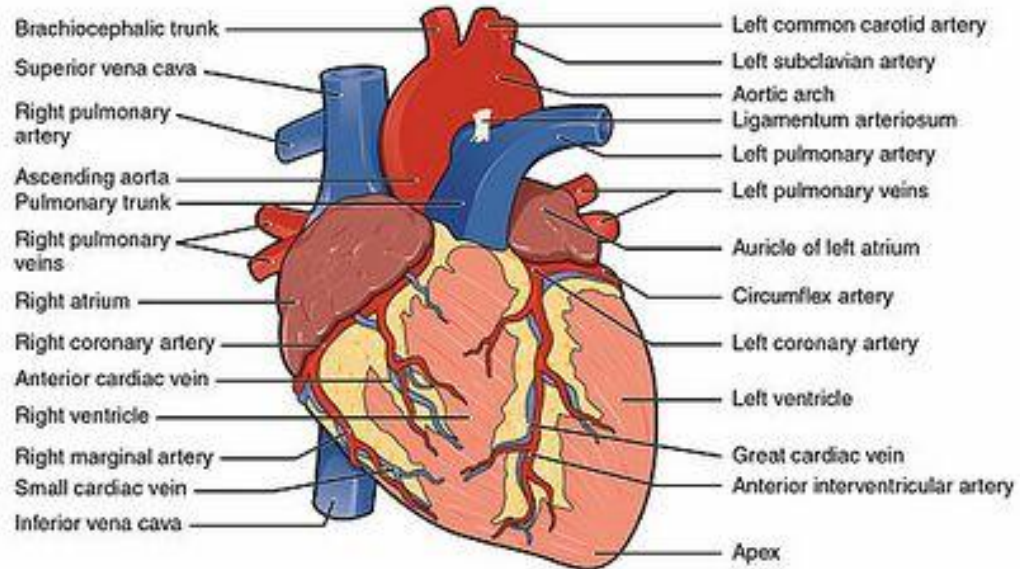


Right heart

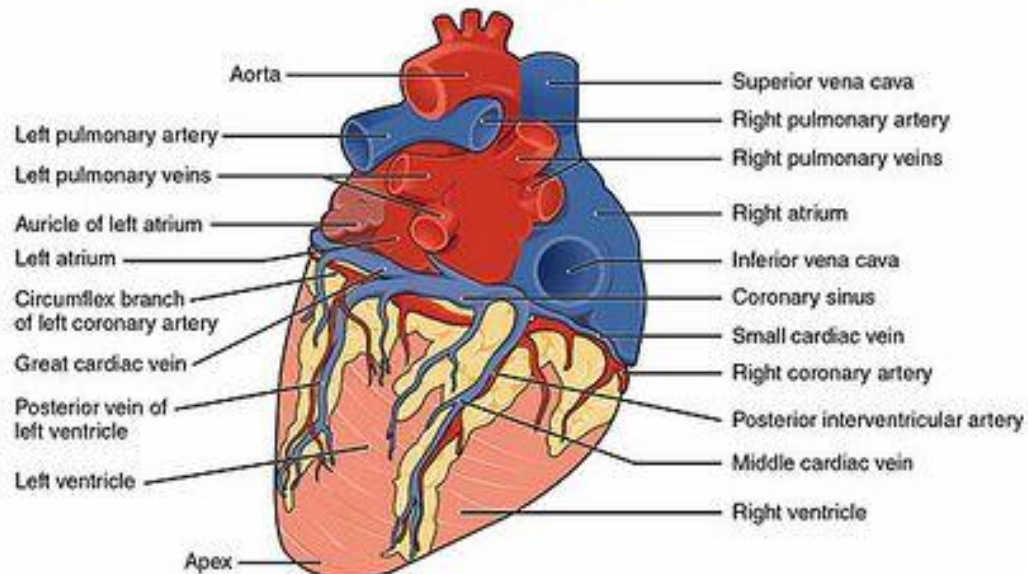
Left heart

GROSS ANATOMY OF THE HEART

Anterior view



Posterior view

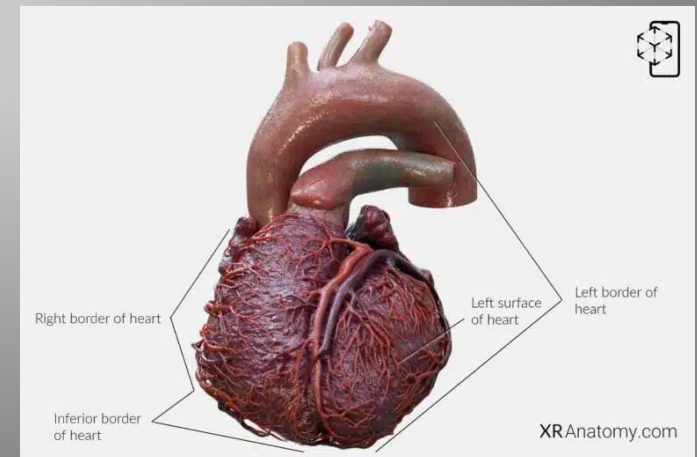


The heart has five anatomical surfaces:

- Base (posterior surface).
- Diaphragmatic surface (inferior surface).
- Sternocostal surface (anterior surface).
- Right pulmonary surface.
- Left pulmonary surface

The heart also has four margins that define its external shape:

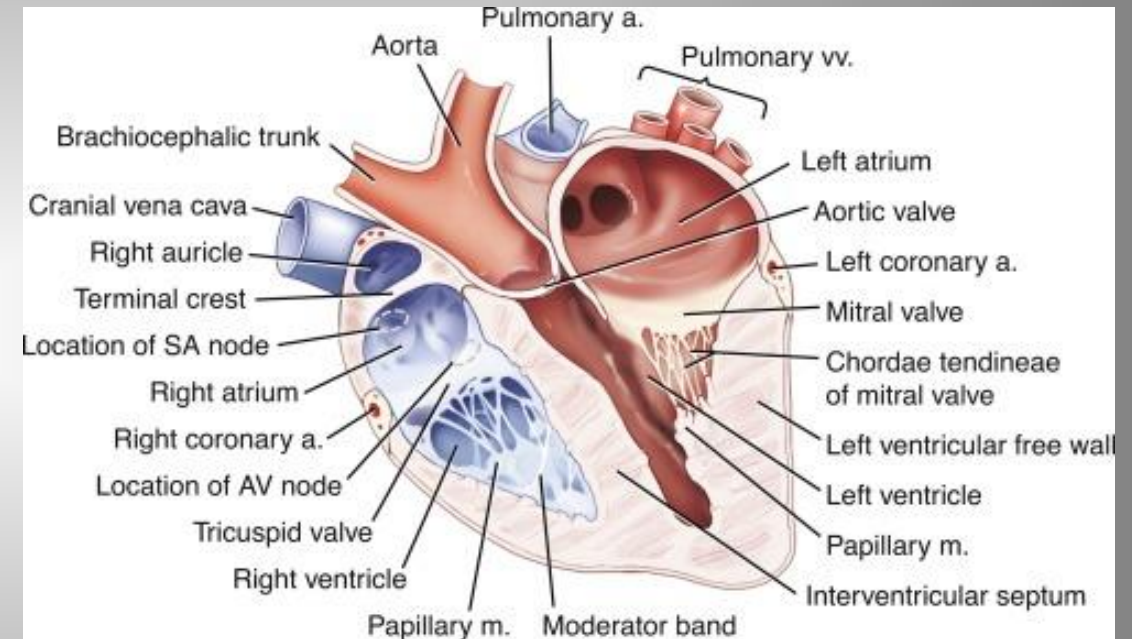
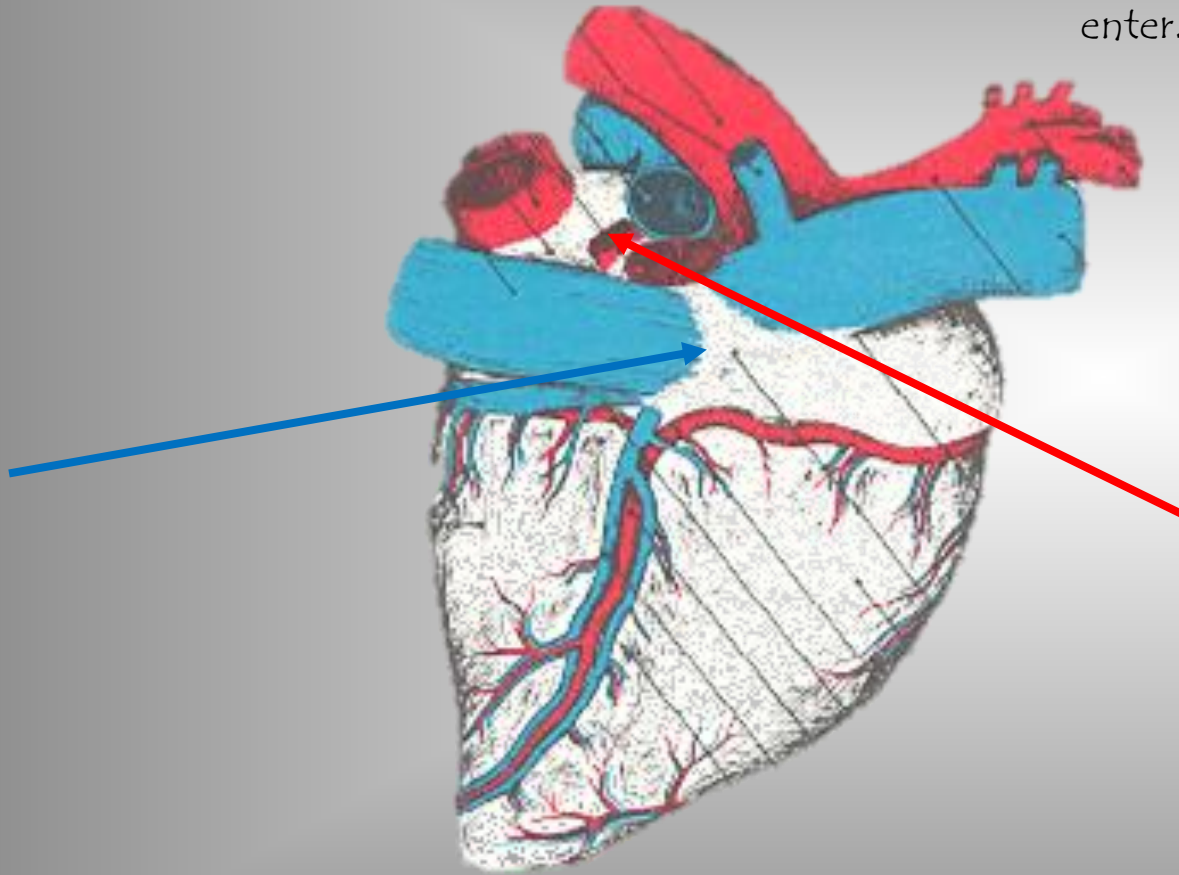
- Right margin
- Left margin
- Superior margin.
- Inferior margin



ATRIAL SURFACE

It is called this way because the atrial mass reaches its maximum extension in this view.

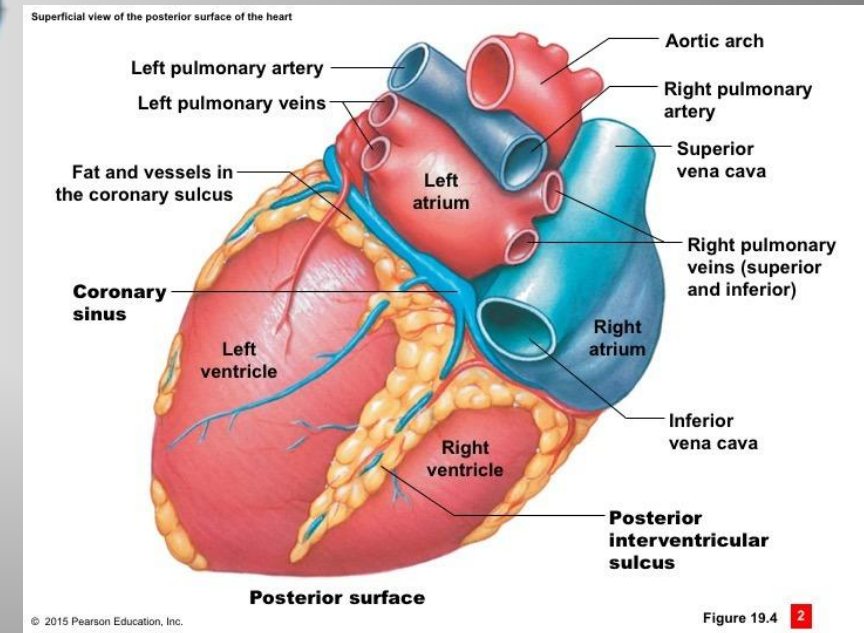
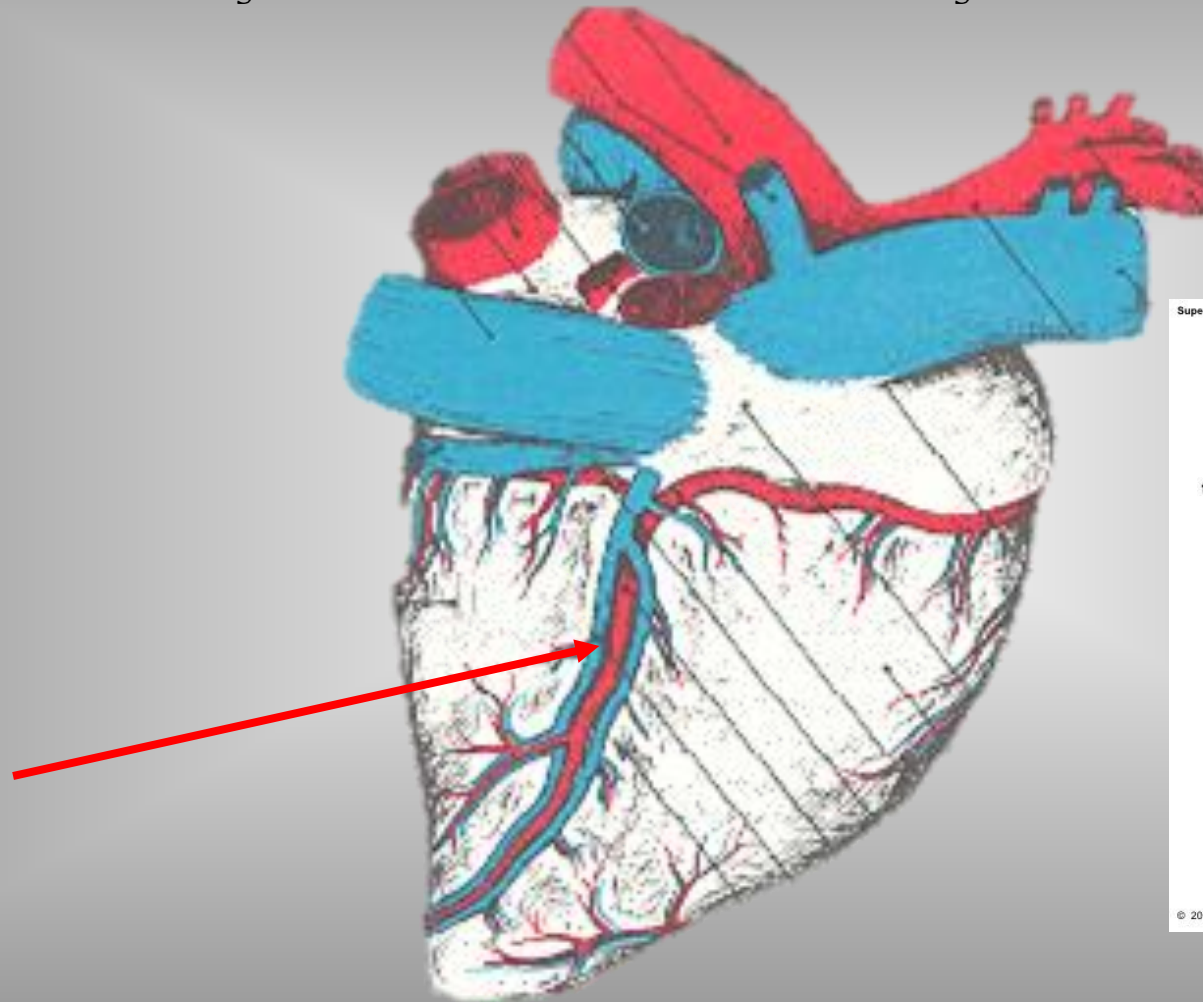
In the **RIGHT ATRIUM** open: a) **Cranial vena cava**, marked by the terminal groove, and the **azygos vein**; b) Caudally (from the left side) the **caudal vena cava** and the **great cardiac vein** enter.



In the **LEFT ATRIUM** open: a) Pulmonary veins

ATRIAL SURFACE

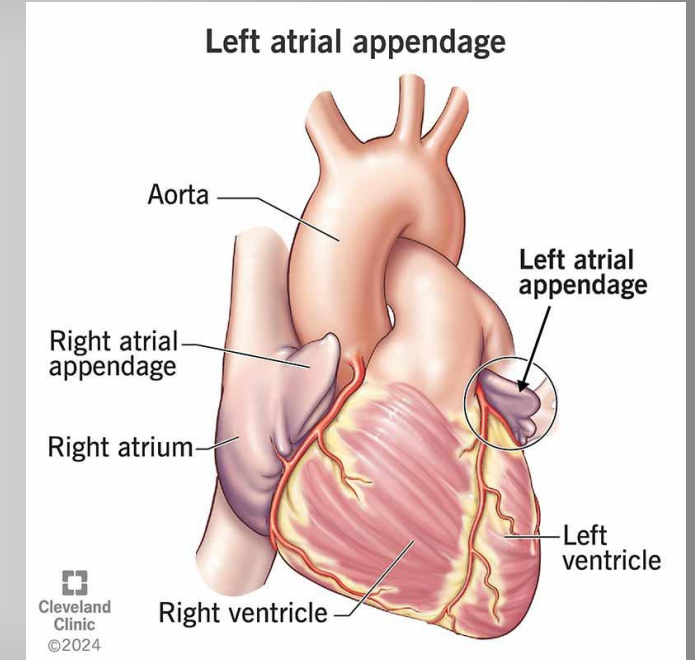
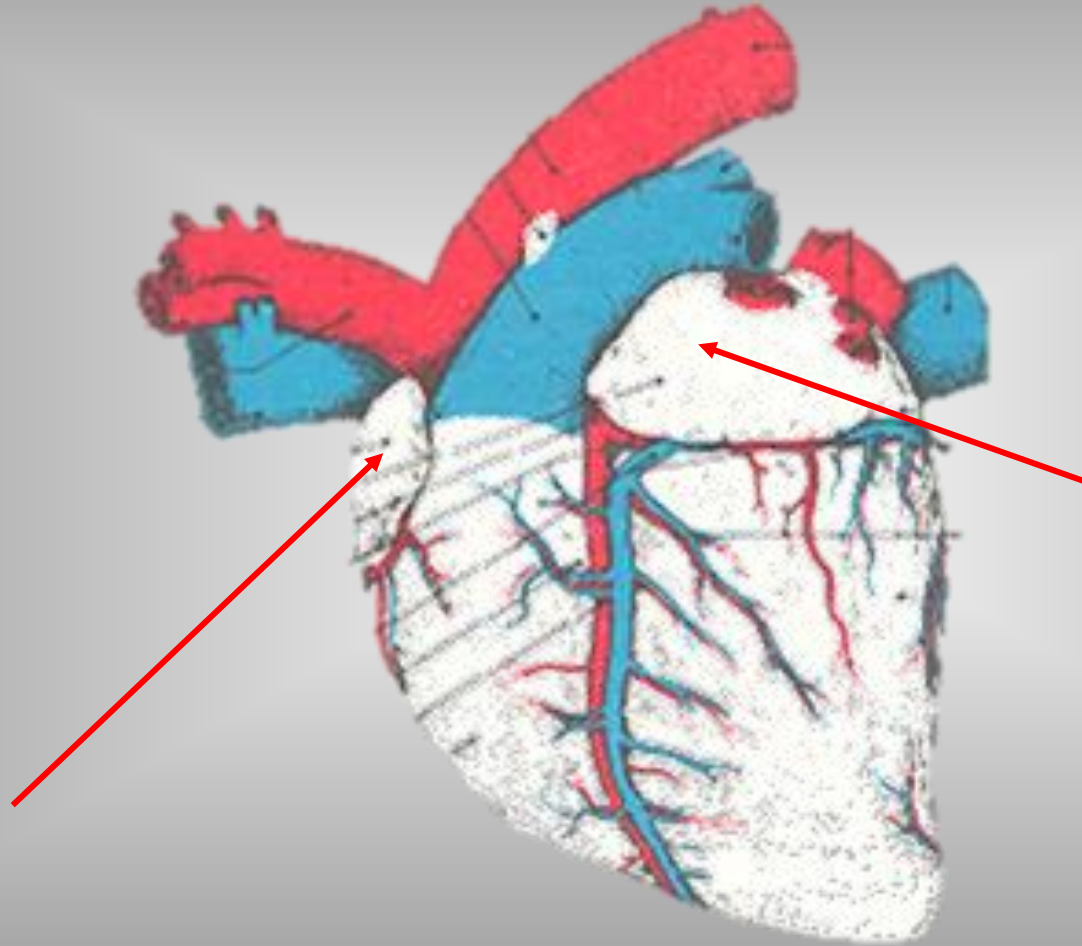
Between the right atrium and the left atrium there is a groove called the **INTERATRIAL GROOVE**.



The **SUBSINUOSAL (OR SUB-SINUSAL) INTERVENTRICULAR GROOVE** divides the right surface of the heart into two parts.

AURICULAR SURFACE

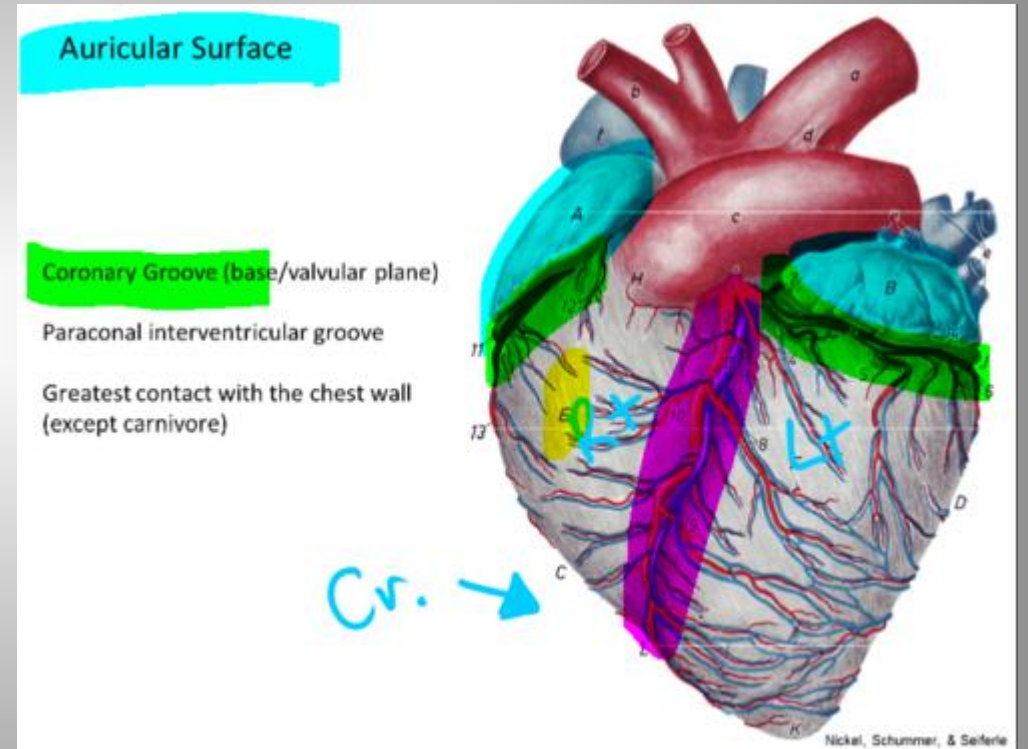
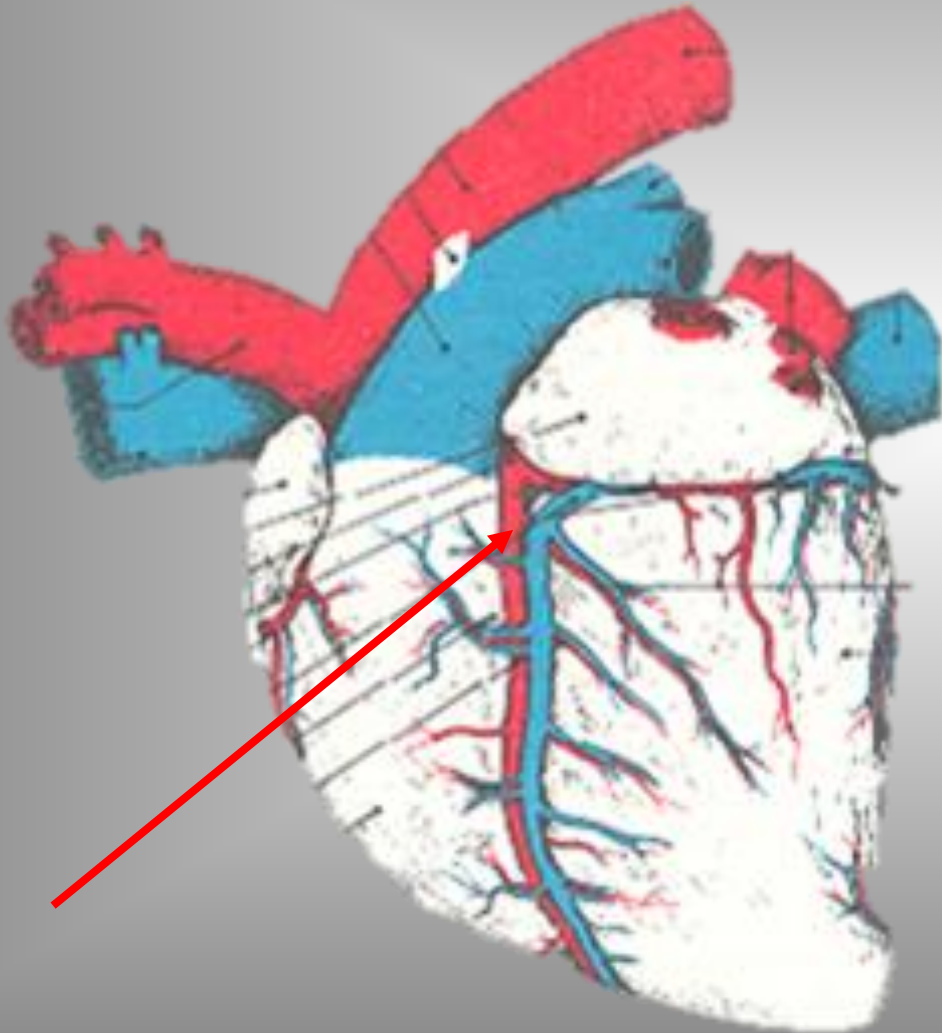
From this side the **TWO AURICLES** (also called atrial appendages because of their ear-like shape) can be seen.



The coronary groove is incomplete on this surface because the **pulmonary trunk** emerges here, from which the two **pulmonary arteries** arise.

AURICULAR SURFACE

At this level, the PARACONAL INTERVENTRICULAR GROOVE is visible.



INTERNAL ANATOMY OF THE HEART

THE HEART CONTAINS FOUR CHAMBERS—
THE RIGHT AND LEFT ATRIA AND RIGHT AND LEFT VENTRICLES, THROUGH WHICH
BLOOD IS PUMPED

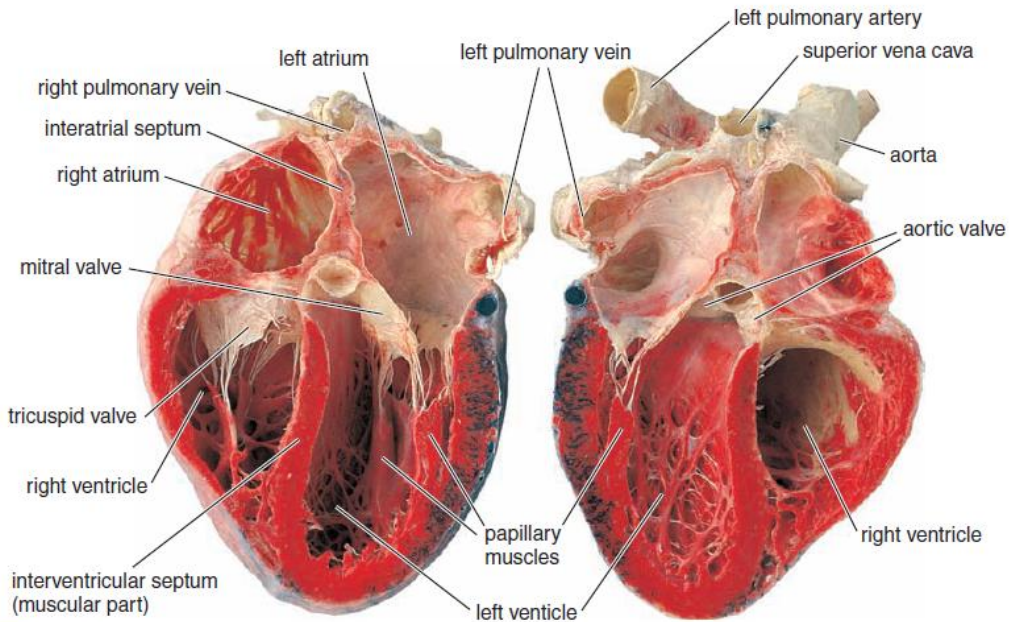
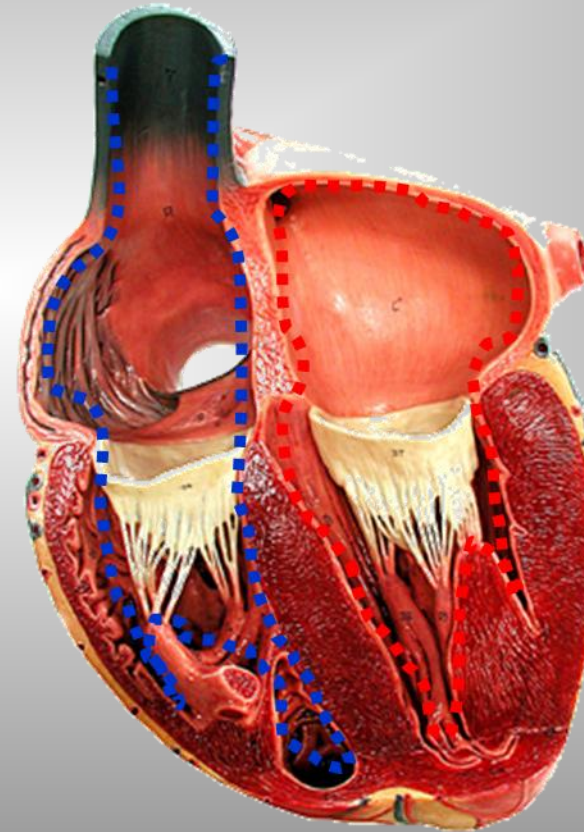


FIGURE 13.1 ▲ **Photograph of the human heart.** This specimen was sectioned in the oblique plane to visualize all of the chambers of the heart. The posterior part of the heart is on the *left*; the anterior part has been removed and is shown on the *right*. Note the thickness of the ventricular walls and the intermuscular septum. The interatrial septum, which separates the atria, is also visible.



An **interatrial septum** and an **interventricular septum** separate the right and left sides of the heart.

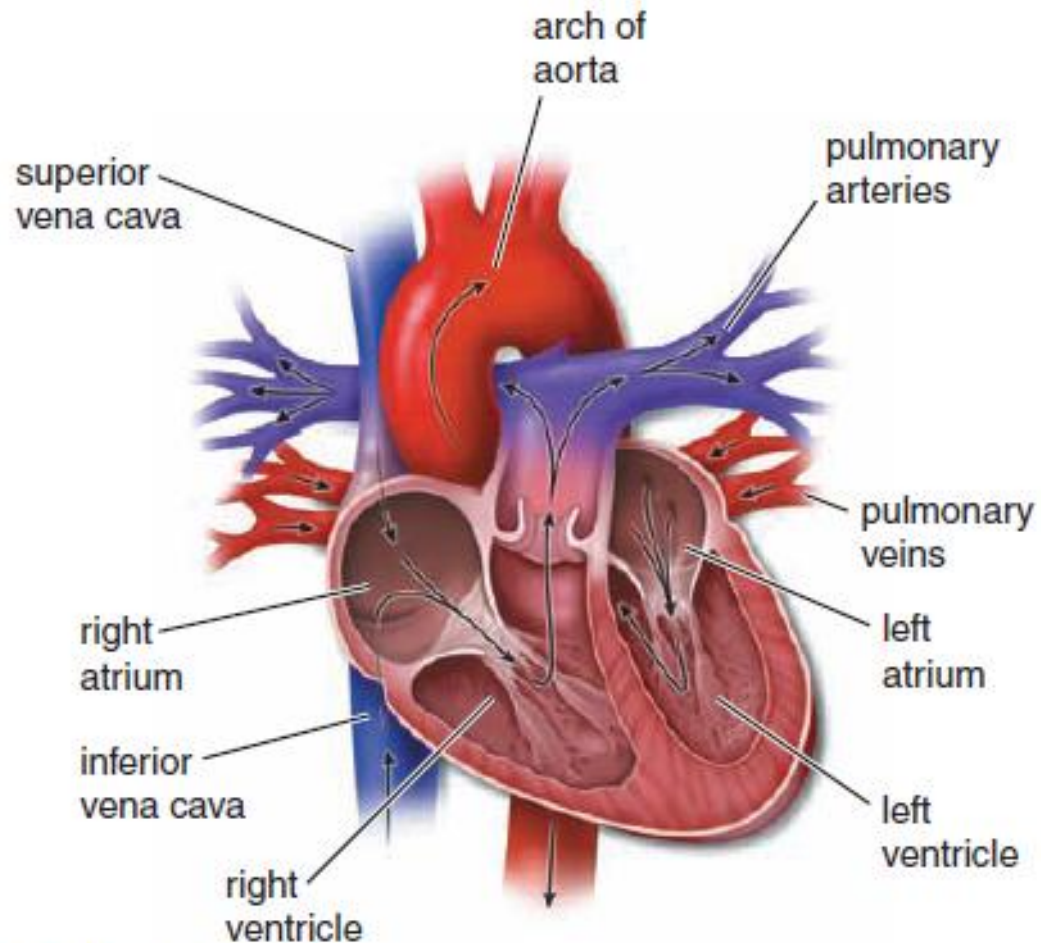


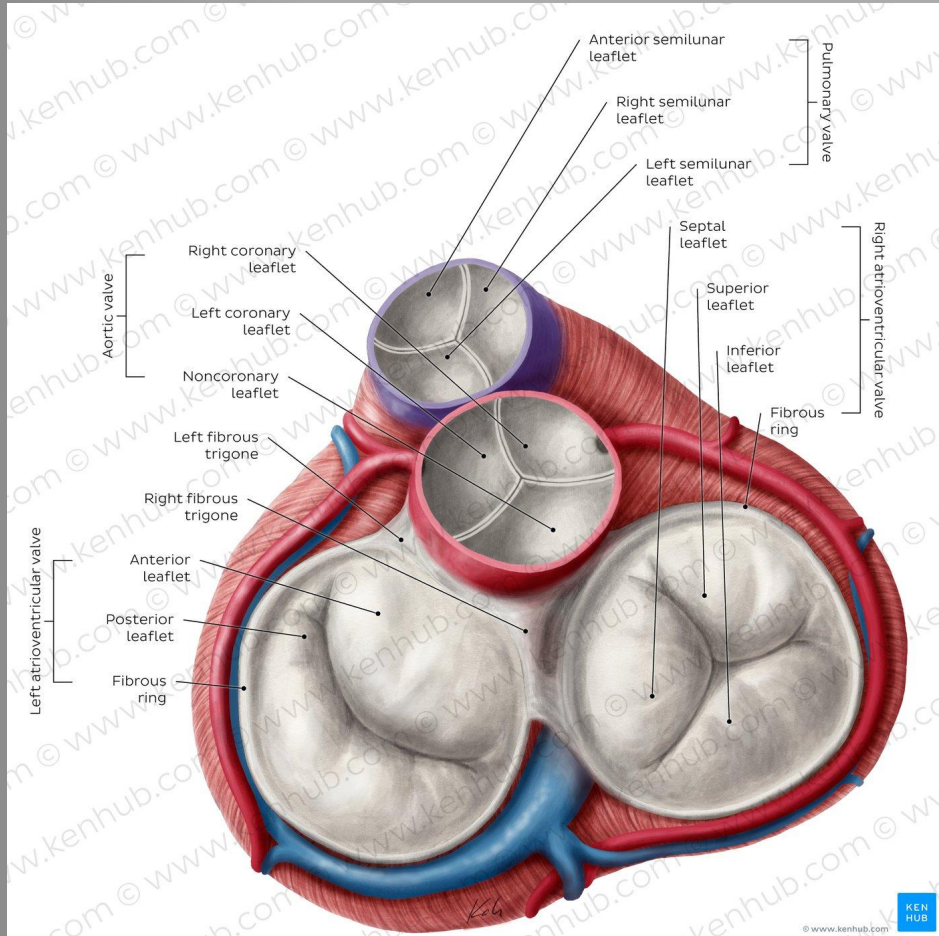
FIGURE 13.2 ▲ Diagram depicting circulation of blood through the heart. Blood returns from the tissues of the body via the superior vena cava and inferior vena cava. The right ventricle pumps blood to the lungs via the pulmonary arteries. The left atrium receives oxygenated blood from the lungs via the pulmonary veins. The left ventricle pumps blood to the rest of the body via the aorta.

The **right atrium** receives blood returning from the body via the **inferior and superior venae cavae**, the two largest veins of the body

The **right ventricle** receives blood from the right atrium and pumps it to the lungs for oxygenation via the pulmonary arteries.

The **left atrium** receives the oxygenated blood returning from the lungs via the four pulmonary veins.

The **left ventricle** receives blood from the left atrium and pumps it into the aorta for distribution into the remainder of the body.



The heart contains the following:

- A musculature of **cardiac muscle** for contraction to propel the blood.
- A **fibrous skeleton** that consists of four fibrous rings surrounding the **valve orifices**, two fibrous trigones connecting the rings, and the membranous part of the interventricular and interatrial septa.
- A **conducting system** for initiation and propagation of rhythmic depolarizations, which results in rhythmic cardiac muscle contractions (Fig. 13.5). This system is formed by **modified cardiac muscle cells (Purkinje fibers)**

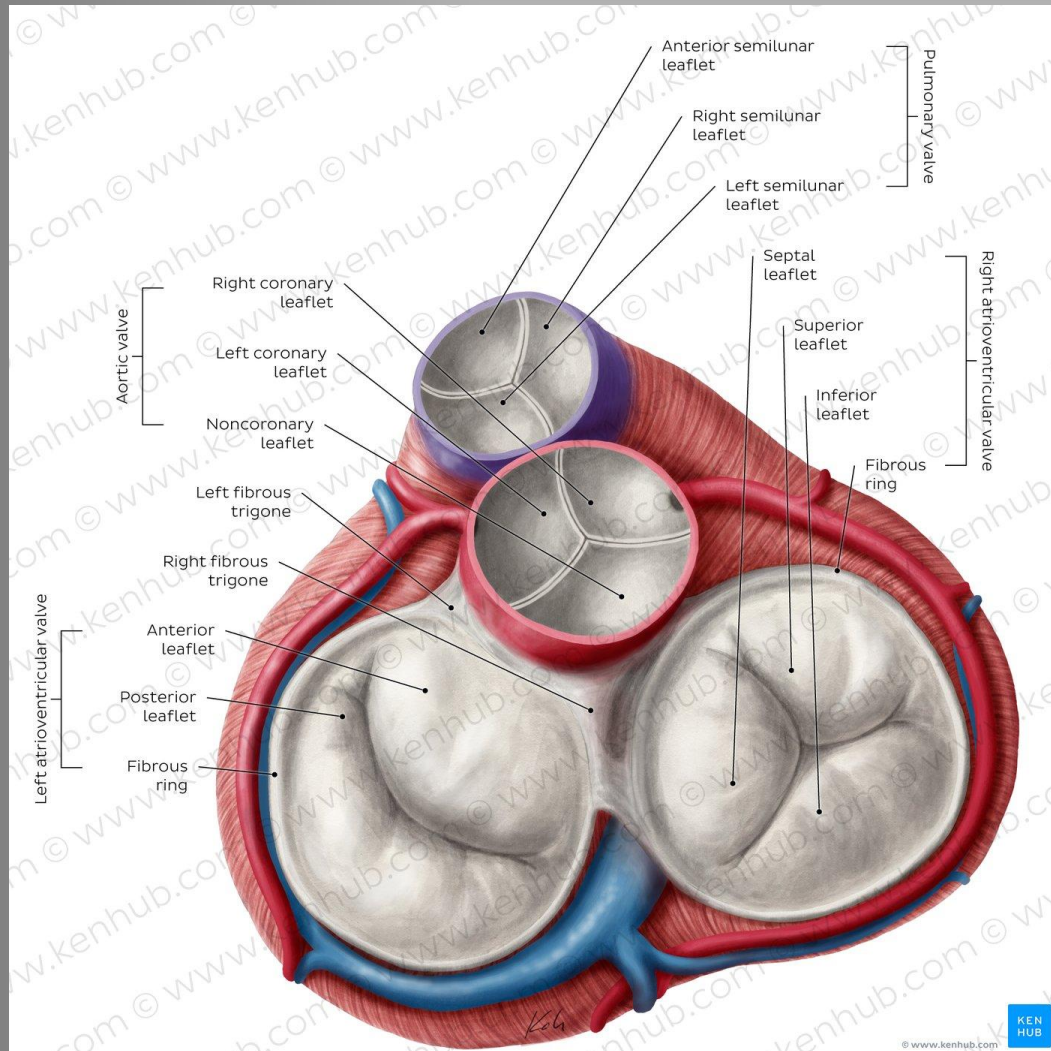
HEART VALVES

HEART VALVES SEPARATE ATRIA FROM VENTRICLES, AND VENTRICLES FROM GREAT VESSELS.

The valves incorporate two or three leaflets (cusps) around the atrioventricular orifices and the roots of great vessels.

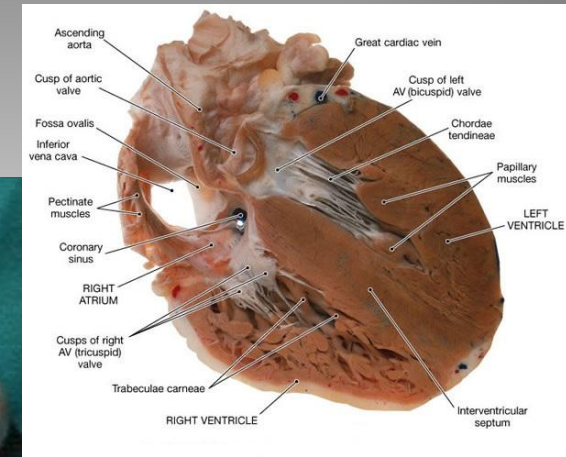
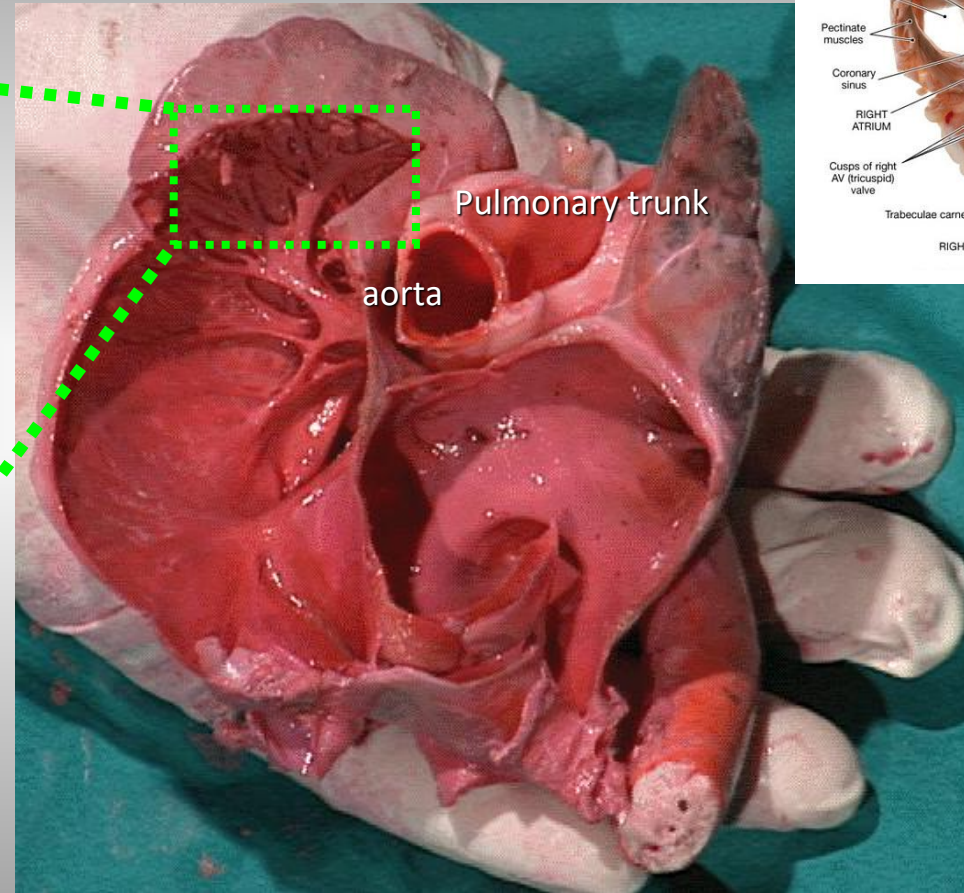
THERE ARE TWO SETS OF VALVES:

- ATRIOVENTRICULAR VALVES**
- SEMILUNAR VALVES**



GENERAL ORGANIZATION OF THE CARDIAC CHAMBERS: ATRIAL CAVITIES: PECTINATE MUSCLES

The walls are rather thin and irregular.



They show (except for the interatrial septum) muscular ridges characteristic of the atria called **pectinate muscles**, which have the form of parallel crests that interconnect with one another through smaller secondary ridges.

GENERAL ORGANIZATION OF THE CARDIAC CHAMBERS:

VENTRICULAR CAVITIES

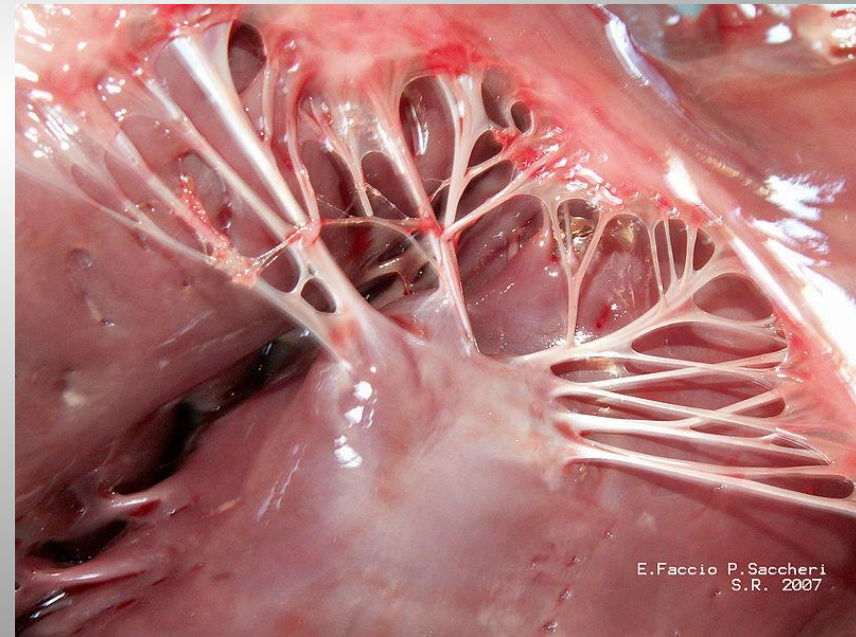
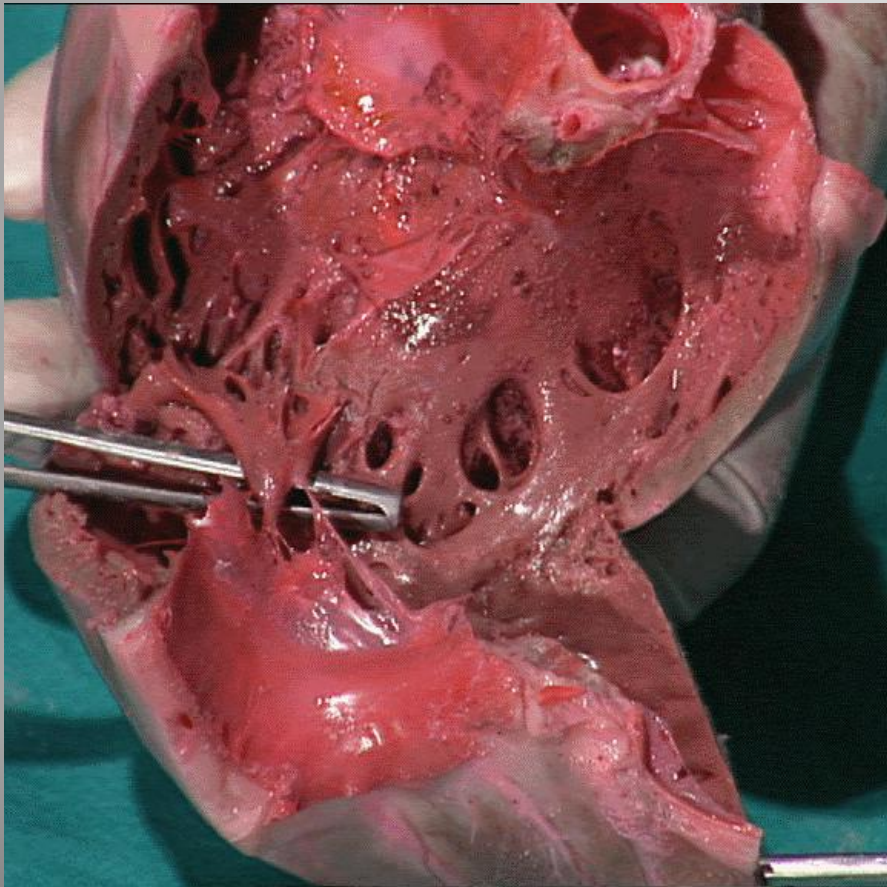
They have much thicker walls than the atria.
The left ventricular wall is thicker.



As in the atrial region, an **interventricular septum** is present..
The right ventricle lies against the left ventricle and has a semicircular cross-section

TRABECULAE CARNEAE

They are thickened muscular projections with a conical shape. They have their base attached to the ventricular wall and a free apex projecting into the ventricular cavity, to which the chordae tendineae attach.



WALL OF THE HEART

The wall of the heart is composed of three layers: EPICARDIUM, MYOCARDIUM, AND ENDOCARDIUM.

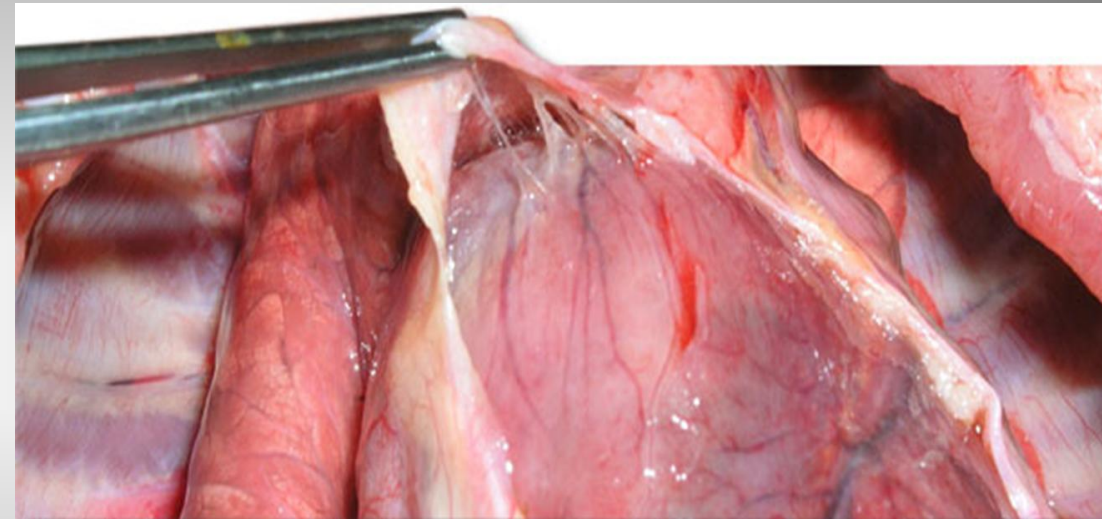
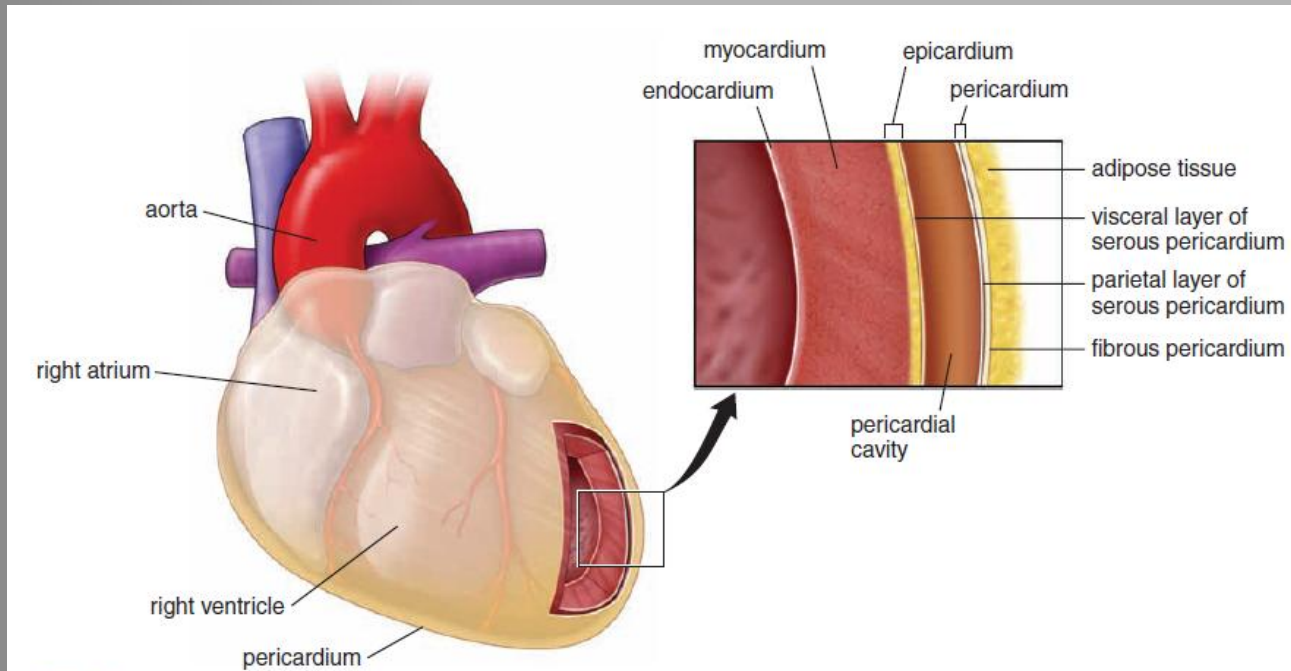
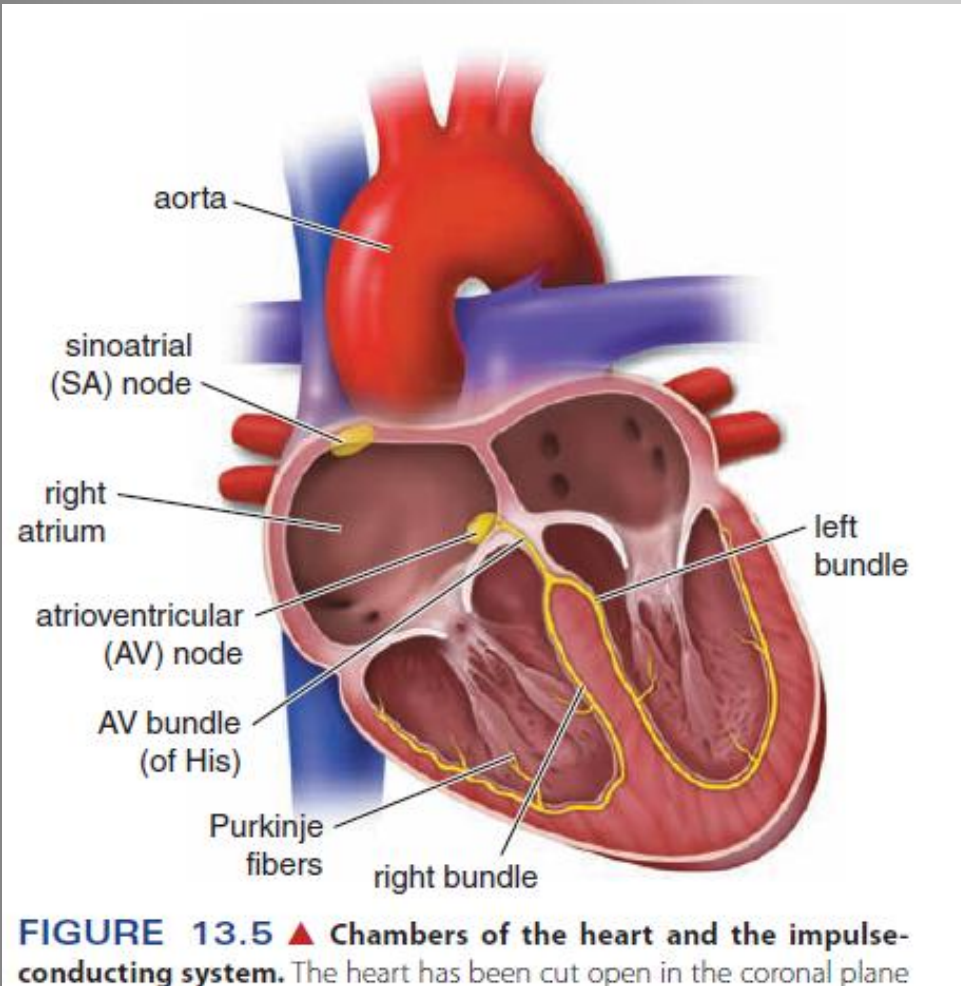


FIGURE 13.6 ▲ Layers of the heart and pericardium. This schematic diagram shows the anatomic relationship between the layers of the

Conducting system of the heart.

Intrinsic Regulation of Heart Rate

Contraction of the heart is synchronized by specialized cardiac conducting cells.



The **CONDUCTING SYSTEM OF THE HEART** consists of two nodes
-the **sinoatrial (or sinu-atrial) node** and
-the **atrioventricular node**
and a **series of conduction fibers or bundles (tracts)**.

The SA node, the **pacemaker of the heart**, initiates an impulse that spreads along the cardiac muscle fibers of the atria and along internodal tracts composed of modified cardiac muscle fibers. The impulse is then picked up at the **atrioventricular (AV) node** and carried across the fibrous skeleton to the ventricles by the **AV bundle (of His)**. The bundle divides into smaller **right** and **left bundle branches** and then into **subendothelial branches**, commonly called **Purkinje fibers**.