Pericardium: it is the fibrous sac which encloses the heart. The fibrous pericardium is relatively thin, but strong and inelastic. It is consisting of:-

1. The parietal layer: which lines the fibrous pericardium and it is closely attached.
2. Visceral layer: covers the heart and part of the large vessels. The visceral layer of the pericardium is firmly attached to the heart forming the epicardium.

The pericardium can be further subdivided into:

1. Pleura of pericardium
2. Fibrous pericardium
3. Serosa of pericardium

Compartments of the heart

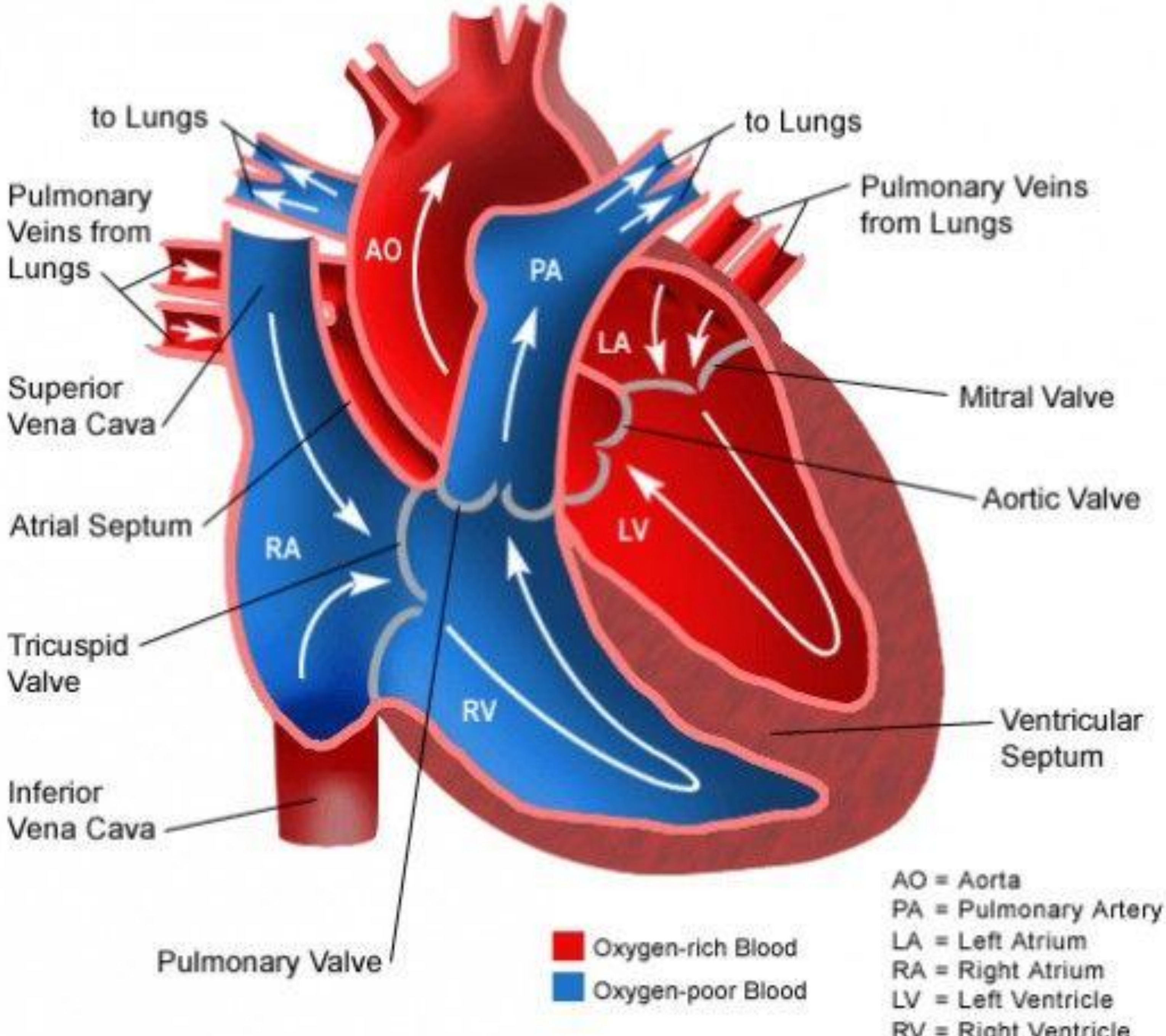
The heart is divided internally by a longitudinal interventricular septum into left and right sides. These in turn are incompletely divided by a transverse septum into blood receiving called atria and the blood-pumping called ventricles.

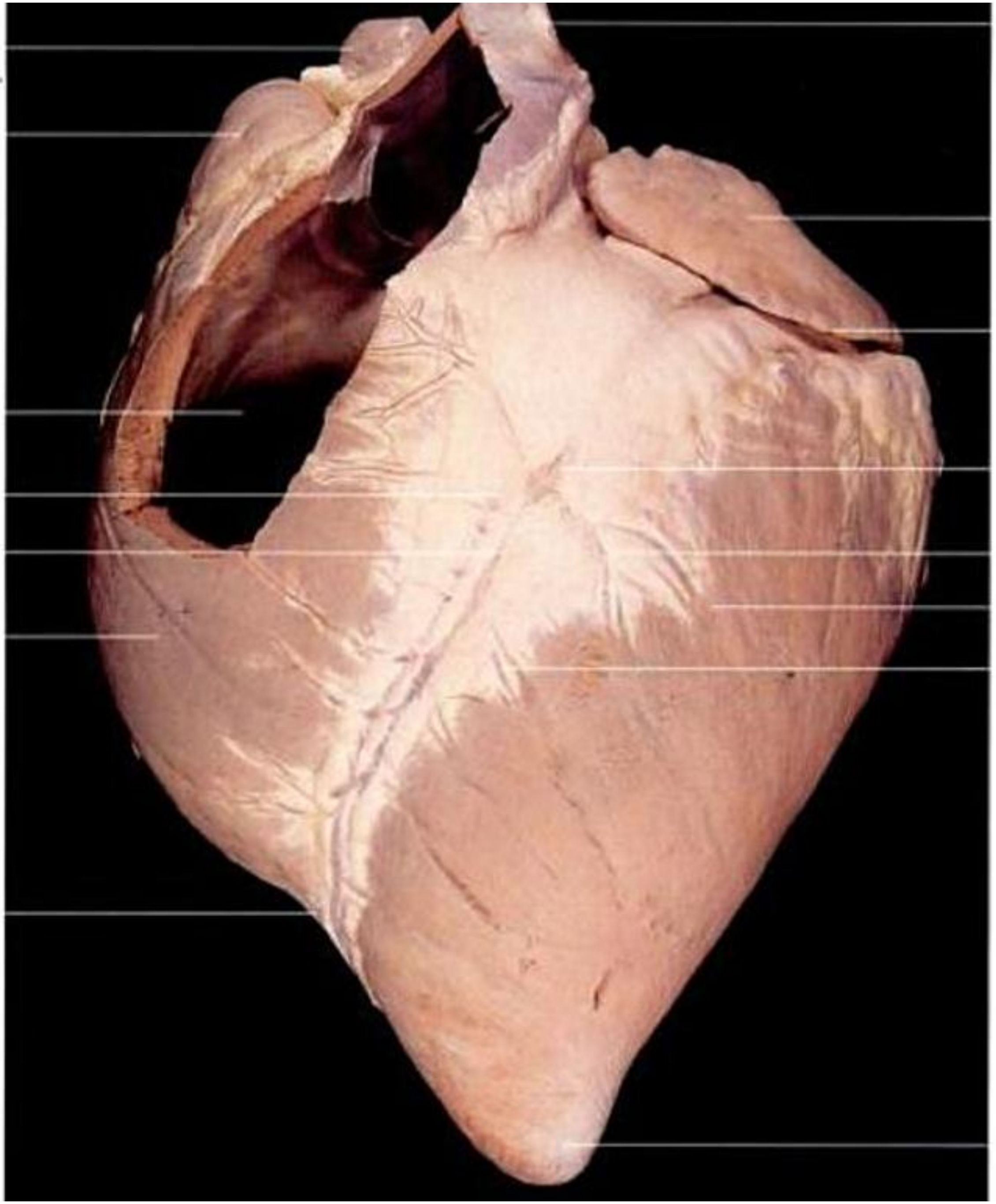
Functions of the pericardium

1) Prevention of heart dilation.
2) Protection of the heart from infection and adhesions to surrounding tissues.
3) Maintenance of the heart in a fixed position in the thorax.
4) Regulation of the interrelations between the stroke volumes of the two ventricles.

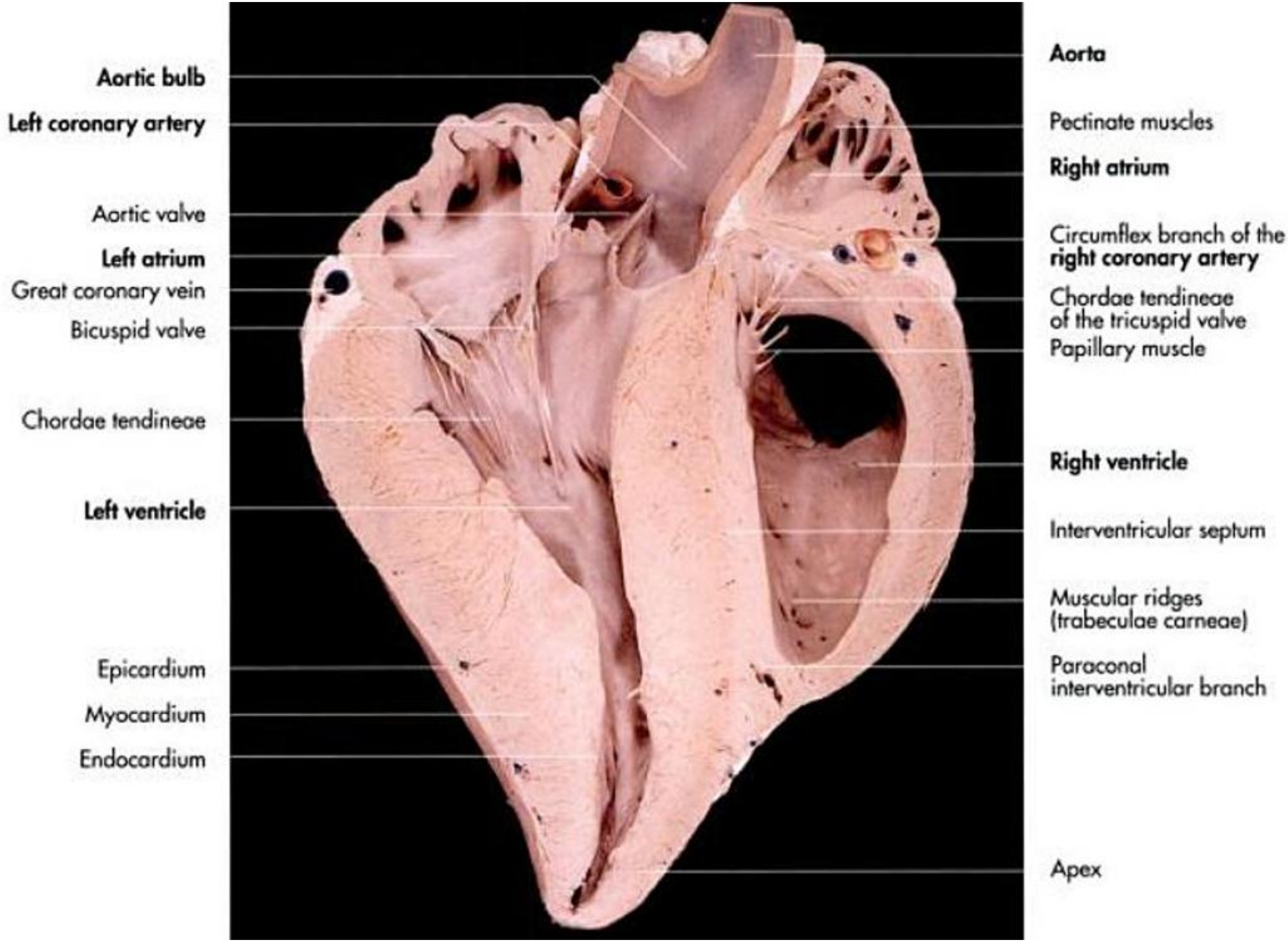
Blood circulation

Normal path of blood flow is similar among all large mammals.
Specifically, systemic deoxygenated blood returns to the right atrium via the caudal (inferior in humans) vena cava and the cranial (superior in humans) vena cava.
At the same time, oxygenated blood returns from the lungs via the pulmonary veins to the left atrium and fills the left ventricle.
After atrial contraction forces, the blood is pushed into the ventricles, then ventricular contraction ejects blood through the major arteries arising from each ventricle, specifically the pulmonary trunk from the right ventricle and the aorta from the left ventricle.
Via the pulmonary arteries, blood travels to the lungs to be oxygenated, whereas aortic blood travels through both the coronary arterial system (to feed the heart) and the systemic circulation (to oxygenate body tissue).


to Lungs
to Lungs
Pulmonary Veins from Lungs
Pulmonary Veins from Lungs
AO
PA
LA
Superior Vena Cava
Mitral Valve
Atrial Septum
Aortic Valve
RA
LV
Tricuspid Valve
RV
Ventricular Septum
Inferior Vena Cava
AO = Aorta
PA = Pulmonary Artery
LA = Left Atrium
RA = Right Atrium
LV = Left Ventricle
RV = Right Ventricle
Pulmonary Valve
Oxygen-rich Blood
Oxygen-poor Blood



Aorta
Right auricle
Right atrium
interventricular branch
Great coronary vein
Right ventricle
Apical notch
Pulmonary trunk
Left auricle
Coronary groove
Left interventricular groove
Proximal collateral branch
Left ventricle
Distal collateral branch
Apex



Aortic bulb
Left coronary artery
Aortic valve
Left atrium
Great coronary vein
Bicuspid valve
Chordae tendineae
Left ventricle
Epicardium
Myocardium
Endocardium
Aorta
Pectinate muscles
Right atrium
Circumflex branch of the right coronary artery
Chordae tendineae of the tricuspid valve
Papillary muscle
Right ventricle
Interventricular septum
Muscular ridges (trabeculae carneae)
Paraconal interventricular branch
Apex

Atria of the heart (Atrium)

1. **The right atrium** forms the right, dorsocranial part of the base of the heart. It receives the blood from the cranial and caudal vena cava and the coronary sinus. It is separated from left atrium by interatrial septum. The opening between the right atrium and right ventricle is the atrioventricular opening.
2. **The left atrium** forms the left, dorsocaudal part of the base of the heart. It receives the oxygenated blood from the pulmonary veins. It is similar to right atrium in shape and structure. It opens into the left ventricle by the left atrioventricular opening.
   Several openings mark the entrance of the pulmonary veins into the left atrium.

Ventricles

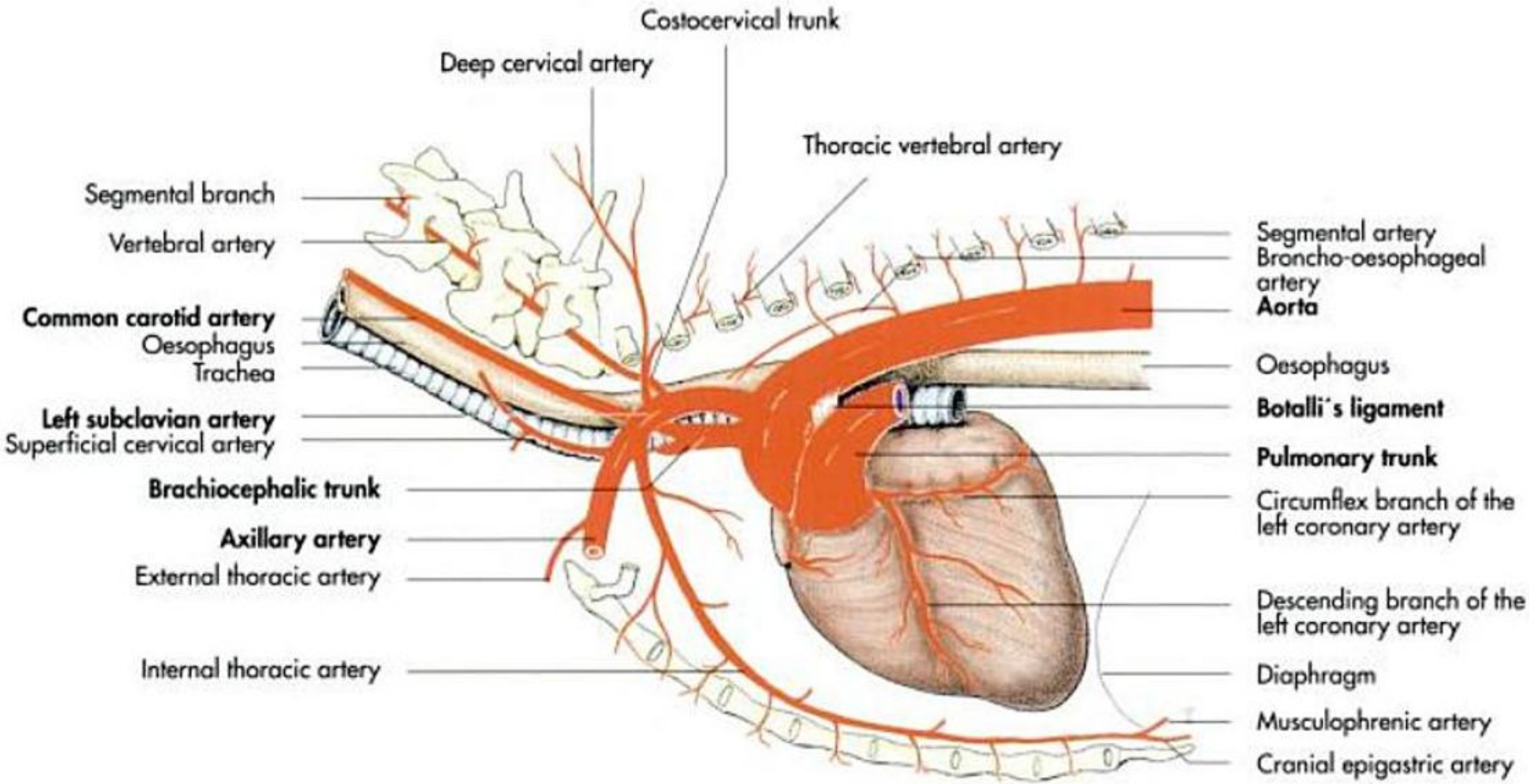
The ventricles constitute the majority of the mass of the heart. They are separated from the atria by a transverse , incomplete septum, which is indicated on the surface by the coronary groove.

1. Right ventricle

The right ventricle is crescent shaped in cross section and moulded on the surface of the cone-shaped left ventricle. It receives the deoxygenated blood from the right atrium and pump it through conus arteriousus into the pulmonary trunk, which conveys the blood to the lung.

2. Left ventricle

The left ventricle open in left atrioventricular opening, it is occupied by the left atrioventricular valve. It is similar to the right atrioventricular valve in form but consist of two cusps. The aortic orifice is the opening from the left ventricle into the ascending aorta, it is close by aortic valve during diastole. The wall of the aorta is dilated to form the three aortic sinuses. The widening of the base of the ascending aorta formed by the aortic sinuses, is the aortic valve. The right and left coronary arteries leave the right and left aortic sinuses.



Arteries of the base of the heart and the cranial mediastinum of the dog (left lateral aspect

Papillary muscles supporting the atrioventricular valves are found on the walls of the ventricles. Similar to human anatomy in the majority of large mammalian animal hearts, the right ventricle has three papillary muscles, and the left ventricle has two, although inter-individual and interspecies variations do occur.

Both ventricles typically have cross-chamber fibrous or muscular bands, which usually contain Purkinje fibres. Within the right ventricle of most dogs, pigs, and ruminants, a band termed the moderator band is typically present.

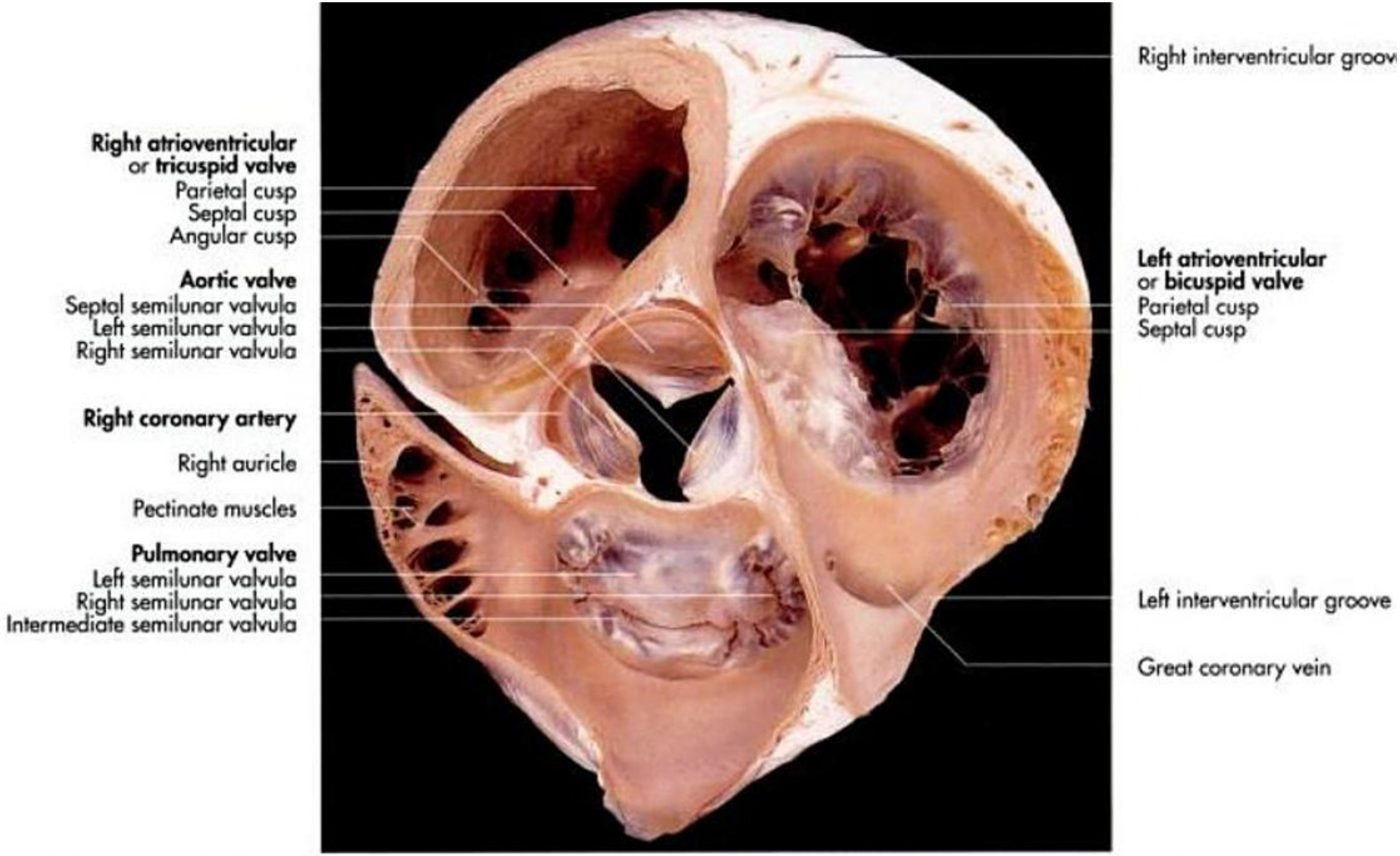
The valves

Large mammalian hearts have four valves with principally similar structures and locations, two atrioventricular valves are located between each atrium and ventricle on both the right and and left sides of the heart, and two semilunar valves lie between the ventricles and the major arteries arising from their outflow tracts. Chordae tendineae connect the fibrous leaflets of both atrioventricular valves to the papillary muscles in each ventricle and serve to keep the valves from prolapsing into the atria during ventricular contraction, thereby preventing backflow of blood into the atria.

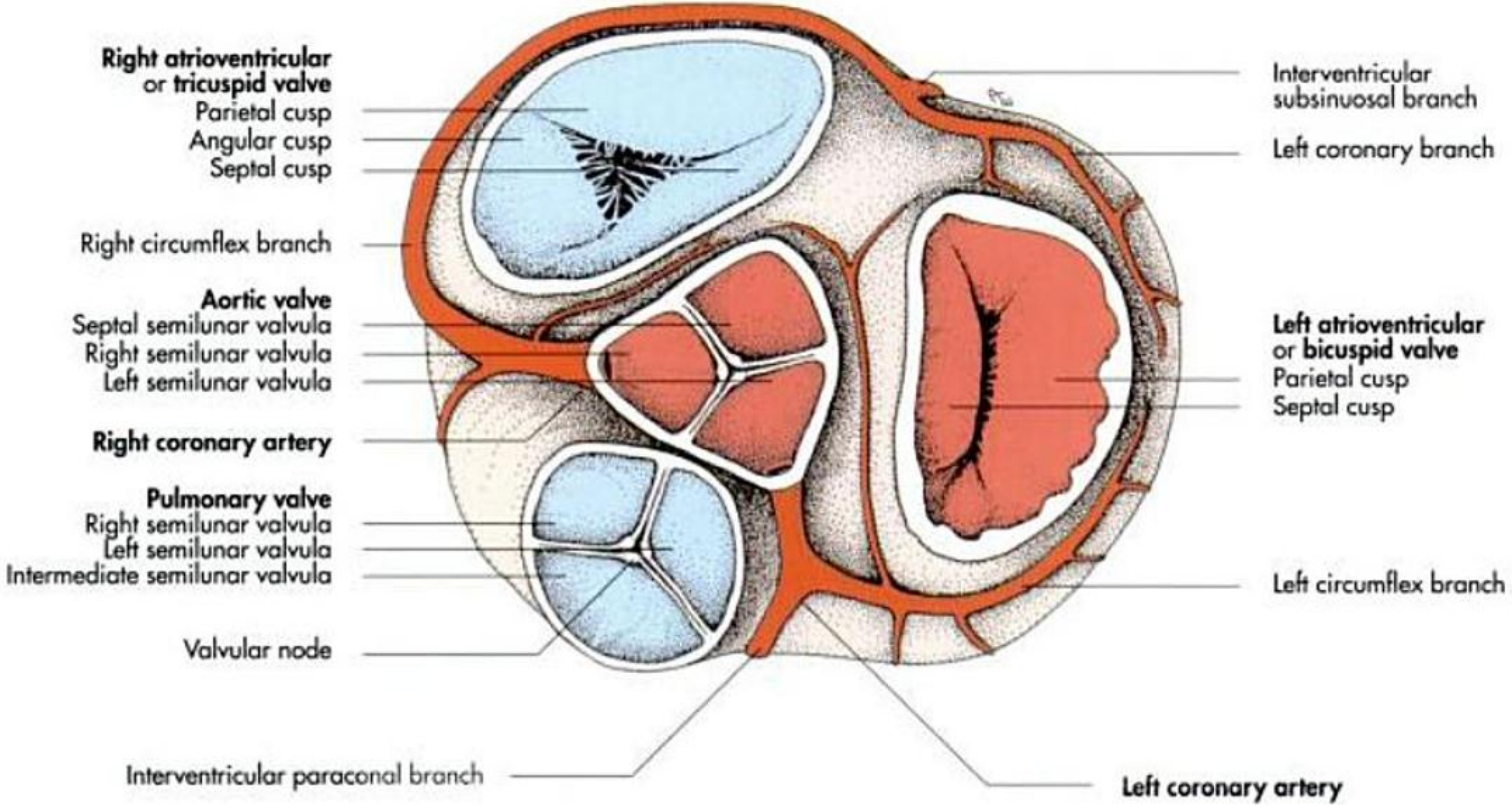
The semilunar valves, the aortic and pulmonic, do not have attached chordae tendineae and close because of pressure gradients developed across them.

The valve separating the right atrium and the right ventricle is termed the tricuspid valve because it has three major cusps: the anterosuperior, inferior, and septal. Typically, there area also three associated papillary muscles in the right ventricle. Interestingly, the commissures between the anterosuperior leaflet and the inferior leaflets are usually fused in dog hearts, giving the appearance of only two leaflets.

Valve separating the left atrium and the left ventricle is termed the mitral or bicuspid valve because it typically has two cusps, the anterior (aortic) and the posterior (mural). However, the human mitral valve actually can be considered to have four cusps, including the two major cusps listed above and two small commissural cusps or scallops. In large mammalian hearts, two primary leafets of the mitral valve are always present, but variations in the number of scallops exist and can be quite marked, giving the impression of extra leaflets .



Right interventricular groov
Right atrioventricular or tricuspid valve
Parietal cusp
Septal cusp
Angular cusp
Aortic valve
Septal semilunar valvula
Left semilunar valvula
Right semilunar valvula
Right coronary artery
Right auricle
Pectinate muscles
Pulmonary valve
Left semilunar valvula
Right semilunar valvula
Intermediate semilunar valvula
Left atrioventricular or bicuspid valve
Parietal cusp
Septal cusp
Left interventricular groove
Great coronary vein



Right atrioventricular
or tricuspid valve
Parietal cusp
Angular cusp
Septal cusp
Right circumflex branch
Aortic valve
Septal semilunar valvula
Right semilunar valvula
Left semilunar valvula
Right coronary artery
Pulmonary valve
Right semilunar valvula
Left semilunar valvula
Intermediate semilunar valvula
Valvular node
Interventricular paraconal branch
Interventricular
subsinuosal branch
Left coronary branch
Left atrioventricular
or bicuspid valve
Parietal cusp
Septal cusp
Left circumflex branch
Left coronary artery

Blood vessels of the heart

The heart is well vascularised, receiving about 5% of the output of the left ventricle in man and even a higher percentage in animals, depending on the animal's condition.

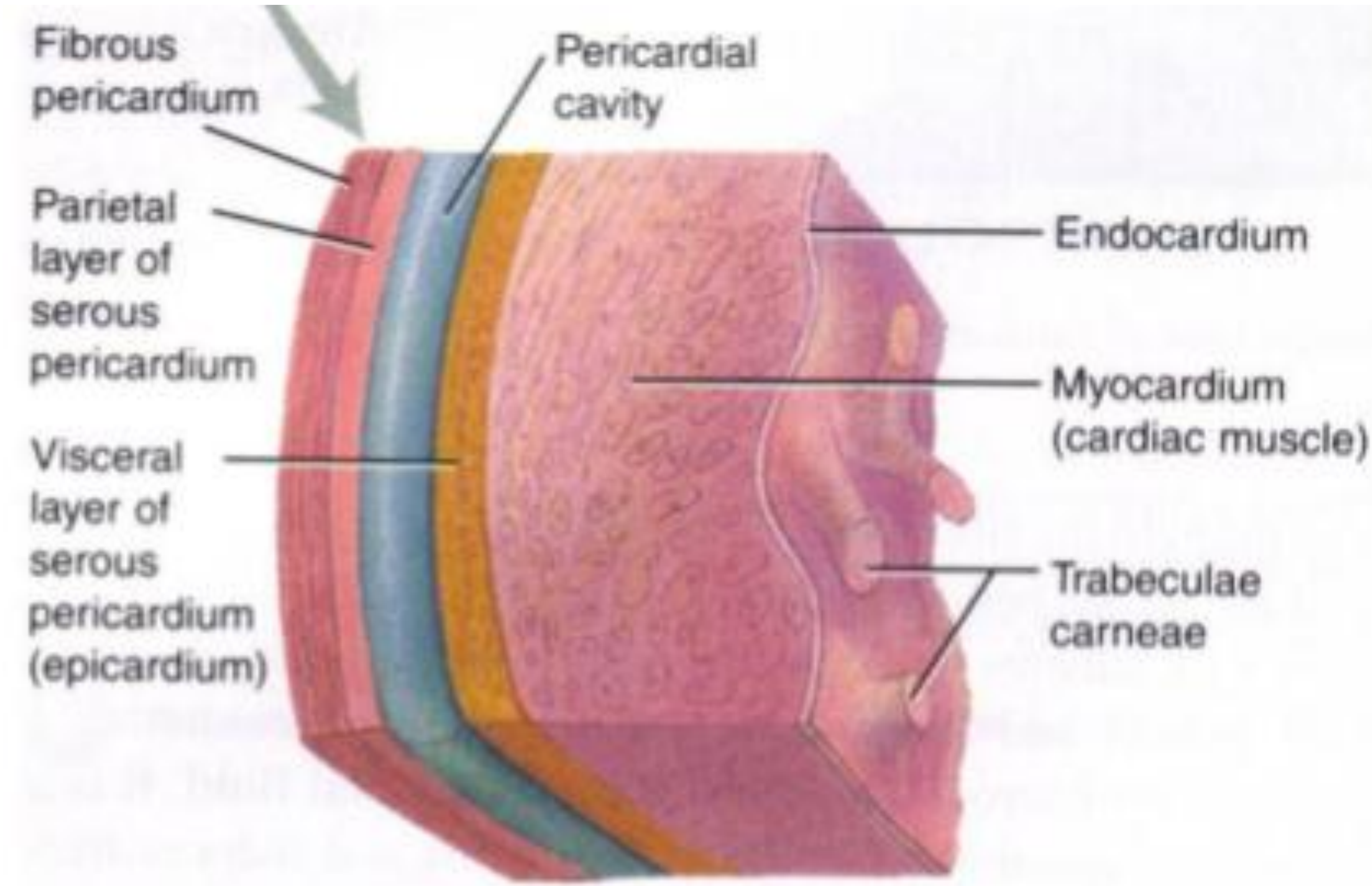
Blood supply to the heart is provided the coronary arteries and their branches. They originate from two of the three sinuses above the semilunar valves at the root of the aorta.

There are the:

- Left coronary artery
- Right coronary artery

Structure of the cardiac wall

- **Endocardium** is a thin, smooth layer that lines the cardiac chambers, covers the atrialauricles and is continuous with lining of blood vessels.
- **Myocardium** or heart muscles males up the majority of the cardiac wall
- **Epicardium** is part of the pericardium



Innervation of the heart

It is provided by the autonomic nervous system. Sympathetic fibres are Supplied by the cervical cardiac nerves and the caudal thoracic nerves, which originate from the stellate ganglion and the middle cervical ganglion. Parasympathetic fibres arise as branches of the vagus nerve either directly or from the recurrent laryngeal nerve.

All nerve fibres from the cardiac plexus within the cranial mediastinum. Most of the sympathetic nerve are postganglionic fibres, whereas the parasympathetic fibres are preganglionic. These form synapses in small ganglia, which are located beneath the epicardium in the wall of atria, mostly adjacent to the large blood vessels. Many of the fibres innervate the conducting tissue, especially sinoatrial and atrioventricular nodes. Efferent fibres of both parasympathetic and the sympathetic system leave the heart. Sympathetic efferent fibres are responsible for pain receptors, while parasympathetic efferent nerves responds to increases in distension

Cardiac function is not dependent on afferent nerves, but these influence both rate and force of contractions to match cardiac output to the body's need for oxygen. Sympathetic stimuli accelerate the **pacemaker rate (chroniotropy)** and increase **contractility (ionotropy)**, while parasympathetic innervation slows the pacemaker rate. The heart both responds to circulating hormones, such as **adrenaline**, and has endocrine actions; for example, the atrial cells produce **atrial natriuretic peptide**, a peptide hormone which plays a role in the regulation of blood pressure.

Lymphatics of the heart

The heart tissue is drained by **lymph capillaries**, which become confluent in small lymph vessels beneath the epicardium. These run toward the base of the heart, where they form bigger lymph vessels close to the junction between the coronary groove and the left interventricular groove. These finally drain into the cranial and caudal **mediastinal lymph nodes** and the **tracheobronchial lymph nodes**.

Functions of the heart

Alternating between contraction and relaxation results in a pumping action that makes the blood circulate through the body. The phase of contraction is called **systole**; relaxation is called **diastole**. During systole the atria of the heart contract first, followed by a contraction of the ventricles, which takes about double the time of the former. The atrioventricular node is of vital importance for the delay between atrial and ventricular contraction, ensuring complete ventricular filling. The walls of the ventricle contract almost simultaneously with the papillary muscles, preventing the prolapse of the valve cusps into the atria. The longitudinal layers of the myocardium shorten the ventricles so that the apex is pulled toward the base of the heart. The circular muscle fibres of the left ventricle and the septum contract like a sphincter. Only contraction of the right ventricular free wall plays a part in right ventricular outflow.

The **volume of blood** pumped by the heart during systole is termed stroke volume. In a 20-kg dog this is approximately 11 ml, which amounts to 1.5 tons of blood pumped in a day. **Cardiac output** is the product of stroke volume and heart rate, and is measured in litres of blood per minute. **Cardiac index** is the cardiac output corrected for body weight.

During **diastole** the myocardium relaxes and the heart chambers fill passively. The return of the blood to the heart is assisted by several factors such as ventilation and contraction of the diaphragm. The atrioventricular valves are open and the semilunar valves are closed during diastole. Backflow of blood against the coronary sinus is responsible for the coronary blood flow. Since blood flow relies on pressure differences, coronary flow is affected by both diastolic blood pressure and right atrial pressure.

The heart can be clinically evaluated by assessing heart rate and rhythm, palpation of pulse pressure, measurement of blood pressure and central venous pressure, and by auscultation of the heart. Closure of the heart valves produces distinctive sounds, which are audible with a **stethoscope**. There are **four heart sounds**, referred to as S4 (atrial sound), S1, S2 and S3. Usually it is possible to hear all four sounds only in some horses, whereas S1 and S2 should be audible in all domestic animals.

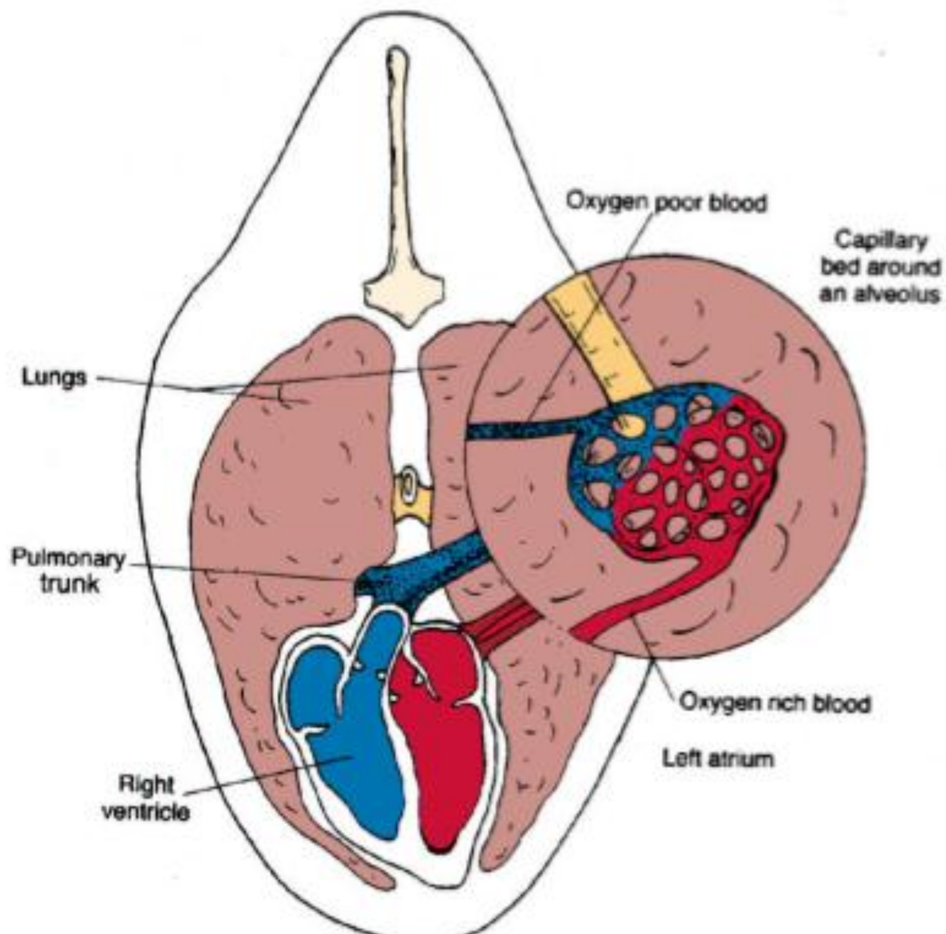
The **first heart sound (S1)** is produced by the simultaneous closure of the atrioventricular valves at the beginning of systole. The **second heart sound (S2)** is produced by the simultaneous closure of the aortic and pulmonic valves, marking the beginning of diastole. The **third heart sound (S3)** is produced by passive ventricular filling, whilst the **fourth**, or **atrial sound (S4)** is produced by atrial contraction.

The area where the sounds are most clearly heard are called the **point of maximal intensity**; in the horse these are:

- **left thorax**, at the level of a horizontal line drawn through the shoulder joint:
  - 3rd intercostal space: pulmonary valve,
  - 4th intercostal space: aortic valve,
  - 5th intercostal space: bicuspid valve,
- **right thorax**:
  - 4th intercostal space: tricuspid valve.

Blood Circulatory Systems

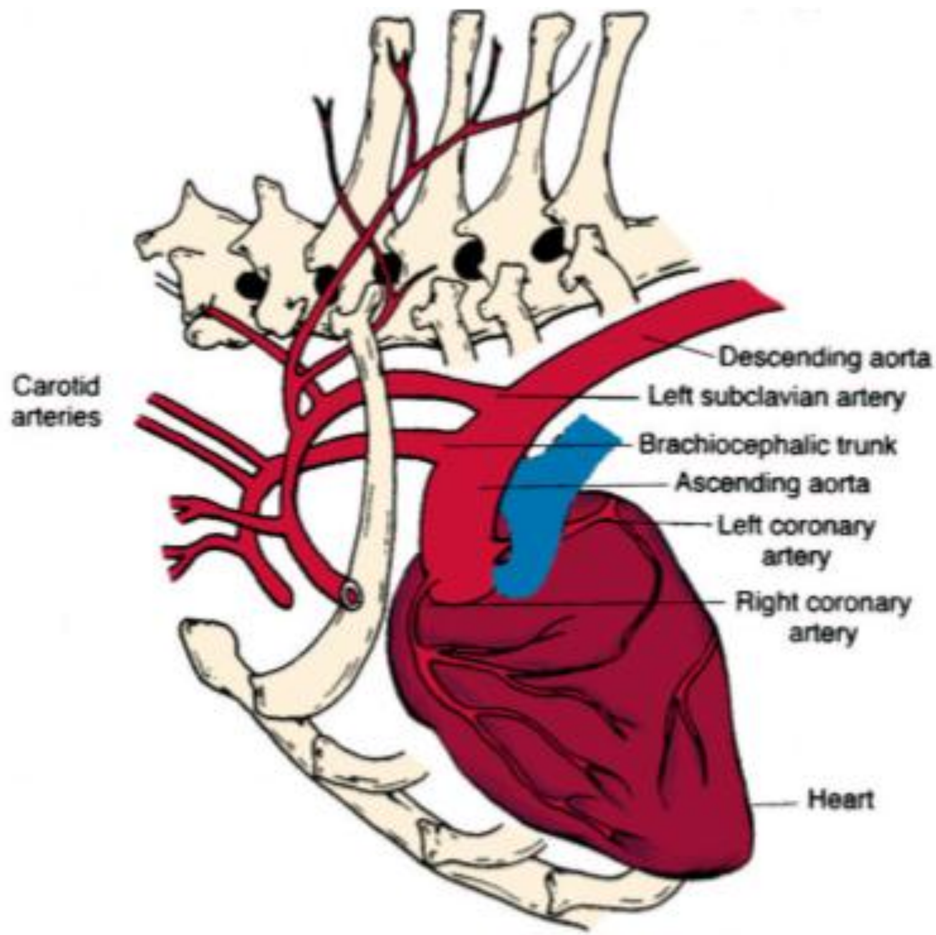
A. Pulmonary
1. circulates blood through the lungs
2. Pressure for this system originates in the right ventricle.
3. Capillaries for this system lien in pulmonary alveoli



Schematic representation of the lungs and the pulmonary circulation. The circled inset represents a

B. Systemic circulation

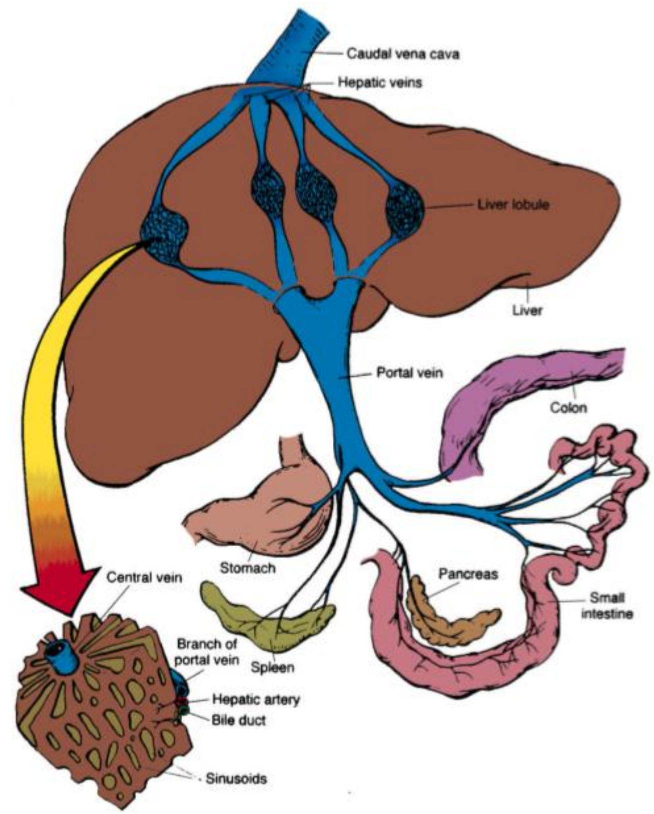
1. carries blood that has returned from the lungs
2. Pressure for this system originates in the left ventricle.
3. Blood traversing this system leaves the left ventricle through the aorta and is returned to the right atrium via the vena cava. a. first branches of the aorta supply the heart through coronary arteries



Cranial aspects of the systemic circulation. The first branches of the aorta supply the heart muscles

Within the systemic circulation, there are a few portal systems

a. veins heading to the heart re branch to form capillary beds which reunite to form veins
b. Primary example is the hepatic portal system:
 i. veins draining viscera all empty into the liver which reforms a capillary bed (liver sinusoids)
ii. This portal system permits the uptake of nutrients from the digestive tract at the liver for metabolism and transport to other tissues.
iii. also permits cleaning of blood or the removal of harmful substances (detoxification)



The mammalian hepatic portal system. Blood in the portal vein from the stomach, spleen, pancrease, and

Blood vessels

blood vessels in the pulmonary and systemic circulations make continuous loops to and from the heart.

In the pulmonary circulation this means the blood vessels are branches from the pulmonary artery and vein.

In the systemic circulation the blood vessels are branches from the aorta and vena cava. All blood vessels are arteries, veins, or capillaries. They are hollow tubes with similar but not identical anatomy and function

Arteries carry blood away from the heart. In the pulmonary circulation they carry deoxygenated blood to the lungs for oxygenation. In systemic circulation they carry oxygenated blood throughout the animal's body.

There are two types of artery: elastic arteries and muscular arteries.

1. Elastic arteries have the greatest ability to stretch when blood passes through them because they have a large number of elastic fibres in the middle layers of their walls. These arteries are found closest to the heart because they have to be able to stretch and recoil without damage each time a surge of blood is ejected from a ventricle during ventricular systole.

The aorta is the largest elastic artery in the body. It has the largest layer of elastic fibers in its wall because it must be able to withstand the entire surge of blood ejected from the left ventricle.

2. Muscular arteries have more smooth muscle fibers than elastic fibers in their walls. They are found farther away from the heart than elastic arteries and usually direct blood to specific organs and tissues. Muscular arteries branch off the smallest elastic arteries and therefore have a smaller diameter. They are located far enough away from the heart that the blood surge is not severe enough to cause damage. Muscular arteries branch into arterioles.

Arterioles are the smallest branches of the arterial tree. They are in effect small muscular arteries and have the narrowest diameter. Blood flow to areas of the animal's body is controlled through contraction of the smooth muscles in their walls under autonomic nervous system control. Arterioles branch into many microscopic blood vessels called **capillaries**.

Capillaries do not occur singly but in groups called capillary beds or capillary networks. One arteriole will give rise to an entire capillary bed. The wall of a capillary is one endothelial cell thick. It has no middle or outer layer. For this reason the exchange of gases and nutrients takes place at this level.

In order to get the blood back to the heart the capillaries join together to form tiny veins called **venules**.

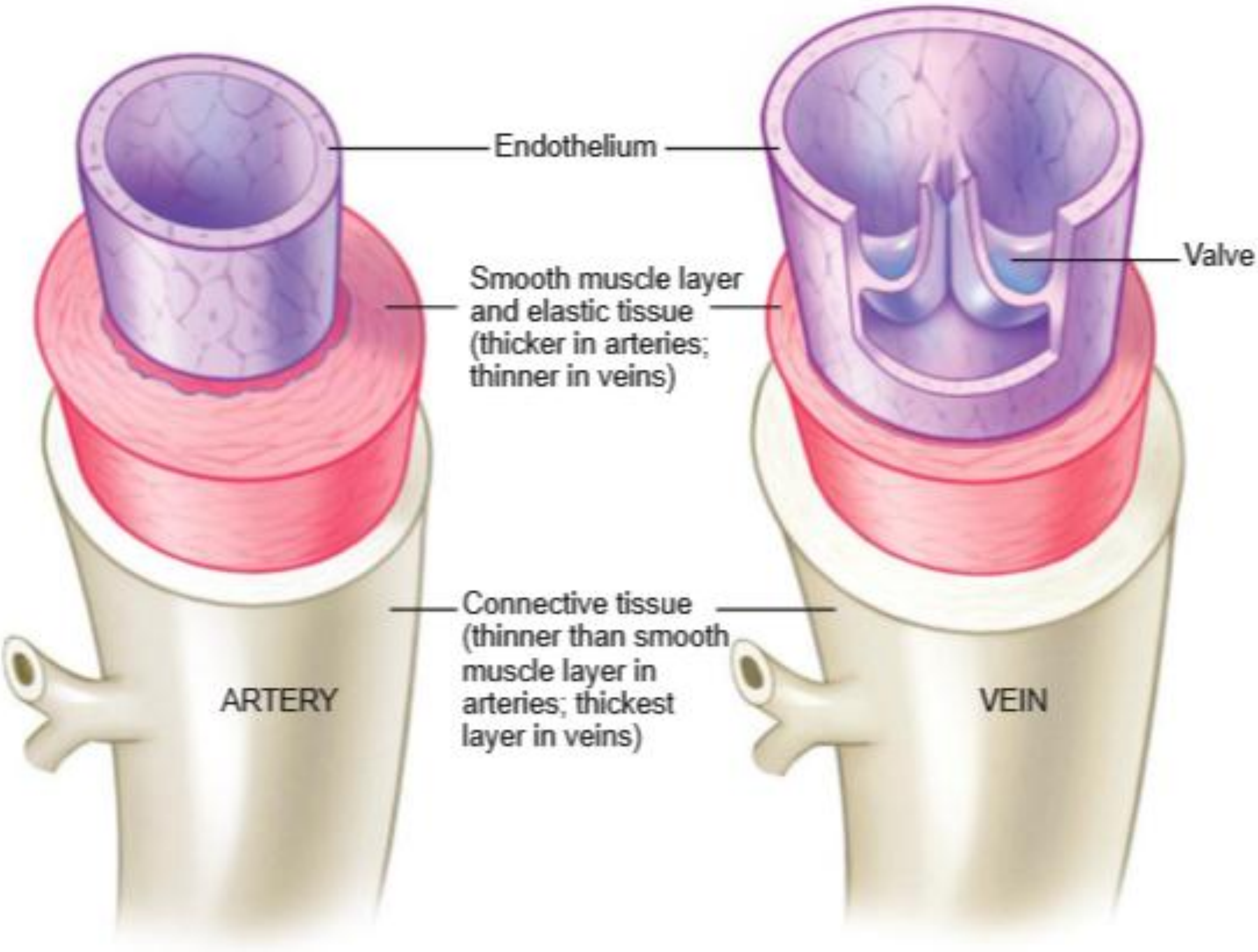
In the pulmonary circulation the venules carry oxygenated blood; in the systemic circulation they carry deoxygenated blood and waste materials.

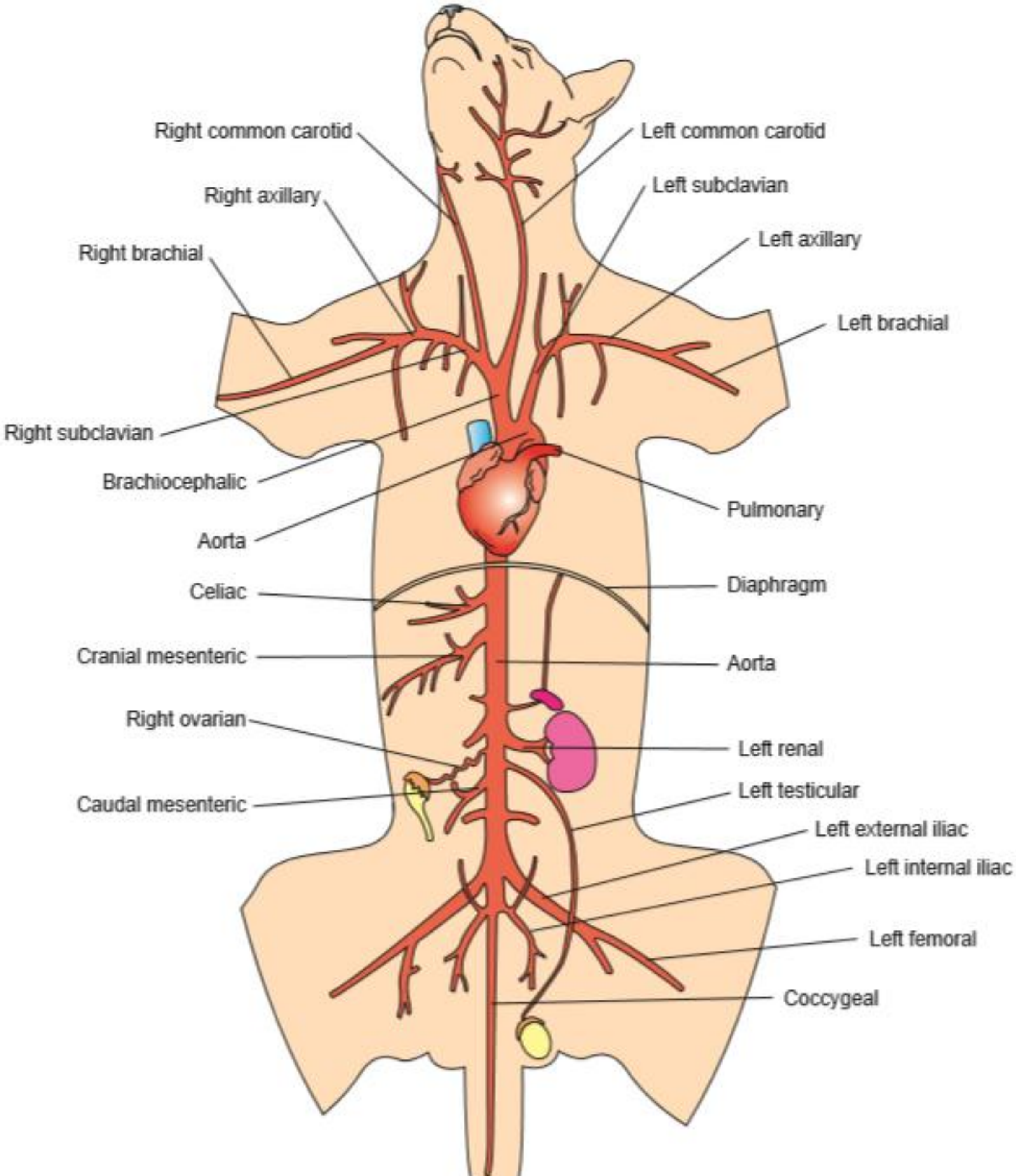
Venules have thin enough walls that some fluid exchange between interstitial fluid and plasma can take place.

Their walls consist of endothelium, a thin muscle layer, and a few fibrous connective tissue cells. White blood cells leave the circulation at the venule level to enter tissues at a site of inflammation.

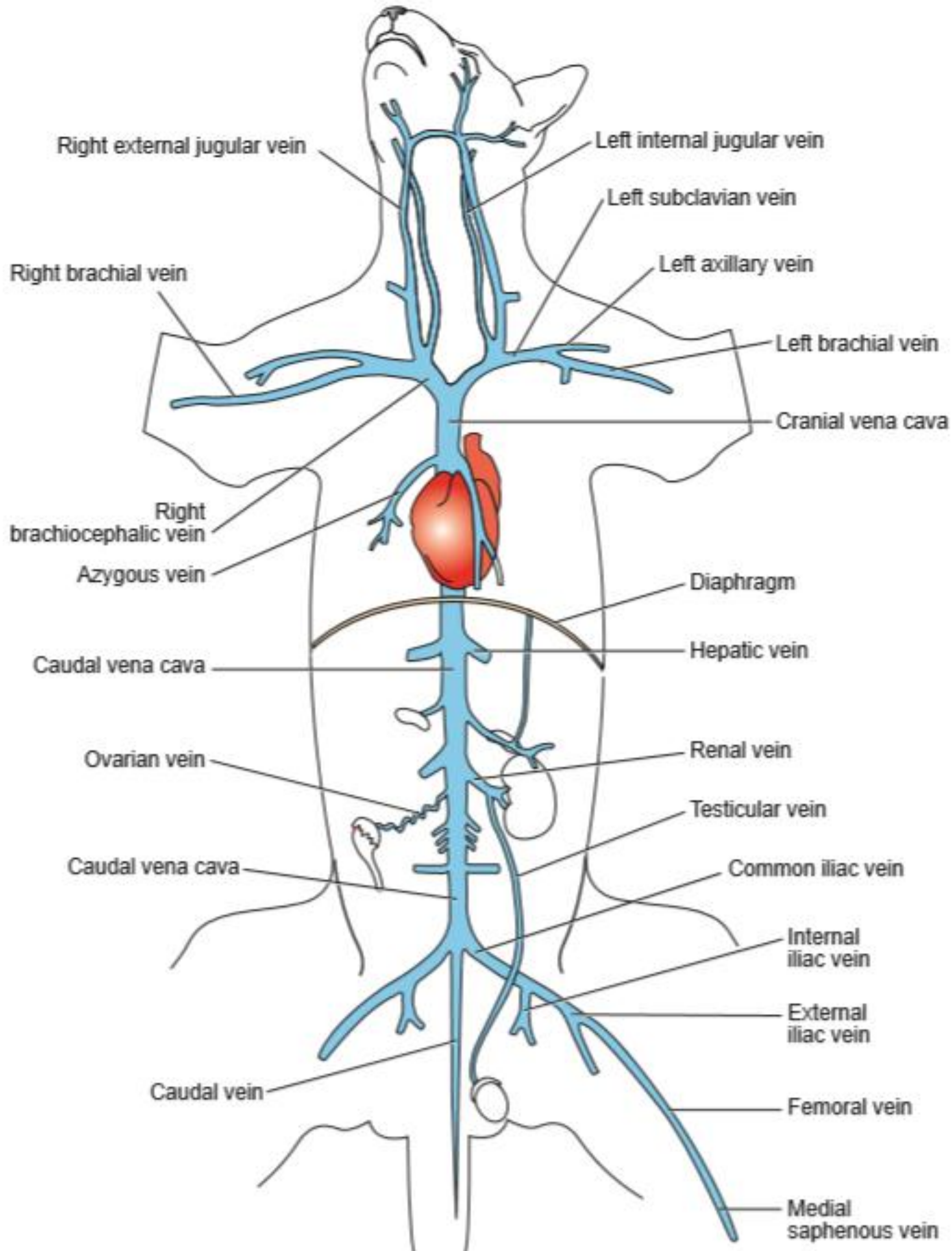
Venules join together to form veins. **Veins** and arteries in a specific area run close to each other so veins are named for their corresponding arteries. For example, the femoral veins that drain blood from the hind legs accompany the femoral arteries that supply blood to the hind legs.

As veins approach the heart they become larger in diameter as more veins draining other areas of the body join together. The largest vein in the animal's body is the vena cava, and all other systemic veins eventually drain into it.


Endothelium
Valve
Smooth muscle layer and elastic tissue (thicker in arteries; thinner in veins)
Connective tissue (thinner than smooth muscle layer in arteries; thickest layer in veins)
ARTERY
VEIN



Right common carotid
Left common carotid
Right axillary
Left subclavian
Left axillary
Right brachial
Left brachial
Right subclavian
Brachiocephalic
Pulmonary
Aorta
Celiac
Diaphragm
Cranial mesenteric
Aorta
Right ovarian
Left renal
Caudal mesenteric
Left testicular
Left external iliac
Left internal iliac
Left femoral
Coccygeal



Right external jugular vein
Left internal jugular vein
Left subclavian vein
Left axillary vein
Right brachial vein
Left brachial vein
Cranial vena cava
Right
brachiocephalic vein
Azygous vein
Diaphragm
Hepatic vein
Caudal vena cava
Ovarian vein
Renal vein
Testicular vein
Caudal vena cava
Common iliac vein
Internal
iliac vein
External
iliac vein
Caudal vein
Femoral vein
Medial
saphenous vein

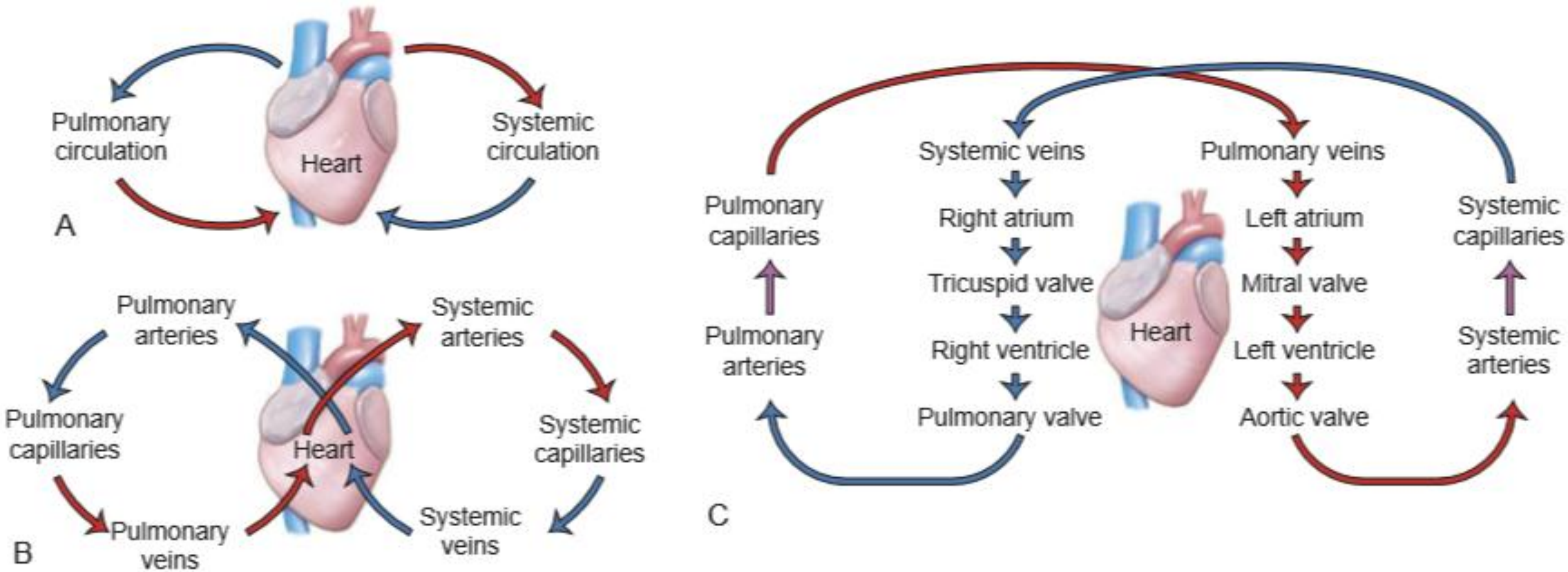


FIGURE 14-15 Schematics of the circulation. A, Pulmonary and systemic circulation, B, vessels of the pulmonary and systemic circulation, C, blood flow through the heart plus the pulmonary and systemic circulation.