**MINISTRY OF EDUCATION AND SCIENCES OF UKRAINE**

**STATE BIOTECHNOLOGICAL UNIVERSITY**

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# A N G I O L O G Y

## *of domestic animals*

**Textbook for students**
**specialty 211: Veterinary Medicine**

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# INTEGRAL GROUP SYSTEMS

The ***integral group systems*** (*integratio* – union) include the following systems:

1. Vascular system
2. System of endocrine glands
3. Nervous system
4. Analyzers

# ANGIOLOGY

**ANGIOLOGY** (from the Greek. *angeion* – vessel) is a branch of anatomy that studies the vascular system. Angiology strictly means the study of vessels, but its scope is conveniently enlarged to include the heart, spleen, and various lymphatic organs.

**THE VASCULAR SYSTEM (SYSTEMA VASORUM)** is the description of the organs of circulation of the blood and lymph – the heart and vessels. ***Vascular system*** consists of:

- circulatory (blood-vascular) system – *systema sanquinifera*
- lymphatic system – *systema lymphatica*
- organs of hematopoiesis – *organa haemopoetica*

## CIRCULATORY SYSTEM

The ***circulatory system*** consists of:

- ***heart*** (cor, s. kardia)
- ***arteries***, which convey blood from the heart to the tissue
- ***vessels of microcirculation*** which situated between an artery and a vein:
    - arteriole
    - precapillary
    - capillary
    - postcapillary
    - venule

- ***veins***, which convey the blood from the tissues to the heart
- ***blood*** (sanquis, s. haima) is a liquid tissue of the organism that circulating in the blood vessels.

The **heart** (cor) is the central hollow muscular organ that pumps blood continuously through the blood vessels by rhythmic contraction; the differences in pressure caused by its contraction and relaxation determine the circulation of the blood and lymph.

It is situated in the middle mediastinal space of the thorax, between the two lungs, and is enclosed in a fibro-serous sac – the pericardium.

The **vessels** are tubular and run through almost all parts of the body. They are designated according to their contents as blood- and lymph-vessels.

The **arteries** (arteriae), as a rule, divide at an acute angle, giving off finer and finer branches.

The wall of arteries consists of three coats. The external coat ***(tunica externa, s. adventitia)*** consists of fibrous connective tissue. In the deeper part are some elastic fibers. The middle coat ***(tunica media)*** is composed of unstriped muscle and elastic tissue in medium-sized arteries. In small vessels there is only the muscular tissue, and in the largest trunks only elastic tissue. The internal coat or intima ***(tunica intima)*** consists of a layer of endothelial cells, resting on an elastic membrane.

The walls of the vessels are supplied with blood by numerous small arteries, called ***vasa vasorum***.

The nerves of the vessels (***nervi vasorum)*** form plexuses around the vessels, from which fibers pass mainly to the muscular tissue of the middle coat.

Artery can be:

• *parietal* arteries (blood supply the body wall)

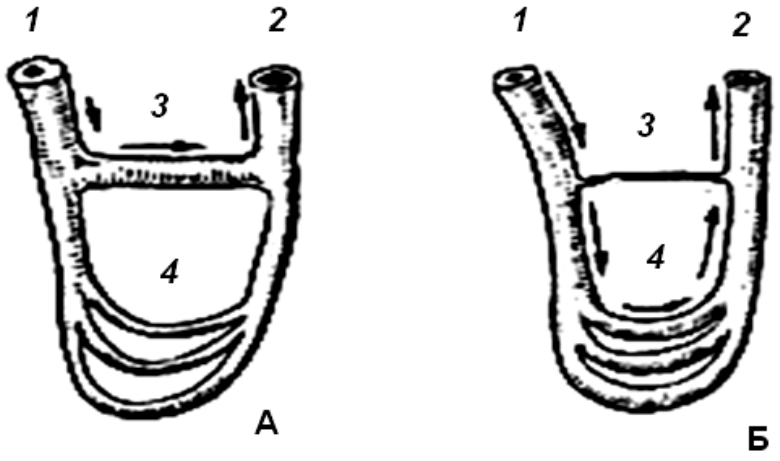
• *visceral* arteries (blood supply the internal organs)

The ***vessels of microcirculation*** are the microscopic tubes in the tissues which permit of the necessary interchange between the blood and the tissues. It is a system of vessels which situated between an artery and a vein:

- arteriole
- precapillary
- capillary
- postcapillary
- venule

Capillaries (vas capillare) are important element of the microcirculation. The capillary has arterial and venous ends.

There are ***arteriolovenular anastomoses*** (anastomosis arteriolovenularis) between the arteriole and venule. It is the path of reduced blood flow from the arterial to the venous bed, excluding the capillary network.




**Arteriolovenular anastomosis**

A – anastomosis is opened, B – anastomosis is closed

*1 – arteriole, 2 – venule, 3 – arteriolovenular anastomosis, 4 – capillary network*

The **veins** (venae) are in general arranged like the arteries, but are usually of greater caliber. When a vein accompanies an artery, it is termed a ***satellite*** vein; in many places two veins accompany a single artery.

The walls of veins are similar in structure to those of the arteries, but are very much thinner; so that veins collapse more or less completely when empty, while arteries do not. The ***middle coat*** is very thin and consists to a large extent of ordinary connective tissue. The ***intima*** is also less elastic than in the arteries. In many veins this coat forms ***semilunar valves***, the free edges of which are directed toward the heart. They are most numerous in the veins of the skin and the deep veins of the limbs (except the foot), while in most veins of the body cavities and viscera they are absent or occur only where the veins open into larger ones or where two veins join.

The veins form very rich ***plexuses*** (plexus venosi) in many places. Some veins which are without independent walls and are enclosed by dense membranes and run usually in bony grooves are termed (venous) sinuses; examples of this are the sinuses of the dura mater of the brain.

## PATHWAYS AND BRANCHING OF VESSELS

The pathways and branching of blood vessels are based to the principles of the structure of the animal body:

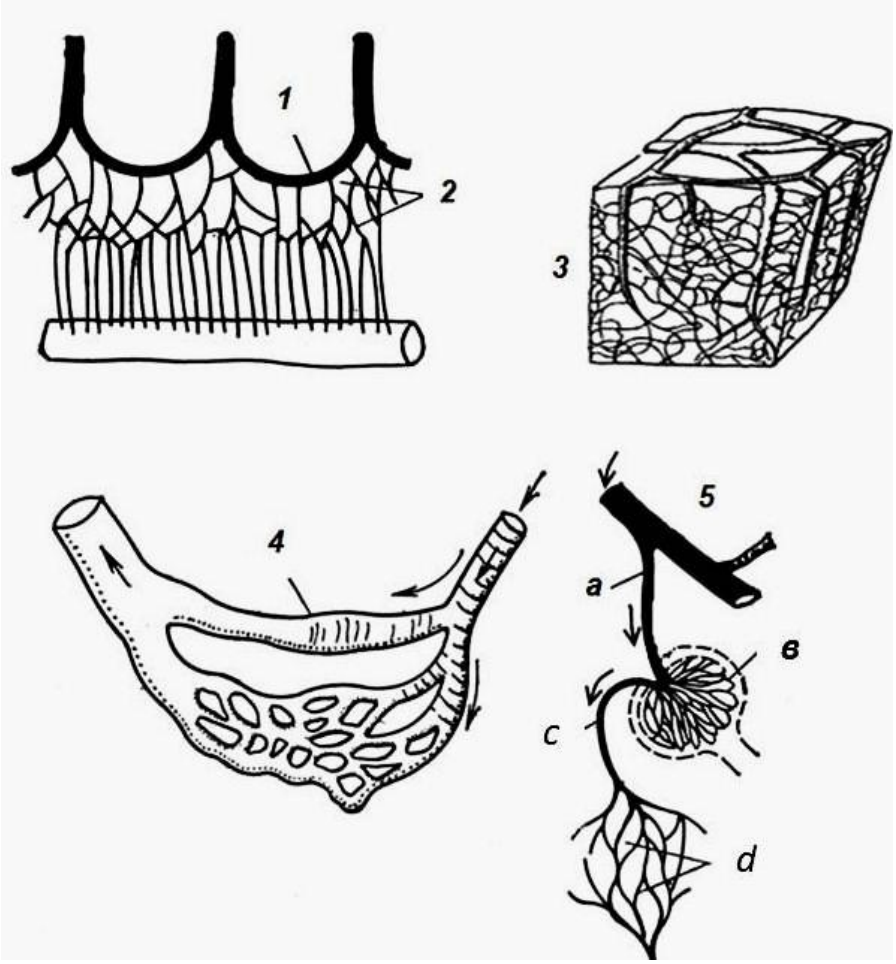
1. Uniaxial
2. Bilateral symmetry
3. Segmentation (metamerism).

The ways of large vessels are based to a number of other patterns.

1. The vessels are going, as a rule, together with the nerves in the **neurovascular bundles**.
2. The main blood vessels of the body, head and limbs have **shortest ways**.
3. The **name** of the vessels often corresponds to name of areas of the body and organs that they serve.
4. The main trunk gives off **lateral branches** to all organs through which it passes.
5. Collateral branches of the arteries form anastomoses.

6. A **collateral vessel** (vas collaterale) is one which pursues a course near and similar to that of a larger vessel.

The intercommunication of branches of adjacent arteries is termed **anastomosis**.




**Types of anastomoses**

*1 – arterial arch of intestinal arteries, 2 – arterial network, 3 – choroid plexus of meninges, 4 – arteriolovenular anastomosis, 5 – vessels of a kidney: a – afferent arteriole, b – rete mirabile of renal glomerulus, c – efferent arteriole, d – peritubular network*

Most commonly the connections are made by a network of numerous fine branches (plexus vasculosus). Relatively large communicating branches (rami communicantes) occur in certain places; they may be transverse or in the form of arches. Wide-meshed networks of vessels are termed ***retia vasculosa***. Terminal or end arteries are such as form isolated networks and do not anastomose with adjacent arteries. A **rete mirabile** is a network intercalated in the course of an artery.

# CIRCULATION

Blood moves through the vessels in one direction. The system of vessels in which blood flows from the heart through any organ, and then returns to the heart, is called **circulation**.

Functionally in the circulatory system there are two circulations – **systemic** or *large* and **pulmonary** or *small*.

The **systemic circulation** is the circulation of the blood to all parts of the body except the lungs. Systemic circulation is the portion of the vascular system which transports oxygenated blood away from the heart to the rest of the body, and returns oxygen-depleted blood back to the heart.

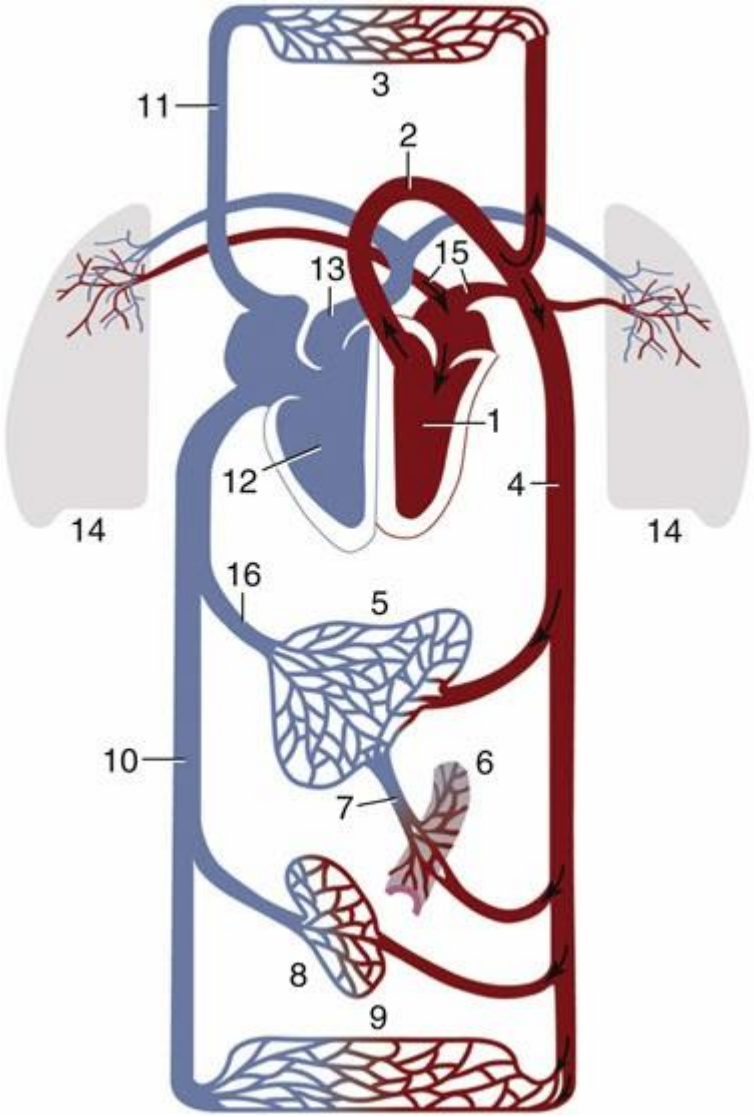
The **systemic circulation** (*circulus sanguinis major*) is a large or trophic. It starts from the left ventricle by an **aorta**. The arteries which are separated from aorta branch out into tiny blood vessels in the organism. These provide tissue metabolism. The blood returns to the heart through the veins. The blood is collected into the cranial and caudal venae cavae. Both flow into the right atrium. In the right atrium ends the systemic circulation by the **venae cavae**.

The pulmonary trunk conveys the blood from the right ventricle of the heart to the lungs, where it is arterialized, and is returned by the pulmonary veins to the left atrium of the heart, and passes into the left ventricle.

The **portal system** is a part of **systemic circulation**. It is the portal vein and its tributaries which come from the stomach, intestine, pancreas, and spleen. The vein enters the liver, where it branches like an artery to microcirculatory bed and then transports to the heart by the hepatic veins and the caudal vena cava.

The **pulmonary circulation** (*circulus sanguinis minor*) is a small or respiratory. It is the portion of the vascular system in which oxygen-depleted blood is pumped away from the heart, via the pulmonary trunk, to the lungs and returned, oxygenated, to the heart via the pulmonary vein.

Oxygen deprived blood from the venae cavae enters the right atrium of the heart and flows into the right ventricle, from which it is then pumped into the pulmonary artery to the lungs. Gas exchange occurs in the lungs, whereby carbon dioxide is released from the blood, and oxygen is absorbed. The pulmonary vein returns the oxygenated blood to the left atrium.




**Schematic drawing of the systemic and pulmonary circulation**

*1* – left ventricle;
*2* – aorta;
*3* – capillary bed of head, neck, and forelimb;
*4* – abdominal aorta;
*5* – liver;
*6* – capillary bed of intestines;
*7* – portal vein;
*8* – capillary bed of kidneys;
*9* – capillary bed of caudal part of the body;
*10* – caudal vena cava;
*11* – cranial vena cava;
*12* – right ventricle;
*13* – pulmonary trunk;
*14* – capillary bed of lungs;
*15* – pulmonary vein;
*16* – hepatic veins.

## CIRCULATION OF FETUS

The placental circulation is distinguished the morphological and physiological features.

***Morphological features*** of placental circulation of fetus:

1. The **oval foramen** is located in the interatrial septum
2. The **arterial duct** connects the pulmonary trunk with the aorta
3. Venous duct connects the umbilical vein and caudal vena cava

4. The umbilical vessels are two arteries and a single vein.

***Physiological features*** of placental circulation of fetus:

1. Fetal tissue receive mixed blood (arterial-venous)
2. Both heart ventricle working on the systemic circulation
3. The pulmonary circulation is not functioning.

The blood of the fetus is oxygenated, receives nutrient matter, and gives off waste matter by close contiguity with the maternal blood in the placenta.

The **umbilical arteries,** right and left, are large vessels which arise from the internal iliac arteries and pass downward and forward in the umbilical folds of peritoneum on either side of the bladder to the umbilicus. Here they are incorporated with the **umbilical vein** and the **urachus** in the **umbilical cord**, ramify in the allantois, and end as the capillaries of the fetal placenta. They conduct the impure blood to the placenta. After birth these vessels retract with the bladder to the pelvic cavity; their lumen becomes greatly reduced and the wall thickened so that they are cord-like and are termed the ligaments of the bladder.

The **umbilical vein** receives the oxygenated blood from the placenta. Its radicles converge to form a single large trunk which separates from the other constituents of the umbilical cord on entering the abdomen. It joins the portal vein, so that the blood conveyed by it passes through the capillaries of the liver before entering the posterior vena cava.

Some of the blood in the umbilical vein is conveyed directly to the vena cava by the **ductus venosus**. This vessel is given off within the liver from a venous sinus formed by the confluence of the portal and umbilical veins and passes directly to the posterior vena cava. The **foramen ovale** is an opening in the septum between the atria, by which the latter communicate with each other. It is guarded by a valve which prevents the blood from passing from the left atrium to the right. After birth the foramen soon closes, but this part of the septum remains membranous, and

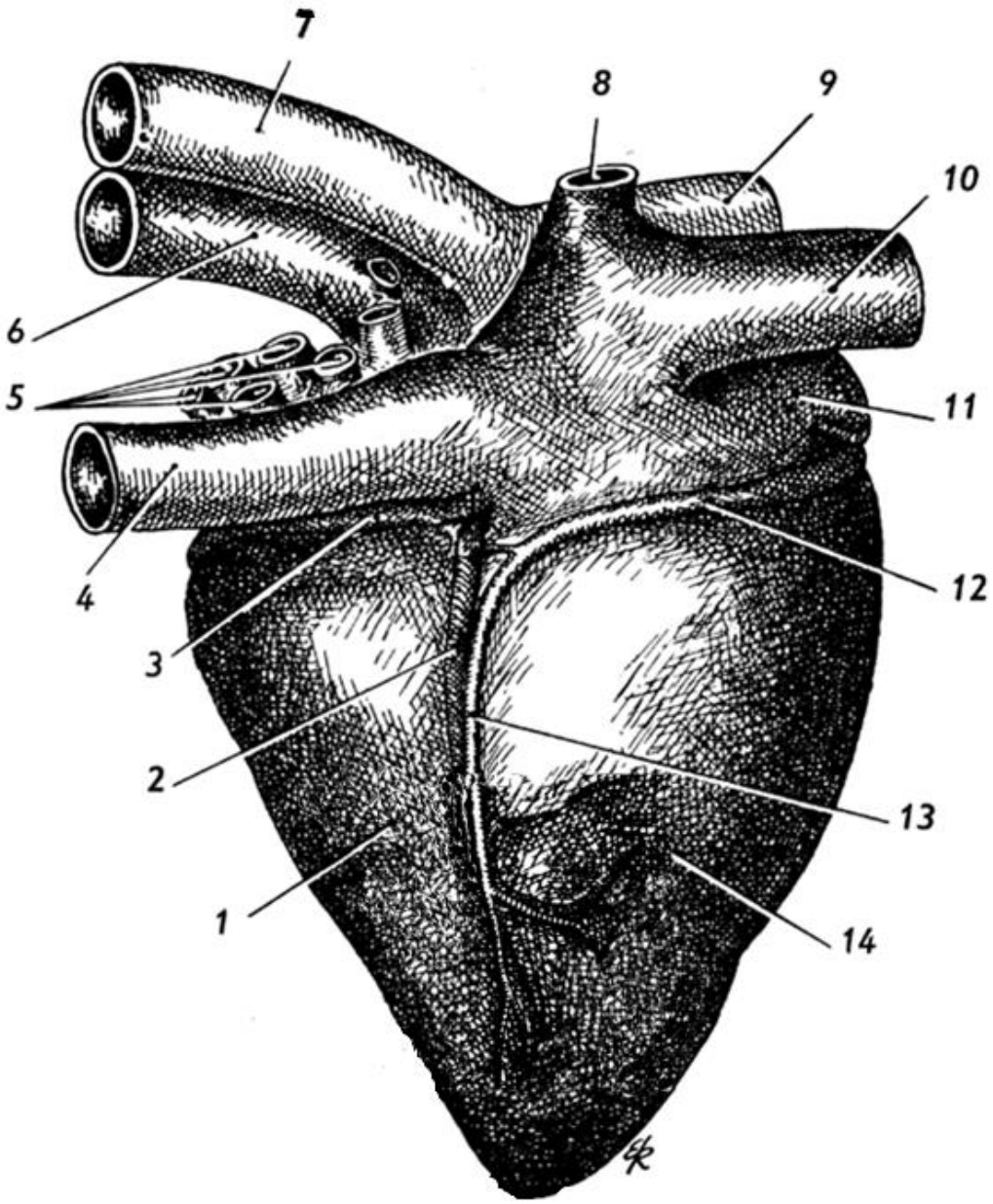
there is a deep **fossa ovalis** in the right atrium which indicates the position of the former opening. In some cases the foramen persists to a variable extent in the adult without apparent disturbance of the circulation.

The **pulmonary circulation** is very limited in the fetus, and most of the blood which enters the pulmonary artery passes through the **ductus arteriosus** to the aorta. This vessel is larger than the divisions of the pulmonary which go to the lungs and joins the left side of the aortic arch. After birth the pulmonary circulation undergoes promptly an enormous increase and the duct is rapidly transformed into a fibrous cord – the **ligamentum arteriosum.**

The only **arterial blood** in the fetus is that carried by the **umbilical vein**. This blood **is mixed** in the liver with the venous blood of the portal vein, and after passing through the capillaries of the liver is carried by the hepatic veins to the posterior vena cava. The latter receives also the venous blood from the posterior part of the trunk and the pelvic limbs. It is generally believed that the blood carried into the right atrium by the posterior vena cava passes largely, if not entirely, through the oval foramen into the left atrium, while the blood flowing into it through the anterior vena cava passes into the right ventricle. On this basis the blood received by the left atrium consists chiefly of mixed blood from the posterior vena cava, since the small amount of blood conveyed by the pulmonary veins is venous. This mixed blood passes into the left ventricle and is forced into the systemic arteries. The venous blood from the anterior part of the body and the thoracic limbs is conveyed by the anterior vena cava to the right atrium, passes into the right ventricle, and is forced into the pulmonary artery. A small amount is carried to the lungs, but the bulk of it passes by the *ductus arteriosus* into the aorta behind the point of origin of the brachiocephalic trunk, and is carried to the posterior part of the body, a large part passing by the umbilical arteries to the placenta.

## H E A R T

The **heart** *(cor, s. kardia)* is the muscular pump of vascular system. It is cone-shaped and obliquely placed in the thorax. The heart forms a part of the mediastinum, the partition which separates the two pleural cavities. It is the largest organ located between the walls of the mediastinal pleurae. It extends from the third rib to the caudal border of the sixth rib.



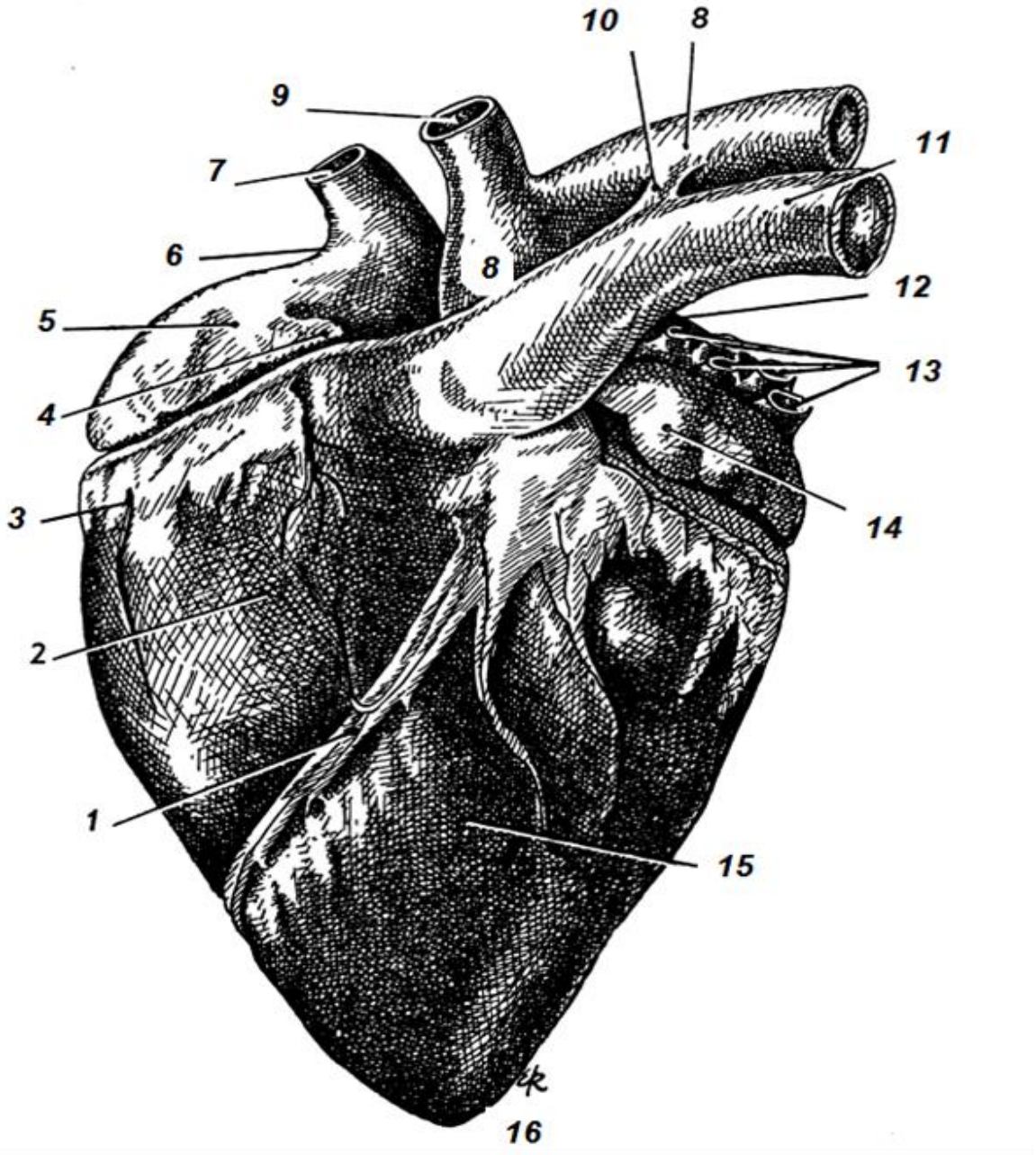

**Heart of horse**

(right aspect)

*1 – left ventricle, 2 – medium vein heart, 3 – great cardiac vein in coronary groove, 4 – caudal vena cava, 5 – pulmonary veins, 6 – pulmonary trunk, 7 – 8 aorta and right azygos vein, 9 – brachiocephalic trunk, 10 – cranial vena cava, 11 – right atrium, 12 – right coronary artery, 13 – subsinuosal groove, 14 – right ventricle.*

The heart has:

- **base** of heart (basis cordis) which faces dorsocranially
- **apex** of heart (apex cordis) which faces ventrocaudally
- **auricles** of atrium (auricula atrii) located at the base of the heart and directed cranially




**Heart of horse** (left aspect)

*1 – paraconal groove, 2 – right ventricle, 3 – coronary groove, 4 – right auricle, 5 – right atrium, 6 – terminal groove, 7 – cranial vena cava, 8 – 9 aorta and brachiocephalic trunk, 10 – arterial ligament (arterial duct of fetus),11 – pulmonary trunk, 12 – left atrium, 13 – pulmonary veins, 14 – left auricle, 15 – left ventricle, 16 – apex of heart.*

**Grooves** of the heart:

- ***coronary groove*** (sulcus coronarius) marks, on the surface of the heart, the separation of the atria and ventricles. It contains much fat, which surrounds the coronary vessels. The coronary groove encircles the heart.
- ***paraconal interventricular groove*** (sulcus interventricularis paraconalis) is a left longitudinal groove
- ***subsinuosal interventricular groove*** (sulcus interventricularis subsinuosus) is a right longitudinal groove
  The interventricular grooves are indistinct surface markings of the separation of the right and left ventricles.
- ***terminal groove*** (sulcus terminalis) lies at the junction of the cranial vein cava with the right atrial auricle.

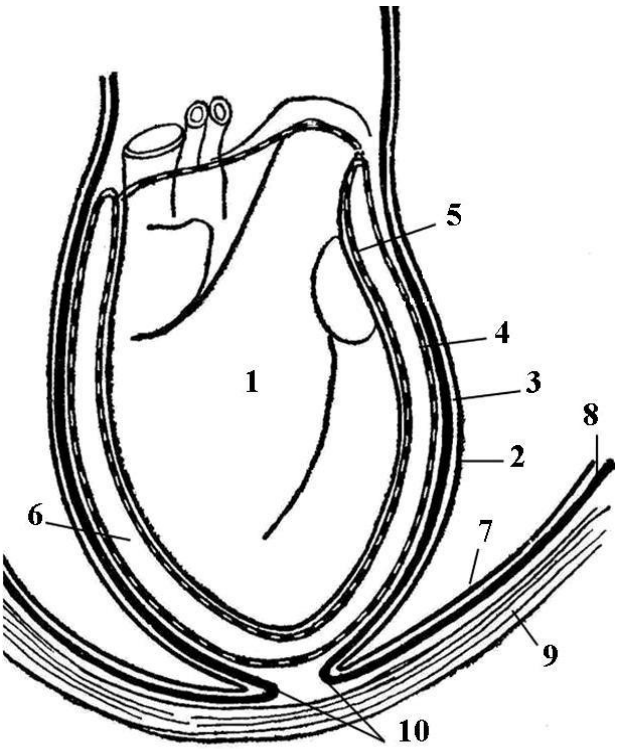
*The apex of the heart belongs to the left ventricle.*

## PERICARDIUM

The heart is almost completely invested by and fits snugly in the pericardium. The **pericardium** makes a fibro-serous sac, but its very tight fit around the heart reduces the lumen to a mere capillary space that contains a small amount of serous fluid to facilitate the easy movement of the heart wall in the pericardial sac.

The pericardium is divided into two parts: ***fibrous (outer)*** *and* ***serous (inner).*** The **serous pericardium** (pericardium serosum) consists of **two** layers ***(parietal*** and ***visceral).*** They form a closed pericardial cavity (cavum pericardii) that contains the liquor pericardii. The visceral and parietal layers of the pericardium continue into each other at a complicated reflection that runs over the atria and the roots of the great vessels. The *visceral layer* (lamina visceralis) is so closely adherent to the heart muscle that it forms the ***external tunic*** or ***epicardium*** of the heart.

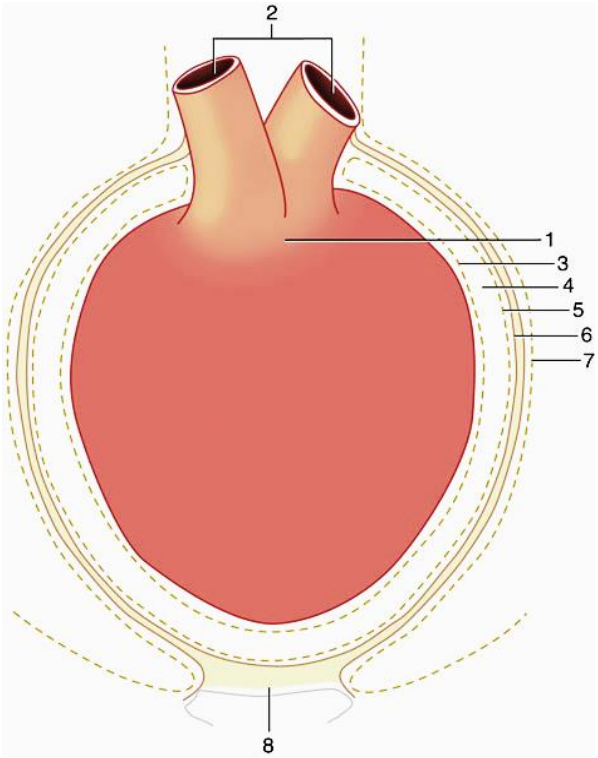
The parietal layer (lamina parietalis) covers the inner surface of the fibrous pericardium and so tightly connected to the fibrous pericardium that it is impossible to separate them.




**Scheme of the pericardium**

*1 — heart*
*2 — pericardial pleura*
*3 — fibrous pericardium*
*4 — parietal layer of serous pericardium*
*5 — epicardium (visceral layer of serous pericardium)*
*6 — pericardial cavity*
*7 — costal pleura*
*8 — fibrous pericardium*
*9 — thoracic wall*
*10 — sternopericardiac ligament*

The **fibrous pericardium** (pericardium fibrosum) is a thin, strong fibrous sac. Its outer surface is covered by the pericardial pleura. The inner surface of the fibrous pericardium is lined by the parietal layer of the serous pericardium. It blends with the adventitia of the great vessels dorsally and forms a ligament at the ventral apex of the sac to attach to the sternum (*sternopericardial ligament* – lig. sternopericardiacum).



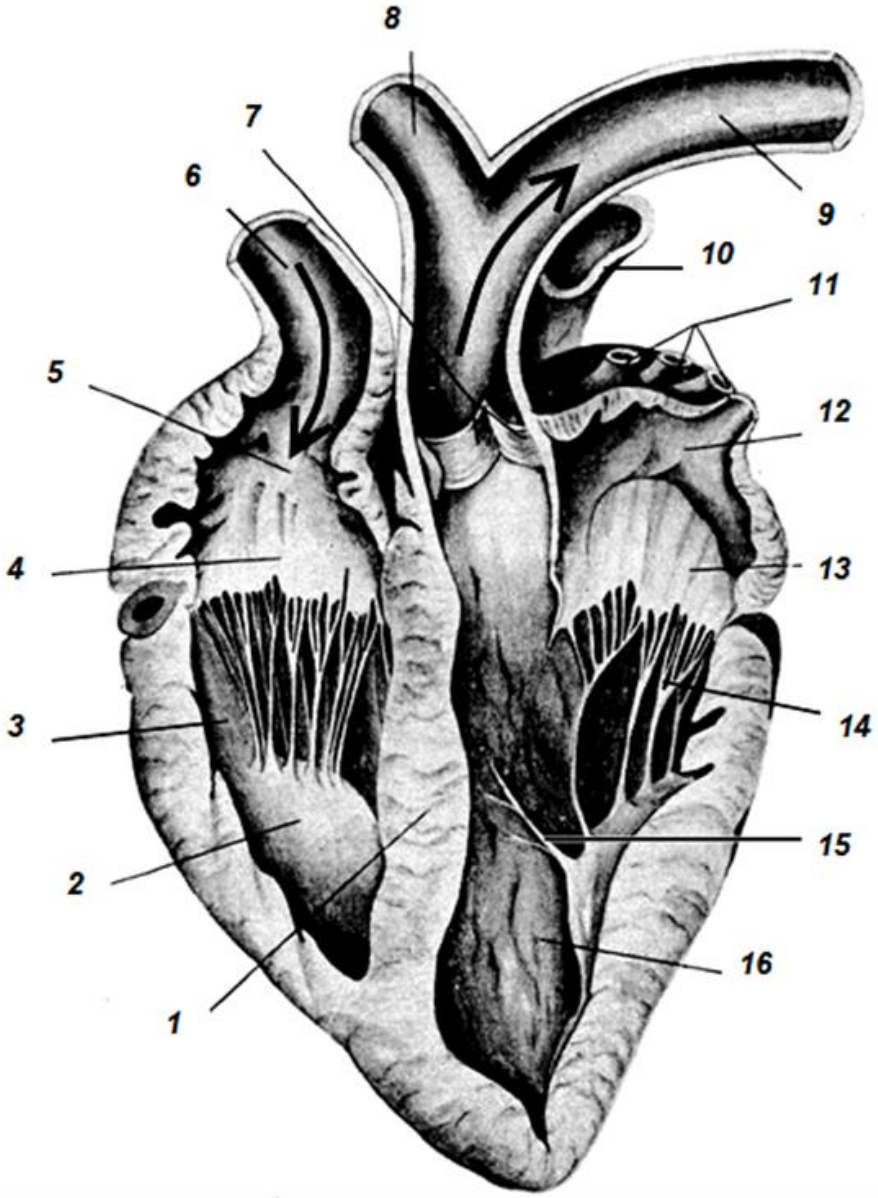

These attachments place severe restraint on the mobility c the heart, although sligh movement does occur with eac respiratory excursion.

**Schematic illustration of the pericardium**

*1 – heart; 2 – great vessels; 3 – epicardium; 4 – pericardial cavity (exaggerated in size); 5 – parietal layer of serous pericardium; 6 – fibrous pericardium; 7 – mediastinal pleura; 8 – sternopericardial ligament.*

## CHAMBERS OF HEART

The heart is separated by the interatrial and interventricular septum into two parts (right and left).




**Chambers of heart**

*1 – interventricular septum, 2 – papillary muscle, 3 – right ventricle, 4 – right atrioventricularvalve, 5 – right atrium, 6 – cranial vena cava, 7 – aortic valve, 8 – brachiocephalic trunk, 9 – aortic arch, 10 – caudal vena cava, 11 – pulmonary veins, 12 – left atrium, 13 – left atrioventricular valve, 14 – chordae tendineae, 15 – transverse muscle,16 – cavity of the left ventricle.*

Each of them is divided transversely into the blood-receiving chambers, the **atria**, and the pumping chambers, the **ventricle**s:

- atrium of heart (atrium cordis dexter et sinister)
- ventricle of heart (ventriculus cordis dexter et sinister)

The ***left atrium*** (atrium sinistrum) receives blood from the lungs and the ***left ventricle*** (ventriculus sinister) pumps it to all parts of the body (systemic circulation).

The ***right atrium*** (atrium dextrum) receives blood from all parts of the body and right ventricle (ventriculus dexter) pumps it to the lungs (pulmonary circulation).

The atria and ventricles are communicated through the *atrioventricular orifices* (right and left) which are located at the level of the coronary groove. The cronary groove contains the main trunks of the coronary vessels within a concealment of fat.

On the interatrial wall is a slitlike depression, the fossa ovalis. There is an opening at the site of the fossa in the fetus, the foramen ovale, which allows blood to pass from the right to the left atrium. The foramen usually closes during the first few postnatal weeks.

## VESSELS ASSOCIATED WITH CHAMBERS OF HEART

The **aorta** leaves the left ventricle near the center of the base of the heart. It is a heavily walled vessel through which all the systemic blood of the body passes. All of the large systemic arteries arise directly from it.

The **pulmonary trunk** (truncus pulmonalis) leaves the right ventricle and its branches are the only arteries in the body which carry unaerated (venous) blood. It divides into the right and left pulmonary arteries.

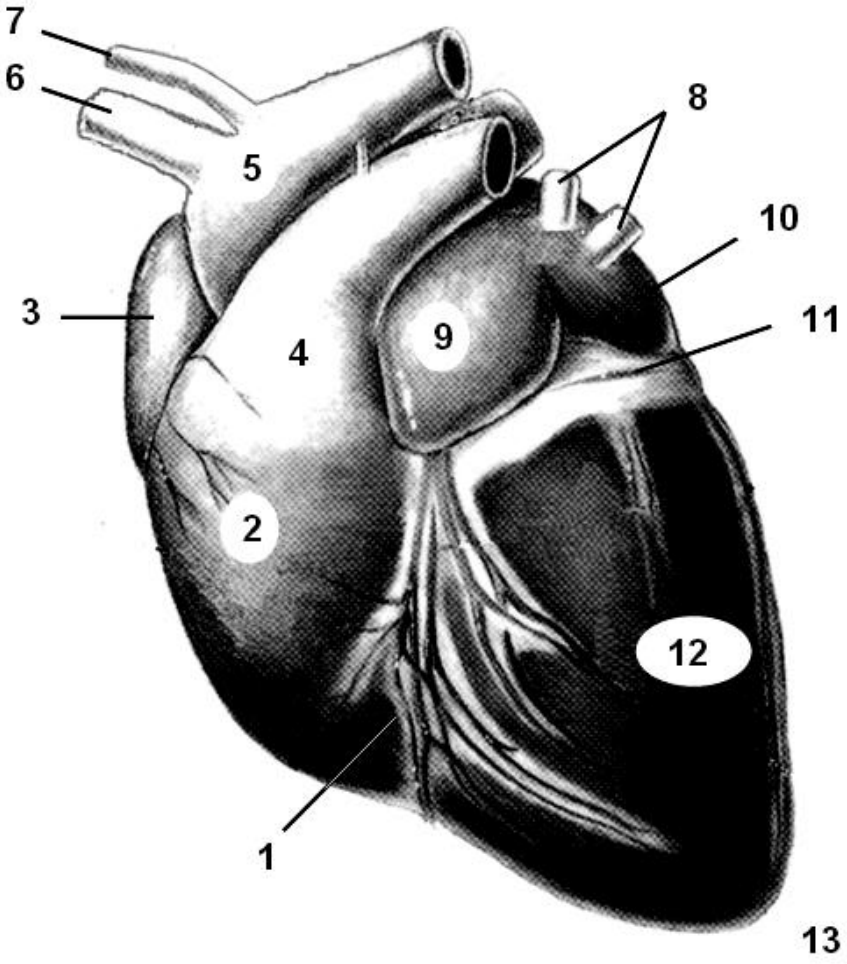
Veins are blood vessels that carry blood from the periphery to the atria of the heart. The **cranial and caudal venae cavae** (vv. cava cranialis et caudalis) return unaerated (venous) blood from the whole body (excluding the heart wall) to the right atrium.

The opening of the cranial vena cava is called the ***venous sinus*** (sinus venarum cavarum).

The **great cardiac vein** returns blood from the heart wall into the right atrium also. The terminal end of the great cardiac vein is

named the ***coronary sinus*** (sinus coronarius). **Small cardiac veins** empty into the right atrium through openings between the mm. pectinati. Accordingly, ***four vesells*** are opening into the right atrium.

The **pulmonary veins** (vv. pulmonales) are valveless and return aerated (arterial) blood from the lungs to the left atrium.




**Heart of dog**

*1 – left atrioventricular groove, 2 – right ventricle, 3 – right auricle, 4 – pulmonary trunk, 5 – aorta, 6 – brachiocephalic a., 7 – the left subclavian a., 8 – pulmonary vv., 9 – left auricle, 10 – left atrium, 11 – coronary groove, 12 – left ventricle, 13 – apex of the heart.*

## VALVULAR APPARATUS OF HEART

Valvular apparatus of heart provides movement of blood in one direction: from the atria to the ventricles and from the ventricles into the aorta and pulmonary trunk.

Valves close atrioventricular and arterial orifices of the heart.

The ***atrioventricular valves*** (valvae atrioventriculares) are irregular, serrated cusps which are located in the atrioventricular ostia. They prevent blood from returning to the atria during the systolic phase of the heartbeat. The free ends of the valves are kept from being pushed into the atria by the tendinous chords (***chordae tendineae)***. Chordae tendineae connect to ***papillary muscles*** (musculi papillares) that located on the inner wall of the left ventricle.

The right atrioventricular orifice (ostium atrioventriculare dextrum) is the large opening from the right atrium into the right ventricle. It is closed by ***tricuspid valve*** *(valva tricuspidalis).* The left atrioventricular orifice is closed by ***bicuspid (***mitral***) valve*** (*valva bicuspidalis (mitralis)).*

### Aortic and Pulmonary Valves

The ***aortic valve*** (valva aortae) consists of three semilunar cusps, or valvulae (valvulae semilunares). This immediately forces the cusps together, closing the valve, thus retaining the blood in the aorta and allowing the left ventricle to fill from the atrium.

The ***pulmonary valve*** (valva trunci pulmonalis) is similar to aortic valve.

## FIBROUS SKELETON OF HEART

The fibrous skeleton of the heart, or “cardiac skeleton”, is the fibrocartilagenous tissue, which separates the thin atrial muscle from the thick muscle of the ventricles. It is formed mainly by the conjunction of the fibrous rings (annuli fibrosi) that encircle the four heart orifices. The skeleton contains islands of fibrocartilage in which nodules of bone (ossa cordis) may develop. Although these bones appear precociously in the hearts of cattle, they are not confined to this species, as is sometimes suggested.

There are two types of narrow rings: first one surrounds the atrioventricular orifices (annulus fibrosus atrioventricularis dexter and sinister), and second one surrounds the arterial orifices. The

aortic fibrous ring (anulus fibrosus aorticus) is the better developed then pulmonary fibrous ring (anulus fibrosus pulmonalis).

Delicate extensions of the fibrous tissue also provide the cores of the cusps of the various valves.

## STRUCTURE OF HEART WALL

The thick middle layer of the wall (**myocardium**) is composed of cardiac muscle, which is a variety of striated muscle peculiar to this organ. It is covered externally by the visceral layer of the serous pericardium (**epicardium)**, and internally by the **endocardium**, a thin smooth-surfaced layer continuous with the lining of the blood vessels. The epicardium is closely attached to the muscular wall.

The **myocardium** is a cardiac muscle It consists of several layers of striated cardiac muscle tissue. The muscular tissue of the atria is almost completely separated from that of the ventricles by the fibrous rings around the atrio-ventrieular orifices.

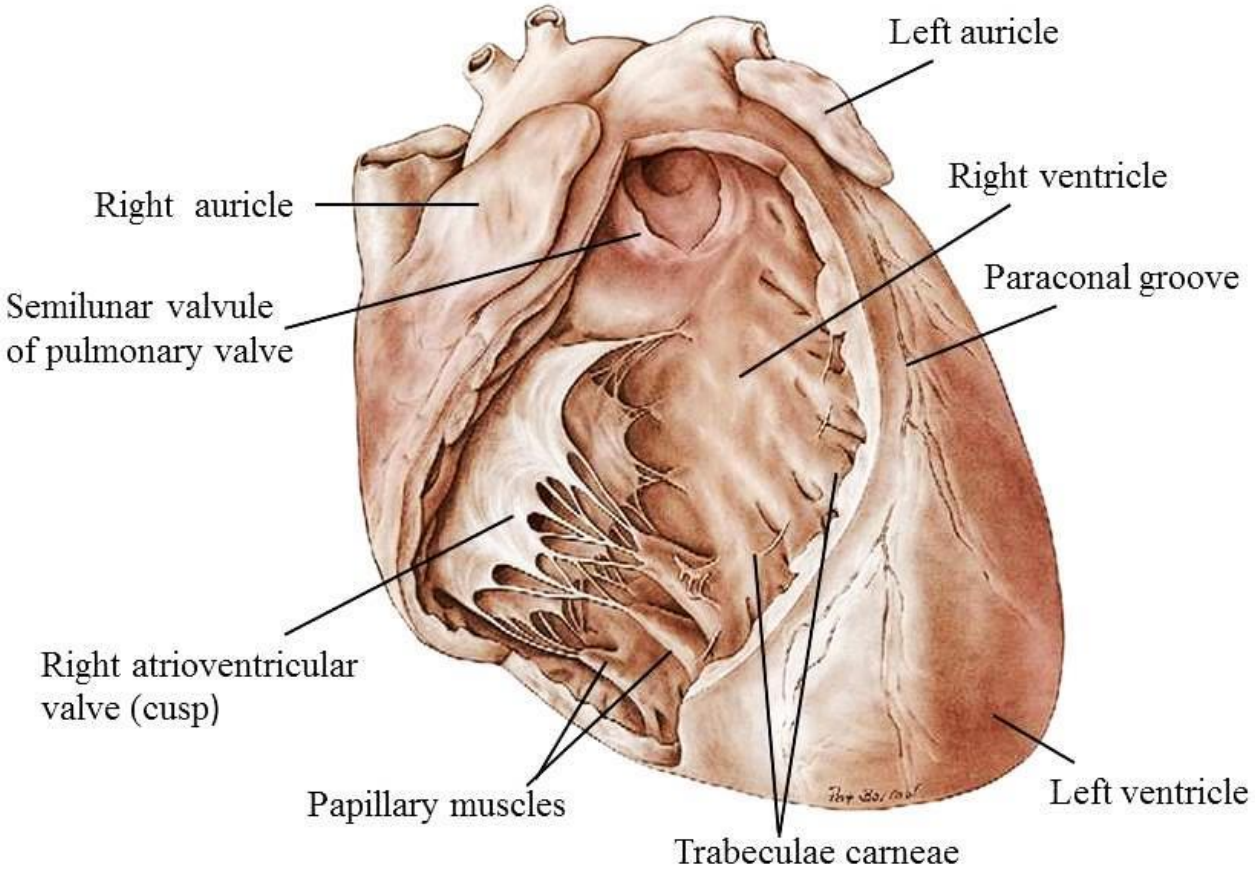
In the atria the muscle bands form the **mm. pectinate**. They are located on internal surface of the wall of the auricles.

The muscular wall of the ventricles is much stronger than that of the atria. That of the left ventricle is in three times as thick as that of the right one. The superficial fibers are attached above to the atrioventricular fibrous rings.

There are some types of the muscles in the ventricles.

The walls of the ventricle bear muscular ridges and bands, termed **trabeculae carneae.** The **papillary muscles** are the conical-shaped muscular projections which continuous at the base with the wall and giving off the chorda tendines to the tricuspid valve. The **septomarginal trabecula** or **moderator band** (trabecula septomarginalis dextra, s. musculi transversi cordis) extends from the interventricular septum to the opposite wall. It prevents over distention of the heart wall.

The **endocardium** lines the cavities of the heart and is continuous with the internal coat of the **vessels** which enter and leave the organ.




**A dissection showing the interior of the right ventricle**

## BLOOD VESSELS OF HEART WALL

Heart vessels (vasa cordis):

- right coronary artery (a. coronaria dextra)
- left coronary artery (a. coronaria sinistra)
- great cardiac vein (v. cordis magna)
- middle cardiac vein (v. cordis media)
- smallest cardiac veins (vv. cordis minimae)

The heart receives its blood-supply through the two **coronary arteries** which arise from the aorta opposite to the cusps of the aortic valve.

The **great cardiac vein** lies in the coronary groove. It opens

into the right atrium below the cranial vein cava. The dilated terminal end of the great cardiac vein is named the **coronary sinus** (sinus coronarius).

The **middle cardiac vein** opens into great cardiac vein.

The **smallest cardiac veins** open into right atria.

## CONDUCTING SYSTEM

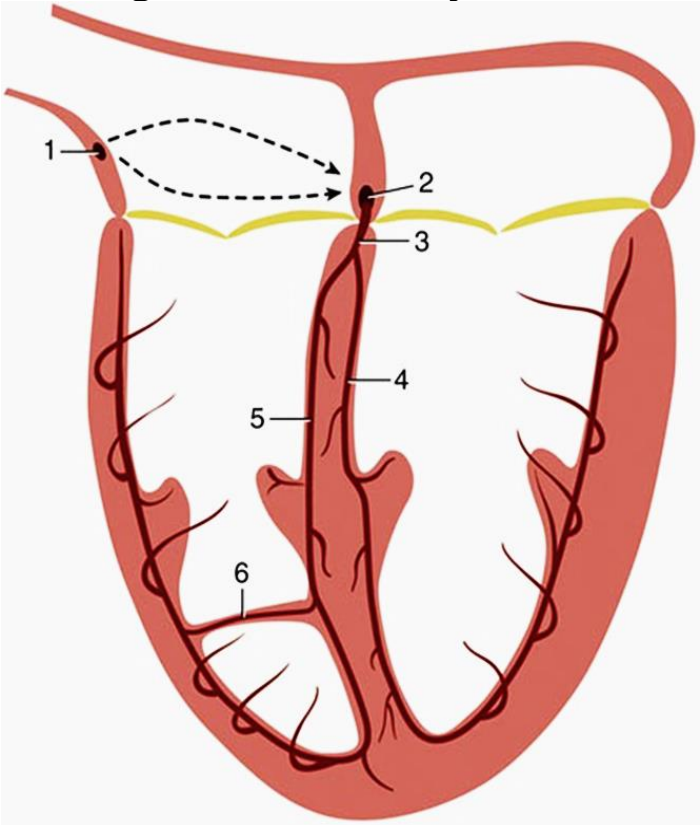
The **conducting system** of heart (systema sinuventricularis cordis – SSC) provides rhythm of the heart. The inherent rhythm of the heart is controlled by a pacemaker, a small, richly innervated **sinoatrial node** of modified cardiac fibers (nodal myofibers).

The conducting system of a heart consists of three parts, which are closely integrated physiologically: (1) the sinuatrial node, (2) the atrioventricular node, and (3) the atrioventricular bundle.

The *sinuatrial node* (nodus sinuatrialis), which is not apparent to the naked eye, lies below the epicardium of the right atrial wall ventral to the cranial caval opening in the *terminal groove*. With each heart cycle a wave of excitation arises in the sinoatrial node and spreads throughout the atrial muscle to reach the *atrioventricular* node. From the atrioventricular node an excitatory stimulus passes rapidly throughout the whole ventricular myocardium via the atrioventricular bundle, which is largely composed of Purkinje fibers, modified cardiac muscle fibers that conduct impulses much more rapidly than those of the common sort. The atrioventricular node consists of modified nodal and Purkinje fibers and is found within the interatrial septum, cranial to the opening of the coronary sinus; it is richly innervated. This node gives origin to the *atrioventricular bundle* (bundle of His), which penetrates the fibrous skeleton before dividing into right and left branches that straddle the interventricular septum

Each branch continues ventrally close to the endocardium and branches to reach all parts of the heart muscle; the right

branch crosses the cavity of the right ventricle by way of the septomarginal band to the outer wall of the right ventricle. The left branch travels to the outer wall of the left ventricle. They disintegrate into Purkinje fibers in the wall of the ventricles.




**Schematic drawing of the conducting system of the heart**

(the broken lines and arrows suggest the passage of the excitation wave through the atrial wall)

*1 – sinoatrial node (pacemaker);*
*2 – atrioventricular node;*
*3 – atrioventricular bundle;*
*4 – left branch;*
*5 – right branch;*
*6 – right branch traversing the septomarginal band.*

## SYSTEMIC ARTERIES

This section presents scheme of branching of the main arterial trunks of the **dog**.

### NOTES TO UNDERSTANDING SCHEME

Schemes demonstrate the branching vessels of the left side of the animal body.

All paired arteries branched similarly.

There are always anastomoses (connecting branches) between two or more arteries going to one organ. It is shown on the scheme by dotted lines.

The same-name left and right arteries that go to one organ anastomosed also.

# ARTERIAL TRUNKS

**AORTA** is a main arterial trunk of the body. It has the following sections:

1. Arch of aorta
2. Thoracic aorta
3. Abdominal aorta
4. Median sacral artery
5. Coccygeal artery

## AORTIC ARCH and THORACIC AORTA (Scheme 1)

**ARCH of AORTA** is an initial section that originates from the left ventricle of the heart to the thoracic aorta. Branch of the first pair of intercostal arteries is the place where it arch changes into thoracic aorta.

The branches of **aortic arch** are following:

- left and right coronary arteries (aa. coronaria cordis dextra et sinistra)
- brachiocephalic artery (a. brachiocephalica)
- left subclavian artery (a. subclavia sinistra)

The blood supply of the *heart wall* leaves the aorta through **left and right coronary arteries**. The coronary arteries arise from the aortic base.

The blood supply *of the head and right side of the neck and the right thoracic limbs* leaves the aorta through **brachiocephalic artery.**

The blood supply of *the left side of the neck* and *the left thoracic limbs* leaves the aorta through **left subclavian artery.**

Brachiocephalic artery gives the left and right common carotid artery (a. carotis communis sinistra et dextra), and continues as the right subclavian artery, which is branched like to

the left subclavian artery.

Subclavian artery (left and right) gives the following branches:

1. Vertebral artery – a. vertebralis
2. Costocervical trunk – truncus costocervicalis
3. Superficial cervical artery – a. cervicalis superficialis
4. Internal thoracic artery – a. thoracica interna
5. External thoracic artery – a. thoracica externa

Branch of the external thoracic artery is the place where it subclavian artery changes into the axillary artery, which is the main artery for the thoracic limbs.

**Vertebral artery** passes in the transverse canal of the cervical vertebrae and anastomoses with the descending branch of the occipital artery close to atlantooccipital joint. It forms a collateral for the common carotid artery.

The vertebral artery gives the following branches at the level of each spine segment:

- spinal branch (ramus spinalis)
- dorsal muscular branch (ramus muscularis dorsalis)
- ventral muscular branch (ramus muscularis ventralis)

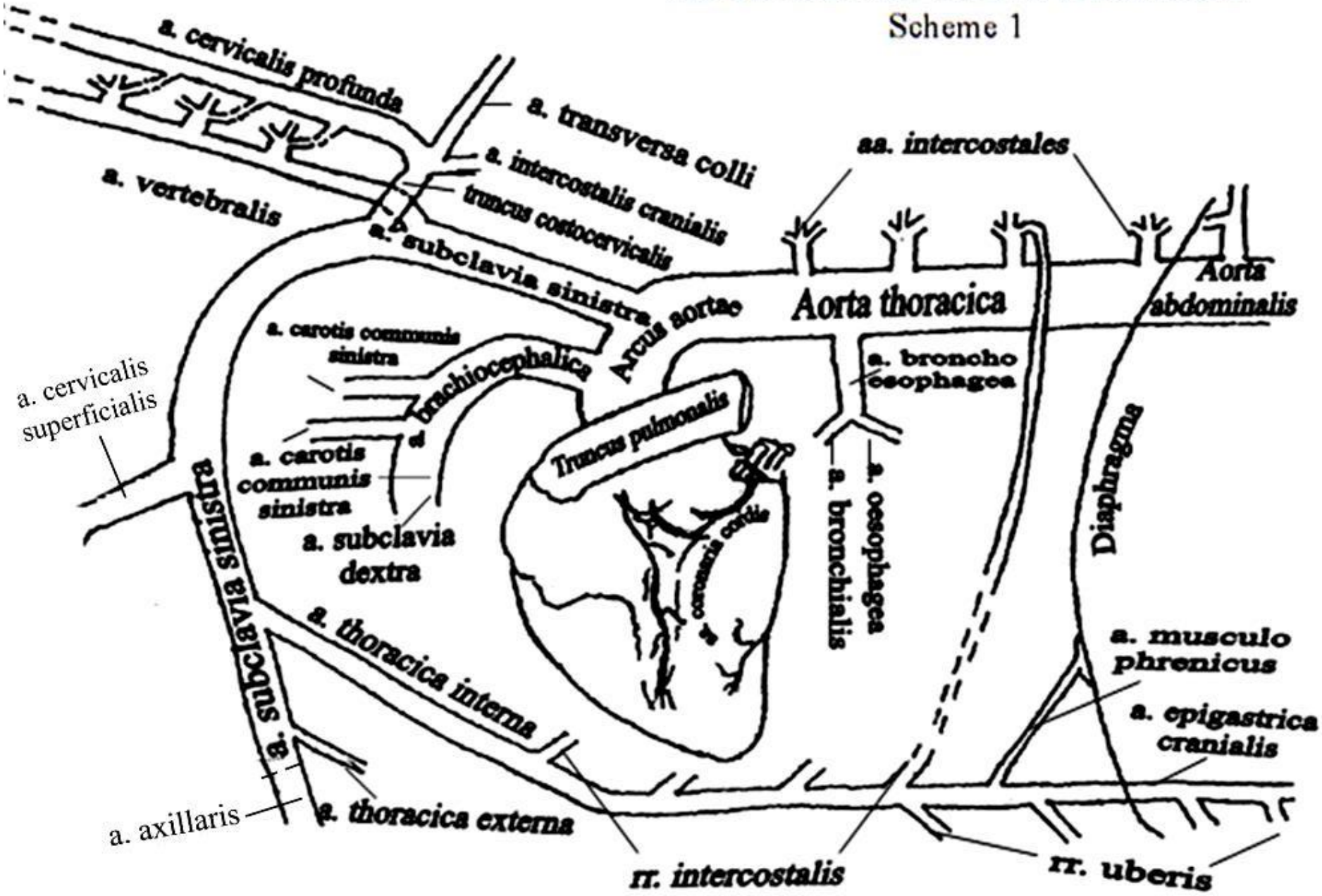
**Costocervical trunk** supplies the nuchal area and dorsal part of ribcage and is a common trunk for the three arteries:

- deep cervical (a. cervicalis profunda)
- transverse cervical (a. transversa colli)
- cranial intercostal (a. intercostalis cranialis)

**Superficial cervical artery** (a. cervicalis superficialis) supplies ventral neck area and the shoulder girdle. It gives the scapular artery (a. transversa scapulae).

## ARCUS AORTAE. AORTA THORACICA

Scheme 1



**Internal thoracic artery** is directed caudally at the dorsal surface of the sternum.

The branches are separated from it:

• intercostal branches (rami intercostales) anastomose with intercostal arteries of the thoracic aorta.

• musculo-phrenic artery (a. musculophrenica)

• branches to the cranial lobes of the mammary gland (rami uberis)

The internal thoracic artery passes through the diaphragm and continues as the cranial epigastric artery. It anastomoses with the caudal epigastric artery on the ventral abdominal wall.

**External thoracic artery** is the final branch of the subclavian artery. It supplies the thoracic muscles.

## THORACIC AORTA

The **thoracic aorta** (aorta thoracica) continues from the aortic arch and enters the abdominal cavity by passing between the obliquely placed crura of the diaphragm, to become the **abdominal aorta**.

The branches of the thoracic aorta are divided into ***visceral*** and ***parietal***.

The visceral branch is a **bronchoesophageal artery**.

The parietal branches are the **intercostal arteries**.

The **bronchoesophageal artery** usually is divides into **bronchial branch** and **esophageal branch** close to the aorta.

The **intercostal arteries** (aa. intercostales) are 7-10 in number on each side.

Each intercostal artery gives off three branches: dorsal, ventral and spinal.

The *dorsal branches* supply the dorsal muscles of the spine and skin (cutaneous branches). It anastomoses with the intercostal arteries of the internal thoracic artery. The *ventral branches* supply

the rib wall. The *spinal branches* supply the meninges of spinal cord.

## ABDOMINAL AORTA

The **abdominal aorta** (aorta abdominalis) is that portion of the aorta which lies in the abdominal cavity. The diaphragm which separates the thoracic from the abdominal cavity is perforated by the aorta.

The abdominal aorta terminates opposite the last lumbar vertebra by bifurcating into:

- *right and left internal iliac arteries* — pelvis (wall and viscera)
- *right and left external iliac arteries* — pelvic limbs
- *middle sacral a.* — becomes *coccygeal a*. of the tail. It is the direct continuation of the aorta caudally, after the internal iliac arteries arise. It gives off two pairs of sacral **spinal branches** (rami spinales), which enter the ventral sacral foramina.

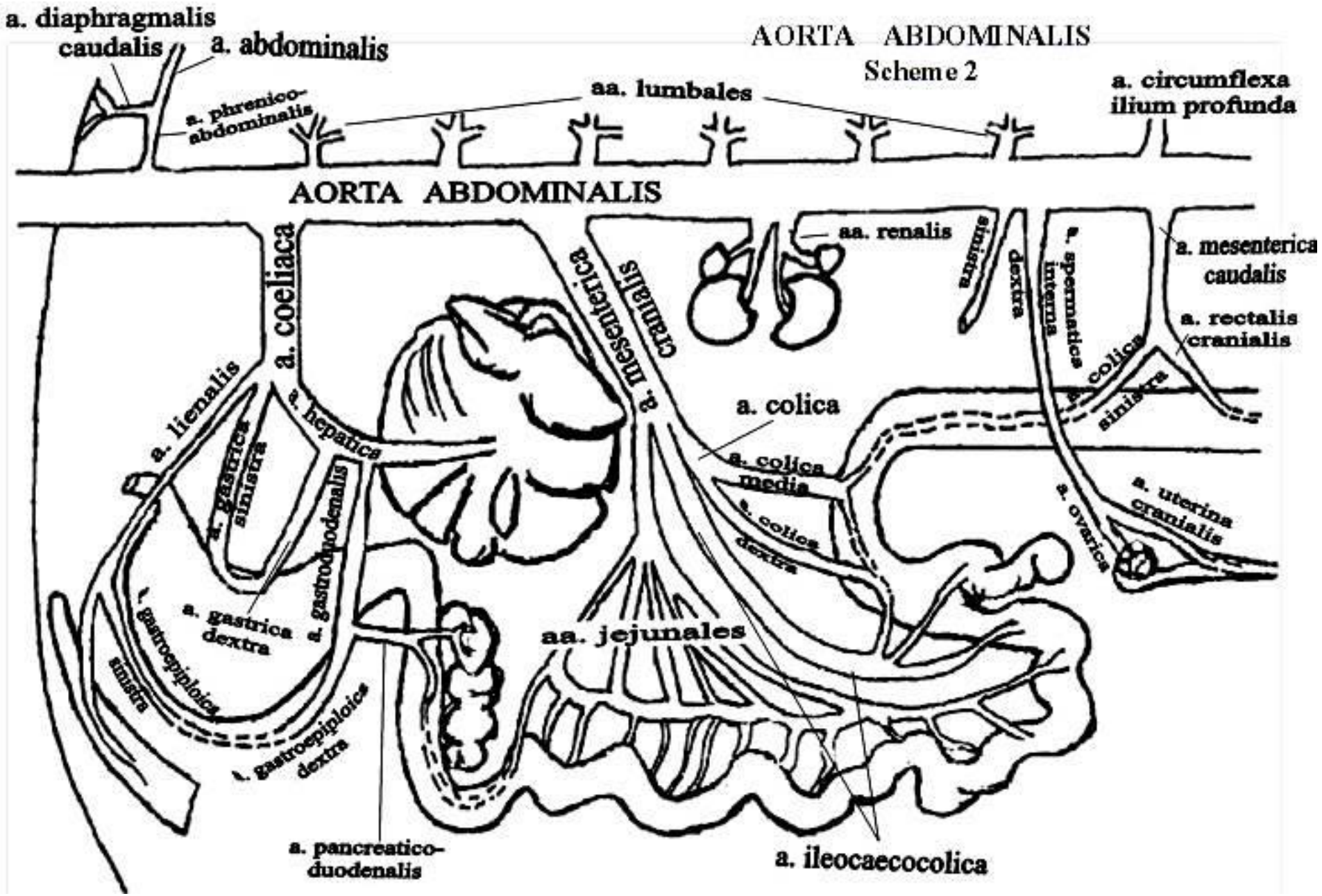
The branches of the abdominal aorta supply both ***visceral*** and ***parietal*** structures.

***Parietal branches*** to the abdominal wall:

1) **phrenicoabdominal a.** *(a. phrenicoabdominalis)* is the common trunk for the phrenic arteries and the cranial abdominal artery. It supplies abdominal wall (via cranial abdominal a.) and diaphragm (via caudal phrenic a.).

2) **lumbar aa.** *(aa. lumbales)* are seven in number. Each artery divides into a *spinal branch* (ramus spinalis), which runs with the nerve into the spinal canal, a *dorsal branch* (ramus dorsalis), which runs dorsally to the dorsal muscles of the lumbar and a *ventral branch* (ramus ventralis), which runs ventrally to the ventral muscles of the lumbar.

3) **deep circumflex iliac a**. *(a circumflexa ilium profunda)* — supply abdominal wall (caudally)


AORTA ABDOMINALIS
Scheme 2
a. diaphragmalis caudalis
a. abdominalis
a. phrenico-abdominalis
aa. lumbales
a. circumflexa ilium profunda
AORTA ABDOMINALIS
a. coeliaca
a. lienalis
a. gastrica sinistra
a. hepatica
a. gastroduodenalis
a. gastrica dextra
a. gastrosplenica sinistra
a. gastroepiploica dextra
a. pancreatico-duodenalis
a. mesenterica cranialis
aa. jejunales
a. ileocaecocolica
aa. renalis
a. testicularis dextra
a. spermatica interna
a. mesenterica caudalis
a. rectalis cranialis
a. colica sinistra
a. colica
a. colica media
a. colica dextra
a. uterina cranialis
a. ovarica

***Visceral branches*** to organs:

1) **celiac a.** — supplies cranial abdominal viscera (esophagus,stomach, duodenum, liver, gall bladder, pancreas, spleen) — the stomach has a quadrant blood supply (right/left & gastric/gastroepiploicaa.)

2) **cranial mesenteric a**.— supplies small and large intestines from duodenum to descending colonalso pancreas.

3) **renal a.** — supplies kidney

4) **internal seminal a.** (ovarian a. or testicular a.) — supplies gonad

5) **caudal mesenteric a**.— supplies descending colon and rectum.

## INTERNAL ILIAC ARTERY

The **internal iliac artery** (a. iliaca interna) is a result from the bifurcation of the aorta under the sixth or seven lumbar vertebra. It terminates as visceral and parietal branches. It gives off parietal branches to the walls of the pelvis and visceral branches to the organs of the pelvic cavity.

***Parietal branches***

1. **Iliolumbar a.** (a. iliolumbalis) supplies the lumbar muscles.

2. **Cranial gluteal a.** (a. glutaea cranialis) supplies the gluteal muscle.

3. **Obturator branch** (r. obturatorius) supplies obturator muscles.

4. **Caudal gluteal a.** (a. glutaea caudalis) is a final branch of the internal iliac a., supplies the femoral extensors of the hip joint.

***Visceral branches***

1. **Umbilical artery (**a. umbilicalis) is divided into:

1.1. **Artery of the ureter** (a. ureterica)

1.2. **Artery of the deferent duct** (a. deferentialis) in male (in female this artery corresponds the **middle uterine a.** (a. uterina media)

1.3. The **cranial vesical a.** (a. vesicalis cranialis)

2. **Internal pudendal a.** (a. pudenda interna), branching into:

2.1. **Urogenital trunk** (truncus urogenitalis) is a common trunk of the two arteries:

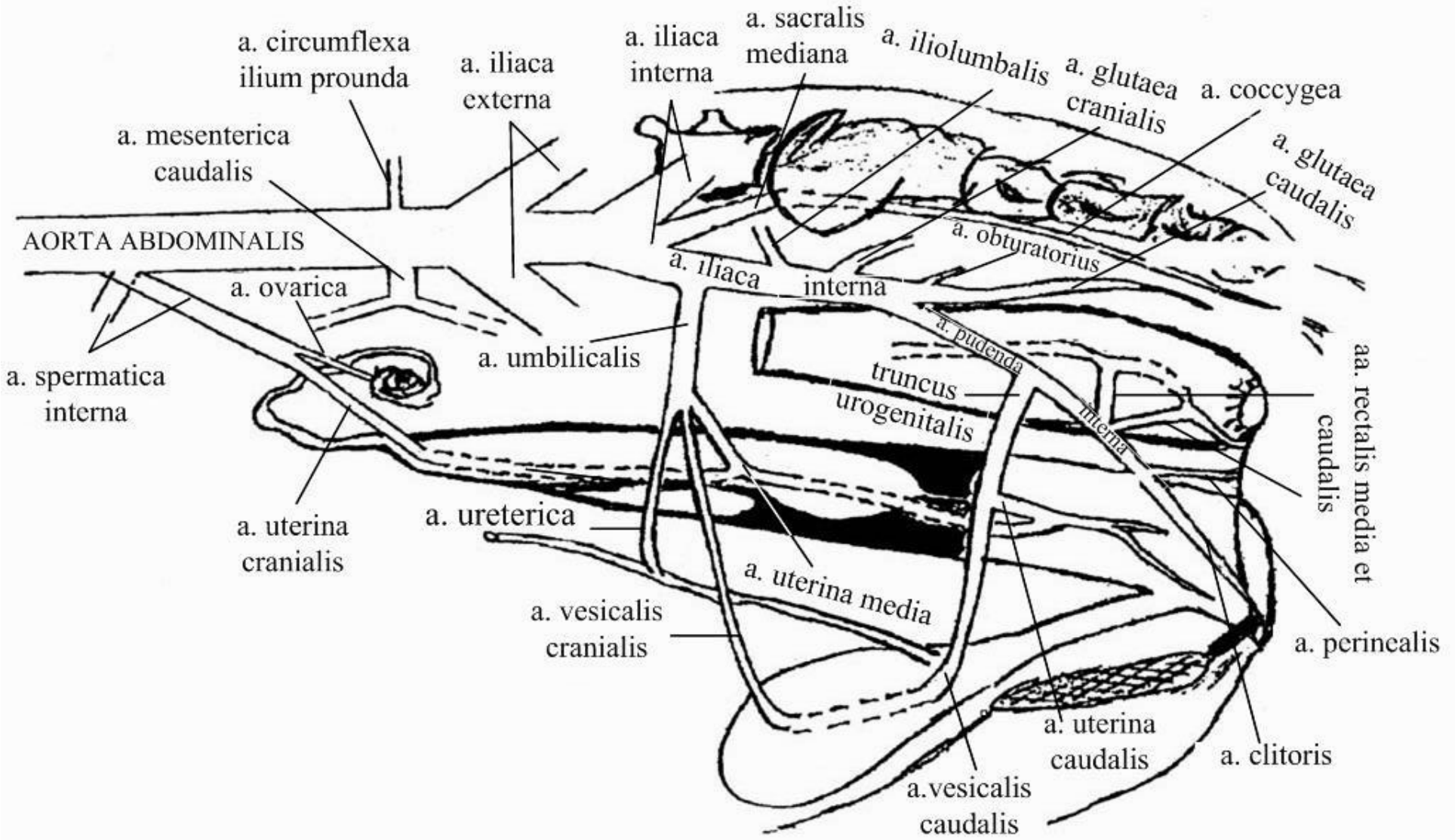
- **caudal vesical a.** (a.vesicalis caudalis) which anastomoses cranial vesical a.
- **arteria of the prostate gland** (a. prostatae). In the female the homologous vessel is much larger and gives off the **caudal uterine artery** (a. uterina caudalis). This runs forward on the side of the vagina, to which it gives branches, and ramifies on the body of the uterus, anastomosing with the cranial and middle uterine aa.

2.2. **Middle and caudal hemorrhoidal aa.** (aa. haemorrhoidalis (s. aa. rectalis) media et caudalis) are anastomosed not only among themselves but also with cranial rectal a. that gives off the caudal mesenteric artery.

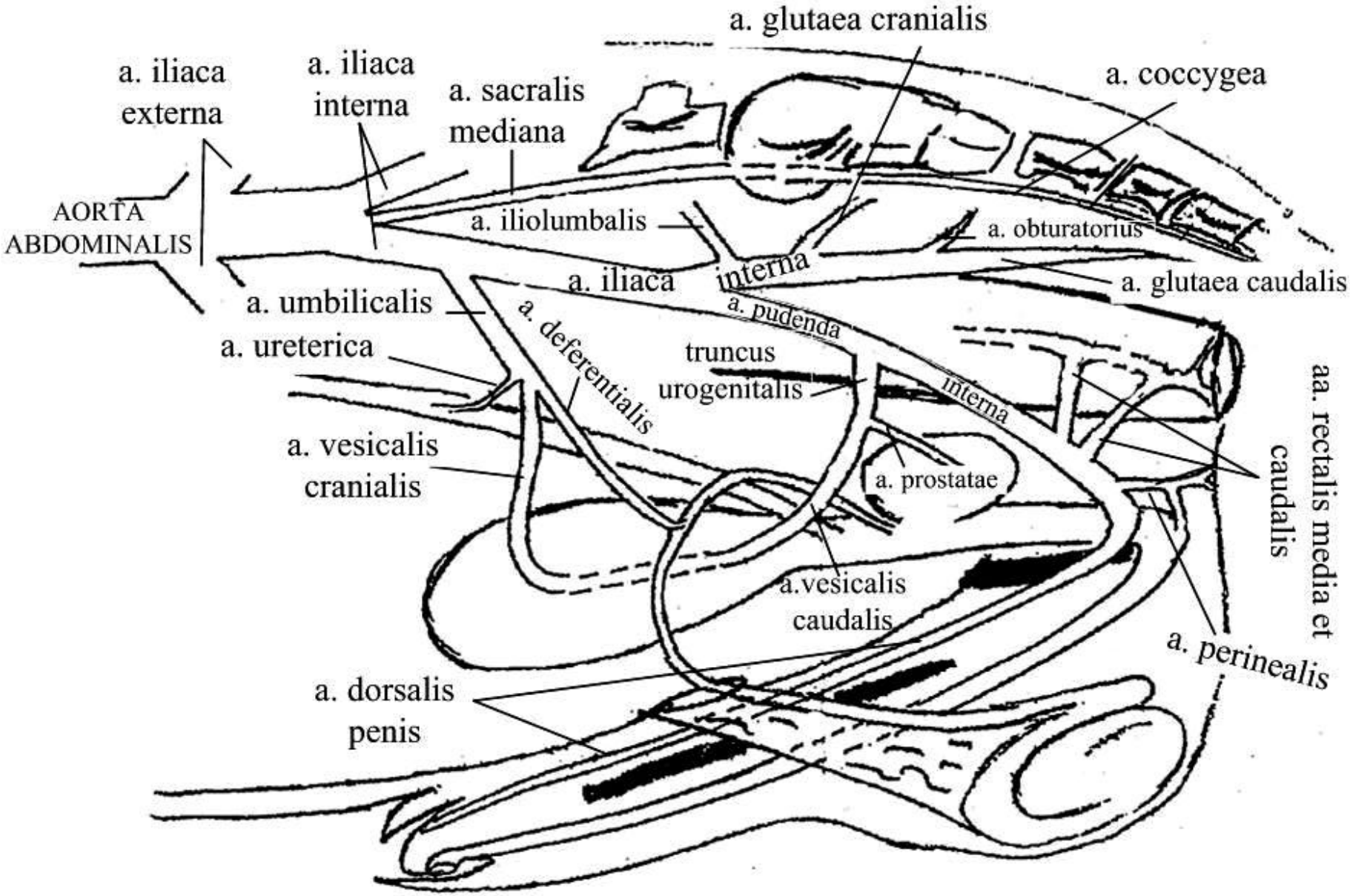
2.3. **Artery of the perineum** (a. perinealis) supplies anus and vulva. It gives off artery of the bulb of the urethra (a. bulbi urethrae) in males and artery of the bulb of the urogenital sinus in the female.

2.4. **Dorsal penile a**. (a. dorsalis penis) is a continuation of the internal pudica. In female this artery corresponds to the **artery of the clitoris** (a. clitoridis). It supplies the clitoris and vulva.

## Scheme 3. ARTERIA ILIACA INTERNA (FEMALE)



**Scheme 4. ARTERIA ILIACA INTERNA (MALE)**



## COMMON CAROTID ARTERIA

The **left and right common carotid arteries** (aa. carotides communes sinistra et dextra) arise from the brachiocephalic artery.

The **common carotid artery** is the main arterial trunk to organs of the head. It lies in the neck visceral space. From it giving branches to the esophagus, trachea, muscles and following arteries:

- **cranial thyroid a.** (a. thyreoidea cranialis), from which branches off the pharyngeal a. (a. pharyngea) which supplies the constrictor muscles of the pharynx.
- **laryngeal a.** (a. laryngea)

The common carotid artery terminates at the level of the atlantooccipital joint by dividing into **internal and external carotid arteries** (a. carotis interna et externa).

The **internal carotid**, much smaller than the external one, leaves the medial side of the parent vessel and runs to the brain. The **external carotid** is the main supply to either half of the head.

The **external carotid artery** (a. carotis externa) is the main continuation of the common carotid to the head. The following branches leave the external carotid artery:

1. **Occipital a.** (a. occipitalis) is the first branch of the external carotid. It is branching into:

1.1. Condylar a. (a. condylaris)

1.2. Caudal artery of the meninges (a. meningea caudalis)

1.3. Spinal a. (a. spinalis)

1.4. Descending branch (r. descendens) is the largest branch of the occipital. It anastomoses with vertebral artery. They form the collateral for the common carotid artery.

2. **Lingual a.** (a. lingualis) is usually the largest collateral branch of the external carotid.

3. **Facial a.** (a. facialis). It arises near the angle of the jaw. The facial artery gives rise to a glandular branch and to muscular branches, before its first large collateral branch, the **sublingual artery** (a. sublingualis) arises. The sublingual artery anastomoses with the lingual artery. The glandular branch is the main supply to the mandibular and sublingual salivary glands. The **arteries of the upper and lower lips (**aa. labialis superior et inferior) are the termination of the facial artery and ramify on the cheek and nose.

4. **Masseteric a.** (a. masseterica)

5. **Great auricular a.** (a. auricularis magna) circles around the caudal half of the base of the ear. It is divided into lateral, intermediate and medial branches which are anastomosing on the edge of the ear.

6. **Superficial temporal a.** (a. temporalis superficialis) is the last branch of the external carotid which continued as the **maxillary artery** (a. maxillaris). The superficial temporal artery gives off the following branches:

6.1. Transverse facial a. (a. transversa faciei)

6.2. Anterior auricular a. (a. auricularis nasalis). It runs between the upper anterior part of the parotid gland and the temporal muscle. It supplies both of these and finally ends in the preauricular muscles.

**The maxillary a.** (a. maxillaris) is a main continuation of the external carotid artery. It gives off many branches which supply the deep structures of the head lying outside of the braincase. For convenience in describing its branches, it may be divided into three parts: the mandibular portion, the pterygoid portion, and the pterygopalatine portion. The mandibular portion extends to the alar canal. The pterygoid portion lies in the canal, and the pterygopalatine portion extends from the alar canal across the pterygopalatine fossa. From it branch off:

1. **Inferior alveolar a.** (a. alveolaris inferior). It runs through the mandibular canal. During its course it sends many small twigs

through the apical foramina to the roots of the teeth (molars, canines and incisors) and others to the bone itself. The final branches of the alveolar artery are the a. incisiva ventralis and a. mentalis.

2. **Middle meningeal a.** (a. meningea media) supplies the dura and adjacent portions of the skull.

3. D**eep temporal a.** (a. temporalis profunda) supplies the temporal muscle

4. **External ophthalmic a.** (a. ophtalmica externa) gives off:

- ramus bulbi
- a. lacrimalis (it terminates in the conjunctiva and skin of the upper eyelid)
- a. frontalis
- a. infratrochlearis

The external ophthalmic artery penetrates through the ethmoidal orifice inside the nasal cavity as the **a. ethmoidalis externa.**

5. **Buccinators a.** (a. buccalis)

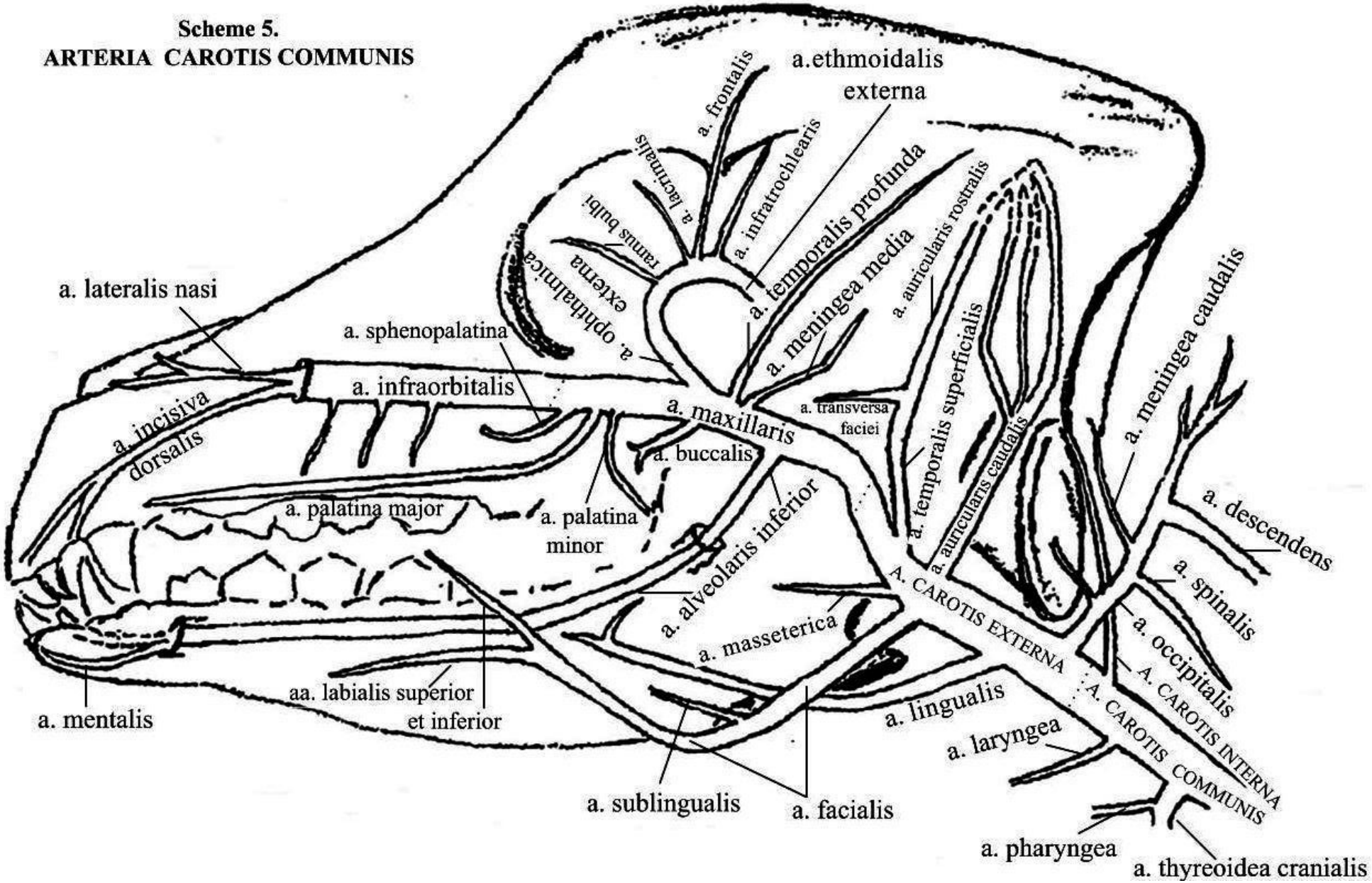
6. **Minor palatine a.** – a. palatinum minor. It is distributed to the adjacent soft and hard palate. It supplies the palatine glands, musculature, and mucosa.

7. **Major palatine a.** (a. palatinum major) supplies the hard palate and sends a branch to the mucosa of the nasal cavity.

8**. Sphenopalatine a.** (a. sphenopalatina) supplies the nasal cavity.

9. **Infraorbital a.** (a. infraorbitalis) is the main continuation of the maxillary. It passes through the maxillary foramen to enter the infraorbital canal. It terminates by dividing into the a. lateralis nasi and a. incisiva dorsalis. The **dental branches** (rr. dentales) arise from the infraorbital a.

**Scheme 5.**
**ARTERIA CAROTIS COMMUNIS**



## EXTERNAL ILIAC ARTERY

The **external iliac artery** (a. iliaca externa) is a largest parietal branch of the abdominal aorta. This paired vessel arises from the lateral surface of the aorta ventral to fifth lumbar vertebra, usually just in front of the origin of the internal iliac.

External iliac artery gives a **deep femoral artery** (a. profunda femoris) and passes into the **femoral artery** (a. femoralis).

**Deep femoral artery** is located caudo-ventrally to the thigh muscles. It gives the following branches:

1. **Pudendo-epigastrical trunk** (truncus pudendo-epigastricus), which gives in order the following branches:

1.1. **Caudal epigastric artery** (a. epigastrica caudalis) supplies the abdominal muscles and anastomoses with the cranial epigastric artery. It is ventral collaterals of the abdominal aorta.

1.2. **External pudenlal artery** (a. pudenda externa) supplies the prepuce (foreskin) and scrotum in males and mammary gland in females.

1.3. **External spermatic artery** (a. spermatica externa) supplies the vaginal tunic of testes. It is absent in female.

2. **Medial circumflex femoral artery** (a circumflexa femoris medialis) anastomosis with a **circumflex lateral** artery in the muscles of the hip joint.

3. **Obturator branch** (ramus obturatorius)

The **femoral artery** (a. femoralis) passes through the medial surface of the thigh.

From femoral artery are given:

1. **Cranial femoral artery** (a. femoris cranialis).

2. **Lateral circumflex femoral artery** (a. circumflexa femoris lateralis) goes off with the cranial femoral artery

(a. femoris cranialis). Both arteries supply hip flexors and knee extensors.

3. **Caudal femoral arteries** (in dogs three in number) proximal, middle and distal (a. femoris caudalis proximalis media et distalis) supply the flexor of knee joint.

4. **Artery saphena** (a. saphena) supply the skin of the crus and pes. It is divided into dorsal and plantar branches.

4.1. **Dorsal branch** (ramus dorsalis) goes under the skin to the pes and is divided into **common dorsal finger arteries** (aa. digitales communes dorsales). Each of them is branching to **special dorsal finger arteries** (aa. digitales dorsales propriae lateralis et medialis).

4.2. **Plantar branch** (ramus plantaris) gives the plantar arteries. It divides into **common planar finger arteries** (aa. digitales plantares communes) Each of them is branching to **special plantar finger lateral** and **medial arteries** (aa. digitales plantares propriae lateralis et medialis).

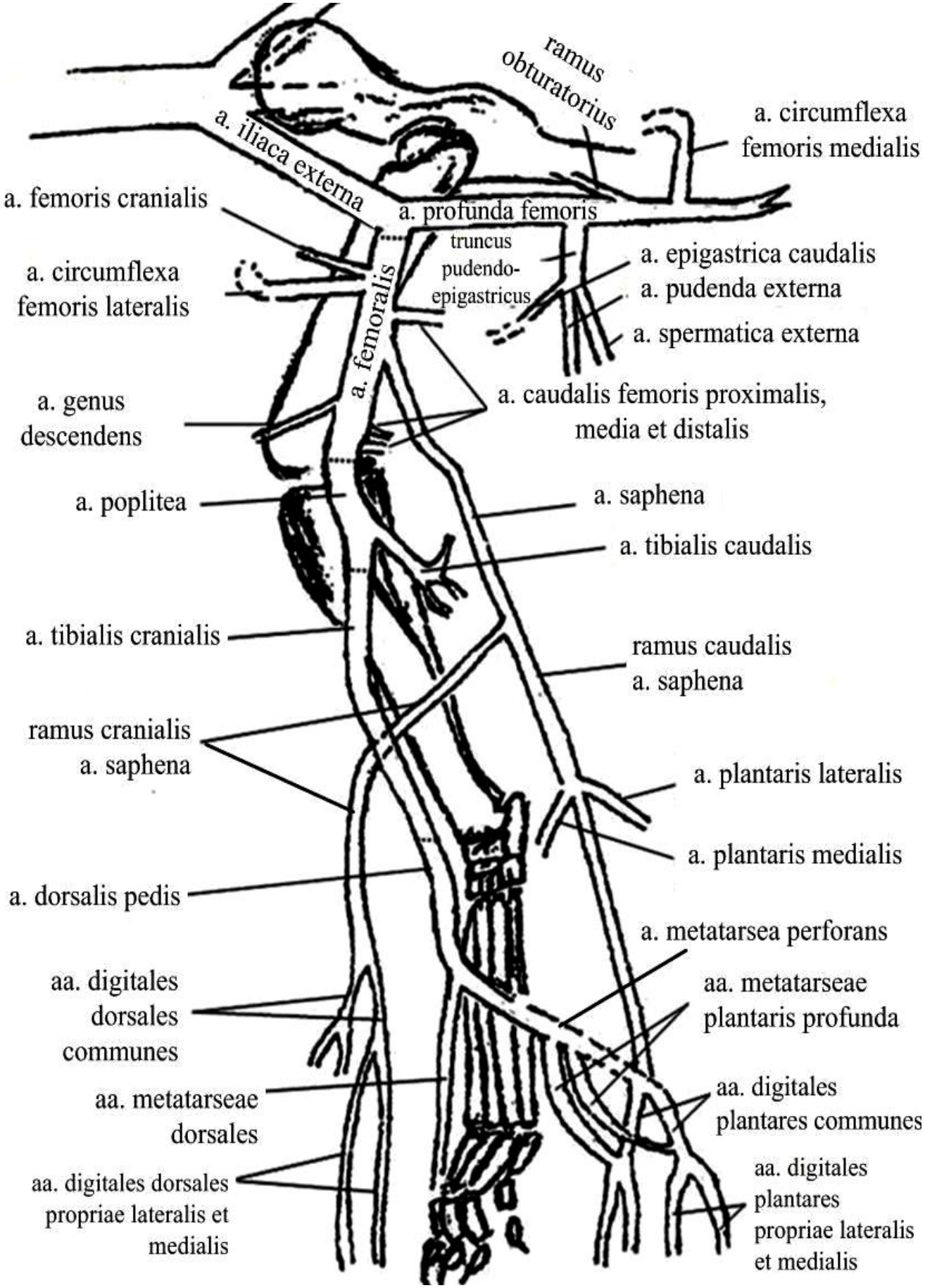
5. **Proximal knee artery** (a. genus suprema) supply the skin of the medial surface of the knee joint.

The **femoral artery** passes into the **popliteal artery** at level of the knee.

Popliteal artery (a. poplitea) gives posterior tibial artery (a. tibialis posterior) and passes into anterior tibial artery (a. tibial anterior).

Anterior tibial artery passes into the dorsal artery of pes (a. dorsalis pedis) at level of metatarsi. It is divided into dorsal metatarsal arteries (a. metatarsea dorsales).

## Scheme 6. ARTERIA ILIACA EXTERNA



## AXILLARY ARTERY

**Axillary artery** (a. axillaris) is a continuation of the subclavian artery and extends from the cranial border of the first rib to the distal border of the conjoined tendon of the teres major and latissimus dorsi muscles.

It is a main arterial trunk for thoracic limb.

At the level of the shoulder joint, it giving off the **subscapular artery** (a. subscapularis), that passes into the brachial a. (a. brachialis).

The subscapular artery supplies the shoulder girdle and ribcage. Its branches are as following:

1. Circumflex lateral artery of brachium (a. circumflexa humeri lateralis) is anastomosed with the same medial artery.
2. Thoracodorsal artery (a. thoracodorsalis) is anastomosed with the fifth intercostal artery.
3. Circumflex artery of scapula (a. circumflexa scapulae).
4. Artery of the triceps brachium (a. tricipitis).

Brachial artery (a. brachialis) lies on the medial surface of the brachium and partially the forearm. The branches of the brachial artery feed the area of the arm, forearm and manus.

From the brachial artery are arising:

1. Circumflex medial artery of brachium (a. circumflexa humeri medialis) is anastomosed with the same lateral artery and circumflex scapular artery.

2. Deep brachial artery (a. profunda brachii).

3. Artery of the biceps (a. bicipitalis).

4. Superficial radial a. (a. radialis superficialis) is divided into two branches (medial and lateral) in the forearm region:

5. Collateral ulnar artery (a. collateralis ulnaris) gives an artery to the humerus (a. nutritia humeri).

6. Collateral radial artery (a. collateralis radialis) supplies the extensors of manus and fingers.

7. Recurrent ulnar artery (a. ulnaris recurrens) nourishes the flexors of the wrist and fingers.

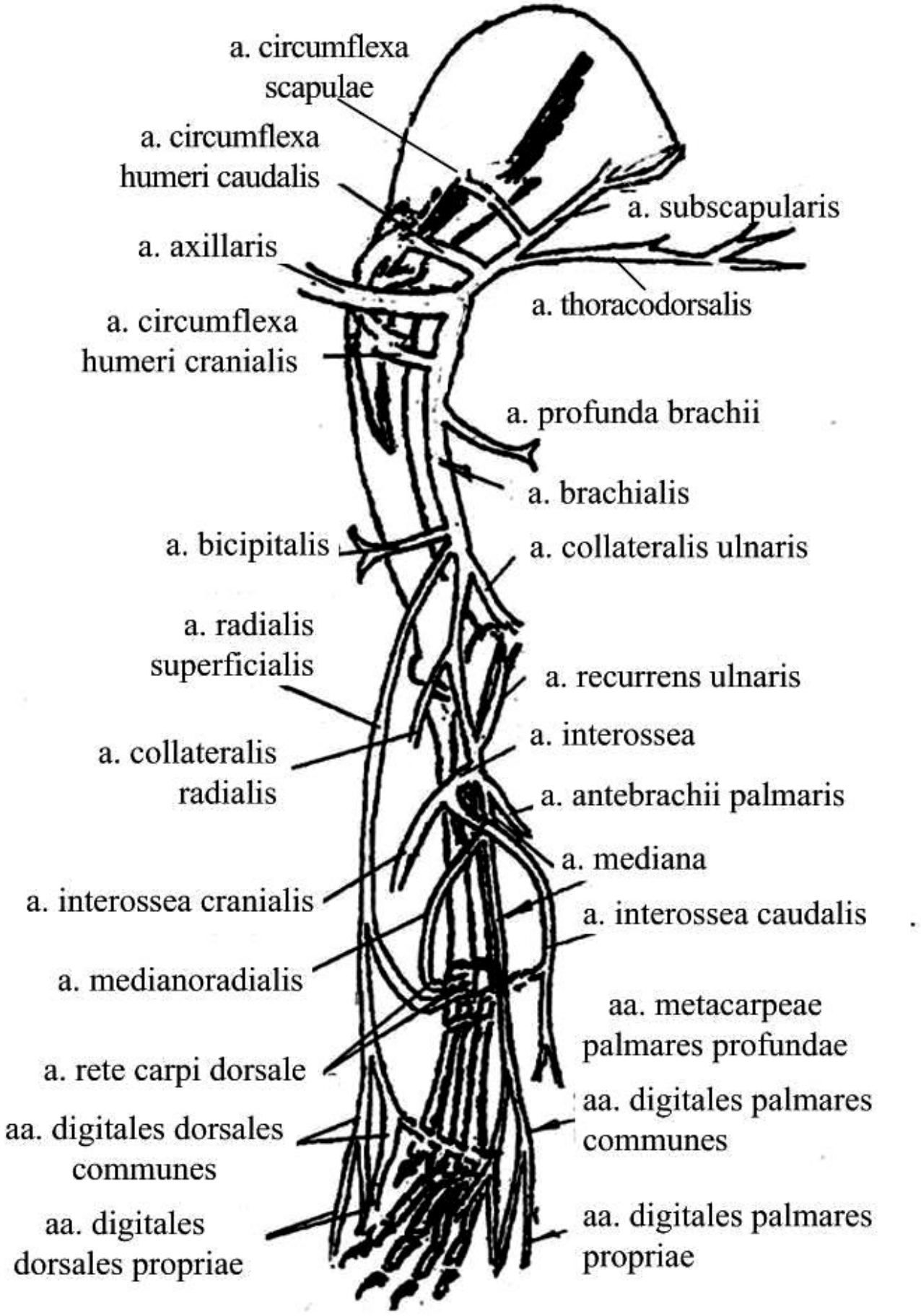
8. General interosseous artery (a. interossea communis) is the last branch of the brachial a. It divided into dorsal interosseous artery (a. interossea dorsalis) and palmar interosseous artery (a. interossea palmaris).

The median artery (a. mediana) is a continuation of the brachial artery. It lies on the medial surface of forearm and gives:

- a. antebrachii palmaris
- a. medianoradialis
- a. rete carpi dorsale

At level of wrist the median artery is divided into common palmar finger arteries (aa. digitales palmares communes) which in turn branch into special palmar finger arteries (aa. digitales palmares propriae).

## Scheme 7. ARTERIA AXILLARIS



## VEINS

Veins follow the same general course as do the arteries.

The accompanying veins are known as ***satellite*** veins, or *venae comitantes,* and often take the same name as the artery they accompany. Although the smaller satellite veins are frequently double, the larger veins are single, as are most of the deep veins.

All systemic veins have *thin walls*, and most have *large lumina* in comparison with the arteries. The pressure in the veins is low, and the blood flows much more slowly in them than in the arteries. Since there is generally no pulse in the venous system, the movement of blood depends primarily on pressure relations in the thorax and on muscular activity. The contraction of muscles results in compression of the veins, thus propelling the contained blood toward the heart.

*Negative pressure* in the thorax during inspiration and the *presence* in most veins of *semilunar valves* which *prevent* back flow augment this effect of the skeletal and visceral muscles. Veins farthest from the heart contain the most valves.

The venous passages in the dura of the central nervous system are known as ***sinuses***.

In the extremities, the veins may be divided into *superficial* and *deep* sets. The veins of the superficial set are large and are clinically important because of the frequent necessity of making venipunctures. In this location they act in cooling the blood as they communicate not only with the deep veins but also with extensive subcutaneous, interconnecting venous plexuses. When the animal is cooled, these plexuses and the larger superficial veins contract so that most of the blood from the extremities must be returned to the heart via the deep veins; this prevents heat loss. When the animal is warmed, and during work, in short-haired specimens the superficial veins and their connecting plexuses dilate and are plainly visible beneath the skin; this dilatation provides a means of heat dissipation.

*There are **fiv**e venous system in the organism.*

The ***veins of systemic circulation*** form **fou**r system:

- cardiac vein
- cranial cava vein
- caudal cava vein
- portal vein

The ***system of pulmonary veins*** is a part of ***pulmonary*** *(or small)* ***circulation***.

## PULMONARY VEINS

The terminal **pulmonary veins** (vv. pulmonales), usually seven or eight in number, return the aerated blood from the lungs and open into the left atrium of the heart. They are destitute of valves. Their tributaries arise in the capillary plexuses in the lobules of the lungs, and unite to form larger and larger trunks which accompany the branches of the bronchi and pulmonary arteries.

## SYSTEMIC VEINS

### VEINS OF HEART

It opens into the right atrium just below the cranial vena cava. It is formed by the union of two tributaries. The **great cardiac vein** (v. cordis magna) begins at the left side of the apex of the heart, ascends in the left longitudinal groove and turns backward in the coronary groove, in which it winds around the posterior border of the heart to the right side and joins the coronary sinus. The **middle cardiac vein** (v. cordis media) begins on the right side of the apex, ascends in the right longitudinal groove and opens into the atrium.

The **small cardiac veins** (vv. cordis minores), three to five in number, are small vessels which open near the coronary groove in spaces between the musculi pectinati.

## CRANIAL VENA CAVA

The **cranial vena cava** (v. cava cranialis) returns to the heart the blood from the head, neck, thoracic limbs, and the greater part of the thoracic wall. Its origin is attached to the first pair of ribs. It passes backward in the anterior mediastinum, at first median and ventral to the common carotid trunk and opens into the right atrium opposite to the third rib.

The cranial vena cava is formed by **left and right bijugular trunks** (truncus bijugularis).

The following veins are opened into cranial vena cava:

1. The **left and right internal thoracic veins** (vv. thoracica interna) is a satellite of the artery of that name. It opens into the cranial vena cava at the first rib.
2. The common trunk of **cervical veins** (v. cervicalis profunda) corresponds to the subclavian artery.
3. The **right vena azygos** is an unpaired vessel which arises at the level of the first lumbar vertebra by radicles coming from the psoas and the crura of the diaphragm. Its tributaries are:

- intercostal veins (vv. intercostales)
- esophageal vein (v. esophagea)
- bronchial vein (v. bronchialis)

The following veins are opened into **bijugular trunks**:

1. **Internal jugular vein** (v. jugularis interna)
2. **External jugular vein** (v. jugularis externa)
3. **Cephalic vein of humeri** (v. cephalica humeri). Upon entering the antebrachium it is known as the *antebrachial part of the cephalic vein* (v. cephalica antebrachii)
4. **Axillar vein** (v. axillaris). It is a continuation of the brachial vein. It receives the cranial circumflex humeral vein, lateral thoracic vein, and subscapular vein. The veins of the *forepaw* (manus) like the arteries are divided into a dorsal and a palmar set. These are not as

completely divided into superficial and deep series as are the arteries and only single series exist dorsally and palmary in the digits.

The **external jugular veins** (vv. jugulares esterni), right and left, are formed by fusion **internal and external maxillary veins**. It arises behind the posterior border of the lower jaw below the temporomandibular articulation by the union of the external and internal maxillary veins. Each passes downward and backward and continues in the *jugular furrow*.

The **internal maxillary vein** (v. maxillaris interna) is larger than the external maxillary. Its principal radicles are:

- **dorsal lingual vein** (v. dorsalis linguae), which is a satellite of the lingual nerve
- **inferior alveolar or dental vein** (v. alveolaris inferior), a satellite of the corresponding artery
- **pterygoid veins** (rami pterygoidei)
- **deep temporal vein** (v. temporalis profunda) is a large vessel which receives tributaries from the temporalis muscle. It is connected with the anterior cerebral vein.

The **external maxillary vein** (v. maxillaris externa) begins by the confluence of the **lingual** (v. lingualis) and **facial** (v. facialis) veins ventral to the mandibular gland.

The **internal jugular vein** (v. jugularis interna) lies at first in association with the internal carotid artery and then in the sheath of the common carotid. The *laryngeal, cranial thyroid* and *ventral encephalic veins* open into internal jugular vein.

## CAUDAL VENA CAVA

The **caudal vena cava** (v. cava caudalis) begins in contact with the ventral surface of the seventh lumbar vertebra by convergence of the **left and right common iliac veins** and **median sacral vein**. It directs cranially, passes through the

foramen venae cavae of the diaphragm and terminates in the caudal part of the right atrium.

The parietal and visceral branches go into the caudal vena cava.

***Parietal branches:***

1. **Phrenicoabdominal** vein (v. phrenicoabdominalis).

2. **Lumbar veins** (vv. lumbales) are satellites of the corresponding arteries.

3. **Deep circumflex iliac vein** (v. circumflexa ilii profunda) collects blood from the lateral abdominal wall. It is a satellite of the corresponding artery and lies caudal to it. The superficial and deep tributaries have the same anastomoses as do the comparable arteries.

***Visceral branches***

1. **Internal spermatic veins** (vv. spermatica interna) are paired.

2. **Renal veins** (vv. renales) are paired.

3. **Hepatic veins** (vv. hepaticae) are the final link of the portal circulatory system.

**Common iliac vein** (v. iliaca communis) is formed by internal and external iliac vein.

The right and left common iliac veins are fused into the caudal vena cava.

**Internal iliac vein** (v. iliaca interna) bring blood from the walls and organs of the pelvic cavity. It is a satellite of the according artery.

**External iliac vein** (v. iliaca externa) collects venous blood from the pelvic limbs, abdominal wall, mammary glands. The medial and lateral vena saphena (vv. saphena medialis et lateralis) arise from it.

## PORTAL VEIN

The **portal vein** (v. portae hepatis) or **hepatic portal vein** is a blood vessel that carries blood from the gastrointestinal tract, gallbladder, pancreas and spleen to the liver. This blood contains nutrients and toxins extracted from digested contents. Approximately 75% of total liver blood flow is through the portal vein, with the remainder coming from the hepatic artery proper. The blood leaves the liver to the heart in the hepatic veins.

The portal vein is not a true vein, because it conducts blood to capillary beds in the liver and not directly to the heart. It is a major component of the hepatic portal system. The portal vein conveys blood between two capillary beds (between alimentary tract capillaries and liver sinusoids).

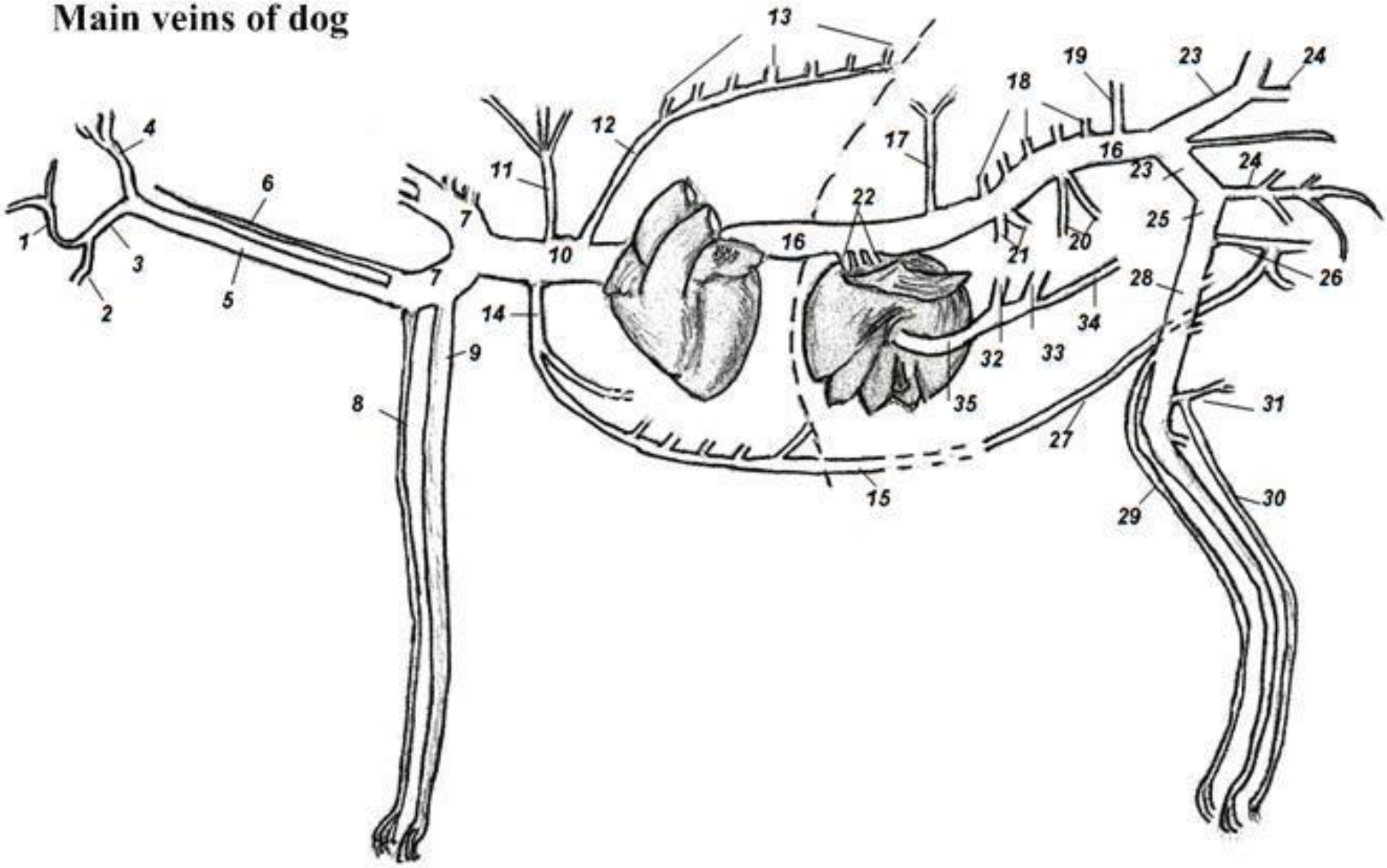
It divides into three branches which enter the liver and ramify in the substance of the gland like an artery, terminating in the lobular capillaries. From the lobules the blood passes into the hepatic veins and through these to the caudal vena cava. Thus the blood which is distributed to the stomach, nearly the entire intestinal tract, the pancreas, and the spleen, passes through two sets of capillaries prior to its return to the heart.

1. The **gastrosplenic vein** (v. gastrolienalis) is formed by the union of two veins: splenic and gasric.
2. The **cranial mesenteric** vein (v. mesenterica cranialis) is the largest of the portal radicles. It is situated to the right of the artery of like name, and its tributaries correspond in general to the branches of the artery.
3. The **caudal mesenteric vein** (v. mesenterica caudalis) is the smallest of the radicles of the portal.

## *Main veins of dog (designation)*

*1 – v. facialis*
*2 – v. lingualis*
*3 – vv. maxillaris externa*
*4 – vv. maxillaris externa*
*5 – v. jugularis externa*
*6 – v. jugularis interna*
*7 – truncus bijugularis*
*8 – v. cephalica humeri*
*9 – v. axillaris*
*10 – vena cava cranialis*
*11 – vv. cervicalis (truncus)*
*12 – v. azygos dextra*
*13 – vv. intercostales*
*14 – vv. thoracica interna dextra et sinistra*
*15 – v. epigastrica cranialis*
*16 – vena cava caudalis*
*17 – v.phrenicoabdominalis*
*18 – vv. lumbales*
*19 – v. circumflexa ilii profunda*
*20 – vv. spermatica interna*
*21 – vv. renales*
*22 – vv.hepaticae*
*23 – v. iliaca communis*
*24 – v. iliaca interna*
*25 – v. iliaca externa*
*26 – v. femoralis profunda*
*27 – v. epigastrica caudalis*
*28 – v. femoralis*
*29 – v. saphena medialis*
*30 – v. saphena lateralis*
*31 – v. femoralis distalis caudalis*
*32 – v. gastrolienalis*
*33 – v. mesenterica cranialis*
*34 – v. mesenterica caudalis*
*35 – v. portae hepatis*

# Main veins of dog



## INDIVIDUAL CREATIVE TASKS
## *WITH ANGIOLOGY*

In order to consolidate the studied material from the vascular system, each student receives an individual creative task. The purpose of the task is to determine the corresponding movement of blood by vessels. Task is based on the specific situation, when a doctor of veterinary medicine injects drugs into the jugular vein of a sick animal, and then, the remnants of drugs are removed from the body via the kidneys.

## *List of individual creative tasks with angiology*

1. To deliver blood from the jugular vein through the knee joint into the kidney.
2. To deliver blood from the jugular vein through the hard palate into the kidney.
3. To deliver blood from the jugular vein through the diaphragm into the kidney.
4. To deliver blood from the jugular vein through the descending colon into the kidney.
5. To deliver blood from the jugular vein through the tongue into the kidney.
6. To deliver blood from the jugular vein through the stomach into the kidney.
7. To deliver blood from the jugular vein through the elbow joint into the kidney.
8. To deliver blood from the jugular vein through the duodenum into the kidney.
9. To deliver blood from the jugular vein through the pancreas into the kidney.
10. To deliver blood from the jugular vein through the bladder into the kidney.
11. To deliver blood from the jugular vein through the scrotum into the kidney.

12. To deliver blood from the jugular vein through testis into the kidney.
13. To deliver blood from the jugular vein through the uterine tube into the kidney.
14. To deliver blood from the jugular vein through the uterus into the kidney.
15. To deliver blood from the jugular vein through the mammary gland into the kidney.

## *Example*

### To Deliver Blood from External Jugular Vein through the Ileum into the Kidney

- Blood from the **external jugular vein** *(v. jugularis externa)* moves caudally into the **bijugular trunk** *(truncus bijugularis)* and into the **cranial vena cava** *(v. cava cranialis)* and back to the heart; the **right atrium**.
- Blood moves from the right atrium into the **right ventricle** through the right atrio-ventricular valve and pulmonary circulation begins; deoxygenated blood is pumped into the **pulmonary trunk** and moves towards the lungs via the left and right **pulmonary arteries**.
- In the lungs, **micro-circulation** takes place; arteries become: arterioles, pre-capillaries, capillaries, post-capillaries, then venules and venous beds are formed. The **pulmonary veins** then take the oxygenated blood back to the heart and deposits into the **left atrium**. Blood moves into the left ventricle through the left atrio-ventricular valve.
- Oxygenated blood is pumped into the **arch of aorta** *(arcus aorta),* and moves on into the **thoracic aorta** *(aorta thoracica)* and past the diaphragm becomes the **abdominal aorta** *(aorta abdominalis).* Blood moves into the **cranial mesenteric artery** *(a. mesenterica cranialis)* and into the

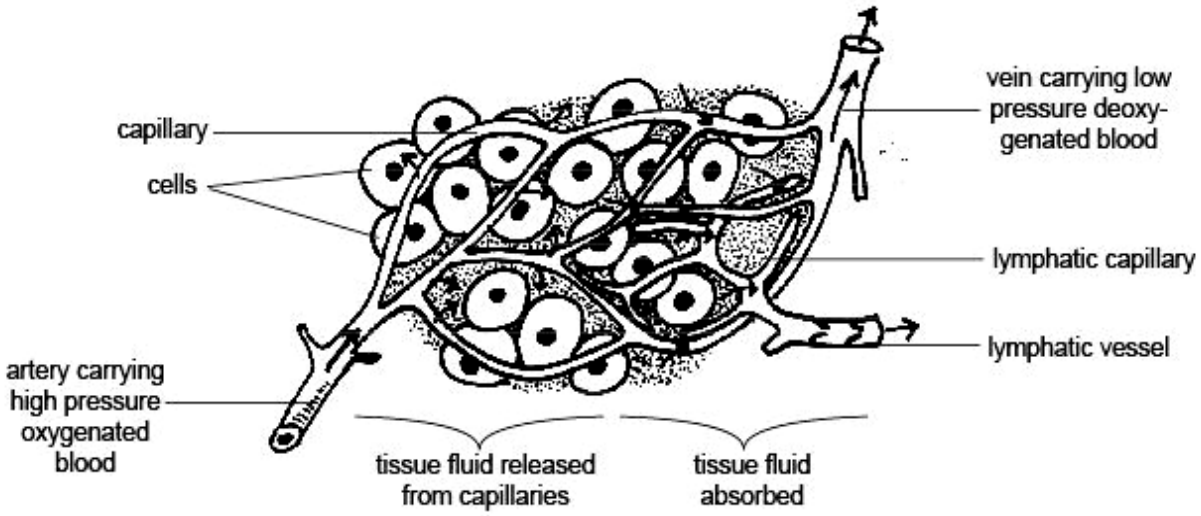
a. ileocaecocolica and reaches the ileum via the **ileal branch** *(ramus ilealis).*

- **Micro-circulation** takes place, i.e. arteries become: arterioles, pre-capillaries, capillaries, post-capillaries, then venules and venous beds are formed. Deoxygenated blood moves into the **ileac branch** *(ramus ileaca)* of the v. ileocaecocolica and on into the **cranial mesenteric vein** *(v. mesenterica cranialis).*
- The cranial mesenteric vein *(v. mesenterica cranialis*) then joins the **hepatic portal vein** *(v. portae hepatis)* which conducts bloods to **capillary beds** (microcirculation) in the liver and blood leaves the liver through the **hepatic veins** which join the **caudal vena cava** *(v. cava caudalis)* and goes back to the heart; **right atrium.**
- Blood moves from the right atrium into the **right ventricle** through the right atrioventricular valve and pulmonary circulation begins; deoxygenated blood is pumped into the **pulmonary trunk** and moves towards the lungs via the left and right **pulmonary arteries**.
- In the lungs, **micro-circulation** takes place; arteries become: arterioles, pre-capillaries, capillaries, post-capillaries, then venules and venous beds are formed. The **pulmonary veins** then take the oxygenated blood back to the heart and deposits into the **left atrium**. Blood moves into the **left ventricle** through the left atrio-ventricular valve.
- Oxygenated blood is pumped into the **arch of aorta** *(arcus aorta),* and moves on into the **thoracic aorta** *(aorta thoracica)* and past the diaphragm becomes the **abdominal aorta** *(aorta abdominalis).* Blood reaches the kidney via the **renal artery** *(a. renalis).*

# LYMPHATIC SYSTEM

The **lymphatic system**, consisting of a network of permeable capillaries, variously sized collecting ducts, a filtering mechanism in the form of lymph nodes, and conducting channels which enter the great veins of the heart, serves as an **adjunct** to the *venous part of the vascular system*.

Pressure within the walls of lymph vessels is lower than that in blood vessels. Lymph flows more slowly than blood. The cell walls of lymph vessels are more permeable than those of the capillary walls of blood vessels. Thus, proteins that may have been delivered to the tissues by the bloodstream but that are too big to reenter the capillaries, along with waste products and large proteins synthesized in the local tissue cells enter the lymphatic vessels for return to the bloodstream. By means of veins and lymphatics the blood and tissue fluid are returned from the capillary bed and tissue spaces to the general circulation. While the blood is traversing from the arterial to the venous side of the capillary bed fluid and proteins escape from it into the tissue spaces. The tissue fluid, which is used in part for cell nutrition, readily enters the lymphatic capillaries, along with foreign particles, if any are present.




**Scheme of the lymph formation process**

The clear, colorless fluid, known as **lymph**, is returned

slowly to the heart via lymphatic ducts which empty mainly into the cranial caval vein.

Although the primary function of the lymphatic system is to return proteins and fluids to the blood, this immune function accounts for the tendency of many infections and other disease processes to cause swelling of the lymph nodes. Bacteria, allergenic particles, and cancerous cells from elsewhere in the body, that have collected in the nodes stimulate lymphocyte proliferation, thereby greatly enlarging the node. Interference with lymphatic flow may cause an accumulation of fluid in the tissues that are drained by the blocked vessel, producing tissue swelling known as *lymphedema*.

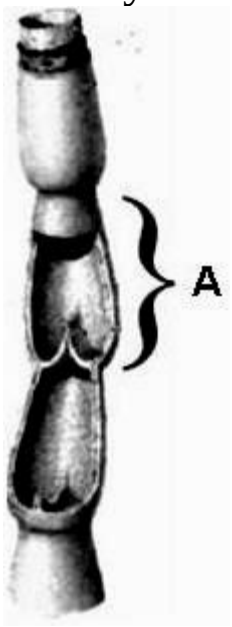
## ANATOMICAL COMPOSITION OF LYMPHATIC SYSTEM

1. **Lymphatic capillaries** – ***vasa lymphocapillaria***
2. **Lymphatic sinuses** – ***sinus lymphaticus***
3. **Lymphatic vessels** – ***vasa lymphatica***
4. **Lymphatic collecting vessels**:
    - thoracic duct – ***ductus thoracicus***
    - right lymphatic duct – ***ductus lymphaticus dexter***
    - tracheal trunks (right and left) [jugular trunk] – ***trunci tracheales dexter et sinister***
    - chyle cistern – ***cisterna chyli***
    - intestinal trunk – ***truncus intestinalis***
    - celiac trunk – ***truncus celiacus***
    - lumbar trunks (right and left) – ***trunci lumbales dexter et sinister***
5. **Lymph node** – ***nodulus lymphaticus***
6. **Lymphatic space** – ***spatium lymphaticum***
7. **Lymph** – ***lympha***

***Lymphatic capillaries*** (vasa lymphocapillaria) are initial part of the lymphatic system, which start with blind tubes, and have a relatively large diameter. The wall of lymphatic capillaries is constructed from one endothelial layer. The lymph capillaries in the villi of the intestine absorb and transport emulsified fat or chyle, and therefore appear milky. They have a significant diameter, so are known as ***sinuses*.**

***Lymphatic vessels*** (vasa lymphatica) are formed by fusion of lymphatic capillaries.

***Lymphatic vessels*** are not necessarily present wherever there are veins. There are no lymph vessels in the brain and spinal cord, or in bone marrow. The mucous membranes and the skin are richly supplied with lymph vessels. The lymphatic vessels have thinner walls than do comparably sized veins, but contain more valves. When the flow of lymph is obstructed the vessels become distended, and, owing to constrictions at the valves, they often resemble a string of beads in appearance. The blockage of lymphatics results in an accumulation of tissue fluid and consequent swelling, known as lymphedema. Lymphatic vessels, when cut, remain open longer than do comparable blood vessels, but they have remarkable regenerative capacities.




The wall of lymphatic vessels consists of *three coats:* internal (intima), middle (tunica media) and external (adventitia).The intima of lymphatic vessels forms valves (valvulae lymphaticae) which transmit lymph just in one direction – from lymphatic capillaries to the lymph nodes, trunks and ducts.

The distance between two adjacent valves of the same lymphatic vessel is called **lymphangion (A),** or valve segment.

*Lymphangion* is a morpho-functional unit of the lymphatic vessel.

The larger ***lymphatic collecting vessels*** are surrounded by smooth muscle and a fibrous adventitia. They occasionally exhibit intrinsic pulsations, although the flow of lymph depends mainly on the movement of adjacent muscles.

***Lymph nodules.*** Solitary and aggregated nodules are found mainly in the wall of the digestive tube. They differ from nodes, in that lymph vessels arise in, rather than pass through them; thus they contain only efferent lymphatic. The various **tonsils** and the **aggregated nodules** are described with the digestive system. The solitary and small aggregated nodules are particularly abundant in the cecum, rectum, anal canal, prepuce, and third eyelid. The lymphoid tissue of the third eyelid is located on its bulbar side. It occasionally becomes infected and hypertrophied, causing conjunctivitis. The lymph nodules of the prepuce are commonly infected in old male dogs, and an almost continuous purulent exudate is discharged from the sheath. The submucous lymph nodules of the large intestine can be seen clearly in the cadaver under proper lighting conditions if the intestine is inflated.

## LYMPHATIC COLLECTING VESSELS

The ***lymphatic collecting vessels*** provide the outflow of lymph and its flow into the venous system. They are the following.

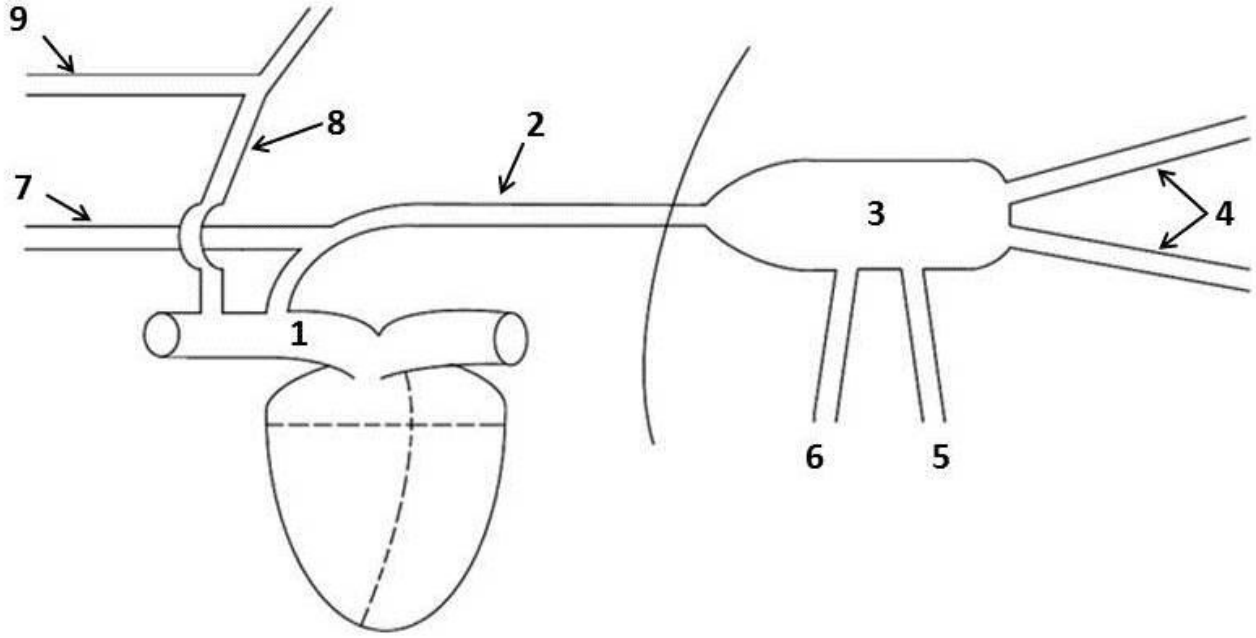
The **thoracic duct** (ductus thoracicus) is the chief collecting trunk of the lymphatic system. The thoracic duct begins in the sublumbar region, as a cranial continuation of the **chyle cistern**. The thoracic duct begin between the crura of the diaphragm where the cisterna attains its minimum width.

The **left tracheal trunk** (truncus trachealis sinister) joins to the cranial part of the thoracic duct.

The **chyle cistern** (cisterna chyli) is an elongated sac, dilated in the middle and constricted at both ends, which lies dorsodextral to the aorta from the fourth to the first lumbar vertebra. **Lumbar trunks** and **intestinal trunk** join to the chyle cistern.

**Lumbar trunks** (trunci lumbales) collect the lymph from the lumbar, ileo-femoral, medial iliac lymph nodes, as well as **intestinal trunk** (truncus intestinalis) collect the lymph from the lymph nodes of the gastrointestinal tract (intestine, stomach, liver, and spleen).

The **coeliac trunk** (truncus coeliacus) exists only in ruminant. It joins to the cranial part of the chyle cistern and collects lymph from the lymph nodes of the chambers of stomach.




**Scheme of lymphatic collecting vessels**

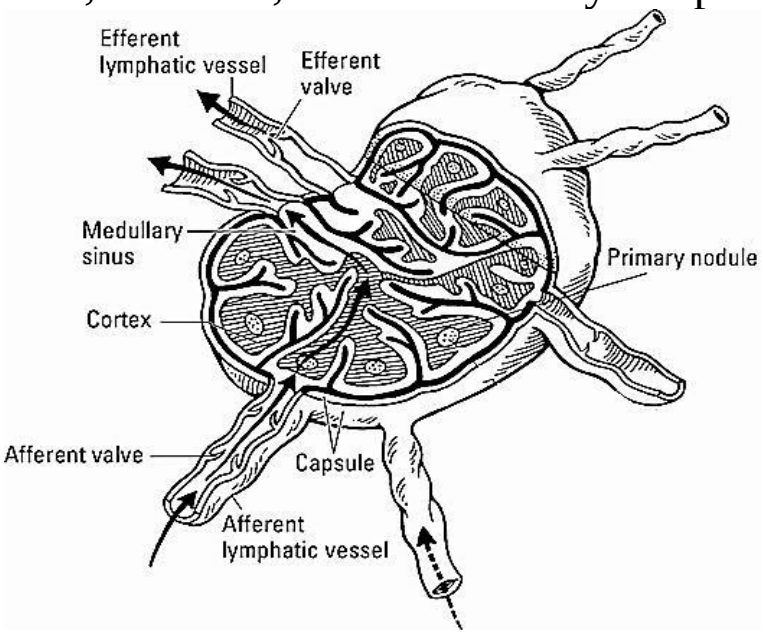
*1 - cranial vena cava, 2 – thoracic duct, 3 – chyle cistern, 4 – lumbar trunks, 5 – intestinal trunk, 6 – celiac trunk, 7 – left tracheal trunk, 8 – right lymphatic duct, 9 – right tracheal trunk.*

The **right lymphatic duct** (ductus lymphaticus dexter) collects lymph from 1/4 of the body (right thoracic limb, right side of the neck, head, and thoracic wall). This duct is short and wide, it carries the lymph into the *cranial vena cava*, sometimes – into the *jugular vein.* It is infused with the right trunks truncus trachealis dexter, which carries a lymph from the lymph nodes of the right half of the neck and head.

**Tracheal trunks** (trunci trachealis) pass along the trachea and collect lymph from the retropharyngeal and deep cervical lymph nodes. The **left tracheal trunk** joins to the *thoracic duct*, and the **right tracheal trunk** – to the *right lymphatic duct*.

## LYMPH NODES

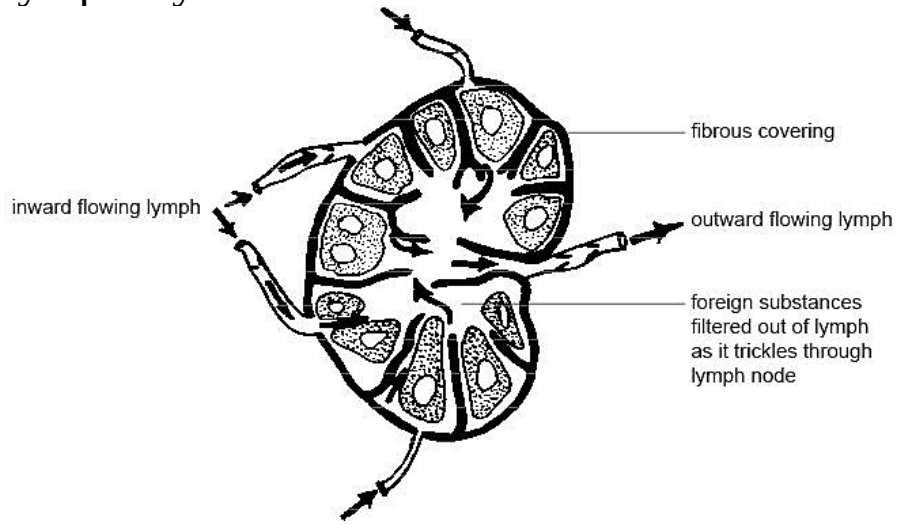
**Lymph nodes** are always located in the course of lymphatic vessels. Those vessels which enter the node are known as *afferent lymph vessels* (vasa lymphatica afferentia). They break up into many minute vessels before perforating the capsule of the node. Many lymphatics perforate the nodal capsule, along with the artery and vein serving the organ, and anastomose to form a single efferent vessel. The *efferent lymph vessels* (vasa lymphatica efferentia) are those which framework consisting of septa and trabeculae. There is a convex surface, and a small flat or concave area, the hilus, which is usually not prominent.




Internally the node contains a poorly defined cortex and medulla.

The structural unit of the lymph node is the ***lymph nodule.*** Each nodule contains light-colored central areas in which the lymphocytes are formed.

Most nodules are located in the cortex. The lymphoid tissue of the medulla is in the form of anastomosing cords of lymphocytes with few nodules.




**Scheme of the lymph node (swine) and the direction of the flow of lymph through it**

## CLASSIFICATION OF LYMPH NODES

### I. By location:

1. *Superficial* – are located directly under the skin, they are available for clinical examination (mandibular, parotid, superficial cervical, superficial inguinal, popliteal lymph nodes).
2. *Deep* – are located under fascia, between muscles and in cavities of body. For example, deep inguinal, bronchial lymph nodes.

### II. Topographic classification (regional lymph nodes):

1. Lymph nodes of the head.
2. Lymph nodes of the neck.
3. Lymph nodes of the thorax and organs of thoracic cavity.
4. Lymph nodes of the thoracic limb.
5. Lymph nodes of the abdominal wall and organs of the abdominal cavity.
6. Lymph nodes of the pelvis and pelvic limb.

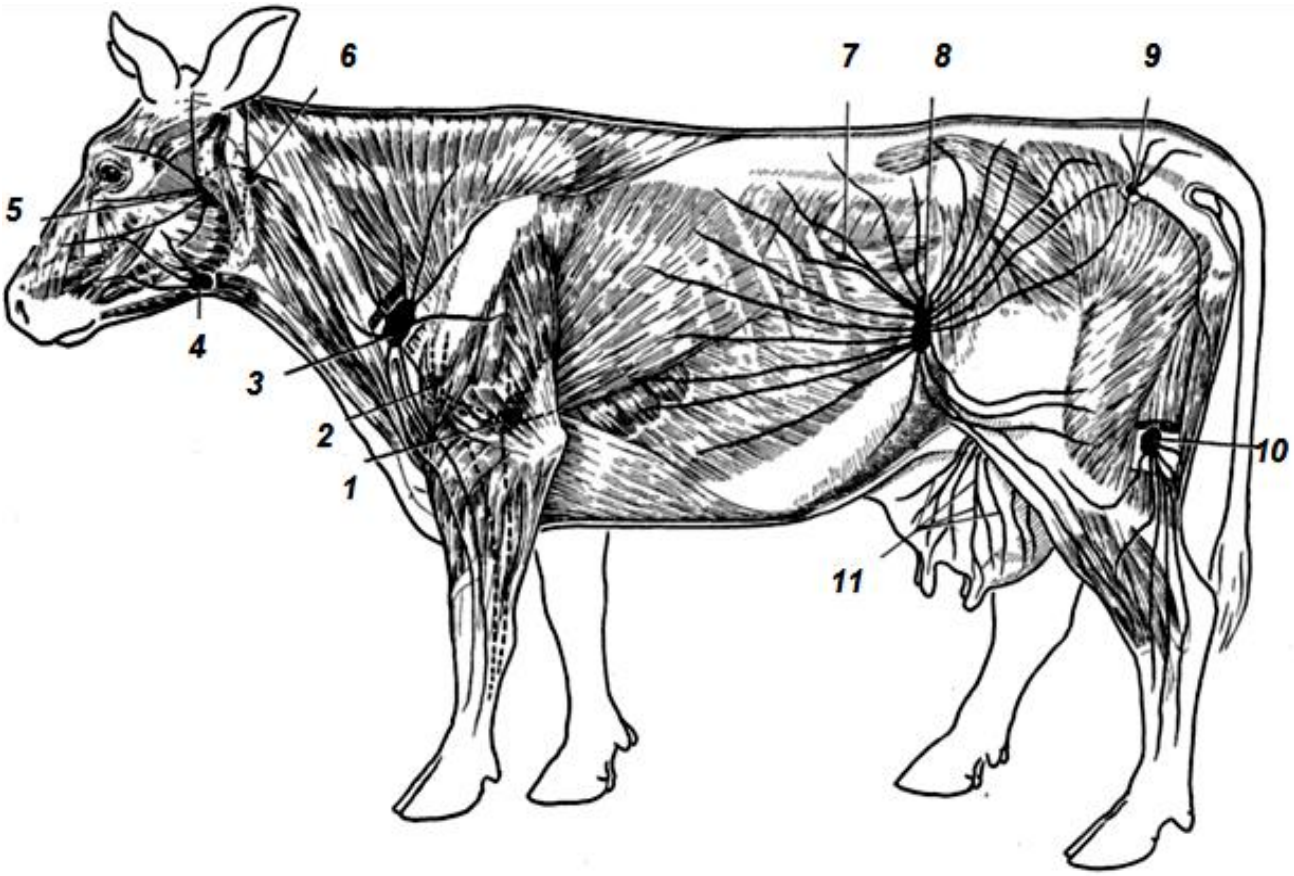
### III. By origin of the roots:

1. Skin (S) – collect lymph from the skin.
2. Muscular (M) – collect lymph from the muscles.
3. Viscera (V) – collect lymph from the internal organs.
4. Mixed – SMV, MV, SM.

## LYMPHATIC CENTERS and LYMPH NODES of the CATTLE

**Lymphatic center** *(lymphocentrum, lc.)* is a group of permanent nodes that are close topographically to each other and have common ***roots*** (afferent lymph vessels from organs in all kinds of animals).

**Root of lymph node** is a part of the body, or organs from which lymph outflows into the lymph node.




**Superficial lymph nodes and vessels of cattle**

*1 – axillar ln., 2 – axillary ln. of the 1st rib, 3 – superficial cervical ln., 4 – mandibular ln., 5 – parotid ln., 6 – lateral retropharyngeal lnn., 7 – lymph node of hunger groove, 8 – subiliac ln., 9 – ischiadic ln., 10 – popliteal ln., 11 – lymphatic vessels to the lymph nodes of udder (superficial inguinal or mammary).*

## LYMPH NODES OF THE HEAD

### I. Parotid lymph centre - lymphocentrum parotideum.

1. ***Parotid lymph node*** *(ln. parotideus)* (SMV) is located ventrally to the temporomandibular joint.

*Roots:* bones, muscles and skin of the head, nasal cavity, lips, outer ear, muscle of the eye.

*Lymph outflow* - into the lateral retropharyngeal lymph node.

### II. Mandibular lymph centre - lymphocentrum mandibulare.

***1. Mandibular lymph node*** (ln. mandibularis), (SMV) lies under the skin on the medial surface of the mandibular branch, behind the vascular incissure.

*Roots:* bones, muscles and skin of the head, nasal and oral

cavity, sublingual and parotid salivary glands, larynx.

*Lymph outflow* – into the lateral retropharyngeal lymph node.

***2. Pterygoid lymph node*** (ln. pterygoideus) is not permanent, lies medially to the parotid salivary gland.

*Roots:* Parotid salivary gland.

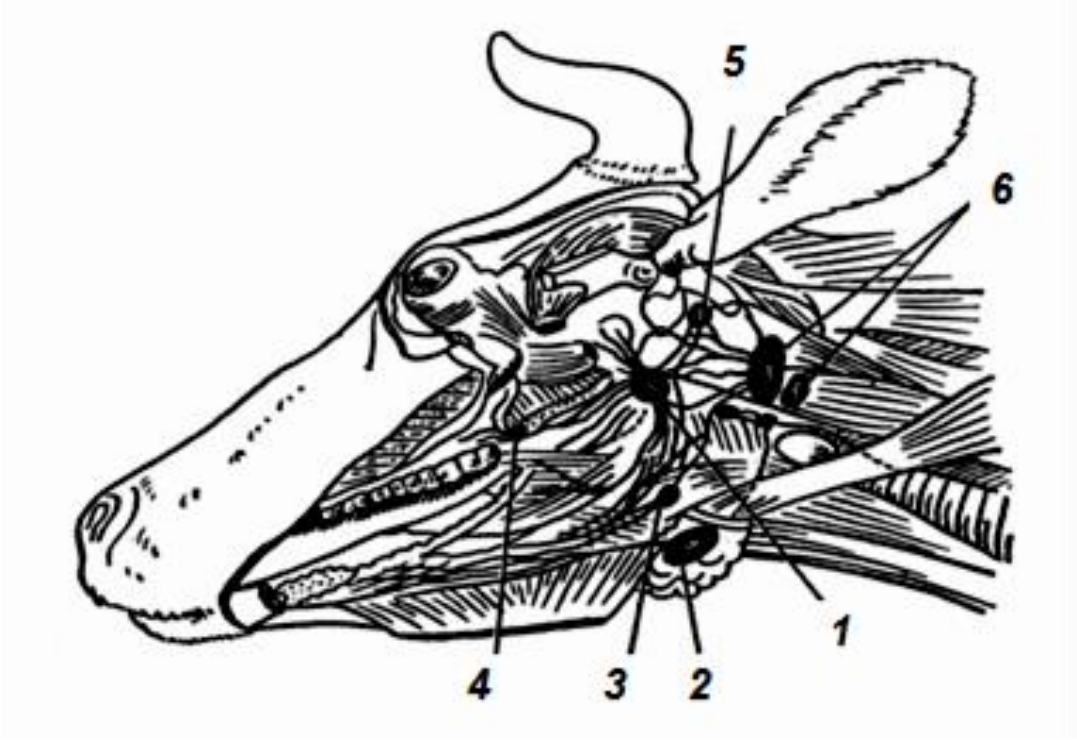
*Lymph outflow* – into the lateral retropharyngeal lymph node.

**III. Retropharyngeal lymph center - lymphocentrum retropharyngeum.**

***1. Medial retropharyngeal lymph node*** (ln. retropharyngeus medialis) (MV) is located dorso-laterally from the pharynx.

*Roots:* nasal cavity and nasal sinuses, larynx, sublingual and mandibular salivary glands, pharynx.

*Lymph outflow* – into the lateral retropharyngeal lymph node and tracheal trunk.




**Deep lymph nodes of the head**

*1 – medial retropharyngeal ln., 2 – mandibular ln., 3 – rostral sublingual ln., 4 – pterygoid ln., 5 – caudal sublingual ln., 6 – lateral retropharyngeal lnn.*

***2. Lateral retropharyngeal lymph node*** (ln. retropharyngeus lateralis) (SMV) is located at the level of the wings of atlas.

*Roots:* oral cavity, salivary glands, pharynx, larynx, auricle, cranial part of the neck, thymus.

*Lymph outflow* – into the tracheal trunk.

**3. *Rostral and caudal hyoid lymph nodes*** (lnn. hyoideus rostralis and caudalis).

*Roots:* tongue, throat.

*Lymph outflow* – into the lateral retropharyngeal lymph node.

## LYMPH NODES OF THE NECK

**I. Superficial cervical lymph centre - lymphocentrum cervicale superficiale.**

***1. Superficial cervical lymph node*** (ln. cervicalis superficialis) (SMV) lies in front of the shoulder joint under the brachiocephalic muscle.

*Roots:* caudal part of the neck, the cranial part of the thorax, thoracic limb.

*Lymph outflow* – on the right - to the tracheal trunk, on the left – to the thoracic duct.

**II. Deep cervical lymph centre – lymphocentrum cervicale profundum.**

***1. Deep cervical lymph nodes*** (lnn. cervicales profundi) (MV). They are divided into **cranial, middle**, and **caudal nodes** as well as **costocervical node**. These lie dorsomedial to the thyroid gland along the carotid sheath, or on the pharynx cranial to the thyroid **(cranial nodes)**; ventrally to the trachea in the middle third of the neck **(middle nodes)**; on the ventral surface of the caudal third of the cervical part of the trachea **(caudal nodes).**

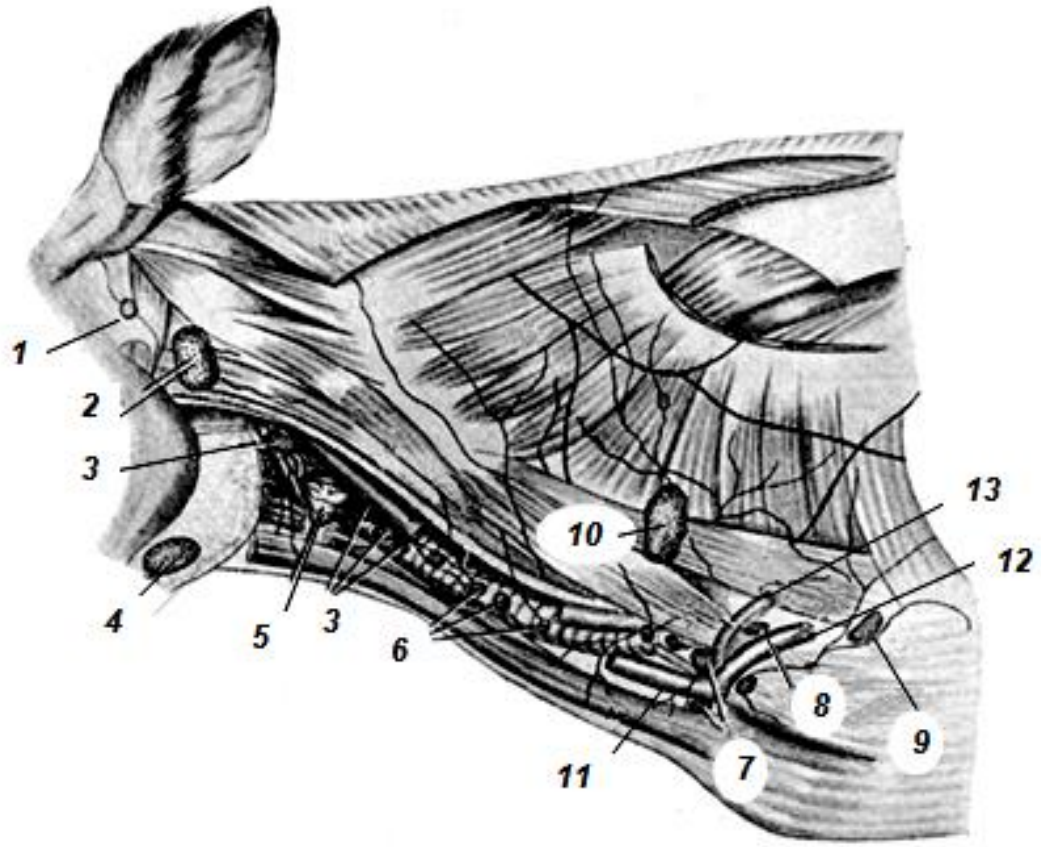
*Roots:* ventral muscles of the neck, larynx, trachea, pharynx, esophagus, thymus, thyroid gland.

*Lymph outflow* **–** into the thoracic duct, right lymphatic duct, tracheal trunk**.**

***2. Costocervical lymph node*** (ln. costocervicalis) (MV) is located cranio-medial from the first rib.

*Roots:* caudal part of the neck, thoracic wall to the 8-th segment, interscapular region, back and trachea.

*Lymph outflow* – into the thoracic duct, tracheal trunk, right limphatic duct.




**Lymph nodes of the head and neck**

*1 – caudal sublingual ln.*
*2 – lateral retropharyngeal ln.*
*3 – cranial deep cervical lnn.*
*4 – mandibular ln.*
*5 – thyroid gland*
*6 – middle deep cervical lnn.*
*7 – caudal deep cervical lnn.*
*8 – axillary ln. of the 1st rib*
*9 – axillary ln.*
*10 – superficial cervical ln.*
*11 – jugular v.*
*12 – axillary v.*
*13 – axillary a.*

## LYMPH NODES OF THE THORACIC LIMB

## I. Axillary lymph centre - lymphocentrum axillare.

***1. Proper axillary lymph node*** (ln. axillaris proprii) (SMV) lies caudally from the shoulder joint.

*Roots:* thoracic limb.

*Lymph outflow* – into the axillary lymph node of the 1st rib, or to the caudal deep cervical lymph nodes.

***2. Axillary lymph nodes of the first rib*** (ln. axillaris primae costae) (M) lies medially from the shoulder joint.

*Roots:* ventral muscles of the neck, thoracic limb.

*Lymph outflow* – into the tracheal trunk, thoracic duct, caudal deep cervical lymph nodes.

## LYMPH NODES OF THE THORAX AND ORGANS OF THE THORACIC CAVITY

**I. Dorsal thoracic lymph centre – lymphocentrum thoracicum dorsale**.

***1. Intercostal lymph nodes*** (lnn. intercostales) lie in the vertebral end of intercostal space under the sympathetic trunk, caudal to the intercostal artery.

*Roots:* thoracic wall, pleura, diaphragm, interscapular region, back.

*Lymph outflow* – into the thoracic duct and mediastinal lymph nodes.

***2. Thoracic aortic lymph nodes*** (lnn. thoracici aortici) lie between the aorta and the bodies of the thoracic vertebrae.

*Roots:* thoracic wall, aorta, pleura, diaphragm.

*Lymph outflow* – into the thoracic duct.

**II. Ventral thoracic lymph centre – lymphocentrum thoracicum ventrale.**

***1. Cranial sternal lymph node*** (ln. sternalis cranialis) lies on the dorsal surface of the *manubrium sterni.*

*Roots:* ventral thoracic wall, diaphragm.

*Lymph outflow* – into the thoracic duct.

***2. Caudal sternal lymph node*** (ln. sternalis caudalis) is located

between the pericardium and the diaphragm at the level of the xiphoid process of sternum.

*Roots:* ventral thoracic wall, ventral abdominal wall, diaphragm, liver.

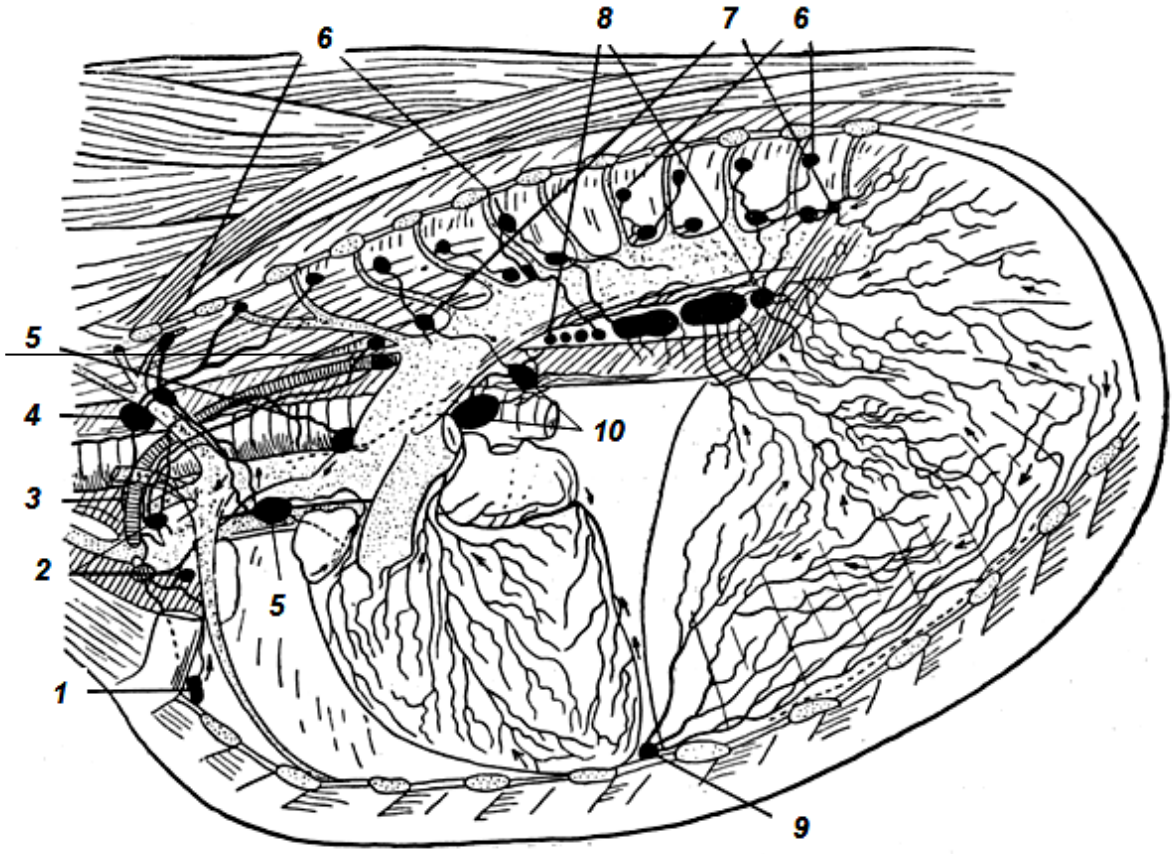
*Lymph outflow* – into the cranial thoracic lymph node.

**III. Mediastinal lymph centre – lymphocentrum mediastinale.**

***1. Cranial mediastinal lymph nodes*** (lnn. mediastinales craniales) lie in the precardial mediastinum dorsally and ventrally from the trachea.

*Roots***:** the thoracic part of the esophagus, trachea, lungs, pleura, thymus, pericardium, heart, aorta.

*Lymph outflow* – into the and right lymphatic duct, as well as in the lymph node.




**Lymphatic vessels and nodes of the thoracic cavity**

*1 – cranial sternal ln.*
*2 – deep cervical lnn.*
*3 – thoracic duct*
*4 – costocervical ln.*
*5 – cranial mediastinal ln.*
*6 – intercostal lnn.*
*7 – thoracic aortic lnn.*
*8 – middle and caudal mediastinal lnn.*
*9 – caudal sternal ln.*
*10 – tracheobronchal lnn.*

***2. Middle mediastinal lymph nodes*** (lnn. mediastinales medii) lie between the aorta and the esophagus dorsally from the heart.

*Roots:* esophagus, trachea, lungs, pleura.

*Lymph outflow* – into the thoracic duct, cranial mediastinal lymph nodes.

***3. Caudal mediastinal lymph nodes*** (lnn. mediastinales caudales) are located between the aorta and the esophagus in the postcardiac mediastinum.

*Roots:* esophagus, pleura, liver, spleen, diaphragm, large omentum..

*Lymph outflow* – into the middle and cranial mediastinal lymph nodes.

**IV. Bronchal lymph centre – lymphocentrum bronchale.**

***1. Pulmonary lymph nodes*** (lnn. pulmonales) lie on the dorsal surfaces of the bronchi, near the bifurcation of the trachea.

*Roots:* trachea, bronchi, lungs, heart, esophagus.

*Lymph outflow* – into the thoracic duct.

***2.*** **Tracheobronchial lymph nodes** (ln. tracheobronchales) lie at the level of the bifurcation of the trachea.

*Roots:* heart, pericardium, trachea, lungs.

*Lymph outflow* – into the cranial mediastinal lymph nodes and thoracic duct.

## LYMPH NODES OF ABDOMINAL WALL AND ORGANS OF THE ABDOMINAL CAVITY

**I. Lumbar lymph centre - lymphocentrum lumbale.**

***1. Lumbar aortic lymph nodes*** (lnn. lumbales aortici) lie dorsally from the abdominal aorta and caudal vena cava.

*Roots:* loin and back, kidneys, adrenal glands, aorta.

*Lymph outflow* **–** into the lumbar trunk.

***2. Proper lumbar lymph nodes*** (lnn lumbales proprii) are located

near the intervertebral foramina.

*Roots:* loin, urinary and genital organs.

*Lymph outflow* – into the chyle cistern and lumbar trunks.

**3. Renal lymph nodes** (lnn. renales) are located on the renal artery near the renal porta.

*Roots:* kidneys and adrenal glands.

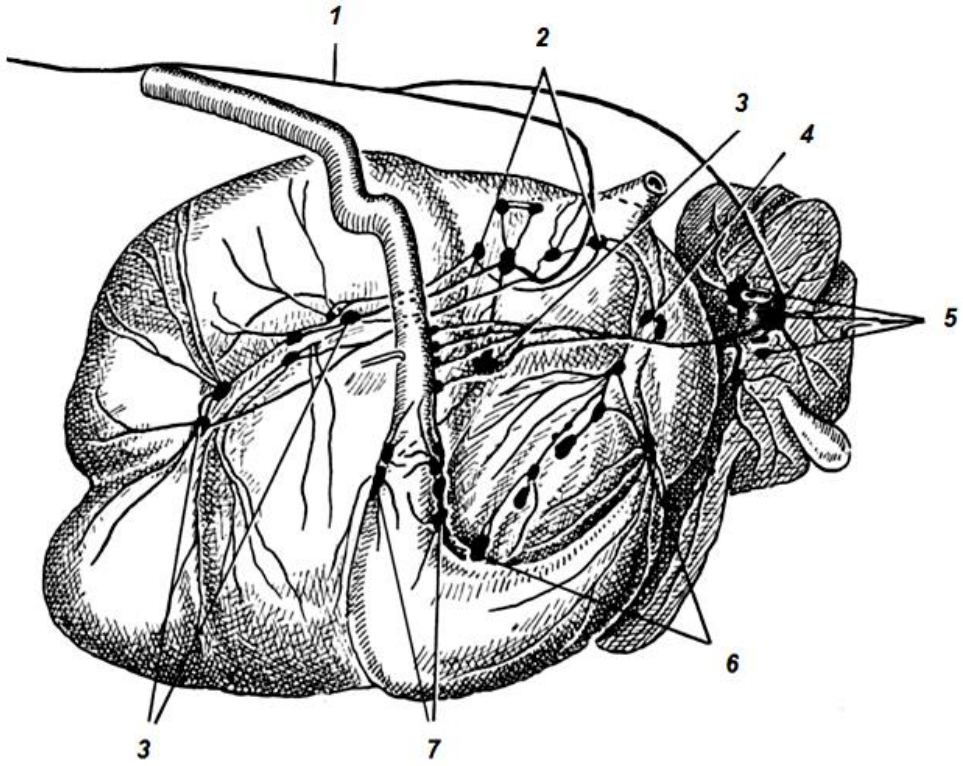
*Lymph outflow* – into the chyle cistern and lumbar trunks.

## II. Celiac lymph centre - lymphocentrum celiacum.

***1. Celiac lymph nodes*** (lnn. coeliaci) lie around the celiac artery.

*Roots:* spleen, stomach.

*Lymph outflow* – into the celiac and intestinal trunks.




**Celiac lymph centre of cattle (right aspect)**

*1 – c**eliac trunk***
*2 – lymph nodes of rumen atrium*
*3 – ruminal lymph nodes*
*4 – reticular lymph nodes*
*5 – hepatic [portal] ln.*
*6 – omasial lymph nodes*
*7 – abomasial lymph nodes*

***2. Gastric lymph nodes*** (lnn. gastrici) lie on each chamber of the stomach along the vessels.

*Roots:* appropriate chambers of the stomach, spleen and duodenum.

*Lymph outflow* – into the celiac and intestinal trunks.

***3. Omental lymph nodes*** (lnn. omentales) lie in the gastrolienal ligament.

*Roots:* omentum, stomach.

*Lymph outflow* – into the lumbar trunk.

***4. Hepatic lymph nodes [portal]*** (lnn. hepatici (portales) are located at the porta of the liver.

*Roots:* liver, pancreas, duodenum.

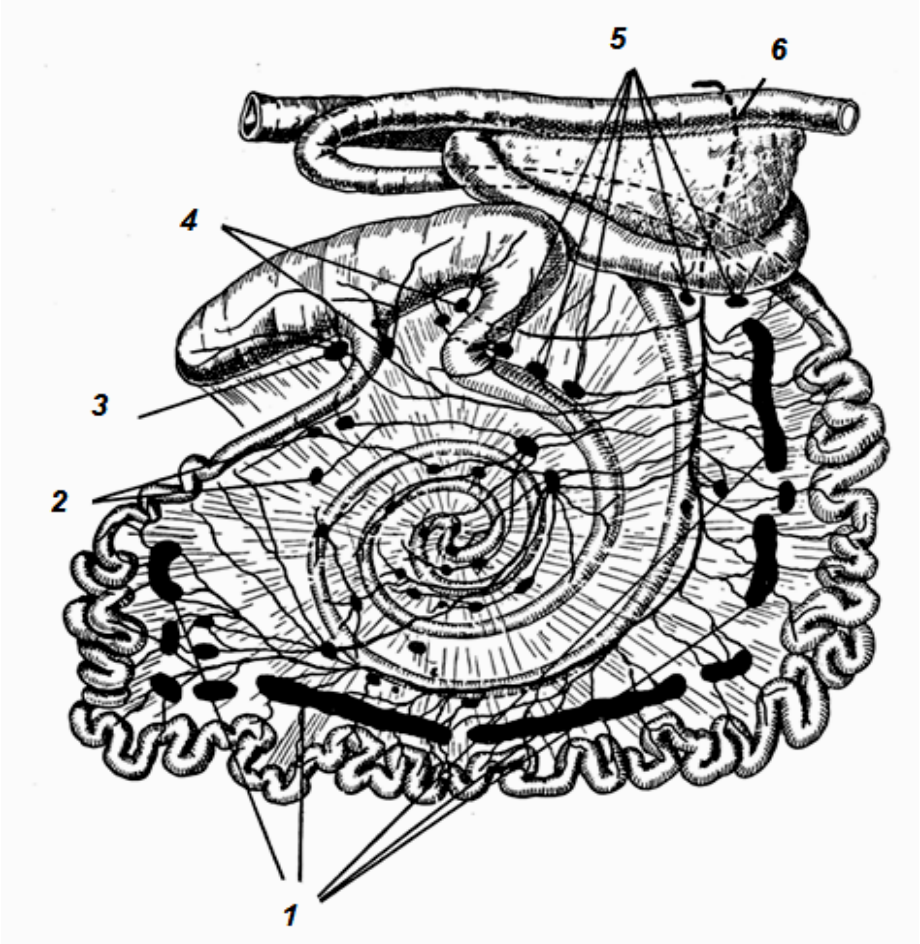
*Lymph outflow* – into the intestinal trunk and mediastinal lymph nodes.

***5. Pancreaticoduodenal lymph nodes*** **(**lnn. Pancreatico-duodenales) lie in the mesoduodenum.

*Roots:* pancreas, duodenum.

*Lymph outflow* – into the intestinal trunk.

**III. Cranial mesenteric lymph centre – lymphocentrum mesentericum craniale.** It includes lymph nodes which are located in the mesenterica.




**Cranial mesenteric lymph centre of the cattle**

*1 – jejunal lnn.,*
*2 – ileal lnn.,*
*3 – cecal lnn.,*
*4 – ileocolic lnn.,*
*5 – colic lnn.,*
*6 – intestinal trunk.*

***1. Cranial mesenteric lymph nodes*** (lnn. mesenterici craniales) lie at the level of the cranial mesenteric artery.

*Roots:* jejunum and ileum.

*Lymph outflow* – into the intestinal trunk.

***2. Jejunal lymph nodes (****lnn. jejunales)* lie in the mesojejunum.

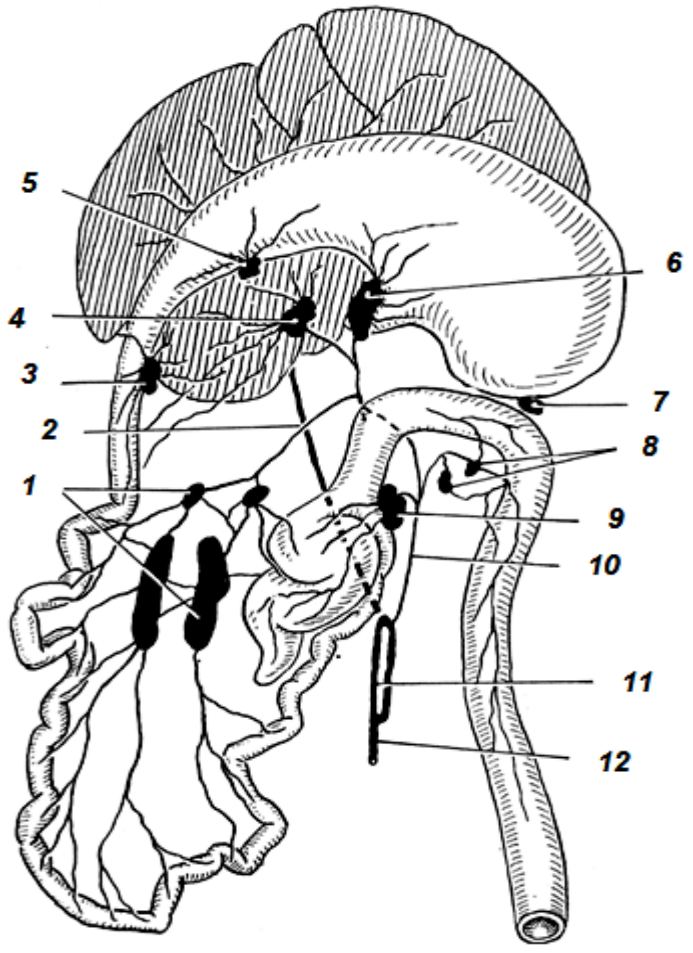
*Roots:* jejunum, ileum, and cecum.

*Lymph outflow* – into the intestinal trunk.

***3. Cecal lymph nodes*** (lnn. caecales) lie in the ileocecal ligament.

*Roots:* cecum and ileum.

*Lymph outflow* – into the intestinal trunk.




**Lymph nodes of the abdominal cavity of dog**

*1 – jejunal lnn.*
*2 – **thoracic duct***
*3 – duodenal lnn.*
*4 – hepatic (portal) lnn.*
*5 – gastric lnn.*
*6 – left portal lnn.*
*7 – lineal lnn.*
*8 – middle colic lnn.*
*9 – right colic ln.*
*10 – **intestinal trunk***
*11 – **chyle cistern***
*12 – **lumbar trunk***

***4. Ileocolic lymph nodes*** (lnn ileocolici) are located in the mesocolon.

*Roots:* ileum, colon.

*Lymph outflow* – into the intestinal trunk.

***5. Colic lymph nodes*** (lnn. colici) lie in the mesocolon inside of the colon labyrinth.

*Roots:* colon

*Lymph outflow* – into the intestinal trunk.

**III. Caudal mesenteric lymph centre – lymphocentrum mesentericum caudale.**

***1. Caudal mesenteric lymph nodes*** **(**lnn. mesenterici caudales) lie at the level of the cranial mesenteric artery.

*Roots:* colon ascendens.

*Lymph outflow* – into the intestinal trunk and medial iliac lymph nodes.

## LYMPH NODES OF PELVIS AND PELVIC LIMB

**I. Iliosacral lymph centre – lymphocentrum ileosacrale.**

***1. Medial iliac lymph nodes*** (lnn. iliaci mediales) lie on the external iliac artery, cranially from the deep circumflex iliac artery.

*Roots:* lumbar region, thigh, testis, spermatic cord, ovary, uterine tube, uterus, kidneys, bladder.

*Lymph outflow* – into the lumbar trunk.

***2. Lateral iliac lymph nodes (****lnn. iliaci laterales)* are impermanent; lie on the deep circumflex iliac artery, at level of tuber coxae.

*Roots:* lumbar region, abdominal wall, diaphragm

*Lymph outflow* – into the medial iliac lymph nodes and lumbar lymph nodes.

***3. Hypogastric lymph nodes*** (lnn. hypogastrici) are located between the internal iliac arteries at the evel of their ramification.

*Roots:* ***:*** wall of pelvic cavity.

*Lymph outflow* – into the medial iliac lymph nodes.

***4. Sacral lymph nodes*** (lnn. sacrales) are located on the wide pelvic ligament. There are lateral and medial lymph nodes.

*Roots:*

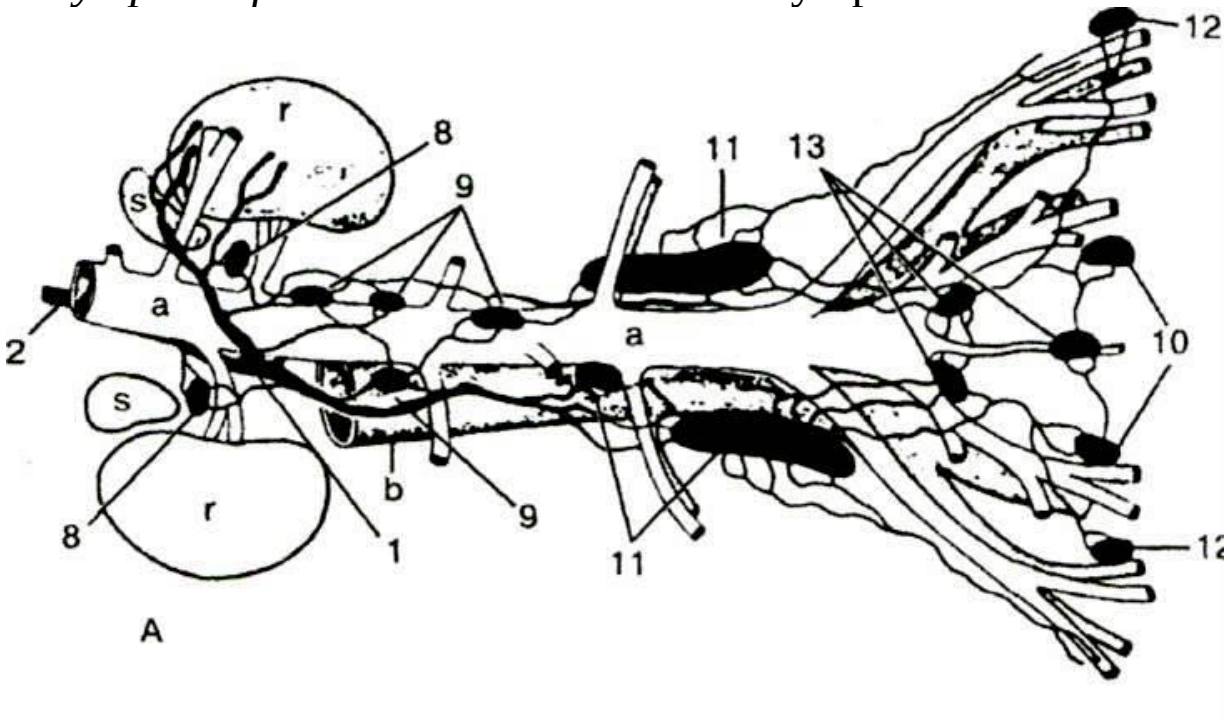
- lateral – muscles of pelvic girdle
- medial – prostate, pelvic part of the urethra, penis, vagina.

*Lymph outflow* – into the medial iliac lymph nodes.

***5. Anorectal lymph nodes*** (lnn. anorectales) lie on the rectum.

*Roots:* rectum, anus.

*Lymph outflow* – into the medial iliac lymph nodes.




**Lymph nodes of the organs of abdominal and pelvic cavities of the dog**

a - abdominal aorta; b - caudal vena cava; r - kidneys; s - adrenal glands

*1 - chyle cistern, 2 - thoracic duct, 8 - renal lnn., 9 - aortic lumbar lnn., 10 – hypogastric lnn,. 11- medial iliac lnn., 12 - ileofemoral (deep inguinal) lnn, 13 - sacral lnn.*

## II. Iliofemoral lymph centre [deep inguinal] – lymphocentrum ileofemorale (inguinale profundum).

***1. Iliofemoral lymph nodes [deep inguinal]*** (lnn. ileofemorales or inguinales profundi) are located on the medial surface of the abdominal wall near the deep femoral artery.

*Roots:* loin, abdominal wall, pelvic limb.

*Lymph outflow* – into the medial iliac lymph nodes and chyle cistern.

***2. Epigastric lymph node*** (ln. epigastricus) is located near the branch of caudal epigastric artery from the deep femoral artery.

*Roots:* abdominal wall, pelvic limb.

*Lymph outflow* – into the medial iliac lymph nodes.

**III. Inguinofemoral lymph centre [superficial inguinal] – lymphocentrum inguinofemorale (inguinale superficiale).**

***1. Superficial inquinal lymph nodes*** (lnn. inquinales superficiales) are located (right and left) on the ventral abdominal wall; in the male – on both sides of the penis; and in the females – under the skin of the base of udder.

*Roots:* external genital organs, udder, hip and leg.

*Lymph outflow* – into the ileofemoral lymph nodes..

***2. Subiliac lymph nodes*** (lnn. subiliaci) is located ahead of the tensor of the wide fascia of the thigh in the knee fold.

*Roots:* skin of the abdominal wall and pelvic limb.

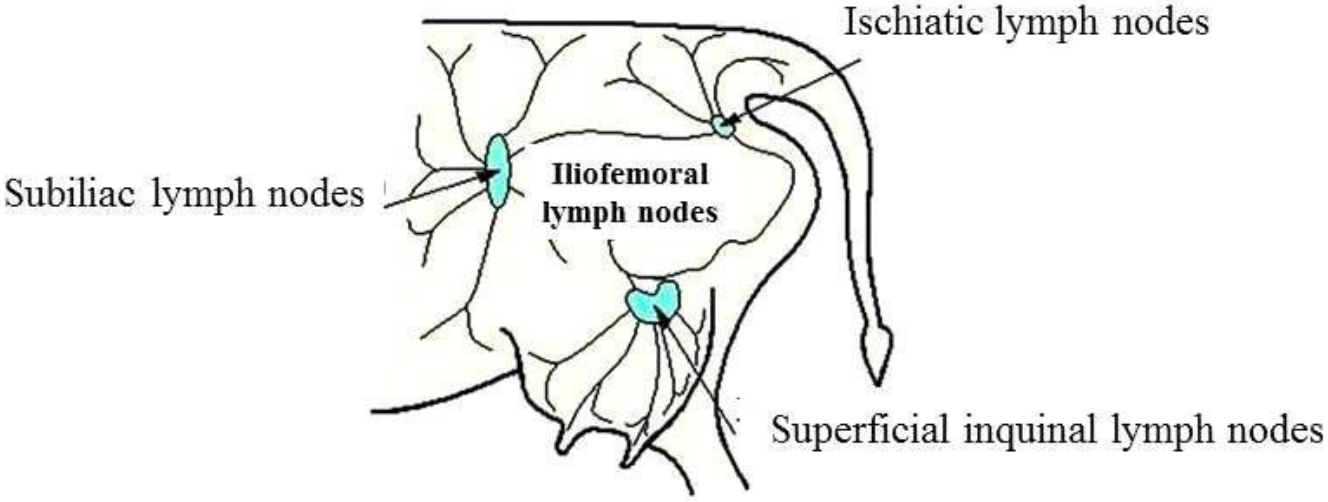
*Lymph outflow* – into the medial iliac lymph node.

**IV. Ischiatic lymph centre – lymphocentrum ischiadicum.**

***1. Ischiatic lymph nodes*** (lnn. ischiadicum) is located outside of the wide pelvic ligament at level of the lesser ischiadic spine.

*Roots:* wall of the pelvic cavity, organs of pelvic cavity.

*Lymph outflow* – into the medial iliac lymph nodes.



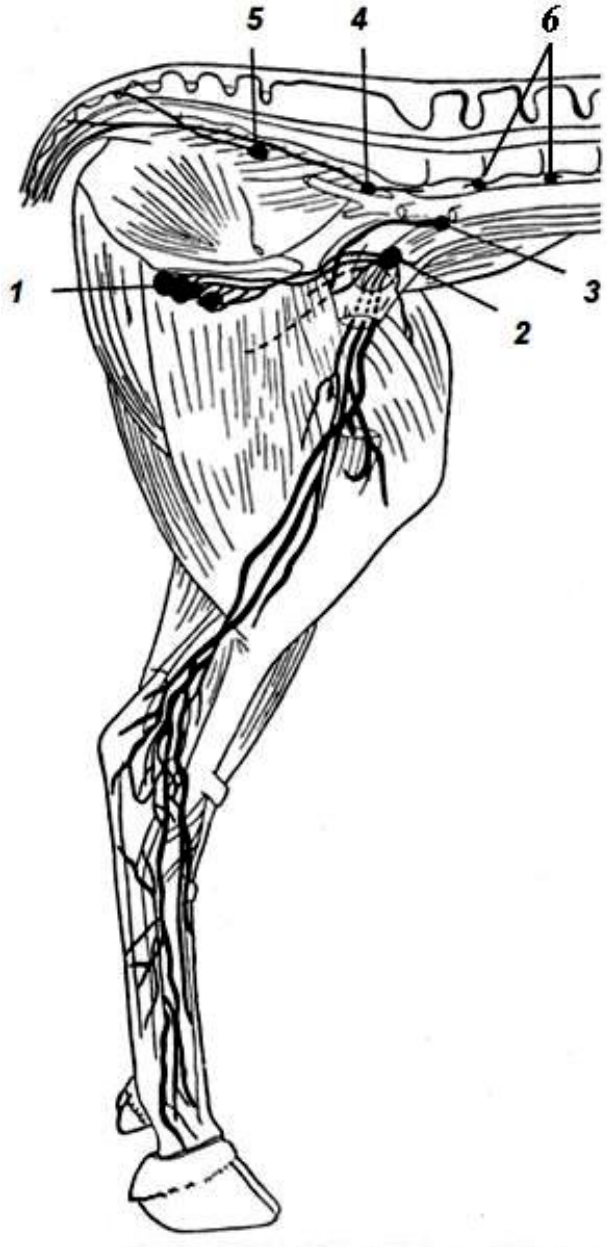

**Scheme of the lymph outflow from udder in cow**

## V. Popliteal lymph centre – lymphocentrum popliteum.

***1. Popliteal lymph nodes*** (ln. popliteus) lies on the lateral head of the m. gastrocnemius.

*Roots:* m. biceps femoris, m. semitendinosus, leg, foot.

*Lymph outflow* – into the deep inguinal lymph nodes, lateral sacral lymph nodes.




**Lymph nodes of the pelvic limb**

*1 – superficial inguinal ln.*
*2 – deep inguinal ln.*
*3 – medial iliac ln.*
*4 – hypogastric ln.*
*5 – medial sacral ln.*
*6 – aortic lumbar lnn.*


**Lymph nodes of the thoracic limb**

*1 – axillar ln. of the 1-rib*
*2 – proper axillar ln.*

## ORGANS OF HAEMATOPOIESIS AND IMMUNOGENESIS

ORGANA HAEMOPOETICA et IMMUNOPOETICA

Blood elements provide the transport of oxygen and carbon dioxide, as well as biological (immune) protection in the organism. Blood cells live for a short time: erythrocytes – 120 days (several months); granular leukocytes – 9 hours; non-granular leukocytes – 24-30 days. The dying blood cells are constantly being replaced by new ones.

The process of formation of blood cells is called **haematopoiesis** (from Greek: haima – blood; poien – to form), modern terminology implies the term – **haematocytopoiesis**.

**There are two types of haematocytopoiesis:**

**1. Embryonic haematocytopoiesis,** which occurs in the embryonic period and provides the development of blood as a tissue.

**2. Postembryonic haematocytopoiesis**is a process of physiological blood regeneration.

## CLASSIFICATION AND ANATOMIC COMPOSITION OF ORGANS OF HAEMATOPOIESIS AND IMMUNOGENESIS

The **central** and **peripheral** organs are distinguished in the system of haemato- and immunopoiesis.

The *central* organs consist of:

1. **Red bone marrow** – *medulla ossium rubra*
2. **Thymus** – *thymus*

The *peripheral* organs consist of:

**1. Lymph nodes –** *lymphonodus*
**2. Spleen –** *lien*
**3. Lymphoid structures of the mucosa of viscera:**
**3.1. tonsils –** *tonsilla*
**3.2. lymphoid nodules –** *lymphonodulus*
**3.3. lymphoid aggregates –** *noduli lymphatici aggregati*

The liver is an organ that performs the function of the haematopoiesis in the embryonic period of ontogenesis.

There are two types of haematopoietic tissue in the body:

- myeloid
- lymphoid

The ***myeloid*** tissue is comprised of the hematopoietic stem cells which are responsible for performing hematopoiesis, production of the blood cells. This type of tissue is present in the bone marrow in the adults and in spleen and liver in the fetus.

The ***lymphoid*** tissue is organized structures that support immune responses. It performs three main functions:

- lymphocyte formation
- formation of immunocompetent cells
- elimination of cell and products of their decomposition

The **immune system** is made up of organs that control the production and maturation of certain defense cells, the lymphocytes. Bone marrow and the thymus are so-called primary lymphoid organs. The bone marrow produces defense cells. Some of these defense cells, the so-called T-lymphocytes (T stands for thymus), which are differentiated in the thymus. That means that this is where they develop into cells that are capable of recognizing non-self proteins, so-called antigens.

The secondary lymphatic organs are the place where the defense cells do their actual work. These organs include the lymph nodes, the spleen, the tonsils and other specialized tissues in the mucous membranes of the bowel, for example. In these places, the defense cells have constant contact with non-self substances and pathogens.

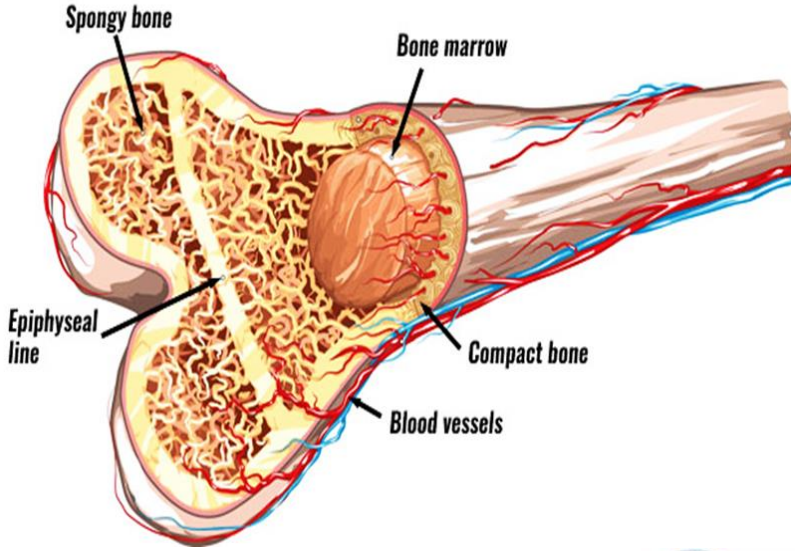
The organs of immune system form the **immunity**. The **immunity** is an ability of *multicellular organisms* to resist the action of harmful agents, while maintaining the genetic integrity and biological identity.

## MYELOID TYPE OF THE HEMATOPOIETIC ORGANS

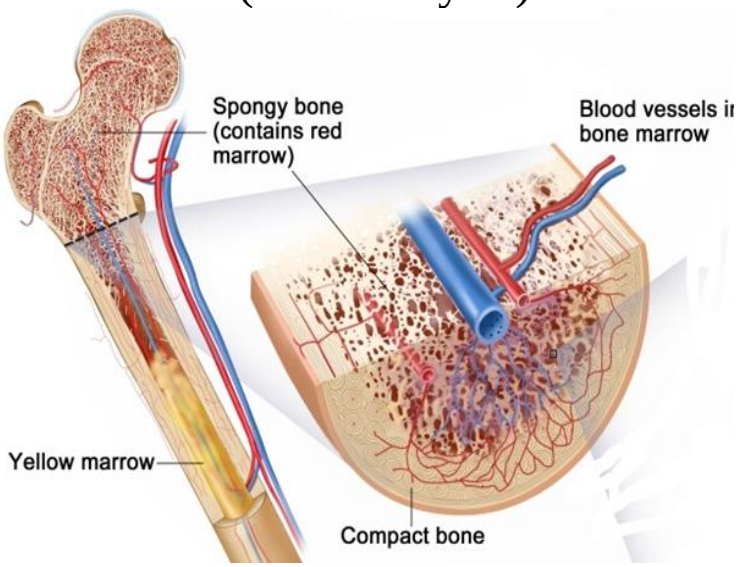
### RED BONE MARROW

The **red bone marrow** *(medulla ossium rubra)* is the central organ of haemato- and immunopoiesis. It is a semi-solid tissue which may be found within the spongy portions of bones and the medullary cavity of the long bones.

The red marrow is a blood-forming organ. It contains several cell types. At the cellular level, the main functional component of bone marrow includes the progenitor cells which are destined to mature into blood and lymphoid cells.




Marrow contains hematopoietic ***stem cells*** which give rise to the three classes of blood cells that are found in circulation: white blood cells (leukocytes), red blood cells (erythrocytes), and platelets (thrombocytes).

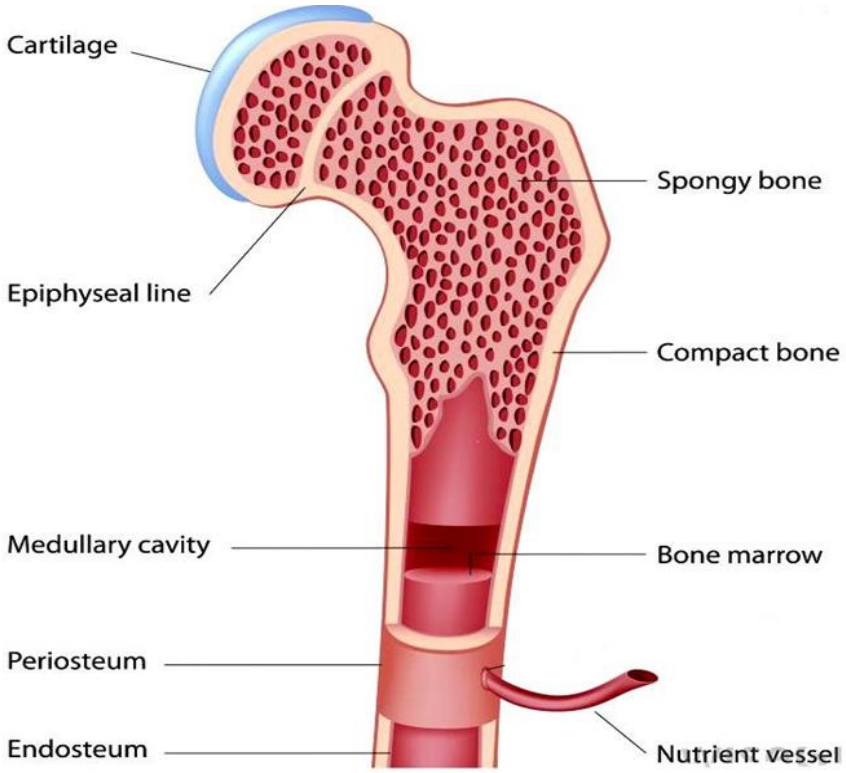



The marrow stroma contains mesenchymal stem cells (MSCs), also known as *marrow stromal cells*. These are multipotent stem cells that can differentiate into a variety of cell types. MSCs have been shown to differentiate, in vitro or in vivo, into osteoblasts, myocytes, chondrocytes, marrow adipocytes and beta-pancreatic “islets cells”.

All the bones are hematopoietic in the fetus (late period) and

in the newborn.

In adults, red marrow is found mainly in the central skeleton, such as the pelvis, sternum, cranium, ribs, vertebrae and scapulae, and variably found in the proximal epiphyseal ends of long bones such as the femur and humerus.




**Sagittal section of the femur.**

**Scheme of the red bone marrow location**

The red bone marrow is partially replaced by adipose tissue and a progressive conversion towards "***yellow" marrow*** (medulla ossium flava) with age. The yellow bone marrow fills the marrow cavity of the tubular bone and has no hematopoietic elements.

In circumstances of chronic hypoxia, the body can convert yellow marrow back to red marrow to increase blood cell production. This process is called ***recapitulation***.

## LYMPHOID TYPE OF THE HEMATOPOIETIC ORGANS

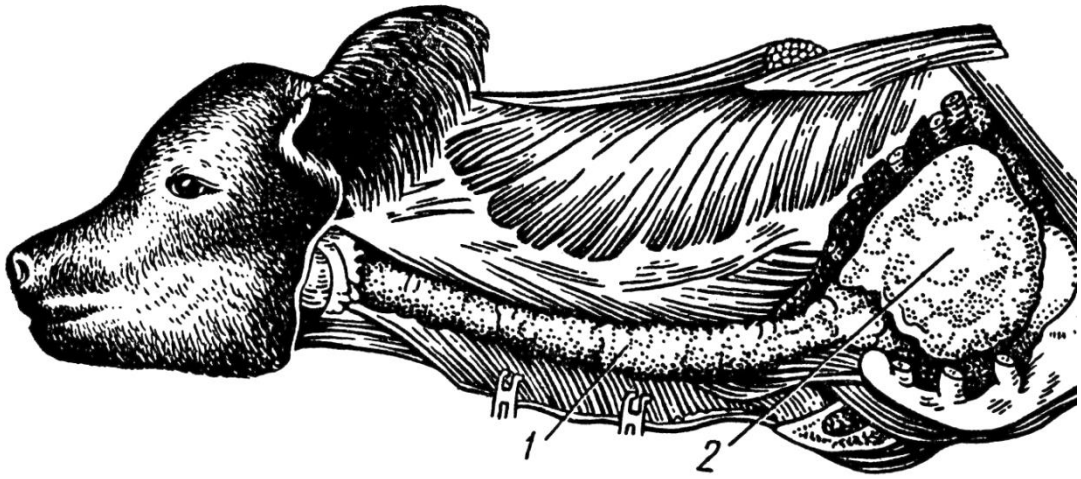
### THYMUS

The thymus is a central organ of the immune system, the primary regulator of immune processes in the body. It is a lobulated organ with a pink tinge in fresh material. It lies in the cranial ventral part of the thoracic cavity. The organ, relatively

large at birth, grows rapidly during the first few postnatal months so that it reaches its maximum development before sexual maturity, or between the fourth and fifth postnatal months, just before the shedding of the deciduous incisor teeth. The thymus begins to involute with the changing of the teeth. Although the process is rapid at first, the organ usually does not atrophy completely even in old age. As it decreases in size and loses its lymphoid structure, it is replaced by fat.

.The thymus is a principal source of the small lymphocytes of the blood, spleen and lymph nodes. The thymus plays a major role, particularly in early life, in maintaining the immunologic integrity of the organism.

The thymus tissue is divided into a cortex and medulla. The cortex produces the immunocompetent T-lymphocytes, which enter the bloodstream for distribution to and multiplication in the peripheral lymphoid organs (nodes and scattered lymph nodules). The medulla is formed of epithelioid cells of more speculative significance.




**Thymus of calf**
1 –cervical part, 2 –thoracic part

Thymus has endocrine function; it produces the hormone ***thymosin*** that affects the lymphocytes of peripheral lymphoid organs. The thymus has a close functional connection with other endocrine glands: the pituitary gland, adrenal glands and gonads.

## LYMPH NODES

**Lymph nodes** (nodi lymphatici, s. lymphonodes) are the peripheral, most numerous organs of lymphoid hematopoiesis and immune defense. Lymph node functions:

1. Lymphoid tissue of lymph nodes produces effector cells of humoral immunity (plasma cells) and cellular immunity (T-killers).

2. The lymph is filtered in the lymph nodes, which release lymph from foreign material of both exogenous origins (coal dust, toxins, microorganisms, etc.) and endogenous origin, in particular tumor cells. "Lymph nodes are either a deadly trap or an oasis for wandering tumor cells" [Virkhov, 1860].

**Lymph node** (lymphonodus, ln) externally covered with a capsule. The stroma, parenchyma, and a system of interconnected channels (sinuses) are inside the node. The lymph moves through the node along the sinuses.

The parenchyma of lymph node is represented by lymphoreticular tissue, which consists of lymphoid nodules, cortex, paracortical area and cortical cords. The lymphocytes, plasma cells, macrophages, reticular cells and basophils are the blood elements of lymph node.

Lymph flows to the lymph node from a certain part of the body (root) through the afferent lymphatic vessels, which flow along nodes convex surface and gather into the marginal sinus.

Further lymph passes through the nodes sinus system and flow into the portal sinus. The efferent lymphatic vessel emerges from portal sinus. Along it, the lymph flow to the next nodes or to the collector vessels (lymphatic trunks or ducts). A major factor of the lymph node function is the lymph circulation through it.

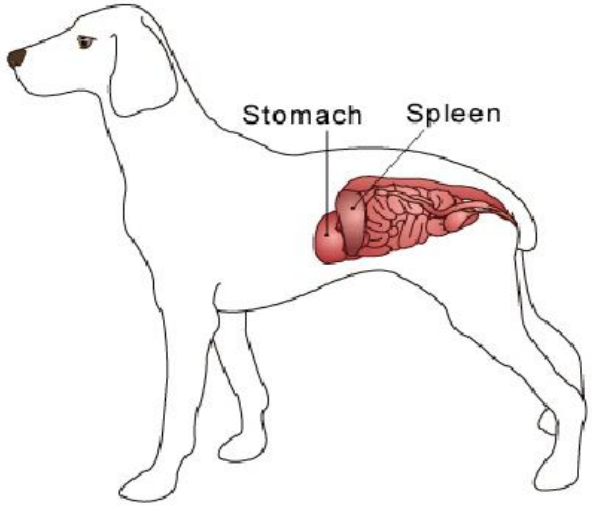
The slow movement of lymph along the node ensures its sufficient contact with the cellular parenchymal elements.

The sinuses of individual lymph nodes contain erythrocytes. They are red and called **hemolymphatic lymph nodes** (lymphonodi hemales).

**SPLEEN**

The spleen (lien) is situated in the left hypogastric region, approximately parallel to the greater curvature of the stomach. It is gray-brown in color, and often has a purple cast. Although it is irregular in shape and outline, it is considerably longer than it is wide and slightly constricted in the middle. The location of the organ is dependent on the size and position of the other abdominal organs, particularly the stomach, to which it is loosely attached.

The spleen is attached to the greater curvature of the stomach by the serous gastrosplenic ligament.




The internal structure of the spleen consists of the parenchyma, the red and white splenic pulp, and a framework which consists of a fibrous tunic, or capsule, and trabeculae. The trabeculae form a complicated network within the organ. The white pulp consists of lymphoid tissue.

The spleen has:

*Surfaces:*

- parietal – facies parietalis, adjacent to the diaphragm
- visceral – facies visceralis, adjacent to the stomach wall

*Ends:*

- dorsal – extremitas dorsalis (faces to the spine)
- ventral – extremitas ventralis (faces to the xiphoid process)

*Margins:*

- cranial – margo cranialis (towards the thoracic cavity)
- caudal – margo caudalis (towards the pelvic cavity)

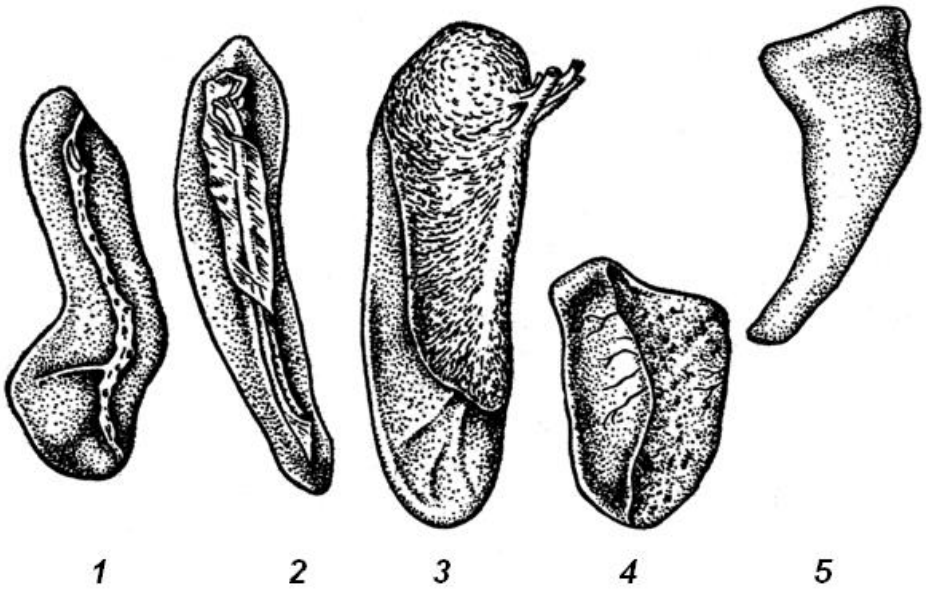
Several diverse functions have been attributed to the spleen:

1. It stores and concentrates the erythrocytes and releases them during times of need.

2. It filters the blood, as the lymph nodes filter the lymph, and removes the worn-out erythrocytes from the circulation. From these cells it produces bilirubin, which is collected by the liver. From the hemoglobin it extracts the iron, which is released here, and is again used by the red bone marrow in the production of new erythrocytes.

3. It produces many of the lymphocytes and probably most of the monocytes, and has an important function in the production of antibodies.

The spleen is not essential to life or even to health, as most of its normal functions are taken over by other tissues in its absence.




**Spleen of domestic animals**
*1 - dog,*
*2 - pig,*
*3 - cattle,*
*4 - goat,*
*5 - horse*

## LYMPHOID FORMATIONS OF THE DIGESTIVE, RESPIRATORY AND URINARY APPARATUS

**TONSILS** are accumulation of lymphoid tissue in the pharyngeal mucosa. All tonsils form a *lymphoid pharyngeal ring*.

The terminology of the tonsils is based on their topography:

1. *Lingual tonsil* is located in the mucosa of the root of tongue.

2. *Palatal tonsil* (paired) is located on the sides of the tongue root.

3. *Unpaired palatal tonsil* is located in the mucosa of soft palate.

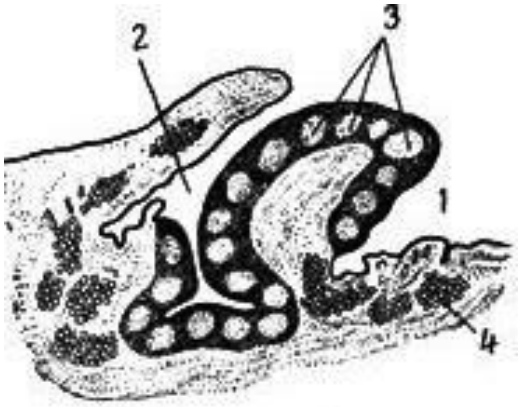
4. *Tonsil of the auditory tube* (paired) is located in the mucosa of nasal pharynx, near the openings of auditory tubes.

5. *Paraepiglottic tonsil* is located at the base of the epiglottis of larynx.

*6. Ileo-cecal tonsils* are located in the mucosa of the ileum papilla (intestine).


**Palatal tonsil (section)**

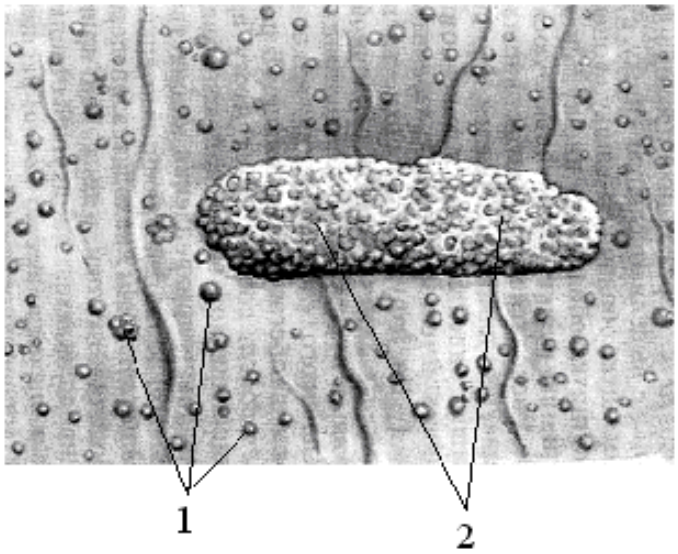
*1 – palatal tonsil,*
*2 – tonsillar sinus,*
*3 – lymphatic nodules,*
*4 – mucous glands,*
*5 – tonsillar fossa (crypt)*




A – horse; B – dog

**SINGLE LYMPHOID NODULES** are accumulation of lymphoid tissue in the mucosa and submucosa of the digestive organs (pharynx, esophagus, stomach, intestines, and gallbladder), respiratory organs (larynx, trachea, and bronchial tubes), and urinary organs (ureter, urethra). Lymphoid nodules are located at different distances from each other and at different depths. Often they lie close to the epithelial layer. Single lymphoid nodules have a rounded or oval shape; their size usually does not exceed 1-3 mm. T- and B-lymphocytes that colonize lymphoid formations, migrate through the epithelium.

**LYMPHOID AGGREGATES** are the accumulation of lymphoid nodules in the intestinal mucosa on the opposite side of the mesentery attachment. Lymphoid aggregates consist of lymphoid nodules and diffuse lymphoid tissue.




**Mucosa of jejunum (microscopically)**

*1 – lymphoid nodules,*
*2 – lymphoid aggregates.*

Macroscopically, from the intestinal lumen, these are clearly demarcated areas of the mucosa. The surface of lymphoid aggregates is hilly, uneven, because the lymphoid nodules are different in size. The shape of lymphoid aggregates is diverse (mostly round or round-oval).

## Questions for self-control

1. Define the terms “hematopoiesis”, “lymphopoiesis”.
2. Structure, topography and functions of the thymus of domestic animals.
3. Name the central and peripheral organs of hemo- and immunopoiesis.
4. Name the lymphoid formations associated with mucous membranes.
5. Define the term "immunity".
6. What are hemolymphatic nodes?

## TEST QUESTIONS

**1. The visceral layer of the serous pericardium is the:**

1. intermal tunic of the heart
2. external tunic of the heart
3. middle tunic of the heart

**2. The muscles of the heart ventricles are the following:**

1. mm. accessorii
2. moderator bands
3. mm. ventricularis
4. mm. pectinati
5. mm. externi
6. mm. papillares

**3. The vessels of pulmonary circulation are the following:**

1. cranial vena cava
2. pulmonary trunk
3. portal vein
4. caudal vena cava
5. pulmonary veins
6. aorta

**4. The "venous sinus" is the opening of following vessel to the atrium:**

1. pulmonary vein
2. caudal vena cava
3. great cardiac vein
4. small cardiac veins
5. cranial vena cava

**5. The "coronary sinus" is the opening of following vessel to the atrium:**

1. pulmonary vein
2. caudal vena cava
3. great cardiac vein
4. small cardiac veins
5. cranial vena cava

**6. The vessels opening to the right atrium are the following:**

1. aorta
2. truncus pulmonalis
3. vv. cavae
4. vv. pulmonales
5. aa. coronaria

6. v. cordis magna
7. v. cordis parvae

**7. The vessels opening to the left atrium are the following:**

1. aorta
2. truncus pulmonalis
3. vv. cavae
4. vv. pulmonales
5. aa. coronaria
6. v. cordis magna
7. v. cordis parvae

**8. The vessels of systemic circulation are following:**

1. cranial vena cava
2. pulmonary trunk
3. portal vein
4. caudal vena cava
5. pulmonary veins
6. aorta

**9. Morphological features of placental circulation of fetus are:**

1. The abdominal aorta do not has the visceral branches
2. The umbilical vessels are two arteries and a single vein
3. Venous duct connects the umbilical vein and the caudal vena cava
4. The presence of right aortic arch
5. The oval foramen is located in the interatrial septum
6. The arterial duct connects the pulmonary trunk with the aorta

**10. The vessels containing arterial blood are the following:**

1. umbilical artery of fetus
2. aorta
3. caudal vena cava
4. pulmonary vein
5. pulmonary artery
6. umbilical vein of fetus

**11. The vessels containing venous blood are the following:**

1. umbilical artery of fetus
2. aorta
3. caudal vena cava
4. pulmonary vein
5. pulmonary artery
6. umbilical vein of fetus

**12. The valves of heart are located at base of the following vessels:**

1. arcus aortae
2. vena cava caudalis
3. truncus pulmonalis
4. vena cava cranialis
5. venae pulmonales

**13. The branches of aortic arch in the dog are the following:**

1. truncus pulmonales
2. subclavia sinistra
3. brachiocephalica
4. subclavia dextra
5. aa. coronaria cordis dextra et sinistra

**14. Parietal branches of abdominal aorta are the following:**

1. brachiocephalica
2. aa. intercostales
3. aa. lumbales
4. renalis
5. iliaca interna
6. circumflexa ilium profunda
7. hepatica
8. phrenicoabdominalis

**15. Parietal branches of thoracic aorta are the following:**

1. brachiocephalica
2. aa. intercostales
3. aa. lumbales
4. renalis
5. iliaca interna
6. circumflexa ilium profunda
7. phrenicoabdominalis

**16. Visceral branches of abdominal aorta are the following:**

1. brachiocephalica
2. aa. intercostales
3. mesenterica cranialis
4. renalis
5. iliaca interna
6. mesenterica caudalis
7. celiaca
8. phrenicoabdominalis

**17. Arterial duct of the fetus connects the following vessels:**

1. umbilical vein with caudal vena
2. pulmonary trunk with aorta
3. pulmonary artery with pulmonary vein
4. abdominal aorta with umbilical artery

**18. Venous duct of the fetus connects the following vessels:**

1. umbilical vein with caudal vena
2. pulmonary trunk with aorta
3. pulmonary artery with pulmonary vein
4. abdominal aorta with umbilical artery

**19. The caudal vena cava is formed by the fusion of the following veins:**

1. v. iliaca interna
2. v. iliaca externa
3. vv. iliaca communis left and right
4. v. sacralis mediana
5. vv.lumbales

**20. The following veins open into the caudal vena cava:**

1. v. mesenterica cranialis
2. vv. hepaticae
3. v. mesenterica caudalis
4. v. renalis
5. v. spermatica interna

**21. The vessels of the heart wall are following:**

1. aorta
2. truncus pulmonales
3. aa. coronaria cordis
4. v. cordis magna
5. vv. pulmonales

**22. The cranial vena cava is formed by the fusion of following veins:**

1. truncus bijugularis left and right
2. v. jugularis interna
3. v. jugularis externa
4. v. azygos dextra
5. vv. thoracica interna

**23. V. porta hepatis is formed by fusion of the following veins:**

1. v. mesenterica caudalis
2. v. azygos dextra
3. v. mesenterica cranialis

4. v. iliaca interna
5. v. renalis
6. v. gastrolienalis

**24. The following veins open into the cranial vena cava:**

1. v. cephalica humeri
2. v. jugularis externa
3. vv. thoracica interna
4. v. azygos dextra
5. v. cervicalis profunda

**25. Parietal branches of caudal vena cava are the following:**

1. v. brachiocephalica
2. vv. intercostales
3. vv. lumbales
4. v. renalis
5. v. iliaca interna
6. v. circumflexa ilium profunda
7. v. phrenicoabdominalis

**26. Umbilical artery of female is divided into the following arteries:**

1. ureterica
2. deferentialis
3. uterina media
4. vesicalis cranialis
5. vesicalis caudalis
6. uterina cranialis
7. pudenda interna

**27. Visceral branches of internal iliac artery are the following:**

1. umbilicalis
2. iliolumbalis
3. glutaea cranialis
4. glutaea caudalis
5. obturatorius
6. circumflexa ilium profunda
7. pudenda interna

**28. The muscular tissue of the heart forms the following types of the muscles:**

1. mm. accessorii
2. moderator bands
3. mm. ventricularis
4. mm. pectinati

5. mm. externi
6. mm. papillares

**29. The body's immune defense is provided by the following organs:**

1. Lymph nodes.
2. Heart.
3. Spleen.
4. Thymus.
5. Pancreas.

**30. The organs of the immune system (A – central; B – peripheral) are the following:**

1. Lymph nodes.
2. Thymus.
3. Tonsils.
4. Red bone marrow.
5. Lymphoid aggregates.
6. Spleen.
7. Single lymph nodules.

**31. Organs of hematopoiesis (A – for fetus; B – central hematopoietic organs) are the following:**

1. Spleen.
2. Red bone marrow.
3. Lymph nodes.
4. Thymus.
5. Tonsils.
6. Liver.
7. Right lymphatic duct.

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